CB3

Report 2021

Education Package for Climate Change

Pre-university Education

Forward by H.E. Minister of Environment

The educational system with all its components is one of the pillars of achieving the transformation of the green economy, because the formation of personality and awareness is the driving force and capable of bringing about change in the patterns of sustainable production and consumption and creating cadres in all disciplines with values, ethical and scientific foundations that qualify them to protect and efficiently manage the available natural resources through modern technologies and tools based on the minds and national capabilities.

The partnership between the Ministry of Environment and the Ministry of Education and Technical Education in Egypt, especially in the field of environmental work, is extremely important, which the whole world has realized that natural resources and life on planet Earth will not be preserved without paying attention to the role of society, especially young people, so that future generations can deal with that complex and intertwined relationship between human activities and nature.

There are many new terms that have appeared on the scene during the past few years, such as the green economy, climate change and biodiversity, all of which refer to achieving the national goals of sustainable development, taking into account the rights of future generations to natural resources and ensuring the sustainability of their provision of the same environmental services. It is simplified and easy for students to realize the importance of preserving them. It also required the Ministry of Education to develop educational curricula and systems to keep pace with global developments and national challenges through a student who understands these issues and their repercussions and effects on his life and the importance of his role in addressing these issues and the impact of each behavior he follows on the sustainability of life.

I expressed my happiness in producing such educational packages, which will greatly contribute to the development of environmental affiliation in the hearts and minds of new generations, and I would like to thank the Center for the Development of Educational Curricula, which has adopted this topic since its inception.

Her Excellency Dr. Yasmine Fouad

Minister of Environment

Forward by H.E. Minister of Education and Technical Education

The Ministry of Education and Technical Education is constantly striving towards developing education in Egypt and providing distinguished community services in all aspects of the basic education system, including students, teachers, supporting bodies, principals and classes. The ministry also aspires to create an enabling environment for students and teachers that allows them an update about the latest developments in international, regional and national issues and participate in confronting them.

Environmental issues are at the forefront of these issues, especially the problems related to climate change, biodiversity and desertification. Fruitful cooperation with the Ministry of Environment culminating in the production of three educational packages that address the teachers and provide them with basic information, extracurricular activities, community based messages, and illustrations, including videos, articles, and power-point presentations with audio recordings regarding the aforementioned issues.

We hope, through such effort, to achieve the desired goals of boosting awareness of teachers and students about environmental problems and their solutions, and providing information based on comprehension rather than memorizing. We hope that this will be reflected into change in societal behavior towards preserving natural resources, reducing pollution, and working to conserve the nature that God has endowed us with.

With my sincere thanks to everyone who contributed to these outcomes, and my best wishes for a better future for our dear country and our great peoples.

His Excellency Professor Tarek Shawky

Minister of Education and Technical Education

Preface

For the sake of a new generation that has the right to a decent life,
For a new generation having the right to a fair share of the its country's natural resources,
For a new generation having the right to be secured against hunger, poverty, illiteracy and illness,
For the sake of a new generation that has the right to breathe clean air and enjoy a clean environment,
For new generations that will pay dues of coexisting with the thoughtlessness of previous generation,
For raising generations that will adopt the concepts of rational use of the natural resources that God has blessed us with, and
In support for enhancing our level of compliance with multi-lateral environmental agreements,

The Capacity Building Project (CB3) executed by the Ministry of Environment, and supported by the Global Environment Facility (GEF) and the United Nations Development Program (UNDP), presents this effort to enhance the capabilities of our teachers and provide them with further sources of knowledge and basic information regarding environmental issues, especially climate change, conservation of biological diversity, combating desertification and achieving environmental sustainability.

We are pleased to contribute to the efforts to establish environmental awareness and belief within the personality of school students under prospective of green transformation within the Egyptian society.

May God protect our country, and may God bless us all.

Ahmad Wagdy

Prof. of Hydrology, Engineering, CU
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Educational Package for Climate Change

This package is developed by
Integral Consult as part of the outputs of the project:

"Enhancing National Capacities for Improved Public Participation for Implementing Rio Conventions (CB3)"

funded by the Global Environment Facility (GEF) / United Nations Development Program (UNDP) and implemented by Ministry of Environment

Citation: Osama, A. [1], Eltouny, N. [1], Gouda, E. [1], Adel, M. [1], Mahmoud, L. [1], Elmenshawi, Y. [1], Akram, S. [1], Wagdy, A.[2.3], Saleh, S.[3], Omar, K.[3], and Sayed, A.[3] (2021). Educational Package for Climate Change. Enhancing National Capacities for Improved Public Participation for Implementing Rio Conventions Project (CB3)". Global Environment Facility (GEF) / United Nations Development Program (UNDP) and Ministry of Environment. Report 202111ES, English version, 150 pp.

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Educational Package for Climate Change

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1 MESSAGE 1: CLIMATE AND WEATHER

1.1 Background Information

Weather: Weather describes daily, weekly or monthly conditions of the atmosphere for a place. Atmospheric conditions consist of temperature, atmospheric pressure[1], relative humidity, precipitation, cloud coverage and wind[2], which are defined in Figure 1-1

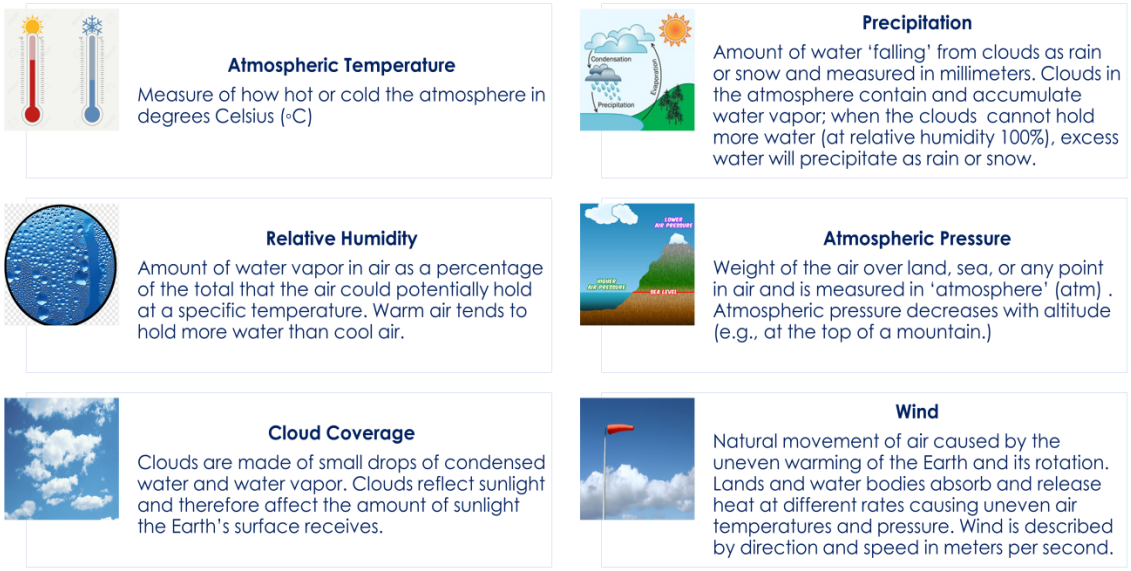


Figure 1-1: Definitions of key components characterizing weather conditions

Decreasing atmospheric pressure with increasing altitude, wind formation and a weekly weather forecast for Cairo[3] are shown in **Error! Reference source not found.** (a), (b), a nd (c) respectively.

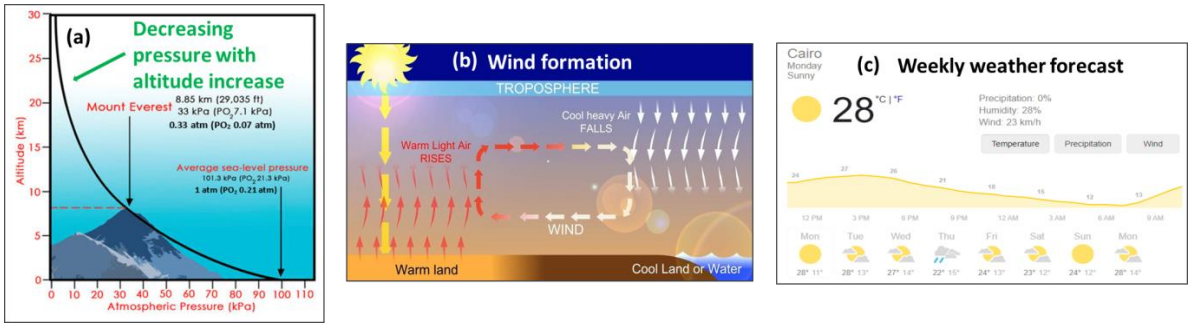


Figure 1-2: (a) Atmospheric pressure with altitude ((modified from reference[4]), (b) wind created by uneven heating Earth[5], and (c) weekly weather forecast for Cairo

[1]An atmosphere represents the average air pressure at sea level and at 15◦C. 1 atm corresponds to 1,013 millibars, or 760 millimeters of mercury.
[2] https://www.weatherwizkids.com/weather-wind.htm
[3] https://weather.com/weather/today/l/30.04,31.24?par=google&temp=c
[4]https://flexbooks.ck12.org/cbook/ck-12-middle-school-physical-science-flexbook-2.0/section/12.3/primary/lesson/air-pressure-and-altitude-ms-ps
[5] https://www.youtube.com/watch?v=Z1hHynbleB8&ab_channel=chrvojeengineering

Most weather occurs in the part of Earth's atmosphere closest to the ground, troposphere

Climate: Climate reflects the average weather conditions over a minimum of 30 years for a specific place. Overall climate for a location in time is described based on characteristics of the atmosphere (air), hydrosphere (oceans, seas, lakes), cryosphere (soils and rocks), land surface, and biosphere (living organisms). The climate of a place, describes what temperatures are like during different seasons, how windy it usually is, or how much rain or snow typically falls. The Köppen climate classification system categorizes different climate regions on Earth based on local vegetation into 5 zones as shown in Figure 1-3.

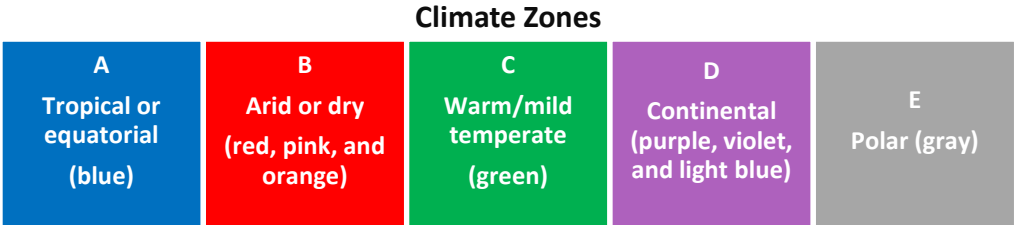


Figure 1-3: Earth climate regions based on the Köppen climate classification system

Climate regions categorized according to the Köppen climate classification system are shown in Figure 1-4.

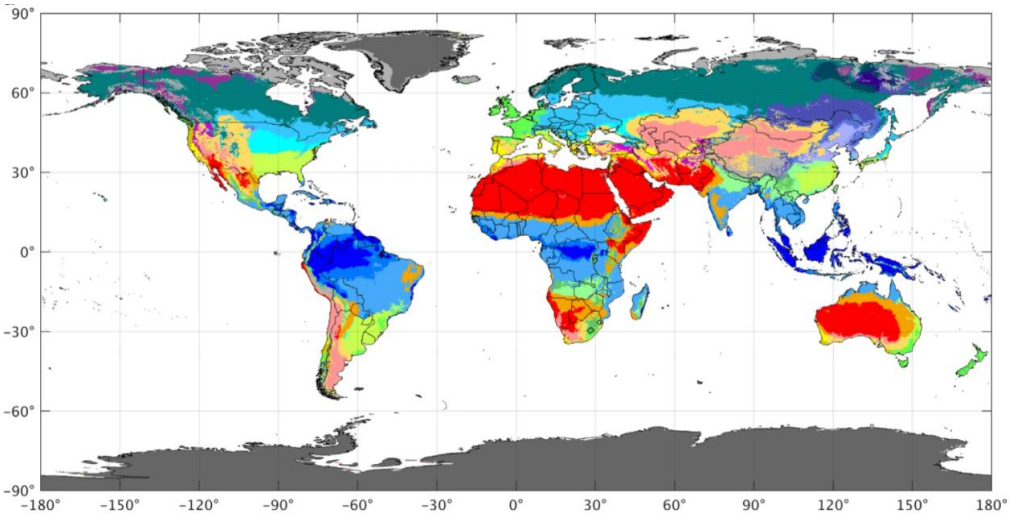


Figure 1-4: Köppen-Geiger climate classification map from 1980-2016[6]

Role of Earth's Rotation and Orbit Changes on Climate

The sun is a major influencer of weather and climates. The amount of sunlight depends on Earth's orbital movement. Earth circles the Sun in roughly 365 days at a rate of about 108,000 kilometers per hour! Earth's orbit defines a nearly circular 2-D plane; the ***ecliptic***. The eccentricity, which is a measure of the amount by which the orbit deviates from a circle

[6] Beck, H., Zimmermann, N., McVicar, T. *et al*. Present and future Köppen-Geiger climate classification maps at 1-km resolution. *Sci Data* **5,** 180214 (2018). https://doi.org/10.1038/sdata.2018.214 https://www.nature.com/articles/sdata2018214/figures/1

varies over about 100,000 years between slightly more or less elliptical (0.34% – 5.8%) as a result of gravitational attractions among the planets. Variations in eccentricity, among other factors, result in cycles of glacial(cold) and interglacial(warm) periods.

The Earth completes a full rotation around the sun every year on a tilted axis, which results in different areas receiving variable sunlight over the year and in different climatic zones [7] as shown in Figure 1-5a. Winter in the northern hemisphere occurs in December when the earth is in a position on the ecliptic where its axis is tilted such that the northern hemisphere is tilted away from the sun, thus in winter radiations from the sun are not perpendicular to earth's surface in the northern hemisphere.

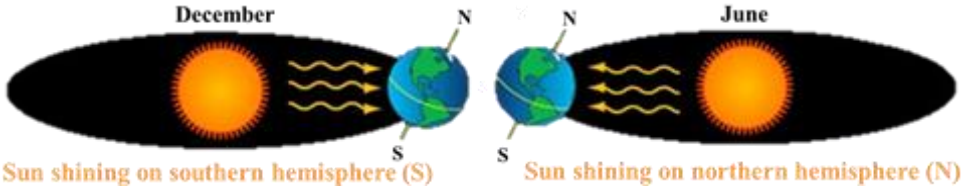


Figure 1-5a: Earth's tilting and revolving around the sun results in different seasons and climate

Angle of the Earth's axis relative to the ecliptic varies between 21.5 ° and 24.5 ° over a period of 41,000 years. Combined effect of the Earth's tilt and its orbital motion result in the seasons, Figure 1-5b. Greater tilt angle means more temperature difference between summer and winter! Tilt angle of the Earth's axis relative to the ecliptic currently at 23.5 °.

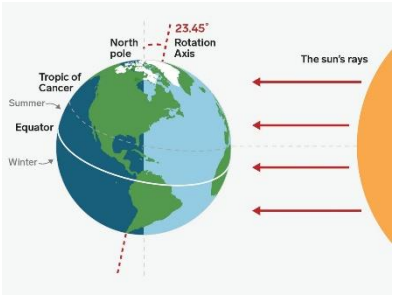


Figure 1-6b: Summer in N. Hemisphere

Orbital movements known as Milankovitch cycles induce natural changes in climate by affecting the amount of sunlight reaching Earth; the timescale of those impacts is on the thousands of year timescale. The three types of cycles are due to changes in the shape of Earth's orbit (eccentricity), the angle that Earth's axis is tilted with respect to Earth's orbital plane (tilt angle), and the direction of Earth's spin axis (wobble) as shown in Figure 1-7 (a). Earth's axis appears stable, but it actually wobbles very slowly, like a spinning top. It takes Earth's axis about 26,000 years to complete a circular "wobble." This wobble is called axial precession

Role of Oceans on Climate

An ocean current is a continuous, directed movement of sea water generated by a number of forces acting upon the water. Forces include wind, breaking waves, temperature and salinity differences. The current moves primarily horizontally across the Earth as shown in **Error! Reference source not found.** (b). The ocean absorbs and stores large amounts of e nergy coming from the Sun and releases it very slowly, which allows the oceans to stabilize global climates resulting in a major influence on weather and climate. Thanks to the very high value for the specific heat of water (water warms up slowly as it acquires a large

[7] https://spaceplace.nasa.gov/seasons/en/

quantity of heat from the sun in order to raise its temperature. Alternatively, water bodies cool down slowly during night releasing energy to surroundings).

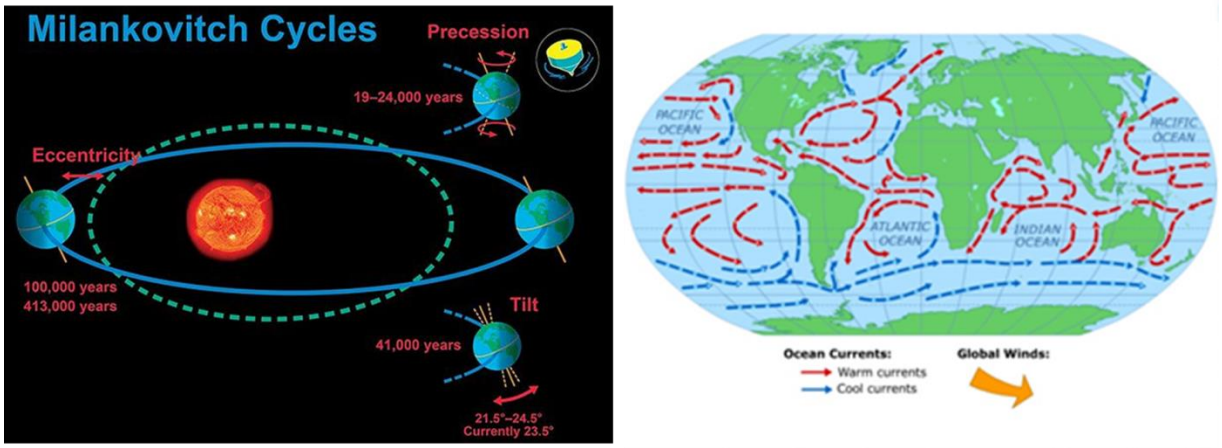


Figure 1-7: (a) The main elements of Milankovich cycles[8] Climate and (b) ocean currents[9]

In short, weather and climate are mainly characterized by conditions consisting of temperature, moisture in the air, i.e., relative humidity, rain and snow, i.e., precipitation, cloud cover and sunlight, and the weight of the air, i.e., atmospheric pressure. However, though weather and climate are related to each other, they are different. The main difference is the timespan.

[8] https://www.universetoday.com/39012/milankovitch-cycle/
[9] https://serc.carleton.edu/eslabs/climate/4a.html

1.1.1 Self-check/quiz

Weather is characterized by:

a) Temperature, atmospheric pressure, wind, relative humidity, wind, cloud coverage and precipitation (correct answer)
b) Milankovich cycles and ocean currents
c) Both a and b

The Koppen classification categorizes Earth into_____ and Egypt is in the ____zone

a) Five zones: polar, tropical, continental, temperate, and arid/dry zones; arid/dry (correct answer)
b) Four seasons: winter, spring, summer and fall; tropical
c) Five zones: polar, tropical, continental, temperate, and arid/dry zones; continental

The main difference between weather and climate is:

a) Climate changes on a time scale of days to weeks and months
b) Weather changes on a time scale of days to weeks
c) Climate changes on a long-term scale of more than 30 years
d) Both b) and c) (correct answer)

1.2 Illustrations of Concepts

Links to various material that can help engage the students and illustrate the concepts of the message are presented in Table 1-1.

Table 1-1: Various illustration aids for the concepts of climate and weather

Concept	Short description of illustration, diagram, video, online course	Reference, link
Elements of weather	The video describes the different elements of weather and how to measure them: temperature - precipitation – humidity – air pressure – wind – cloud	https://www.youtube.com/watch?v=3pPcVxmdC3I&ab_channel=RoseannBaney
Weather and climate	The video includes the definition of weather and climate and how this affects our activities	http://studyjams.scholastic.com/studyjams/jams/science/weather-and-climate/weather-and-climate.htm https://www.nationalgeographic.org/encyclopedia/koppen-climate-classification-system/ https://climate.nasa.gov/blog/2949/why-milankovitch-orbital-cycles-cant-explain-earths-current-warming/
Atmospheric pressure	Definition for atmospheric pressure and relationships to temperature, altitude, moisture	https://scienceexplorers.com/how-to-teach-kids-about-air-pressure/

Concept	Short description of illustration, diagram, video, online course	Reference, link
Difference between weather and climate	The video explains the differences between weather and climate and introduces briefly the concept of climate change and NASA's role in observing the climate	https://climatekids.nasa.gov/weather-climate/
Weather and Climate	Graphical representation of weather and climate and introduces the idea of climate change as well as hints of NASA's role in observing the changing climate	file:///C:/Users/enas.INTEGRAL/Downloads/weather-climate_poster.pdf
Why do we have different seasons?	Earth's tilting and revolving around the sun cause different weather and climate around the world	https://spaceplace.nasa.gov/seasons/en/ https://www.youtube.com/watch?v=nKTB9hFH6nc&feature=youtu.bdfEe&ab_channel=NASAeClips
Milankovich cycles	Earth's orbital changes-Milankovich cycles	https://climate.nasa.gov/blog/2949/why-milankovitch-orbital-cycles-cant-explain-earths-current-warming/
Earth's seasons	Earth orbit affect the amount of energy that the Earth receives from the sun and accordingly different temperature (seasons).	https://spaceplace.nasa.gov/seasons/en/ https://www.sciencemag.org/news/2019/05/500-million-year-survey-earths-climate-reveals-dire-warning-humanity
Factors that affect climate change – Earth orbit the sun	Hands-On Activity: Reasons for the Seasons	sdo.gsfc.nasa.gov/assets/docs/Book2_resources.pdf https://climate.ncsu.edu/edu/Composition

1.3 Student Engagement Activities

1.3.1 Activity 1

Objective: The objective of this experiment is to measure and collect atmospheric temperature every day for a month for different areas across Egypt and demonstrate trends and variability (by day and region.)

Materials: one outdoor thermometer and access to internet for research.

Procedure:

A- Classroom activity

1. Demonstrate to students on safe use and reading of a thermometer
2. Select location for daily measurements
3. Place outdoor thermometer at the same location and at the same time everyday
4. Collect the reading for the outside air temperature using Table 1-2

5. Describe the presence or absence of sun, cloud, and/or precipitation (rain/snow etc.)

Discussion questions: Do weather conditions vary from day to day for a specific location? If yes, how (i.e., do temperature, sun, cloud coverage, precipitation increase, decrease, or remain the same?)

Table 1-2: Template for reporting and comparing weather conditions

Location	**Date**	**Time**	**Temperature (◦C)**	**Sun** (yes/no/partial)	**Cloud coverage** (yes/no/partial)	**Precipitation (mm)**

1.3.2 Activity 2

Objective: The objective of this exercise is to distinguish between characteristics of weather and climate.

Materials: paper and 12 flash cards with information in the answered table

Procedure: Place the right flashcard in the right box of the empty table

Point of comparison	**Weather**	**Climate**
Definition		
Components		
Variability		
Forecasting		
Duration		
Science		

Correct answers:

Point of comparison	**Weather**	**Climate**
Definition	Day-to-day condition of the atmosphere, and its variation over a short period, ranging from minutes to days to weeks.	Long term and average atmospheric conditions/patterns for a specific place, over a minimum of 30 years
Components	Day-to-day atmospheric conditions include temperature, atmospheric pressure, relative humidity, precipitation, wind, clouds	Average atmospheric pressure, precipitation, temperature, humidity, sunshine, wind types, speeds and direction, fog, frost, and storms over a long period of time

Forecasting	Hourly, daily, and weekly measurements of atmospheric conditions (temperature, humidity, cloud cover, wind speed, etc.)	Measurements and analysis of atmospheric conditions over a long period of time (e.g., 30 years or more)
Duration	Short-term: hourly, daily and weekly	Long term: more than 30 years
Science	Meteorology	Climatology

2 MESSAGE 2: EARTH'S CLIMATE HISTORY

2.1 Background Information

2.1.1 Earth's Climate History

Earth's history spans over 4.6 billion years, which are divided into units of time called eons, eras, periods, epochs, and ages. The main eras of the Earth's history are Archean, Proterozoic, Paleozoic, Mesozoic, and Cenozoic eras as illustrated in Figure 2-1. The Cenozoic Era began ~ 66 million years ago and extends to the present day.

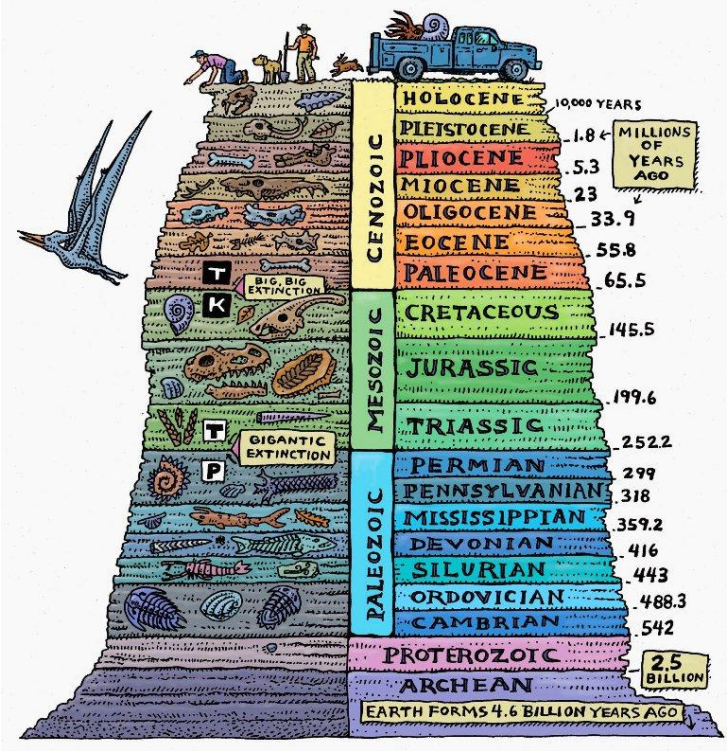


Figure 2-1: Earth's geochronological time scale[10]

Paleo climatologists define and analyze past climates and patterns through geotechnical methods including written records on several geologic features that go back to hundreds and thousands of years. These historical records help humans understand how the Earth's climate has changed over time, why these changes happened, and whether these changes are part of the Earth's natural cycles or are induced by human activities.

Tree rings: are used by scientists to study and understand the Earth's past climate. This field of science is called dendrochronology. Scientists use tree rings to measure the age of a tree and understand the local climatic conditions the tree was exposed to during its lifetime. During growing season of the trees, the trunk grows in a thicker layer of new wood called a tree ring; the differences in the color of the wood between the rings signify different growth years. Early in the growing season, trees grow relatively fast and produce less-dense

[10] http://www.geologyin.com/2016/12/10-interesting-facts-about-geological.html

and pale wood. At the end of the growing season, they produce denser, darker wood. Narrow rings may signify poor growing conditions caused by climate stressors such as droughts. Studying certain chemicals in the wood can provide information on precipitation and temperature patterns[11]. Figure 2-2 shows an example of a tree ring analysis.

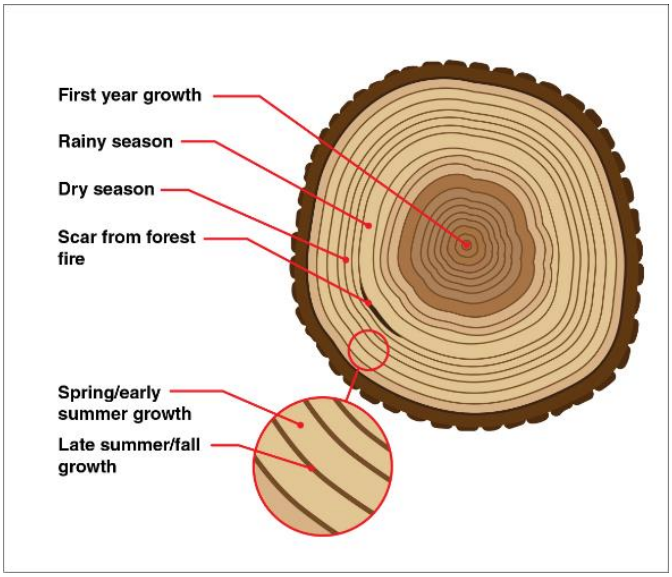


Figure 2-2 Example of tree rings analysis (Source: Science news[12])

Glacial ice cores: are core samples that are extracted from an ice sheet or a high mountain glacier that represents the annual buildup of layers over the years. Cores are drilled manually for shallow core sample or using power drills for deep core samples as shown in Figure 2-3. Analysis of the particles in each layer provide information about the past climatic conditions as they remain in the ice thousands of years later, showing physical evidence of events such as volcanic eruptions. As the ice layers compacts over time, tiny air bubbles are formed which can determine the types and concentrations of atmospheric gases such as carbon dioxide and methane, which affect climate. A sample of an ice core and preliminary analysis is shown in Figure 2-3.

[11] https://sites.google.com/site/drnormanherr/CSCS-Activities/cscs-investigations---biology/tree-rings-climate

[12] https://www.sciencenews.org/article/tree-story-book-explores-what-tree-rings-can-tell-us-about-past

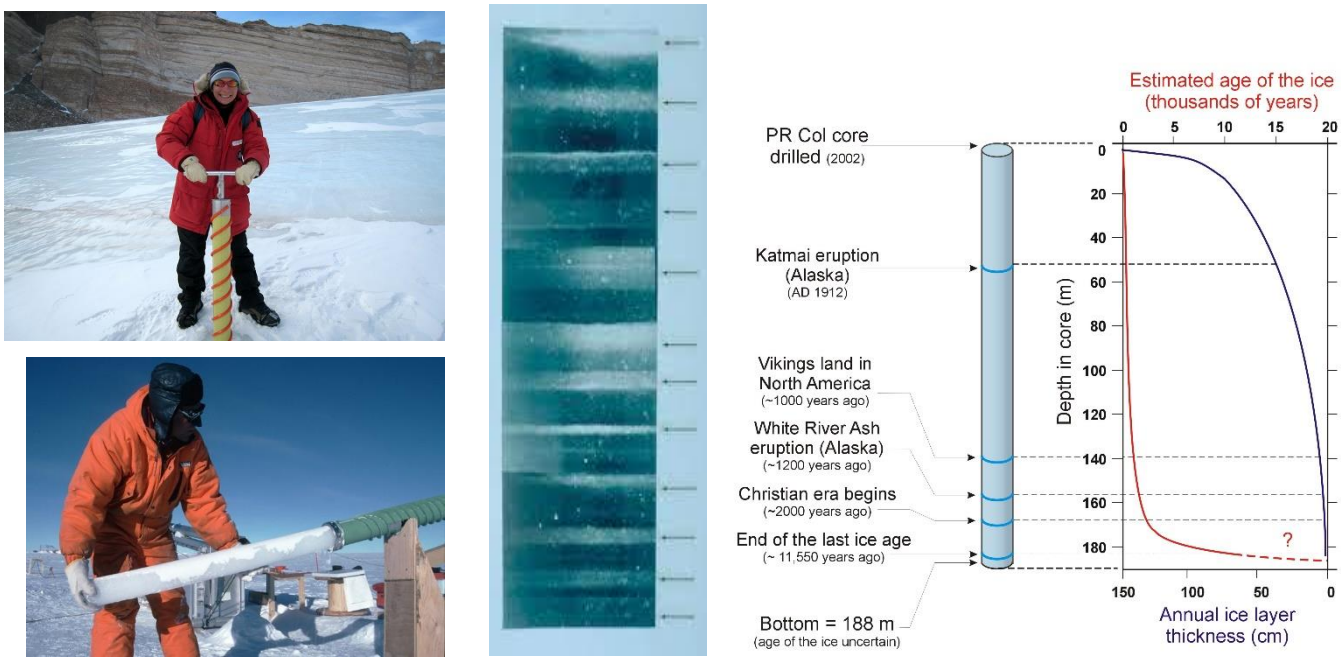


Figure 2-3 Ice cores extraction and analysis (srouce: climate.nasa and Natural Resources Canada)

Pollen and fossil analysis of sediments and rocks: pollen grains are distinctive for every plant class and are often found preserved in sediments (e.g., soil, sand, and volcanic matter), in addition to bones and remains (fossils) of human and animal species found in sediments and rock formations. Therefore, composition and sedimentation rates change based on local environmental conditions. Studying the fossils and pollens indicate the type and age of species that were available in the past[13]. Example of sediment samples and some types of pollen grains found within its different layers are presented in Figure 2-4.

