3. Subject Content

The AS course is divided into two units: AS 1, and AS 2. Students following the A Level course must study two further units: A2 1 and A2 2. The content of each of these units is set out below.

3.1 Unit AS 1: The earth's capacity to support human activity – an introduction to sustainable technologies

Global awareness of climate change and concern over its impacts have challenged government decision makers and drawn scientists and engineers into a deeper understanding of the causes of global warming – the primary source of climate change. Population growth and increased resource consumption contribute to changed lifestyles; this necessitates greater attention to the effects of fossil fuel usage, and the development of technologies which will contribute to more sustainable alternatives. This unit addresses the impacts of fossil fuel usage, considers the potential for biomaterial development and tackles the need for significant investment in the development of renewable energy sources. As a precursor to the in-depth exploration of two major renewable energy supplies candidates will examine the generation, distribution and storage of electricity from non-fossil fuel sources using the principles of energy conservation.

This unit will be assessed by a 1 hr 30 min written paper.

Content	Learning Outcomes
Reliance on fossil fuels to sustain human activity on earth	Students should be able to: • list coal, oil and gas as the principal fossil fuels on earth • understand the importance of fossil fuels in the development of modern society by examining their uses as energy sources and as raw materials for manufacturing (e.g. plastics, pharmaceutics, transport and fibres) • present the case for global action on the conservation of fossil fuels using reference to lifespans, location of reserves and accessibility • discuss the evidence presented by the global scientific

Content	Learning Outcomes
	community (Intergovernmental Panel on Climate Change(IPCC) Report, 2007), linking the combustion of fossil fuels with global warming and climate change • explain the concept of carbon trading • comment on the value of carbon trading schemes as a viable option for reducing global carbon emissions

The plastic generation and the development of bio plastics	• understand the global reliance of crude oil as both a fuel source and an industrial feedstock of enormous significance
	• understand that global production of plastic continues to increase each year and that plastic production is the largest single user of crude oil outside the energy and transport sectors
	• explain that the gases formed by fractional distillation are cooled, liquified and stored for use as feed stocks in the plastics industry
	• understand that the pollution difficulties associated with plastics fall into two main areas:
	    • polymers and plastics made from crude oil derivatives cannot be broken down by micro-organisms or easily recycled (e.g. great pacific garbage patch)
	    • the incineration of plastic materials release a cocktail of toxic gasses such as carbon monoxide, hydrogen cyanide and hydrochloric acid
	• assess the need for a global move towards a more sustainable use and manufacture of plastic
	• describe some of the uses of plastics designed to be either biodegrading or photodegrading, to include agricultural films, packaging and labeling

Content	Learning Outcomes
	• describe how modern plastic manufacturing processes can utilize options such as: ◦ incorporating additives such as d2w ™ into the polymer during the manufacturing process to enable oxo-degradation and then biodegradation by aerobically respiring bacteria ◦ making plastics suitable for thermal degradation through heat and light, facilitating biodegradation and making plastics with a short life cycle ◦ producing bioplastics which decompose once in contact with the earth and elements i.e. they are compostable • describe the manufacture of bioderived polyethylene (BPE), a recyclable plastic • describe how bio-plastics made in this way can be composted and thereby improve soil composition, particularly in regions where soil structure is poor
Counting the cost of reliance on fossil fuels	• recognise the trends in fossil fuels (coal, oil, gas) usage in industrialized Western countries • discuss the global economic impact of emerging economies (e.g. Brazil, India, China and Russia) in relation to demand for fossil fuels supplies • assess the environmental impact resulting from the global use of fossil fuels, to include, habitat degradation, impact on biodiversity, air emissions, contamination of land and water • explain the concept of 'fuel security' and understand how the global demand for finite fossil fuel supplies influences geopolitics across the world
Global action on energy	• explain the need for global action on energy conservation and climate change, to include, Rio earth summit, Kyoto

