Integrating education with consumer behaviour relevant to energy efficiency and climate change at the Universities of Russia, Sri Lanka and Bangladesh (BECK)

Co-funded by the Erasmus+ Programme of the European Union

Module Handbook: Energy and Climate: Sustainable Development

By:
University of Barisal, Bangladesh
June 2021

Co-funded by the Erasmus+ Programme of the European Union

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1 Introduction

Energy is the prime needs to our society for heating, cooling, electricity and transportation which is a major driver for the emission of greenhouse gases hence the consequences of climate change and impacts on human health. The overall purpose of the Module is to introduce the concept of energy (renewable and non-renewable) and climate change within a context of sustainable development. Climate change is one of the major challenges of our time and adds considerable stress to our societies and to the environment.

The Energy and Climate change module is to introduce the overview of renewable and non-renewable energy and concept of climate change and its impacts on human health. Students will acquire the knowledge to understand technical, social and spatial dimensions of energy systems and how these interact with environmental parameters to change the climate. Also obtain knowledge and experience of some of the key technologies used in developing renewable energy and protecting the environment.

The module is delivered with the aid of the Moodle platform and may either be presented as face-to-face lectures or, alternatively, as a series of lecture videos for asynchronous learning.

2 Module details

Programme title: Department of Geology and Mining, Faculty of Science and Engineering

Level: BS (Honours)

Module title: Energy and Climate: Sustainable Development

Module credits: 2 ECTs

Semester(s)/Year in which to be offered: Two semester (3 and 4) full time, yearly intake, 2021-2022 Session

Indicative learning hours: 50 hours (30 hours of lectures; 20 hours of independent work)

Module tutors: 1 (Dr. Dhiman Kumer Roy) 2.(Abu Jafor Mia)

3 Aims and intended learning outcomes of the module

3.1 Aims of the module

The module aims to:

•Introduce students to basic physical principles of different sources of energy, production, how they can be obtained.

• Provide ideas on how to perform feasibility studies related to the sources of energy, how to quantify, and evaluate any environmental and economic issues.

- Module provides knowledge on energy science and system based on current consumption of fossil fuels and its impacts on the society.

- Make students aware of energy policy and possible energy strategies to preserve economic prosperity, and protect environment.
- Encourage students to understand the crucial role of energy in the society and implications stemming from their own consumption of energy.
  - Explain the production of energy methods from renewable sources.
- Provide necessary concept, knowledge and skills on climate change topics related to the possible causes and impacts of climate change and the role being played by anthropogenic effects.
- Explain and identify the natural and anthropogenic drivers of climate change and geological history of earth's climate.

3.2 Learning outcomes

This course provides clear, concise, lucid and up-to-date information in obtaining basic understanding about energy and climate change. This module will be of great benefits to students and researchers and of particular interest to the civil servants in ministries, environmental managers in private and civil sectors and interested citizens. It is anticipated that successful completion of this module will benefit students both in terms of developing their knowledge and understanding in the area of energy and climate change. After studying the module in the context of energy and climate change, a student should be able to-

Knowledge and Understanding

- Understand the energy flow in the Earth's system, exploration, production, transportation, conservation and consumption
  - Explain the differences between renewable and non-renewable energy sources
  - Identify renewable and non-renewable energy sources and use and effectiveness of energy sources.
  - Demonstrate understanding of the different types of renewable energy technologies to provide energy.
  - The perspectives on climate change causes, impacts and mitigation/adaptation possibilities from a range of sciences: natural science, economics, political science and sociology
- The basic association of climate change with human energy requirements
- The impacts of climate change on natural resources, especially air, and consequent effects on human health
- This course provides students with basic theoretical knowledge and techniques for understanding, assessing, and mitigating environmental issues
- Understand key components of energy systems in the world, including opportunities and limitations from resource, technology, environmental and social perspectives;

Transferable/Key Skills and other attributes

On completion of the module a student will have had the opportunity to:

- Evaluate the advantages and disadvantages of renewable and non-renewable energies and technologies
- Able to create a potential list of appropriate renewable energy that can be used in a particular socio-economic condition
- Able to evaluate the impacts of renewable and non-renewable energy resources and its impacts on global climate and human health.
- Students will be able to conduct an independent, limited research or development project in renewable energy systems.

4 Semester dates and module structure

The module is intended to be taught during the 2021-2022 Session of 2nd year (3 and 4 semester). The face-to-face and or online lectures will be arranged as a single, 60 minutes lecture (each).

Lecture No	Lecture topic
1, 2, 3 & 4	Energy and Fossil Fuel
5	A journey of fossil fuel from field to market
6 & 7	Biomass
8 & 9	Solar Energy
10, 11 & 12	Hydropower Energy
13, 14, 15 & 16	Nuclear Energy
17 & 18	Geothermal Energy
19 & 20	Climate Change and Causes
21 & 22	Indicators of Climate Change
23, 24 & 25	Global Effects of Climate Change
26 & 27	Global Impacts – Air pollution

5 Teaching methods

The module is delivered as a series of 26 lectures. These may be either delivered as face-to-face or online lectures of 60 minutes each which include in-class activities or as a series of video presentations.

Assignments are a major part of pedagogy. Designing assignments can therefore be one of the most influential elements of classroom teaching. Thoughtful assignment design can support student learning by helping students practice meaningful tasks that carry on into their careers or across the curriculum. In both cases, assignments (both group and individual assignments) and other activities such as quizzes, discussion forums and midterm assessments are provided using the Moodle platform.

Students are given here authentic tasks in a meaningful context and the focus is fixed on student's ability in reflecting their own experience thoughtfully. They are encouraged to elaborate their knowledge in group so that they can produce instead of replicating what comes from the instructor.

Teaching strategy involves the use of visualization as a teaching and learning form in increasing and developing the critical thinking of students. Visualisation is a very important component of understanding, and critical thinking determines the quality of the understanding.

6 Module assessments and assessment procedure

The method of evaluating learning outcomes will be a written examination (60%) consisting of both theory-based and calculation-based questions and internal assessment (Midterm examination 20%; quizzes, assignment 10%; class response, and presence in the class 10%. Results: grade A^+ (80%-100%), A (75-79%), A^-(70%-74%), B^+ (65%-69%), B (60%-64%), B^- (55%-59%), C+ (50%-54%), C (45%-49%), D (40%-44%), F <40%.

Grade Letter	Grade Point	Marks Obtained (%)	Generalized description of competence in the subject
A+	**4.00**	**80-100**	**Excellent understanding and application of concepts and skills** • thoroughly understands all or nearly all concepts and/or skills • routinely makes connections to similar concepts and skills • applies creatively to own life and to support new learning
A	**3.75**	**75-79**	**Very Good understanding and application of concepts and skills** • understands most concepts and skills • often makes connections to similar concepts and skills • sometimes applies to own life and to support new learning
A-	**3.50**	**70-74**	**Good understanding and application of concepts and skills** • understands most concepts and skills • occasionally makes connections to similar concepts and skills

B+	**3.25**	**65-69**	**Basic understanding and applications of concepts and skills;** • understands some key concepts and skills • rarely makes connections to similar concepts and skills
B	3.00	60-64	**Very Basic understanding and applications of concepts and skills;**
B-	2.75	55-59	Limited acquisition of intended course outcomes. Understanding of the theoretical principles of the subject and ability to carry out standard calculations demonstrated with minor errors only.
C+	2.50	50-54	Very Limited acquisition of intended course outcomes. Understanding of the theoretical principles of the subject
C	2.25	45-49	Comprehensive theoretical understanding of the subject and correct performance of standard calculations demonstrated without errors.
D	2.00	40-44	Very limited demonstrate the required understanding and application of concepts and skills
F	0.00	<40	Does **Not** yet Demonstrate the required understanding and application of concepts and skills; students with a final grade of less than 40% are not granted course credit.

There are two options for the delivery of the examination - an online version and a paper-based version:

1. For the online option, students will sit customized exams under controlled conditions (either at testing centres, or in otherwise secured environments, with or without proctoring as necessary) where their individual identities can be verified and their conduct during the exam can be monitored.
2. Another option is the paper-based examination being completed by students in an examination room where their conduct is monitored by invigilators.

In addition to the final examination, students will complete midterm assessments during the module in order to assess their progress and ensure their readiness for the final examination.

7 Assessment feedback

Assessment criteria and grade descriptors can usefully show students where and why particular marks were awarded to their assessed work and act as a structure for the provision feedback and feed forward. Feedback is given to students based on their performance in the midterm assessments. The feedback provided to students indicates both the student's overall level of preparation and also specifies the areas on which further revision should be focused. Assessment can assist the moderation process by providing a record of the standard a marker judged each piece of assessed work demonstrated for each assessment criterion. Feedback from the final examination takes the form of an overall grade.

8 Staff details and sources of help

The lecture course and design of the program will be set up under the supervision of Dr. Dhiman Kumer Roy. Sources of help beyond the staff mentioned above include the course textbooks and internet-based course materials.

9 Syllabus outline and teaching materials

9.1 Lecture 1, 2, 3 & 4 - Energy and Fossil Fuel

9.1.1 Introduction to the lecture

This lecture provides an overview of the module. It introduces the module's objectives, content, structure, technical information and the forms and criteria of assessment and the course reference materials.

This lecture has 2 parts. This lecture introduces the basics of energy science. It provides an overview of key concepts such as energy and power, global energy scenario in relation to the fossil fuel, world global problem. Part 1 describes the overview of energy use and related issues, energy consumption patterns, economic and environmental considerations, renewable and non-renewable energy sources. Part 2 provide an overview of fossil fuels, world production of fossil fuels, formation of fossil fuels, types of fossil fuels, declining fossil fuel, fuel efficiency, fossil fuel resources, production and consumption, resource and reserve, coal reserved and mining, environmental concern, carbon dioxide in the atmosphere, global fossil carbon emission, emission of carbon dioxide, carbon dioxide and global mean temperature, production of electricity from fossil fuel.

9.1.2 Aim and key learning outcomes of the lecture

The aim of the lecture “Energy and fossil fuel” is to ensure students understand the module objectives and they can access course content.

After completing lecture “Energy and fossil fuel” students will be able to:

- Access all relevant module information and materials;
- Understand the scope of the module;
- Know the basic concept of energy and energy sources;

- Explain the energy flow in the Earth's system, exploration, production, transportation, conservation and consumption;
- Identify the principal energy sources used worldwide, and classify them either renewable or non-renewable;
- Know the reason of declining fossil fuel and the increasing rate of carbon dioxide in the atmosphere.

9.1.3 Lecture notes and hand outs

The lecture slides / hand outs are contained in Appendix A.1 – Lecture "Energy and fossil fuel" Slides.

9.1.4 Assignments, activities and practice questions

Students should be encouraged to source as much information for themselves on these topics as possible. Practice questions based on the lecture slides.

9.1.5 Recommended sources of further information

Roger A. Hinrich and Merlin Kleinbach. 2013. Energy, its use and the environment. 5th edition, Brooks/Cole, Cengage Learning

Robert A. Ristinen; Jack J. Kraushaar and Jeffrey T. Brack. 2016. Energy and the Environment. 3rd edition, John Wiley & Sons Inc.

Peter E Hodgson. 2010. Energy, the environment and climate change. Imperial College Press, London.

Michael, Stephenson. 2018. Energy and Climate change: An introduction to geological controls, interventions and mitigations. Elsevier Inc. ISBN 978-0-12-812021-7.

David, Coley. 2008. Energy and Climate change: Creating a sustainable Future. Wiley Inc, 1st edition.

IPCC https://www.ipcc.ch/

Journal articles related to energy and climate change.

9.2 Lecture 5 – A journey of fossil fuel from field to market

9.2.1 Introduction to the lecture

This lecture provides an overview of the journey of fossil fuel from field to market. This lecture discusses the key concepts such as exploration and survey for fossil fuel in terms of geology, rock formation, porosity, permeability, seismic technology. It also introduces the way of retrieving oil in the field through permitting, drilling, well completion and casing well and cementing in the field. This lecture provides an overview of planning production of oil in the field, shipping crude oil, refining through distillation, processing and preparation to market and finally shipping petroleum products.

9.2.2 Aim and key learning outcomes of the lecture

The aim of the lecture is to provide a brief concept to understand the importance of fossil fuel and its journey from field through production to market by shipping.

After completing lecture "Journey of fossil fuel from field to market" students will be able to:

- Understand the exploration process of fossil fuel in the field i.e. geology, rock formation, porosity and permeability, geological history.
- Know the process of retrieving fossil fuel in the field through several procedures i.e. drilling, well completion, casing, cementing.
- Know about fossil fuel production in onshore and offshore through several process i.e. cleaning oil, shipping crude oil, refining (distillation, processing) and finally to market.

9.2.3 Lecture notes and hand outs

The lecture slides / hand outs are contained in Appendix A.2 – Lecture "A journey of fossil fuel from field to market" Slides.

9.2.4 Assignments, activities and practice questions

Students should be encouraged to source as much information for themselves on these topics as possible. Practice questions based on the lecture slides.

9.2.5 Recommended sources of further information

https://library.e.abb.com/public/34d5b70e18f7d6c8c1257be500438ac3/Oil%20and%20gas%20production%20handbook%20ed3x0_web.pdf

9.3 Lecture 6 & 7 - Biomass

9.3.1 Introduction to the lecture

Lecture Biomass introduces the basic concept of biomass energy, its energy conversion processes and environmental impacts. In this lecture has 3 parts. Part 1 provides an overview of fundamental concept of biomass, types of biomass, sources of biomass, carbon neutral, global energy sources of biomass, use of biomass and converting biomass to other forms of energy. Part 2 provides theoretical concept of biomass conversion technologies, bioenergy technologies, biomass direct combustion, biogas-gasification, biofuels, biorefineries and biochar. Part 3 provides an overview of environmental impacts i.e. advantages for biomass energy and disadvantages.

9.3.2 Aim and key learning outcomes of the lecture

The aim is to build upon the previous lecture but shift the focus from the investment to the investors and, in so doing, raising the issue of the sources of finance and the terms under which it is provided.

After completion of Lecture "Biomass" students will be able to:

- Explain how to obtain energy from biomass.
- Have a broad knowledge of the main sources of biomass, the origins of these sources, and the means by which they can be exploited for electricity generation

• Understand the principles underlying the design and operation of waste and biomass to energy systems.

- Production of clear and concise analyses of benefits and problems relating to the production and use of different forms of biomass energy

9.3.3 Lecture notes and hand outs

The lecture slides / hand outs are contained in Appendix A.3 – Lecture "Biomass" Slides.

9.3.4 Assignments, activities and practice questions

Students should be encouraged to source as much information for themselves on these topics as possible. Practice questions based on the lecture slides.

9.3.5 Recommended sources of further information

Roger A. Hinrich and Merlin Kleinbach. 2013. Energy, its use and the environment. 5th edition, Brooks/Cole, Cengage Learning

Robert A. Ristinen; Jack J. Kraushaar and Jeffrey T. Brack. 2016. Energy and the Environment. 3rd edition, John Wiley & Sons Inc.

Peter E Hodgson. 2010. Energy, the environment and climate change. Imperial College Press, London.

Michael, Stephenson. 2018. Energy and Climate change: An introduction to geological controls, interventions and mitigations. Elsevier Inc. ISBN 978-0-12-812021-7.

David, Coley. 2008. Energy and Climate change: Creating a sustainable Future. Wiley Inc, 1st edition.

Journal article related to biomass energy.

9.4 Lecture 8 & 9 – Solar Energy

9.4.1 Introduction to the lecture

Solar energy is used for direct conversion of sunlight to electricity with advantages of minimum maintenance. Lecture on solar energy has 3 parts. Part 1 of solar energy introduces the concept of solar energy, fundamentals of solar energy, radiant energy, quantity of solar energy and advantages and disadvantages of solar energy. Part 2 of this lecture provides an on solar cell principles and cell manufacture. This lecture discusses the photovoltaic cell (PV), principles of solar electric system, cross section of PV cell, principles of PV cell and solar cell manufacture. Part 3 provides information on solar PV facts & trends i.e. world solar power production, solar cell production volume in the world and photovoltaic market.

9.4.2 Aim and key learning outcomes of the lecture

The aim is to introduce students to the concept of renewable solar energy system and its global production and describe the procedure to manufacture solar cell.

After completing of this lecture students will be able to:

- Explain the principles that underlie various natural phenomena for the production of solar energy.
- Develop a comprehensive technological understanding of solar PV system.
- Provide in-depth understanding of PV cell design.
- Design a basic photovoltaic system to meet energy.
- Compare the advantages and disadvantages of solar energy production.
- Understand the present scenario of global solar energy production and consumption.

9.4.3 Lecture notes and hand outs

The lecture slides / hand outs are contained in Appendix A.4 – Lecture "solar energy" Slides.

9.4.4 Assignments, activities and practice questions

Students should be encouraged to source as much information for themselves on these topics as possible. Practice questions based on the lecture slides.

9.4.5 Recommended sources of further information

Roger A. Hinrich and Merlin Kleinbach. 2013. Energy, its use and the environment. 5th edition, Brooks/Cole, Cengage Learning

Robert A. Ristinen; Jack J. Kraushaar and Jeffrey T. Brack. 2016. Energy and the Environment. 3rd edition, John Wiley & Sons Inc.

Peter E Hodgson. 2010. Energy, the environment and climate change. Imperial College Press, London.

C. S. Solanki. 2011. Solar Photovoltaics – Fundamentals, Technologies and Applications, 2nd ed. (PHI Learning,)

9.5 Lecture 10, 11 & 12 – Hydropower Energy

9.5.1 Introduction to the lecture

Hydropower lecture is divided into 3 parts. Part 1 focuses on the basic concept of hydro energy i.e. definition of hydro power, history of hydro power, advantage and disadvantages of hydro power and modern usage of hydro power. Part 2 provides an overview on hydro power plant. This part discusses the layout, elements of a hydro power plant, mechanism and types of hydro power plant. This part also discusses the quantification electricity production of a hydro power plant. Part 3 focuses on the environmental and social impacts, life cycle assessment of environmental impacts and planning hydro power system by students.

9.5.2 Aim and key learning outcomes of the lecture

The aim is to introduce students to understand the hydro power system, generation of electricity and impacts of hydro power system.

On completion of lecture "Hydropower Energy, students will be able to:

- Describe the general historical development of hydropower.
- Classify hydropower based on capacity, storage type, and head.
- Learn key components of a micro/small-scale hydropower system.
- Understand the layout of a hydropower plant.
- Describe working principles of a hydropower system.
- Know the hydropower energy production, distribution and trends in the world.

9.5.3 Lecture notes and hand outs

The lecture slides / hand outs are contained in Appendix A.5 – Lecture "Hydropower Energy" Slides.

9.5.4 Assignments, activities and practice questions

Students should be encouraged to source as much information for themselves on these topics as possible. Practice questions based on the lecture slides.

9.5.5 Recommended sources of further information

Roger A. Hinrich and Merlin Kleinbach. 2013. Energy, its use and the environment. 5th edition, Brooks/Cole, Cengage Learning

Robert A. Ristinen; Jack J. Kraushaar and Jeffrey T. Brack. 2016. Energy and the Environment. 3rd edition, John Wiley & Sons Inc.

https://nptel.ac.in/content/storage2/courses/105105110/pdf/m5l01.pdf

Journal articles on the hydropower energy.

9.6 Lecture 13, 14, 15 & 16 – Nuclear Energy

9.6.1 Introduction to the lecture

Nuclear energy lecture provides an overview of fundamentals of nuclear energy, nuclear history, nuclear reactor, nuclear power plant, fuel cycle, radioactivity, nuclear waste, nuclear recycling, and journey of uranium from mine to reactor (i.e. mining, milling, conversion and enrichment. This lecture discusses the mechanism of a reactor, components of a reactor, and types of reactor. It also provides knowledge on the electricity generation from a reactor. This lecture focuses on the nuclear waste, waste composition, recycling, nuclear accident (Three Mile Island, Chernobyl and Fukushima), disadvantage and advantages of nuclear energy.

9.6.2 Aim and key learning outcomes of the lecture

This lecture aims to provide core knowledge of nuclear power plant and to develop a critical awareness of the nuclear basics, reactor basics, reactor operation and design, waste disposal, and key issues relating to health and safety.

On completion of lecture Nuclear Energy, students will be able to:

- Know the fundamentals and history of nuclear energy.
- Identify and discuss the purpose of key components of nuclear power plant for a variety of different configurations
- Identify and discuss the purpose of key components of nuclear power plant for a variety of different configurations
- Have a critical understanding of nuclear plant health, safety and environmental issues

9.6.3 Lecture notes and hand outs

The lecture slides / hand outs are contained in Appendix A.6 – Lecture “Nuclear Energy” Slides.

9.6.4 Assignments, activities and practice questions

Students should be encouraged to source as much information for themselves on these topics as possible. Practice questions based on the lecture slides.

9.6.5 Recommended sources of further information

Roger A. Hinrich and Merlin Kleinbach. 2013. Energy, its use and the environment. 5th edition, Brooks/Cole, Cengage Learning

Robert A. Ristinen; Jack J. Kraushaar and Jeffrey T. Brack. 2016. Energy and the Environment. 3rd edition, John Wiley & Sons Inc.

Murray, R and Holbert, K.E. 2020. Nuclear energy: An introduction to the concepts, systems, and applications of nuclear processes. 8th edition, Elsevier.

9.7 Lecture 17 & 18 – Geothermal Energy

9.7.1 Introduction to the lecture

Lecture of Geothermal energy has 3 parts. Part 1 focuses on the fundamental concept of geothermal energy, history of geothermal energy, present global status of geothermal utilization, advantages, origin, nature of geothermal energy and global geothermal sites. Part 2 provides an overview of mechanism for geothermal power plant. Part 3 discusses on the utilization of geothermal resources and its environmental impacts.

9.7.2 Aim and key learning outcomes of the lecture

The aim is to introduce students to the concept, utilization, mechanism and environmental impacts of geothermal energy.

On completion of lecture "Geothermal energy" students will be able to:

- Identify the fundamental concept, physical characteristics and processes in geothermal systems.
- Differentiate between types of geothermal resources and their location
- Know the mechanism of geothermal power plant and its types.
- Distinguish between the different types of geothermal technologies and appropriate uses o f them.
- Identify environmental impacts and benefits of geothermal energy exploitation

9.7.3 Lecture notes and hand outs

The lecture slides / hand outs are contained in Appendix A.7 – Lecture "Geothermal energy" Slides.

9.7.4 Assignments, activities and practice questions

Students should be encouraged to source as much information for themselves on these topics as possible. Practice questions based on the lecture slides.

9.7.5 Recommended sources of further information

Roger A. Hinrich and Merlin Kleinbach. 2013. Energy, its use and the environment. 5th edition, Brooks/Cole, Cengage Learning.

Robert A. Ristinen; Jack J. Kraushaar and Jeffrey T. Brack. 2016. Energy and the Environment. 3rd edition, John Wiley & Sons Inc.

9.8 Lecture 19 & 20 – Climate Change and Causes

9.8.1 Introduction to the lecture

This lecture introduces the factors that control the global climate change. It provide an overview on the fundamental concept of climate change, role of atmospheric gases, role of surface solar radiation, role of space weather and cosmic ray effects, role of volcanic activity, role of variations of the earth's orbital characteristics i.e. eccentricity, precession and obliquity and insolation. This lecture provides a geological history of the climate change through geological period.

9.8.2 Aim and key learning outcomes of the lecture

The aim is to introduce students to the reason for climate change (natural and anthropogenic)

On completion of lecture "Climate change and causes", students will be able to:

- Examine basic causes of climate change.
- Describe the components, drivers, and interactions of climate.
- Explain the relationship between human activities and climate change

9.8.3 Lecture notes and hand outs

The lecture slides / hand outs are contained in Appendix A.8 – Lecture "Climate change and causes" Slides.

9.8.4 Assignments, activities and practice questions

Students should be encouraged to source as much information for themselves on these topics as possible. Practice questions based on the lecture slides

9.8.5 Recommended sources of further information

Trevor M. letcher. 2009. Climate change: observed impacts on planet earth. Elsevier.

Roger A. Hinrich and Merlin Kleinbach. 2013. Energy, its use and the environment. 5th edition, Brooks/Cole, Cengage Learning

Robert A. Ristinen; Jack J. Kraushaar and Jeffrey T. Brack. 2016. Energy and the Environment. 3rd edition, John Wiley & Sons Inc.

9.9 Lecture 21 & 22 - Indicators of Climate Change

9.9.1 Introduction to the lecture

Indicators of climate change lecture provide an overview on the indicators that preserve the evidence of global climate change. This lecture focuses on the question that how do we know global climate change. This lecture discusses the evidence for rapid climate change i.e. global temperature, ocean acidification, warming ocean, sea level rise, extreme events, declining arctic sea ice, glacial retreat and decreased snow cover.

9.9.2 Aim and key learning outcomes of the lecture

The aim is to deepen students understanding of climate change indicators.

On completion of lecture “Indicators of climate change” students will be able to:

- Understand the indicators of climate change.
- Know how global climate is changing and factors that control the global climate change.

9.9.3 Lecture notes and hand outs

The lecture slides / hand outs are contained in Appendix A.9 – Lecture “Indicators of climate change” Slides.

9.9.4 Assignments, activities and practice questions

Students should be encouraged to source as much information for themselves on these topics as possible. Practice questions based on the lecture slides

9.9.5 Recommended sources of further information

Trevor M. Letcher. 2009. Climate change: observed impacts on planet earth. Elsevier.

IPCC Fifth Assessment Report, Summary for Policymakers.

9.10 Lecture 23, 24 & 25 - Global Effects of Climate Change

9.10.1 Introduction to the lecture

Global effects of climate change lecture introduce the concept of global climate change effects on the atmosphere. This lecture provides an overview of fossil fuel impacts on the level of carbon dioxide, ozone depletion in the stratosphere, bad and good ozone, origin of good and bad ozone, causes of ozone depletion, idea on ozone reserve in the stratosphere. It also focuses on the relation between greenhouse effects and climate change, climate change over geological periods, basic information on climate change, overview of greenhouse gases i.e. CO2, CH4, N2O, fluorinated gas, ratio of greenhouse gas emission, source of greenhouse gas, trends in global emission, emission by country and basic concept of causes of climate change.

9.10.2 Aim and key learning outcomes of the lecture

The aim is to bring in to consideration the global climate change in relation to greenhouse gases and its impacts on the stratosphere.

On completion of lecture "Global effects of climate change" students will be able to:

- To understand the influence of human being on the global atmosphere and climate.
- Understand the depletion of ozone in the Stratosphere "a hole in the sky".
- Know the mechanism of global climate change caused by greenhouse gases.

9.10.3 Lecture notes and hand outs

The lecture slides / hand outs are contained in Appendix A.10 – Lecture "Global effects of climate change" Slides.

9.10.4 Assignments, activities and practice questions

Students should be encouraged to source as much information for themselves on these topics as possible. Practice questions based on the lecture slides.

9.10.5 Recommended sources of further information

Roger A. Hinrich and Merlin Kleinbach. 2013. Energy, its use and the environment. 5th edition, Brooks/Cole, Cengage Learning

Robert A. Ristinen; Jack J. Kraushaar and Jeffrey T. Brack. 2016. Energy and the Environment. 3rd edition, John Wiley & Sons Inc.

9.11 Lecture 26 & 27 - Global impacts-Air pollution

9.11.1 Introduction to the lecture

Global impacts of air pollution lecture provide an overview of global impacts of air pollution due to the climate change. This lecture discusses the earth's atmosphere (characteristics, composition), thermal inversion (temperature variation, adiabatic lapse rate, thermal inversion process and smog), pollutants (carbon dioxide, nitrogen oxide, hydrocarbon emission, sulphur dioxide and particulates s pollutants). This lecture focuses on the impacts of air pollution due to global climate change on the human health.

9.11.2 Aim and key learning outcomes of the lecture

The aim is to understand the concept of global climate change impacts on the air pollution and its consequent effects on the human health.

On completion of lecture "Global impacts-Air pollution" students will be able to:

- Understand the general concept on the characteristics of atmosphere.
- Understand the impacts of climate change on the atmosphere.
- Know the mechanism of atmospheric changes due to climate change.
- Know the impacts of air pollution on the human health.

9.11.3 Lecture notes and hand outs

The lecture slides / hand outs are contained in Appendix A.10 – Lecture “Global impacts-Air pollution” Slides.

9.11.4 Assignments, activities and practice questions

Students should be encouraged to source as much information for themselves on these topics as possible. Practice questions based on the lecture slides.

9.11.5 Recommended sources of further information

Roger A. Hinrich and Merlin Kleinbach. 2013. Energy, its use and the environment. 5th edition, Brooks/Cole, Cengage Learning

Robert A. Ristinen; Jack J. Kraushaar and Jeffrey T. Brack. 2016. Energy and the Environment. 3rd edition, John Wiley & Sons Inc.

10 Appendix A – Lecture slides

10.1 Appendix A.1 – Lecture 1, 2 & 3 Slides

Energy and Climate : Sustainable Development

1

Energy and Climate : Sustainable Development

- Energy is the prime needs to our society for heating, cooling, electricity and transportation which is a major driver for the emission of greenhouse gases hence the consequences of climate change and impacts on human health.
- The overall purpose of the Module is to introduce the concept of energy (renewable and non-renewable) and climate change within a context of sustainable development.
- Climate change is one of the major challenges of our time and adds considerable stress to our societies and to the environment.

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Cont'd……

- The Energy and Climate change module is to introduce the overview of renewable and non-renewable energy and concept of climate change and its impacts on human health.
- Students will acquire the knowledge to understand technical, social and spatial dimensions of energy systems and how these interact with environmental parameters to change the climate.
- Also obtain knowledge and experience of some of the key technologies used in developing renewable energy and protecting the environment.

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Cont'd……

- The module is delivered with the aid of the Moodle platform and may either be presented as face-to-face lectures or, alternatively, as a series of lecture videos for asynchronous learning.

4

Module details

Programme title: Department of Geology and Mining, Faculty of Science and Engineering

Level: BS (Honours)

Module title: Energy and Climate: Sustainable Development

Module credits: 2 ECTs

Semester(s)/Year in which to be offered: Two semester (3 and 4) full time, yearly intake, 2021-2022 Session

Indicative learning hours: 50 hours (30 hours of lectures; 20 hours of independent work)

Module tutors: 1 (Dr. Dhiman Kumer Roy)

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Aim of the module

- Introduce students to basic physical principles of different sources of energy, production, how they can be obtained.
- Provide ideas on how to perform feasibility studies related to the sources of energy, how to quantify, and evaluate any environmental and economic issues.
- Module provides knowledge on energy science and system based on current consumption of fossil fuels and its impacts on the society.
- Make students aware of energy policy and possible energy strategies to preserve economic prosperity, and protect environment.

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Aim of the module

➢ Encourage students to understand the crucial role of energy in the society and implications stemming from their own consumption of energy.

➢Explain the production of energy methods from renewable sources.

➢Provide necessary concept, knowledge and skills on climate change topics related to the possible causes and impacts of climate change and the role being played by anthropogenic effects.

➢Explain and identify the natural and anthropogenic drivers of climate change and geological history of earth's climate.

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Learning outcomes

➢ This course provides clear, concise, lucid and up-to-date information in obtaining basic understanding about energy and climate change.

➢This module will be of great benefits to students and researchers and of particular interest to the civil servants in ministries, environmental managers in private and civil sectors and interested citizens.

➢ It is anticipated that successful completion of this module will benefit students both in terms of developing their knowledge and understanding in the area of energy and climate change.

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Learning outcomes

➢After studying the module in the context of energy and climate change, a student should be able to

Knowledge and Understanding

•Understand the energy flow in the Earth's system, exploration, production, transportation, conservation and consumption

•Explain the differences between renewable and non-renewable energy sources

•Identify renewable and non-renewable energy sources and use and effectiveness of energy sources.

•Demonstrate understanding of the different types of renewable energy technologies to provide energy.

•The perspectives on climate change causes, impacts and mitigation/adaptation possibilities from a range of sciences: natural science, economics, political science and sociology

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Learning outcomes

➢After studying the module in the context of energy and climate change, a student should be able to

Knowledge and Understanding•

•The basic association of climate change with human energy requirements

•The impacts of climate change on natural resources, especially air, and consequent effects on human health

•This course provides students with basic theoretical knowledge and techniques for understanding, assessing, and mitigating environmental issues

•Understand key components of energy systems in the world, including opportunities and limitations from resource, technology, environmental and social perspectives;

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Learning outcomes

Transferable/Key Skills and other attributes

On completion of the module a student will have had the opportunity to:

•Evaluate the advantages and disadvantages of renewable and non-renewable energies and technologies

•Able to create a potential list of appropriate renewable energy that can be used in a particular socio-economic condition

•Able to evaluate the impacts of renewable and non-renewable energy resources and its impacts on global climate and human health.

•Students will be able to conduct an independent, limited research or development project in renewable energy systems.

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Semester dates and module structure

The module is intended to be taught during the 2021-2022 Session of 2nd year (3 and 4 semester). The face-to-face and or online lectures will be arranged as a single, 60 minutes lecture (each).

