SQA Advanced Unit Specification

General information for centres

Unit title: Renewable Energy Systems: Technology

Unit code: HV5N 48

Unit purpose: This unit has been designed to provide candidates with a knowledge and understanding of natural systems and processes that can be exploited as sources of renewable energy. Candidates will gain familiarity with the physics and engineering of the equipment used for extracting the available energy, and understand how energy transfer processes impact on efficiency and cost. A wide range of renewable energy sources are considered either individually or by reference to common or shared properties, and candidates will emerge with a level of technical knowledge that will permit them to undertake accurate quantitative comparisons between technologies, and the ability to calculate the potential or effectiveness of a particular system or solution. The way energy is used, particularly in buildings, is also considered and technological solutions that reduce energy waste are examined. The focus in the unit is strongly on general principles and the candidate is not expected to design or construct complete systems, or assess in detail the operation of any specialist system. Specialist Renewable Energy Systems units have been developed to allow candidates to study individual renewable energy technologies in greater depth than are possible in this unit.

On completion of the unit the candidate will be able to:

1 explain the operation and characteristics of electrical generator systems
2 explain the characteristics and optimal design of prime movers used in renewable energy applications
3 analyse the effectiveness of wind, wave, tidal and hydroelectric systems
4 evaluate energy transportation issues including hydrogen-based solutions
5 investigate the characteristics of photovoltaic (PV) systems
6 analyse the heating requirements of buildings to reduce energy end-use

Credit points and level: 2 SQA Credits at SCQF level 8: (16 SCQF credit points at SCQF level 8*)

**SCQF credit points are used to allocate credit to qualifications in the Scottish Credit and Qualifications Framework (SCQF). Each qualification in the Framework is allocated a number of SCQF credit points at an SCQF level. There are 12 SCQF levels, ranging from National 1 to Doctorates*

Recommended prior knowledge and skills: *Entry to this unit is at the discretion of the centre however a basic knowledge and understanding of electrical, electronic and mechanical engineering principles is essential. This knowledge and understanding may be evidenced by possession of the following SQA Advanced Units:*

HV44 47	*Principles of Engineering Systems*
HP46 47	*DC and AC Principles*
HT74 47	*Engineering Principles*

For candidates unfamiliar with renewable energy, it is recommended that they first complete the SCQF level 7, two-credit unit HV48 47 *Renewable Energy Systems: Overview of Energy Use***.** This unit provides an introduction to the basic principles behind and the terminology used with renewable energy systems.

Core skills: There are opportunities to develop the following core skill and core skill components in this unit, although there is no automatic certification of core skill or core skills components:

- Problem Solving SCQF level 6
- Communication SCQF level 6
- Information Technology SCQF level 6
- Numeracy SCQF level 6

Context for delivery: This is one of 10 dedicated renewable energy units that together comprise a specialist thread within the SQA Advanced Diploma in Engineering Systems framework and form the whole award. The unit provides a general introduction to renewable energy systems technologies. Many of these technologies can be explained in terms of basic electrical, electronic and mechanical engineering principles. Candidates should have a knowledge and understanding of these principles before embarking on this unit.

This unit is largely theoretical in nature but it is desirable that candidates should be able to observe renewable energy systems in operation during the delivery of the unit. On completion of the unit candidates should have a general knowledge and understanding of a number of renewable energy systems technologies. They should also be able to undertake an evaluation of the performance of a renewable energy system. Candidates seeking more specialist knowledge and understanding of one or more renewable energy technologies (eg wind, wave and tidal, solar etc) should study the appropriate renewable energy systems specialist unit, or units.

Assessment: The following assessment strategy is strongly recommended:

Outcomes 1, 2 and 3

The assessment for Outcomes 1, 2 and 3 should be combined to form one assessment paper. The assessment should be based on **one** of the following types of renewable energy system: wind, hydroelectric, wave or tidal. The assessment paper should be taken at a single assessment event, lasting three hours, and carried out under supervised, controlled conditions. The assessment should be conducted under open-book conditions in which candidates are allowed to bring any handouts or notes into the assessment.

Outcomes 4, 5 and 6

Assessment for Outcomes 4, 5 and 6 should comprise of an assignment which should be conducted in the candidates own time. The assignment should take in the order of 10 hours to complete. Candidates should be presented with a complex, realistic problem involving the determination of the most suitable combination of renewable energy source(s) and energy end-use efficiency measures to heat a building. Candidate evidence should be presented in the form of a report of between 2,500 to 3,000 words plus diagrams.

