Unit 14: Energy Changes, Sources and Applications

Unit code: Y/502/5554

QCF Level 3: BTEC National

Credit value: 10

Guided learning hours: 60

Aim and purpose

The aim of this unit is to enable learners to develop, through a practical vocational skills approach, an understanding of the important fundamental physics concepts of energy and how it is measured, with considerations of 'useful' and 'wasted' energy.

Unit introduction

In the world there are increasing demands for:

- a greater awareness of the quantities of energy used at home, at work or in industry and how to measure them
- a greater understanding of how to save energy used at home, at work or in industry
- the need to work towards improved energy efficiency and how to ensure greater sustainability
- the development of new and alternative energy sources.

It is important that learners have knowledge and understanding of the implications of the above with issues such as the design of different buildings (for example homes, offices and factories) and how their energy needs are met.

Learners will study how energy changes can cause a rise or fall in temperature or changes of state, as well as the relationship with volume and pressure. They will develop an understanding of the different energy-transfer mechanisms – conduction, convection and radiation – and the relationships between them. Learners will cover the basic properties of electrical energy sources used to power portable equipment.

Learners will develop vocational practical skills and knowledge of techniques through carrying out practical investigations. These include skills such as handling of laboratory apparatus, interpreting and safely following laboratory procedures and processes, recording and analysing data, carrying out risk analysis, communication skills in recording and using information, and using correct symbols and terminology.

Learners could explore issues:

- how to monitor energy consumption when the temperature changes or changes of state are involved
- how to more effectively insulate buildings through the use of, for example, double glazing
- the potential benefits and limitations of using solar panels to, for example, power remote instrumentation
- the potential benefits and limitations of different cells and implications for their use at home, at work or in industry.

Learning outcomes

On completion of this unit a learner should:

1 Know the fundamental concepts associated with energy and its measurement

2 Be able to investigate how changes of temperature or physical state relate to changes in internal energy

3 Understand the differences and relationships between different energy-transfer mechanisms

4 Understand the properties of electrical energy sources.

Unit content

1 Know the fundamental concepts associated with energy and its measurement

Definitions: work as force × distance moved in direction of force ($W = Fd$); energy in terms of work; kinetic energy ($KE = ½\ mv^2$); gravitational potential energy ($PE_g = mgh$); elastic potential energy ($PE_e = ½\ kx^2$); power as the rate of transfer of energy

Concepts: principle of the conservation of energy; recognition of energy types as forms of potential or kinetic energies; useful energy, wasted energy and efficiency

Quantities and units: energy (joule); power (watt, kilowatt)

2 Be able to investigate how changes of temperature or physical state relate to changes in internal energy

Temperature: degree of hotness; temperature scales (Kelvin, celsius) and fixed points (absolute zero); thermal expansion

Energy changes: transfer of energy can cause a rise or fall in temperature or changes of state; calculations, eg specific heat capacity ($Q = mc\Delta t$), specific latent heat ($Q = mL$); fusion; vaporisation; condensation; applications

Gases: effect of changing temperature, pressure and volume of a gas; experimental evidence for a gas law eg Charles' law, Boyle's law, pressure law; the ideal gas law; kinetic theory dealt with qualitatively; applications

3 Understand the differences and relationships between different energy-transfer mechanisms

Energy-transfer mechanisms: conduction (transfer of kinetic energy between atoms, electrons or molecules); thermal conductivity of solids, liquids and gases; convection (bulk motion of liquids); radiation (absorption, emission and relation to surface properties); Stefan's law of radiation ($W = e\sigma AT^4$); temperature gradient, ie $\frac{Q}{t} = kA\left(\frac{T_1 - T_2}{L}\right)$; applications

Relationships: differences between forced and natural convection

4 Understand the properties of electrical energy sources

Structure and operating principles of common primary and secondary cells: characteristics, merits and limitations for particular applications; capacity and behaviour under load; ampere-hours, milliampere-hours; disposal hazards; applications

Fuel cells: cells eg simple cell, the leclanche dry cell and the lead-acid cell, zinc-air fuel cells (ZAFC), proton exchange membrane or solid polymer, direct methanol fuel cells, recent developments, their prospects and limitations

Solar cells: recent developments; their prospects and limitations

Assessment and grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The assessment criteria for a pass grade describe the level of achievement required to pass this unit.

