SQA Advanced Unit Specification

General information for centres

Unit title: Renewable Energy Systems: Wind Power

Unit code: HV5R 48

Unit purpose: This unit has been designed to provide candidates with a good technical knowledge and understanding of the principles of operation of wind turbines. The unit also highlights the importance of environmental and economic factors when planning the installation of a turbine or turbine group. The candidate will be encouraged to develop an objective approach to the planning of a wind power system by quantifying such factors as mean power output and variability using meteorological information appropriate to the site. The candidate will be expected to make scientifically competent recommendations based on this data. Installation effort, reliability and maintenance issues are also to be considered. The content of the unit is largely theoretical, but basic engineering principles will be reinforced through a practical investigation of operational turbines and/or the behaviour of models in the laboratory. The focus of the unit is solely on large wind turbines.

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

1 analyse the response of different turbine and rotor designs to a variety of wind conditions
2 evaluate the economic performance and environmental impact of a turbine in a variety of locations
3 apply an operational understanding of wind turbines to a theoretical or practical problem context

Credit points and level: 1 SQA Credit at SCQF level 8: (8 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 the unit is at the discretion of the centre however candidates should have a general knowledge and understanding of energy use, the consequences of energy use and renewable versus non-renewable energy sources. This knowledge and understanding may be evidenced by possession of the following SQA Advanced Unit HV48 47 *Renewable Energy Systems: Overview of Energy Use*. It would also be helpful if the candidate first completed the double-credit SCQF level 8 Unit HV5N 48 *Renewable Energy Systems: Technology* for a basic introduction to the physics of wind turbines.

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 unit has been developed for the SQA Advanced Diploma in Engineering Systems. If this unit is delivered as part of another group award, it is recommended that it should be taught and assessed within the subject area of the group award to which it contributes.

Assessment: The assessment strategy for this unit is as follows:

All three outcomes should be assessed on a sample basis through a single **case study** where the candidate is presented with an actual problem situation, or, alternatively, a complex and realistic theoretical problem situation. The findings of the case study should be presented in the form of a report of 2,800–3,200 words. The assignment and reports are to be done in the candidates own time and it is expected they will take up to 12 hours to complete. The report must be referenced.

SQA Advanced Unit Specification: statement of standards

Unit title: Renewable Energy Systems: Wind Power

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

Analyse the response of different turbine and rotor designs to a variety of wind conditions

Knowledge and/or skills

- Structural force on a tower or support
- Reliability of mechanical systems subject to force
- Effect of wind speed on the output power
- Rotation speed as a function of blade mass, area and angle
- Effect of varying the number of blades
- Protection strategies in strong wind
- Monitoring and control techniques

Outcome 2

Evaluate the economic performance and environmental impact of a turbine in a variety of locations

Knowledge and/or skills

- Global energy potential of wind power from geographical data
- Trends in energy cost
- Energy return for a range of turbine sizes based on realistic efficiency and price estimates
- Turbine noise during operation
- Effect on flora and fauna
- Social effects
- Comparison of onshore and offshore wind farms

Outcome 3

Apply an operational understanding of wind turbines to a theoretical or practical problem context

Knowledge and/or skills

- Identification of key factors of a problem scenario
- Accurate quantitative analysis of data
- Development of an appropriate solution
- Report findings effectively

Evidence requirements

Evidence for the knowledge and/or skills items in Outcomes 1, 2 and 3 should be provided on a sample basis. The case study (see page 5 for more details) used to assess the three outcomes must be specified to a sufficient extent that the candidate will be effectively assessed on at least **four out of seven** knowledge and/or skills items from Outcome 1, **four out of seven** knowledge and/or skills items from Outcome 2 and **all four** knowledge and/or skills items from Outcome 3.

Where sampling takes place, a candidate's response can be judged to be satisfactory if candidates have demonstrated that they can:

Outcome 1

- calculate the structural forces of a tower or support
  — range of forces
  — range of tower geometries
  — range of materials
- describe the effect of a force on reliability
  — axle and bearings
  — bending and shearing
  — cyclic stresses and gyroscopic effect
  — performance of gearbox
  — turbulence
  — blades upwind or downwind
- produce a graph of force or pressure as a function of wind speed
  — typical variation with height
  — effect of geographical factors such as hills and trees
- calculate the forces for a specific blade design
  — mass
  — area
  — angle of attack
  — start-up velocity
- compare the performance of a range of configurations
  — number of blades (difference between odd and even)
  — horizontal
  — vertical
- specify standard methods used to protect the wind turbine from high winds
  — feathering
  — stalling
  — turning rotor away from the wind
  — controlling pitch for optimal performance
- describe monitoring and control strategies
  — types of anemometer
  — logging wind speed profiles as for planning purposes
  — monitoring of moving parts
  — structural analysis