SQA Advanced Unit Specification: statement of standards

Unit title: Renewable Energy Systems: Technology

Unit code: HV5N 48

The sections of the unit stating the outcomes, knowledge and/or skills, and evidence requirements are mandatory.

Where evidence for outcomes is assessed on a sample basis, the whole of the content listed in the knowledge and/or skills section must be taught and available for assessment. Candidates should not know in advance the items on which they will be assessed and different items should be sampled on each assessment occasion.

Outcome 1

Explain the operation and characteristics of electrical generator systems

Knowledge and/or skills

- Principle of operation of generator
- Mechanical coupling
- Generator output characteristics
- AC and DC conversion circuitry
- Common generator faults
- Sensors selection
- Comparison and evaluation of monitoring software

Outcome 2

Explain the characteristics and optimal design of prime movers used in renewable energy applications

Knowledge and/or skills

- Force or torque production on a turbine or propeller
- Energy extraction from a fluid by a variety of blade configurations
- Optimal prime mover configurations
- Conversion of linear motion to cyclical motion
- Common faults in prime movers
- Monitoring sensors

Outcome 3

Analyse the effectiveness of wind, wave, tidal and hydroelectric systems

Knowledge and/or skills

- Wind turbine designs
- Hydroelectric turbines
- Commercial machines for extracting energy from tidal power
- Commercial machines for extracting energy from wave power
- Trends in energy extraction from wind, wave, tidal and hydroelectric

Evidence requirements

Evidence for the knowledge and/or skills items in Outcomes 1, 2 and 3 should be provided on a sample basis. The evidence may be provided in response to specific questions. Each candidate will need to demonstrate that she/he can answer correctly questions based on a sample of the items shown under the knowledge and/or skills items in all three outcomes. In any assessment of the outcomes a minimum of **ten out of eighteen** knowledge and/or skills items should be sampled across the three outcomes with a minimum of **three** knowledge and/or skills items being sampled from each of the three outcomes.

Where sampling takes place, a candidate's response can be judged to be satisfactory where evidence provided is sufficient to meet the requirements for each item by showing the candidate is able to:

Outcome 1

- explain the operation of one type of generator commonly used in renewable energy systems
- draw a system which includes gearing and a driving force as a mechanical diagram
- sketch the output of a generator based on information from the generator's specification and/or data sheets
- draw a circuit diagram of a circuit that converts one specified AC voltage to one specified DC voltage, or vice versa, and explain the operation of this circuit
- state three common faults associated with a particular installed generator
- select specific sensors to measure two important parameters of the generator system and specify the signal conditioning hardware that is required to give a useable output voltage (a linear output is not essential)
- describe and compare two software packages that can be used in monitoring generator performance

Outcome 2

- draw a diagram to illustrate the forces incident on a turbine or propeller blade and describe the operation of the turbine or propeller
- calculate the work done on a three blade configuration with variations in the area and angle of blade, and the number of blades (ignore turbulence)
- state the properties of air and water that affect energy transfer
- draw a graph of the input and output of a specific mechanical element used to convert linear to cyclical motion
- identify three faults associated with a particular prime mover system related to the points of greatest stress and where relative movement takes place
- select specific sensors to measure two important parameters of the prime mover system and specify the signal conditioning hardware that is required to give a useable output voltage (a linear output is not essential)

Outcome 3

- describe and compare the range of turbines available for wind or hydroelectric or wave or tidal systems (ie the choice of energy source should depend on what type of system is specified in the assessment — for example, if a wind system is specified then the range of wind turbines should be described and compared)
- for the renewable energy system specified in the assessment describe the overall operation of the system. Details of the efficiency with which the available energy is extracted by the system should be included in the description
- for the renewable energy system specified in the assessment describe the operation of individual sub-system elements with particular reference to low frequency operation, reliability aspects of the driving force including technological attempts to overcome forces that could destroy the renewable energy system (eg excessive wind speeds, destructive power of waves etc)
- describe energy trends available for wind OR hydroelectric power OR wave OR tidal systems (ie the choice of energy source should depend on what type of system is specified in the assessment — for example, if a wave system is specified than wave energy trends should be described)

The assessment for Outcomes 1, 2 and 3 should be combined to form one assessment paper. The assessment should be based on **one** of the following types of renewable energy system: wind, hydroelectric, wave or tidal. The assessment paper should be taken at a single assessment event, lasting 3 hours, and carried out under controlled, supervised conditions. Assessment should be conducted under open-book conditions in which candidates are allowed to bring any handouts or notes into the assessment.

