



## CURRICULUM DEVELOPMENT

Renewing the Sustainable Energy Curriculum – Curriculum Frameworks and Guidance for Course Delivery

# Curriculum Framework Guide

A guide to support institutions in developing and teaching tertiary level programmes for sustainable energy professionals



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<b>SECTION 1 - INTRODUCTION .....</b>	<b>5</b>
<b>SECTION 2 - THE CURRICULUM FRAMEWORKS .....</b>	<b>8</b>
HOW TO USE THE CURRICULUM FRAMEWORKS .....	12
CURRICULUM FRAMESET 1: RENEWABLE ENERGY SYSTEMS .....	15
CURRICULUM FRAMESET 2: ENERGY EFFICIENCY .....	25
CURRICULUM FRAMESET 3: POLICY AND ENABLERS .....	35
CURRICULUM FRAMESET 4: CARBON MANAGEMENT .....	40
CURRICULUM FRAMESET 5: SUSTAINABLE ENERGY MAJORS IN OTHER DEGREES.....	45
<b>SECTION 3 - GUIDANCE ON FIVE KEY QUESTIONS RELATED TO PROGRAM DESIGN AND COURSE DELIVERY .....</b>	<b>52</b>
<b>SECTION 4 - APPROACH AND METHODOLOGY FOR DEVELOPING THE CURRICULUM FRAMEWORKS .....</b>	<b>59</b>



# Section 1 – Introduction

# INTRODUCTION

This Curriculum Frameworks Guide has been produced to assist Australian Universities in designing and offering programs and courses in Sustainable Energy. The guide is a result of an Australian Government Office for Learning and Teaching Innovation Grant involving teaching staff from five Australian Universities.



*“Curriculum renewal in higher education can be difficult, time-consuming, and arduous, but the payoff is a curriculum that is current, responsive, proactive and effective.” (ALTC Good Practice Report: Curriculum Renewal, Narayan and Edwards, 2011).*

Ongoing curriculum renewal is more difficult but vital for multidisciplinary courses preparing graduates to work in a specialised rapidly changing field. After more than 15 years of offering tertiary level “sustainable energy” qualifications in Australian Universities there was a clear need to assess how these courses are taught and develop curriculum frameworks to guide Universities designing/redesigning programs and courses to provide graduates with the relevant skills, knowledge and attributes (capabilities) seen by graduates and employers as required to work in this rapidly changing field.

This guide presents the sustainable energy curriculum frameworks developed by the “Renewing the sustainable energy curriculum – providing internationally relevant skills for a carbon constrained economy” project, which was conducted over a two-and-a-quarter year period.

The project was led by Murdoch University and brought together a team of team of academics from four other Australian Universities that have recognised courses or programs in sustainable energy to develop a set of curriculum frameworks for tertiary level sustainable energy programs. The project also sought to provide guidance relating to a number of key questions related to the design and delivery of the resulting programs and courses. The collaborators included The Australian National University, Queensland University of Technology, Murdoch University, The University of New South Wales and the University of South Australia.

The main aim of the project was to scope and develop sustainable energy curriculum frameworks for Australian higher education Institutions that meet the needs of Australian and international student graduates and employers, both now and into the near future. This included:

- Developing a list of sustainable energy skills, knowledge and generic graduate attributes required by employers, which were then formulated into curriculum frameworks.

As well as developing the curriculum frameworks the project also aimed to gain an understanding of five key questions related to programme design and course delivery including:

1. The mixture of inter/multi-disciplinary content vs specialised content that should be included in sustainable energy programmes. For example how much and what type of policy and “enablers” content should be included as core content in sustainable engineering degrees and alternatively what type of technical knowledge should be included as core content in humanities courses with a focus on policy and enablers?
2. Whether Universities should develop and offer specialist courses and programmes (e.g. BEng in Sustainable Energy) at undergraduate level versus embedding the relevant skills and knowledge into existing discipline training such as an existing Electrical Engineering or Power Engineering degree;
3. The feasibility and desirability of providing sustainable energy teaching by face-to-face mode only versus online and flexible delivery;

4. The need for and amount of work integrated learning that is optimal, or acceptable during sustainable energy degrees and what type and level of involvement industry practitioners should have in the delivery of the courses; and
5. The need for and how to enable sufficient internationalisation of the curriculum and course content so that it meets the needs of international students studying in Australia or at affiliated international institutions and Australian graduates seeking to work overseas.

The curriculum frameworks are designed to be relevant to specialist sustainable energy engineering and energy studies programmes, as well as conventional engineering, science and humanities programmes which have a sustainable energy focus or major. This guide presents the sustainable energy curriculum frameworks and accompanying advice on the five key questions related to the curriculum/programme design and course delivery.

The research based approach used to develop the curriculum frameworks is described in more detail in Section 4:

The finalised project materials and publications, including this one, are available from the project website - <http://www.murdoch.edu.au/projects/secfp/>. The website also contains a list of sustainable energy programmes offered in Australian Universities.



## **Section 2 – The Curriculum Frameworks**



# Curriculum Frameworks

Curriculum frameworks for Sustainable Energy programmes in Australian Universities



Curriculum frameworks have been developed for sustainable energy programmes or qualifications at different levels within the Australian Qualifications Framework (AQF) including:

1. Undergraduate sustainable energy engineering (e.g. BEng) courses with specialisations in renewable energy systems or energy efficiency;
2. Postgraduate sustainable energy engineering coursework programmes (MEng) with specialisations in renewable energy systems or energy efficiency;
3. Postgraduate science/technical coursework programmes (e.g. MSc) with specialisations in renewable energy systems, energy efficiency and carbon management;
4. Postgraduate humanities, social science or business (e.g. MA or MBA) coursework programmes with a specialisation in policy and enablers; and
5. Conventional engineering, science and humanities programmes with a sustainable energy focus or major;

The relationship between the first four curriculum frameworks is shown in Figure 1.

Curriculum Framework Relationships Map	Policy / Enablers (MA)	RE Systems (BEng / MEng/MSc)	Energy Efficiency & Management (BEng / MEng / MSc)	Carbon Management (MSc)
Graduate attributes (Grad Cert)	<b>Prerequisites</b> <ul style="list-style-type: none"> <li>High school maths, physics and chemistry</li> <li>IT skills</li> <li>Statistics</li> <li>First year university level economics</li> </ul> <b>Humanities/Social Science Attributes</b> <ul style="list-style-type: none"> <li>Governance &amp; social responsibility</li> <li>Public policy</li> <li>Community consultation</li> <li>Social &amp; environmental impact/evaluation</li> <li>Change management</li> </ul>	<b>Prerequisites (MEng)</b> <ul style="list-style-type: none"> <li>First year university level maths, physics and chemistry</li> <li>IT skills</li> <li>Statistics</li> <li>EAust Attributes</li> </ul> <b>Mech Eng – electrical and transmissions prereq</b> <b>Electrical/power Eng – thermodynamics prereq</b> <b>Other (Civil, Environmental) – thermodynamics, electrical and transmission prereq</b> <b>or</b> <b>Technical/Science Attributes (MSc)</b> <ul style="list-style-type: none"> <li>IT &amp; laboratory skills</li> <li>Technical management</li> </ul>	<b>Prerequisites (MEng)</b> <ul style="list-style-type: none"> <li>First year university level maths, physics and chemistry</li> <li>IT skills</li> <li>Statistics</li> <li>EAust Attributes</li> </ul> <b>or</b> <b>Technical/Science Attributes (MSc)</b> <ul style="list-style-type: none"> <li>IT &amp; laboratory skills</li> <li>Technical management</li> </ul>	<b>Prerequisites</b> <ul style="list-style-type: none"> <li>First year university level maths, physics and chemistry</li> <li>IT skills</li> <li>Statistics</li> </ul> <b>Technical/Science Attributes</b> <ul style="list-style-type: none"> <li>IT &amp; laboratory skills</li> <li>Technical management</li> </ul>
Introductory level (Graduate Diploma)	<b>Policy content</b> <ul style="list-style-type: none"> <li>Conventional &amp; Sustainable Energy in Society</li> <li>Energy Policy 1</li> <li>Energy Economics 1</li> <li>Sustainable Energy Business and project Management</li> </ul> <b>Technical/Science content</b> <ul style="list-style-type: none"> <li>Energy Efficiency &amp; Management 1</li> <li>Carbon Management Strategy 1</li> <li>Electricity Network Systems</li> <li>Renewable Energy Systems 1</li> </ul>	<b>Policy content</b> <ul style="list-style-type: none"> <li>Conventional &amp; Sustainable Energy in Society</li> <li>Energy Policy 1</li> <li>Energy Economics 1</li> <li>Sustainable Energy Business and project Management</li> </ul> <b>Technical/Science content</b> <ul style="list-style-type: none"> <li>Energy Efficiency &amp; Management 1</li> <li>Carbon Management Strategy 1</li> <li>Electricity Network Systems</li> <li>Renewable Energy Systems 1</li> </ul>	<b>Policy content</b> <ul style="list-style-type: none"> <li>Conventional &amp; Sustainable Energy in Society</li> <li>Energy Policy 1</li> <li>Energy Economics 1</li> <li>Sustainable Energy Business and project Management</li> </ul> <b>Technical/Science content</b> <ul style="list-style-type: none"> <li>Energy Efficiency &amp; Management 1</li> <li>Carbon Management Strategy 1</li> <li>Electricity Network Systems</li> <li>Renewable Energy Systems 1</li> </ul>	<b>Policy content</b> <ul style="list-style-type: none"> <li>Conventional &amp; Sustainable Energy in Society</li> <li>Energy Policy 1</li> <li>Energy Economics 1</li> <li>Sustainable Energy Business and project Management</li> </ul> <b>Technical/Science content</b> <ul style="list-style-type: none"> <li>Energy Efficiency &amp; Management 1</li> <li>Carbon Management Strategy 1</li> <li>Electricity Network Systems</li> <li>Renewable Energy Systems 1</li> </ul>
Medium level (Diploma)	<b>Policy content</b> <ul style="list-style-type: none"> <li>Energy Policy 2 – Climate Change Policy</li> <li>Energy Economics 2</li> <li>Change Management</li> <li>Community Consultation &amp; Social/Environmental Impact Assessment</li> </ul>	<b>RE systems content (Choose 4 from)</b> <ul style="list-style-type: none"> <li>Advanced RE Systems 1 - Solar Photovoltaic</li> <li>Advanced RE Systems 2 - Solar Thermal</li> <li>Advanced RE Systems 3 – Wind Energy</li> <li>Advanced RE Systems 4 – Bioenergy</li> <li>Advanced RE Systems 5 – Remote and Micro-grid RE Systems</li> <li>Advanced RE Systems 6 – Conventional and Emerging Renewable Energy</li> </ul>	<b>Energy efficiency &amp; management content</b> <ul style="list-style-type: none"> <li>Energy Efficiency, System Analysis and Auditing</li> <li>Environmental Building Services and Energy Efficient Building Design</li> <li>Industrial and Commercial Energy Efficiency</li> <li>Change Management</li> </ul>	<b>Carbon management content</b> <ul style="list-style-type: none"> <li>Lifecycle Assessment</li> <li>Greenhouse Gas Inventory</li> <li>Carbon Accounting, Offsets &amp; Trading</li> <li>Change Management</li> </ul>
Advanced level (Masters)	<b>Two Recommended Electives and Advanced Thesis/Research Project (1/2 semester)</b> <b>or</b> <b>Advanced Thesis/Research Project (1 semester)</b> <b>Recommended Electives</b> <ul style="list-style-type: none"> <li>Energy Policy 3 - Supply and Infrastructure, or</li> <li>Energy Economics 3 - Market Reform, or</li> <li>Energy Policy Research and Evaluation</li> </ul>	<b>Two Recommended Electives (choose from above list or recommended streams below) and Advanced Thesis/Research Project (1/2 semester)</b> <b>or</b> <b>Advanced Thesis/Research Project (1 semester)</b> <b>Specializations</b> <ul style="list-style-type: none"> <li>Prescincts and Buildings</li> <li>Renewable Energy for Sustainable Development</li> <li>Sustainable Transport</li> </ul>	<b>Two Recommended Electives and Advanced Thesis/Research Project (1/2 semester)</b> <b>or</b> <b>Advanced Thesis/Research Project (1 semester)</b> <b>Recommended Electives</b> <ul style="list-style-type: none"> <li>Carbon Management Strategy 2, or</li> <li>Energy Efficiency and Decarbonisation in Precincts, or</li> <li>Greenhouse Gas Inventory</li> </ul>	<b>Carbon management content and Carbon Management Strategy 2</b> <b>Recommended Elective and Energy Efficiency, System Analysis &amp; Auditing, or</b> <b>Energy Efficiency and Decarbonisation in Precincts</b> <b>Advanced Thesis/Research Project (1/2 semester)</b>

**Figure 1: Sustainable energy curriculum framework relationships.**

The need for degree or programme curriculum frameworks in four areas of specialisation was identified by analyzing the roles of existing sustainable energy graduates, the type of work they do and the areas in which they are employed. These areas have been determined to be: policy/enablers; renewable energy systems; energy efficiency and management; and the newly emerged area of carbon management. Working backwards from the fields of employment, the required knowledge and skills for each pathway were mapped in terms of graduate and discipline specific attributes (including prerequisites for entry) and sustainable energy capabilities (skills and knowledge) for undergraduate and postgraduate programmes. Based on feedback from surveys of graduates and industry the skills were classified as being at introductory level, medium level or advanced level, and either core or elective. The details of this process are presented in Section 4.

No curriculum frameworks have been developed for specialised undergraduate “multidisciplinary Sustainable Energy” programmes as in their feedback graduates and industry representatives did not feel these types of programmes were best to train graduates at that level. Based on the analysis of roles currently undertaken by graduates and responses to the surveys curriculum frameworks have been developed for undergraduate Bachelor of Engineering degrees with specialisations in “renewable energy systems” and “energy efficiency”. Four curriculum frameworks have been developed for postgraduate masters by coursework programmes, suggesting which postgraduate programme type, structure and title provides the best pathway for each of the four specialisation roles graduates will work in. These frameworks include:

- MA (two years) specialising in Sustainable Energy Policy and Enablers;
- MEng/MSc (two years) specialising in Renewable Energy Systems;

- MEng/MSc (two years) specialising in Energy Efficiency; and
- MSc (two years) specialising in Carbon Management.

A curriculum framework has been developed at postgraduate level for the emerging role and area of “Carbon Management” as this was identified during the research for the project as a new distinct and growing role especially in the next 10 to 15 years. Although this is an overarching role, of which sustainable energy is a substantial but not the only part, it has been included in the project for two reasons:

1. There is a very large amount of overlap between the capabilities required for carbon management and the three “sustainable energy” specialisation areas.
2. There is no other field with which this emerging area can be better associated.

One of the key aspects of the postgraduate curriculum frameworks is that each of the four areas of specialisation has its specific set of prerequisites and discipline specific capabilities that need to be attained before graduating in that specialisation. This has not been explicitly spelt out in existing programmes and provides a clear understanding for students who have trained at undergraduate level in a different discipline whether they can realistically train for a specific area, or what additional capabilities they may need to acquire in order to work in that area.

The curriculum framework relationships map provides an overview of all four of the specialisations and how they relate to each other in terms of the common and distinct content covered in each area. Each specialisation has an overarching curriculum framework map which provides details of the programmes and further detail of the units that should be included in that programme. There are then a series of learning outcome maps showing the detailed learning outcomes associated with each unit.

The Australian Qualifications Framework (AQF) requirements have been considered when developing these curriculum frameworks. The Masters courses presented in the frameworks are all Masters by Coursework and as such the only requirements for research or projects that the courses are required to fulfil are that “graduates will have undertaken a programme of structured learning with some independent research, and project work or practice-related learning”. Based on consultation with university representatives it was determined that a reasonable amount of research or project work typically included in a Masters by Coursework ranges from a half semester through to a full semester. Each Masters by Coursework structure has a Thesis/Research Project unit requiring a minimum of half a semester’s work.

The structures presented in the curriculum frameworks are based on a “normal” student load being four units (sometimes called courses) per semester, which is the typical approach in most Australian Universities.

The curriculum frameworks are presented in the following sub-sections by specialisation area and then a sub-section presenting curriculum frameworks for sustainable energy majors in conventional undergraduate or postgraduate degrees. The next sub-section presents a generic guide to interpreting and using the curriculum frameworks.

## How to Use the Curriculum Frameworks



This section describes how to interpret and use each set of the curriculum frameworks.

The curriculum frameworks are clustered by specialisation type with a set of curriculum frameworks for each specialisation. Each set of curriculum frameworks has an “overarching” map which shows the types of qualification (and roles) suited for each specialisation and a map of the skills and knowledge areas (clustered as units) that best make up the capabilities required to be taught in that specialisation and qualification.

In the overarching map the individual skills and knowledge are clustered into coherent units and these are then arranged into three levels depending on the depth and level at which the unit content is covered. The three levels are introductory level, medium level and advanced level. Each overarching map also presents the pre-requisite knowledge and discipline specific capabilities that a graduate in that type of degree with that specialisation is expected to have (postgraduate degrees) or to acquire during the degree (undergraduate degrees). These maps are what programme coordinators use to inform the development of the programme structure.

Each overarching curriculum map then has a set of “learning outcome” maps that detail the learning outcomes that should be in each “unit” in the overarching map. This is the detailed curriculum map for each type of degree/programme, showing what learning outcomes should be taught in each unit/course. These learning outcome maps are what individual unit coordinators or teaching staff use to inform the development of what should be taught and what outcomes achieved in each unit.

Figure 2 shows a typical overarching curriculum map, in this case for a specialisation in energy efficiency. Figure 3 then shows how to interpret the key parts of the overarching curriculum map. Figure 4 shows a typical learning outcomes map for the units in Figure 3.

High level Curriculum Framework Map	Energy Efficiency & Management (BEng)	Energy Efficiency & Management (MEng)	Energy Efficiency & Management (MSc)
<b>Graduate attributes</b>	<b>Prerequisites</b> <ul style="list-style-type: none"> <li>BEng – High school level maths, physics, and chemistry</li> <li>IT skills</li> <li>Statistics</li> </ul>	<b>Prerequisites</b> <ul style="list-style-type: none"> <li>First year university level maths, physics and chemistry</li> <li>IT skills</li> <li>Statistics</li> </ul> <b>Engineering Attributes</b> <ul style="list-style-type: none"> <li>IEAust Attributes</li> </ul>	<b>Prerequisites</b> <ul style="list-style-type: none"> <li>First year university level maths, physics and chemistry</li> <li>IT skills</li> <li>Statistics</li> </ul> <b>Technical/Science Attributes</b> <ul style="list-style-type: none"> <li>IT &amp; laboratory skills</li> <li>Technical management</li> </ul>
<b>Introductory level</b>	<b>1<sup>st</sup> year common engineering units</b> <ul style="list-style-type: none"> <li>Maths 1</li> <li>Maths 2</li> <li>Physics 1</li> <li>Physics 2</li> <li>Engineering Design Group Project                             <ul style="list-style-type: none"> <li>Computing for Engineers</li> </ul> </li> <li>Circuits and Systems 1</li> <li>Conventional &amp; Sustainable Energy in Society</li> </ul> <b>2<sup>nd</sup> year common engineering units</b> <ul style="list-style-type: none"> <li>Mathematical Methods and Statistics</li> <li>Engineering Materials &amp; Chemistry</li> <li>Fluid Mechanics</li> <li>Thermodynamics and Heat Transfer</li> <li>Circuits and Systems 2</li> <li>Applied PV and Electronic Instrumentation</li> <li>Control Systems and Process Dynamics</li> <li>University breadth/general education unit</li> </ul>	<b>YEAR 1</b> <ul style="list-style-type: none"> <li><b>Policy content</b> <ul style="list-style-type: none"> <li>Energy Policy 1</li> <li>Energy Economics 1</li> <li>Sustainable Energy Business and Project Management</li> <li>Conventional and Sustainable Energy in Society</li> </ul> </li> <li><b>Technical/Science content</b> <ul style="list-style-type: none"> <li>Energy Efficiency and Management 1</li> <li>Carbon Management Strategy 1</li> <li>Renewable Energy Systems 1</li> <li>Electricity Network Systems</li> </ul> </li> </ul>	<b>YEAR 1</b> <ul style="list-style-type: none"> <li><b>Core units (1 semester)</b> <ul style="list-style-type: none"> <li>Energy Efficiency, System Analysis and Auditing</li> <li>Environmental Building Services and Energy Efficient Building Design</li> <li>Industrial and Commercial Energy Efficiency</li> <li>Change Management</li> </ul> </li> <li><b>Recommended Electives</b> <ul style="list-style-type: none"> <li>Carbon Management Strategy 2</li> <li>Energy Efficiency and Decarbonisation in Precincts</li> <li>Greenhouse Gas Inventory</li> </ul> </li> </ul>
<b>Medium level</b>	<b>3<sup>rd</sup> year engineering units</b> <ul style="list-style-type: none"> <li>Advanced Thermofluids</li> <li>Energy Policy 1</li> <li>Energy Economics 1</li> <li>Sustainable Energy Business and Project Management</li> <li>Energy Efficiency and Management 1</li> <li>Carbon Management Strategy 1</li> <li>Renewable Energy Systems 1</li> <li>Electricity Network Systems</li> </ul>	<b>YEAR 2</b> <ul style="list-style-type: none"> <li><b>Core units (1 semester)</b> <ul style="list-style-type: none"> <li>Energy Efficiency and Decarbonisation in Precincts</li> <li>Advanced Energy Efficiency</li> </ul> </li> <li><b>Recommended Electives</b> <ul style="list-style-type: none"> <li>Energy Efficiency and Decarbonisation in Precincts</li> <li>Advanced Energy Efficiency</li> </ul> </li> </ul>	<b>Two Electives (see recommended choices above) and Advanced Thesis/Research project (1/2 semester)</b> <p>or</p> <b>Advanced Thesis/Research Project (1 semester)</b>
<b>Advanced level</b>	<b>4<sup>th</sup> year</b> <ul style="list-style-type: none"> <li>Leadership and Ethics</li> <li>Thesis 1 or Internship 1</li> <li>Thesis 2 or Internship 2</li> <li>Energy Efficiency, System Analysis and Auditing                             <ul style="list-style-type: none"> <li>Change Management or Energy Efficiency and Decarbonisation in Precincts</li> </ul> </li> <li>Environmental Building Services and Energy Efficient Building Design</li> <li>Industrial and Commercial Energy Efficiency</li> <li>University breadth/general education unit</li> <li>Recommended Elective                             <ul style="list-style-type: none"> <li>Change Management or Energy Efficiency and Decarbonisation in Precincts</li> </ul> </li> </ul>		

Figure2: Overarching curriculum framework map for an energy efficiency specialisation.

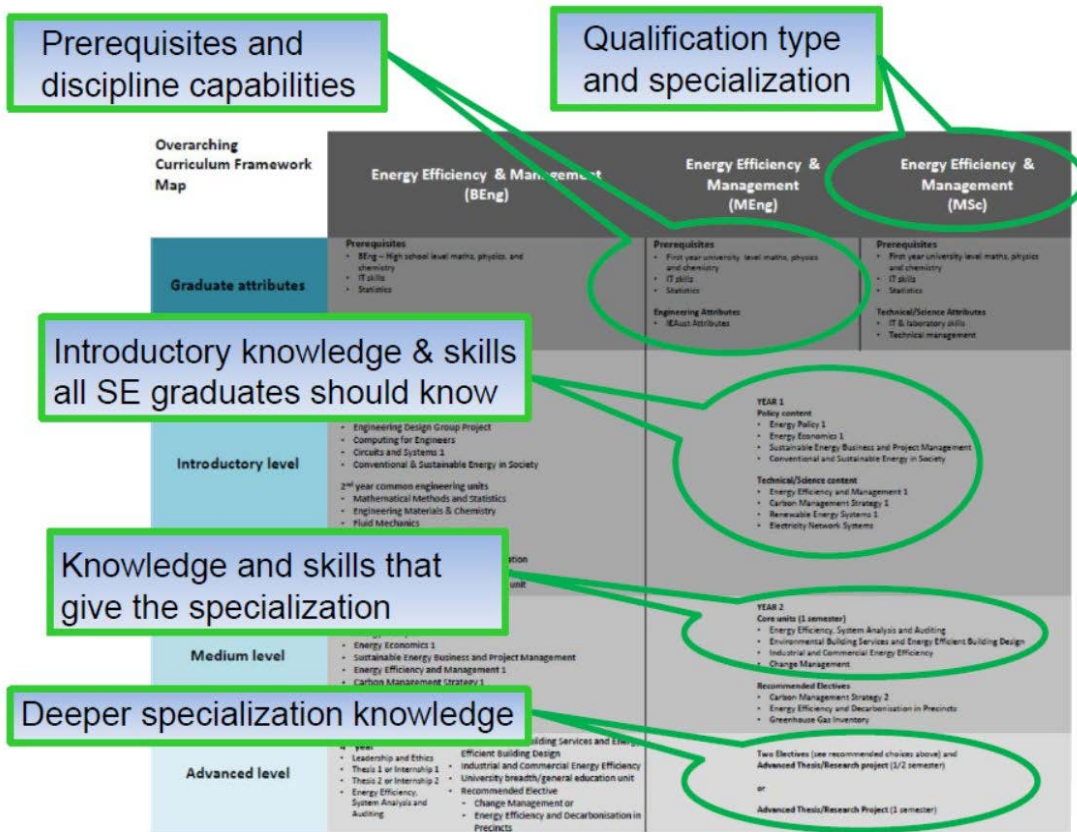


Figure 3: Explanation of major components of a typical overarching curriculum framework map using the example of the energy efficiency specialisation.