[13] https://www.britannica.com/science/fossil-record

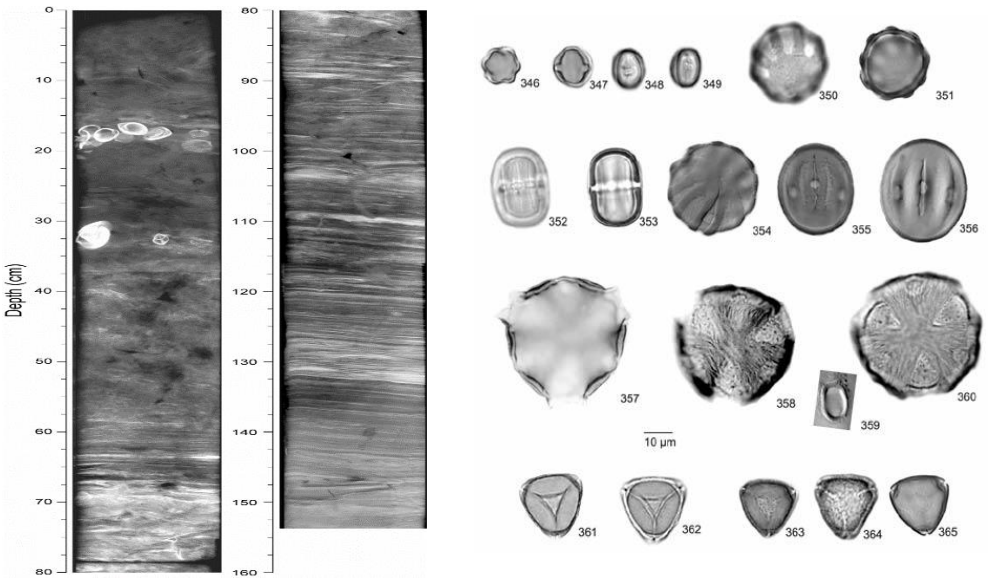


Figure 2-4 Left: Sediments core sample showing the deposited layers and fossils and pollens preserved in them. Right: examples of the shapes of different pollen grains found in sediments (source: NIWA NZ[14])

Figure 2-5 Example of rocks deposited layers over the years, and bones and fossils preserved in them (Source: Encyclopedia Britannica)

Earth's Atmospheric Composition: The present atmosphere is composed of 78% nitrogen (N_2), 21% oxygen (O_2), Argon 0.9% and 0.1% trace gases (very small amounts.) Trace gases include carbon dioxide (CO_2), nitrous oxides (N_2O), methane (CH_4), and ozone (O_3) among others. Water vapor is also present in the atmosphere varying between 0-4% depending on the location. Earth's atmospheric composition has varied over its history; variations are shown in Figure 2-6. For a long period of time (more than 2.5 b years, the earth's atmosphere was anoxic (with no Oxygen) allowing only anaerobic organisms to prevail. A remarkable milestone in earth's history happened when cyanobacteria (which are still existing) started performing photosynthesis absorbing CO_2 and releasing O_2 as a byproduct of its respiration to the atmosphere. Current O_2 levels in the atmosphere were not achieved until recently (about 500 million years ago)

[14] https://niwa.co.nz/climate/faq/how-do-we-determine-past-climate

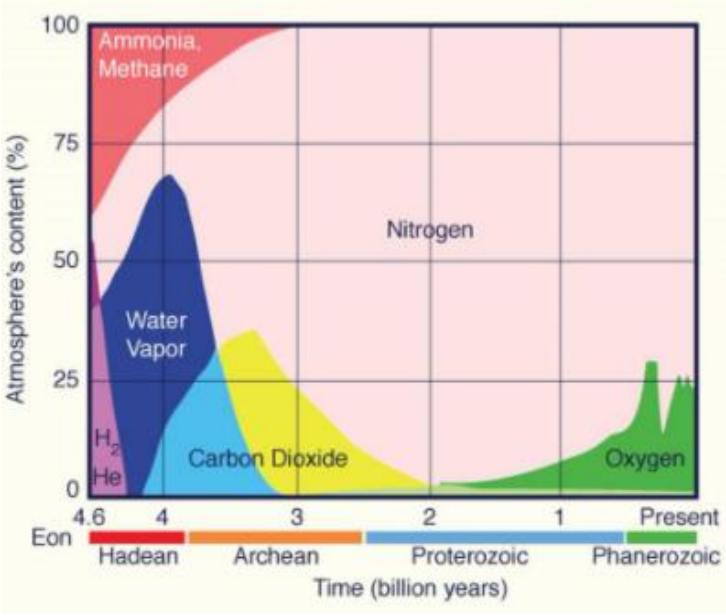


Figure 2-6: Composition of the Earth's atmosphere through geologic time[15]

Glacial and Interglacial Cycles: Over the course of its history, Earth's climate has undergone major changes during cycles known as glacial and interglacial periods. A glacial period is a cold period where the Earth's continental ice sheets grow and expand resulting in colder temperatures. For example, 600 and 800 million years ago during the Proterozoic period, Earth underwent an ice age, where ice sheets in polar regions reached sea level near Egypt[16] (**Error! Reference source not found.** a) An interglacial period is a warm period w here the ice sheets shrink, leading to a warmer temperature. The Earth is currently in an interglacial period, the Holocene period, which began 20,000 years ago[17]. For example, 54 and 48 million years ago during the Eocene period, high volcanic activity released high amounts of CO_2 causing Earth's global temperatures to increase[18,19](**Error! Reference s ource not found.Error! Reference source not found.** b).

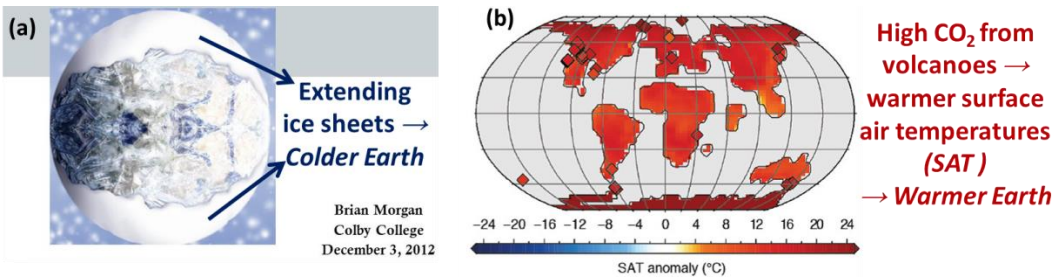


Figure 2-7: Earth's temperature in the (a) Proterozoic and (b) Eocene periods

Climate and Mass Extinction Events: Climatic conditions define the type of species and ecosystems that can be sustained on Earth. The widespread, rapid, and sharp decline in the biodiversity on Earth at a rate faster than the rate of reproduction or reconstruction of

[15] http://ponce.sdsu.edu/plants_and_animals.html
[16] https://www.climate.gov/news-features/climate-qa/whats-hottest-earths-ever-been, accessed 28/12/2020
[17] Haywood, A.M. et al. (2019). What can Palaeoclimate Modelling do for you?. Earth System Environment. Vol (3), pp 1:18.
[18] https://www.ncdc.noaa.gov/global-warming/early-eocene-period, accessed 28/12/2020
[19] https://wordybirdsci.com/tag/larsenc/

species or ecosystems is defined as mass extinction events. Major climatic changes such as the ice ages (glacial periods) and warmer periods (interglacial periods) are the primary drivers for mass extinction events of species and ecosystems. In the last 540 million years, Earth experienced 5 to 20 mass extinction events; the five major extinction events are highlighted in the sharp spikes in Figure 2-8 and Table 2-1[20].

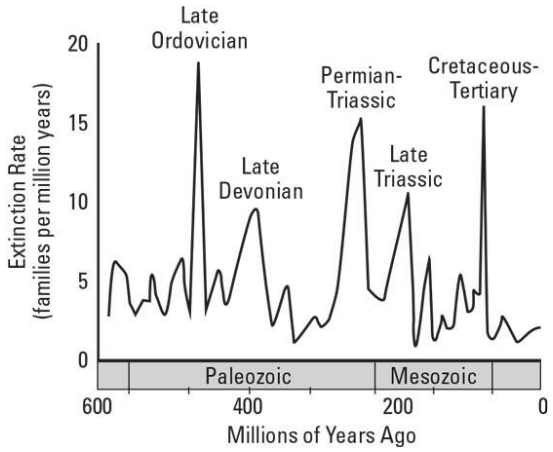
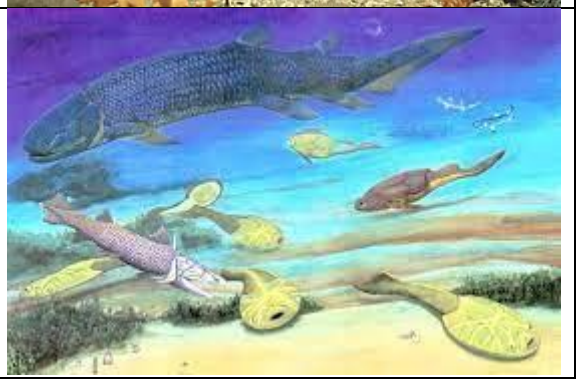
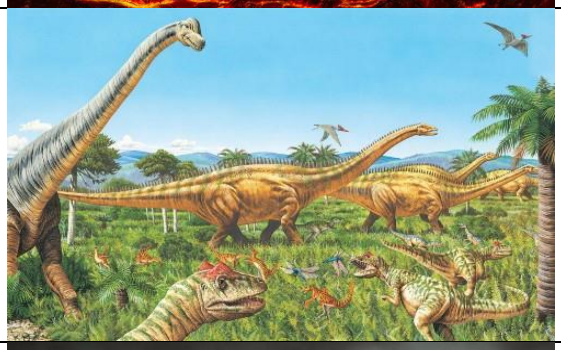


Figure 2-8: Major mass extinction events in Earth's history[21]

Table 2-1 Description of the five major mass extinction events

Extinction	Description	Illustrative images
Late Ordovician 440 million years ago in the Paleozoic Era	Massive glaciation locked up water in ice caps that covered huge parts of the south polar land mass, resulting in reducing marine oxygen level causing wipeout of small marine organisms.	
Late Devonian 365 million years ago in the Paleozoic Era	Many tropical marine species and reef-building creatures went extinct as oxygen levels dropped drastically, and invasive species dominated.	

[20] https://www.nationalgeographic.com/science/article/mass-extinction
[21] https://www.dummies.com/education/science/major-extinction-events-in-earths-history/

Permian-Triassic 250 million years ago in the late Paleozoic Era	The largest mass extinction event in Earth's history caused by massive volcanic eruptions and it affected a wide range of species, including many vertebrates. 96 percent of all marine species and about 3/4 species on land died out	
Late Triassic-Jurassic 210 million years ago in the Mesozoic Era	The sudden extinction of about 80 percent of all land and marine species allowed dinosaurs to strive and flourish.	
Cretaceous-Tertiary 65 million years ago in the late Mesozoic Era	Most recent mass extinction caused by a major asteroid impact. It wiped out non-avian dinosaurs, and between 50-70 percent of plants and animals. It is considered a major turning point in Earth's history as it marked the end of the Cretaceous geologic period and the beginning of the Tertiary period.	

In short, over the course of 4.6 billion years of history, Earth's atmospheric composition and climate have undergone various changes going from anoxic environment to an oxygen and nitrogen rich one and from extreme cold glacial periods to warmer interglacial periods affecting the type of life and species sustainable on Earth; extreme changes have driven several mass extinction events.

2.1.3 Self-check/ quiz

The scale that captures the Earth's history, and is divided into units of time called eons, eras, periods, epochs, and ages is called:

a. The Earth's budget
b. The Earth's geological time scale (correct answer)
c. The Earth's mass extinction
d. Paleoclimatology

The Earth's climate has undergone major changes due to:

a. Glacial periods (ice age)

b. Mass extinction
c. Interglacial periods
d. a and c (correct answer)

Mass extinction events are defined as ____, and have been associated with major climate change events such as _____, with ____ major events over the past 500 million years

a) the migration of animals from one continent to another, changes in global surface temperatures, 2
b) the widespread, rapid, and sharp decline in the biodiversity on Earth at a rate faster than the rate of reproduction or reconstruction of species or ecosystems, shorter life span of species, 3
c) the widespread, rapid, and sharp decline in the biodiversity on Earth at a rate faster than the rate of reproduction or reconstruction of species or ecosystems, large changes in global surface temperatures, 5 (correct answer)

2.2 Illustrations of Concepts

Links to various material that can help engage the students and illustrate the concepts of the message are shown in Table 2-2.

Table 2-2: Various illustration aids for the concepts of Earth's climate throughout history

Concept	Short description of illustration, diagram, video, online course	Reference, link
Ice Age	Video telling us interesting and mysterious facts about ice age.	https://youtu.be/Gf_xE59hzk4
Early Eocene period	Talks about Earth's climate 48 million years ago example of interglacial time	https://www.ncdc.noaa.gov/global-warming/early-eocene-period
Proterozoic Glacial	Example of Earth's glacial time	https://www.climate.gov/news-features/climate-qa/whats-hottest-earths-ever-been
Mass Extinction	Short film explaining how dinosaurs got extinct.	https://www.biointeractive.org/classroom-resources/day-mesozoic-died https://www.nationalgeographic.org/media/age-earth/
The 5-mass extinction	Poster	https://www.biointeractive.org/sites/default/files/media/file/2019-08/mass-extinctions-2015-poster.pdf

2.3 Student Engagement Activities

2.3.1 Activity 1

Objective: the objective of this activity is to understand and link variability in Earth's atmospheric composition and surface temperature, and extinction events over time.

Materials: Reporting form for describing climate, Figures within Message 2.

Procedure: Divide the class into groups and each group should pick a period and describe the climate in terms of top 3 most abundant gases in the atmosphere, average surface temperature, and extinction events, where applicable in Table 2-3.

Table 2-3: Reporting form for describing climate

	Period – Era-Earth age	**Atmospheric Composition CO_2, O_2, N_2, H_2O vapor, CH_4, H_2 and other (%)**	**Average surface temperature (◦C)**	**Mass extinction events (Yes/No)**
Team 1	Hadean			
Team 2	Archean			
…	Proterozoic			
	Paleozoic			
	Mesozoic			
	Cenzoic			

2.3.2 Activity 2

Objective: the objective is to illustrate Earth's long history and major events.

Materials: ruler, paper, pencils, colored pencils/markers or colored paper for each era (blue, red, green, yellow), scissors, tape.

Procedure:

1. Divide the students into 4 teams- each team would select one era
2. Use the ruler to measure out each era
3. Divide each era according to the time and scale shown in Table 2-4
4. List the major event corresponding to the time
5. Connect completed eras to another to build Earth's geological time using tape

Table 2-4: Major events in Earth's geological time[22]

Time	**Scale**	**Major Event**	**Era**
Today	0 cm	The Present	**Cenozoic Era (write in blue)**
~ 100,000 ya	0.1 mm	Homo Sapiens (Modern Form of Human Species)	
~ 22 mya	2.2 cm	Grasses	
~ 33 mya	3.3 cm	First Apes	
~ 50 mya	5 cm	Eohippus (First Known Horse)	
65 mya	6.5 cm	**Cenozoic Era**	
~ 65 mya	6.5 cm	Dinosaurs Extinction	**Mesozoic Era (write in red)**
~ 140 mya	14 cm	First Flowering Plants	
~ 200 mya	20 cm	Earthworms	
~ 220 mya	22 cm	First Mammals	
~ 240 mya	24 cm	Start of the age of dinosaurs	
248	24.8 cm	**Mesozoic Era**	

[22] http://www2.mbusd.org/staff/pware/pdf/GeologicalTimeline.pdf

Time	Scale	Major Event	Era
~ 330 mya	33 cm	Winged Insects	**Paleozoic Era (write in green)**
~ 380 mya	38 cm	First Insects	
~ 390 mya	39 cm	First Sharks	
~ 395 mya	39.5 cm	Amphibians	
~ 400 mya	40 cm	Ferns	
~ 440 mya	44 cm	First Land Plants	
~ 440 mya	44 cm	First Jawed Fish	
540 mya	54 cm	**Paleozoic Era**	
~ 550 mya	55 cm	Jellyfish	**Precamberian Time (write in orange)**
~ 1.8 bya	1 m 8 cm	First Eukaryotes	
~ 2.4 bya	2 m 40 cm	Significant rise in oxygen, to ~2% level	
~ 3.5 bya	3 m 50 cm	Prokaryotes (bacteria)	
~ 4.6 bya	4 m 60 cm	Formation of Earth and Moon	
4.6 bya	4 m 60 cm	**Precamberian Time**	

3 MESSAGE 3: HEAT TRANSFER MECHANISMS

3.1 Background Information

3.1.1 Heat Transfer Mechanisms

The climate system is regulated by the balance between the energy received from the sun and the outgoing energy from Earth. Some of the energy received from the sun is reflected by the Earth's atmosphere back into space, and the rest goes through the atmosphere and interacts with the Earth's surface, including land, rocks, oceans, clouds, gases and particulates in the atmosphere. This energy provides the needed heat to warm the Earth as shown in Figure 3-1. A considerable amount of heat is absorbed during daytime by oceans and seas to warm it up.

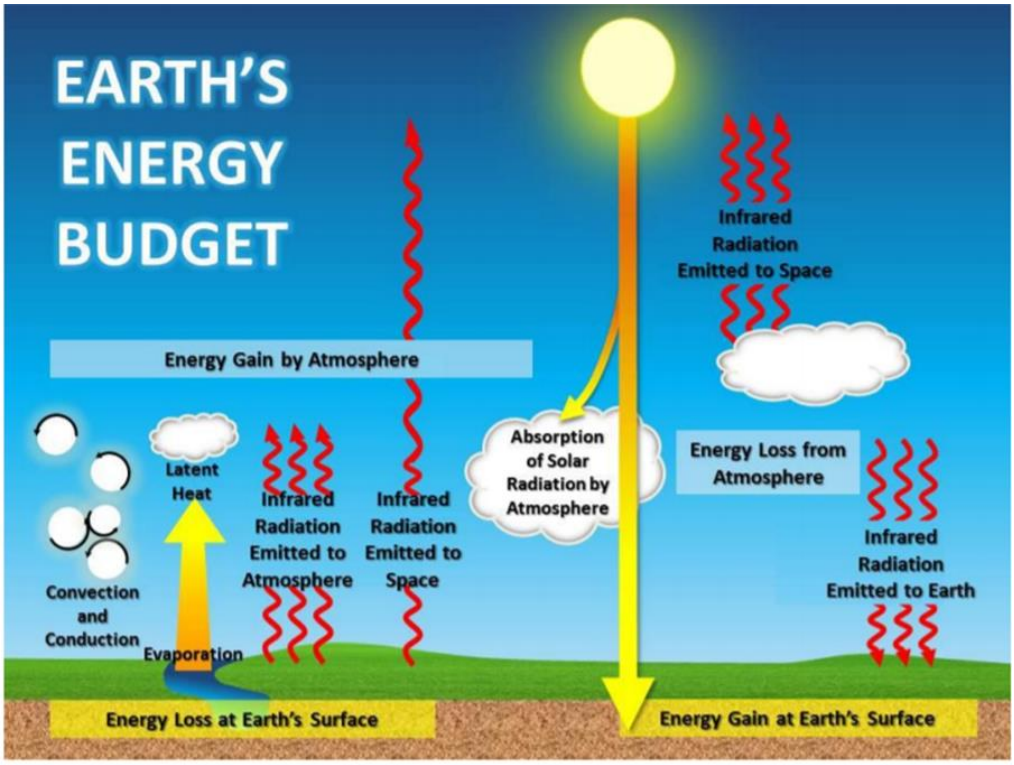


Figure 3-1: Heat transfer mechanism contributing to Earth's energy budget[23]

Heat Transfer Mechanisms: There are three main mechanisms of heat transfers, responsible for conveying energy from sun to earth then distributing it across the earth (**Error! Reference source not found.**.). If you touch a hot boiler pot your figure gets b urnt because a large quantity of heat is transferred to your skin by *conduction*. If the pot is filled with water and place over a burner, all the water will experience a raise in temperature although the burner is in contact with the lower layer of water only. Heat is distributed by *convection* within the water pot (hot water rises and cold water sinks). An electric heater (using a hot coil) at the far corner of the room will make you feel warm because heat is transferred through the air by radiation (electromagnetic waves).

[23] http://www.ces.fau.edu/nasa/module-2/energy-budget.php

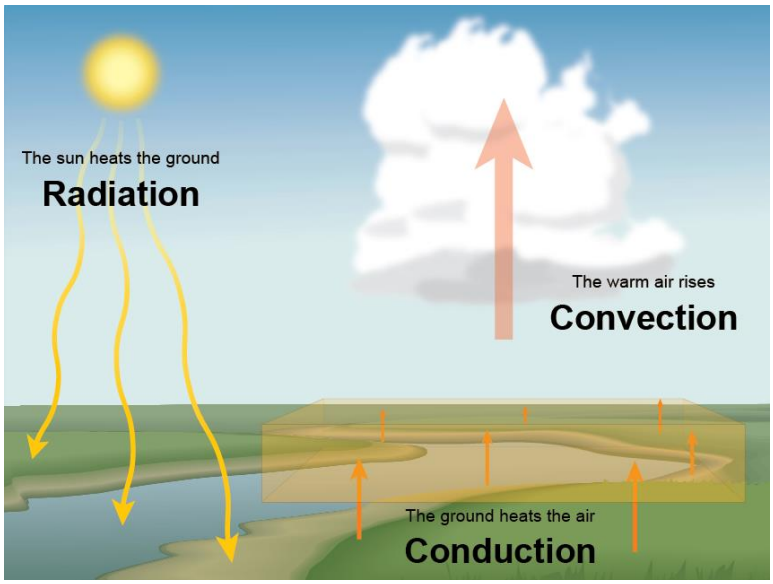


Figure 3-2: Heat transfer mechanisms driving the climate system[24]

1. **Radiation**: the mechanism by which the sun's energy travels through vacuum then through the atmosphere and reaches Earth, and the mechanism by which Earth's surface reflects some of the absorbed energy back into space (or to the atmosphere).
2. **Conduction**: it is the direct transfer of heat from a warmer substance to a cooler substance, which is the mechanism by which lands and oceans spread the heat received by the sun into the adjacent layer of the atmosphere. The heat energy transfers when molecules collide with each another. Therefore, conduction occurs where air is in direct contact with the surface (e.g., land or water).
3. **Convection**: it is the transfer of heat in a fluid, either gas or liquid, which is the mechanism by which heat is transferred in the atmosphere or in bodies of water. Heat transfers from hotter to cooler parts of the fluid. For example, as air warms near the surface, it expands and becomes less dense than the layers of air above, so it rises. As it cools, its density increases and it descends, as illustrated in Figure 3-3. Without the merit of convection, lands and water bodies around the equator would have experienced very high temperatures, not suitable for living, while areas near the poles would have been extremely cold and also unsuitable for sustaining life forms that we know. Solar energy received by radiation is unevenly distributed over Earth, because the Sun heats equatorial regions more than polar regions. The atmosphere and ocean work non-stop to even out solar heating imbalances through evaporation of surface water, convection, rainfall, winds, and ocean circulation.

[24] https://scied.ucar.edu/conduction

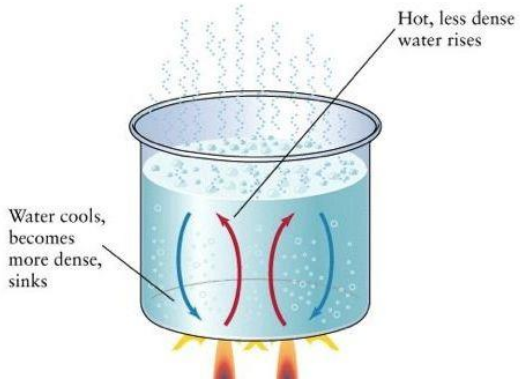


Figure 3-3: Example of heat transfer by convection[25]

The role of Oceans in Heat Transfer: The ocean has a major role in stabilizing Earth's climate system as it can absorb and release large amounts of heat over long periods of time. Waves, tides, and currents are responsible for constantly shifting heat from warmer to cooler latitudes and to deeper levels where heat eventually melts ice caps, evaporates surface water, or reheats the atmosphere. The heat energy of the ocean increases if it stores more heat than it releases which directly affects the global climate[26]. A map illustrating warming of the ocean in terms of heat content and shown by the red shades over the period of 1993-2019 is shown in Figure 3-4.

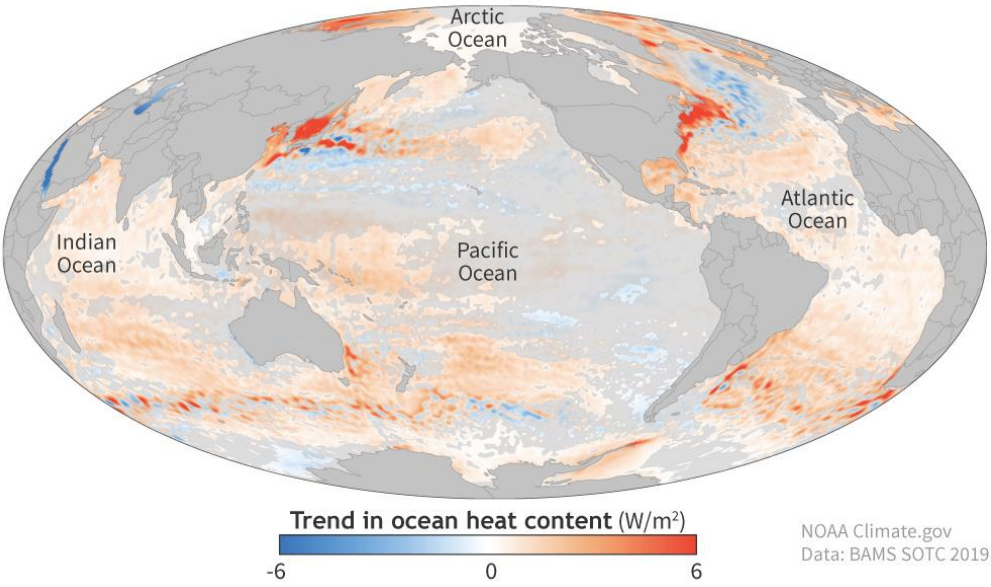


Figure 3-4: Change in ocean heat content from 1993-2019[27]

In short, there are three main mechanisms of heat transfers, responsible for conveying energy from sun to earth then distributing it across the earth; radiation describes how the sun's energy travels through vacuum and then through the

[25] https://studiousguy.com/examples-convection-everyday-life/
[26]https://www.climate.gov/news-features/understanding-climate/climate-change-ocean-heat-content#:~:text=Not%20only%20does%20water%20cover,in%20stabilizing%20Earth's%20climate%20system.
[27] https://www.climate.gov/news-features/understanding-climate/climate-change-ocean-heat-content

atmosphere reaching Earth's surfaces (e.g., lands and oceans.) Conduction describes direct heat transfer from oceans and lands into the adjacent layer of the atmosphere. And, convection, describes how heat is transferred in the atmosphere or in bodies of water.

3.1.2 Self-check/quiz

What is the term that describes the fluid motion of hot air rising or cool air sinking?

a) Conduction
b) Radiation
c) Convection (correct answer)

The sun releases energy into space through:

a) Conduction
b) Radiation (correct answer)
c) Convection

When sunlight heats the ground, which in turn heats the air directly above it, this is an example of?

a) Conduction (correct answer)
b) Radiation
c) Convection

3.2 Illustrations of Concepts

3.2.1 List of materials and links for more illustrations

Links to various material that can help engage the students and illustrate the concepts of the message are shown in Table 3-1.

Table 3-1: Various illustration aids for the concepts of heat transfer mechanisms

Concept	Short description of illustration, diagram, video, online course	Reference, link
Heat Transfer (Conduction, Convection, Radiation)	Video explains the three heat transfer methods and showing an example for each method.	https://www.youtube.com/watch?v=kNZi12OV9Xc
Heat Energy	Video explains heat energy and presents facts about heat energy. There is also a mini quiz about the video.	https://study.com/academy/lesson/what-is-heat-energy-facts-calculation-quiz.html
Heat transfer mechanisms	Self-check quiz on heat transfer mechanisms	https://www.proprofs.com/quiz-school/quizshow.php?title=heat-transfer-convection-conduction-radiation&q=1

Concept	Short description of illustration, diagram, video, online course	Reference, link
		https://study.com/academy/practice/heat-transfer-quiz-worksheet-for-kids.html https://study.com/academy/practice/quiz-worksheet-common-mechanisms-of-heat-transfer.html http://www.ces.fau.edu/nasa/images/Energy/EnergyTheDriverOfClimate.pdf
Heat transfer by radiation	Student activity (experiment)	https://www.esrl.noaa.gov/gmd/education/info_activities/pdfs/LA_radiation.pdf
Heat transfer in the context of climate science	Academic overview on the fundamentals of climate science	http://www.ces.fau.edu/nasa/images/Energy/EnergyTheDriverOfClimate.pdf
Heat transfer in the context of climate science	Academic overview on the transfer of the Sun's Energy through Earth's Systems with illustrations and suggested additional readings and sources	Florida Department of Education: https://fl-pda.org/independent/courses/elementary/science/section3/3c6.htm https://climatekids.nasa.gov/ocean/#:~:text=The%20ocean%20is%20great%20at,coal%2C%20and%20natural%20gas.)&text=The%20ocean%20absorbs%20carbon%20dioxide%20from%20the%20atmosphere%20wherever%20air%20meets%20water.

3.3 Student Engagement Activities:

3.3.1 Activity 1

Objective: The objective of this activity is to demonstrate the three heat transfer mechanisms (conduction, convection, and radiation) using a hot cooking pot as illustrated in **Error! Reference source not found.**.

Materials: cooking pot, water, small stove.

Procedures:

1. Fill the cooking pot with water and put it on the small stove
2. Leave the water to boil for 3-4 minutes
3. Fill the empty diagram

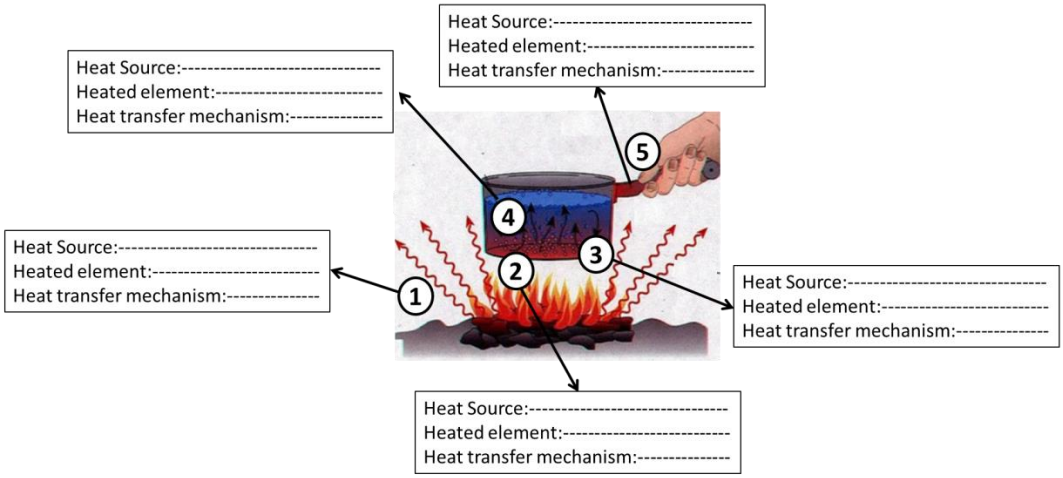
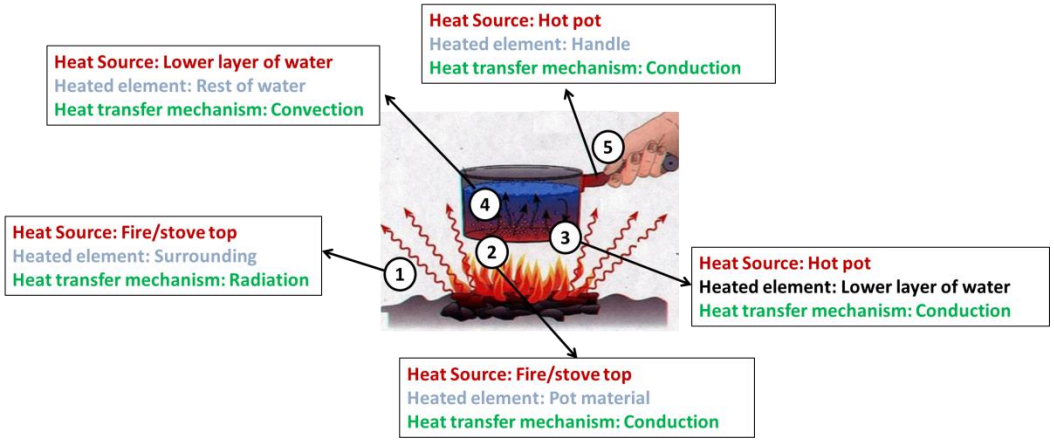


Figure 3-5: Exercise on heat transfer mechanisms

Correct answers:



3.3.2 Activity 2

Objective: the objective to identify solar radiation

Materials: Playground, outdoor space

Procedures:

1. Stand in a sunny spot first
2. Stand in a shaded area

Discussion questions: How do sunny and shaded areas differ (*hint: feeling warmer/cooler*)? Why? What kind of heat transfer is responsible?