Assessment guidelines

The assessment paper should be composed of a number of extended-response questions.

For the assessment candidates should be presented with the description of a complete wind OR hydroelectric OR wave OR tidal power renewable energy system and given a full specification for each system sub-units. The driving force and the load should also be provided. Using this information, the candidates must analyse the system in a methodical manner by completing specified tasks relating to the sampled knowledge and skills items. This is illustrated below (outcome/bullet point in brackets):

- describe the operation of the generator (1.1)
- describe the operation of the prime mover (2.1 or 2.2)
- represent the system by equivalent mechanical and electrical diagrams (1.2, 1.4)
- draw a graph of the output voltage as it varies with input force (1.3)
- select sensors and specify conditioning circuits (1.6 or 2.6)
- describe automated monitoring software (1.7)
- identify common faults (1.5 or 2.5)
- compare with other equipment that can be used for the same application (3.1 or 3.2 or 3.3 or 3.4)
- discuss current developments in exploiting this particular resource (3.5)

Outcome 4

Evaluate energy transportation issues including hydrogen-based solutions

Knowledge and/or skills

- Power losses in electrical power systems
- Storage of energy
- Advantages and disadvantages of hydrogen as a carrier
- Electrolysis
- Fuel cells
- Design of simple systems powered by a fuel cell

Outcome 5

Investigate the characteristics of photovoltaic (PV) systems

Knowledge and/or skills

- Solar spectrum
- Semiconductor diode and the photoelectric effect
- Costs and efficiencies of PV materials and technologies
- Alignment and installation factors
- Energy generation in buildings using PV materials and technologies

Outcome 6

Analyse the heating requirements of buildings to reduce energy end-use

Knowledge and/or skills

- Heat losses in buildings
- Insulation material
- Properties of glass
- Influence of microclimate on building design
- Solar hot-water heating systems
- Heat pumps
- Optimal renewable energy solution for a building

Evidence requirements

Evidence for the knowledge and/or skills items in Outcomes 4, 5 and 6 should be provided on a sample basis. The evidence may be provided in response to specific questions.

Each candidate will need to demonstrate that she/he can answer correctly questions based on a sample of the items shown under the knowledge and/or skills items in all three outcomes. In any assessment of the outcomes the last bullet point in Outcome 6 **must** be assessed on all occasions plus a minimum of **nine out of eighteen** knowledge and/or skills items should be sampled across the three outcomes with a minimum of **three** knowledge and/or skills items being sampled from each of the three outcomes.

Where sampling takes place, a candidate's response can be judged to be satisfactory where evidence provided is sufficient to meet the requirements for each item by showing the candidate is able to:

Outcome 4

- calculate the power losses in a cable at three different voltage levels
- describe the energy losses associated with one method of storing energy (eg pump storage)
- state three advantages and three disadvantages of hydrogen as a carrier
- describe the operation of idealised electrolysis
- describe fuel cell operation including a statement of the theoretical thermodynamic energy losses
- design an engineering system with 'off the shelf' components that addresses the problems of supply and storage of hydrogen fuel (NB: it is not necessary to construct the system)

Outcome 5

- draws graphs from tabular data of the energy available at a specific latitude over the year for a frequency in the visible light region and a frequency in the IR (Infrared) region of the spectrum
- explain the operation of a semiconductor diode in terms of N and P-type junction theory and also explain the photoelectric effect in diodes
- compare the cost per kWh for at least three different types of PV technology
- describe how a structure is aligned or designed to maximise the annual energy incident on PV technology installed on part of the structure
- calculate the energy output produced by three different types of PV technology installed on a specified structure assuming optimum alignment

Outcome 6

- calculate the heat losses from a simple building (without any glass) when the temperatures and building properties are specified
- compare savings in energy costs against increased insulation costs by calculating the energy losses from a simple building with a minimum of three different thicknesses of insulation applied
- explain the properties of glass in terms of acting as a heat source and as contributing to heat losses
- calculate the heat gained and heat losses associated with a building for a given change in external conditions
- describe the principles behind solar hot-water systems
- describe the principles behind ground and air source heat pumps
- for a given building wire frame specification, climate data and the geography of the proposed site, choose the optimal location, orientation, insulation, and type of renewable energy source(s) to minimise carbon impact but within reasonable cost

Outcomes 4, 5 and 6 should be assessed by one assignment which should be completed in the candidate's own time. The assignment should take in the order of 10 hours to complete. The candidate should be presented with a complex, realistic problem involving the determination of the most suitable combination of renewable energy source(s) and energy end-use efficiency measures to heat a building. The combination selected must be supported by a quantitative comparative analysis. It is permissible to present the candidate with a set of key questions to help direct the analysis and assist with the structure of the final report. This will also ensure all sampled knowledge and skills items are being assessed.