Curriculum Framework Learning Outcomes Map	Energy Efficiency & Management (MEng / MSc)			
<b>Introductory level</b>	<p><b>Energy Policy 1</b></p> <ul style="list-style-type: none"> <li>Identify the objectives of energy policy such as economic efficiency, energy conservation, avoiding environmental degradation, economic development, sustainability, government revenue, urban transport, urban settlement, and the development of new energy technologies.</li> <li>Identify and describe contemporary energy policy issues.</li> <li>Recognise energy policy institutions.</li> <li>Describe how energy policy is made and changed.</li> <li>Read and critically analyse energy policy documents.</li> <li>Understand domestic and international energy policies, including community service obligations, industry development, policy instruments and how they are applied.</li> <li>Understanding of the public policy processes and institutions that give rise to the shape, direction and outcomes in the energy sector.</li> <li>Issues in energy policy and the commercialization of renewable energy systems</li> <li>Explain the need for international coordination of energy policies.</li> <li>Explain why particular policy instruments are chosen over others.</li> </ul>	<p><b>Energy Economics 1</b></p> <ul style="list-style-type: none"> <li>Recognise the variety of market structures found in the energy sector.</li> <li>Interpret and discuss the economic and social aspects of renewable and non-renewable energy systems.</li> <li>Understand economic theory relevant to the energy sector (cost benefit analysis, levelised cost, discounted cash flow analysis).</li> <li>Understanding of energy facilities, taxation of the energy sector and role of public utilities and government industry regulations.</li> <li>Define externalities in energy supply systems as the major areas for economic regulation by government.</li> <li>Identify, detail and analyse the techniques used for making investment decisions.</li> <li>Detail the economics of the main support policies that have been used to assist the market penetration of renewable energy technologies.</li> <li>Demonstrate an understanding of mass and energy balance principles and how they relate to economic systems of production.</li> </ul>	<p><b>Sustainable Energy Business and Project Management</b></p> <ul style="list-style-type: none"> <li>Understand the fundamentals of sustainable energy business management.</li> <li>Understand the fundamentals of sustainable energy project management.</li> <li>Understand the RD&amp;D cycle including financing.</li> <li>Understand the importance of safety standards in the energy supply and demand sector.</li> <li>Identify and interpret appropriate AS &amp; ISO quality and environmental management standards, e.g. ISO 90001, ISO 14001.</li> <li>Understand the importance and process of an Environmental &amp; Social Impact Assessment.</li> <li>Understand relevant climate and energy law.</li> <li>Understand the nature of human behaviour within the context of the promotion of environmentally sustainable behaviour.</li> <li>Be able to develop and present a business case for sustainable energy technologies.</li> </ul> <p><b>Carbon Management Strategy 1</b></p> <ul style="list-style-type: none"> <li>Understand the basic science of human induced climate change and identify corresponding impacts at global, regional and local levels.</li> </ul>	<p><b>Conventional &amp; Sustainable Energy in Society</b></p> <ul style="list-style-type: none"> <li>Describe the concept of energy and the associated concept of the conservation of energy.</li> <li>Explain the concept of energy flows through the environment.</li> <li>Understand global context and issues of climate change, sustainability and energy.</li> <li>Explain the patterns of energy production and consumption with respect to a country's stage of development, economy and politics.</li> <li>Link the changing patterns of energy production and consumption to each country's level of development, economy and politics.</li> <li>Explain the principles of energy conversion.</li> <li>Identify major energy consuming sectors and ways of reducing consumption.</li> <li>Discuss energy resources and their social impact in the context of world distribution and monopolisation (OPEC).</li> <li>Discuss the different types of conventional and sustainable energy resources and conversion techniques</li> <li>Identify the social, economic, environmental and technical issues associated with conventional and sustainable energy resources and conversion techniques.</li> </ul>
<b>Learning outcomes</b>	<p><b>Energy Efficiency &amp; Management 1</b></p> <ul style="list-style-type: none"> <li>Explain the concept of energy efficiency.</li> <li>Discuss some of the reasons for inefficient energy systems.</li> <li>Be able to read and interpret a household or industrial electricity meter.</li> <li>Calculate the cost of energy for a facility given the details of the tariff structure.</li> <li>Discuss the effectiveness of labelling programmes and efficiency standards.</li> <li>Set up an effective energy plan based on sound principles.</li> <li>Apply the theory and practice of energy audits and the energy auditing standard.</li> <li>Demonstrate how tariffs apply in energy management schemes.</li> <li>Discuss opportunities for energy management in building design, air conditioning, lighting and industrial plant.</li> <li>Be able to analyse the economic viability of energy management options.</li> <li>Be able to develop an energy management system compliant with the ISO50001 standard.</li> </ul>	<p><b>Renewable Energy Systems 1</b></p> <ul style="list-style-type: none"> <li>Demonstrate an understanding of the operation of the main conventional and sustainable energy systems.</li> <li>Drawing a block diagram of different renewable energy systems showing the layout of the components in the system.</li> <li>Indicating on such diagrams, the power flows that occur within such systems.</li> <li>Describing the role of the various components in these systems.</li> <li>Describe the approaches used in designing and sizing these systems.</li> <li>Understand the relevant system design standards.</li> <li>Undertake simple design and sizing tasks for a number of the systems covered.</li> <li>Demonstrate an ability to use relevant systems design and modelling software.</li> </ul>	<ul style="list-style-type: none"> <li>Understand international &amp; national policies, protocols and frameworks regulating climate change and greenhouse gas (GHG) reduction.</li> <li>Understand how to measure and report GHG emissions and conduct a greenhouse emissions audit for an organisation.</li> <li>Understand the main greenhouse gas emitting sectors in the economy and their expected future growth or reduction.</li> <li>Understand GHG marginal abatement cost (MAC) curves and how to use them to evaluate carbon reduction options.</li> <li>Understand mandatory and voluntary carbon/emissions trading schemes and potential strategies that businesses can adopt to optimise their response.</li> <li>Understand national and international Carbon Offset Standards, and how they enable accreditation of GHG (carbon) offsets and the accreditation of carbon Neutrality for companies and products.</li> <li>Understand how to develop a Carbon Management Response Plan in an organisation.</li> </ul>	<p><b>Electricity Network Systems</b></p> <ul style="list-style-type: none"> <li>Do simple energy and power calculations and calculations based on Ohm's Law including electricity transmission losses.</li> <li>Understand the different types of grids from large scale to mini- or micro-grids.</li> <li>Explain how electricity is distributed through a network (or grid) and describe the various components of an interconnected grid system, proceeding from the generation to the utilization of power.</li> <li>Understand the min transmission and power electronics components and their role in grids</li> <li>Understand the different thermal, physical and chemical energy storage technologies.</li> <li>Understand how the electricity grid is operated and managed and the various grid connection and management issues.</li> <li>Discuss methods for increasing the environmental sustainability of grid power systems.</li> <li>Understand the concept of smart grids.</li> </ul>

Figure 4: A typical learning outcomes map for a MEng or MSc with the energy efficiency specialisation.

Figure 5 and Figure 6 show the link between the overarching curriculum frameworks and the associated learning outcomes maps.

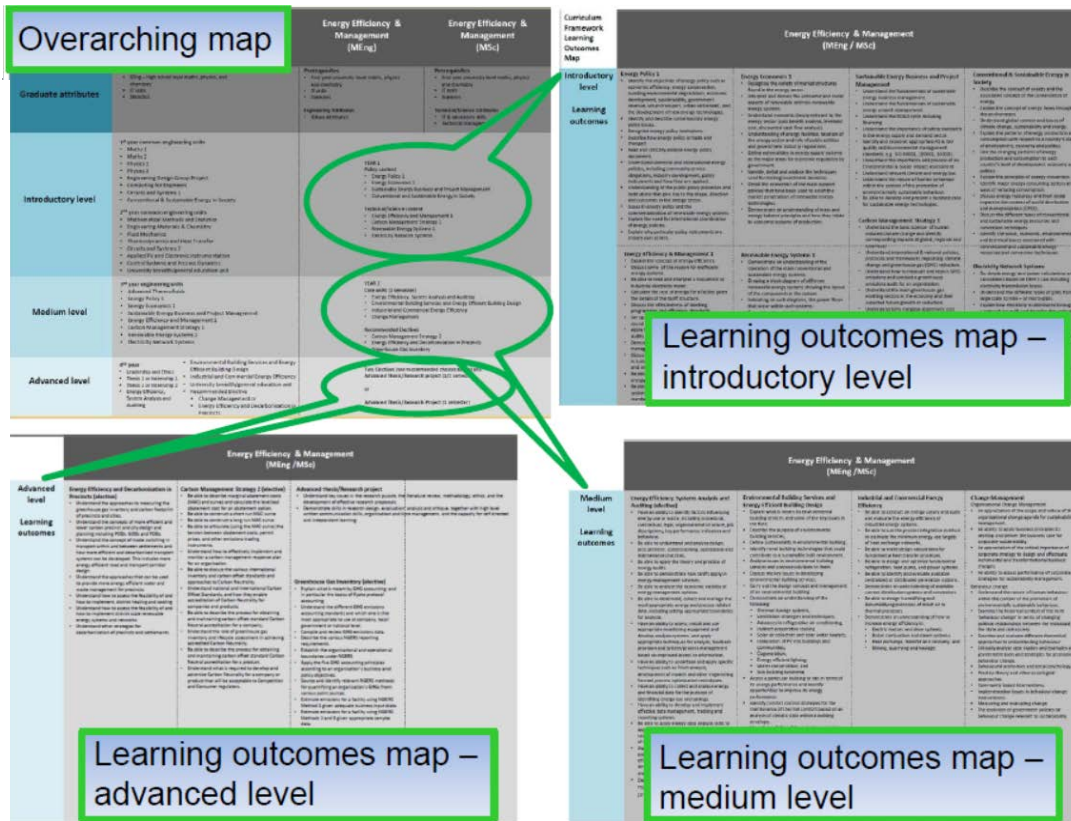


Figure 5: Linkage between the overarching curriculum framework map and the learning outcome maps.

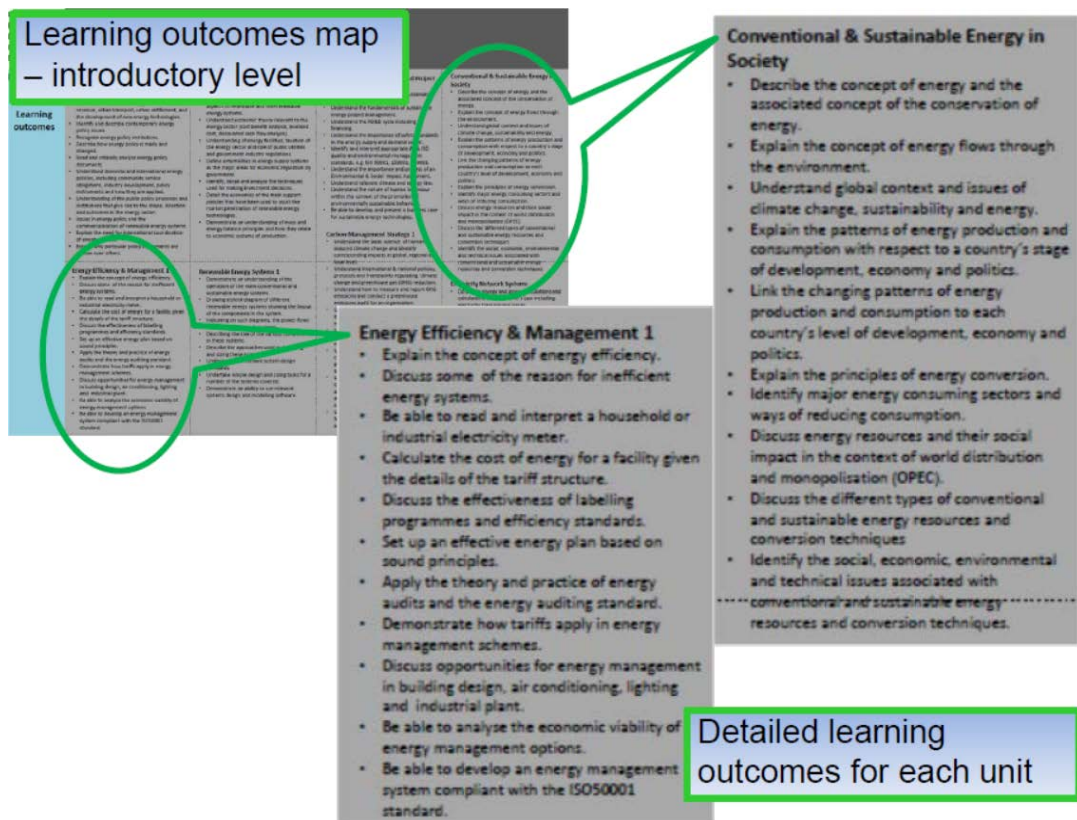


Figure 6: The linkage between the learning outcome map and the learning outcomes lists for each unit.

# Curriculum Framework Set 1: Renewable Energy Systems

The curriculum framework and set of curriculum maps in this section provide guidance for the development of programmes at undergraduate and postgraduate level specializing in **renewable energy systems**.



## Renewable Energy Systems Overarching Curriculum Framework Map

Overarching Curriculum Framework Map	RE Systems (BEng)	RE Systems (MEng)	RE Systems (MSc)
<b>Graduate attributes</b>	<b>Prerequisites</b> <ul style="list-style-type: none"> <li>• BEng – High school level maths, physics, and chemistry</li> <li>• IT skills</li> <li>• Statistics</li> </ul>	<b>Prerequisites</b> <ul style="list-style-type: none"> <li>• MEng - First year university level maths, physics and chemistry</li> <li>• IT skills</li> <li>• Statistics</li> </ul> <b>Engineering Attributes</b> <ul style="list-style-type: none"> <li>• IEAust Attributes</li> </ul> <b>Mech Eng – electrical and transmissions prereq</b> <b>Electrical/power Eng – thermodynamics prereq</b> <b>Other (Civil, Environmental) – thermodynamics, electrical and transmission prereq</b>	<b>Prerequisites</b> <ul style="list-style-type: none"> <li>• First year university level maths, physics and chemistry</li> <li>• IT skills</li> <li>• Statistics</li> </ul> <b>Technical/Science Attributes</b> <ul style="list-style-type: none"> <li>• IT &amp; laboratory skills</li> <li>• Technical management</li> </ul>
<b>Introductory level</b>	<b>1<sup>st</sup> year common engineering units</b> <ul style="list-style-type: none"> <li>• Maths 1</li> <li>• Maths 2</li> <li>• Physics 1</li> <li>• Physics 2</li> <li>• Engineering Design Group Project</li> <li>• Computing for Engineers</li> <li>• Circuits and Systems 1</li> <li>• Conventional &amp; Sustainable Energy in Society</li> </ul>	<b>2<sup>nd</sup> year common engineering units</b> <ul style="list-style-type: none"> <li>• Mathematical Methods and Statistics</li> <li>• Engineering Materials &amp; Chemistry</li> <li>• Fluid Mechanics</li> <li>• Thermodynamics and Heat Transfer</li> <li>• Circuits and Systems 2</li> <li>• Applied PV and Electronic Instrumentation</li> <li>• Control Systems and Process Dynamics</li> <li>• University breadth/general education unit</li> </ul>	<b>YEAR 1</b> <b>Policy content</b> <ul style="list-style-type: none"> <li>• Energy Policy 1</li> <li>• Energy Economics 1</li> <li>• Sustainable Energy Business and Project Management</li> <li>• Conventional and Sustainable Energy in Society</li> </ul> <b>Technical/Science content</b> <ul style="list-style-type: none"> <li>• Energy Efficiency and Management 1</li> <li>• Carbon Management Strategy 1</li> <li>• Renewable Energy Systems 1</li> <li>• Electricity Network Systems</li> </ul>
<b>Medium level</b>  Incl. minimum 500 hours of work experience	<b>3<sup>rd</sup> year engineering units</b> <ul style="list-style-type: none"> <li>• Advanced Thermofluids</li> <li>• Energy Policy 1</li> <li>• Energy Economics 1</li> <li>• Sustainable Energy Business and Project Management</li> <li>• Energy Efficiency and Management 1</li> <li>• Carbon Management Strategy 1</li> <li>• Renewable Energy Systems 1</li> <li>• Electricity Network Systems</li> </ul>		<b>RE Systems content (Choose 4 from)</b> <ul style="list-style-type: none"> <li>• Advanced RE Systems 1 - Solar Photovoltaic</li> <li>• Advanced RE Systems 2 - Solar Thermal</li> <li>• Advanced RE Systems 3 - Wind Energy</li> <li>• Advanced RE systems 4 - Bioenergy</li> <li>• Advanced RE Systems 5 - Remote and Micro-grid RE systems</li> <li>• Advanced RE Systems 6 - Conventional and Emerging RE Systems</li> </ul>
<b>Advanced level</b>	<b>4<sup>th</sup> year specialisation</b> <ul style="list-style-type: none"> <li>• Leadership and Ethics</li> <li>• Thesis 1 or Internship 1</li> <li>• Thesis 2 or Internship 2</li> <li>• Advanced RE Systems 1 - Solar Photovoltaic</li> </ul>	<ul style="list-style-type: none"> <li>• Advanced RE Systems 2 - Solar Thermal</li> <li>• Advanced RE Systems 3 – Wind Energy</li> <li>• Advanced RE systems 4- Bioenergy</li> <li>• Advanced RE Systems 5 - Remote and Micro-grid RE Systems</li> </ul>	<b>Two Recommended Electives (choose from above list or recommended streams below) and Advanced Thesis/Research Project (1/2 semester) or Advanced Thesis/Research Project (1 semester)</b>
<b>Possible Masters Specialisations</b>	<b>RE for Sustainable Development</b> <ul style="list-style-type: none"> <li>• Renewable Energy for Sustainable Development</li> </ul>	<b>Sustainable Transport</b> <ul style="list-style-type: none"> <li>• Sustainable Transport 1 - Technologies and Systems</li> <li>• Sustainable Transport 2 - Alternative Fuels</li> </ul>	<b>Precincts and Buildings</b> <ul style="list-style-type: none"> <li>• Building Integrated Renewable Energy Systems</li> <li>• Environmental Building Services and Energy Efficient Building Design</li> <li>• Energy Efficiency and Decarbonisation in Precincts</li> </ul>

## **Bachelor of Engineering Specializing in Renewable Energy Systems**

This set of curriculum framework learning outcome maps provides guidance for programme coordinators and unit coordinators in the planning and development of an undergraduate Bachelor of Engineering degree with a specialisation in renewable energy systems.



## Learning Outcomes Maps

### Curriculum Framework Learning Outcomes Map

### RE Systems (BEng)

#### Introductory level

#### Learning outcomes

##### Maths 1

- Introduction to differential and integral calculus, and basic ordinary differential equations.

##### Maths 2

- Calculus and matrix algebra form the basis of the mathematical knowledge required to model physical, environmental, biological and engineering systems and investigate their behaviour.
- Vector and matrix operations, determinants, inverses and eigenvalues will be considered along with differentiation, integration, sequences and series, differential equations, introductory multivariable calculus and multiple integration.

##### Physics 1

- Principles of classical physics, including: motion in one and two dimensions, force, Newton's Laws, work, energy, momentum, non linear oscillatory and circular motion, heat, hydrostatics, flow rates, electricity, DC circuits, magnetism.

##### Physics 2

- Engineering foundations, skills and knowledge to understand energy and mass transfer in simple systems.
- Developing practical skills and understanding of the basics of the physical processes.

##### Engineering Design Group Project

- Engineering design, sustainability, climate change, ethics, social justice and engineers' engagement with the community.
- Build key skills for engineers, including concept development, critical thinking and evaluation skills, clear communication, research and information literacy skills and the skills involved in successfully functioning within a team environment to complete a given task.

##### Computing for Engineers

- Microcontroller hardware and computer-based engineering tools, commonly used in Engineering and Science for the design, analysis and operation in various technological domains.
- Hardware-oriented microcontroller laboratory sessions and computer-based workshops.
- Develop programming skills and learn about the constraints of developing for real-time environments.

##### Circuits and Systems 1

- Skills for the analysis of direct current (DC) electrical circuits and systems.
- Fundamentals of electricity, DC circuits, nodal and mesh analysis, superposition and linearity, network laws and theorems, capacitors and inductors, operational amplifiers and their applications, basic RL, RC and RLC circuits and associated natural and forced responses.

##### Conventional & Sustainable Energy in Society

- Describe the concept of energy and the associated concept of the conservation of energy.
- Explain the concept of energy flows through the environment.
- Understand global context and issues of climate change, sustainability and energy.
- Explain the patterns of energy production and consumption with respect to a country's stage of development, economy and politics.
- Link the changing patterns of energy production and consumption to each country's level of development, economy and politics.
- Explain the principles of energy conversion.
- Identify major energy consuming sectors and ways of reducing consumption.
- Discuss energy resources and their social impact in the context of world distribution and monopolisation (OPEC).
- Discuss the different types of conventional and sustainable energy resources and conversion techniques
- Identify the social, economic, environmental and technical issues associated with conventional and sustainable energy resources and conversion techniques.

## RE Systems (BEng)

### Introductory level

### Learning outcomes

#### Mathematical Methods and Statistics

- Fourier series, multivariable calculus, linear algebra and Laplace transforms.
- Exploratory data analysis.
- Probability and distribution theory including binomial, Poisson and normal.
- Large sample theory including the Central Limit Theorem.
- Statistical inference including estimation, confidence intervals and hypothesis testing.
- One-sample and two-sample tests.
- Linear regression.
- Analysis of variance.
- Design and analysis of experiments.
- Applications will be drawn from mechanical, mining, photovoltaic and chemical engineering and surveying.

#### Engineering Materials and Chemistry

- Stoichiometry, atomic and molecular structure, states of matter, equilibrium, oxidation and reduction, electrochemistry.
- An introduction to organic chemistry and polymers.
- Microstructure and structure-property relationships of the main types of engineering materials (metals, ceramics, polymers and composites).
- Micromechanisms of elastic and plastic deformation.
- Fracture mechanisms for ductile, brittle, creep and fatigue modes of failure in service.
- Corrosion.
- Metal forming by casting and wrought processes; phase equilibria of alloys.
- Microstructural control by thermomechanical processing and application to commercial engineering materials.

#### Fluid Mechanics

- Fluid properties.
- Fluids in static equilibrium.
- Buoyancy.
- Pressures in accelerating fluid systems.
- Steady flow energy equations.
- Flow measurement.
- Momentum analysis.
- Dimensional analysis and similarity.
- Pipe flow.
- Incompressible laminar and turbulent flow in pipes; friction factor. Laminar flow between parallel plates and in ducts.
- Elementary boundary layer flow; skin friction and drag.
- Pumps and turbines. Pump and pipeline system characteristics.

#### Thermodynamics and Heat Transfer

- Thermodynamic concepts, systems, property, state, path, process.
- Work and heat.
- Properties of pure substances, tables of properties and equations of state.
- First law of thermodynamics.
- Analysis of closed and open systems.
- Second law of thermodynamics, Carnot cycle, Clausius inequality, entropy, irreversibility, isentropic efficiencies.
- Air-standard cycles. Vapour cycles.

#### Circuits and Systems 2

- Analysis of alternating current (AC) electrical circuits and systems.
- Steady-state analysis of circuits with sinusoidal excitation, the different types of power associated with AC circuits, three-phase circuits, magnetically coupled circuits, frequency response, resonance, bandwidth, two port networks, and principles of electromechanics.

#### Applied PV and Electronic Instrumentation

- Understand and explain the operation of different components of photovoltaic systems.
- Evaluate and understand a variety of photovoltaic applications.
- Gain an appreciation of the issues related to photovoltaic technology.
- Background in analog electronics and instrumentation
- Ability to select the most appropriate instrumentation system for a given engineering measurement and control problem.
- System design is focused on stand-alone PV systems but other specific applications such as Remote Area Power Supply systems and Grid-Connected PV systems.

#### Control Systems and Process Dynamics

- Foundations in the dynamics, modeling and control of process-oriented systems.

#### University breadth/general education unit

- Understanding and communication across the sciences, technologies, engineering, mathematics, social sciences, humanities, business education and law.

## RE Systems (BEng)

**Medium  
level**

**Learning  
outcomes**

**Incl.  
minimum  
500 hours of  
work  
experience**

### Advanced Thermo fluids

- Basic concepts of heat transfer, units, dimensions, exchange mechanism. Steady-state conduction, multi-dimensional conduction. Structure of boundary layers. Internal and external laminar and turbulent forced convection. Heat exchanger design. Radiative heat transfer. Dimensional analysis. Modelling of turbomachines and thermal systems. Experiments and heat transfer measurements. Utilisation of energy, availability — open and closed systems; generalised thermodynamic relations; kinetic theory of gases; non-reactive ideal gas mixtures. Combustion, chemical equilibrium, chemical kinetics and emission control. Compressible flow.

### Energy Efficiency & Management 1

- Explain the concept of energy efficiency.
- Discuss some of the reason for inefficient energy systems.
- Be able to read and interpret a household or industrial electricity meter.
- Calculate the cost of energy for a facility given the details of the tariff structure.
- Discuss the effectiveness of labelling programmes and efficiency standards.
- Set up an effective energy plan based on sound principles.
- Apply the theory and practice of energy audits and the energy auditing standard.
- Demonstrate how tariffs apply in energy management schemes.
- Discuss opportunities for energy management in building design, air conditioning, lighting and industrial plant.
- Be able to analyse the economic viability of energy management options.
- Be able to develop an energy management system compliant with the ISO50001 standard.

### Energy Policy 1

- Identify the objectives of energy policy such as economic efficiency, energy conservation, avoiding environmental degradation, economic development, sustainability, government revenue, urban transport, urban settlement, and the development of new energy technologies.
- Identify and describe contemporary energy policy issues.
- Recognise energy policy institutions.
- Describe how energy policy is made and changed.
- Read and critically analyse energy policy documents.
- Understand domestic and international energy policies, including community service obligations, industry development, policy instruments and how they are applied.
- Understanding of the public policy processes and institutions that give rise to the shape, direction and outcomes in the energy sector.
- Issues in energy policy and the commercialization of renewable energy systems
- Explain the need for international coordination of energy policies.
- Explain why particular policy instruments are chosen over others.

### Renewable Energy Systems 1

- Demonstrate an understanding of the operation of the main conventional and sustainable energy systems.
- Drawing a block diagram of different renewable energy systems showing the layout of the components in the system.
- Indicating on such diagrams, the power flows that occur within such systems.
- Describing the role of the various components in these systems.
- Describe the approaches used in designing and sizing these systems.
- Understand the relevant system design standards.
- Undertake simple design and sizing tasks for a number of the systems covered.
- Demonstrate an ability to use relevant systems design and modelling software.

### Energy Economics 1

- Recognise the variety of market structures found in the energy sector.
- Interpret and discuss the economic and social aspects of renewable and non-renewable energy systems.
- Understand economic theory relevant to the energy sector (cost benefit analysis, levelised cost, discounted cash flow analysis).
- Understanding of energy facilities, taxation of the energy sector and role of public utilities and government industry regulations.
- Define externalities in energy supply systems as the major areas for economic regulation by government.
- Identify, detail and analyse the techniques used for making investment decisions.
- Detail the economics of the main support policies that have been used to assist the market penetration of renewable energy technologies.
- Demonstrate an understanding of mass and energy balance principles and how they relate to economic systems of production.

### Electricity Network Systems

- Do simple energy and power calculations and calculations based on Ohm's Law including electricity transmission losses.
- Understand the different types of grids from large scale to mini – or micro-grids.
- Explain how electricity is distributed through a network (or grid) and describe the various components of an interconnected grid system, proceeding from the generation to the utilization of power.
- Understand the min transmission and power electronics components and their role in grids
- Understand the different thermal, physical and chemical energy storage technologies.
- Understand how the electricity grid is operated and managed and the various grid connection and management issues.
- Discuss methods involving both new and conventional technologies for increasing the efficiency and environmental sustainability of grid power systems.
- Understand the concept of smart grids.

### Sustainable Energy Business and Project Management

- Understand the fundamentals of sustainable energy business management.
- Understand the fundamentals of sustainable energy project management.
- Understand the RD&D cycle including financing.
- Understand the importance of safety standards in the energy supply and demand sector.
- Identify and interpret appropriate AS & ISO quality and environmental management standards. e.g. ISO 90001, 150001, 140001.
- Understand the importance and process of an Environmental & Social Impact Assessment.
- Understand relevant climate and energy law.
- Understand the nature of human behaviour within the context of the promotion of environmentally sustainable behaviour.
- Be able to develop and present a business case for sustainable energy technologies.

### Carbon Management Strategy 1

- Understand the basic science of human induced climate change and identify corresponding impacts at global, regional and local level.
- Understand international & national policies, protocols and frameworks regulating climate change and greenhouse gas (GHG) reduction.
- Understand how to measure and report GHG emissions and conduct a greenhouse emissions audit for an organisation.
- Understand the main greenhouse gas emitting sectors in the economy and their expected future growth or reduction.
- Understand GHG marginal abatement cost (MAC) curves and how to use them to evaluate carbon reduction options.
- Understand mandatory and voluntary carbon/emissions trading schemes and potential strategies that businesses can adopt to optimise their response.
- Understand national and international Carbon Offset Standards, and how they enable accreditation of GHG (carbon) offsets and the accreditation of Carbon Neutrality for companies and products.
- Understand how to develop a Carbon Management Response Plan in an organisation.

## RE Systems (BEng)

### Advanced Learning outcomes

#### Leadership and Ethics

- Strategic management – the management of both human and financial resources.
- The law – as it relates to contract and tort, copyright and intellectual property.
- Ethics – the engineering code of ethics and its operation in engineering practice.
- Professionalism – the roles and responsibilities of the professional engineer.

#### Advanced RE Systems 4 - Bioenergy

- Have a good understanding of what “biomass” and “bioenergy” are and the various forms of biomass materials.
- Know how to identify and quantify different biomass resources including:
  - Woody biomass;
  - Non-woody biomass; and
  - Dry and liquid waste.
- Be familiar with the biomass supply chain including harvesting, transport and processing;
- Have an appreciation of the complexities and costs associated with biomass delivery.
- Have an understanding of biomass processing and the transformation of biomass into bioenergy. This includes:
  - Thermal biomass conversion;
  - Biochemical conversion of waste biomass resources; and
  - Landfill gas utilisation;
- Be familiar with biomass feedstocks suitable for biodiesel, bioethanol, biogas and bio-oil and understand the production process for biofuels.
- Have an understanding of the limitations of various conversion technologies for transforming biomass into (heat, power, electricity, transport fuels) useful energy products.
- Understand the concept of using biomass fuels to displace fossil fuels and be able to highlight the environmental and social aspects of using biomass for energy purposes.

#### Thesis 1

- Exposure to, and experience with, a significant engineering project, with emphasis upon industrially based projects.
- Involves elements of specification, design, implementation, testing, documentation, demonstration and presentation. .

or

#### Internship 1

- Exposure to industrial engineering projects and involves elements of specification, design, implementation, testing, documentation, demonstration and presentation.
- Prepare a project report, deliver seminars describing the project, and attend meetings with academic and industry supervisors as required.

