

Accreditation Period

Units 1 and 2

2016–2021

Units 3 and 4

2017–2021

Victorian Certificate of Education

ENVIRONMENTAL SCIENCE

STUDY DESIGN



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Important information

Accreditation period

Units 1 and 2: 1 January 2016 – 31 December 2021

Units 3 and 4: 1 January 2017 – 31 December 2021

Implementation for Units 1 and 2 of this study commences in January 2016.

Implementation for Units 3 and 4 of this study commences in January 2017.

Sources of information

The [VCAA Bulletin](#) is the only official source of changes to regulations and accredited studies. The *VCAA Bulletin* also regularly includes advice on VCE studies. It is the responsibility of each VCE teacher to refer to each issue of the *VCAA Bulletin*. The *VCAA Bulletin* is available as an e-newsletter via free subscription on the VCAA's website at: www.vcaa.vic.edu.au.

To assist teachers in developing courses, the VCAA publishes online the *Advice for teachers*, which includes teaching and learning activities for Units 1–4, and advice on assessment tasks and performance level descriptors for School-assessed Coursework in Units 3 and 4.

The current [VCE and VCAL Administrative Handbook](#) contains essential information on assessment processes and other procedures.

VCE providers

Throughout this study design the term 'school' is intended to include both schools and other VCE providers.

Copyright

VCE schools may reproduce parts of this study design for use by teachers. The full VCAA Copyright Policy is available at: www.vcaa.vic.edu.au/Footer/Pages/Copyright.aspx.

Introduction

Scope of study

Environmental science is an interdisciplinary science that explores the interactions and interconnectedness between humans and their environments and analyses the functions of both living and non-living elements that sustain Earth systems.

In VCE Environmental Science, Earth is understood as a set of four interdependent systems: the atmosphere, biosphere, hydrosphere and lithosphere. The study explores how the relationships between these systems produce environmental change over a variety of time scales. Students investigate the extent to which humans modify their environments and the consequences of these changes in local and global contexts with a focus on pollution, biodiversity, energy use and climate change; they explore the conceptual, behavioural, ethical and technological responses to these changes. Students examine data related to environmental monitoring over various time scales, case studies, research, models, frameworks and theories to understand how knowledge in environmental science has evolved and continues to evolve in response to new evidence and discoveries. An understanding of the complexities and diversity of environmental science leads students to appreciate the interconnectedness of the content areas both within environmental science, and across environmental science and the other sciences. Students recognise that diverse practical implementation approaches can result from varied value systems and beliefs.

An important feature of undertaking a VCE science study is the opportunity for students to engage in a range of inquiry tasks that may be self-designed, develop key science skills and interrogate the links between theory, knowledge and practice. They work collaboratively as well as independently on a range of tasks. In VCE Environmental Science inquiry methodologies can include laboratory investigations, fieldwork which may also involve use of technologies and sampling techniques, examination of case studies, simulations, animations, literature reviews and the use of local and global databases. Students pose questions, formulate hypotheses and collect, analyse and critically interpret qualitative and quantitative data. They analyse the limitations of data, evaluate methodologies and results, justify conclusions, make recommendations and communicate their findings. Students investigate and evaluate issues, changes and alternative proposals by considering both shorter and longer term consequences for the individual, environment and society. Knowledge of the safety considerations and ethical standards associated with environmental science investigations is integral to the study of VCE Environmental Science.

As well as an increased understanding of scientific processes, students develop capacities that enable them to critically assess the strengths and limitations of science, respect evidence-based conclusions and gain an awareness of the ethical, social and political contexts of scientific endeavours.

Rationale

VCE Environmental Science enables students to explore the challenges that past and current human interactions with the environment presents for the future by considering how Earth's atmosphere, biosphere, hydrosphere and lithosphere function as interrelated systems. In undertaking this study, students examine how environmental actions affect, and are affected by, ethical, social and political frameworks.

In VCE Environmental Science students develop a range of inquiry skills involving practical experimentation and research, analytical skills including critical and creative thinking, and communication skills. Students use scientific and cognitive skills and understanding to analyse contemporary issues related to environmental science, and communicate their views from an informed position.

VCE Environmental Science provides for continuing study pathways within the field and leads to a range of careers. Diverse areas of employment range from design, including landscape or building architecture, engineering and urban planning, environmental consultancy and advocacy, which may involve employment in air, water and/or soil quality monitoring and control, agriculture, construction, mining and property management and water quality engineering. Environmental scientists also work in cross-disciplinary areas such as bushfire research, environmental management and conservation, geology and oceanography.

Aims

This study enables students to:

- examine Earth as a dynamic and complex set of four interacting systems (atmosphere, biosphere, hydrosphere and lithosphere) that undergo change over various time scales and that affect, and are affected by, human activities
- develop knowledge and understanding of key models, concepts and principles of environmental science that reflect the contemporary nature and diversity of the disciplines involved, and that integrate scientific, economic, sociocultural and political perspectives

and more broadly to:

- understand the cooperative, cumulative, evolutionary and interdisciplinary nature of science as a human endeavour, including its possibilities, limitations and political and sociocultural influences
- develop a range of individual and collaborative science investigation skills through experimental and inquiry tasks in the field and in the laboratory
- develop an informed perspective on contemporary science-based issues of local and global significance
- apply their scientific understanding to familiar and to unfamiliar situations, including personal, social, environmental and technological contexts
- develop attitudes that include curiosity, open-mindedness, creativity, flexibility, integrity, attention to detail and respect for evidence-based conclusions
- understand and apply the research, ethical and safety principles that govern the study and practice of the discipline in the collection, analysis, critical evaluation and reporting of data
- communicate clearly and accurately an understanding of the discipline using appropriate terminology, conventions and formats.

Structure

The study is made up of four units:

Unit 1: How are Earth's systems connected?

Unit 2: How can pollution be managed?

Unit 3: How can biodiversity and development be sustained?

Unit 4: How can the impacts of human energy use be reduced?

Each unit deals with specific content contained in areas of study and is designed to enable students to achieve a set of outcomes for that unit. Each outcome is described in terms of key knowledge and is complemented by a set of key science skills.

The study is structured under a series of curriculum framing questions that reflect the inquiry nature of the discipline.

Entry

There are no prerequisites for entry to Units 1, 2 and 3. Students must undertake Unit 3 prior to undertaking Unit 4. Units 1 to 4 are designed to a standard equivalent to the final two years of secondary education. All VCE studies are benchmarked against comparable national and international curriculum.

Duration

Each unit involves at least 50 hours of scheduled classroom instruction over the duration of a semester.

Changes to the study design

During its period of accreditation minor changes to the study will be announced in the [VCAA Bulletin](#). The *VCAA Bulletin* is the only source of changes to regulations and accredited studies. It is the responsibility of each VCE teacher to monitor changes and advice about VCE studies published in the *VCAA Bulletin*.

Monitoring for quality

As part of ongoing monitoring and quality assurance, the VCAA will periodically undertake an audit of VCE Environmental Science to ensure the study is being taught and assessed as accredited. The details of the audit procedures and requirements are published annually in the [VCE and VCAL Administrative Handbook](#). Schools will be notified if they are required to submit material to be audited.

Safety and wellbeing

This study may involve the handling of potentially hazardous substances and the use of potentially hazardous equipment. It is the responsibility of the school to ensure that duty of care is exercised in relation to the health and safety of all students undertaking the study. Teachers and students should observe appropriate safety precautions when undertaking practical work. All laboratory work should be supervised by the teacher. It is the responsibility of schools to ensure that they comply with health and safety requirements.