Outcome 2

- explain the global importance of wind power as a renewable energy resource
  — local and prevailing wind
  — global wind energy
  — examination of typical data
- estimate of current and future energy costs
  — kWh definition and cost to produce electricity by various means
  — 'green energy' subsidies and impact on cost effectiveness
  — projected cost of energy as fossil fuel reserves becomes depleted
  — grid connectivity method and costs
- calculate the energy return for a specific type of turbine using actual wind data
- describe the characteristics of rotor and turbine noise with rotation speed
  — amplitude
  — frequency
  — variation with blade design
- describe the environmental effects of a wind turbine or turbine groups
  — ornithological issues
  — effect on soil and substructure
  — access and maintenance roads
  — effect on plant life
  — environmental cost of construction and installation
- describe the societal aspects of the installation of wind turbines
  — aesthetic issues
  — effect on existing industries
  — installation and maintenance work creation
  — reduction in CO_2 production
  — variability of supply and storage issues (hydrogen)
- compare onshore and offshore wind farm installations
  — environmental issues
  — installation and maintenance factors
  — power output
  — methods for conveying power to consumers

Outcome 3

- identify key factors specific to the scenario in each of the following topics
  — optimal location of with respect to micro-climate
  — type and quantity of turbines
  — reliability, installation and maintenance issues
  — environmental issues
  — transmission of energy and balancing supply with demand
- quantitatively analyse data accumulated for a number of competing solutions
  — choice of turbine and rotor configuration
  — expected value of the energy produced over the lifetime of the installation
  — cost of installation and maintenance
  — impact of environmental factors
  — cost of energy transmission
- select and justify the optimal solution
- produce a report which clearly describes the candidate's findings

All sampled knowledge and/or skills items should be assessed through a single case study where the candidate is presented with an actual problem situation, or, alternatively, a complex and realistic theoretical problem situation. The scenario to the case study should address the need to provide a significant quantity of energy from a renewable energy source (this should typically be in the range 1MW to 1000 MW.) By considering the microclimate and the performance of the machines, the candidate should estimate the mean power and energy supply variability; the forces on towers and blades should also be calculated as this has a bearing on reliability and maintenance cost (Outcome 1). The economic return must be calculated over the lifetime of the system, taking into consideration the current value of the energy produced and the future value as estimated from energy cost trends. The costs associated with environmental impact (including the infrastructure for conveying the energy to the end-user) must also be identified (Outcome 2). Having gathered all the information, the candidate should specify the optimal configuration of turbines for the site (Outcome 3). The report may comment on issues such as supply variability and the methods of delivering the energy to the end-user.

The findings of the case study should be presented as a report of 2,800–3,200 words. The assignment and reports should be to be done in the candidates own time and it is expected to take up to 12 hours to complete. The report should include any necessary calculations and include evidence of analysis and evaluation and 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. A checklist should be used to record oral evidence of the candidate’s knowledge and understanding.

Candidates should have access to course notes, relevant textbooks, research papers, reports, technical information, meteorological data (in electronic form) and the Internet while producing the report.

Assessment guidelines

Candidates must be encouraged to used appropriate software to produce the report and to prepare diagrams and drawings. Hand-written submissions should be discouraged. It may be necessary to provide some assistance with formatting and the selection of an appropriate style, and the candidate should be encouraged to include a title page and contents list to the document.

The candidate should be introduced to the concept of formal report writing and the necessity of logical development and clarity.

The difference between plagiarism and referencing the work of others should be made clear and a standard method of referencing should be specified. As the assignment may include some research, it is important that candidates have access to the appropriate resources. It should be made clear that only credible Internet sites should be referred to (and referenced).

Administrative information

Unit code:	HV5R 48
Unit title:	Renewable Energy Systems: Wind Power
Superclass category:	XK
Original date of publication:	November 2017
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History of changes:

Version	Description of change	Date

Source: SQA

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

For further information, please call SQA's Customer Contact Centre on 44 (0) 141 500 5030 or 0345 279 1000. Alternatively, complete our Centre Feedback Form.

SQA Advanced Unit specification: support notes

Unit title: Renewable Energy Systems: Wind Power

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 40 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 Systems: Technology (2 credits, SCQF level 8)
- Renewable Energy Store: Hydrogen (1 credit, SCQF level 8)
- Renewable Energy Systems: Biomass (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: 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)

The figures in brackets indicate the SQA Credit value and SCQF level of the unit respectively.

The double-credit unit, *Renewable Energy Systems: Overview of Energy Use* is a basic generic introduction to the subject and aims to present both a local and global perspective of energy use. *Renewable Energy Systems: Technology* describes the basic technology associated with renewable energy devices. The remaining units take a specialised look at each of the technologies currently believed to be significant, and there is the opportunity to specialise. It is important that all these units are seen as providing an integrated programme of study covering the energy issues with a focus on renewable energy systems. As such every opportunity should be sought to combine the delivery and assessment of any of these units.