Assessment and grading criteria					
To achieve a pass grade the evidence must show that the learner is able to:		**To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:**		**To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:**	
P1	describe the fundamental concepts associated with energy, using examples at home, work or in industry [EP3,4; TW1,5; SM3]	**M1**	perform calculations involving changes of state for industrial processes	**D1**	explain the behaviour and response of industrial systems in terms of latent heat, specific heat capacity, temperature changes and the gas laws
P2	carry out an investigation into one gas law, relating them to industrial processes [TW1,5]	**M2**	calculate pressure, volume and temperature changes for gases in given industrial processes	**D2**	explain gas pressure and how it affects industrial processes
P3	explain the processes of conduction, convection and radiation and their industrial applications	**M3**	using industrial examples, calculate energy flow for given thermal conductivities and temperature gradients, and emissivities	**D3**	explain the differences between heat-transfer mechanisms in solids, liquids, gases and combinations of substances, in terms of molecular motion, bulk motion and surface properties in industrial processes
P4	explain the difference between primary and secondary cells.	**M4**	describe the characteristics, merits and limitations of primary and secondary cells related to their industrial applications.	**D4**	evaluate the use of primary and secondary cells for portable applications.

PLTS: This summary references where applicable, in the square brackets, the elements of the personal, learning and thinking skills applicable in the pass criteria. It identifies opportunities for learners to demonstrate effective application of the referenced elements of the skills.

Key	IE – independent enquirers	RL – reflective learners	SM – self-managers
	CT – creative thinkers	TW – team workers	EP – effective participators

Essential guidance for tutors

Delivery

This unit covers much of the foundation work relating to energy, energy changes and transfer mechanisms to complement advanced scientific studies. Learners will have been introduced to the concept of energy as part of *Unit 1: Fundamentals of Science*. This unit aims to develop the quantitative aspects and qualitative understanding.

Practical investigation will form the backbone of the delivery strategy. Learners should carry out measurements and see effects for themselves, rather than passive note taking and bookwork. Learners are not expected to carry out a series of standard practicals and should develop their own investigations, for example, investigating the effectiveness of double glazing on reducing the rate at which thermal energy is lost. It is important that all the work for this unit is related to industrial applications of energy, highlighting differences in lab-based investigations compared with industry. Consideration should be given to implications for industry, for example high pressure requires thickened pipes.

During delivery of this unit, tutors should adopt the sequence in the content section. This sequence starts by linking the concept of energy to physical work. Learners should recognise that energy is the capacity to do work. All the common energy labels, such as electrical energy, chemical energy and solar energy, are referring to kinetic or potential energies. These are energies due to the motion or state of physical objects. Two concrete examples of potential energy are indicated in the *Unit content* but tutors should make the learners aware of other forms of potential energy. It would be valuable for learners to carry out a practical investigation of PE to KE conversion (or KE to PE, or PE to PE etc). This could be done on a simple level, by finding the height reached by a projectile fired by a spring, for example.

It is important for learners to see that temperature is related to the internal energy of a substance. It is not necessary for learners to do a detailed or quantitative study of distributions of quanta in a hot solid. They should recognise that the kinetic energy of the atoms or molecules is related to the temperature. Tutors should focus on how industrial processes make use of this concept.

