NATIONAL OPEN UNIVERSITY OF NIGERIA

CLIMATE CHANGE AND DEVELOPMENT

DES 219

FACULTY OF SOCIAL SCIENCES

COURSE GUIDE

Course Developers:
Professor Olarewaju O. Ifatimehin
Department of Geography and Environmental Studies
Kogi State University
and
Dr. Saheed O. Olayiwola
Department of Economics
Federal University of Technology, Akure

Course Editor
Professor J.A. Angbas
Department of Economics,
Plateau State University, Bokkos

© 2019 by NOUN Press
National Open University of Nigeria,
Headquarters,
University Village,
Plot 91, Cadastral Zone,
Nnamdi Azikiwe Expressway,
Jabi, Abuja.

Lagos Office
14/16 Ahmadu Bello Way,
Victoria Island, Lagos.

e-mail: centralinfo@nou.edu.ng
URL: www.nou.edu.ng

All rights reserved. No part of this book may be reproduced, in any form or by any means, without permission in writing from the publisher. Printed: 2018 ISBN: 978-058-023-X.

Printed:

ISBN:

CONTENT

Introduction

Welcome to DES 219: CLIMATE CHANGE AND DEVELOPMENT

DES 219: Climate change and development is a two-credit and one-semester course. The course is made up of twelve units spread across fifteen lectures weeks. This course guide provides an insight to issues revolving around climate change and development and brings those who are beginning the study of climate change close to the frontiers of knowledge. It gives information about the course materials and how to work through it. It also suggests general guidelines on the required time to successfully achieve each unit aims and objectives. Answers to your tutor marked assignments (TMAs) are provided within the contents of the material.

Course Content

This course is on climate change and its impacts on present and future socio-economic development. The overall purpose of the course is to introduce the concept of climate change within a context of social, economic, geography and sustainable development. The topics covered include science of climate change, economics of climate change, global warming and climate change and sustainable development.

Course Aims

The aims of this course are to give you an in-depth understanding of the phenomenon of climate change and how it affects development along the following:

- The perspectives on causes of climate change, impacts and mitigation/adaptation and possibilities from economics, geography, political science and sociology
- The basic association between climate change with human socio-economic development
- The impacts of climate change on utilisation of natural resources and consequent effects on human welfare
- The integration of different scientific perspectives on climate change through the concept of sustainable development

Course Objectives

To achieve the aims of this course, there are overall objectives which the course is out to achieve though, there are set out objectives for each unit. The unit objectives are included at the beginning of a unit; you should read them before working through the unit. You may want to refer to them during your study of the unit to check on your progress. You should always look at the unit objectives after completing each unit. This is to assist the students in accomplishing the tasks entailed in this course. In this way, the student can be sure he/she has done what was required of he/she by the unit. The objectives serve as study guides, such that students could know if he/she is able to grab the knowledge of each unit through the sets of objectives in each one. At the end of the course period, the students are expected to be able to: what climate change means and the basic definitions and terminologies that are common. The student will thus:

- Understand the economics of climate change, ranging from the quantification of potential impacts to the design of policy instruments
- Understand responses to climate change
- Examine critically a range of media and perspectives on climate change and sustainable development
- Apply the concept of sustainable development to integrate a range of climate change perspectives
- Interpret scientific, statistical and other data
- Search for and make judgements on evidence from a range of sources
- Marshall evidence, and develop and communicate in your own words an argument.
- Construct knowledge on climate change through communicative exchange with others and develop transboundary competence.
- Understand the connection between inequality and climate issues
- Understand the link between climate change and sustainable development

Working through the Course

To successfully complete this course, you are required to read the study units, referenced books and other materials on the course.

Each unit contains self-assessment exercises called Student Assessment Exercises (SAE). At some point in the course, you will be required to submit assignments for assessment purposes. At the end of the course there is a final examination. This course should take about 15weeks to complete and some components of the course are outlined under the course material subsection.

Course Material

The major components of the course, what you have to do and how you should allocate your time to each unit in order to complete the course successfully on time are listed follows:

1. Course guide
2. Study unit
3. Textbook
4. Assignment file
5. Presentation schedule

Study Unit

There are 12 units in this course which should be studied cautiously and meticulously.

MODULE ONE: THE SCIENCE OF CLIMATE CHANGE

Unit 1: Introduction: Understanding Climate Change
Unit 2: Models of Climate Change
Unit 3: Observed Climate change and future projections
Unit 4: Global Warming

MODULE TWO: ECONOMICS OF CLIMATE CHANGE

Unit 1: Climate Change and Economic Development
Unit 2: The Economics of Climate Change through the Dominant Neoclassical Lens
Unit 3: Cost-Benefit Analysis and Sectoral Impacts of Climate Change
Unit 4: The Challenges from Economics and Ecological Perspectives and Sustainable Development

MODULE THREE: INSTITUTIONS, POLICY AND GOVERNANCE

Unit 1: Climate Change, Policy Frameworks and Protocols
Unit 2: Climate Change, Development and Policy Options
Unit 3: Climate Change Financing
Unit 4: Climate Change Action Plans

Each study unit will take at least two hours, and it include the introduction, objective, main content, self-assessment exercise, conclusion, summary and reference. Other areas border on the Tutor-Marked Assessment (TMA) questions. Some of the self-assessment exercise will necessitate discussion, brainstorming and argument with some of your colleagues.

There are also textbooks under the reference and other (on-line and off-line) resources for further reading. They are meant to give you additional information. You are required to study the materials; practice the self-assessment exercise and tutor-marked assignment (TMA) questions for greater and in-depth understanding of the course. By so doing, the stated learning objectives of the course would have been achieved.

Textbook and References

For further reading and more detailed information about the course, the following materials are recommended:

Tom Tietenberg and Lynne Lewi (2012). Environmental & Natural Resource Economics. Pearson 9th edition.

Gordon Wilson, Victor Fairén, Javier García-Sanz, Ignacio Zúñiga, Daniel Otto, Helmut Breitmeir, Dina Abbott and Carolien Kroeze(2012) Module 1: Introduction to climate change in the context of sustainable development. T869 LECH-e Module1 Textbook 20.

John Chung-En Liu, Yoram Bauman and Yating Chuang (2019). Climate change and economics 101: Teaching the Greatest Market Failure. Sustainability 2019, 11, 1340; doi:10.3390/su11051340 www.mdpi.com/journal/sustainability

Assignment File

Assignment files and marking scheme will be made available to you. This file presents you with details of the work you must submit to your tutor for marking. The marks you obtain from these assignments shall form part of your final mark for this course. Additional information on assignments will be found in the assignment file and later in this Course Guide in the section on assessment.

There are three assignments in this course. The three course assignments will cover:

Assignment 1 - All TMAs' question in Units 1 – 4 (Module 1)

Assignment 2 - All TMAs' question in Units 5 – 8 (Module 2)

Assignment 3 - All TMAs' question in Units 9 – 12 (Module 3)

Presentation Schedule

The presentation schedule included in the course material gives you the important dates for the completion of tutor-marking assignments and attending tutorials. You are required to submit all your assignments by due date. You should guide against falling behind in your work.

Assessment

There are two types of assessments in the course. First is the tutor-marked assignments; and the second is a written examination.

In attempting the assignments, you are expected to apply the information, knowledge and techniques gathered during the course. The assignments must be submitted to your course tutor for formal Assessment in accordance with the deadlines stated in the Presentation Schedule and the Assignments File. The works you submit to your course tutor for assessment constitute 30 % of the total course mark.

At the end of the course, you will need to sit for a final written examination of two hours' duration. This examination will constitute 70% of your total course mark.

Tutor-Marked Assignments (TMAs)

There are three tutor-marked assignments to be submitted in this course. The TMAs constitute 30% of the total score. You are encouraged to work all the questions thoroughly.

Assignment questions for the units in this course are contained in the Assignment File. You will be able to complete your assignments from the information and materials contained in your set books, reading and study units. However, it is desirable that you demonstrate that you have read and researched more widely than the required minimum. You should use other references to have a broad viewpoint of the subject and also to give you a deeper understanding of the subject.

When you have completed each assignment, send it, together with a TMA form, to your tutor. Make sure that each assignment reaches your tutor on or before the deadline given in the Presentation File. If for any reason, you cannot complete your work on time, contact your tutor before the assignment is due to discuss the possibility of an extension. Extensions will not be granted after the due date unless there are exceptional circumstance

Final Examination and Grading

The final examination will be of two hours' duration and have a value of 70% of the total course grade. The examination will consist of questions which reflect the types of self-assessment practice exercises and tutor-marked problems you have previously encountered. All areas of the course will be assessed

Revise the entire course material using the time between finishing the last unit in the module and that of sitting for the final examination. You might find it useful to review your self-assessment exercises, tutor-marked assignments and comments on them before the examination. The final examination covers information from all parts of the course.

Course Marking Scheme

The Table presented below indicates the total marks (100%) allocation.

Assignment	**Marks**
Assignments (Best two out of three marked assignments)	30%
Final Examination	70%
Total	**100%**

Course Overview

The Table presented below indicates the units, number of weeks and assignments to be taken to successfully complete the course, Climate Change and Development (DES 219).

Units	**Title of Work**	**Week's Activities**	**Assessment (end of unit)**
	Course Guide		
MODULE 1:	**The Science of Climate Change**		

1	Introduction: Understanding Climate Change	Week 1	Assignment No. 1
2	Models of Climate Change	Week 2	Assignment No. 2
3	Observed Climate change and future projections	Week 3	Assignment No. 3
4	Global Warming	Week 4	Assignment No. 4
Module 2: Economics of Climate Change			
1	Climate Change and Economic Development	Week 5	Assignment No.5
2	The Economics of Climate Change through the Dominant Neoclassical Lens	Week 6	Assignment No. 6
3	Cost-Benefit Analysis and Sectoral Impacts of Climate Change	Week 7	Assignment No. 7
4	The Challenges from Economics and Ecological Perspectives and Sustainable Development	Week 8	Assignment No. 8
Module 3: Institutions, Policy and Governance			
1	Climate Change, Policy Frameworks and Protocols	Week 9	Assignment No. 9
2	Climate Change, Development and Policy Options	Week 10	Assignment No. 10
3	Climate Change Financing	Week 11	Assignment No. 11
4	Climate Change Action Plans	Week 12 and 13	Assignment No. 12
		Week 14 and 15	Examination
	Total	**15 Weeks**	

How to Get the Most from this Course

In distance learning, the study units replace the University lecturer. This is one of the great advantages of distance learning; you can read and work through specially designed study materials at your own pace and at a time and place that suit you best.

Think of it as reading the lecture instead of listening to a lecturer. In the same way that a lecturer might set you some reading to do, the study units tell you when to read your books or other material, and when to embark on discussion with your colleagues. Just as a lecturer might give you an in-class exercise, your study units provides exercises for you to do at appropriate points.

Each of the study units follows a common format. The first item is an introduction to the subject matter of the unit and how a particular unit is integrated with the other units and the course as a whole. Next is a set of learning objectives. These objectives let you know what you should be able to do by the time you have completed the unit.

You should use these objectives to guide your study. When you have finished the unit you must re-check whether you have achieved the objectives. If you make a habit of doing this you will significantly improve your chances of passing the course and getting the best grade.

The main body of the unit guides you through the required reading from other sources. This will usually be either from your set books or from a readings section.

Self-assessments are interspersed throughout the units, and answers are given at the end of the units. Working through these tests will help you achieve the objectives of the unit and prepare you for the assignments and the examination. You should do each self-assessment exercises as you come to it in the study unit. Also, ensure to master some major historical dates and events during the course of studying the material.

The following is a practical strategy for working through the course. If you run into any trouble, consult your tutor. Remember that your tutor's job is to help you. When you need help, don't hesitate to call and ask your tutor to provide it.

1. Read this Course Guide thoroughly.

2. Organize a study schedule. Refer to the `Course overview' for more details. Note the time you are expected to spend on each unit and how the assignments relate to the units. Important information, e.g. details of your tutorials, and the date of the first day of the semester is available from study centre. You need to gather together all this information in one place, such as your diary or a wall calendar. Whatever method you choose to use, you should decide on and write in your own dates for working breach unit.

3. Once you have created your own study schedule, do everything you can to stick to it. The major reason that students fail is that they get behind with their course work. If you get into difficulties with your schedule, let your tutor know before it is too late for help.

4. Turn to Unit 1 and read the introduction and the objectives for the unit.

5. Assemble the study materials. Information about what you need for a unit is given in the Overview' at the beginning of each unit. You will also need both the study unit you are working on and one of your set books on your desk at the same time.

6. Work through the unit. The content of the unit itself has been arranged to provide a sequence for you to follow. As you work through the unit you will be instructed to read sections from your set books or other articles. Use the unit to guide your reading.

7. Up-to-date course information will be continuously delivered to you at the study centre.

8. Work before the relevant due date (about 4 weeks before due dates), get the Assignment File for the next required assignment. Keep in mind that you will learn a lot by doing the assignments carefully. They have been designed to help you meet the objectives of the course and, therefore, will help you pass the exam. Submit all assignments no later than the due date.

9. Review the objectives for each study unit to confirm that you have achieved them. If you feel unsure about any of the objectives, review the study material or consult your tutor.

10. When you are confident that you have achieved a unit's objectives, you can then start on the next unit. Proceed unit by unit through the course and try to space your study so that you keep yourself on schedule.

11. When you have submitted an assignment to your tutor for marking do not wait for its return `before starting on the next units. Keep to your schedule. When the assignment is returned, pay particular attention to your tutor's comments, both on the tutor-marked assignment form and also written on the assignment. Consult your tutor as soon as possible if you have any questions or problems.

12. After completing the last unit, review the course and prepare yourself for the final examination. Check that you have achieved the unit objectives (listed at the beginning of each unit) and the course objectives (listed in this Course Guide).

Tutors and Tutorials

There are some hours of tutorials (2-hours sessions) provided in support of this course. You will be notified of the dates, times and location of these tutorials. Together with the name and phone number of your tutor, as soon as you are allocated a tutorial group.

Your tutor will evaluate and comment on your assignments, keep a close watch on your progress and on any difficulties you might encounter during the course. You must mail your tutor-marked assignments to your tutor well before the due date (at least two working days are required). They will be marked by your tutor and returned to you as soon as possible.

Do not hesitate to contact your tutor by telephone, e-mail, or discussion board if you need help. The following might be circumstances in which you would find help necessary. Contact your tutor if.

• You do not understand any part of the study units or the assigned readings

• You have difficulty with the self-assessment exercises

• You have a question or problem with an assignment, with your tutor's comments on an assignment or with the grading of an assignment.

You should try your best to attend the tutorials. This is the only chance to have face to face contact with your tutor and to ask questions which are answered instantly. You can raise any problem encountered in the course of your study. To gain the maximum benefit from course tutorials, prepare a question list before attending them. You will learn a lot from participating in discussions actively.

Summary

The course, Climate Change and Development (DES 219), will expose you to the phenomenon of climate change and the economy, concepts of global warming, science of climate change, changes affecting the natural systems, key risk factors to the environment (including physical, human factors, government policies and regulatory considerations), Implications of climate change scenarios to development, global and local institutions and their efforts in curbing negative effects of climate change.

On successful completion of the course, you would have developed sufficient critical thinking skills with the material necessary for efficient and effective discussion on issues related to climate change and socio-economic development.

We wish you success with the course and hope that you will find it interesting and convenient.

MODULE ONE: THE SCIENCE OF CLIMATE CHANGE

Unit 1: Understanding Climate Change

CONTENTS

1.0 INTRODUCTION

Climate is conventionally defined as the long-term average of weather conditions, such as temperature, cloudiness, and precipitation; trends in these conditions for decades or longer are a primary measure of climate change. The climate is naturally variable. Evidence shows that throughout earth's history, there have been numerous global climate changes that were much larger than those experienced in recent times. For most of the last 500 million years, the earth was probably much warmer than it is today. Some data suggest that an increase has occurred in average temperatures at the earth's surface of as much as 1°C since the mid-1800s, with continued trends of about one to two tenths of a degree per decade in recent years (IPCC, 2001). There are considerable uncertainties and ongoing scientific debate about the reasons for such changes and what they mean for the future. Computer-run climate models used by the IPCC assign most of the cause for this trend to increases in the atmospheric concentrations of greenhouse gases, due mainly to the burning of fossil fuels.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- Understand the historical overview of Climate Change Science
- Know the causes of Climate Change
- Know the effects of Climate Change
- Also know the Steps that can be taken to reduce greenhouse gases in the atmosphere.

3.0 MAIN CONTENT

3.1 Historical Overview of Climate Change Science

To better understand the science of climate change, it is helpful to review the long historical perspective that has led to the current state of climate change. This unit starts by clarifying the concepts of climate change and global warming, then change of climate within human history using a wide-ranging subset of examples.

A related term, "climatic change", was proposed by the World Meteorological Organization (WMO) in 1966 to encompass all forms of climatic variability on time-scales longer than 10 years, but regardless of cause. During the 1970s, the term climate change replaced climatic change to focus on anthropogenic causes, as it became clear that human activities had a potential to drastically alter the climate. Climate change was incorporated in the title of the Intergovernmental Panel on Climate Change (IPCC) and the UN Framework Convention on Climate Change (UNFCCC). Climate change is now used as both a technical description of the process, as well as a noun used to describe the problem.

Climate change and global warming are terms that are sometimes used synonymously, but they have different meanings in the sense that a ‘warming” is only one phase of the larger climate system on Earth that naturally features change. Physical evidence on Earth and in space has helped scientists understand that there are many factors that can contribute to the changing of the planet’s climate on a long-term basis. Examples of these factors are solar radiation levels, Earth’s orbit around the sun, volcanic activity, ocean currents, and even plate tectonics. The periods of warming and cooling are referred to as inter-glacials and glacials, respectively, with the latter being partly characterized by enormous sheets of ice extending from the poles.

Recent periods of change within human history include the Medieval Warm Period (A.D.1000-1270) and the Little Ice Age (A. D. 1270-1850) (Singer & Avery, 2007) The history of climate change discussion among people goes farther back in time than one might think. Weart (2007) notes that climate change was conceptualized in ancient times, with knowledge of the subject growing as the technology to study it improved over time. An important figure in climate science history who warned of possible problems was Guy Stewart Callendar, whose idea of carbon dioxide as a heat trapping agent was indeed borne out by computer climate simulations in the 1970s- "Even subtle changes in the Earth's orbit could make a difference. To the surprise of many, studies of ancient climates showed that astronomical cycles had partly set the timing of the ice ages. Apparently, the climate was so delicately balanced that almost any small perturbation might set off a great shift" (Weart, 2007). More recently, Earth's climate has been studied by the Intergovernmental Panel on Climate Change, an organization made up of many scientists who specialize in climate studies. The IPCC has issued four reports over recent years that have studied the connections between human activity and climate change. One of the most recent report, "Climate Change 2007", declared that the consensus of the group is that there is 90% certainty that global warming is directly related to human greenhouse gas emissions.

SELF-ASSESSMENT EXERCISE
Provide a Detailed narrative on the term Climate Change

3.2 CAUSES OF CLIMATE CHANGE

Climate can change due to forces external to the climate system (e.g., arrangement of continents, volcanic eruptions, and changes in the intensity of sunlight). It can also change as a result of forces internal to the climate system (e.g., atmospheric composition, clouds), or because of anthropogenic (human-caused) changes (e.g., large-scale modifications of the land surface and atmospheric composition of greenhouse gases).

On the broadest scale, the rate at which energy is received from the Sun and the rate at which it is lost to space determine the equilibrium temperature and climate of Earth. This energy is distributed around the globe by winds, ocean currents, and other mechanisms to affect the climates of different regions. Factors that can shape climate are called climate forcings or "forcing mechanisms". These include processes such as variations in solar radiation, variations in the Earth's orbit, variations in the albedo or reflectivity of the continents, atmosphere, and oceans, mountain-building and continental drift and changes in greenhouse gas concentrations.

Climate change can either occur due to external forcing or due to internal processes. Internal unforced processes often involve changes in the distribution of energy in the ocean and atmosphere, for instance changes in the thermohaline circulation. External forcing mechanisms can be either anthropogenic (e.g. increased emissions of greenhouse gases and dust) or natural (e.g., changes in solar output, the earth's orbit, volcano eruptions).Whether the initial forcing mechanism is internal or external, the response of the climate system might be fast (e.g., a sudden cooling due to airborne volcanic ash reflecting sunlight), slow (e.g. thermal expansion of warming ocean water), or a combination (e.g., sudden loss of albedo in the Arctic Ocean as sea ice melts, followed by more gradual thermal expansion of the water). Therefore, the climate system can respond abruptly, but the full response to forcing mechanisms might not be fully developed for centuries or even longer.

Anthropogenic is something/anything that is made by humans. An example of something that could be considered anthropogenic are excessive greenhouse gasses. Anthropogenic Factors of the Environment**.** changes which influence the organic world and are introduced into nature by human activity. In reworking nature and adapting it to their own needs, people influence the lives of animals and plants by altering their habitats. The influence may be indirect or direct. Greenhouse gas. The vast majority of anthropogenic carbon dioxide emissions (i.e., emissions produced by human activities) come from combustion of fossil fuels, principally coal, oil, and natural gas, with additional contributions coming from deforestation, changes in land use, soil erosion and agriculture (including livestock).

3.2.1 Internal variability

Scientists generally define the five components of earth's climate system to include atmosphere, hydrosphere, cryosphere, lithosphere (restricted to the surface soils, rocks, and sediments), and biosphere. Natural changes in the climate system result in internal "climate variability". Examples include the type and distribution of species, and changes in ocean-atmosphere circulations.

A. **Ocean-atmosphere variability**

The ocean and atmosphere can work together to spontaneously generate internal climate variability that can persist for years to decades at a time. Examples of this type of variability include the El Niño–Southern Oscillation, the Pacific decadal oscillation, and the Atlantic Multi-decadal Oscillation. These variations can affect global average surface temperature by redistributing heat between the deep ocean and the atmosphere and/or by altering the cloud/water vapor/sea ice distribution which can affect the total energy budget of the earth. The oceanic aspects of these circulations can generate variability on centennial timescales due to the ocean having hundreds of times more mass than in the atmosphere, and thus very high thermal inertia. For example, alterations to ocean processes such as thermohaline circulation play a key role in redistributing heat in the world's oceans. Due to the long timescales of this circulation, ocean temperature at depth is still adjusting to effects of the Little Ice Age which occurred between the 1600 and 1800s.

B. Random forcing

From a climate perspective, the weather can be considered as being random. If there are little clouds in a particular year, there is an energy imbalance and extra heat can be absorbed by the oceans. Due to climate inertia, this signal can be 'stored' in the ocean and be expressed as variability on longer time scales than the original weather disturbances.

3.2.2 External forcing mechanisms

A. Green House gasses

The scientific consensus on climate change is "that climate is changing and that these changes are in large part caused by human activities", and it "is largely irreversible". Whereas greenhouse gases released by the biosphere are often seen as a feedback or internal climate process, greenhouse gases emitted from volcanoes are typically classified as external by climatologists. Greenhouse gases, such as CO_2, methane and nitrous oxide, heat the climate system by trapping infrared light. Human's main impact is by emitting CO_2 from fossil fuel combustion, followed by aerosols (particulate matter in the atmosphere), and the CO_2 released by cement manufacture. Other factors, including land use, ozone depletion, animal husbandry (ruminant animals such as cattle produce methane, and deforestation, are also play a role.

B. Volcanoes

Volcanoes are also part of the extended carbon cycle. Over very long (geological) time periods, they release carbon dioxide from the Earth's crust and mantle, counteracting the uptake by sedimentary rocks and other geological carbon dioxide sinks. The US Geological Survey estimates are that volcanic emissions are at a much lower level than the effects of current human activities, which generate 100–300 times the amount of carbon dioxide emitted by volcanoes. The annual amount put out by human activities may be greater than the amount released by super eruptions, the most recent of which was the Toba eruption in Indonesia 74,000 years ago.

C. **Orbital variations**

Slight variations in Earth's motion lead to changes in the seasonal distribution of sunlight reaching the Earth's surface and how it is distributed across the globe. There is very little change to the area-averaged annually averaged sunshine; but there can be strong changes in the geographical and seasonal distribution. The three types of kinematic change are variations in Earth's eccentricity, changes in the tilt angle of Earth's axis of rotation, and precession of Earth's axis.

D. Solar output

The Sun is the predominant source of energy input to the Earth's climate system. Other sources include geothermal energy from the Earth's core, tidal energy from the Moon and heat from the decay of radioactive compounds. Both long- and short-term variations in solar intensity are known to affect global climate.

E. Plate Tectonics

Over the course of millions of years, the motion of tectonic plates reconfigures global land and ocean areas and generates topography. This can affect both global and local patterns of climate and atmosphere-ocean circulation. The position of the continents determines the geometry of the oceans and therefore influences patterns of ocean circulation. The locations of the seas are important in controlling the transfer of heat and moisture across the globe, and therefore, in determining global climate. The size of continents is also important. Because of the stabilizing effect of the oceans on temperature, yearly temperature variations are generally lower in coastal areas than they are inland. A larger supercontinent will therefore have more area in which climate is strongly seasonal than will several smaller continents or islands.

3.2.4 Steps that can be taken to reduce Greenhouse Gases in the Atmosphere.

Despite remaining unanswered questions, the scientific understanding of climate change is now sufficiently clear to justify taking steps to reduce the amount of greenhouse gases in the atmosphere. Because carbon dioxide and some other greenhouse gases can remain in the atmosphere for many decades, centuries, or longer, the climate change impacts from concentrations today will likely continue well beyond the 21st century and could potentially accelerate. Failure to implement significant reductions in net greenhouse gas emissions will make the job much harder in the future both in terms of stabilizing their atmospheric abundances and in terms of experiencing more significant impacts.

Governments have proven they can work together successfully to reduce or reverse negative human impacts on nature. A classic example is the successful international effort to phase out of the use of chlorofluorocarbons (CFCs) in aerosols and refrigerants that were destroying the Earth's protective ozone layer. At the present time there is no single solution that can eliminate future warming. As early as 1992, Policy Implications of Greenhouse Warming found that there are many potentially cost-effective technological options that could help stabilize greenhouse gas concentrations. Personal, national, and international choices could have an impact; for example, driving less, regulating emissions, and sharing energy technologies could be beneficial.

Self-Assessment Exercise

List and explain any 4 causes of Climate Change

3.3 Effects of Climate Change

Climate change will affect ecosystems and human systems such as agricultural, coastal, transportation, and health infrastructure in ways that we are only beginning to understand. There will be winners and losers from the impacts of climate change, even within a single region, but globally the losses are expected to far outweigh the benefits. The larger and faster the changes in climate, the more difficult it will be for human and natural systems to adapt without adverse effects. Unfortunately, the regions that will be most severely affected are often the regions that are the least able to adapt. Bangladesh, one of the poorest nations in the world, is projected to lose 17.5% of its land if sea level rises about 40 inches (1 meter), displacing millions of people. Several islands in the South Pacific and Indian oceans will be at similar risk of increased flooding and vulnerability to storm surges. Coastal flooding will likely threaten animals, plants, and fresh water supplies. Tourism and local agriculture could be severely challenged.

Many developed nations, including the United States, are also threatened. Nations with wealth have a better chance of using science and technology to anticipate, mitigate, and adapt to sea-level rise, threats to agriculture, and other climate impacts. Adaptations could include revising construction codes in coastal zones or developing new agricultural technologies. The developed world will need to assist the developing nations to build their capacity to meet the challenges of adapting to climate change.

Climate change will likely affect human health in the future. Potential impacts include heat stress, increased air pollution, and lack of food due to drought or other agricultural stresses. Climate change can also influence the spread of infectious diseases. Temperature, precipitation, and humidity can affect the lifecycle of many disease pathogens and carriers, modifying the timing and intensity of disease outbreaks. For example, some studies have predicted that global climate change could lead to a widespread increase in malaria transmission by expanding mosquito habitat and range.

Click on: https://www.youtube.com/watch?v=M3Iztt4D2UE

Self-Assessment Exercise
Identify any effect of Climate Change around you

4.0 CONCLUSION

In this unit we can conclude that Climate generally refers to the average weather over long periods of time. The climate is affected by changes in solar energy, as well as complex interactions between the air, water, land, ice, and living world. Over billions of years, as the earth has changed, so too has the climate. One feature of earth's climate is the greenhouse effect. This effect causes the earth's surface and lower atmosphere to be warmer than it would be otherwise.

5.0 SUMMARY

In this unit, we have discussed vividly on the science of climate change such as historical overview of climate change, the causes of climate change, effects of climate change, as well as ways in which greenhouse gasses emission can be reduced.

6.0 TUTOR-MARKED ASSIGNMENTS

1. What are the causes of global climate change?

2. Explain the various effects of climate change

3. How can we reduce the emission of greenhouse gasses?

7.0 REFERENCES/FURTHER READING

Edwards, Paul Geoffrey; Miller, Clark A. (2001). Changing the atmosphere: expert knowledge and environmental governance. Cambridge, Massachusetts: MIT Press. ISBN 0-262-63219-5.

Francis, J. (2019). Rough Weather Ahead: Recent disasters show how climate change is making winter storms, flooding rains and summer heat waves more extreme, *Scientific American*, *320*, (6)46–53

Ruddiman, William F. (2005). *Plows, plagues, and petroleum: how humans took control of climate*. Princeton, N.J: Princeton University Press. ISBN 0-691-13398-0.

Wagner, Frederic H., ed. (2009). *Climate Change in Western North America: Evidence and Environmental Effects.* ISBN 978-0-87480-906-0.

McKitrick, R.R. & P.J. Michaels (2004). A test of corrections for extraneous signals in gridded surface temperature data. *Climate Research 26*(2), 159-173. *Erratum. Climate Research 27*(3): 265-268.

UNIT 2 CLIMATE CHANGE MODELS

CONTENTS

1.0 INTRODUCTION

Climate change models aim to understand the physical processes that produce climate and predict the effects of their changes and interactions. These interactions operate at different space-scales and have different response times, some simplifications are therefore required in modelling climate change. For example, atmospheric processes have time-scales of hours or a few days, whereas deep ocean processes have time-scales of hundreds of years, and these times increase up to thousands of years for the processes related to ice sheets. Therefore, there is a variety of climate models depending on the number of different processes included and the range of time intervals considered. A trade-off between these features is necessary due to limitations of computational resources. Models are developed for particular purposes and should be evaluated on that standard. Often, a simple model is adequate to explain the fundamental mechanisms of an exact process that might be unknown by the complexity of a larger model.

2.0 OBJECTIVES

At the end of this unit, students should be able to understand:

(i) The concept of feedback in its many dimensions and its importance in analysing, and attempts to model, climate.
(ii) The mechanisms by which climate changes over both long and shorter time periods.
(iii) The role in climate change of forcing agents, both natural and those deriving from human activity.

(iv) The main models that have been developed to simulate climate, how it changes historically and how it is predicted to change.