This unit relates specifically to large wind turbines and has been written to allow candidates to gain some understanding of the power of the wind (both locally and globally) and the significance of the cubic dependence on wind speed – when the wind is light, the non energy is produced, and when the wind is very strong, the turbine and support structure is susceptible to damage. This means care must be taken with the design of the components with the objective of improving reliability. However, whilst there is considerable research activity in this field, there has been no dramatic change in the basic configuration and performance of wind turbines over the last 100 years. In fact, the most significant development is the utilisation of the linear scaling effect to make bigger and bigger machines. Machines with a capacity of 6 MW have been available since 2006, and there is no reason why a quadrupling of dimensions cannot result in 20 MW wind turbines being produced over the next few years. There is some justification for this because of the desperate need to reduce the world’s dependence on fossil fuels and bigger machines give a better economic return, particularly as the baseline cost of energy continues to increase.

However, in growing to these overwhelming sizes, the former belief that wind turbines are beneficial to the environment has been considerably weakened, so much so that the choice to install wind turbines is not longer a straightforward decision but seen as a balance between competing needs.

It is no longer enough for an engineer specialising in the planning of alternative energy installations to have a good level of technical knowledge. It is also important for the engineer to understand the environmental impact and the needs of society. These issues should be taken into account and must enter into the planning process, though, in truth, they are often very difficult to quantify. These issues are considered in this Unit, though the bottom line is always an objective analysis based on accurate quantifiable data.

Candidates should be encouraged to engage in individual research throughout the unit, particularly the design of rotors to extract the maximum energy and the methods for improving reliability.

It is recommended that the content of the unit should be as out lined below:

Outcome 1

This is a substantial outcome with a significant amount of theory.

Describe the effects of a force on a structure. This will be a maximum at the base. Consider various geometries and the properties of different metals and alloys that will enable the structure to withstand the forces whilst reducing the weight and volume of the tower. Compare covered and open structures. Explain that oscillation with potentially destructive resonances can be set up for certain force profiles.

Off–centre forces can cause problems with blades, axle, bearings and gearbox. Explain the faults arising from bending and shearing. Describe the cyclic stresses arising from the tower momentarily blocking the wind and gyroscopic forces as the rotor turns into the direction of the wind. Describe how a gearbox is needed to convert the slow motion of the blades to the higher speed needed by the generator. Explain the effect of turbulence behind the blades and the impact on efficiency. In a horizontal turbine, the generator is at the top of the tower — describe the difference in placing generator upwind and down wind of the tower in terms of the bending of the blades, alignment with the wind direction and turbulence effects.

Candidates should be presented with data concerning the variation of wind energy with velocity, height and also the effect of geographical features such as hills, buildings and trees. A distinction should be made between prevailing and local wind effects.

Look at specific blade designs and develop equations that show the effect of mass, surface area and angle of attack on the dynamics of the system. Derive the start-up velocity and define a level of force that may damage the rotor, generator or connecting structures. Examine different commercial designs and compare vertical and horizontal axis systems. Explain the consequences of increasing the number of blades on the performance of the machine.

At high wind speeds, the forces may damage the turbine. Describe strategies in common use to reduce the force under these conditions. This includes feathering the blades, stalling the system, and turning the blades out of the wind. This may be combined with a general strategy for actively altering the pitch of the blades to optimise performance. All turbines will have monitoring and control systems and these should be described. This includes condition monitoring.

In general, a site will be monitored with anemometers before turbines are installed. Describe different types of anemometer and how data can be logged using computer software.

Outcome 2

Describe that wind energy arises ultimately from solar energy and the angular momentum of the rotating Earth. Quantify the energy content of wind globally. Distinguish between prevailing winds and wind associated with local geographical effects. Use actual data to show the energy available in a relevant area.

Estimate the cost per kilowatt-hour (which should be defined) of producing energy from wind based on the purchase and installation cost of a number of turbine types and the effect of 'economies of scale'. Include the effect of national and European subsidies. Show how viability improves as the cost of energy generated from fossil fuels increases — consider a number of scenarios. For a number of turbine types, use actual wind data to calculate the value of the energy produced over the anticipated lifetime of the machine.

Explain the methods of putting the energy on the grid and the difficulty of matching generation with consumer demand. Consider how the 'hydrogen economy' could be a solution to this problem. Characterise noise in terms of amplitude and frequency and explain how the volume changes with wind velocity and distance from source for a number of machine types. Understand that noise is generally associated with unbalance and inefficiency.