#### Advanced RE Systems 1 – Solar Photovoltaic

- Be able to calculate the position of the sun, the incidence of solar radiation on a plane and the available solar resource.
- Be able to discuss common applications for common stand-alone and grid applications.
- Be able to describe components of either a standalone or grid-connected photovoltaic system.
- Understand the process of designing, commissioning and testing simple PV systems including:
  - Simulation and system design;
  - Component sizing, housings and layout;
  - Cabling and earthing;
  - Commissioning and testing;
  - Monitoring and
  - Safety and standards.
- Understand the current environment with respect to grid connected systems and the possible benefits and limitations of distributed generation.

#### Thesis 2

- Exposure to, and experience with, a significant engineering project, with emphasis upon industrially based projects.
- Involves elements of specification, design, implementation, testing, documentation, demonstration and presentation.
- Thesis 2 can build on and extend Thesis 1 or be a separate project.

or

#### Internship 2

- Exposure to industrial engineering projects and involves elements of specification, design, implementation, testing, documentation, demonstration and presentation.
- Prepare a project report, deliver seminars describing the project, and attend meetings with academic and industry supervisors as required.
- Internship 2 can build on and extend Internship 1 or be a separate project.

#### Advanced RE Systems 2 – Solar Thermal

- Have a good understanding of the techniques for exploiting solar radiation for thermal applications at low, medium and high temperatures.
- Be able to specify, design and install solar thermal systems.
- Understand and explain the characteristics of solar radiation, selective surfaces and heat exchangers.
- Be able to specify and design low temperature applications – water and space heating.
- Be able to specify and design absorption chillers.
- Be able to specify and design medium temperature applications – process heat for industry.
- Be able to specify and design high temperature applications – steam cycle electricity generation, solar chemistry.
- Be able to specify and design thermal storage systems.

#### Advanced RE Systems 3 – Wind Energy

- Have a good understanding of the engineering aspects of wind energy technology including:
  - Wind monitoring;
  - Design, manufacture and performance of wind turbine components;
  - Power conditioning;
  - Control and safety;
  - planning, design and installation of wind farms and small wind systems; and
  - Environmental and social issues.
- Be able to design and calibrate a wind monitoring system.
- Be able to analyse recorded wind data and predict long term wind behaviour.
- Be able to analyse the performance of a wind turbine.
- Understand the design aspects of the installation of a small wind system .
- Be able to design the layout of a wind farm subject to environmental and social constraints.

#### Advanced RE Systems 5 - Remote and Micro-grid RE systems

- Be able to describe the typical components of a Remote Area Power Supply (RAPS) system .
- Be able to discuss different types of RAPS systems and in each case describe the typical features of the system load profile.
- Be able to discuss the advantages and disadvantages of diesel hybrid systems and describe the operation of these systems.
- Be able to sketch and describe the different configurations of diesel hybrid systems and describe the operation of these systems.
- Be able to calculate the daily performance of different hybrid systems by analysing the hour by hour operation of the systems.
- Understand the process of designing, commissioning and testing of RAPS systems including:
  - Simulation and system design;
  - Component sizing, housings and layout;
  - Cabling and earthing;
  - Commissioning and testing;
  - Monitoring and
  - Safety and standards.
- Be able to use computer programs to estimate the performance and economics of RAPS and micro-grid systems.

## **Master of Engineering or Master of Science Specializing in Renewable Energy Systems**

This set of curriculum framework learning outcome maps provides guidance for programme coordinators and unit coordinators in the planning and development of a postgraduate coursework Masters of Engineering or Master of Science degree with a specialisation in renewable energy systems.

## Learning Outcomes Maps

### Curriculum Framework Learning Outcomes Map

#### RE Systems (MEng/MSc)

#### Introductory level

#### Learning outcomes

<p><b>Conventional &amp; Sustainable Energy in Society</b></p> <ul style="list-style-type: none"> <li>Describe the concept of energy and the associated concept of the conservation of energy.</li> <li>Explain the concept of energy flows through the environment.</li> <li>Understand global context and issues of climate change, sustainability and energy.</li> <li>Explain the patterns of energy production and consumption with respect to a country's stage of development, economy and politics.</li> <li>Link the changing patterns of energy production and consumption to each country's level of development, economy and politics.</li> <li>Explain the principles of energy conversion.</li> <li>Identify major energy consuming sectors and ways of reducing consumption.</li> <li>Discuss energy resources and their social impact in the context of world distribution and monopolisation (OPEC).</li> <li>Discuss the different types of conventional and sustainable energy resources and conversion techniques</li> <li>Identify the social, economic, environmental and technical issues associated with conventional and sustainable energy resources and conversion techniques.</li> </ul>	<p><b>Energy Policy 1</b></p> <ul style="list-style-type: none"> <li>Identify the objectives of energy policy such as economic efficiency, energy conservation, avoiding environmental degradation, economic development, sustainability, government revenue, urban transport, urban settlement, and the development of new energy technologies.</li> <li>Identify and describe contemporary energy policy issues.</li> <li>Recognise energy policy institutions.</li> <li>Describe how energy policy is made and changed.</li> <li>Read and critically analyse energy policy documents.</li> <li>Understand domestic and international energy policies, including community service obligations, industry development, policy instruments and how they are applied.</li> <li>Understanding of the public policy processes and institutions that give rise to the shape, direction and outcomes in the energy sector.</li> <li>Issues in energy policy and the commercialization of renewable energy systems</li> <li>Explain the need for international coordination of energy policies.</li> <li>Explain why particular policy instruments are chosen over others.</li> </ul>	<p><b>Energy Economics 1</b></p> <ul style="list-style-type: none"> <li>Recognise the variety of market structures found in the energy sector.</li> <li>Interpret and discuss the economic and social aspects of renewable and non-renewable energy systems.</li> <li>Understand economic theory relevant to the energy sector (cost benefit analysis, levelised cost, discounted cash flow analysis).</li> <li>Understanding of energy facilities, taxation of the energy sector and role of public utilities and government industry regulations.</li> <li>Define externalities in energy supply systems as the major areas for economic regulation by government.</li> <li>Identify, detail and analyse the techniques used for making investment decisions.</li> <li>Detail the economics of the main support policies that have been used to assist the market penetration of renewable energy technologies.</li> <li>Demonstrate an understanding of mass and energy balance principles and how they relate to economic systems of production.</li> </ul>	<p><b>Carbon Management Strategy 1</b></p> <ul style="list-style-type: none"> <li>Understand the basic science of human induced climate change and identify corresponding impacts at global, regional and local level.</li> <li>Understand international &amp; national policies, protocols and frameworks regulating climate change and greenhouse gas (GHG) reduction.</li> <li>Understand how to measure and report GHG emissions and conduct a greenhouse emissions audit for an organisation.</li> <li>Understand the main greenhouse gas emitting sectors in the economy and their expected future growth or reduction.</li> <li>Understand GHG marginal abatement cost (MAC) curves and how to use them to evaluate carbon reduction options.</li> <li>Understand mandatory and voluntary carbon/emissions trading schemes and potential strategies that businesses can adopt to optimise their response.</li> <li>Understand national and international Carbon Offset Standards, and how they enable accreditation of GHG (carbon) offsets and the accreditation of Carbon Neutrality for companies and products.</li> <li>Understand how to develop a Carbon Management Response plan in an organisation.</li> </ul>
<p><b>Sustainable Energy Business and Project Management</b></p> <ul style="list-style-type: none"> <li>Understand the fundamentals of sustainable energy business management.</li> <li>Understand the fundamentals of sustainable energy project management.</li> <li>Understand the RD&amp;D cycle including financing.</li> <li>Understand the importance of safety standards in the energy supply and demand sector.</li> <li>Identify and interpret appropriate AS &amp; ISO quality and environmental management standards. e.g. ISO 90001, 150001, 140001.</li> <li>Understand the importance and process of an Environmental &amp; Social Impact Assessment.</li> <li>Understand relevant climate and energy law.</li> <li>Understand the nature of human behaviour within the context of the promotion of environmentally sustainable behaviour.</li> <li>Be able to develop and present a business case for sustainable energy technologies.</li> </ul>	<p><b>Electricity Network Systems</b></p> <ul style="list-style-type: none"> <li>Do simple energy and power calculations and calculations based on Ohm's Law including electricity transmission losses.</li> <li>Understand the different types of grids from large scale to mini – or micro-grids.</li> <li>Explain how electricity is distributed through a network (or grid) and describe the various components of an interconnected grid system, proceeding from the generation to the utilization of power.</li> <li>Understand the min transmission and power electronics components and their role in grids</li> <li>Understand the different thermal, physical and chemical energy storage technologies.</li> <li>Understand how the electricity grid is operated and managed and the various grid connection and management issues.</li> <li>Discuss methods involving both new and conventional technologies for increasing the efficiency and environmental sustainability of grid power systems.</li> <li>Understand the concept of smart grids.</li> </ul>	<p><b>Energy Efficiency &amp; Management 1</b></p> <ul style="list-style-type: none"> <li>Explain the concept of energy efficiency.</li> <li>Discuss some of the reason for inefficient energy systems.</li> <li>Be able to read and interpret a household or industrial electricity meter.</li> <li>Calculate the cost of energy for a facility given the details of the tariff structure.</li> <li>Discuss the effectiveness of labelling programmes and efficiency standards.</li> <li>Set up an effective energy plan based on sound principles.</li> <li>Apply the theory and practice of energy audits and the energy auditing standard.</li> <li>Demonstrate how tariffs apply in energy management schemes.</li> <li>Discuss opportunities for energy management in building design, air conditioning, lighting and industrial plant.</li> <li>Be able to analyse the economic viability of energy management options.</li> <li>Be able to develop an energy management system compliant with the ISO50001 standard.</li> </ul>	<p><b>Renewable Energy Systems 1</b></p> <ul style="list-style-type: none"> <li>Demonstrate an understanding of the operation of the main conventional and sustainable energy systems.</li> <li>Drawing a block diagram of different renewable energy systems showing the layout of the components in the system.</li> <li>Indicating on such diagrams, the power flows that occur within such systems.</li> <li>Describing the role of the various components in these systems.</li> <li>Describe the approaches used in designing and sizing these systems.</li> <li>Understand the relevant system design standards.</li> <li>Undertake simple design and sizing tasks for a number of the systems covered.</li> <li>Demonstrate an ability to use relevant systems design and modelling software.</li> </ul>

## RE Systems (Meng/MSc)

### Medium level

### Learning outcomes

#### Advanced RE Systems 1 – Solar Photovoltaic

- Be able to calculate the position of the sun, the incidence of solar radiation on a plane and the available solar resource.
- Be able to discuss common applications for common stand-alone and grid applications.
- Be able to describe components of either a standalone or grid-connected photovoltaic system.
- Understand the process of designing, commissioning and testing simple PV systems including:
  - Simulation and system design;
  - Component sizing, housings and layout;
  - Cabling and earthing;
  - Commissioning and testing;
  - Monitoring; and
  - Safety and standards.
- Understand the current environment with respect to grid connected systems and the possible benefits and limitations of distributed generation.

#### Advanced RE Systems 3 – Wind Energy

- Have a good understanding of the engineering aspects of wind energy technology including:
  - Wind monitoring;
  - Design, manufacture and performance of wind turbine components;
  - Power conditioning;
  - Control and safety;
  - Planning, design and installation of wind farms and small wind systems; and
  - Environmental and social issues.
- Be able to design and calibrate a wind monitoring system.
- Be able to analyse recorded wind data and predict long term wind behaviour.
- Be able to analyse the performance of a wind turbine.
- Understand the design aspects of the installation of a small wind system .
- Be able to design the layout of a wind farm subject to environmental and social constraints.

#### Advanced RE Systems 2 – Solar Thermal

- Have a good understanding of the techniques for exploiting solar radiation for thermal applications at low, medium and high temperatures.
- Be able to specify, design and install solar thermal systems.
- Understand and explain the characteristics of solar radiation, selective surfaces and heat exchangers.
- Be able to specify and design low temperature applications – water and space heating.
- Be able to specify and design absorption chillers.
- Be able to specify and design medium temperature applications – process heat for industry.
- Be able to specify and design high temperature applications – steam cycle electricity generation, solar chemistry.
- Be able to specify and design thermal storage systems.

#### Advanced RE Systems 5 - Remote and Micro-grid RE systems

- Be able to describe the typical components of a Remote Area Power Supply (RAPS) system.
- Be able to discuss different types of RAPS systems and in each case describe the typical features of the system load profile.
- Be able to discuss the advantages and disadvantages of diesel hybrid systems and describe the operation of these systems.
- Be able to sketch and describe the different configurations of diesel hybrid systems and describe the operation of these systems.
- Be able to calculate the daily performance of different hybrid systems by analysing the hour by hour operation of the systems.
- Understand the process of designing, commissioning and testing of RAPS systems including:
  - Simulation and system design;
  - Component sizing, housings and layout;
  - Cabling and earthing;
  - Commissioning and testing;
  - Monitoring; and
  - Safety and standards.
- Be able to use computer programs to estimate the performance and economics of RAPS and micro-grid systems.

#### Advanced Thesis/Research Project

- Understand key issues in the research puzzle, the literature review, methodology, ethics, and the development of effective research proposals.
- Demonstrate skills in research design, evaluation, analysis and critique, together with high level written communication skills, organisation and time management, and the capacity for self directed and independent learning.

#### Advanced RE Systems 6 - Conventional and Emerging RE Systems

- Have a good understanding of the various forms of conventional renewable energy generation such as hydro-electric and geothermal.
- Have a good understanding of the various forms of emerging technologies such as wave, tidal and OTEC.
- Be able to identify and quantify the resources for these technologies.
- Be able to describe how these renewable systems work and their key components.
- Be able to undertake simple system sizing and design calculations for the different types of system.
- Have an understanding of the complexities and costs associated with delivery of hydro, geothermal, wave and tidal resources.

#### Advanced RE Systems 4 - Bioenergy

- Have a good understanding of what "biomass" and "bioenergy" are and the various forms of biomass materials.
- Know how to identify and quantify different biomass resources including:
  - Woody biomass;
  - Non-woody biomass; and
  - Dry and liquid waste.
- Be familiar with the biomass supply chain including harvesting, transport and processing.
- Have an appreciation of the complexities and costs associated with biomass delivery.
- Have an understanding of biomass processing and the transformation of biomass into bioenergy. This includes:
  - Thermal biomass conversion;
  - Biochemical conversion of waste biomass resources; and
  - Landfill gas utilisation;
- Be familiar with biomass feedstocks suitable for biodiesel, bioethanol, biogas and bio-oil and understand the production process for biofuels.
- Have an understanding of the limitations of various conversion technologies for transforming biomass into (heat, power, electricity, transport fuels) useful energy products.
- Understand the concept of using biomass fuels to displace fossil fuels and be able to highlight the environmental and social aspects of using biomass for energy purposes.

## RE Systems (MEng/MSc)

### Advanced level

### Learning outcomes

#### Building Integrated Renewable Energy Systems (elective)

- Be able to design buildings that are climate-appropriate, implementing energy efficiency measures and producing energy from renewable sources.
- Be able to use techniques for prediction of building thermal, lighting performance and solar access, and energy efficient design.
- Be able to use building energy simulation software.
- Understand what is required for the integration of renewable energy systems into the building envelope including technical issues related to the use of PV and wind in buildings and the urban environment such as partial shading, mismatch and system sizing and configuration.
- Be able to undertake system performance assessment and prediction.

#### Sustainable Transport 2 - Alternative Fuels (elective)

- Understand the different conventional and emerging biofuels suitable for transport use including:
  - Biodiesel;
  - Bioethanol;
  - Biomethane; and
  - Biobutanol and methanol.
- Understand where and how each biofuel may be used in transport applications.
- Be able to undertake a feedstock analysis for the different biofuel types.
- Understand how each biofuel is made.
- Understand the conventional and emerging ways of using hydrogen as a fuel in transport applications.
- Understand the hydrogen production and use cycle including:
  - Production processes;
  - Distribution and Storage; and
  - Use (e.g. fuel cells).
- Understand the socio economic and environmental impacts of using biofuels for transport applications.
- Be able to do LCA and systems analysis for biofuels and their systems.
- Understand the different policy and regulatory options for promoting the use of biofuels.
- Be able to apply the Quality and Risk Management processes to biofuel systems.

#### Environmental Building Services and Energy Efficient Building Design (elective)

- Explain what is meant by environmental building services and some of the key issues in the field.
- Describe the purpose of environmental building services.
- Define sustainability in environmental building;
- Identify novel building technologies that could contribute to a sustainable built environment.
- Analyse issues in environmental building services and propose solutions to them.
- Discuss the key issues in developing environmental building services.
- Carry out the design concept and management of an environmental building.
- Demonstrate an understanding of the following:
  - Thermal storage systems;
  - Ventilation strategies and techniques;
  - Advances in refrigerative air conditioning;
  - Indirect evaporative cooling;
  - Solar air collectors and solar water heaters;
  - Integration of PV into buildings and communities;
  - Cogeneration;
  - Energy efficient lighting;
  - Water conservation; and
  - Sick building syndrome.
- Assess a particular building or site in terms of its energy performance and identify opportunities to improve its energy performance.
- Identify comfort control strategies for the maintenance of thermal comfort based on an analysis of climatic data within a building envelope.
- Use solar radiation data and solar geometry tools to evaluate solar access for a building.
- Understand the scientific basis behind heat flow calculations and identify the factors which affect heat transfer into and out of buildings.

#### Sustainable Energy Solutions for Developing Countries (elective)

- Understand how to improve the use of traditional energy uses in developing countries including:
  - Human and animal power;
  - Fuelwood and charcoal; and
  - Crop residues.
- Understand the options for using renewable energy sources to enhance sustainable development and meet energy needs in developing countries, including:
  - Small scale renewable energy systems;
  - Electrification using solar;
  - Cooking with renewable energy; and
  - Wind and solar power.
- Understand the options for using transport and biofuels in developing countries.
- Understand what must be considered to achieve successful implementation of sustainable energy in developing countries. This includes the role of the following enablers:
  - Technology selection and transfer;
  - Gender issues
  - Markets and microfinance; and
  - Project planning.

#### Energy Efficiency and Decarbonisation in Precincts (elective)

- Understand the approaches to measuring the greenhouse gas inventory and carbon footprint of precincts and cities.
- Understand the concepts of more efficient and lower carbon precinct and city design and planning including PODs, GODs and TODs.
- Understand the concept of mode switching in transport within and between settlements and how more efficient and decarbonised transport systems can be developed. This includes more energy efficient road and transport corridor design.
- Understand the approaches that can be used to provide more energy efficient water and waste management for precincts.
- Understand how to assess the feasibility of and how to implement, district heating and cooling
- Understand how to assess the feasibility of and how to implement district scale renewable energy systems and networks.
- Understand other strategies for decarbonisation of precincts and settlements.

#### Sustainable Transport 1 - Technologies and Systems (elective)

- Be able to explain the performance, characteristics, engine and drive train design of conventional Internal Combustion Engine (ICE) vehicles.
- Be able to explain how to design more efficient ICE vehicles.
- Understand and be able to explain the design and operation of electric and hybrid vehicles and their components including:
  - Power electronics;
  - Electric propulsion systems;
  - Energy storage devices;
  - Traction motor and transmission;
  - Regenerative braking and energy recovery; and
  - Control and monitoring systems.
- Be able to explain the different types of hybrid vehicles including:
  - Series and parallel systems; and
  - Torque and speed coupling.
- Be able to simulate and predict electric and hybrid vehicle performance.
- Understand the options for smart transport networks and network technology.
- Be able to undertake transport systems analysis to improve their performance.
- Be able to explain the use of information and communication technologies for improved network performance.
- Be able to explain the concept of intelligent transport systems.
- Understand the role of transport economics and pricing in system performance.
- Understand the scope and role of pricing mechanisms and regulation in transport markets.
- Understand the institutional, organisational and political factors in the deployment of transport systems.



# Curriculum Framework Set 2: Energy Efficiency

The curriculum framework and set of curriculum maps in this section provide guidance for the development of programmes at undergraduate and postgraduate level specializing in energy efficiency.



## Energy Efficiency Overarching Curriculum Framework Map

Overarching Curriculum Framework Map	Energy Efficiency & Management (BEng)	Energy Efficiency & Management (MEng)	Energy Efficiency & Management (MSc)
<b>Graduate attributes</b>	<b>Prerequisites</b> <ul style="list-style-type: none"> <li>BEng – High school level maths, physics, and chemistry</li> <li>IT skills</li> <li>Statistics</li> </ul>	<b>Prerequisites</b> <ul style="list-style-type: none"> <li>First year university level maths, physics and chemistry</li> <li>IT skills</li> <li>Statistics</li> </ul> <b>Engineering Attributes</b> <ul style="list-style-type: none"> <li>IEAust Attributes</li> </ul>	<b>Prerequisites</b> <ul style="list-style-type: none"> <li>First year university level maths, physics and chemistry</li> <li>IT skills</li> <li>Statistics</li> </ul> <b>Technical/Science Attributes</b> <ul style="list-style-type: none"> <li>IT &amp; laboratory skills</li> <li>Technical management</li> </ul>
<b>Introductory level</b>	<b>1<sup>st</sup> year common engineering units</b> <ul style="list-style-type: none"> <li>Maths 1</li> <li>Maths 2</li> <li>Physics 1</li> <li>Physics 2</li> <li>Engineering Design Group Project</li> <li>Computing for Engineers</li> <li>Circuits and Systems 1</li> <li>Conventional &amp; Sustainable Energy in Society</li> </ul> <b>2<sup>nd</sup> year common engineering units</b> <ul style="list-style-type: none"> <li>Mathematical Methods and Statistics</li> <li>Engineering Materials &amp; Chemistry</li> <li>Fluid Mechanics</li> <li>Thermodynamics and Heat Transfer</li> <li>Circuits and Systems 2</li> <li>Applied PV and Electronic Instrumentation</li> <li>Control Systems and Process Dynamics</li> <li>University breadth/general education unit</li> </ul>	<b>YEAR 1</b> <b>Policy content</b> <ul style="list-style-type: none"> <li>Energy Policy 1</li> <li>Energy Economics 1</li> <li>Sustainable Energy Business and Project Management</li> <li>Conventional and Sustainable Energy in Society</li> </ul> <b>Technical/Science content</b> <ul style="list-style-type: none"> <li>Energy Efficiency and Management 1</li> <li>Carbon Management Strategy 1</li> <li>Renewable Energy Systems 1</li> <li>Electricity Network Systems</li> </ul>	
<b>Medium level</b>	<b>3<sup>rd</sup> year engineering units</b> <ul style="list-style-type: none"> <li>Advanced Thermofluids</li> <li>Energy Policy 1</li> <li>Energy Economics 1</li> <li>Sustainable Energy Business and Project Management</li> <li>Energy Efficiency and Management 1</li> <li>Carbon Management Strategy 1</li> <li>Renewable Energy Systems 1</li> <li>Electricity Network Systems</li> </ul>	<b>YEAR 2</b> <b>Core units (1 semester)</b> <ul style="list-style-type: none"> <li>Energy Efficiency, System Analysis and Auditing</li> <li>Environmental Building Services and Energy Efficient Building Design</li> <li>Industrial and Commercial Energy Efficiency</li> <li>Change Management</li> </ul> <b>Recommended Electives</b> <ul style="list-style-type: none"> <li>Carbon Management Strategy 2</li> <li>Energy Efficiency and Decarbonisation in Precincts</li> <li>Greenhouse Gas Inventory</li> </ul>	
<b>Advanced level</b>	<b>4<sup>th</sup> year</b> <ul style="list-style-type: none"> <li>Leadership and Ethics</li> <li>Thesis 1 or Internship 1</li> <li>Thesis 2 or Internship 2</li> <li>Energy Efficiency, System Analysis and Auditing</li> </ul>	<ul style="list-style-type: none"> <li>Environmental Building Services and Energy Efficient Building Design</li> <li>Industrial and Commercial Energy Efficiency</li> <li>University breadth/general education unit</li> <li>Recommended Elective                             <ul style="list-style-type: none"> <li>Change Management or</li> <li>Energy Efficiency and Decarbonisation in Precincts</li> </ul> </li> </ul>	
		<b>Two Electives (see recommended choices above) and Advanced Thesis/Research project (1/2 semester)</b>  or  <b>Advanced Thesis/Research Project (1 semester)</b>	

## **Bachelor of Engineering Specializing in in Energy Efficiency**

This set of curriculum framework learning outcome maps provides guidance for programme coordinators and unit coordinators in the planning and development of an undergraduate Bachelor of Engineering degree with a specialisation in energy efficiency.

## Learning Outcomes Maps

### Curriculum Framework Learning Outcomes Map

## Energy Efficiency & Management (BEng)

### Introductory level

### Learning outcomes

#### Maths 1

- Introduction to differential and integral calculus, and basic ordinary differential equations.

#### Maths 2

- Calculus and matrix algebra form the basis of the mathematical knowledge required to model physical, environmental, biological and engineering systems and investigate their behaviour.
- Vector and matrix operations, determinants, inverses and eigenvalues will be considered along with differentiation, integration, sequences and series, differential equations, introductory multivariable calculus and multiple integration.

#### Physics 1

- Principles of classical physics, including: motion in one and two dimensions, force, Newton's Laws, work, energy, momentum, non linear oscillatory and circular motion, heat, hydrostatics, flow rates, electricity, DC circuits, magnetism.

#### Physics 2

- Engineering foundations, skills and knowledge to understand energy and mass transfer in simple systems.
- Developing practical skills and understanding of the basics of the physical processes.

#### Engineering Design Group Project

- Engineering design, sustainability, climate change, ethics, social justice and engineers' engagement with the community.
- Build key skills for engineers, including concept development, critical thinking and evaluation skills, clear communication, research and information literacy skills and the skills involved in successfully functioning within a team environment to complete a given task.

#### Computing for Engineers

- Microcontroller hardware and computer-based engineering tools, commonly used in Engineering and Science for the design, analysis and operation in various technological domains.
- Hardware-oriented microcontroller laboratory sessions and computer-based workshops.
- Develop programming skills and learn about the constraints of developing for real-time environments.

#### Circuits and Systems 1

- Skills for the analysis of direct current (DC) electrical circuits and systems.
- Fundamentals of electricity, DC circuits, nodal and mesh analysis, superposition and linearity, network laws and theorems, capacitors and inductors, operational amplifiers and their applications, basic RL, RC and RLC circuits and associated natural and forced responses.

#### Conventional & Sustainable Energy in Society

- Describe the concept of energy and the associated concept of the conservation of energy.
- Explain the concept of energy flows through the environment.
- Understand global context and issues of climate change, sustainability and energy.
- Explain the patterns of energy production and consumption with respect to a country's stage of development, economy and politics.
- Link the changing patterns of energy production and consumption to each country's level of development, economy and politics.
- Explain the principles of energy conversion.
- Identify major energy consuming sectors and ways of reducing consumption.
- Discuss energy resources and their social impact in the context of world distribution and monopolisation (OPEC).
- Discuss the different types of conventional and sustainable energy resources and conversion techniques.
- Identify the social, economic, environmental and technical issues associated with conventional and sustainable energy resources and conversion techniques.

## Energy Efficiency & Management (BEng)

### Introductory level

### Learning outcomes

#### Mathematical Methods and Statistics

- Fourier series, multivariable calculus, linear algebra and Laplace transforms.
- Exploratory data analysis.
- Probability and distribution theory including binomial, Poisson and normal.
- Large sample theory including the Central Limit Theorem.
- Statistical inference including estimation, confidence intervals and hypothesis testing.
- One-sample and two-sample tests.
- Linear regression.
- Analysis of variance.
- Design and analysis of experiments.
- Applications will be drawn from mechanical, mining, photovoltaic and chemical engineering and surveying.

#### Engineering Materials and Chemistry

- Stoichiometry, atomic and molecular structure, states of matter, equilibrium, oxidation and reduction, electrochemistry.
- An introduction to organic chemistry and polymers.
- Microstructure and structure-property relationships of the main types of engineering materials (metals, ceramics, polymers and composites).
- Micromechanisms of elastic and plastic deformation.
- Fracture mechanisms for ductile, brittle, creep and fatigue modes of failure in service.
- Corrosion.
- Metal forming by casting and wrought processes; phase equilibria of alloys.
- Microstructural control by thermomechanical processing and application to commercial engineering materials.