3.0 MAIN CONTENT

3.1 ENERGY BALANCE MODELS

Climate models are the energy balance models (EBMs). These models attempt to determine the evolution of surface air temperature due to changes in global radiative balance. The simplest EBM is the 0-D (zero dimensional) model, which takes the Earth as a uniform sphere. The rate of surface temperature variation is proportional to the difference between the energy received and the energy emitted by the Earth. An equilibrium temperature is attained when both received and emitted energies are equal. The emitted energy (by area unit) is given by the formula for the black body radiation, corrected by a coefficient which accounts for the absorption in the atmosphere. The received energy is the fraction of solar radiation which is not subject to that reflected by the surface (the albedo). However, the albedo is dependent on temperature, since low temperature should imply a larger snow and ice cover, thereby a larger albedo. Therefore, in order to close the model, it is needed to assume a particular form for this dependence. It is the simplest example of parameterisation in a climate model. A parameterisation is a simplified description of a case or phenomenon whose space-scale is smaller than the minimum space-scale which the model is able to resolve. Hence, a global albedo is used as an average value of albedos of different regions of the Earth. Parameterisation is a main ingredient of climate models, but the simplified descriptions on which the process depends also mean that parameterisation is dependent on the assumptions made by the modeller who creates them. Thus, parameterisation can be a source of model uncertainty.

The 0-D model is useful to estimate the global mean temperature responses to changes in radiative forcings. Above the 0-D model is the (one-dimensional) 1-D zone-averaged model. Here, the Earth is not taken as a uniform sphere, but its surface is divided by latitudinal zones. Thus, the albedo can be made dependent on latitude as well as on temperature. Besides the energy emitted to space, a transfer of energy from one latitudinal zone to its colder neighbour is also important. The energy emitted to space is parameterized as a linear function of temperature, the formula also taking into account the absorption of long-wave emitted radiation by clouds and aerosols in the atmosphere. The energy transfer to a neighbour zone is taken as being proportional to the difference between the zone temperature and a mean global temperature. Originally this model was designed to study essentially the sensitivity of the Earth's equilibrium mean temperature to changes in the terrestrial orbit around the Sun.

SELF ASSESSMENT EXERCISE
Discuss the Energy Balanced Model (EBMs)

3.2 RADIATIVE-CONVECTIVE MODELS

Radiative-convective models are other types of 1-D models. In these models the referred dimension is the altitude over ground level. Radiative is the act of emitting or radiating absorbed energy or heat back to the atmosphere). The atmosphere is resolved in a number of layers, likely of different thickness. Each layer radiates as a black body upwards and downwards. The ground radiates upwards. Each layer is characterized by absorptivity (i.e. the fraction of radiation absorbed at a given wavelength). The radiative balance of these flows results in a temperature profile along the vertical direction. However, the temperature profile obtained in this way tends to show vertical gradients exceeding the lapse adiabatic rate (i.e. the temperature gradient above which the atmosphere fails to be mechanically stable against buoyancy forces). In this situation, movements of atmospheric gases between layers transfer energy by convection to restore the stability. Thus, this energy carried by convection must be added to radiative energy in the energy balance equations. These processes are numerically simulated until a stable equilibrium state is attained.

The radiative-convective models are amenable to many improvements. Contents of layers can include different types of gases and aerosols, together with their characteristic absorptivities of radiation of different wavelengths. These models have been used for the development of schemes for cloud formation and evolution. Clouds have different and opposed effects on the climate. On one hand, clouds increase the albedo and, consequently, tend to produce a decrease of received radiation, leading to a lower mean temperature. On the other hand, clouds retain the radiation upwards from the ground, producing a greenhouse effect. These effects depend on the type of clouds, and height and size of droplets. Therefore, while the global effect of clouds is far from obvious, these radiative-convective models are the best tool to develop cloud schemes to be included in more complex climate models.

Other models are the two-dimensional (2D) models. These models can be classified into two types according to the dimensions explicitly considered. For example, these two dimensions can be latitude and longitude, neglecting altitude over the ground. These models are very useful in the simulations of large scale atmospheric movements. In the 2D models, the dimensions considered are the latitude and the altitude. For instance, over each latitudinal belt in a Budyko-Sellers model, we can consider an atmospheric column divided in vertical layers. Now, there are horizontal radiation fluxes between adjacent columns as well as vertical fluxes between layers within the same column (Figure 1.1). Equally, the convective fluxes required to restore the lapse adiabatic rate can act horizontal as well as vertically.

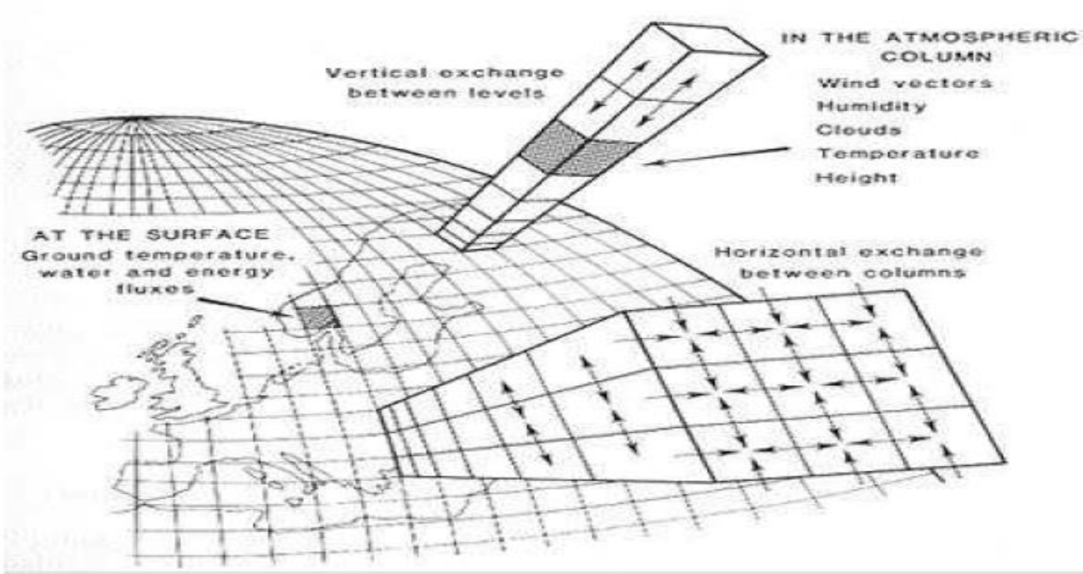


Figure 1.1 Adapted from McGuffie and Henderson-Sellers (2005)

SELF ASSESSMENT EXERCISE

Discuss different types of radiative-convective models

3.3. OCEAN MODELS

Early ocean models were designed to simulate oceanic currents. This ocean model must include three phenomena:

i) surface currents driven by winds

ii) deep currents driven by gradients of temperature and salinity

iii) tides driven by gravitational effects.

The ocean basin model is rectangular. The circulation is driven by surface winds, ocean bottom friction, pressure gradients and Coriolis force (the force that arises from the Earth moving in a rotating system). The aim of the model was to study the influence of these factors on the velocity of the surface currents. Two-box model of Stommel (Stommel, 1961) is another different kind of model. The ocean is modelled by two boxes: one corresponding to equatorial latitudes and the other corresponding to polar latitudes (Figure 1.2). Each of these boxes contains well mixed water at a given temperature T1 (Box 1), T2 (Box 2) and a given salinity S1 (Box 1), S2 (Box 2). Both boxes exchange heat and moisture fluxes, HS, with the atmosphere. The boxes are connected by pipes through which water is transferred. The strength of the fluxes between the boxes, q, is assumed to be proportional to differences of temperature as well as differences in salinity. Each box can be further divided in two vertical layers to separate surface currents from deep currents. These models can be used to study thermohaline circulation (THC) or simulate the onset of glaciations.

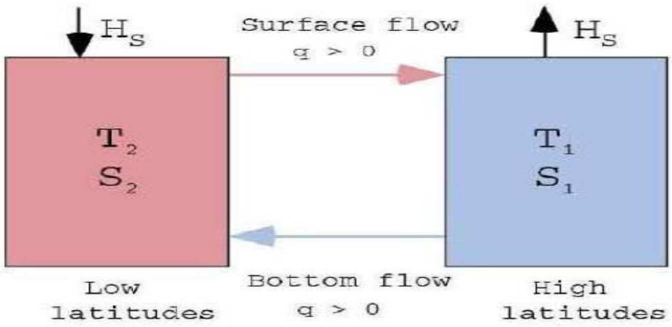


Figure 1.2: The two-box ocean model. Adapted from Marotzke (1991)

A type of Ocean models is the Simple 1-D models (similar to atmospheric radiative-convective models) which have been proposed for oceans. Figure 1.3 shows an upwelling-diffusion climate model which takes into account radiation transfers with the atmosphere. The model intends sinking of polar cold waters and convective fluxes through movement of atmospheric gases

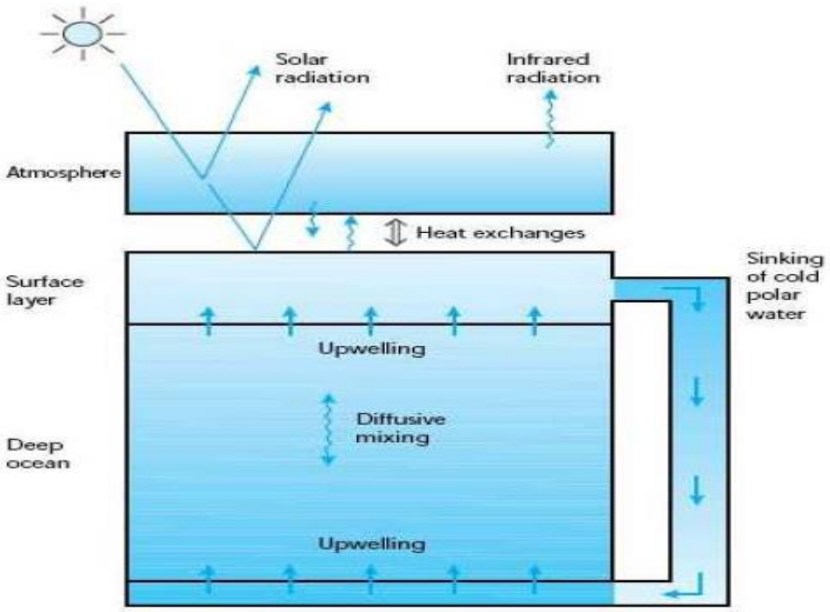


Figure 1.3 Illustration of the upwelling-diffusion climate model, consisting of a single atmospheric box, a surface layer representing both land and the ocean mixed-layer, and a deep ocean layer.

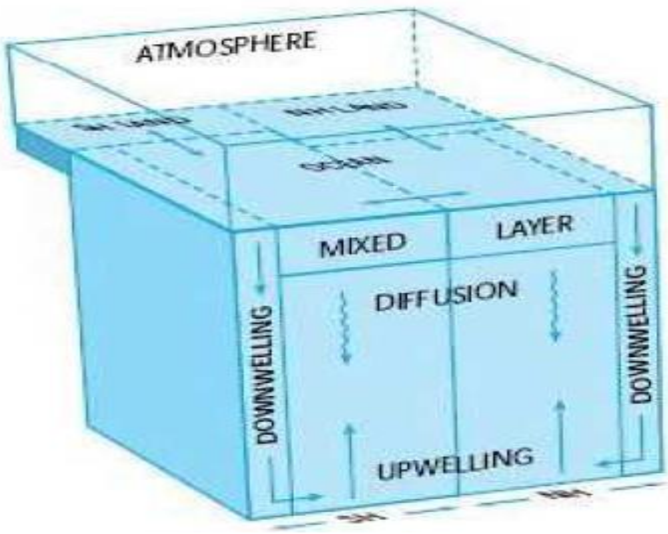


Figure 1.4 Sketch of a 2D model. Source: An Introduction to Simple Climate Models Used in the IPCC Second Assessment Report. IPCC Technical Paper 2, P28. http://www.ipcc.ch/pdf/technical-papers/paper-II-en.pdf

SELF ASSESSMENT EXERCISE

What do you understand by an Ocean Model? Discuss different types of ocean models known to you.

3.4. GLOBAL CLIMATE MODELS (GCMS)

The most complex climate models are the GCMs. The GCMs models aim at mimicking the general circulation of both atmosphere and oceans. This type of model works in all three dimensions and contemplates both dynamic (physical movement of air and waters) and thermodynamic (heat movement) features. An example of GCMs models is the Atmospheric GCMs. These models (usually referred to as AGCMs) are constructed from early models of weather forecast. They are built around a dynamical core represented by a set of mathematical equations describing the behaviour of a compressible fluid (air) on a rotating body. The variables which appear on these equations, and characterize the fluid, are the prognosis variables: wind velocities, temperature, pressure and mass components. The amount of water vapour (the most important greenhouse gas) is included in the dynamical core.

Parameterisation is one of the most important schemes for AGCMs concerns radiation. It usually incorporates daily and annual solar cycles. When a GCM is used for simulations of paleoclimates or for very long term climate forecasts, variations of the solar constant due to changes in the Earth's orbit are also included. The solar radiation is eventually absorbed or scattered by clouds, gases and aerosols. Some models also include explicitly chemical reactions in which atmospheric gases and aerosols are involved. For instance, very well-known are the effects of chorofluorocarbon (CFC) aerosol gases on the ozone stratospheric depletion.

3.4.1 Clouds and precipitation

Cloud parameterisation is one of the most debated schemes and is dependent on assumptions made by the modeller. Clouds have multiple feedback effects on the climate: they determine the flux of radiation, produce precipitation, redistribute the atmospheric mass, redistribute energy through latent heat, etc. Early schemes described statistically the cloud field and used pre-specified, empirically determined values for albedos. More recent schemes diagnose the formation and distribution of clouds from the prognosis variables of the dynamical core. These schemes deal with clouds of different forms and heights of formation (basically cumulus and stratiform clouds), and give the corresponding albedo and absorption as a function of distribution and size of the water droplets that they contain. Precipitation parameterisation is based on the modelling of the microphysical behaviour of clouds. In this scheme aerosols enter through their role as nucleation centres (particles on which water condensation occurs).

3.4.2 Boundary layer

Other atmospheric processes which have to be parameterised are the boundary layer processes. The boundary layer is the layer in direct contact with the ground, where the surface friction has a great effect on the momentum and heat fluxes. Moreover, effects of solar variations during the day are very sensitive with respect to temperature and moisture. So, these processes cannot be treated specifically even if a finer vertical resolution is used. Finally, boundary layer models need to conserve enstrophy; otherwise, the numerical schemes tend to yield a wrong energy transfer to smaller and smaller space-scales. As the computational resources allow the use of finer grids, more local processes can be included in the models. Therefore, recent AGCM models show also a good performance in weather forecasts.

3.4.3 Ocean GCMs

Early ocean models represented the oceans as a set of boxes interchanging fluxes. However, advances in computation power have led to the development of Ocean GCMs (OGCMs) comparable to the AGCMs. The dynamical core is similar to the core of the AGCMs, with water playing the role of air, and salinity that of humidity. Moreover, whereas ocean processes are generally slower than atmospheric processes, the spatial scale of the former is smaller than that of the latter – because ocean eddies have a smaller size. Thus, the dimension of grid-cells can be as small as 1º x 1º (corresponding to about 12.000 square kilometres for a cell near to the equator). In some models the grid is progressively refined for latitudes smaller than 30º in order to obtain a better resolution of processes nearer to the equator. Obviously, the grid does not span the entire surface of the Earth, but only the ocean basins. Therefore, the profile of continents must be simulated. Typical values for the number of vertical layers go from 16 to 40.

3.4.4 Modelling the Land

Land schemes include several types of soils with different uses and vegetation cover. Up to ten different types of land are considered in some models, ranging from broadleaf evergreen to glacial ice. Each soil has a parameterised albedo, inversely proportional to vegetation cover. The vegetation is also important for the balance of carbon dioxide and water vapour through photosynthesis and evapotranspiration. Recent models also include a complete carbon cycle in soils. The inclusion of the terrestrial carbon cycle introduces a new feedback into the climate system with important effects on large time scales. The subsoil is characterised by its capacity for water storage. Water in the superficial layer can be either evaporated to the atmosphere, with subsequent release of latent heat and possible cloud formation as it condenses, or filtered to deeper layers. However, when the precipitation rate exceeds the storage capacity, the excess becomes runoff which is released as fresh water in river estuaries. A good ability of models to uncover features of the present climate and observed changes during the recent past is a clear requirement and ensures that all the important processes have been adequately represented.

SELF ASSESSMENT EXERCISE

Discuss different types of GCMs models.

3.5 MODEL VALIDATION

Model validation is the ability to simulate present or recent past climates a guarantee for the accuracy of a model's projections of climate change. The dynamical cores of climate models are based on fundamental physical principles which are invariant with time. However, the parameterisations, while also based on physical laws, introduce approximations which hold in most situations but may break down in others that are quite different from current conditions. Thus, in order to validate a model, it is necessary to carry out a series of experiments to ascertain the model's response to a variation of forcings. Different models often use different schemes or parameterisations; so a convergence of results of different models gives confidence about them.

Validation can be made at both an overall system level and for a particular component or scheme level. Due to feedbacks in the model, it can be the case that a scheme tuned to certain climate processes results in a good validation for the complete system or even for a different scheme concerned with other processes. These modes of validation of climate models have changed substantially in recent years, along with the multiplication of models. The number of GCMs has increased steadily from the last decade of past century. From two models used in the First IPCC Assessment in 1990, the number mounted to 23 in the Fourth IPCC Assessment in 2007. This allows for models also to be validated by comparing one another. This has led to establishment of a Programme for Climate Model Diagnosis and Inter-comparison (PCMDI).

Climate sensitivity is an important measure of the internal feedbacks on a model. This is defined as the equilibrium global mean surface temperature change following a doubling of atmospheric CO_2 concentration. The climate sensitivity provides a simple way to quantify and compare the climate response simulated by different models to a specified perturbation. In spite of the difficulty of an exact measurement for the real climate, the climate sensitivity remains a useful concept because many aspects of a climate model scale well with global average temperature. There is considerable confidence that climate models provide credible quantitative estimates of future climate change, particularly at continental scales and above. This confidence comes from the foundation of the models in accepted physical principles and from their ability to reproduce observed features of current climate and past climate changes. Confidence in model estimates is higher for some climate variables (e.g., temperature) than for others (e.g., precipitation). Over several decades of development, models have consistently provided a robust and clear picture of significant climate warming in response to increasing greenhouse gases.

SELF ASSESSMENT EXERCISE
Discuss climate sensitivity

4.0 CONCLUSION

Many aspects of climate change may be the object of controversy, there are some basic facts that are considered well-established knowledge and on which rest the foundations of any argument in favour of global warming predictions.

(i) It is well known from classical physics that certain gases (water vapour, carbon dioxide, methane and nitrous oxide, among others) do absorb and emit significantly within the thermal infrared range. As components of the atmosphere they do that with the infrared radiation emitted from the Earth's surface. Part of this absorbed energy is re-emitted back into space, where it ultimately came from; but the other part is trapped in the atmosphere. These gases are naturally present in the atmosphere and help in maintaining the Earth's mean temperature. An increase in their concentrations has invariably a positive feedback on the atmosphere's temperature and thus on that of the Earth. Systematic instrumental measurements made all over the World in the last fifty years have detected a significant increase in the concentration of these gases in the atmosphere.

(ii) A trend towards a rise in the "atmosphere mean temperature" (0.4 to 0.8 ºC) has been observed since the beginning of the instrumental record.

(iii) Since the beginning of the industrial revolution, more than 200 hundred years ago, huge quantities of carbon sequestered in fossil fuels have been released in the form of carbon dioxide into the atmosphere as a result of human activities, altering significantly the pre-existing natural carbon cycle.

(iv) Human activities have also released into the atmosphere small particles (known as aerosols), essentially from burning fossil fuels. Some of these particles are known to reflect incoming radiation and it is presumed that a similar effect may happen when they are airborne, as far as the incoming solar radiation is concerned. Aerosols would thus have a cooling effect, something which is consistent with observed drops in temperature after volcanic eruptions. It also appears that the observed temperature rise is connected to human emissions and disruption of the pre-industrial carbon cycle, although the actual extent of the correlation is difficult to appraise, partly due to not well-assessed or yet unknown feedback processes in the climate system. What is subject to debate is the magnitude of the global warming and its impact on climate, not the fact that emissions of greenhouse gases lead to a temperature rise.

(v) In order to capture both the relationship between the previous well-established facts and the factors paramount in the climate system, climate scientist resort to what are known as climate models, which are computer-run, mathematical simulations of physical models.

5.0 SUMMARY

Climate is an extremely complex system, with a high number of intervening variables and cross-effects, many of which are still poorly known and imperfectly modelled due to the limitations of present computer power. Models are nevertheless continuously upgraded and sharpened and are presently able to represent fairly well, for example, the evolution of climate in the last 200 years. They provide a powerful instrument in the hands of climate scientists for unravelling the mysteries of the climate machinery and its future evolution in response to the human alteration of nature of global proportions.

6.0 TUTOR-MARKED ASSIGNMENTS

1. Discuss different types of models of climate
2. What are the major components of model validation?
3. Write short notes on Ocean model and Global climate models (GCMs)

7.0 REFERENCES/FURTHER READING

Spencer Weart (2008). The Discovery of Global Warming, Harvard University Press, Revised and Expanded Edition (Partial view available on Google Books).

John Houghton (2009). Global Warming: The Complete Briefing, Cambridge University Press,
4th Edition (Partial view available on Google Books).
Mark Maslin (2007).Global Warming: Causes, Effects, and the Future. Voyageur Press, 2nd Edition.
Stephen Schneider (1990). Global Warming: Are We Entering the Greenhouse Century? Lutterworth Press (Partial view available on Google Books).
S. Fred Singer and Denis T. Avery (2007).Unstoppable Global Warming: Every 1,500 Years. Rowman& Littlefield Publishers, Inc., Updated Expanded edition (Partial view available
Bjorn Lomborg (2008).Cool It: The Sceptical Environmentalist's Guide to Global Warming, Vintage, Reprint edition.Lomborg is generally referred to as a statistician, but he can be
better defined as a political scientist. He does not strictly deny global warming but criticises instead the overemphasis given
Loutre, M.F. (2002). "Climate: An exceptionally long interglacial ahead?" Science 297 (5585):
1287–8.Archer, D., Eby, M., Brovkin, V., Ridgwell, A., Cao, L., Mikolajewicz, U.,

UNIT 3: OBSERVED CLIMATE CHANGE AND FUTURE PREDICTIONS

CONTENTS

1.0 INTRODUCTION

Climate generally refers to the average weather over long periods of time. The climate is affected by changes in solar energy, as well as complex interactions between the air, water, land, ice, and living world. Over billions of years, as the earth has changed, so too has the climate. One feature of earth's climate is the greenhouse effect. This effect causes the earth's surface and lower atmosphere to be warmer than it would be otherwise. At the same time, the atmosphere also cools the surface through convection of heated air. The following chapters explore in more detail how human and natural factors affect earth's climate, and the changes that may occur over the next 100 years.

2.0 OBJECTIVES

At the end of this unit, the students should be able to:

1. Understand the observed changes in temperatures and precipitation on earth
2. Know the observed changes in the frozen parts of the earth
3. Know observed changes in the oceans and sea levels
4. Also know the Global and Regional climate projections

3.0 MAIN CONTENT

3.1 CHANGES IN CLIMATIC VARIABLES ON EARTH

3.1.1 Observed Changes in Temperatures

At any moment, temperatures on earth range from about -40 ºC to +40 ºC, but local temperatures outside of this range are not uncommon. Current estimates obtained from thermometers at ground level, as well as weather balloons and satellite records, show that the earth's average temperature has increased in recent decades, though they differ by exactly how much. Recent increases are on the scale of about one to two tenths of a degree per decade.

The global average surface temperature is estimated by averaging thermometer measurements from thousands of land stations across the earth, combined with those of sea-surface temperature from ships and buoys. Over the past 150 years there have been many changes in the kinds of equipment used, where the monitoring takes place, how many places were sampled, and so forth. Data from over the oceans has been particularly difficult to obtain. Temperature data collected for climate analysis must be adjusted to remove all influences that arise due to urbanization and other land-use changes, as well as changes in equipment, station location, and the number of operational stations over time. The resulting index indicates that average temperature has increased about 1ºC over the past 150 years.

Many weather stations continue to operate in cities or at airports, where the high concentration of buildings and human activities often causes these areas to be more than a few degrees warmer than the surrounding rural areas. This is called the urban heat island effect, and is not related to greenhouse gases. A series of studies in recent years presented evidence that as much as half the increase in the average of temperatures over land since 1980 can be attributed to a failure to fully correct for local urbanization and other land surface changes, as well as other data quality problems (de Laat and Maurellis 2004, 2006; McKitrick and Michaels 2004, 2007). In its recent report, the IPCC acknowledged these studies but dismissed the findings. However, the IPCC did not present any counterevidence.

3.1.2 Observed changes in Precipitation

There is little evidence of a strong, long term change in precipitation patterns, either globally or regionally. Precipitation has, however, changed abruptly in some areas, and it has increased slightly in many northern regions over the last 100 years. In many northern areas, rising temperatures have resulted in more wintertime precipitation falling as rain rather than snow.

SELF-ASSESSMENT EXERCISE

Provide a good explanation on noticeable changes in temperature and precipitation in your immediate environment.

3.2 Observed Changes in the Frozen Parts of the Earth

The cryosphere is the frozen part of the earth's water system, and consists of snow, river and lake ice, glaciers and ice caps, ice shelves and ice sheets, and frozen ground. The cryosphere also provides an indirect way to see the effect of climate, but since it is affected by several factors, interpretation of changes is complex. For example, a local change in ice cover (for instance, the recession of a glacier) may be due to an increase in local average temperature, but it also may be the result of changes in precipitation, local sensitivity to changing solar radiation, or a combination of the above.

3.2.1 Snow

Snow cover has decreased in most regions compared to the 1800s, especially in the spring and summer. Between 1966 and 2004, there was a decreasing trend in average Northern Hemisphere snow cover in spring and summer, but not substantially less in winter.

3.2.2 River and Lake Ice

Long-term (approximately 150-year) records show a general trend towards later freezing and earlier break-up of northern river and lake ice. There is, however, considerable variability in surveys of Canadian rivers since the late 1960s. The IPCC emphasizes that river and lake ice data must be interpreted with care.

3.2.3 Sea Ice

Since satellite measurements began in 1978, the Arctic sea ice area has steadily declined, with the rate of decrease greater in the summer than in the winter. The thickness of sea ice in the central Arctic has decreased since 1980, with most of the decrease occurring abruptly between the late 1980s and late 1990s. However, the IPCC notes that sea ice thickness is one of most difficult climate variables to measure. A study by NASA scientists, published after the IPCC report, concluded that cyclical patterns in the Arctic Ocean circulation, rather than global warming trends, explain many of the recent changes seen in the far North (Morison et al. 2007).

3.2.4 Glaciers

Glaciers are affected by changes in temperature, precipitation, and solar insolation (the amount of solar radiation received at the glacier). Data have been collected for relatively few glaciers worldwide, but of those sampled, most have been losing mass over the 20th century. The biggest losses have been in Patagonia, Alaska, northwest USA, and southwest Canada. Regional patterns are complex, and there are places where glaciers have been advancing in the past decade. The thickness of the glacier on top of Mount Kilimanjaro has not changed much over the 20th century, although the ice is retreating at the vertical walls. Solar radiation has been identified by the IPCC as the main driver of this decrease.

3.3 Observed Changes in the Oceans and Sea Levels

The ocean plays an important role in climate variability. For example, ocean currents transfer heat from one location to another, and the ocean is able to hold about 1,000 times more heat than the atmosphere. It has proven difficult to thoroughly sample the ocean. Measurements only began in the 1950s and trends are often impossible to identify due to variations in the datasets. Temperatures in some parts of the ocean are difficult to measure, and there are large regions in the Southern Hemisphere that are not well sampled. A worldwide network (www.argo.net) for sampling ocean temperatures, currents, and salinity was only completed in the fall of 2007.

3.3.1 Heat Content

The average temperature of the global ocean between the surface and the top 700 meters is estimated to have risen by 0.10ºC between 1961 and 2003. High rates of warming were observed between 1993 and 2003, but the IPCC notes that since 2003, the oceans have started to cool.

3.3.2 Salinity

Ocean salinity can decrease if fresh meltwater from the cryosphere enters the oceans. Data on salinity are sparse in some areas, particularly in the Southern Hemisphere. However, salinity has decreased in the polar areas of the Pacific, and increased in the tropical areas of the Atlantic and Indian oceans. Current observations do not provide a reliable estimate of a global average change in ocean salinity.

3.3.3 Carbon Absorption

The oceans absorb and store large quantities of carbon. The amount of carbon dioxide captured by the oceans decreased between 1970 and 1994, likely because the carbon content of the oceans themselves has increased, thus limiting their ability to absorb more carbon. This increase in carbon has led to an increase in surface water acidity, which can adversely affect some marine organisms.

3.3.4 Sea Level

Two major processes change the global mean (average) sea level: thermal expansion (the expansion of water as it warms) and the exchange of water between oceans, ice, the atmosphere, and other water reservoirs. Globally, sea levels are estimated to have risen on average by about 15 to 20 centimeters over the last 100 years, which is an increase of about 1.5 millimeters to 2 millimeters per year. Since the early 1990s, sea levels have been rising at a slightly higher rate of about 3 millimeters per year. Sea level changes are not the same globally. In some areas, the sea level is rising at several times the average rate, while in other areas sea levels are falling. While scientific knowledge of sea level changes has improved significantly, there are still uncertainties which make it difficult to understand how each of the various processes has contributed to sea level rise over the last 100 years.

SELF-ASSESSMENT EXERCISE

Proffer a detailed narrative on the situation of the Atlantic Ocean on Lagos

3.4 GLOBAL AND REGIONAL CLIMATE PROJECTIONS

The IPCC report presents many specific forecasts of changes in the earth's weather patterns over the next 100 years, based on the assumption of strong greenhouse gas-induced warming.

3.4.1 Global Climate Projections

a. Temperature: Depending on which of several scenarios of future global greenhouse gas concentrations is used, climate models project that average temperatures could increase from a minimum of 1.1ºC to a maximum of 6.4ºC. The same models also predict that greenhouse gases will cause warming in the tropical troposphere to be about double the warming at the surface. As of the present, this has not been observed. In most available data series, the troposphere appears to be warming less than the surface.

b. Precipitation: Evaporation and precipitation are expected to increase in a warmer climate. The models predict that precipitation will increase in the tropics and at the poles, and decrease in the subtropics and middle latitudes. The intensity of precipitation is projected to increase, particularly in tropical areas and at the poles.

c. Snow and ice: Current models show a wide range in the response of Northern Hemisphere sea ice to temperature increases, from very little change to a strong accelerating reduction over the 21st century. Antarctic sea ice is projected to decrease more slowly than in the Arctic. Models project an overall decrease in glacier volume, but there is uncertainty in how to estimate future changes. In general, snow cover area and the total amount of snow is projected to decrease in the Northern Hemisphere, with increases in a few regions.

d. Sea levels: Depending on the emissions scenario, the average sea level is projected to rise between 18 cm and 59 cm. This will be due mostly to thermal expansion, though melting of glaciers, ice caps, and the Greenland ice sheet is also projected to contribute to the rise.

e. Tropical cyclones: Models that examine tropical cyclones on a large scale predict a decrease in the total number of tropical cyclones and little to no change in the intensity (strength) of individual cyclones on average. On the other hand, models that examines tropical cyclones at a higher resolution and on a smaller scale project that tropical cyclones will become more intense.