Learners should carry out simple experiments to measure the specific heat or latent heat of a substance. The aim is for learners to experience techniques used to measure physical quantities, rather than to learn a standard experimental technique. Learners could, for example, use a data logger to record the temperature, at regular intervals, of a container of crushed ice heated by an electric immersion heater. This experiment allows the determination of values for specific heat capacity and latent heat fusion of water. There is a very simple experiment for determining the latent heat of vaporisation of water. Water is boiled with the kettle on a balance so that change in mass can be noted. The power of the kettle is known, so the latent heat can be calculated from the electrical energy transferred during the time it takes for a measured mass loss. The industrial applications and implications must again be the focus here.

The treatment of thermal conductivity could be linked to insulation of buildings or the effectiveness of double glazing. It is useful for the learners to see the heat flow equation as 'push = flow × resistance'. In this case the 'push' is indicated by the temperature difference, the flow is the energy flow and the resistance is the inverse of the conductance (conductance = conductivity area/length). Learners should comment on the effects of surface layers and the industrial applications.

This is a good time to draw out the parallels in different flow systems, ie flow of fluid, flow of charge and flow of heat. This point need not be laboured, but it is useful for learners to draw parallels across different systems, as it will help their understanding of science. Forced convection produces a faster cooling rate than natural convection. Learners' experience should tell them this. At this level, learners should be aware of the five-fourths power law for cooling by natural convection and the linear law for cooling in a steady draught. Quantitative questions requiring the recall of those laws are not necessary. When dealing with thermal radiation, learners should understand what is meant by a black body radiator, be able to complete calculations using Stefan's law and be able to explain the industrial applications and implications.

The treatment of energy sources is restricted to those used to power portable equipment. Learners need to understand the basic principles, so they should study the simple cell, the Leclanche dry cell and the lead-acid cell. They should consult catalogues of cell suppliers and get to know the range of cell types available. They should know how they differ from those studied in terms of energy capacity, convenience, load performance, suitability for particular applications etc. Fuel cells are being developed as energy sources for vehicles and other devices. Learners should know how fuel cells differ from conventional cells.

They should also investigate the energy per square metre delivered by sunlight, so they understand the potential benefits and limitations of using solar panels to power remote instrumentation.

Outline learning plan

The outline learning plan has been included in this unit as guidance and can be used in conjunction with the programme of suggested assignments.

The outline learning plan demonstrates one way in planning the delivery and assessment of this unit.

Topic and suggested assignments/activities and/assessment
Introduction to unit content and programme outline. Theory input: definitions of work, kinetic energy, gravitational potential energy and power including the principle of conservation of energy. Practical activity: practical investigations measuring quantities of energy undergoing conversion (PE to KE, or KE to PE, or PE to PE). Learner activity: calculation of efficiency from 'useful' and 'wasted' energy in home and work contexts. Learner home study task: research industrial examples of energy conversion.
Theory input: transfer of heat energy causing rise in temperature or change of state. Practical activity: measurement of specific heat capacity, specific latent heat of fusion and vaporisation. Learner activity: temperature and state changes calculations in home and work contexts. Learner home study task: research industrial examples of energy transfer causing temperature and state changes **Assignment 1: Monitoring Industrial Energy Consumption in Order to Improve Energy Efficiency** Assignment designed to assess learning of fundamental concepts of energy and its measurement. **(P1, M1, D1)**
Theory input: effect of changing temperature on pressure and volume of gases. Practical activity: experimental investigation of a gas law (eg Charles' Law). Learner activity: ideal gas law calculations. Learner home study task: research industrial processes involving gas laws. **Assignment 2: Report on the Outcomes of an Investigation into One Gas Law, Relating Outcomes to Industrial Processes (P2, M2, D2)**

Topic and suggested assignments/activities and/assessment
Theory input: differences and relationships between thermal energy-transfer mechanisms.
Practical activity: demonstrations of conduction, convection and radiation including practical investigation modelling, for example double glazing.
Learner activity: different flow mechanisms and calculation of energy flow.
Learner home study task: explain transfer mechanisms in solids, liquids and gases and apply to home, work and industrial contexts.
Assignment 3: Explain the Processes of Conduction, Convection and Radiation and Their Industrial Applications (P3, M3, D3)
Theory input: properties of electrical energy sources.
Practical activity: investigate the energy per square metre delivered by sunlight.
Learner activity: basic principles of primary and secondary cells.
Learner home study task: research suitability of particular cells for specific applications.
Assignment 4: Explaining the Properties of Electrical Energy Sources (P4, M4, D4)
Review of unit and assignment programme.

