GEOL 10040: Earth, Environment and Society

MODULE COORDINATOR: Prof. Frank McDermott

ADDITIONAL LECTURERS: Dr Laia Comas Bru
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CREDITS: 5	**MODULE LEVEL**: 1	**SEMESTER**: II

PRE-REQUISITES/PRIOR LEARNING:

This is an introductory level module and no prior knowledge is required.

OVERVIEW OF MODULE:

Planet Earth is a complex interconnected system in which human activities can have disproportionate and unintended impacts. The effect of human activities on the `health' of our planet is now a major concern globally, not only to scientists, but also to economists, policymakers and governments. This open elective module explores the causes and consequences of human induced changes and how they interact with Earth's natural processes. Key topics include climate change and geohazards, the carbon economy, the global energy landscape, the role of sustainable and renewable energy, as well as the provision of metal, non-metal and water resources for a rapidly expanding human population in the 21st century. The module also deals with possible approaches for the mitigation of climate change and environmental degradation, the effects of societal decisions on greenhouse gas emissions and the possible role of geo-engineered solutions. The concept of sustainable development and the near and long-term future of Planet Earth are also discussed. This module complements GEOL10050 Earth and Humanity. GEOL10040 focusses on how humans affect the environment, whereas GEOL10050 deals with how the Earth has affected and continues to influence humanity.

LEARNING OUTCOMES:

The overall goal module is to provide students with a sound knowledge of Earth systems so that they can make rational judgements about the problems surrounding climate change, environmental degradation and possible solutions. Students will learn about the interconnected nature of Earth's systems and the strong coupling that exists between the solid Earth and its hydrosphere, biosphere and atmosphere, using climate change as an example. Students will also learn to quantitatively assess the nature of risk, comparing natural (geohazard) risks with those associated with human behaviour. The module will provide students with a global view of important issues that impact on Earth's environment ranging from energy usage to societal attitudes surrounding the use and recycling of Earth's resources.

ASSESSMENT:

Multiple Choice Questionnaire: 35%
(30-minute MCQ mid-term exam on first part of course)

Multiple Choice Questionnaire: 65%
(1-hour MCQ end of semester exam on second part of course)

LECTURES:

Lecture 1: Planet Earth and its evolution. *(Dr L. Comas Bru)*
The geological and historical context for present-day environmental and climate change. The geological record as a record of past change. Measurement of geological time. The scale of geological time in relation to societal development, human perspective and experience. The 'Anthropocene'.

Lecture 2: The Earth as a 'system'. *(Dr L. Comas Bru)*
The inter-connectedness and coupling of the solid Earth, the hydrosphere, biosphere and atmosphere. Qualitative description of concepts such as 'steady state', 'fluxes' and 'residence times' in the context of Earth Systems and Earth evolution. The concept of feedback mechanisms.

Lecture 3: Climate change as an example of a major Earth Systems issue. *(Dr L. Comas Bru)*
How do we know that climate is changing? How does Earth's climate change naturally on different timescales? What is the evidence for human-induced change? Solar forcing and the world according to 'Climate sceptics'.

Lecture 4: The Intergovernmental Panel on Climate Change (IPCC) Reports (FAR to AR5). *(Dr L. Comas Bru)*
A conservative scientific consensus? Scenarios for future emissions and their influence on future climate. What are the unknowns and how large are the uncertainties? Humans as geological agents.

Lecture 5: Global and local impacts of climate change. *(Dr L. Comas Bru)*
Changes in air temperature and rainfall amount and distribution. Impacts on agriculture, local and global ecosystems. Impacts on mountain glaciers, high latitude ice-sheets and sea ice. Ocean circulation changes. Impact on sea-level. Ocean warming and acidification. Impact on corals reefs. Likely impact of climate change on species, disease and human populations.

Lecture 6: How does Ireland's per capita emissions of greenhouse gases (GHG) compare with other countries? *(Dr L. Comas Bru)*
Which industries/activities are the main contributors. How will climate change affect Ireland? Changes in regional patterns of warming and rainfall distribution. Impact of sea-level rise. What is Ireland's National Climate Change Strategy?