3.4.2 Regional Climate Projections

New sources of uncertainty and complexity arise when attempting to project climate changes at local and regional levels. General projections of regional changes are summarized in the IPCC report; however, at this time, the uncertainties in regional projections are substantial.

SELF-ASSESSMENT EXERCISE

Discuss the importance of these projections to the understanding of Climate Change studies

4.0 CONCLUSION

In this unit it is clear that the climate is naturally variable. Evidence shows that throughout earth's history, there have been numerous global climate changes that were much larger than those experienced in recent times. While predictions of climate change 50 or 100 years from now cannot be reliably made, it is plausible that further increases in greenhouse gas levels this century will have an overall warming influence on the climate.

5.0 SUMMARY

In this unit, we have discussed extensively on observed climate change and future projections especially observed changes in temperatures, precipitation, observed changes in the frozen parts of the earth, in the oceans and sea levels as well as global and regional climate projections.

6.0 TUTOR-MARKED ASSIGNMENTS

1. What are the observed changes in global temperatures and precipitation over the past 100 years?
2. What are the observed changes in the frozen parts of the earth?
3. What are the observed changes in the oceans and sea level over the last decades?
4. What are the likely future global and regional climatic conditions?

7.0 REFERENCES

De Laat, A.T.J. and A.N. Maurellis (2004). Industrial CO2 emissions as a proxy for anthropogenic influence on lower tropospheric temperature trends. Geophysical Research Letters 31: L05204, doi:10.1029/2003GL019024.

De Laat, A.T.J. and A.N. Maurellis (2006). Evidence for influence of anthropogenic surface processes on lower tropospheric and surface temperature trends. International Journal of Climatology 26:897-913.

Goddard Institute for Space Studies (2007). Zonal-mean annual land-ocean temperature index.Digital data available online at http://data.giss.nasa.gov/gistemp

McKitrick, R.R. and P.J. Michaels (2007). Quantifying the influence of anthropogenic surface processes and inhomogeneities on gridded global climate data. Journal of Geophysical Research—Atmospheres 112: D24S09, doi:10.1029/2007JD008465.

McKitrick, R.R. and P.J. Michaels (2004). A test of corrections for extraneous signals in gridded surface temperature data. Climate Research 26(2): 159-173. Erratum. Climate Research 27(3): 265-268.

Morison, J., J. Wahr, R. Kwok, and C. Peralta-Ferriz (2007). Recent trends in Arctic Ocean mass distribution revealed by GRACE. Geophysical Research Letters 34: L07602, doi:10.1029/ 2006GL029016.

UNIT 4: GLOBAL WARMING

CONTENTS

1.0 INTRODUCTION

Global warming is the long-term rise in the average temperature of the Earth's climate system. It is a major aspect of current climate change discourse, and has been demonstrated by direct temperature measurements and by measurements of various effects of the warming. The term commonly refers to the mainly human induced factors that cause increase in global surface temperatures and its projected continuation. In this context, the terms global warming and climate change are often used interchangeably, but climate change includes both global warming and its effects, such as changes in precipitation and impacts that differ by region.There were prehistoric periods of global warming, but observed changes since the mid-20th century have been much greater than those seen in previous records covering decades to thousands of years. This unit discusses the current evidence of global warming its relation to climate change.

2.0 OBJECTIVES

After studying this unit, you should be able to:

- understand the current evidence for global warming
- understand the current warming in relation to climate changes throughout the Earth's history
- explain factors forcing climate change, and the extent of anthropogenic influence

3.0 MAIN CONTENT

3.1 ESCALATING TEMPERATURES

Figure 1.5 shows that global temperatures have increased over the last 120 years, in spite of year to year, or even decadal decreases, as happened in the period 1940–1960.

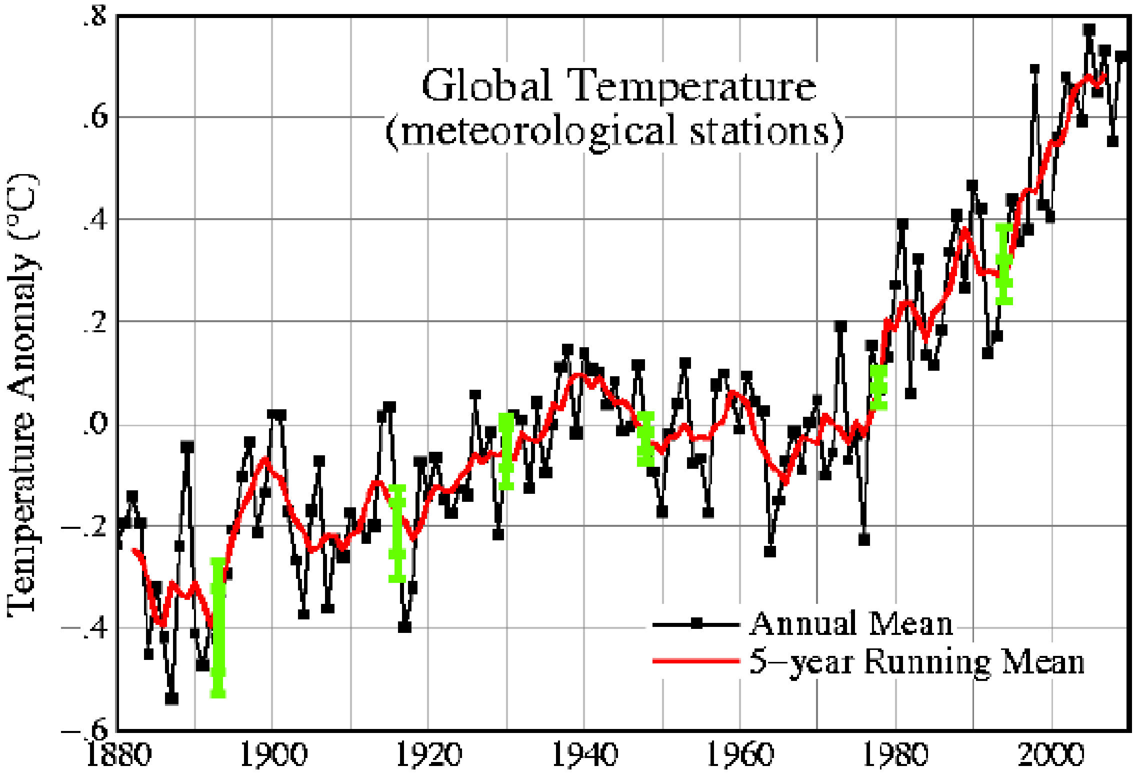


Figure 1.5: Graph of global annual surface temperatures relative to 1951–1980 mean temperature (Air and ocean data from weather stations, ships and satellites).
Source: http://data.giss.nasa.gov/gistemp/graphs/

Instrumental measurements starting around the middle of the 19th century plus the extrapolations made on values of temperatures in previous centuries lead to the conclusion that never in the last millennium have temperatures shown such a high rate of increase. But temperatures and mean precipitations do not only go up but also show more variability over the planet in the last one hundred years. Important differences between land and sea, between different regions, between seasons, or even between day and night constitute a natural phenomenon. What characterizes the last hundred years is that those differences are becoming superior to the statistical variability. Winters are warming faster than summers. This is mostly prominent in Eastern and Southern Europe, where the number of cold days has notably reduced while days with suffocating temperatures are more frequent (See Figure 1.6).

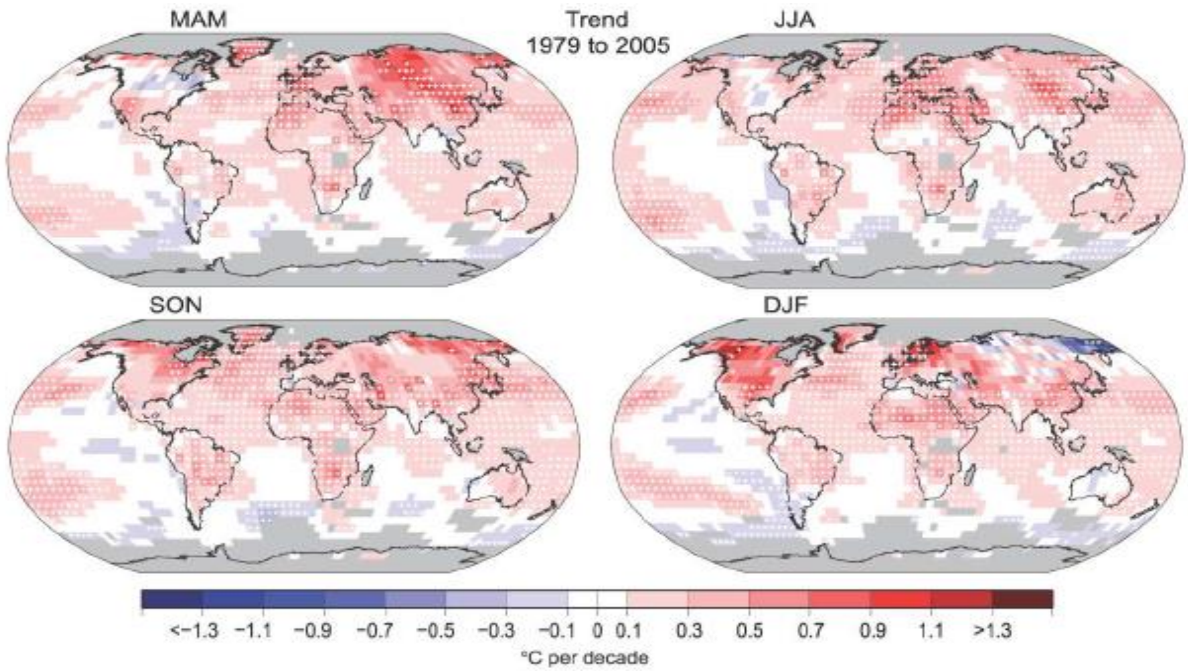


Figure 1.6: Linear trend of seasonal March-April-May (MAM), June-July-August (JJA), September-October-November (SON) and December-January-February (DJF) temperature for 1979 to 2005 (°C per decade).
Source: IPCC Fourth Assessment Report, Surface and Atmospheric Climate Change.

This global warming is not only detected in thermometer readings all over the world. There is much evidence coming from other sources.

SELF ASSESSMENT EXERCISE
Briefly discuss escalating temperatures.

3.2 PRECIPITATIONS

In meteorology, precipitation is any product of the condensation of atmospheric water vapour that falls under gravity. The main forms of precipitation include drizzle, rain, sleet, snow, graupel and hail. Evaporation goes with the scaling up of temperatures. It accounts for the 2 percent rise in precipitations that has been observed over the last one hundred years. But this is not good news because the beneficial effect is mitigated by the large regional differences. Observations show that changes are occurring in the amount, intensity, frequency and type of precipitation. These aspects of precipitation exhibit large natural variability, and El Niño and changes in atmospheric circulation patterns such as the North Atlantic Oscillation have a large influence. Pronounced long term trends from 1900 to 2005 have been observed in precipitation amount in some places: significantly wetter in eastern North and South America, northern Europe and northern and central Asia, but drier in the Sahel, southern Africa, the

Mediterranean and southern Asia. More precipitation now falls in the form of rain instead of snow in northern regions. Widespread increases in heavy precipitation events have been observed, even in places where total amounts have decreased. These changes are associated with increased water vapour in the atmosphere arising from the warming of the world's oceans, at lower latitudes. There are also increases in some regions in the occurrences of both droughts and floods".

Oceans levels and temperatures also have been rising since the end of the 19th century and the trend has been accelerating, starting in the early 1990s. In some locations, part of this change may be due to natural causes. But, the alterations observed at the planetary scale cannot but be connected to global warming. Instrumental readings lead to an estimate of 0.6ºC for the global increase since 1860. However, that warming is unfairly distributed. Ocean dynamics and local conditions induce differences in warming among the different seas. The North Atlantic has been warming less than the North and Baltic Seas, due to influences from the Arctic and the Ocean Conveyor Belt. Sea levels have increased up to 25 cm in some places. The extent of the phenomenon varies locally, as happens with tides, and depends on many factors, such as sea floor topography, irregularity of the coast line, land subsidence (as in Bangladesh) or isostatic land rises. Narvik, in Northern Norway, registers a 3mm rise per year, while Marseille, on the French Mediterranean Coast, 1mm/year. Surface water expands as a result of climbing temperatures. Expanding sea water then readjusts itself vertically as it is constrained by the continental limits of oceanic basins. Moreover, melting continental ice packs contribute further to ascending sea level, but by a much smaller amount. The trend has gained momentum since the early 1990s. Due to its thermal inertia sea water has been warming much less than the atmosphere. That means that even if temperatures are someday stabilised, the oceans will continue to show noticeable effects, and, in particular, they will continue their expansion.

Most glaciers in the World are melting. In fact, the process has been particularly marked since the beginning of the 20th century. In the course of the last hundred years Mounts Kenya and Kilimanjaro, for example, have lost 92 percent and 82 percent of their glaciers, respectively. The melt is too fast in order to invoke global warming as the ultimate cause. The melt was already apparent well before global warming started to be significant (Figure 1.7).

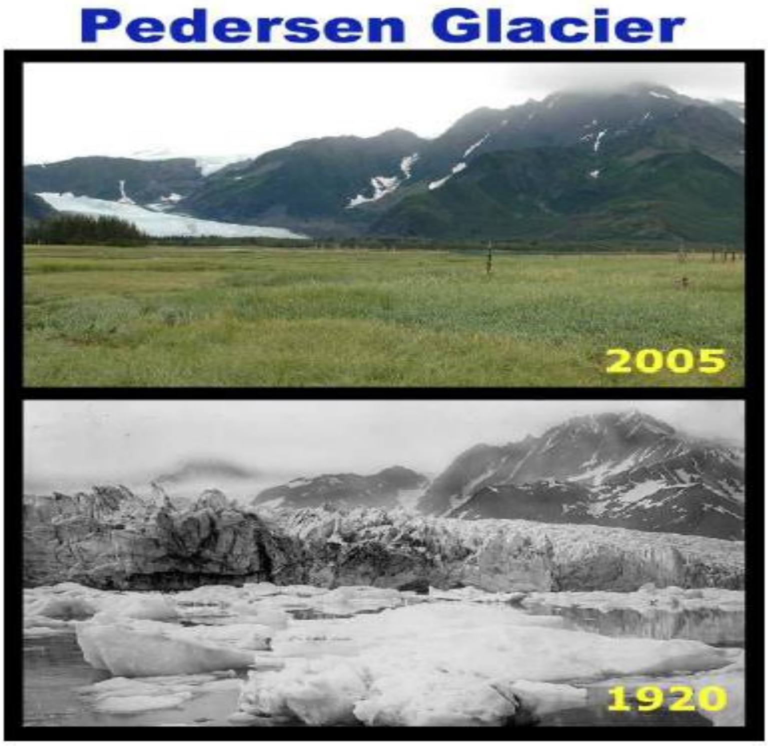


Figure 1.7 Pictures of a melting glacier (Pedersen Glacier Kenai Fjords National Park, Alaska) in 1920 and 2005. Source: Global Warming Art, http://www.globalwarmingart.com/wiki/File:Pedersen_Glacier_jpg.

SELF ASSESSMENT EXERCISE

Write short note on precipitation.

3.3 THE ENERGY BUDGET

Past climatic events have left their mark on the Earth's surface. Research on these footprints has shown that climate has undergone many changes during the Earth's history. With sophisticated and complex techniques, scientists have been able to proceed to a reconstruction of the history of the climate of our planet. The reconstruction of the recent past is certainly more accurate and reliable than that of the distant past, being related to the availability of pieces of evidence where transformations of the Earth's crust remove with time. Paleoclimatology has nevertheless allowed us to have a pretty good image of the last 800,000 years, due to air bubbles trapped in the Greenland and Antarctic ice packs, while little is known of how climate was and evolved 500 million years ago. What we know is nonetheless more than enough to convince us of the existence of both colder and hotter periods than the present – both types thriving with life – and also of transitions between those extreme types. What is singular to the present rise of temperatures is that there is a consensus of the scientific community linking it specifically to human activities, particularly, to the burning of fossil fuels. On the other hand, it poses a threat to life and our present civilisation.

So the question can be asked as to why human activities are behind the temperature switch? The answer lies in the modifications brought about by the flow of energy throughout the climate system by gases emitted from burning fuels: the so-called greenhouse gases.

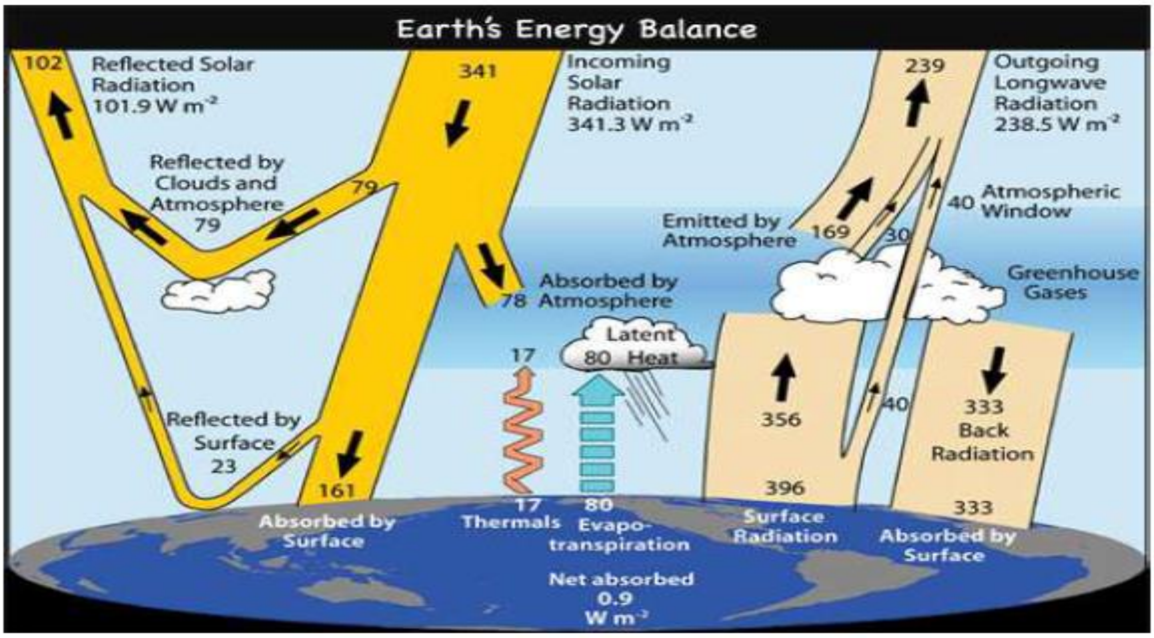


Figure 1.8 Estimate of the Earth's annual and global mean energy balance.
Source: IPCC Fourth Assessment Report, chapter 1, Historical Overview of Climate Change Science.
http://www.ipcc.ch/publications_and_data/ar4/wg1/en/faq-1–1.html.

The flows of energy to which we refer to are shown in Figure 1.8. The latest estimations show that the Earth receives at the top of the atmosphere (TOA), in the form of shortwave radiation is directly returned by both the atmosphere and the planet's surface. Consequently, constitutes the absorbed solar radiation (ASR) by the planet, which sets the atmosphere and oceans into motion and thus defines climate. This absorbed energy follows a course of transformations and of complex exchanges between the climate agents. Figure 1.8 outlines the major features of this energy flow. This energy cannot remain on Earth. Otherwise, the planet would be heating up to untenable levels. In fact, it is returned to the outer space in form of long wave radiation – outgoing (infrared) long wave radiation (OLR). As shown in Figure 1.8, it is estimated that at the TOA the outgoing radiation is 238.5 W/m2. This means that 0.9 W/m2 are not returned to the outer space: they have been captured by the Earth's atmosphere. The result is that the Earth is heating up and thus temperatures are rising.

SELF ASSESSMENT EXERCISE

Why are temperatures rising? Why is this so worrying if variability is intrinsic to climate?

3.4 RADIANT ENERGY AND TEMPERATURES

The fundamental difficulty of trying to understand what is behind the energy imbalance and the ensuing temperature rise can now be addressed. A discussion of incoming and outgoing short wave and long wave radiation has ensued. What do we mean by that? Energy is known, and traded, in a number of different forms. We have heard about the epithets thermal, mechanical, chemical, electrical, elastic, nuclear, and so on, when referring to energy. The Earth, taken as a whole, which means including its atmosphere, exchanges energy with the outer space almost exclusively through a single form: radiant or light energy, that is, in the form of electromagnetic waves. This radiant energy is intrinsic to all bodies whose temperature is above the absolute zero on what is called the Kelvin (K) scale (0ºK which = –273ºC). For the simple fact of having a temperature above the absolute zero, a body emits light in a way which has been known to physics since the 19th century: the black body radiation. Moreover, it turns out that black body radiation provides us with a set of very precise working equations that relate the temperature of an object to the light it emits. A blackbody radiates energy at every wavelength although the intensity at which a given wavelength is emitted depends on the temperature of the body. If we draw the intensity at which a wavelength is emitted in terms of wavelengths we obtain a bell-shaped, universal curve: the theoretical black body curve at a given temperature, also known as the black body spectrum. Figure 1.9 depicts four examples at different temperatures (in degrees Kelvin). We observe that the peak decreases in magnitude and shifts its position to the longer wavelengths region as the temperature lowers. It means that the light emitted by very hot bodies (> 7,000 K) is essentially ultraviolet light (short wave radiation). As the body becomes colder (in the range 4,000 K – 7,000 K) most radiant energy is in the form of visible light, or infrared light (long wave radiation) for temperatures below 4,000 K.

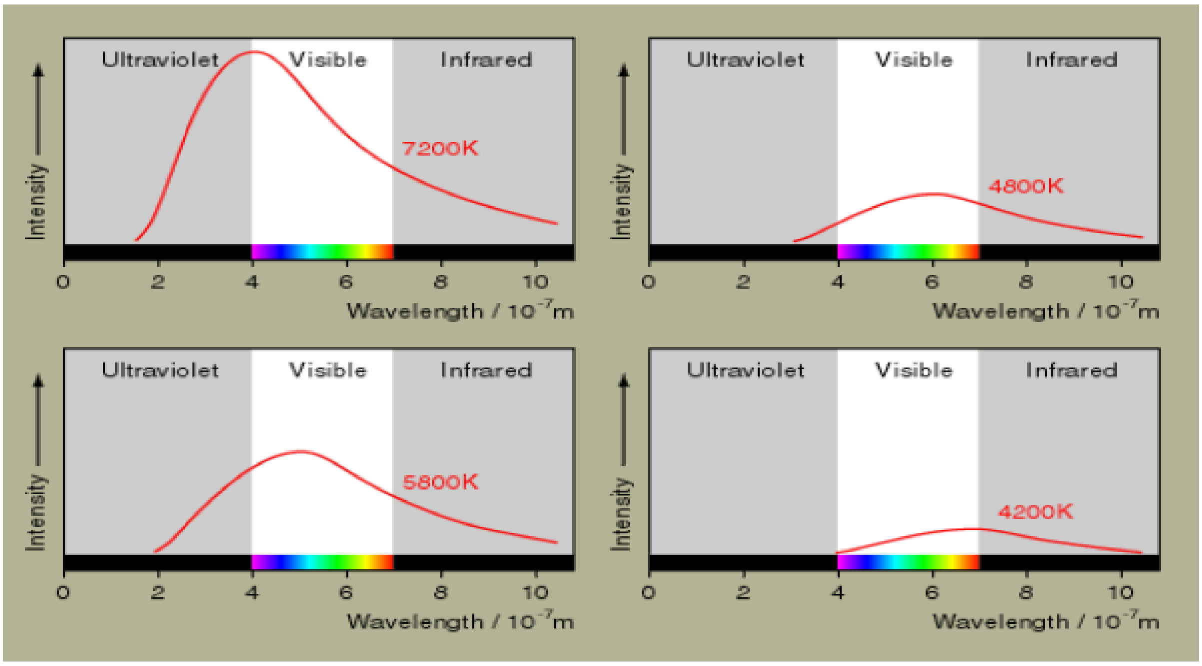


Figure 1.9: Displacement of the blackbody radiation spectrum with decreasing temperature (in ºK). Hotter objects emit preferably in the short wavelength window and, as a body becomes cooler its emission shifts to longer wavelengths (lower frequency and less energetic light).
Source: Education Resources of the Hong Kong Space Museum, http://www.lcsd.gov.hk/CE/Museum/Space/EducationResource/Universe/framed_e/lecture/c h05/ch05.html

The temperature of the outer, visible part of the Sun (the photosphere) is approximately 5,700 K. The peak is consequently in the visible range. This is why we see the Sun shine. On the other hand, the mean temperature of the Earth is 288 K (15 ºC). The Earth radiates in the infrared range. This is why our planet does not "shine", though that does not mean that it does not radiate light: its light is simply not visible; it is instead sensed as plain heat.

SELF ASSESSMENT EXERCISE
Write short notes on radiant energy and temperatures

3.5 GREENHOUSE GASES

All gases which absorb infrared radiation are greenhouse gases: water vapour, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ozone (O_3) and man-made molecules such as fluorinated gases or halocarbon compounds. The efficacy with which a gas contributes to the greenhouse effect depends on both its concentration in the atmosphere and its capacity to absorb infrared light.

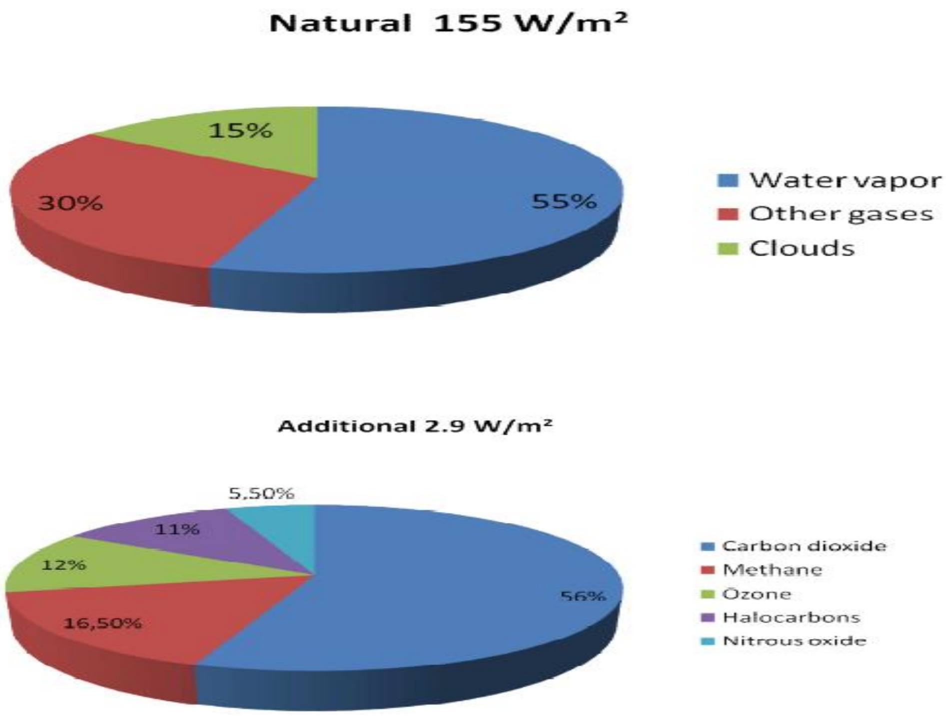


Figure 1.10: (Top) Relative contributions of some of the natural components of the atmosphere to radiative forcing (i.e. the contribution to the greenhouse effect). (Bottom) Man-made contribution to radiative forcing for main greenhouse gases; percentages denote the contribution for each type of gas – not to be confused to the actual concentration for that gas in the atmosphere.

Figure 1.10 shows the figures for the contribution of each of these agents. The top chart refers to the natural contribution. Here, water vapour accounts for more than half of the total, while other gases (including naturally present carbon dioxide) account only for 30%. The bottom chart displays the added contributions, which result from human activities. Carbon dioxide collects the major part. Currently, methane amounts to 16.5% of the effect, which is a share in clear disproportion to its actual concentration. Its impact, molecule by molecule, is several times more powerful than that of carbon dioxide and it represents a potentially very dangerous source given the huge quantities of trapped methane that can be released if temperatures continue to rise.

Seasonal variations in annual cycle are due to the growth of vegetation during the warm season, which retrieves through photosynthesis CO_2 from the atmosphere, while the decomposition of that same vegetation during the cold season releases CO_2. These oscillations for the CO_2 concentration follow the seasonal fluctuations of the Northern Hemisphere due to higher concentration of continental landmasses in that hemisphere. This accumulation of carbon dioxide is the result of two hundred years of the combustion of fossil fuels – coal, oil and gas – which were produced years ago as the result of the burial by sediments of plants and animals in anaerobic conditions. This CO_2 accumulation is happening at an ever increasing pace: in the decade 1998–2008 carbon emissions rose by an average of 2.5 percent – nearly four times as fast as in the 1990s. It has been estimated that about fifty percent of anthropogenic carbon dioxide ever emitted has been removed from the atmosphere. In spite of that, its atmospheric concentration continues to rise. In the short term, the efficiency of oceans as CO_2 sinks may be weakened by global warming, as the gas solubility in water decreases with temperature.

Water vapour is the most important greenhouse gas. It produces more atmospheric warming than any other gas, even if a water molecule is less efficient in absorbing infrared radiation than a CO_2 molecule. The equilibrium vapour pressure of liquid water, and correspondingly the maximum amount of water in the atmosphere, augments exponentially with temperature. If this is a well-known physical fact, the consequences are not so clear. As a result, the infrared thermal radiation redirected by water vapour will consequently be boosted by the global warming produced by other gases (and itself), and temperatures will rise more. But, on the other hand, cloud formation will be stimulated in a vapour rich atmosphere, and clouds are known to have a mixed effect on infrared thermal radiation. Water in the form of liquid droplets also absorbs infrared thermal radiation. Depending on their type, clouds behave differently with respect to incoming solar radiation. In a simple term, it can be said that low altitude clouds do usually reflect solar radiation, and allegedly cool the atmosphere, while high altitude clouds, on the contrary, show the opposite behaviour and warm it. However, our understanding of clouds and their effect on global warming and climate is incomplete. It is still not obvious if a higher atmospheric vapour content will have a positive or a negative influence on global warming.