3.3.3 Activity 3

Objective: Illustrate the concept of heat transfer by Conduction

Materials: 2 cups filled with hot water, 2 utensils with different materials (wood, metal)

Procedures:

Step1: Place each utensil in hot water.
Step2: Leave utensils in the water for a minute.
Step3: Carefully touch the ends of each utensil.

Discussion questions:

Which material produce more heat? Let the students answer this question who touch the utensils.

3.3.4 Activity 4

Objective: Demonstrating heat transfer through different materials

Materials: a hot plate, a water pot, three spoons/objects made of different materials: metal, wood and plastic, three cuts of butter, stop watch

Procedures:

Step1: Place the water pot on the hot plate to heat up
Step 2: Once the water starts boiling, carefully add the three spoons/objects
Step 3: Wait a few minutes for the spoons to heat up.
Step 4: Ask the students to write their hypothesis or what they think would happen if you placed a cut of butter on each spoon

Step 5: Place the butter on each spoon and start the stop watch to measure time taken to melt the butter on each spoon in

Table 3-2.

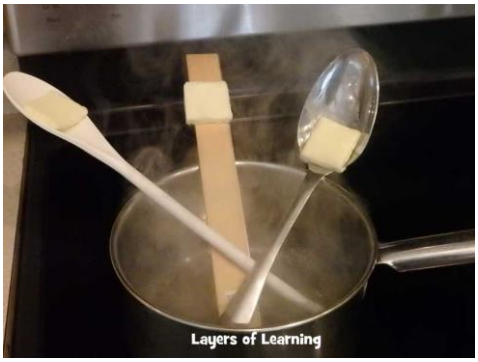


Figure 3-6: Experiment setup [28]

Table 3-2: Table to record the time

Time in seconds	Metal spoon	Wooden spoon	Plastic spoon

Discussion questions

Which of the three materials best conducts heat? Arrange them in order from the fastest heat conductor to the slowest.

[28] https://layers-of-learning.com/heat-conduction-experiment/ (accessed on 20 May, 2021)

3.3.5 Activity 5

Objective: Some colors absorb more heat than others

Materials: Three thermometers, black paper, white paper, outdoor space

Procedures:

Step 1: Put three thermometers in a sunny place.
Step 2: Cover the bulb of one with black paper. Cover the bulb of one with white paper.
Step 3: Predict which thermometer will get the hottest. Number them 1-3, with one as the hottest.
Step 4: Wait a few minutes.
Step 5: Record your results by coloring the tubes of the thermometers.
Step 6: Look at the results and number the thermometers 1-3 with one as the hottest.

Discussion questions:

How well did you predict?

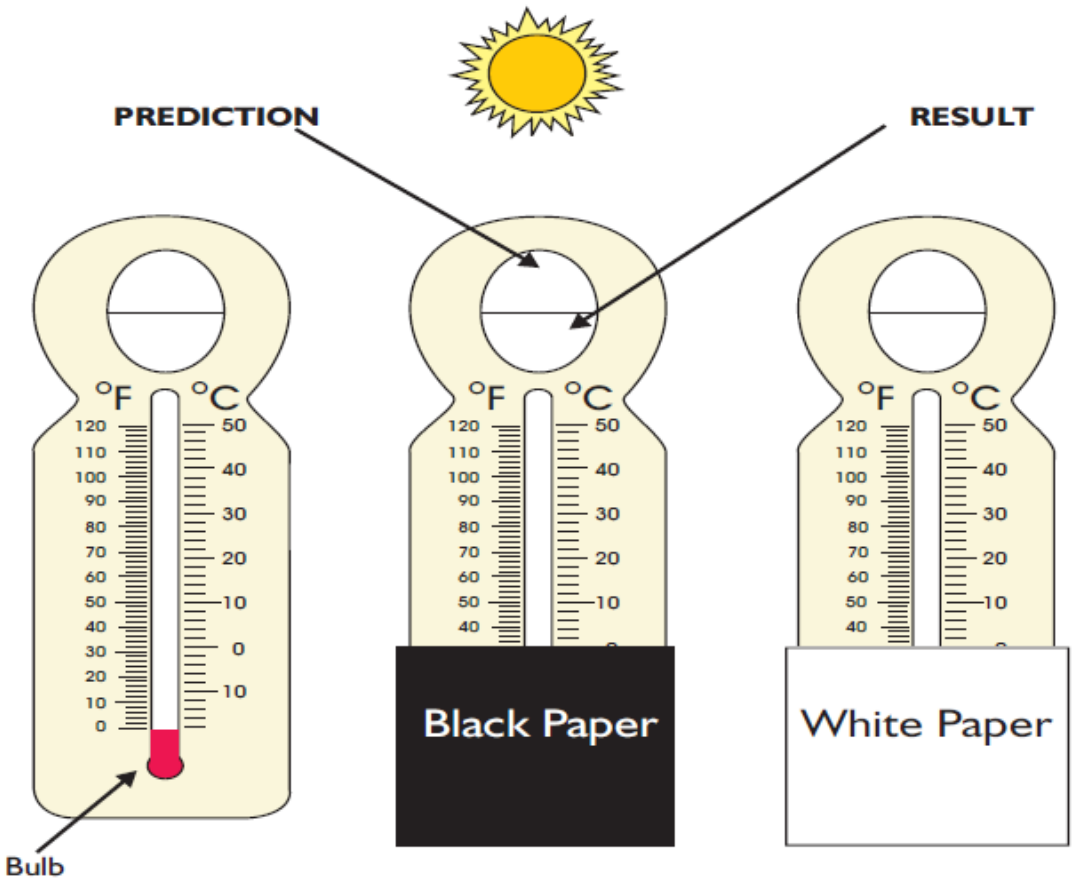


Figure 3-7: Recording observation

4 MESSAGE 4: EARTH'S THERMODYNAMIC BALANCE

4.1 Background Information

It is easily observed that a metallic spoon quickly gains energy when brought near a flame. Every material has its own specific heat, which is the amount of heat it needs to raise its temperature. Heat energy is transferred to the spoon through the air by radiation and the spoon experiences a gain in its temperature. When the spoon is moved away from the flame, it starts cooling because the spoon now loses energy by radiating it back to the air. If we replace the metallic spoon by a wooden spoon, the same observations are noted with one major difference; the temperature rise for the wooden spoon will be much less than the metallic one. Also, the time taken by the wooden spoon to cool down will be longer. This is expected as the specific heat for woods is 4 to 5 multiples of that for iron or copper or aluminum.

The climate system is stabilized by a balance between the incoming energy from the sun and the outgoing energy from Earth as illustrated in Figure 4-1; the balance is also referred to as Earth's energy balance (or thermodynamic balance). The balance is governed by the law of conservation of energy, which states that energy cannot be created or destroyed, and can only be transferred from one system or form to another (i.e., incoming energy entering the Earth equals outgoing energy).

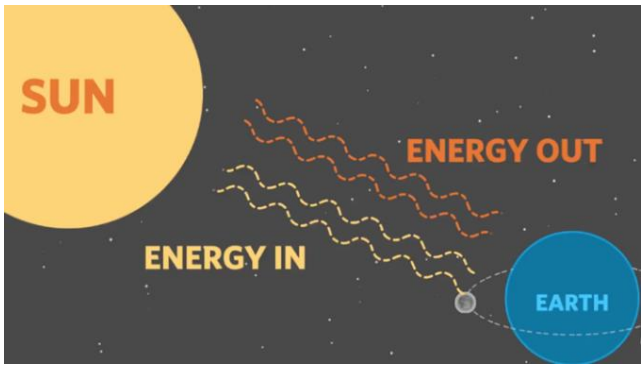


Figure 4-1: Application of law of conservation of energy to the Earth's energy balance

Solar irradiance is defined as the amount of solar energy received by a unit area at earth's surface of per unit of time. Solar irradiance, at earth's surface, represents the rate at which solar light energy falls onto a unit surface and is measured in watts per square meter (W/m^2)[29] (**Error! Reference source not found.** (a)). Remember that Watt is a unit for m easuring power i.e. for measuring energy per unit time (Joules per second). Solar (light) energy consists of a train (spectrum) of electromagnetic waves ranging from low to high energy. High energy is associated with short wave lengths (ultraviolet range), while low energy waves are associated with long wave lengths (infrared range).

[29] Energy: the driver of climate. Center of Environmental Science at Florida Atlantic University. Available at http://www.ces.fau.edu/nasa/images/Energy/EnergyTheDriverOfClimate.pdf (accessed: January 5, 2021)

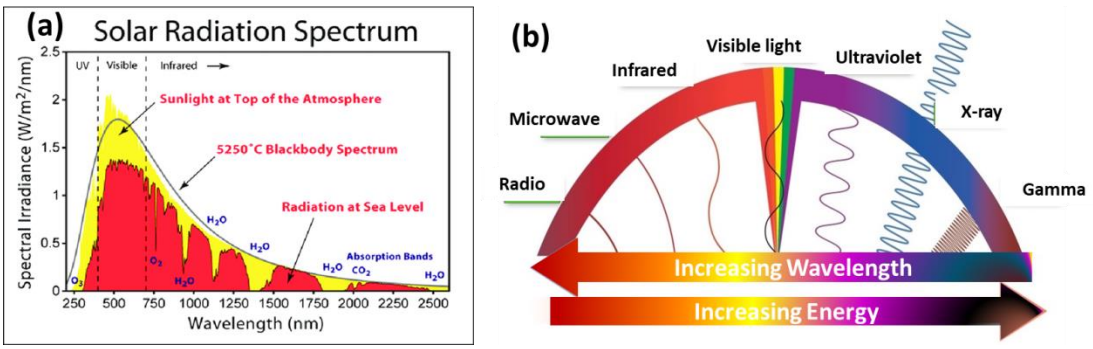


Figure 4-2: Solar irradiance spectrum above atmosphere and at surface[30] and electromagnetic spectrum[31]

While the sun emits radiation of all wavelengths, the type and intensity of the waves reaching Earth's surface varies depending on factors including the Earth's orientation to the Sun and interactions with matter as radiation reaches the atmosphere. Interactions include absorption and reflection of the radiation. The very top of the atmosphere is rich in ozone (O_3), which absorbs most of the incoming high energy shortwave ultraviolet radiation. As radiation travels into the lower layers of the atmosphere, it experiences partial reflection and absorption from clouds and atmospheric particulates and gases. Radiation received at the surface of the earth mainly falls in the visible and infrared regions of the spectrum shown in Figure 4-3.

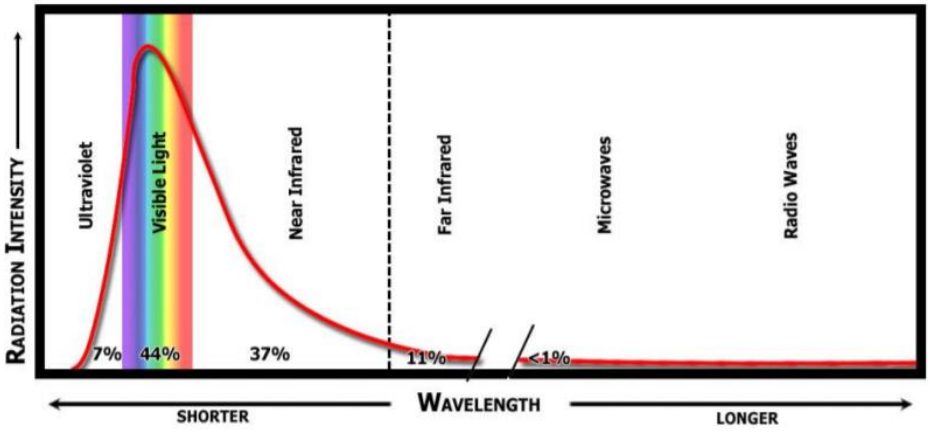


Figure 4-3: Radiation intensity of electromagnetic waves reaching the Earth[32]

Energy flows describing the Earth's energy balance are depicted in Figure 4-4.

[30] https://www.researchgate.net/figure/Solar-irradiance-spectrum-above-atmosphere-and-at-surface_fig3_312225770
[31] https://www.sciencelearn.org.nz/image_maps/63-the-electromagnetic-spectrum
[32] http://www.ces.fau.edu/nasa/module-2/radiation-sun.php

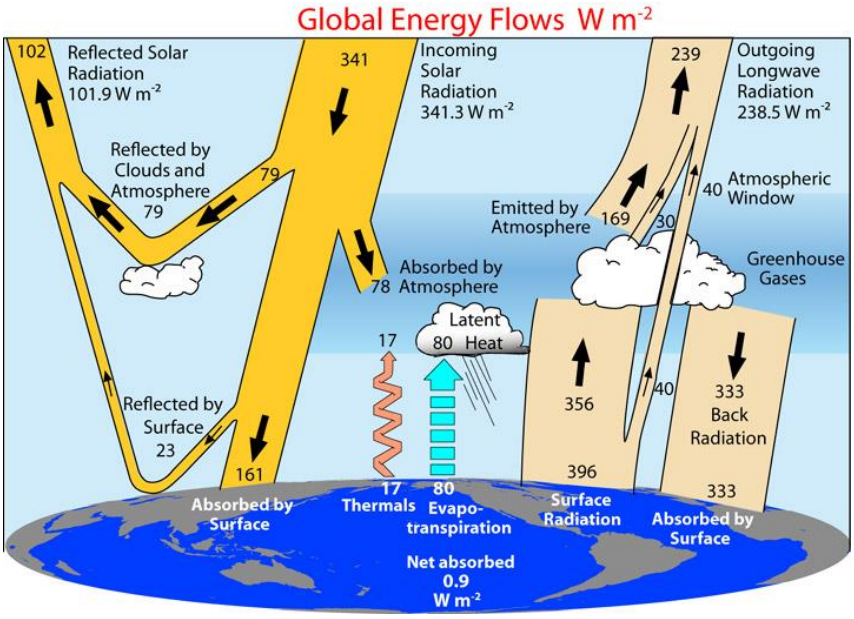


Figure 4-4: Earth's energy balance[33]

- Incoming solar (light) energy from the sun at top of atmosphere is equivalent to 341 W/m^2
- About 79 W/m^2 of the incoming energy is reflected to space by clouds (mainly),
- 23 W/m^2 of the energy reaching down to earth's surface is reflected to space. Ice (around poles and glaciers) reflects most of the incoming radiations.
- Of the remaining energy passing, ~161 W/m^2 is absorbed by the Earth's surface (land and Oceans), while ~ 78 W/m^2 is absorbed by the atmosphere. The absorbed energy is then redistributed across the earth and atmosphere mainly by convection (air and water currents). About 80 W/ m^2 are expended as latent heat to evaporate water from oceans and sea (which will later form clouds and eventually condenses back to rain while releasing the latent heat).
- Liquid water molecules absorb incoming heat energy, which causes change from liquid to gas, i.e., evaporation; the absorbed heat is stored in the vapor and is called the latent heat of evaporation. When water vapor condenses back into rain (liquid water), energy in the form of latent heat (~80 W/m^2) is released to the atmosphere.

On the other hand;

- Around 17 W/m^2 of the energy absorbed by earth's surface (previously estimated at 161 W/m^2) is released and redistributed by convection (heat transfer between Earth's surface and air). This amount of energy is referred to as sensible heat, which comes from contact with the warmer air resulting from the release of latent heat. Both; latent (80 W/m^2) and sensible (80 W/m^2) heat are responsible for the movement of air molecules that induce winds.

[33] https://scied.ucar.edu/learning-zone/how-climate-works/energy-budget

- At night, the earth cools down and its surface radiates back lower energy and longer wavelengths in the infrared region at 396 W/m^2. At this stage, a simple thermodynamic balance for earth would show that its average surface temperature would be -18 ºC; a temperature so low that all water on earth would freeze, oceans would turn into ice and life, as we know it, would not exist.
- In fact, most of infrared radiations emitted by earth while cooling (356 W/m^2) is absorbed by clouds and certain gases within the atmosphere, called greenhouse gases while only about 40 W/m^2 from the total emitted infrared radiations (396 W/m^2) is radiated back into space. Around 332 W/m^2 is reemitted (back radiation) and absorbed by the earth's surface due to greenhouse gases in the atmosphere
- Outgoing longwave radiation is ~239 W/m^2, where atmosphere and clouds emit around 199 W/m^2 into space

Therefore, incoming solar radiation is higher in energy and has shorter wavelengths than those re-emitted during cooling of earth's surface and then captured and reemitted due to the greenhouse effect. A satellite map showing the infrared radiation emitted by Earth in September 2008 is illustrated in Figure 4-5.

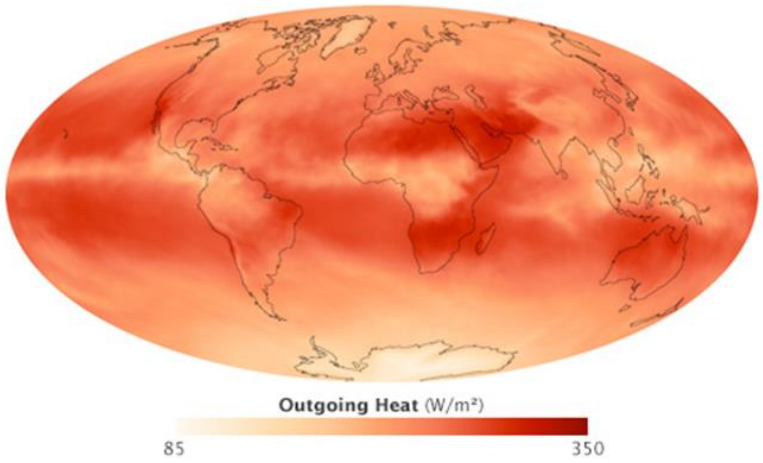


Figure 4-5: A satellite map showing the distribution of infrared radiation emitted by Earth in September 2008[34]

In short, the climate system is stabilized by a balance between the incoming energy from the sun and the outgoing energy from Earth. On Earth, radiation interacts with surfaces such as oceans, lands, gases, particles, clouds, resulting in some radiation being trapped and some leaving the atmosphere. Incoming solar radiation is higher in energy and has shorter wavelengths than those re-emitted during cooling of earth's surface and then captured and reemitted due to the greenhouse effect and corresponding to infrared radiation.

[34] https://www.giss.nasa.gov/research/briefs/schmidt_05/

4.1.1 Self-check/ quiz

Earth absorbs energy from the sun and eventually emits an equal amount of energy due to:

a) Conservation of matter
b) Conservation of energy/ First law of thermodynamics (correct answer)
c) Climate change
d) Radiation

Back radiated energy from the surface and absorbed and reemitted by the atmosphere has

a) The same wavelength as all energy incoming from the sun
b) Longer wavelength corresponding to infrared region of the electromagnetic spectrum (correct answer)
c) Shorter wavelength corresponding to ultraviolet region of the electromagnetic spectrum
d) None of the above

Incoming energy from the sun to the Earth and responsible for energy balance is mainly in the _____of the electromagnetic spectrum

a) UV, visible, infrared regions, (correct answer)
b) UV, gamma and x-ray
c) UV, gamma, and infrared
d) Visible only

4.2 Illustrations of Concepts

Links to various material that can help engage the students and illustrate the concepts of the message are shown in Table 4-1.

Table 4-1: Various illustration aids for the concepts of earth's thermodynamic balance

Concept	Short description of illustration, diagram, video, online course	Reference, link
Earth's Energy Balance	Video explains the Earth's Energy Balance and shows how it may influence the Earth's temperature.	https://youtu.be/DOAqECd70Ww https://energyeducation.ca/encyclopedia/Earth%27s_energy_budget https://earthobservatory.nasa.gov/features/EnergyBalance
	Activities for Earth's energy balance	https://climate.ncsu.edu/edu/EnergyBalance
	Solar power drives Earth's climate. Energy from the Sun heats the surface, warms the atmosphere, and powers the ocean currents	https://earthobservatory.nasa.gov/features/EnergyBalance
	what if" scenarios with our planet's energy balance.	https://scied.ucar.edu/interactive/earths-energy-balance

4.3 Student Engagement Activities

4.3.1 Activity 1

Objective: the objective of this activity is to demonstrate the components of the Earth's energy balance and the mechanisms of energy exchange between the Sun and Earth.

Materials: flash cards, the diagram of Earth's energy balance.

Procedures:

1. Distribute and explain the diagram of the Earth's energy balance, which consists of the main elements of the Energy balance system: the sun, space, atmosphere, Earth's surface (land and oceans), and clouds. The diagram should not contain any arrows
2. **Distribute flash cards containing key steps/processes based on description in the background material**
3. Students will fill in the diagram by drawing the correct arrows to illustrate the incoming energy from the sun and outgoing energy from the Earth and assign the processes using the flash cards

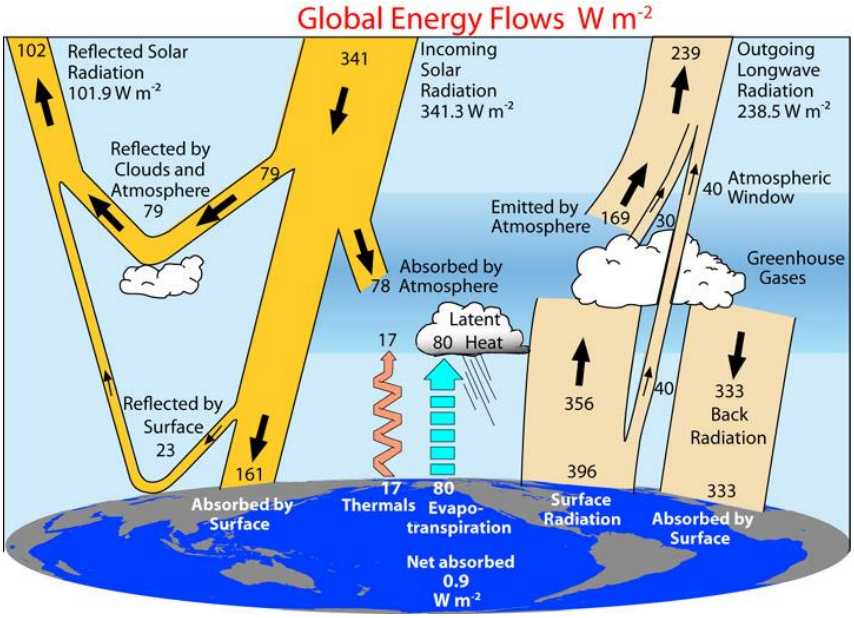
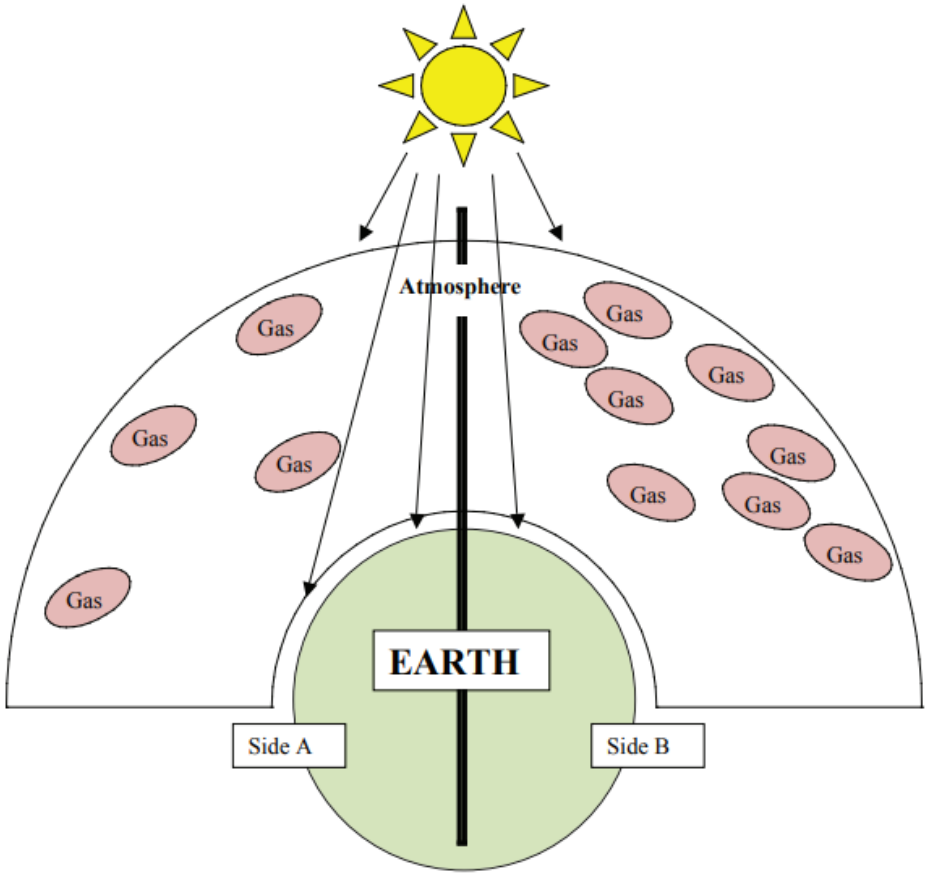


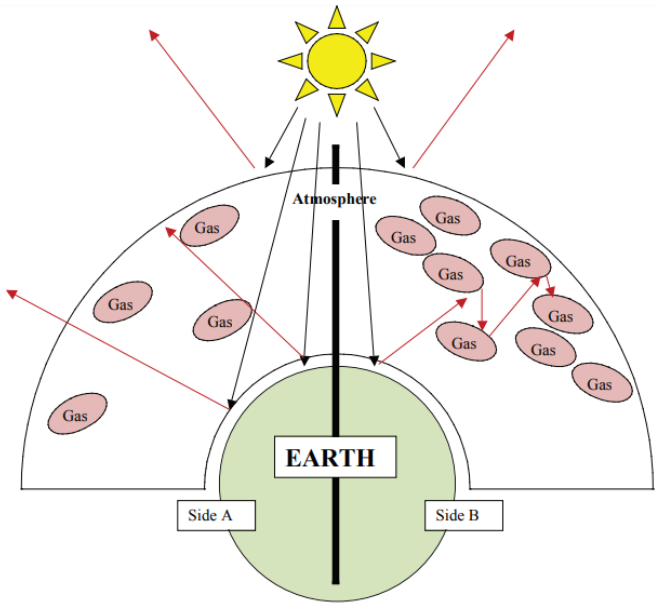
Figure 4-6: Earth energy balance diagram (arrows should be deleted)

4.3.2 Activity 2

Solar radiation is light we cannot see. It comes from the sun, hits the Earth and is reflected back up into our atmosphere. Our atmosphere has greenhouse gases such as carbon dioxide; it also has nitrogen, and oxygen. Side A has less Greenhouse gases in the atmosphere than side B. How will this change the light coming from the sun? Draw lines from the sun showing sun light directions. Show that a greater amount of greenhouse gas in the atmosphere has an effect on how much solar radiation is refracted and absorbed.



Example of answer:



4.3.3 Activity 3

Objective: The experiment shows that water has high specific heat

Material: 2 balloons, water, 2 lightened candles or gas lighters/match, stop watch

Procedures:

Step1: Fill up one balloon with air and the second one is partially filled with water (water balloon)

Step 2: Carefully approach each balloon with lightened candle/gas lighter

Step 3: Start the stop watch and record your observation in Table 4-2.

Table 4-2: Record observation

Time in seconds	Air balloon	Partially filled water balloon

Discussion questions:

How long did it take for the air balloon to pop?

How long did it take for the partially filled water balloon to pop?

Which balloon has higher specific heat and why?

Answer: The water balloon has higher specific heat. The air balloon pops faster while the water balloon remains for a longer time because water takes mor energy to heat and raise its temperature when compared to air.

5 MESSAGE 5: CLIMATE FORCING

5.1 Background Information

Earth's energy balance is dependent on incoming and outgoing radiation; changes imposed on either incoming or outgoing radiation will cause a shift in the balance, i.e., an imbalance. Climate forcing is defined as "the energy imbalance imposed on the climate system either externally (naturally) or by human activities[35]." Positive forcing of the energy balance results when more energy is incoming from the Sun compared with that outgoing from Earth. Positive forcing has a warming effect on the climate. Negative forcing results when incoming energy from the sun is less than the outgoing energy from earth thus resulting in a cooling effect on the climate. In simple words it is a factor which ***forces*** the earth's climate to change.

Climate forcing is classified into radiative and non-radiative forcing. Radiative forcing describes changes imposed on Earth's radiation balance by directly affecting the radiation budget as shown in Figure 5-1. Non-radiative forcing is due to causes not directly interacting with radiation. For example, changes in evapotranspiration rates due to agriculture irrigation.

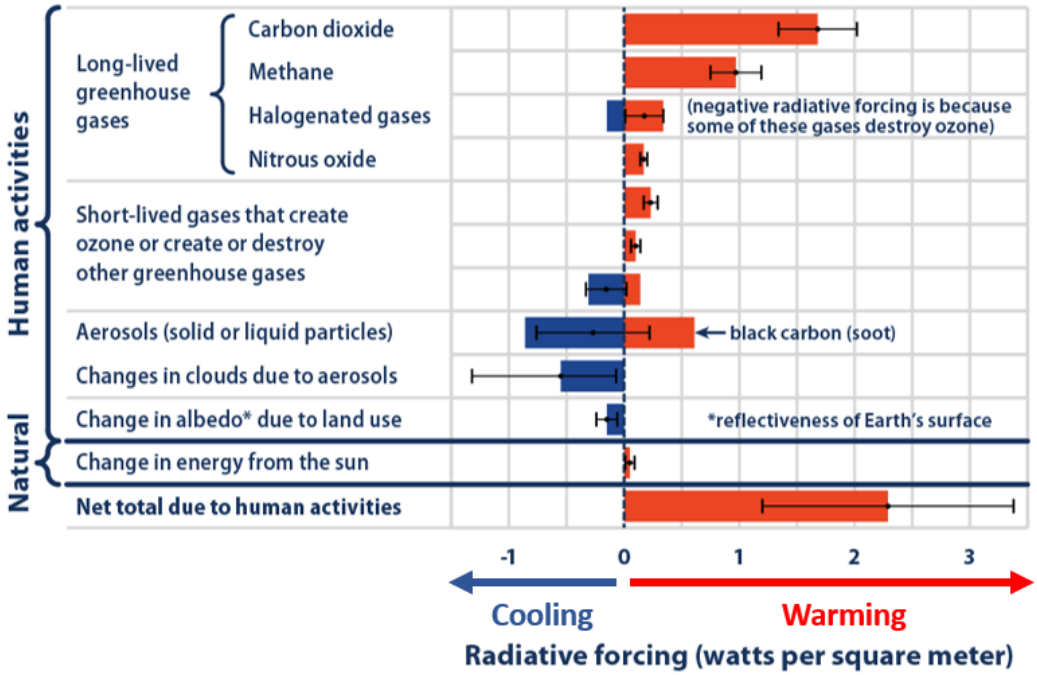


Figure 5-1: Radiative forcing caused by human activities since 1750[36]

Direct radiative forcing results when the changes in energy balance are caused by direct interaction with radiation. For example, more GHGs lead to more absorption and re-emission of infrared radiations causing direct radiative forcing. ***Indirect radiative forcing***

[35] https://www.nap.edu/read/11175/chapter/3#15
[36] https://www.epa.gov/climate-indicators/climate-change-indicators-climate-forcing

results if the energy imbalance is due to a component of the climate system[37] that has undergone changes itself. For example, changes in the sizes of cloud particles, which then encounter radiation cause indirect radiative forcing. Radiative forcing is determined from the difference between incoming and outgoing energy and is expressed in W/m^2.

Drivers of radiative forcing consist of changes in solar irradiance, emissions from volcanic eruptions, changes in concentrations of GHGs and small solid/liquid particles suspended in the air also known as aerosols, all of which cause changes or imbalances in the incoming and outgoing energy between the Earth and the Sun (space). The Earth's energy balance is illustrated in Figure 5-2, which shows the flow of radiation into and out of the Earth's surface.