Explain known effects of wind turbines and wind farms on the natural environment and wildlife, including the effect of access, construction and maintenance roads. Consider onshore, near shore and offshore installations.

Consider social issues including the creation of work, impact on tourism and outdoor leisure activities. Consider the effect on existing industries and also the aesthetic appeal and how this should affect siting decisions. Weigh in the benefit of the overall reduction in CO_2 release into the atmosphere.

Compare inshore and offshore installations and describe the technical issues.

Outcome 3

A problem scenario will be specified with sufficient complexity to make it possible to adequately assess the unit. Sufficient instruction should be given to ensure that candidates cover at least the minimum number of knowledge and/or skills items required to be sampled in each outcome.

The scenario should if possible be realistic and should include some geographic variability so that the candidate can take these into account when selecting an optimal site. There must be environmental and social factors. Annual wind data should be supplied to enable the output from the turbines to be calculated.

Guidance on the delivery and assessment of this unit

Although the unit can be taught entirely theoretically, it is recommended that candidates should observe and monitor the operation of large turbines through site visits. If may be beneficial to install sensors for noise, stress, and vibration to obtain real data that can be evaluated in class (this activity may be combined with a number of other units. When looking at the properties of blades and rotors, it would be useful to create scale models and compare these in the laboratory (using a wind tunnel if available to reveal turbulence).

Candidates will have opportunities to develop reading communication skills while reading materials on wind power systems from both paper based and electronic sources. Lecturers may choose to ask candidates questions on the materials they have read to check understanding. Candidate may develop their written communication skills through the preparation of the investigation report for Outcomes 1, 2, and 3.

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 apply an operational understanding of wind turbines to a theoretical or practical problem context.

Identifying and considering all relevant environmental and economic factors, they seek appropriate solutions. Variables such as mean power output and variability are examined using meteorological information appropriate to the site. Monitoring and control strategies are identified and considered. Different turbine and rotor designs are fully discussed, analysed and evaluated to present scientifically competent recommendations based on data.

Access to and evaluation of current information on the principles and operation of wind turbines, using paper based and internet sources, will develop key skills in communication and information technology. Candidates should be provided with guidance on the style, conventions and structure appropriate to the Practical Investigation. Resources available could include software packages to support accuracy and the effective presentation of written and graphic information. Opportunities for candidates to discuss issues, respond to questions and feedback and develop practical oral communication skills in formative laboratory work.

A series of complex calculations and measurements of structural forces and stresses underpins the findings and conclusions in the report. Numeracy skills will be naturally enhanced, with the focus on 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 the operation of wind turbines.

Open learning

This unit is suitable for complete delivery by distance learning. If candidate is engaged in employment associated with wind power, the assessment can be an actual work-related case study.

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: Wind Power

The quantity of fossil fuel stored underground is rapidly diminishing, and we are recognising the effect on the planet of burning carbon-based fuel at the current rate: There are predictions of a catastrophic temperature rise resulting from a global greenhouse effect triggered by a rising carbon dioxide concentration in the atmosphere. Nevertheless, energy is needed to ensure economic growth and prosperity, but this has to come from other sources. Whilst there are many alternative energy sources either being commercially exploited or subject to active research, one of the most significant is considered to be wind power. There is a vast amount of energy in wind (particularly in Scotland), and it would seem relatively straightforward to extract — after all windmills have been in use for hundreds of years.

In this unit you will look at the design of modern wind turbines and look at the best way to extract energy. There are a lot of questions you want to be able to answer by conducting a sound engineering analysis of the machines and their environs. For example, why do the turbines have to be so large? Are they reliable? Why do they tend to have an odd number of blades? Why are turbines with three blades so common? What happens in high winds? How much energy do they really produce? What is the lifetime of a wind turbine?

We are also interested in the future trends. As the price of conventional energy inevitably rises, the economics of wind farms will surely improve and the fraction of the national energy requirement supplied from wind will increase. But what happens when there is no wind? How do we balance supply and demand — do we produce hydrogen as a storage mechanism or do we need backup systems run from fossil fuel sources?

Although the technical aspects of the subject are interesting, the real issue at the moment is the siting of single wind turbines and large wind farms. There are a lot of arguments from all sides with proponents exaggerating the performance of the wind turbines, and the objectors questioning the efficiency of the machines and the low quantity of energy produced in comparison to the environmental and economic damage. Like all long-running arguments, each side has its points and the only way to arbitrate is to adopt a scientific attitude by producing accurate information which is made available to all to form the basis for decision-making.

In working through this unit, you will learn how to extract all the appropriate information concerning a wind development, not just engineering information but also economic and environmental issues, and learn to take objective decisions concerning the merits of a development.

There is only one assessment, a case study where you have to apply your knowledge and skill to either a real wind power development proposal or an artificial scenario with the necessary complexity.