Relevant acts and regulations include:

- *Occupational Health and Safety Act 2004*
- *Occupational Health and Safety Regulations 2007*
- *Occupational Health and Safety Management Systems (AS/NZ 4801)*
- *Dangerous Goods (Storage and Handling) Regulations 2012*
- *Dangerous Goods Storage and Handling Code of Practice 2000*
- *Hazardous Substances Code of Practice 2000*
- *Electrical Safety Act 1998*

Ethical conduct of experimental investigations

It is not expected that animals will be used in the teaching of this study. If using animals in teaching, schools must comply with the current legislation including:

- the *Prevention of Cruelty to Animals Act 1986* and its Regulations 2008
- the *Australian Code of Practice for the Care and Use of Animals for Scientific Purposes 2014* (8th edition), www.nhmrc.gov.au/guidelines/publications/ea28

Employability skills

This study offers a number of opportunities for students to develop employability skills. The *Advice for teachers* companion document provides specific examples of how students can develop employability skills during learning activities and assessment tasks.

Legislative compliance

When collecting and using information, the provisions of privacy and copyright legislation, such as the Victorian *Privacy and Data Protection Act 2014* and *Health Records Act 2001*, and the federal *Privacy Act 1988* and *Copyright Act 1968*, must be met.

Assessment and reporting

Satisfactory completion

The award of satisfactory completion for a unit is based on the teacher's decision that the student has demonstrated achievement of the set of outcomes specified for the unit. Demonstration of achievement of outcomes and satisfactory completion of a unit are determined by evidence gained through the assessment of a range of learning activities and tasks.

Teachers must develop courses that provide appropriate opportunities for students to demonstrate satisfactory achievement of outcomes.

The decision about satisfactory completion of a unit is distinct from the assessment of levels of achievement. Schools will report a student's result for each unit to the VCAA as S (Satisfactory) or N (Not Satisfactory).

Levels of achievement

Units 1 and 2

Procedures for the assessment of levels of achievement in Units 1 and 2 are a matter for school decision. Assessment of levels of achievement for these units will not be reported to the VCAA. Schools may choose to report levels of achievement using grades, descriptive statements or other indicators.

Units 3 and 4

The VCAA specifies the assessment procedures for students undertaking scored assessment in Units 3 and 4. Designated assessment tasks are provided in the details for each unit in the VCE study designs.

The student's level of achievement in Units 3 and 4 will be determined by School-assessed Coursework (SACs) and/or School-assessed Tasks (SATs) as specified in the VCE study designs, and external assessment.

The VCAA will report the student's level of achievement on each assessment component as a grade from A+ to E or UG (ungraded). To receive a study score the student must achieve two or more graded assessments and receive S for both Units 3 and 4. The study score is reported on a scale of 0–50; it is a measure of how well the student performed in relation to all others who took the study. Teachers should refer to the current [VCE and VCAL Administrative Handbook](#) for details on graded assessment and calculation of the study score. Percentage contributions to the study score in VCE Environmental Science are as follows:

- Unit 3 School-assessed Coursework: 20 per cent
- Unit 4 School-assessed Coursework: 30 per cent
- End-of-year examination: 50 per cent.

Details of the assessment program are described in the sections on Units 3 and 4 in this study design.

Authentication

Work related to the outcomes of each unit will be accepted only if the teacher can attest that, to the best of their knowledge, all unacknowledged work is the student's own. Teachers need to refer to the current [VCE and VCAL Administrative Handbook](#) for authentication procedures.

Cross-study specifications

Units 1–4: Key science skills

The development of a set of key science skills is a core component of the study of VCE Environmental Science and applies across Units 1 to 4 in all areas of study. In designing teaching and learning programs and in assessing student learning for each unit, teachers should ensure that students are given the opportunity to develop, use and demonstrate these skills in a variety of contexts when undertaking their own investigations and when evaluating the research of others. As the complexity of key knowledge increases from Units 1 to 4 and as opportunities are provided to undertake investigations, students should aim to demonstrate the key science skills at a progressively higher level.

The key science skills are common to all VCE science studies and have been contextualised in the following table for VCE Environmental Science.

Key science skill	VCE Environmental Science Units 1–4 skills
Develop aims and questions, formulate hypotheses and make predictions	<ul style="list-style-type: none"> determine aims, hypotheses, questions and predictions that can be tested identify independent, dependent and controlled variables
Plan and undertake investigations	<ul style="list-style-type: none"> determine appropriate type of investigation: conduct experiments (including use of controls); solve a scientific or technological problem; simulations; scenario modelling; use of databases; access secondary data, including data sourced through the internet that would otherwise be difficult to source as raw or primary data through fieldwork, a laboratory or a classroom select and use equipment, materials and procedures appropriate to the investigation, taking into account potential sources of error and uncertainty select appropriate sampling procedures in fieldwork (including grids, quadrats, transects and mark-recapture) and consider sampling size for fieldwork
Comply with safety and ethical guidelines	<ul style="list-style-type: none"> apply ethical principles when undertaking and reporting investigations, including ethical use of living things and ecosystem components in research apply relevant occupational health and safety guidelines while undertaking practical investigations, including following relevant bioethical guidelines when handling live materials
Conduct investigations to collect and record data	<ul style="list-style-type: none"> work independently and collaboratively as appropriate and within identified research constraints systematically generate, collect, record and summarise both qualitative and quantitative data

Key science skill	VCE Environmental Science Units 1–4 skills
Analyse and evaluate data, methods and scientific models	<ul style="list-style-type: none"> • process quantitative data using appropriate mathematical relationships and units • organise, present and interpret using data tables, line graphs, percentages, percentage change, calculations of mean as a measure of central tendency, extrapolation and interpolation • identify contradictory or provisional data • analyse data to identify cause-and-effect relationships and linear, non-linear or cyclical patterns that may be evident • take a qualitative approach when identifying and analysing experimental data with reference to accuracy, precision, reliability, validity, errors (random and systematic) and degree of confidence and certainty in data • explain the merit of replicating procedures and the effects of sample sizes in obtaining reliable data • evaluate investigative procedures and possible sources of bias, and suggest improvements • explain how models are used to organise and understand observed phenomena and concepts related to environmental science, identifying limitations of the models • distinguish between opinion, anecdote and evidence, including weak and strong evidence, and scientific and non-scientific ideas
Draw evidence-based conclusions	<ul style="list-style-type: none"> • determine to what extent evidence from an investigation supports the purpose of the investigation, and make recommendations, as appropriate, for modifying or extending the investigation • draw conclusions consistent with evidence and relevant to the question under investigation • identify when judgments or decisions associated with socio-scientific issues related to environmental science may be based on other social, political, economic and/or ethical factors and not solely on scientific evidence • critically evaluate various types of information related to environmental science from journal articles, mass media and opinions presented in the public domain • discuss the implications of research findings and proposals
Communicate and explain scientific ideas	<ul style="list-style-type: none"> • use appropriate environmental science terminology, representations and conventions, including standard abbreviations, graphing conventions and units of measurement • discuss relevant environmental science information, ideas, concepts, theories and models and the connections between them • identify and explain formal environmental science terminology about investigations and concepts • use clear, coherent and concise expression • acknowledge sources of information and use standard scientific referencing conventions

Scientific investigation

Students undertake scientific investigations across Units 1 to 4 of this study. Scientific investigations may be undertaken in groups, but all work for assessment must be completed individually. Students maintain a logbook of practical activities in each unit of this study for recording, authentication and assessment purposes.

Students communicate findings for the investigation in Outcome 3, Unit 4 of this study in a scientific poster. The poster may be produced electronically or in hard copy format and should not exceed 1000 words. Students must select information carefully so that they meet the word limit. The production quality of the poster will not form part of the assessment.