SELF-ASSESSMENT EXERCISE

Proffer reasons why CO_2 is most mentioned among other Greenhouse in Climate Change scenario

4.0 CONCLUSION

The effects of global warming include rising sea levels, regional changes in precipitation, more frequent extreme weather events such as heat waves, and expansion of deserts. Surface temperature increases are greatest in the Arctic, which has contributed to the retreat of glaciers, permafrost, and sea ice. Overall, higher temperatures bring more rain and snowfall, but for some regions droughts and wildfires increase instead. Climate change threatens to diminish crop yields, harming food security, and rising sea levels may flood coastal infrastructure and force the abandonment of many coastal cities. Environmental impacts include the extinction or relocation of many species as their ecosystems change, most immediately the environments of coral reefs, mountains, and the Arctic. Due to the persistence of CO_2 in the atmosphere and the inertia of the climate system, climatic changes and their effects will continue even if carbon emissions are stopped. Possible societal responses to global warming include mitigation by emissions reduction, adaptation to its effects, and climate engineering.

5.0 SUMMARY

Global warming has reached a level such that we can attribute with a high degree of confidence a cause and effect relationship between the greenhouse effect and the observed warming. Public attention increased over the year, and global warming became the dominant popular term, commonly used in public discourse. This unit discusses global warming and its effects on planet earth. The unit discusses different causes of global warming and its evolvement over the years. The unit concluded by stating that the effects of global warming include rising sea levels, regional changes in precipitation, more frequent extreme weather events such as heat waves, and expansion of deserts.

6.0 TUTOR-MARKED ASSIGNMENT

1. Define global warming and discuss different causes of global warming
2. What are the effects of greenhouse gases on our planet earth?
3. Write short note on the energy budget.

7.0 REFERENCES/FURTHER READING

Spencer Weart (2008). The Discovery of Global Warming, Harvard University Press, Revised and Expanded Edition (Partial view available on Google Books).

John Houghton (2009). Global Warming: The Complete Briefing, Cambridge University Press, 4th Edition (Partial view available on Google Books).

Mark Maslin (2007). Global Warming: Causes, Effects, and the Future. Voyageur Press, 2nd Edition.
Stephen Schneider (1990). Global Warming: Are We Entering the Greenhouse Century? Lutterworth Press (Partial view available on Google Books).

S. Fred Singer and Denis T. Avery (2007). Unstoppable Global Warming: Every 1,500 Years.
Rowman& Littlefield Publishers, Inc., Updated Expanded edition (Partial view available
Bjorn Lomborg (2008). Cool It: The Skeptical Environmentalist's Guide to Global Warming, Vintage, Reprint edition. Lomborg is generally referred to as a statistician, but he can be
better defined as a political scientist. He does not strictly deny global warming but criticises instead the overemphasis given
Loutre, M.F. (2002). "Climate: An exceptionally long interglacial ahead?" Science 297 (5585):
1287–8.

MODULE TWO: ECONOMICS OF CLIMATE CHANGE

UNIT 1: CLIMATE CHANGE AND ECONOMIC DEVELOPMENT

CONTENTS

1.0 INTRODUCTION

This unit introduces you to the central importance of economic analysis and issues on climate change and development. Climate change impacts can be measured as an economic cost. This is particularly linked to market transactions and therefore directly affects economic growth (GDP). Monetary measures of non-market impacts, such as impacts on human health and ecosystems, are more difficult to calculate. However, attempting to quantify the economic costs of global warming as a percentage of GDP has its inherent problems because it omits the ecological effects of climate that are difficult to associate with a monetary value such as loss of human life or biodiversity, or those effects that will have economic consequences later on. Most economic studies looking at the effects of climate change have suggested that climate change does negatively affect the global economy, though the issue remains intensely debated. This unit gives a broad discussion on climate change and development and various issues related to it.

2.0 OBJECTIVES

After studying this unit, you should be able to:

1. Identify the key concepts of externalities and market failure and how minimize their adverse effects
2. Have a basic understanding of alternative approaches to the economics of climate change.
3. Use your knowledge and understanding to engage with others on issues surrounding climate change and economic development.

3.0 MAIN CONTENT

3.1 THE EXTERNALITY FRAMEWORK

Climate change, energy, technology and the economy are closely related. The dominant model of the economy is predicated on growth of economic activity which requires resources and technology to enact transformations into goods and services needed for consumption. The bulk of useful energy is globally generated through burning of fossil fuels (oil, coal, gas), which releases their stored energy as heat. Some economic literature describes climate change as the greatest market failure the world has ever seen. Market failure is the economic situation defined by an inefficient distribution of goods and services in the free market. In this situation a deliberate government policy is required to ensure efficient allocation of resources. Externality, a form of market failure is the effect of economic activities of a particular economic agent on the welfare of a bystander. It occurs when one person's actions affect another person's well-being and the relevant costs and benefits are not reflected in market prices. A positive externality arises when my neighbours benefit from my cleaning up my yard. If I cannot charge them for these benefits, I will not clean the yard as often as they would like. (Note that the free-rider problem and positive externalities are two sides of the same coin). A negative externality arises when one person's actions harm another. When polluting, factory owners may not consider the costs that pollution imposes on others.

The framework of "externalities"—a form of market failure— has been employed to conceptualize climate change. This conceptualization has two implications; the first is about the overall coverage of climate change. This explains how the policy debate about global warming is an example of economists engaging in "normative economics" to study what the goals of economic policy should be. Secondly, the externality framework focuses on the idea that societies do not pay the "true" costs of burning fossil fuels. This is based on the assumption that the optimal level of pollution should not be zero, but should be determined by using marginal analysis to compare the benefits and costs of emissions. Once we know the optimal emission level, the economic solution is to "internalize" the externalities, leaving market forces to achieve the policy goal. In the case of climate change, this means putting a price on carbon. In this regard, the key message is that incentive-based regulations are more efficient than command-and-control regulations. If the physical science of manmade global warming is correct, then policymakers are confronted with a massive negative externality. When firms or individuals embark on activities that contribute to greater atmospheric concentrations of greenhouse gases, they do not take into account the potentially large harms that their actions impose on others. As Chief Economist of the World Bank Nicholas Stern stated in his famous report, climate change is "the greatest example of market failure we have ever seen.

The two most common incentive-based regulations are: tradable emission rights (cap-and-trade) and Pigouvian tax. Besides tradable pollution rights and Pigouvian taxes, there is also the Coase Theorem, in which property rights serve as a powerful tool to solve environmental problems. However, many economists have concluded that a cap-and-trade system would not be the best way to curb CO_2 emissions and "most economists, regardless of political philosophy, believe that a carbon tax is an easier and more transparent and efficient solution than cap-and-trade". The policy discussions in this case were often significantly outdated. It does not provide any exposure to the real-world climate policies in effect. For example, in California, which started its cap-and-trade programme in 2013 and recently extended it beyond 2020; in China, which has piloted regional carbon markets since 2013 and established a national system in 2017; or in British Columbia, which has had a carbon tax since 2008?

SELF ASSESSMENT EXERCISE
Discuss the concept of market failure and externality within the context of climate change.

3.1 CLIMATE CHANGE BEYOND EXTERNALITIES

The externality framework provides a coherent and powerful way to think about the climate. But such an all-encompassing issue also intersects with many other economic theories and practical concerns. This section discusses various useful points of engagement used for climate change beyond the typical externalities and environmental economics.

3.1.1 GDP Accounting, Economic Growth and Climate Change

Climate change is as much a macroeconomic issue as a microeconomic one. The externality framework, however, mostly features in the micro section, leaving climate issues absent in the macro section. The framework of GDP accounting is a natural place to bring climate change into the macroeconomic curriculum. GDP accounting leads us to the topic of economic growth and carbon emissions can be taken into account. There are lots of arguments on whether economic growth is compatible with fighting climate change. Many scholars reject the Malthusian view on the limits to growth. For example, Krugman and Wells (2015) argue that long-run economic growth and curbing greenhouse gas emissions can go hand in hand. The connection between growth and environment is tenuous as argued by some economic growth proponents. Increases in economic growth need not mean increases in pollution; limiting growth is the wrong solution. Growth has allowed economies to reduce pollution, be more sensitive to environmental considerations..." On the other hand, a few authors are more cautious about the desirability of economic growth. They stress that the type of economic growth matters, as shown in the following quotes:

"Yet the desirability of further economic growth for a society that is already quite wealthy has been questioned on several grounds." "Growth has costs, and economics requires us to look at both costs and benefits of growth, the wrong type of growth may produce undesirable side effects, including global warming and polluted rivers, land, and air." Economic growth occurs when there is an increase in the production of goods and services in the country. That is an increase in gross domestic product. This can only occur when resources are efficiently utilized. That is when there is production efficiency, consumption efficiency and economic efficiency.

Economics can yield valuable insights to examine climate change through the lens of collective action. Colander (2013) and Hall and Lieberman (2013), note that international actions are constrained by the free-rider problem. A free-rider problem is when resources are consumed without paying appropriate price by the user. The free rider problem is an issue in economics. It is considered an example of a market failure. That is, it is an inefficient distribution of goods or services that occurs when some individuals are allowed to consume more than their fair share of the shared resource or pay less than their fair share of the costs. Free riding prevents the production and consumption of goods and services through conventional free-market methods. To the free rider, there is little incentive to contribute to a collective resource since they can enjoy its benefits even if they don't. As a consequence, the producer of the resource cannot be sufficiently compensated. The shared resource must be subsidized in some other way, or it will not be created. Colander argues that climate actions often fall short: “Because there is no world government that can force countries to comply with any global effort to address carbon emissions, any policy has to be voluntary, making it easy for one country to opt out (free ride).” From another angle, Parkin (2016) describes cutting global carbon emissions as a “prisoners’ dilemma” and notes that the Nash equilibrium is for all countries to keep increasing their emissions even though everyone would be better off if everyone cut their emissions. There is also the issue of “the tragedy of the commons”: that individual’s self-interested behaviours can lead to the demise of common goods such as the climate. While relating climate change to the tragedy of commons, for example, Chiang (2014) cites Ostrom to suggest that tragedy is not always the destiny: when certain institutional conditions are met, user management of common pool resources is typically successful.

SELF ASSESSMENT EXERCISE

Discuss the phenomenon of externality resulting from climate change and how it affects economic efficiency.

3.3 ECONOMIC FACTORS SURROUNDING GLOBAL WARMING

The phenomenon of global warming has generated huge concerns today due to its impact on resource availability. It refers to a gradual increase in the overall temperature of the earth's atmosphere generally attributed to the greenhouse effect caused by increased levels of carbon dioxide, CFCs, and other pollutants. This has severe implications for the world population in attaining sustainable development. This is perhaps why scholars have committed to suggesting was in curbing its effects.). For example, Nicholas Stern, a former vice president of the World Bank, estimated the economic costs of dealing with global warming (Stern Review on the Economics of Climate Change, Oct 30, 2006). According to him, it would cost 1% of global economic activity in 2050 to cut CO_2 60%–80% below 1990 levels. The costs would be 5 to 20 times higher if we didn’t act now. The worst effects of climate change could be avoided by 4% of gross domestic product (GDP), with an upper bound of 20%. Most people valued future benefits less than current costs and would invest only if the projected payoff was large enough. The Stern Report treated current and future generations equally. He estimated $7 trillion in costs if we didn’t blunt global warming within a decade. ‘‘Our actions over the coming few decades could create risks of major disruption to economic and social activity, later in this century and in the next, on a scale similar to those associated with the great wars and the economic depression of the first half of the 20th century,''

3.3.1 Economics of Global Warming Solutions

Pacala and Socolow have written about the scientific, technical, and industrial know-how to solve the carbon and climate problem for the next half-century. A portfolio exists to prevent the doubling of carbon dioxide (CO_2); this portfolio has been divided into seven equal wedges. Seven of the following fifteen options must be accomplished by 2050. The first category, efficiency and conservation, include four possible options for wedges:

(i) Increase the fuel economy of two billion cars (four times as many as today) from 30 mpg to 60 mpg.

(ii) Reduce the average annual distance driven of 2 billion cars from 10,000 miles to 5,000 miles.

(iii) Reduce mid-century carbon dioxide (CO_2) emissions from buildings by about one-fourth

(iv) Increase efficiency of coal-fired power plants from 40% to 60% and still allow for a doubling of the quantity of coal-based electricity.

The second category is to decarbonize electricity and fuels:

(v) Increase natural gas for power by fourfold and displace 1,400 GW of baseload coal.

(vi) Install carbon capture and storage (CCS) at 800 GW baseload coal plants or equivalent to 3500 Norwegian Sleipner projects.

(vii) Institute carbon dioxide (CO_2) capture and storage with a six-fold increase in hydrogen from coal and natural gas plants for off-site use.

(viii) Institute carbon dioxide (CO_2) capture and storage with synfuels equivalent to 200 South African Sasol projects.

(ix) Build more nuclear fission power plants at the pace of 1975–1990 for 700 GW base load coal capacity.

(x) Increase wind turbines about 50 times today's deployment, covering 3% of the area of the United States.

(xi) Increase photovoltaics by 700 times today's deployment.

(xii) Produce hydrogen for automobile fuel cells from wind turbines at about 100 times today's wind turbine deployment.

(xiii) Produce 34 billion barrels of ethanol, which would be 50 times larger than today's output of Brazilian sugar cane and U.S. corn ethanol.

The third category is natural sinks:

(xiv) Reduce tropical forest clear-cutting to zero over 50 years and reforest approximately 500–1,000 million acres of land.

(xv) Apply conservation tillage to all of the world's 4,000 million acres of cropland.

Each of these represents a considerable challenge, but seven need to be accomplished completely to stabilize carbon dioxide (CO_2) levels by 2050. Good leadership is required to make this happen. The economics of climate change uses economic theory and computer models to study the interactions among government policies, the climate system, and the economy. It ties to provide solution to the problem of global warming with the use of economics tools of analysis.

Click on: https://www.youtube.com/watch?v=AkOmYPYBMrI

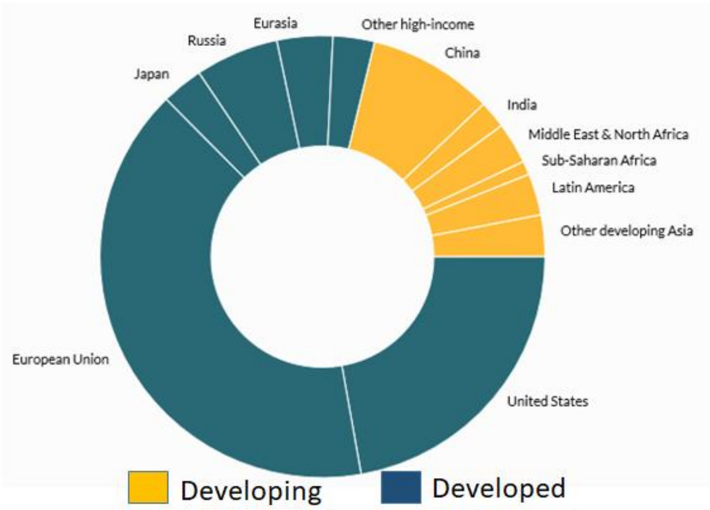
SELF ASSESSMENT EXERCISE

Discuss the economics of global warming solution.

3.4. CLIMATE CHANGE AND GLOBAL INEQUALITY

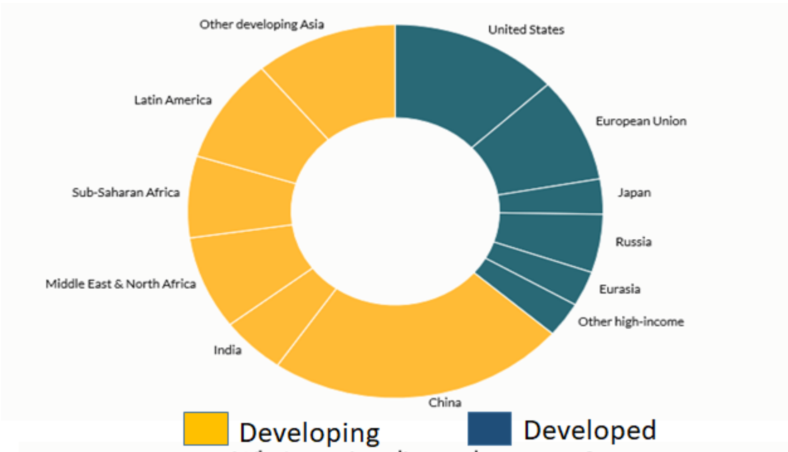
In recent years, many scholars and activists have adopted a "climate justice" framework to advocate for a new approach to addressing the negative impact of climate change. They have gone as far as to argue that equity should be fundamental in climate change policy research. This discussion has been based on two different approaches. The first approach concerns the fact that countries have made, and continue to make, vastly unequal contributions to the problem. Krugman and Wells (2015) have captured this issue in one succinct sentence: "historically, the wealthy nations have been responsible for the bulk of these emissions because they have consumed far more energy per person than poorer countries." Focusing on trade, Case, Fair, and Oster (2014) have a thoughtful discussion linking carbon emissions to consumption, not just production: A study found that in 2004, 23 per cent of the greenhouse gas emissions produced by China were created in the production of exports. In other words, these emissions come not as a result of goods that China's population enjoys but as a consequence of the consumption of the United States and Europe. Trade with China may be a way for developed nations to avoid their commitments to pollution reduction.

A second approach to inequality is to note that countries face different impacts from climate change and possess different capacities-which could be due to cultural factors, technology of even the will- to adapt. O'Sullivan, Sheffrin, and Perez (2014) bring home the message that poor populations and countries are, and will be, hurt the most. The adverse effects of increases in temperature seem to afflict mainly the poor countries, most of whom are dependent on agriculture. Rich countries do not suffer from increases in temperature." The Charts below show the spatial variation in production and impacts of the climate change across the world.



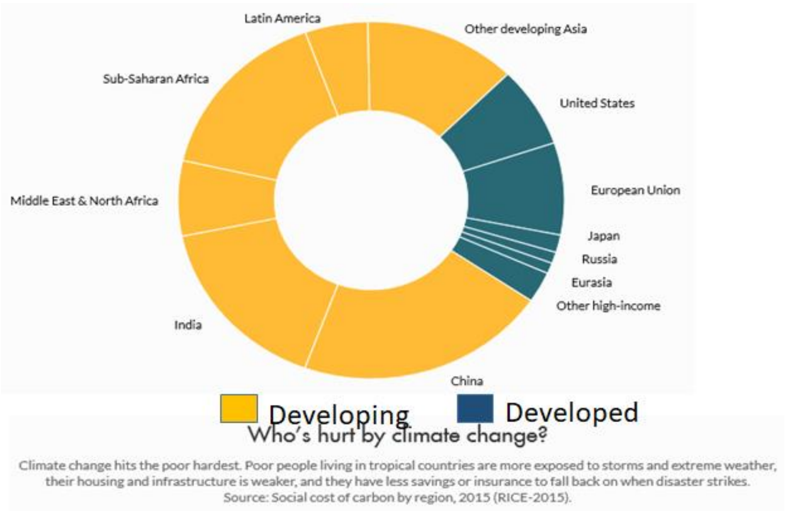
Who caused climate change historically?

The historical concentration of industry and wealth in developed countries means that they are responsible for 79 percent of the emissions from 1850 to 2011. Source: CO2 emissions excluding LUCF, 1850–2011 (CAIT v2.0).



Who's causing climate change now?

Sixty-three percent of annual emissions are produced by developing countries. The economic growth behind that is a very good thing, but it has a dangerous side effect—carbon emissions. Source: GHG emissions including LUCF, 2011 (CAIT v2.0)



However, some scholars do not link climate change with inequality. Improving fuel efficiency is potentially an important part of climate change mitigation. The other important aspect is switching from burning fossil fuels to forms of useful energy generation which do not involve the release of greenhouse gases. The chemical equations make it clear that its production and release into the atmosphere is an inevitable by-product of burning fossil fuels, the heat energy from which is needed for economic and livelihood activity. Hence there is a linear chain as shown in Figure 2.1 below:

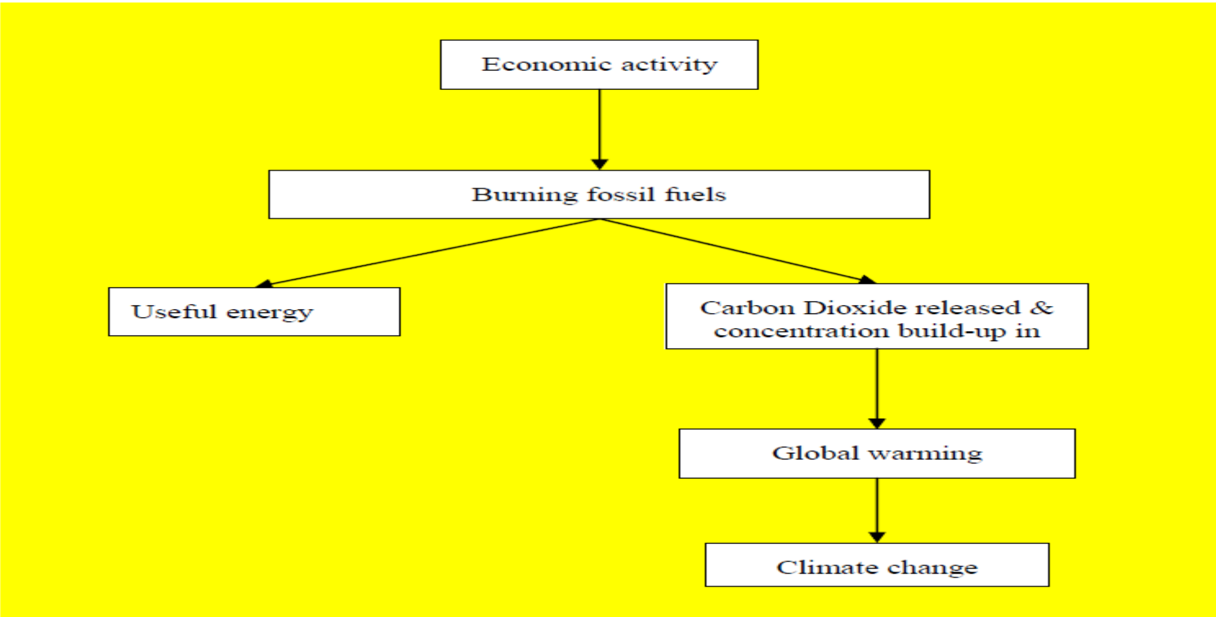


Figure 2.1 From economic activity to climate change through burning fossil fuels

So, is climate change good or bad in economic terms? You will probably have already gathered that this question provokes argument. Two answers that are in direct opposition to each other are identified, both of which accept the scientific arguments about anthropogenic global warming.

- The release of carbon dioxide into the atmosphere is benign or even positive for economic activity and hence human welfare. For example, linking increased carbon dioxide concentration to agricultural production, some parts of the world which are currently cold and dry might benefit from becoming warmer and wetter. The melting polar ice caps might reveal new sources of oil.
- While there may be some economic benefits, these will be far outweighed by the economic costs of the massive disruption that climate change will cause in many parts of the world. These include disruption caused by extreme and unpredictable weather patterns, rising sea levels displacing millions of people, and so on. Economists have a well-worn tool for weighing up the balance of benefits and costs of an activity.

Both of these scenarios, however, carry the same utilitarian assumption that economic activity is ultimately in the service of human welfare. It is why, governments worry about climate change because of the risk to economic growth policy. Governments especially worry about the second scenario above. Even if a few countries might appear to benefit, they cannot escape from the economic interconnection of the world, which is commonly referred to as 'globalisation. Any benefits which accrue to a few countries will be an illusion if the rest of the world suffers economically and is not able to engage in trade with them. However, the basic assumption that economic growth equals human welfare requires investigation.

SELF ASSESSMENT EXERCISE
Discuss argument surrounding climate change and global inequality.

4.0 CONCLUSION

It has been argued that equity should be fundamental issue in climate change policy research. And this has been viewed using two approaches. The first concern the fact that countries have made, and continue to make, unequal contributions to the climate change problem while the second approach noted that countries face different impacts from climate change and possess different capacities to adapt. And this brings home the message that poor populations and countries are and will be the most hurt.

5.0. SUMMARY

This unit looked at climate change and global inequality. It discusses different approaches of looking at inequality both in contribution to the climate change problem and the consequences of climate change on both poor countries and rich countries. The unit submitted that climate change may not be link to inequality because improving fuel efficiency is potentially an important part of climate change mitigation. However, the unit concluded that any benefits which accrue to a few countries will be an illusion if the rest of the world suffers economically and is not able to engage in trade with them and submitted the assumption that economic growth equals human welfare requires investigation.

6.0. TUTOR-MARKED ASSIGNMENTS

1. Mention and explain various argument surrounding climate change and global inequality.
2. Discusses different approaches of looking at inequality both in contribution to the climate change problem and the consequences of climate change on poor and rich countries
3. Explain the economics of global warming.
4. Discuss externality and market failure in climate change

7.0 REFERENCES/FURTHER READING

Spencer Weart (2008). The Discovery of Global Warming, Harvard University Press, Revised and Expanded Edition (Partial view available on Google Books).

John Houghton (2009). Global Warming: The Complete Briefing, Cambridge University Press, 4th Edition (Partial view available on Google Books).

Mark Maslin (2007). Global Warming: Causes, Effects, and the Future. Voyageur Press, 2nd Edition.

Stephen Schneider (1990). Global Warming: Are We Entering the Greenhouse Century? Lutterworth Press (Partial view available on Google Books).

S. Fred Singer and Denis T. Avery (2007). Unstoppable Global Warming: Every 1,500 Years. Rowman& Littlefield Publishers, Inc., Updated Expanded edition (Partial view available

Bjorn Lomborg (2008). Cool It: The Skeptical Environmentalist’s Guide to Global Warming, Vintage, Reprint edition.

Loutre, M.F. (2002). “Climate: An exceptionally long interglacial ahead?” Science 297 (5585): 1287–8.

UNIT 2: THE ECONOMICS OF CLIMATE CHANGE THROUGH THE DOMINANT NEOCLASSICAL LENS

CONTENTS

1.0 INTRODUCTION

Market failure is part of the semantic of the neoclassical economics which is considered basically a theory of capitalism. An essential feature of capitalism is its ability to build continuously on itself and hence grow wealth through a spontaneous and unconscious process from within. This process is called immanent development and is predicated on a self-regulating market, where goods and services are exchanged according to the laws of supply and demand. Thus, if people are producing similar goods and services, there is competition amongst them for customers who choose according to a combination of price and quality of what is on offer. This in turn creates the incentives to innovate (so as to remain relevant or competitive in the market place). This unit looks at the economics of climate change within the context of the neoclassical economics. It starts with the discussion of the pubic choice school of economics and also looks at the issues of the tragedy of commons.

2.0 OBJECTIVES

After studying this unit, you should be able to:

(i) Understand the contribution of the Neoclassical to climate change

(ii) Use your knowledge and understanding to reflect the concept of the tragedy of commons on issues surrounding climate change and economic development.

3.0 MAIN CONTENT

3.1 THE PUBLIC CHOICE SCHOOL OF ECONOMICS

This concerns subjecting government, politicians and public sector officials to economic analysis, usually from a neoclassical perspective. It starts from the premise that politicians and public sector officials are no different from other individuals. They are driven by private self-interest which results in public sector bureaucrats attempting to expand their powers, budgets and privileges, and leads to over-powerful states. Such individuals will always attempt to privately gain from opportunities created by state regulations (known as 'rent-seeking'). Thus, public servants can be made by institutional norms, values and rules to act in the public interest. It is easy to see how public choice theorists are interested in the notion of government failure when it attempts to intervene so as to correct 'market failure', and that the former can turn out to be worse than the latter.

Thus neoclassical economics contends that self-regulating markets can correct just about everything according to laws of supply and demand. For example, if our lives are being degraded significantly through greenhouse gas emissions from industrial production, we will demand more carbon friendly products (such as electric cars) which will accordingly be supplied by the 'invisible hand' of the market. This suggests that the self-regulating invisible hand of the market will take care of climate change for us.

Among conventional economists, (such as neo-classical economists) very few claims that markets in practice conform more than approximately to this abstract ideal. Some obviously conform more closely than others and there is thus a spectrum of deviation from the ideal. The extreme deviation is market failure with respect to global warming. Economists generally agree that substantial deviations from perfect markets require a correcting factor. Two broad categories of correcting factor which involve government intervention or intervention through an international agreement between governments can be identified:

(i) Interventions which either establish or enable a market which functions correctly, through for example a robust legal framework which protects individual property rights.

(ii) Interventions which involve more directed actions by government (or supra-government bodies such as the European Union).

Classical and Neoclassical economists tend to be happy with the first category of intervention, but ideologically opposed to the second, though most will accept in practice some form of directed intervention. These groups of economists believe that the market is the best arbiter in allocating scarce resources and should be allowed to function without hindrance; they therefore suggest minimal intervention through rule making. Only national Governments can command the resources and means to intervene in the market economy promote desirable outcomes and address real or potential market failures. The legitimacy of directed intervention in the economy by government, its extent and timing, is highly contested, the debate being summarised historically under the heading, 'State versus Market'. Since states are not also perfect, which has led the Public Choice School of Economics to argue that government failures may be worse than the market failures they seek to correct.

SELF ASSESSMENT EXERCISE

According to neoclassical economists, the self-regulating invisible hand of the market will take care of climate change for us. Discuss this argument within the context of the Public Choice School of Economics.

3.2 A CLASSIC EXAMPLE OF MARKET FAILURE: THE TRAGEDY OF THE COMMONS

Market failures represent the extreme of market imperfections, where the mechanisms have failed to deliver their self-correcting role. An obvious classic example in relation to 'free' natural resources – i.e. situations where markets for the natural resource don't exist -- was provided in 1968 with the publication of Garrett Hardin's 'The tragedy of the commons' (Hardin, 1968). Hardin explained his argument through the example of herdsmen sharing a common piece of land (the commons) for grazing their cattle. It is in the interests of each 'rational' herdsman to keep adding cattle to his stock on the land. The benefits which accrue to him personally of doing so outweigh the costs of possible overgrazing, because the latter are shared by all herdsmen. Thus, he concluded:

'Therein is the tragedy. Each man is locked into a system that compels him to increase his herd without limit – in a world that is limited. Ruin is the destination towards which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons. Freedom in a commons brings ruin to all. This analysis has been seized upon by many economist (note that Hardin was a biologist) to argue for private property rights in natural resources, in order to provide the necessary incentives to conserve them. Private property rights form another basic tenet of neoclassical economics and market failures are deemed inevitable where they don't exist. They concern the private ownership of goods, services, intelligence (as in intellectual property rights), and so on where the owner's rights include:

- The right to use something (for example to farm land), and conversely the right to exclude others from using it.
- The right to alienate it (to give it away, to sell or otherwise dispose of it).
- The right to transform it (for example, to use it as an input to a production process).
- The right to appropriate it (for example, to eat or sell farm produce).

Thus, to illustrate, assume that each herder has private property rights to (i.e. 'owns') a piece of land, and propose that one herder wishes to add to his stock. The herder has two options:

(i) He grazes the extra stock on the land that he owns. Here, he risks degrading his own land through overgrazing. The result may be no net gain and even a loss if cattle die prematurely because they are weak through lack of food.