#### Fluid Mechanics

- Fluid properties.
- Fluids in static equilibrium.
- Buoyancy.
- Pressures in accelerating fluid systems.
- Steady flow energy equations.
- Flow measurement.
- Momentum analysis.
- Dimensional analysis and similarity.
- Pipe flow.
- Incompressible laminar and turbulent flow in pipes; friction factor. Laminar flow between parallel plates and in ducts.
- Elementary boundary layer flow; skin friction and drag.
- Pumps and turbines. Pump and pipeline system characteristics.

#### Thermodynamics and Heat Transfer

- Thermodynamic concepts, systems, property, state, path, process.
- Work and heat.
- Properties of pure substances, tables of properties and equations of state.
- First law of thermodynamics.
- Analysis of closed and open systems.
- Second law of thermodynamics, Carnot cycle, Clausius inequality, entropy, irreversibility, isentropic efficiencies.
- Air-standard cycles. Vapour cycles.

#### Circuits and Systems 2

- Analysis of alternating current (AC) electrical circuits and systems.
- Steady-state analysis of circuits with sinusoidal excitation, the different types of power associated with AC circuits, three-phase circuits, magnetically coupled circuits, frequency response, resonance, bandwidth, two port networks, and principles of electromechanics.

#### Applied PV and Electronic Instrumentation

- Understand and explain the operation of different components of photovoltaic systems.
- Evaluate and understand a variety of photovoltaic applications.
- Gain an appreciation of the issues related to photovoltaic technology.
- Background in analog electronics and instrumentation
- Ability to select the most appropriate instrumentation system for a given engineering measurement and control problem.

#### Control Systems and Process Dynamics

- Foundations in the dynamics, modelling and control of process-oriented systems.

#### University breadth/general education unit

- Understanding and communication across the sciences, technologies, engineering, mathematics, social sciences, humanities, business education and law.

## Energy Efficiency & Management (BEng)

**Medium level**

**Learning outcomes**

### Advanced Thermofluids

- Basic concepts of heat transfer, units, dimensions, exchange mechanism. Steady-state conduction, multi-dimensional conduction. Structure of boundary layers. Internal and external laminar and turbulent forced convection. Heat exchanger design. Radiative heat transfer. Dimensional analysis. Modelling of turbomachines and thermal systems. Experiments and heat transfer measurements. Utilisation of energy, availability — open and closed systems; generalised thermodynamic relations; kinetic theory of gases; non-reactive ideal gas mixtures. Combustion, chemical equilibrium, chemical kinetics and emission control. Compressible flow.

### Carbon Management Strategy 1

- Understand the basic science of human induced climate change and identify corresponding impacts at global, regional and local level.
- Understand international & national policies, protocols and frameworks regulating climate change and greenhouse gas (GHG) reduction.
- Understand how to measure and report GHG emissions and conduct a greenhouse emissions audit for an organisation.
- Understand the main greenhouse gas emitting sectors in the economy and their expected future growth or reduction.
- Understand GHG marginal abatement cost (MAC) curves and how to use them to evaluate carbon reduction options.
- Understand mandatory and voluntary carbon/emissions trading schemes and potential strategies that businesses can adopt to optimise their response.
- Understand national and international Carbon Offset Standards, and how they enable accreditation of GHG (carbon) offsets and the accreditation of carbon Neutrality for companies and products.
- Understand how to develop a Carbon Management Response Plan in an organisation.

### Energy Policy 1

- Identify the objectives of energy policy such as economic efficiency, energy conservation, avoiding environmental degradation, economic development, sustainability, government revenue, urban transport, urban settlement, and the development of new energy technologies.
- Identify and describe contemporary energy policy issues.
- Recognise energy policy institutions.
- Describe how energy policy is made and changed.
- Read and critically analyse energy policy documents.
- Understand domestic and international energy policies, including community service obligations, industry development, policy instruments and how they are applied.
- Understanding of the public policy processes and institutions that give rise to the shape, direction and outcomes in the energy sector.
- Issues in energy policy and the commercialization of renewable energy systems.
- Explain the need for international coordination of energy policies.
- Explain why particular policy instruments are chosen over others.

### Energy Efficiency & Management 1

- Explain the concept of energy efficiency.
- Discuss some of the reason for inefficient energy systems.
- Be able to read and interpret a household or industrial electricity meter.
- Calculate the cost of energy for a facility given the details of the tariff structure.
- Discuss the effectiveness of labelling programmes and efficiency standards.
- Set up an effective energy plan based on sound principles.
- Apply the theory and practice of energy audits and the energy auditing standard.
- Demonstrate how tariffs apply in energy management schemes.
- Discuss opportunities for energy management in building design, air conditioning, lighting and industrial plant.
- Be able to analyse the economic viability of energy management options.
- Be able to develop an energy management system compliant with the ISO50001 standard.

### Energy Economics 1

- Recognise the variety of market structures found in the energy sector.
- Interpret and discuss the economic and social aspects of renewable and non-renewable energy systems.
- Understand economic theory relevant to the energy sector (cost benefit analysis, levelised cost, discounted cash flow analysis).
- Understanding of energy facilities, taxation of the energy sector and role of public utilities and government industry regulations.
- Define externalities in energy supply systems as the major areas for economic regulation by government.
- Identify, detail and analyse the techniques used for making investment decisions.
- Detail the economics of the main support policies that have been used to assist the market penetration of renewable energy technologies.
- Demonstrate an understanding of mass and energy balance principles and how they relate to economic systems of production.

### Electricity Network Systems

- Do simple energy and power calculations and calculations based on Ohm's Law including electricity transmission losses.
- Understand the different types of grids from large scale to mini – or micro-grids.
- Explain how electricity is distributed through a network (or grid) and describe the various components of an interconnected grid system, proceeding from the generation to the utilization of power.
- Understand the min transmission and power electronics components and their role in grids
- Understand the different thermal, physical and chemical energy storage technologies.
- Understand how the electricity grid is operated and managed and the various grid connection and management issues.
- Discuss methods involving both new and conventional technologies for increasing the efficiency and environmental sustainability of grid power systems.
- Understand the concept of smart grids.

### Sustainable Energy Business and Project Management

- Understand the fundamentals of sustainable energy business management.
- Understand the fundamentals of sustainable energy project management.
- Understand the RD&D cycle including financing.
- Understand the importance of safety standards in the energy supply and demand sector.
- Identify and interpret appropriate AS & ISO quality and environmental management standards. e.g. ISO 90001, 150001, 140001.
- Understand the importance and process of an Environmental & Social Impact Assessment.
- Understand relevant climate and energy law.
- Understand the nature of human behaviour within the context of the promotion of environmentally sustainable behaviour.
- Be able to develop and present a business case for sustainable energy technologies.

### Renewable Energy Systems 1

- Demonstrate an understanding of the operation of the main conventional and sustainable energy systems.
- Drawing a block diagram of different renewable energy systems showing the layout of the components in the system.
- Indicating on such diagrams, the power flows that occur within such systems.
- Describing the role of the various components in these systems.
- Describe the approaches used in designing and sizing these systems.
- Understand the relevant system design standards.
- Undertake simple design and sizing tasks for a number of the systems covered.
- Demonstrate an ability to use relevant systems design and modelling software.

## Energy Efficiency & Management (BEng)

### Advanced level

### Learning outcomes

#### Leadership and Ethics

- Strategic management – the management of both human and financial resources.
- The law – as it relates to contract and tort, copyright and intellectual property.
- Ethics – the engineering code of ethics and its operation in engineering practice.
- Professionalism – the roles and responsibilities of the professional engineer.

#### Thesis 1 and Thesis 2

- Exposure to, and experience with, a significant engineering project, with emphasis on industrially based projects.
- Involves elements of specification, design, implementation, testing, documentation, demonstration and presentation. .
- Thesis 2 can build on and extend Thesis 1 or be a separate project.

#### OR

#### Internship 1 and Internship 2

- Exposure to industrial engineering projects and involves elements of specification, design, implementation, testing, documentation, demonstration and presentation.
- Prepare a project report, deliver seminars describing the project, and attend meetings with academic and industry supervisors as required.
- Internship 2 can build on and extend Internship 1 or be a separate project.

#### Energy Efficiency and Decarbonisation in Precincts (elective)

- Understand the approaches to measuring the greenhouse gas inventory and carbon footprint of precincts and cities.
- Understand the concepts of more efficient and lower carbon precinct and city design and planning including PODs, GODs and TODs.
- Understand the concept of mode switching in transport within and between settlements and how more efficient and decarbonised transport systems can be developed. This includes more energy efficient road and transport corridor design.
- Understand the approaches that can be used to provide more energy efficient water and waste management for precincts.
- Understand how to assess the feasibility of and how to implement, district heating and cooling.

#### Energy Efficiency and Decarbonisation in Precincts Continued

- Understand how to assess the feasibility of and how to implement district scale renewable energy systems and networks.
- Understand other strategies for decarbonisation of precincts and settlements.

#### Energy Efficiency, Systems Analysis and Auditing (elective)

- Have an ability to identify factors influencing energy use or waste, including procedural, contractual, legal, organisational structure, job descriptions, key performance indicators and behaviour.
- Be able to understand and analyse design, procurement, commissioning, operational and maintenance practices.
- Be able to apply the theory and practice of energy audits.
- Be able to demonstrate how tariffs apply in energy management schemes.
- Be able to analyse the economic viability of energy management options.
- Be able to determine, collect and manage the most appropriate energy and process related data, including setting appropriate boundaries for analysis.
- Have an ability to assess, install and use appropriate monitoring equipment and develop analysis systems. and apply appropriate techniques for analysis, feedback provision and system/process management based on improved access to information.
- Have an ability to undertake and apply specific techniques such as Pinch analysis, development of models and other engineering focused process optimisation techniques.
- Have an ability to collect and analyse energy and financial data for the purpose of identifying energy use and savings.
- Have an ability to develop and implement effective data management, tracking and reporting systems.
- Be able to apply energy data analysis skills to apply a range of methods to explore relationship between energy use and a range of variables that may influence it.
- Be able to set up an effective energy management plan based on sound principles.

#### Environmental Building Services and Energy Efficient Building Design

- Explain what is meant by environmental building services and some of the key issues in the field.
- Describe the purpose of environmental building services;
- Define sustainability in environmental building;
- Identify novel building technologies that could contribute to a sustainable built environment.
- Analyse issues in environmental building services and propose solutions to them.
- Discuss the key issues in developing environmental building services.
- Carry out the design concept and management of an environmental building.
- Demonstrate an understanding of the following:
  - Thermal storage systems;
  - Ventilation strategies and techniques;
  - Advances in refrigerative air conditioning;
  - Indirect evaporative cooling;
  - Solar air collectors and solar water heaters;
  - Integration of PV into buildings and communities;
  - Cogeneration;
  - Energy efficient lighting;
  - Water conservation;
  - Sick building syndrome.
- Assess a particular building or site in terms of its energy performance and identify opportunities to improve its energy performance.
- Identify comfort control strategies for the maintenance of thermal comfort based on an analysis of climatic data within a building envelope.
- Use solar radiation data and solar geometry tools to evaluate solar access for a building.
- Understand the scientific basis behind heat flow calculations and identify the factors which affect heat transfer into and out of buildings.

#### Change Management (Elective)

- Organisational change management
  - Capacity to develop and implement sustainable energy strategies within organisations.
  - An appreciation of the scope and nature of the organisational change agenda for sustainability management.
  - An ability to apply business principles to develop and deliver the business case for corporate sustainability.

#### Change Management Continued.

- An appreciation of the critical importance of corporate strategy to design and effectuate incremental and transformational business changes.
  - An ability to assess performance of corporate strategies for sustainability management.
- Behaviour change
- Understand the nature of human behaviour within the context of the promotion of environmentally sustainable behaviour.
  - Examine the historical context of the term 'behaviour change' in terms of changing political relationships between the individual, the state and civil society.
  - Describe and evaluate different theoretical approaches to understanding behaviour.
  - Critically analyse case studies and examples of government tools and strategies for promoting behaviour change.
  - Behavioural economics and social psychology.
  - Practice theory and other sociological approaches.
  - Community based interventions.
  - Implementation issues in behaviour change interventions.
  - Measuring and evaluating change.
  - The evolution of government policies on behaviour change relevant to sustainability.

#### Industrial and Commercial Energy Efficiency

- Be able to conduct an energy survey and audit and evaluate the energy efficiency of industrial energy systems.
- Be able to use the process integration method to estimate the minimum energy use targets of heat exchange networks.
- Be able to make design calculations for fundamental heat transfer processes.
- Be able to design and optimize fundamental refrigeration, heat pump, and power systems.
- Be able to identify and evaluate available centralized or distributed generation options.
- Demonstrate an understanding of available current distribution systems and constraints.
- Be able to design humidifying and dehumidifying processes of moist air in thermal processes.
- Demonstrate an understanding of how to increase energy efficiency in:
  - Electric motors and drive systems;
  - Boiler combustion and steam systems;
  - Heat exchange, transfer and recovery; and
  - Mining, quarrying and haulage.

## **Master of Engineering or Master of Science Specializing in Energy Efficiency**

This set of curriculum framework learning outcome maps provides guidance for programme coordinators and unit coordinators in the planning and development of either a postgraduate coursework Masters of Engineering degree or Master of Science degree with a specialisation in energy efficiency.

## Learning Outcomes Maps

### Curriculum Framework Learning Outcomes Map

## Energy Efficiency & Management (MEng / MSc)

### Introductory level

### Learning outcomes

<p><b>Energy Policy 1</b></p> <ul style="list-style-type: none"> <li>Identify the objectives of energy policy such as economic efficiency, energy conservation, avoiding environmental degradation, economic development, sustainability, government revenue, urban transport, urban settlement, and the development of new energy technologies.</li> <li>Identify and describe contemporary energy policy issues.</li> <li>Recognise energy policy institutions.</li> <li>Describe how energy policy is made and changed.</li> <li>Read and critically analyse energy policy documents.</li> <li>Understand domestic and international energy policies, including community service obligations, industry development, policy instruments and how they are applied.</li> <li>Understanding of the public policy processes and institutions that give rise to the shape, direction and outcomes in the energy sector.</li> <li>Issues in energy policy and the commercialization of renewable energy systems</li> <li>Explain the need for international coordination of energy policies.</li> <li>Explain why particular policy instruments are chosen over others.</li> </ul>	<p><b>Energy Economics 1</b></p> <ul style="list-style-type: none"> <li>Recognise the variety of market structures found in the energy sector.</li> <li>Interpret and discuss the economic and social aspects of renewable and non-renewable energy systems.</li> <li>Understand economic theory relevant to the energy sector (cost benefit analysis, levelised cost, discounted cash flow analysis).</li> <li>Understanding of energy facilities, taxation of the energy sector and role of public utilities and government industry regulations.</li> <li>Define externalities in energy supply systems as the major areas for economic regulation by government.</li> <li>Identify, detail and analyse the techniques used for making investment decisions.</li> <li>Detail the economics of the main support policies that have been used to assist the market penetration of renewable energy technologies.</li> <li>Demonstrate an understanding of mass and energy balance principles and how they relate to economic systems of production.</li> </ul>	<p><b>Sustainable Energy Business and Project Management</b></p> <ul style="list-style-type: none"> <li>Understand the fundamentals of sustainable energy business management.</li> <li>Understand the fundamentals of sustainable energy project management.</li> <li>Understand the RD&amp;D cycle including financing.</li> <li>Understand the importance of safety standards in the energy supply and demand sector.</li> <li>Identify and interpret appropriate AS &amp; ISO quality and environmental management standards. e.g. ISO 90001, 150001, 140001.</li> <li>Understand the importance and process of an Environmental &amp; Social Impact Assessment.</li> <li>Understand relevant climate and energy law.</li> <li>Understand the nature of human behaviour within the context of the promotion of environmentally sustainable behaviour.</li> <li>Be able to develop and present a business case for sustainable energy technologies.</li> </ul> <p><b>Carbon Management Strategy 1</b></p> <ul style="list-style-type: none"> <li>Understand the basic science of human induced climate change and identify corresponding impacts at global, regional and local level.</li> </ul>	<p><b>Conventional &amp; Sustainable Energy in Society</b></p> <ul style="list-style-type: none"> <li>Describe the concept of energy and the associated concept of the conservation of energy.</li> <li>Explain the concept of energy flows through the environment.</li> <li>Understand global context and issues of climate change, sustainability and energy.</li> <li>Explain the patterns of energy production and consumption with respect to a country's stage of development, economy and politics.</li> <li>Link the changing patterns of energy production and consumption to each country's level of development, economy and politics.</li> <li>Explain the principles of energy conversion.</li> <li>Identify major energy consuming sectors and ways of reducing consumption.</li> <li>Discuss energy resources and their social impact in the context of world distribution and monopolisation (OPEC).</li> <li>Discuss the different types of conventional and sustainable energy resources and conversion techniques</li> <li>Identify the social, economic, environmental and technical issues associated with conventional and sustainable energy resources and conversion techniques.</li> </ul>
<p><b>Energy Efficiency &amp; Management 1</b></p> <ul style="list-style-type: none"> <li>Explain the concept of energy efficiency.</li> <li>Discuss some of the reason for inefficient energy systems.</li> <li>Be able to read and interpret a household or industrial electricity meter.</li> <li>Calculate the cost of energy for a facility given the details of the tariff structure.</li> <li>Discuss the effectiveness of labelling programmes and efficiency standards.</li> <li>Set up an effective energy plan based on sound principles.</li> <li>Apply the theory and practice of energy audits and the energy auditing standard.</li> <li>Demonstrate how tariffs apply in energy management schemes.</li> <li>Discuss opportunities for energy management in building design, air conditioning, lighting and industrial plant.</li> <li>Be able to analyse the economic viability of energy management options.</li> <li>Be able to develop an energy management system compliant with the ISO50001 standard.</li> </ul>	<p><b>Renewable Energy Systems 1</b></p> <ul style="list-style-type: none"> <li>Demonstrate an understanding of the operation of the main conventional and sustainable energy systems.</li> <li>Drawing a block diagram of different renewable energy systems showing the layout of the components in the system.</li> <li>Indicating on such diagrams, the power flows that occur within such systems.</li> <li>Describing the role of the various components in these systems.</li> <li>Describe the approaches used in designing and sizing these systems.</li> <li>Understand the relevant system design standards.</li> <li>Undertake simple design and sizing tasks for a number of the systems covered.</li> <li>Demonstrate an ability to use relevant systems design and modelling software.</li> </ul>	<ul style="list-style-type: none"> <li>Understand international &amp; national policies, protocols and frameworks regulating climate change and greenhouse gas (GHG) reduction.</li> <li>Understand how to measure and report GHG emissions and conduct a greenhouse emissions audit for an organisation.</li> <li>Understand the main greenhouse gas emitting sectors in the economy and their expected future growth or reduction.</li> <li>Understand GHG marginal abatement cost (MAC) curves and how to use them to evaluate carbon reduction options.</li> <li>Understand mandatory and voluntary carbon/emissions trading schemes and potential strategies that businesses can adopt to optimise their response.</li> <li>Understand national and international Carbon Offset Standards, and how they enable accreditation of GHG (carbon) offsets and the accreditation of carbon Neutrality for companies and products.</li> <li>Understand how to develop a Carbon Management Response Plan in an organisation.</li> </ul>	<p><b>Electricity Network Systems</b></p> <ul style="list-style-type: none"> <li>Do simple energy and power calculations and calculations based on Ohm's Law including electricity transmission losses.</li> <li>Understand the different types of grids from large scale to mini – or micro-grids.</li> <li>Explain how electricity is distributed through a network (or grid) and describe the various components of an interconnected grid system, proceeding from the generation to the utilization of power.</li> <li>Understand the min transmission and power electronics components and their role in grids</li> <li>Understand the different thermal, physical and chemical energy storage technologies.</li> <li>Understand how the electricity grid is operated and managed and the various grid connection and management issues.</li> <li>Discuss methods for increasing the environmental sustainability of grid power systems.</li> <li>Understand the concept of smart grids.</li> </ul>



## Energy Efficiency & Management (MEng /MSc)

**Medium  
level**

**Learning  
outcomes**

### Energy Efficiency, Systems Analysis and Auditing (elective)

- Have an ability to identify factors influencing energy use or waste, including procedural, contractual, legal, organisational structure, job descriptions, key performance indicators and behaviour.
- Be able to understand and analyse design, procurement, commissioning, operational and maintenance practices..
- Be able to apply the theory and practice of energy audits.
- Be able to demonstrate how tariffs apply in energy management schemes.
- Be able to analyse the economic viability of energy management options.
- Be able to determine, collect and manage the most appropriate energy and process related data, including setting appropriate boundaries for analysis.
- Have an ability to assess, install and use appropriate monitoring equipment and develop analysis systems, and apply appropriate techniques for analysis, feedback provision and system/process management based on improved access to information.
- Have an ability to undertake and apply specific techniques such as Pinch analysis, development of models and other engineering focused process optimisation techniques.
- Have an ability to collect and analyse energy and financial data for the purpose of identifying energy use and savings.
- Have an ability to develop and implement effective data management, tracking and reporting systems.
- Be able to apply energy data analysis skills to apply a range of methods to explore relationship between energy use and a range of variables that may influence it.
- Awareness and understanding of new and existing technologies, their feasibility and cost effectiveness, as well as other research and development occurring within the sector and overseas.
- Be able to set up an effective energy management plan based on sound principles.

### Environmental Building Services and Energy Efficient Building Design

- Explain what is meant by environmental building services and some of the key issues in the field.
- Describe the purpose of environmental building services;
- Define sustainability in environmental building;
- Identify novel building technologies that could contribute to a sustainable built environment.
- Analyse issues in environmental building services and propose solutions to them.
- Discuss the key issues in developing environmental building services.
- Carry out the design concept and management of an environmental building.
- Demonstrate an understanding of the following:
  - Thermal storage systems;
  - Ventilation strategies and techniques;
  - Advances in refrigerative air conditioning;
  - Indirect evaporative cooling
  - Solar air collectors and solar water heaters;
  - Integration of PV into buildings and communities;
  - Cogeneration;
  - Energy efficient lighting;
  - Water conservation; and
  - Sick building syndrome.
- Assess a particular building or site in terms of its energy performance and identify opportunities to improve its energy performance.
- Identify comfort control strategies for the maintenance of thermal comfort based on an analysis of climatic data within a building envelope.
- Use solar radiation data and solar geometry tools to evaluate solar access for a building.
- Understand the scientific basis behind heat flow calculations and identify the factors which affect heat transfer into and out of buildings.

### Industrial and Commercial Energy Efficiency

- Be able to conduct an energy survey and audit and evaluate the energy efficiency of industrial energy systems.
- Be able to use the process integration method to estimate the minimum energy use targets of heat exchange networks.
- Be able to make design calculations for fundamental heat transfer processes.
- Be able to design and optimize fundamental refrigeration, heat pump, and power systems.
- Be able to identify and evaluate available centralized or distributed generation options.
- Demonstrate an understanding of available current distribution systems and constraints.
- Be able to design humidifying and dehumidifying processes of moist air in thermal processes.
- Demonstrate an understanding of how to increase energy efficiency in:
  - Electric motors and drive systems;
  - Boiler combustion and steam systems;
  - Heat exchange, transfer and recovery; and
  - Mining, quarrying and haulage.

### Change Management

#### Organisational Change Management

- An appreciation of the scope and nature of the organisational change agenda for sustainability management.
- An ability to apply business principles to develop and deliver the business case for corporate sustainability.
- An appreciation of the critical importance of corporate strategy to design and effectuate incremental and transformational business changes.
- An ability to assess performance of corporate strategies for sustainability management.

#### Behaviour change

- Understand the nature of human behaviour within the context of the promotion of environmentally sustainable behaviour.
- Examine the historical context of the term 'behaviour change' in terms of changing political relationships between the individual, the state and civil society.
- Describe and evaluate different theoretical approaches to understanding behaviour.
- Critically analyse case studies and examples of government tools and strategies for promoting behaviour change.
- Behavioural economics and social psychology.
- Practice theory and other sociological approaches.
- Community based interventions.
- Implementation issues in behaviour change interventions.
- Measuring and evaluating change.
- The evolution of government policies on behaviour change relevant to sustainability.

## Energy Efficiency & Management (MEng /MSc)

### Advanced level

### Learning outcomes

#### Energy Efficiency and Decarbonisation in Precincts (elective)

- Understand the approaches to measuring the greenhouse gas inventory and carbon footprint of precincts and cities.
- Understand the concepts of more efficient and lower carbon precinct and city design and planning including PODs, GODs and TODs.
- Understand the concept of mode switching in transport within and between settlements and how more efficient and decarbonised transport systems can be developed. This includes more energy efficient road and transport corridor design.
- Understand the approaches that can be used to provide more energy efficient water and waste management for precincts.
- Understand how to assess the feasibility of and how to implement, district heating and cooling
- Understand how to assess the feasibility of and how to implement district scale renewable energy systems and networks
- Understand other strategies for decarbonisation of precincts and settlements.

#### Carbon Management Strategy 2 (elective)

- Be able to describe marginal abatement costs (MAC) and curves and calculate the levelised abatement cost for an abatement option.
- Be able to construct a short run MAC curve.
- Be able to construct a long run MAC curve.
- Be able to articulate (using the MAC curve) the tension between abatement costs, permit prices, and other emissions trading instruments.
- Understand how to effectively implement and monitor a carbon management response plan for an organisation.
- Be able to discuss the various international inventory and carbon offset standards and approaches to Carbon Neutrality.
- Understand national and international Carbon Offset Standards, and how they enable accreditation of Carbon Neutrality for companies and products;
- Be able to describe the process for obtaining and maintaining carbon offset standard Carbon Neutral accreditation for a company;
- Understand the role of greenhouse gas inventory and lifecycle assessment in achieving accredited Carbon Neutrality.
- Be able to describe the process for obtaining and maintaining carbon offset standard Carbon Neutral accreditation for a product.
- Understand what is required to develop and advertise Carbon Neutrality for a company or product that will be acceptable to Competition and Consumer regulators.

#### Advanced Thesis/Research project

- Understand key issues in the research puzzle, the literature review, methodology, ethics, and the development of effective research proposals.
- Demonstrate skills in research design, evaluation, analysis and critique, together with high level written communication skills, organisation and time management, and the capacity for self directed and independent learning.

#### Greenhouse Gas Inventory (elective)

- Explain what is meant by GHG accounting and in particular the basics of Kyoto protocol accounting.
- Understand the different GHG emissions accounting standards and which one is the most appropriate to use at company, local government or national level.
- Compile and review GHG emissions data.
- Describe the various NGERs reporting requirements.
- Establish the organisational and operational boundaries under NGERs.
- Apply the five GHG accounting principles according to an organisation's business and policy objectives.
- Source and identify relevant NGERs methods for quantifying an organisation's GHGs from various point sources.
- Estimate emissions for a facility using NGERs Method 1 given adequate business input data.
- Estimate emissions for a facility using NGERs Methods 2 and 3 given appropriate sample data.
- Assess the uncertainty of emissions estimates under NGERs.
- Understand the GHG inventory auditing process and explain in detail the appropriate use of auditing reports.
- Explain what is meant by life cycle assessment and its use in GHG emissions estimation.
- Understand the role of greenhouse gas inventory and lifecycle assessment in achieving accredited Carbon Neutrality.
- Understand how to use the relevant protocol to develop a greenhouse gas emissions inventory for a local government area or region.

## Curriculum Framework Set 3: Policy and Enablers

The curriculum framework and set of curriculum maps in this section provide guidance for the development of programmes at postgraduate level specializing in **energy policy and enablers**.