The following template is to be used by students in the development of the scientific poster for the investigation undertaken.

Section	Content and activities
Title	Question under investigation is the title
Introduction	Explanation or reason for undertaking the investigation, including a clear aim, a hypothesis and/or prediction and relevant background environmental science concepts
Methodology	Summary that outlines the methodology used in the investigation and is authenticated by logbook entries
	Identification and management of relevant risks, including the relevant health, safety and ethical guidelines followed in the investigation
Results	Presentation of collected data/evidence in appropriate format to illustrate trends, patterns and/or relationships
Discussion	Analysis and evaluation of primary data
	Identification of outliers and their subsequent treatment
	Identification of limitations in data and methods, and suggested improvements
	Linking of results to relevant environmental science concepts
Conclusion	Conclusion that provides a response to the question
References and acknowledgments	Referencing and acknowledgment of all quotations and sourced content as they appear in the poster.

Unit 1: How are Earth's systems connected?

In this unit students examine Earth as a set of four interacting systems: the atmosphere, biosphere, hydrosphere and lithosphere. Students apply a systems perspective when exploring the physical requirements for life in terms of inputs and outputs, and consider the effects of natural and human-induced changes in ecosystems. They investigate the physical environment and its components, the function of local ecosystems and the interactions that occur in and between ecological components over different timescales. Students consider how the biotic and abiotic components of local ecosystems can be monitored and measured.

A student practical investigation related to ecosystem monitoring and/or change is undertaken in this unit. The investigation draws on content from Area of Study 1 and/or Area of Study 2.

Area of Study 1

How is life sustained on Earth?

Life on Earth is dependent on four major inputs: energy, nutrients, air and water. In this area of study students examine the processes and interactions occurring within and between Earth's four systems – the atmosphere, biosphere, hydrosphere and lithosphere – that affect the availability, accessibility and usability of these inputs for life. They examine the outputs of processes and interactions occurring within and between the four systems, and distinguish between outputs that can be reused as inputs and those that require treatment as wastes.

Outcome 1

On completion of this unit the student should be able to compare the processes and timeframes for obtaining the key inputs required for life on Earth, describe strategies for the minimisation of waste product outputs, and explain how Earth's four systems interact to sustain life.

To achieve this outcome the student will draw on key knowledge outlined in Area of Study 1 and the related key science skills on [pages 11 and 12](#) of the study design.

Key knowledge

Earth and its major systems

- evidence of the age of Earth as 4.5 billion years (from data derived from the decay of radioisotopes in rocks and minerals) and of its layered structure as a solid metallic inner core, a liquid metallic outer core and a silicate mantle and crust (based on the study of seismic waves and meteorites)
- the atmosphere, biosphere, hydrosphere and lithosphere as interrelated components of Earth's natural systems and how they are governed by physical, chemical and biological processes
- the concepts of environment and ecosystems in terms of Earth's four major systems and their uniqueness and interdependencies.

Processes for creating the essential conditions to sustain life on Earth

- the movement of energy through Earth's systems: initial input of energy from the Sun and Earth's internal systems; and relative proportion of different solar energy wavelengths that penetrate the atmosphere being absorbed, stored, or reflected, to the proportion of different electromagnetic energy wavelengths that leave Earth's atmosphere as part of the greenhouse effect

- bio-geochemical cycles (water, carbon, nitrogen and phosphorus) and processes that provide energy, minerals, soil, clean air and water (surface water and groundwater) to sustain life on Earth
- energy fluxes and cycles involving changes to the physical state of matter (gas, liquid or solid), including the transformation of energy as it flows through the system.

Inputs for life

- sources of essential inputs (energy, nutrients, air and water) required for life in terms of origin, form, supply, location, distribution and use
- photosynthesis and chemosynthesis, and aerobic and anaerobic respiration, as processes used by living organisms to obtain and utilise energy and nutrients for survival.

Outputs of life

- the distinction between reusable and waste outputs resulting from the processes for life
- the cycling of matter across systems where waste outputs from one system become inputs for another system
- the environmental consequences of different methods (natural and human) of measuring, extracting and processing water, minerals, metals or soil, including consideration of the production of reusable outputs and wastes
- the variability of timeframes required for cleaning water, purifying air, and reforming soils and minerals by Earth's systems due to latitude, environmental conditions and biota
- the social, legal, environmental and ethical factors arising from the production, storage and removal of wastes.

Area of Study 2

How is Earth a dynamic system?

In this area of study students explore changes in systems that can occur over different time scales (short, medium or long term), have cyclic or unpredictable patterns, and can be caused by natural- or human-induced factors. They examine the flow of matter and energy in selected environmental events and phenomena with reference to natural and unpredictable or abrupt environmental changes in Earth's four systems. Students learn how environmental changes may be monitored and measured. They collect and analyse primary and secondary data to determine the linear, non-linear or cyclical patterns that may be evident. Students discuss how changes over time can be explained by interactions between different environmental processes and how these changes may affect all four Earth systems.

Outcome 2

On completion of this unit the student should be able to describe the flow of matter and energy, nutrient exchange and environmental changes in ecosystems across Earth's four systems over different time scales.

To achieve this outcome the student will draw on key knowledge outlined in Area of Study 2 and the related key science skills on [pages 11 and 12](#) of the study design.

Key knowledge

Systems thinking

- systems thinking as a framework for exploring relationships in environmental systems by identifying inputs, outputs, components and structures that may be visible or invisible to the human eye
- open, semi-permeable or closed systems in terms of energy and matter
- the interrelatedness of systems: hierarchical interactions (sub-systems, system in focus, and supra-system) including changes in one system that affect others in the hierarchy.

Environmental factors that affect Earth over time

- techniques for measuring and monitoring changes in the environment
- the effects of environmental changes on Earth's systems that relate to the survival of living things, including a focus on at least one example from each of the following time scales:
 - short term (seconds to years): daily, diurnal, nocturnal, circadian, seasonal, tidal, and El Niño-Southern Oscillation events
 - medium term (multiple years to hundreds of years): solar output cycles, glacial melting, vegetation succession, land cover changes, and desertification
 - long term (thousands to millions of years): plate tectonics, evolutionary mechanisms, Milankovitch cycles, thermohaline circulation, mass extinction of species, and geomagnetic reversals
- the effects of unpredictable and/or abrupt environmental changes resulting in localised extinction and speciation, or ecosystem shock, with reference to at least one example from the following events: floods, droughts, fire, earthquake, volcanic activity, the emergence of new diseases and/or rapid erosion events.

Area of Study 3

Practical investigation

Ecosystems are subject to change in response to biotic or abiotic disturbances, or changes in the frequency at which they are disturbed, affecting the atmosphere, biosphere, hydrosphere and lithosphere. In this area of study students design and conduct a practical investigation into the monitoring of ecosystems or their components and/or change in ecosystems.

The investigation requires the student to develop a question, plan a course of action that attempts to answer the question, undertake an investigation to collect the appropriate primary qualitative and/or quantitative data, organise and interpret the data and reach a conclusion in response to the question. The investigation should take a systems thinking approach and relates to knowledge and skills developed in Areas of Study 1 and/or 2. It may be conducted by the student through laboratory work and/or fieldwork.

Outcome 3

On completion of this unit the student should be able to design and undertake an investigation related to ecosystem monitoring and/or change, and draw a conclusion based on evidence from collected data.

To achieve this outcome the student will draw on key knowledge outlined in Area of Study 3 and the related key science skills on [pages 11 and 12](#) of the study design.