Lecture 7: The Stern Report and the economic cost of Climate Change. *(Dr L. Comas Bru)*
Impacts on developed and developing economies. The economic case for GHG emission reduction. GHG emission reduction and the Kyoto Protocol. Ireland's Kyoto targets. Carbon 'footprints' and other environmental audits. Emission offsets, credits and carbon trading. Pollutants other than CO_2. (e.g. SO_2, nitrogen oxides, low-level ozone). Ozone depletion. International Protocols on GHG and CFC emission reductions.

Lecture 8: The Global Energy landscape. *(Dr L. Comas Bru)*
Renewable and non-renewable energy sources. Present and likely future trends in energy use. Energy usage and consumption patterns.

Lecture 9: The Carbon Economy. *(Dr L. Comas Bru)*
Where are the world's major reserves of oil, gas and coal? Geopolitics of oil. What is 'peak oil'? Environmental consequences of oil production and refining. Ireland's offshore energy resources and potential. Coal reserves and 'clean' coal technology. Unconventional oil and gas and technology challenges.

Lecture 10: Carbon Capture and Storage (CSS). *(Dr L. Comas Bru)*
Geological and economic considerations of different methods including geological, ocean, mineral carbonation Carbon capture and Sequestration technologies. Examples of CCS demonstration projects. What is Ireland's CCS potential?

Lecture 11: Nuclear Energy. *(Dr L. Comas Bru)*
Historical perspectives and recent developments. Advantages and disadvantages. Influence of catastrophic events on societal perception of nuclear power. Nuclear waste disposal. Nuclear energy for Ireland? Nuclear fusion research.

Lecture 12: Sustainable and Renewable Energy 1 *(Dr L. Comas Bru)*
Wind, wave, tidal, solar and biofuel sources. Present and likely future contributions of different sources. Advantages/disadvantages of different sustainable/renewable energy sources. Energy storage problems.

Lecture 13: Sustainable and Renewable Energy 2 *(Dr L. Comas Bru)*
Geothermal energy. Shallow and deep sources. Examples of geothermal energy projects in different countries. Potential geothermal resources in Ireland and examples of successful geothermal projects in Ireland and elsewhere. Summary of Ireland's energy future.

Lecture 14: Geohazards in the context of risk assessment. *(Dr I. Lokmer)*
Exploration of natural hazards in the context of large scale earth processes. The distinction and relationship between hazard and risk. Prediction versus forecasting and the nature of predictability in natural and man-made systems.

Lecture 15: Global geohazards. *(Dr I. Lokmer)*
Review of specific global geohazards such as earthquakes, tsunamis, volcanoes, landslides, radon gas and flooding. Hazard interaction. Hazard mitigation. Societal perception and response to geohazards.

Lecture 16: Geohazards in Ireland. *(Dr I. Lokmer)*
Specific examples of geohazards in Ireland. Hazard 'prediction', planning and mitigation. Role of planning in minimising and mitigating hazards.

Lecture 17: Use of metals past, present and future. *(Assoc. Prof. J.F. Menuge)*
Archaeological and historical perspectives on metal sources and uses by humans. Rising metal production and diversification of metal use in the 20th especially in high-tech and energy industries.

Lecture 18: Metal reserves; the challenge of future uses; environmental effects of mining.
(Assoc. Prof. J.F. Menuge)
Current methods for mining, beneficiation and smelting of metals. Ore deposits, resources and reserves. Factors that change metal supply and demand. Metal recycling. Security of supply of metals. The future of metal mining.

Lecture 19: Non-metallic resources. *(Dr L. Comas Bru)*
Aggregates, gypsum, clays, silica sand, dimension stone and their uses. Cement and concrete manufacture and CO_2 emissions. Environmental aspects of quarrying and mining for metallic and non-metallic resources – land use, water, acid mine drainage, dust and energy use. The complexity of metal use in the 21st century

Lecture 20: Water as a resource. *(Dr L. Comas Bru)*
Challenges in supplying potable and irrigation water to an increasing global population. 'Water mining' and 'Water wars'. Basic concepts in hydrology such as evapotranspiration and infiltration. Basic concepts in hydrogeology. Societal pressures on water resources and impact of over-development on surface and groundwater supplies.