### Energy Policy and Enablers Overarching Curriculum Framework Map

Overarching Curriculum Framework Map	Policy / Enablers (MA)
<b>Graduate attributes</b>	<p><b>Prerequisites</b></p> <ul style="list-style-type: none"> <li>• High school maths, physics and chemistry</li> <li>• IT skills</li> <li>• Statistics</li> <li>• First year university level economics</li> </ul> <p><b>Humanities/Social Science Attributes</b></p> <ul style="list-style-type: none"> <li>• Governance &amp; social responsibility</li> <li>• Public policy</li> <li>• Community consultation</li> <li>• Social &amp; environmental impact/evaluation</li> <li>• Change management</li> </ul>
<b>Introductory level</b>	<p><b>Policy content</b></p> <ul style="list-style-type: none"> <li>• Conventional &amp; Sustainable Energy in Society</li> <li>• Energy Policy 1</li> <li>• Energy Economics 1</li> <li>• Sustainable Energy Business and Project Management</li> </ul> <p><b>Technical/Science content</b></p> <ul style="list-style-type: none"> <li>• Energy Efficiency &amp; Management 1</li> <li>• Carbon Management Strategy 1</li> <li>• Electricity Network Systems</li> <li>• Renewable Energy Systems 1</li> </ul>
<b>Medium level</b>	<p><b>Policy content</b></p> <ul style="list-style-type: none"> <li>• Energy Policy 2 - Climate Change Policy)</li> <li>• Energy Economics 2</li> <li>• Community Consultation &amp; Social/Environmental Impact Assessment</li> <li>• Change Management</li> </ul>
<b>Advanced level</b>	<p>Two electives (see recommended choices above) and Advanced Thesis/Research Project (1/2 semester) or Advanced Thesis/Research Project (1 semester)</p> <p><b>Recommended Electives</b></p> <ul style="list-style-type: none"> <li>• Energy Policy 3 - Supply and Infrastructure</li> <li>• Energy Economics 3 - Market Reform</li> <li>• Energy Policy Research and Evaluation</li> </ul>

## **Master of Arts Specializing in Sustainable Energy Policy and Enablers**

This set of curriculum framework learning outcome maps provides guidance for programme coordinators and unit coordinators in the planning and development of a postgraduate coursework Masters of Arts degree with a specialisation in sustainable energy policy and enablers.

## Learning Outcomes Maps

### Curriculum Framework Learning Outcomes Map

#### Policy / Enablers (MA)

Introductory level Learning outcomes	Energy Policy 1	Energy Economics 1	Conventional & Sustainable Energy in Society	Sustainable Energy Business and Project Management
	<p><b>Energy Policy 1</b></p> <ul style="list-style-type: none"> <li>Identify the objectives of energy policy such as economic efficiency, energy conservation, avoiding environmental degradation, economic development, sustainability, government revenue, urban transport, urban settlement, and the development of new energy technologies.</li> <li>Identify and describe contemporary energy policy issues.</li> <li>Recognise energy policy institutions.</li> <li>Describe how energy policy is made and changed.</li> <li>Read and critically analyse energy policy documents.</li> <li>Understand domestic and international energy policies, including community service obligations, industry development, policy instruments and how they are applied.</li> <li>Understanding of the public policy processes and institutions that give rise to the shape, direction and outcomes in the energy sector.</li> <li>Issues in energy policy and the commercialization of renewable energy systems.</li> <li>Explain the need for international coordination of energy policies.</li> <li>Explain why particular policy instruments are chosen over others.</li> </ul>	<p><b>Energy Economics 1</b></p> <ul style="list-style-type: none"> <li>Recognise the variety of market structures found in the energy sector.</li> <li>Interpret and discuss the economic and social aspects of renewable and non-renewable energy systems.</li> <li>Understand economic theory relevant to the energy sector (cost benefit analysis, levelised cost, discounted cash flow analysis).</li> <li>Understanding of energy facilities, taxation of the energy sector and role of public utilities and government industry regulations.</li> <li>Define externalities in energy supply systems as the major areas for economic regulation by government.</li> <li>Identify, detail and analyse the techniques used for making investment decisions.</li> <li>Detail the economics of the main support policies that have been used to assist the market penetration of renewable energy technologies.</li> <li>Demonstrate an understanding of mass and energy balance principles and how they relate to economic systems of production.</li> </ul>	<p><b>Conventional &amp; Sustainable Energy in Society</b></p> <ul style="list-style-type: none"> <li>Describe the concept of energy and the associated concept of the conservation of energy.</li> <li>Explain the concept of energy flows through the environment.</li> <li>Understand global context and issues of climate change, sustainability and energy.</li> <li>Explain the patterns of energy production and consumption with respect to a country's stage of development, economy and politics.</li> <li>Link the changing patterns of energy production and consumption to each country's level of development, economy and politics.</li> <li>Explain the principles of energy conversion.</li> <li>Identify major energy consuming sectors and ways of reducing consumption.</li> <li>Discuss energy resources and their social impact in the context of world distribution and monopolisation (OPEC).</li> <li>Discuss the different types of conventional and sustainable energy resources and conversion techniques.</li> <li>Identify the social, economic, environmental and technical issues associated with conventional and sustainable energy resources and conversion techniques.</li> </ul>	<p><b>Sustainable Energy Business and Project Management</b></p> <ul style="list-style-type: none"> <li>Understand the fundamentals of sustainable energy business management.</li> <li>Understand the fundamentals of sustainable energy project management.</li> <li>Understand the RD&amp;D cycle including financing.</li> <li>Understand the importance of safety standards in the energy supply and demand sector.</li> <li>Identify and interpret appropriate AS &amp; ISO quality and environmental management standards. e.g. ISO 90001, 150001, 140001.</li> <li>Understand the importance and process of an Environmental &amp; Social Impact Assessment.</li> <li>Understand relevant climate and energy law.</li> <li>Understand the nature of human behaviour within the context of the promotion of environmentally sustainable behaviour.</li> <li>Be able to develop and present a business case for sustainable energy technologies.</li> </ul> <p><b>Carbon Management Strategy 1</b></p> <ul style="list-style-type: none"> <li>Understand the basic science of human induced climate change and identify corresponding impacts at global, regional and local level.</li> </ul>
	<p><b>Renewable Energy Systems 1</b></p> <ul style="list-style-type: none"> <li>Demonstrate an understanding of the operation of the main conventional and sustainable energy systems.</li> <li>Drawing a block diagram of different renewable energy systems showing the layout of the components in the system.</li> <li>Indicating on such diagrams, the power flows that occur within such systems.</li> <li>Describing the role of the various components in these systems.</li> <li>Describe the approaches used in designing and sizing these systems.</li> <li>Understand the relevant system design standards.</li> <li>Undertake simple design and sizing tasks for a number of the systems covered.</li> <li>Demonstrate an ability to use relevant systems design and modelling software.</li> </ul>	<p><b>Energy Efficiency &amp; Management 1</b></p> <ul style="list-style-type: none"> <li>Explain the concept of energy efficiency.</li> <li>Discuss some of the reason for inefficient energy systems.</li> <li>Be able to read and interpret a household or industrial electricity meter.</li> <li>Calculate the cost of energy for a facility given the details of the tariff structure.</li> <li>Discuss the effectiveness of labelling programmes and efficiency standards.</li> <li>Set up an effective energy plan based on sound principles.</li> <li>Apply the theory and practice of energy audits and the energy auditing standard.</li> <li>Demonstrate how tariffs apply in energy management schemes.</li> <li>Discuss opportunities for energy management in building design, air conditioning, lighting and industrial plant.</li> <li>Be able to analyse the economic viability of energy management options.</li> <li>Be able to develop an energy management system compliant with the ISO50001 standard.</li> </ul>	<p><b>Electricity Network Systems</b></p> <ul style="list-style-type: none"> <li>Do simple energy and power calculations and calculations based on Ohm's Law including electricity transmission losses.</li> <li>Understand the different types of grids from large scale to mini – or micro-grids.</li> <li>Explain how electricity is distributed through a network (or grid) and describe the various components of an interconnected grid system, proceeding from the generation to the utilization of power.</li> <li>Understand the min transmission and power electronics components and their role in grids.</li> <li>Understand the different thermal, physical and chemical energy storage technologies.</li> <li>Understand how the electricity grid is operated and managed and the various grid connection and management issues.</li> <li>Discuss methods involving both new and conventional technologies for increasing the efficiency and environmental sustainability of grid power systems.</li> <li>Understand the concept of smart grids.</li> </ul>	<ul style="list-style-type: none"> <li>Understand international &amp; national policies, protocols and frameworks regulating climate change and greenhouse gas (GHG) reduction.</li> <li>Understand how to measure and report GHG emissions and conduct a greenhouse emissions audit for an organisation.</li> <li>Understand the main greenhouse gas emitting sectors in the economy and their expected future growth or reduction.</li> <li>Understand GHG marginal abatement cost (MAC) curves and how to use them to evaluate carbon reduction options.</li> <li>Understand mandatory and voluntary carbon/emissions trading schemes and potential strategies that businesses can adopt to optimise their response.</li> <li>Understand national and international Carbon Offset Standards, and how they enable accreditation of GHG (carbon) offsets and the accreditation of carbon Neutrality for companies and products.</li> <li>Understand how to develop a Carbon Management Response Plan in an organisation.</li> </ul>

## Policy / Enablers (MA)

### Medium level

### Learning outcomes

#### Energy Policy 2 - Climate Change Policy

- Describe the modelling of climate change scenarios and to assess the potential impacts of climate change on ecosystems and human society.
- Describe the policy framework for addressing the causes and impacts of global warming/climate change.
- History of global warming/climate change science and politics.
- Understand radiative transfer within the earth atmosphere system and the general circulation of the atmosphere.
- Recognise the significance of greenhouse gases in establishing the natural energy balance of the earth/atmosphere system and their influence on the temperature structure of the atmosphere.
- Recognise natural climate variability and distinguish between climate variability and climate change.
- Understanding of the basic principles, strengths and weaknesses and differences between climate models.
- Identify international policy approaches to address climate change.
- Describe the mechanisms for monitoring and reporting greenhouse gas emissions and sinks.
- Describe the range of policy measures available for reducing greenhouse gas emissions in the different sectors.
- Describe the potential social and environmental impacts of the different technologies for reducing greenhouse gas emissions.
- Discuss and evaluate the role of adaptation and mitigation to addressing the impacts of climate change.

#### Energy Economics 2

- Explain key government economic practices including taxation, regulation, and privatisation.
- Recognise how the structure of energy markets flows from theories about how markets can achieve efficiency objectives beneficial to consumers.
- Describe the role that energy resources play in influencing the structure of energy markets.
- State why government regulation of natural monopoly is such a central feature of modern energy markets.
- List the issues involved in providing open access to a natural monopoly such as a gas pipeline of electricity distribution network.
- Explain why competitive markets are preferred to non-competitive markets.
- Analyse the failure of the OPEC cartel.
- Explain the difference between Net Pool and Gross Pool electricity markets.
- Explain the role of capacity markets in Net Pools.
- Outline the reasons for safeguarding against risks associated with product prices interest rates and exchange rates.
- Define and detail the basic hedging techniques of forward sales, futures contracts options and swaps.
- Explain the importance of economic rent and neutrality in the design of taxes for natural resource industries.
- Explain why renewable energy faces a number of hurdles before it can become significant in the energy economy.
- Describe how the structure of conventional energy markets works against greater use of renewable energy.
- Detail the economics of the main support policies that have been used to assist the market penetration of renewable energy technologies.

#### Change Management

##### Organisational change management

- Capacity to develop and implement sustainable energy strategies within organisations.
- An appreciation of the scope and nature of the organisational change agenda for sustainability management.
- An ability to apply business principles to develop and deliver the business case for corporate sustainability.
- An appreciation of the critical importance of corporate strategy to design and effectuate incremental and transformational business changes.
- An ability to assess performance of corporate strategies for sustainability management.

##### Behaviour change

- Understand the nature of human behaviour within the context of the promotion of environmentally sustainable behaviour.
- Examine the historical context of the term 'behaviour change' in terms of changing political relationships between the individual, the state and civil society.
- Describe and evaluate different theoretical approaches to understanding behaviour.
- Critically analyse case studies and examples of government tools and strategies for promoting behaviour change.
- Behavioural economics and social psychology.
- Practice theory and other sociological approaches.
- Community based interventions.
- Implementation issues in behaviour change interventions.
- Measuring and evaluating change.
- The evolution of government policies on behaviour change relevant to sustainability.

#### Community Consultation & Social/Environmental Impact Assessment

- Full scope of planning needed for effective public participation.
- Foundations of public participation on which to build effective processes.
- Planning process starting with gaining internal commitment and identifying the strategic focus.
- Ways to identify communities and their issues
- How to select the appropriate level of public participation.
- How to set clear, shared objectives for effective public participation.
- How to develop a public participation plan.
- Understand information needed to support effective public participation and how to communicate it.
- How to identify and write key messages and apply them in a range of communication tools.
- How to gather, summarise and analyse feedback.
- The principles of risk communication to avoid community outrage.
- How to prepare for, implement and document techniques for public participation/stakeholder engagement. (Based on IAP2 certificate)
- Understanding impact assessment: principles, methods, and emerging trends.
- Achieving the full potential of social impact assessment.
- The cultural heritage component of impact assessment: class room and field training in methods and issues.
- Cumulative effects and follow-up in impact assessment.
- Increasing tangibility in SEA through valuation of ecosystem services.
- Involuntary resettlement: principles and practice.
- Mainstreaming biodiversity conservation in energy projects: what can impact assessment offer?
- Quality assurance in EIA: guide and review.
- Theory and practice of multi-criteria analysis for environmental impact assessment of projects and plans.
- Issues in health impact assessment for the energy industry. (Based on IAIA training course)

## Policy / Enablers (MA)

### Advanced level

### Learning outcomes

#### Energy Policy 3 - Supply & infrastructure (elective)

- Analyse drivers for transition to sustainable energy including institutional framework that shapes how energy is supplied and used, including institution barriers to sustainable energy.
- Understand the process of Regulatory Impact Assessments.
- An understanding of the key concepts, principles and issues relating to development of sustainable energy.
- Outline policy approaches to the control of externalities.
- Explain why energy security requires policy to establish an internal system to provide dependable and secure energy supplies based on an indigenous energy supply.

#### Energy Policy Research and Evaluation (elective)

- Describe the key elements in public policymaking.
- Understand the role of evidence-based research and systematic analysis in the development of policy.
- Demonstrate the key function of policy evaluation as part of policy learning processes.
- Examine the iterative and innovative dimensions of policy research and evaluation.

#### Energy Economics 3 - Market Reform (elective)

- Understand and discuss the principles underlying electricity industry restructuring in Australia and in other jurisdiction.
- Appreciate and explain the complexities of ensuring resource adequacy within a restructured electricity industry.
- Explain how gross and net pool models for electricity trading are structured and how they operate in practice.
- Describe the issues involved in integrating renewable energy into electricity grids and provide insight into possible ways of addressing existing barriers.
- Appreciate the impact of wind energy penetration in the National Electricity Market and discuss possible strategies to manage it.
- Reconcile electricity industry restructuring with sustainability.
- Outline how to manage risks in the energy industry.
- Define the role of financial instruments in competitive electricity industries as well as be able to undertake basic derivative market calculations.
- Describe transmission network planning and pricing in a competitive electricity industry.
- Understand and explain how electricity spot prices are calculated.
- Explain the principles behind the use of life cycle costing.
- Explain the assumptions inherent in such life cycle costs.

#### Advanced Thesis/Research Project (elective)

- Understand key issues in the research puzzle, the literature review, methodology, ethics, and the development of effective research proposals.
- Demonstrate skills in research design, evaluation, analysis and critique, together with high level written communication skills, organisation and time management, and the capacity for self directed and independent learning.

# Curriculum Framework Set 4: Carbon Management

The curriculum framework and set of curriculum maps in this section provide guidance for the development of programmes at postgraduate level specializing in **carbon management**.



## Carbon Management Overarching Curriculum Framework Map

Overarching Curriculum Framework Map	Carbon Management (MSc)
Graduate attributes	<p><b>Prerequisites</b></p> <ul style="list-style-type: none"> <li>• First year university level maths, physics and chemistry</li> <li>• IT skills</li> <li>• Statistics</li> </ul> <p><b>Technical/Science Attributes</b></p> <ul style="list-style-type: none"> <li>• IT &amp; laboratory skills</li> <li>• Technical management</li> </ul>
Introductory level	<p><b>Policy content</b></p> <ul style="list-style-type: none"> <li>• Conventional and Sustainable Energy in Society</li> <li>• Energy Policy 1</li> <li>• Energy Economics 1</li> <li>• Sustainable Energy Business and Project Management</li> </ul> <p><b>Technical/Science content</b></p> <ul style="list-style-type: none"> <li>• Energy Efficiency &amp; Management 1</li> <li>• Carbon Management Strategy 1</li> <li>• Electricity Network Systems</li> <li>• Renewable Energy Systems 1</li> </ul>
Medium level	<p><b>Carbon management content</b></p> <ul style="list-style-type: none"> <li>• Lifecycle Assessment</li> <li>• Greenhouse Gas Inventory</li> <li>• Carbon Accounting, Offsets &amp; Trading</li> <li>• Change Management</li> </ul>
Advanced level	<p>Carbon management content and</p> <ul style="list-style-type: none"> <li>• Carbon Management Strategy 2</li> </ul> <p><b>Recommended Elective and</b></p> <ul style="list-style-type: none"> <li>• Energy Efficiency, System Analysis &amp; Auditing</li> </ul> <p>or</p> <ul style="list-style-type: none"> <li>• Energy Efficiency and Decarbonization in Precincts</li> </ul> <p><b>Advanced Thesis/Research Project</b></p>



## **Master of Science Specializing in Carbon Management**

This set of curriculum framework learning outcome maps provides guidance for programme coordinators and unit coordinators in the planning and development of a postgraduate coursework Masters of Science degree with a specialisation in carbon management.

## Learning Outcomes Maps

### Curriculum Framework Learning Outcomes Map

Carbon Management (MSc)				
<b>Introductory level</b>  <b>Learning outcomes</b>	<b>Conventional &amp; Sustainable Energy in Society</b> <ul style="list-style-type: none"> <li>Describe the concept of energy and the associated concept of the conservation of energy.</li> <li>Explain the concept of energy flows through the environment.</li> <li>Understand global context and issues of climate change, sustainability and energy.</li> <li>Explain the patterns of energy production and consumption with respect to a country's stage of development, economy and politics.</li> <li>Link the changing patterns of energy production and consumption to each country's level of development, economy and politics.</li> <li>Explain the principles of energy conversion.</li> <li>Identify major energy consuming sectors and ways of reducing consumption.</li> <li>Discuss energy resources and their social impact in the context of world distribution and monopolisation (OPEC).</li> <li>Discuss the different types of conventional and sustainable energy resources and conversion techniques.</li> <li>Identify the social, economic, environmental and technical issues associated with conventional and sustainable energy resources and conversion techniques.</li> </ul>	<b>Energy Policy 1</b> <ul style="list-style-type: none"> <li>Identify the objectives of energy policy such as economic efficiency, energy conservation, avoiding environmental degradation, economic development, sustainability, government revenue, urban transport, urban settlement, and the development of new energy technologies.</li> <li>Identify and describe contemporary energy policy issues.</li> <li>Recognise energy policy institutions.</li> <li>Describe how energy policy is made and changed.</li> <li>Read and critically analyse energy policy documents.</li> <li>Understand domestic and international energy policies, including community service obligations, industry development, policy instruments and how they are applied.</li> <li>Understanding of the public policy processes and institutions that give rise to the shape, direction and outcomes in the energy sector.</li> <li>Issues in energy policy and the commercialization of renewable energy systems</li> <li>Explain the need for international coordination of energy policies.</li> <li>Explain why particular policy instruments are chosen over others.</li> </ul>	<b>Energy Economics 1</b> <ul style="list-style-type: none"> <li>Recognise the variety of market structures found in the energy sector.</li> <li>Interpret and discuss the economic and social aspects of renewable and non-renewable energy systems.</li> <li>Understand economic theory relevant to the energy sector (cost benefit analysis, levelised cost, discounted cash flow analysis).</li> <li>Understanding of energy facilities, taxation of the energy sector and role of public utilities and government industry regulations.</li> <li>Define externalities in energy supply systems as the major areas for economic regulation by government.</li> <li>Identify, detail and analyse the techniques used for making investment decisions.</li> <li>Detail the economics of the main support policies that have been used to assist the market penetration of renewable energy technologies.</li> <li>Demonstrate an understanding of mass and energy balance principles and how they relate to economic systems of production.</li> </ul>	<b>Carbon Management Strategy 1</b> <ul style="list-style-type: none"> <li>Understand the basic science of human induced climate change and identify corresponding impacts at global, regional and local level.</li> <li>Understand international &amp; national policies, protocols and frameworks regulating climate change and greenhouse gas (GHG) reduction.</li> <li>Understand how to measure and report GHG emissions and conduct a greenhouse emissions audit for an organisation.</li> <li>Understand the main greenhouse gas emitting sectors in the economy and their expected future growth or reduction.</li> <li>Understand GHG marginal abatement cost (MAC) curves and how to use them to evaluate carbon reduction options.</li> <li>Understand mandatory and voluntary carbon/emissions trading schemes and potential strategies that businesses can adopt to optimise their response.</li> <li>Understand national and international Carbon Offset Standards, and how they enable accreditation of GHG (carbon) offsets and the accreditation of carbon Neutrality for companies and products.</li> <li>Understand how to develop a Carbon Management Response Plan in an organisation.</li> </ul>
	<b>Sustainable Energy Business and Project Management</b> <ul style="list-style-type: none"> <li>Understand the fundamentals of sustainable energy business management.</li> <li>Understand the fundamentals of sustainable energy project management.</li> <li>Understand the RD&amp;D cycle including financing.</li> <li>Understand the importance of safety standards in the energy supply and demand sector.</li> <li>Identify and interpret appropriate AS &amp; ISO quality and environmental management standards. e.g. ISO 90001, 150001, 140001.</li> <li>Understand the importance and process of an Environmental &amp; Social Impact Assessment.</li> <li>Understand relevant climate and energy law.</li> <li>Understand the nature of human behaviour within the context of the promotion of environmentally sustainable behaviour.</li> <li>Be able to develop and present a business case for sustainable energy technologies.</li> </ul>	<b>Electricity Network Systems</b> <ul style="list-style-type: none"> <li>Do simple energy and power calculations and calculations based on Ohm's Law including electricity transmission losses.</li> <li>Understand the different types of grids from large scale to mini – or micro-grids.</li> <li>Explain how electricity is distributed through a network (or grid) and describe the various components of an interconnected grid system, proceeding from the generation to the utilization of power.</li> <li>Understand the min transmission and power electronics components and their role in grids</li> <li>Understand the different thermal, physical and chemical energy storage technologies.</li> <li>Understand how the electricity grid is operated and managed and the various grid connection and management issues.</li> <li>Discuss methods involving both new and conventional technologies for increasing the efficiency and environmental sustainability of grid power systems.</li> <li>Understand the concept of smart grids.</li> </ul>	<b>Energy Efficiency &amp; Management 1</b> <ul style="list-style-type: none"> <li>Explain the concept of energy efficiency.</li> <li>Discuss some of the reason for inefficient energy systems.</li> <li>Be able to read and interpret a household or industrial electricity meter.</li> <li>Calculate the cost of energy for a facility given the details of the tariff structure.</li> <li>Discuss the effectiveness of labelling programmes and efficiency standards.</li> <li>Set up an effective energy plan based on sound principles.</li> <li>Apply the theory and practice of energy audits and the energy auditing standard.</li> <li>Demonstrate how tariffs apply in energy management schemes.</li> <li>Discuss opportunities for energy management in building design, air conditioning, lighting and industrial plant.</li> <li>Be able to analyse the economic viability of energy management options.</li> <li>Be able to develop an energy management system compliant with the ISO50001 standard.</li> </ul>	<b>Renewable Energy Systems 1</b> <ul style="list-style-type: none"> <li>Demonstrate an understanding of the operation of the main conventional and sustainable energy systems.</li> <li>Drawing a block diagram of different renewable energy systems showing the layout of the components in the system.</li> <li>Indicating on such diagrams, the power flows that occur within such systems.</li> <li>Describing the role of the various components in these systems.</li> <li>Describe the approaches used in designing and sizing these systems.</li> <li>Understand the relevant system design standards.</li> <li>Undertake simple design and sizing tasks for a number of the systems covered.</li> <li>Demonstrate an ability to use relevant systems design and modelling software.</li> </ul>

## Carbon Management (MSc)

### Medium level

### Learning outcomes

#### Greenhouse Gas Inventory

- Explain what is meant by GHG accounting and in particular the basics of Kyoto protocol accounting.
- Understand the different GHG emissions accounting standards and which one is the most appropriate to use at company, local government or national level.
- Compile and review GHG emissions data.
- Describe the various NGRS reporting requirements.
- Establish the organisational and operational boundaries under NGRS.
- Apply the five GHG accounting principles according to an organisation's business and policy objectives.
- Source and identify relevant NGRS methods for quantifying an organisation's GHGs from various point sources.
- Estimate emissions for a facility using NGRS Method 1 given adequate business input data.
- Estimate emissions for a facility using NGRS Methods 2 and 3 given appropriate sample data.
- Assess the uncertainty of emissions estimates under NGRS.
- Understand the GHG inventory auditing process and explain in detail the appropriate use of auditing reports.
- Explain what is meant by life cycle assessment and its use in GHG emissions estimation.
- Understand the role of greenhouse gas inventory and lifecycle assessment in achieving accredited Carbon Neutrality.
- Understand how to use the relevant protocol to develop a greenhouse gas emissions inventory for a local government area or region.

#### Lifecycle Assessment

- Explain what is meant by life cycle assessment and how it is used in environmental impact assessment.
- Explain what is meant by Life Cycle Thinking and supply chain management.
- Explain what is meant by burden shifting.
- Outline a product or services life cycle using the life cycle thinking framework.
- Describe the issues associated with "green" claims using a life cycle thinking approach.
- Explain how to complete a life cycle assessment.
- Understand how to use the ISO 14040 LCA standard when undertaking lifecycle assessments.
- Describe the relationship between the goal, scope and system boundary of a life cycle assessment.
- Demonstrate an understanding of IOA notation and an understanding of using basic matrix algebra for economic Input-Output Analysis and Life Cycle Assessment.
- Demonstrate an understanding of LCI analysis notation.
- Demonstrate an understanding of system boundaries.
- Demonstrate an understanding of the different interpretations of final demand.
- Demonstrate an understanding of hybrid inventory models and be able to solve problems using this method.
- Demonstrate an understanding of the method and results of a 'cradle to end of use phase' LCA.
- Demonstrate how to use Process or IO LCA software to generate lifecycle assessments of items or products.
- Demonstrate an understanding of lifecycle energy use and carbon emissions for different sectors of the economy.

#### Carbon Accounting, Offsets & Trading

- Understand marginal abatement cost curves and where offsets sit within options for carbon reduction.
- Explain the design and operation of an emissions trading scheme.
- Understand the various mandatory and voluntary offset standards and trading schemes at international, national and state levels.
- Understand national and international Carbon Offset Standards, and how they enable accreditation of greenhouse gas (carbon) offsets.
- Describe the process for receiving carbon offset standard accreditation of a carbon offset;
- Explain the anatomy of an offset.
- Understand how to establish a suitable base year, baseline or base case, and set recalculation triggers.
- Understand the various methodologies for accrediting carbon offsets for different sectors and abatement types.
- Explain the importance of reconciling offsets and demonstrate their appropriateness.

#### Change Management

- Organisational change management
- Understand the capacity to develop and implement sustainable energy strategies within organisations.
  - Have an appreciation of the scope and nature of the organisational change agenda for sustainability management.
  - Have an ability to apply business principles to develop and deliver the business case for corporate sustainability.
  - Have an appreciation of the critical importance of corporate strategy to design and effectuate incremental and transformational business changes.
  - Have an ability to assess performance of corporate strategies for sustainability management.
- Behaviour change
- Understand the nature of human behaviour within the context of the promotion of environmentally sustainable behaviour.
  - Be able to examine and understand the historical context of the term 'behaviour change' in terms of changing political relationships between the individual, the state and civil society.
  - Be able to describe and evaluate different theoretical approaches to understanding behaviour.
  - Be able to critically analyse case studies and examples of government tools and strategies for promoting behaviour change.
  - Understand behavioural economics and social psychology.
  - Understand the use of practice theory and other sociological approaches.
  - Understand community based interventions.
  - Understand the implementation issues in behaviour change interventions.
  - Understand how to measure and evaluate behaviour change.
  - Understand the evolution of government policies on behaviour change relevant to sustainability.

## Carbon Management (MSc)

### Advanced level

### Learning outcomes

#### Carbon Management Strategy 2

- Be able to describe marginal abatement costs (MAC) and curves and calculate the levelised abatement cost for an abatement option.
- Be able to construct a short run MAC curve.
- Be able to construct a long run MAC curve.
- Be able to articulate (using the MAC curve) the tension between abatement costs, permit prices, and other emissions trading instruments.
- Understand how to effectively implement and monitor a carbon management response plan for an organisation.
- Be able to discuss the various international inventory and carbon offset standards and approaches to Carbon Neutrality.
- Understand national and international Carbon Offset Standards, and how they enable accreditation of Carbon Neutrality for companies and products;
- Be able to describe the process for obtaining and maintaining carbon offset standard Carbon Neutral accreditation for a company;
- Understand the role of greenhouse gas inventory and lifecycle assessment in achieving accredited Carbon Neutrality.
- Be able to describe the process for obtaining and maintaining carbon offset standard Carbon Neutral accreditation for a product.
- Understand what is required to develop and advertise Carbon Neutrality for a company or product that will be acceptable to Competition and Consumer regulators.