Key knowledge

- the environmental science concepts specific to the investigation and their significance, including definitions of key terms, and environmental science representations
- the characteristics of scientific research methodologies and techniques of primary qualitative and quantitative data collection relevant to the investigation including experiments and/or fieldwork (air, water and/or soil sampling and testing environmental indicators, thermodynamics, photosynthesis, chemosynthesis, respiration and/or quadrat and transect sampling); precision, accuracy, reliability and validity of data; and minimisation of experimental bias
- ethics and issues of research including identification and application of relevant health, safety and bioethical guidelines, and use of animals
- methods of organising, analysing and evaluating primary data to identify patterns and relationships including sources of error and limitations of data and methodologies
- observations and experiments that are consistent with, or challenge, current scientific models, theories or frameworks

- the nature of evidence that supports or refutes a hypothesis, model or theory
- options, strategies or solutions to issues related to ecosystem monitoring and/or change
- the key findings of the selected investigation and their relationship to bio-geochemical, ecosystem and/or environmental concepts
- the conventions of scientific report writing including scientific terminology and representations, standard abbreviations and units of measurement.

Assessment

The award of satisfactory completion for a unit is based on a decision that the student has demonstrated the set of outcomes specified for the unit. Teachers should use a variety of learning activities and assessment tasks that provide a range of opportunities for students to demonstrate key knowledge and key skills in the outcomes.

The areas of study, including the key knowledge and key skills listed for the outcomes should be used for course design and the development of learning activities and assessment tasks. Assessment must be a part of the regular teaching and learning program and should be completed mainly in class and within a limited timeframe.

All assessment at Units 1 and 2 are school-based. Procedures for assessment of levels of achievement in Units 1 and 2 are a matter for school decision.

For this unit students are required to demonstrate achievement of three outcomes. As a set these outcomes encompass all areas of study in the unit.

Suitable tasks for assessment may be selected from the following:

For Outcomes 1 and 2

- a fieldwork report
- a case study
- a report of a practical activity involving the collection of primary data
- annotations of a practical work folio of activities or investigations
- a research investigation involving the collection of secondary data
- a model of an aspect of Earth systems
- a logbook of practical activities
- analysis of data/results including generalisations/conclusions
- media analysis/response
- problem solving involving environmental science concepts, skills and/or issues
- a test comprising multiple choice and/or short answer and/or extended response
- a reflective learning journal/blog related to selected activities or in response to an issue

For Outcome 3

- a report of a student-designed and/or adapted and/or extended investigation related to ecosystem monitoring and/or change that can be presented in various formats, for example digital presentation, oral presentation, written report or graphic organiser.

Where teachers allow students to choose between tasks they must ensure that the tasks they set are of comparable scope and demand.

Practical work is a central component of learning and assessment. As a guide, between 3½ and 5 hours of class time should be devoted to student practical work and investigations for each of Areas of Study 1 and 2. For Area of Study 3, between 6 and 8 hours of class time should be devoted to undertaking the investigation and communicating findings.

Unit 2: How can pollution be managed?

In this unit students explore the concept of pollution and associated impacts on Earth's four systems through global, national and local perspectives. They distinguish between wastes, contaminants and pollutants and examine the characteristics, measurement and management of pollution. They analyse the effects of pollutants on the health of humans and the environment over time. Students consider the rules for use, treatment and disposal of pollutants and evaluate the different perspectives of those who are affected by pollutants. They explore the significance of technology, government initiatives, communities and individuals in redressing the effects of pollutants, and consider how values, beliefs and evidence affect environmental decision making.

Pollutants can be produced through natural and human activities and can generate adverse effects for living and non-living things when released into ecosystems. Students examine how pollutant effects produced in one of Earth's four systems may have an impact on the other systems. They explore the factors that affect the nature and impact of pollution including pollutant sources, transport mechanisms and potential build-up due to long-term or repeated exposure. Students compare three pollutants of national and/or global significance with reference to their effects in the atmosphere, biosphere, hydrosphere and lithosphere, and discuss management options.

Students undertake an in-depth case study of the management strategies that apply to a pollutant of local concern related to ecosystem monitoring and/or change. The investigation draws on content from Area of Study 1 and/or Area of Study 2.

Area of Study 1

When does pollution become a hazard?

In this area of study students examine biotic and abiotic indicators of pollution in various environments. Using selected examples, they distinguish between pollutants that result in bioaccumulation, and air- or water-borne pollutants. Students explore the chemical and physical characteristics, sources and transport mechanisms of pollutants and consider how levels of safety standards are set. They analyse the effects of pollutants on environmental and living systems and consider approaches to monitor and manage pollutants.

Outcome 1

On completion of this unit the student should be able to compare a selected pollutant that results in bioaccumulation with an air- or water-borne pollutant, with reference to their sources, characteristics and dispersal, explain how they can be measured and monitored, and describe treatment options.

To achieve this outcome the student will draw on key knowledge outlined in Area of Study 1 and the related key science skills on [pages 11 and 12](#) of the study design.

Key knowledge

Characteristics, sources and transport mechanisms of pollutants

- the distinction between wastes, contaminants and pollution, including natural and manufactured sources
- the physical and chemical characteristics of common pollutants that have a negative effect on terrestrial, aquatic, atmospheric and living systems with reference to their persistence, mobility, toxicity and likelihood of bioaccumulation, including one pollutant that results in bioaccumulation and one air- or water-borne pollutant
- the distinction between various sources of pollutants including point or diffuse (fugitive or mobile), direct or indirect, intentional or neglectful, and pollution sinks, and implications for management strategies
- direction, distance and rate of dispersal of pollutants through different processes that transport pollutants, including air circulation, the water cycle and bioaccumulation.

Measurement and monitoring of pollutants

- the physical, chemical and biological indicators for monitoring the state of a local ecosystem or environmental issue including turbidity, pH, light intensity, biological oxygen demand in streams; salinity level in soils or water; presence/absence of pollution intolerant species in streams; and presence/absence of introduced species
- the setting of safety standards based on concentrations that are hazardous for living organisms
- risk assessment tools, monitoring technologies and remediation techniques
- evaluation strategies measuring direct and indirect impacts of pollutants for human and environmental health with reference to risk, exposure, dosage, tolerance limits, LD50, chronic and acute toxicity, allergies, specificity, disruption of system regulation, and synergistic action.

Treatment and management of pollutants

- bio-physical and/or chemical inactivation, substitution or elimination of pollutants
- the natural processes and the human engineered machines that mimic the natural processes that act as pollution sinks
- the factors that can change the rate of removal of active pollutants or the rate of decay, including the presence of aerobic or anaerobic conditions, and the length of time
- new technologies that reduce pollution.

Area of Study 2

What makes pollution management so complex?

Pollutants may be categorised by the Earth systems they affect, the chemical form that poses greatest threat to life, or the method used to make the pollutant inactive. Any particular pollutant may fall into multiple categories. By examining a pollutant using different methods of categorising, a more complete exploration of a pollutant is achieved.

In this area of study, students investigate three pollutants of national or global concern. They explain how pollutants move through, and affect, the atmosphere, biosphere, hydrosphere and lithosphere, and compare treatment and management options for each pollutant. Students also explore the limitations of the categorisation of pollution as air, water and soil pollution.

Students investigate a question for each of the three categories of pollution: air, water and soil.

Category 1: Air pollution

Contamination of the atmosphere that disturbs the natural composition and chemistry of the air may be caused by particulate matter such as dust or excessive gases such as carbon dioxide that cannot be effectively removed through natural cycles, including the carbon and nitrogen cycles. Undesirable levels of noise may have negative consequences for the survival of animal species that are reliant on sound for locating social groups and mating purposes. Strict government regulations are put in place to control radioactive pollution since it is difficult to reverse the damage caused by exposure.