Lecture 21: Water replenishment and likely effect of climate change. *(Dr L. Comas Bru)*
Water replenishment and likely effect of climate change on the distribution of rainfall and consequences for water resources. Water resources in Ireland in the future. Water quality. Quality requirements for different uses. Role of aquifer type in determining groundwater quality. Surface and groundwater quality globally and in Ireland.

Lecture 22: Mitigation of Climate Change and Environmental degradation. *(Dr L. Comas Bru)*
Societal response and changes in GHG emission scenarios. Geoengineering and the concept of engineered solutions to climate change with examples. Society and sustainable development. Earth System Governance. The near and long-term future of planet Earth.

WEEKLY ONLINE EXERCISES:

Week 1: Cycles in the Earth System.
This assignment explores a number of cycles within the Earth system. The information is divided into nine bite-sized blocks so that students can study small portions at a time and log in/out at any time. Topics covered: (1) The Earth's structure, (2) Plate tectonics, (3) The rock cycle, (4) Atmospheric structure, (5) The 'Greenhouse Effect', (6) Atmospheric circulation, (7) The water cycle, (8) The carbon cycle, (9) Ocean circulation.

Week 2: Forcing and Feedbacks in the Earth System.
Mechanisms that affect climate (external and internal, natural and anthropogenic) and some of the feedback loops within the Earth's climate system. Topics covered: (1) Orbital forcing (external and natural), (2) Solar forcing (external and natural), (3) Volcanic forcing (internal and natural), (4) Land cover forcing (internal and natural/anthropogenic), (5) Greenhouse Gas forcing (internal and natural/anthropogenic), (6) Ice-Albedo feedback loop, (7) Atmospheric water vapour feedback loop.

Week 3: Impacts of Climate Change on a Vulnerability Hotspot: Case study of the Mediterranean Region.
The impacts of climate change occurring and likely to occur within the Mediterranean Region. This region is a "hotspot of vulnerability" because climate change will increase temperatures and decrease precipitation in the region, causing enhanced aridity. Topics covered: (1) The Mediterranean Region, (2) Mediterranean Climate, (3) Mediterranean Climate Change, (4) Water Resources in the Mediterranean, (5) Mediterranean Marine Ecosystems, (6) Natural terrestrial Ecosystems in the Mediterranean, (7) Mediterranean Urbanisation.

Week 4: Ozone depletion.
How humans have influenced composition of the atmosphere. In particular, stratospheric ozone depletion, and how measures have been put in place to mitigate this. Topics covered: (1) What is ozone?, (2) What is the ozone "hole"?, (3) What causes ozone depleted?, (4) The Montreal Protocol.

Week 5: Counting Carbon.
Carbon emissions from the burning of fossil fuels. In particular, this assignment focuses on the values given to carbon emissions. The second part focuses on carbon capture and sequestration (storage), a new technology for reducing atmospheric carbon dioxide concentrations. The economic costs involved for emission and storage, and how these amounts can be verified. Topics covered: (1) Carbon Emissions: Carbon dioxide, (2) Carbon Emissions: Methane, (3) Carbon capture and sequestration (storage), (4) The CCS process, (5) How much carbon can CCS potentially store?, (6) Geosequestration, (7) Marine sequestration, (8) Mineral sequestration, (9) Economic costs of CCS, (10) Accounting and verifying CCS.

Week 6: Ireland's Energy Future.
Current energy sources and use in Ireland and the future of energy in Ireland. The security of energy is a major challenge to the Earth: will there be enough energy to meet requirements, the cost of this energy, and limiting the environmental damage. Topics covered: (1) Energy sources in Ireland, (2) Energy sources in the World and Europe, (3) Energy use in Ireland, (4) Energy security, (5) Alternative energy sources, (6) The nuclear debate, (7) Ireland's energy future.