Content	Learning Outcomes

conservation and climate change	protocol and Copenhagen accord
	
	• understand how European, UK and Northern Ireland policies are working to set targets aimed at reducing greenhouse gas emissions and improving energy efficiency
	    • European (EU) Energy Policy (2011)
	    • EU Energy Efficiency Plan 2011
	    • EU 2020 Energy Strategy
	    • UK DECC The Energy Act 2010
	    • NI Strategic Energy Framework 2010
	
	• relate the need to prioritise renewable energy development within changing national and international environmental targets
	
	• identify a range of renewable energy sources, including; wind, solar, hydroelectric, geothermal, tidal & wave, biomass
	
	• define *energy density* as the amount of energy stored in a given system or region of space per unit volume or mass and compare the energy densities of different renewable energies and fossil fuels

The principles of energy production	• define the law of Conservation of Energy • outline the main phases involved in generating electricity from fossil fuels, i.e. the combustion of fuel to produce steam which is used to drive a turbine coupled to a generator • understand that many renewable sources of energy drive the turbine directly, e.g. wind, hydroelectric, wave and tidal • for each of the renewable energy sources listed above identify the energy changes involved in the generation process

Content	Learning Outcomes
	• describe how electricity is distributed through the National grid • explain the concept of a SMART grid and outline how it facilitates the incorporation of electricity generated from renewable sources • discuss the environmental and long term economic benefits to be gained from the development of a SMART grid utlising Irish, UK and European interconnections • describe the role of CHP (Combined Heat and Power), also known as cogeneration, in improving energy efficiencies in traditional power plants

Energy storage	• list the problems associated with the delivery of energy from renewable sources, primarily;
	    • the reliability of wind, wave and sun
	    • the intermittency of wind, wave, sun and tide
	
	• relate the problems outlined above to the need to develop energy storage facilities which will support the storage of energy produced from renewable sources
	
	• outline the basic operational systems involved in energy storage for both of the following technologies:
	    • compressed air energy storage (CAES)
	    • pumped hydro
	
	• describe the types of locations where energy storage would be of the greatest benefit as well as being cost effective

Unit AS 2 Additional renewable energy technologies

Candidates will study two out of the three renewable sources covered in this unit, wind, solar, or biomass.
This unit complements the unit AS 1, by seeking knowledge, understanding and analyses of the renewable energy sources. Candidates are required to appraise the technical, environmental and economic aspects of the energy output from sources of wind, solar, and biomass.

Coursework assessment will consist of an analysis of a pre-determined location for which students will consider the suitability of wind and solar or biomass as two alternative energy sources. Using a range of statistical and scientific data including land use, energy yields, energy plant performance and whole life costs, students will be expected to produce an output portfolio which will consist of a report and recommendations to support the preferred renewable energy source or sources for the pre-determined site.

Students should be aware that any proposed development relating to the installation of a renewable energy supply must be carried out with the context of an Environmental Impact Assessment which is designed to identify the potential environmental, social and economic impacts of any development project.

The task and materials required for its completion will be issued in September of 2013 for first submission in summer 2015 and second submission 2016. CCEA will review our assessment tasks every year to ensure that they continue to set an appropriate challenge and remain valid, reliable and stimulating.

In addition students will be expected to be familiar with the following content;

Content	**Learning Outcomes**

Energy from wind	Students should be able to:
	
	• describe the differences between the two main types of wind turbine;
	  • vertical axis wind turbine (VAWT)
	  • horizontal axis wind turbine (HAWT)
	
	For horizontal axis wind turbine only:
	
	• understand the relationship between power output and swept area
	
	• use the formula π x r^2 to calculate the swept area for different rotor diameters
	
	• understand what is meant by the Betz Limit and explain how it is related to 'real world wind turbine power efficiencies'
	
	• explain the terms 'rotor collected energy' and 'rated energy output' and detail the reasons for the energy shortfall between them
	
	• describe the impact of temperature and altitude on the power output from a wind turbine
	
	• explain the relationship between wind speed and power production and interpret power curves/profiles for different. wind speeds
	
	• understand the terms *hub height* and *rotor diameter* and explain the critical factors used to determine hub height for a specific project, for e.g. wind resource assessment,