(ii) He may therefore approach another herder to buy or rent land off him so that he can maintain his grazing resource at the appropriate level. In effect, the allocation of private property rights in this situation has established a market for land.

With the second option, the price that the herder may have to pay in rent or purchase is the result of a complex tacit calculation made by both parties and which appears as the invisible guiding hand of the market at work. Thus the prospective buyer/tenant has to calculate the maximum price he is prepared to pay in order for this option to be worthwhile. The seller has to calculate the price he needs to extract to make it worthwhile giving up herding the land himself. The really complicated bit, however, is that each must conduct his own internal risk analysis – again likely to be tacit and unconscious – of things not working out as planned. For example, for the buyer/tenant, what if there is a prolonged drought just after the deal is done and all the grass dries up? For the seller, what if a second herder is willing to sell or rent and undercuts him?

It is beyond the scope of this module to enter into the debate about the tragedy of the commons in relation to property rights and natural resource management, except to note that the commons are rarely free in Hardin's sense of unregulated access. In relation to atmospheric pollution by carbon dioxide and other greenhouse gases, establishing private property rights is clearly untenable. How could one establish private property rights over the air we breathe? How could we exclude others from its use and from polluting it with yet more greenhouse gases which know no boundaries? Thus, global warming represents a market failure, unable to provide a self-correcting mechanism. However, intervention by government, or perhaps even a global coalition of governments, to correct for the failure requires an evidence base for the decisions taken, involving answers to the following basic questions:

- What are the costs of the global warming market failure?
- What are the costs and benefits of different kinds of intervention and their timing?
- Is the net balance sheet positive or negative?
- Who bears the costs and who claims the benefits?

The answers to these questions inform the extent, content and form of the intervention, where to intervene, and who intervenes. The most widely used tool in economics for informing such decisions is cost-benefit analysis (CBA) which, as the term indicates, weighs up the costs and benefits of this or that intervention, where a net benefit will support a decision to go ahead, and will represent value for the money spent.

SELF ASSESSMENT EXERCISE

Discuss 'tragedy of the commons' within the context of climate change.

4.0 CONCLUSION

The neoclassical economics assumed that a self-regulating market can automatically adjust everything according to laws of supply and demand. But this may not be so in the presence of a market failure. One obvious example in relation to free natural resources is the tragedy of the commons. Global warming represents a market failure because it is unable to provide a self-correcting mechanism. But intervention by government or global coalition of governments, to correct for the failure requires an evidence base for the decisions taken.

5.0 SUMMARY

This unit looked at climate change within the context of neoclassical theory of economics. It discusses climate change in the context of the public choice school of economics and considered the classical example of the market failure called the tragedy of the commons. The unit raised possible questions that need to be addressed in case of possible intervention by the government or coalition of governments to correct the market failure as a result of climate change.

5.0 TUTOR-MARKED ASSIGNMENTS

1. Assess Cost-Benefit analysis (CBA) as a tool in economics for informing decisions aboutthe paramount questions that need to be answer in the case of government intervention to correct market failure due to global warming.
2. Thus neoclassical economics argued that self-regulating markets can correct everything according to laws of supply and demand. Examine the applicability of this statement in the context of global warming

7.0 REFERENCES/FURTHER READING

Spencer Weart (2008). The Discovery of Global Warming, Harvard University Press, Revised
and Expanded Edition (Partial view available on Google Books).

John Houghton (2009). Global Warming: The Complete Briefing, Cambridge University Press,
4th Edition (Partial view available on Google Books).

Mark Maslin (2007). Global Warming: Causes, Effects, and the Future. Voyageur Press, 2nd Edition.

Stephen Schneider (1990). Global Warming: Are We Entering the Greenhouse Century? Lutterworth Press (Partial view available on Google Books).

S. Fred Singer and Denis T. Avery (2007). Unstoppable Global Warming: Every 1,500 Years.
Rowman & Littlefield Publishers, Inc., Updated Expanded edition (Partial view available

Bjorn Lomborg (2008). Cool It: The Skeptical Environmentalist’s Guide to Global Warming, Vintage, Reprint edition.

UNIT 3: COST-BENEFIT ANALYSIS AND SECTORAL IMPACTS OF CLIMATE CHANGE

CONTENTS

1.0 INTRODUCTION

Climate change is a global phenomenon resulting from the collective actions/activities of individuals across the globe. Climate change result majorly as a result of emission of greenhouse gases with carbon dioxide as the highest contributor (75%) (Kaddo,2016). Many still consider this phenomenon as a future event; thus not attributing the present occurrences such as flood, increase in heat, diseases, water shortage, drought amongst others taking place within the ecosystem to it. Some of these impacts are already taking significant toll on humans and it has been reported that greater toll on these suffering is expected to occur as time progresses. It has been posited also that reversion of the process of climate change is impossible even if significant action against greenhouse gas emission is taken. The management of the situation by decreasing on the actions affecting the greenhouse effect is currently advised. Without collective action plans as contained in the Sustainable Development Goals (SDGs), efforts at curtailing this problem will not be feasible even in the distant future. This is because the heavy reliance on fossil fuels by humans for energy has great impact on climate change, this without doubt has contributed to the gradual rise in global warming over time with noticeable greater impacts beginning from the period of the Industrial Revolution

(Kaddo, 2016). However, the impact of climate change on the physical, biological and the human spheres within the ecosystem is without doubt overwhelming and needs collective efforts to tackle the challenges it posed.

2.0 OBJECTIVES

It is expected that the following should be internalized at the end of this unit:

(i) The concept of cost-benefit analysis
(ii) The contributions of human and nature to climate change
(iii) The effects of climate change on the physical, biological and human systems
(iv) Measures to curtail the effect of global warming and climate change.

3.0 MAIN CONTENT

3.1 CLIMATE CHANGE: THREATS AND IMPACTS

Climate change is the result of global warming which is a long term rise in the average temperature of the Earth's climate. The term Climate change may be used sometimes interchangeably with global warming, however it is important to note that the two are not the same as climate change is more encompassing as it includes both global warming and its effects, (Intergovernmental Panel on Climate Change, 2013; 2018). The cause of climate change is thought to be associated with release of greenhouse gases which acts like a cover/blanket around the earth. Whereas it is a natural phenomenon that traps energy in the atmosphere and causes it to be warm, this event is referred to as the greenhouse effect and the constant buildup of this process due to both natural events (volcanoes eruptions) and human activities (burning of fossil fuels) releases more greenhouse gases in the form of methane, carbon dioxide, water vapour, and dinitrogen-oxide into the atmosphere.

Climate change impact is significant on ecosystems, economies, and societies, with severe impacts on every sphere. Although there has been observed changes in the level of green gas emission starting in the mid-20th century with the rise of the Industrial Revolution. Notwithstanding changes observed within this period have seen greater impact when compared to all periods in history. Report on global warming currently at 1.1^{o}C with estimations at 2.7^{o}C to 4.8^{o}C at the end of the century buttresses this point (IPCC, 2013). This will have much impact on the environment as the thinning and shrinking of the Arctic sea ice is rapidly on the

rise, with the global mean sea level at 61-110cm (WRCP Global Sea Level Budget Group, 2018). The rising increase in Green House Gases (GHG) Especially Carbon dioxide from industrial productions, vehicular activities and other sources is putting the human the increasing human population at risk of the impacts of climate change. The human carbon foot print is on the increase at the midst of the global outcry on the increasing risk and impacts.
Click on: https://www.youtube.com/watch?v=OYexpYl_-eE

SELF ASSESSMENT EXERCISE
Discuss the threats and impacts of climate change and how it affects human lives.

3.1.1 CLIMATE CHANGE AND COST–BENEFIT ANALYSIS

The Stern Review is the most significant analysis of the economics of climate change in this century. Stern endorsed strong climate action, arguing that the costs can be kept to 1% of global income, while the benefits are at least 5% and possibly 20% of global income. The topic is a suitable avenue to introduce students to the logic of cost–benefit analysis, as well as economists' efforts to quantify the impacts of climate change. The cost–benefit analysis (CBA) of climate change is, in part, a question of how today's society, through the choice of discount rates, weighs the costs and benefits to be realized by future generations. Chiang (2014) discusses this intergenerational perspective by saying that "...small changes in emissions today may have little effect on the current generation, but will have sizable effects many decades out." He also taps into the behavioural economics literature to describe that we tend to overvalue present benefits relative to future costs, thus not taking enough action.

A cost-benefit analysis purports to measure in money terms all the benefits and all the costs to be expected over the future of some mooted project, and to admit the project if the sum of the benefits exceeds the sum of the costs by a significant margin'. There are several reasons why CBA has evolved into a standard economic tool to aid decision-making. Below are three of the most important:

- In theory, it is simple and neat. CBA reduces the complexities of decision making to a single number, the ratio of benefits to costs. Market failures can occur for many reasons, but of primary importance for this section is that they often occur because they have to deal with phenomena on which it is difficult to assign an economic value. Many government interventions fall into this category, and CBA provides a legitimate way of taking such externalities as they are called into account. CBA thus can take a wide view rather than a narrow view. An example of the latter would be a decision to invest in a new coal-fired power station that is based purely on an assessment of the costs associated with building, running and maintaining the power station, and the expected returns on this investment. Alternatively, additional consideration of the costs of emissions, including carbon dioxide emissions, and the adverse consequences for the population would constitute a wide view.

- Economic investment becomes even more uncertain as we project further into the future, which is why market capitalism is good at making short term decisions but often fails on the long-term. CBA specifically projects into the future to provide a longer-term view. In practice, however, CBA is anything but simple, the main criticisms being:
- Assigning a monetary value to something where the market has already failed to do so is highly contentious. If, for example, people have to leave coastal homes because of rising sea levels, the cost of providing new homes inland is not hard to estimate. What value, however can be put on the wholesale disruption to the lives of these people? To cast the net wider, what value can be put on the lives of the people who already live inland and who might be disrupted by an influx of coastal dwellers? To take a different example, what value can be put on the disruption caused to a local community by erecting a wind farm literally next door as a contribution to reducing a country's carbon footprint?

These problems are compounded when projecting into the future, which has to be done because climate change has a strong temporal dimension. Its impacts are already being felt today, but much of the prediction is about the probably greater impacts into the future. Put crudely, the issue concerns assigning a value to intervening today where the benefits are likely to accrue principally to future generations.

A third issue relates to the claim that CBA offers a wide view of an intervention decision, beyond straightforward investment costs and returns. But, how wide is wide and conversely how narrow is narrow? In other words, there can be a tricky decision on what to include and what to exclude in the CBA. To follow the example in the first of these criticisms, above, how is the decision taken whether to include or exclude the disruption costs to the lives of those inland dwellers who might have to absorb an influx of coastal 'refugees' into their communities? A further criticism of CBA which relates to the inclusion/exclusion issue is that often it only calculates the net social benefit. It does not discriminate necessarily in situations where some gain while others lose. To take a different example: a government decision to intervene to protect rain forests in Nigeria might be a sound decision for the Government and the population as a whole, especially if it attracts money from the international Clean Development Mechanism Rain forest dwellers who depend on the forest for their livelihoods, however, might become worse off. The deepest criticism, however, is that CBA is not the neutral tool that it is claimed to be. The boundaries of what to include and exclude from the calculation, the values placed on different costs and benefits both now and in the future, reflect the interests and values of the most powerful stakeholders.

Some costs of climate change are relatively easy to estimate as there already exist ways of expressing them in monetary terms. Thus one can work out by country or region the costs to agriculture, or even benefits in some northern latitudes, of a particular temperature rise. The aggregation across the world of these individual country/region costs and benefits can then easily be worked out for agriculture. The same can be done for other sectors of the economy. The overall sum will represent the net cost aggregated across the sectors of the economy which are analysed and across the world. Much more difficult is converting into money the damage costs that don't normally have a market value. For example, how does one value the trauma associated with losing your home and means of livelihood because of rising sea levels, or with flooding from excessive rainfall? How does one value the amenity loss associated with climate-related biodiversity changes? How does one aggregate these kinds of cost across locations – a species loss in one country might be an addition to another country. On a different scale, how might one value the damage done by a far-reaching, but unlikely, abrupt climate change event? We should not assume that people and groups of people are passive in the face of climate change. Some damages will possibly be offset by local adaptation – for example a community of farmers in Sub-Saharan Africa selectively breeding drought resistant strains of their staple crop.

The discussion of adaptation in different parts of the world leads to a more general consideration of how we value the costs incurred by different groups of people, those who are poorer or richer than ourselves. This is where the equity weighting factor enters the calculation. In contrast to equity weighting, discounting the future is a standard feature of CBA where net benefits (or costs) extend some way into the future. In a straightforward investment CBA, such as a road or bridge, the future returns on investment are discounted to a 'net present value' (NPV). The time discount rate is expressed as a percentage, meaning the proportion by which the net future benefits decline in present value year on year. Thus, to give an illustrative example, a time discount rate of 5% will mean that a net benefit of one million naira in year 15 of the project will have a net present value of about half a million naira. This is because it decreases by 5% each year working back to the present in what is the reverse of a compound interest calculation. If however the time discount rate is only 2%, the NPV of one million naira in year 15 will be approximately 760,000 naira, while if it is 10% it will be approximately 240,000 naira. In sum, the higher the discount rate the lower the NPV of the net benefit accrued over time.

A very pragmatic approach is taken to assign the time discount rate for a conventional investment project. The reasoning is as follows: the highest risks of the investment will be in the present and these risks will diminish over time. Therefore, the present returns on the investment should be weighted higher than the returns in the lower risk environment of the future. This is similar to deposits of personal savings. The 'safer' deposit in a trusted bank account attracts a lower rate of interest than a deposit in something riskier (e.g. share dealing). Practically, discount rates are chosen in line with the rate of return that might be obtained by investing the money elsewhere. The Stern Review effectively rejected this justification for discounting future returns in the context of the net benefits of climate change, arguing that it is tantamount to valuing the welfare of future generations less than our own. This is an issue of inter-generational equity, as enshrined in the oft-quoted definition of sustainable development of the United Nations World Commission on Sustainable Development in 1987 (WCED).

Click on: https://www.youtube.com/watch?v=A1_xp5sRVmM

SELF ASSESSMENT EXERCISE

Discuss Cost-Benefit Analysis (CBA) within the context of climate change.

3.3 IMPACTS OF CLIMATE CHANGE ON DIFFERENT SECTORS

The rise in the global warming puts the environment at a very precarious position as the entire ecosystems are currently facing serious crisis. Major environmental changes have resulted in the extinction or relocation of species with economic importance to the balancing of the ecosystem. Furthermore, weather conditions have been greatly affected by climate change, with the record of warmer temperature, increase in water vapor and consequently heavy and intense rainfall occurs. Besides the increase in rainfall frequency, the melting of the ice glaziers also take place and they both further result into rise in sea levels and flooding (Riebeek, 2010). Although the melting of the ice glaziers is important as it aid in irrigation farming, providing source of drinking water and the continuous flow of streams, the rapid rate of the melting is alarming.

3.3.1 AGRICULTURE

Climate change threatens agriculture by diminishing crop yields thus bringing about food insecurity. The severity of droughts, wildfires and flooding currently being experienced especially in the developing world affects global food production and brings about hunger, loss of livelihoods, and high migration rate. The level of droughts affects crop production and the rates of wildfires caused by the drought destroy crops and other beneficial microorganisms in the soil supporting a good crop yield. The bulk of this impact is reported to have devastation in the sub-Saharan regions of African and the South-East Asia (UN Environment, 2018). This has serious implication on development which could threaten the attainment of the sustainable development goals of the United Nations.

3.3.2 STORMS AND FLOODS

The increase in temperature due to global warming increases the level of moisture trapped in the atmosphere with the warming of the oceans, as well as vegetation therefore bringing about frequency in heavy rainfall and consequently experiences of storms and flooding. The direct consequences of this include hunger, loss of lives and livelihood, infrastructure, migration rate, displacement, diseases, loss of biodiversity amongst others. Urban centres are worst hit by this incessant flood events as basic infrastructure especially drainage facilities are either inadequate or not available. Where available they are overwhelmed by the frequency and volume of the run off from the rains, thereby resulting into catastrophe.

3.3.3 HEAT WAVES

The rise in temperature due to global warming affects the entire ecosystems from melting of the ice to bleaching of the coral reefs, the entire human race is equally affected with the increase in discomfort rates with further results in diseases and deaths. It was reported that globally the years, 2014, 2015, 2016 and 2017 with recorded temperature records as the hottest years since the 1980s, with 2016 as the warmest (NASA, NAOO, 2017). This event has left great devastation in its wake as thousands of lives were lost in major parts of Europe, Asia and Africa. Significantly two examples of the impact of climate change on human lives is the extreme rise in temperature in Korea in 2013 and India in the year 2019 where substantial numbers were left dead and many struck with major health issues. The diagram below shows the trend in global temperature in over a century.

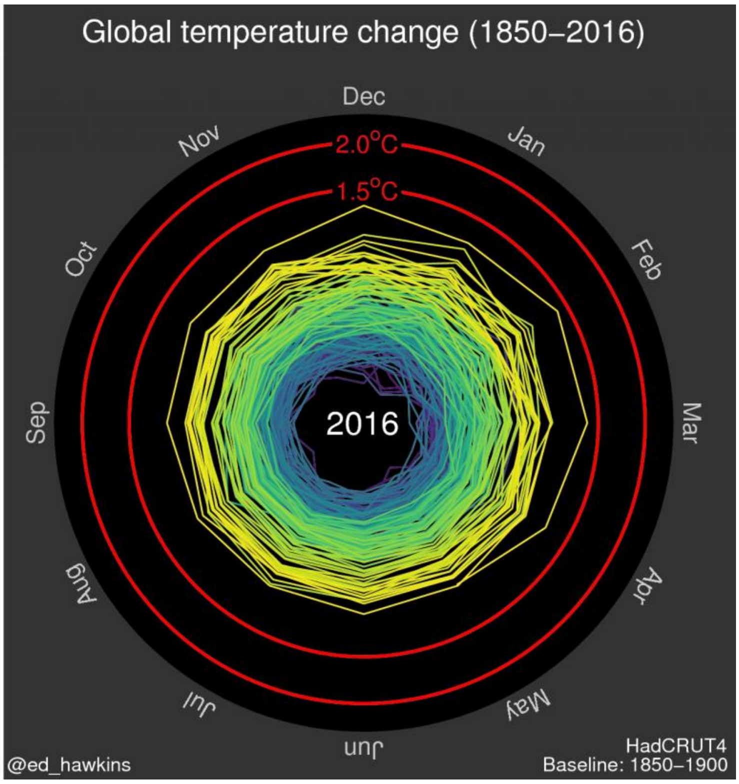


Figure 1: Global temperature Change (1850-2016)
Source: Hawkins, 2016

3.3.4 SHORTAGE OF DRINKING WATER

Climate change has affected the supply of safe drinking water for both human and other living things. With the increase in sea levels, fresh water bodies have been intruded with this saltwater thus making the water unfit for consumption. The implication is that species including human will face deaths and some will be forced to relocate, which will have a critical effect on the ecosystem. The effect is termed as one of the largest global risks as an estimated 4 billion people in global population live under severe conditions of water scarcity (Global Risks Report, 2019)

3.3.5 DEFORESTATION

Forests play a crucial role in shaping global temperatures and by implication its climate. They affect the world's climate by absorbing carbon dioxide, the main greenhouse gas responsible for global warming, thereby help in regulating the climatic condition over time. Besides this important role that it plays, it serves as habitat to ecologically important species of plants and animals. It goes to say that all hands must be on deck to ensure the continuity of the forest reserve but and take appropriate measures to keep it in its optimum state.

With global warming effect on the rise, increases in temperature, drought and wildfires, large areas of forest are being destroyed as seen in the Amazon forest. Consequently the release of the stored up carbon dioxide in these plants are further emitted into the atmosphere and increasing the level of greenhouse gas.

3.3.6 DESTRUCTION OF MARINE ECOSYSTEMS

Ocean acidification which occurs when ocean absorbs excess carbon dioxide puts the lives of ocean creatures in jeopardy. This level of acidity has been reported to reach about a million tons and it has led to the death of many marine species with others migrating while those who survive losses their natural endowments (Mckie, 2015). Also, the bleaching of the coral reef due to high temperature puts the lives of marine species at risk, although they are reported to consist less than 0.1% of world's ocean floor, they support a quarter of all marine species (Mccutcheon, 2016). The presences of mangroves play an important role as in serve as nurseries for fishes' filter sediments and protect coastal ecosystems and shorelines from violent storms. Climate change impact has changed all that as drought due to lack of rainfall, rise in sea surface temperature has led to the loss of major mangroves in the world.

SELF ASSESSMENT EXERCISE

Discuss the impacts of climate change on different sectors of the Nigerian economy.

4.0 CONCLUSION

Climate change is no longer an event of the future and should not be seen as such. The impact being experienced in our planet currently is without any doubt in dire need of urgent and collective attention. The emission of greenhouse gas; an identified cause of the phenomenon will continue to be on the rise as human consumption of fossil fuels for energy will not diminish unless an environmental friendly replacement is found and incorporated.

5.0 SUMMARY

Climate change in the world can be cause by many activities; both natural and human influenced. However, the major contributor to this phenomenon is man through his energy consumption rates. These actions bring about the emission of greenhouse gases into the atmosphere, causing a rise in the level of temperature (global warming). This has a great impact on the health of man himself, his immediate surroundings and the entire ecosystems. Climate change is irreversible, however, the situation can be managed, especially if actions as contained in the SDGS documents geared towards a safer and viable environment are adopted by this present generation as the next may not be able to do much with the worsen state it may be then.

6.0 TUTORED-MARKED ASSIGNMENT

1. Identify ways through which global warming and climate change impact on the ecosystems.
2. What are the various issues involve in the use of costs-benefit analysis (CBA) in the context of climate change.

7.0 REFERENCES/FURTHER READINGS

Global Risks Report (2019). World Economic Forum. Web search 13 Oct. 2019

IPCC (2013). Summary for Policymakers in Climate Change: The Physical Science Basis. Contribution of Working Group 1 to the fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., Qin, D., Plattner, G.K., Tignor, M., Allen, S.K., Boschung, T., Nauels, A., Xia, Y., Bex, V., and Midgley, P.M., (eds)]. Cambridge University Press, Cambridge , United Kingdom and Ney York, NY, U.S.A

IPCC (2018). Special Report on Global Warming of 1.5oC (SR15) Incheon, South Korea.

Intergovernmental Panel on Climate Change.
Kadoo, J.R., (2016). Climate Change: Causes, Effects, and Solutions. *A with Honours Projects.164.* https://spark.parkland.edu/ah/164
NASA (2008). Effect of Global Climate Change and Global Warming: Vital Signs of the planet.
National Aeronautics and Space Administration. Web search 13 Oct. 2019.
NASA/NAOO (2017). Data Showing 2016 Warmest Year on Record Globally. National Aeronautics and Space Administration and National Oceanic and Atmospheric Administration. Web search 13 Oct 2019.
Riebeek, H., (2010) "Global Warming" Feature Articles NASA. Web search, 13 Oct.2019.
UN (2018). UN Environment 2018 Annual Report. United Nations Environment Programme.
WRCP Global Sea Budget Group (2018). Global Sea Level Budget 1993-Present. Earth System
Science Data, 10(3), 1551-1590. https://doi.org/10.5194/essd-10-1551-2018

UNIT 4: THE CHALLENGES FROM ECONOMICS AND ECOLOGICAL PERSPECTIVES AND SUSTAINABLE DEVELOPMENT

CONTENTS

1.0 INTRODUCTION

The increasing pressure of the long-term trend of climate change and the availability of essential natural resources will have significant impact on economic development with a range of possible adverse effects on global society. In what follows, current best knowledge on these two factors and their possible future evolution is examined. Paradoxically, while their impact on society and social security may be greater than other exogenous factors such as demographic or labour market development, policy-makers, employers and other stakeholders have put in place very limited effective measures to anticipate and mitigate these impacts. Indeed, some commentators argue that current measures exacerbate or accelerate the impacts. The impacts of climate change and natural resource scarcity are often similar and interdependent.

2.0 OBJECTIVES

At the end of this unit, the students should be able to;

1. Understand climate change and limits on natural resources
2. Describe the economic and ecological perspectives and climate change

3.0 MAIN CONTENT

3.1 THE CHALLENGES FROM ECONOMIC PERSPECTIVE

Richer countries and their citizens can do much to lessen harmful climate change through their lifestyle and consumer choices. For example, they might reduce the amount they travel and generally adopt simplified lifestyles which require less energy. Alternatively, they might try and maintain their lifestyle but are prepared to pay more for lower-energy alternatives, for example, build a low-energy home, own a hybrid car rather than a conventional car, and buy locally sourced food rather than food which has many air miles attached to it. All of the above is significant and does depend on voluntary behaviour which runs contrary to normal expectations about lifestyle and incentives associated with economic behaviour. The stark reality is that most people will not voluntarily change their behaviour in the name of climate change without appropriate economic incentives and a reasonable assurance that their lifestyles will be maintained. 'Voluntary simplicity' as has been applied to some East European states is significant but not sufficient. This is where economics matters in climate change. It has a privileged role in policymaking as it sets incentives for behavioural change for both producers and consumers. It also provides warning about what is likely to happen to lifestyles if nothing is done at scale to meet the challenge.

Any deal on climate change, whether local, national or international, will be informed by the science, but ultimately will be based on some common ground of what we can afford in the present compared with the economic costs of not doing anything. As far as an international deal is concerned, finance ministers around the world will play a huge role. This is the reality and the most compelling reason for exploring economics in relation to climate change. Thus:

- Global warming conceptualised as market failure provides a strong conventional reason for intervening
- Discounting the future is a key consideration because climate change, and hence its economics, stretches into the future and raises issues about the welfare of future human generations as well as about the present generation
- Opportunity costs raise issues about choice of intervention between climate change and other pressing global problems.

The economic perspective of climate change considers issues of equity, justice, rights and so on if it is in one's self-interest to do so. Thus the economics of climate change is interested in the argument of classical and neoclassical economics justification rather than the normative justification that is generally found in alternative approaches. This would hardly matter if they achieve the same result, except that the former appears to have a distasteful connotation of pragmatism in contrast to the 'pure and lofty' thoughts of the latter.

SELF ASSESSMENT EXERCISE

Discuss the challenges of climate change from an economic perspective.

3.2 ECOLOGICAL PERSPECTIVES AND SUSTAINABLE DEVELOPMENT

3.2.1 Climate change and limits on natural resources

Global economic activity and growth depends on a readily available and accessible supply of essential resources. However, most non-renewable resources that are at present the dominant component of energy production and industrial capacity are becoming increasingly scarce while demand is increasing due to population growth and the urge for economic development. The question of the availability of certain resources is complex. Figure 1.1 shows the current availability of some of the critical resources at their current consumption rates. In reality the exact number of years left of economically-viable extraction for each resource will depend on a number of factors. First, as the price of the resource increases, previously uneconomic sources become viable due to increased investment into extraction technologies or difficult-to-mine areas becoming financially worthwhile (such as deep ocean drilling). Second, technology change (possibly driven by increases in the prices of resources) or policy change (for example, by putting an absolute global cap on carbon emissions and therefore a limit on the use of fossil fuel) may allow resource switching which lowers demand. Third, but most importantly, economic growth and activity will alter consumption patterns over time. For example, assuming an increase in future consumption based on a continuation of historic trends (over the past 20 years there has been an average annual increase in consumption by approximately 1 per cent for oil, 2 per cent for gas and 2.5 per cent for coal) would result in oil running out in 41 years, gas in 38 years and coal in 53 years. The overarching trend has been one of increasing consumption and while some efficiencies have been seen, these are driven by price increases. Therefore, resource prices are likely to significantly increase over the short to medium term due to increased demand.

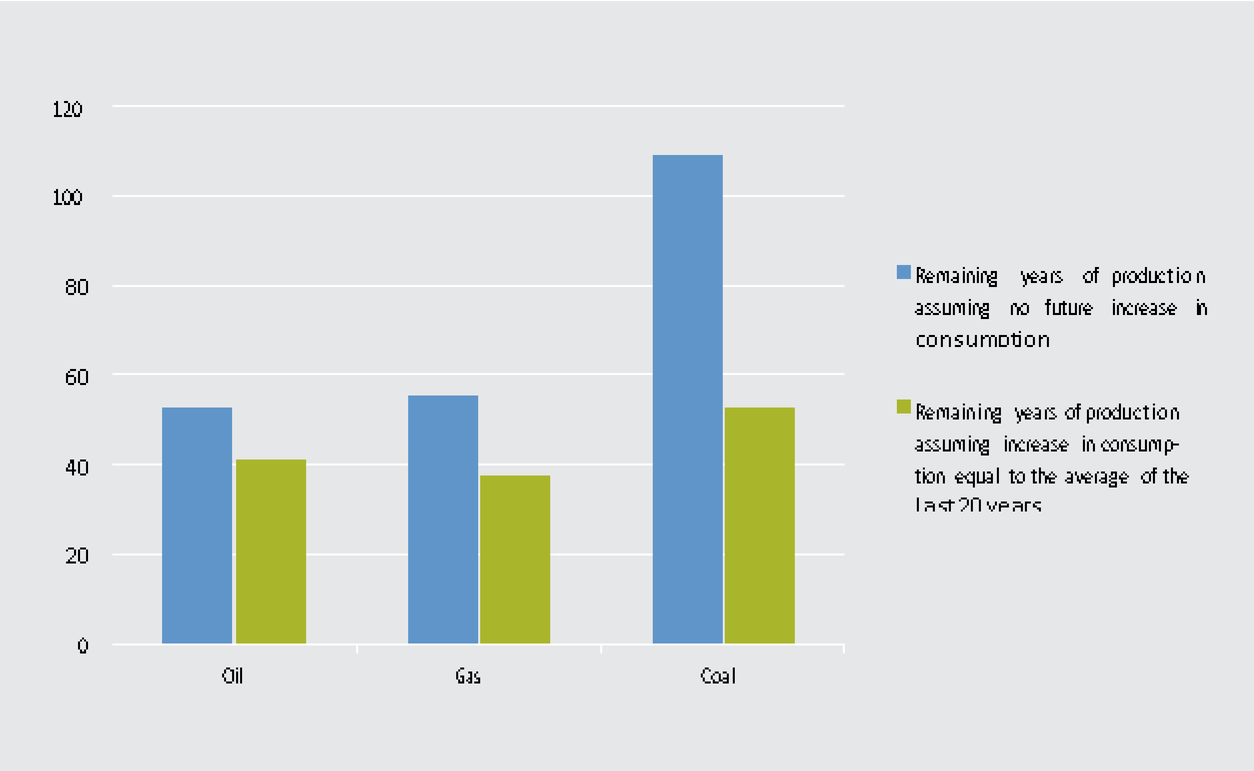


Figure 2.1. Remaining years of production for a variety of energy commodities

3.2.2 Trends, challenges and scenarios

To push for economic growth over the past century, the world economy has relied on relatively cheap access to both renewable resources, such as forests, and non-renewable – and thus finite – resources such as oil and minerals. This means that infinite growth in a finite world is not possible and therefore the limited nature of resources will at some point start to place limits on economic growth.