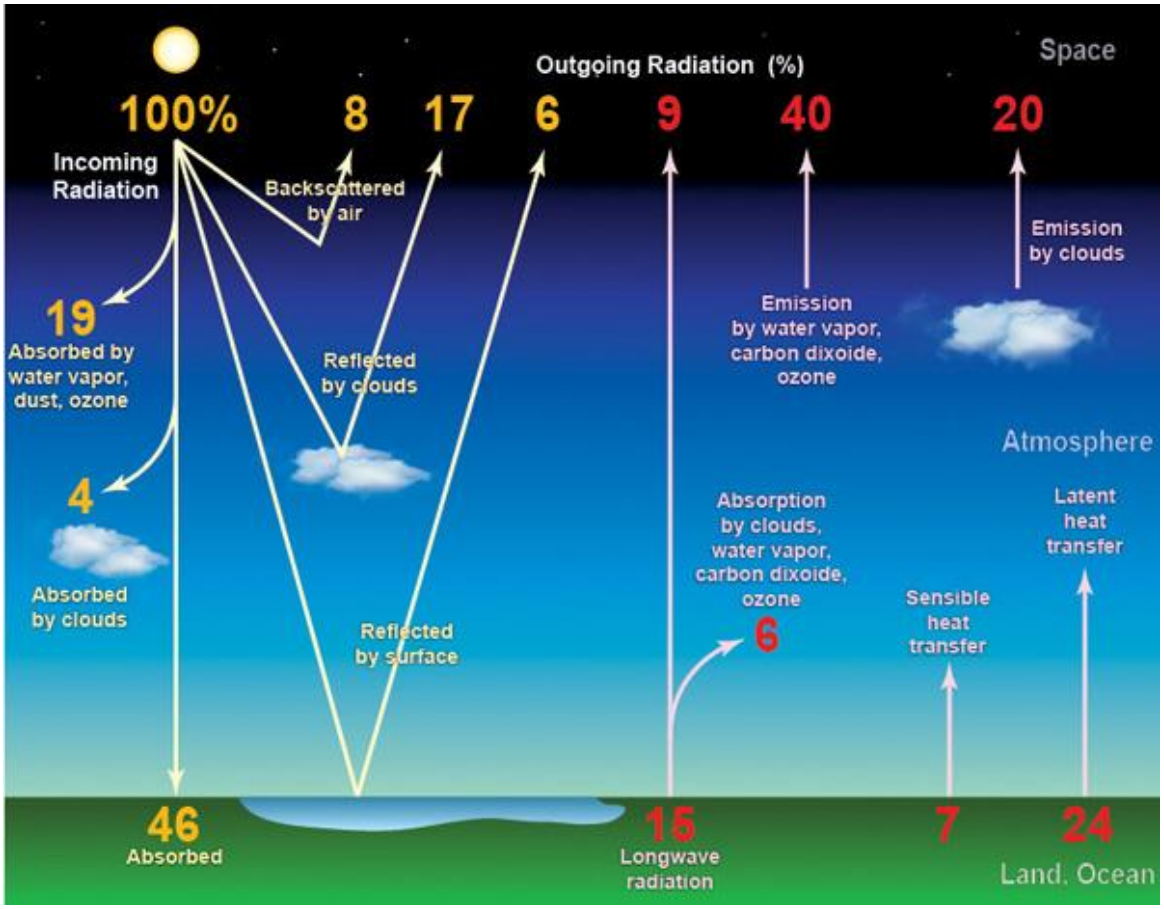


Figure 5-2 the Earth's energy balance

Error! Reference source not found. displays the principal drivers of radiative forcing. P ositive forcing contributes to the warming of Earth, whereas negative forcing contributes to cooling the Earth's surface.

Table 5-1: Examples for human-induced (anthropogenic) forcing and natural forcing

Type of forcing	Human-caused	Natural forcing

[37] Climate system consists of five major components: the atmosphere, the hydrosphere, the cryosphere, the land surface and the biosphere influenced by various external forcing mechanisms including the Sun.

Positive	GHGs from manmade activities: CO_2, CH_4, N_2O, O_3 in lower atmosphere/troposphere, halocarbons, SF_6	Natural changes in GHGs concentrations in troposphere : CO_2, CH_4, N_2O, O_3
		Earth's orbital changes; eccentricity, axis tilt, wobble
	Aerosol: Black carbon (BC also known as soot)	Solar irradiance
		Aerosols: biomass (BC and OC)
Negative	Aerosols: Sulfate aerosols, nitrate aerosols	Aerosols: Ash and other particles from volcanic eruptions
	Aerosols: organic carbon (OC)	Aerosols: mineral dust and marine aerosols (sea salt)
	Clouds (*indirect effect*)	Clouds
		Earth's orbital changes

The effect of cooling resulting from the Mount Pinatubo volcanic eruptions in 2001 in the Philippines, where layers of aerosols blocked solar radiation and reduced the global average temperatures by 0.6 ºC for almost 2 years is shown in **Error! Reference source n ot found.**.

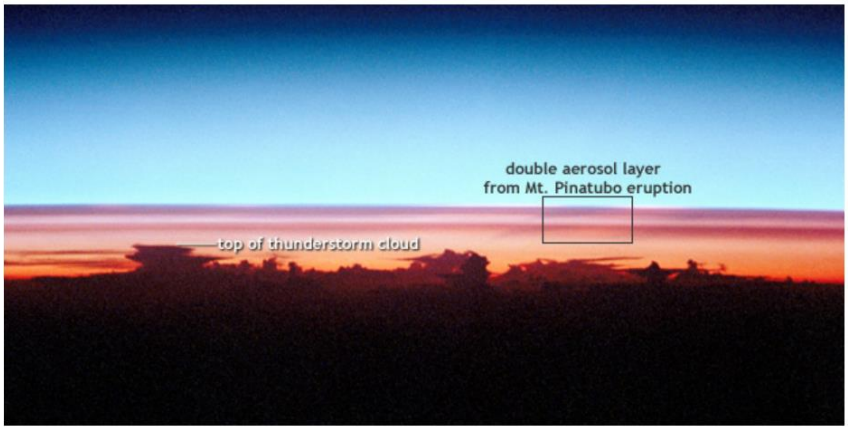


Figure 5-3: The effect of cooling resulting from volcanic eruptions[38]

Radiative forcing caused by individual gases and aerosols and total radiative forcing since 1750 to 2011[39] are presented in Figure 5-4. The radiative forcing of a particular factor, such as carbon dioxide (CO_2) concentrations represents the change in the energy balance that results from the increase in CO_2 concentrations. Positive forcing caused by human activities results from long-lived GHGs (CO_2, CH_4, N_2O, and Halogenated gases), short-lived gases that create ozone or create or destroy other GHGs, and the use of aerosols (solid or liquid particles), and changes in clouds due to aerosols. As shown in Figure 5-4a, CO_2 has the

[39] Myhre, G., D. Shindell, et al., 2013: Anthropogenic and Natural Radiative Forcing. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change

highest human-caused positive radiative forcing of 1.82 W/m^2, followed by methane and carbon black (aerosol). Figure 5-4b shows that the biggest contributors to negative radiative forcing are sulphate aerosols followed by nitrate aerosols resulting from human activities. The third contributor to negative forcing is naturally existing mineral dust and marine aerosols (sea salt). Organic carbon aerosols result from biogenic sources as well as human activities such as the combustion of fossil fuel and biomass; organic carbon aerosols are released either as primary aerosol particles or as volatile organic compounds, which undergo further atmospheric reactions with other gases and particles resulting in secondary organic aerosols. Organic carbon aerosols consist of many different hydrocarbon-based compounds and contribute to negative forcing [40]. The total net forcing of the Earth is positive (increased warming) reaching a rate of 2.29 W/m2 in 2011 compared to 0.57 W/m2 in 1950 as illustrated in Figure 5-4c.

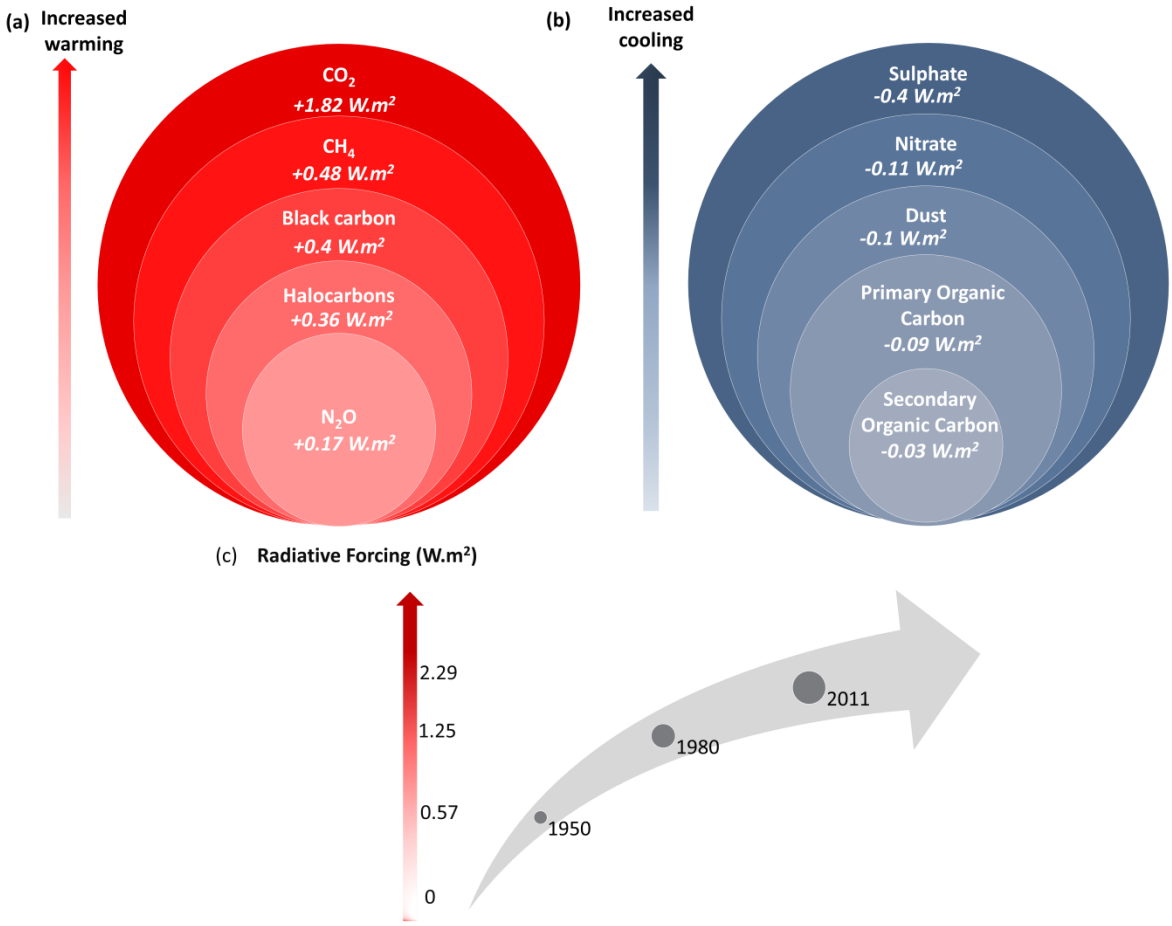


Figure 5-4: (a) positive, (b) negative radiative forcing caused by gases and aerosols and (c) total radiative forcing changes from 1750 to 2011

Feedback occurs when outputs of a system are routed back as inputs as part of parts of a chain of cause-and-effect that forms a circuit or loop. (+ive) or cooling (-ive)**.** For example: more burning of fossil fuels on earth to generate energy is a positive forcing because it generates more GHGs and causes warming of the climate. However, warming,

[40] https://www.ipcc.ch/site/assets/uploads/2018/03/TAR-06.pdf

in turn, leads to more evaporation from oceans which increases the water vapor content of the atmosphere. Water vapor, being in itself an effective GHG, will result in further warming. This effect is called a (+ive) ***feedback***. Negative feedback occurs when its effect tends to reverse the forcing effect.

In short, Earth's energy balance is dependent on incoming and outgoing radiation; changes imposed on incoming or outgoing radiation either externally (naturally) or by human activities will cause a shift in the balance, i.e., an imbalance, a forcing. A positive forcing signifies changes cause less outgoing energy resulting in warming, while, a negative forcing signifies incoming energy from the sun is less than the outgoing energy from earth thus resulting in a cooling effect on the climate. Changes are due to direct interactions between radiation and surfaces consisting of lands, oceans, gases and particles in the atmosphere, and clouds. The present total net forcing is positive and the Earth is warming; principal gases causing a positive forcing are carbon dioxide, methane, halocarbons and nitrous oxide, and black carbon particles. Negative forcing is caused by aerosols both of natural and anthropogenic origins consisting of mineral dusts, sulphate and nitrate aerosols and organic carbon aerosols.

5.1.1 Self-check / quiz

Negative forcing agents affect Earth by _____, while positive forcing agents affect Earth by _____

a) Warming and cooling
b) Cooling and warming (correct answer)
c) No changes and warming

Positive forcing agents include

a) All aerosols and gases produced by human activities
b) Aerosol-radiation interaction and clouds
c) Well mixed greenhouse gases CO_2, CH_4, N_2O, halocarbons and some aerosols (black carbon) (correct answer)

The overall RF today compared with pre-industrial times is _____ causing a _____ and is mainly due to _____

a) Positive, warming, increased levels of CO_2, N_2O, CH_4, halocarbons (correct answer)
b) Negative, cooling, aerosols and clouds
c) Negative, warming, increased levels of CO_2, N_2O, CH_4, halocarbons

5.2 Illustrations of Concepts

Links to various material that can help engage the students and illustrate the concepts of the message are shown in Table 5-2.

Table 5-2: Various illustration aids for the concepts of climate radiative forcing

Concept	Short description of illustration, diagram, video, online course	Reference, link
Radiative Forcing Components	Video explains different radiative forcing components and how each one influences the climate and how each one differs from the other.	https://youtu.be/hVvzVs1AKGY https://climate.nasa.gov/blog/2949/why-milankovitch-orbital-cycles-cant-explain-earths-current-warming/
Radiative forcing	Definitions of concepts	https://www.nap.edu/read/11175/chapter/3#27 https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_Chapter08_FINAL.pdf https://eol.jsc.nasa.gov/SearchPhotos/photo.pl?mission=STS043&roll=22&frame=11 https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_Chapter08_FINAL.pdf
	Anthropogenic and natural radiative forcing *N.B: more advanced resource*	https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_Chapter08_FINAL.pdf
	Video showing role of Earth's orbitals on climate	https://climate.nasa.gov/blog/2949/why-milankovitch-orbital-cycles-cant-explain-earths-current-warming/
	Graph showing radiative forcing of different agents between 1750 and 2011	https://science2017.globalchange.gov/chapter/2/
Global warming	Video explaining global warming and the influence of the forcing.	https://youtu.be/oJAbATJCugs

5.3 Student Engagement activities

5.3.1 Activity 1

Objective: the objective is to demonstrate the role of human activities on climate by identifying components from daily lives causing RF.

Procedure: Each group should select radiative forcing component, identify their anthropogenic sources, and classify type of forcing.

Group	Human-caused agents	Main sources	Type of forcing (positive/negative)
	CO_2		
	CH_4		
	N_2O		
	O_3 (lower atmosphere/troposphere)		

	Halocarbons		
	SF_6		
	Aerosol: Black carbon (BC also known as soot)		
	Sulfate aerosols,		
	Nitrate aerosols		
	Organic carbon (OC) (primary)		

5.3.2 Activity 2

Carbon dioxide is an important element of radiative forcing. Carbon dioxide has a positive forcing that traps more energy incoming from the Sun and has a warming effect on the climate. Understanding the carbon cycle explains the sources of positive and negative climate forcing. The source of positive climate forcing is the same that emit more carbon dioxide than it absorbs. Contrarily, the source of negative climate forcing is the same that absorb carbon dioxide more than it emits.

Carbon dioxide exists naturally in the Earth's atmosphere as shown in Figure 5-5. It is naturally cycled between the atmosphere, the oceans, the land, and the plants during photosynthesis. The oceans and plants absorb millions of tons of carbon dioxide from the Earth's atmosphere yearly. However, this carbon dioxide is emitted back into the atmosphere through respiration, fires, and the oceans. The natural process of emitting and absorbing carbon dioxide sustains the Earth's carbon dioxide balance. Human activities, such as the burning of fossil fuels (coal, oil, and natural gas) add carbon dioxide to the Earth's atmosphere.

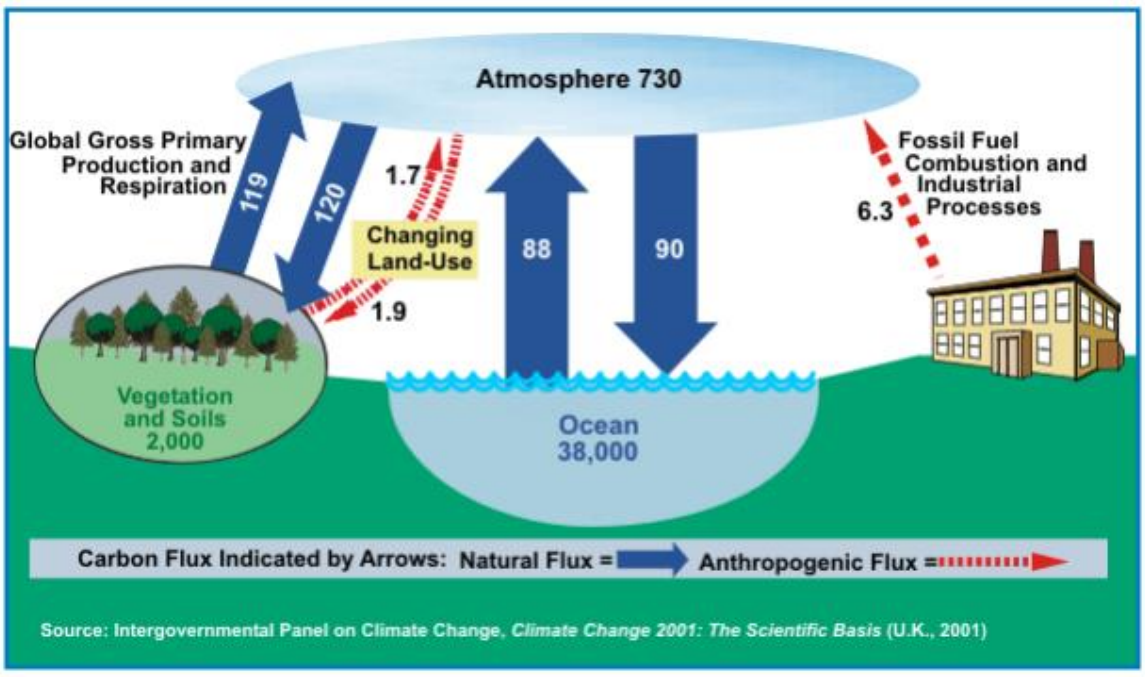


Figure 5-5: The carbon cycle

Determine from Figure 5-5 the main sources of climate forcing and their type (positive or negative) and their effect (cooling or warming) and fill the answers in the table below.

Source of climate forcing	Type of forcing (positive/negative)	Their effect

Correct answer:

Source of climate forcing	Type of forcing (positive/negative)	Their effect
Vegetation and soils	Negative	Cooling
Fossil fuel combustion	Positive	Warming
Ocean	Negative	Cooling
Changing land use	Negative	Cooling

6 MESSAGE 6: GREENHOUSE GASES

6.1 Background Information

6.1.1 Concept of greenhouse effect

The greenhouse effect is the Earth's natural warming, which results when certain gases in the atmosphere trap infrared radiation emitted from the surface of the earth while cooling that would otherwise escape into space in the absence of these gases as shown in Figure 6-1. Fifty percent of the sun's energy reaching Earth is reflected back to space. The other 50 %is absorbed by the Earth's climate system to provide sufficient heat for lands, oceans, and the atmosphere. The absorbed heat is then radiated back in the form of invisible infrared light. Some of this infrared light passes the atmosphere and continues into space (atmospheric window), and the rest gets absorbed by greenhouse gases then redirected back to Earth, which builds up additional warming inside the Earth's system.

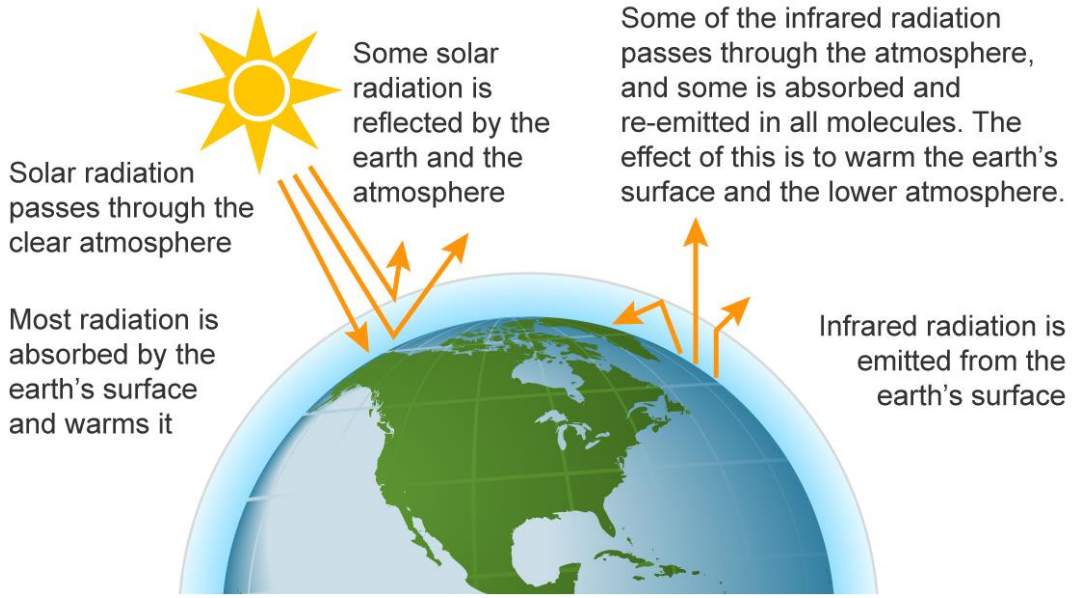


Figure 6-1: Greenhouse Effect[41]

6.1.2 Greenhouse gases (GHGs)

Due to their chemical nature and shapes/structures, GHGs are capable of absorbing and re-emitting infrared radiation. Infrared radiation is low energy enough that it does not destroy the structure of the gas, but only gives it extra energy (vibration of molecules) that is then released back and thereby 'trapping' heat. The principal gases responsible for trapping heat, i.e., the greenhouse effect, are water vapor, carbon dioxide, methane, nitrous oxide, and halocarbons (e.g., fluorinated gases such as Freon used in refrigeration and cooling, dichloro diphenyl trichloroethane (DDT) used in insecticides, and Methyl Chloride used in solvents, cleaning metals, and adhesives)

[41] http://www.change-climate.com/Greenhouse_Gases.htm

GHG emissions result from both natural and anthropogenic sources. Natural sources include:

- Decomposition of animal species and vegetation: when animals and plants die, their dead organisms are eaten up by decomposers[42] and the carbon in them returns to the atmosphere as carbon dioxide or methane. In some conditions, decomposition is blocked and the plant and animal remains may fossilize[43].
- Natural wild fires: their primary natural causes include drought, heat, and lightning, and very small percentage are caused by spontaneous combustion of dry fuel such as sawdust and leaves. Natural wildfires maintain ecosystem balance, unlike human-caused forest fires, which are considered dangerous and cause adverse effects on the Earth's climate system.
- Outgassing of volcanoes: Volcanic eruptions release GHGs, including water vapor, carbon dioxide (CO2), sulfur dioxide (SO2), carbon monoxide (CO), hydrogen sulfide (H2S), hydrogen gas, nitrogen, and methane (CH4). Lighter gases such as hydrogen and helium escape into space, but the heavier gases remain in the atmosphere
- Wetlands: Wetlands are complex systems of plants, soil, and aquatic life that serve as a reservoir capturing and cleaning water. Yet, wetlands are considered a large natural source of methane in the atmosphere. Because of their wet soil, soil microbes and plants forcibly metabolize under anaerobic conditions (i.e., lack of oxygen), leading to methane production. The methane is released to the atmosphere via diffusion, transported through plant tissue and gas bubbles. The stability of water in wetlands and the transport efficiency through plants can affect the amounts of methane released from its soil[44].
- Earthquakes: Scientists found evidence that beneath the Earth's seas, there are pockets of methane trapped in the Earth's shallow layers of its crust in the form of methane hydrates, which is a solid ice-like crystalline structure of methane and water. Earthquakes cause these pockets to fracture and the methane gas is released into the atmosphere bubbling upwards through the sea waters[45].

Anthropogenic sources of emissions primarily include burning of fossil fuels for energy production, agricultural practices, land-use change, waste management and treatment activities, and numerous industrial processes as shown in Figure 6-2.

[42] Organisms that eat dead organisms, plants and vegetation, and organic matter and breaks them down into simpler material

[43] https://www.bbc.co.uk/bitesize/guides/zx6sdmn/revision/4

[44] https://www.sciencedaily.com/releases/2019/06/190619085703.htm

[45] https://phys.org/news/2013-07-earthquakes-trigger-undersea-methane-reservoirs.html

a) Anthropogenic sources of greenhouse gases

b) Natural sources of greenhouse gases

Figure 6-2: Anthropogenic and natural sources of greenhouse gases

How much any GHG influences global warming depends on three key factors as shown in

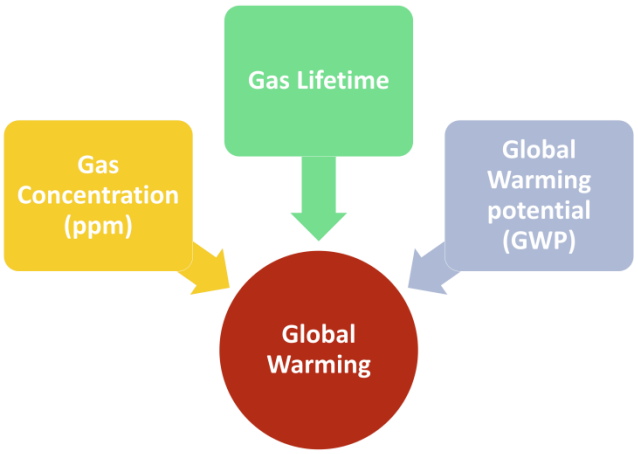


Figure 6-3. The three factors include the amount or concentration of the gas present in the atmosphere measured in parts per million by volume, how long it stays trapped in the atmosphere representing its lifetime, and its global warming potential (GWP), which reflects how effective the gas is at trapping heat in the atmosphere over a 100-year period *relative to* CO_2 when used as the reference. GHG emissions are usually represented in terms of mass of carbon dioxide equivalents (CO_2e), which are calculated by multiplying emissions masses of any GHG by the GWP of the gas relative to CO_2.

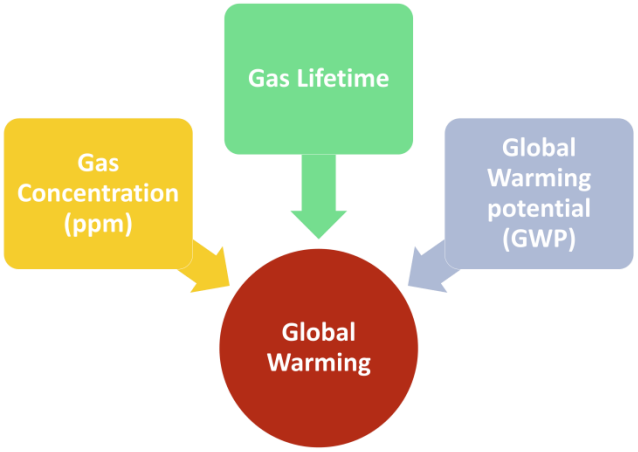


Figure 6-3: GHG factors affecting global warming

Sinks for GHG emissions are natural or manmade elements that absorb GHGs from the atmosphere in order to maintain balance in the climate system. The biggest natural systems that serve as sinks are forests and oceans. In oceans, corals, plankton, fish, algae and photosynthetic bacteria are the main elements absorbing carbon. In the case of forests, carbon absorption is done through photosynthesis processes by plants and trees. Leaves absorbs CO_2 from atmosphere and water from soil to synthesize carbohydrates (food). Solar energy is transferred into chemical energy within the bonds of the produced food. Oxygen is released to the atmosphere as a bi-product to support several forms of aerobic organisms. Besides natural sinks, there are man-made methods designed to capture and store, remove, or sequester carbon that would otherwise be released into the atmosphere. Examples of carbon sequestration methods include storing carbon in the Earth's crust by injecting it, forest regrowth and wetlands restoration to improve their carbon sink characteristics, enhanced ocean absorption of CO_2 by dissolving carbonate minerals to bicarbonates, direct air capturing of carbon, capturing carbon coming out of industrial processes, and improved land management and use[46].

Enhanced greenhouse effect

Though GHGs made life possible on Earth, the rapid increase in concentrations of those gases in the atmosphere due to anthropogenic activities in the past 100 years due to the industrial revolution has shifted the energy balance causing an enhanced greenhouse effect. Key GHGs, their source, concentration in the atmosphere, lifetime and GWP are illustrated in Table 6-1.

Table 6-1: Key GHGs and their source and concentrations in the atmosphere

GHG	Main human activity source	Concentration in atmosphere pre industrial revolution (ppm)	Concentration in atmosphere in 2018 (ppm)	Lifetime (years)	GWP
Carbon Dioxide	Burning of fossil fuels, cement	280	408	300 to 1,000	1

[46] https://climatechange.ucdavis.edu/science/carbon-sequestration/

	production, and land-use change				
Methane	Fossil fuels, rice paddles, livestock, waste dumps	0.715	1.869	12	28
Nitrous Oxide	Fertilizers production and use, combustion in industrial processes	0.27	0.331	121	265
Halo-carbons	Electronics refrigerants, industrial processes, aluminum production, electrical equipment insulation	Almost all fluorinated compounds did not naturally exist in the atmosphere preindustrial times	Varies depending on gas type	1.5 to 10,000 up to 50,000 based on gas type	138 up to 23,500 dependin g on gas type

In short, the greenhouse effect is the Earth's natural warming, which results when certain gases in the atmosphere (greenhouse gases GHGs) trap infrared radiation emitted from the surface of the earth that would otherwise escape into space in the absence of these gases. How much any GHG influences global warming depends on the amount or concentration of the gas present in the atmosphere, how long it stays trapped in the atmosphere representing its lifetime, and its global warming potential (GWP), which reflects how effective the gas is at trapping heat in the atmosphere over a 100-year period *relative to* CO_2 when used as the reference. The principal GHGs responsible for trapping heat, i.e., the greenhouse effect, are water vapor, carbon dioxide, methane, nitrous oxide, and halocarbons. The rapid increase in concentrations of those gases in the atmosphere due to anthropogenic activities has resulted in the enhanced greenhouse effect.

6.1.3 Self-check quiz

Natural or artificial producers of greenhouse gases are ___ and natural or artificial reservoir that absorbs and stores greenhouse gases are _____

a) Emissions, sinks
b) Emission sources, sinks (correct answer)
c) Emissions, gases

The greenhouse effect is defined as _____

a) Heating due to sun’s UV radiation,
b) Cooling due to escaping heat in the atmosphere
c) Warming due to heat trapped by gases in the atmosphere (correct answer)

The main responsible gases for enhanced Greenhouse Effect are:

a) Water Vapor
b) Carbon Dioxide
c) Methane
d) Nitrous Dioxide
e) Halocarbons
f) All of the above (correct answer)

How much any greenhouse gas influences global warming depends on its:

a) Concentration
b) Lifetime
c) Global Warming Potential
d) All of the above (correct answer)

6.2 Illustrations of Concepts

Links to various material that can help engage the students and illustrate the concepts of the message are shown in Table 6-2.

Table 6-2: Various illustration aids for the concepts of greenhouse gases

Concept	Short description of illustration, diagram, video, online course	Reference, link
Greenhouse Gases	Flash Cards for the most important greenhouse gases and information about each greenhouse gas.	https://climatekids.nasa.gov/greenhouse-cards/
Greenhouse Gases	Chart illustrating the annual contribution of natural and anthropogenic activities to global GHG emissions	https://www.sciencedirect.com/science/article/pii/S1674927818300376#fig2 https://www.globalchange.umich.edu/globalchange1/current/lectures/Perry_Samson_lectures/evolution_atm/
Greenhouse Effect	Video explaining the greenhouse effect and how it's leading to that Earth is getting warmer. It shows also things that we can do to save our Earth.	https://youtu.be/DYHAZaasdxI
Greenhouse Effect	Video explaining what is the greenhouse effect.	https://youtu.be/SN5-DnOHQmE
Carbon sinks	Video explaining carbon sinks	https://www.youtube.com/watch?v=OoW2PlvMpZs
Experiment	Video showing an experiment showing the difference with and without greenhouse gases and how there's a difference in temperature.	https://youtu.be/Zst7B-B3P2E

6.3 Student Engagement Activities:

6.3.1 Activity 1

Objective: the objective is to demonstrate greenhouse effect by investigating changes in water temperature[47].

Materials: 2-litre bottles, water, thermometer, plastic wrap, indoor light bulb.