Lecture No	Lecture topic
1, 2, 3 & 4	Energy and Fossil Fuel
5	A journey of fossil fuel from field to market
6 & 7	Biomass
8 & 9	Solar Energy
10, 11 & 12	Hydropower Energy
13, 14, 15 & 16	Nuclear Energy
17 & 18	Geothermal Energy
19 & 20	Climate Change and Causes
21 & 22	Indicators of Climate Change
23, 24 & 25	Global Effects of Climate Change
26 & 27	Global Impacts – Air pollution

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Module assessment

Grade Letter	Grade Point	Marks Obtained (%)	Generalized description of competence in the subject
A+	**4.00**	**80-100**	**Excellent understanding and application of concepts and skills**
A	**3.75**	**75-79**	**Very Good understanding and application of concepts and skills**
A-	**3.50**	**70-74**	**Good understanding and application of concepts and skills**
B+	**3.25**	**65-69**	**Basic understanding and applications of concepts and skills;**
B	3.00	60-64	**Very Basic understanding and applications of concepts and skills;**
B-	2.75	55-59	Limited acquisition of intended course outcomes
C+	2.50	50-54	Very Limited acquisition of intended course outcomes.
C	2.25	45-49	Comprehensive theoretical understanding of the subject and correct performance of standard calculations demonstrated without errors.
D	2.00	40-44	Very limited demonstrate the required understanding and application of concepts and skills
F	0.00	<40	Does **Not** yet Demonstrate the required understanding and application of concepts and skills; students with a final grade of less than 40% are not granted course credit.

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ENERGY and Fossil Fuel

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Introduction to the Lecture

- This lecture provides an overview of the module. It introduces the module's objectives, content, structure, technical information and the forms and criteria of assessment and the course reference materials.
- This lecture has 2 parts.
- This lecture introduces the basics of energy science. It provides an overview of key concepts such as energy and power, global energy scenario in relation to the fossil fuel, world global problem.

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Introduction to the Lecture

- Part 1 describes the overview of energy use and related issues, energy consumption patterns, economic and environmental considerations, renewable and non-renewable energy sources.
- Part 2 provide an overview of fossil fuels, world production of fossil fuels, formation of fossil fuels, types of fossil fuels, declining fossil fuel, fuel efficiency, fossil fuel resources, production

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Contd…

- and consumption, resource and reserve, coal reserved and mining, environmental concern, carbon dioxide in the atmosphere, global fossil carbon emission, emission of carbon dioxide, carbon dioxide and global mean temperature, production of electricity from fossil fuel.

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Learning outcomes

- After completing lecture "Energy and fossil fuel" students will be able to:
- Access all relevant module information and materials;
- Understand the scope of the module;
Know the basic concept of energy and energy sources.
- Explain the energy flow in the Earth's system, exploration, production, transportation, conservation and consumption;

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Learning outcomes

- After completing lecture "Energy and fossil fuel" students will be able to:
- Identify the principal energy sources used worldwide, and classify them either renewable or non-renewable;
- Know the reason of declining fossil fuel and the increasing rate of carbon dioxide in the atmosphere.

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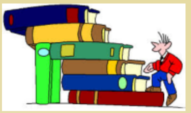
Books and Reference

Textbook 	Hinrichs, R. and Kleinbach, M. 2006, Energy, its Use and the Environment, 4th Edition, Cengage Learning.
Supplemental book and materials: 	Ristinen, R.A, and Kraushaar, J.J., 2006. Energy and the Environment. John Wiley & Sons Inc. Related website address will be given (if necessary).

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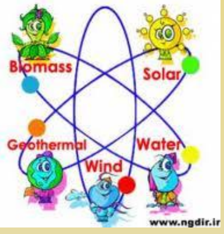
ENERGY and POWER

- **Work** is the application of force through a distance.
- **Energy** is the capacity to do work.
- **Power** is the rate of flow of energy, or the rate at which work is done.



Global Energy Scenario

- ❑ Energy has become a vital component of human life
- ❑ Energy is also an indicator of economic and social improvement
- ❑ Most of the energy supply utilized worldwide, from non-renewable energy resources
- ❑ relationship between energy supply and economic growth and development is evident

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- ❑ Consumption of fossil fuels is dramatically increasing
- ❑ Excessive fossil fuel consumption not only leads to an increase in the rate of diminishing fossil fuel reserves
- ❑ it also has a significant adverse impact on the environment, resulting in increased health risks and the threat of global climate change
- ❑ Therefore, it is important to understand energy resources and their limitations, as well as the environmental consequences of their use.

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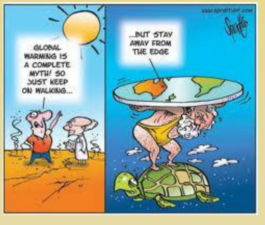
Problem and Questions

1. How do this energy form?
2. Where are they found?
3. How long will the supplies of these vital energy last?
4. What will do when they are exhausted?
5. What happen on environment?
6. How to control the effects of use these energy on environment?



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World Global Problems

- Decrease in fossil fuel reserves due to world population growth and increasing energy demand.

- Global climate change due to the increase of CO_2 concentration in the atmosphere.

- Increase in levels of wastes (solid/liquid) due to increase in population among world.

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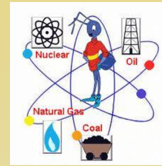
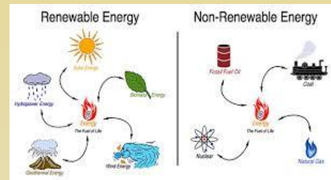
NONRENEWABLE AND RENEWABLE RESOURCES





Just a story

HMMMM....

What do you think nonrenewable resources are?

Break it down...

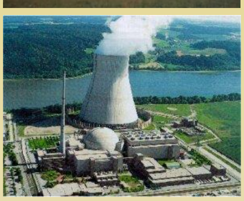
Nonrenewable?

Resource?

NONRENEWABLE RESOURCES

A nonrenewable resource is a natural resource that cannot be re-made or re-grown at a scale comparable to its consumption.

NUCLEAR ENERGY

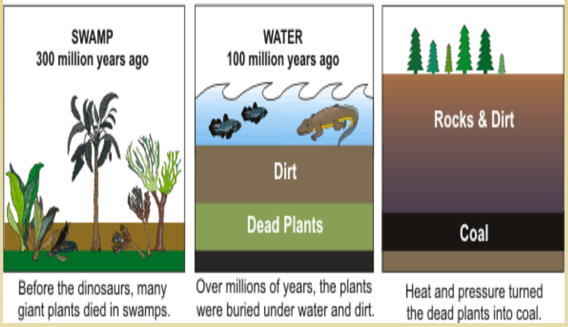


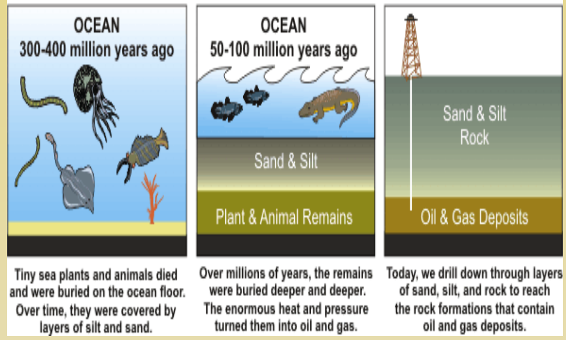
Nuclear fission uses uranium to create energy.

Nuclear energy is a nonrenewable resource because once the uranium is used, it is gone!

COAL, PETROLEUM, AND GAS

Coal, petroleum, and natural gas are considered nonrenewable because they can not be replenished in a short period of time. These are called fossil fuels.





WHAT WAS THE DIFFERENCE BETWEEN COAL AND OIL/GAS?

HMMMM....

If nonrenewable resources are resources that cannot be re-made at a scale comparable to its consumption, what are renewable resources?

RENEWABLE RESOURCES

Renewable resources are natural resources that can be replenished in a short period of time.

- Solar
- Geothermal
- Wind
- Biomass
- Water

SOLAR

Energy from the sun.

Why is energy from the sun renewable?

GEOTHERMAL

Energy from Earth’s heat.

Why is energy from the heat of the Earth renewable?

WIND

Energy from the wind.

Why is energy from the wind renewable?

BIOMASS

Energy from burning organic or living matter.

Why is energy from biomass renewable?

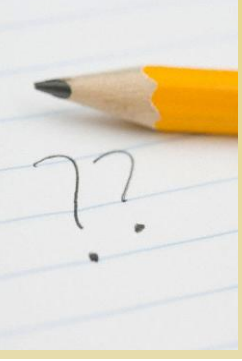
WATER or HYDROELECTRIC

Energy from the flow of water.

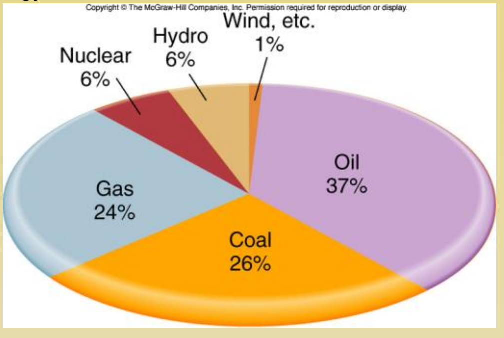
Why is energy of flowing water renewable?

SUMMARY

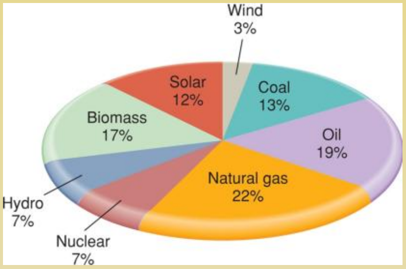
What are the differences between nonrenewable and renewable resources?



Worldwide Commercial Energy Production



An Alternative Energy Future?



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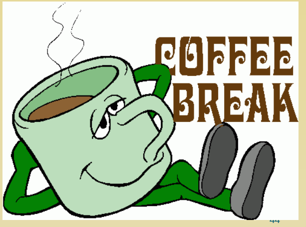
Let's have some questions!!!!!!!!!!!!



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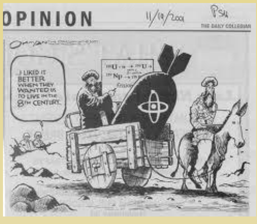
Energy Fundamentals and Use (Part 1)



Robert A. Ristinen / Jack J. Kraushaar- Chap - 1

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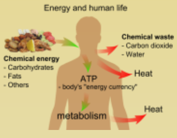
Introduction

- Energy involves our everyday lives in many different ways.
- Energy in food-essential for living beings- human, animal and plant
- Evolution of our planet related to energy...



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Introduction

- Energy in forms other than food--essential for functioning of a technical society

- More energy goes in the form of engine fuel to produce food than we obtained in the food.

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Introduction

To maintain the present patterns, we need vast amounts of energy.

- Fossil fuels (86%), solar, wind, hydro, nuclear etc
- Fossil fuels take long time MY to form.

- Muscular effort of human and animal and wood was the main energy source (150 years ago)
- Now we don't depend on muscle or animal.

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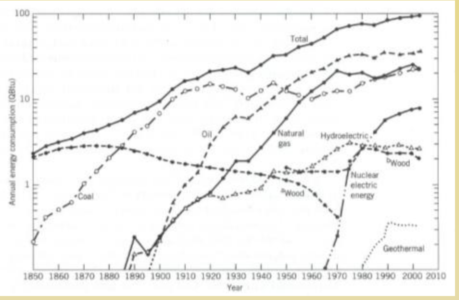
Energy consumption- US since 1850



Ristinen & Kraushaar-Fig 1.1

Exploitation of world's fossil fuels

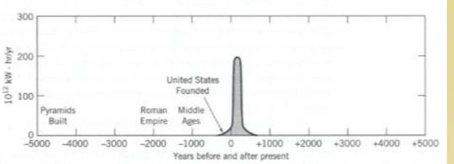
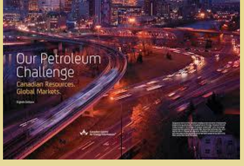


Figure 1.2 The complete exploitation of the world's fossil fuels will span only a relatively brief time in the 10,000 year period shown centered around the present. (*Source*: Reprinted with permission from M. K. Hubbert, *Resources and Man*, Washington, D.C., National Academy of Sciences, 1969. Historical events added.)

Why do we use so much energy

- We don't use our energy resources as efficiently as we could (US, Canada)



- Large discrepancy in energy consumption between the citizens of developed and developing country.

Gross domestic product per capita- US

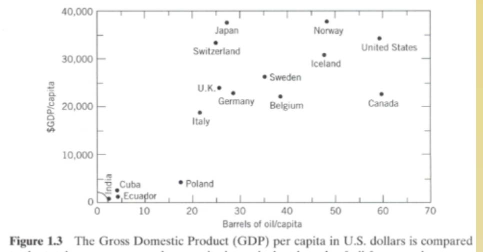


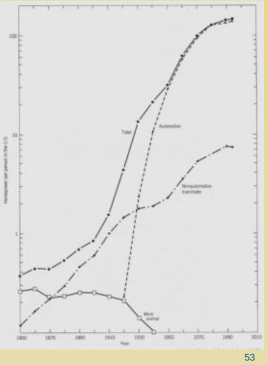
Figure 1.3 The Gross Domestic Product (GDP) per capita in U.S. dollars is compared to the total energy consumed per capita in equivalent barrels of oil for several countries. The small quarter-circle at the lower left corner is discussed in the text. (*Source*: *United Nations Statistical Yearbook*; data January 2003.)

- No relation with GDP and standard of living, however, relationship exists between GDP and energy consumption.

Horse power per capita-US

- Nonindustrialized country use their energy from muscle

- In 1850 in US one person needed 0.38 horsepower of which 0.26 came from animal



Energy Basics & Forms

What energy is ?

What forms it can take?

Nature of Energy

- Energy is all around you!
  - You can hear energy as sound.
  - You can see energy as light.
  - And you can feel it as wind.

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Nature of Energy

- You use energy when you:
  - hit a softball.
  - lift your book bag / material.
  - compress a spring.

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Nature of Energy

- What is energy that it can be involved in so many different activities?

  - Energy can be defined as the ability to do work.
  - If an object or organism does work (exerts a force over a distance to move an object) the object or organism uses energy.

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Nature of Energy

- Because of the direct connection between energy and work, energy is measured in the same unit as work: joules (J).
- In addition to using energy to do work, objects gain energy because work is being done on them.

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Forms of energy

- Energy can transform from one form to another form without loss

Common forms of energy

1. Chemical energy
2. Heat energy
3. Mass energy
4. Kinetic energy
5. Potential energy
6. Electric energy
7. Electromagnetic Radiation

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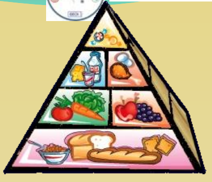
Chemical Energy

1. Chemical energy:



- Chemical energy is the energy stored in chemical bonds
- Energy released by chemical reaction

Ex: Coal, wood paper, burning

Chemical energy convert to heat energy

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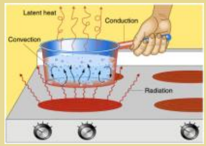
Heat Energy

Heat energy:

- Energy associated with random molecular motions within any medium, because moving particles produce heat.
- Thermal energy interchangeable with heat energy
- Heat energy is related to the concept of temperature

Increase heat increase temperature
Decrease heat decrease temperature



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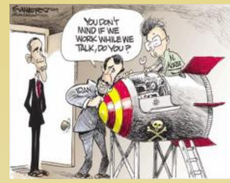
Mass Energy

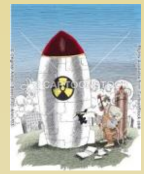
Mass energy: Energy comes from atomic nucleus, Ex- nuclear reactor and weapon

- Mass can be converter to energy
- Energy can be converted to mass (Albert Einstein)

$E= mc^2$

M-mass; C-speed of light





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Kinetic Energy

- The energy of motion is called kinetic energy.
- The faster an object moves, the more kinetic energy it has.
- The greater the mass of a moving object, the more kinetic energy it has.
- Kinetic energy depends on both mass and velocity.

$K.E. = 1/2\ mv^2$

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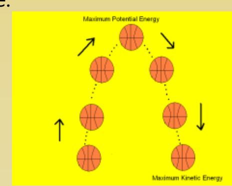
Potential Energy

Potential energy: Potential energy associated with forced field i.e. object position .

PE= w x h

w- weight at a height, h- height above the surface



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Potential-Kinetic Energy

Kinetic-Potential Energy Conversion

Roller coasters work because of the energy that is built into the system. Initially, the cars are pulled mechanically up the tallest hill, giving them a great deal of potential energy. From that point, the conversion between potential and kinetic energy powers the cars throughout the entire ride.

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Electrical Energy

Electric energy: Flow of electrons (or other charged particles)

- Mechanical energy is converted to electric energy in a generator.

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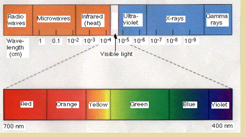
Electromagnetic radiation

Electromagnetic Radiation:

Energy in the form of a wave (energy radiated from the sun)

The energy radiated by the sun travels to the earth and elsewhere by electromagnetic radiation



POWER

Power is the time rate of using or delivering, energy

• Power = energy/time (rate of use energy)

• Energy = power x time (E = p x t) Joules per second

Units of Energy

• The Joule (J): is the metric unit of energy. One metric unit of force (N) acting through one metric unit of distance (m) is equivalent expenditure of one joule.

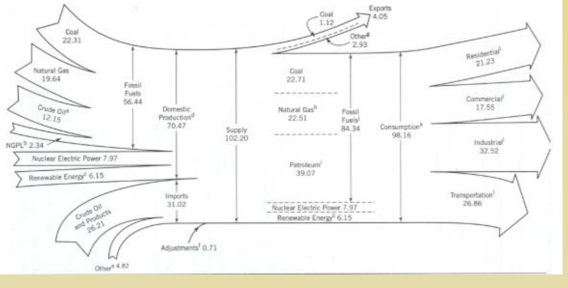
• The British Thermal Unit (Btu): amount of heat energy required to raise the temperature of one lb water by one degree Fahrenheit.

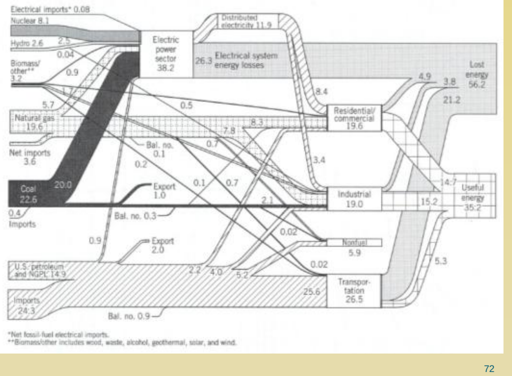
Units of Energy

• The Calorie (c): amount of energy required to raise the temperature of one gram of water by one degree Celsius. C ≠ c

• The Foot-Pound (ft-lb): A force of one pound acting through a distance of one foot by definition expends one ft-lb energy.

Energy consumption in the United States in 2003





World Energy consumption

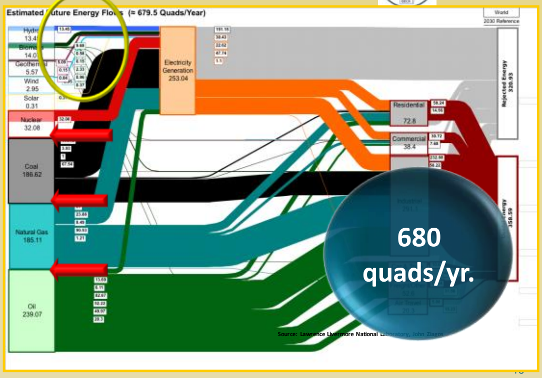


Figure 1.7 Each person in the United States consumes an energy equivalent of 58 barrels of oil burned as fuel each year.

Using generally available information, estimate the dollar value of the equivalent amount of oil which we each use annually.

Solution

Given:

58 barrel/(yr · person); see Figure 1.7.

42 gallons/barrel; see Energy Equivalents chart inside front cover.

Oil is approximately $1.25/gallon; estimated from reported crude oil prices.

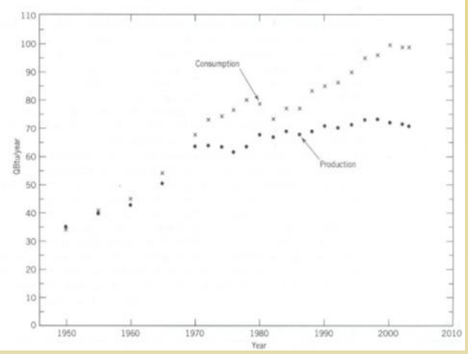
$$58 \frac{\text{bbl}}{(\text{yr} \cdot \text{person})} \times 42 \frac{\text{gal}}{\text{bbl}} \times 1.25 \frac{\$}{\text{gal}} = \mathbf{3045} \frac{\$}{(\text{yr} \cdot \text{person})}$$

Note that the units of bbl and gal cancel in this calculation. We can extend the answer to obtain the cost per day of this oil.

$$3045 \frac{\$}{(\text{yr} \cdot \text{person}} \times \frac{1 \text{ yr}}{365 \text{ day}} = \mathbf{8.34} \frac{\$}{(\text{day} \cdot \text{person})}$$

Here the units of yr have canceled.

Energy Consumption and Production



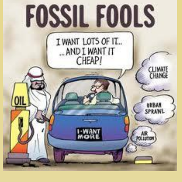
Fossil Fuels

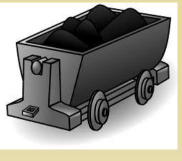
Part (2)

Fossil Fuels

Outlines:

- Fossil fuels-Formation
- Coal-Types-Formation
- Coal resources, production and consumption
- Coal mining technology
- Environmental impacts of coal mining





Fossil Fuels 85% of the world's commercial energy

Natural gas

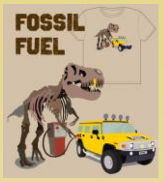
Coal

Oil

What are Fossil Fuels

- Partially decayed remains of plants, animals and microorganisms
- 300 million years ago

• much of earth's climate was mild and warm
– plants grew year round in vast swamps
• as swamp plants and aquatic microorganisms died



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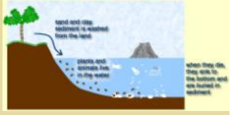
What are Fossil Fuels

Contd…

- fell into or sunk in water, decomposed very little due to lack of oxygen
- heat and pressure that accompanied burial of organic material by sediments
- converted decomposed organic material into carbon-rich materials we now call fossil fuels



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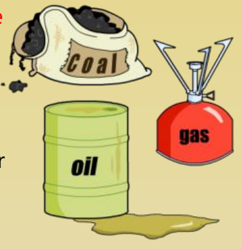
What are Fossil Fuels

Contd…

- Industrial societies need a lot of energy and, at the moment, rely on fossil fuels as the main source of this energy.
- Coal, oil and natural gas are fossil fuels. They are carbon-based materials that formed over millions of years from the remains of ancient plants and animals.



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Fossil Fuels

Fossil fuels are so useful because they contain stored chemical energy, which is converted into large amounts of useful heat energy when the fuels are burned.

- the total amount of fossil fuels available is limited and so
- they are classed as non-renewable energy resources

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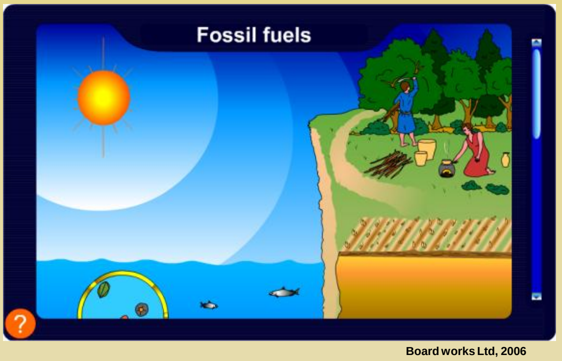
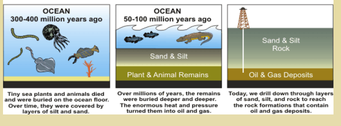


Board works Ltd, 2006

Formation Fossil Fuels

Common conditions

- High Organic Production
- Burial of organic material
- Reducing conditions – little or no free oxygen
- Reducing conditions preserve organic matter



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Types of Fossil Fuels

- Petroleum
- Natural Gas
- Coal
- Kerogen ("Oil Shale")
- Bitumen ("Tar Sands")




Why do we use fossil fuels

- **why fossil fuels special?**

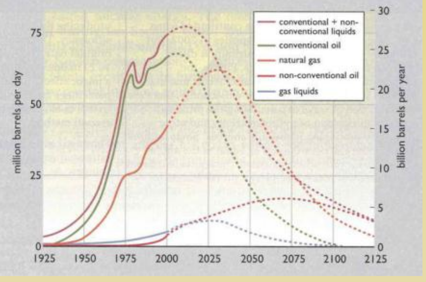
Energy content.

Gasoline: 115,000 BTU/gal = 120 MJoules/gal
Coal: 15,000 BTU/lb = 15 MJoules/lb

Wood: 7,500 BTU/lb = 7.5 MJoules/lb
A "horse" (working 1 hour) = 2.5 MJoules.
A human ... = 0.2 MJoules

Fossil Fuels are ***transportable***.

Declining Fossil Fuels



Forecasts Boyle, *Renewable Energy, Oxford University Press (2004)*

Coal

Coal

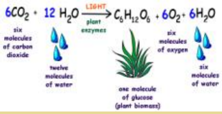
- Solid fossil fuel formed in several stages
- Land plants that lived 300-400 million years ago
- Subjected to intense heat and pressure over many millions of years
- Mostly carbon, small amounts of sulfur


Coal – what do we use it for?

- Stages of coal formation
  - 300 million year old forests
  - peat > lignite > bituminous > anthracite
  - Primarily strip-mined
- Used mostly for generating electricity
  - 62% of the world's electricity
  - 52% of the U.S. electricity
- Enough coal for about 200-1000 years
  - U.S. has 25% of world's reserves
- High environmental impact

How coal was formed

About 350 million years ago, trees and other plants **photosynthesized** and stored the Sun's energy.



Dead plants fell into swampy water and the mud prevented them from rotting away.

Over the years, the mud piled up and squashed the plant remains.

After millions of years under this pressure, the mud became rock and the dead plants became **coal**.

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Formation of Coal

The formation of coal from dead plant matter requires burial, pressure, heat and time

The process works best under anaerobic conditions (no oxygen) since the reaction with oxygen during decay destroys the organic matter

It is the carbon content of the coal that supplies most of its heating value

The greater the carbon to oxygen ratio the harder the coal, the more reduced the state of the carbons and the more potential energy it contains

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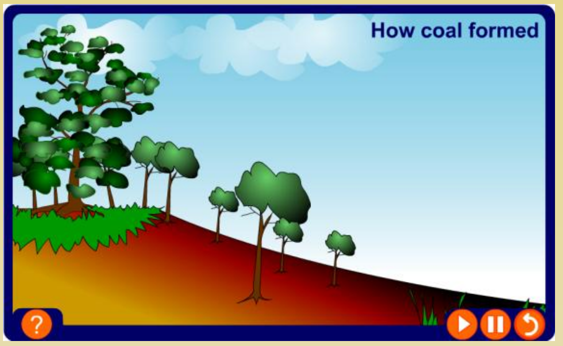
Formation of coal in flow diagram

$$\text{Dead wood} \xrightarrow[\text{chemical action}]{\text{bacterial and}} \text{Peat} \xrightarrow[\text{Pressure}]{\Delta} \text{Lignite coal}$$

$$\text{Lignite coal} \xrightarrow[\text{Pressure}]{\Delta} \text{Bituminous coal} \xrightarrow[\text{Pressure}]{\Delta} \text{Anthracite coal}$$

Coal formation



Board works Ltd, 2006

Formation of Coal

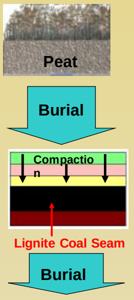
The Formation of Coal Involves Several Steps:

1) Formation of Peat.

- Swamps are areas where organic matter from plants accumulate. As the plants die and get buried they compact to become peat. With time and more compaction, almost all of the water is lost and three different grades of coal result.

2) Formation of Lignite Coal.

- Compaction of the peat due to burial drives off volatile components like water and methane, eventually producing a black-colored, organic-rich coal called *lignite* .



Formation of Coal

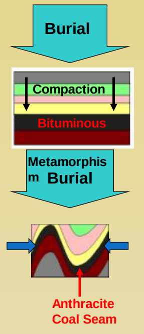
The Formation of Coal Involves Several Steps:

3) Formation of Bituminous Coal.

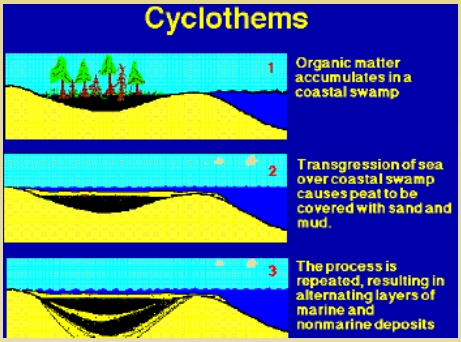
- Further compaction and heating results in a more carbon- rich coal called *bituminous* coal.
- Soft coal which consist of about 85% carbon and burns readily but produces a lot of smoke.

4) Formation of Anthracite Coal.

- If the rock becomes metamorphosed, a high grade coal called *anthracite* is produced.
- Hard dark coal which consist of 90% to 95% carbon and burns very hot and clean. Forms as a result of metamorphic conditions.
- Anthracite coal produces the most energy when burned.



Cycle of Coal Formation



http://earthsci.org

Classification of Coal

The products of coalification are divided into four major categories based on the carbon content of the material

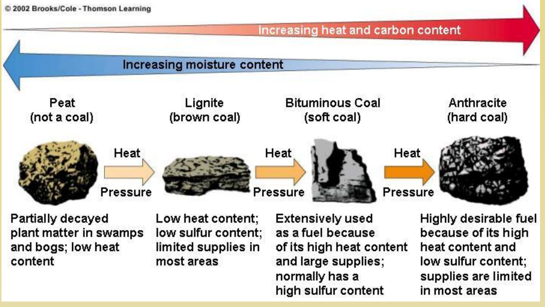
Peat

Lignite

Bituminous

Anthracite

Classification of Coal



Nature of coal formation

exposed during formation to

– higher heat and pressure

» drier (lower water content)

» more compact (harder)

» higher heating value (=higher energy content)

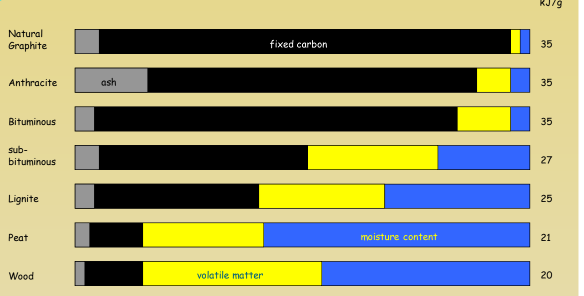
– lower heat and pressure

» wetter (higher water content)

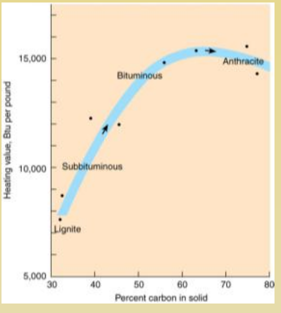
» less compact (softer)

» lower heating value (=lower energy content)

Coal types and composition



Fuel Efficiency



As the coals becomes harder, their carbon content increases, and so does the amount of heat released

Anthracite produces twice the energy (BTUs) of lignite

Coal resource, production, consumption

Coal overview

Overview BP website (BP.com)

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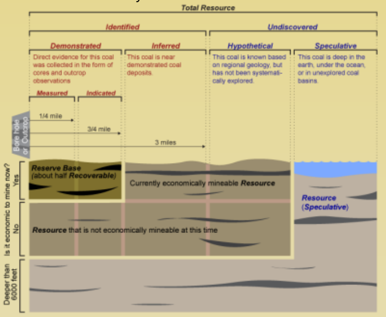
Terminology- Resource and Reserve

Resource : is how much coal is actually in the ground
Reserve: This term refers to coal which is both “demonstrated” (meaning we know it exists) and is deemed to be economically and technologically mineable at any time



http://www.groundtruthtrekking.org/Issues/AlaskaCoal/CoalTerminology.html

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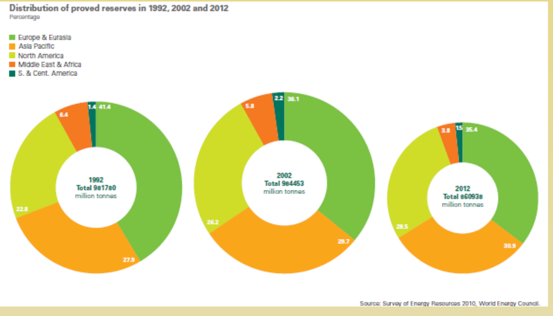
Proved coal reserve at the end of 2004



2004 BP website (BP.com)

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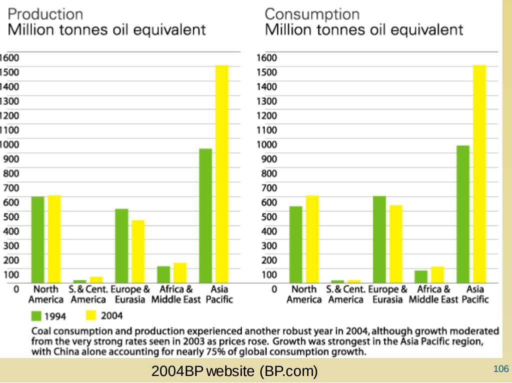
Coal production-Coal consumption



2004BP website (BP.com)

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Coal Mining

Strip Mining **Subsurface Mining**

Coal Mine

Coal occur in seams or beds
Thickness from inches to more than 100 ft

Two types of mining e.g.