Candidate evidence should be presented in the form of a report of 2,500 to 3,000 words plus diagrams. The report must be referenced.

Centres should make every reasonable effort to ensure the report is the candidate's own work. Where copying or plagiarism is suspected candidates may be interviewed to check their knowledge and understanding of the subject matter.

Assessment guidelines

Candidates should be presented with the design of a particular building and any relevant specifications. They should also be advised how the building can be orientated on site and be provided with details of the local microclimate and geological factors. Using this information, candidates must determine the optimal combination of renewable energy source(s) and energy-saving measures by completing specified tasks relating to the sampled knowledge and skills items, for example (outcome/element in brackets):

- calculate heat losses in the building structure (6.1)
- explain the benefits of insulation and special glass (6.2 or 6.3)
- explain the operation of a range of PV cells (5.2 or 5.3)
- discuss alignment issues and select optimal installation position and building orientation (5.1 or 5.4)
- calculate the annual output for a range of PV types for that particular location (5.5)
- compare solar hot-water system with solar PV (6.5)
- describe the operation and potential of installing a heat pump (6.6)
- explain problems of balancing supply with demand and how hydrogen can help (4.2 or 4.3)
- show how domestic systems could exploit stored hydrogen (4.5 or 4.6)
- select an optimal solution for the building (6.7)

Administrative information

Unit code: HV5N 48

Unit title: Renewable Energy Systems: Technology

Superclass category: XK

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Version	Description of change	Date

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SQA acknowledges the valuable contribution that Scotland's colleges have made to the development of SQA Advanced Qualifications.

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SQA Advanced Unit Specification: support notes

Unit title: Renewable Energy Systems: Technology

This part of the unit specification is offered as guidance. The support notes are not mandatory.

While the exact time allocated to this unit is at the discretion of the centre, the notional design length is 80 hours.

Guidance on the content and context for this unit

This unit has been written as one of the 10 renewable energy units within the SQA Advanced Diploma in Engineering Systems. These are:

- ♦ Renewable Energy Systems: Overview of Energy Use (2 credits, SCQF level 7)
- ♦ Renewable Energy Store: Hydrogen (1 credit, SCQF level 8)
- ♦ Renewable Energy Systems: Wind Power (1 credit, SCQF level 8)
- ♦ Renewable Energy Systems: Wave and Tidal Energy (1 credit, SCQF level 8)
- ♦ Renewable Energy Systems: Solar (1 credit, SCQF level 8)
- ♦ Renewable Energy Systems: Biomass (1 credit, SCQF level 8)
- ♦ Renewable Energy Systems: Geothermal Energy (1 credit, SCQF level 8)
- ♦ Renewable Energy Systems: Hydroelectricity (1 credit, SCQF level 8)
- ♦ Renewable Energy Systems: Microgeneration Systems (1 credit, SCQF level 7)

This two-credit unit *Renewable Energy Systems: Technology* describes the basic technology associated with renewable energy devices. The two-credit unit *Renewable Energy Systems: Overview of Energy Use* provides an introduction to the subjects of energy usage and trends, environmental impact of energy use, and renewable energy sources from both a global and local perspective. The remaining one-credit units examine each of the technologies currently believed to be significant in greater depth, and, as such, provide an opportunity for candidates to specialise in some of these technologies. It is important that all these units are seen as providing an integrated programme of study covering energy issues with a focus on renewable energy systems. As such every opportunity should be sought to combine the delivery and assessment of the units.

The emphasis in all the 10 units should be on allowing candidates to develop knowledge and understanding of the energy and environmental issues facing this country and others as well as giving them the knowledge, understanding and skills required to understand how renewable energy systems generate power as electricity or other energies/fuels. It is important that environmental as well as technological issues and developments are discussed as each has a bearing on the other. The one-credit specialist units will allow candidates to develop a deeper knowledge and understanding of how these systems work from an engineering systems perspective and should enhance the core units in the SQA Advanced Diploma in Engineering Systems.