Procedure:

1. Bring 2-litre bottles and cut them into two halves
2. Fill both halves with water, place a thermometer inside, and wrap one half in plastic wrap
3. Allow both halves of the bottle to sit in direct sunlight or subject them to an indoor light bulb for 30-50 minutes
4. Measure water temperature in both halves and observe the varying temperatures due to greenhouse entrapment in the covered half of the bottle

6.3.2 Activity 2

Objective: Landfill is a main source of Methane, which is one of the important greenhouse gases. The students will observe how when waste goes to landfill, it produces methane. The experiment enables the students to watch the chemical breakdown of each food source and the relative amount of gas it produces.

Materials: 3 balloons of different color – 3 plastic bottles – water - three types of fruit/vegetables waste of your choice (example: banana – green pepper – tomatoes). Bananas will show fast results.

Procedure:

1. Place each fruit waste in a bottle
2. Fill each bottle completely with water to create anaerobic (oxygen – lacking) environment that simulates the conditions found in a landfill.
3. Place the balloons on the tip of the bottle (the balloons will inflate to indicate the production of methane gas; some balloons will inflate faster than other as some foods are prone to produce more gases during decomposition than others)
4. Write down observations

[47] https://sealevel.jpl.nasa.gov/files/archive/activities/ts1hiac1.pdf

Figure 6-4: Simulation of landfill conditions that produce methane

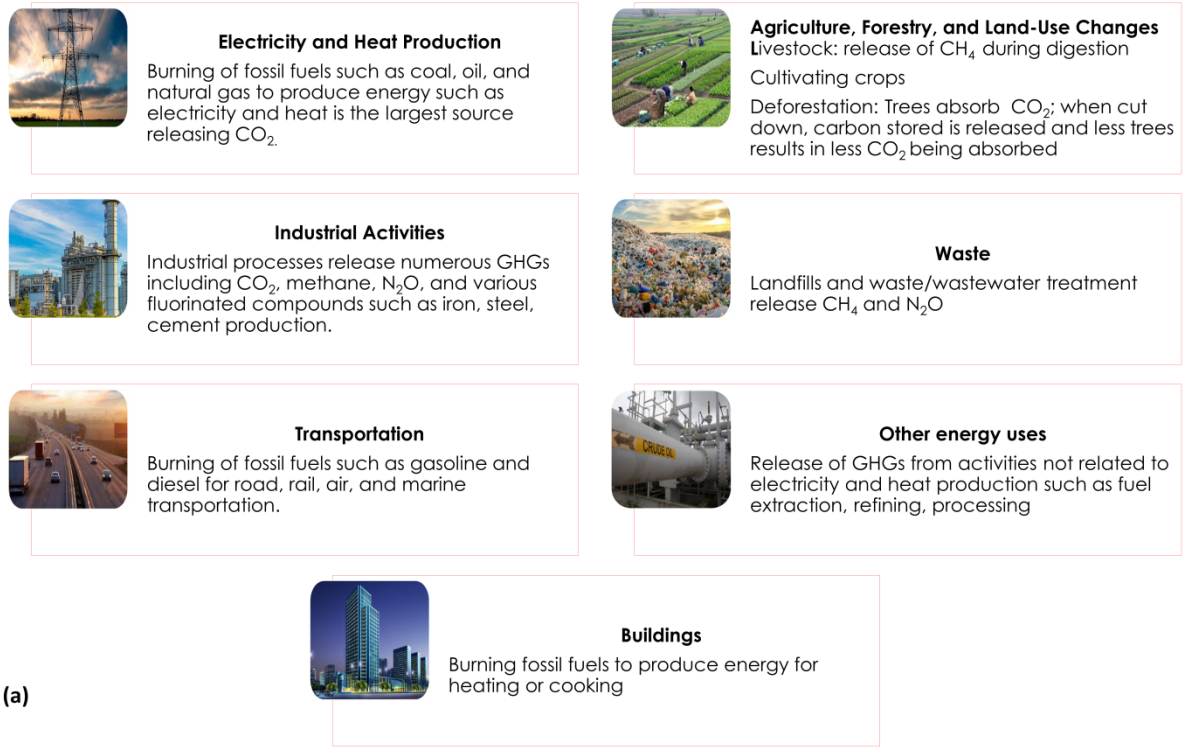
7 MESSAGE 7: GLOBAL WARMING

7.1 Background Information

Global warming is the trapping of heat by GHGs resulting in increased average surface temperatures over time. The rate of global warming has increased since pre-industrial times, primarily due to burning of fossil fuels for energy production[48].

7.1.1 Anthropogenic GHGs emissions sources

Sources and global emissions[49] of GHGs are shown in **Error! Reference source not found.** (a) and (b). The global sources of emissions are made of a number of activities and sectors that involve mainly burning of fossil fuels to produce energy such as electricity and heat production, transportation, industrial activities, buildings and other energy uses. Meanwhile, waste sector produces methane and nitrous oxide as a result of decomposition of organic waste. In the Agriculture sector, the livestock release methane during digestion, also cultivating crops produces nitrous oxide as a result of applying fertilizers. In addition, deforestation reduces the carbon absorbed by the cutout trees. Out of these sectors, the energy sector is the largest contributor to GHG emissions responsible for 73%of emissions.



(a)

[48]Overview: Weather, Global Warming and Climate Change. NASA. Available at https://climate.nasa.gov/resources/global-warming-vs-climate-change/ (accessed: 4 January, 2021)
[49]Based on data in https://wriorg.s3.amazonaws.com/s3fs-public/world-greenhouse-gas-emissions-sankey-chart-2019_2.jpg

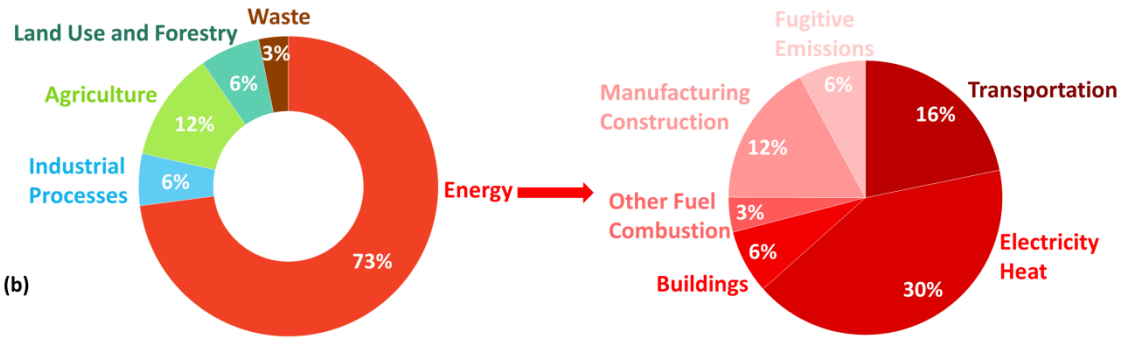


Figure 7-1: (a) Sources and (b) Contribution to global warming for key sectors to GHG emissions in 2016

7.1.2 Rise in Atmospheric CO_2 levels

The amount of CO_2 in the atmosphere has increased since the start of the Industrial Revolution in 1750. Carbon dioxide concentrations have undergone a fast growth rate, which skyrocketed since the 1960s with CO_2 reaching 408 parts per million in 2018. Part per million here being the concentration of CO_2 in the atmosphere and is equivalent to 408 particles of CO_2 in 1 million particles of air. The increase in CO_2 levels from pre-industrial times till today is shown in Figure 7-2. In 2021, the CO_2 concentration is expected to exceed 415 ppm and the total GHG concentration to approach 500 ppm.

According to the WMO Greenhouse Gas Bulletin, the following statistics are formulated:

	CO_2	Methane	Nitrous oxide
2019 global mean abundance	410.5±0.2 ppm	1877±2 ppb	332.0±0.1 ppb
2019 abundance relative to year 1750[a]	148%	260%	123%
2018-19 absolute increase	2.6 ppm	8 ppb	0.9 ppb
2018-19 relative increase	0.64%	0.43%	0.27%
Mean annual absolute increase of last 10 years	2.37 ppm yr^{-1}	7.3 ppb yr^{-1}	0.96 ppb yr^{-1}

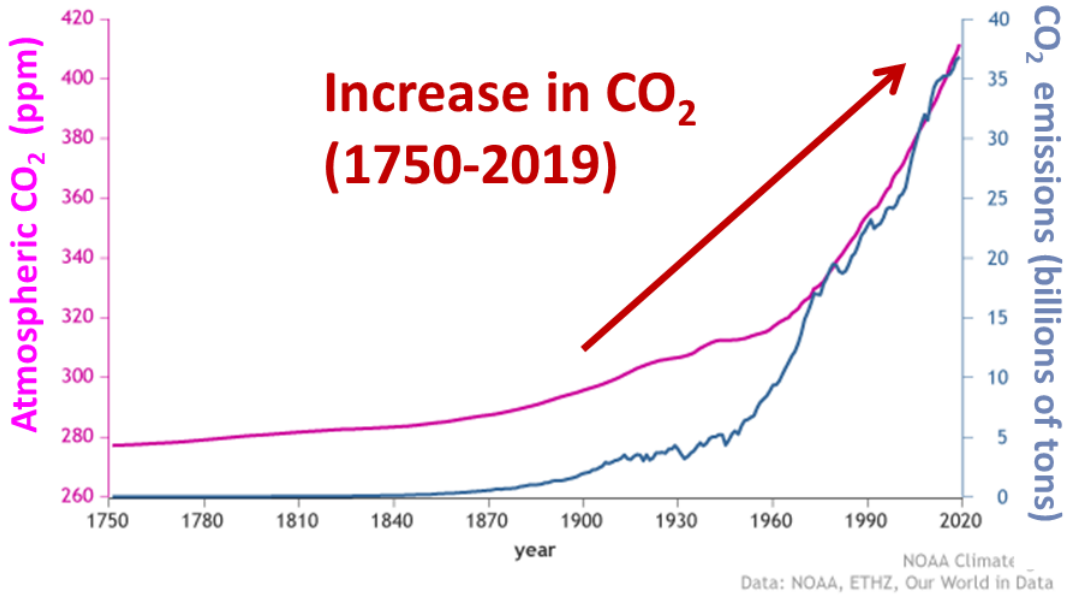


Figure 7-2: CO_2 concentrations and emissions in the atmosphere before and after the industrial revolution[50]

As shown in Figure 7-2, the concentration of CO_2 in the atmosphere (represented by the magenta line) is linked to the amount of CO_2 emissions released (the blue line). Before the industrial revolution until the 1800's, CO_2 emissions were fairly constant resulting in constant CO_2 concentrations in the atmosphere. At the beginning of the 1900's, the amount of emissions released from human activities increased exponentially, causing an equivalent increase in the concentration of CO_2 in the atmosphere. This shows the direct correlation between human-caused emissions that do not escape the atmosphere and increase its CO_2 concentration, resulting in global warming and climate change.

7.1.3 Rise in Global Surface Temperature

Earth's global average temperature increased by around 1 ◦C since 1880 (pre-industrial times), where two-thirds of this increase occurred since 1975. The rate of increase until 1981 was 0.08◦C/decade[51]. However, the rate of increase since 1981 has more than doubled, reaching around 0.2 ◦C/decade as illustrated in Figure 7-3[52].

[50]https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide

[51] https://earthobservatory.nasa.gov/world-of-change/global-temperatures

[52] Global Temperature Report 2019. Berkely Earth. Available at http://berkeleyearth.org/archive/2019-temperatures/ (accessed: 4 January, 2021)

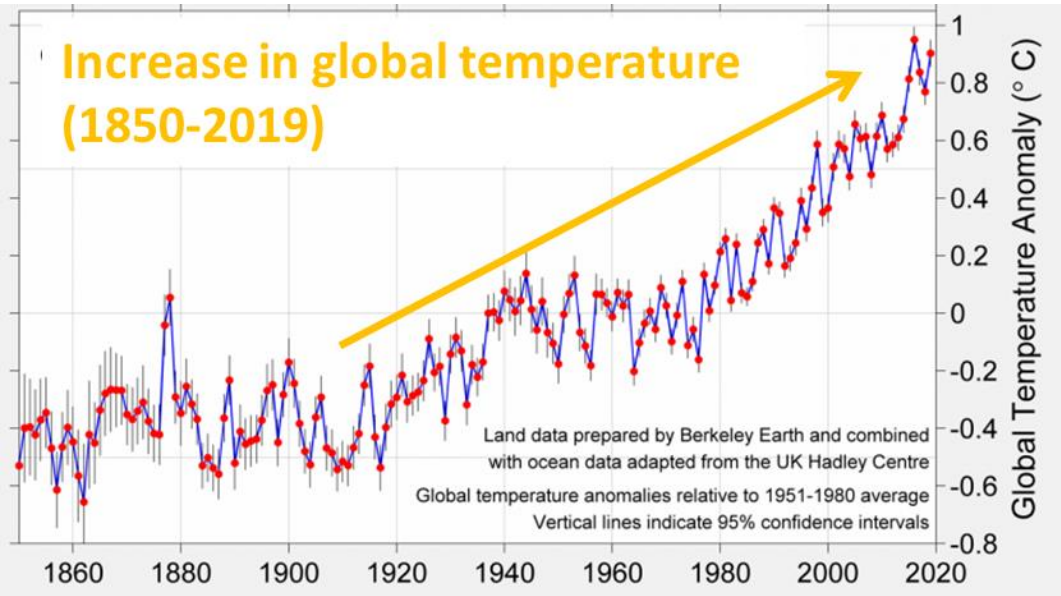


Figure 7-3: Global average temperature between 1850-2019[53]

If no action is taken to decrease global warming, predictions of global average temperature may reach 18.5 ◦C by 2100, an **increase of 3 to 4 ◦C over 80 years**[54].

In short, global warming is the trapping of heat by GHGs resulting in increased average surface temperatures over time. The amount of CO_2 in the atmosphere has increased since the start of the Industrial Revolution in 1750; in 2021, the concentration of CO_2 is expected to exceed 415 ppm and the total GHG concentration to approach 500 ppm. The increase in GHG concentration has resulted in Earth's global average temperature increasing by around 1 ◦C since 1880. Furthermore, the rate of increase since 1981 has more than doubled, reaching around 0.2 ◦C/decade and predictions of global average temperature may reach 18.5 ◦C by 2100, an increase of 3 to 4 ◦C over 80 years.

7.1.4 Self-check - Quiz

What is global warming?

a) Trapping of heat by GHGs resulting in increased average surface temperatures over time (correct answer)
b) Heating oceans
c) Surface temperature

What is the largest sector contributing to global greenhouse gas emissions?

a) Electricity and heat production (correct answer)
b) Agriculture and forestry
c) Transportation

[53] http://berkeleyearth.org/2019-temperatures/
[54] Temperature- Earth in the Future. PennState University. Available at https://www.e-education.psu.edu/earth103/node/1015

Cutting trees contributes to global warming because

a) Trees are a main sink for carbon sink and with less trees, more CO_2 remains in the atmosphere (correct answer)
b) Trees release CO_2
c) Animals will have no shelter

7.2 Illustrations of Concepts

Links to various material that can help engage the students and illustrate the concepts of the message is shown in Table 7-1.

Table 7-1: Various illustration aids for the concepts of global warming

Concept	Short description of illustration, diagram, video, online course	Reference, link
Global Warming	Video explaining the global warming and its effects.	https://youtu.be/Vh8XVkzsn1Y
	Global warming introduction and effects	https://www.nrdc.org/stories/global-warming-101 https://climate.nasa.gove/vital-signs/global-temperature/
	Before and after images of Earth, evidence, causes, effect and solutions to climate change through global warming	https://climate.nasa.gov/
	Climate causes and effects	https://www.nationalgeographic.com/environment/global-warming/global-warming-overview/
	Illustration showing the effects of global warming on different ecosystems	https://www.joboneforhumanity.org/what_is_global_warming_sign_up
	Global average temperature predictions by 2100	Temperature- Earth in the Future. PennState University. Available at https://www.e-education.psu.edu/earth103/node/1015 (Accessed: 4 January, 2021)
	CO_2 concentrations and emissions in the atmosphere over past 800 000 years	https://climate.nasa.gov/evidence/
GHGs	Detailed global GHGs emissions by sector and end-use activity and type of gas for 2016	https://wriorg.s3.amazonaws.com/s3fs-public/world-greenhouse-gas-emissions-sankey-chart-2019_2.jpg

7.3 Student Engagement Activities

7.3.1 Activity 1

Scientists have been recording the concentration of carbon dioxide since 1958 as shown in Figure 7-4.

S/N	Year	Annual mean	S/N	Year	Annual mean	S/N	Year	Annual mean
1	1959	316	20	1978	335	39	1997	364
2	1960	317	21	1979	337	40	1998	367
3	1961	318	22	1980	339	41	1999	368
4	1962	318	23	1981	340	42	2000	370
5	1963	319	24	1982	341	43	2001	371
6	1964	320	25	1983	343	44	2002	373
7	1965	320	26	1984	345	45	2003	376
8	1966	321	27	1985	346	46	2004	377
9	1967	322	28	1986	347	47	2005	380
10	1968	323	29	1987	349	48	2006	382
11	1969	325	30	1988	352	49	2007	384
12	1970	326	31	1989	353	50	2008	386
13	1971	326	32	1990	354	51	2009	387
14	1972	327	33	1991	356	52	2010	390
15	1973	330	34	1992	356	53	2011	392
16	1974	330	35	1993	357	54	2012	394
17	1975	331	36	1994	359	55	2013	396
18	1976	332	37	1995	361			
19	1977	334	38	1996	363			

Note: Unit is parts per million (ppm), rounded.

Figure 7-4: Average CO_2 concentration since 1959

Create a graph that displays the data in Table 1, showing the relationship between the annual atmospheric carbon dioxide level and year. Based on your graph, answer the following questions:

- What patterns do you notice in the atmospheric carbon dioxide levels?
- How would you explain the patterns you noticed in the atmospheric carbon dioxide levels?
- Based on your graph, what do you predict the atmospheric carbon dioxide levels to be in 20 years and why?

8 MESSAGE 8: SIGNS OF CHANGING CLIMATE

8.1 Background Information

The Earth's average temperature increase due to increase in concentrations of anthropogenic GHGs is only one of the signs of a changing climate as shown in Figure 8-1.

Figure 8-1: Signs of a changing climate

Changing Rain and Snow Patterns: As temperatures rise and the air warms up, more moisture evaporates from land and water into the atmosphere. More moisture generally means more rain and snow and more heavy downpours in varying places, times and quantities than before. This results in changing ecological processes and species distributions in many habitats, higher flood and drought risks, and declining crop and livestock quality, and shifting of crop belts (for example, pineapples which are currently grown in tropical regions may be cultivated the future in further areas.

Increased frequency and intensity of extreme weather events including floods, heavy rains and storms, drought, heatwaves, and fires. Hurricanes and tropical storms are becoming stronger due to warmer top layer of the ocean, which provides more energy resulting in faster winds and heavier downpours. At the other extreme, some parts of the world are experiencing extended periods of dry weather caused by a lack of rain or snow, i.e., more severe droughts. Droughts are linked to changes in how water moves between atmosphere, land, and oceans (i.e., water cycle), which can affect precipitation levels[55]. Rising temperatures have also been linked to increased risks and wildfire season length[56]. Warmer temperatures causing higher evaporation coupled with less rain lead to drier

[55]https://www.nationalgeographic.org/article/understanding-droughts/?utm_source=BibblioRCM_Row
[56] https://www.carbonbrief.org/global-risk-of-wildfires-on-the-rise-as-the-climate-warms-study-says

conditions and the risk of wildfires. Observations of extreme weather events are shown in in Figure 8-2. Extreme events may be disastrous to agriculture especially during the pollination season.

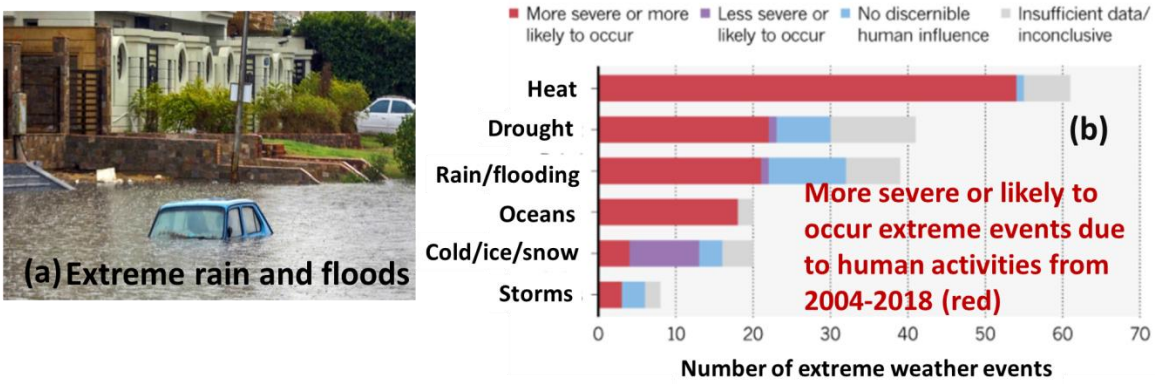


Figure 8-2: (a) Dragon storm hitting Egypt in March 2020 and (b) Global extreme weather events likely attributed to human activities (red)[57] from 2004-2018 based on studies. Heat: heatwaves and wildfires; oceans: marine heat, coral bleaching, disruption in marine ecosystems

Melting glaciers and shrinking ice sheets: Ice sheets and glaciers are located in the Arctic and Antarctica. Rising global surface temperatures have caused the increase in the rate of melting and loss of sea ice [58] shown in **Error! Reference source not found.**. More than 9 .6 billion tons of glacial ice has melted globally since 1961 and is increasing at a rate of 335 billion tons/year causing an average 2.7 cm sea level increase since 1961.[59]

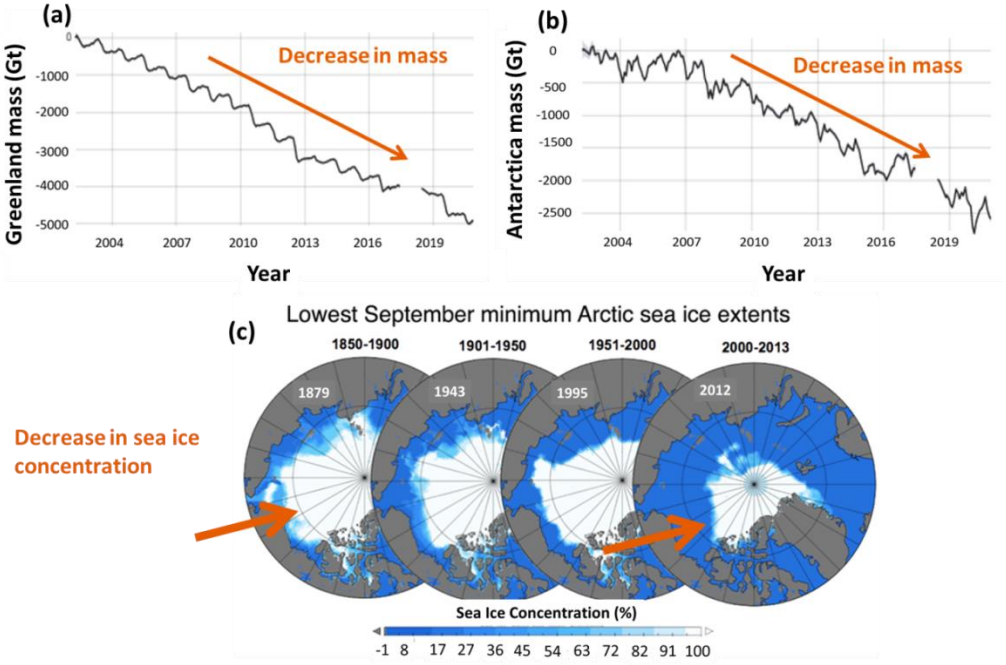


Figure 8-3: (a) Greenland, (b) Antarctica ice mass change from 2004-2019 and (c) Arctic from 1850-2013

[57] https://www.nature.com/articles/d41586-018-05849-9
[58] https://climate.nasa.gov/vital-signs/ice-sheets
[59] https://www.iberdrola.com/environment/melting-glaciers-causes-effects-solutions

The melting of glaciers and ice sheets has several implications contributing to further warming[60] as shown in Figure 8-4.

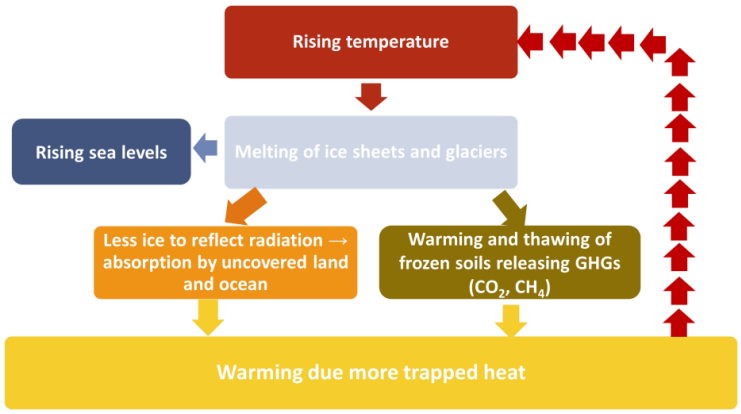


Figure 8-4: The implications of melting ice sheets and glaciers on global warming

Rising Sea Level: As water gets warmer, it expands and takes up more volume. Melting glaciers and ice sheets also cause sea level rise.[61] Global sea level rose about 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 as shown in Figure 8-5[62]. Over the five-year period May 2014 -2019, the rate of global mean sea-level rise has amounted to 5 mm per year, compared with 4 mm per year in the 2007-2016 ten-year period. This is substantially faster than the average rate of 3.2 mm/year between 1993 and 2010. Some speculate that global sea level rise could increase by up to 2.5 meters for high GHG emissions scenarios (if global average temperature increases by more than 4 ◦C) as illustrated in Figure 8-5. The Egyptian delta is particularly highly vulnerable to inundations due to sea level rise with considerable loss of fertile lands and jobs.

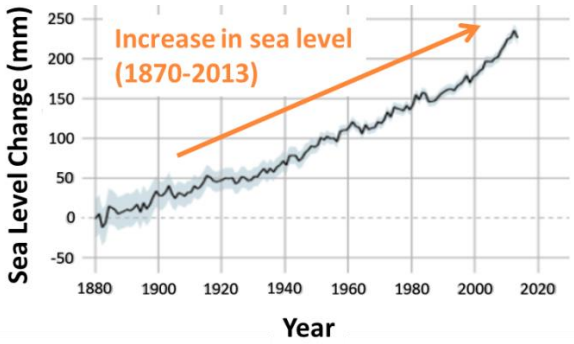


Figure 8-5: Sea level increase observed from 1870-2013

Loss and extinction of species: The rise in temperatures has influenced the rate of species lost due to their inability to adapt to changing surrounding[63]. Climate change is estimated

[60] https://scied.ucar.edu/learning-zone/climate-change-impacts/climate-and-ice
[61] https://www.climate.gov/news-features/understanding-climate/climate-change-global-sea-level#:~:text=Global%20warming%20is%20causing%20global,expanding%20as%20the%20water%20warms.&text=This%20shift%20of%20liquid%20water,largely%20due%20to%20groundwater%20pumping.
[62] https://climate.nasa.gov/vital-signs/sea-level/
[63] https://www.nationalgeographic.com/news/2014/4/140331-global-warming-climate-change-ipcc-animals-science-environment/

to have caused extinction of 8% of global species[64]. For example, the increase of CO_2 in the atmosphere causes more CO_2 to dissolve in oceans, where it reacts with seawater and forms carbonic acid leading to increased ocean acidity, which hinders the formation of shells and skeletons for marine species such as coral reefs[65].

Climate change is affecting all geographic regions, with varying intensities. Sea level rise, rising temperature, extreme weather and precipitation patterns, and warming seawater are among the principal impacts of climate change in Egypt, resulting in severe consequences on the population, the environment, and various economic sectors. The intensity of these consequences is a function of the vulnerability of the affected environmental or human systems. increased number of hot days, increased health risks associated (e.g., Asthma, allergies, and diarrheal diseases) with sun strokes and extreme heat, increased flash flooding events in low-lying areas (Sinai, Parts of Cairo, Aswan, Red Sea, Alexandria, etc) from once every four years to about one or more per year. In 2015, Egyptian Ministry of Health recorded more than 100 casualties due to extreme heat waves, and at least 11 deaths in floods. In addition, crop reduction is already a reality due to changes in growing conditions, affecting the main crops such as wheat and maize. Other signs of climate change include low livestock productivity due to effects loss of land and habitats, and water stress on feeding, growth, and reproduction of livestock and animals due to effects of rising temperatures, changing rain patterns and rising sea-level.

In short, the increase in concentrations of anthropogenic GHGs has translated into several signs of a changing climate consisting of rising surface temperatures, changing rain and snow patterns, increased frequency and intensity of extreme weather events including floods, heavy rains and storms, drought, heatwaves, and fires, melting glaciers and shrinking ice sheets, rising sea levels, and loss and extinction of species.

8.1.1 Self-check/quiz

Which one of these is a sign of climate change?

a) Sea level rise (the correct answer)
b) Famine
c) Pandemics

Which of the following are consequences associated with climate change?

a) Ice sheets are declining, glaciers retreat globally, and increased ocean acidification
b) Rising average global surface temperatures
c) More extreme weather like droughts, heat waves, and hurricanes
d) Global sea levels are rising

[64] https://science.sciencemag.org/content/348/6234/571
[65]https://www.nationalgeographic.org/media/acidification-reefs/#:~:text=The%20impact%20of%20ocean%20acidification,seawater%20to%20form%20carbonic%20acid.&text=However%2C%20it%20will%20take%20global,world's%20fragile%20coral%20reef%20ecosystems.

e) All of the above (the correct answer)

The melting of glaciers results in

a) Increased sea level
b) Less reflection of solar radiation causing warming
c) Release of more GHGs such as CO_2 and CH_4 due to uncovering of frozen soil
d) All of the above (correct answer)

8.2 Illustrations of Concepts

Links to various material that can help engage the students and illustrate the concepts of message 8 are shown in Table 8-1.

Table 8-1: Various illustration aids for the concepts of signs of changing climate

Concept	Short description of illustration, diagram, video, online course	Reference, link
Climate Change	Video explaining the climate change and what leads to climate change and its effects.	https://youtu.be/Sv7OHfpIRfU
	Before and after images of Earth, evidence, causes, effect and solutions to climate change through global warming	https://climate.nasa.gov/
Hurricanes	Definition and causes of hurricanes	https://www.bbc.com/news/world-45112674
Extreme weather events	Attributing human influence to extreme weather events- Interactive map	https://www.carbonbrief.org/mapped-how-climate-change-affects-extreme-weather-around-the-world
Signs of changing climate	Sea level rise quiz	https://climate.nasa.gov/quizzes/sea-level-quiz/
	An interactive exploration of how global warming is affecting sea ice, glaciers, and continental ice sheets worldwide.	https://climate.nasa.gov/interactives/global-ice-viewer/#/1
	Precipitation quiz	https://climate.nasa.gov/quizzes/water-cycle/ https://www.livescience.com/ocean-currents-speeding-up.html
	Ocean acidification	https://oceanservice.noaa.gov/facts/coralreef-climate.html
	Droughts around the world	https://www.thebalance.com/drought-definition-effects-examples-and-solutions-4157896

8.3 Student Engagement Activities

8.3.1 Activity 1[66]

Objective: the objective is to identify sea level rise due to warming.

Materials: 1-L bottles, water, straw, clay, marker, indoor light bulb.

Procedure:

1. Fill a 1-L bottle with water to the rim
2. Insert a straw inside the bottle and wrap a piece of clay around the opening leaving no gaps for water to escape
3. Mark the water level in the bottle at base
4. Subject the bottle to direct sunlight or indoor light bulb record the water level at regular time intervals and observe the changes that will occur in water height due to heat

8.3.1 Activity 2

Objective: the objective is to identify sea level rise due to melting glaciers.

Materials: Plastic containers, rocks/ clay, ice cubes, cold water, marker.

Procedure:

1. Prepare a plastic containers and pour the water in the container to a certain level and mark the water level with the marker
2. Place the ice cubes in the container
3. Record and observe the rise in water level in the container after placing the ice cubes

8.3.1 Activity 3[67]

Objective: the objective is to identify ocean acidification.

Materials: two plastic cups, acid base indicator, soda, vinegar, spoon.

Procedure:

1. Prepare two plastic cups and pour 40 ml of acid-base indicator solution in each cup
2. Add 2 grams of soda and 5 ml of vinegar to one of the cups and mix the ingredients well together

[67] https://www.exploratorium.edu/snacks/ocean-acidification-in-cup

3. Observe the color changing in the cup where the baking soda and vinegar were added to the acid solution stimulating the release of carbon dioxide and acidification of water

9 MESSAGE 9: IMPACT OF CHANGING CLIMATE

9.1 Background Information

Climate change is causing direct and indirect adverse impacts on the environment, society and public health, as well as the economies. Impacts can be classified into physical impacts, biodiversity impacts, ecosystem vulnerability impacts, and socio-economic impacts.