In 1972, the Club of Rome published the Limits to Growth (Meadows and Club of Rome, 1972). This used system dynamics theory to analyze the long-term causes and consequences of growth in the world's population and its economy. The model measured the impacts of resource scarcity, food production, pollution levels, population growth and changes to economic activity (services and industrial output). It showed that without substantive policy intervention, resource availability could significantly reduce industrial output per capita. Not only will resource limits severely impact economic growth but pollution levels could reach a level that would severely impact food production. The overall message of the report was that under this "business as usual" scenario, even with optimistic projections of resource availability, the impacts on the world economy would see a peak in productivity by the middle of this century This will be followed by mass global famine and industrial output collapsing to levels below those seen in the nineteenth century. Subsequent analysis has continued to support the general conclusions within the original report (Meadows, Randers, and Meadows, 2004; Röckstrom et al., 2009) and further work has shown economic and political consequences of such limits (Lagi, Bertrand and Bar-Yam, 2012; Lee et al., 2012).

While limits apply to a range of resources, with resources such as indium particularly in short supply, energy resources have received the most focus because of their importance in driving economic growth. Over the past decade there has been a paradigm shift in underlying energy markets leading to a step change in the price and volatility of key resources. This has mainly been driven by increasing demand alongside fossil fuel supplies being extracted from non-conventional sources, such as shale or deep offshore, which have become economic due to the higher prices of oil and gas on international markets. For example, oil prices have seen an almost fourfold increase since 2005

- Average oil price per barrel 1985-2005 8: USD 24 ± 10 (mean / standard deviation)
- Average oil price 2006–2014: USD 83 ± 19 (mean / standard deviation)

Over a similar period, the impacts of climate change have also been more evident with increasing financial losses. For example, in the United States, estimates show that 2012 was the second most costly year, after Hurricane Katrina in 2005, for insurance losses related to climate disasters with over USD 139 billion in damages (AON Benfield, 2013). These losses are driven by three factors:

- Society has a tendency to build infrastructure in regions which are particularly vulnerable to climate change, for example on coasts, and the economic value of this at-risk infrastructure has increased with increasing levels of development in these areas. The magnitude and frequency of extreme weather events has increased with climate change (more extreme events including rainfall, droughts and wind) (IPCC, 2012).
- Over the past three years, floods in Thailand has resulted in huge economic losses of USD 30 billion (WEF, 2013), Hurricane Sandy in the United States resulted in losses of over USD 50 billion (US Department of Commerce, 2013) and Horn of Africa droughts in 2011 threatened the livelihoods of 9.5 million people. Typhoon Haiyan in the Philippines is estimated to have killed 10,000 individuals and created hundreds of thousands of displaced persons. The global distribution of the population exposed to

cyclones by 2030. With an increase in both the frequency and severity of extreme events globally, we will see increasing numbers of displaced people seeking refuge elsewhere. Many of these displaced persons will live in precarious environments with often limited access to the formal labour market and in countries with different cultures and languages.

- The total cumulative global cost of climate change has been estimated at between USD 2 trillion and USD 4 trillion by 2030 across different scenarios (Mercer, 2011). This is not going to continue over future decades. The production of food and water infrastructure depends on inexpensive fossil fuel energy, the increase in the price of energy input will mean additional volatility of global markets and the likelihood will be an upward pressure on water and food prices globally.

How quickly prices rise and/or whether alternative technologies or processes can be put in place to alleviate some of this pressure is dependent on an early response at scale into production, supply chains, consumption and markets by governments and/or the private sector. This uncertainty on future price is likely to lead to short-term shocks and in particular increasing volatility which in turn will impact financial markets and, in turn, human welfare and income security. Jones et al. (2013) brought together the latest evidence on resource trends and climate change exploring the potential impact on the global economy and the financial sector. In particular the report focused on pensions and investment returns over a medium to long-term time horizon through the use of scenarios and actuarial modelling. The report suggests that even modest impacts from increased uncertainty and on global economic growth could have significant impacts on pension fund assets and costs.

Alongside the physical pressures from climate change and resource trends, changes in local demographics will also influence the outcomes of these global challenges. For example, ageing populations put different demands on energy, food systems and health impacts (both mental and physical health) will change. Labour markets will be indirectly affected due to the differing nature of economic development and risk. In addition, physical risks from climate change, together with the demands for increased investment in infrastructure to extract increasingly scarce resources may limit the capital availability of governments. This in turn may limit the available fiscal space for social security budgets where these are partially or fully tax financed.

The connectedness of food, water and energy systems is becoming more apparent and will be a driver for future pressures on social systems. As regions become less productive economically, and see large physical shocks from climate change due to the increasing frequency and magnitude of extreme events, the likelihood of large-scale movements of people will result. Some migration and displacement may improve the demographic profile of a particular region and could alleviate pressures on social security systems (increasing the percentage of people able to work) while others could overwhelm local systems. In simple parlance, this will alter the availability or allocation of resources and complicate the cost of production. Therefore, the scale and pace of such potential population movements will be important, as will be political efforts to control such flows. Anticipating and addressing these risks and challenges at a government level involves a transition to a new paradigm or approach, which will have economic and political benefits and risks associated with it.

3.2.3 GOVERNMENT RESPONSES

Given the impact of climate change and limits to natural resources on economic growth, the analysis of government responses can be categorized into four broad future growth trajectories. These are (Jones et al., 2013):

a. “Growth is the solution”: Commentators argue that economic growth brings with it technological innovation that would bring about the required changes to meet resource constraint and other challenges faced by the modern world such as poverty and inequality.

b. “Green growth”: By examining and changing indicators of growth to be more aligned with resource constraints (and climate change) global economic development would more naturally develop the required solutions to the global challenges, without harming people’s “standard of living”.

c. “End of growth”: The finite size of the planet combined with the fact that the economy is now operating on a worldwide scale means that growth cannot continue and must stabilize to remain within global boundaries. Economies need to be restructured to accommodate a zero growth future.

d. “Beyond the limits”: Resource limits and/or climate change have been ignored for too long and the global economy and population is now too large to be supported at current rates of consumption. Since long-term decline is inevitable, the best course of action is to manage this decline.

Currently the overarching paradigm adopted by governments around the world is “growth is the solution”. However, given the future impacts of resource constraints and the inherent delays and imperfections in the market (for example, an excessive focus on the short term) this is likely to lead to short-term shocks and price volatility at the very least. In addition, if new technologies are introduced that are more efficient in their use of resources this can occasionally increase the overall use of a particular resource over the short term as more output per unit input is possible making the activity more economically productive. Therefore, “growth is the solution” could actually hasten the time when resource limits start to have an economic impact. Following shocks caused by resource constraints, the reaction of governments, for example in their decision over money supply and where to direct investment, will be the immediate major determinant of the impact on the economy and the financial sector.

3.2.4 RISK IN TRANSITION

Even when governments proactively set an agenda and strategy for the future (for example, emission targets) to tackle some of these issues there is a risk in transition. Some of these risks can be large, such as governments opting for one particular technology which may not in the end provide the necessary solution in time to prevent shocks. Other risks can be more local (either physically or financially) in nature but still cause uncertainty and changes in labour markets. Managing these risks can create substantial market distortions. For example, nuclear power often creates large market distortions with the state providing insurance and future price guarantees and uncertain decommissioning costs being absorbed by governments to the possible detriment of other energy sources (Hultman, Koomey and Kammen, 2007).

The United Kingdom Government introduced the Climate Change Bill in 2008 which set in place targets for reducing carbon emissions. As part of the measures introduced to help achieve those targets the United Kingdom Department for Energy and Climate Change introduced a feed-in-tariff to encourage uptake of solar photovoltaic technology. However, the design of the feed-in-tariff was not sufficiently flexible, so a surge in demand meant the costs were unaffordable by government and the scheme was subsequently changed.

While individual examples of labour market impacts are currently relatively few, compared with the total size of national job markets, as economic transformation increases in size, these types of collapses in employment and investor confidence could have a more significant impact.

Another issue that is central to global agreements on action to tackle climate change is energy access and market development. Ensuring access to energy for those in fuel poverty to underpin health and education is an important driver for developing countries. As markets change, ensuring growth and protecting jobs is important in developed countries. Both of these issues have seen substantial subsidies from governments. Estimates put the total global fossil fuel subsidy at over USD 500 billion per annum with over USD 110 per adult per annum in top 11 rich-country emitters (Whitley, 2013). As government budgets face increasing pressure, the impacts of climate change become more evident and the price of fossil fuels continue to increase, these subsidies will become more difficult to justify in their present form.

3.2.5 GREEN ECONOMY OPPORTUNITIES

The International Energy Agency (IEA, 2010) estimate that USD 270 trillion (approximately USD 7 trillion per year) will be invested into energy supply and use under a "business as usual" scenario up to 2050. To meet the commitments already made under the United Nations Framework Convention on Climate Change (UNFCCC) an additional USD 46 trillion (17 per cent), or approximately USD 1.7 trillion per annum would be needed to be invested. In 2010 global clean energy investment reached just USD 243 billion (WEF, 2011; Pew Charitable Trusts, 2010) and therefore a fourfold increase in investment is required to meet targets. Energy supply is only part of the investment required, with environmental products and services projected to double from USD 1,370 billion per year at present to USD 2,740 billion by 2020 (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, 2007, as referenced in Cedefop, 2009). This includes energy efficiency, sustainable transport, water supply, sanitation and waste management. Adaptation investment, in particular in agriculture, will add to the significant global investment over the next few decades.

Jobs will be created in a number of sectors and lost in others. Social security systems will need to be flexible to cope with the issues raised by transition towards a greener economy, in particular those related to the re-skilling of labour markets. Skill shortages are already reported in a number of sectors including the biofuels industry12 in Brazil, the renewable energy and environment industry in Bangladesh, Germany, and the United States and in the construction sector in Australia, China, Europe and South Africa (BVET, 2007; London Energy Partnership, 2007, as referenced in Cedefop 2009). The focus of training and re-skilling efforts by government agencies need to reflect this transformation Solutions to resource constraints and climate change not only include large-scale infrastructure projects requiring engineering and project manager skills. In addition, a substantial effort in development, lifestyles and behavioural change is required. This involves increased investment in education systems, restructuring financial systems, a shift in the narrative that highlights the opportunities enabling behaviour change, new methods to capture and reprocess waste in the retail sector, shifts in regulation and a re-purposed health system (see, for example, WBCSD, 2010).

Green economic growth is a significant opportunity for countries, governments and private-sector players all over the world. However, the nature and speed of the transformation to new low carbon and resource efficient modalities is not without risk. As economic and physical shocks increase in scale, countries that are better prepared will be able to respond more effectively.

5.0 SUMMARY

While climate impacts are debated in the global political arena, the scale, urgency and connectedness of the challenges explored here do not appear to be widely understood. Similarly, the future increase in resource prices and increase in demand due to growing global economic activity are receiving less political attention. Possibly this is due to the predominance of the free-market paradigm that believes that markets will naturally develop affordable alternative technologies at scale in an appropriate time frame. In the absence of an appropriate response at scale there is a risk of reduced and/or stagnating economic growth, reduced access to commodities and hence increased prices, reduced international and national security, increasing climate disruption and reductions to life expectancy with increases in morbidity. The global resource system is already stressed. The interaction between food, energy, climate, water and economic systems is becoming better understood. Appropriate action is required to proactively manage future risks as well as cope with impacts already evident. The impact on social security systems will be significant.

6.0 TUTOR MARKED ASSIGNMENTS

1. Critically explain climate change and limits on natural resources
2. What are the economic challenges of climate change?

7.0 REFERENCES/FURTHER READINGS

ArzedelGranado, J.; Coady, D.; Gillingham, R. 2010. The unequal benefits of fuel subsidies: A review of evidence for developing countries (IMF Working paper, No. 10/202). Washington, DC, International Monetary Fund.

Arnott, R. D.; Chaves, D. B. 2012. "Demographic changes, financial markets and the economy",

in Financial Analysts Journal, Vol. 68, No. 1.

Bachelet, M. (coord.). 2011. Social protection floor for a fair and inclusive globalization (Report of the Social Protection Floor Advisory Group). Geneva, International Labour Office. Also available in French and Spanish.

Borjas, G. J. 2013. Immigration policy and economics (Conference paper, 27th General Assembly of the CISS, San Salvador, 24–26 July).

Brimblecombe, S. 2013. "A multivariable definition of adequacy: Challenges and opportunities",

in International Social Security Review, Vol. 66, Nos. 3–4. Business Green. 2013. Solar industry damages claim reaches £140m. London.

BVET. 2007. Skills for sustainability. Sydney, New South Wales Department for Education and Training – Board of Vocational Education and Training.

Cedefop. 2009. Future skill needs for the green economy (Research paper). Luxembourg, Publications Office of the European Union; Thessaloniki, European Centre for the Development of Vocational Training (Cedefop).

Cichon, M. 2013. "The Social Protection Floors Recommendation, 2012 (No. 202): Can a six-page document change the course of social history?", in International Social Security Review, Vol. 66, Nos. 3–4.

EIA. 2011. International energy outlook 2011. Washington, DC, US Energy Information Administration.

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. 2007. Green Tech made in Germany: Innovation atlas. Munich, Valhen.

Fritze, J. G. et al. 2008. "Hope, despair and transformation: Climate change and the promotion of mental health and wellbeing", in International Journal of Mental Health Systems, Vol. 2, No. 13.

Helliwell, J.; Layard, R.; Sachs, J. (eds). 2013. World happiness report 2013. New York, NY, United Nations – Sustainable Development Solutions Network.

Hultman, N.; Koomey, J.; Kammen, D. 2007. "What history can teach us about the future costs of US nuclear power", in Environmental Science & Technology, April

MODULE THREE: INSTITUTIONS, POLICY AND GOVERNANCE

UNIT 1: CLIMATE CHANGE, POLICY FRAMEWORKS, AND PROTOCOLS

CONTENTS

1.0 INTRODUCTION

Climate change is one of the greatest environmental and economic threats facing the world today. There is a growing need to develop strategies that will reduce current levels of greenhouse gases in the atmosphere and curtail future emissions. This has informed the current global collating actions aimed at addressing this phenomenon. The United Nations Framework Convention for Climate Change (UNFCCC) and the Kyoto Protocol represent an international strategy to combat these effects. Admittedly, these instruments have not, and cannot retard climate change to zero. Adaptation efforts should therefore equally be directed towards helping countries cope with the changing weather patterns. The Kyoto protocol has, to some extent tried to address this, especially in case of developing countries. These instruments also require state parties to take action at the national level to realise their objects. Uganda, as a party to the Kyoto protocol, has developed a number of policies and laws for the implementation of the protocol at the national level. This unit addresses issues such as the Climate change Policy Framework, Provisions of the United Framework Convention on Climate Change (UNFCCC), The Kyoto Protocol, Main Issues and Negotiation Streams and towards a Post- 2020 regime

1.0 OBJECTIVES

At the end of this unit, students should be able to:

- Describe the main aims and provisions of the UNFCCC and its Kyoto Protocol.
- Identify the main organizations and bodies that operate under the UNFCCC and its Kyoto Protocol.
- Explain why the UNFCCC and its Kyoto Protocol are important to developed and developing countries.
- Analyze key points relevant for a post-2020 climate change regime

3.0 MAIN CONTENT

3.1 THE CLIMATE POLICY FRAMEWORK

Climate change is a global problem and a “common concern to mankind. GHG emissions contribute to climate change irrespective of their origin, all countries will be affected if no action is taken. A global agreement is needed to regulate emissions and help countries to adapt. A framework convention setting out basic obligations of all ‘Parties’ to combat climate change was signed in 1992 in Rio and came into force in 1994. Currently this convention has 195

Parties, including 194 states and 1 regional organization. Article 3.1 stresses the principle of equity and ‘common but differentiated responsibilities.

3.2 PROVISIONS OF THE UNITED FRAMEWORK CONVENTION ON CLIMATE CHANGE (UNFCCC)

The UNFCCC is a “Rio Convention”, one of three adopted at the “Rio Earth Summit” in 1992. Its sister Rio Conventions are the UN Convention on Biological Diversity and the Convention to Combat Desertification. The three are intrinsically linked. It is in this context that the Joint Liaison Group was set up to boost cooperation among the three Conventions, with the ultimate aim of developing synergies in their activities on issues of mutual concern. It now also incorporates the Ramsar Convention on Wetlands. Preventing “dangerous” human interference with the climate system is the ultimate aim of the UNFCCC.

The convention recognized that there is a problem and this was remarkable for its time. In 1994, when the UNFCCC took effect, there was less scientific evidence of climate change than there is now. The UNFCCC borrowed a very important line from one of the most successful multilateral environmental treaties in history (the Montreal Protocol, in 1987): it bound member states to act in the interests of human safety even in the face of scientific uncertainty.

The ultimate objective of the Convention is to stabilize greenhouse gas concentrations "at a level that would prevent dangerous anthropogenic (human induced) interference with the climate system." It states that "such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner. The UNFCCC aim to achieve stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system within a time frame sufficient to:

1. Allow ecosystems to adapt naturally to climate change,
2. Ensure that food production is not threatened, and
3. Enable economic development to proceed in a sustainable manner.”

The idea is that, as they are the source of most past and current greenhouse gas emissions, industrialized countries are expected to do the most to cut emissions on home ground. They are called Annex I countries and belong to the Organization for Economic Cooperation and

Development (OECD). They include 12 countries with "economies in transition" from Central and Eastern Europe. Annex I countries were expected by the year 2000 to reduce emissions to 1990 levels. Many of them have taken strong action to do so, and some have already succeeded. Industrialized nations agree under the Convention to support climate change activities in developing countries by providing financial support for action on climate change-- above and beyond any financial assistance they already provide to these countries. A system of grants and loans has been set up through the Convention and is managed by the Global Environment Facility. Industrialized countries also agree to share technology with less-advanced nations. The key dimension of UNFCC also included;

i. Industrialized countries (Annex I) have to report regularly on their climate change policies and measures, including issues governed by the Kyoto Protocol (for countries which have ratified it).
ii. They must also submit an annual inventory of their greenhouse gas emissions, including data for their base year (1990) and all the years since.
iii. Developing countries (Non-Annex I Parties) report in more general terms on their actions both to address climate change and to adapt to its impacts - but less regularly than Annex I Parties do, and their reporting is contingent on their getting funding for the preparation of the reports, particularly in the case of the Least Developed Countries.

The Convention acknowledges the vulnerability of all countries to the effects of climate change and calls for special efforts to ease the consequences, especially in developing countries which lack the resources to do so on their own. In the early years of the Convention, adaptation received less attention than mitigation, as Parties wanted more certainty on impacts of and vulnerability to climate change. When IPCC's Third Assessment Report was released, adaptation gained traction, and Parties agreed on a process to address adverse effects and to establish funding arrangements for adaptation. Currently, work on adaptation takes place under different Convention bodies. The Adaptation Committee, which Parties agreed to set up under the Cancun Adaptation Framework as part of the Cancun Agreements, is a major step towards a cohesive, Convention-based approach to adaptation.

3.2.1 DIFFERENT RESPONSIBILITIES FOR DIFFERENT PARTY GROUPS

1. **Annex I Parties**

Group of 43 developed countries, that were part of the OECD in 1992, and countries with economies in transition (EIT). Their responsibilities include;

- **i.** Take the lead in reducing GHG emissions
- **ii.** Submit regular national communications and biennial reports
- **iii.** Submit annual inventory of GHG emissions

2. Annex II Parties

Group of 23 developed countries but not countries with EIT (subset of Annex I countries). Their responsibilities include;

- i. Provide financial & other resources to developing countries for mitigation and adaptation
- ii. Facilitate the transfer of climate-friendly technologies

3. Non-Annex I Parties

Mostly developing countries. Their responsibilities include;

- i. Report on mitigation and adaptation actions
- ii. Submit national communications and biennial update reports (BURs)

3.3 THE KYOTO PROTOCOL

The Kyoto Protocol is an international agreement linked to the United Nations Framework Convention on Climate Change, which commits its Parties by setting internationally binding emission reduction targets. Recognizing that developed countries are principally responsible for the current high levels of GHG emissions in the atmosphere as a result of more than 150 years of industrial activity, the Protocol places a heavier burden on developed nations under the principle of "common but differentiated responsibilities. The Kyoto Protocol was adopted in Kyoto, Japan, on 11 December 1997 and came into force on 16 February 2005. The detailed rules for the implementation of the Protocol were adopted at COP 7 in Marrakesh, Morocco, in 2001, and are referred to as the "Marrakesh Accords." Its first commitment period started in 2008 and ended in 2012.

In Doha, Qatar, on 8 December 2012, the "Doha Amendment to the Kyoto Protocol" was adopted. The amendment includes:

i. New commitments for Annex I Parties to the Kyoto Protocol who agreed to take on commitments in a second commitment period from 1 January 2013 to 31 December 2020;
ii. A revised list of greenhouse gases (GHG) to be reported on by Parties in the second commitment period; and
iii. Amendments to several articles of the Kyoto Protocol which specifically referenced issues pertaining to the first commitment period and which needed to be updated for the second commitment period.

On 21 December 2012, the amendment was circulated by the Secretary-General of the United Nations, acting in his capacity as Depositary, to all Parties to the Kyoto Protocol in accordance with Articles 20 and 21 of the Protocol. During the first commitment period, 37 industrialized countries and the European Community committed to reduce GHG emissions to an average of five percent against 1990 levels. During the second commitment period, Parties committed to reduce GHG emissions by at least 18 percent below 1990 levels in the eight-year period from 2013 to 2020; however, the composition of Parties in the second commitment period is different from the first.

3.3.1 THE KYOTO MECHANISMS

Under the Protocol, countries must meet their targets primarily through national measures. However, the Protocol also offers them additional means to meet their targets by way of three market-based mechanisms. The Kyoto mechanisms are:

•International Emissions Trading

•Clean Development Mechanism (CDM)

•Joint implementation (JI)

The mechanisms help to stimulate green investment and help Parties meet their emission targets in a cost-effective way. Monitoring emission targets. Under the Protocol, countries' actual emissions have to be monitored and precise records have to be kept of the trades carried out. Registry systems track and record transactions by Parties under the mechanisms. The UN Climate Change Secretariat, based in Bonn, Germany, keeps an international transaction log to verify that transactions are consistent with the rules of the Protocol. Reporting is done by

Parties by submitting annual emission inventories and national reports under the Protocol at regular intervals. A compliance system ensures that Parties are meeting their commitments and helps them to meet their commitments if they have problems doing so.

The Kyoto Protocol, like the Convention, is also designed to assist countries in adapting to the adverse effects of climate change. It facilitates the development and deployment of technologies that can help increase resilience to the impacts of climate change. The Adaptation Fund was established to finance adaptation projects and programmes in developing countries that are Parties to the Kyoto Protocol. In the first commitment period, the Fund was financed mainly with a share of proceeds from CDM project activities. In Doha, in 2012, it was decided that for the second commitment period, international emissions trading and joint implementation would also provide the Adaptation Fund with a 2 percent share of proceeds.

The Kyoto Protocol is seen as an important first step towards a truly global emission reduction regime that will stabilize GHG emissions, and can provide the architecture for the future international agreement on climate change.

In Durban, the Ad Hoc Working Group on the Durban Platform for Enhanced Action (ADP) was established to develop a protocol, another legal instrument or an agreed outcome with legal force under the Convention, applicable to all Parties. The ADP is to complete its work as early as possible, but no later than 2015, in order to adopt this protocol, legal instrument or agreed outcome with legal force at the twenty-first session of the Conference of the Parties and for it to come into effect and be implemented from 2020.

3.3.2 RELEVANCE OF THE KYOTO PROTOCOL

The relevance of the Kyoto Protocol includes the following;

i. Supplements and strengthens the Convention
ii. Identifies & regulates six gases as GHGs (Annex A). The regulated gases include Carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O), Hydro fluoro carbons (HFCs), Per fluoro carbons (PFCs), Sulphur hexa fluoride (SF_6) and Nitrogen trifluoride (NF_3)
iii. Provides opportunities for mitigation and adaptation in developing countries

iv. Sets out individual, legally binding emission targets for Annex I Parties (Annex B). The key areas for emission reduction include energy, Industrial processes, Waste, Agriculture and Solvent and other product use

3.3.3 MITIGATION COMMITMENTS: 2008-2012

The 37 industrialized countries and the European Community committed to:

i. Reduce their emissions by at least 5% below 1990 levels in the 2008-2012 period
ii. Ensure their amount of CO_2 equivalent emissions do not exceed assigned amounts
iii. Each Kyoto Protocol Annex B Party had assigned amount units (AAUs) for the 2008-2012 commitment period
iv. Reduce GHG emissions by at least 18% below 1990 levels

3.4 MAIN ISSUES AND NEGOTIATION STREAMS

3.4.1 ADAPTATION

Adapting to the adverse effects of climate change is, along with mitigation, a major area of action under the UN Climate Change regime. The world is already experiencing changes in mean temperature, shifts in the seasons and an increasing frequency of extreme weather events. As the climate changes, societies will have to learn to adapt. The faster the climate changes, the harder it could be.

Adaptation, in the simplest terms, refers to the actions that countries will need to take to respond to the impacts of climate change that are already happening, while at the same time preparing for future impacts. It refers to changes in processes, practices and structures that can reduce our vulnerability to climate change impacts, such as sea level rise or food insecurity. It also includes making the most of any beneficial opportunities associated with climate change, such as increased crop yields or longer growing seasons in some regions.

Adaptation solutions take many shapes and forms, depending on the unique context of a community, business, organization, country or region. There is no 'one-size-fits-all-solution'—adaptation can range from building flood defences, setting up early warning systems for cyclones and switching to drought-resistant crops, to redesigning communication systems, business operations and government policies. Many nations and communities are already taking steps to build resilient societies and economies, but far greater action will be needed to cost effectively manage the risks, now and in the future.

Successful adaptation activities also call for the effective engagement of stakeholders—including national, regional, multilateral and international organizations, the public and private sectors, and civil society—and the management of knowledge for adaptation at each step.

Parties to the UNFCCC and the Paris Agreement recognize that adaptation is a global challenge faced by all with local, sub-national, national, regional and international dimensions. It is a key component of the long-term global response to climate change to protect people, livelihoods and ecosystems. Parties acknowledge that adaptation action should follow a country-driven, gender-responsive, participatory and fully transparent approach, considering vulnerable groups, communities and ecosystems, and should be based on and guided by the best available science and, as appropriate, traditional knowledge, knowledge of indigenous peoples and local knowledge systems, with a view to integrating adaptation into relevant socioeconomic and environmental policies and actions.

3.4.2 CLIMATE FINANCE

Climate finance refers to local, national or transnational financing—drawn from public, private and alternative sources of financing—that seeks to support mitigation and adaptation actions that will address climate change. The Convention, the Kyoto Protocol and the Paris Agreement call for financial assistance from Parties with more financial resources to those that are less endowed and more vulnerable. This recognizes that the contribution of countries to climate change and their capacity to prevent it and cope with its consequences vary enormously. Climate finance is needed for mitigation, because large-scale investments are required to significantly reduce emissions. Climate finance is equally important for adaptation, as significant financial resources are needed to adapt to the adverse effects and reduce the impacts of a changing climate.

In accordance with the principle of "common but differentiated responsibility and respective capabilities" set out in the Convention, developed country Parties are to provide financial resources to assist developing country Parties in implementing the objectives of the UNFCCC. The Paris Agreement reaffirms the obligations of developed countries, while for the first time also encouraging voluntary contributions by other Parties. Developed country Parties should also continue to take the lead in mobilizing climate finance from a wide variety of sources, instruments and channels, noting the significant role of public funds, through a variety of actions, including supporting country-driven strategies, and taking into account the needs and priorities of developing country Parties. Such mobilization of climate finance should represent a progression beyond previous efforts.

It is important for all governments and stakeholders to understand and assess the financial needs of developing countries, as well as to understand how these financial resources can be mobilized. Provision of resources should also aim to achieve a balance between adaptation and mitigation. Overall, efforts under the Paris Agreement are guided by its aim of making finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development. Assessing progress in provision and mobilization of support is also part of the global stock take under the Agreement. The Paris Agreement also places emphasis on the transparency and enhanced predictability of financial support

3.4.3 TECHNOLOGY TRANSFER

The development and transfer of climate technologies is critical for achieving the ultimate objective of the Convention. The Convention notes that all Parties shall promote and cooperate in the development and transfer of technologies that reduce emissions of GHGs. It also urges developed country Parties to take all practicable steps to promote, facilitate and finance the transfer of, or access to, climate technologies to other Parties, particularly to developing countries. Furthermore, the Convention states that the extent to which developing country Parties will effectively implement their commitments will depend on the effective implementation by developed country Parties of their commitments under the Convention related to financial resources and transfer of technology.

3.4.4 CAPACITY BUILDING

Addressing climate change in a sustainable way requires considerable efforts, and not all countries have the capacity—the knowledge, the tools, the public support, the scientific expertise and the political will, know-how—to do so. Capacity-building is about enhancing the ability of individuals, organizations and institutions in developing countries and in countries with economies in transition to identify, plan and implement ways to mitigate and adapt to climate change. Capacity-building under the UN climate change regime takes place at (on) three levels: developing educational, training and awareness-raising activities; fostering the development of organizations and institutions, including their missions, mandates, cultures, structures, competencies, and human and financial resources, as well as the cooperation between organizations, institutions and creating enabling environments through economic and regulatory policies and accountability frameworks in which institutions and individuals operate.

3.4.5 NATIONALLY DETERMINED CONTRIBUTIONS

Nationally Determined Contributions, or NDCs, are at the heart of the Paris Agreement. In short, they represent the contribution of each Party towards meeting the objective of this Agreement. For example, NDCs should, in aggregate, set the world on a trajectory towards peaking of global emissions as soon as possible and rapid reductions thereafter towards a balance of emissions and removals. This is why, through their NDCs, each Party should specify, among other things, its plans to reduce its emissions.

The Paris Agreement requires each Party to prepare, communicate and maintain successive NDCs that it intends to achieve, and to pursue domestic mitigation measures, with the aim of achieving the objectives of such contributions. Parties are expected to do so every five years and to aim at increasing their ambition with each subsequent NDC. Further, the Paris Agreement expects developed country Parties to lead by undertaking economy-wide absolute emission reduction targets and encourages developing country Parties to move towards such targets over time, in the light of different national circumstances.

3.4.6 TRANSPARENCY

Reporting is one of the cornerstones of the UN climate change regime: it provides transparency and is the basis for understanding and gauging the implementation of the Convention, the Kyoto Protocol and the Paris Agreement. To achieve the objective of the Convention, Parties need accurate, consistent and internationally comparable data on trends in GHG emissions and on efforts to change these trends. Communicating information on the most effective ways to reduce emissions and adapt to the adverse effects of climate change also puts the world collectively on the path towards more sustainable forms of development.