Questions that may be explored in this investigation include:

- Can cities be smog free?
- What health hazards are associated with living indoors?
- Should technologies that produce carbon dioxide be banned?
- Can demolition and construction sites be managed sufficiently to control the effects of particulates?
- How can cities be designed to avoid the urban heat island effect?
- Should car-free days become compulsory?
- Are nanochemicals safe?
- How do endocrine disruptors work in the body, and how can they be avoided?

- What effect would elevated noise levels have on reproductive patterns of birds reliant on mating calls to find a mate?
- Is infrasound pollution?
- Should housing be built directly under aeroplane flight paths?
- Are some radioactive materials more dangerous than others?
- Is it only living things that are affected by radioactive pollution?
- Has the global response to the hole in the ozone layer made a difference over time?
- Why do chlorofluorocarbons present an environmental risk, and how were alternatives developed?

Category 2: Water pollution

Chemical, particulate, or bacterial matter can degrade the quality and purity of water in oceans, rivers, lakes, and underground reservoirs. Water pollution may be caused by factors such as increased sediment from soil erosion, mining activities, indiscriminate waste disposal and littering, leaching of soil chemicals into water supplies, and organic material decay in water supplies.

Questions that may be explored in this investigation include:

- Should ocean oil spills be cleaned up or should reliance on natural processes for their dispersal and chemical degradation be the preferred course of action?
- How can acid mine drainage from waste rock storage at mine sites and the resultant surface and groundwater pollution be managed?
- What are the downstream consequences of disposal of medication into water systems?
- Should fish that bioaccumulate heavy metals be culled?
- Can the Great Barrier Reef be quarantined to alleviate coral bleaching?
- What issues are associated with storm water runoff?
- Should dioxins and other persistent organic pollutants be banned?
- What is the evidence for and against the impact of fracking on groundwater security?
- How are fish and wildlife populations that require water of a certain degree of purity, and within a narrow temperature range for survival, affected by agricultural run-off, the dumping of human and animal wastes into water supplies, or thermal pollution resulting from processes that change ambient water temperature?
- What dangers do underground oil tank leakages pose?
- Should all roads be paved to minimise erosion impacts on waterways?
- Can all contaminants be removed by reverse osmosis filters?
- Does it matter which detergents people use?

Category 3: Soil pollution

Contamination of soils can prevent natural growth and balance in both natural and managed ecosystems. Soil contamination can lead to poor growth and reduced crop yields, loss of wildlife habitat, water and visual pollution, soil erosion, and desertification. Sources of soil pollution include hazardous waste spills, unsustainable farming practices, strip mining, deforestation, and littering.

Questions that may be explored in this investigation include:

- Do pesticides kill more than pests?
- Is salination linked to desertification?
- Why does lead-acid battery recycling pose an environmental threat?
- What is the extent of pollution associated with large-scale farming?
- What are the salination risks associated with different types of crop irrigation methods?
- How are mining practices regulated to minimise environmental impacts?

- How do the chemical properties of biodegradable plastics differ from those of non-biodegradable plastics to enable more rapid environmental degradation?
- Do the heavy metal deposits in surface water systems left over from historic gold mining sites present a hazard?
- Should food ‘take-away’ containers be banned?
- What happens to rubbish buried in landfills?
- What makes materials biodegradable?
- How do the toxicities of different forms of mercury (elemental, organic and inorganic) compare?

Outcome 2

On completion of this unit the student should be able to compare the sources, nature, transport mechanism, effects and treatment of three selected pollutants, with reference to their actions in the atmosphere, biosphere, hydrosphere and lithosphere.

To achieve this outcome the student will draw on key knowledge outlined in Area of Study 2 and the related key science skills on [pages 11 and 12](#) of the study design.

Key knowledge

- the sources of the three selected pollutants
- the chemical and physical properties of the three selected pollutants
- the movement through the atmosphere, biosphere, hydrosphere and lithosphere of the three selected pollutants
- the measurement and monitoring of the three selected pollutants
- the effects on living things and the environment of the three selected pollutants including toxicity
- the treatment and management options related to effects of the three selected pollutants including new technologies
- the social, economic, legal and ethical implications relevant to pollution management options of the three selected pollutants.

Area of Study 3

Case study

Recognition of the impacts on public health and on the environment due to the pollution generated by human activities has grown. Pollution management technologies and legislation to improve the quality of water, air and land have been developed in response. A shifting emphasis from pollution management towards pollution prevention also reflects social and behavioural change in responding to pollution as an issue.

In this area of study students apply and extend their knowledge and skills developed in Areas of Study 1 and 2 to investigate a case study involving the management of a selected pollutant of local interest. Students prepare a communication that explains the relevant scientific concepts, identifies different management options including social, economic, legal and ethical implications, and presents a justified position on a preferred solution. Material for the investigation may be gathered from laboratory work, fieldwork, computer simulations and modelling, literature searches, environmental databases and interviews with experts.

Outcome 3

On completion of this unit the student should be able to investigate and communicate a substantiated response to an issue involving the management of a selected pollutant of local interest.

To achieve this outcome the student will draw on key knowledge outlined in Area of Study 3 and the related key science skills on [pages 11 and 12](#) of the study design.

Key knowledge

- the characteristics of effective science communication: accuracy of scientific information; clarity of explanation of scientific concepts, ideas and models; contextual clarity with reference to importance and implications of findings; conciseness and coherence; and appropriateness for purpose and audience
- the scientific concepts specific to the investigation: nature of the pollutant; impact of pollutant on the atmosphere, biosphere, hydrosphere and lithosphere; direct effects of the pollutant on living things and the environment; definitions of key terms; and use of appropriate scientific terminology, conventions and representations
- the use of data representations and models in organising and explaining observed phenomena and environmental science concepts, and their limitations
- the nature of evidence and information: distinction between opinion, anecdote and evidence, weak and strong evidence, and scientific and non-scientific ideas; validity, reliability and authority of data including sources of possible errors or bias relating to those who benefit and those whose health is impacted
- the influence of social, economic, legal and ethical factors relevant to pollution management options.

Assessment

The award of satisfactory completion for a unit is based on a decision that the student has demonstrated the set of outcomes specified for the unit. Teachers should use a variety of learning activities and assessment tasks that provide a range of opportunities for students to demonstrate key knowledge and key skills in the outcomes.

The areas of study and key knowledge and key skills listed for the outcomes should be used for course design and the development of learning activities and assessment tasks. Assessment must be a part of the regular teaching and learning program and should be completed mainly in class and within a limited timeframe.

All assessment at Units 1 and 2 are school-based. Procedures for assessment of levels of achievement in Units 1 and 2 are a matter for school decision.

For this unit students are required to demonstrate achievement of three outcomes. As a set these outcomes encompass all areas of study in the unit.

Suitable tasks for assessment may be selected from the following:

For Outcome 1

- a report of a fieldwork exercise
- a report of a practical activity involving the collection of primary data
- a research investigation involving the collection of secondary data
- annotations of a practical logbook of activities or investigations
- analysis of data/results including generalisations/conclusions
- a model of an aspect of Earth systems
- media analysis/response
- problem solving involving environmental concepts, skills and/or issues
- a test comprising multiple choice and/or short answer and/or extended response
- a reflective learning journal/blog related to selected activities or in response to an issue.

For Outcome 2

- a comparison of the sources, nature, transport mechanism, effects and treatment of three selected pollutants, with reference to their actions in the atmosphere, biosphere, hydrosphere and lithosphere.

For Outcome 3

- a report of a case study involving the management of a selected pollutant of local interest.

Where teachers allow students to choose between tasks they must ensure that the tasks they set are of comparable scope and demand.