In designing this unit, the list of topics lecturers might wish to follow has been identified. This list is shown on the following pages. Recommendations as to how much time should be spent on each outcome has also been given. This has been done to help lecturers decide what depth of treatment should be given to the knowledge and/or skills items attached to each of the outcomes.

However, it should be emphasised that the list of topics is not mandatory (ie renewable energy technologies is a rapidly-developing field with new subjects arising all the time). If the list of topics is used, the emphasis and context may have to be varied to suit local needs and/or candidate interests. Adherence to the list of topics will ensure continuity of teaching and learning.

The list of topics is as follows:

Outcome 1

Explain the operation and characteristics of electrical generator systems (12 hours)

Describe electrical generators used in renewable energy systems and relate the output voltage/current to the rotation frequency. Represent generator systems by mechanical diagrams that include any gearing or coupling. Produce diagrams showing the output waveform from a calculation of the internal magnetic field strength and the coil geometry, and show how the voltage and current varies with load. Discuss how the voltage can be frequency stabilised and set to match mains 230V AC. Describe the circuits that will enable a generator output to be fed onto the grid. Explain the possible fault conditions that can occur with generators and how the onset of some faults might be detected using appropriately positioned sensors linked up to specialist software. Sensors might include vibration and temperature sensors at bearings, inductive sensors to monitor the rotational speed, voltage and current sensors at the output. Explain the types of devices available for each category of measurement and the signal conditioning needed to get an adequate voltage signal for measurement by computer or direct display. Candidates should ideally be shown sensors attached to a generator (with the appropriate signal conditioning circuitry accessible) so that they can capture real data. Commercial monitoring packages can be used to analyse this data with the candidates being able to compare and evaluate the features of different packages. If software or realistic data is not available, features may be compared using downloadable demonstration versions of some of the software packages.

Outcome 2

Explain the characteristics and optimal design of prime movers used in a renewable energy applications (11 hours)

Explain the force associated with a moving fluid and how it varies with velocity and the density of the fluid. Revise vector diagrams and trigonometry (if necessary) and show how forces are projected in the direction of motion. Calculate the pressure on blades of different sizes, geometries and orientations. Calculate the torque and identify the stress points in the system: the points most likely to fail if the force is excessive. Consider the effect of driving forces on bearings. Demonstrate the optimal weight/area/number of blades combination in different situations. It is acceptable to treat this as a theoretical exercise, but the use of a wind tunnel to illustrate the principles would be beneficial, particularly if candidates are able to explore and experiment with different designs. Candidates should be encouraged to investigate the wide range of commercially available turbine shapes and consider the reasons the available configurations are so diverse. Describe how linear motion (such as from some tidal or wave power devices, or engines) can be converted to rotational motion without necessarily using a turbine.

Describe the faults that can occur on prime movers with reference to stress or contact points where friction may be an issue. Explain how the strengths of materials used in prime mover designs may have a bearing on faults that occur. Explain the sensors that can be used to measure the driving force, be it airflow, wave force, tidal height or water pressure. Note that the prime mover can itself be a sensor/transducer. In each case state the optimal sensor choice under particular conditions and describe the signal conditioning applicable to each device.

Outcome 3

Analyse the effectiveness of wind, wave, tidal and hydroelectric systems (10 hours)

Describe the properties of small wind turbines for microgeneration (300 W-3 kW), medium sized devices (15–30 kW) and very large turbines (1–10 MW). Specify the range of wind speeds over which they operate and the cost per kWh generated. Discuss in general terms environmental and installation factors.

Explain the operation of a hydroelectric turbine. Calculate the stored energy and the pressure as a function of height. Derive the relationship between water flow rate and the efficiency with which energy can be released. Discuss the optimal position for the turbine (as far below the water level as possible, perhaps piping the water to a lower level).

Describe the main types of device used to extract wave and tidal energy, including estuary barrier systems, and explain how close these are to commercial deployment. Explain the problems with the incredible variability in wave power that currently makes this technology the least exploited. Emphasise the huge potential to generate large amounts of energy with this technology.
Of all the ideas that have been proposed only consider those that have some economic potential. State the quantities of energy that may be available from each of the four renewable energy resources. In each case, explain what the trend has been in each sector as the technology has advanced over the last thirty years (since the first oil crisis). Encourage candidates to research current activities in each sector and thereby predict future advances in technologies.