Week 7: Sustainable Energy and the Environment.
The two types of sustainable energy that have a large potential in Ireland's future energy; hydro power and wind energy. However, not everyone is happy implementing such technologies because of their potential damage to pristine environments and the countryside caused by building the sustainable energy infrastructure. Therefore, we will look at whether the sustainable energy solutions are really as environmentally friendly and green as they are promoted to be and whether people should learn to accept some of the problems,such as the visual disturbances, for a greater good of reducing carbon emissions. Topics covered: (1) Sustainable energy: what are the problems?, (2) Sustainable vs. fossil fuels: what are the costs?, (3) Wind energy in Ireland, (4) Onshore wind energy, (5) Wind farms and bog slides, (6) Offshore wind energy, (7) Offshore wind power in Ireland, (8) Storing Energy, (9) Ocean Energy.

Week 8: Mass Volcanoes, Earthquakes and Tsunamis.
Volcanoes and Earthquakes are the two most often thought of geohazards, and when they occur they can be catastrophic. The most deadly tsunamis generally occur as a result of earthquakes and have therefore been included in this weeks work. We will also look at how climate change may affect the frequency of these events and the potential destruction caused by them. A number of case studies will be included in this weeks work. Topics covered: (1) Volcanoes, (2) Volcano Hazards - Lava Flows, Pyroclastic Flows, Lahars, Mt. Rainier Lahar hazard, (3) Volcanic eruptions caused by climate change, (4) Earthquakes, (5) Earthquakes and climate change, (6) Tsunamis.

Week 9: Geohazards and Climate Interactions.
Geological hazards (geohazards), and in particular, how geohazards can be caused and influenced by climate change. All of the hazards covered are natural and have been around for many years. However, the impact that they are having on society appears to be increasing. This is due to increasing population and population density, increasing infrastructure which is susceptible to damage, and due to rapid changes in the climate. Topics covered: (1) Landslides and slope stability, (2) Bog slides, (3) Soluble rock and undermining, (4) Flooding, (5) Wildfires, (6) Off-shore geohazards.

Week 10: Ore geology and metallic mineral resources.
The basics of ore geology and metallic minerals, and examples of some large mines around the world and some of the mines in Ireland. Topics covered: (1) Metals and metallic ore, (2) Ore deposit formation-hydrothermal deposits, magmatic deposits, secondary enrichment deposits, sedimentary deposits, residual mineral deposits, placer deposits, (3) Ore locations and mineral exploration, (4) Bingham Canyon Mine, Utah, (5) HamersleyBasin Iron Ore Mine, Australia, (6) CBG Bauxite (Aluminium Ore) MiningOperations, Guinea, (7) Gold mining in Johannesburg, (8) Tara Zn mine, Navan, Ireland, (9) Other Irish examples.

Week 11: The Nitrates Directive.
The Nitrates Directive, an EU Directive that aims to protect water from nitrate pollution arising from agricultural practices. The first part of the assignment deals with nitrates, what they are, how they form and why they pose a threat to water quality. The second part of the assignment introduces the Nitrates Directive and some of the measures adopted in Ireland. Students then examine a report on nitrates in drinking water produced jointly by the Environmental Protection Agency (EPA) and the Health Service Executive (HSE). At the end of the assignment students look at a study carried out by the British Geological Survey investigating nitrate pollution in Malta. Topics covered: (1) The Nitrogen Cycle, (2) The difference between nitrates, nitrites, ammonium and ammonia, (3) The Haber Process, (4) The Nitrates Directive, (5) Eutrophication, (6) Methaemoglobinaemia (Blue Baby Syndrome), (7) How to reduce nitrate levels in drinking water, (8) Nitrate pollution in Malta.

Week 12: Plan B. Geoengineering the Climate.
The controversial topic of geoengineering the climate; the deliberate large-scale manipulation of the planetary environment to counteract anthropogenic climate change. Although this is not a technique for avoiding the challenge of reducing carbon emissions by using renewable energy sources and cutting consumption (a key point clearly stated by the all the scientists and policy makers involved), if drastic measures are not taken quickly to reduce carbon emissions, these futuristic ideas may become a reality. Topics covered: (1) The need for a "Plan B" option, (2) Carbon dioxide removal techniques - land use management, biomass/biochar, enhancement of natural weathering reactions, CCS, enhancement of oceanic uptake, (3) Solar radiation management techniques - changing the reflectivity of the planet, cloud reflectivity, sulphate aerosol injection, shields and deflectors, (4) Oversight and Governance issues.