Assessment

All the pass grade criteria must be met in order for a learner to achieve this unit. This unit requires learners to build up a portfolio of laboratory investigations, reports and calculations. The majority of the pass criteria can be achieved through practical activity.

For P1, learners must describe the fundamental concepts of energy, in the context of industrial applications. They must be able to define each term and know the associated unit of measure, as listed in the *Unit content*. For M1, learners must do accurate calculations involving changes of state of substances used in industrial processes.

For P2, learners must investigate a gas law. Experiments are available interactively on the web, but learners should perform at least one in a real laboratory. The Charles' law tube is a fairly inexpensive piece of equipment containing a small amount of mercury. A risk assessment must be carried out. For M2, learners must perform calculations to determine the changes in pressure, volume and temperature for gases used in industrial processes, as given by the tutor.

For D1 and D2, learners must apply the principles, in the *Unit content*, to at least one industrial system.

For P3, learners must investigate conduction, convection and radiation. They could do this through cooling experiments, and this would be a useful opportunity for learners to use data loggers. Learners need to highlight and explain differences in their investigations compared with those used in industry.

For M3, learners must calculate energy flow for given thermal conductivities and temperature gradients, in an industrial application. They could involve the more practical applications of thermal conductivity in the insulation of buildings, for example heat energy lost through single and double glazed windows. The data for industrial calculations that use Stephan's law will need to be provided by the tutor.

For D3, learners must explain the heat transfer mechanisms in solids, liquids, gases and combinations of substances. In doing so, they must describe molecular motion, bulk motion and surface properties, and highlight the differences of each in solids, liquids and gases. Learners must use examples contextualised to industrial processes.

For P4, learners must describe the characteristics of primary cells and secondary cells and then highlight the differences between these two types of cells including their uses.

For M4, learners must describe the characteristics of primary and secondary cells used for industrial applications. They must also comment on the merits and limitations of the primary and secondary cells and the implications of these for their industrial applications.

For D4, learners must evaluate the use of primary and secondary cells for mobile electronic units. They could compare two portable devices which use primary and secondary cells, eg MP3 players, torches.

Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Edexcel assignments to meet local needs and resources.

Criteria covered	Assignment title	Scenario	Assessment method
P1, M1, D1	Monitoring Industrial Energy Consumption in Order to Improve Energy Efficiency	You are carrying out an energy audit on an industrial building.	Presentation to peer group on an energy audit informed by a number of suitable energy calculations.
P2, M2, D2	Report on the outcomes of an Investigation into One Gas Law, Relating outcomes to Industrial Processes	Your laboratory is commissioned to carry out a practical investigation of a gas law.	Written laboratory report on findings from a Gas Law practical investigation.
P3, M3, D3	Explain the Processes of Conduction, Convection and Radiation and Their Industrial Applications	You work for an 'energy-saving' advice service that is asked to produce scientific evidence to support recommendations made on a number of 'green' home improvements.	Illustrated article on how to make an industrial building more energy efficient.
P4, M4, D4	Explaining the Properties of Electrical Energy Sources	You work for an electrical supplier researching and producing a leaflet to inform the public on up-to-date developments in the manufacture of cells.	Leaflet on properties of electrical energy sources.

Links to National Occupational Standards, other BTEC units, other BTEC qualifications and other relevant units and qualifications

This unit forms part of the BTEC in Applied Science sector suite. This unit has particular links with the following units shown below in the BTEC Applied Science suite of qualifications:

Level 1	Level 2	Level 3
Eco-friendly Energy (FLT)	Energy and Our Universe	Fundamentals of Science
	Physical Applications of our World	Scientific Practical Techniques
	Electronics in Action	Electrical Circuits and Their Industrial Applications
		Electronics for Science Technicians

Essential resources

Learners need access to appropriate laboratory facilities and to ICT equipment. They should also have access to a range of Level 2 and Level 3 physics books.