#### Energy Efficiency, Systems Analysis and Auditing (elective)

- Have an ability to identify factors influencing energy use or waste, including procedural, contractual, legal, organisational structure, job descriptions, key performance indicators and behaviour.
- Have an awareness and understanding of new and existing technologies, their feasibility and cost effectiveness, as well as other research and development occurring within the sector and overseas.
- Be able to understand and analyse design, procurement, commissioning, operational and maintenance practices.
- Be able to set up an effective energy plan based on sound principles.
- Be able to apply the theory and practice of energy audits.
- Be able to demonstrate how tariffs apply in energy management schemes.
- Be able to analyse the economic viability of energy management options.
- Have the energy and other data collection skills required to determine, collect and manage the most appropriate energy and process related data, including setting appropriate boundaries for analysis.
- Have an ability to assess, install and use appropriate monitoring equipment and develop analysis systems. and apply appropriate techniques for analysis, feedback provision and system/process management based on improved access to information.
- Have an ability to undertake and apply specific techniques such as Pinch analysis, development of models and other engineering focused process optimisation techniques.
- Have an ability to collect and analyse energy and financial data for the purpose of identifying energy use and savings.
- Have an ability to develop and implement effective data management, tracking and reporting systems.
- Be able to apply energy data analysis skills to apply a range of methods to explore relationship between energy use and a range of variables that may influence it.

#### Advanced Thesis/Research Project

- Understand key issues in the research puzzle, the development of effective research proposals, literature review, methodology, ethics, and the
- Demonstrate skills in research design, evaluation, analysis and critique, together with high level written communication skills, organisation and time management, and the capacity for self directed and independent learning.

#### Energy Efficiency and Decarbonisation in Precincts (elective)

- Understand the approaches to measuring the greenhouse gas inventory and carbon footprint of precincts and cities.
- Understand the concepts of more efficient and lower carbon precinct and city design and planning including PODs, GODs and TODs.
- Understand the concept of mode switching in transport within and between settlements and how more efficient and decarbonised transport systems can be developed. This includes more energy efficient road and transport corridor design.
- Understand the approaches that can be used to provide more energy efficient water and waste management for precincts.
- Understand how to assess the feasibility of and how to implement, district heating and cooling
- Understand how to assess the feasibility of and how to implement district scale renewable energy systems and networks
- Understand other strategies for decarbonisation of precincts and settlements.

## Curriculum Framework Set 5: Sustainable Energy Majors in Other Degrees

The curriculum framework and set of curriculum maps in this section provide guidance for the development of **sustainable energy majors** in other conventional degrees.



### Sustainable Energy Major in Other Degrees Framework Relationships Map

Majors Curriculum Framework Relationships Map	Conventional BA (e.g. Public Policy, Commerce, Economics)	Related BEng (e.g. Mechanical or Electrical/Power Engineering)	Conventional BSc (e.g. Environmental Science, Physics)
<b>Graduate attributes</b>	<b>Prerequisites</b> <ul style="list-style-type: none"> <li>High school maths, physics and chemistry</li> <li>IT skills</li> <li>Statistics</li> <li>First year university level economics</li> </ul>	<b>Prerequisites</b> <ul style="list-style-type: none"> <li>First year university level maths, physics and chemistry</li> <li>IT skills</li> <li>Statistics</li> </ul>	<b>Prerequisites</b> <ul style="list-style-type: none"> <li>First year university level maths, physics and chemistry</li> <li>IT skills</li> <li>Statistics</li> </ul>
<b>Major in Sustainable Energy</b>	Based on 3 core units and one elective <ul style="list-style-type: none"> <li>Conventional and Sustainable Energy in Society</li> <li>Energy Policy 1</li> <li>Energy Economics 1</li> </ul> And choose one of <ul style="list-style-type: none"> <li>Energy Efficiency and Carbon Management, or</li> <li>Renewable Energy Systems and Networks</li> </ul>	Based on 4 core units <ul style="list-style-type: none"> <li>Conventional and Sustainable Energy in Society</li> <li>Energy Economics and Policy</li> <li>Energy Efficiency and Management 1</li> <li>Renewable Energy Systems 1</li> </ul>	Based on 4 core units <ul style="list-style-type: none"> <li>Conventional and Sustainable Energy in Society</li> <li>Energy Economics and Policy</li> <li>Energy Efficiency and Carbon Management</li> <li>Renewable Energy Systems and Networks</li> </ul>

## **Conventional Bachelor of Arts**

This set of curriculum framework learning outcome maps provides guidance for programme coordinators and unit coordinators in the planning and development of a sustainable energy major in a conventional Bachelor of Arts or Bachelor of Business degrees such as Public Policy, Commerce or Economics.

## Learning Outcomes Map

		Conventional BA (e.g. Public Policy, Commerce, Economics)				
Major in Sustainable Energy	Learning Outcomes	<b>Conventional &amp; Sustainable Energy in Society</b> <ul style="list-style-type: none"> <li>Describe the concept of energy and the associated concept of the conservation of energy.</li> <li>Explain the concept of energy flows through the environment.</li> <li>Understand global context and issues of climate change, sustainability and energy.</li> <li>Explain the patterns of energy production and consumption with respect to a country's stage of development, economy and politics.</li> <li>Link the changing patterns of energy production and consumption to each country's level of development, economy and politics.</li> <li>Explain the principles of energy conversion.</li> <li>Identify major energy consuming sectors and ways of reducing consumption.</li> <li>Discuss energy resources and their social impact in the context of world distribution and monopolisation (OPEC).</li> <li>Discuss the different types of conventional and sustainable energy resources and conversion techniques.</li> <li>Identify the social, economic, environmental and technical issues associated with conventional and sustainable energy resources and conversion techniques.</li> </ul>	<b>Energy Policy 1</b> <ul style="list-style-type: none"> <li>Identify the objectives of energy policy such as economic efficiency, energy conservation, avoiding environmental degradation, economic development, sustainability, government revenue, urban transport, urban settlement, and the development of new energy technologies.</li> <li>Identify and describe contemporary energy policy issues.</li> <li>Recognise energy policy institutions and describe how energy policy is made and changed.</li> <li>Read and critically analyse energy policy documents.</li> <li>Understand domestic and international energy policies, including community service obligations, industry development, policy instruments and how they are applied.</li> <li>Understanding of the public policy processes and institutions that give rise to the shape, direction and outcomes in the energy sector.</li> <li>Issues in energy policy and the commercialization of sustainable energy systems.</li> <li>Explain the need for international coordination of energy policies.</li> <li>Explain why particular energy policy instruments are chosen over others.</li> </ul>	<b>Energy Economics 1</b> <ul style="list-style-type: none"> <li>Recognise the variety of market structures found in the energy sector.</li> <li>Interpret and discuss the economic and social aspects of renewable and non-renewable energy systems.</li> <li>Understand economic theory relevant to the energy sector (cost benefit analysis, levelised cost, discounted cash flow analysis).</li> <li>Understanding of energy facilities, taxation of the energy sector and role of public utilities and government industry regulations.</li> <li>Define externalities in energy supply systems as the major areas for economic regulation by government.</li> <li>Identify, detail and analyse the techniques used for making investment decisions.</li> <li>Detail the economics of the main support policies that have been used to assist the market penetration of renewable energy technologies.</li> <li>Demonstrate an understanding of mass and energy balance principles and how they relate to economic systems of production.</li> </ul>	<b>Energy Efficiency and Carbon Management (elective)</b> <ul style="list-style-type: none"> <li>Explain the concept of energy efficiency and discuss some of the reason for inefficient energy systems.</li> <li>Be able to read and interpret a household or industrial electricity meter and calculate the cost of energy for a facility given the details of the tariff structure.</li> <li>Demonstrate how tariffs apply in energy management schemes.</li> <li>Discuss the effectiveness of labelling programmes and efficiency standards.</li> <li>Discuss opportunities for energy management in building design, air conditioning, lighting and industrial plant.</li> <li>Understand international &amp; national policies, protocols and frameworks regulating climate change and greenhouse gas (GHG) reduction.</li> <li>Understand how to measure and report GHG emissions and conduct a greenhouse emissions audit for an organisation.</li> <li>Understand the main greenhouse gas emitting sectors in the economy and their expected future growth or reduction.</li> <li>Understand GHG marginal abatement cost (MAC) curves and how to use them to evaluate carbon reduction options.</li> <li>Understand national and international Carbon Offset Standards, and how they enable accreditation of GHG (carbon) offsets and the accreditation of Carbon Neutrality for companies and products.</li> <li>Be able to analyse and present a business case for the economic viability of energy efficiency and carbon reduction options.</li> </ul>	<b>Renewable Energy Systems and Electricity Networks (elective)</b> <ul style="list-style-type: none"> <li>Demonstrate an understanding of the operation of the main conventional and sustainable energy systems.</li> <li>Be able to draw a block diagram of different renewable energy systems showing the layout of the components in the system and indicating the power flows that occur within such systems.</li> <li>Be able to describe the role of the various components in these systems including: <ul style="list-style-type: none"> <li>Generation;</li> <li>Power electronics; and</li> <li>Storage.</li> </ul> </li> <li>Understand the different types of grids from large scale to mini – or micro-grids.</li> <li>Explain how electricity is distributed through a network (or grid) and describe the various components of an interconnected grid system, proceeding from the generation to the utilization of power.</li> <li>Do simple energy and power calculations and calculations based on Ohm's Law including electricity transmission losses.</li> <li>Describe the approaches used in designing and sizing renewable energy based systems and understand the relevant system design standards.</li> <li>Undertake simple design and sizing tasks for a number of the systems covered.</li> <li>Understand how the electricity grid is operated and managed and the various grid connection and management issues.</li> <li>Discuss methods involving both new and conventional technologies for increasing the efficiency and environmental sustainability of grid power systems.</li> <li>Understand the concept of smart grids.</li> </ul>

## Related Bachelor of Engineering

This set of curriculum framework learning outcome maps provides guidance for programme coordinators and unit coordinators in the planning and development of a sustainable energy major in a **related** Bachelor of Engineering, such as Mechanical or Electrical/Power Engineering.



## Learning Outcomes Map


		Related BEng (e.g. Mechanical or Electrical/Power Engineering)			
Major in Sustainable Energy	Learning Outcomes	<b>Conventional &amp; Sustainable Energy in Society</b> <ul style="list-style-type: none"> <li>Describe the concept of energy and the associated concept of the conservation of energy.</li> <li>Explain the concept of energy flows through the environment.</li> <li>Understand global context and issues of climate change, sustainability and energy.</li> <li>Explain the patterns of energy production and consumption with respect to a country's stage of development, economy and politics.</li> <li>Link the changing patterns of energy production and consumption to each country's level of development, economy and politics.</li> <li>Explain the principles of energy conversion.</li> <li>Identify major energy consuming sectors and ways of reducing consumption.</li> <li>Discuss energy resources and their social impact in the context of world distribution and monopolisation (OPEC).</li> <li>Discuss the different types of conventional and sustainable energy resources and conversion techniques.</li> <li>Identify the social, economic, environmental and technical issues associated with conventional and sustainable energy resources and conversion techniques.</li> </ul>	<b>Energy Economics and Policy</b> <ul style="list-style-type: none"> <li>Identify the objectives of energy policy such as economic efficiency, energy conservation, avoiding environmental degradation, economic development, sustainability, government revenue, urban transport, urban settlement, and the development of new energy technologies.</li> <li>Understand domestic and international energy policies, including community service obligations, industry development, policy instruments and how they are applied.</li> <li>Understanding of the public policy processes and institutions that give rise to the shape, direction and outcomes in the energy sector.</li> <li>Read and critically analyse energy policy documents.</li> <li>Identify and describe contemporary energy policy issues including issues related to the commercialization of sustainable energy systems.</li> <li>Explain why particular policy instruments are chosen over others.</li> <li>Recognise the variety of market structures found in the energy sector.</li> <li>Understand economic theory relevant to the energy sector (cost benefit analysis, levelised cost, discounted cash flow analysis).</li> <li>Understanding of energy facilities, taxation of the energy sector and role of public utilities and government industry regulations.</li> <li>Define externalities in energy supply systems as the major areas for economic regulation by government.</li> <li>Interpret and discuss the economic and social aspects of sustainable and conventional energy systems.</li> <li>Detail the economics of the main support policies that have been used to assist the market penetration of renewable energy technologies.</li> </ul>	<b>Energy Efficiency &amp; Management 1</b> <ul style="list-style-type: none"> <li>Explain the concept of energy efficiency.</li> <li>Discuss some of the reason for inefficient energy systems.</li> <li>Be able to read and interpret a household or industrial electricity meter.</li> <li>Calculate the cost of energy for a facility given the details of the tariff structure.</li> <li>Discuss the effectiveness of labelling programmes and efficiency standards.</li> <li>Set up an effective energy plan based on sound principles.</li> <li>Apply the theory and practice of energy audits and the energy auditing standard.</li> <li>Demonstrate how tariffs apply in energy management schemes.</li> <li>Discuss opportunities for energy management in building design, air conditioning, lighting and industrial plant.</li> <li>Be able to analyse the economic viability of energy management options.</li> <li>Be able to develop an energy management system compliant with the ISO50001 standard.</li> </ul>	<b>Renewable Energy Systems 1</b> <ul style="list-style-type: none"> <li>Demonstrate an understanding of the operation of the main conventional and sustainable energy systems.</li> <li>Drawing a block diagram of different renewable energy systems showing the layout of the components in the system.</li> <li>Indicating on such diagrams, the power flows that occur within such systems.</li> <li>Describing the role of the various components in these systems.</li> <li>Describe the approaches used in designing and sizing these systems.</li> <li>Understand the relevant system design standards.</li> <li>Undertake simple design and sizing tasks for a number of the systems covered.</li> <li>Demonstrate an ability to use relevant systems design and modelling software.</li> </ul>

## Conventional BSc

This set of curriculum framework learning outcome maps provides guidance for programme coordinators and unit coordinators in the planning and development of a sustainable energy major in a related Bachelor of Science degree, such as Environmental Science or Physics.

## Learning Outcomes Map

		Conventional BSc (e.g. Environmental Science, Physics)		
Major in Sustainable Energy	Conventional & Sustainable Energy in Society	Energy Economics and Policy	Energy Efficiency and Carbon Management	Renewable Energy Systems and Electricity Networks
	Learning Outcomes	<ul style="list-style-type: none"> <li>Describe the concept of energy and the associated concept of the conservation of energy.</li> <li>Explain the concept of energy flows through the environment.</li> <li>Understand global context and issues of climate change, sustainability and energy.</li> <li>Explain the patterns of energy production and consumption with respect to a country's stage of development, economy and politics.</li> <li>Link the changing patterns of energy production and consumption to each country's level of development, economy and politics.</li> <li>Explain the principles of energy conversion.</li> <li>Identify major energy consuming sectors and ways of reducing consumption.</li> <li>Discuss energy resources and their social impact in the context of world distribution and monopolisation (OPEC).</li> <li>Discuss the different types of conventional and sustainable energy resources and conversion techniques.</li> <li>Identify the social, economic, environmental and technical issues associated with conventional and sustainable energy resources and conversion techniques.</li> </ul>	<ul style="list-style-type: none"> <li>Identify the objectives of energy policy such as economic efficiency, energy conservation, avoiding environmental degradation, economic development, sustainability, government revenue, urban transport, urban settlement, and the development of new energy technologies.</li> <li>Understand domestic and international energy policies, including community service obligations, industry development, policy instruments and how they are applied.</li> <li>Understanding of the public policy processes and institutions that give rise to the shape, direction and outcomes in the energy sector.</li> <li>Read and critically analyse energy policy documents.</li> <li>Identify and describe contemporary energy policy issues including issues related the commercialization of sustainable energy systems.</li> <li>Explain why particular policy instruments are chosen over others.</li> <li>Recognise the variety of market structures found in the energy sector.</li> <li>Understand economic theory relevant to the energy sector (cost benefit analysis, levelised cost, discounted cash flow analysis).</li> <li>Understanding of energy facilities, taxation of the energy sector and role of public utilities and government industry regulations.</li> <li>Define externalities in energy supply systems as the major areas for economic regulation by government.</li> <li>Interpret and discuss the economic and social aspects of sustainable and conventional energy systems.</li> <li>Detail the economics of the main support policies that have been used to assist the market penetration of renewable energy technologies.</li> </ul>	<ul style="list-style-type: none"> <li>Explain the concept of energy efficiency and discuss some of the reason for inefficient energy systems.</li> <li>Be able to read and interpret a household or industrial electricity meter and calculate the cost of energy for a facility given the details of the tariff structure.</li> <li>Discuss the effectiveness of labelling programmes and efficiency standards.</li> <li>Demonstrate how tariffs apply in energy management schemes.</li> <li>Discuss opportunities for energy management in building design, air conditioning, lighting and industrial plant.</li> <li>Understand international &amp; national policies, protocols and frameworks regulating climate change and greenhouse gas (GHG) reduction.</li> <li>Understand how to measure and report GHG emissions and conduct a greenhouse emissions audit for an organisation.</li> <li>Understand the main greenhouse gas emitting sectors in the economy and their expected future growth or reduction.</li> <li>Understand GHG marginal abatement cost (MAC) curves and how to use them to evaluate carbon reduction options.</li> <li>Understand national and international Carbon Offset Standards, and how they enable accreditation of GHG (carbon) offsets and the accreditation of Carbon Neutrality for companies and products.</li> <li>Be able to analyse and present a business case for the economic viability of energy efficiency and carbon reduction options.</li> </ul>



## **Section 3 – Guidance on Five Key Questions Related to Programme Design and Course Delivery**

# Five Key Questions About Programme Design and Course Delivery

This section provides guidance on five key questions related to programme design and the delivery of courses.



In association with the development of the curriculum frameworks the project sought to determine the best approach to, and provide advice on, five key questions related to designing the sustainable energy programmes and delivering the skills and knowledge. These five key questions are:

- The mixture of inter/multi-disciplinary content vs specialised content that should be included in sustainable energy programmes. For example how much and what type of policy and enablers content should be included as core content in sustainable engineering degrees and alternatively what type of technical knowledge should be included as core content in humanities courses on policy and enablers;
- Whether Universities should develop and offer specialist courses and programmes (e.g. BEng in Sustainable Energy) at undergraduate level versus embedding the relevant skills and knowledge into existing discipline training (an existing engineering electrical or power degree);
- The feasibility and desirability of providing sustainable energy teaching by face-to-face mode only versus online and flexible delivery;
- The need for and amount of work integrated learning that is optimal, or acceptable during sustainable energy degrees and what type and level of involvement industry practitioners should have in the delivery of the courses;
- The need for and how to enable sufficient internationalisation of the curriculum and course content so that it meets the needs of international students studying in Australia or at affiliated international institutions, and Australian graduates seeking to work overseas.

In order to gain an understanding of, and provide guidance on these questions the project took a three research pronged approach:

- A review of best practice guides and other related publications from previous OLT projects;
- Responses to questions related to these questions in the graduate and industry representative surveys; and
- A survey of staff in selected international Universities offering well recognised or best practice sustainable energy programmes to see how they approached these questions in the offering of their courses.

## Inter/multi-disciplinary content vs specialised content

A long running discussion in the sustainable energy area has been the amount of inter- or multi-disciplinary knowledge vs specific specialised knowledge that graduates, particularly of technical programmes should have. It is commonly believed for example that industry think that sustainable energy engineers should focus on technical and engineering knowledge and not learn about energy policy or other enablers. This is particularly true where there is already a fairly crowded curriculum

such as in undergraduate sustainable energy engineering. On the other hand it is believed that graduates in policy and enablers do not need to understand renewable energy technology in any depth.

It is necessary to gain a clear understanding of this before curriculum frameworks can be developed. Questions about this subject were included in the graduate and industry representative surveys. The responses showed that 76 per cent of all graduates and 74 per cent of engineering graduates believed that knowledge of policy and enablers was important or very important. Eighty six percent of all and 66 per cent of engineering industry representatives believed that knowledge of policy and enablers was important or very important. These are similar percentages for the responses regarding knowledge of power generation technologies and higher than knowledge of transmission, storage and network systems. It is clear that existing graduates and industry believe that all graduates of sustainable energy programmes, whether technical or non-technical should have a good knowledge of policy and enablers. This feedback has been incorporated into the sustainable energy curriculum frameworks.

It should also be noted that 94 per cent of all graduates and 95 per cent of all industry representatives surveyed believed that generic skills and professional attributes were important or very important.

Europe has the most sustainable energy courses, a number of which are best practice. Some of them such as the course at the University of Oldenburg are more than 25 years old. A review of leading masters, graduate and postgraduate courses in renewable energy in the IRENA Renewable Energy Learning Partnership (IRELP) global database has been undertaken by Volker Schneider [Volker Schneider 2013]. The review concludes that graduate and postgraduate programmes in renewable energy or specific fields (e.g. solar/PV/wind or geothermal) in Europe are very technical and engineering driven and focussed on real world environments. Courses in areas such as energy efficiency, industrial ecology, energy management and general sustainability are often more academic and multidisciplinary in nature. In these cases the curriculum is focussed on providing a broader conceptual and interdisciplinary approach to energy management and sustainability.

**Recommendation:** All graduates of sustainable energy programmes, whether technical or non-technical should have a good knowledge of policy and enablers and key technical knowledge. Knowledge related to both of these areas should be included in any sustainable energy programme or course curriculum. It is important to include, and make explicit in all programmes the required generic attributes and discipline specific capabilities needed to work effectively as a graduate in that area.

## Specialist undergraduate programmes versus embedding sustainable energy in existing discipline training

As well as the knowledge content of courses it is important to understand the programmes or degrees that are seen by employers and graduates to be most likely to provide the skills and knowledge they need. In the Australian context, where the sustainable energy industry is still relatively small, although growing, it is important to understand which types of programmes will lead to good employability amongst graduates. For example is it better to develop and offer specialised sustainable energy engineering degrees or is it as good, or better, to offer a sustainable energy major/specialisation in a conventional engineering degree. Will a multi-disciplinary, non-engineering undergraduate sustainable energy degree be seen as providing the skills and knowledge graduates need to work in the industry? This will in turn inform the types of curriculum frameworks

developed.

Questions about this subject were included in the graduate and industry representative surveys. It was clear from the results that graduates (whether from engineering or multi-disciplinary programmes themselves) believed that engineering degrees (both undergraduate and postgraduate) were the ones most likely to provide the skills and knowledge needed by graduates in the sustainable energy industry. A similar view was held by industry representatives. Interestingly the graduates did not see significant difference between the suitability of specialised sustainable energy engineering degrees and those having a major in a conventional engineering degree. On the other hand more industry representatives believed that having a major in a conventional engineering degree was likely to provide the skills and knowledge needed.

Specialist undergraduate multi-disciplinary (non-engineering) degrees were not seen as a good way to provide the necessary skills and knowledge. This is reflected in the offerings at Australian Universities where there are no longer any undergraduate multi-disciplinary sustainable energy degrees offered. A specialised postgraduate multi-disciplinary (non-engineering) degree was however seen as a good way of providing the skills and knowledge needed.

These findings have been reflected in the new sustainable energy curriculum frameworks.

**Recommendation:** Institutions should decide based on desired marketing position, capability, capacity and other considerations whether they wish to offer a specialist undergraduate degree in sustainable energy or offer sustainable energy as a major or stream within a conventional undergraduate engineering degree. There is no evidence from graduates or industry that one is better than the other for meeting the needs of, or gaining employment in, the sustainable energy industry. There is no support in industry at this stage for a multidisciplinary undergraduate degree in sustainable energy, and this area of specialisation is best provided through a specialist postgraduate programme.

## Teaching by face-to-face mode only versus online and flexible delivery

With the rapid growth of the internet and portable IT devices more and more students, especially postgraduate students, are seeking to have flexibility in the way in which courses and course content are delivered and accessed. There is ongoing debate in the University system about the increased adoption of more flexible and online teaching and learning methods.

"Why in the world would students come along and sit in a passive lecture with 300 other students when they can access material online themselves. It makes no sense to me"

Australian National University Vice-Chancellor Ian Young – The Age Oct 2<sup>nd</sup> 2012

Murdoch University has been successfully offering its postgraduate multi-disciplinary Energy Studies programme online, without the need to attend campus, around the world for almost 15 years. There are also a few programmes offered fully online in Europe.

Blended learning, which mixes face-to-face and online learning is rapidly growing.

Questions about the desirability of different modes of delivering course content were included in the graduate and industry representative surveys. Amongst the graduates blended learning was the most highly rated mode of delivery by both engineering and multi-disciplinary graduates. In the industry survey conventional campus based face-to-face was the

most highly rated course delivery mode amongst engineers. Amongst multi-disciplinary industry representatives blended learning was the most highly rated mode of delivery.

The review of the European IRELP database by Schneider (Volker Schneider, 2013) showed that close to 90 per cent of the courses are full-time with face-to-face instruction on campus. Approximately 10-15 per cent of programmes offer part-time study options combined with distance learning and online study resources. Relatively few “online only” courses exist in European institutions. Examples include:

- The Master Propio on Renewable Energy of the University of Zaragoza;
- The MSc in Renewable Energy and Energy Management of the University of Ulster; and
- The Online Masters in Photovoltaics offered by the University of Freiburg.

**Recommendation:** Where possible Universities should strive to use blended learning to deliver their sustainable energy courses offering the increased flexibility this brings. There is also a place particularly for multi-disciplinary programmes to be made available fully online.

## Work integrated learning and involvement of industry in teaching

For a practical industry focussed area such as sustainable energy graduates seek to have skills and knowledge that is relevant, current and prepares them for the workplace. Two key ways to assist this are to incorporate work integrated learning (WIL) into the curriculum and ensure that industry practitioners are actively involved in the teaching. In order to assist Universities in how much WIL and industry involvement in teaching they should have this study has surveyed graduates and industry representatives to determine their recommendation. It has also reviewed the approach in other best practice programmes.

According to Orrell [2011] in the ALTC “Good Practice Report: Work-integrated learning” the most common use of work integrated learning

“is to describe different programmes where students engage with workplaces and communities as a formal part of their studies. Terms such as practicum, field-work, internships, cooperative education and clinical placement describe these programmes.”

and

“A commonly expected outcome of these student WIL experiences is gaining new knowledge, understandings and capabilities, and mastering skills considered essential to particular workplaces.”

Some professions, such as Engineering have a formal requirement that graduates will undertake a minimum amount of internship during their undergraduate course.

In order to provide currency and relevance to the knowledge and skills taught to graduates it is important to have industry practitioners involved directly in teaching and/or project supervision in sustainable energy programmes.

Questions related to the importance of work integrated learning and direct industry practitioner involvement in teaching in sustainable energy programmes were included in the graduate and industry representative surveys.



Eighty seven percent of engineering graduates and ninety four percent of multi-disciplinary graduates rated work integrated learning (defined as placement for some period of time in a position in industry) as Very Important. Engineering graduates felt that between two and 12 weeks (mean of four weeks) should be required in a postgraduate (two-year coursework masters) degree. Multi-disciplinary non-engineering graduates felt that between two and 12 weeks (mean of six weeks) should be required in a postgraduate (two-year coursework masters) degree. This was supported by industry who felt that even more time should be required for WIL with between four and 11 weeks (mean of 10 weeks) being required in a postgraduate (two-year coursework masters) degree.

However when questioned approximately sixty five percent of engineering and multi-disciplinary non-engineering graduates felt their SE qualification /programme did not have enough adequate work integrated learning. Apart from undergraduate engineering sustainable engineering degree there is currently no requirement for WIL as part of any Australian sustainable energy courses, although it is encouraged. The IRELP database study by Schneider [Volker Schneider, 2013] found that most European sustainable and renewable energy programmes include an internship and close mentorship by academic staff. Based on the required internships and project work, many European masters programmes create strong ties between students and industry facilitating employment in the renewable energy sector upon graduation.

It appears that there is a need to better, formally include and then appropriately support WIL in the curriculum of Australian postgraduate sustainable energy programmes.