Strip (60%) and sub-surface

Strip: removed overburden rock and placed aside

Disadvantage of strip mining: erosion, acid mine drainage, hazardous to surrounding vegetation and aquatic life

Environmental Concerns

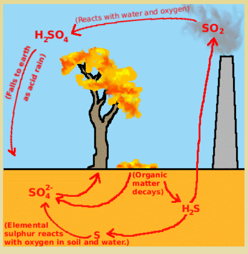
- Acid Mine Drainage
- Acid rain
- Increasing atmospheric CO_2
- subsidence
- Coal seam fires

Acid Mine Drainage

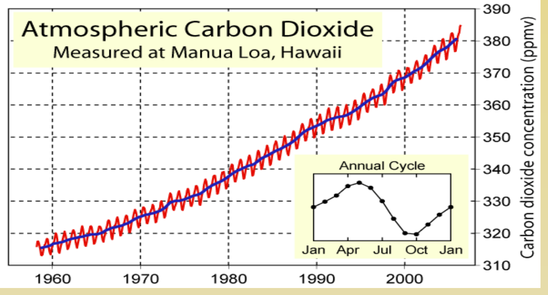
- Sulphur in the exposed coal combine with oxygen and water vapor to form sulfuric acid (H_2SO_4)
- This acidic water is harmful to vegetation and aquatic life.

Acid Rain

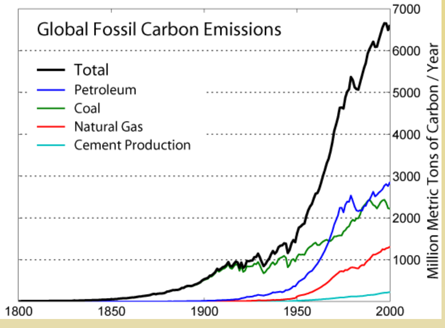
- From burning of coal releases SO_2.
- There are 1 to 2% S



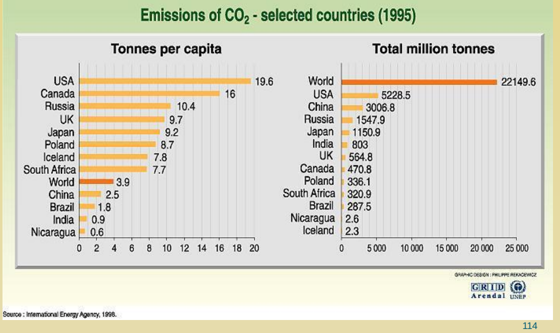
Increasing Carbon Dioxide



Global Fossil Carbon Emission



Emission of Carbon Dioxide



Carbon Dioxide & Mean Temp.

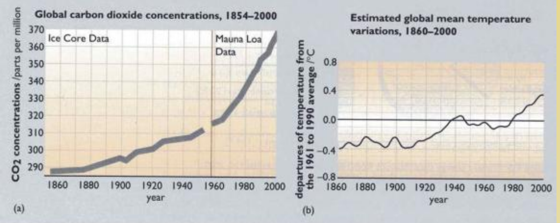


Figure 1.6 (a) Atmospheric concentrations of carbon dioxide (CO_2), 1854–2000. Carbon dioxide data from 1958 were measured at Mauna Loa, Hawaii; pre-1958 data are estimated from ice cores (b) estimated global mean temperature variations, 1860–2000 (source: Intergovernmental Panel on Climate Change, 2001)

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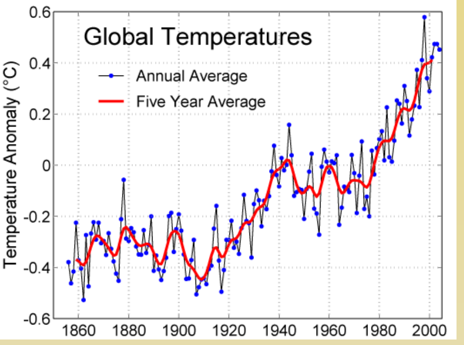
Global temp.



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Subsidence and Coal Seam Fires

Subsidence

Coal Seam Fire

How do fossil fuels produce electricity?

Power stations that are fuelled by coal and oil, operate on the same basic principle.

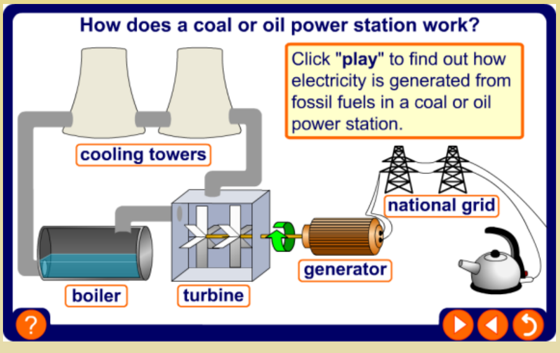
The fuel is burned and the heat produced is used to boil water. This creates high-pressure, superheated steam, which is then used to turn a turbine.

The turbine turns a generator and so generates electricity.

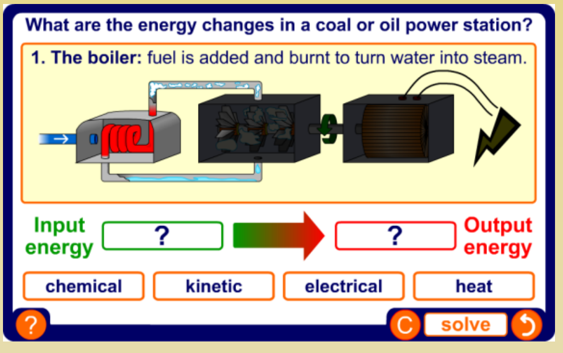
The cooling towers cool the steam, which condenses as water and can then be recycled in the power station.

Natural-gas-fired power stations do not use steam. The natural gas is burnt and the hot gases produced are used directly to turn the turbine.

What happen in a coal station



Energy Conversion



10 Appendix A – Lecture slides

10.2 Appendix A.1 – Lecture 5 Slides

A Journey of Fossil Fuels: Field to Market

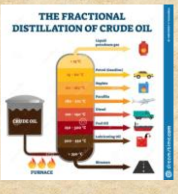
Introduction to the lecture

- This lecture provides an overview of the journey of fossil fuel from field to market.
- This lecture discusses the key concepts such as exploration and survey for fossil fuel in terms of geology, rock formation, porosity, permeability, seismic technology.
- It also introduces the way of retrieving oil in the field through permitting, drilling, well completion and casing well and cementing in the field.

2

Introduction to the lecture

- This lecture provides an overview of planning production of oil in the field, shipping crude oil, refining through distillation, processing and preparation to market and finally shipping petroleum products.



3

Aim and Learning outcomes

- The aim of the lecture is to provide a brief concept to understand the importance of fossil fuel and its journey from field through production to market by shipping.
- After completing lecture "Journey of fossil fuel from field to market" students will be able to:
  - Understand the exploration process of fossil fuel in the field i.e. geology, rock formation, porosity and permeability, geological history.

4

Aim and Learning outcomes

- After completing lecture "Journey of fossil fuel from field to market" students will be able to:
  - Know the process of retrieving fossil fuel in the field through several procedures i.e. drilling, well completion, casing, cementing.
  - Know about fossil fuel production in onshore and offshore through several process i.e. cleaning oil, shipping crude oil, refining (distillation, processing) and finally to market.

5

Talk outline

Exploration and Survey
- Geology
- Rock Formation
- Porosity & Permeability
- Seismic technology

Retrieving the Oil
- Permitting & Leasing land
- Drilling
- Well completion
- Casing well & Cementing

Production
- Subsea operation
- Cleaning oil

6

Talk outline

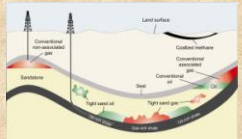
Shipping Crude Oil

Refining
- Distillation
- Processing
- Preparation to market

Shipping Petroleum Products

7

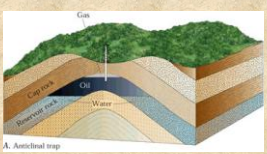
Exploration - Geology



- Geologist use knowledge on rock, geological history and technology
- Sedimentary rocks are more potential for petroleum
- Drill exploratory wells/ wildcat

8

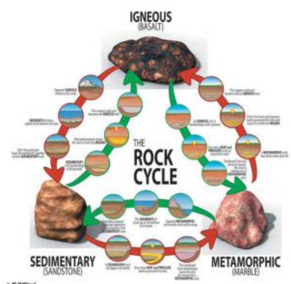
Exploration – Rock Formation



- Stratigraphy is the study of rock formation, age and other information
- Different types of rock have varying potential for holding oil or gas in reservoir

9

Exploration – Rock Formation



Igneous rock: formed from magma or liquid rock.

Metamorphic rock: Due to heat and pressure, igneous or sedimentary rock transformed to metamorphic rock.

Sedimentary rock: Build by layer of sediment over time. Most oil found in sedimentary rock. It has many pores and ideal for oil and gas reservoir.

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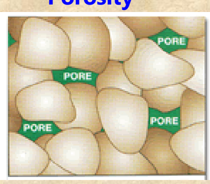
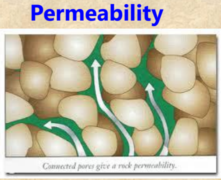
Exploration – Porosity & Permeability

Porosity



Permeability



Connected pores give a rock permeability.

- Rocks are not completely solid ,have tiny holes, in which air or other fluids were trapped during formation
- Porosity measure the number and kind of pores in rock
- Fluid can move between these pores in varying degree
- Permeability is a measure of the ability of a rock to move fluid through its pores.

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Exploration - Geologic History

- Geological history is an important factor to
- Understand the environment that existed million years ago
- Oil and gas are the remains of ancient sea life
- Important to locate the area of ancient ocean existed

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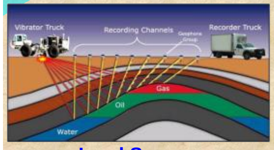
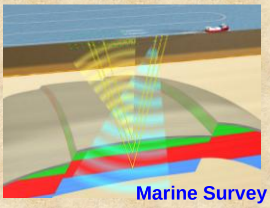
Exploration - Seismic Technology



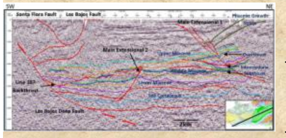
Land Survey



Marine Survey

- Seismic technology uses sound waves
- To know deep in the ground
- Seismic waves can travel through some materials more easily, depend on density of rock
- Marine survey uses air gun

Exploration - Interpreting Seismic Output



- Seismic data is interpreted in high tech ways (3D visualization)
- Advanced 3D visualization project known as CAVE (Cave Automatic Virtual Environment)
- Wall and floor are used as projection surface
- Newest type is 4D seismic technology
- The fourth dimension is time- to see how change over time

Retrieving the Oil - Permitting and Leasing Land

- Companies must get permission to drill
- Permission from state government and leases from landowners to drill private land
- There are also environmental protection measure to take in account before drilling

Retrieving the Oil - Drilling

- Large drilling rig is brought to the site
- Drill bits have sharp teeth that rotate to tear apart rock while the well is drilled
- The rock, torn by the drill bit called debris
- Drillers use mud to lift debris out of the well
- Mud is formulated with precise density

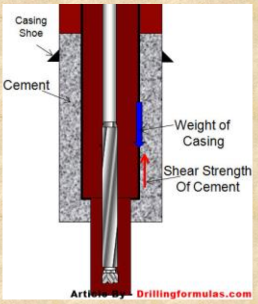
Retrieving the Oil - Well completion

- After drilling, well must be completed before producing
- 3 main steps in well completion
  - allowing oil into the well to bring surface
  - water does not get into the well
  - keeping underground rock out of the wall
- Stability of the reserve must be considered

Retrieving the Oil - Casing

- Drill pipe does not stay in the well
- Replaced by longer, wider casing pipe
- Final & deepest well is placed after drilling complete

Retrieving the Oil - Cementing



- After casing, cement is used to fill gap between casing pipes and wall
- To create a better bond with casing, mud and cement

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Production - Onshore and offshore operation

- After well completion, can go into production
- If not enough natural drive
- Need pumps to lift the oil
- Well has a lot of pressure, blow out preventer (BOP) is used
- For offshore, well cap must be resistant to corrosion of saltwater

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Production - Cleaning the oil

- After bringing (oil) to the surface, must be cleaned
- Refiner have specific standard
- Field processing is used to separate out oil, gas and saltwater
- Simple settling procedure
- Pressurized separators is used to separate quickly
- To remove excess water, heat-water is applied

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Shipping Crude Oil

- Refineries are usually near consumption market
- Well to refinery: Pipeline and oil tanker trucks

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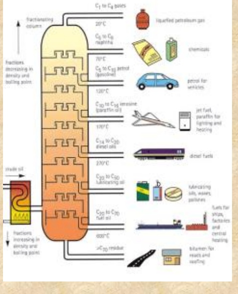
Refining - Distillation



- Crude oil form-make it into products
- Petroleum must be refined-separated into many parts
- Distillation is a process of separation of substance based on boiling range
- Number of products come from refining process

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Refining - Processing

- Different parts go through chemical processing into useful products
- Three main types----
  - Cracking breaks long HC chain
  - Unification combines small chain
  - Alteration rearrange HC chain

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Refining - Preparation to Market

Co-funded by the Erasmus+ Programme of the European Union

- After all the products is separated from the crude oil then prepared to go to market

- This last step is known as treatment
- Additives are used to add with gasoline

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Shipping Petroleum Products

Co-funded by the Erasmus+ Programme of the European Union

Petroleum products are shipped to markets

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10 Appendix A – Lecture slides

10.3 Appendix A.1 – Lecture 6 & 7 Slides

Biomass Energy

Introduction to the lecture

- Lecture Biomass introduces the basic concept of biomass energy, its energy conversion processes and environmental impacts.
- In this lecture has 3 parts.
- Part 1 provides an overview of fundamental concept of biomass, types of biomass, sources of biomass, carbon neutral, global energy sources of biomass, use of biomass and converting biomass to other forms of energy.

Introduction to the lecture

- Part 2 provides theoretical concept of biomass conversion technologies, bioenergy technologies, biomass direct combustion, biogas-gasification, biofuels, biorefineries and biochar.
- Part 3 provides an overview of environmental impacts i.e. advantages for biomass energy and disadvantages.

Aim and Learning outcomes

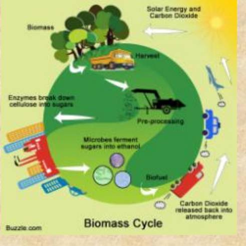
- The aim is to build upon the previous lecture but shift the focus from the investment to the investors and, in so doing, raising the issue of the sources of finance and the terms under which it is provided.
- After completion of Lecture “Biomass” students will be able to:
  - Explain how to obtain energy from biomass. Have a broad knowledge of the main sources of biomass, the origins of these sources, and the means by which they can be exploited for electricity generation.

Aim and Learning outcomes

- After completion of Lecture “Biomass” students will be able to:
  - Understand the principles underlying the design and operation of waste and biomass to energy systems.
  - Production of clear and concise analyses of benefits and problems relating to the production and use of different forms of biomass energy

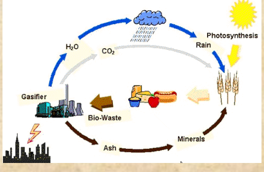
Talk outline

- **Part-I**
- **Introduction – Biomass Energy**
  - **Fundamentals**



Talk outline

- **Part-II**
- **Biomass Energy Conversion Processes**



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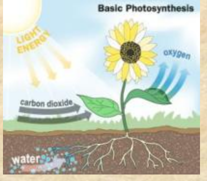
Talk outline

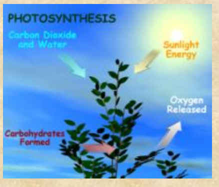
- **Part-III**
  - **Environmental impacts**

8

Biomass Basics

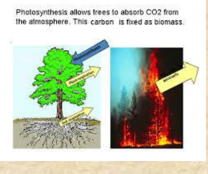
Biomass —Plants and Animals



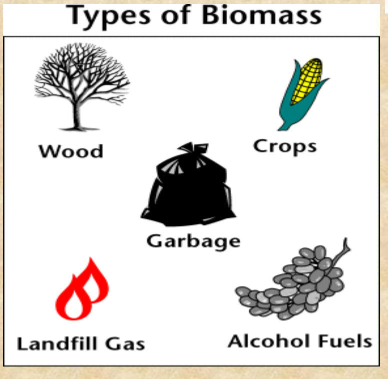


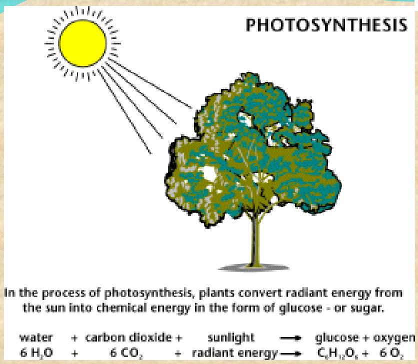
- Biomass is organic material made from plants and animals.
- Biomass contains stored energy from the sun.
- Plants absorb the sun's energy in a process called photosynthesis.
- The chemical energy in plants gets passed on to animals and people that eat them.

Cont'd.......

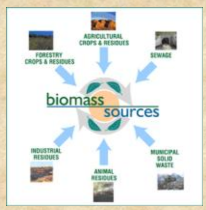


- Biomass is a renewable energy source because we can always grow more trees and crops
- Some examples of biomass fuels are wood, crops and some garbage.
- When burned, the chemical energy in biomass is released as heat
- Wood waste or garbage can be burned to produce steam for making electricity, or to provide heat to industries and homes.





Sources of Biomass



- Agriculture
- Residues from forestry, specific industries (e.g. furniture production), food processing
- Solid municipal and industrial wastes
- Used wood e.g. from old furniture, used timber
- Marine systems: the oceans of our world contain much more biomass than existing on the continents

Corn

http://www.geo.msu.edu/geo333/corn.html

15

Soybeans

http://agproducts.unl.edu/

16

Sugar Cane

http://www.nrel.gov/biomass/photos.html

17

Grass

http://www.nrel.gov/biomass/photos.html

18

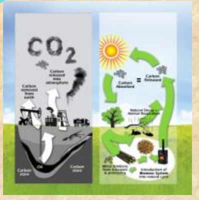
Wood Chips & Sawdust

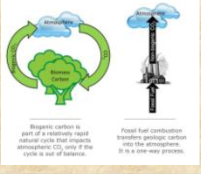
http://www.nrel.gov/biomass/photos.html http://www.energytrust.org/RR/bio/

Municipal Solid Waste

http://www.eeingeorgia.org/eic/images/landfill.jpg

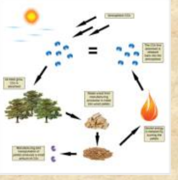
Carbon Neutral





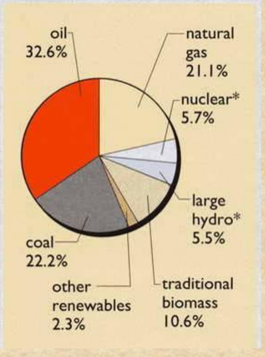
- Energy is produced from biomass by basically burning organic matter to release its stored chemical energy
- That it has accumulated through the process of photosynthesis
- Using biomass contributes very little to the build-up of greenhouse gases

Carbon Neutral



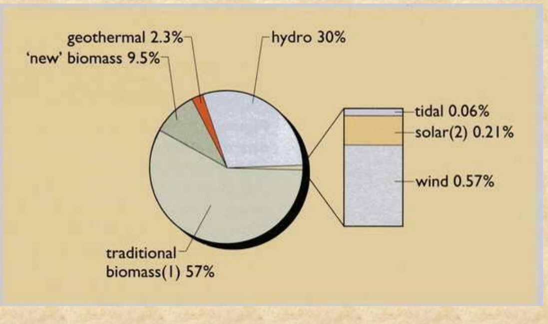
- Although plants will release their stored carbon dioxide (CO_2) when burned
- That CO_2 is recaptured and used by other plants as they grow
- Therefore, theoretically there is no net gain of carbon dioxide because of a cycle of usage

Global Energy Sources 2002



Boyle, *Renewable Energy*, Oxford University Press (2004)

Renewable Energy Use – 2001

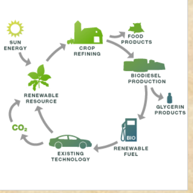


Boyle, *Renewable Energy*, Oxford University Press (2004)

Converting Biomass to Other Forms of Energy

- Burning biomass is not the only way to release its energy
- Biomass can be converted to other useable forms of energy, such as methane gas or transportation fuels, such as ethanol and biodiesel
- Methane gas is the main ingredient of natural gas
- Smelly stuff, like rotting garbage, and agricultural and human waste, release methane gas — also called "landfill gas" or "biogas."

Cont'd........



- Crops like corn and sugar cane can be fermented to produce ethanol
- Biodiesel, another transportation fuel, can be produced from left-over food products like vegetable oils and animal fats

Cont'd........

- Burning Wood Is Nothing New
- The most common form of biomass is wood
- For thousands of years people have burned wood for heating and cooking
- Wood was the main source of energy in the United States and the rest of the world until the mid-1800s
- Wood continues to be a major source of energy in much of the developing world

Biomass Conversion Technologies
or
Creating Energy from Biomass

Bioenergy Technologies

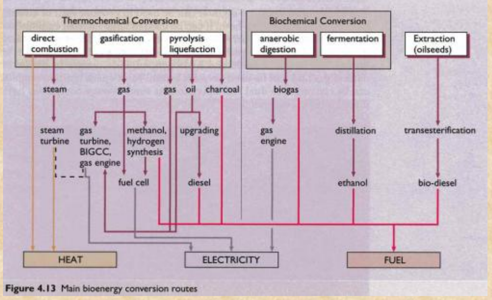


Figure 4.13 Main bioenergy conversion routes

Boyle, *Renewable Energy*, Oxford University Press (2004)

Biomass Direct Combustion

- Biomass power technologies convert renewable biomass fuels to heat and electricity
- The biomass fuel is burned in a boiler to produce high-pressure steam
- This steam is introduced into a steam turbine, where it flows over a series of turbine blades, causing the turbine to rotate
- The turbine is connected to an electric generator
- The electric generator rotates, producing electricity.

Biogas - Gasification

- By converting biomass into a gas, it can then be made available for a broader range of energy device
- Gasifiers operate by heating biomass in an environment where the solid biomass breaks down to form a flammable gas
- Anaerobic digestion is a commercially proven technology and is widely used for recycling and treating wet organic waste and waste waters
- It is a type of fermentation that converts organic material into biogas
- Which mainly consists of methane (approximately 60%) and carbon dioxide (approximately 40%) and is comparable to landfill gas.

31

Biofuels

- Liquid biofuels include pure plant oil, biodiesel, and bioethanol.
- Biodiesel is based on esterification of plant oils
- Ethanol is primarily derived from sugar, maize, and other starchy crops
- Global production of biofuels consists primarily of ethanol, followed by biodiesel production

32

Biorefineries and Biochar

- An emerging concept is biorefineries.
- A biorefinery involves the co-production of a spectrum of bio-based products (food, feed, materials, chemicals) and energy (fuels, power, heat) from biomass
- Biochar is a fine-grained charcoal high in organic carbon and largely resistant to decomposition
- Biochar is produced by heating biomass in the absence (or under reduction) of air.

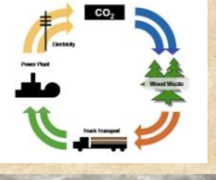
33

Environmental Impacts

The advantages for biomass energy

- Most of them are renewable, e.g., wood, mustard oil and crop residues
- Solve energy crisis in the future
- Some of them are re-using the waste, e.g., crop residues, sewage
- High energy efficiency
- Generally it does not polluted the atmosphere as much as oil and coal.

The disadvantages



- Serious air pollution was found when burning plants matters, e.g., CO2, CO, solid particulate matter
- Emission some toxic gases and ash

Cont'd....

- It takes too much energy to collect, dry and transport the residues to power plants
- Reduce soil nutrient replenishment

- The source of biomass can use fertilize soil, e.g., crop residues and animal manure.
- Cutting too many woods is a kind of deforestation can cause, soil erosion and natural disasters

Cont'd....

- Raising the price of food, wood and wood products indirectly
- May cause accident
- It uses large area to grow biomass

10 Appendix A – Lecture slides

10.4 Appendix A.1 – Lecture 8 & 9 Slides

Solar Energy

1

Introduction to the lecture

- Solar energy is used for direct conversion of sunlight to electricity with advantages of minimum maintenance.
- Lecture on solar energy has 3 parts.
- Part 1 of solar energy introduces the concept of solar energy, fundamentals of solar energy, radiant energy, quantity of solar energy and advantages and disadvantages of solar energy.
- Part 2 of this lecture provides an on solar cell principles and cell manufacture.

2

Introduction to the lecture

- This lecture discusses the photovoltaic cell (PV), principles of solar electric system, cross section of PV cell, principles of PV cell and solar cell manufacture.
- Part 3 provides information on solar PV facts & trends i.e. world solar power production, solar cell production volume in the world and photovoltaic market.

3

Aim and Learning outcomes

- The aim is to introduce students to the concept of renewable solar energy system and its global production and describe the procedure to manufacture solar cell.
- After completing of this lecture students will be able to:
  - Explain the principles that underlie various natural phenomena for the production of solar energy.
  - Develop a comprehensive technological understanding of solar PV system.

4

Aim and Learning outcomes

- After completing of this lecture students will be able to:
  - Provide in-depth understanding of PV cell design.
  - Design a basic photovoltaic system to meet energy.
  - Compare the advantages and disadvantages of solar energy production.
  - Understand the present scenario of global solar energy production and consumption.

5

Talk outline

- **Part-I**
- **Introduction – Solar Energy**
  - **Fundamentals of Solar Energy**

6

Talk outline

- **Part-II**
  - **Solar Cell Principles**
  - **Cell Manufacture**

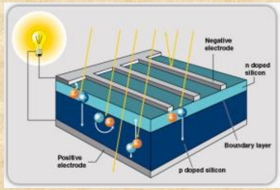
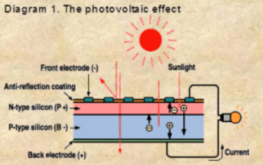


Diagram 1. The photovoltaic effect



7

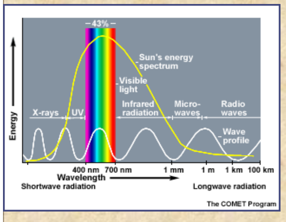
Talk outline

- **Part-III**
  - **Photovoltaic system, Facts and Trends**

8

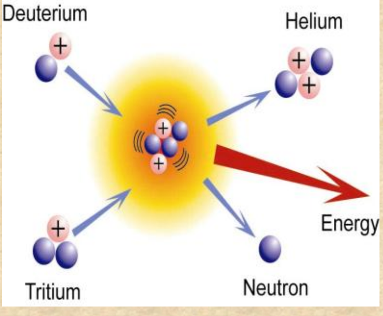
Solar Energy

What is Solar Energy?



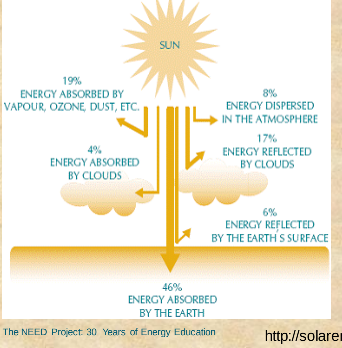
- Originates with the thermonuclear fusion reactions occurring in the sun
- Represents the entire electromagnetic radiation (visible light, infrared, ultraviolet, x-rays, and radio waves).

Radiant Energy



11

How much solar energy?



- The surface receives about 46% of the total solar energy that reaches the Earth. Only this amount is usable.

The NEED Project: 30 Years of Energy Education

http://solarenergybeginning.wordpress.com/

Advantages and Disadvantages

Advantages

- All chemical and radioactive polluting byproducts of the thermonuclear reactions remain behind on the sun
- While only pure radiant energy reaches the Earth
- Energy reaching the earth is incredible.
- By one calculation, 30 days of sunshine striking the Earth have the energy equivalent of the total of all the planet's fossil fuels, both used and unused!

Advantages and Disadvantages

Disadvantages

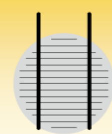
- Sun does not shine consistently
- Solar energy is a diffuse source. To harness it, we must concentrate it into an amount and form that we can use, such as heat and electricity
- Addressed by approaching the problem through:
  1) collection, 2) conversion, 3) storage

Solar Cell Principles

Solar Electric (Photovoltaic)

Definitions: PV Cell

- **Cell:** The basic photovoltaic device that is the building block for PV *modules*.

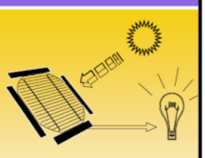


PV Cells have efficiencies approaching 21.5%

Florida Solar Energy Center

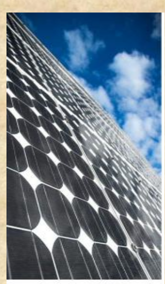
What Are Solar Cells?

- Thin wafers of silicon
  - Similar to computer chips
  - much bigger
  - much cheaper!
- Silicon is abundant (sand)
  - Non-toxic, safe
- Light carries energy <u>into</u> cell
- Cells <u>convert</u> sunlight energy into electric current- they do not store energy
- Sunlight is the "fuel"



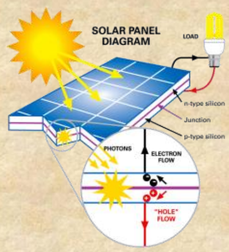
Florida Solar Energy Center

Solar Electric Systems



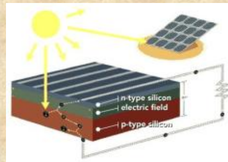
- Photovoltaic (PV) systems convert light energy directly into electricity
- Commonly known as "solar cells."
- The simplest systems power the small calculators we use every day
- More complicated systems will provide a large portion of the electricity in the near future
- PV represents one of the most promising means of maintaining our energy intensive standard of living while not contributing to global warming and pollution.

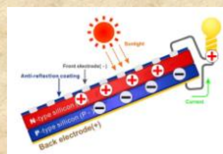
How Does it Work - Principles



- The principles behind the direct use of sun's energy for the production of electricity was discovered in 1887 by Heinrich Hertz
- Sunlight is composed of **photons** or bundles of radiant energy
- When photons strike a PV cell, they may be reflected or absorbed (transmitted through the cell)

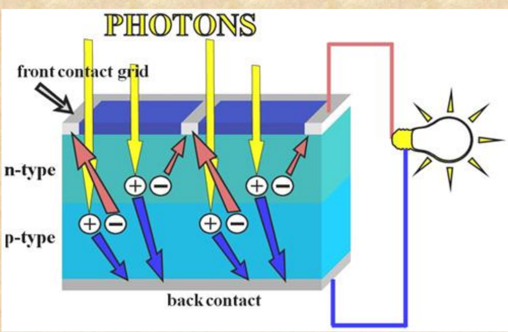
How Does it Work - Principles





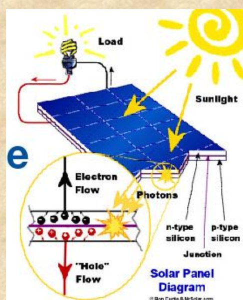
- When absorbed on negative plate, electron are emitted with an amount of kinetic energy is known as photoelectric effects
- Only the absorbed photons generate electricity
- An electron in a metal atom is able to capture a photon and obtain the energy necessary to escape

Cross Section of PV Cell



http://en.wikipedia.org/wiki/Solar_cells

How Does it Work - Principles

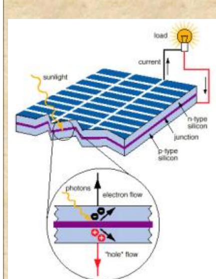


- If the energy of the incoming photon exceeds the binding energy of the electron in the metal
- When the photons are absorbed, the energy of the photons is transferred to electrons in the atoms of the solar cell

How Does it Work?

- Solar cells are usually made of two thin pieces of **silicon**, the substance that makes up sand and the second most common substance on earth
- One piece of silicon has a small amount of boron added to it, which gives it a tendency to attract electrons. It is called the **p-layer** because of its positive tendency.