Outcome 4

Evaluate energy transportation issues including hydrogen-based solutions (10 hours)

Explain that electrical power lines have heating losses the amount of which depends on the line voltage. Explain that too high a voltage will lead to insulator breakdown and that this imposes a limit on upper voltage levels. State that traditional power generation plant such as found in coal, oil or nuclear power stations provide the base load demand. Peak load demands are often met by equipment that can be started up relatively quickly (eg gas turbine plant, hydroelectric power stations) although the cost per kWh is considerably higher than that obtained from base load power stations. Describe the operation of hydroelectric storage schemes used to deal with 'surplus energy' at night times. *Explain* that such schemes, as with other traditional forms of bulk storage, have high losses and low efficiencies.

Describe how hydrogen is a potential solution because the electrolysis process is highly efficient and there is no energy decay during storage. The efficiency of energy recovery using a fuel cell can theoretically approach 100%, but mention that the efficiency currently attained by electrolysers and fuel cells is much less than this and that devices are costly — research & development is needed.

Explain the disadvantages of using hydrogen (eg bulk storage issues, pressurisation and health and safety issues). Describe the operation of a particular electrolyser and fuel cell. It would be beneficial for candidates to see a real system operating in the laboratory — a small electrolyser powered by a PV panel or small wind turbine directly feeding hydrogen to a store to which is attached a fuel cell. This shows how hydrogen acts as a storage buffer when the primary energy source is unavailable. Candidates should consider the design of engineering systems that could be operated by a fuel cell and give some thought to how to overcome the problems with energy storage, perhaps using standard gas bottles with pressure and flow regulation. They may also consider how the bottles could be recharged. A typical system would consist of fuel storage → gas flow regulation → fuel cell → DC motor.

Outcome 5

Investigate the characteristics of photovoltaic (PV) systems (10 hours)

Revise the electromagnetic spectrum and the energy spectrum of the sun showing atmospheric and other absorption points. Distinguish between visible, UV (ultraviolet) and IR (infrared) parts of the spectrum. Calculate surface energy density and how this varies with angle of elevation. Show the effects of the seasons on the energy output. Describe the typical energy profile at a location. This information may be obtained from historic Meteorological Office tables.

Revise semiconductor properties and diode operation. Describe the photoelectric effect. Explain how a junction can be optimised for a particular frequency or range of frequencies that matches the greatest spectral output. Discuss the range of materials available with an efficiency of between 5% and 20%. Candidates should be encouraged to research new materials under investigation that aim to double this efficiency. Compare with the efficiency of natural materials like chlorophyll. Look at the cost output ratio of various materials and show that the least efficient systems are currently the most popular because of the much lower unit cost.

Consider various simple building structures and calculate the angle that arrays should be orientated to optimise the energy produced annually. Consider the best compass direction to locate a building to maximise energy output from an array attached to the building. Discuss installation issues. Discuss the advantages and disadvantages of moveable structures. For optimal alignment and location of an array and building calculate the annual energy output for a variety of commercial and experimental PV materials, and relate this to the installation cost.

Candidates should be encouraged to experiment with some small PV arrays in the laboratory and may produce plots of how the output varies with angle and solar intensity and compare this to the manufacturer's specifications. The effect of dirt and residue can also be evaluated.

Outcome 6

Analyse the heating requirements of buildings to reduce energy end-use (18 hours)

Revise the basic principles of thermodynamics to re-familiarise the candidates with the concepts. Discuss the thermodynamics of buildings in terms of regular structures that can be grouped together to build more complex structures. Make the basic element a rectangular sealed box. Define an internal heat source and show how the temperature rises in an enclosed space with perfect insulation.

Explain that the strategy in reducing energy end-use is to track the routes by which all energy internally produced is lost and put in place measures to reduce the loss of this energy. Show that in real enclosures where the temperature inside is greater than outside heat is lost through conduction and radiation. Use Fourier's law to calculate the amount of heat lost in a building. Show the effect on heat losses of adding different thickness of insulation to the building. Compare energy savings with different thicknesses of insulation against the cost of the insulation. Consider discounted and nett costs. By showing that the enclosure has an internal temperature gradient because of convection (cold air is heavier than warm), explain that it is more cost effective to insulate some surfaces than others. Discuss the problems with cooling a building when the external temperature is high and the high costs involved. Consider the use of reversible heat pumps.

Discuss the properties of glass as a material that can act as a heat source because of the greenhouse effect. Examine the structural properties and costs of glass. Encourage candidates to research the 'smart glass' concept.