Eighty eight percent of engineering, multi-disciplinary graduates and industry representatives rated work direct teaching and/or project supervision by industry practitioners as Important or Very Important. However when questioned only 50 per cent of graduates (both engineering and multi-disciplinary non-engineering) felt their SE qualification /programme had enough direct teaching or project supervision by industry practitioners. Again it appears that there is a need for academics and institutions to include more direct teaching or project supervision by industry practitioners in the delivery of their courses.

It is acknowledged that the involvement of industry in either WIL or teaching/supervision activities is not always easy given the small and distributed nature of the Australian sustainable energy industry. Commitment and good relationship between academics in programmes and industry, coupled with an innovative approach will be needed. The curriculum frameworks reflect this identified need for WIL as a requirement within the programmes.

**Recommendation:** All sustainable energy programmes, whether technical or non-technical should require and facilitate some form of work integrated, workplace based, learning into their curriculum, such as internship or industry based thesis. It is also important that industry practitioners have direct teaching and or project supervision involvement in sustainable energy programmes and courses. Strong ties between students and industry will facilitate better employment in the sustainable energy sector upon graduation.

## International relevance

Australia is seen as a leading provider of sustainable energy training and has developed a number of globally pioneering sustainable energy University programmes. This attracts many international students to study in Australian institutions. A significant number of Australian students are also being employed and working internationally. If Australia's University courses, and Australian graduates are going to remain internationally competitive it is important that they are internationally

relevant and internationalised. When the curriculum frameworks were developed it was important to ensure that they, and the graduates from them, are internationally relevant

The survey asked graduates and industry representatives questions regarding the international relevance of existing Australian sustainable energy courses, and what if anything should be changed to make them more so if needed. Seventy six percent of Sustainable Energy Engineering graduates rated the skills and knowledge taught in their qualification as very internationally relevant. On the other hand only 36 per cent of multi-disciplinary course graduates rated their skills and knowledge as internationally relevant. About 52 per cent of sustainable energy engineering graduates felt their training would make them very sought after and employable overseas whilst only 33 per cent of multi-disciplinary graduates felt their qualification would make them employable overseas. The following quote from a sustainable energy engineering graduate seemed to reflect the view of many graduates.

*“Almost all the skills I learnt were very internationally relevant. However, further skills in addition to those learnt during my degree were also needed to before I was able to gain work overseas.”*

Several students suggested that the extra knowledge needed was local knowledge about local policies and rating tools which should not be taught in the degree, but picked up later as needed. Based on the feedback from graduates it appears that the current sustainable energy engineering courses are suitably internationally relevant and there does not need to be any significant revision or change to the current curriculums and units to address this.

On the other hand the multi-disciplinary sustainable energy courses are not seen in their current form as being sufficiently internationally relevant. Some of the areas where they needed to be improved included:

- Too local/Australian focused with very little from the rest of the world;
- Too Remote area power supply (RAPS) based;
- Need more contract and project management, that is transferrable skills;
- A need to educate students on tools and software for employment not just providing knowledge.

Based on the feedback of the graduates it appears that the current curriculums and courses of the multidisciplinary programmes need to be revised in order to more internationally relevant. In the words of one graduate they need:

“a better learning curriculum that is both commercially relevant and recent.”

This feedback has been incorporated into the development of the curriculum frameworks.

**Recommendation:** That the curriculum of all sustainable energy programmes whether Engineering or non-engineering should contain knowledge that is current and internationally and commercially relevant.



## **Section 4 – Approach and Methodology for Developing the Curriculum Frameworks**

# Frameworks Development

This section describes the approach and methodology used to develop the sustainable energy frameworks

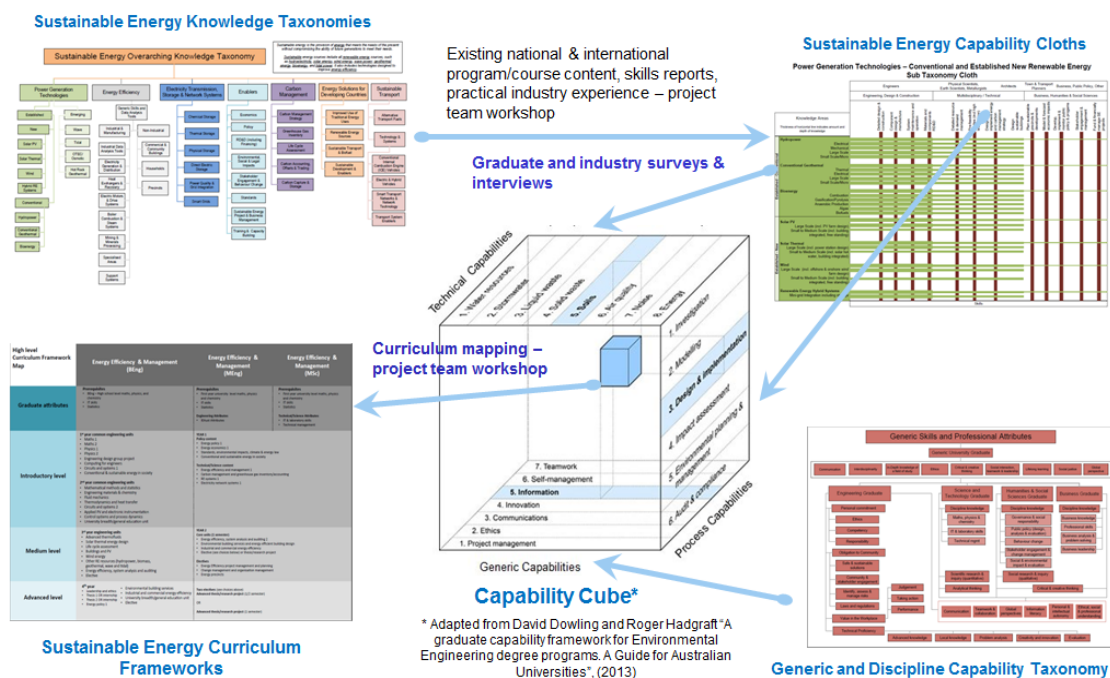


## Methodology and Approach

*“Following a quality assurance model, curriculum design and change should be a combined effort of teaching staff, administrators, researchers, students and potential employers. Involvement of all stakeholders in the renewal process can produce an end result that is vital, practical and prepares graduates for immediate entry into a competitive workforce”*

*ALTC Good Practice Report: Curriculum Renewal [Narayan and Edwards, 2011]*

In order to develop the final curriculum frameworks the project adapted and extended the approach of Dowling and Hadgraft [March 2013] used by them for Environmental Engineering degrees and established curriculum mapping approaches (such as that promoted by the University of West Florida - see [http://uwf.edu/cutla/curriculum\\_map\\_graduate\\_ALP.cfm](http://uwf.edu/cutla/curriculum_map_graduate_ALP.cfm)). The key elements of the approach to developing the final curriculum frameworks is summarised in the following figure.



**Figure 7: Schematic showing the framework, approach and process for developing the sustainable energy curriculum frameworks.**

The following section describes in detail the research based approach and techniques that were used to achieve the project outcomes.

# Determining what knowledge and skills are required

The first step in developing the curriculum frameworks was to develop an understanding of the *knowledge* (called technical capabilities by Dowling and Hadgraft), skills (called process capabilities by Dowling and Hadgraft) and the *generic and discipline specific capabilities* required by sustainable energy graduates working in the range of roles required by industry. These then needed to be presented in a manner that could be easily understood and commented on by industry and graduates. Research was undertaken to derive a catalogue of knowledge and skills taught in existing Australian and international sustainable energy programmes and courses as well as relevant sustainable energy skills reports. This included an extensive list of learning outcomes and objectives covering a wide range of knowledge and skills. Based on this research, the industry experience of the senior researcher and a workshop involving the project team members a set of sustainable energy “knowledge taxonomies” were developed. These taxonomies visually present in a diagrammatic form the range of knowledge areas considered to constitute “sustainable energy” and their relationship to each other. The overarching taxonomy diagram developed (Figure 8) shows seven main areas of sustainable energy knowledge. Each of these areas then has a set of sub taxonomy diagrams presenting the knowledge required in more detail. Figure 9 shows the relationship between the overarching taxonomy and the sub taxonomies, while Figure 10 shows an example of a sub taxonomy. The full sets of knowledge taxonomies with accompanying narrative are available from the project website <<http://www.murdoch.edu.au/projects/secfp/>>.

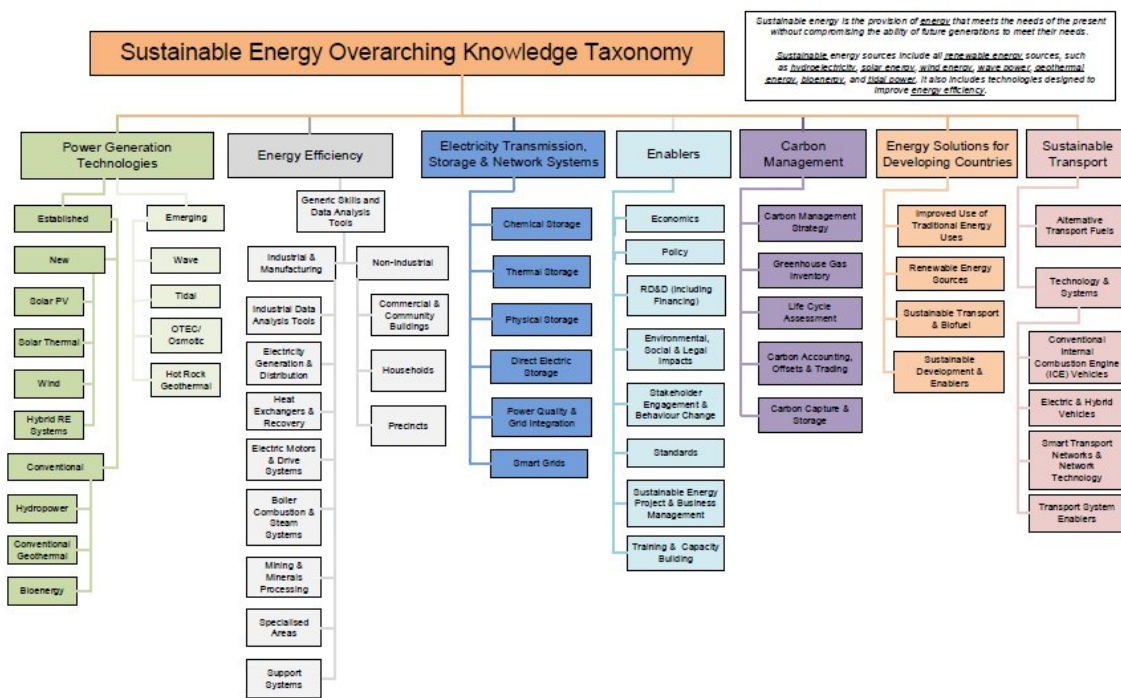


Figure 8: Overarching sustainable energy knowledge taxonomy diagram showing the seven main knowledge areas.

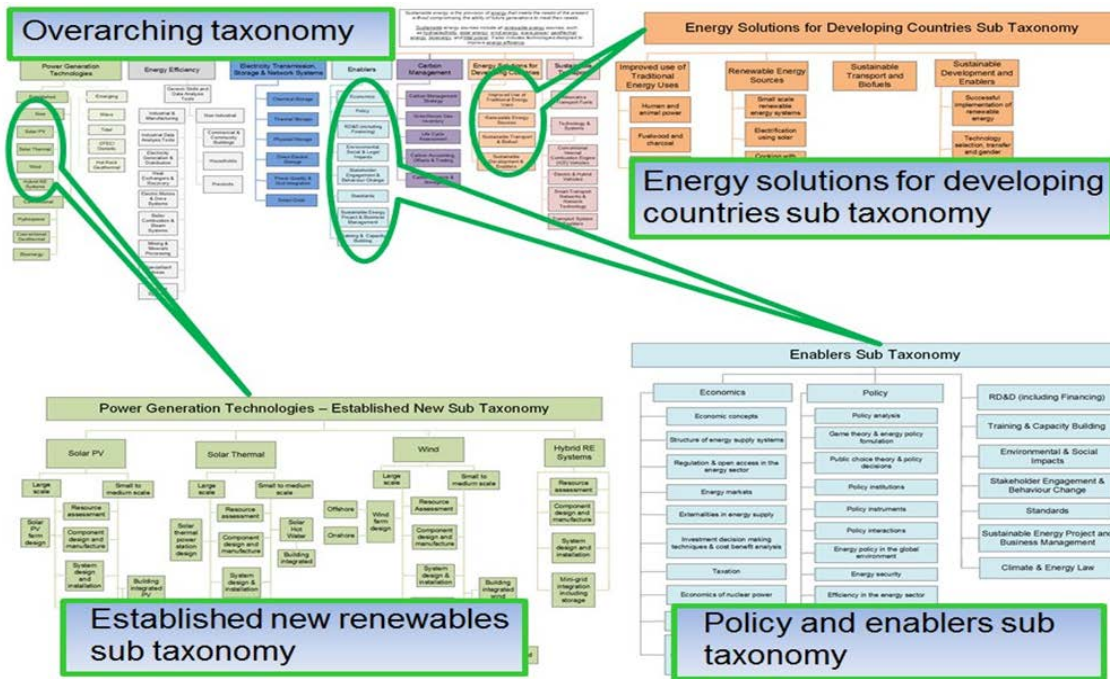


Figure 9: Relationship of the overarching knowledge taxonomy to the sub taxonomies.

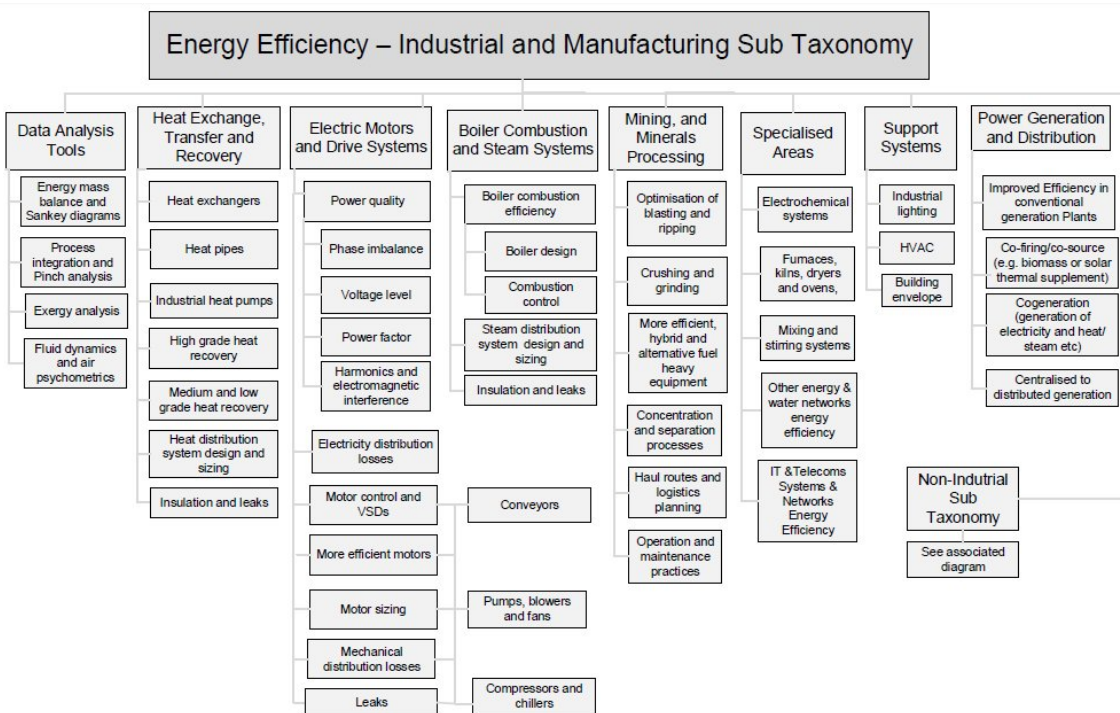


Figure 10: Example sustainable energy knowledge sub taxonomy – industrial and manufacturing.

Extending the framework and approach of Dowling and Hadgraft [March 2013] a set of draft skills and knowledge (or capability) “cloths” were developed. These cloths correspond to the process capabilities and technical capabilities sides of the Dowling and Hadgraft capability cube. The cloths present in a visual manner the type (core or elective) and level (introductory, medium or advanced) of knowledge required as horizontal bars and the types of skills required as vertical bars. Figure 11 shows the overarching capability cloth. Figure 12 shows the relationship of the overarching capability cloth to the sub cloths. Figure 13 shows a typical capability sub cloth, in this case for Conventional and Established Renewable Energy Generation.

# Sustainable Energy Overall Skills and Knowledge Cloth

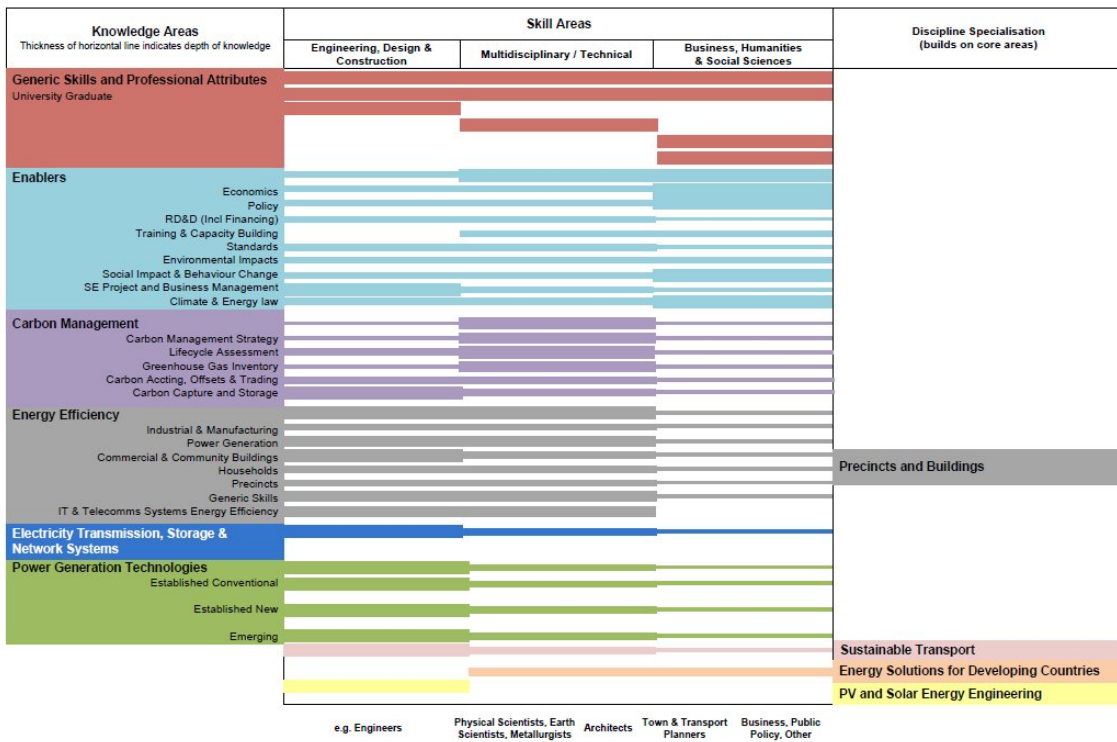


Figure 11: Overarching skills and knowledge cloth showing depth of knowledge for various sustainable energy areas for different discipline and role types.

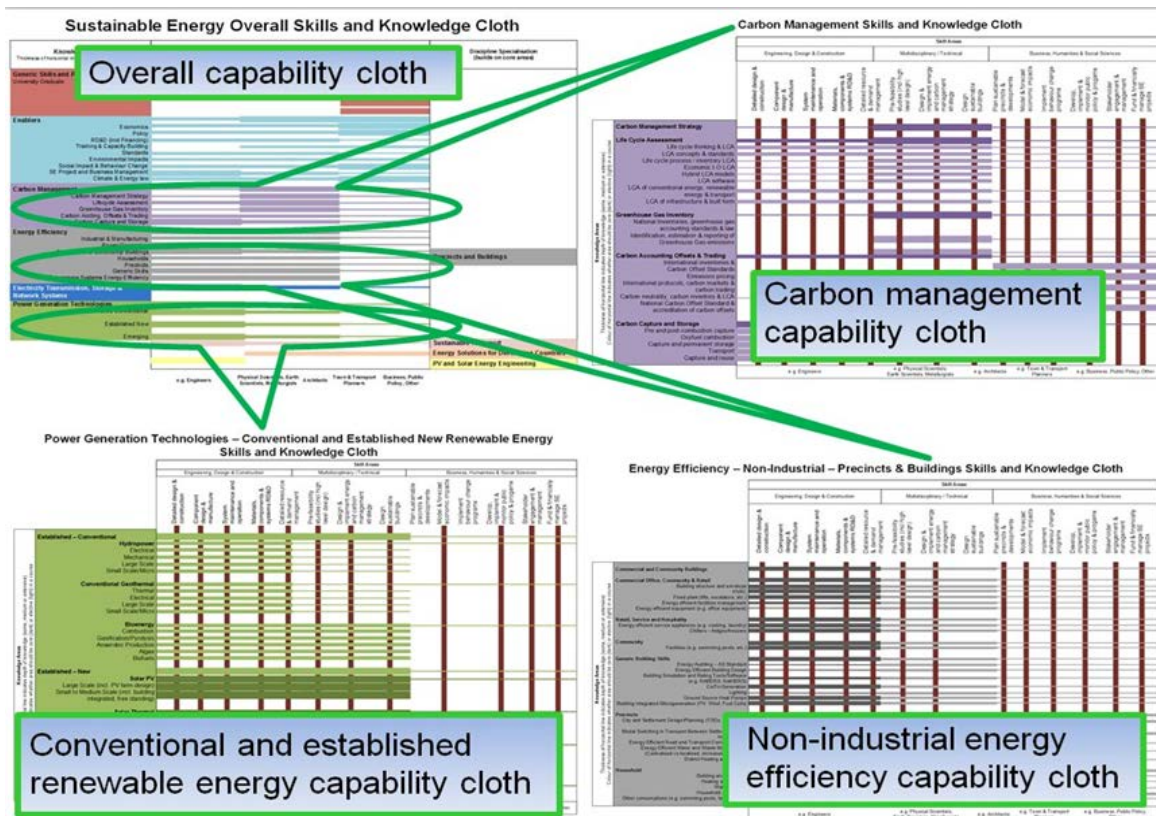


Figure 12: Relationship of the overarching capability cloth to the sub cloths.

**Power Generation Technologies – Conventional and Established New Renewable Energy Skills and Knowledge Cloth**

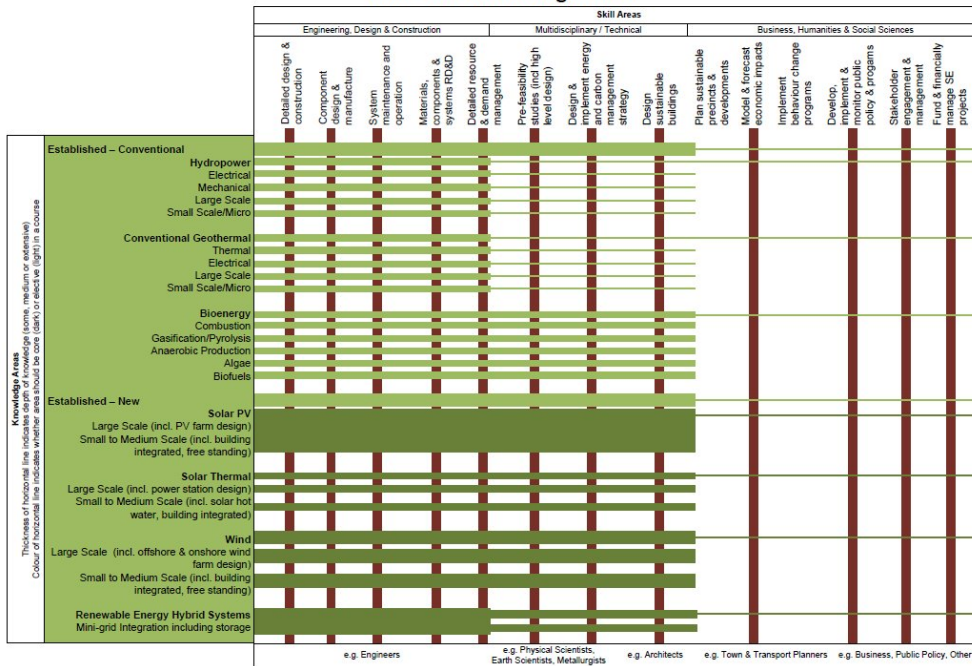


Figure 13: Example capabilities cloth – established renewable energy generation.

Figure 14 shows how to interpret the capability sub cloths. The skills are grouped in three conventional discipline areas (engineering, multidisciplinary/technical and business, humanities and social sciences) corresponding to the types or roles (shown on the bottom axis of the cloths) graduates are known to undertake. The colour shading (dark or light) of the horizontal knowledge bars shows whether the knowledge area is considered core (essential) or elective (required) and the thickness of the horizontal bars (thin, medium or thick) indicates the level (introductory, medium or advanced) of that knowledge.

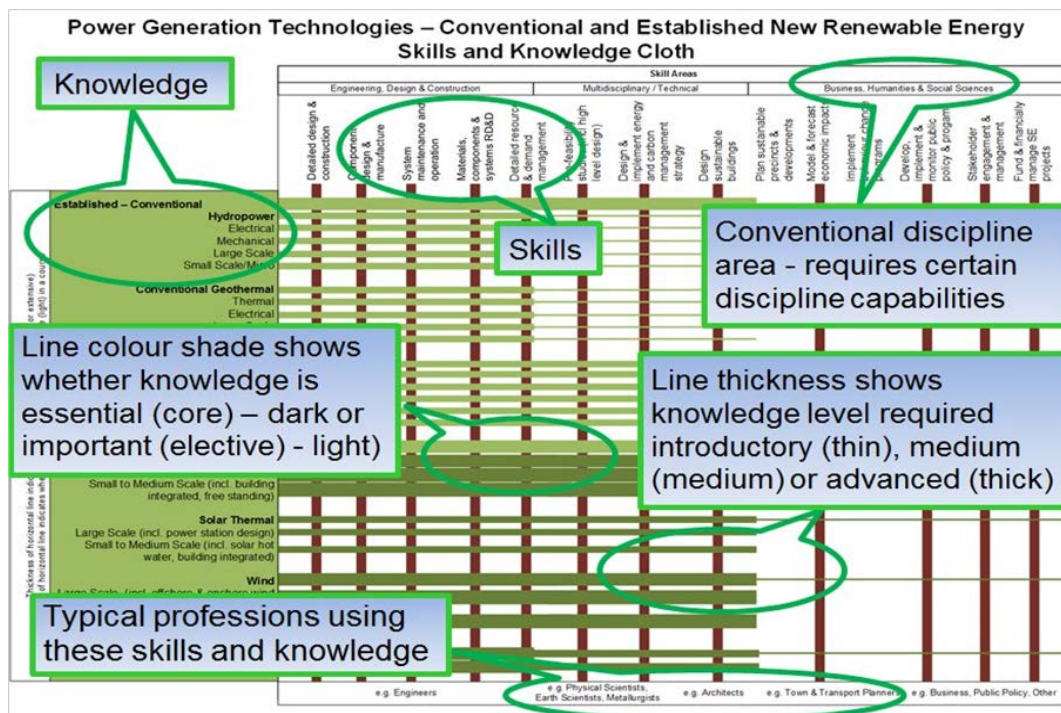
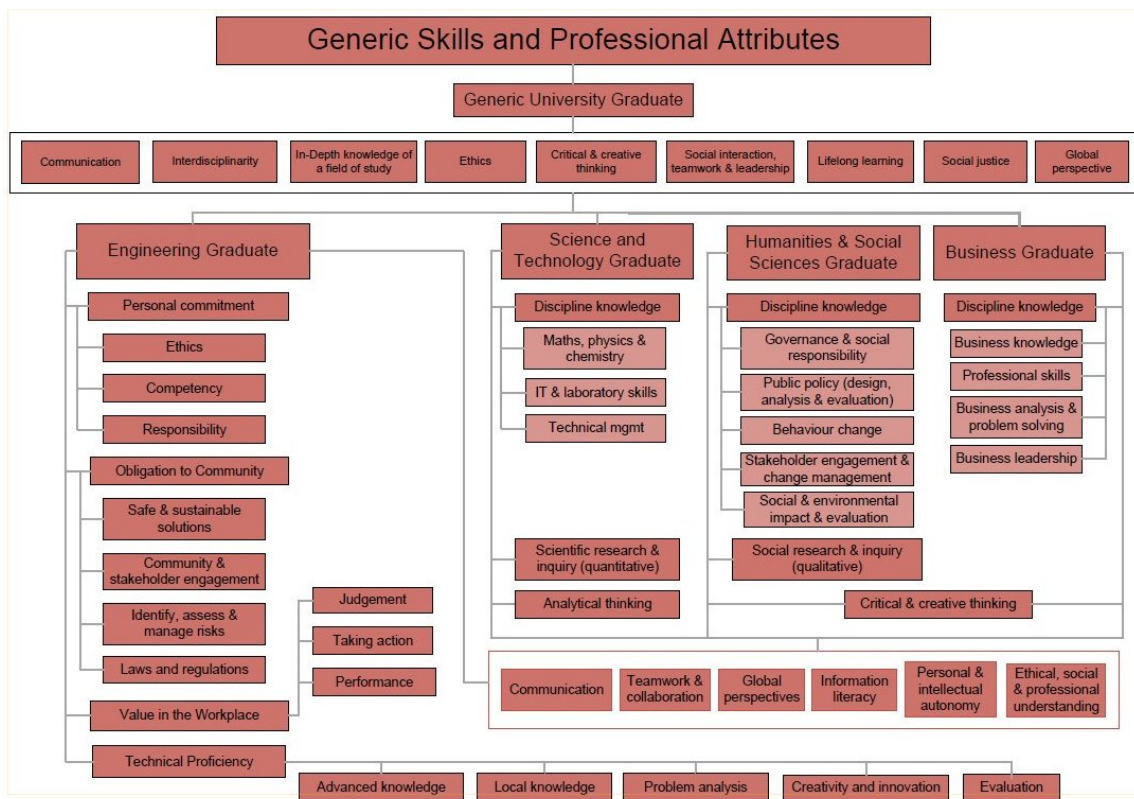


Figure 14: Explanation of major components of a typical capability sub cloth map using the example of the energy efficiency specialisation.