How Does it Work?

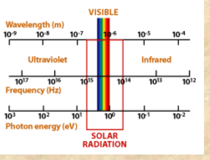


- The other piece of silicon has a small amount of phosphorous added to it, giving it an excess of free electrons
- This is called the **n-layer** because it has a tendency to give up negatively charged electrons

Best Place For Solar Panels?

- South Facing roof, adequate space
- No shading (time of year, future tree growth)
- Roof structure, condition

Light & the Photovoltaic Effect



- Certain semiconductor materials absorb certain wavelengths
- The shorter the wavelength the greater the energy
- Ultraviolet light has more energy than infrared light
- Crystalline silicon, utilizes all the visible spectrum plus some infrared radiation

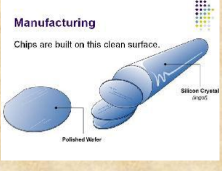
How Solar Cells are Made ??

Cooking ?????

Solar Cell Manufacture

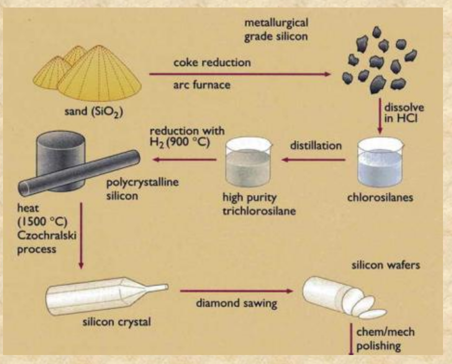
- To make a solar cell, silica (SiO_2) is first refined and purified
- Then melted and solidified in such a way that the silicon atoms are arranged into perfect lattice
- To introduce a seed crystalline silicon into a molten mass of pure silicon and slowly draw it out
- Known as Czochralski process

Solar Cell Manufacture

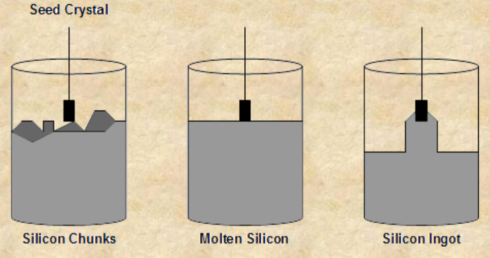


- The cylindrical ingot is formed
- Then sliced into wafers about 0.5 mm thick
- Doped with impurities of phosphorus to create negative layer
- Also doped with boron to form the positive layer

Creating Silicon Wafers



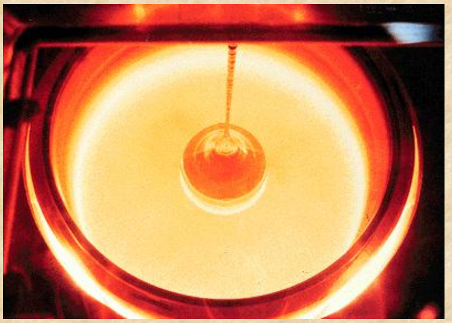
Growing Silicon Ingots



Czochralski Process

http://en.wikipedia.org/wiki/Czochralski_process

Drawing a Silicon Ingot



http://www.answers.com/topic/silicon

Silicon Ingots & Wafers

http://www.sumcosi.com/english/products/products2.html

Silicon Solar Cell

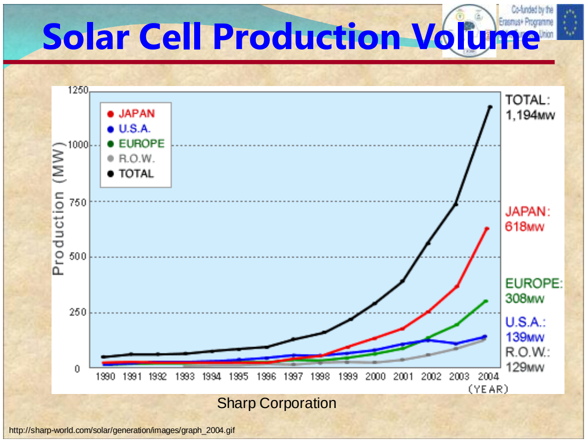
http://en.wikipedia.org/wiki/Image:Solar_cell.png

Solar PV Facts & Trends

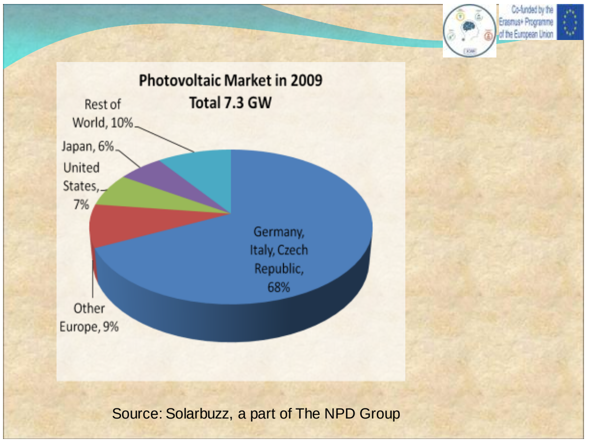
World Solar Power Production

Country	PV Capacity				
	Cumulative			Installed in 2004	
	Off-grid PV [kW]	Grid-connected [kW]	Total [kW]	Total [kW]	Grid-tied [kW]
Australia	48,640	6,760	52,300	6,670	780
Austria	2,687	16,493	19,180	2,347	1,833
Canada	13,372	512	13,884	2,054	107
France	18,300	8,000	26,300	5,228	4,183
Germany	26,000	768,000	794,000	363,000	360,000
Italy	12,000	18,700	30,700	4,700	4,400
Japan	**84,245**	**1,047,746**	**1,131,991**	**272,368**	**267,016**
Korea	5,359	4,533	9,892	3,454	3,106
Mexico	18,172	10	18,182	1,041	0
Netherlands	4,769	44,310	49,079	3,162	3,071
Norway	6,813	75	6,888	273	0
Spain	14,000	23,000	37,000	10,000	8,460
Switzerland	3,100	20,000	23,100	2,100	2,000
United Kingdom	776	7,386	8,164	2,261	2,197
United States	189,600	175,600	365,200	90,000	62,000

http://en.wikipedia.org/wiki/Solar_panel



Solar Cell Production Volume
Production (MW)
JAPAN
U.S.A.
EUROPE
R.O.W.
TOTAL
TOTAL: 1,194MW
JAPAN: 618MW
EUROPE: 308MW
U.S.A.: 139MW
R.O.W.: 129MW
(YEAR)
Sharp Corporation
http://sharp-world.com/solar/generation/images/graph_2004.gif



Photovoltaic Market in 2009
Total 7.3 GW
Rest of World, 10%
Japan, 6%
United States, 7%
Germany, Italy, Czech Republic, 68%
Other Europe, 9%
Source: Solarbuzz, a part of The NPD Group

10 Appendix A – Lecture slides

10.5 Appendix A.1 – Lecture 10, 11 & 12 Slides

Hydropower Energy

1

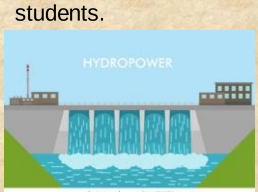
Introduction to the lecture

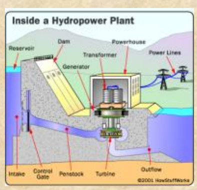
- Hydropower lecture is divided into 3 parts.
- Part 1 focuses on the basic concept of hydro energy i.e. definition of hydro power, history of hydro power, advantage and disadvantages of hydro power and modern usage of hydro power.
- Part 2 provides an overview on hydro power plant. This part discusses the layout, elements of a hydro power plant, mechanism and types of hydro power plant.

2

Introduction to the lecture

- This part also discusses the quantification electricity production of a hydro power plant.
- Part 3 focuses on the environmental and social impacts, life cycle assessment of environmental impacts and planning hydro power system by students.





3

Aim and Learning outcomes

- The aim is to introduce students to understand the hydro power system, generation of electricity and impacts of hydro power system.
- On completion of lecture “Hydropower Energy, students will be able to:
  - Describe the general historical development of hydropower.
  - Classify hydropower based on capacity, storage type, and head.

4

Aim and Learning outcomes

- On completion of lecture “Hydropower Energy, students will be able to:
  - Learn key components of a micro/small-scale hydropower system.
  - Understand the layout of a hydropower plant.
  - Describe working principles of a hydropower system.
  - Know the hydropower energy production, distribution and trends in the world.

5

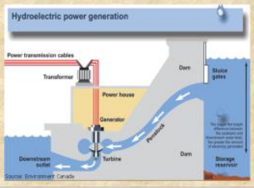
Talk outline

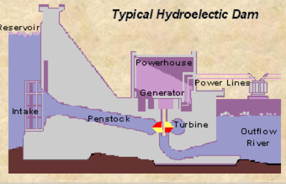
- **Part-I**
- **Introduction – Hydro Energy**
  - **Hydropower History**
  - **Advantage and disadvantage of hydropower**
  - **Modern usage of hydropower**

6

Talk outline

- **Part-II**
- **How does a hydro power plant work**
  - **Layout of hydropower plant**
  - **Elements of hydro power plant**
  - **Mechanism of hydropower plant**
  - **Types of plant**
  - **How much electricity can be produced**



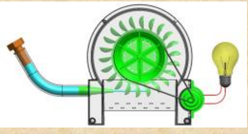


Talk outline

- **Part-III**
  - **Environmental and social impacts**
  - **Lifecycle assessment of environmental impacts**
  - **Planning your own Hydro System**

8

What is Hydropower



➢Hydroelectric power (often called hydropower) is considered a renewable energy source

A renewable energy source is one that is not depleted (used up) in the production of energy

Through hydropower, the energy in falling water is converted into electricity without "using up" the water.

Cont'd......

➢ Hydropower energy is ultimately derived from the sun, which drives the water cycle

In the water cycle, rivers are recharged in a continuous cycle

Because of the force of gravity, water flows from high points to low points

There is **kinetic energy** present in the flow of water.

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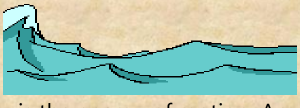

Kinetic energy is the energy of motion. Any moving object has kinetic energy.

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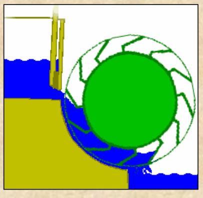

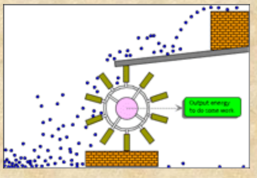

➢Humans first learned to control the kinetic energy in water by using waterwheels

A waterwheel is a revolving wheel fitted with blades

Waterwheels convert the kinetic energy of flowing water to mechanical energy.

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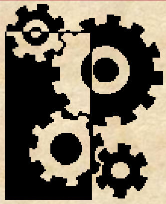
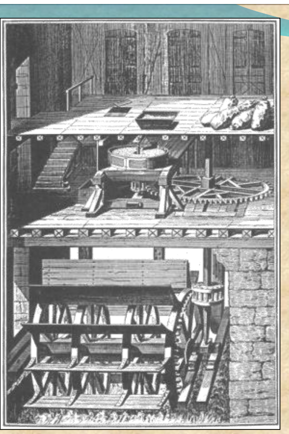


- Mechanical energy is a form of kinetic energy, such as in a machine.
- Mechanical energy has the ability to do work
- Any object that is able to do work has mechanical energy.



- Early waterwheels used mechanical energy to grind grains and to drive machinery such as sawmills

Cont'd……

- After the discovery of electricity
- It was realized that a turbine's mechanical energy could be used to activate a generator and produce electricity
- The first hydroelectric power plant was constructed in 1882 in Appleton, Wisconsin
- It produced 12.5 kilowatts of electricity which was used to light two paper mills and one home.

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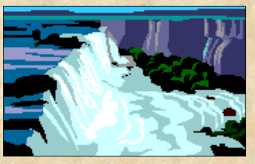
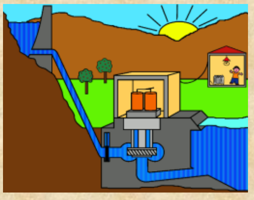
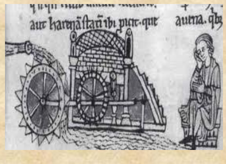




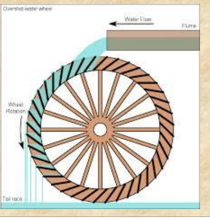
- Hydroelectric power systems convert the kinetic energy in flowing water into electric energy.

History of Hydropower



- Hydropower has been used for centuries
- The Greeks used water wheels to grind wheat into flour more than 2,000 years ago
- In the early 1800s, American and European factories used the water wheel to power machines

History of Hydropower



- The water wheel is a simple machine
- The water wheel is located below a source of flowing water
- It captures the water in buckets attached to the wheel and
- The weight of the water causes the wheel to turn
- That energy can then be used to grind grain, drive sawmills, or pump water.

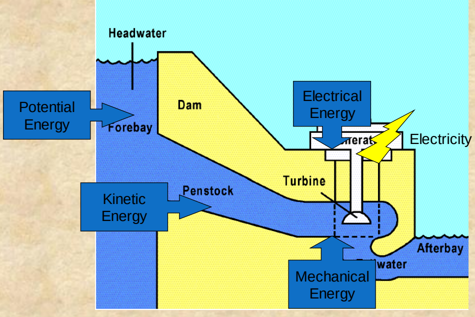
History of Hydropower

- In the late 19th century, the force of falling water was used to generate electricity
- The first hydroelectric power plant was built on the Fox River in Appleton, WI in 1882
- In the following decades, many more hydroelectric plants were built

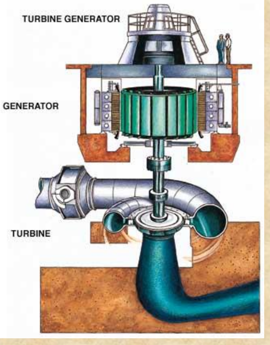
History of Hydropower

- By the late 1940s, the best sites for big dams had been developed
- At that time, plants burning coal or oil could make electricity more cheaply than hydro plants

Hydropower to Electric Power



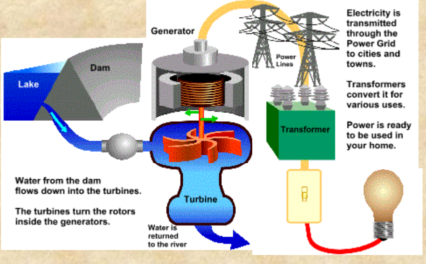
How a Hydroelectric Power System Works



- Flowing water is directed at a turbine (remember turbines are just advanced waterwheels).
- The flowing water causes the turbine to rotate,
- Converting the water's kinetic energy into mechanical energy.

How a Hydroelectric Power System Works

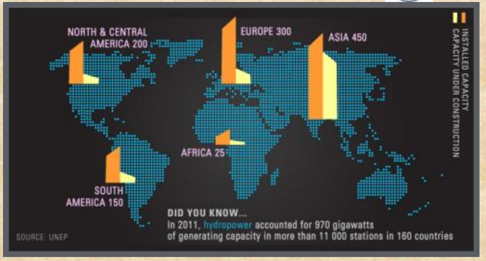
The mechanical energy produced by the turbine is converted into electric energy using a turbine generator. Inside the generator, the turbine spins a magnet inside coils of copper wire. It is a fact of nature that moving a magnet near a conductor causes an electric current.



Hydropower in Context

Global View

world distribution of hydropower



Hydropower is the most important and widely-used renewable source of energy.
Hydropower represents 19% of total electricity production.
China is the largest producer of hydroelectricity, followed by Canada, Brazil, and the United States (Source: Energy Information Administration).

World Trends in Hydropower

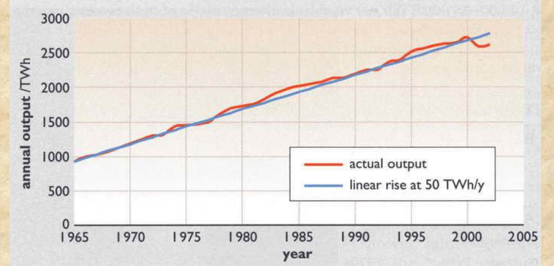


Figure 5.4 World annual hydroelectricity output, 1965–2002 (source: BP, 2003)

Boyle, *Renewable Energy*, 2nd edition, Oxford University Press, 2003

World hydro production

Producers	TWh	% of World total
Canada	338	12.4
Brazil	306	11.2
United States	306	11.2
People's Rep. of China	284	10.4
Russia	158	5.8
Norway	106	3.9
Japan	104	3.8
India	75	2.8
France	64	2.3
Venezuela	61	2.2
Rest of the World	924	34.0
World	**2 726**	**100.0**

2003 data

Installed Capacity (based on production)	GW
United States	94
Canada	69
Brazil	65
People's Rep. of China	58
Japan	46
Russia	44
Norway	28
India	27
France	25
Venezuela	13
Rest of the World	307
World	**776**

2002 data
Sources: United Nations, IEA.

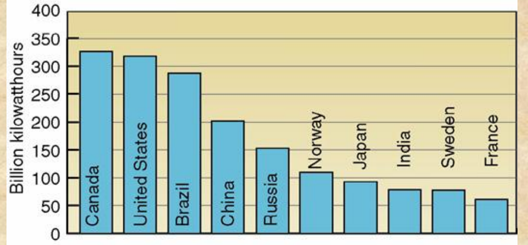
Country (based on first 10 producers)	% of hydro in total domestic electricity generation
Norway	98.9
Brazil	83.8
Venezuela	66.0
Canada	57.5
Russia	17.2
People's Rep. of China	14.9
India	11.9
France	11.4
Japan	9.9
United States	7.5
Rest of the World*	15.2
World	**16.3**

2003 data

** Excludes countries with no hydro production.*

IEA.org

Major Hydropower Producers



Source: EIA, Annual Energy Review 1999, July 2000, Table 11.15

Advantage to hydroelectric power

- **Advantages to hydroelectric power:**
- Fuel is not burned so there is minimal pollution
- Water to run the power plant is provided free by nature
- Hydropower plays a major role in reducing greenhouse gas emissions
- Relatively low operations and maintenance costs
- The technology is reliable and proven over time
- It is renewable - rainfall renews the water in the reservoir, so the fuel is almost always there

Disadvantage to hydroelectric power

Disadvantages to power plants that use coal, oil, and gas fuel:

- They use up valuable and limited natural resources
- They can produce a lot of pollution
- Companies have to dig up the Earth or drill wells to get the coal, oil, and gas

Hydroelectric power is not perfect, though, and does have some disadvantages:

Hydroelectric power is not perfect, though, and does have some disadvantages:

- High investment costs
- Hydrology dependent (precipitation)
- In some cases, loss or modification of fish habitat
- Fish entrainment or passage restriction
- In some cases, changes in reservoir and stream water quality
- In some cases, displacement of local populations

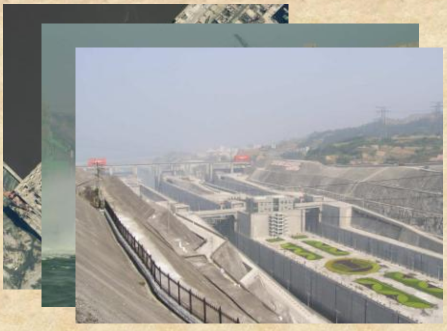
World's Largest Dams

Name	Country	Year	Max Generation	Annual Production
Three Gorges	China	2009	18,200 MW	
Itaipú	Brazil/Paraguay	1983	12,600 MW	93.4 TW-hrs
Guri	Venezuela	1986	10,200 MW	46 TW-hrs
Grand Coulee	United States	1942/80	6,809 MW	22.6 TW-hrs
Sayano Shushenskaya	Russia	1983	6,400 MW	
Robert-Bourassa	Canada	1981	5,616 MW	
Churchill Falls	Canada	1971	5,429 MW	35 TW-hrs
Iron Gates	Romania/Serbia	1970	2,280 MW	11.3 TW-hrs

Ranked by maximum power.

"Hydroelectricity," Wikipedia.org

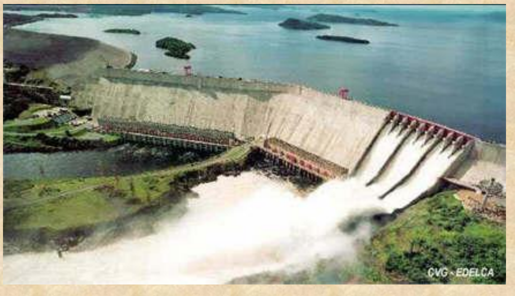
Three Gorges Dam (China)



Itaipú Dam (Brazil & Paraguay)

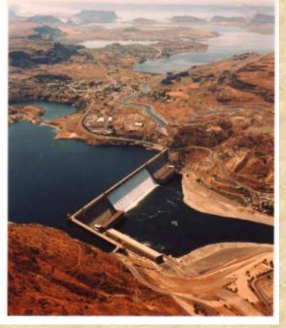
"Itaipu," Wikipedia.org

Guri Dam (Venezuela)



http://www.infodestinations.com/venezuela/espanol/puerto_ordaz/index.shtml

Grand Coulee Dam (US)



www.swehs.co.uk/docs/coulee.html

Talk outline

- **Part-I**
- **Introduction – Hydro Energy**
  - **Hydropower History**
  - **Advantage and disadvantage of hydropower**
  - **Modern usage of hydropower**

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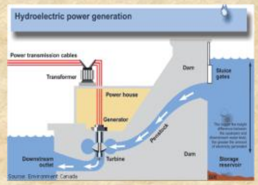
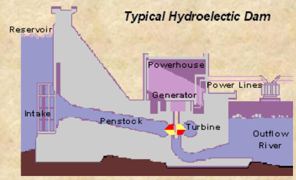
Talk outline

- **Part-II**
- **How does a hydro power plant work**
  - **Layout of hydropower plant**
  - **Elements of hydro power plant**
  - **Mechanism of hydropower plant**
  - **Types of plant**
  - **How much electricity can be produced**





Talk outline

- **Part-III**
  - **Environmental and social impacts**
  - **Lifecycle assessment of environmental impacts**
  - **Planning your own Hydro System**

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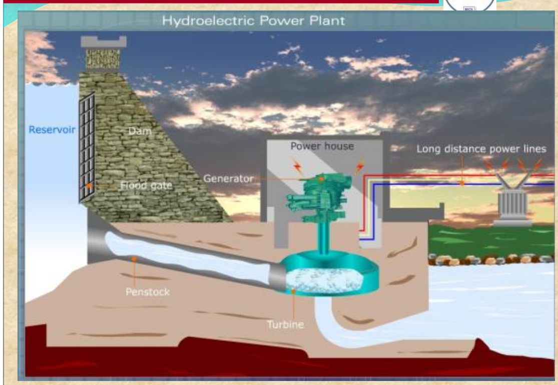
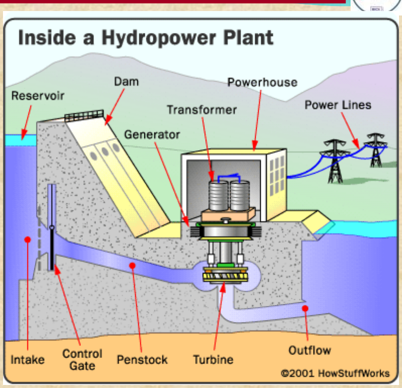
Layout of a hydropower plant



Layout of a hydropower plant



Layout of a hydropower plant

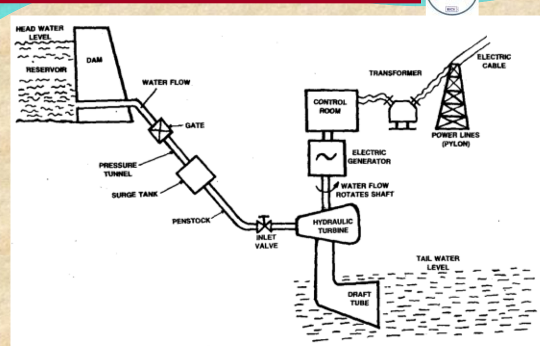
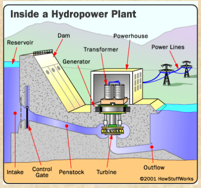
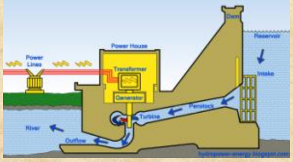


FIG. 3.6: LAYOUT OF HYDRO-ELECTRIC POWER PLANT

Components of a Hydro-Power Plant





The essential features of a hydro power plant are as below:

1. Catchment area.
2. Reservoir.
3. Dam.
4. water way.
5. Power house.
6. Tail water way or outlet.

Components of a Hydro-Power Plant

1.Catchment Area

- The catchment area of a hydro plant is the whole area behind the dam, draining a stream or river across which the dam has been built at a suitable place.

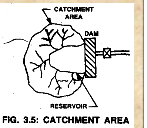
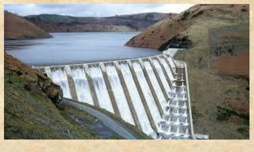


FIG. 3.5: CATCHMENT AREA

Components of a Hydro-Power Plant



2- Water reservoir:

- In a reservoir the water collected from the catchment area is stored behind a dam.
- Catchment area gets its water from rain and streams.
- The level of water surface in the reservoir is called Head water level.
- Note: Continuous availability of water is a basic necessity for a hydro-electric power plant.

Components of a Hydro-Power Plant

3- Dam :

- The purpose of the dam is to store the water and to regulate the out going flow of water.
- The dam helps to store all the incoming water. It also helps to increase the head of the water.
- In order to generate a required quantity of power it is necessary that a sufficient head is available.

Dam are classified based on following factors:

a) Function
b) Shape
c) Construction material
d) Design

e) Based on function the dam may be called as storage dam, diversion dam.

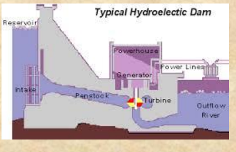
b) Based on the shape the dam may of trapezoidal section & arch type.

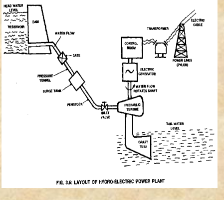
c) The materials used for constructing dams are earth, rock pieces, stone masonry.

d) According to structural design the dam maybe classified as:

i. Gravity dam
ii. Arch dam
iii. Buttress dam

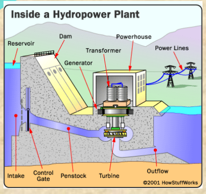
Components of a Hydro-Power Plant





4- Water Ways.

- Water ways are the passages, through which the water is conveyed to the turbines from the dam.
- These may include tunnels, forebay, penstocks and also surge tanks.
- A forebay is an enlarged passage for drawing the water from the reservoir or the river and giving it to the pipe lines or canals.



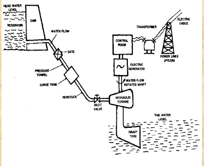


FIG. 3.6: LAYOUT OF HYDRO-ELECTRIC POWER PLANT

Spillway:

- Excess accumulation of water endangers the stability of dam construction.
- Also in order to avoid the over flow of water out of the dam especially during rainy seasons spillways are provided.
- This prevents the rise of water level in the dam.
- Spillways are passages which allows the excess water to flow to a storage area away from the dam.

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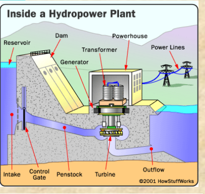

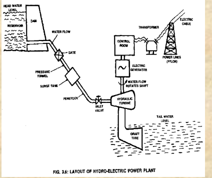

FIG. 3.6: LAYOUT OF HYDRO-ELECTRIC POWER PLANT

Gate:

- A gate is used to regulate or control the flow of water from the dam.
- Pressure tunnel: It is a passage that carries water from the reservoir to the surge tank.

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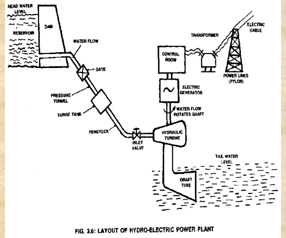

FIG. 3.6: LAYOUT OF HYDRO-ELECTRIC POWER PLANT

Surge tank:

- A Surge tank is a small reservoir or tank in which the water level rises or falls due to sudden changes in pressure.

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Purpose of surge tank:

- To serve as a supply tank to the turbine when the water in the pipe is accelerated during increased load conditions and
- As a storage tank when the water is decelerating during reduced load conditions.
- To reduce the distance between the free water surface in the dam and the turbine, thereby reducing the water-hammer effect on penstock and also protect the upstream tunnel from high pressure rise.

52

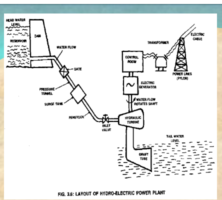
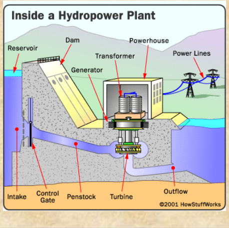


FIG. 3.6: LAYOUT OF HYDRO-ELECTRIC POWER PLANT



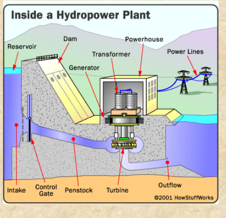
Penstock:

- Penstock is a closed pipe of steel or concrete for supplying water under pressure to the turbine

Inlet valve :

- Water from the penstock flows to the turbine through the inlet valve.
- The valve may be partially closed or open thereby regulating the pressure of water flowing to the turbine.

Hydraulic turbine(Prime mover) :

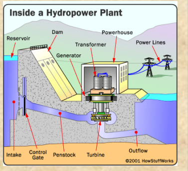


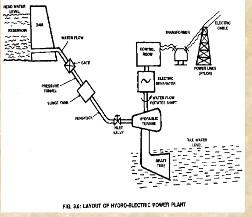
- The hydraulic turbine converts the energy of water into mechanical energy.
- The mechanical energy(rotation) available on the turbine shaft is coupled to the shaft of an electric generator and electricity is produced.
- The water after performing the work on turbine blades is discharged through the draft tube.
- The prime movers which are in common use are Pelton wheel, Francis turbine and Kaplan turbine.

5- Power House.

The power house is a building in which the turbines, alternators and the auxiliary plant are housed. Some important items of equipment provided in the power house are as follows:

i. Turbines
ii. Generators
iii. Governors
iv. Relief valve for penstock setting
v. Gate valve
vi. Transformer
vii. Switch board equipment and instruments
viii. Oil circuit breaker
ix. Storage batteries
x. Outgoing connections
xi. Cranes
xii. Shops & offices





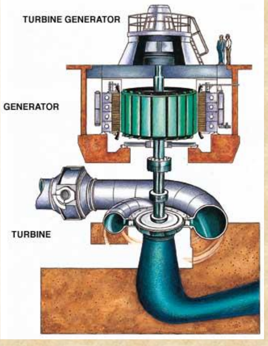
Draft tube:

- It is connected to the outlet of the turbine.
- It allows the turbine to be placed above the tail water level.

6- Tail water level or Tail race:

- Tail water level is the water level after the discharge from the turbine. The discharged water is sent to the river, thus the level of the river is the tail water level.

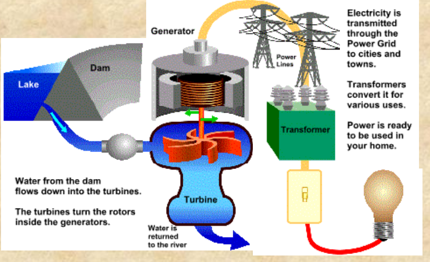
How a Hydroelectric Power System Works



- Flowing water is directed at a turbine (remember turbines are just advanced waterwheels).
- The flowing water causes the turbine to rotate,
- Converting the water's kinetic energy into mechanical energy.

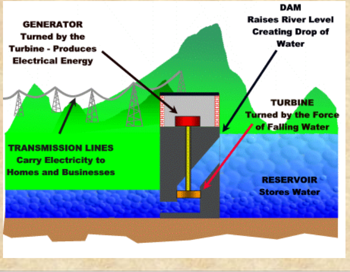
How a Hydroelectric Power System Works

The mechanical energy produced by the turbine is converted into electric energy using a turbine generator. Inside the generator, the turbine spins a magnet inside coils of copper wire. It is a fact of nature that moving a magnet near a conductor causes an electric current.



How a Hydroelectric Power System Works

The mechanical energy produced by the turbine is converted into electric energy using a turbine generator. Inside the generator, the turbine spins a magnet inside coils of copper wire. It is a fact of nature that moving a magnet near a conductor causes an electric current.



Classification of hydro-Electric power plant

The classification of hydro electric power plant depend on the following factors:

1) Quantity of water:

It is following types.

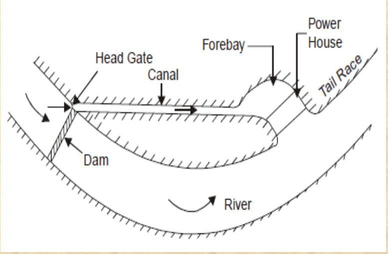
i. Run of river plant.
ii. Storage plant.
iii. Pumped storage.