Describe the principles of solar hot-water heating systems. Explain that such systems take energy principally from the IR part of the spectrum, but heat is also obtained from the optical part of the spectrum through the greenhouse effect. Compare the cost and efficiency of such systems with different PV materials. Describe parabolic focussing systems to achieve higher temperatures. Describe the operation of a heat pump and the advantages it has over direct heating. Explain the different types of reference 'reservoir' that can be used. Explain the temperature below ground as a function of depth and geothermal energy. Describe the cost of installing such systems.

A major objective of the Unit is to show how to design a 'green building'. The building must be less reliant on carbon-based fuels by integrating renewable energy sources on site and promoting energy end-use efficiency through effective design. Cost is an important criterion, and candidates should at this stage know the typical cost per kWh of each of the renewable energy technologies (including installation). Explain how the most appropriate grouping of technologies can be selected based on the local microclimate, the building design, location within the boundaries of the site, and orientation of building and any arrays to maximise the energy produced. Present a set of typical case studies showing varying energy solutions for different conditions. Emphasise the use of integration of different energy sources to provide a reliable supply.

Guidance on the delivery and assessment of this unit

This unit may be delivered by a combination of lecturing, group work, investigation (including the use of the internet), laboratory work and case studies. The internet contains a rich and varied range of materials relating to renewable energy technologies. As noted in the Guidance on content and context section observation of practical systems (eg electrical generator with sensors) and laboratory work (experiments on PV arrays) should be very much encouraged to help candidates to relate theory to practice.

This unit is largely theoretical in nature. However, access to renewable energy technologies either at the centre or through industrial or site visits would be beneficial. This is particularly important as formal assessments deal with real systems. A very important objective is to enable candidates to recognise the cost of installing a technology compared with the energy produced (or saved) by the installation. Only with this knowledge can design and installation decisions be taken that have value in the real world where cost is often the overriding factor.

However, candidates must also look to the future and recognise that technologies that are impractical now or too costly can be viable in the future because of inevitable technological advances and the general trend of a rising energy costs. Candidates should be encouraged to research these issues, particularly with reference to Outcomes 3 and 5.

It is important to understand that this unit is fundamentally an engineering unit that brings together a range of engineering concepts and principles of relevance in the specialist field of renewable energy technology. As such, it is vital that the unit outcomes are always delivered with reference to how the concepts and principles are applied in a renewable energy context. The emphasis in candidate learning must be basic principles first, applications second. The applications should never blur the underlying basic principles as it will be essential that candidates understand these if they go on to study one or more of the specialist renewable energy units.

It is not practical to teach candidates the full range of engineering knowledge required to support the unit during the available delivery time. It is advisable that candidates have a certain level of prior knowledge of engineering. Candidates who have previously studied an engineering award at SCQF level 7 are likely to possess much of the necessary engineering knowledge and understanding at the correct level. However, there will be candidates who have only limited engineering knowledge and understanding. It is therefore advisable to establish with candidates their level of knowledge of engineering subjects prior to the start of the unit in order to plan the delivery to include some additional teaching of engineering subjects where this is deemed necessary. To assist with this process listed below is the recommended knowledge candidates should have in each engineering subject area prior to taking the unit. The list below also shows the new knowledge that should be taught in the individual engineering subject areas during the delivery of the unit.

ELECTRONICS

- *Prior knowledge*: semiconductor materials, PN junction, operational amplifiers, gain and offset
- *New knowledge*: optical properties of semiconductor materials

ELECTRICAL ENGINEERING

- *Prior knowledge:* voltage, current, resistance, load, ohm’s law, ac and dc voltage, phase and frequency, induction, properties of coils, magnets, forces on current bearing conductor in a magnetic field, transformers
- *New knowledge:* detailed mechanical and operational properties of generators, heat loss in cables, electrolysis

MECHANICS

- *Prior knowledge:* force, mass, distance, velocity, acceleration, newton’s laws, pressure, stress, strain, tension, properties of materials, vectors, balancing forces
- *New knowledge:* fluid mechanics, linear to rotational motion, vector projection calculations, operation of blades and turbines, coupling, rotating machinery

THERMODYNAMICS

- *Prior knowledge:* pressure, volume, temperature, constant, laws of thermodynamics, specific heat capacity, adiabatic change, isothermal Boltzmann’s change, conversion of heat to work
- *New knowledge:* conduction and radiation laws, heat pump, conduction, convection, insulation

TRANSDUCERS, MEASURTEMENT & CONTROL

- *Prior knowledge:* properties of sensors available for a range of parameter measurement, linearity, sensitivity, accuracy, repeatability
- *New knowledge:* selection of sensor types, scale, offset

Details on the approaches to assessment are given under Evidence requirements and assessment guidelines after Outcomes 3 and 6 in the SQA Advanced Unit Specification: statement of standards section. It is recommended that these sections be read carefully before proceeding with the assessment of candidates. It is strongly recommended that candidates be provided with clear details about unit assessment at the start of the unit.