Content	Learning Outcomes
	terrain, turbine size, visual impact • understand the factors that affect maximum energy production in wind turbines • define *wind survival speed* as the maximum wind speed that a turbine is designed to withstand before sustaining damage • understand that all wind turbines are designed with some element of power control • explain how 'yawing' ensures that the turbine faces on-coming wind • appreciate the relationship between the mass of a turbine, blade length and that wind power • assess how turbine performance in commercial wind farms is influenced by the blade length, strength of materials and siting requirements • discuss how commercial wind farm ventures seek to optimise location for both energy production and reasonable turbine establishment and interconnection costs • describe the main features of an environmental impact assessment in regard to locating a new wind resource
Energy from the sun	• provide an approximation of the amount of solar energy available for UK energy purposes per annum • identify the two approaches (solar thermal and photovoltaic) used within solar panels • explain how an automated tracking system can be used to maximize energy output from solar panels • demonstrate a practical understanding of the operation of a *flat plate* solar thermal panel which is used to heat water

Content	Learning Outcomes
	for both domestic and commercial purposes • calculate the amount of roof space typically required for a domestic flat plate solar thermal panel taking into consideration issues such as, solar radiation levels, shading, collector type, family size, and lifestyle of users • evaluate the benefits to households from the installation of a flat plate solar thermal panel • describe the composition and structure of a photovoltaic cell and explain the role of the semiconductor wafer in the production of electricity • list the four material types of photovoltaic (PV) panels (monocrystalline, polycrystalline, thick-filmed, thin-filmed) and discuss the advantages and disadvantages of each type • explain how planning regulations can affect the installation of solar panels and discuss the range of incentives available to homeowners considering such installation, including potential for sale of surplus electricity through the NI ROC (Renewable Obligation Certificate) system • describe how passive solar design techniques can be applied to new and existing buildings, including reference to window placement, orientation, size and glazing type, thermal mass and thermal insulation

Content	Learning Outcomes
Energy from biomass	• define the term *biomass* as biological material from living or recently living organisms and give examples of categorised types, to include: organic materials, wood, agricultural and municipal wastes, agricultural crops • with particular emphasis on Northern Ireland identify some of the main plant crops which are grown commercially to produce biomass, e.g. willow, poplar, elephant grass, maize, sugar cane • compare the advantages and disadvantages of the use of biomass as a fuel source • state that combustion accounts for over 90% of all energy obtained from biomass • compare and contrast the use of woodchip and wood pellet burners to convert biomass to heat and power • outline the process of gasification as the means by which biomass is converted into a mixture of carbon monoxide and hydrogen, commonly known as syngas • identify the principal uses of syngas as a fuel source • understand that biogas is primarily a mixture of methane and carbon dioxide, produced by the biological breakdown of organic matter in the absence of oxygen i.e. anaerobic digestion • in outline only, describe the four main stages of anaerobic digestion, i.e., hydrolysis, acidogenesis, acetogenesis and methanogenesis • discuss the advantages and disadvantages of the use of commercial anaerobic digesters

Unit A2 1 Technologies for a sustainable future

The concept of 'One Planet Living' has international application as the global capacity to support increased demands on natural resources is rapidly diminishing. This sustainability principle demands the integration of environmental, social and economic impacts; there are numerous solutions and all require a balance across engineering and scientific solutions. Managing of resources such as energy and materials, as well as awareness of land use patterns, demographic trends and the application of bio-remediation processes have all parts to play in reaching a situation in which the one planet living concepts can be applied in the developed world. This unit takes a look into the future by considering bio-remediation options, evaluating the impacts of essential processes in the resource management chain, reviewing the use of low-carbon sources for society's transport movements and exploring the different needs of urban and rural communities.

This unit will be assessed by a 2 hour written paper.