2) Availability of Head of Water:

a) Low head plant. Operating head < 15m.
b) Medium head plant. Operating head 15 to 50m.
c) High head plants Operating head > 50m.

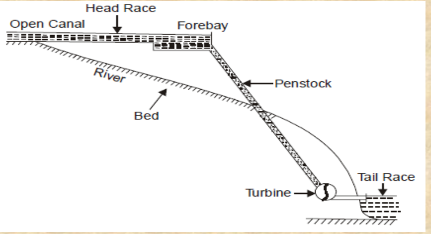
a) Low head plant

- Operating head is less than 15m.
- Vertical shaft Francis turbine or Kaplan turbine.
- Small dam is required.



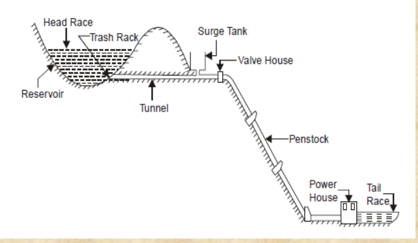
a) Medium head plant

- Operating head is less than 15 to 50m.
- Francis turbines.



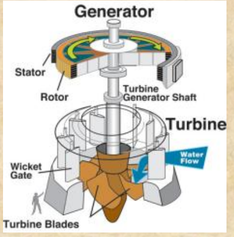
a) High head plant

- Operating head exceed 50m.
- Pelton turbines.
- surge tank is attached to the penstock to reduce water hammer effect on the penstock.

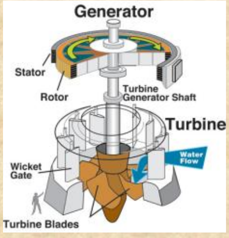


Hydraulic Turbines

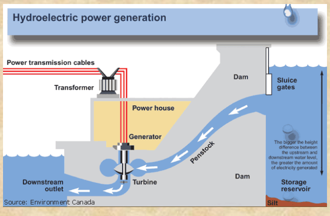
- Turbines are used to convert the energy water of falling water into mechanical energy.
- Water turbine is a rotary engine that takes energy from moving water.
- Flowing water is directed on to the blades, creating a force on the blades



Hydraulic Turbines



- **Types of turbines:**
- **Impulse**
- **Reaction**



Power generation

The amount of electricity that can be generated by a hydropower plant depends on two factors:

- **flow rate** - the quantity of water flowing in a given time; and
- **head** - the height from which the water falls.

The greater the flow and head, the more electricity produced.

Flow Rate = the quantity of water flowing
Head = the height from which water falls

A standard equation for calculating energy production:

$$\text{Power} = \frac{(\text{Head}) \times (\text{Flow}) \times (\text{Efficiency})}{11.8}$$

Power = the electric power in kilowatts or kW

Head = the distance the water falls (measured in feet)

Flow = the amount of water flowing (measured in cubic feet per second or **cfs**)

Efficiency = How well the turbine and generator convert the power of falling water into electric power. This can range from 60% (0.60) for older, poorly maintained hydroplants to 90% (0.90) for newer, well maintained plants.

11.8 = Index that converts units of feet and seconds into kilowatts

As an example, let's see how much power can be generated by the power plant.

The dam is 357 feet high, the **head** (distance the water falls) is 235 feet. The typical **flow rate** is 2200 cfs. Let's say the turbine and generator are 80% efficient.

$$\text{Power} = \frac{(\text{Head}) \times (\text{Flow}) \times (\text{Efficiency})}{11.8}$$

$$\text{Power} = \frac{235\text{ft.} \times 2200 \text{ cfs} \times .80}{11.8}$$

$$\text{Power} = \frac{517{,}000 \times .80}{11.8}$$

$$\text{Power} = \frac{413{,}600}{11.8}$$

Power = 35,051 kilowatts (kW)

Planning your own hydro system

- How to measure head and flow

A standard equation for calculating energy production:

$$\text{Power} = \frac{(\text{Head}) \times (\text{Flow}) \times (\text{Efficiency})}{11.8}$$

Power = the electric power in kilowatts or kW

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11.8 = Index that converts units of feet and seconds into kilowatts

Planning your own hydro system

Measuring head:
Head can be measured as vertical distance (feet or meters)
Or as pressure (pounds per square inch)

1 vertical feet = 0.433 psi
1 psi = 2.31 vertical feet

Direct distance measurement:

10 Appendix A – Lecture slides

10.6 Appendix A.1 – Lecture 13, 14, 15 & 16 Slides

Nuclear Energy

1

Introduction to the lecture

➢ Nuclear energy lecture provides an overview of fundamentals of nuclear energy, nuclear history, nuclear reactor, nuclear power plant, fuel cycle, radioactivity, nuclear waste, nuclear recycling, and journey of uranium from mine to reactor (i.e. mining, milling, conversion and enrichment.

➢ This lecture discusses the mechanism of a reactor, components of a reactor, and types of reactor. It also provides knowledge on the electricity generation from a reactor.

2

Introduction to the lecture

➢This lecture focuses on the nuclear waste, waste composition, recycling, nuclear accident (Three Mile Island, Chernobyl and Fukushima), disadvantage and advantages of nuclear energy.

3

Aim and Learning outcomes

➢ This lecture aims to provide core knowledge of nuclear power plant and to develop a critical awareness of the nuclear basics, reactor basics, reactor operation and design, waste disposal, and key issues relating to health and safety.

➢ On completion of lecture Nuclear Energy, students will be able to:

➢Know the fundamentals and history of nuclear energy.

4

Aim and Learning outcomes

➢ On completion of lecture Nuclear Energy, students will be able to:

➢ Identify and discuss the purpose of key components of nuclear power plant for a variety of different configurations.

➢ Identify and discuss the purpose of key components of nuclear power plant for a variety of different configurations.

➢ Have a critical understanding of nuclear plant health, safety and environmental issues

5

Hiroshima - Before – During

6

Hiroshima - After - Bombing

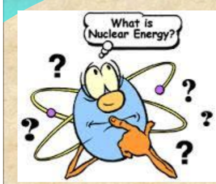


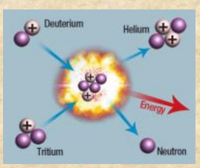

Talk outline

- Introduction – Nuclear Energy
- Nuclear History
- Nuclear Reactor
- Nuclear Power Plant
- Fuel Cycle
- Radioactivity
- Nuclear waste
- Nuclear recycling
- Fast and Thermal Reactor
- Nuclear Accident
- Environmental Safety

8

Overview of Nuclear Power – What is Nuclear





- Nuclear energy is natural resources that turn into heat and electricity
- We can extract more heat and electricity from a given amount of it than from an equivalent amount of anything else
- A chunk of coal and chunk of natural uranium, both weighing the same (1 kg)
- If we could suck all the energy out of the coal, it would run a 100W light-bulb for about 4 days

9

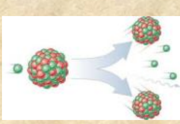
Overview of Nuclear Power – What is Nuclear


- Uranium-run the bulb for about 180 years
- Sucked all the energy from uranium, the light bulb could burn for 24,000 years
- Nuclear reactors produce energy without releasing any pollutants into the environment.

10

Overview of Nuclear Power – What is Nuclear

So why do we still use coal or anything else ?????

- The reactors to split atoms and release the energy are mostly large, complicated, and expensive
- However, Once built, reactor operation costs very little
- Buying a few tonnes of uranium every 4 years is much cheaper than buying weekly trainloads of coal
- The high cost of constructing nuclear reactors has caused much financial trouble for nuclear energy

11

Overview of Nuclear Power – What is Nuclear

So why do we still use coal or anything else ?????


- Several facilities involved in the nuclear fuel cycle can be used to produce materials that could be used in nuclear weapons
- Enrichment plants can theoretically produce weapons-grade material along with reactor-grade
- Recycling plants separate plutonium from nuclear waste, which can be stolen and used in bombs
- This fact complicates progress in advanced nuclear technology, politically

12

Overview of Nuclear Power – What is Nuclear

So why do we still use coal or anything else ?????

- The relatively small amount of nuclear fuel that goes into reactors becomes very nasty radioactive **nuclear waste** when it comes out.
- The nature of **radioactive** waste is terrifying to all -- you can't see it, smell it, or taste it, but it can be in the room **hurting you**
- Nuclear scientists **know ways** to turn this waste into something that decays to harmlessness
- But the processes developed so far are expensive and challenging.

13

Overview of Nuclear Power – What is Nuclear

So why do we still use coal or anything else ?????

- Nuclear power is perceived as dangerous because of the accidents at Fukushima, Chernobyl, and Three Mile Island
- These high-profile accidents compared to those associated with coal and gas
- However, where coal and gas usually only kill or injure coal miners and gas refinery workers,
- Nuclear accidents are indiscriminate

14

Overview of Nuclear Power – What is Nuclear

So what do you think ?????

→

→

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Promise and Problems of Nuclear Energy

Dhiman Roy PhD

Date: November 3, 2013

16

Talk outline

- **Introduction – Nuclear Energy**
- **Nuclear History**
- **Fuel Cycle**
- **Nuclear Reactor**
- **Nuclear Power Plant**
- **Radioactivity**
- **Nuclear waste**
- **Nuclear recycling**
- **Fast and Thermal Reactor**
- **Nuclear Accident**
- **Environmental Safety**

17

What is Nuclear Energy?

- Nuclear energy comes from mass to energy conversion
- Splitting heavier atom
- Joining smaller atoms
- Follows Einstein's formula $E=MC^2$; M= mass, C= speed of light

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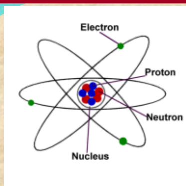
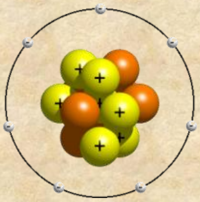
What is Nuclear Energy - Atom

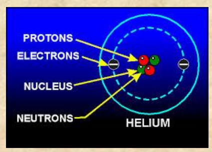




- An atom is the basic unit of an element.
- An atom is a form of matter which may not be further broken down using any chemical means.
- A typical atom consists of protons, neutrons and electrons.
- Hydrogen, helium, oxygen and uranium are examples of atoms.

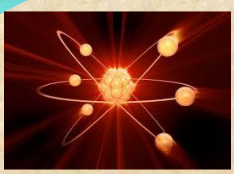
What is Nuclear Energy – Atom Characteristics

- Each proton has a positive electrical charge and electron—negative electrical charge
- Each neutron is electrically neutral



- The nucleus of an atom contains protons and neutrons.
- The nucleus carries a positive electrical charge.

What is Nuclear Energy?

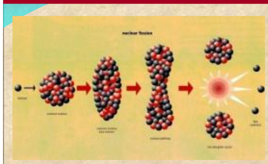


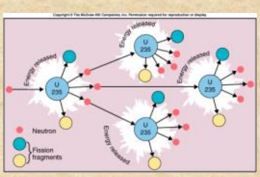
- 1930s and '40s, recognized as a potential energy as a weapon.
- Technology developed used this energy in a chain reaction
- To create bombs
- We will discuss this history……

What is Nuclear Energy - Today

- Nuclear reactor produce 20% and 76% electricity in the USA and France respectively
- They produce electricity without emitting any pollutants into atmosphere
- However, they create radioactive nuclear waste

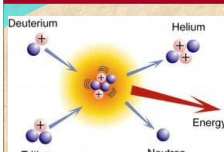
Nuclear Energy- Fission and Fusion

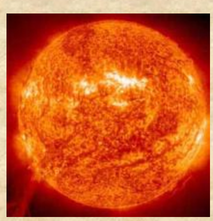




- Fission is the splitting of a large atom such as Uranium or Plutonium
- Into two smaller atoms, called fission products
- During fission---release---Neutrons +Energy
- That enable chain reaction
- All commercial nuclear plants use fission reaction to generate electricity

Nuclear Energy- Fission and Fusion





- Fusion is the combining of two small atoms such as Hydrogen or Helium
- To produce heavier atoms and energy
- These energy can release more energy than fission
- Without producing radioactive by products
- This type of reaction occur in sun
- Using hydrogen as a fuel and producing helium as a waste

Energy Density of Various Fossil Sources

How long a 100 Watt light bulb could run from using 1 kg of various materials

Material	Energy Density (MJ/kg)	100W light bulb time (1kg)
Wood	10	1.2 days
Ethanol	26.8	3.1 days
Coal	32.5	3.8 days
Crude oil	41.9	4.8 days
Diesel	45.8	5.3 days
Natural Uranium	$5.7x10^5$	182 *years*
Reactor Grade Uranium	$3.7x10^6$	1171 *years*

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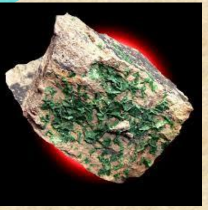

- Natural Uranium has undergone no enrichment – 0.7% U-235 and 99.03% U-238
- After processing reactor grade uranium has 5% U-235
- However, 1 kg weapons grade uranium has 95% U-235
- Need to know mining, processing and milling of uranium

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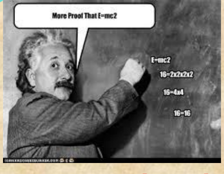
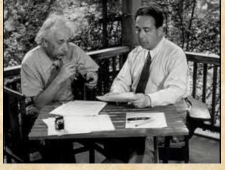
History of Nuclear energy





- **What about Nuclear History**

27

History of Nuclear Energy

- No scientific work started aiming nuclear energy product
- Actually, Roentgen discovered the X-ray (1895)
- Foundation of medical technology
- In France one scientist noticed - ray emitted spontaneously from Uranium salt
- Maries curie and her husband identify radioactivity from element-polonium and Radium

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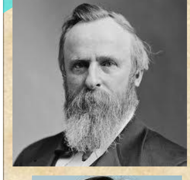
History of Nuclear Energy



- Then Rutherford discovered two types rays; alpha and beta
- Hahn and Strassman shoot neutrons at uranium atoms and saw some strange behaviors
- Meitner and her nephew identify fission; releasing energy
- Szilard recognized that fission as a potential way to get energy through chain reaction

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History of Nuclear Energy

- Szilard and others wrote a letter to USA president Roosevelt, warning of nuclear energy (with Einstein sign)
- Roosevelt authorized a small study into uranium
- Fermi (1942) successfully created first man made uranium chain reaction
- Manhattan project on nuclear energy started

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History of Nuclear Energy

- Finally, they got nuclear energy in the form of two bombs
- One by Uranium and another by plutonium
- Then you saw the first use of that nuclear power in the form of bombing at Hiroshima and Nagasaki (world war-II)
- Atomic bomb- Little Boy and Fat Man
- Public realized that the US developed bombs

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Fission energy- Application

- An experimental liquid-metal cooled reactor in Idaho called EBR-I was attached to a generator in 1951, producing the first nuclear-generated electricity
- Admiral Rickover pushed to use reactors to power submarines, since they wouldn't need to refuel, or to use oxygen for combustion

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Fission energy- Expansion

- Through the 60s and 70s, lots of nuclear reactors are built for making electricity
- They work well and produce cheap, emission-free electricity with a very low mining and transportation
- In 1974, France decided to make a major push for nuclear energy, and ended up with 75% of their electricity coming from nuclear reactors

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Fission energy- Expansion

- The 1979 Three Mile Island accident and the 1986 Chernobyl accident further slowed the development of nuclear reactors
- Tighter regulations brought costs higher

34

Why/what need to know????

- But the things how you will get uranium?
- From where you will get these uranium?
- Is it possible to use uranium just after mining?
- If not or the answer is not known then we need to go for some fundamentals talk like--- mining ---- milling----- conversion----- enrichment.

35

Why need to know????

- So, let's go to see the mining and processing of uranium
- Then we will go– how to use this uranium to get huge energy to upgrade your life style.....

36

A Journey of Uranium from Mine to Reactor

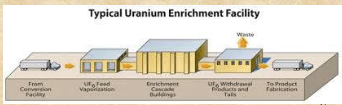
- Life cycle of Uranium involves

Mining

Milling

Conversion and

Enrichment



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A Journey – Need Separation Process

- Uranium is mined can not be fed directly into nuclear power station
- Uranium contain chemical impurities U-235 – 0.7%; U-238 isotopes 99.3%
- Therefore, a number of chemical and physical separation processes are required to convert uranium ore to optimized nuclear fuel

Mining ----- Milling ----- Conversion ------ Enrichment

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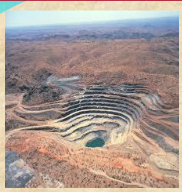
A Journey – Need Separation Process



- Uranium ore exploration: Activities related to finding and development of the uranium ores for uranium production
- Uranium ore mining: activities related to the extracting uranium ore from ground
- Uranium ore processing: activities related to the milling and refining of the ore to produce uranium concentrates including in-situ leaching

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A Journey – Need Separation Process

- Conversion: activities related to the refining and conversion
- Enrichment: related to the isotopic enrichment of UF6 to obtain enriched U-235
- Uranium fuel fabrication: related to the production of nuclear fuel to be inserted in the nuclear reactor

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A Journey – Uranium Abundance, Occurrence

- Abundance: average concentration of U in the crust is 2-4 ppm
- U is more abundant (4 times) than antimony, cadmium, silver
- Occurrence: occurs in hundreds of minerals– Uranite, autinite, monazite sands and associated as Rare Earth Elements (REEs)
- Deposits: vein in granite rocks; sandstone deposits, porphyry deposit

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A Journey – Uranium

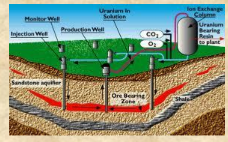
- Oil, coal, natural gas, and uranium are energy resources, for electricity generation
- The fuel for a nuclear power plant is uranium, which is relatively abundant in the Earth's crust
- Uranium is 500 times more common than gold and about as common as tin.

42

A Journey – Uranium

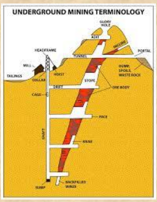
- Natural uranium consists of the isotopes U-238 (approx. 99.3%) and U-235 (approx. 0.7%), and traces of U-234
- Natural uranium is not dangerous from a purely radiation point of view,
- But it is a chemically toxic, heavy metal that is hazardous if allowed to enter the body.

A Journey – Uranium-Mining (extraction)

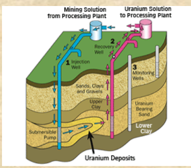


- Uranium is extracted from the Earth's crust in different ways, Open Pit Mining, Under-ground Mining and In-Situ Leaching.
- The choice depends on relative costs and factors such as size, shape, depth, and concentration of the ore deposits
- Several substances are often extracted from the same mine in order to achieve a profitable operation.

A Journey – Uranium-Mining - Methods



- There are three basic methods of obtaining uranium from ores:
  - Open pit mining
  - Underground mining
  - In-situ Leaching



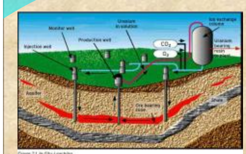
A Journey – Uranium - Open pit mining

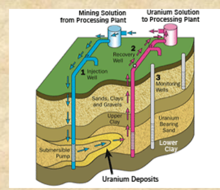
- Open-pit mining, open-cut mining or opencast mining is a surface mining technique of extracting rock or minerals from the earth by their removal from an open pit or borrow
- The ore is hauled to a mill for milling

A Journey – Uranium – Underground mining

- Underground mining (soft rock) refers to a group of underground mining techniques used to extract coal, oil shale and other minerals or geological materials from sedimentary rocks
- The ore is hauled to a mill for milling

A Journey – Uranium – In-situ Leaching





- A large number of vertical bore holes to introduce a leaching solution and to extract it from shallow deposit between impermeable layers (??-migration)
- 36% world production
- Dissolution of uranium
- Injection wells pump a weak solvent across ore deposit
- Remove loaded solvent
- Uranium removed by solvent extraction

A Journey – Uranium-Milling

- Delivery of ore to processing plant by trucks or conveyors
- Primary and secondary crushing to provide a fine powder
- Leaching of U from solid by acid to separate U from many insoluble impurities
- Filtration and clarification of U solid and other elements; send to a trailing pond

A Journey – Uranium-Milling

- Treated with ammonia to yield a uranium dioxide powder with U content approximately 70%
- Known as "yellow cake"
- Packing in 200 liter steel drums for delivery to customer

A Journey – Uranium- Conversion

- The uranium concentrate, must be further refined before it can be used as fuel for nu- clear reactors
- Nitric acid is added, yielding a uranyl nitrate solution
- Solids are extracted from the uranyl nitrate solution in three steps

A Journey – Uranium- Conversion

- Water is vaporized, yielding a concentrated uranyl nitrate hexahydrate solution
- Concentrated uranyl nitrate hexahydrate is heated to yield uranium trioxide (UO_3)

A Journey – Uranium- Conversion

- Hydrofluoric acid is added to uranium trioxide (UO_3) to yield uranium tetrafluoride (UF_4)
- Then UF_4 reacts with fluorine gas to yield hexa fluoride gas (UF_6)
- The UF_6 gas is passed through several filters and finally through cold traps, and collected as crystalline UF_6
- The UF_6 is liquefied by heating and drained into specially designed steel cylinders for shipment

A Journey – Uranium- Enrichment

- Most nuclear reactors require fuel with a U-235 content of 3–5%
- At 65°C and warmer UF_6 is a gas and can be enriched either by gaseous diffusion or by gas centrifugation
- Both processes enrich UF_6 from 0.7% U-235 to the required level (the rest of the uranium is U-238)

A Journey – Uranium- Fabrication

- The uranium arrives as enriched, solid UF_6 at the fuel fabrication facility
- It is heated into gaseous state.
- Ammonia, gaseous oxygen, and gaseous hydrogen are added to yield uranium dioxide powder
- The UO_2 powder is compressed into cylindrical pellets weighing 6–7 grams.

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A Journey – Uranium- Fabrication

- The pellets are entered to a structure resembling ceramics
- 300–370 of them are placed in zirconium alloy (zircaloy) tubes
- Zircaloy is an alloy of zirconium (98%), tin (1,5%), and small amounts of iron, nickel, and chromium.

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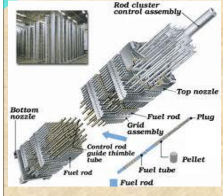
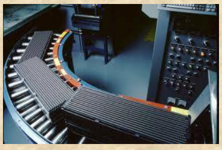
A Journey – Uranium- Fabrication





- The tubes are pressurized with helium and sealed to form fuel rods
- Then bundled into fuel assemblies
- A boiling water reactor (BWR) holds between 400 and 700 fuel assemblies comprising a maximum of 70 000 fuel rods
- A pressurized water reactor (PWR) holds some 160 fuel assemblies with a maximum of 42 000 fuel rods.

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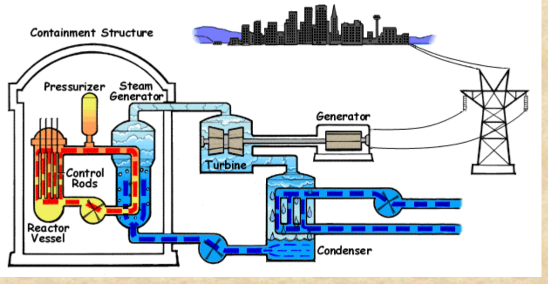
Mechanism of a Reactor



58

What is a Nuclear Reactor

- A nuclear reactor is a system that contains and controls sustained nuclear chain reactions
- Reactors are used for generating electricity, moving aircraft carriers and submarines etc
- Fuel-- made up of heavy atoms that split when they absorb neutrons, is placed into the reactor vessel (basically a large tank) along with a small neutron source.

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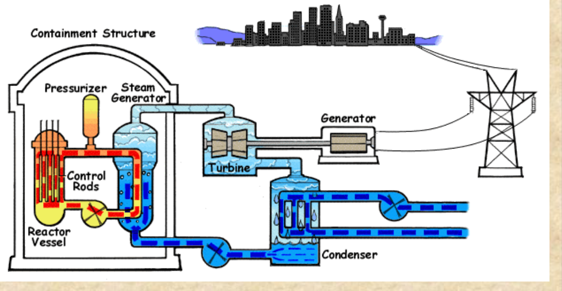
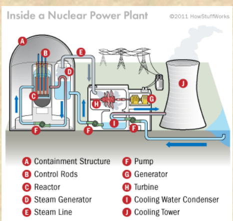
Nuclear Reactor: Components



- Core, Coolant, Turbine, Containment, Cooling Tower

60

Nuclear Reactor: Components



- **Core:** of the reactor contains all of the nuclear fuel and generates all of the heat
- **Coolant:** is the material that passes through the core, transferring the heat from the fuel to a turbine. It could be water, heavy-water, liquid sodium, helium, or something else
- **Turbine:** transfers the heat from the coolant to electricity, just like in a fossil-fuel plant.

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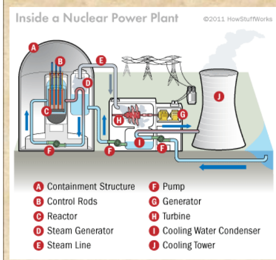
Nuclear Reactor: Components



- **Containment:** is the structure that separates the reactor from the environment
- These are usually dome-shaped, made of high-density, steel-reinforced concrete
- **Cooling Tower:** are needed by some plants to dump the excess heat that cannot be converted to energy

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Nuclear Reactor: Types

- There are very many different types of nuclear reactors with different fuels, coolants, fuel cycles, purposes--

- Pressurized water reactor
- Boiling water reactor
- Sodium cooled fast reactor
- Liquid Fluoride thorium reactor
- Canada Deutorium-Uranium reactor
- High temperature gas cooled reactor

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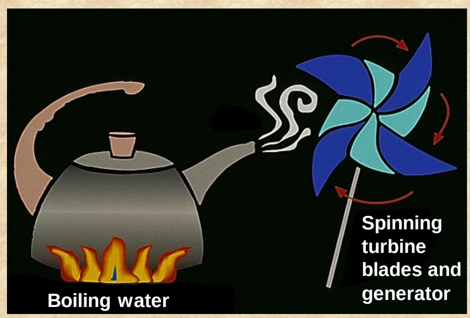
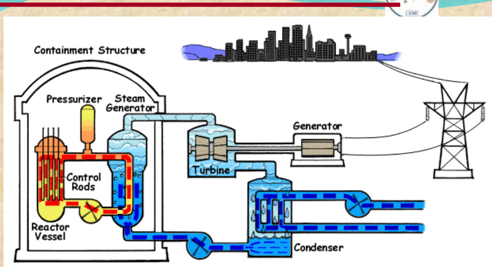
Idea of a Nuclear Power Plant



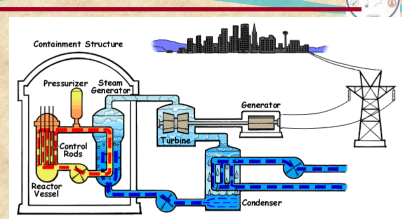
Mechanism of Reactor – Electricity Generation



- In a nuclear reactor neutrons are used to split uranium nuclei
- The energy is transformed to heat,
- Which in turn is used to heat the water in the reactor.

65

Mechanism of Reactor – Electricity Generation



- The steam drives a turbine connected to a generator
- Which converts the energy to electricity
- After passing through the turbine the steam is condensed to water in a condenser
- Through heat exchange with a cooling agent (seawater), and after filtering the water is re-circulated into the reactor.

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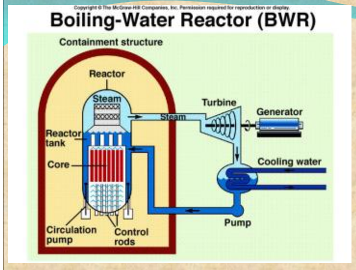
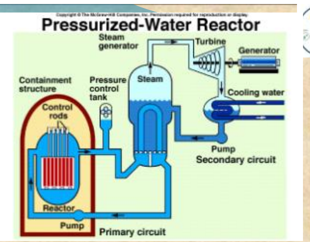


- The heat generated by the fission of or uranium releases energy that heats water to produce steam to turn turbines to generate electricity.

- In addition to fuel rods containing uranium, reactors contain control rods of cadmium, boron, graphite, or some other non-fissionable material used to control the rate fission by absorbing neutrons.

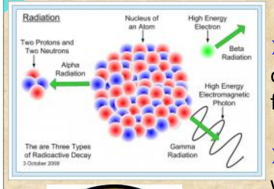


- In the PWR (70% of reactors in the world) the water is kept under high pressure so that steam is not formed in the reactor

- Such an arrangement reduces the risk of radiation in the steam but adds to the cost of construction by requiring a secondary loop for the steam generator.

Nuclear Waste

Nuclear Waste - Radioactivity



- Radioactivity is the emission of energetic particles or waves from atoms

- Natural radiation occurs when unstable nuclei transform to some other nucleus by emitting radiation

- Alpha, Beta and Gamma radiation

Nuclear Waste

- Nuclear waste is the material that nuclear fuel becomes after it is used in a reactor

- It looks exactly like the fuel that was loaded into the reactor

- But since nuclear reactions have occurred, the contents aren't quite the same

- Before producing power, the fuel was mostly Uranium (or Thorium),

Cont'd

- Afterwards, many Uranium atoms have split into various isotopes

- The waste, sometimes called spent fuel, is dangerous radioactive, and remains so for thousands of years

- When it first comes out of the reactor, it is so toxic

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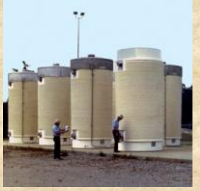


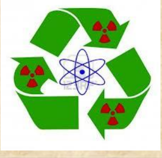
- After about 3-4 years of use, the Fuel rods become spent-level of fission drops beneath a certain level
- Rods are taken out of reactor stored nearby in water filled pools
- Stored until they cool down enough to be shipped for permanent storage or to be recycled
- These storage facilities are next to the reactor plants, vulnerable to terrorist attack or accidents

Nuclear Waste - Composition

	Charge	Discharge
Uranium	100%	93.4%
Enrichment	4.20%	0.71%
Plutonium	0.00%	1.27%
Minor Actinides	0.00%	0.14%
Fission products	0.00%	5.15%

Heavy metal composition of 4.2% enriched nuclear fuel before and after running for about 3 years. Minor actinides include neptunium, americium, and curium.

Nuclear Waste - Recycling



- Nuclear waste is recyclable
- Once Uranium fuel is used in a reactor, it can be treated and put into another reactor as fuel
- In fact, typical reactors only extract a few percent of the energy in their fuel

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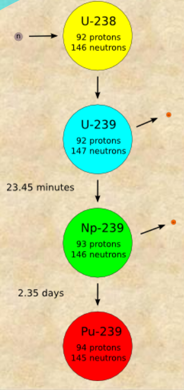

- The "useless" U-238 is the secret to recycling nuclear fuel
- When it absorbs a single neutron, it goes through a series of nuclear reactions and turns into isotope of Plutonium, Pu-239
- Then it is possible to use that Pu-239 to continue powering reactor
- When a nucleus has more neutrons than it would like to have, it often beta-decays by breaking a neutron into a proton and an electron.

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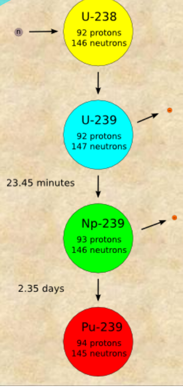

- When U-238 absorbs a neutron in a nuclear reactor, it becomes U-239
- Which is just the isotope of Uranium with one extra neutron than U-238
- This beta-decays quickly and becomes Np-239
- Then, the Np-239 beta-decays again to become Pu-239
- Which is a fissile isotope that can power nuclear reactors.

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Nuclear Accident

- Let's investigate why the nuclear power industry has not grown, despite it's obvious promise. We should begin with the dangers of nuclear power.
- **Myth**: The risk of explosion is the greatest problem with nuclear plants
  - **Fact**: Nuclear plants can't blow up like nuclear bombs because of the distribution of material and insufficient enrichment of uranium-235
  - Human error is the biggest threat (i.e. **Chernobyl** and **Three Mile Island**)
    - In the two examples above, a loss of cooling water lead to overheating, which caused the core to melt.
      - Meltdown can result in the release of radioactive material

Nuclear Accident

- Three major accidents
  - Three mile island accident (1979)
  - Chernobyl accident (1986)
  - Fukushima accident (2011)

Nuclear Accident - Three mile island accident

- The first ever incident of reactor meltdown in nuclear power history in the USA on 28 March 1979
- The accident began with a malfunction in the secondary cooling circuit
- Due to misleading instrumentation, the operator made an incorrect response which finally led to a loss of reactor cooling and a partial meltdown of the fuel in the reactor
- Residents nearby took initiatives and evacuated themselves temporarily after the incident
- There was no reported case of injury or death

Nuclear Accident - Chernobyl

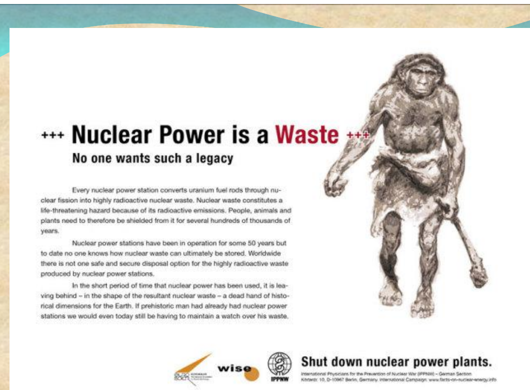
- Explosions occurred at Chernobyl Nuclear Power Plant in the former Union of Soviet Socialist Republics (USSR) on 26 April 1986.
- The large amount of radioactivity subsequently released affected areas as far as several hundred kilometers away from the plant
- These resulted in a steam explosion within the reactor
- Within a few weeks, the accident had caused the deaths of 30 workers and radiation injuries to over a hundred others
- Some 335,000 people were evacuated. At present, apart from approximately 7,000 cases of thyroid cancer recorded

Nuclear Accident - Fukushima

- On 11 March 2011, a Richter Scale 9 earthquake triggered a massive (15m) tsunami east of Sendai in Japan
- Which disabled electric power in five out of six generating units at Fukushima Daiichi Nuclear Power Plant in Japan
- Although Units 1 to 3 of the plant have automatically shut down at the earthquake
- The loss of electric power for reactor cooling eventually led to the meltdown of the nuclear reactors
- Around 100,000 people up to 40km were evacuated..