Practical work is a central component of learning and assessment. As a guide, between 3½ and 5 hours of class time should be devoted to student practical work and investigations for each of Areas of Study 1 and 2. For Area of Study 3, between 6 and 8 hours of class time should be devoted to undertaking the investigation and communicating findings.

Unit 3: How can biodiversity and development be sustained?

In this unit students focus on environmental management through the examination and application of sustainability principles. They explore the value and management of the biosphere by examining the concept of biodiversity and the services provided to all living things. They analyse the processes that threaten biodiversity and apply scientific principles in evaluating biodiversity management strategies for a selected threatened endemic species. Students use a selected environmental science case study with reference to the principles of sustainability and environmental management to explore management at an Earth systems scale, including impact on the atmosphere, biosphere, hydrosphere and lithosphere.

A student practical investigation related to biodiversity or energy use from an environmental management perspective is undertaken in either Unit 3 or Unit 4, or across both Units 3 and 4, and is assessed in Unit 4, Outcome 3. The findings of the investigation are presented in a scientific poster format as outlined in the template on [page 13](#).

Area of Study 1

Is maintaining biodiversity worth a sustained effort?

Australia is one of seventeen countries described as being ‘mega diverse’ in terms of its terrestrial and marine life. Although this group of countries accounts for 10 per cent of the global surface, they contain more than 70 per cent of the biodiversity on the planet.

In this area of study students examine biodiversity as a means of investigating the management of a single Earth system – the biosphere. They examine the categories of biodiversity, the role of biodiversity in sustaining ecosystems, the provision of ecosystem services for human well-being and the strategies employed to counteract threats, both natural and human induced, so as to maintain biodiversity in the short, medium and long term. Students investigate through field and practical activities how biodiversity is measured. They examine the effectiveness of management strategies in the context of a selected threatened endemic species, based on scientific evidence, to ensure sustainability of biodiversity.

Outcome 1

On completion of this unit the student should be able to explain the importance of Earth’s biodiversity, analyse the threats to biodiversity, and evaluate management strategies to maintain biodiversity in the context of one selected threatened endemic species.

To achieve this outcome the student will draw on key knowledge outlined in Area of Study 1 and the related key science skills on [pages 11 and 12](#) of the study design.

Key knowledge

Importance of biodiversity

- the definition and categories of biodiversity (genetic, species and ecosystem)
- the importance of genetic diversity within a species or population in withstanding changes in environmental selection pressures that will either confer an advantage (adaptation) or disadvantage for a particular genetic trait (excluding mechanisms of gene function)
- ecosystems as a source of renewable services that impact on human well-being including provisioning services (food, water, pharmaceuticals), regulating services (carbon sequestration, climate control), and supporting services (soil formation, nutrient and water recycling, air and water purification).

Biodiversity change over time

- evidence of variation in rate and extent of change in biodiversity over time including significant mass extinctions and periods of rapid species diversification that can be inferred from the fossil record
- the impact of humans on the present rate of species extinction
- the isolation of populations over short (volcanic eruptions or fire), medium (El Niño) and long (tectonic plate movement and evolution) time scales that can produce different species that are unable to interbreed, are endemic to a location, form a diversity hotspot, or become extinct, including explanation of why some ecosystems are more diverse than others.

Measuring changes in biodiversity

- sampling methods used for assessing species diversity including grids, transects, different shaped quadrats (including consideration of edge effects), and mark-recapture
- assessment of genetic diversity through variations in morphology as an indicator of genetic make-up of individuals within a species
- measurement of species diversity, including species richness, endemism and species diversity, and the application of simple indices, including Simpson's Index
- the measures of ecosystem diversity including the number of different ecosystems in a biosphere and the variety of ecological processes that occur in different physical settings
- conservation classification of species and how this depends on measures including changes in the geographic range and number of individuals within that range, the date the species was last recorded, and the extent of habitat.

Threats to biodiversity

- predictions of species population survival using probabilities including likelihood of extinction
- human and non-human threats to biodiversity including: creation and isolation of small populations through habitat modification and over-exploitation; genetic swamping, inbreeding, and demographic variation due to small population size; loss of pollinators, dispersal agents, host species or symbionts that affect reproduction and persistence of species; bioaccumulation that concentrates environmental poisons in food chains; and exotic species that compete for habitat, shelter and food
- assessment of threat in defining conservation categories for a species and/or ecosystem, including extinct in the wild, conservation dependent, critically endangered, endangered, and vulnerable.

Protection and restoration of biodiversity

- strategies for maintaining and growing populations that also build species resilience to changes in the environment, including: protected areas; retaining remnant vegetation; wildlife corridors or zones; translocation of animals; habitat regeneration, restoration or replacement; captive breeding and reintroduction programs; gene banks for the collection of specimens and genetic material; and reduction and improved targeting of pesticides in agricultural and urbanised areas
- the application of relevant international, national, state and local legal treaties, agreements and regulatory frameworks that apply to the protection of threatened species including the Convention on International Trade in Endangered Species (CITES), IUCN Red List of Threatened Species, World Heritage areas, *Environment Protection and Biodiversity Conservation Act 1999* (Australia), *Victorian Flora and Fauna Guarantee Act*, and local government conservation covenants
- sustainability principles relevant to biodiversity conservation including: inter- and intra-generational equity including funding of selected species; the precautionary principle in relation to habitat change or introduction of species; ethical principles for managing biodiversity including justice and beneficence; and value systems including anthropocentrism, biocentrism and ecocentrism.

Area of Study 2

Is development sustainable?

In this area of study students examine the application of environmental science to sustainability and environmental management. They explore definitions of sustainability and consider how these may be interpreted and applied in addressing environmental issues. Students select one environmental science case study to be studied in depth. The selected case study should have a completed management strategy, including risk assessment. Students assess the environmental impacts and risks associated with the environmental science case study, examine the elements of environmental management and its relationship to sustainability principles, and evaluate the effectiveness of the environmental management plan implemented by the organisation. They determine the stakeholders involved, including community, business, industry and government agency where relevant, and evaluate scientific data related to the monitoring of the case study.

Suitable environmental science case studies include:

- *geotechnical and transport engineering* that may include construction of roads, freeways, railways, airports, mines, shopping centres, and housing developments
- *environmental engineering* that may include coastal erosion protection, mine revegetation, municipal recycling system, and freeway revegetation
- *water conservation and water engineering* that may include studies of pollution in bays and oceans, sewage treatment plants, desalination plants, river diversion tunnels, and stormwater drainage systems
- *energy and pollution minimisation strategies* that may include air quality monitoring, electrostatic precipitation in smoke stacks, waste minimisation plan, cleaner production plan, waste heat re-use in industry, and energy efficient housing and commercial buildings
- *soil remediation and soil erosion* that may include bioremediation of soils, studies of dryland salinity, and total catchment management to reduce soil erosion
- *broadacre, intensive or alternative agricultural practices* that may include feedlots, irrigation, organic farming, and biological controls in farming
- *land management and development* that may include ecotourism, green roofs and infrastructure, and urban housing projects.

Outcome 2

On completion of this unit the student should be able to explain the principles of sustainability and environmental management and analyse and evaluate a selected environmental science case study.

To achieve this outcome the student will draw on key knowledge outlined in Area of Study 2 and the related key science skills on [pages 11 and 12](#) of the study design.