9.1.1 Physical Impacts

Scientific measurements of historical climate patterns, trend observations and studies made by NASA has shown that the Earth's average global temperature has risen by a little more than 1 ◦C in less than 100 years[68]. Egypt experienced warming trends since 1960 with greater warming in summer at around 0.31°C per decade than during winter at 0.07°C per decade[69]. Climate change result in various adverse effects including:

- **Extreme heat waves:** heat waves are defined as periods (up to 3-7 days) of abnormally and unexpectedly hot and usually humid weather[70]. Hotter days lead to higher evaporation rate of moisture in soils (drought), resulting in dried vegetation and loss in agricultural yields and reduction in livestock growth and milk production affecting food security and may lead to famines. Health effects of extreme heat include heat strokes, dehydration, exhaustion, cramps causing muscular pains and spasms, and higher pollen concentrations and longer pollen seasons causing respiratory effects from pollen and other allergens. Warmer climate may increase rates of hospital admissions due to cardiovascular disease, respiratory disease, cerebrovascular disease, and spread of infectious vector-borne diseases which could increase death rates. Extreme heat waves also lead to more frequent and larger wildfires in forests. In addition, it has indirect consequences such as increasing the demand for electricity for cooling.

- **Extreme weather events:** More frequent and aggressive climate events causing natural disasters such as droughts, hurricanes and storms, extreme precipitation, and floods71. Flooding of urban areas such as cities and rural areas (i.e., agricultural lands), which result in damage to infrastructure and assets (homes, buildings, etc.) and loss of agriculture due to degraded water quality from the run-off of pollutants including heavy metals and pesticides into water streams and lakes, which also poses health threats. Degraded water quality creates breeding environment for disease-

[68] https://earthobservatory.nasa.gov/world-of-change/global-temperatures

[69] https://www.climatelinks.org/sites/default/files/asset/document/Egypt%20Climate%20Info%20Fact%20Sheet_FINAL.pdf

[70] American Meteorological Society. Glossary: heat Wave. Available at https://glossary.ametsoc.org/wiki/Heat_wave (accessed: January 20th, 2021)

[71] Global Change Organization. Highlights: Extreme Weather. Available at https://nca2014.globalchange.gov/highlights/report-findings/extreme-weather (accessed: January 20th, 2021)

carrying insects such as mosquitoes carrying malaria. Other health threats include increasing casualties and injuries due to more frequent storms and flash or coastal floods. Floods contaminate freshwater supplies, and increase exposure to pathogens, causing diarrheal diseases (e.g., salmonellosis and campylobacteriosis).
Fruit bearing trees such as citrus species (oranges and mandarins) begin to produce their flowers in the month of March after the end of the cold weather winter. By spring, pollination begins, which in turn leads to the formation of fruit set (the first fruit stage). The fruit set is a transition phase of the ovary from the flower to the developing fruit, and takes place a few days after the floral opening. If a cold weather front or excessive winds (extreme events) is encountered at this period, the tress experience excessive fall of freshly pollinated fruit sets or even losing the flowers before pollination. This results in great loss of the agriculture produce when harvested. Unfortunately, such events are frequently recorded in Egypt during the last 10 years. Sensitive plantations (like Mango trees) are severely harmed.

- **Melting of glaciers** at rapid rates results in faster, more turbulent currents in the ocean that disrupt heat transfer and water movement on Earth.

- **Sea level rise[72]:** Sea level rise result in more frequent and severe floods and hurricanes, especially in coastal regions (e.g., Alexandria), intrusion of seawater into fresh underground water aquifers, and soil erosion and increased salinity. This affects the quality and quantity of agricultural production and contributes to food insecurity due to loss of habitat for fish, birds, and plants. Food insecurity will result in prevalence of malnutrition and undernutrition, and could increase mortality rate.

9.1.2 Biodiversity impacts

Biodiversity (or biological diversity) is the diversity and variability of species existing within different terrestrial and marine ecosystems. The types of biodiversity include genetic diversity (genetic variability found within species), ecosystem diversity (variety of habitats and community of living organisms and their components within a geographic area), and species diversity (abundance and wealth of populations of different species in a given area).

There are natural and human-induced factors that affect biodiversity shown in Figure 9-1.

[72] NOAA Climate. Available at https://www.climate.gov/news-features/understanding-climate/climate-change-global-sea-level (accessed: January 20th, 2021)

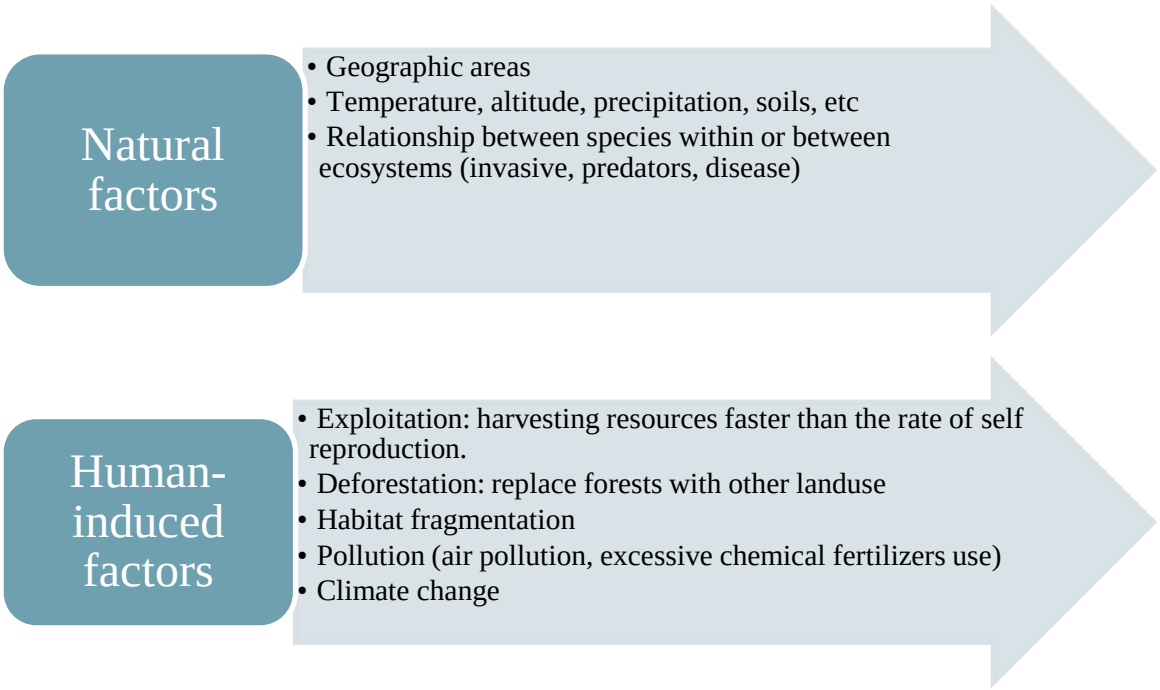


Figure 9-1: Natural and human-induced factors that affect biodiversity

The climate system strongly affects the adaptability and quality of populations and ecosystems and their interactions with each other. Increased floods, droughts, wildfires, extreme weather, and ocean warming affect biodiversity by causing:

- Shifts in migration patterns in species: Some species are forced to migrate from their natural habitats to foreign cooler regions because of the warmer climate
- Shifts in species distribution: due to migration or expansion of species fetching more suitable climatic conditions to survive. A serious example is the shift of the Malaria belt where Anopheles mosquitoes are capable of production in further lands. Malaria transmission is largely constrained by the suitability of climate for Anopheles mosquitoes and Plasmodium parasite development. Thus, as climate changes, shifts in geographic locations suitable for transmission, and differing lengths of seasons of suitability do occur leading to further spreading of the disease.
- Changes in reproduction patterns in species, resulting in changes in population sizes (declining or extinct populations)
- Changes in timing of biological cycles and behaviors, species dynamics and interactions, and growth seasons (e.g., some animals wake from hibernation sooner or migrate at varying times, causing imbalance within their ecosystem)
- increased frequency of pest and disease outbreaks, degrading the quality of habitats

Climate change is currently affecting more than 40,000 species, amounting to 19% of species on Earth. The International Union for Conservation of Nature IUCN Red List is an indicator of the health of global biodiversity[73] and the Red List Index (RLI) reflects the health status of species. RLI projections of global species survival for mammals, birds, amphibians, reef-forming corals and cycads are illustrated in Figure 9-2. According to IUCN, the most threatened species in Egypt include 18 mammals, 16 birds, 13 reptiles, 76 fish, 56 other invertebrates, and 8 plants[74]. Examples include the Egyptian tortoise, Sinai tiger, Barbary sheep, Egyptian vulture, Black-crowned crane, and Sinai Wild Rose and Primrose as shown in Figure 9-3.

Figure 9-2: IUCN Biodiversity Red List Index projections

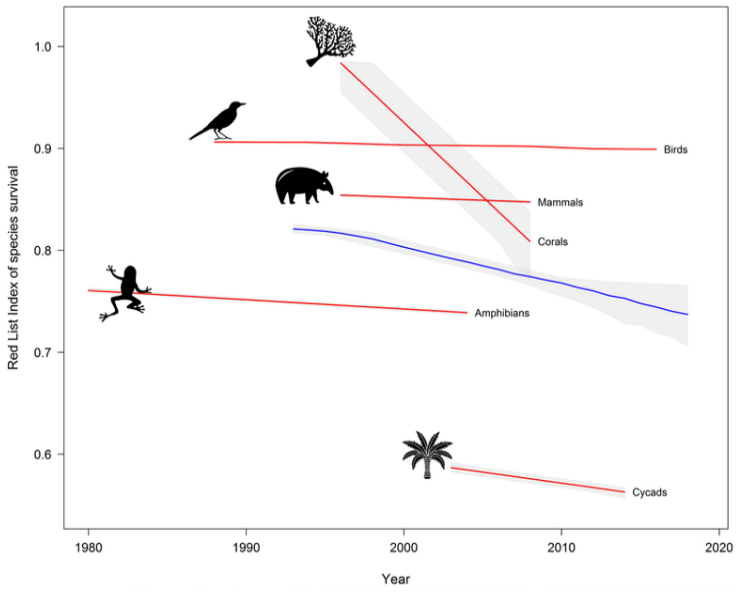


Figure 9-3: Examples of threatened species in Egypt. From left to right: Egyptian vulture, Egyptian Tortoise, and Wild Sinai Rose

[73] Health of global biodiversity is determined using criteria such as original population size, rate of population decline, geographic range of distribution, and quantitative study on the probability of species extinction

[74] IUCN Red List Statistics. Available at https://www.iucnredlist.org/statistics (accessed January 20th, 2021)

Conservation Status of Endemic plants:

- Among the more than 2,300 plant species present in Egypt, only about 44 species are endemic which distributed in different geographic and ecological ranges in Egypt (El-Khalafy, 2018). Despite the painstaking work during the previous years to conserve endangered species in Egypt by establishing Protected Areas and developing monitoring and conservation programs, the current state of conservation of endemic species in Egypt is still unknown at the global level and is not included in the global red lists (Omar and Elgamal 2021 b).
- The lack of geographical, ecological and conservation status information for endemic species in Egypt (about 44 species) will result in the absence and disregard of future conservation planning, which will lead to a significant deterioration in the status of populations and habitat for those species in the near future.
- The preliminary national Red List includes 457 species (or close to 20% of the flora) classified in the following categories: 14 extinct, 123 endangered, 54 vulnerable, 173 rare and 93 not determined (El-Hadidi & Hosni, 2000). The IUCN criteria and categories were not used for a number of geographically restricted species primarily because of the lack of sufficiently precise data to establish their Areas of Occupancy (AOO).
- The IUCN global Red List contains 380 plant taxa with a distribution area that includes Egypt, or 9.6% of the total flora of Egypt, 15 species of which are in one of the threatened categories (CR, EN, VU) (Omar 2019).
- From the 44 endemic species, only 11 have listed as globally threatened species by Omar, (2014), Omar (2017 a-e), and Omar and Elgamal (2021 d-h) on the IUCN Red List. The distribution range and population size for these 11 species are extremely small and severely threatened by continuous extensive human activities (over harvesting and over grazing) that pushing them to brink extinction so fast. It has revealed that there is a continuing decline in habitat quality and number of sites for these species, with evidence of declines in subpopulation numbers and numbers of mature individuals.
- These plants are subject to continuous and rapid destruction and deterioration as a result of climate change and drought, and there are no field activities to stop the bleeding and save them from extinction.

- During the past ten years, with the support of the Ministry of Environment, UNDP, Conservation Leadership Program (CLP), Rufford, and Ford Foundations many important steps have been taken in the field of biodiversity conservation. These steps aimed to improve knowledge and decision making about the conservation status of endemic species in whole Egypt and determine the impact of climate change on its conservation status as a baseline followed by establishment and implementation of a Long term conservation recovery program for the most globally threatened endemic plant species in St. Catherine Protected Area (SCPA) through Community-based management approach program depend on research, restoration, building capacities, participation, and documentation.

- These steps resulted in the listing of 11 endemic plant species on the global IUCN Red List as Critically and Endangered threatened with extinction. During these studies, the geographical distribution of the target species, the extent of their spread and occupation, the ecological and population status, and the threats to them, its impact and severity were determined. High-accuracy programs have been

developed using stabilization zooning and modelling programs to determine the best suitable habitat for recovery process (in situ) and to provide recommendations and action plans for the rehabilitation of the most affected species. The results showed a continuous deterioration in the population of the population and the condition of the habitats, and recommended a quick intervention to stop the continuous bleeding and a quick rehabilitation program (Omar, 2014; Omar 2017 a-e; and Omar and Elgamal 2021 d-h).

Table-: List of globally Red List threatened endemic plants in Egypt

No	Scientific Name	Family Name	Red list Category	Red list Criteria
1	*Primula boveana*	PRIMULACEAE	Critically Endangered	B1ab(i,ii,iii,iv,v)+2ab(i,ii,iii,iv,v)
2	*Rosa arabica*	ROSACEAE	Critically Endangered	B1ab(i,ii,iii,iv,v); C2a(i)
3	*Silene oreosinaica*	CARYOPHYLLACEAE	Critically Endangered	B1ab(ii,iii)+2ab(ii,iii)
4	*Ballota kaiseri*	LAMIACEAE	Critically Endangered	B1ab(i,ii,iii,iv)
5	*Micromeria serbaliana*	LAMIACEAE	Critically Endangered	B1ab(ii,iii)
6	*Anarrhinum pubescens*	PLANTAGINACEAE	Endangered	B1ab(i,ii,iii,iv,v)+2ab(i,ii,iii,iv,v); C2a(i)
7	*Bufonia multiceps*	CARYOPHYLLACEAE	Endangered	B1ab(i,ii,iii,v)+2ab(i,ii,iii,v); C2a(i)
8	*Euphorbia obovata*	EUPHORBIACEAE	Endangered	B1ab(iii,v)+2ab(iii,v)
9	*Phlomis aurea*	LAMIACEAE	Endangered	B1ab(iii,v)+2ab(iii,v)
10	*Silene leucophylla*	CARYOPHYLLACEAE	Endangered	B1ab(i,ii,iii)+2ab(i,ii,iii)
11	*Silene schimperiana*	CARYOPHYLLACEAE	Endangered	B1ab(ii,iii)+2ab(ii,iii)

9.1.3 Ecosystem Vulnerability

An ecosystem is a geographic area in which plants, animals, other living organisms, and non-living environmental and climatic conditions interact together to form a community of life. Principal ecosystems include Deserts, Mountains, Forests, grasslands, permafrost[75] and Tundra[76] which are categorized as terrestrial ecosystems (i.e., existing on land). Other principal ecosystems include aquatic or marine systems such as oceans, rivers, lakes, marshlands, and wetlands. Ecosystems are driven by the same factors affecting other biodiversity elements. Human-induced climate change has direct and indirect impacts on both terrestrial and aquatic ecosystems as shown in Figure 9-4.

Is Corona outbreak related to climate change? The COVID19 pandemic is suspected of originating in bats and pangolins as a consequence of risk of viruses that jump from wildlife to humans when the original habitat is disturbed. These leaps happen at edges of the world's tropical forests, where deforestation is increasingly bringing people into contact with animals' natural habitats. *Yellow fever, Malaria, Venezuelan equine encephalitis, Ebola* –

[75] Definition of permafrost by National Geographic. Available at https://www.nationalgeographic.org/encyclopedia/permafrost/ (accessed: January 20th , 2021)
[76] National Geographic defines them as treeless regions with extreme cold and low rainfall, and they are typically permanently frozen

all of these pathogens have spilled over from one species to another at the margins of forests due to human interference without respecting the natural environment.

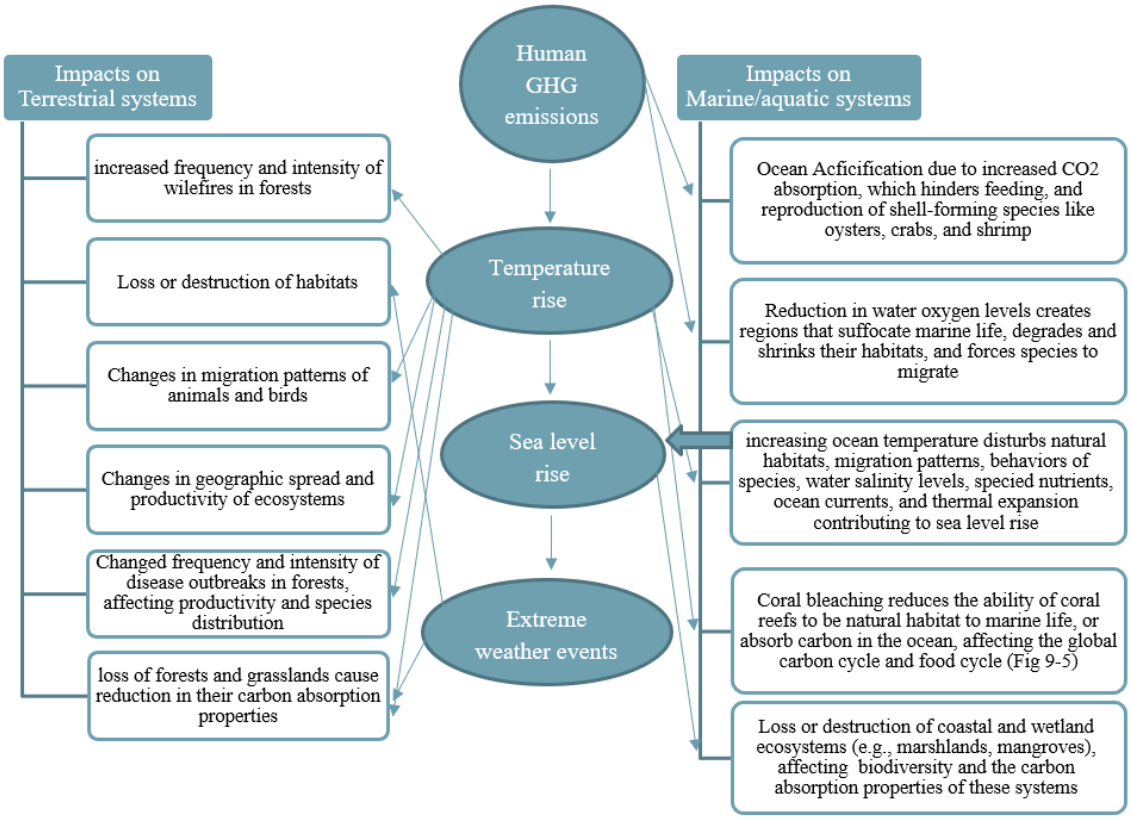


Figure 9-4: Impacts of climate change on terrestrial and aquatic ecosystems

Figure 9-5: Coral Bleaching[77]

[77] When corals are subjected to changes in temperature, light, or nutrients, they expel the algae living in their tissues, causing them to turn completely white

9.1.4 Socio-economic impacts

The impacts of climate change extend beyond the direct environmental impacts, and their effects extend to the society and the economy as well.

Impacts such as temperature rise and changes in precipitation causing droughts or floods result in loss of agricultural lands, soil collapse and fluctuation in crop production, and loss of soil fertility, erosion, and salinization. Droughts, heat waves, and unpredictable rain patterns also result in Limited seasons for growing various crops affecting food security and nutrition. Loss of livelihoods due to land loss or degradation of soil or water quality will affect the rural communities' skills and expertise (human capital) and will increase rural-urban migration and reduced agricultural production. For example, in Alexandria, more than 195,000 jobs would be lost in addition to lost jobs in fishing and tourism (increased poverty).

Heavier downpours due to changing rain patterns will also increase surface water run-off that carry pollutants and waste into water streams such as lakes and rivers causing chemical contamination, toxic algal blooms formation along rivers' coasts, affecting water quality for humans, animals, or plants. Sea level rise causes coastal flooding that result in saltwater intrusion into coastal lands, affecting freshwater aquifers and soil quality.

Climate change will cause water supply shortages in regions and communities relying on freshwater streams for their livelihood. Countries that depend on irrigated agriculture due to scarcity of rain (like Egypt) are particularly affected since crop water requirements will increase with increased temperature. Water scarcity will force farmers to abandon agricultural lands and migrate to urban area, thus increasing desertification.

Scientists predict that by 2050, more than 200 million people will be forced out of their homes because of direct and indirect climate change impacts, referred to as climate migrants. For example, in Egypt, displacement of around 10.5% of the total population from Alexandria, Damietta, Port Said, Kafr Elsheikh, and Dakahlia among others (internal or external migration) is projected due to increased flooding. Annual average of about 2.4 million people are projected to be affected by flooding between 2070 and 2100.

Climate change will result in increased intensity and number of Asthma and allergies cases (due to high pollen concentrations), increased risks of skin cancer, eye cataracts, heat strokes, diarrheal diseases and heart-related conditions, and increased mortality rates and malnutrition[78].

In short, climate change is causing direct and indirect adverse impacts on the environment, society and public health, as well as the economies. Physical impacts such as extreme heat waves and weather events have direct implications threatening health due to spread of diseases and degraded water quality, food security, and integrity of other systems such as forests. Physical impacts affect biodiversity by disturbing migration pathways of species,

[78] World Health Organization, Global Database on Child Growth and Malnutrition.

their distribution, reproduction patterns etc. Human-induced climate change has impacted both terrestrial and aquatic ecosystems by compromising their integrity; examples include coral bleaching and ocean acidification, destruction of natural habitat. The latter is suspected to be responsible for the latest COVID-19 pandemic, where natural habitats of bats and pangolins have been destroyed. Impacts of climate change in socio-economic conditions include increased rural-urban migration, loss of livelihoods, in particular in the agriculture sector, and increased threats to public health.

9.1.5 Self-check quiz

Coral bleaching is one of climate change impacts on:

a) ecosystems vulnerability (correct answer)
b) Sea level rise
c) Ocean currents
d) Extreme precipitation

Which of the following is considered a biodiversity impact due to climate change?

a) Extreme weather events
b) Shifts in migration patterns in species (correct answer)
c) Droughts and flood events
d) Hurricanes

The rise of global average temperature of the Earth results in:

a) Extreme weather events
b) warmer oceans
c) Loss of habitats
d) All the above (correct answer)

9.2 Illustrations of Concepts

Links to various material that can help engage the students and illustrate the concepts of the impact of climate change are shown in Table 9-1.

Table 9-1: Various links to more illustrations of the impact of climate change

Concept	Short description of illustration, diagram, video, online course	Reference, link
Definition of permafrost	Definition of permafrost by National Geographic	https://www.nationalgeographic.org/encyclopedia/permafrost/
Definition of heatwave	Definition of heatwave by American Meteorological Society	https://glossary.ametsoc.org/wiki/Heat_wave
Need of Ice on Earth	This video shows us how important is ice on Earth and why we need ice on Earth.	https://youtu.be/iGG7mD9LwAc
Climate Change influence on species	Flash cards about species that gets effected by climate change and how the get effected.	https://www.wwf.org.uk/learn/effects-of/climate-change https://www.iucnredlist.org/statistics

Concept	Short description of illustration, diagram, video, online course	Reference, link
Extreme weather events caused by climate change	A description of extreme weather events caused by climate change such as heat waves, droughts, heavy downpours, floods, hurricanes	https://nca2014.globalchange.gov/highlights/report-findings/extreme-weather
Impacts of Sea level rise on coastal regions	Example: A sea level rise of 50 cm in Alexandria could lead to the displacement of more than two million people from their homes, the loss of 214,000 jobs and the loss of land valued at more than $ 35 billion due to the expected flooding of many parts of the city, as illustrated in the figures provided in the references.	https://earth.org/data_visualization/sea-level-rise-by-the-end-of-the-century-alexandria/ https://www.nytimes.com/interactive/2019/10/29/climate/coastal-cities-underwater.html https://www.climate.gov/news-features/understanding-climate/climate-change-global-sea-level
Ecosystem services	Illustration and definition of the four different types of ecosystem services, including examples of each	https://tunza.eco-generation.org/m/view.jsp?board=ourActions&viewID=47345 https://www.nwf.org/Educational-Resources/Wildlife-Guide/Understanding-Conservation/Ecosystem-Services
Coral bleaching	Brief explanation and illustration of coral bleaching	https://oceanservice.noaa.gov/facts/coral_bleach.html#:~:text=Warmer%20water%20temperatures%20can%20result,bleaches%2C%20it%20is%20not%20dead.

9.3 Student Engagement Activities

9.3.1 Activity 1

Procedure:

1. Divide the class into 5 groups and ask each group to design a poster based on research of one of the principal ecosystems and illustrate the main impacts of climate change on each of them
2. Assign one type of ecosystem to each group
    - Group 1: Oceans
    - Group 2: Forests
    - Group 3: Mountains
    - Group 4: Wetlands

- Group 5: Permafrost

3. Provide guiding research questions:
   - What are the elements of this ecosystem?
   - How does climate change affect the different elements?
   - What are the consequences of these impacts on the environment, society, and economy?
   - Find two specific real-life examples to explain the consequences
4. Students to be given one week for research and poster design
5. Students to present their posters and their research outcomes to the other groups
6. Teacher chooses “best poster design” to be hanged in the classroom

10 MESSAGE 10: SOCIOECONOMIC IMPACTS OF CHANGING CLIMATE

10.1 Background Information

Climatic change impacts are posing threats to the social and economic conditions of hundreds of millions of people around the world. Socioeconomic risks include increased food insecurity, loss of livelihoods, freshwater scarcity, energy insecurity, Forced displacement/environmental migration, and degraded human health.

10.1.1 Impacts on Food Security

Food security is defined as the availability of food and access to it. Main factors that affect food security include affordability, nutrition, and availability. Climate change affects all aspects of the food cycle including production, availability, access, quality and stability of food systems. Impacts such as temperature rise, ocean warming, and loss of habitats pose threats on global food security as summarized in Figure 10-1.

Figure 10-1: Impacts of climate change on food security

Low-income communities are particularly at higher risk of food insecurity than other groups. Scientists projected that up to 183 million additional people will be at risk of hunger by 2100[79].

10.1.2 Loss of Livelihoods

Livelihood is the activities and capabilities required for a means of securing life necessities and supporting family's living. Communities relying on agriculture, fishing, raising livestock, and forestry sectors for their livelihood are the most affected by impacts of climate change including rise in temperature, changes in weather patterns, storm surges, ocean warming, sea level-rise and loss of habitats and ecosystems. More specifically, consequences of these impacts are shown in Figure 10-2. Urban communities are also affected. For example, extreme weather events can damage houses, water resources, and transport infrastructure and cause unemployment and loss of assets.

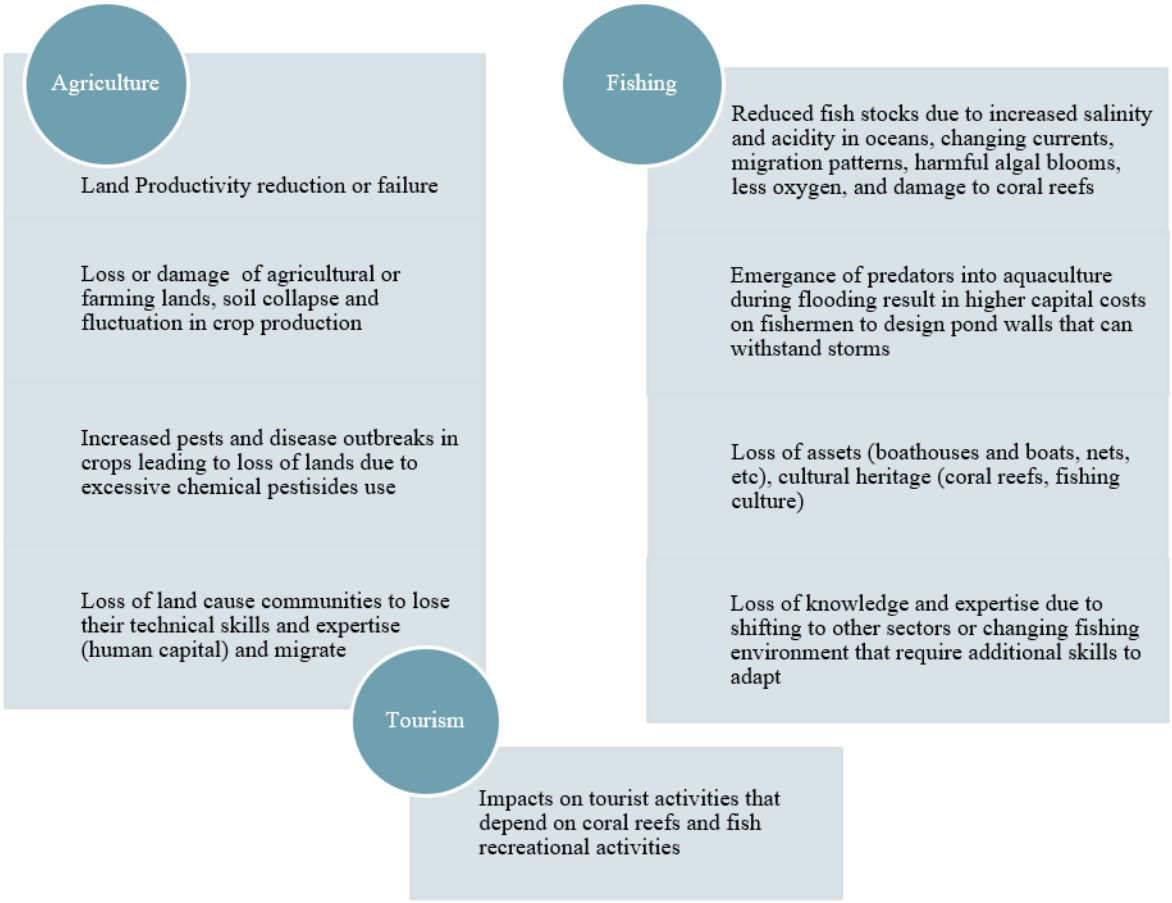


Figure 10-2: Impact of Climate Change on livelihoods

10.1.3 Water Resources

Water resources are sources of fresh water that are necessary for survival of society. Fresh water sources include groundwater, rivers, lakes, and reservoirs. The global hydrological

[79] Special Report on Climate change: Food security. Available at https://www.ipcc.ch/srccl/chapter/chapter-5/ (accessed January 21st, 2021)

cycle[80], how water moves between the atmosphere, land, and water bodies, is changing due to rising temperatures. Variations in weather and rainfall patterns, drought, flood, storms, and changes in groundwater quality (e.g., saltwater intrusion into freshwater sources) are but few expectations. Climate change affects water resources in two ways: water supply (availability and accessibility), and water quality as shown in Figure 10-3.