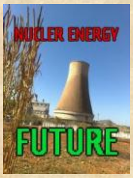
Disadvantage of Nuclear Power

- Possibly catastrophic accidents
- Nuclear waste dangerous for thousands of years
- Risk of nuclear proliferation associated with some designs
- High capital costs
- Long construction periods
- High maintenance costs
- High cost of decommissioning plants
- Designs of current plants are all large-scale



http://perth.indymedia.org/storyuploads/13114/en_4b.jpg

Advantage of Nuclear Power



- Huge energy producing capability
- No greenhouse gas emissions during operation
- Does not produce air pollutants
- The quantity of waste produced is small
- Small number of major accidents
- Low fuel costs; Large fuel reserves
- Future designs may be small and modular

Group Discussion

Topic:

Nuclear power is a safe source of energy

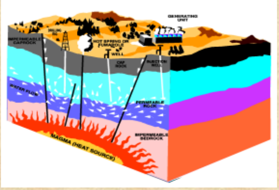
Video on Nuclear Reactor

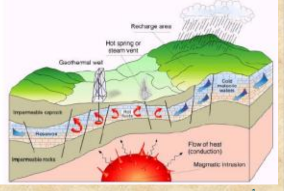
How it is working

10 Appendix A – Lecture slides

10.7 Appendix A.1 – Lecture 17, & 18 Slides

Geothermal Energy





1

Introduction to the lecture

- ➢ Lecture of Geothermal energy has 3 parts.
- ➢ Part 1 focuses on the fundamental concept of geothermal energy, history of geothermal energy, present global status of geothermal utilization, advantages, origin, nature of geothermal energy and global geothermal sites.
- ➢ Part 2 provides an overview of mechanism for geothermal power plant.
- ➢ Part 3 discusses on the utilization of geothermal resources and its environmental impacts.

2

Aim and Learning outcomes

- ➢ The aim is to introduce students to the concept, utilization, mechanism and environmental impacts of geothermal energy.
- ➢ On completion of lecture "Geothermal energy" students will be able to:
  - ➢ Identify the fundamental concept, physical characteristics and processes in geothermal systems.
  - ➢ Differentiate between types of geothermal resources and their location.

3

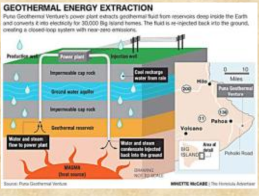
Aim and Learning outcomes

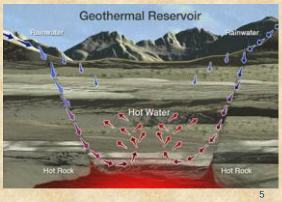
- ➢ On completion of lecture "Geothermal energy" students will be able to:
  - ➢ Know the mechanism of geothermal power plant and its types.
  - ➢ Distinguish between the different types of geothermal technologies and appropriate uses o f them.
  - ➢ Identify environmental impacts and benefits of geothermal energy exploitation.

4

Talk outline

- **Part-I**
- **Introduction – Geothermal Energy**
  - **Geothermal History**
  - **Present status of geothermal utilization**
  - **Origin and nature of Geothermal Energy**

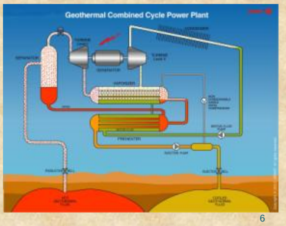




5

Talk outline

- **Part-II**
- **How does a Geothermal power plant work?**
  - **Geothermal power plant**



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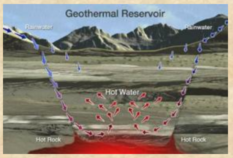
Talk outline

- **Part-III**
  - **Utilization of geothermal resources**
  - **Environmental impacts**

7

What is Geothermal Energy



- Heat is a form of energy and geothermal energy is literally the heat contained within the Earth
- Geothermal energy in modern technologies is derived from natural heat
- In effect, the earth serves as a boiler in which geothermal fluids can achieve the high temperatures and pressures
- Typically, these fluids occur in reservoirs at depths of up to 3000 meters and can be recovered by drilling wells

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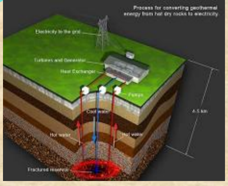
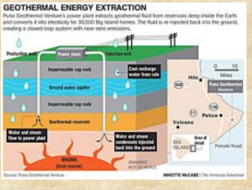
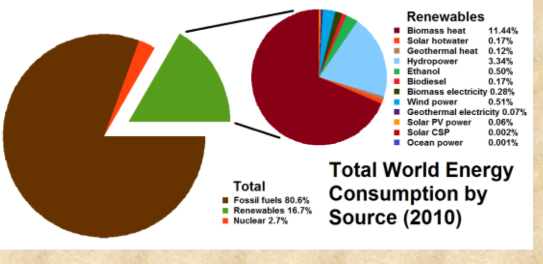




- The amount of thermal energy is very large but useful energy is very limited to certain sites
- These resources are not infinite and can be depleted at a particular site under intensive exploration
- However, geothermal energy can be developed in a favorable locations

Global Overview of Geothermal Energy



Geothermal in Context - USA

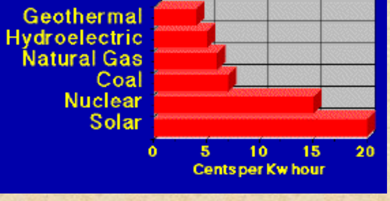
Energy Source	2000	2001	2002	2003	2004[p]
Total [a]	**98.961**	**96.464**	**97.952**	**98.714**	**100.278**
Fossil Fuels	**84.965**	**83.176**	**84.070**	**84.889**	**86.186**
Coal	22.580	21.952	21.980	22.713	22.918
Coal Coke Net Imports	0.065	0.029	0.061	0.051	0.138
Natural Gas[b]	23.916	22.861	23.628	23.069	23.000
Petroleum[c]	38.404	38.333	38.401	39.047	40.130
Electricity Net Imports	**0.115**	**0.075**	**0.078**	**0.022**	**0.039**
Nuclear Electric Power	**7.862**	**8.033**	**8.143**	**7.959**	**8.232**
Renewable Energy	**6.158**	**5.328**	**5.835**	**6.082**	**6.117**
Conventional Hydroelectric	2.811	2.242	2.689	2.825	2.725
Geothermal Energy	**0.317**	**0.311**	**0.328**	**0.339**	**0.340**
Biomass[d]	2.907	2.640	2.648	2.740	2.845
Solar Energy	0.066	0.065	0.064	0.064	0.063
Wind Energy	0.057	0.070	0.105	0.115	0.143

U.S. Energy Consumption by Energy Source, 2000-2004 (Quadrillion Btu)

http://www.eia.doe.gov/cneaf/solar.renewables/page/geothermal/geothermal.html

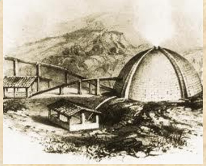
Advantages of Geothermal

Advantages
- Low CO_2 emissions
- Cost



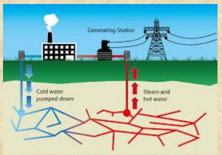
http://www.earthsci.org/mineral/energy/geother/geother.htm

History of Geothermal Energy



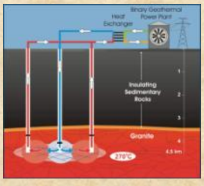
- In the early part of the nineteenth century the geothermal fluids were already being exploited for their energy content
- A chemical industry was set up in Italy, in the zone now known as Larderello, to extract boric acid from the hot
- The boric acid was obtained by evaporating the hot fluids in iron boilers, using the wood from nearby forests as fuel
- In 1827 Francesco Larderel, founder of this industry, developed a system for utilizing the heat of the boric fluids in the evaporation process,

History of Geothermal Energy



- Exploitation of the natural steam for its mechanical energy began at the same time
- Between 1910 and 1940 the low pressure steam was brought into use to heat the industrial and residential buildings
- The first attempt at generating electricity from geothermal steam was made at Larderello in 1904
- The success of this experiment indicated the industrial value of geothermal energy

Present status of Geothermal Energy



- After the Second World War many countries were attracted by geothermal energy
- Considering it to be economically competitive with other forms of energy
- In some cases, it was the only energy source available locally
- The countries that utilize geothermal energy to generate electricity by geothermal electric capacity worldwide in 1995 (a world total of 6833 MWe) and in the year 2000 (7974 MWe)

Cont'd……

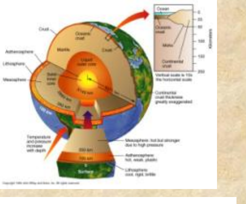
Country	1995 (MW_e)	2000 (MW_e)	1995-2000 increase in MW_e	% increase
Argentina	0.67	0	-0.67	n/a
Australia	0.17	0.17	0	0
China	28.78	29.17	0.39	1.35
Costa Rica	55	142.5	87.5	159
El Salvador	105	161	56	53.3
Ethiopia	0	8.52	8.52	infinite
France	4.2	4.2	0	0
Guatemala	0	33.4	33.4	infinite
Iceland	50	170	120	240
Indonesia	309.75	589.5	279.75	90.3
Italy	631.7	785	153.3	24.3
Japan	413.705	546.9	133.195	32.2
Kenya	45	45	0	0
Mexico	753	755	2	0.3
New Zealand	286	437	151	52.8
Nicaragua	70	70	0	0
Philippines	1 227	1 909	682	55.8
Portugal	5	16	11	220
Russia	11	23	12	109
Thailand	0.3	0.3	0	0
Turkey	20.4	20.4	0	0
USA	2 816.7	2 228	-588	n/a
Total	6 833	7 974	1 141	17

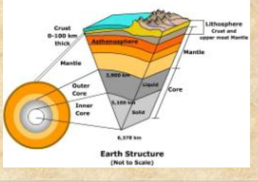
Cont'd…….

- There are now 58 countries reporting direct uses, compared to 28 in 1995 and 24 in 1985
- The most common non-electric use worldwide
- Heat pumps (34.80%), followed by bathing (26.20%), space heating (21.62%), greenhouses (8.22%), aquaculture (3.93%), and industrial processes (3.13%).

Country	Power (MW_t)	Energy (TJ/yr)
Algeria	100	1586
Argentina	25.7	449
Armenia	1	15
Australia	34.4	351
Austria	255.3	1609
Belgium	3.9	107
Bulgaria	107.2	1637
Canada	377.6	1023
Caribbean Islands	0.1	1
Chile	0.4	7
China	2282	37908
Colombia	13.3	266
Croatia	113.9	555
Czech Republic	12.5	128
Denmark	7.4	75
Egypt	1	15
Finland	80.5	484
France	326	4895
Georgia	250	6307
Germany	397	1568
Greece	57.1	385
Guatemala	4.2	117
Honduras	0.7	17
Hungary	472.7	4086
Iceland	1469	20170
India	80	2517
Indonesia	2.3	43
Israel	63.3	1713
Italy	325.8	3774
Japan	1167	26933
Jordan	153.3	1540
Kenya	1.3	10
Korea	35.8	753
Lithuania	21	599
Macedonia	81.2	510
Mexico	164.2	3919
Nepal	1.1	22
Netherlands	10.8	57
New Zealand	307.9	7081
Norway	6	32
Peru	2.4	49
Philippines	1	25
Poland	68.5	275

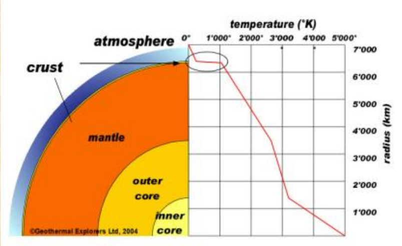
Origin and nature of Geothermal Energy





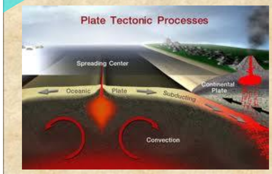
- Geothermal energy has its origin in the molten core of the earth
- Temperature is about 4000 c
- The thermal energy is produced by the decay of radioactive materials within the interior
- Interior of the earth consists of central molten core surround by semi-fluid materials called molten mantle
- Covered by crust --- 30-90 km

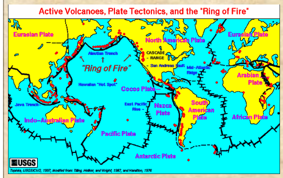
Origin and nature of Geothermal Energy



- The temperature of the earth increases
- Proportionally with depth
- 30 degree cen. per km
- Base of the crust is 1000 degree cen. Increases to the center

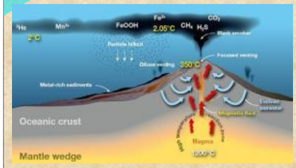
Origin and nature of Geothermal Energy

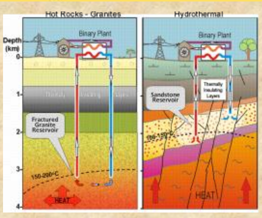




- In some regions hot molten materials comes through faults and cracks
- These regions are mainly at the junctions of tectonic plates
- That make up the earth's crust
- Most of the world's geothermal sites today located near the edge of the Pacific plate

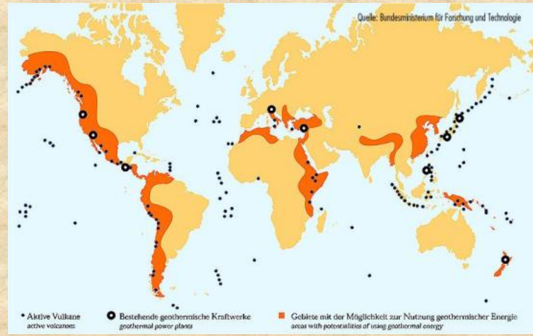
Origin and nature of Geothermal Energy





- Commonly known as hydrothermal systems
- i.e. thermal energy of the magma is stored in water or stem that fills the pores and fractures in the rock
- Can be classified as wet stem and dry stem

Global Geothermal Sites



http://www.deutsches-museum.de/ausstell/dauer/umwelt/img/geothe.jpg

Geothermal Site Schematic

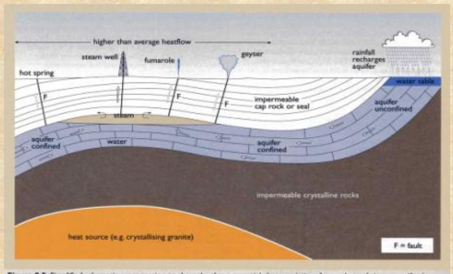


Figure 9.5 Simplified schematic cross-section to show the three essential characteristics of a geothermal site: an aquifer (e.g. fractured limestone with solution cavities); an impermeable cap rock to seal the aquifer (e.g. clays or shales); and a heat source (e.g. crystallising granite). Steam and hot water escape naturally through faults (F) in the cap rock, forming fumaroles (steam only), geysers (hot water and steam), or hot springs (hot water only). The aquifer is unconfined where it is open to the surface in the recharge area, where rainfall infiltrates to keep the aquifer full, as indicated by the water table just below the surface. The aquifer is confined where it is beneath the cap rock. Impermeable crystalline rocks prevent downward loss of water from the aquifer

Boyle, *Renewable Energy*, 2nd edition, 2004

Geysers

Clepsydra Geyser in Yellowstone

http://en.wikipedia.org/wiki/Geyser

Hot Springs

http://www.eia.doe.gov/cneaf/solar.renewables/page/geothermal/geothermal.html

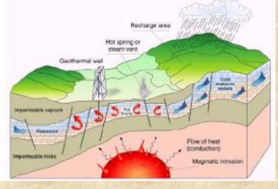
Fumaroles

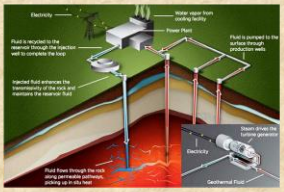
http://lvo.wr.usgs.gov/cdf_main.htm

http://volcano.und.edu/vwdocs/volc_images/img_white_island_fumerole.html

Geothermal System

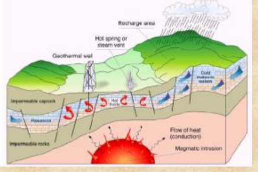
Co-funded by the Erasmus+ Programme of the European Union

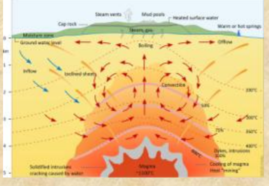




Geothermal System

Co-funded by the Erasmus+ Programme of the European Union

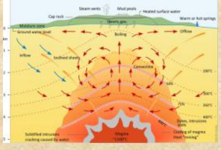


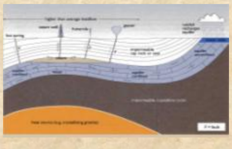


- It can be described schematically as '*convecting water in the upper crust of the Earth*
- A geothermal system is made up of three main elements: a *heat source*, a *reservoir* and a *fluid*
- Which is the carrier that transfers the heat

Geothermal System

Co-funded by the Erasmus+ Programme of the European Union





- The reservoir is a volume of hot permeable rocks from which the circulating fluids extract heat
- The reservoir is generally overlain by a cover of impermeable rocks and connected to a surficial recharge area
- Through which the meteoric waters can replace or partly replace the fluids that escape from the reservoir through springs or are extracted by boreholes.

Exploration of Geothermal Energy-Methods

Co-funded by the Erasmus+ Programme of the European Union

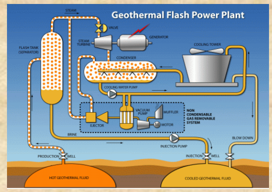
- Geological and Hydrological studies
- Geochemical surveys
- Geophysical surveys
- Drilling of exploratory wells

Utilization of Geothermal Resources

- Geothermal energy can be used for
- Electricity production
- commercial
- industrial, and
- residential direct heating purposes

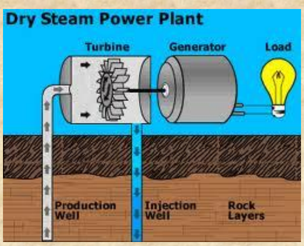
How does a power plant work

There are four commercial types of geothermal power plants: a. flash power plants, b. dry steam power plants, c. binary power plants, and d. flash/binary combined power plants.



- **a. Flash Power Plant**: Geothermally heated water under pressure is separated in a surface vessel (called a steam separator) into steam and hot water (called "brine" in the accompanying image).
- The steam is delivered to the turbine, and the turbine powers a generator. The liquid is injected back into the reservoir.

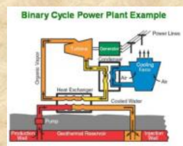
How does a power plant work

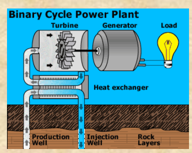


b. Dry Steam Power Plant:

- Steam is produced directly from the geothermal reservoir to run the turbines that power the generator, and
- No separation is necessary because wells only produce steam

How does a power plant work





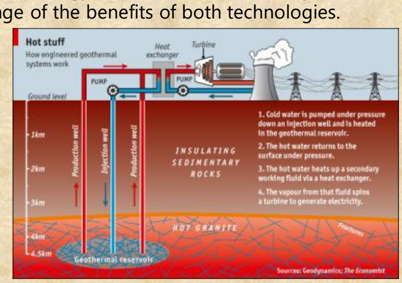
c. Binary Power Plant:

- Economic production of electricity from geothermal resources lower than 150°C (302°F)
- Typically use an Organic Rankine Cycle system.
- The geothermal water heats isobutane, pentafluoropropane, which boils at a lower temperature than water.
- The two liquids are kept completely separate through the use of a heat exchanger, which transfers the heat energy from the geothermal water to the working fluid
- The secondary fluid expands into gaseous vapor.

How does a power plant work

d. Flash/Binary Combined Cycle:

- This type of plant, which uses a combination of flash and binary technology, has been used effectively to take advantage of the benefits of both technologies.



Environmental Impacts

The first perceptible effect on the environment is that of ***drilling***

The next stage, **installation** of the pipelines that will transport the geothermal fluids, and construction of the *utilization plants*, will also affect animal and plant life and the surface morphology

Environmental problems also arise **during plant operation**. Geothermal fluids (steam or hot water) usually contain *gases* such as carbon dioxide (CO_2), hydrogen sulphide (H_2S), ammonia (NH_3), methane (CH_4), and trace amounts of other gases, as well as *dissolved chemicals* whose concentrations usually increase with temperature. For example, sodium chloride (NaCl), boron (B), arsenic (As) and mercury (Hg) are a source of pollution if discharged into the environment.

Environmental Impacts

Air pollution may become a problem when **generating electricity in conventional power-plants.** Hydrogen sulphide is one of the main pollutants. Carbon dioxide is also present in the fluids used in the geothermal power plants,

Discharge of waste waters is also a potential source of chemical pollution. Spent geothermal fluids with high concentrations of chemicals such as boron, fluoride or arsenic should be treated, re-injected into the reservoir, or both

Extraction of large quantities of fluids from geothermal reservoirs may give rise to *subsidence* phenomena, i.e. a gradual sinking of the land surface. This is an irreversible phenomenon, but by no means catastrophic, as it is a slow process distributed over vast areas.

The withdrawal and/or re-injection of geothermal fluids may trigger or increase the frequency of *seismic events* in certain areas.

10 Appendix A – Lecture slides

10.8 Appendix A.1 – Lecture 19 & 20 Slides

Climate Change and Causes

1

Introduction to the lecture

- This lecture introduces the factors that control the global climate change.
- It provide an overview on the fundamental concept of climate change, role of atmospheric gases, role of surface solar radiation, role of space weather and cosmic ray effects, role of volcanic activity, role of variations of the earth's orbital characteristics i.e. eccentricity, precession and obliquity and insolation.
- This lecture provides a geological history of the climate change through geological period.

2

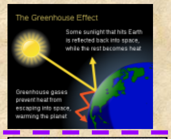
Aim and Learning outcomes

- The aim is to introduce students to the reason for climate change (natural and anthropogenic).
- On completion of lecture "Climate change and causes", students will be able to:
  - Examine basic causes of climate change.
  - Describe the components, drivers, and interactions of climate.
  - Explain the relationship between human activities and climate change

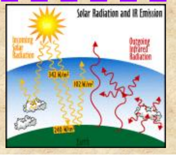
3

Talk outline

Introduction



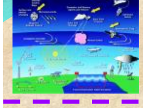
Role of atmospheric gases



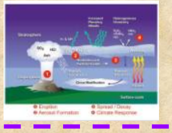
Surface solar radiation

4

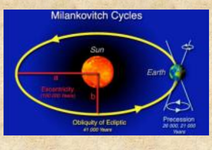
Talk outline



Space weather and cosmic ray effects



Role of volcanic activity

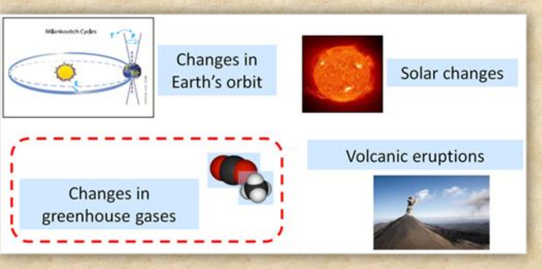


Variation of the earth's orbit

5

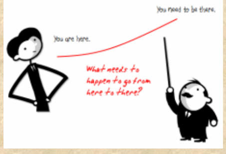
Talk outline

A Geological history of climate change



6

Learning Objectives



➢ Explain various causes of climate change.

➢ Explore the key scientific concepts of global climate change.

➢understand the physical basis of the natural greenhouse effect, including the meaning of the term radiative forcing, compounds and particles.

➢Analyze the causes of climate change and see how human activities affect the climate.

7

Introduction -

➢ The phrases CLIMATE CHANGE and GLOBAL WARMING and more recently GLOBAL COOLING are now part of our lives and rarely does a day go by without a mention in the press or on the radio of the possible causes of climate change and its consequences.

➢Climate change has come upon us in a relatively short space of time and is accelerating with alarming speed.

➢It is perhaps the most serious problem that the civilized world has had to face

8

Introduction -

➢ The changes in the climate over the last millennium have been found by studying tree rings, ice cores and corals. The results are consistent, which confirms their accuracy.

➢During the last forty years more extensive data have been obtained by instruments carried aloft by balloons and by satellites.

➢The most important long-term effects are changes in the average temperature and in the sea level.

➢ Climate is one of the determining features of civilization, so any change in the climate can have momentous consequences.

9

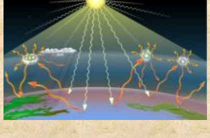
Role of atmospheric gases

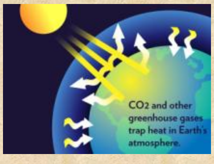
➢ If the general public in the developed world is confused about

- what the greenhouse effect is,
- what the important greenhouse gases are, and
- whether greenhouse gases really are the predominant cause of the recent rise in temperature of the earth's atmosphere, it is hardly surprising.

10

Role of atmospheric gases





➢ It is necessary to understand the origin of the greenhouse effects: primary and secondary effects.

➢ Physical chemistry properties of greenhouse gases

➢Lifetime of a greenhouse gas in the Earth's atmosphere.

➢ Long-lived greenhouse gases.

11

Role of atmospheric gases

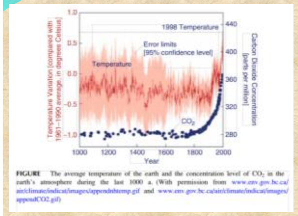
➢The earth is a planet in dynamic equilibrium, in that it continually absorbs and emits electromagnetic radiation.

➢It receives ultra-violet and visible radiation from the sun, it emits infra-red radiation and energy balance says that 'energy in' must equal 'energy out' for the temperature of the planet to be constant.

➢Evidence for the presence of greenhouse gases absorbing infra-red radiation in the atmosphere comes from satellite data.

12

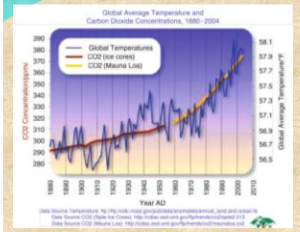
Role of atmospheric gases



➢There is no doubt that the concentration of CO2 in our atmosphere has risen from ca. 280 parts per million by volume (ppmv) to current levels of ca. 380 ppmv over the last 260 a.

➢ It is also not in doubt that the average temperature of our planet has risen by ca. 0.5–0.8 K over this same time window.

Role of atmospheric gases



➢Even more recent data of the last 100a, where the correlation seems to be better established will not convince the sceptic.

➢ That said, as demonstrated most clearly by the recent IPCC 2007report, the consensus of world scientists, and certainly physical scientists, is that a strong correlation does exist.

Role of atmospheric gases

➢ Data suggest that the temperature of the earth actually decreased between 1750 and ca. 1920 whilst the CO2 concentration increased from 280 to ca. 310 ppm over this time window.

➢ The drop in temperature around 1480 AD in the 'little ice age' is not mirrored by a similar drop in CO2 concentration.

➢ All that said, however, the apparent 'agreement' between rises of both CO2 levels and Te over the last 50 a is very striking.

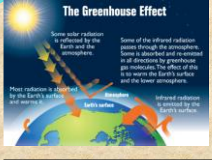
➢The most likely explanation surely is that there are a multitude of effects, one of which is the concentrations of greenhouse gases in the atmosphere, contributing to the temperature of the planet.

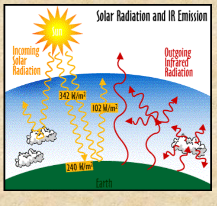
Role of atmospheric gases

➢ CO2 and CH4 currently contribute ca. 81% of the total radiative forcing of long-lived greenhouse gases, but it is too simplistic to say that control of CO2 levels will be the complete solution, as is often implied by politicians and the media.

➢ It is certainly true that concentration levels of CO2 in the earth's atmosphere are a very serious cause for concern, and many countries are now putting in place targets and policies to reduce them.

Role of surface solar radiation





➢The flux density and wavelength of electro-magnetic radiation emitted from a body depend on its temperature.

➢ On the earth's surface the wavebands that contain the most energy, and are therefore of prime interest in the context of climate influences, are those emitted by the sun and the earth.

Role of surface solar radiation

➢Global radiation decreased significantly (i.e. dimming) from the beginning of widespread measurements in the 1950s to the late 1980s over large parts of the globe and then partly recovered (i.e. brightening) in many places.

➢ The areal extent of these changes is not certain because of the large spatial variability, but the mean trends are evident in satellite estimates of global radiation.

➢The trends are apparently caused by anthropogenic aerosols which reduce surface short wave radiation directly and indirectly through their influence on cloud properties.

Role of surface solar radiation

- Changes in radiation have played a part in regional and global changes in daily temp. range (positively correlated) as well as soil moisture (negatively correlated) and potential evaporation rates (positively correlated).

- Dimming may have offset global warming between the 1950s and 1980s while the more recent brightening may have unmasked the full extent of global warming, as seen in the accelerated temperature increase since the early1990s.

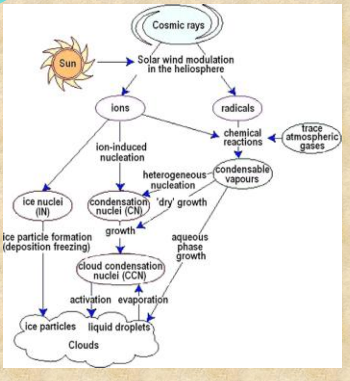
Role of space weather and cosmic ray

- There are a number of space phenomena that influence the Earth's climate and determined its long-term and short-term changes. These include:
  - the variability of the Sun's irradiation flux energy
  - the variations of the Earth's orbital characteristics;
  - the variable solar activity
  - the precipitation of energetic electrons and protons from the Earth's magnetosphere during magnetic disturbances
  - the variable Earth's magnetic field's

Role of space weather and cosmic ray

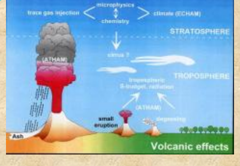
- There are a number of space phenomena that influence the Earth's climate and determined its long-term and short-term changes. These include:
  - the moving of the solar system around the galactic centre and crossing the Galaxy arms
  - the impacts of the solar system with galactic molecular dust cloud
  - the impacts of the solar system with interplanetary zodiac dust cloud
  - asteroid impacts and nearby supernova explosion

Role of space weather and cosmic ray



Possible paths of solar modulated CR influence on different processes in the atmosphere leading to the formation of clouds and their influence on climate.

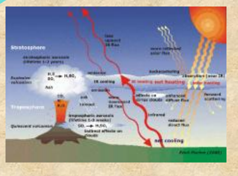
Role of volcanic activity in climate



- Volcanic activity is an important natural cause of climate variations because tracer constituents of volcanic origin impact the atmospheric chemical composition and optical properties.

- This study focuses on the recent period of the Earth's history and does not consider a cumulative effect of the ancient volcanic degassing that formed the core of the Earth's atmosphere billions of years ago.

Role of volcanic activity in climate



- At present, a weak volcanic activity results in gas and particle effusions in the troposphere (lower part of atmosphere), which constitute, on an average, the larger portion of volcanic mass flux into the atmosphere.

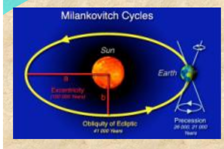
- However, the products of tropospheric volcanic emissions are short-lived and contribute only moderately to the emissions from large anthropogenic and natural tropospheric sources.

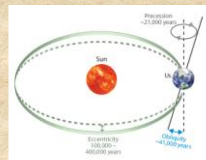
Role of volcanic activity in climate

- Volcanic emissions comprised of gases (H_2O, CO_2, N_2, SO_2, H_2S) and solid (mostly silicate) particles, that are usually referred to as volcanic ash.
- Volcanic ash particles are relatively large, exceeding 2 mm in diameter, and therefore deposit relatively quickly, that is, within a few weeks.
- They are responsible for short-term regional-to-continental perturbations of the Earth's radiative balance and meteorological parameters.
- Volcanic eruption has impacts on the tropospheric cooling and stratospheric warming, effects on hydrologic cycle, atmospheric circulation, ocean heat and sea level and sea ice.