Opportunities for developing core skills

All elements of the core skill of Problem Solving, that is, critical thinking, planning, organising, reviewing and evaluating, will be naturally developed and enhanced as candidates undertake an in depth Investigation for Outcomes 3, 4 and 5. Identifying and considering a complex range of factors including energy transportation, systems and efficiencies they seek solutions to various theoretical and practical problems. Variables, including costs of materials and technologies, are fully discussed. The optimal combination of renewable energy sources and energy-saving measures is identified, justified and evaluated in a comprehensive report.

Access to and evaluation of complex technical information, using paper based and internet sources, will support knowledge and develop key skills in communication and information technology. Candidates should be provided with guidance on the format, style and structure acceptable in written reports. They should be advised that technical accuracy of complex ideas and information should be supported by clearly annotated drawings and diagrams. Resources available could include appropriate software packages to support accuracy and the effective presentation of written and graphic information. Input from the assessor at various stages of report writing can provide opportunities for candidates to discuss issues, respond to questions and feedback and develop oral communication skills in a practical context.

A series of complex calculations and measurements underpins the findings and conclusions in the Investigative report. Numeracy skills will be naturally enhanced, with the focus on accuracy and the practical interpretation, application and presentation of complex numerical and graphical data. Formative practical activities should be designed to develop accuracy, flexibility and confidence in handling concepts in the context of renewable energy technology.

Open learning

Due to the theoretical nature of this unit, with its principal focus on engineering concepts and principles in the context of renewable energy technologies, the unit can be delivered through open learning and/or online delivery. While it is desirable for candidates to undertake experiment work on real systems, such work can also be largely simulated in an online environment through video clips and interactive multimedia activities.

Where open learning is considered due regard to assessment planning would be required by the centre concerned to ensure the sufficiency and authenticity of candidate evidence. Arrangements would be required to be put in place to ensure that the combined assessment paper for Outcomes 1, 2 and 3 is done under controlled, supervised conditions.

For information on normal open learning arrangements, please refer to the SQA guide *Assessment and Quality Assurance of Open and Distance Learning (SQA 2000).*

Equality and inclusion

This unit specification has been designed to ensure that there are no unnecessary barriers to learning or assessment. The individual needs of learners should be taken into account when planning learning experiences, selecting assessment methods or considering alternative evidence.

Further advice can be found on our website www.sqa.org.uk/assessmentarrangements.

General information for candidates

Unit title: Renewable Energy Systems: Technology

This unit is one of 10 units on the very important subject of renewable energy systems. The unit has been designed to give you an overview of many of the technologies used in renewable energy systems. Many of these technologies can be explained in terms of basic electrical, electronic and mechanical engineering principles so it will be important that you have a knowledge and understanding of some of these principles before starting the unit although some of them may be taught to you during the delivery of the unit.

During the delivery of the unit you will study such subjects as the operation and characteristics of electrical generator systems used in renewable energy systems, the characteristics and optimal design of prime movers used in renewable energy applications, energy transportation issues including the use of hydrogen for carrying and storing energy and the characteristics of photovoltaic systems. You will also be provided with opportunities to analyse the effectiveness of a wave, wind, tidal or hydroelectric system and analyse the heating requirements of a building to reduce energy end-use

Delivery of the unit will consist of lecturing, group work, investigation (including the use of the internet), classroom discussions/debate and case studies. The internet contains a rich and varied range of materials on renewable energy system devices and technologies. Your lecturers may also take you on industrial visits to examine different types of renewable energy systems in operation.

Assessment in the unit is likely to comprise of the following two assessments: for Outcomes 1, 2 and 3 a combined assessment paper, lasting three hours and sat at a single assessment event under controlled, supervised, open-book conditions. The assessment will be based on **one** of the following types of renewable energy system: wind, hydroelectric, wave or tidal. Assessment for Outcomes 4, 5 and 6 will comprise of an assignment which you will complete in your own time and should take approximately 10 hours to complete. You will be presented with a complex, realistic problem involving the determination of the most suitable combination of renewable energy source(s) and energy end-use efficiency measures to heat a building. You will be required to produce a report of between 2,500 to 3,000 words plus diagrams for this assignment.