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Content	**Learning Outcomes**
One planet living and future development	Students should be able to: • understand how the increasing world population affects the demand for the earth's resources: fuel, water, food and shelter • debate the role of technology in meeting global requirements within the context of the relationship *I= PAT (I = impact, P = population, A = Affluence, T = damage caused by technology)* in comparing environmental impacts • define and explain the concept and measurement of Ecological Footprint for individuals and nations and the link between Ecological Footprint and Carbon Footprint. • describe the concept of One Planet Living (OPL) and review this OPL approach for major events, for e.g. .the 2012 London Olympic Games
Waste	• discuss the over reliance on landfill within Northern

Content	Learning Outcomes
management **Waste to energy technologies**	Ireland and the difficulties associated with locating and developing new landfill sites • list the major waste types and the priority waste streams as identified in the N I Waste Management Strategy (2006-2020) • describe how the key EU Strategies and Directives identified in the NI Waste Management Strategy (2006-2020) are driving improvements in waste management practice in NI • explain what is meant by the term 'waste management hierarchy' with reference to reduce, reuse, recycle • outline the main processes involved in recycling the common domestic waste items listed below; - glass - aluminum - paper - plastics • explain the process by which waste in landfill breaks down over time and identify the factors that influence the rate at which methane and leachate are produced • demonstrate how modern engineered landfill sites are designed to address the problems identified above, including use of the terms 'dry tomb' and 'bioreactor'. • explain how the 'landfill tax' is used to encourage reduction in levels of landfill as well as supporting environmental initiatives • describe the concepts of 'embodied energy' and 'energy recovery' • discuss the advantage and disadvantages of using of incineration as a method of recovering energy from waste

Content	Learning Outcomes
Bioremediation	• outline key terms associated with anaerobic digestion, including low and high solids, resistance time, single and multi-stage • explain the stages associated with anaerobic digestion including mechanical pretreatment, hydrolysis, acidogenesis, acetogenesis, methanogenesis • identify the types of waste that can be treated by composting. • understand and explain why composting is unsuitable for treating any form of catering waste • explain bioremediation as a method of using micro-organisms in the treatment of toxic wastes • recognise the role of a range of named micro-organisms and the pollutants they deal with • provide examples of the types of sites where in-situ bioremediation may be carried out in preparation for future re-development of the area as a Brown Field site. Include typical site pollutants such as: - oil spills - chlorinated pesticides - heavy metals - diesel oil - polychlorinated biphenyls (PCB) • outline the role of genetic engineering in modifying micro-organisms used in bioremediation to further enhance the scope of the technology • explain the use of Bioreactor systems to treat small to medium scale amounts of contaminated soil, for example, the Hydrologix® Systems Bioreactor for diesel contamination treatment
Phytoremediation	

Content	Learning Outcomes
Phytoextraction **Bio-hydrometallurgy (bio-refining)**	• describe how plants can be used in decontamination of industrial pollution of soil, to include the removal of: copper, cadmium, strontium, rubidium, arsenic and antimony • identify the use of examples such as Alpine Pennygrass and Indian Mustard in the decontamination of soil contaminated with metal ions such as cadmium, zinc, copper, lead, gold and uranium • describe how plant species can be used as an alternative way of extracting metal from metal ore mine tailings by a process known as Phytoextraction. Examples should include, White Mustard (*Sinapis Alba)* in the extraction of copper and Sunflower (*Helianthus annuus*) for the extraction of gold. • define bio-hydrometallurgy as the use of bacteria to extract metals from low grade ore • understand that traditional metal smelting technologies are energy intensive and highly polluting • identify *Thiobacillus ferrooxidans* as bacteria capable of refining copper, zinc, lead and uranium • describe how a site can be prepared for biorefining and that the most suitable sites are close to traditional mining facilities where there is a readily available source of low grade ore or mine tailing • discuss two advantages and disadvantages of biorefining
Hydrogen fuel cell opportunities	• examine the key points of hydrogen chemistry with particular emphasis on those properties that relate to its extraction and use as a fuel • outline the bulk production of hydrogen by the following methods, steam reforming of fossil gases, electrolysis of water, photocatalytic water splitting

Content	Learning Outcomes

	• describe in outline the process of energy conversion that occurs in the most common forms of hydrogen fuel cells, i.e. Polymer Electrolyte Membrane (PEM), Alkaline, Phosphoric Acid, Molten carbonate and Solid Oxide
	