Key knowledge

- assessment of beneficial and harmful impacts on the four Earth systems (atmosphere, biosphere, hydrosphere, lithosphere) of one selected environmental science project
- comparison of definitions of sustainability including distinction between sustainability and ecologically sustainable development
- sustainability principles: intergenerational equity, intragenerational equity; conservation of biodiversity and ecological integrity; user pays principle; efficiency of resource use; precautionary principle
- challenges to sustainability: population, food, water, energy
- management of the project: length of time for project, planned targets, regulatory frameworks that limit management plans

- stakeholder involvement: role of the community, media, environmental interest groups, non-government and government agencies in encouraging responsible environmental practices and identification of values systems that affect decision-making
- techniques for monitoring the project: historical and current data comparisons as measures of effectiveness of management strategies
- response to change: impact minimisation, risk management, and application of new technologies.

School-based assessment

Satisfactory completion

The award of satisfactory completion for a unit is based on whether the student has demonstrated the set of outcomes specified for the unit. Teachers should use a variety of assessment tasks to provide a range of opportunities for students to demonstrate the key knowledge and key skills in the outcomes.

The areas of study and key knowledge and key skills listed for the outcomes should be used for course design and the development of learning activities and assessment tasks.

Assessment of levels of achievement

The student's level of achievement in Unit 3 will be determined by School-assessed Coursework. School-assessed Coursework tasks must be a part of the regular teaching and learning program and must not unduly add to the workload associated with that program. They must be completed mainly in class and within a limited timeframe.

Where teachers provide a range of options for the same School-assessed Coursework task, they should ensure that the options are of comparable scope and demand.

The types and range of forms of School-assessed Coursework for the outcomes are prescribed within the study design. The VCAA publishes *Advice for teachers* for this study, which includes advice on the design of assessment tasks and the assessment of student work for a level of achievement

Teachers will provide to the VCAA a numerical score representing an assessment of the student's level of achievement. The score must be based on the teacher's assessment of the performance of each student on the tasks set out in the following table.

Contribution to final assessment

School-assessed Coursework for Unit 3 will contribute 20 per cent to the study score.

Outcomes	Marks allocated*	Assessment tasks
<p>Outcome 1</p> <p>Explain the importance of Earth's biodiversity, analyse the threats to biodiversity, and evaluate management strategies to maintain biodiversity in the context of one selected threatened endemic species.</p>	50	<p>An account presented in one of the following formats:</p> <ul style="list-style-type: none"> • a written report drawing on data collected from fieldwork or other sources (approximately 50 minutes and/or up to 1000 words) • a multimodal presentation (approximately 10 minutes) • a written response to a set of questions (approximately 50 minutes) • an oral presentation drawing on data collected from fieldwork or other sources (approximately 10 minutes).
<p>Outcome 2</p> <p>Explain the principles of sustainability and environmental management and analyse and evaluate a selected environmental science case study.</p>	50	<p>An evaluation presented in one of the following formats:</p> <ul style="list-style-type: none"> • a multimodal presentation (approximately 10 minutes) • a written response to a set of questions (approximately 50 minutes) • a written report (up to 1000 words) • an oral presentation (approximately 10 minutes).
Total marks	100	

*School-assessed Coursework for Unit 3 contributes 20 per cent.

Practical work and assessment

Practical work is a central component of learning and assessment. As a guide, between 3½ and 5 hours of class time should be devoted to student practical work and investigations for each of Areas of Study 1 and 2.

External assessment

The level of achievement for Units 3 and 4 is also assessed by an end-of-year examination, which will contribute 50 per cent to the study score.

Unit 4: How can the impacts of human energy use be reduced?

In this unit students analyse the social and environmental impacts of energy production and use on society and the environment. They explore the complexities of interacting systems of water, air, land and living organisms that influence climate, focusing on both local and global scales, and consider long-term consequences of energy production and use. Students examine scientific concepts and principles associated with energy, compare efficiencies of the use of renewable and non-renewable energy resources, and consider how science can be used to reduce the impacts of energy production and use. They distinguish between natural and enhanced greenhouse effects and discuss their impacts on living things and the environment, including climate change.

Measurement of environmental indicators often involves uncertainty. Students develop skills in data interpretation, extrapolation and interpolation, test predictions, and recognise the limitations of provisional and incomplete data. They learn to differentiate between relationships that are correlative and those that are cause-and-effect, and make judgments about accuracy, validity and reliability of evidence.

A student practical investigation related to biodiversity or energy use from an environmental management perspective is undertaken either in Unit 3 or Unit 4, or across both Units 3 and 4, and is assessed in Unit 4, Outcome 3. The findings of the investigation are presented in a scientific poster format as outlined in the template on [page 13](#).

Area of Study 1

What is a sustainable mix of energy sources?

In this area of study students examine the concepts associated with the use of different forms of energy by human societies. Focus moves from understanding the relationship between the uses of local sources of energy to examining the global impacts of these uses, including consideration of the consequences over short (seconds to years), medium (multiple years to hundreds of years) and long (thousands to millions of years) time scales. Students investigate through field and practical activities the extent, availability, consequences, and alternative forms of energy available while considering the environmental, social and ethical challenges involved.

Outcome 1

On completion of this unit the student should be able to compare the advantages and disadvantages of a range of energy sources, evaluate the sustainability of their use, and explain the impacts of their use on society and the environment.

To achieve this outcome the student will draw on key knowledge outlined in Area of Study 1 and the related key science skills on [pages 11 and 12](#) of the study design.

Key knowledge

Fossil fuels

- timeframes and processes required for the formation of fossil fuels
- uncertainty in calculating remaining fossil fuel deposits
- the process of fossil fuel combustion (exothermic and endothermic reactions not required), and consequences for the carbon cycle
- changes in the rate of the use of fossil fuels over time, including the concept of peak oil.

Comparison of different energy sources

- the characteristics of renewable and non-renewable energy sources, including biomass, solar, hydro-electric, wind, tidal, oil, coal, natural and coal seam gas, nuclear, geothermal
- the conservation of energy (First Law of Thermodynamics) in energy conversions
- efficiency of energy conversions between different forms of energy including mechanical, kinetic, heat, and potential
- the impact on the environment and society of accessibility, extraction, conversion, transport, processing and use of energy resources
- the extent to which different energy sources can supply current energy needs and projections of future energy needs.

Use of science to reduce the impacts of energy use

- strategies for increasing the efficiency of energy conversions, and for the management of waste products in fuel combustion
- mechanical, chemical and biological processes involved in rehabilitating sites where energy sources have been extracted
- sustainability principles relevant to energy consumption and extraction including conservation of ecosystems and species that are displaced or impacted by human efforts to acquire energy, and intra- and inter-generational equity including accessibility to energy.

Area of Study 2

Is climate predictable?

In this area of study students investigate the astronomical, solar, and Earth systems and human-based factors that have altered important relationships between the energy, water and nutrient cycles, resulting in the enhanced greenhouse effect and climate change. They compare natural and enhanced greenhouse effects and their significance for sustaining ecological integrity.

Outcome 2

On completion of this unit the student should be able to explain the causes and effects of changes to Earth's climate, compare methods of measuring and monitoring atmospheric changes, and explain the impacts of atmospheric changes on living things and the environment.

To achieve this outcome the student will draw on key knowledge outlined in Area of Study 2 and the related key science skills on [pages 11 and 12](#) of the study design.

Key knowledge**Major factors that alter Earth's atmosphere**

- the structure of the atmosphere and the relative proportions of different gases, including greenhouse gases, that regulate the natural and enhanced greenhouse effects
- the astronomical cycles that affect natural variability in climate, including Milankovitch cycles (variations in Earth's eccentricity, axial tilt and precession) and solar cycles
- the solar energy that is absorbed, re-emitted and reflected by atmospheric gases and Earth's surface, including the albedo effect, the interaction of energy with greenhouse gases, and the First Law of Thermodynamics
- carbon sequestration in land, water and air that results in short-term (<100 years) and long-term (>1000 years) carbon storage
- the lifespans of greenhouse gases and their ability to absorb infra-red radiation and hence their warming potentials
- the altered proportions of different gases in the atmosphere over time resulting from human activities including use of fossil fuels.