There are seven sets of capability cloths, corresponding to the seven main sustainable energy knowledge areas in the taxonomy. These cloths are the core of the approach and enabled a framework for engaging with graduates and industry representatives about the type and depth of capabilities required by graduates. The full set of “skills and knowledge cloths” with accompanying narrative are available from the project website <<http://www.murdoch.edu.au/projects/secfp/>>.

In order to develop curriculum frameworks for the programmes corresponding to range of multidisciplinary areas in which sustainable energy graduates work the approach in the Dowling and Hadgraft [2013] was modified to develop and differentiate a set of “generic” and “discipline” capabilities required by graduates. These generic (also known as generic attributes) and discipline specific capabilities were organised and presented in a taxonomy diagram similar to the knowledge taxonomies. In order to cover the range of roles potentially undertaken by sustainable energy graduates, as well as the generic capabilities (or attributes) required by all University graduates three sets of discipline specific capabilities were identified, corresponding to the three conventional discipline areas in the capability cloths – Engineering, multidisciplinary/technical and business, humanities and social sciences. The capabilities were derived from existing generic and discipline capability/attributes lists published by Universities. The generic and discipline specific capability taxonomy diagram (shown in Figure 15) with accompanying narrative is available from the project website <<http://www.murdoch.edu.au/projects/secfp/>>.



**Figure 15: Generic and discipline specific capabilities taxonomy diagram.**

## Ensuring the outcomes are relevant to industry

In order to ensure the curriculum frameworks led to programmes and courses that train graduates with the knowledge and skills relevant to industry it was essential to have significant graduate and industry representative input. An online survey instrument (with some responder initiated follow up interviews) was used to validate and calibrate the draft capability cloths. The surveys developed by the project team were coded and administered online using Murdoch University’s well developed online survey system. Separate surveys were used to acquire the response of graduates and those of the employers/industry representatives. Graduates were recruited by email by project team members at each member university based on contact details from alumni and graduate lists. Industry representative recruitment was done through key Industry associations who promoted the project

and survey to their members by email and newsletter. The online surveys also sought background information regarding the area of the industry in which they worked, the type of role they had and their responses regarding the five key questions about delivering the knowledge and skills. In light of the analysis of the detailed responses to the surveys (examples shown in Figures 16 and 17) the capability cloths were revised (calibrated).

Skill and Knowledge Requirements - Industry	Degree type*	N	Not at all important	Somewhat important	Important	Very important
Power Generation Technologies	Eng.	31	6%	17%	42%	35%
	Multi.	17	25%	6%	25%	44%
	All	64	11%	11%	36%	42%
Generic Skills & Professional Attributes	Eng.	31	0	9%	28%	63%
	Multi.	17	6%	0	31%	63%
	All	64	2%	4%	33%	61%
Energy Solutions for Developing Countries	Eng.	31	46%	27%	0%	27%
	Multi.	17	63%	13%	18%	6%
	All	64	49%	22%	7%	22%
Energy Efficiency	Eng.	31	33%	47%	13%	7%
	Multi.	17	31%	25%	37%	6%
	All	64	33%	37%	22%	8%
Transmission, Storage & Network Systems	Eng.	31	10%	22%	10%	58%
	Multi.	17	7%	33%	27%	33%
	All	64	7%	28%	19%	46%
Sustainable Transport	Eng.	31	13%	27%	37%	23%
	Multi.	17	13%	31%	44%	12%
	All	64	11%	26%	39%	24%
Enablers (Policy, Economics etc.)	Eng.	31	13%	13%	42%	32%
	Multi.	17	6%	0	44%	50%
	All	64	9%	15%	40%	36%

Figure 16: Results of the graduate survey showing which of the seven knowledge taxonomies were considered by them to be the most important for graduates to know.

	Degree type	N	Need for inclusion			Core or Elective		Coverage rating		
			Not needed	Needed	Essential	Core	Elect	Some	Medium	Extensive
Power Generation Technologies - Established Renewables	Eng.	24		Essential 95%		Core 90%			Extensive 75%	
	Multi.	11		Essential 100%		Core 100%			Extensive 70%	
Solar PV	Eng.	24		Essential 90%		Core 90%			Extensive 85%	
	Multi.	11		Essential 80%		Core 90%			Extensive 70%	
Solar Thermal	Eng.	24		Essential 75%		Core 65%			Extensive 65%	
	Multi.	11		Essential 65%		Core/Elective 50%			Extensive 70%	
Wind	Eng.	24		Essential 75%		Core 80%			Extensive 70%	
	Multi.	11		Essential 65%		Core 65%			Extensive 55%	
Hydropower	Eng.	24		Essential 55%		Core 55%			Extensive 50%	
	Multi.	11		Needed/Essential 45%		Elective 65%			Medium 55%	
Hydro Geothermal	Eng.	24		Needed 60%		Elective 65%		Some/medium/Extensive 33%		
	Multi.	11		Needed 55%		Elective 65%		Some 55%		
Biomass (including Waste to Energy)	Eng.	24		Essential 55%		Core/Elective 50%			Extensive 55%	
	Multi.	11		Needed 65%		Elective 65%		Some/Medium 45%		

Figure 17: Example of the results of the graduate survey used to calibrate and finalise the capability cloths.

## Mapping the curriculum frameworks

The sustainable energy knowledge and skills and the generic and discipline specific capabilities were mapped into a set of draft curriculum frameworks for the relevant types and level of qualifications in the AQF that are typically offered by Universities. After identifying the types and levels of degree/qualification that correspond to the three discipline areas in the capability cloths, and feedback from graduates, a curriculum mapping approach similar that used by the University of West Florida and other Universities was used (see for example <[http://uwf.edu/cutla/curriculum\\_map\\_graduate\\_ALP.cfm](http://uwf.edu/cutla/curriculum_map_graduate_ALP.cfm)>). Five sets of curriculum frameworks have been developed for sustainable energy programmes/qualifications including:

- Undergraduate sustainable energy engineering programmes (e.g. BEng) with specialisations in renewable energy systems or energy efficiency;
- Postgraduate sustainable energy engineering coursework programmes (e.g. MEng) with specialisations in renewable energy systems or energy efficiency;
- Postgraduate sustainable energy science/technical coursework programmes (E.g. MSc) with specialisations in energy efficiency and carbon management;
- Postgraduate sustainable energy humanities and social science coursework programmes (e.g. MA) with a specialisation in policy and enablers; and
- Conventional engineering, science and humanities programmes with a sustainable energy focus or major.

Figure 18 shows the relationships between the four different programme curriculum maps (not including majors in conventional degrees) with some units common to all programmes and other units distinct to particular programmes. Figure 19 shows a typical overarching curriculum framework map (in this case for the energy efficiency specialisation) and Figure 20 shows the corresponding curriculum framework learning outcomes map. How to interpret these curriculum maps is explained in detail in Section 2 above.

Curriculum Framework Relationships Map	Policy / Enablers (MA)	RE Systems (BEng / MEng/MSc)	Energy Efficiency & Management (BEng / MEng / MSc)	Carbon Management (MSc)
<b>Graduate attributes (Grad Cert)</b>	<b>Prerequisites</b> <ul style="list-style-type: none"> <li>High school maths, physics and chemistry</li> <li>IT skills</li> <li>Statistics</li> <li>First year university level economics</li> </ul> <b>Humanities/Social Science Attributes</b> <ul style="list-style-type: none"> <li>Governance &amp; social responsibility</li> <li>Public policy</li> <li>Community consultation</li> <li>Social &amp; environmental impact/evaluation</li> <li>Change management</li> </ul>	<b>Prerequisites (MEng)</b> <ul style="list-style-type: none"> <li>First year university level maths, physics and chemistry</li> <li>IT skills</li> <li>Statistics</li> <li>IEAust Attributes</li> </ul> Mech Eng – electrical and transmissions prereq Electrical/power Eng – thermodynamics prereq Other (Civil, Environmental) – thermodynamics, electrical and transmission prereq or <b>Technical/Science Attributes (MSc)</b> <ul style="list-style-type: none"> <li>IT &amp; laboratory skills</li> <li>Technical management</li> </ul>	<b>Prerequisites (MEng)</b> <ul style="list-style-type: none"> <li>First year university level maths, physics and chemistry</li> <li>IT skills</li> <li>Statistics</li> <li>IEAust Attributes</li> </ul> or <b>Technical/Science Attributes (MSc)</b> <ul style="list-style-type: none"> <li>IT &amp; laboratory skills</li> <li>Technical management</li> </ul>	<b>Prerequisites</b> <ul style="list-style-type: none"> <li>First year university level maths, physics and chemistry</li> <li>IT skills</li> <li>Statistics</li> </ul> <b>Technical/Science Attributes</b> <ul style="list-style-type: none"> <li>IT &amp; laboratory skills</li> <li>Technical management</li> </ul>
<b>Introductory level (Graduate Diploma)</b>	<b>Policy content</b> <ul style="list-style-type: none"> <li>Conventional &amp; Sustainable Energy in Society</li> <li>Energy Policy 1</li> <li>Energy Economics 1</li> <li>Sustainable Energy Business and project Management</li> </ul> <b>Technical/Science content</b> <ul style="list-style-type: none"> <li>Energy Efficiency &amp; Management 1</li> <li>Carbon Management Strategy 1</li> <li>Electricity Network Systems</li> <li>Renewable Energy Systems 1</li> </ul>	<b>Policy content</b> <ul style="list-style-type: none"> <li>Conventional &amp; Sustainable Energy in Society</li> <li>Energy Policy 1</li> <li>Energy Economics 1</li> <li>Sustainable Energy Business and project Management</li> </ul> <b>Technical/Science content</b> <ul style="list-style-type: none"> <li>Energy Efficiency &amp; Management 1</li> <li>Carbon Management Strategy 1</li> <li>Electricity Network Systems</li> <li>Renewable Energy Systems 1</li> </ul>	<b>Policy content</b> <ul style="list-style-type: none"> <li>Conventional &amp; Sustainable Energy in Society</li> <li>Energy Policy 1</li> <li>Energy Economics 1</li> <li>Sustainable Energy Business and project Management</li> </ul> <b>Technical/Science content</b> <ul style="list-style-type: none"> <li>Energy Efficiency &amp; Management 1</li> <li>Carbon Management Strategy 1</li> <li>Electricity Network Systems</li> <li>Renewable Energy Systems 1</li> </ul>	<b>Policy content</b> <ul style="list-style-type: none"> <li>Conventional &amp; Sustainable Energy in Society</li> <li>Energy Policy 1</li> <li>Energy Economics 1</li> <li>Sustainable Energy Business and project Management</li> </ul> <b>Technical/Science content</b> <ul style="list-style-type: none"> <li>Energy Efficiency &amp; Management 1</li> <li>Carbon Management Strategy 1</li> <li>Electricity Network Systems</li> <li>Renewable Energy Systems 1</li> </ul>
<b>Medium level (Diploma)</b>	<b>Policy content</b> <ul style="list-style-type: none"> <li>Energy Policy 2 – Climate Change Policy</li> <li>Energy Economics 2</li> <li>Change Management</li> <li>Community Consultation &amp; Social/Environmental Impact Assessment</li> </ul>	<b>RE systems content (Choose 4 from)</b> <ul style="list-style-type: none"> <li>Advanced RE Systems 1 - Solar Photovoltaic</li> <li>Advanced RE Systems 2 - Solar thermal</li> <li>Advanced RE Systems 3 - Wind Energy</li> <li>Advanced RE Systems 4 - Bioenergy</li> <li>Advanced RE Systems 5 - Remote and Micro-grid RE Systems</li> <li>Advanced RE Systems 6 - Conventional and Emerging Renewable Energy</li> </ul>	<b>Energy efficiency &amp; management content</b> <ul style="list-style-type: none"> <li>Energy Efficiency, System Analysis and Auditing</li> <li>Environmental Building Services and Energy Efficient Building Design</li> <li>Industrial and Commercial Energy Efficiency</li> <li>Change Management</li> </ul>	<b>Carbon management content</b> <ul style="list-style-type: none"> <li>Lifecycle Assessment</li> <li>Greenhouse Gas Inventory</li> <li>Carbon Accounting, Offsets &amp; Trading</li> <li>Change Management</li> </ul>
<b>Advanced level (Masters)</b>	Two Recommended Electives and Advanced Thesis/Research Project (1/2 semester) or Advanced Thesis/Research Project (1 semester)  <b>Recommended Electives</b> <ul style="list-style-type: none"> <li>Energy Policy 3 - Supply and Infrastructure; or</li> <li>Energy Economics 3 - Market Reform; or</li> <li>Energy Policy Research and Evaluation</li> </ul>	Two Recommended Electives (choose from above list or recommended streams below) and Advanced Thesis/Research Project (1/2 semester) or Advanced Thesis/Research Project (1 semester)  <b>Specializations</b> <ul style="list-style-type: none"> <li>Precincts and Buildings</li> <li>Renewable Energy for Sustainable Development</li> <li>Sustainable Transport</li> </ul>	Two Recommended Electives and Advanced Thesis/Research Project (1/2 semester) or Advanced Thesis/Research Project (1 semester)  <b>Recommended Electives</b> <ul style="list-style-type: none"> <li>Carbon Management Strategy 2; or</li> <li>Energy Efficiency and Decarbonisation in Precincts; or</li> <li>Greenhouse Gas Inventory</li> </ul>	Carbon management content and Carbon Management Strategy 2  <b>Recommended Elective and</b> <ul style="list-style-type: none"> <li>Energy Efficiency, System Analysis &amp; Auditing; or</li> <li>Energy Efficiency and Decarbonisation in Precincts</li> </ul> Advanced Thesis/Research Project (1/2 semester)

Figure 18: The curriculum framework relationships map.

Overarching Curriculum Framework Map	Energy Efficiency & Management (BEng)	Energy Efficiency & Management (MEng)	Energy Efficiency & Management (MSc)
<b>Graduate attributes</b>	<b>Prerequisites</b> <ul style="list-style-type: none"> <li>BEng – High school level maths, physics, and chemistry</li> <li>IT skills</li> <li>Statistics</li> </ul>	<b>Prerequisites</b> <ul style="list-style-type: none"> <li>First year university level maths, physics and chemistry</li> <li>IT skills</li> <li>Statistics</li> </ul> <b>Engineering Attributes</b> <ul style="list-style-type: none"> <li>IEAust Attributes</li> </ul>	<b>Prerequisites</b> <ul style="list-style-type: none"> <li>First year university level maths, physics and chemistry</li> <li>IT skills</li> <li>Statistics</li> </ul> <b>Technical/Science Attributes</b> <ul style="list-style-type: none"> <li>IT &amp; laboratory skills</li> <li>Technical management</li> </ul>
<b>Introductory level</b>	<b>1<sup>st</sup> year common engineering units</b> <ul style="list-style-type: none"> <li>Maths 1</li> <li>Maths 2</li> <li>Physics 1</li> <li>Physics 2</li> <li>Engineering Design Group Project</li> <li>Computing for Engineers</li> <li>Circuits and Systems 1</li> <li>Conventional &amp; Sustainable Energy in Society</li> </ul> <b>2<sup>nd</sup> year common engineering units</b> <ul style="list-style-type: none"> <li>Mathematical Methods and Statistics</li> <li>Engineering Materials &amp; Chemistry</li> <li>Fluid Mechanics</li> <li>Thermodynamics and Heat Transfer</li> <li>Circuits and Systems 2</li> <li>Applied PV and Electronic Instrumentation</li> <li>Control Systems and Process Dynamics</li> <li>University breadth/general education unit</li> </ul>	<b>YEAR 1</b> <b>Policy content</b> <ul style="list-style-type: none"> <li>Energy Policy 1</li> <li>Energy Economics 1</li> <li>Sustainable Energy Business and Project Management</li> <li>Conventional and Sustainable Energy in Society</li> </ul> <b>Technical/Science content</b> <ul style="list-style-type: none"> <li>Energy Efficiency and Management 1</li> <li>Carbon Management Strategy 1</li> <li>Renewable Energy Systems 1</li> <li>Electricity Network Systems</li> </ul>	
<b>Medium level</b>	<b>3<sup>rd</sup> year engineering units</b> <ul style="list-style-type: none"> <li>Advanced Thermofluids</li> <li>Energy Policy 1</li> <li>Energy Economics 1</li> <li>Sustainable Energy Business and Project Management</li> <li>Energy Efficiency and Management 1</li> <li>Carbon Management Strategy 1</li> <li>Renewable Energy Systems 1</li> <li>Electricity Network Systems</li> </ul>	<b>YEAR 2</b> <b>Core units (1 semester)</b> <ul style="list-style-type: none"> <li>Energy Efficiency, System Analysis and Auditing</li> <li>Environmental Building Services and Energy Efficient Building Design</li> <li>Industrial and Commercial Energy Efficiency</li> <li>Change Management</li> </ul> <b>Recommended Electives</b> <ul style="list-style-type: none"> <li>Carbon Management Strategy 2</li> <li>Energy Efficiency and Decarbonisation in Precincts</li> <li>Greenhouse Gas Inventory</li> </ul>	
<b>Advanced level</b>	<b>4<sup>th</sup> year</b> <ul style="list-style-type: none"> <li>Leadership and Ethics</li> <li>Thesis 1 or Internship 1</li> <li>Thesis 2 or Internship 2</li> <li>Energy Efficiency, System Analysis and Auditing</li> </ul> <ul style="list-style-type: none"> <li>Environmental Building Services and Energy Efficient Building Design</li> <li>Industrial and Commercial Energy Efficiency</li> <li>University breadth/general education unit</li> <li>Recommended Elective <ul style="list-style-type: none"> <li>Change Management or</li> <li>Energy Efficiency and Decarbonisation in Precincts</li> </ul> </li> </ul>	<b>Two Electives (see recommended choices above) and Advanced Thesis/Research project (1/2 semester)</b> or <b>Advanced Thesis/Research Project (1 semester)</b>	

Figure 19: A typical overarching curriculum frameworks map – energy efficiency.

Curriculum Framework Learning Outcomes Map	Energy Efficiency & Management (MEng / MSc)			
<b>Introductory level</b>	<b>Energy Policy 1</b> <ul style="list-style-type: none"> <li>Identify the objectives of energy policy such as economic efficiency, energy conservation, avoiding environmental degradation, economic development, sustainability, government revenue, urban transport, urban settlement, and the development of new energy technologies.</li> <li>Identify and describe contemporary energy policy issues.</li> <li>Recognise energy policy institutions.</li> <li>Describe how energy policy is made and changed.</li> <li>Read and critically analyse energy policy documents.</li> <li>Understand domestic and international energy policies, including community service obligations, industry development, policy instruments and how they are applied.</li> <li>Understanding of the public policy processes and institutions that give rise to the shape, direction and outcomes in the energy sector.</li> <li>Issues in energy policy and the commercialization of renewable energy systems</li> <li>Explain the need for international coordination of energy policies.</li> <li>Explain why particular policy instruments are chosen over others.</li> </ul>	<b>Energy Economics 1</b> <ul style="list-style-type: none"> <li>Recognise the variety of market structures found in the energy sector.</li> <li>Interpret and discuss the economic and social aspects of renewable and non-renewable energy systems.</li> <li>Understand economic theory relevant to the energy sector (cost benefit analysis, levelised cost, discounted cash flow analysis).</li> <li>Understanding of energy facilities, taxation of the energy sector and role of public utilities and government industry regulations.</li> <li>Define externalities in energy supply systems as the major areas for economic regulation by government.</li> <li>Identify, detail and analyse the techniques used for making investment decisions.</li> <li>Detail the economics of the main support policies that have been used to assist the market penetration of renewable energy technologies.</li> <li>Demonstrate an understanding of mass and energy balance principles and how they relate to economic systems of production.</li> </ul>	<b>Sustainable Energy Business and Project Management</b> <ul style="list-style-type: none"> <li>Understand the fundamentals of sustainable energy business management.</li> <li>Understand the fundamentals of sustainable energy project management.</li> <li>Understand the RD&amp;D cycle including financing.</li> <li>Understand the importance of safety standards in the energy supply and demand sector.</li> <li>Identify and interpret appropriate AS &amp; ISO quality and environmental management standards: e.g. ISO 90001, 150001, 140001.</li> <li>Understand the importance and process of an Environmental &amp; Social Impact Assessment.</li> <li>Understand relevant climate and energy law.</li> <li>Understand the nature of human behaviour within the context of the promotion of environmentally sustainable behaviour.</li> <li>Be able to develop and present a business case for sustainable energy technologies.</li> </ul>	<b>Conventional &amp; Sustainable Energy in Society</b> <ul style="list-style-type: none"> <li>Describe the concept of energy and the associated concept of the conservation of energy.</li> <li>Explain the concept of energy flows through the environment.</li> <li>Understand global context and issues of climate change, sustainability and energy.</li> <li>Explain the patterns of energy production and consumption with respect to a country's stage of development, economy and politics.</li> <li>Link the changing patterns of energy production and consumption to each country's level of development, economy and politics.</li> <li>Explain the principles of energy conversion.</li> <li>Identify major energy consuming sectors and ways of reducing consumption.</li> <li>Discuss energy resources and their social impact in the context of world distribution and monopolisation (OPEC).</li> <li>Discuss the different types of conventional and sustainable energy resources and conversion techniques</li> <li>Identify the social, economic, environmental and technical issues associated with conventional and sustainable energy resources and conversion techniques.</li> </ul>
<b>Learning outcomes</b>	<b>Energy Efficiency &amp; Management 1</b> <ul style="list-style-type: none"> <li>Explain the concept of energy efficiency.</li> <li>Discuss some of the reason for inefficient energy systems.</li> <li>Be able to read and interpret a household or industrial electricity meter.</li> <li>Calculate the cost of energy for a facility given the details of the tariff structure.</li> <li>Discuss the effectiveness of labelling programmes and efficiency standards.</li> <li>Set up an effective energy plan based on sound principles.</li> <li>Apply the theory and practice of energy audits and the energy auditing standard.</li> <li>Demonstrate how tariffs apply in energy management schemes.</li> <li>Discuss opportunities for energy management in building design, air conditioning, lighting and industrial plant.</li> <li>Be able to analyse the economic viability of energy management options.</li> <li>Be able to develop an energy management system compliant with the ISO50001 standard.</li> </ul>	<b>Renewable Energy Systems 1</b> <ul style="list-style-type: none"> <li>Demonstrate an understanding of the operation of the main conventional and sustainable energy systems.</li> <li>Drawing a block diagram of different renewable energy systems showing the layout of the components in the system.</li> <li>Indicating on such diagrams, the power flows that occur within such systems.</li> <li>Describing the role of the various components in these systems.</li> <li>Describe the approaches used in designing and sizing these systems.</li> <li>Understand the relevant system design standards.</li> <li>Undertake simple design and sizing tasks for a number of the systems covered.</li> <li>Demonstrate an ability to use relevant systems design and modelling software.</li> </ul>	<b>Carbon Management Strategy 1</b> <ul style="list-style-type: none"> <li>Understand the basic science of human induced climate change and identify corresponding impacts at global, regional and local level.</li> <li>Understand international &amp; national policies, protocols and frameworks regulating climate change and greenhouse gas (GHG) reduction.</li> <li>Understand how to measure and report GHG emissions and conduct a greenhouse emissions audit for an organisation.</li> <li>Understand the main greenhouse gas emitting sectors in the economy and their expected future growth or reduction.</li> <li>Understand GHG marginal abatement cost (MAC) curves and how to use them to evaluate carbon reduction options.</li> <li>Understand mandatory and voluntary carbon/emissions trading schemes and potential strategies that businesses can adopt to optimise their response.</li> <li>Understand national and international Carbon Offset Standards, and how they enable accreditation of GHG (carbon) offsets and the accreditation of Carbon Neutrality for companies and products.</li> <li>Understand how to develop a Carbon Management Response Plan in an organisation.</li> </ul>	<b>Electricity Network Systems</b> <ul style="list-style-type: none"> <li>Do simple energy and power calculations and calculations based on Ohm's Law including electricity transmission losses.</li> <li>Understand the different types of grids from large scale to mini – or micro-grids.</li> <li>Explain how electricity is distributed through a network (or grid) and describe the various components of an interconnected grid system, proceeding from the generation to the utilization of power.</li> <li>Understand the min transmission and power electronics components and their role in grids</li> <li>Understand the different thermal, physical and chemical energy storage technologies.</li> <li>Understand how the electricity grid is operated and managed and the various grid connection and management issues.</li> <li>Discuss methods for increasing the environmental sustainability of grid power systems.</li> <li>Understand the concept of smart grids.</li> </ul>

Figure 20: A typical curriculum frameworks learning outcomes map – energy efficiency.

Feedback derived from the graduate and industry surveys in regard to the five key questions relating to programme design and course delivery was considered when designing the curriculum frameworks. In particular this included:

- The balance of inter/multi-disciplinary knowledge vs specialist knowledge (e.g. engineering technical knowledge vs policy enablers knowledge etc.);
- The use of specialist undergraduate courses and programmes versus embedding skills and knowledge into existing discipline training (e.g. a specialised undergraduate course versus embedding in an existing engineering degree); and
- Whether specialist programmes should be offered at undergraduate or postgraduate level;

A number of well-known and respected sustainable energy programmes are offered by international Universities. In order to ensure that any best practice or lessons learned from the development and offering of these programmes was incorporated into the outcomes of this project a questionnaire survey was used. Email questionnaires and some follow up interviews (responder requested) were undertaken with key staff from a range of international institutions that have recognised sustainable energy programmes. The survey sought information about their programmes, their curriculum development and teaching/delivery approach as well as how they address the five key programme design and course delivery questions.

The draft curriculum frameworks were refined at a workshop involving the project team members and were then trialed using the existing programmes at the member Universities. The curriculum frameworks and associated cloths and knowledge taxonomies were then circulated to key stakeholders, including the external reference group for review and comment. The finalised five sets of curriculum frameworks are presented in detail in Section 2 and are available from the project website <<http://www.murdoch.edu.au/projects/secfp/>>.

The curriculum frameworks that have been developed and are reported in this document are seen as a work in progress and they will be refined and revised as feedback is received from the academics using them and other stakeholders. Any feedback should be provided via the contact details on the project website.

## References

*Bhava Narayan and Silvia Edwards (2011) "Good Practice report: curriculum renewal" Australian Learning and Teaching Council. ISBN 978-1-921856-83-9. 64 pages.*

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*Volker Schneider (2013) "European Postgraduate Programs in Sustainable Energy" report, ECI Publication no Cu0195. 10 pages.*