Under the Convention, all Parties must communicate certain information to the COP, through the secretariat, within agreed time lines. The two main elements of this information are the details on their activities to implement the Convention—that is, their climate change policies and measures—and their national inventories of GHGs. The required contents of national reports and the timetable for their submission are different for Annex I Parties and Parties not included in Annex I to the Convention (non-Annex I Parties), in accordance with the principle of common but differentiated responsibilities and respective capabilities.

Under the Kyoto Protocol, Annex I Parties are required to include supplementary information relating to their implementation of the protocol. All Parties to the Paris Agreement will report under its enhanced transparency framework for action and support. The Paris Agreement requires each Party to prepare, communicate and maintain successive NDCs that it intends to achieve, and to pursue domestic mitigation measures, with the aim of achieving the objectives of such contributions. Parties are expected to do so every five years and to aim at increasing their ambition with each subsequent NDC. Further, the Paris Agreement expects developed country Parties to lead by undertaking economy-wide absolute emission reduction targets and encourages developing country Parties to move towards such targets over time, in the light of different national circumstances.

3.4.7 SCIENCE

Effective interaction between climate science and policy is important for moving climate negotiations forwards. Scientific research continues to inform the international climate regime, as well as national and regional climate policies. The UN climate change process, under the supreme (COP, CMP, CMA) and subsidiary bodies (SBSTA and SBI), uses scientific information on climate change through a number of work streams.

In 2010, the COP agreed on a long-term global goal (LTGG) to reduce GHG emissions so as to hold the increase in global average temperature below 2 °C above pre-industrial levels. The COP also decided to periodically review the adequacy of this LTGG in the light of the ultimate objective of the Convention and to periodically review the overall progress towards achieving the LTGG, including a consideration of the implementation of the commitments under the Convention. This review – carried out for the first time in 2013–2015 – was also to consider strengthening the LTGG, including in relation to temperature rises of 1.5 °C.

3.4.8 NEGOTIATIONS

United Nations climate change conferences have grown exponentially in size over the past two decades—from small working sessions into the largest annual conferences currently held under the auspices of the United Nations—and are now among the largest international meetings in the world. The intergovernmental negotiations have likewise become increasingly complex and involve an ever-increasing number of officials from governments all over the world, at all levels, as well as huge numbers of representatives from civil society and the global news media.

These conferences are the foremost global forums for multilateral discussion of climate change matters, and have an incredibly busy schedule. The conferences, which rotate annually among the five United Nations regional groups, serve as the formal meetings of the Conference of the Parties (COP), the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol (CMP) and the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement (the CMA).

They also include sessions of the subsidiary bodies (the SBSTA and the SBI) and any ad hoc negotiating groups. The UNFCCC secretariat supports all institutions involved in the negotiations, as well as the Bureau of the COP/CMP/CMA, which is the executive body that advises the President of the conference.

3.4.9 MITIGATION

The mitigation mechanism includes: Reducing Emissions from Deforestation and Forest Degradation (REDD+), Land Use, Land-use Change and Forestry (LULUCF), Nationally Appropriate Mitigation Action (NAMA) and Reporting on National Implementation and Monitoring Reporting and Verification (MRV)

3.5 TOWARDS A POST- 2020 REGIME

Negotiations 2012 used Two Track Approach namely;

1. Long Term Cooperative Action (LCA)

The Ad Hoc Working Group on Long-term Cooperative Action under the Convention (AWG-LCA) was established as a subsidiary body under the Convention by decision 1/CP.13 (the Bali Action Plan) to conduct a comprehensive process to enable the full, effective and sustained implementation of the Convention through long-term cooperative action, now, up to and beyond 2012, in order to reach an agreed outcome to be presented to the COP for adoption. Significant achievements that have resulted from the five years of work of the AWG-LCA include decision 1/CP.16 (the Cancun Agreements), decision 2/CP.17 (Outcome of the AWG-LCA) and subsequent implementing decisions related to the many institutional arrangements created - including the Cancun Adaptation Framework, the Technology Mechanism, institutions on Finance, the Forum on Response Measures and the Durban Forum on Capacity-Building. The COP, at its eighteenth session, adopted the decision 1/CP.18 (Agreed outcome pursuant to the Bali Action Plan) and noted that this decision, together with decisions adopted by the COP at its sixteenth and seventeenth sessions, constitutes the agreed outcome pursuant to decision 1/CP.13.

2. Further Commitments Under the Kyoto Protocol (KP)

In 2005, the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol (CMP) at its first meeting in Montreal, by its decision 1/CMP.1, established the Ad Hoc Working Group on Further Commitments for Annex I Parties under the Kyoto Protocol (AWG-KP). The AWG-KP was established to discuss future commitments for industrialized countries under the Kyoto Protocol. The AWG-KP reported to the CMP. In 2012, the CMP, at its eighth session, adopted decision 1/CMP.8 (the Doha Amendment). In doing so, the CMP decided that the AWG-KP had fulfilled the mandate set out in decision 1/CMP.1, and that its work was concluded.

3.5.1 PROGRESS MADE UNDER THE TWO TRACKS

1. Copenhagen Accord

•Global commitment to keep temperature increase below 2°C

•Principle financial commitments from developed countries:

•USD 30 billion for period of 2010-2012

•USD 100 billion a year by 2020

2. Cancun Agreements

•Formalization of Annex I Parties' pledges made in Copenhagen Accord

•Green Climate Fund

•Cancun Adaptation Framework and Adaptation Committee

•Technology Mechanism

3.5.2. AD HOC WORKING GROUP ON THE DURBAN PLATFORM FOR ENHANCED ACTION

Established to develop the post-2020 climate change regime**,** The ADP to develop under the Convention and applicable to all Parties, either: A protocol**,** Another legal instrument and an agreed outcome with legal force**.** The ADP is to complete its work no later than 2015**.** The instruments developed will come into effect and be implemented from 2020**.** The Ad Hoc Working Group on the Durban Platform for Enhanced Action (ADP) is a subsidiary body that was established by decision 1/CP.17 in December 2011. The mandate of the ADP is to develop a protocol, another legal instrument or an agreed outcome with legal force under the Convention applicable to all Parties, which is to be completed no later than 2015 in order for it to be adopted at the twenty-first session of the Conference of the Parties (COP) and for it to come into effect and be implemented from 2020. By the same decision, the COP launched a work plan on enhancing mitigation ambition to identify and to explore options for a range of actions that can close the ambition gap with a view to ensuring the highest possible mitigation efforts by all Parties. The two-work stream of the ADP is to;

i. To take steps to negotiate a global climate change agreement to be adopted by 2015 and enter into force 2020
ii. To agree how to raise global ambition before 2020 to speed up response to climate change

3.5.3 KEY ISSUES TO RESOLVE

i. Closing mitigation gap
ii. Form of legal framework for 2020 and beyond
iii. Finance for mitigation and adaptation
iv. Effective implementation of technology transfer mechanism
v. Up-scaling of capacity development for implementation

4.0 CONCLUSION

The overall objective of the Climate Change Policy is to guide Partner States and other stakeholders on the preparation and implementation of collective measures to address Climate Change globally assuring sustainable social and economic development. The Policy prescribes statements and actions to guide Climate Change adaptation and mitigation to reduce the vulnerability and enhance adaptive capacity and build socioeconomic resilience of vulnerable populations and ecosystems. Adaptation to Climate Change is of priority to the UNFCCC in view of the high vulnerability of the region to the impacts of Climate Change, with the emerging associated challenges, especially food security.

5.0 SUMMARY

Since climate change is a global issue, international solutions must be found. The main platform where international negotiations on climate change happen is the UN Framework Convention on Climate Change (UNFCCC). The main negotiation issues are climate change adaptation, mitigation, finance, technology and capacity building. Under the Kyoto Protocol developed countries committed to reduce their greenhouse gas emissions between 2008-2012.

The Protocol has been renewed for the period 2012-2020.The current negotiations are about reaching an agreement that will go beyond 2020.

6.0 TUTOR-MARKED ASSIGNMENT

1. Identify the main negotiation issues on climate change
2. Highlight the relevance of post 2020 climate change regime
3. Briefly explain the provisions of the UNFCCC and its Kyoto Protocol
4. What is the relevance of the Kyoto Protocol?

7.0 REFERENCES/FURTHER READINGS

UNITAR (2013). Climate Change Diplomacy: Negotiating Effectively under the UNFCCC, Module I – VIII.

UNFCCC (2004). The First Ten Years

NFCCC (2006). UNFCCC Handbook

UNFCCC (2008). Kyoto Protocol Reference Manual: On Accounting of Emissions and Assigned Amount

UNFCCC & UNEP (2002). Climate Change Information Kit

UNFCCC. Official Website.

UNIT 2: CLIMATE CHANGE, DEVELOPMENT AND POLICY OPTIONS

CONTENTS

1.0 INTRODUCTION

This unit introduces 'Climate Change, Development and Policy Options'. Tackling climate change and achieving development are two major challenges facing the world. They are also intimately related. Human activities fundamental to development – industry, land use, energy generation and transport – are root causes of anthropogenic climate change. Conversely, climate change impacts hold the greatest threat for the livelihood activities and development prospects of poor and marginalized people. Climate change and underdevelopment are both global and national problems that are the focus of major research endeavors and of global and national policies, investments and other interventions. In this section, we briefly review the history of development and of climate change as recognized problems requiring understanding and action.

2.0 OBJECTIVES

By the end of this unit, students should be able to:

- review the scale of problems posed by climate change and development, and how they interact
- explain why the problems posed by climate change and development are particularly difficult to address
- critically discuss major interactions between mitigation and adaptation as the two major forms of response to climate change challenges.
- describe the broad history of national and international attempts to promote development
- describe the broad history of the threat of climate change as a global and national problem, and of national and international attempts to respond to this threat.

3.0 MAIN CONTENT

3.1 CLIMATE CHANGE IMPACTS

It is now widely accepted that human activities, such as burning fossil fuels for energy, transport and industry, along with forest clearance and livestock keeping, are major contributors to the increase in average global temperatures. The Intergovernmental Panel on Climate Change (IPCC) states that 'the atmospheric concentrations of carbon dioxide (CO_2), methane, and nitrous oxide have increased to levels unprecedented in at least the last 800 000 years. CO_2 concentrations have increased by 40% since pre-industrial times, primarily from fossil fuel emissions and secondarily from net land use change emissions' (IPCC, 2013: p. 7). The IPCC has an extremely high confidence level of 95% probability that global climate change is anthropogenic, caused by excessive greenhouse gas (GHG) emissions. At the global scale, the atmospheric concentration of CO_2 had increased from a pre-industrial value of approximately 280 parts per million (ppm) to over 400 ppm by 2013 (NOAA, 2013).

3.2 Concept of Development

While 'climate change' is relatively easy to define, this is not the case with the term 'development'. As with many 'good' abstract concepts (such as equity, justice and human rights), most people recognise the existence of development and would probably agree that its achievement is desirable and a good goal for societies to work towards. There is, however, considerable disagreement about just what development means.

We can think about development in terms of two major (and interrelated) dimensions. The first dimension makes a distinction between development goals and development processes. The second dimension distinguishes between the core concerns of development, identified here as economic and human development. This is illustrated in the table in 4.1

4.1 **Dimensions of development**

	Processes	**Goals**
Economic development	Economic policies; infrastructural and market development; investment; economic and social structural changes; technical change; efficiency	Improvements in material living standards; income, consumption, employment, savings and investment; food security; income and wealth distribution; poverty reduction, environmental protection
Human or social development	Equitable economic growth; empowerment; governance; change in formal and informal rights and social and economic relations	Capabilities; access to health and education services; rights; equity; freedom, empowerment; particular focus on minority and marginalised groups, on gender relations; security; dignity

As with many characterizations of development, the distinctions made in the table in1.1provide some useful insights, but development is too complex to fit into four neat and distinct boxes in a table! First, the distinction between processes (or means of achieving development) and goals is not rigid. With regard to economic development, some of the goals are necessary parts of the process (investment, for example, is placed in both boxes). Sen (2001) describes 'development as freedom', and the internal and external development of capabilities are both goals and means of achieving freedom (to live, to participate in society, to choose, to consume, etc.). Indeed, from a human development perspective, the separation of processes from goals may be seen as arising from a particular economic or technical and reductionist view of development. Our understanding of development is often affected by our background – our culture and personal history, as well as our professional education, training and experience.

The destruction of societies, cultures and livelihoods by ‘development’ is often associated with globalization and with inequities in power relations. Loss of access to or degradation of natural resources is another process that is often associated with ‘development’ (with the destruction of societies, cultures and livelihoods which depend on those resources).

Loss of access to natural resources occurs when traditional (generally poor) users do not have formal property rights or the means and power to protect their rights from other more powerful interests. Degradation of resources as a result of pollution or overuse can be analyzed in a similar way: the fundamental problem is a lack of protected property rights. Of course, the degradation of resources does not just affect the poor and marginalized (although it affects them most). In the world we live in today (and especially in the context of climate change), it is not possible to discuss development without considering questions about sustainability and sustainable development.

3.3 SUSTAINABLE DEVELOPMENT

There are no clear and agreed definitions of sustainability and sustainable development. It is helpful to identify three dimensions of sustainability and hence of sustainable development.

i. Environmental sustainability describes the ability of environmental resources to support an activity or set of activities.
ii. Economic sustainability describes the ability of an activity or set of activities to yield economic benefits greater than economic costs.
iii. Social sustainability describes the ability of social structures and/or behaviour to support an activity without being undermined by it.

One definition of sustainable development that has gained popularity, after the Brundtland report (WCED, 1987) was published, was that it is ‘development which meets the needs of the present without compromising the ability of future generations to meet their own needs’. Various definitions have emerged since then. Drexhage and Murphy (2010:p. 6) distil three principles that the definitions have in common: that there is a commitment to equity and fairness (prioritizing the improvement of conditions of the world's poorest and including the rights of future generations), employment of the precautionary principle ('where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation' (Rio Declaration on Environment and Development, Principle 15 – UN, 1992)) and recognition of the interdependency of the three pillars so that there is 'integration, and understanding and acting on the complex interconnections that exist between the environment, economy, and society'. Our main focus in examining climate change and development is on the problems of uneven development and poverty in poorer countries, but we also consider a number of lessons and interactions between these and development processes and goals in more wealthy societies.

The growing focus on uneven development and, in particular, poverty in international development has been associated with international agreement at the United Nations on Development Goals being a unifying framework for international development activities. Eight Millennium Development Goals (MDGs) were agreed in 2000, and in 2015 they were replaced by the more comprehensive Sustainable Development Goals (SDGs).

3.4 CLIMATE CHANGE AND DEVELOPMENT INTERACTIONS

There are two ways in which our separate examinations of climate change and development suggest that the major global challenges of climate change and development interact. First, climate change impacts most heavily on poor and vulnerable people, and is therefore likely to set back development gains made in the past. Second, climate change poses a threat to sustainable development. Climate change clearly has the potential to impact, directly or indirectly, all 17 SDGs. The achievement of some of the goals, such as those related to sustainable consumption and production patterns, and sustainably using marine and terrestrial ecosystems, could result in reduced emissions in comparison with business as usual.

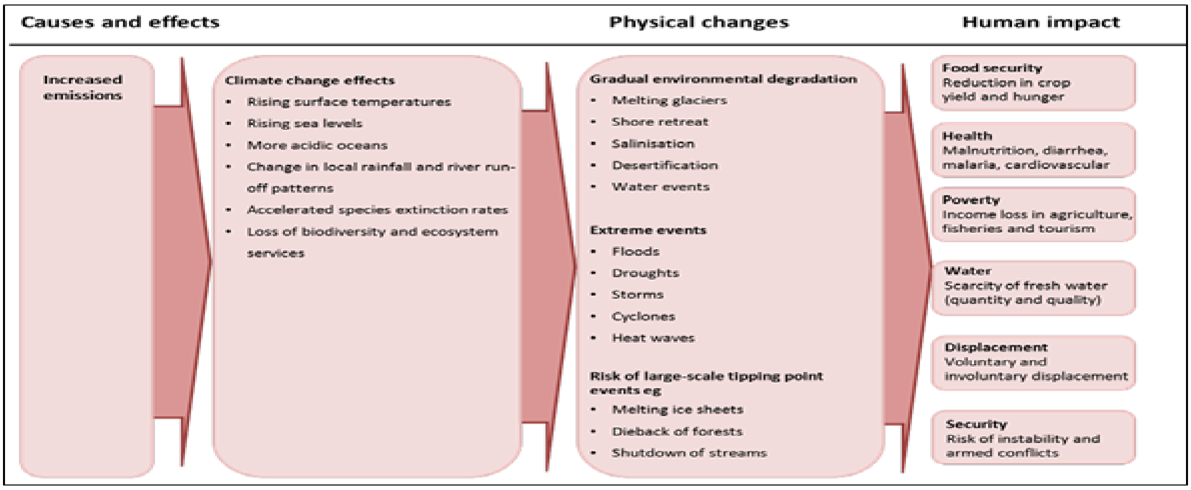
3.5 CLIMATE CHANGE THREATS TO DEVELOPMENT PROGRESS

A major difficulty in the consideration of climate change impacts on development is the considerable uncertainty about the rate and nature of global warming, about the consequent rate and nature of its effects on different parts of the climate system, and then about the rate and nature of the effects of changes in these climate variables on human and economic development. Such uncertainty means that considerable care needs to be taken in interpreting estimates of climate change impacts on development. However, understanding of the physical, biological and social sciences of climate change impacts is rapidly advancing. The previous estimates of climate change and its impacts have frequently been found to be more conservative than current estimates (see, for example, Richardson et al, 2009), and this suggests that policy and planning should take account of the more serious potential impacts. Hallegatte et al (2016: p. 2) state that 'climate change represents a significant obstacle to the sustained eradication of poverty, but future impacts on poverty are determined by policy choices: rapid, inclusive, and climate-informed development can prevent most short-term impacts whereas immediate pro-poor, emissions-reduction policies can drastically limit long-term ones'.

Indications of the ways that climate change is already undermining and negating existing development achievements has been documented for some years now, for instance in the 'Human Impact Report: Climate Change: The Anatomy of a Silent Crisis' (GHF, 2009). This report recognises the uncertainty and difficulties inherent in quantifying climate change impacts on development and the risks of either overstating or understating these impacts. However, it does attempt to draw together and triangulate across a wide range of information sources, including IPCC and other peer- reviewed and more conservative scientific reports and models, insurance industry information, international organisation reports and case studies. The report estimates that, in 2008/2009, 325 million people were affected annually by climate change, with a further 315 thousand annual deaths due to climate change (these may be compared with annual global estimates of 24 million people needing medical attention after traffic accidents in 2004, 247 million cases of malaria in 2006, 22 thousand deaths from the Indian Ocean Tsunami in 2006 and 519 thousand deaths annually from breast cancer from 2004 to 2008) (GHF, 2009: p. 11). These figures are calculated assuming that 40% of increased weather events and 4% of people affected and deaths caused by environmental degradation are attributable to climate change (GHF, 2009: pp. 9, 11).

Global economic losses from climate change are estimated at US$125 billion and are projected to more than double from 2010 to 2030 (GHF, 2009: pp. 19, 20). Critical human impacts of climate change arise through impacts on human habitat, food security, health, poverty, water scarcity, displacement and security.

4.2 The links from increased GHG emissions to human impacts



Source: Dalberg analysis, in GHF (2009) p. 23

It seems likely that climate change will make the achievement of the SDGs very difficult. Wright et al (2015) state that: Climate change will significantly hamper LDCs' [least developed countries] ability to achieve the SDGs on poverty, hunger, health, water, growth, infrastructure, cities, marine resources and ecosystems. It may also decrease LDCs' ability to meet goals on education, gender, energy, inequality, sustainable consumption and production, peace, and implementation. And extreme climate change will make combating climate change itself more difficult. Climate impacts are also very likely to increase the cost of meeting all SDGs in LDCs, especially under high- emission scenarios.'

It is difficult to determine with any precision the current or future impacts of climate change on development. It is clear, however, that the scale of impacts is likely to be large, and that there will be many negative impacts to which poor people are particularly vulnerable. Climate change is therefore likely to set back many of the development gains made in the past. Climate change makes development all the more urgent and important if development can help build resilience to climate change impacts and the adaptive capacity for poor and vulnerable people. Similarly, the potential seriousness of climate change impacts on poor people, and its likely negative impact on development processes and goals, make tacking climate change all the more urgent.

3.6 CLIMATE CHANGE THREATS TO SUSTAINABLE DEVELOPMENT

Climate change represents a fundamental threat to current patterns of development, as it is clear that development which involves large-scale emissions of GHGs is not sustainable. The climate system does not have the capacity to absorb large amounts of GHGs without substantial changes in the climate, changes which undermine global natural and economic systems on which we currently depend. These include our water supplies, food systems, health, infrastructure and settlements. Understanding these threats requires an understanding of the science of climate change, impacts of different human activities on climate change and impacts of climate change on human activities and welfare. Major areas of human activity and welfare to consider here are agriculture, energy generation, transport, industry, settlement, water supplies, health, food supplies, lifestyles and vulnerabilities, and responses to disasters.

A consideration of the implications of climate science and the impacts for sustainable development needs to be set in the context of a broader understanding of the nature of climate change and development problems.

3.7 A BRIEF HISTORY OF DEVELOPMENT POLICY

In its most general sense, development is a process that has gone on throughout human history as individuals and societies have attempted to better themselves. In Europe, concerted efforts to improve the conditions of disadvantaged sectors in society began in the 19th and early 20th centuries often spearheaded by religious or socialist groups. Such efforts were accompanied by the study of disadvantage, and eventually led, *inter alia*, to legislation and the establishment of government departments concerned with improving or protecting social welfare. However, ‘development’ as a major government activity and field of endeavour extending beyond national borders emerged only after the Second World War, as a result of the need to rebuild the war-torn countries in Europe. European, US and international organisations involved in reconstruction in Europe then turned their attention to the problems faced by countries in Africa, Asia and Latin America. As these countries began to gain their independence, people and governments in former colonial countries recognised that they had both obligations and opportunities to raise economic activities and living standards in their former colonies.

Development rapidly became mixed up with the Cold War, as international development assistance was seen as an extension of foreign policy, and the capitalist West (United States, Canada, Europe and Australasia) competed with the socialist East (Soviet Union, Eastern Europe and China) to attract and keep Asian, African and Latin American countries within their spheres of influence and trade. Understandings of ‘development’ changed, and became increasingly contested, with different theorists, Northern and Southern governments, international agencies and others, putting different emphases on political, social, economic and technological change as the key constraints to and drivers of change. The collapse of the Soviet Union and the end of the Cold War led to, and coincided with, important changes in the practice and theory of international development, which has since largely been dominated by the West. There have, however, been continuing alternative currents, notably in some Latin American countries, such as Venezuela, Cuba and Bolivia, in some non-governmental organisations (NGOs), and anti-globalisation and environmental movements in the West, and most recently in the emergence of China as a major investor and economic player in Africa.

Cutting across and within these streams were other approaches to development, which included the:

- basic needs approach, which stressed the importance of investments to provide people with secure access to food, shelter, water and education and health services, often through community-based organization
- environmental and natural resource management approaches, which stressed the importance of natural resources in development and the threats posed by changing access to and productivity of natural resources
- gender approaches, which stressed the different situations and roles of women and men in societies and in development processes
- the sustainable livelihoods approach, which stressed the need for holistic and people-centred analysis and action
- participatory and empowerment approaches, with greater involvement of poor people in the definition and analysis of problems and priorities, and in action
- poverty reduction approach, which came to be enshrined in the MDGs articulated and set out as the overarching focus for all international development efforts at the end of the 20th century

3.8 A BRIEF HISTORY OF CLIMATE CHANGE POLICY

Awareness of climate change as an issue facing humans, and action to address it, are not as recent as we might think. For instance, suggestions of climate change caused by humans were being voiced in the times of Classical Greece (Hughes, 1985); albeit not on a global scale.

What is newer, relatively speaking, is a preoccupation with the scale at which human activity has environmental consequences and, in particular, with the global magnitude of anthropogenic climate change, and a more thorough understanding of the atmospheric physics behind it. The importance of the atmosphere in maintaining the temperature at the surface of the earth, the role in this of absorption of solar radiation by carbon dioxide and methane, and the potential for global temperature increases as a result of industrial activities releasing carbon dioxide were first identified by Fourier, Tyndale and Arrhenius in 1827, 1859, and 1896, respectively, in France, Britain and Sweden. It was not until the late 1970s, however, that the World Meteorological Organization (WMO) began to express concern that human activities – notably the emission of carbon dioxide – might lead to serious warming of the lower atmosphere. Scientific concerns about global warming grew during the 1980s and, in 1988 (a year when North America faced an intense heat wave and drought), these spilled over into political concerns. As a result, the WMO and UNEP established the Intergovernmental Panel on Climate Change (IPCC) to investigate and report on scientific evidence on and possible international responses to climate change.

The IPCC has been central to the subsequent debates and processes around the development of climate change policies. Its first assessment report (in 1990) fed into the drafting of the United Nations Framework Convention on Climate Change (UNFCCC) in 1991. This was signed by 166 nations at the Earth Summit in Rio de Janeiro in 1992 and came into force in 1994. The UNFCCC did not contain any specific national or international targets to reduce GHG emissions, but it contained key points or principles that have been foundational in subsequent international climate change debates and processes. It set out the following:

- an objective of stabilising the climate to prevent 'dangerous anthropogenic interference with the climate system' in a time frame that would allow natural systems to adapt without major damage to food systems and economic development
- the need for countries to monitor and limit their GHG emissions and for different national limits, taking account of countries' different responsibilities and capacities
- particular concerns for developing countries – and especially those most vulnerable to damaging climate change impacts, such as small island states

- the importance of precautionary measures to respond to the severity of climate change threats, despite real scientific uncertainties regarding climate change processes and impacts.

In the absence of specific targets, the UNFCCC fell short of the aspirations of many environmentalists. However, it was an important step in establishing foundational principles to guide subsequent negotiations over national reductions in GHG emissions. These culminated in a Conference of Parties (COP) meeting in Kyoto, Japan, in 1997.

This was the third Conference of Parties meeting (COP 3) where delegates agreed what is known as the Kyoto Protocol. This established developed country emissions targets for 2008–2012 and three main mechanisms for meeting them:

- an emissions trading scheme, which allowed international trade in emission allowances
- the Clean Development Mechanism (CDM), which allowed developed country signatories emission credits for investing in emissions savings in developing countries; the only Kyoto mechanism that allowed for investment in developing countries
- joint implementation, which allowed emission saving investments in other industrial (Annex 1) countries, including emerging economy countries, to be credited to signatory developed countries, promoting more cost-effective emission saving than could otherwise be achieved.

However, a number of countries (notably the United States and Australia) subsequently refused to ratify the Kyoto agreement, arguing that developing countries also needed to limit their emissions. These arguments were supported by major public debates questioning the scientific basis for climate change predictions – with substantial investments by the oil industry, in particular, in lobbying groups questioning or denying climate change.

By 2009 the existence and dangers of climate change were increasingly being recognized with:

- growing scientific evidence and understanding of climate change and its impacts, and increasing representation of this in the press; the publication of the IPCC's Fourth Assessment Report in 2007 played a critical role in this (the Fifth Assessment Report published in 2013/2014 further contributed to an improved understanding of the impacts and drivers of climate change and reiterated the extremely high confidence level that climate change was anthropogenic)

- public awareness and concern about unusual weather patterns (for example, the extreme heat of the 2003 European summer; Hurricane Katrina and other storms around the world; floods, droughts and fires in Europe, the United States and Australia)
- political change (notably the US Administration and in Australia).

National governments face major difficulties agreeing national contributions to international reductions in global emissions of GHGs. On the one hand, there is widespread recognition that drastic emissions reductions are needed, but on the other:

- governments (and most importantly their electorates) do not want to bear the costs of such reductions in terms of increased energy costs, investments in new technologies and infrastructure, and lifestyle changes
- there are fears that countries with higher emission allowances will benefit from competitive advantages in international trade, while countries with lower emission allowances will suffer disadvantages and hence suffer economically
- rich (developed) countries with high emissions per capita face very large economic and social adjustment costs if they are to make substantial reductions in their emissions
- poor (developing) countries have lower current emissions per capita, but do not want either to be denied opportunities for economic growth and increased standards of living associated with increasing emissions, or to be forced down a more costly and slower development path constrained by keeping down GHG emissions
- poor (developing) countries need large financial and other resources to enable them to adapt to and cope with climate change impacts; in this, they are looking to richer (developed) countries to provide a substantial part of these resources, as richer countries are better able to provide the necessary finance, and are primarily responsible for the GHGs causing climate change.

Differences in countries' perceptions were sharpened by the awareness in developing countries that developed countries continue to be the major greenhouse emitters, currently benefit from and are trying to defend high levels of emissions per person and are least vulnerable to climate change impacts. Developed countries, on the other hand, see per capita and total emissions rising fastest in rapidly growing, large developing countries – most notably China – and argue that this growth must be limited if global emissions are to be contained.

3.9 POLICY OPTIONS

There are several main types of policies for reducing greenhouse gas emissions. Here is some information on them. There are at least five main ways a government can help move us toward reducing greenhouse gas (GHG) emissions:

a. Regulations, sometimes called "command and control" measures by which government tells businesses what they can, cannot, or must do, and how. Example: EPA regulations on carbon emissions of power plants or mileage targets for automobiles.
b. Subsidies for low-GHG energy sources or for reductions in GHG emissions by fossil-fuel companies.
c. Cap-and-trade systems. Stipulate the total GHG emissions for an economic sector, assign "pollution permits," and let companies sell and buy permits.
d. Carbon taxes, also call carbon fee and dividend. A tax is placed on carbon emissions at the source (e.g. a mine or a import port-of-entry). Oil companies have voiced their support for this approach. And over 150 corporations have signed "The Carbon Price Communique" that calls for carbon pricing.
e. Supporting scientific research and new technologies that promise to mitigate our contribution to global warming.

4.0 CONCLUSION

The anticipated global temperature increases are likely impacts on various systems. The expected temperature increases lead to very significant impacts on water supply and availability, on the integrity of ecosystems, on food production, on coastal areas and those living there, and on human health. There will also be ‘singular events’: structural and, in the medium term, irreversible changes in the behaviour of the ocean and climate system with major impacts on the climate. These impacts will affect the basic needs of life – food, water, shelter, health – for billions of people and, often, it will be poorer people living in poorer countries who will be the most affected. This raises profound ethical and justice issues, since these people have generally made the lowest contribution to the causes of global climate change (the emission of GHGs), and their lack of resources means that they are the least able to combat the impacts of climate change.