25

Role of variation: Earth's orbit





- The climate of the Earth is characterised by trends, aberrations and quasiperiodic oscillations varying over a broad range of time-scales .
- The trends are largely controlled by plate tectonics, and thus tend to change gradually on a million year (Ma) time scale. Aberrations occur when certain thresholds are passed and are manifested in the geological record as unusually rapid (less than a few thousand of years) or extreme changes in climate.

26

Role of variation: Earth's orbit

- The quasiperiodic oscillations are mostly astronomically paced; they are driven by astronomical perturbations that affect the Earth's orbit around the Sun and the orientation of the Earth's rotation axis with respect to its orbital plane.
- These perturbations are described by three main astronomical cycles: eccentricity (shape of the Earth's orbit), precession (date of perihelion) and obliquity (angle between the equator and orbital plane), which together determine the spatial and seasonal pattern of insolation received by the Earth, eventually resulting in climatic oscillations of tens to hundreds of thousands of years.
- The expression of these astronomical-induced climate oscillations is found in geological archives of widely different ages and environments.

27

Role of variation: Earth's orbit

- Role of variation of the earth's orbital characteristic has effects on global climate change through eccentricity, precession and obliquity, insolation.
- The role of orbital forcing in climate change has been unequivocally shown by their characteristic patterns in sedimentary archives, ice cores and proxy records.
- Although our knowledge of orbital forcing is concerned with longterm natural climate cycles, it is of fundamental importance to assess and remediate global climate change problems on short-term periods.

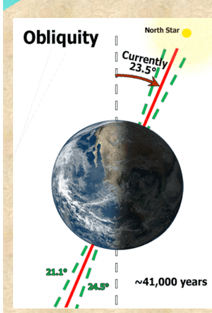
28

Role of variation: Earth's orbit

- In particular, the integration of climate modelling experiments with geological observations will provide these insights required for a better understanding of climate change in the past and near future.
- Considerable challenges will have to be addressed before the full spectrum of orbital-induced climatic variability has been unravelled, including the phase behaviour of different parts of the climate system, feedback mechanisms and the impact on ecosystem dynamics.

29

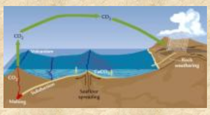
Role of variation: Earth's orbit



- From all the evidence, it is most likely that the climate change that we are currently experiencing is not due to variations of the Earth's orbital movements.
- With the fast rising CO_2 concentrations in the atmosphere, general orbital theories dealing with the icehouse world conditions will probably not account for future predictions.
- Integrating our knowledge of geological times when greenhouse gas conditions were those as being predicted, we might be able to decipher the role of orbital forcing in future climate change scenarios.

30

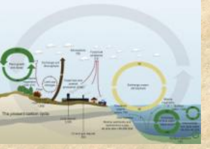
A geological history of climate change

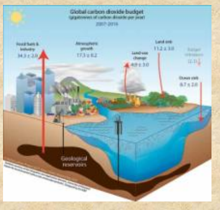


- Earth's climate is now changing in response to an array of anthropogenic perturbations, notably the release of greenhouse gases; an understanding of the rate, mode and scale of this change is now of literally vital importance to society.
- There is presently intense study of current and historical (i.e. measured) changes in both perceived climate drivers and the Earth system response.
- Such studies typically lead to climate models that, in linking proposed causes and effects, are aimed at allowing prediction of climate evolution over an annual to centennial scale.

31

A geological history of climate change





- Anthropogenic climate change is probably the largest experiment humanity has ever conducted.
- One of the major goals of climate science is to understand the system so we can predict how it will respond. But we are also interested in understanding and reconstructing past climate so we can study the geologic past.
- Our discussion in one lecture will only scratch the surface, and will be focused on the geologic controls on, and record of, past climates.

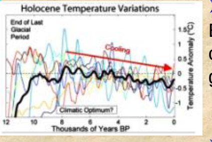
32

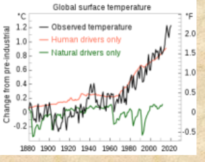
A geological history of climate change

- The history of Earth's climate system, as deduced from forensic examination of strata, has shown a general very long-term stability, which has probably been maintained by a complex interaction between the biosphere, atmosphere, hydrosphere, cryosphere and lithosphere.
- Superimposed on this overall stability has been a variety of climate perturbations on timescales ranging from multi-million year to sub-decadal, inferred to have been driven, amongst others, by variations in palaeogeography, greenhouse gas concentrations, astronomically forced insolation and inter-regional heat transport.

33

A geological history of climate change





- Current anthropogenic changes to the Earth system, particularly as regards changes to the carbon cycle, are geologically significant.
- Their effects may likely include the onset of climate conditions of broadly pre-Quaternary style such as those of the 'mid-Pliocene warm period', with higher temperatures (particularly at high latitudes), substantially reduced polar ice cover, and modified precipitation and biotic patterns.

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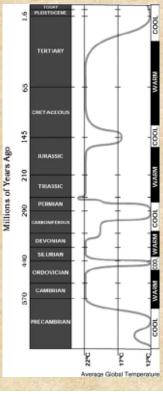
A geological history of climate change



A graph showing estimated changes in global Earth temperature during geological time and alternating cold and warm periods (modified from Scotese 2008).

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10 Appendix A – Lecture slides

10.9 Appendix A.1 – Lecture 21, & 22 Slides

Indicators of Climate Changes

Introduction to the lecture

- Indicators of climate change lecture provide an overview on the indicators that preserve the evidence of global climate change.
- This lecture focuses on the question that how do we know global climate change.
- This lecture discusses the evidence for rapid climate change i.e. global temperature, ocean acidification, warming ocean, sea level rise, extreme events, declining arctic sea ice, glacial retreat and decreased snow cover.

2

Aim and Learning outcomes

- The aim is to deepen students understanding of climate change indicators.
- On completion of lecture “Indicators of climate change” students will be able to:
  - Understand the indicators of climate change.
  - Know how global climate is changing and factors that control the global climate change.

3

Indicators of Climate Changes

Climate Change: How Do We Know?

- Earth's climate has changed throughout history.
- Just in the last **650,000** years there have been seven cycles of glacial advance and retreat, with the abrupt end of the last ice age about **11,700** years ago marking the beginning of the modern climate era — and of human civilization.
- Most of these climate changes are attributed to very small variations in Earth’s orbit that change the amount of solar energy our planet receives.

Climate Change: How Do We Know?

- The current warming trend is of particular significance because most of it is extremely likely (greater than 95% probability) to be the result of human activity since the mid-20th century (IPCC, 2003).
- Earth-orbiting satellites and other technological advances have enabled scientists to see the big picture, collecting many different types of information about our planet and its climate on a global scale. This body of data, collected over many years, reveals the signals of a changing climate.

Climate Change: How Do We Know?

- The heat-trapping nature of carbon dioxide and other gases was demonstrated in the mid-19th century (Fourier, 1824). Their ability to affect the transfer of infrared energy through the atmosphere is the scientific basis of many instruments flown by NASA. There is no question that increased levels of greenhouse gases must cause Earth to warm in response.
- Ice cores drawn from Greenland, Antarctica, and tropical mountain glaciers show that Earth's climate responds to changes in greenhouse gas levels

Climate Change: How Do We Know?

- Ancient evidence can also be found in tree rings, ocean sediments, coral reefs, and layers of sedimentary rocks. This ancient, or paleoclimate, evidence reveals that current warming is occurring roughly ten times faster than the average rate of ice-age-recovery warming.
- Gaffney, O. & Steffen, W., 2017 stated that Carbon dioxide from human activity is increasing more than 250 times faster than it did from natural sources after the last Ice Age.

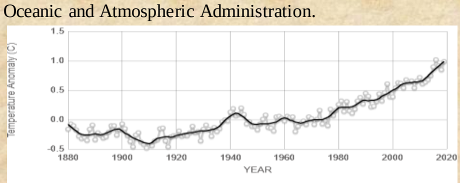
The evidence for rapid climate change is compelling

- **Global Temperature Rise**
- **Ocean Acidification**
- **Warming Ocean**
- **Sea Level Rise**
- **Extreme Events**
- **Declining Arctic Sea Ice**
- **Shrinking Ice Sheets**
- **Glacial Retreat**
- **Decreased Snow Cover**

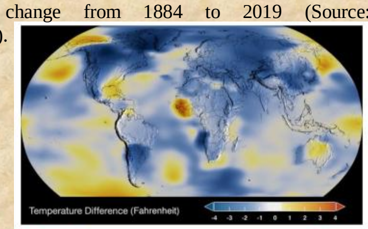
Global Temperature Rise

- The planet's average surface temperature has risen about 2.05 degrees Fahrenheit (1.14 degrees Celsius) since the late 19th century, a change driven largely by increased carbon dioxide and other human-made emissions into the atmosphere (NOAA, 2020).
- Most of the warming occurred in the past 40 years, with the six warmest years on record taking place since 2014. Not only was 2016 the warmest year on record, but eight months out of that year — from January through September, with the exception of June — were the warmest on record for those respective months (NASA, 2019).

This graph illustrates the change in global surface temperature relative to 1951-1980 average temperatures. Nineteen of the 20 warmest years all have occurred since 2001, with the exception of 1998. The year 2016 ranks as the warmest on record (source: NASA/GISS). This research is broadly consistent with similar constructions prepared by the Climatic Research Unit and the National Oceanic and Atmospheric Administration.



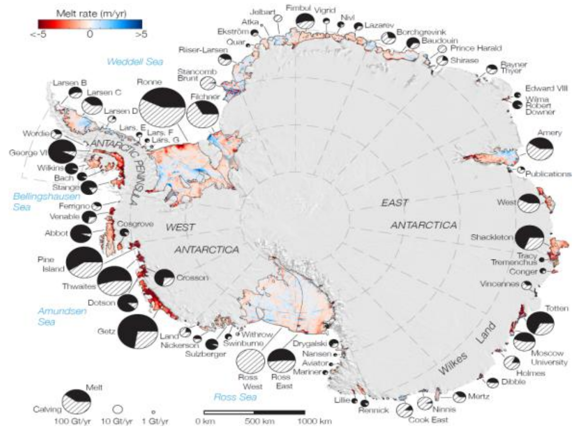
The time series below shows the five-year average variation of global surface temperatures. Dark blue indicates areas cooler than average. Dark red indicates areas warmer than average.
The "Global Temperature" figure on shows global temperature change from 1884 to 2019 (Source: NASA/GISS).



Warming Ocean

- The ocean has absorbed much of this increased heat, with the top 100 meters (about 328 feet) of ocean showing warming of more than 0.6 degrees Fahrenheit (0.33 degrees Celsius) since 1969 (Levitus *et al.*, 2017). Earth stores 90% of the extra energy in the ocean.
- **Warming ocean causing most Antarctic ice shelf mass loss**

This photo shows the ice front of Venable Ice Shelf, West Antarctica, in October 2008.



- Rates of basal melt of Antarctic ice shelves (melting of the shelves from underneath) overlaid on a 2009 mosaic of Antarctica created from data from NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) instrument aboard NASA's Terra and Aqua spacecraft.
- Red shades denote melt rates of less than 5 meters (16.4 feet) per year (freezing conditions), while blue shades represent melt rates of greater than 5 meters (16.4 feet) per year (melting conditions).
- The perimeters of the ice shelves in 2007-2008, excluding ice rises and ice islands, are shown by thin black lines.
- Each circular graph is proportional in area to the total ice mass loss measured from each ice shelf, in gigatons per year, with the proportion of ice lost due to the calving of icebergs denoted by hatched lines and the proportion due to basal melting denoted in black (Image credit: NASA/JPL-Caltech/UC Irvine/Columbia University).

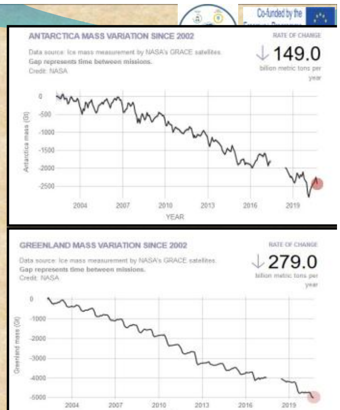
Shrinking Ice Sheets

- The Greenland and Antarctic ice sheets have decreased in mass. Data from NASA's Gravity Recovery and Climate Experiment show Greenland lost an average of 279 billion tons of ice per year between 1993 and 2019, while Antarctica lost about 148 billion tons of ice per year (Velicogna, I. et al., 2020).

Image: Flowing meltwater from the Greenland ice sheet

Data from NASA's GRACE and GRACE Follow-On satellites show that the land ice sheets in both Antarctica (upper chart) and Greenland (lower chart) have been losing mass since 2002. The GRACE mission concluded science operations in June 2017.

GRACE Follow-On began data collection in June 2018 and is now continuing the mass change data record for both ice sheets. This data record includes the latest data processing improvements and is continually updated as more data are collected (with a lag of up to two months).



Glacial Retreat

- Glaciers are retreating almost everywhere around the world — including in the Alps, Himalayas, Andes, Rockies, Alaska, and Africa (National Snow and Ice Data Center & World Glacier Monitoring Service)

Image: The disappearing snowcap of Mount Kilimanjaro, from space.

Decreased Snow Cover

- According to Robinson, D. A. *et al.*, 2014, Satellite observations reveal that the amount of spring snow cover in the Northern Hemisphere has decreased over the past five decades and the snow is melting earlier.

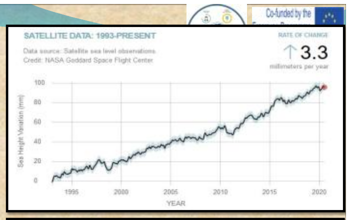
Sea Level Rise

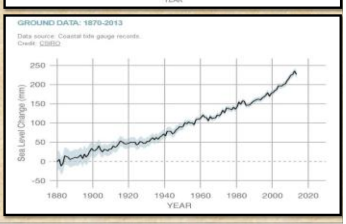
- Global sea level rose about 8 inches (20 centimeters) in the last century. The rate in the last two decades, however, is nearly double that of the last century and accelerating slightly every year (Nerem, *et al.*, 2018).

Image: Republic of Maldives: Vulnerable to sea level rise

Sea level rise is caused primarily by two factors related to global warming: the added water from melting ice sheets and glaciers and the expansion of seawater as it warms. The first graph tracks the change in sea level since 1993 as observed by satellites.

The second graph, derived from coastal tide gauge data, shows how much sea level changed from about 1870 to 2013.

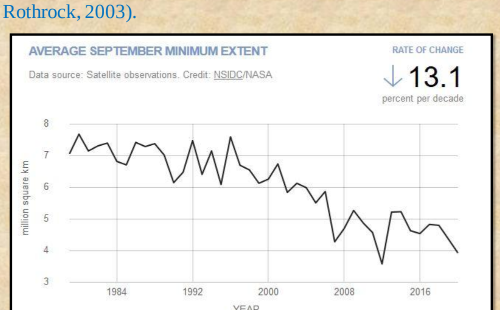




Declining Arctic Sea Ice

- Arctic sea ice reaches its minimum each September. September Arctic sea ice is now declining at a rate of 13.1 percent per decade, relative to the 1981 to 2010 average. This graph shows the average monthly Arctic sea ice extent each September since 1979, derived from satellite observations.
- The animated time series below shows the annual Arctic sea ice minimum since 1979, based on satellite observations. The 2012 sea ice extent is the lowest in the satellite record.

Both the extent and thickness of Arctic sea ice has declined rapidly over the last several decades (PIOMAS, Zhang and Rothrock, 2003).



Extreme Events

- Some extreme weather and climate events have increased in recent decades, and new and stronger evidence confirms that some of these increases are related to human activities.
- As the world has warmed, that warming has triggered many other changes to the Earth's climate. Changes in extreme weather and climate events, such as heat waves, natural hazards like floods, hurricanes, cyclones and droughts, are the primary way that most people experience climate change.
- Human-induced climate change has already increased the number and strength of some of these extreme events. Over the last 50 years, most of the countries has seen increases in prolonged periods of excessively high temperatures, heavy downpours, and in some regions, severe floods, hurricanes, cyclones and droughts etc.

Carbon Brief's (2017) analysis reveals:

- 69% of the 355 extreme weather events and trends included in the map were found to be made more likely or more severe by human-caused climate change.
- 9% of events or trends were made less likely or less severe by climate change, meaning 78% of all events experienced some human impact. The remaining 22% of events and trends showed no discernible human influence or were inconclusive.
- Heatwaves account for 47% of such events, while droughts and heavy rainfall or floods each make up 15%.
- Of the 125 attribution studies that have looked at extreme heat around the world, 93% found that climate change made the event or trend more likely or more severe.
- For the 68 studies looking at rainfall or flooding, 54% found human activity had made the event more likely or more severe. For the 61 drought events studied, it's 61%.

- The events and trends shown on the previous map are covered by 308 individual scientific papers or rapid studies. Where a single study covers multiple events or locations, these have been separated out.
- Combining the evidence over the past 20 years, the literature is heavily dominated by studies of extreme heat (35%), rainfall or flooding (19%) and drought (17%). Together, these make up more than two-thirds of all published studies (72%).
- As the chart below shows, the number of events studied each year has grown substantially over the past decade.

Number of attribution studies by extreme weather event type and year. Note: the total number of events dipped in 2017 because the Bulletin of the American Meteorological Society special report for that year was published in early 2018 rather than late 2017. Chart by Carbon Brief using Highcharts.

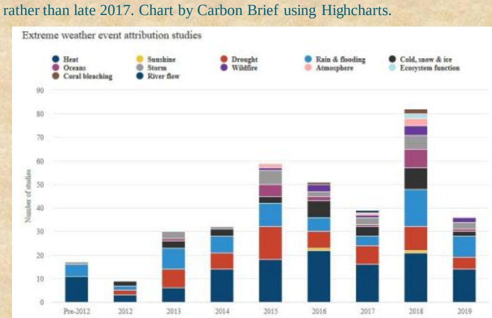
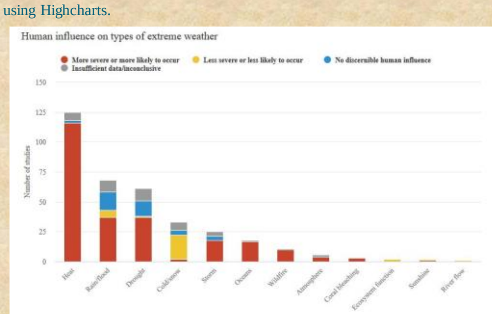
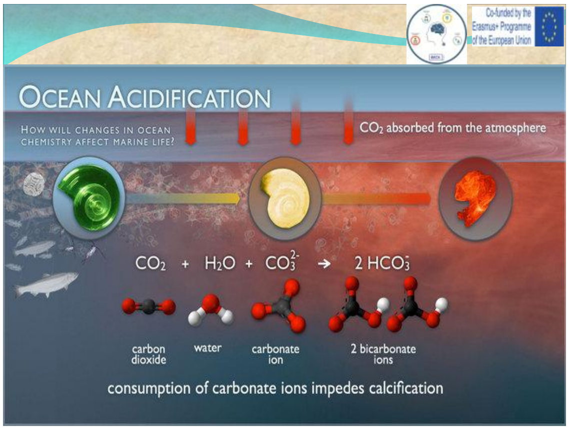


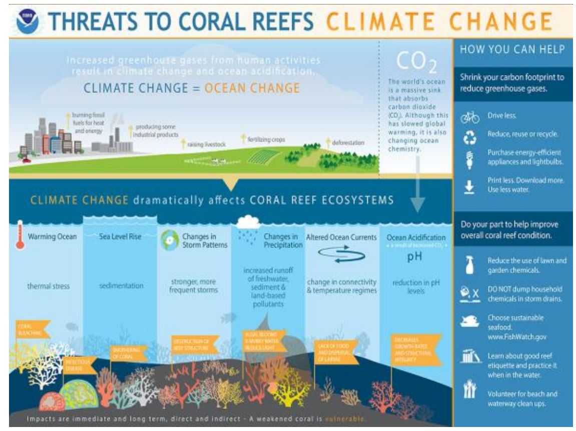
Chart shows the number of studies for each type of extreme event that fall within each category of human influence: More severe/likely (red), less severe/likely (yellow), no influence (blue) and inconclusive (grey). Chart by Carbon Brief using Highcharts.



Ocean Acidification

- Since the beginning of the Industrial Revolution, the acidity of surface ocean waters has increased by about 30% (NOAA report, 2016). This increase is the result of humans emitting more carbon dioxide into the atmosphere and hence more being absorbed into the ocean. The ocean has absorbed between 20% and 30% of total anthropogenic carbon dioxide emissions in recent decades (7.2 to 10.8 billion metric tons per year) (C. L. Sabine et.al., 2014).





- Climate change is the greatest global threat to coral reef ecosystems. Scientific evidence now clearly indicates that the Earth's atmosphere and ocean are warming, and that these changes are primarily due to greenhouse gases derived from human activities.
- As temperatures rise, mass coral bleaching events and infectious disease outbreaks are becoming more frequent. Additionally, carbon dioxide absorbed into the ocean from the atmosphere has already begun to reduce calcification rates in reef-building and reef-associated organisms by altering seawater chemistry through decreases in pH. This process is called ocean acidification.
- Climate change will affect coral reef ecosystems, through sea level rise, changes to the frequency and intensity of tropical storms, and altered ocean circulation patterns. When combined, all of these impacts dramatically alter ecosystem function, as well as the goods and services coral reef ecosystems provide to people around the globe.

Scientific evidence for warming of the climate system is unequivocal.

- Intergovernmental Panel on Climate Change

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10 Appendix A – Lecture slides

10.10 Appendix A.1 – Lecture 23, 24 & 25 Slides

Global Effects of Climate Change

Introduction to the lecture

- Global effects of climate change lecture introduce the concept of global climate change effects on the atmosphere.

- This lecture provides an overview of fossil fuel impacts on the level of carbon dioxide, ozone depletion in the stratosphere, bad and good ozone, origin of good and bad ozone, causes of ozone depletion, idea on ozone reserve in the stratosphere.

Introduction to the lecture

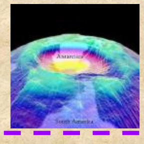
- It also focuses on the relation between greenhouse effects and climate change, climate change over geological periods, basic information on climate change, overview of greenhouse gases i.e. CO_2, CH_4, N_2O, fluorinated gas, ratio of greenhouse gas emission, source of greenhouse gas, trends in global emission, emission by country and basic concept of causes of climate change.

Aim and Learning outcomes

- The aim is to bring in to consideration the global climate change in relation to greenhouse gases and its impacts on the stratosphere.
- On completion of lecture "Global effects of climate change" students will be able to:
  - To understand the influence of human being on the global atmosphere and climate.
  - Understand the depletion of ozone in the Stratosphere "a hole in the sky".
  - Know the mechanism of global climate change caused by greenhouse gases.

Talk outline

Introduction



Ozone Depletion in the Stratosphere

Greenhouse Effect and Climate Change

Learning Objectives

- To understand the influence of human being on the global atmosphere and climate

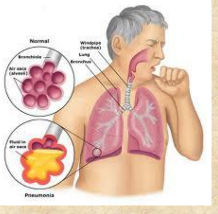
- Depletion of ozone in the Stratosphere "a hole in the sky"
- Global climate change caused by greenhouse gases

Introduction - What to do??

- To reduce the rate at which we emit carbon dioxide into atmosphere
- As we know that production of CO2 is controlled by burning fossil fuels
- Is it possible to cut the rate of production of energy from fossil fuels ?
- Is it possible to reduce the use of fossil fuels to reduce CO2 in the atmosphere ?

7

Ozone Depletion in the Stratosphere



Ozone:

- Ozone (O_3), a colorless and highly reactive gas, is a major ingredient of photochemical smog
- Causes coughing and breathing problems, lung and heart diseases, reduces resistance to colds and pneumonia, and irritates the eyes, nose, and throat

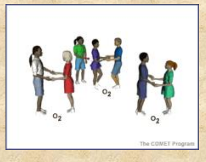
8

Ozone Depletion - Ozone

- Damages plants, rubber in tires, fabrics, and paints
- Ozone in the troposphere near ground level is often referred to as "bad" ozone, while ozone in the the stratosphere as "good" ozone.

9

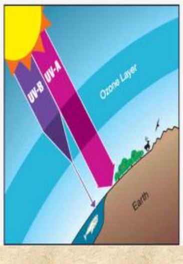
Ozone Depletion – why good and bad



- Essentially, ozone (O3) is an unstable and highly reactive form of oxygen. The ozone molecule is made up of three oxygen atoms that are bound together, whereas the oxygen we breathe (O2) contains only two oxygen atoms
- From a human perspective, ozone is both helpful and harmful, both good and bad

10

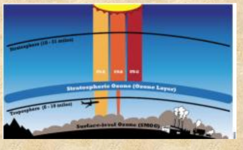
Ozone Depletion – Good Ozone

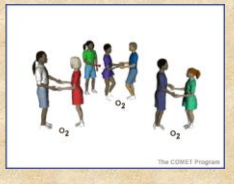


- Small concentrations of ozone occur naturally in the stratosphere, which is part of the Earth's upper atmosphere.
- At that level, ozone helps to protect life on Earth by absorbing ultraviolet radiation from the sun, particularly UVB radiation
- can cause skin cancer, damage crops, and destroy some types of marine life

11

Ozone Depletion – Origin Good Ozone

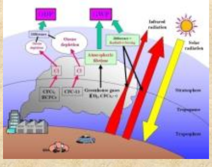




- Ozone is created in the stratosphere when ultraviolet light from the sun splits an oxygen molecule into two single oxygen atoms.
- Each of those oxygen atoms then binds with an oxygen molecule to form an ozone molecule.

12

Ozone Depletion – Origin Good Ozone



- Depletion of stratospheric ozone poses serious health risks for humans and environmental hazards for the planet, and
- many nations have banned or limited the use of chemicals that contribute to ozone depletion.

13

Ozone Depletion – Origin bad Ozone

- Ozone is created in the stratosphere when Ozone is also found much nearer the ground, in the troposphere, the lowest level of Earth's atmosphere.
- Unlike the ozone that occurs naturally in the stratosphere, troposphere ozone is man-made,
- an indirect result of air pollution created by automobile exhaust and emissions from factories and power plants.

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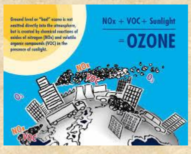
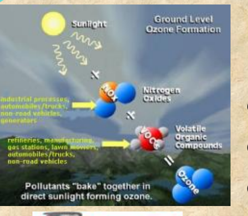
Ozone Depletion – Origin bad Ozone

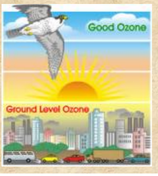


- When gasoline and coal are burned, nitrogen oxide gases (NOx) and volatile organic compounds (VOC) are released into the air.
- During the warm, sunny days of spring, summer and early fall, NOx and VOC are more likely to combine with oxygen and form ozone.

15

Ozone Depletion – Origin bad Ozone

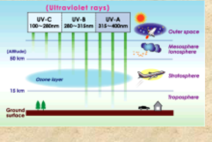




- During those seasons, high concentrations of ozone are often formed during the heat of the afternoon and early evening, and are likely to dissipate later in the evening as the air cools.

16

Ozone Depletion



- A layer of ozone in the lower stratosphere keeps about 95% of the sun's harmful ultraviolet (UV-A and UV-B) radiation from reaching the earth's surface.
- Measurements show considerable seasonal depletion (thinning) of ozone concentrations in the stratosphere above Antarctica and the Arctic and a lower overall ozone thinning everywhere

17

Ozone Depletion

- Ozone depletion in the stratosphere poses a serious threat to humans, other animals, and some primary producers (mostly plants) that use sunlight to support the earth's food webs

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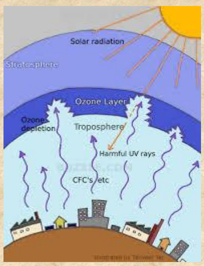
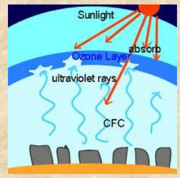
Ozone Depletion - Rate



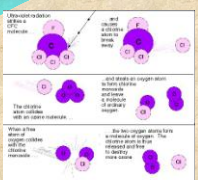
- 1956-1968 the ozone concentration was constant about 300 Dobson Unit (mill atmosphere-centimeter of ozone)
- In 1984 ----- 200 Dobson
- In 1991 ----- 150 Dobson
- Measure by satellites and high altitude air craft

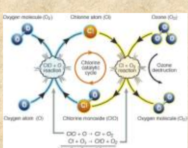
Ozone Depletion



- Ozone is depleting due to the injection of CFC (chlorofluorocarbons) gas into the atmosphere
- More widely used Ferron-11, 12, $CFCl_3$, $CFCl_2$
- These chemicals used in the air conditioner, refrigerator etc
- CFC – are triples from 1970-1980

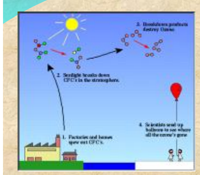
Ozone Depletion





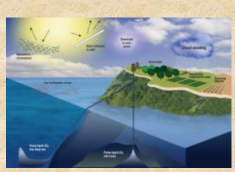
- These CFCs can be transported high
- Disassociate CFCs into free chlorine and other molecules – free chlorine can act as a catalyst
  $Cl + O_3$ ---- $ClO + O_2$
  $ClO + O$ ---- - $Cl + O_2$
- The process continue again and again

Ozone Depletion



- Chlorine atom can destroy 100000 O_3 molecules
- Bromine also leads to destruct O_3 layer – 25 % sharing
- Extensive cloud system transport catalyst to destruct ozone layer
- Cloud system carry aerosol, nitric acid, water vapor etc
- Small fraction Cl destroy O_3 rapidly

Ozone Depletion - Hypothesis



- It had been thought that the ozone layer in troposphere will move up and cover the deficiency of stratosphere
- **BUT NO !!!!!!**

Why should we worry about ozone depletion?

- More biologically damaging UV-A and UV-B radiation will reach the earth's surface.
- Causes problems with human health, crop yields, forest productivity, climate change, wildlife populations, air pollution, and degradation of outdoor materials.

We can reverse stratospheric ozone depletion

- In 1987, representatives of 36 nations met in Montreal, Canada, and developed the Montreal Protocol to cut emissions of CFCs.
- In 1992, adopted the Copenhagen Protocol-out of key ozone-depleting chemicals signed by 195 countries.
- The ozone protocols set an important step by using prevention to solve a serious environmental problem.

Three big ideas

- All countries need to step up efforts to control and prevent outdoor and indoor air pollution.
- Reducing the projected harmful effects of rapid climate disruption during this century requires emergency action to increase energy efficiency, sharply reduce greenhouse gas emissions, rely more on renewable energy resources, and slow population growth.
- We need to continue phasing out the use of chemicals that have reduced ozone levels in the stratosphere and allowed more harmful ultraviolet radiation to reach the earth's surface.

Greenhouse effect and climate change

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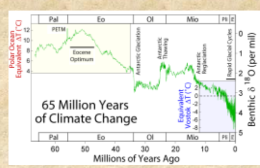
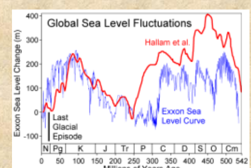
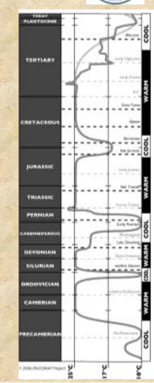
Climate change over geological period (past)







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Climate change basic information

Climate change is happening - Our earth is warming

- Earth's average temperature has risen by 1.4°F over the past century,
- Rise another 2 to 11.5°F over the next hundred years.
- Small changes in the average temperature of the planet can translate to large and potentially dangerous shifts in climate and weather.

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Climate change basic information

evidence is clear

- Rising global temperatures have been accompanied by changes in weather and climate
- Changes in rainfall, resulting in more floods, droughts, or intense rain, as well as more frequent and severe heat waves.
- Oceans are warming and becoming more acidic, ice caps are melting, and sea levels are rising

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Climate change basic information

Humans are largely responsible for recent climate change

- Over the past century, human activities have released large amounts of carbon dioxide and other greenhouse gases into the atmosphere.
- The majority of greenhouse gases come from burning fossil fuels to produce energy,
- Although deforestation, industrial processes, and some agricultural practices also emit gases into the atmosphere.

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Climate change basic information

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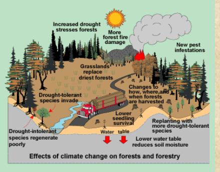

- Greenhouse gases act like a blanket around Earth,
- Trapping energy in the atmosphere and causing it to warm.
- This phenomenon is called the greenhouse effect
- However, the buildup of greenhouse gases can change Earth's climate and result in dangerous effects to human health and welfare and to ecosystems.