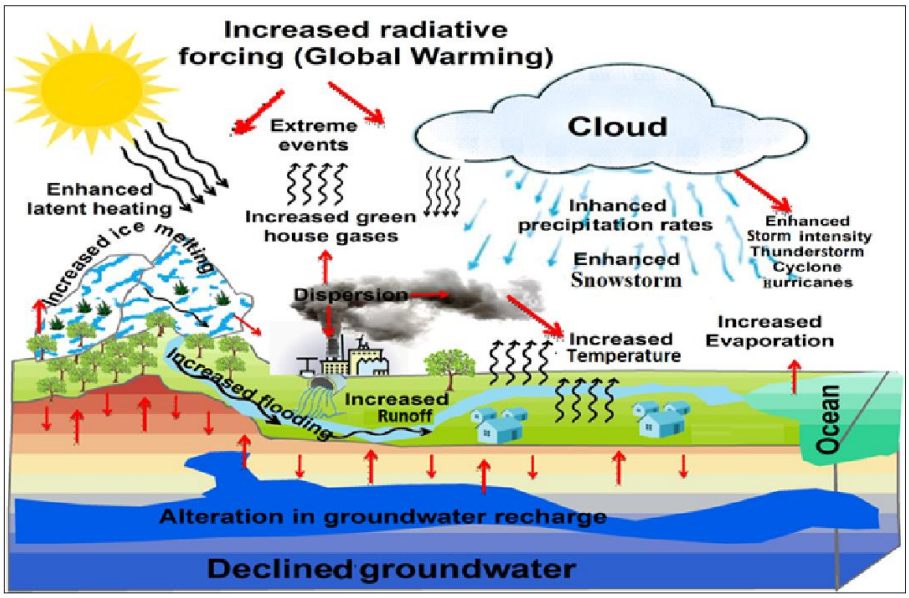


Figure 10-3: Climate change impacts on the global hydrological cycle

10.1.3.1 Impacts on Water Supply[81]

Rising temperatures increase evaporation rates from surface water causing drying out of some areas, reduction in flows in rivers and lakes to groundwater aquifers, and overall reduction and variability in rainfall. At the same time, the excess condensed water vapor in the atmosphere will then fall as excess precipitation in other areas causing floods. Furthermore, warmer global temperatures cause more rain than snow, and causes earlier melt of snow. These changes cause water supply shortages in regions and communities relying on freshwater streams for their livelihood. Regions are affected differently by water shortage. The global level of stress over freshwater resource availability is illustrated by country in Figure 10-4. Egypt's water stress level is considered high (No. 43 worldwide on the list of water stressed areas)[82]. Countries which depend on irrigated agriculture due to scarcity of rain (like Egypt) are particularly affected by global warming as crop water requirements will increase with increased temperature. This will impose additional stress on groundwater resources which are mainly nonrenewable in Egypt, meaning that water extracted from groundwater for development purposes (agriculture or otherwise) will not be replenished.

[80] The natural balance between rates of precipitation and evaporation
[81] Climate Impacts on water Resources. US Environmental Protection Agency. Available at https://19january2017snapshot.epa.gov/climate-impacts/climate-impacts-water-resources_.html (Accessed: January 21st , 2021)
[82] These Countries Are the Most at Risk from a Water Crisis. Bloomberg. Available at https://www.bloomberg.com/graphics/2019-countries-facing-water-crisis/ (accessed: January 21st, 2021)

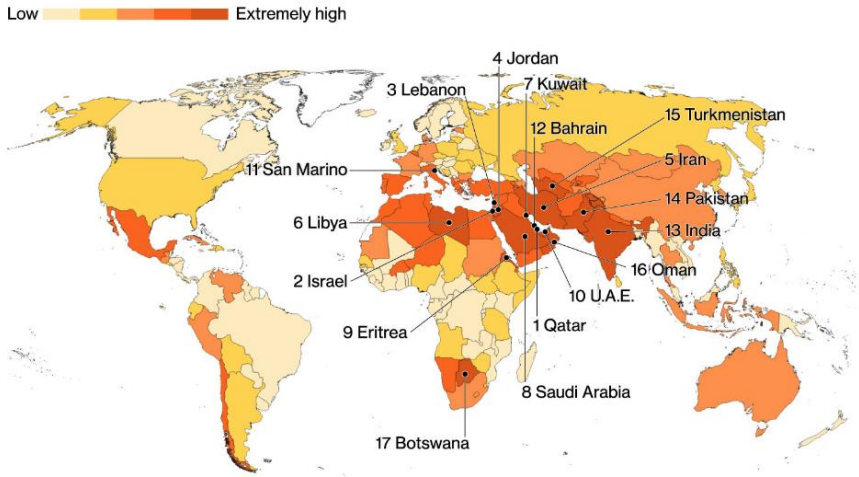


Figure 10-4: Effects of climate change on water supply (source: WRI Aqueduct Atlas)

10.1.3.2 Impacts on Water Quality

Increases in heavy precipitation events and storm surges will overwhelm water handling infrastructure such as sewer systems and water treatment plants due to the increased volumes of water. Heavier downpours will also increase surface water run-off that carry pollutants and waste into water streams such as lakes and rivers causing chemical contamination, toxic algal blooms formation along rivers' coasts, affecting water quality for humans, animals, or plants. Sea level rise causes coastal flooding that result in saltwater intrusion into coastal lands, affecting freshwater aquifers.

10.1.4 Forced Displacement/ Climate Migration

Scientists predict that by 2050, more than 200 million people will be forced to flee their homes because of direct and indirect climate change impacts, referred to as climate migrants[83]. The main drivers of climate –induced migration include:

- Increased droughts: Lands in constant drought are expected to increase from 2 to 10 % by 2050, making many regions of the world less livable due to extreme weather events and disasters, loss of asset or livelihoods, extreme hot or cold weather, and food and water insecurity.
- Increased melting of glaciers and coastal and flash flooding pose safety threats on nearby communities, especially in areas of lower altitudes
- The area of coastal wetlands is projected to decrease due to sea level rise. This will result in loss of assets and livelihoods of the communities benefiting from these areas and pose safety threats as the loss of wetlands reduce the adaptive capacity against flooding and heavy downpour events.
- Indirect consequences include loss of jobs, loss of breadwinners in the family due to natural disasters or climate-related health problems, damage or deterioration of basic

[83] Migration and Climate Change. IPCC. Available at https://www.ipcc.ch/apps/njlite/srex/njlite_download.php?id=5866 (accessed: January 21st, 2021)

infrastructure and services (i.e., sewage, transport, public services, schools, food production, etc.)

10.1.5 Impacts on Human Health

Climate change exposes humans to various direct and indirect health risks. Considerations such as age, gender, economic resources, and location influence the intensity and exposure to climate-induced risks. Global temperature rise increases heat waves and extreme weather, which catalyze contamination pathways and disease transmission dynamics. This affects public health directly and indirectly as shown in Figure 10-5[84].

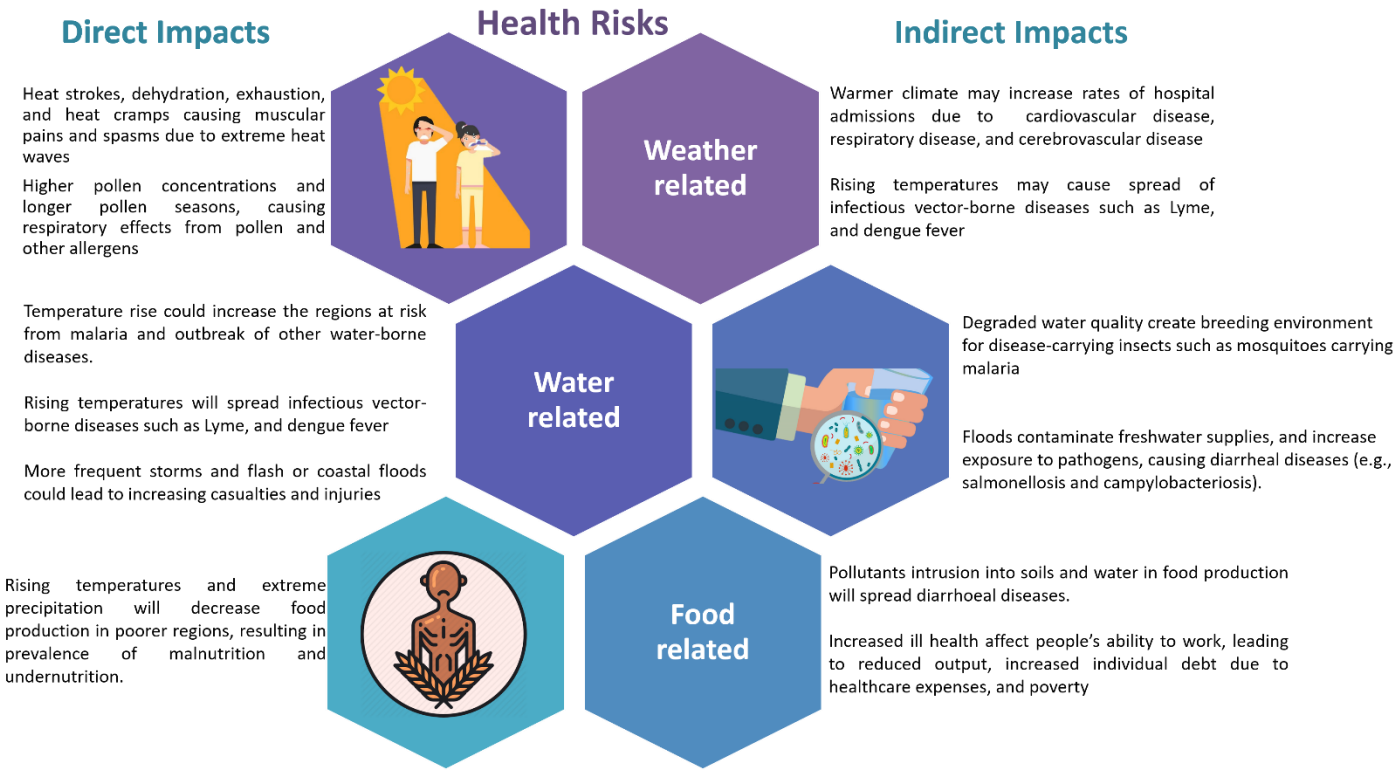


Figure 10-5: Direct and indirect impacts of climate change on public health

Impacts of climate change on socio-economic conditions include increased food insecurity particularly due to risks affecting agriculture, loss of livelihoods in tourism, agriculture, and fishing industries, freshwater scarcity, energy insecurity, forced displacement/environmental migration due to floods and drought, and degraded human health due to increase in contamination of water resources and disease transmission pathways.

[84] Climate Effects on Health. US Centre for Disease Prevention and Control. Available at https://www.cdc.gov/climateandhealth/effects/default.htm (accessed: January 21st, 2021)

10.1.6 Self-check quiz

Climate change affects water resources due to disturbance in:

a. Global carbon cycle
b. Global hydrological cycle (correct answer)
c. Weather events
d. Sea level rise

Egypt's water stress level is considered:

a. Low
b. Extremely high
c. High (correct answer)
d. Moderate

Climate change pose threats on global food security, including:

a. Loss of agricultural lands and crop yields (correct answer)
b. Reduced glaciers
c. Ecosystem vulnerability
d. None of the above

10.2 Illustrations of Concepts

Links to various material that can help engage the students and illustrate the concepts of socioeconomic impacts of climate change are shown in Table 10-1.

Table 10-1: Various illustration aids for the concepts of socioeconomic impacts of climate change

Concept	Short description of illustration, diagram, video, online course	Reference, link
Impacts of climate change	The video showcases the causes and effects of climate change on the environment and human lives	https://www.youtube.com/watch?v=G4H1N_yXBiA&ab_channel=NationalGeographic
Extreme weather events Poster	Main events of hurricane Katrina and its impacts on what?	https://earthzine.org/how-can-earth-observation-help-us-analyze-the-impact-of-a-hurricane/#:~:text=This%20system%20provides%20information%20about,evacuation%20and%20prevention%20measures%20seriously.

Concept	Short description of illustration, diagram, video, online course	Reference, link
Climate change impacts on health	A report on climate effects on human health	https://www.cdc.gov/climateandhealth/effects/default.htm
Climate change impacts on food security	A report by FAO on risks and responses to food security challenges related to climate change	http://www.fao.org/3/a-i5188e.pdf https://www.ipcc.ch/srccl/chapter/chapter-5/
Climate change impacts on global hydrological cycle	Climate change impacts on water supply and the disturbance to the global hydrological cycle	https://19january2017snapshot.epa.gov/climate-impacts/climate-impacts-water-resources_.html
Impacts on freshwater supply	Academic research on the loss of livelihood due to water supply disturbance: example from Himalaya Himalayan mountainous region in North India suffers from increased melting of snow and change in its timing, causing water shortage and loss of their agriculture livelihood that rely on melting of ice from the top of the mountain into water streams Describes the countries that are the most at risk from a water crisis	https://www.researchgate.net/publication/284095226_Climate_Change_and_Rural_Out-migration_in_Himalaya https://www.bloomberg.com/graphics/2019-countries-facing-water-crisis/ https://www.bloomberg.com/graphics/2019-countries-facing-water-crisis/
Climate change impacts on migration	Article explaining definition and causes of climate-induced migration	http://www.sameworld.eu/en/discover-the-project/environmental-migrant https://www.ipcc.ch/apps/njlite/srex/njlite_download.php?id=5866
Behavioral change towards being more responsible about our resources	Game	https://climatekids.nasa.gov/leaps-flutters/

10.3 Student Engagement Activities

10.3.1 Activity 1

1. Play a short video for the students: https://kidsagainstclimatechange.co/lessons-for-teachers/
2. Divide students into small groups and give each group a piece of large chart paper and some markers and ask them to divide it into two columns, labeling one column, KNOW, and the other column WONDER
3. Ask the groups to list what the know for a fact and what they wonder may be a direct socioeconomic impact of the climate change signs illustrated in the video and our role in fighting climate change

10.3.2 Activity 2

By comparing the past and present conditions, one can see that there have been changes in the climate we live in. These changes affect the environment and how people live. The climate we live in now is different from the climate our parents and grandparents lived in. The older a person gets the more experience he has seen and experienced. For this activity, identify at least 3 relatives from 3 different generations. We will compare the climate the three generations lived in. The three generations are: 1) grandparents, 2) parents, 3) your age group. Ask all three of them the following questions and write the answers down in Table 10-2.

1. Temperature:
    a. What were the temperature conditions in winter when you were my age?
    b. What were the temperature conditions in summer when you were my age?
2. Rainfall
    a. In which month did it start to rain and in which month did the rain end?
    b. Were there floods? How often were they?
    c. Were there droughts? How often were they?
    d. Was the rain more or less than it is now?
3. Vegetation and animals
    a. Which fruits and vegetables did you eat and are they still around?
    b. Which animals and insects were common and are they here now?
    c. Which crops did you grow and eat where you were my age?
    d. Were the harvests more or less than they are now?

Table 10-2: Answers record

Answers	Grandparent	Parent	My age
Winter temperature			
Summer temperature			
Rainfall start			
Rainfall end			
Floods: how often?			
Droughts: how often?			

Fruits and vegetables they ate			
Animals and insects that were common			
Crops that you grew and ate?			
Were harvest more or less than they are now?			

Compare the answers from the 3 different generations and answer the following questions:

1. Has climate changed from the time your grandparent was your age?
2. How reliable do you think the information is?

11 MESSAGE 11: EGYPTIAN SITUATION

11.1 Background Information

Egypt is experiencing various climate change impacts whose severity is expected to increase by 2050. Sea level rise, rising temperature, extreme weather and precipitation patterns, and warming seawater are among the principal impacts of climate change in Egypt, resulting in severe consequences on the population, the environment, and various economic sectors. The intensity of these consequences is a function of the vulnerability of the affected environmental or human systems.

Vulnerability is defined as the degree to which a system is susceptible to adverse effects of climate change. It is a function of the exposure, sensitivity, and adaptive capacity[85] of the affected systems such as food and agriculture, water resources, health, energy security, tourism, ecosystem services, and infrastructure.

11.1.1 Impacts on Coastal Ecosystems

Approximately 30% of the Mediterranean coastline will be impacted by climate change. The Nile delta in Egypt is one of the most vulnerable deltas to sea level rise, coastal erosion and damage, loss of land and flooding. Sea level rise across the Nile Delta will also result in loss and damage of wetlands of the Nile delta, and salinization of fresh water resources due to saltwater intrusion.

Similarly, a sea level rise of 50 cm in Alexandria by 2050 could lead to the displacement of more than two million people from their homes, the loss of 200,000 jobs and the loss of land (due to erosion) valued at more than $3.5 billion due to the expected flooding of many parts of the city[86]. It also accelerates the weathering of the buildings and historical archaeological sites, and overwhelms infrastructure causing inclination or collapse.

Other coastal areas at risk of sea level rise include parts of Beheira, Damietta, and Suez governorates, in addition to several other smaller areas such as north of Lake Bardaweel area. The projected impacts due to a 0.5m (50cm) rise and 1m (100cm) rise from the state recorded in 2002 (baseline) are preliminary illustrated in the maps in Figure 11-1[87]. According to Egypt's Ministry of Water Resources and Irrigation, the sea level rose by an average of 1.8 millimeters each year until 1993. Over the following 20 years, it rose by 2.1 millimeters a year. Since 2012, however, the rate became 3.2 millimeters each year.[88]

[85] IPCC defines exposure as the nature and degree to which a system is exposed to significant climate variations, sensitivity as the measure of the extent or intensity of the expected impact on the affected system., and adaptive capacity as the ability of a system to adjust to and manage climate change impacts
[86]

[87] Elsharkawy H., Rashed H., & Rached I. (2009). The impacts of Sea Level Rise on Egypt, 45th ISOCARP Congress

[88] https://learningenglish.voanews.com/a/rising-sea-levels-threaten-egypt-s-alexandria/5067579.html

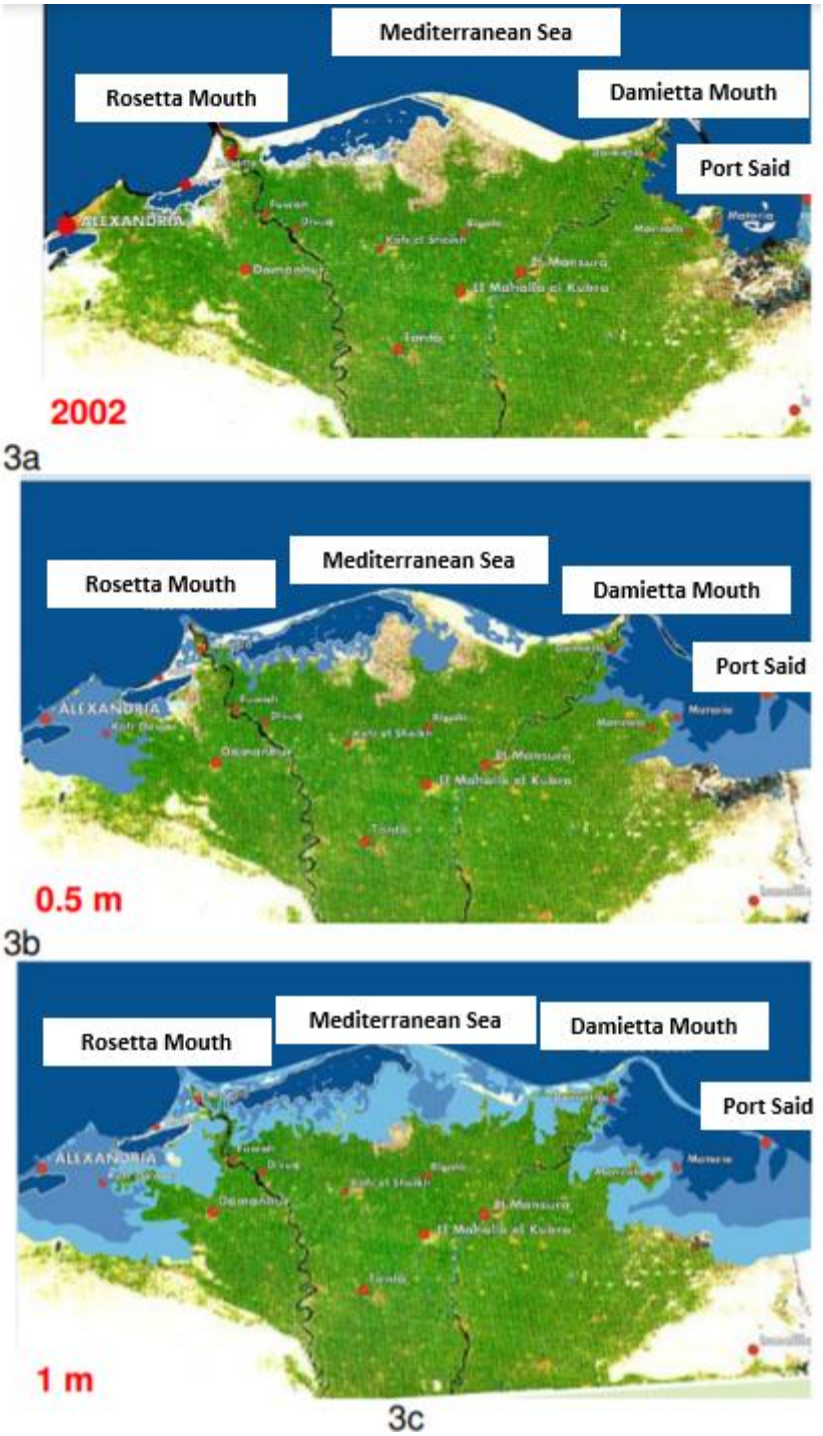


Figure 11-1: The North Coastline of Egypt under sea level rise impact

11.1.2 Impacts on Water Resources

The Nile supplies 95% of the total renewable water resources in Egypt. Potable and municipal water supply is considered an essential part of the Egyptian water budget due to the continuous increase in population and standard of living. Agriculture, however, is considered the main consumer of water since it consumes almost 80% of the country's water budget supplemented mainly by the Nile water and groundwater. On the other hand, Egypt has a growing industrial base with a reported average of 35,000 factories in different fields (steel, cement, aluminum, ceramics, porcelain, chemical fertilizers, paper mills, etc.).

These heavy industries require a tremendous amount of water as part of the manufacturing process and the cooling of the machinery. Finally, tourism in Egypt is one of the important sources of national income. Water consuming elements within the tourism field could range from the irrigation of green areas in the hotels and resorts, the washing requirements, and kitchen uses to the sailing ferries in the Nile and its branches.[89]

With a current water availability (from renewable and nonrenewable resources) of less than 650 m^3 /capita/year, Egypt is classified as a water scarce country, and water availability indicator will be further aggravated. The Nile delta region is classified as an area of high-water stress risk, and Sinai Peninsula is at extremely high risk, as indicated in the map in Figure 11-2. Hence, water stress is expected to significantly decrease available water and in turn negatively affect the agriculture, municipal, industrial, and tourism sectors.

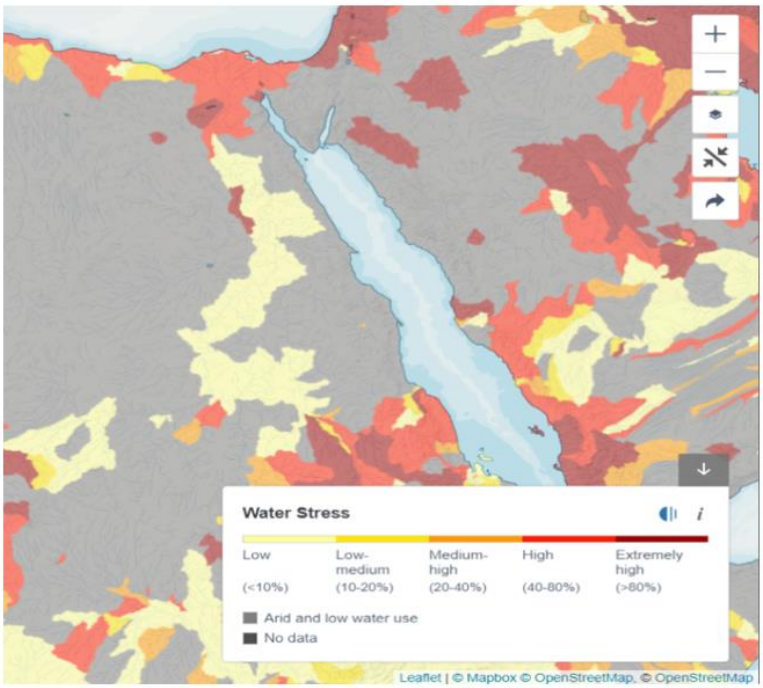


Figure 11-2: Water stress levels in Egypt

The increased risk of flooding due to sea level rise and changing weather and rainfall patterns will also result in inundations or submergence of low-lying lands of the Nile Delta (mainly agricultural and urban areas), severe soil salinization, and ecosystems damage along the Nile banks, canals, and wetlands (e.g., Al Manzala lake region), and higher frequency and intensity of flash floods. These impacts have direct and indirect consequences on agriculture, fisheries, public health, and energy sectors as they rely on freshwater resources. Tourism sector is also expected to be gravely affected as erosion and inundation of sandy beaches occurs, and thus, the gradual regression of shorelines.

[89] https://unfccc.int/sites/default/files/resource/TNC%20report.pdf

11.1.3 Impacts on Agriculture and Food Security

The areas at risk include Valley and Delta of the Nile, Northern coasts of the Western Desert and Sinai, and the Oases and Southern areas. Rising temperatures and changing weather and rainfall patterns affect the agriculture sector through:

- Reduction in soil fertility. An increase in temperature is likely to reduce soil moisture, moisture storage capacity and the quality of the soil, which are vital nutrient for agricultural crops.
- Loss of agricultural lands, soil collapse and fluctuation in crop production due to droughts, floods and soil erosion and salinization, especially in crops that are dependent on abundant freshwater supply such as legumes
- Increased frequency and intensity of pests, weeds, and disease outbreaks in crops, which leads to resorting to chemical pesticides that increase local pollution levels in the air, water and soil
- Inland migration of the saltwater/freshwater interface. Saltwater intrusion into fresh groundwater sources driven by sea level rise, will degrade the water quality rendering it unsuitable for various uses will lead to soil salinization and Egypt may seriously experience a decline in freshwater availability and quality
- Low livestock productivity due to effects of rising temperatures, loss of land and habitats, and water stress on feeding, growth, and reproduction of livestock and animals.
- Shortage of freshwater resources will force farmers to abandon agricultural lands and migrate to urban area, thus increasing desertification (indirect impact)

11.1.4 Impacts on Public Health

The health risks posed by extreme weather conditions are already a reality in Egypt. In 2015, Egyptian Ministry of Health recorded more than 100 casualties due to extreme heat waves, and at least 11 deaths in floods. The rise in temperature is increasing the intensity and number of people suffering from conditions such as Asthma and allergies (due to high pollen concentrations). It also increases the risks of skin cancer, eye cataracts, heat strokes, and heart-related conditions.

Increase in temperature and decrease in precipitation may increase diarrheal diseases incidence as hot and dry conditions start earlier and last longer year after another. Deaths attributed to climate-induced diarrheal diseases in children under 15 years old is projected to be about 15.2% of total deaths from these diseases in 2050. Climatic conditions such as temperature, precipitation and humidity have a strong influence on the life cycles of the vectors and the infectious viruses they carry. Warmer conditions are projected to accelerate and increase the transmission of water and foodborne diseases such as dengue fever, malaria, and schistosoma.

Rising temperatures, water stress (availability and quality), flooding, drought, extreme storms, and displacement negatively affects agricultural and food production in both

quantity and quality. This increases the risks of malnutrition and undernutrition, especially within vulnerable groups such as children and low-income households[90].

In Egypt, it is frequently encountered during or around March/April that a hot stream of low elevation (near the ground) is confronted by a cold jet of higher elevation coming from southern Europe through the Mediterranean. When these two meet, an unstable weather condition arises since the cold moist air is heavier in density and would like to settle down while the hot air of lower density would tend to rise up. The severity of these events has been escalating during the last ten years accompanied by strong winds, cyclones, and thunderstorms and causing widespread flooding and damage.

11.1.5 Impacts on Energy Security

Climate change, through rising temperatures, decreased precipitation and increased surface water evaporation, and it is increasing the demand on energy in Egypt for air conditioning and water desalination (using saltwater to produce freshwater). In addition, the impacts of climate change on the agricultural sector is increasing the practices that consume a lot of energy such as spraying chemical fertilizers, pumping from groundwater, different irrigation methods, and different harvesting patterns in order to maintain productivity. Energy supply is also affected by climate change. Water is required for energy production at a rate between 38 to 500 liters per 1,000 KWh of electricity produced, depending on the type of fossil fuel used. Therefore, water stress due to climate change can affect energy security in Egypt, causing power outages in extreme weathers and higher energy production and distribution costs.

11.1.6 Opportunities for Renewable Energy and Green Tourism in Egypt

Egypt has an abundance of land, sunlight, and high wind speeds, giving it a prime location for renewable energy production. Renewable energy can support fulfilling the increasing demand on energy in Egypt and contributing less to global GHG emissions. The Energy Strategy 2035[91] set targets to increase renewable energy supply to 20% of total energy produced in Egypt by 2022 and 42% by 2035[92]. Sources will primarily include wind, solar, and hydropower energy as shown in Figure 11-3.

[90] Climate and Health Profile: Egypt. World Health Organization. Available at https://www.who.int/globalchange/resources/country-profiles/PHE-country-profile-Egypt.pdf?ua=1 (accessed: January 21st, 2021)
[91] published by the Government of Egypt in 2015
[92] Egypt Energy Strategy 2035. NREA. Available at http://nrea.gov.eg/test/en/About/Strategy (accessed: January 21st , 2021)

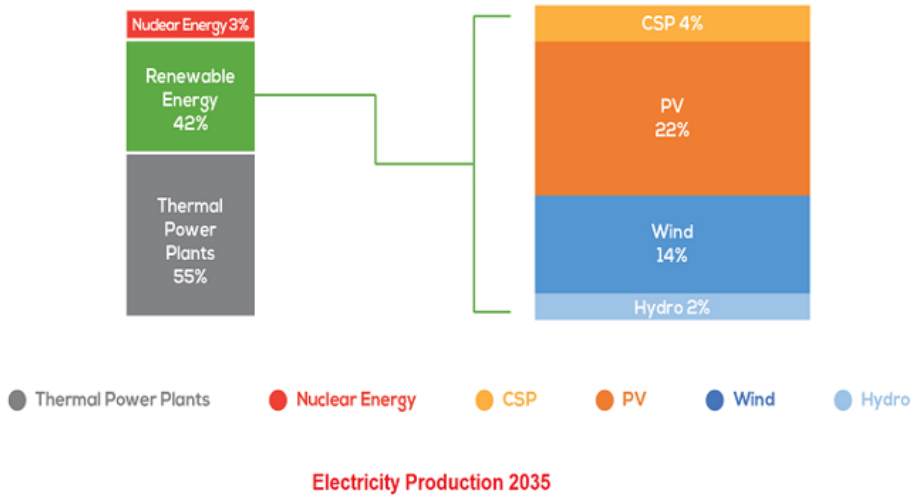


Figure 11-3: Egypt Energy Strategy 2035 targets for Renewable Energy Production

Egypt enjoys 2,000 to 3,000 kWh/m^2/year of direct solar radiation. The sun shines up to 11.9 hours a day as shown in Figure 11-4, with only few cloudy days, which presents a golden opportunity for solar energy. The biggest solar energy power park in the world is in Benban, Aswan with a size of 37 square kilometers.

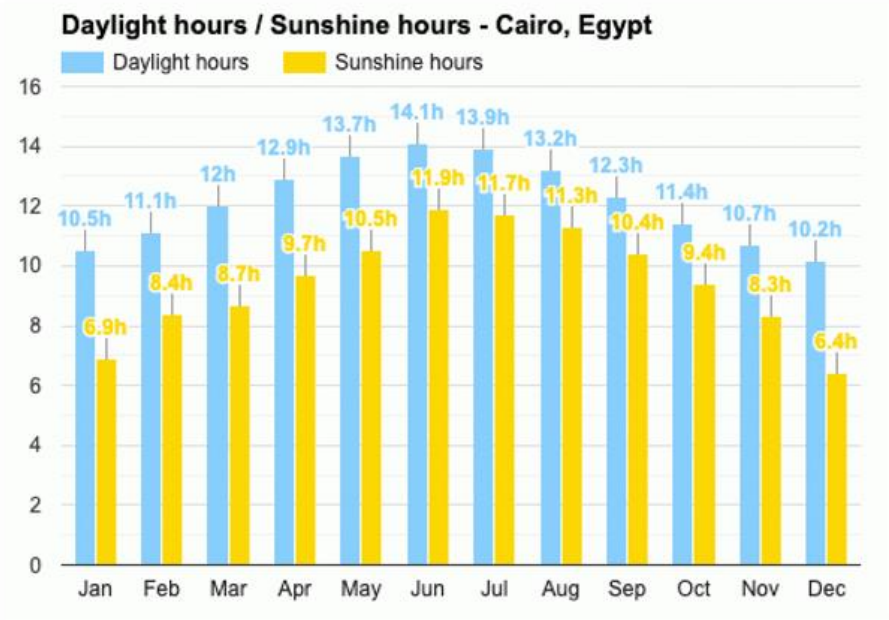


Figure 11-4: Average sunshine hours per day in Egypt

Since tourism is of such high economic value to Egypt, it is essential to protect the country's scarce water and energy resources as well as its scenic landscapes. Adopting green tourism policies and technologies was one of the Ministry of Tourisms initiatives to establish that goal in the near future where they added a Green Tourism Unit in 2013, with a specific focus on the conservation of natural resources. Another initiative of the Ministry of Tourism was the Green Star Hotel program that encourages hospitality owners to train staff to be more aware of environmentally friendly practices such as reductions in the use of

water and energy such as the ones we see in eco-lodges across the Red Sea.[93] Another example of encouraging green tourism in Egypt is the techno-economic feasibility study that RCREEE and the Green Tourism Unit of the Egyptian Ministry of Tourism have agreed to conduct for the integration of Solar Photovoltaic in hotels in Marsa Alam with a capacity of 2.5 MW as shown in Figure 11-5.[94].