Measurements that give useful information about changes in the climate

- methods used for measuring and understanding past and present changes in the atmosphere: ice core samples, paleo-botany, atmospheric and ocean temperature monitoring, climate models
- magnitude and rate of change in individual atmospheric gas concentrations over different time periods (seasonally, annually and over millenia) due to natural events and human actions, including exponential increase in CO₂ post-industrial revolution
- measures used to assess the rate of climate change: global average annual temperatures, regional and global sea level rise, and global snow and ice coverage.

Consequences of changing the composition of gases in the atmosphere

- the impacts for organisms, including humans, and ecosystems of the natural greenhouse effect and the enhanced greenhouse effect
- analysis and reporting of climate data including the interpretation of confidence measures of climate projections (calculation of standard deviation and probabilities are not required)
- projected consequences and uncertainties of the enhanced greenhouse effect on the four major Earth systems (atmosphere, biosphere, hydrosphere, lithosphere), and on the health of living things and on the environment, at a selected location.

Area of Study 3

Practical investigation

A student-designed or adapted practical investigation related to biodiversity or energy use from an environmental management perspective is undertaken in either Unit 3 or Unit 4, or across both Units 3 and 4. The investigation relates to knowledge and skills developed across Units 3 and 4 and is undertaken by the student through laboratory work and/or fieldwork.

The investigation requires the student to identify an aim, develop a question, formulate a hypothesis and plan a course of action to answer the question and that complies with safety and ethical guidelines. The student then undertakes an experiment or sampling exercise that involves the collection of primary qualitative and/or quantitative data, analyses and evaluates the data, identifies limitations of data and methods, links experimental results to science ideas, reaches a conclusion in response to the question and suggests further investigations which may be undertaken. Results are communicated in a scientific poster format according to the template provided on [page 13](#). A practical logbook must be maintained by the student for record, authentication and assessment purposes.

Outcome 3

On completion of this unit the student should be able to design and undertake a practical investigation related to biodiversity or energy use from an environmental management perspective, and present methodologies, findings and conclusions in a scientific poster.

To achieve this outcome the student will draw on key knowledge outlined in Area of Study 3 and the related key science skills on [pages 11 and 12](#) of the study design.

Key knowledge

- independent, dependent and controlled variables
- the environmental science concepts specific to the investigation and their significance, including definitions of key terms, and environmental science representations
- the characteristics of scientific research methodologies and techniques of primary qualitative and quantitative data collection relevant to the selected investigation, including experiments and/or fieldwork (environmental monitoring, thermodynamics and/or use of ecological mapping techniques such as grids, transects, quadrats, mark-recapture); precision, accuracy, reliability and validity of data; and minimisation of experimental bias

- ethics and issues of research including identification and application of relevant health, safety and bioethical guidelines
- methods of organising, analysing and evaluating primary data to identify patterns and relationships including sources of error and uncertainty, and limitations of data and methodologies
- models and theories, and their use in organising and understanding observed phenomena and environmental science concepts including their limitations
- the nature of evidence that supports or refutes a hypothesis, model or theory
- the key findings of the selected investigation and their relationship to biodiversity, sustainability, thermodynamic and/or climate science concepts
- the conventions of scientific report writing and scientific poster presentation including scientific terminology and representations, symbols, formulas, units of measurement, standard abbreviations and acknowledgment of references.

School-based assessment

Satisfactory completion

The award of satisfactory completion for a unit is based on whether the student has demonstrated the set of outcomes specified for the unit. Teachers should use a variety of assessment tasks to provide a range of opportunities for students to demonstrate the key knowledge and key skills in the outcomes.

The areas of study and key knowledge and key skills listed for the outcomes should be used for course design and the development of learning activities and assessment tasks.

Assessment of levels of achievement

The student's level of achievement in Unit 4 will be determined by School-assessed Coursework. School-assessed Coursework tasks must be a part of the regular teaching and learning program and must not unduly add to the workload associated with that program. They must be completed mainly in class and within a limited timeframe.

Where teachers provide a range of options for the same School-assessed Coursework task, they should ensure that the options are of comparable scope and demand.

The types and range of forms of School-assessed Coursework for the outcomes are prescribed within the study design. VCAA publishes *Advice for teachers* for this study, which includes advice on the design of assessment tasks and the assessment of student work for a level of achievement

Teachers will provide to the VCAA a numerical score representing an assessment of the student's level of achievement. The score must be based on the teacher's assessment of the performance of each student on the tasks set out in the following table.

Contribution to final assessment

School-assessed Coursework for Unit 4 will contribute 30 per cent of the study score.

Outcomes	Marks allocated*	Assessment tasks
<p>Outcome 1</p> <p>Compare the advantages and disadvantages of a range of energy sources, evaluate the sustainability of their use, and explain the impacts of their use on society and the environment.</p>	30	<p>An evaluation using at least one task selected from:</p> <ul style="list-style-type: none"> • annotations of at least two practical activities from a practical logbook • a report of a student investigation • a model of energy concepts • a graphic organiser • an evaluation of research • media analysis/response • an analysis of data including generalisations and conclusions • a response to structured questions • a reflective learning journal/blog related to selected activities or in response to an issue. (approximately 50 minutes or up to 1000 words)
<p>Outcome 2</p> <p>Explain the causes and effects of changes to Earth's climate, compare methods of measuring and monitoring atmospheric changes, and explain the impacts of atmospheric changes on living things and the environment.</p>	30	<p>An explanation using at least one task selected from:</p> <ul style="list-style-type: none"> • annotations of at least two practical activities from a practical logbook • a report of a student investigation • a model of climate concepts • a graphic organiser • an evaluation of research • media analysis/response • an analysis of data including generalisations and conclusions • a response to structured questions • a reflective learning journal/blog related to selected activities or in response to an issue. (approximately 50 minutes or up to 1000 words)
<p>Outcome 3</p> <p>Design and undertake a practical investigation related to biodiversity or energy use from an environmental management perspective, and present methodologies, findings and conclusions in a scientific poster.</p>	30	<p>A structured scientific poster according to the VCAA template outlined on page 13. (not exceeding 1000 words)</p>
Total marks	90	

*School-assessed Coursework for Unit 4 contributes 30 per cent.

Practical work and assessment

Practical work is a central component of learning and assessment. As a guide, between 3½ and 5 hours of class time should be devoted to student practical work and investigations for each of Areas of Study 1 and 2. In Area of Study 3, between 7 and 10 hours of class time should be devoted to the investigation to be undertaken in either Unit 3 or Unit 4, or across both Units 3 and 4, including the writing of the sections of the scientific poster.

External assessment

The level of achievement for Units 3 and 4 is also assessed by an end-of-year examination.

Contribution to final assessment

The examination will contribute 50 per cent.

End-of-year examination

Description

The examination will be set by a panel appointed by the VCAA. All the key knowledge that underpins the outcomes in Units 3 and 4 and the cross-study key science skills are examinable.

Conditions

The examination will be completed under the following conditions:

- Duration: 2 hours.
- Date: end-of-year, on a date to be published annually by the VCAA.
- VCAA examination rules will apply. Details of these rules are published annually in the [VCE and VCAL Administrative Handbook](#).
- The examination will be marked by assessors appointed by the VCAA.

Further advice

The VCAA publishes specifications for all VCE examinations on the VCAA website. Examination specifications include details about the sections of the examination, their weighting, the question format/s and any other essential information. The specifications are published in the first year of implementation of the revised Units 3 and 4 sequence together with any sample material.