	• describe a range of applications of hydrogen fuel cells to include:
	    • stationary generation as back up or in remote locations
	    • stand alone power supplies for telecommunications installations
	    • transportation including cars, buses, trains, boats, portable power generators
	
	• demonstrate an understanding of the infrastructure required for generation, distribution, storage and delivery of hydrogen
	
	• explain the challenges presented by the use of hydrogen as an energy source, e.g. non-competitive production costs, transportation issues and safe storage

Transport system challenges	• discuss the challenges for futuristic transport systems of the movement of people and goods in terms of economic viability, environmental impacts, dependence on fossil fuels and user safety • understand the role of new vehicle technologies including: hydrogen fuelled vehicles, bio-fuelled vehicles, electric and hybrid vehicles and vehicle shape and aerodynamics • describe the physical infrastructures required for each of the technologies described to function effectively • demonstrate an understanding of the basic steps in the industrial production of bio ethanol from biomass • describe the main stages in the manufacture of biodiesel

Content	Learning Outcomes

	from vegetable oils (e.g. soybean, recycled cooking oil)
	
	• discuss the advantages of using bio ethanol and biodiesel as substitute fuels for private and commercial vehicles
	
	• discuss why the increasing global production of biofuels is a contentious issue. The following issues should be considered:
	    • environmental impact of the intensive farming of energy crops
	    • designation of land away from food production into cash energy crops, particularly in the developing world
	    • destruction of wild habitats

Emerging technologies
 	
Wave & tidal
	• discuss why the production of energy from wave and tides is a priority concern for Northern Ireland
	
	• appreciate the constraints on the development of wave and tidal technology for e.g. limited availability of suitable sites, high cost of development
	• compare and contrast the two major generating methods for tidal power
	    - tidal stream generators – use of kinetic energy of moving water to drive turbines e.g. SeaGen, Strangford Lough
	    - tidal barrage – use of potential energy in the difference in height between high and low tides e.g. Rance Estuary France.
	
	• outline the operational processes within two main types of wave energy converters, Point Absorber and Attenuator
	
	• describe the environmental impact of tidal and wave energy devices, to include:

Content	Learning Outcomes
	◦ marine life and habitat ◦ toxic pollution ◦ visual and noise impact ◦ conflict with other sea users.
SMART Materials	• define what is meant by the term SMART material (i.e. a materials that changes properties in response to stimulation from its environment) • provide examples of how SMART materials could be used to reduce environmental impacts through better monitoring and control
Carbon Capture & Storage (CSS)	• explain what is meant by 'Carbon Capture' and its potential for reducing carbon dioxide emissions • discuss the three phases identified in the carbon capture process i.e. trapping and separating, transport and storage (underground and underwater)
Geo-engineering	• debate the advantages and risks associated with geo-engineering as the deliberate modification of the earth's atmosphere to offset the effects of climate change
The development of urban and rural sustainable communities	• discuss using appropriate examples such as eco villages the main characteristics of an urban development which links sustainability, zero-carbon concepts and the role of technology, to include: ◦ reduced energy usage both for heating and cooling ◦ micro generation in urban areas and the use of Smart Grid technology ◦ lower cost and more comfortable and versatile buildings ◦ integrated and flexible transport facilities ◦ planned waste management systems which deal with waste source ◦ the use of Brownfield sites ◦ systems to deal with water shortage ◦ sustainable urban drainage schemes

Content	Learning Outcomes
	◦ use of green spaces to moderate the urban heat island ◦ use of green spaces that work for people and wildlife, e.g. the production of food in urban areas • identify issues, linked to technology, which underpin the development of sustainable rural communities, including ◦ cost and environmental impacts of linking isolated dwellings to water, waste water, energy supply, communication and transportation networks ◦ application of independent energy solutions using indigenous energy sources, e.g. biomass, agricultural waste treatment, wind power and small scale district heating solutions ◦ potential for use of local water sources ◦ use of small scale waste water treatment solutions (provision and operation of septic tanks) ◦ benefits of local food production and consumption from environmental, economic and social perspectives ◦ impact of communication technologies to enhance accessibility to rural areas without generating new travel demands (e.g. Project Kelvin Northern Ireland).