Employer engagement and vocational contexts

Visits to relevant companies and from company employees would be valuable in delivering the unit. The use of vocational contexts is essential for delivery and assessment. Centres should aim to develop links with local businesses and factories where it is possible to measure energy losses and observe good practice in energy efficiency.

Indicative reading for learners

Textbooks

Breithaupt J – *New Understanding Physics for Advanced Level: Core Book And Course Study Guide (New Understanding Physics)* (Nelson Thornes Ltd, 2000) ISBN 9780748743162

Ellse M and Honeywill C – *Electricity and Thermal Physics (Nelson Advanced Science: Physics)* (Nelson Thornes Ltd, 2005) ISBN 9780748776634

Johnson K et al – *Advanced Physics for You* (Nelson Thornes Ltd, 2000) ISBN 9780748752966

Websites

www.ase.org.uk	The Association for Science Education
www.efunda.com/formulae/heat_transfer/home/overview.cfm	Information on heat transfer
www.fuelcells.org	The Online Fuel Cell Information Resource
www.iop.org	Institute of Physics
www.jersey.uoregon.edu/vlab/Piston/index.html	Gas law experiment instructions
www.mpoweruk.com/secondary.htm	Information on secondary batteries
physics.indiana.edu/~brabson/p310/selectivesurfaces.html	Worksheet on selective surfaces

Delivery of personal, learning and thinking skills

The table below identifies the opportunities for personal, learning and thinking skills (PLTS) that have been included within the pass assessment criteria of this unit.

Skill	When learners are …
Team workers	[TW1,5] collaborating with others to plan a visit to a business or factory and taking responsibility for their role
Self-managers	[SM3] organising time and resources and planning action to produce an energy audit at business premises or in a factory
Effective participators	[EP3,4] engaging in research and data collection of energy losses and measures taken to improve energy efficiency.

Although PLTS are identified within this unit as an inherent part of the assessment criteria, there are further opportunities to develop a range of PLTS through various approaches to teaching and learning.

Skill	When learners are …
Independent enquirers	[IE2] planning and carrying out research into locations or sites they plan to visit, plus their own research into energy transfers within industrial processes
Creative thinkers	[CT5] trying different ways to tackle a problem, working with others to find imaginative solutions and outcomes that are of value
Reflective learners	[RL2,4] setting goals and targets within the planning of their work, inviting feedback from others in the group on their 'green' proposals.

Functional Skills – Level 2

Skill	When learners are …
ICT – Find and select information	
Select and use a variety of sources of information independently for a complex task	researching exploration, extraction and processing of resources
Access, search for, select and use ICT-based information and evaluate its fitness for purpose	planning for visits or planning a presentation
ICT – Develop, present and communicate information	
Enter, develop and format information independently to suit its meaning and purpose including: • text and tables • images • numbers • records	producing tables, graphs and maps as part of the report write-up stage following visits; incorporating photographs
Bring together information to suit content and purpose	bringing together information for reports
Present information in ways that are fit for purpose and audience	producing energy reports
Mathematics	
Identify the situation or problem and the mathematical methods needed to tackle it	applying appropriate mathematical methods to solve problems
Use appropriate checking procedures and evaluate their effectiveness at each stage	carrying out calculations accurately
Draw conclusions and provide mathematical justifications	evaluating solutions to problems solved through use of mathematical methods
English	
Speaking and listening – make a range of contributions to discussions and make effective presentations in a wide range of contexts	discussing business/factory visits and laboratory work risk assessments; presenting the result of research into chosen areas
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	researching background information for business/factory visits; researching chosen industrial applications from a wide range of sources
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	writing visit reports.