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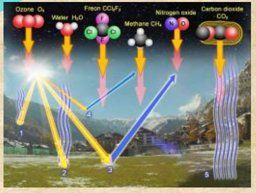
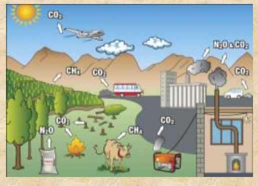
Overview of Greenhouse Gases





- Gases that trap heat in the atmosphere are called greenhouse gases--- Carbon dioxide, methane, Nitrous oxide, Fluorinated gases
- Important role-emissions and removals of the main greenhouse gases to and from the atmosphere

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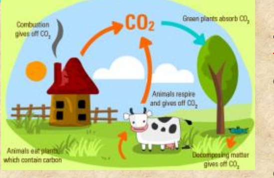
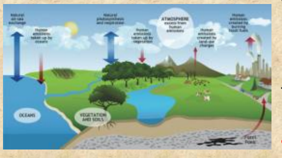
Overview of Greenhouse Gases – CO_2





- Carbon dioxide enters the atmosphere through burning fossil fuels (coal, natural gas and oil), solid waste, trees and wood products
- Also as a result of certain chemical reactions e.g., manufacture of cement
- Carbon dioxide is removed from the atmosphere (or "sequestered") when it is absorbed by plants as part of the biological carbon cycle

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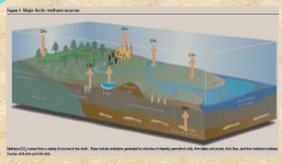
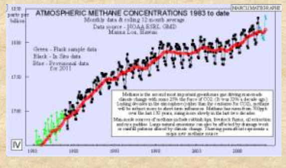
Greenhouse Gases – Methane (CH4)





- Methane is emitted during the production and transport of coal, natural gas, and oil
- Methane emissions also result from livestock and other agricultural practices and by the decay of organic waste in municipal solid waste landfills

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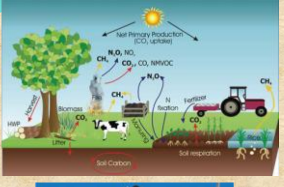
Greenhouse Gases – Nitrous Oxide (N_2O)



- Nitrous oxide is emitted during agricultural and industrial activities, as well as during combustion of fossil fuels and solid waste.

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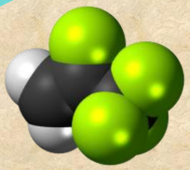
Greenhouse Gases – Fluorinated gas



- Industrial processes, refrigeration, and the use of a variety of consumer products contribute to emissions of F-gases,
- which include ----- hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6).

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Greenhouse Gases

Each gas's effect on climate change depends on three main factors--

1. **How much** of these gases are in the atmosphere?

- **Concentration, or abundance**, is the amount of a particular gas in the air. Larger emissions of greenhouse gases lead to higher concentrations in the atmosphere

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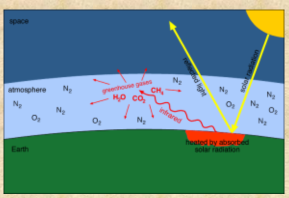
Greenhouse Gases

2. How long do they stay in the atmosphere?



- Each of these gases can remain in the atmosphere for different amounts of time, ranging from a few years to thousands of years

3. How strongly do they impact global temperatures?

- Some gases are more effective than others at making the planet warmer and "thickening the Earth's blanket."

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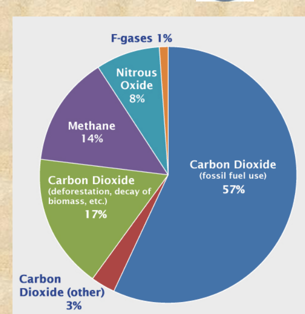
Global Greenhouse Gas Emission- gas

At the global scale, the key greenhouse gases emitted by human activities are--



IPCC-2007

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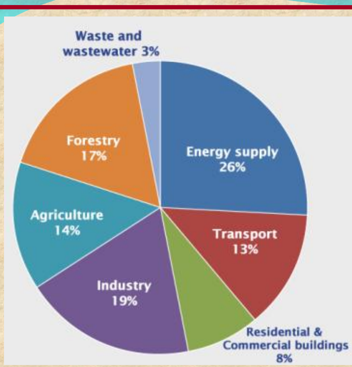
Global Greenhouse Gas Emission- source



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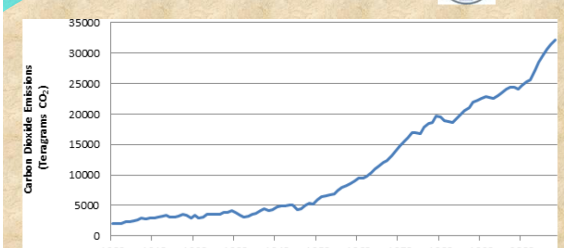
Trends in global emission



- Global carbon emissions from fossil fuels have significantly increased since 1900. Emissions increased by over 16 times between 1900 and 2008 and by about 1.5 times between 1990 and 2008.

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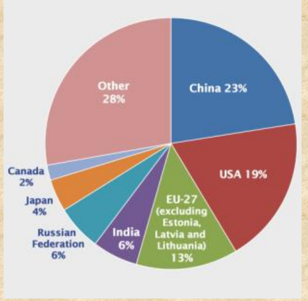
Emission by country



- In 2008, the top carbon dioxide (CO_2) emitters were China, the United States, the European Union, India, the Russian Federation, Japan, and Canada.
- These data include CO_2 emissions from fossil fuel combustion, as well as cement manufacturing and gas flaring.

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Climate change- Earth climate is Changing

- Earth's climate is changing in ways that affect our weather, oceans, snow, ice, ecosystems, and society
- Natural causes alone cannot explain all of these changes
- Human activities are contributing to climate change, primarily by releasing billions of tons of carbon dioxide (CO_2) and other heat-trapping gases, known as greenhouse gases, into the atmosphere every year

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Climate change- Earth climate is Changing

Natural causes alone cannot explain recent changes

- Natural processes such as changes in the sun's energy, shifts in ocean currents, and others affect Earth's climate.
- However, they do not explain the warming that we have observed over the last half-century.

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Climate change- Earth climate is Changing

Human causes can explain these changes

- Emissions of greenhouse gases - come from a variety of human activities
- Burning fossil fuels for heat and energy, clearing forests, fertilizing crops, storing waste in landfills, raising livestock, and producing some kinds of industrial products.

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Climate change- Earth climate is Changing

Climate will continue to change unless we reduce our emissions

- During the 21st century, global warming is projected to continue and climate changes are likely to intensify
- Scientists have used climate models to project different aspects of future climate, including temperature, precipitation, snow and ice, ocean level, and ocean acidity
- Projected to increase worldwide by 2°F to 11.5°F by 2100. Learn more about the projections of future climate change.

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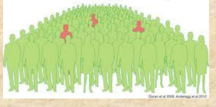
Climate change- Causes

Earth's temperature is a balancing act

97 out of 100 climate experts think humans are changing global temperature



- Earth's temperature depends on the balance between energy entering and leaving the planet's system .
- When incoming energy from the sun is absorbed by the Earth system, Earth warms.
- When the sun's energy is reflected back into space, Earth avoids warming. When energy is released back into space, Earth cools.

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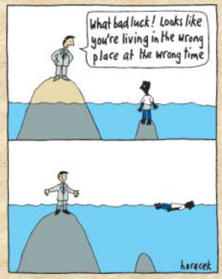
Climate change- Causes

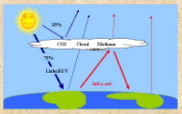
Earth's temperature is a balancing act



- **Analyzing** a number of indirect measures of climate such as ice cores, tree rings, glacier lengths, pollen remains, and ocean sediments, and by studying changes in Earth's orbit around the sun
- Climate system **varies** naturally over a wide range of time scales.
- Prior to the Industrial Revolution in the 1700s can be explained by natural causes

Climate change- Causes

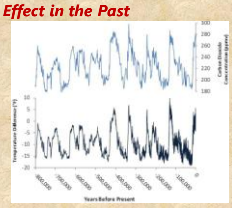
The Greenhouse Effect causes the atmosphere to retain heat



- When **sunlight** reaches Earth's surface, it can either be **reflected back** into space or **absorbed** by Earth
- **Greenhouse gases (GHGs)** like water vapor (H_2O), carbon dioxide (CO_2), and methane (CH_4) **absorb energy**, slowing or preventing the loss of heat to space.
- In this way, GHGs act like **a blanket**, making Earth warmer than it would otherwise be.
- This **process** is commonly known as the **"greenhouse effect"**.

Climate change- Causes

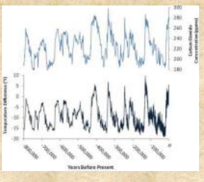
The Role of the Greenhouse Effect in the Past



- In the **distant past** (prior to about 10,000 years ago), CO_2 levels tended to track the glacial cycles.
- During warm **'interglacial'** periods, **CO_2** levels have been **higher.** During cool **'glacial'** periods, CO_2 levels have been **lower.**
- This is because the **heating or cooling** of Earth's surface can cause changes in **greenhouse gas concentrations.**

Climate change- Causes

The Role of the Greenhouse Effect in the Past



- Estimates of the **Earth's changing carbon dioxide (CO_2)** concentration (top) and Antarctic temperature (bottom),
- Based on analysis of **ice core** data extending back 800,000 years.
- Until the past century, natural factors caused atmospheric **CO_2 concentrations** to **vary** within a range of about **180 to 300 ppmv.**
- The past century's temperature changes and **rapid CO_2 rise** to 390 ppmv in 2010

Climate change- Causes

The Recent Role of the Greenhouse Effect

- Since the **Industrial Revolution** began around **1750**,
- **Human activities** have **contributed** substantially to climate change by adding **CO_2** and other heat-trapping gases to the atmosphere
- These **greenhouse gas** emissions have **increased** the greenhouse effect and caused Earth's surface **temperature to rise**

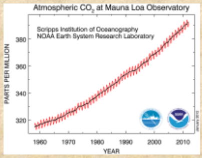
Climate change- Causes

The Main Greenhouse Gases

- Carbon dioxide is the **primary** greenhouse gas that is **contributing** to **recent climate change**
- CO_2 is **absorbed** and emitted naturally as part of the **carbon cycle,** through animal and plant respiration, volcanic eruptions, and **ocean-atmosphere exchange**
- **Human activities,** such as the burning of fossil fuels and changes in land use, **release large amounts of carbon** to the atmosphere, causing **CO_2** concentrations in the atmosphere to **rise.**

Climate change- Causes

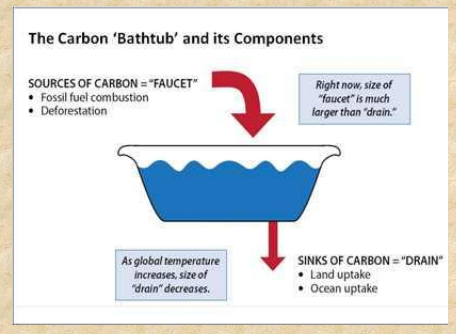
The Main Greenhouse Gases



- Atmospheric CO_2 concentrations have increased by almost 40% since pre-industrial times
- Approximately 280 parts per million by volume (ppmv) in the 18th century to 390 ppmv in 2010
- Some volcanic eruptions released large quantities of CO_2 in the distant past
- Human activities now emit more than 135 times as much CO_2 as volcanoes each year

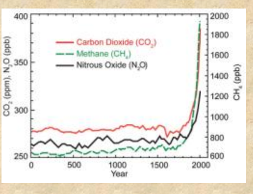
Climate change- Causes

Carbon Bathtub



Climate change- Causes

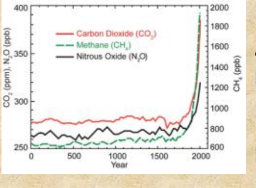
The Main Greenhouse Gases- Methane



- Methane is produced through both natural and human activities
- Natural wetlands, agricultural activities, and fossil fuel extraction and transport all emit CH_4
- Greenhouse gas (GHG) concentrations in the atmosphere over the last 2,000 years.

Climate change- Causes

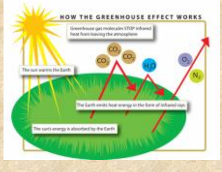
The Main Greenhouse Gases- Nitrous Oxide

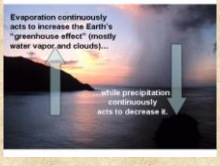


- Nitrous oxide is produced through natural and human activities,
- Mainly through agricultural activities and natural biological processes.
- Fuel burning and some other processes also create N_2O
- Concentrations of N_2O have risen approximately 18% since the start of the Industrial Revolution

Climate change- Causes

Other Greenhouse gases

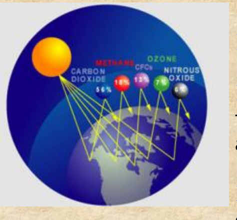




- Water vapor is the most abundant greenhouse gas and also the most important in terms of its contribution to the natural greenhouse effect,
- Some human activities can influence local water vapor levels.
- However, on a global scale, the concentration of water vapor is controlled by temperature, which influences overall rates of evaporation and precipitation

Climate change- Causes

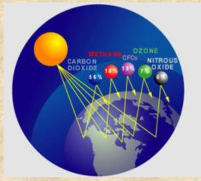
Other Greenhouse gases



- Tropospheric ozone (O3), which also has a short atmospheric lifetime,
- Is a potent greenhouse gas
- Chemical reactions create ozone from emissions of nitrogen oxides and volatile organic compounds
- In addition to trapping heat, ozone is a pollutant that can cause respiratory health problems and damage crops and ecosystems.

Climate change- Causes

Other Greenhouse gases



- Chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6),
- Together called F-gases, are often used in coolants, foaming agents, fire extinguishers, solvents, pesticides, and aerosol
- Unlike water vapor and ozone, these F-gases have a long atmospheric lifetime

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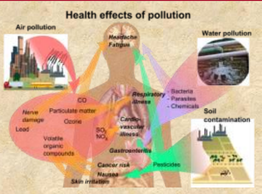
10 Appendix A – Lecture slides

10.11 Appendix A.1 – Lecture 26 & 27 Slides

Global Impacts – Air Pollution



1

Introduction to the lecture

- Global impacts of air pollution lecture provide an overview of global impacts of air pollution due to the climate change.
- This lecture discusses the earth's atmosphere (characteristics, composition), thermal inversion (temperature variation, adiabatic lapse rate, thermal inversion process and smog), pollutants (carbon dioxide, nitrogen oxide, hydrocarbon emission, sulphur dioxide and particulates s pollutants).
- This lecture focuses on the impacts of air pollution due to global climate change on the human health.

2

Aim and Learning outcomes

- The aim is to understand the concept of global climate change impacts on the air pollution and its consequent effects on the human health.
- On completion of lecture "Global impacts-Air pollution" students will be able to:
  - Understand the general concept on the characteristics of atmosphere.
  - Understand the impacts of climate change on the atmosphere.
  - Know the mechanism of atmospheric changes due to climate change.
  - Know the impacts of air pollution on the human health.

3

Talk outline

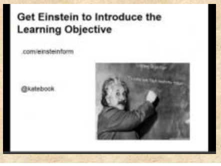
Earth's Atmosphere
- Characteristics
- Composition

Thermal Inversion
- Temperature variation
- Adiabatic Lapse Rates (ALR)
- Thermal Inversion process
- Smog

Pollutants
- Carbon monoxide (CO)
- The oxides of Nitrogen
- Hydrocarbon emission
- Sulfur dioxide
- Particulates as pollutants

4

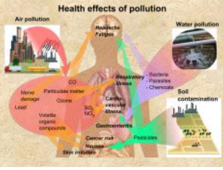
Learning Objectives



- We should know about our earth
- To understand the mechanism of environmental pollution
- To know the harmful effects of pollution
- To control the pollution level

5

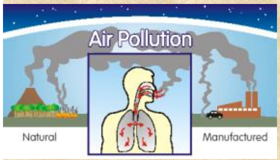
Our Home - Planet



- We have only one home-Earth
- Polluting our environment in many ways
- Air pollution from fossil fuels
- Have adverse effects on the environment
- Difficult to mitigate the problems

6

What is Air Pollution

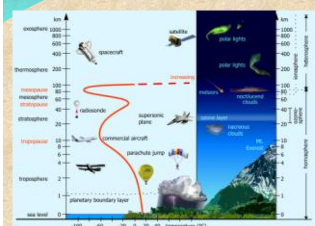


- ➢ The result of emission into the air of hazardous substances
- ➢ at a rate that exceeds the capacity of natural processes
- ➢ in the atmosphere to convert, deposit, or dilute them...

Earth Atmosphere - Characteristics

- ➢ Atmosphere weights about 5.7×10^7 tons
- ➢ One-millionth of the earth weight
- ➢ Earth surface covered by 200 million square km
- ➢ Atmosphere extends up to 100 miles over earth surface
- ➢ Half of the air below 18000 ft altitude above sea level
- ➢ Density – 1.3 kg/m^3 , pressure – 14.7 lb/in^2

Earth Atmosphere - Characteristics



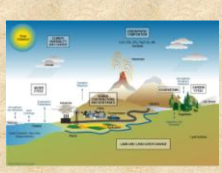
- ➢ Density and pressure decrease with increasing altitude
- ➢ Above 50000 ft pressure decrease to 1.6 lb/in^2 from 14.7 lb/in^2
- ➢ Above 600 miles atmospheric pressure is essentially zero
- ➢ Temperature gradient vary from one altitude to another
- ➢ i.e. temperature vary with the height

Earth Atmosphere - Composition

Gases	Mean percentage	Mean residence time
Nitrogen (N_2)	78	10[illegible] years
Oxygen (O_2)	21	10[illegible] years
Argon (Ar)	0.9	—
Water vapour	variable 0-3	8-10 days
Carbon dioxide (CO_2)	0.035	50-200 years
Methane (CH_4)	0.00017	7-10 years
Hydrogen (H_2)	0.00006	—
Nitrous oxide (N_2O)	0.000033	130 years
Carbon monoxide (CO)	4 – 20x10[illegible]	5 months
Ozone (O_3)		
• tropospheric	10[illegible] – 10[illegible]	weeks-months
• stratospheric	10[illegible] – 5x10[illegible]	months
Ammonia (NH_3)	10[illegible] – 10[illegible]	3 days
Sulphur dioxide (SO_2)	10[illegible] – 5x10[illegible]	3 days
Nitrogen oxides (NO_x)	10[illegible] – 5x10[illegible]	3 days
CFC (Freons)	10[illegible]	50-150 years
Peroxyacetylnitrate (PAN)	10[illegible] – 5x10[illegible]	—
Volatile organic compounds (VOCs)	10[illegible] – 10[illegible]	—

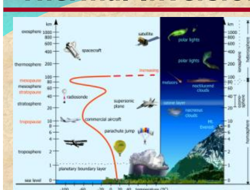
- ➢ Composition fluctuate with altitude and location
- ➢ Water vapor present usually 1%, can be high – 3%
- ➢ Carbon dioxide fluctuate with time of year and location
- ➢ Some gases are present in small amounts
- ➢ Play vital in absorption solar radiation

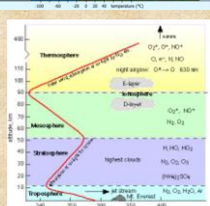
Earth Atmosphere - Composition



- ➢ Human being also changing composition of the atmosphere
- ➢ Results of these changes are not always predictable
- ➢ Therefore, we need to have a clear concept regarding pollution of the earth

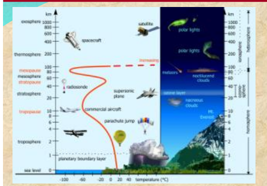
Thermal Inversion – Temperature variation

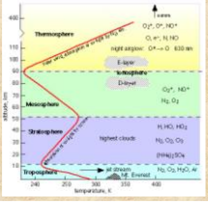




- ➢ Up to 10000 meters, temp. decrease with increasing altitude
- ➢ Temperature at ground is 20°C; - 60°C at 10000 m
- ➢ Above troposphere, temp. increase until 50000 meters through stratosphere
- ➢ Negative temp. gradient exists near earth

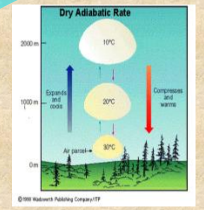
Thermal Inversion – Temperature variation

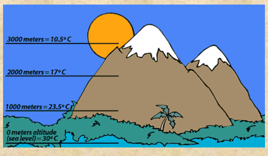




- It has important role for the dispersal of pollutants
- Due to warm air from machine or smokestack air move upward from ground till 10000 m
- No immediate problem at ground

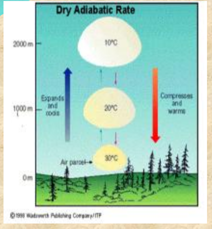
Thermal Inversion – Adiabatic Lapse Rate (ALR)

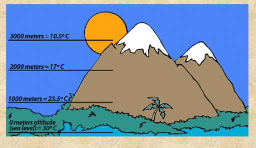




- Relationship between temp and altitude is determined by thermodynamic principles
- Temperature – altitude relationship at lower atmosphere is known as Adiabatic Lapse Rate (ALR)

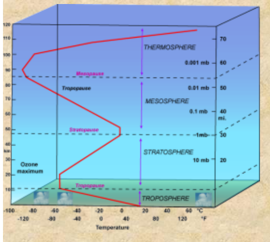
Thermal Inversion – Adiabatic Lapse Rate (ALR)





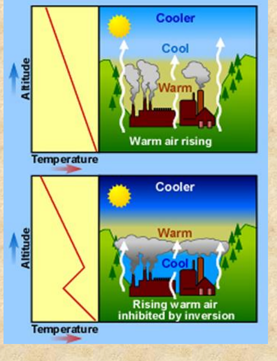
- Adiabatic means no heat energy gain or loss of some defined volume of gas
- Lapse indicates temp decreasing with increasing altitude

Thermal Inversion – Adiabatic Lapse Rate (ALR)



- If a warm air move upward
  - air will expand
  - Naturally temp decrease due to altitude
  - The loss of temp- dry air- -1°C/100m; wet air- -0.35°C/100m
  - Average ALR is -0.65°C/100m
- In simple: ALR is the rate at which the temp. of volume of gas will decrease naturally with altitude and vice-versa

Thermal Inversion – Thermal inversion process

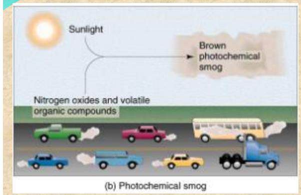


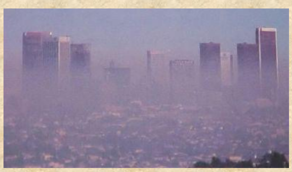
- Warm air will rise in the ambient cool air
- Due to ALR, the air at some point will be not warm respect to surrounding
- It will cease and will not rise
- In this case polluted air will not rise vertically and dispersed and trapped
- This condition is called thermal inversion

Thermal Inversion – Smog

- Smog is a kind of air pollution, originally named for the mixture of smoke and fog in the air
- Classic smog results from large amounts of coal burning in an area and is caused by a mixture of smoke and sulfur dioxide.

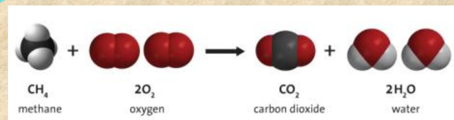
Thermal Inversion – Smog





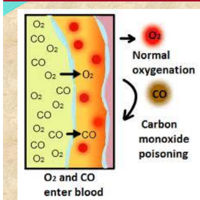
- Smog formed by the interaction of solar energy with the types of primary air pollutants emitted by automobiles and trucks

Pollutants – Carbon monoxide (CO)



- Most of the serious air pollution is produced – direct or indirect combustion of fuels
- Ideal reaction during burning fossil fuels as – Carbon (C) + Oxygen (O2) ⟶ Carbon dioxide

Pollutants – Carbon monoxide (CO)

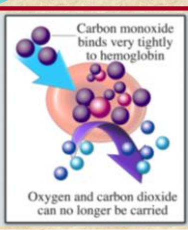


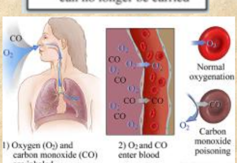
- Incomplete combustion of the carbon form carbon monoxide;
- $2\,C + O_2 \longrightarrow 2\,CO$
- This process take place when oxygen is insufficient to form carbon dioxide
- Source of CO is gasoline fueled internal combustion engine

Pollutants – Carbon monoxide (CO)

- Fuel burning under high pressure and temperature and lack of oxygen
- Carbon monoxide is colorless, odorless gas that is toxic at high concentration
- Its toxicity increase when combined with hemoglobin

Pollutants – Carbon monoxide (CO)





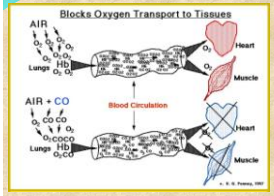
- It form carboxyhemoglobin
- Hemoglobin present in the red blood cells that carries oxygen to the tissues
- CO has more affinity to hemoglobin (200 times higher) than oxygen
- It block the normal distribution of oxygen in the blood

Pollutants – Carbon monoxide (CO)

- The effects of CO depends on the concentration and duration of exposure

Concentration (ppm)	Duration (hrs)	Cause
100	10	Headache, reduce ability to think
300	10	Nausea, loss of consciousness
600	10	Death
1000	4	death

Pollutants – Carbon monoxide (CO)



- CO – half life is 0.2 years
- Then it converted to Carbon dioxide with OH molecules in the tropopause
- Every year 290 millions ton's released to atmosphere

Talk outline

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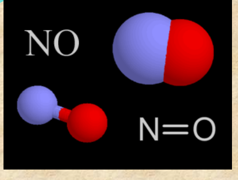
- The oxides of Nitrogen
- Hydrocarbon emission
- Sulfur dioxide
- Particulates as pollutants

Pollutants – Oxides of Nitrogen (1)

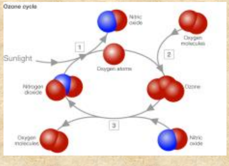


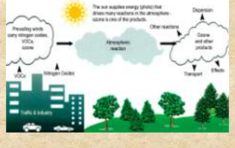
- Nitrogen-Oxygen mixture air is heated to over 1100 degree Celsius
- The N and O will combine to form Nitrogen oxide (NO)
- If the cooling process slow, the reaction will reverse and decompose back into N_2 and O_2

Pollutants – Oxides of Nitrogen (2)

- If cooling process is rapid in case of engine it will not decompose and will exhaust as NO
- Internal combustion of a engine will release 4000 ppm NO (if no control)
- Coal fired steam generator 200 to 1200 ppm of NO
- NO is less toxic than NO_2

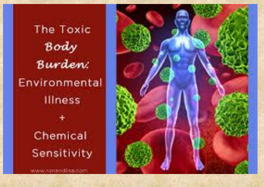
Pollutants – Oxides of Nitrogen (3)





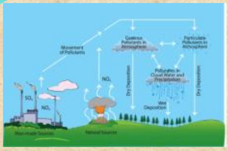
- NO is much more prevalent in engine combustion, NO_2 also produce
- However, NO react with ozone, O_3 and form NO_2
- After 10 hrs 50% of NO will convert to NO_2
- As NO_2 is more toxic than NO, therefore more importance for environment study

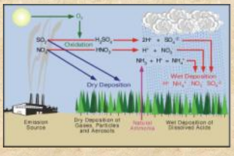
Pollutants – Oxides of Nitrogen (4)



- Sometimes NO and NO_2 together noted as NO_x
- NO is colorless , NO_2 is reddish brown gas
- NO_2 can be smelled at 0.5 ppm in the air and 5 ppm begins to affect respiratory system

Pollutants – Oxides of Nitrogen (5)





- 20 to 50 ppm- strong odor, eyes become irritated, damage to the lungs, liver and heart
- at 150 ppm-serious lung problems if 3-8 hrs exposure
- NO_2 in the atmosphere are converted to nitric acid in the presence of water (HNO_3)
- NO_x play important role in photochemical reaction to form smog NO_2+sunlight ⟶ NO+O

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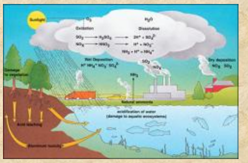
Pollutants – Oxides of Nitrogen (6)



- In this reaction ultraviolet and blue portions of the spectrum-absorbed
- Resulting atomic oxygen can react with O_2 to form O_3, $O+O_2 \rightarrow O_3$; $O_3+NO \rightarrow NO_2+O_2$
- This reaction cycle continues as sunlight present

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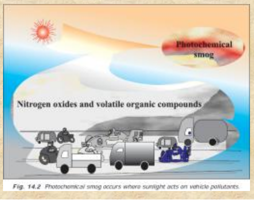
Pollutants –Hydrocarbon emission and photochemical smog (1)



- 60 Years ago in 1943 Los Angel experienced new kind of air pollution
- For several years nature and origin of this type pollution is mystery
- Finally A.J. Haagen-Smith and his colleagues solved the problem. However research continue till now

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Pollutants –Hydrocarbon emission and photochemical smog (2)

- Various hydrocarbons form strong oxidant such as ozone, O_3
- For photochemical smog- basic ingredients are sunlight, NO_2 and hydrocarbon
- Most of the NO_2 and HC are related to automobile emission
- In Los Angels air 56 different species of the HC observed

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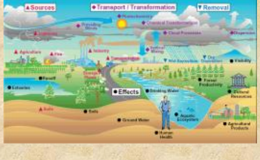
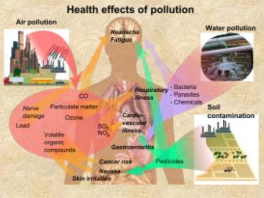
Pollutants –Hydrocarbon emission and photochemical smog (3)





- Various HC sources come from different sources
- Aromatic olefins, formaldehyde and acroleins that cause eye irritating
- Photochemical smog - chronic sinus trouble, bronchitis other respiratory problems also lung cancer and chronic pulmonary diseases
- Two plant diseases - smog injury and grape stipple

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Pollutants –Hydrocarbon emission and photochemical smog (4)

- Main sources - CO, NO, HC are sourced from petroleum powered transportation system, combustion engine automobiles
- Automobile is the main source of pollution
- 1970's automobiles - the main source
- Now decreased. Even the emission is toxic

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Pollutants – Sulfur dioxide (1)

- Sulfur is present in fossil fuels
- Sulfur dioxide is an important atmospheric pollutants
- when fossil fuels is burned -various compounds of sulfur converted to SO_2
- Colorless , nonflammable gas

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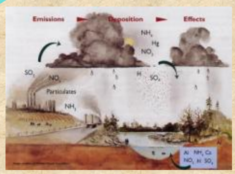
Pollutants – Sulfur dioxide (2)



- Major sources are stationary, coal and oil burning electric power plant
- Next are copper, zinc, lead industries
- 1/3 of the sulfur compounds come from man-made source
- Natural source of sulfur mainly decay of terrestrial and marine organic matter

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Pollutants – Sulfur dioxide (3)

- Present in the form of H_2S, converted to SO_2 in one or two days reacting with O_3
- SO_2 oxidized to form SO_3, which combine with moisture to form H_2SO_4 or sulfate salt
- Building material marble, limestone are severely affected by SO_2

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Pollutants – Sulfur dioxide (4)

- Various crops and trees suffer damage
- Before coal burning, coal washed with water and due to high density FeS_2 removed from solution
- It can be removed from the stacked gases after burning

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Pollutants – Particulates as pollutants (1)

- Particulates as pollutants is different from gaseous pollutants
- Particulate can be solid or liquid having certain size and chemical composition
- Aerosol is a solid or liquid matter suspended in the atmosphere

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Pollutants – Particulates as pollutants (2)

- Source : ocean spray, dust from fields, volcanic ash and forest fire
- Natural : 14 times higher than man made
- Man made particulates are emitted from high density populated area
- Fly ash and coal combustion

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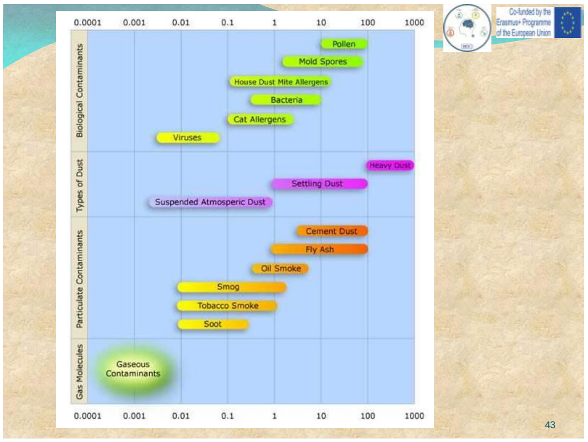
0.0001
0.001
0.01
0.1
1
10
100
1000
Biological Contaminants
Pollen
Mold Spores
House Dust Mite Allergens
Bacteria
Cat Allergens
Viruses
Types of Dust
Heavy Dust
Settling Dust
Suspended Atmosperic Dust
Particulate Contaminants
Cement Dust
Fly Ash
Oil Smoke
Smog
Tobacco Smoke
Soot
Gas Molecules
Gaseous Contaminants
Co-funded by the Erasmus+ Programme of the European Union
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