5.0 SUMMARY

This unit has provided an introduction to the interactions between climate change and development and the potential for very serious impacts of climate change on development and poor people. It has also flagged the likelihood that we will not avoid the sorts of climate change that are of greatest import to people living in conditions of poverty, precarity and marginalisation. Unfortunately, there are also very serious challenges to policies promoting mitigation and some forms of adaptation. Many of these are linked to the overwhelming prioritisation of economic growth over other considerations, even when this growth is implicated in generating inequality and environmental problems. The idea of maintaining and increasing growth is enshrined in every mainstream development paradigm, and even in the more recent notion(s) of the green economy, much debate is focussed on making growth greener, rather than exploring alternative understandings of terms like development, well-being and prosperity. The level and type of global commitment to tackling climate change demonstrated in the Paris Agreement of 2015 reflects this continued growth prioritisation. Ultimately, until it is clear that the generation of economic growth can and will be pursued in ways which bring global greenhouse gas emissions down quickly enough to avoid 'dangerous' climate change, the question of whether our development model can become the solution, rather than the problem, will remain open.

6.0 TUTOR-MARKED ASSIGNMENTS

i. Discusses threats of climate change to development. From your reading of the unit as a whole, what are the threats that development poses to addressing climate change?

ii. List the features of climate change and of climate change impacts that make it so difficult to address.

iii. There is continued uncertainty about climate change processes and impacts due to our lack of understanding about them. How does this affect responses to climate change and what are the implications for professionals working on issues related to climate change?

iv. Identify 5 policy Options for climate change mitigation

7.0 REFERENCES/FURTHER READINGS

Drexhage, J. & Murphy, D. (2010) Sustainable Development: From Brundtland to Rio 2012. New York, United Nations.

Faccer, K., Nahman, A. & Audouin, M. (2014) Interpreting the green economy: emerging discourses and their considerations for the Global South. Development Southern Africa, 31 (5), 642–657.

GHF. (2009) Human Impact Report: Climate Change: The Anatomy of a Silent Crisis. Geneva, Global Humanitarian Forum (GHF).

IPCC.(2001) 2001 A Report of Working Group II, Climate Change 2001: Impacts, Adaptation, and Vulnerability.[Online]. Cambridge, Cambridge University Press. Available from: https://www.ipcc.ch/ipccreports/tar/ [5 September 2019]

IPCC. (2013) Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (Eds.)]. Cambridge, United Kingdom and New York, NY, USA, Cambridge University Press.1535 pp.

IPCC.(2014) Summary for policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, andL.L. White (Eds.)]. Cambridge, United Kingdom and New York, USA, Cambridge University Press. pp. 1–32. Available from: http://www.ipcc.ch/pdf/assessment-report/ar5/wg2/ ar5_wgII_spm_en.pdf [Accessed 5 September 2019]

Sen, A. (2001) Development as Freedom. Oxford, Oxford University Press.

The Economist (2009) Go on, guess. The Economist, Friday 29 May 2009.

WCED.(1987). Our Common Future. Oxford, UK, Oxford University Press

Unit 3: CLIMATE CHANGE FINANCING

CONTENTS

1.0 INTRODUCTION

Climate finance refers to local, national or transnational financing—drawn from public, private and alternative sources of financing—that seeks to support mitigation and adaptation actions that will address climate change. The Convention, the Kyoto Protocol and the Paris Agreement call for financial assistance from Parties with more financial resources to those that are less endowed and more vulnerable. This recognizes that the contribution of countries to climate change and their capacity to prevent it and cope with its consequences vary enormously. Climate finance is needed for mitigation, because large-scale investments are required to significantly reduce emissions. Climate finance is important for adaptation, as significant financial resources are needed to adapt to the adverse effects and reduce the impacts of a changing climate. This unit discusses different sources of financing climate change adaptation, financing gap, inefficiency in climate change financing instruments and mitigation financing.

2.0 OBJECTIVES

At the end of this unit, you should be familiar with

(i) Different sources of climate change financing

(ii) Mitigation financing

(iii) Climate change adaptation financing

(iv) Solution to climate change financing inefficiency.

3.0 MAIN CONTENT

3.1 THE FINANCING GAP

Solving climate change problem will cost trillions. How many depends on how ambitious the global response is, how it is structured, how the measures are timed, how effectively they are implemented, where mitigation takes place, and how the money is raised. International community, national governments, local governments, firms, and households will bear the cost. The cost of cutting global greenhouse gas emissions by 50 percent by 2050 could be in the range of 1–3 percent of GDP. This is the minimum cost most scientists believe is needed to have a reasonable chance of limiting global warming close to 2°C above preindustrial temperatures. But mitigation costs are sensitive to policy choices. They increase steeply with the stringency of the emission reduction target and with the certainty of reaching it. Global mitigation costs will also be higher if the world deviates from the least cost emission reduction path and also increase substantially if developing countries are not included in the initial mitigation effort (this led to the establishment of the Clean Development Mechanism under the Kyoto Protocol). Similarly, not considering all mitigation opportunities would increase overall costs.

It is also important to distinguish between mitigation costs (the incremental costs of a low-carbon project over its lifetime) and incremental investment needs (the additional financing requirement created as a result of the project). Because many clean investments have high up-front capital costs, followed later by savings in operating costs, the incremental financing requirements tend to be higher than the lifetime costs. For fiscally constrained developing countries these high up-front capital costs can be a significant disincentive to invest in low-carbon technologies. Focusing on the 450 ppm target, mitigation costs in developing countries is between $140 billion and $175 billion a year by 2030 with associated financing needs of $265 to $565 billion a year. For adaptation the most comparable estimates are the medium-term figures produced by the United Nations Framework Convention on Climate Change (UNFCCC) and the World Bank, which range from $30 billion to $100 billion. Many, but not all, of the identified adaptation needs would require public expenditures. According to the UNFCCC secretariat, private funding would cover about a quarter of identified investment, although this estimate is unlikely to capture the full private investment in adaptation. These numbers give a rough indication of the adaptation cost, but they are neither particularly accurate nor fully comprehensive. Most were derived from rules of thumb, dominated by the cost of climate proofing future infrastructure. They underestimate the diversity of the likely adaptation responses and ignore changes in behaviour, innovation, operational practices, or locations of economic activity. They also ignore the need for adaptation to nonmarket impacts such as those on human health and natural ecosystems. Some of the omitted options could reduce the adaptation bill (for example, by obviating the need for costly structural investments); others would increase it. The estimates also do not consider residual damages beyond effective adaptation. Adaptation cost estimates also ignore the close links between adaptation and development. Although few studies are clear on this point, they measure the extra spending to accommodate climate change over and above what would have been spent on climate- sensitive investments, such as those accommodating the consequences of income and population growth or correcting an existing adaptation deficit. But, in practice, the distinction between adaptation funding and development funding is not easy. Investments in education, health sanitation, and livelihood security, for example, constitute good development. They also help reduce socioeconomic vulnerability to both climatic and non-climatic stress factors. Certainly in the short term, development assistance is likely to be a key complement to close adaptation deficits, to reduce climate risks, and to increase economic productivity.

SELF ASSESSMENT EXERCISE

Discuss mitigation costs and adaptation financing.

3.2 MITIGATION FINANCE

Trillions of dollars will be spent to upgrade and expand the world's energy and transport infrastructure in the coming decades. These massive investments present an opportunity to decisively shift the global economy to a low- carbon path—but they also raise the risk of a high-carbon lock-in if the opportunity is missed. New infrastructure investments need to be steered to low-carbon outcomes. Both public and private flows will be needed to fund these investments. Many instruments as shown in Table 4.3 already exist. But we have a role in catalyzing climate action: mobilizing additional resources; reorienting public and private flows toward low carbon and climate- resilient investments; and supporting the research, development, and deployment of climate- friendly technologies.

The public sector will provide capital for big infrastructure projects, but a large part of the investment to create a low carbon economy—from energy-efficient energy—will come from the private sector. Currently, governments account for less than 15 percent of global economy wide investment, although they largely control the underlying infrastructure investments that affect the opportunities for energy efficient products. There are various ways to encourage private investment in mitigation, but the most prominent market instrument involving developing countries has been the Clean Development Mechanism (CDM).

Table 4.3: Existing Instruments of Climate Finance

Type of Instrument	Mitigation	Adaptation	Research, Development, and Diffusion
Market- based mechanisms to lower the costs of climate action and create incentives	Emissions trading (CDM, JI, voluntary), tradable renewable energy certificates, debt instruments (bonds)	Insurance (pools, indexes, weather derivatives, catastrophe bonds), payment for ecosystem services, debt instruments (bonds)	
Grant resources and concessional finance (levies and contributions including official development assistance and philanthropy) to pilot new tools, scale up and catalyze action, and act as seed money to leverage the private sector.	GEF, CTF, UN-REDD, FIP, FCPF	Adaptation Fund, GEF, LDCF, SCCF, PPCR and other bilateral and multilateral funds	GEF, GEF/IFC Earth Fund, GEEREF
Other instruments	Fiscal incentives (tax benefits on investments, subsidized loans, targeted tax or subsidies, export credits), norms and standards (including labels), inducement prizes and advanced market commitments, and trade and technology agreements		

Source: World Bank (2009)

It has triggered more than 4,000 recognized emission reduction projects to date. Other similar mechanisms, such as Joint Implementation (the equivalent mechanism for industrial countries) and voluntary carbon markets are important for some regions (transition countries) and sectors (forestry) but are much smaller. Under the CDM, emission reduction activities in developing countries can generate "carbon credits"—measured against an agreed baseline and verified by an independent entity under the aegis of the UNFCCC—and trade them on the carbon market. For example, a European power utility may acquire emission reductions (through direct purchase or financial support) from a Chinese steel plant embarking on an energy- efficiency project. The financial revenues the CDM generates are modest relative to the amount of mitigation money that will have to be raised. But they constitute the largest source of sanitation energy, energy efficiency, and fuel switching. This could raise $18 billion ($15 billion to $24 billion) in direct carbon revenues for developing countries, depending on the price of carbon. In addition, each dollar of carbon revenue leverages on average $4.60 in investment and possibly up to $9.00 for some renewable energy projects. It is estimated that some $95 billion in clean energy investment benefited from the CDM over 2002–08. In comparison, official development assistance for mitigation was about $19 billion over 2002–07, and sustainable energy investment in developing countries totaled approximately $80 billion over 2002–08.

Donors and international financial institutions are establishing new financing vehicles to scale up their support for low carbon investment. Total finance under these initiatives amounts to $19 billion up to 2012, although this figure combines mitigation and adaptation finance. Combining the donor funds (and counting them as if committed solely to mitigation) with the projected CDM finance produces mitigation finance of roughly $37 billion up to 2012, or less than $8 billion a year. This falls far short of the estimated mitigation costs in developing countries of $140 to $175 billion a year in 2030, and even farther short of the associated financing requirements ($265 to $565 billion).

The main existing source of adaptation funding is international donors, channeled either through bilateral agencies or through multilateral institutions like the Global Environment Facility (GEF) and the World Bank. The establishment of the Adaptation Fund in December 2007, a funding mechanism with its own independent source of finance, was an important development. Its main income source is the 2 percent levy on the CDM, an innovative financing source that could raise between $300 million and $600 million mitigation finance to developing countries. Between 2001, the first year CDM projects could be registered, and 2012, the end of the Kyoto commitment period, the CDM is expected to produce some 1.5 billion tons of carbon dioxide equivalent (CO2e) in emission reductions, much through renewable over the medium term, depending on the carbon price. Excluding private finance, $2.2 billion to $2.5 billion is projected to be raised for adaptation from now to 2012, depending on what the Adaptation Fund raises. The potential adaptation finance available is less than $1 billion a year, against funding requirements of $30 to $100 billion a year over the medium term.

SELF ASSESSMENT EXERCISE
Discuss the existing instruments of climate finance.

3.3 INEFFICIENCIES IN EXISTING CLIMATE FINANCE INSTRUMENTS

Inefficiency could take what is already projected to be a very large and costly endeavour and make it even more expensive. So there is an obvious case for ensuring that climate finance is generated and spent efficiently. Three aspects of the efficiency of climate finance are considered below: the fragmentation of climate finance into multiple funding sources, the limitations of carbon offset markets for mitigation, and the potential costs of taxing certified emission reductions (CERs) to finance the Adaptation Fund.

(i) Fragmentation of Climate Finance

There is a risk of proliferation of special-purpose climate funds. Fragmentation of this sort threatens to reduce the overall effectiveness of climate finance because as transaction costs increase, recipient country ownership lags, and alignment with country development objectives becomes more difficult. Each new source of finance, whether for development or climate change, carries with it a set of costs. These include transaction costs (which rise in aggregate as the number of funding sources increases), inefficient allocation (particularly if funds are narrowly defined), and limitations on scaling up. The current fragmentation and the low level of resources highlight the importance of the on-going negotiations about a climate-financing architecture adequate to mobilize resources at scale and to deliver efficiently across a wide range of channels and instruments. While there is not an exact parallel between climate finance and development aid, some of the lessons from the aid effectiveness literature are highly relevant to climate finance. Concern about the negative effects of aid fragmentation was one of the key drivers of the Paris Declaration on Aid Effectiveness. In that declaration, reaffirmed in the Accra Agenda for Action, both aid donors and recipients committed to incorporate the key tenets of ownership, alignment, harmonization, results orientation, and mutual accountability into their development activities. The Paris Declaration raises important issues for financing climate investments in developing countries, many of which are widely accepted and reflected in negotiation documents, such as the Bali Action Plan:

- Ownership. Building a shared consensus that climate change is a development issue, a central tenet of this Report, will be key in building country ownership. This consensus view must then be built into country development strategies.
- Alignment. Ensuring alignment between climate actions and country priorities is the second critical step in increasing the effectiveness of climate finance. Moving from the project to the sector and program level can facilitate this process. Predictability and sustainability of finance is another key aspect of alignment. Stop start climate- action programs, driven by the volatility of finance, will reduce overall effectiveness.
- Harmonization. To the extent that the various climate funds have divergent purposes, this fragmentation of climate finance presents a great challenge to harmonizing different sources of finance and exploiting synergies among adaptation, mitigation, and development finance.
- Results. The results agenda for climate action is not substantially different from those of other development domains. Designing and implementing meaningful outcome indicators will be key to maintaining public support for climate finance and building country ownership for climate action.
- Mutual accountability. Weak progress toward Kyoto targets by many developed countries puts their accountability for climate action in the spotlight. An essential part of any global agreement on climate change must be a framework that holds high-income countries accountable for moving toward their own emission targets and for providing climate finance and that also holds developing countries accountable for climate actions and uses of climate finance, as established in the Bali Action Plan. Beyond provision of resources, monitoring and reporting of climate finance flows and verification of results are a central topic of the ongoing climate negotiations.

In addition to the sources of finance, an important question is what investments climate funds should finance and the associated financing modalities. While some climate investments will be for individual projects — low-carbon power plants, for example — efficiencies can, in many instances, be gained by moving to the sector or program level. For adaptation, finance at the country level should in most cases be commingled with overall development finance, not used for specific adaptation projects. More generally, the climate finance could emulate the poverty reduction strategy approach implemented in many low-income countries. This entails linking aid resources targeted at reducing poverty to a poverty reduction strategy prepared by the recipient country. Based on an analysis of poverty and a definition of country priorities, as validated participatory processes with civil society, the strategy becomes the basis for broad budget support by donors to finance a program of action aimed at reducing poverty. Individual projects become the exception rather than the rule. If countries integrate climate action into their development strategies, a similar approach to climate finance should be feasible.

(ii) The Efficiency Cost of Adaptation Funding

An important source of adaptation finance, and the key revenue source of the Adaptation Fund, is a 2 percent levy on the CDM, a tax that could be extended to include other trading schemes, such as Joint Implementation. This is a promising route to raising financial resources for the Adaptation Fund, which offers clear addition. But it also raises some basic economic issues. Perhaps the most important objection is that the CDM levy is taxing a good (mitigation finance) rather than a bad (emissions). More generally, the levy raises two basic questions:

- What is the scope for raising additional adaptation finance through the levy, and what is the loss in economic efficiency (or deadweight loss, in economic jargon) associated with the tax?
- How is the tax burden distributed between the sellers (developing countries) and buyers (developed countries)?

Analysis based on the U.K. government's GLOCAF model shows that the ability of an extended carbon trading scheme to raise additional adaptation revenues will depend on the type of global climate deal that is agreed. Revenues will vary depending on the expected demand, particularly whether demand will be constrained by supplementary restrictions to promote domestic abatement, and to a lesser extent on the expected supply, including whether a future regime could encompass credits from avoided deforestation and from other sectors and regions that currently produce little carbon trade. Revenues will also depend on the tax rate. At the current rate of 2 percent the levy could be expected to raise around $2 billion a year in 2020 if demand is unconstrained but less than half that amount if restrictions are placed on the purchase of credits. In the scenarios where demand is constrained, buyers do not respond strongly to the tax, and much of the tax burden is thus passed on to them. But this response changes if constraints on demand are eased. At that point the tax incidence shifts decidedly against developing countries, which have to shoulder more than two-thirds of the tax burden to keep the price of their credits competitive. That is, developing countries would make the main contribution to the Adaptation Fund (through forgone carbon market revenues).

(iii) Ensuring the Transparent, Efficient, and Equitable use of Funds

However successful the attempts at raising additional funds may be will be scarce, so funds have to be used effectively and allocated transparently and equitably. On the mitigation side, fund allocation will be dominated by efficiency considerations. Mitigation is a global public good, and its benefits are the same wherever abatement takes place (although the allocation of mitigation costs raises equity issues). With the right framework in place—essentially a carbon market that allows the exploration of abatement opportunities on a global scale while protecting host- country interests—a combination of carbon markets, other performance- based systems, and public funds aimed at niches overlooked by the market can allocate capital fairly effectively. The allocation of adaptation finance, by contrast, raises important questions of fairness as well as efficiency. Unlike that for mitigation the allocation of adaptation resources has strong distributional implications. Money spent protecting small island states is no longer available for African farmers. The question of how to classify adaptation finance is still debated, and the controversy spills over to how to allocate this finance. Developing countries are inclined to view adaptation finance as compensation for damages, invoking a global polluter- pays principle. From the developing- country viewpoint, therefore, the question of how adaptation finance is used is beyond the purview of high income countries. But the latter countries feel strongly that scarce financial resources should be used efficiently, whatever the justification for or provenance of the funds. It can certainly be argued that the efficient and equitable allocation and use of adaptation finance are in everybody's interest. Wasteful use of resources can undermine public support for the whole climate agenda. That makes the transparent, efficient, and equitable allocation of adaptation funding paramount. As an example of how development institutions have handled the allocation of finance, consider the approach taken by the International Development Association (IDA), which constructs an index combining the need for finance, the absorptive capacity of the government, and the performance of the central government. The IDA approach is not without its faults. Because the formula is uniform across countries, it essentially imposes the same development model on all countries.36 This is already problematic for standard development issues and may be even more so for climate change, where much less is known about the right adaptation model. Even so, an empirical approach to allocating adaptation finance that aims to address these concerns could serve at least three purposes: it could reduce transaction costs if lobbying and negotiation are not part of the allocation process; it could support the results agenda with an allocation process based on empirical measures; and it could support mutual accountability through transparency in allocations. The measure of need for finance should be closely related to the concept of climate vulnerability. As conceived by the IPCC, vulnerability is a function of the capacity to adapt, the sensitivity to climate factors, and the exposure to climate change. The measure of need for finance could be some population-weighted index of sensitivity and exposure, perhaps with a poverty weight as well. For large countries in particular, the distribution of impacts and differences in vulnerability between localities would also have to be taken into account.

(iv) Matching Financing Needs and Sources of Funds

Combating climate change is a massive socioeconomic, technological, institutional, and policy challenge. Particularly for developing countries it is also a financing challenge. By about 2030 the incremental investment needs for mitigation in developing countries could be $140 to $175 billion (with associated financing requirements of $265 to $565 billion) a year. The financing needs for adaptation by that time could be $30 to $100 billion a year. This is additional funding beyond baseline development finance needs, which also remain essential and will help in part to close existing adaptation gaps. Though growing, current climate- related financial flows to developing countries cover only a tiny fraction of the estimated needs. No single source will provide that much additional revenue, and so a combination of funding sources will be required. For adaptation funding might come from the current adaptation levy on the CDM, which could raise around $2 billion a year by 2020 if extended to a wider set of carbon transactions.

Proposals like the sale of AAUs, a levy on international transport emissions, and a global carbon tax could each raise around $15 billion a year. For mitigation at the national level the majority of funding will have to come from the private sector. But public policy will need to create a business environment conducive to low-carbon investment, including but not limited to an expanded, efficient, and well- regulated carbon market. Complementary public funding—most likely from fiscal transfers—may be required to overcome investment barriers (such as those related to risk) and to reach areas the private sector is likely to neglect. Stringent emission targets will also be required—initially in high-income countries, eventually for many others—to create enough demand for offsets and to support the carbon price.

Once the majority of countries have emission caps under an international climate agreement, markets can autonomously generate much of the needed national mitigation finance as consumption and production decisions respond to carbon prices, whether through taxes or cap-and- trade. But national carbon markets will not automatically generate international flows of finance. Flows of mitigation finance to developing countries can come from fiscal flows, from linking national emission trading schemes, or potentially from trading AAUs. Flows from developed to developing countries can thus be achieved in several ways. But these flowsare central to ensuring that an effective and efficient solution to the climate problem is also an equitable solution

SELF ASSESSMENT EXERCISE

Discuss issues that surround inefficiencies in existing climate finance instruments

4.0 CONCLUSION

Climate finance refers to local, national or transnational financing drawn from different sources of financing to support mitigation and adaptation actions that will address climate change. Combating climate change is a massive socioeconomic, technological, institutional, and policy challenge and also financing challenge for developing countries. In addition to the sources of finance, an important question is what investments climate funds should finance and the associated financing modalities. However successful the attempts at raising additional funds may be scarce, hence funds have to be used effectively and allocated transparently and equitably. This is because inefficiency could take what is already projected to be a very large and costly endeavour and make it even more expensive.

5.0 SUMMARY

This unit discusses different sources of financing available for climate change, mitigation and adaptation actions. It also considered unequal capacities of developed and developing countries in raising fund for climate change action. The unit stress the need to efficiently utilizes available fund and ensure equity in financing disbursement. This is because inefficiency in utilization may make financing efforts costly and expensive.

6.0 TUTOR-MARKED ASSIGNMENTS

1. Discuss various available financing sources for climate change, mitigation and adaptation.
2. What are the inefficiencies issues that surround the existing climate finance instruments.
3. Discuss the efficiency cost of adaptation funding.
4. Discuss the existing instruments of climate finance.

7.0 REFERENCES/FURTHER READINGS

Agrawala, S., and S. Fankhauser(2008) Economic Aspects of Adaptation to Climate Change: Costs, Benefits and Policy Instruments. Paris: Organisation for Economic Co-operation and Development.

Alcamo, J., and T. Henrichs (2002) "Critical Regions: A Model- based Estimation of World Water Resources Sensitive to Global Changes." Aquatic Sciences 64 (4): 352–62.

Aldy, J. E., E. Ley, and I. Parry (2008) A Tax Based Approach to Slowing Global Climate Change. Washington, DC: Resources for the Future.

Arnell, N. W. (2004) "Climate Change and Global Water Resources: SRES Emissions and Socio Economic Scenarios." Global Environmental Change 14 (1): 31–52.

Bättig, M. B., M. Wild, and D. M. Imboden(2007) "A Climate Change Index: Where Climate Change May Be Prominent in the 21st Century." Geophysical Research Letters 34 (1): 1–4.

Barbier, E. B. (2009) A Global Green New Deal. Geneva: United Nations Environment Programme. Bosello, F., R. Roson, and R. S. J. Tol.(2006) "Economy- Wide Estimates of the Implications of Climate Change: Human Health." Ecological Economics 58 (3): 579–91.

Bovenberg, A. L., and L. Goulder.(1996) "Optimal Environmental Taxation in the Presence of Other Taxes: General Equilibrium Analyses." American Economic Review 86 (4): 985–1000.

World Bank (2009). World Development Report 2010: Development and Climate Change World Bank Publications; 2010 ed. edition (November 6, 2009)

UNIT 4: CLIMATE CHANGE ACTION PLANS

CONTENTS

1.0 INTRODUCTION

Climate change is the latest challenge to sustainable human development. The scientific evidence is clear: climate change is likely to have negative impacts on efforts to achieve Nigeria's development objectives, including the targets set out in *Nigeria Vision 20:2020* and the Sustainable Development Goals. In particular, climate change will impede efforts to reduce the poverty experienced by the majority of Nigerians. Climate change is already having an impact in Nigeria. Weather-related disasters have become more frequent in the past four decades and the trend continues. The nation's natural and agricultural ecosystems, including freshwater and coastal resources, are highly susceptible to the effects of climate change. These vulnerability factors make clear the urgent need to respond to the challenge of climate change in a comprehensive and systematic manner that, at the same time, addresses development priorities, taking account of the gender-differentiated needs and roles of the society. It is in line with this challenges that the Government of Nigeria acknowledges the importance of developing a national response to climate change, and is taking steps to build a governance structure to manage the issue.

2.0 OBJECTIVES

At the end of this unit, students should be able to:

- Identify the major ways of reducing the risk of climate change

- Know the supposed action plan by a country
- Know how a state should mitigate climate change
- Also know how local communities and households can reduce the risk of climate change

3.0 MAIN CONTENT

3.1 WAYS TO MITIGATE THE RISK OF CLIMATE CHANGE

Cities, towns, villages and counties are best able to assess their own vulnerability to a changing climate, and to initiate adaptation measures when changes cannot be avoided. Local governments have direct control or a strong influence on most of the state's greenhouse gas (GHG) emission sources (including buildings, transportation, land use and community services), so local action is critical to reducing heat-trapping emissions. They can take action in two main ways to minimize the risks of climate change and reduce its long-term costs:

Reducing GHG Emissions: Starting now to reduce GHG emissions and create permanent carbon sinks that remove GHG emissions from the atmosphere - these actions will help stabilize atmospheric levels of carbon dioxide at manageable levels and avoid severe climatic changes.

Adapting to a Changing Climate: Altering the built and natural environment in anticipation of predicted climatic changes, or in response to actual changes, will alleviate the risks associated with unavoidable changes in climate. Typical adaptation actions include planning, communication and preparedness for extreme weather events; incorporating expected changes into land-use decision-making processes; guiding development out of flood-prone areas; improving the resiliency of shorelines, natural systems, and critical infrastructure; applying cost-effective green technologies and using natural systems to reduce vulnerabilities; and conserving healthy forest, wetland and river ecosystems and agricultural resources, which are vital to successful climate change adaptation. The above action plans can however only be successful if there is the right political will devoid of sentiments especially when governments realise the urgency and destructive effect of climate change.

3.2 EXPECTED ACTION PLAN OF A CENTRAL GOVERNMENT

1. Enact a comprehensive law or body of laws to provide a mechanism for achieving Nigeria's adaptation policy objectives.
2. Mainstream climate change adaptation into all existing and new National Development Plans and official Vision statements (such as *Vision 20:2020*).
3. Respond actively and effectively to global and regional initiatives on climate change adaptation.
4. Mandate the Authority responsible for Climate Change to carry out the following functions: planning and setting priorities (including support for information and data collection), implementation, mobilization of resources, evaluation.

3.3 EXPECTED ACTION PLAN FOR A STATE GOVERNMENT

1. Have a focal Ministry, Department or Agency mandated to lead and provide strong coordination for all the climate change adaptation activities.

2. Mainstream climate change adaptation into all existing and new Development Plans and official Vision statements, and into all existing and new policies and programmes.

3. Ensure that climate change adaptation is taken into account when drawing up the State's Annual Budget.

4. Actively and consistently strengthen inter-ministerial and inter-agency coordination and cooperation in climate change adaptation in the State.

5. Create an enabling environment for the organized private sector to invest in climate change adaptation, including business opportunities presented by climate change adaptation options.

3.4 EXPECTED ACTION PLAN FOR LOCAL COMMUNITIES AND HOUSEHOLDS

1. Strengthen the adaptive capacity of communities by providing information and technical know-how, facilitating access to micro-credit and other measures.
2. Put in place a climate change adaptation communication and outreach strategy with the objective of enabling a level of understanding that will allow all stakeholders to participate actively in climate change adaptation.

3. Learn how they can adapt to climate change.
4. Be willing to share information with other stakeholders on their experiences in climate change impacts and adaptation
5. Prepare to make attitudinal changes in order to build capacity for adaptation.
6. Recognize that adaptation to climate change can be informed by, and build on, what they are already doing.

3.5 EXPECTED ACTION PLAN FOR INTERNATIONAL ORGANIZATIONS AND DONORS

1. Provide technical and financial support for capacity building, reducing barriers to adaptation, and implementation of climate change adaptation policies, programmes, and other measures.
2. Provide technical support for research, monitoring and evaluation of the mainstreaming process in order to develop understanding of what contributes to its success.
3. Provide technical support in identifying disaster risk reduction initiatives, as well as poverty reduction and natural resource management programmes, which cost-effectively address climate change vulnerability.

3.6 WHAT IS EXPECTED OF SCHOOLS TO REDUCE THE RISK OF CLIMATE CHANGE

Schools are expected to create a Climate Change Adaptation Resources page which should be organized by federal and state efforts. This page is expected to provide information about what the Nigerian federal and any local governments are doing to adapt to climate change.

Click on: https://www.youtube.com/watch?v=WSJTKyDuI6I

4.0 CONCLUSION

In this unit we can conclude that for the risk of climate change to be reduced, all levels of governments including communities, households and individuals have roles to play. The success or otherwise of the involvement by these actors will depend upon the collective commitment to the goal of reducing climate change. This unit proffered expected action plans for the federal, state and local governments, as well as communities, households and non-government organizations.

5.0 SUMMARY

In this unit, we have recommended action plan on climate change by thefederal, state and local governments, as well as communities, households and non-government organizations while the expectations of schools in Nigeria on ways to reduce climate change risk was suggested

6.0 TUTOR-MARKED ASSIGNMENT

1. What roles can the federal government play to mitigate against the risk of climate change in Nigeria?
2. What action plan can you put up in your locality to mitigate climate change risk?

7.0 REFERENCES/FURTHER READINGS

ADB (Asian Development Bank). 2015. Joint Report on Multilateral Development Banks' Climate Finance. Manila: Asian Development Bank. https://www.adb.org/documents/joint-report-mdbs- climate-finance-2015.

CPI (Climate Policy Initiative). 2017. Global Landscape of Climate Finance. https://climatepolicyinitiative.org/publication/global-landscapeof-climate-finance-2017/.

Hallegatte, S., and J. Rentschler. 2015. "Risk Management for Development: Assessing Obstacles and Prioritizing Action." Risk Analysis 35 (2): 193–210.

Hallegatte, S., A. Vogt-Schilb, M. Bangalore, and J. Rozenberg. 2017. Unbreakable: Building the Resilience of the Poor in the Face of Natural Disasters. Climate Change and Development Series. Washington, DC: World Bank. http://documents.worldbank.org/curated/ en/512241480487839624/Unbreakable-building-the-resilience-of-the-poor-in-the-face-of-natural-disasters.

IPCC (Intergovernmental Panel on Climate Change) (2014a). Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, ed. C.B. Field V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White. Cambridge: Cambridge University Press.