Unit A2 2 Environmental building performance and measurement

Society is frequently encouraged to change its environmental habits and to address new lifestyles; this is most pertinent in our homes as we become more aware of the economic and social benefits of ensuring that our buildings are designed and built to high standards. The UK Code for Sustainable Homes sets these standards at several levels with an aspiration that all new homes will be 'Zero Carbon' by 2016. Unit A2 2 addresses the broad area of environmental impact and considers several elements of this Sustainable Homes code, allowing all students to assess their homes, school, college or leisure facilities.

Coursework will be set to ensure that all students engage with the nine elements of the Code and carry out assessments.

Content	Learning Outcomes
Environmental building performance	Students should be able to: • describe the drivers and benefits of providing buildings which meet high environmental standards, address social needs and are examples of good design • give examples of a number of contemporary buildings in Northern Ireland which have achieved significant environmental profiles, for example, the Titanic Quarter Signature Building, Waterways Ireland Building, Public Records Office Building • show an understanding of the principal environmental building performance measurement system, for Zero Carbon Homes i.e. BREEAM (Building Research Establishment Environmental Assessment Method) • explain the concept of Zero Carbon Homes Hierarchy and demonstrate how it can be applied to new buildings • discuss the challenge of the UK government's policy of "Zero Carbon Homes' by 2016
Sustainable Homes	• discuss the rationale behind the Government's aspirations of bringing all building stock up to high standard of

Content	Learning Outcomes
	environmental and social impact through the 'Code for Sustainable Homes (CSH)' • demonstrate an awareness of the key elements of CSH and their weightings, across the nine areas of: energy and CO_2 ; water; materials; surface water run-off; waste; pollution; health and well-being; management and ecology • show a knowledge of CSH assessments to include levels of award, cost implications and allocation of scores or credits • access and use CSH Calculators in areas such as water, materials, energy

Energy & Carbon Dioxide	• explain the CSH content for *Energy and* CO_2 emissions to include:
	  • dwelling emission rate
	  • fabric energy efficiency
	  • energy display devices
	  • drying space
	  • energy labelled white goods
	  • external lighting
	  • low and zero carbon technologies
	  • cycle storage
	  • home office

Water	• explain the CSH content for *Water* to include:
	  • indoor water use
	  • external water use

Materials	• explain the CSH content for *Materials* to include:
	  • environmental impact of materials
	  • responsible sourcing of materials – basic building elements
	  • responsible sourcing of materials – finishing elements

Surface water run-off	• explain the CSH content for *Surface Water Run-off* to include: • management of surface water run-off from

Content	Learning Outcomes
	developments • flood risk

Waste	• explain the CSH content for *Waste* to include:
	  • storage of non-recyclable waste and recyclable household waste
	  • construction site waste management
	  • composting

Pollution	• explain the CSH content for *Pollution* to include:
	  • global warming potential (GWP) of insulants
	  • NO_x emissions

Health & Well-being	• explain the CSH content for *Heath and Well-being* to include:
	  • day lighting
	  • sound insulation
	  • private space
	  • lifetime homes

Management	• explain the CSH content for *Management* to include:
	  • home user guide
	  • considerate constructors scheme
	  • construction site impacts
	  • security

Ecology	• explain the CSH content for *Ecology* to include:
	  • ecological value of site
	  • ecological enhancement
	  • protection of ecological features
	  • change in ecological value of site
	  • building footprint
	
	• comment on examples of buildings which are assessed against the CSH guide such as Northern Ireland Housing Executive stock, Habitat for Humanity homes
	
	• review the impact of CSH on the retro-fitting of buildings, to include:

Content	Learning Outcomes
	- cost comparison - construction techniques • explain maintenance and operational responsibilities to retain CSH standards such as energy monitoring, water usage, waste recycling