Figure 11-5: Solar power station in Marsa Alam

In short, principal impacts of climate change in Egypt relate to risks to coastal ecosystems due to sea level rise, scarce water resources affecting the agriculture, municipal, industrial, and tourism sectors. The agriculture sector is affected by compromised soil integrity, water scarcity and degraded quality due to pollution and saltwater intrusion, increases in frequency and intensity of pests, weeds, and disease outbreaks in crops. Public health is also affected by extreme heat waves and floods. Another impact relates to energy insecurity due to rising temperatures and water scarcity, which would increase the demand on energy in Egypt for air conditioning and water desalination (using saltwater to produce freshwater). Alongside detrimental impacts of climate change, there are opportunities for renewable energy. Egypt has an abundance of land, sunlight, and high wind speeds, giving it a prime location for renewable energy production.

[93] https://www.egypttoday.com/Article/6/66382/Egypt%E2%80%99s-return-to-eco-tourism-tops-%E2%80%98Green-Destinations%E2%80%99
[94] https://www.rcreee.org/content/rcreee-supports-green-tourism-egypt

11.1.7 Self-check /quiz

Vulnerability is defined as:

a. The measure of how much the Earth's climate will cool or warm after a change in the climate system
b. The degree to which a system is susceptible to adverse effects of climate change (correct answer)
c. The ability of a system to adjust to and manage climate change impacts
d. None of the above

Which area in Egypt will be most affected by sea level rise?

a. Mediterranean and Nile Delta region (correct answer)
b. Western Desert
c. Aswan
d. Red Sea Governorate

Climate change affects the agriculture sector in Egypt due to:

a. Rising temperatures
b. Changing precipitation and weather patterns
c. Sea level rise
d. All of the above (correct answer)

11.2 Illustration of Concepts

Links to various material that can help engage the students and illustrate the concepts of the Egyptian situation are shown in Table 11-1.

Table 11-1: Various illustration aids for the concepts of the Egyptian situation

Concept	Short description of illustration, diagram, video, online course	Reference, link
Vulnerability	Egypt's vulnerability to climate change	https://www.adaptation-undp.org/explore/northern-africa/egypt#:~:text=Egypt's%20large%20population%20makes%20the,to%20analyze%20possible%20adaptation%20measures.
Egyptian situation	Case Study: Egypt's Vulnerability and Adaptation Needs Assessment	https://unfccc.int/sites/default/files/resource/3_Egypt_Climate%20Change%20Vulnerability%20%26%20Adaptation%20in%20Egypt9-7me.pdf https://learningenglish.voanews.com/a/rising-sea-levels-

		threaten-egypt-s-alexandria/5067579.html https://www.who.int/globalchange/resources/country-profiles/PHE-country-profile-Egypt.pdf?ua=1 https://www.egypttoday.com/Article/6/66382/Egypt%E2%80%99s-return-to-eco-tourism-tops-%E2%80%98Green-Destinations%E2%80%99 https://www.rcreee.org/content/rcreee-supports-green-tourism-egypt
Sea level rise impacts in Alexandria	Article about the rising threats of sea level rise in Alexandria, with testimony interviews with residents of the city Tabulated statistics on potential loss of lands, beaches, agricultural yield, and employment in Alexandria	https://apnews.com/article/e4fec321109941798cdbefae310695aa https://www.ess.co.at/GAIA/CASES/EGY/impact.html
NREA's Energy Strategy 2035	The strategy of the Government of Egypt to increase renewable energy production between 2015 – 2035	http://nrea.gov.eg/test/en/About/Strategy

11.3 Student Engagement Activities

11.3.1 Activity 1

Objective: the objective of this activity is to develop students' own definitions which helps them build conceptual understanding.

Procedure:

1. Conduct this activity in pairs or teams to build students' collaboration skills. Place the word vulnerability in the center of the graphic organizer
2. Facilitate a discussion with students exploring why this word is key vocabulary to this message
3. Ask students to brainstorm characteristics of vulnerability and add responses to the area with the corresponding heading on the graphic organizer
4. Ask students to continue their exploration as they research the topic using a variety of resources including their notes
5. Next, ask students to add examples and non-examples in the graphic organizer.
6. Using the information provided, ask students to develop their own definition of the word vulnerability that is clear and concise. An example to guide work is started below

7. After completing the example together, assign a new vocabulary word to each group of students to work on collaboratively
8. Groups will share their graphic organizes and lead discussions to check for understanding of each vocabulary word
9. Compile final definitions and post so all students have access for later work

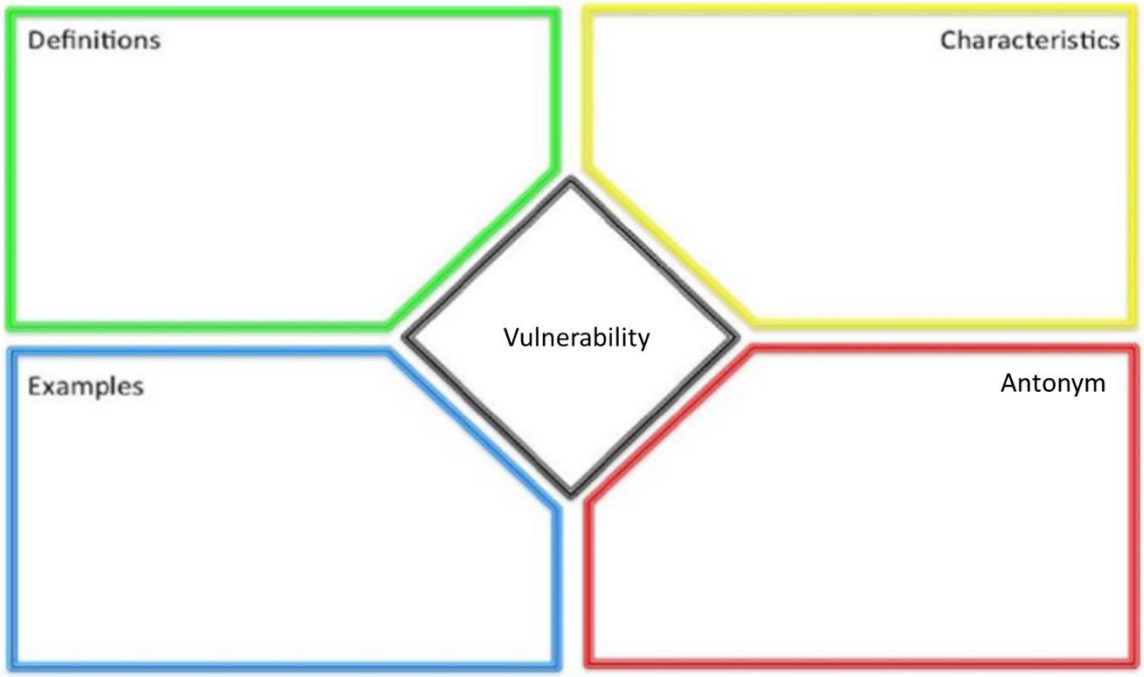


Figure 11-6: Graphic organizer

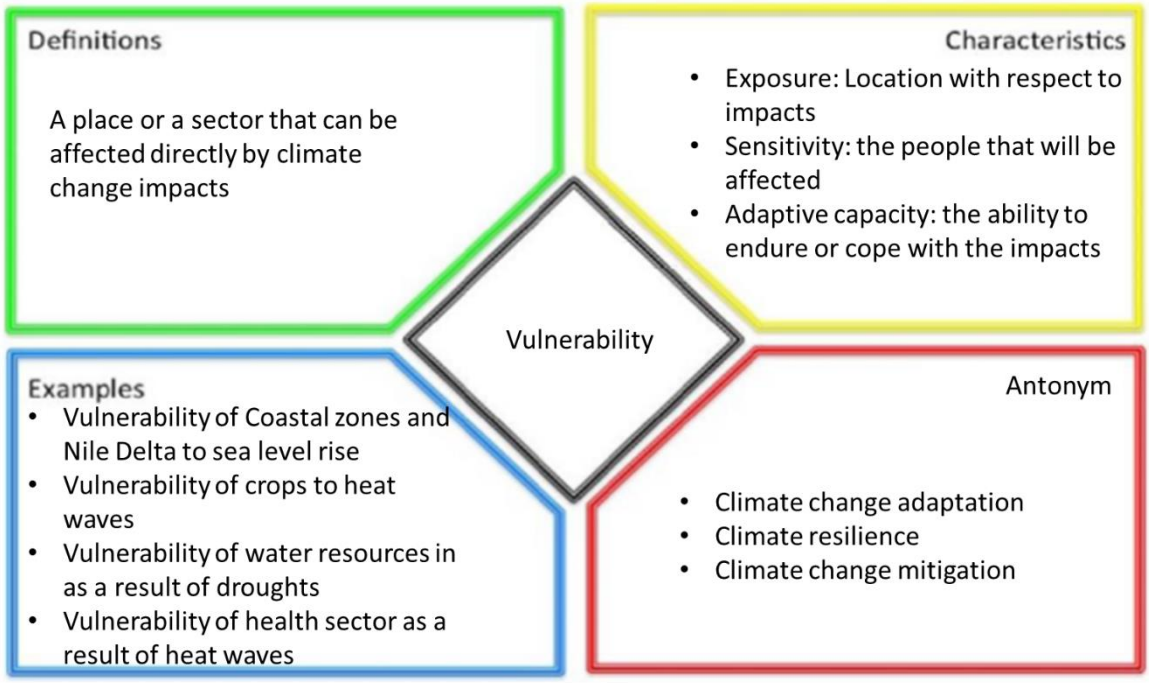


Figure 11-7: Graphic organizer of definitions

11.3.2 Activity 2

1. Based on the definitions of exposure, sensitivity, and adaptive capacity, fill out the following table by matching each of the following climate change impacts on food, water, and health sectors in Egypt with the corresponding vulnerability component they address
    - IPCC defines exposure, sensitivity, and adaptive capacity as:
        - Exposure: the nature and degree to which a system is exposed to climate change

- Sensitivity: the measure of the extent or intensity of the expected impact on the affected system/environmental element
- Adaptive Capacity: the ability of a system to adjust to and manage climate change impacts

2. Write the following climate change impacts on pieces of paper and distribute on students:
    a. Projected change in crop yield
    b. Ability to deal with change in crop yield by making available different irrigation system
    c. Population health deterioration because of malnutrition
    d. Agriculture crops damage
    e. Population's life threat
    f. Sea level rise can cause the low-lying areas in the Delta to be flooded
    g. Farmers lose their jobs
    h. Food import dependency
    i. Increase in population may cause people to be hungry
    j. Medical staff well trained and available to everyone
    k. People can get sunstroke (their body temperature increase)
    l. Heat waves

	Exposure	**Sensitivity** **Who and what is affected?**	**Adaptive Capacity**
a	X		
b			
c			
d			
e			
f			
g			
h			
i			
j			
k			
l			

Answer:

Exposure	**Sensitivity**	**Capacity**
Projected change in crop yield	• Farmers lose their jobs • Food import dependency • Increase in population may cause people to be hungry	• Ability to deal with change in crop yield by making available different irrigation system • Population health deterioration because of malnutrition

Sea level rise can cause the low-lying areas in the Delta to be flooded	• Agriculture crops damage • Population's life threat	Presence of natural protection such as sand dunes that can prevent the water from flooding the Delta
Heat waves	People can get sunstroke (their body temperature increase)	Medical staff well trained and available to everyone

12 MESSAGE 12: CLIMATE RESILIENCE

12.1 Background Information

12.1.1 Resilience

A resilient tree is one whose branches are elastic enough to bend down during high winds then regain their original status after the storm passes, whereby the tree experiences minimum damage. Climate resilience is the ability to anticipate, prepare for, and respond to hazardous events, trends, or disturbances related to climate. Improving climate resilience involves assessing how climate change will create new, or alter current, climate-related risks, and taking steps to better cope with these risks. In order to build resilience for climate change, it is necessary to simultaneously implement measures that would reduce or alleviate the adverse effects of climate shocks in the future (adaptation), as well as measures that reduce GHG emissions and the human-caused climate change (mitigation). The interconnection between both measures is what creates more resilient communities, economies, and environment. The relationship between adaptation, mitigation, and resilience is illustrated in the exemplary diagram shown in Figure 12-1.

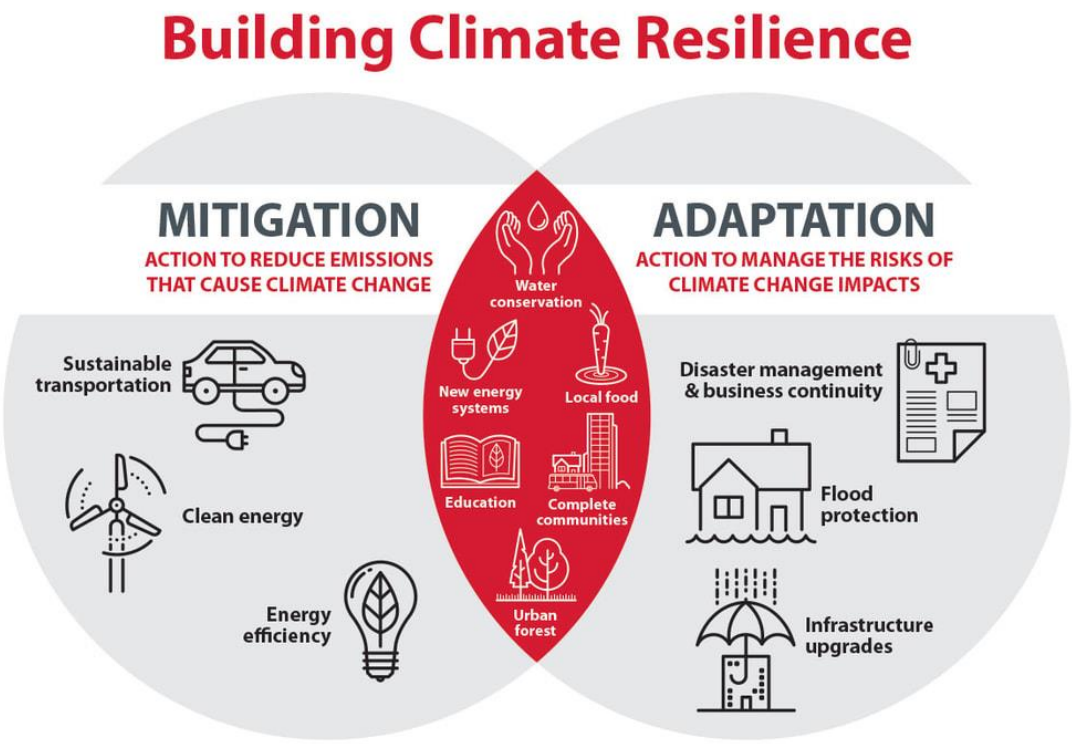


Figure 12-1 Examples of Resilience building measures (source: Calgary City Council[95])

Climate change affects both natural and human-made systems. Therefore, building climate resilience must include natural and ecological systems, built environment systems (e.g., infrastructure, public services, roads, hospitals, schools, etc.), social systems (healthcare insurance, social support, and aid programs, etc.), and economic systems including the most affected sectors such as agriculture, energy, water, industry, and tourism.

12.1.1.1 Climate resilience in Energy

Climate resilience in energy can be achieve by improving energy management practices (e.g., energy efficiency, conservation, and consumption reduction), improving risk management measure to enhance and protect the capacity of existing infrastructure against climate change effects (i.e., extreme weather events)(adaptation), and reducing greenhouse gas emissions associated with the production, distribution, and transmission of energy (mitigation). Examples of resilience-building measures for energy include:

- Developing and implementing Energy Performance standards in new and existing buildings

[95]https://www.calgary.ca/uep/esm/energy-savings/climate-change.html?redirect=/climateprogram

- Developing and implementing energy efficiency standards and labels for electric appliances (Egypt started to implement this measure by setting standards for household appliances)
- Switching streetlighting and government buildings to LED energy-saving lighting
- Building wind turbines to capitalize on wind energy as a renewable source of energy instead of fossil-sourced polluting energy.
- Placing solar cells on top of the buildings and parking shades
- locating, designing and operating new power infrastructure with future climate predictions in mind (e.g., building power generation plants in high areas and against wind direction to avoid flooding or damage)
- protecting existing energy generation and distribution facilities by improving maintenance, building fences to prevent floods, and/or use different materials or technologies for the different parts of the station to replace old/inefficient ones (i.e., retrofitting)
- Improve disaster and emergency preparedness plans for all facilities in order to provide fast responses and protection of assets and people in events of floods, storms, or other extreme weather events.

12.1.1.2 Climate resilience in Agriculture and rural development

Resilience in agriculture and rural areas can be achieved by adopting climate-smart agricultural practices[96] and improving capacity of farmer communities to be able to better adapt to effects of climate change on their resources, lands, and livelihoods. Examples of resilience-building practices include:

- Switching to different crops that use less water and withstand harsher weather
- Changing growing seasons to cope with the changing weather and climate through the years
- Reduce rice plantation areas as they consume a lot of water, and potentially replace some of these areas with other similar crops such as maize (Egypt is currently promoting reduction of rice cultivation as a climate adaptation measure[97])
- Improve the farmers' access to seeds in order to improve their productivity and switch to climate-resilient crops
- Improving lending and financing schemes for farmers to be able to make up for productivity or land losses due to climate change
- Using less harmful or no pesticides to avoid further degrading soil quality which is already affected by climate change (i.e., promote organic farming)
- Rainwater harvesting to be used for irrigation
- Improve irrigation methods and technologies to conserve water (e.g., irrigation using dripping methods instead of water soaking methods)

[96] Defined as farming practices that improve farm productivity and profitability, help farmers adapt to the negative effects of climate change and mitigate climate change effects (source: World Bank https://www.worldbank.org/en/topic/climate-smart-agriculture)

[97] Ministry of Water Resources and Irrigation (MWRI)'s National Water Resources Plan 2037

- Improve efficiency of water pumps used in irrigation to avoid losses and conserve water and energy (since most pumps use energy to pump water)
- Limit and restrict urban encroachment in rural and agricultural areas. Avoiding land-use change (i.e., building on agricultural lands)

12.1.1.3 Climate resilience in urban development (buildings and cities)

- Developing and implementing green infrastructure (green roofs, vertical gardens, community gardens and parks, greening open spaces and increasing tree cover, etc). examples are shown in **Error! Reference source not found.** below.

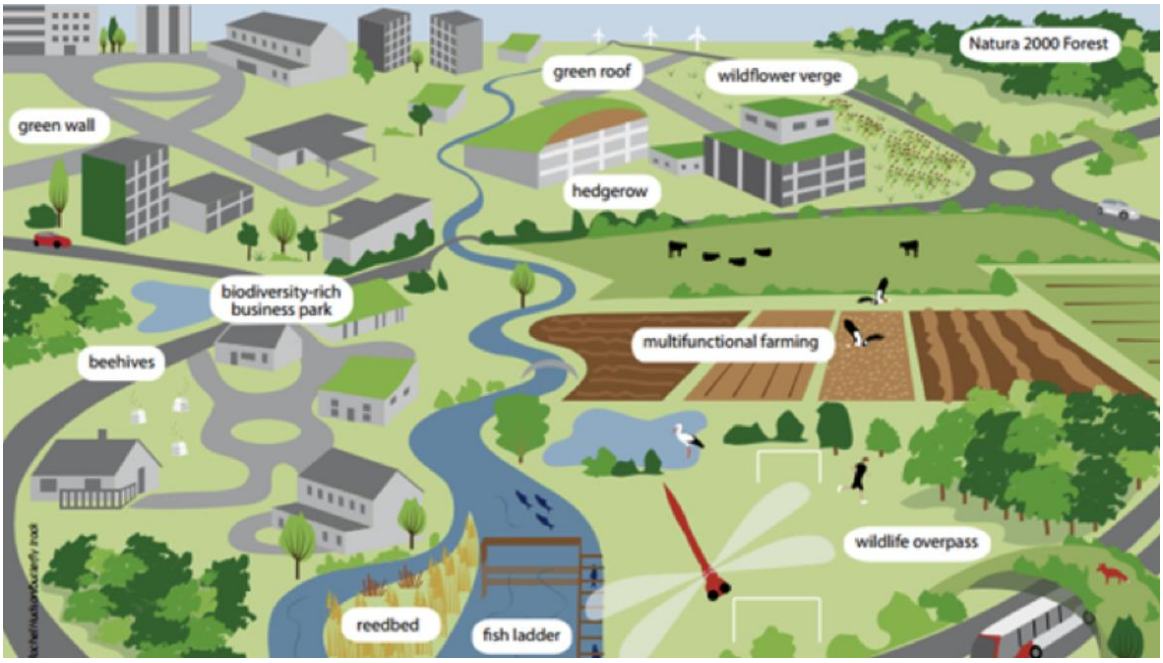


Figure 12-2: Examples of green infrastructure in urban areas[98]

- Adopting innovative design in buildings to reduce demand for energy needed for cooling, heating, ventilation, and electricity such as using high-efficiency windows and insulation in walls, ceilings, and floors, minimizing electric lighting and Make Use of Skylight Windows, and using operable windows or skylights (can be closed

[98] https://stateofgreen.com/en/partners/state-of-green/news/12-examples-of-climate-resilient-city-solutions/

and opened) to allow for hot air to escape during hot weather and hence reduce need for cooling[99]. Other examples of resilient building design is shown in

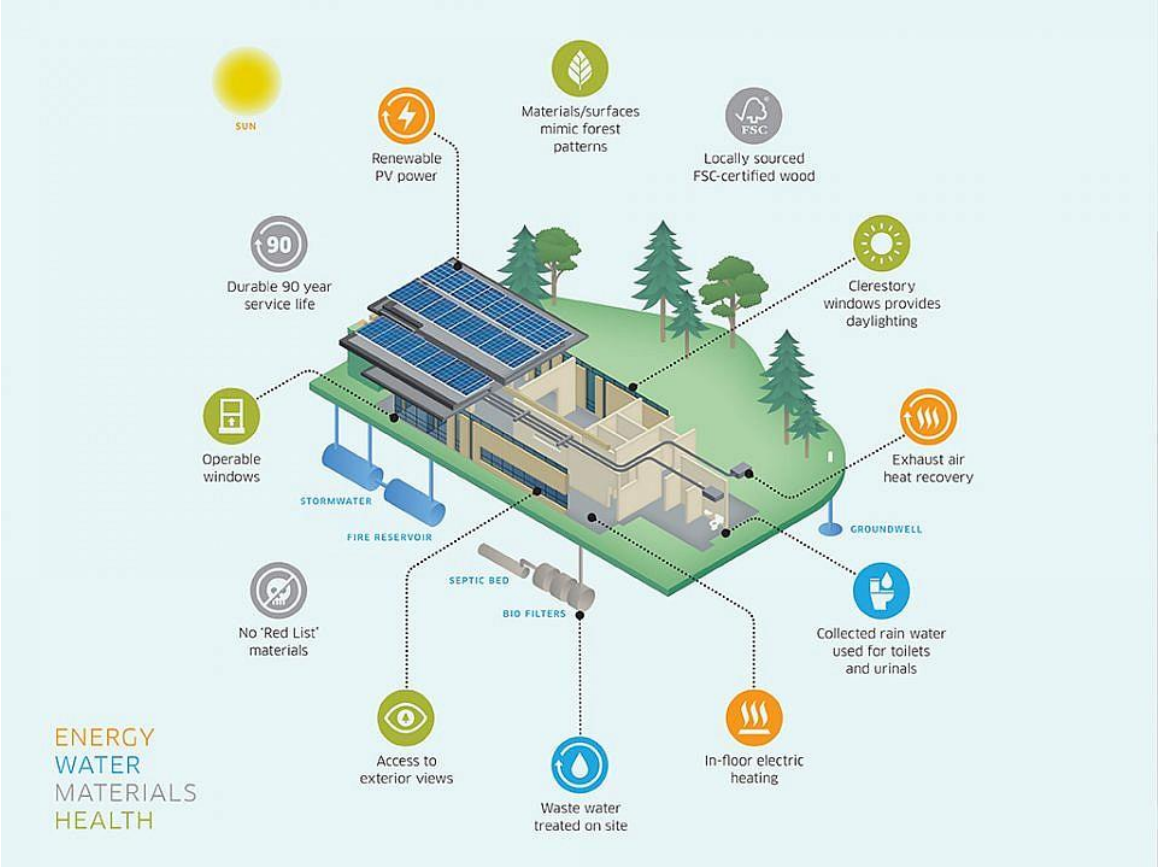


Figure 12-3 Examples of Green Building design considerations (source: Green Building and Architecture Magazine[100])

- Using Electric and low-emissions vehicles instead of fossil-fueled vehicles
- Using Low or zero-emissions mass transportation modes such as trams, trains, subway, boats, or buses. Avoid using private cars whenever possible
- integrating storm-water opportunities/risks within urban planning
- improving climate data collection, monitoring and early warning systems
- Improving health and social support for the most vulnerable groups such as women and children in order to address health impacts of climate change including dehydration, heat strokes, cardiovascular conditions, maternal and child malnutrition or diarrheal diseases.
- Providing social aids for communities in case of storms or floods or other extreme weather events or natural disasters

12.1.1.4 Climate resilience in water sector

[99] https://www.nrel.gov/docs/fy01osti/25807.pdf
[100] https://gbplusamag.com/15bffsec-sustainability-diagram-credit-norman-studio-for-dialog-960x720/

- Improve the efficiency of water storage mechanisms using all options such as dams, reservoirs, ponds, aquifer recharge groundwater storage, and soil water storage
- Build wastewater collection/treatment/reuse facilities to use water more efficiently and reduce wastewater
- desalination of seawater (this option needs to be based on renewable energy to reduce emissions related to the desalination process)
- collecting and reusing rainwater for irrigation
- improving drainage systems in order to avoid losses of water due to evaporation in hot weather
- Improving floodwater collection systems in order to protect assets and people, as well as use it for irrigation or other uses.

12.1.2 Sustainability

Sustainability is defined as the processes and actions through which humankind can meet their present needs without compromising the ability of future generations to meet their own needs. Sustainability is an all-encompassing human development approach that considers the intersectionality of environmental, social, and economic aspects. The three aspects of sustainability are referred to as the pillars of sustainability. The superposition between the three elements describes the best sustainability scenario as indicated in Figure 12-4[101].

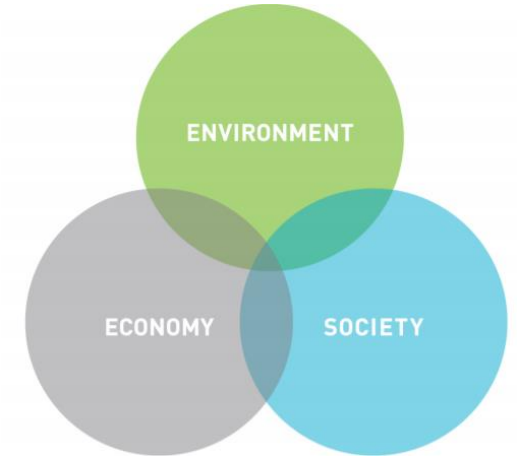


Figure 12-4: The three pillars of sustainability

Resilience typically focuses on developing measures to address the impacts of climate change. For climate resilience methods and approaches to become sustainable, the underlying drivers and causes of vulnerability must be considered: exposure, sensitivity, and adaptive capabilities of the affected environment, economy, and society. Nonetheless, short-term disaster reduction, adaptation and building resilience for apparent risks and

[101] What is Sustainability. McGill University Office of Sustainability. Available at https://www.mcgill.ca/sustainability/files/sustainability/what-is-sustainability.pdf (accessed: January 21st , 2021)

impacts is a critical step towards achieving the long-term sustainable resilience that reduce vulnerabilities across the three pillars[102].

In summary, the terms sustainability and resilience can be considered two sides of the same coin since they both target sustainable development. While the concept of sustainability targets actions that can be taken to avoid, at least in part, climate change and their negative consequences on people and the environment, resilience is about tackling and overcoming these changes by integrating various approaches to obtain a better outcome.[103]

In short, building climate change resilience involves simultaneously implementation of measures reducing adverse effects of climate shocks in the future (adaptation), as well as measures reducing GHG emissions (mitigation). In the energy sector, climate resilience includes reducing GHG emissions, protecting infrastructures against extreme weather events, improving energy management practices. In the agriculture sector, climate resilience pertains to adopting climate-smart agricultural practices and enabling farmers to adapt to changes. In the urban development sector, measures involve green and innovative designs and materials in buildings to reduce energy demand and adapted to climate change impacts such as floods. In the water sector, resilience pertains to improved water resources management practices.

12.2 Illustration of Concepts

Links to various material that can help engage the students and illustrate the concepts of climate resilience are shown in Table 12-1.

Table 12-1: Links to more illustrations of climate resilience

Concept	Short description of illustration, diagram, video, online course	Reference, link
Reduce food waste game	It's a fun game about encouraging reducing less food waste	https://www.epa.gov/sites/production/files/2020-11/documents/foodwastecoloringbookfinalnov022020.pdf
Sustainability	Definition of sustainability: What is Sustainability. McGill University Office of Sustainability	https://www.mcgill.ca/sustainability/files/sustainability/what-is-sustainability.pdf
Resilience	Definition of resilience and examples of climate resilience urban solutions	https://www.ipcc.ch/site/assets/uploads/2018/03/SREX-Chap8_FINAL-1.pdf https://stateofgreen.com/en/partners/state-of-green/news/12-examples-of-climate-resilient-city-solutions/

[102] Toward a sustainable and resilient future. (2012). IPCC Cambridge University Press. Available at https://www.ipcc.ch/site/assets/uploads/2018/03/SREX-Chap8_FINAL-1.pdf (accessed: January 21st, 2021)
[103] https://www.ipcc.ch/site/assets/uploads/2018/03/SREX-Chap8_FINAL-1.pdf

12.3 Student Engagement Activities

12.3.1 Activity 1

1. Connect with a local organization that works on the most relevant issues to your community
2. Send an email or Facebook message to an environmental organization in your local area such as GoClean or Very Nile. Ask them about their activities and how they try to help the environment
3. Invite someone from the local community to come and speak to the class about the work that they do and how it creates positive effects on the economy, society, and environment (i.e., sustainability)

An example from a school that reached out to Mohammed Hamdy, Founder of 'Go Clean', to give students an inspirational speech about his recycling project is shown in Figure 12-5. The teachers also paraded down the Year 6 pod runway in trendy, fashionable outfits made of recyclables. This topic is designed to raise awareness of environmental issues facing us in Egypt and around the world.

Figure 12-5: Pictures from inspirational speech about recycling project

12.3.2 Activity 2

Recall the experiment from activity 2 of greenhouse gases Figure 12-6.

Objective: investigate the type of landfill that our waste travels to determine which types are considered climate resilient and which are not.

Figure 12-6: Simulation of landfill conditions that produce methane

Guiding questions:

Which type of landfill do you think our waste travels to?

a) Methane-recapture landfill, in which the methane that is produced is trapped and used to produce electricity
b) Traditional landfill that does not capture the gases that are produced
c) The waste is open burned in the streets

Which type do you think is climate resilient and why?

12.4 How to Change Student Behavior?

Food waste causes great amount of greenhouse gas emissions. Solid waste disposal sites contributed to 9% of Egypt's GHG inventory in 2015. When food is placed in the trash and sent to a landfill, it breaks down anaerobically, which means in the absence of oxygen. This decomposition process creates carbon dioxide and methane gas. When food is composted, it breaks down in the presence of air. The decomposition of food generates carbon dioxide and water vapor. Composting creates fertilizers than can be used in planting trees. Although, composting generates CO_2, it generates a much less amount of GHG than landfills.

There are many individual ways to avoid food waste. Conduct food waste audit to track how much good food ended up in the trash can. Record every food you throw in the trash for a week as shown in Table 12-2. This will enable you to know where your food waste comes from and so you can address how to decrease it.

Table 12-2: Food waste audit

Day	Food	Quantity	Composted	Trash can
Saturday				
Sunday				
Monday				
Tuesday				
Wednesday				
Thursday				
Friday				

Guiding questions:

- Which is more harmful to the environment carbon dioxide or methane?
- How are you contributing to climate resilience and sustainability?

13 MESSAGE 13: CLIMATE ADAPTATION

13.1 Background Information

Climate Adaptation refers to the adjustments in ecological, social, or economic systems that are taken in response to actual or projected impacts of climate change. These adjustments are typically changing in processes, practices, or structures to manage damages, reduce future damage, or create new opportunities due to climate change. The processes or actions can be anticipatory (i.e., actions that prevent damage from future projected impacts), reactive (actions that protect from actual or recurring impacts), or transformative (structural change that reduce the root cause of vulnerability to climate change). Adaptation can be carried out on individual, community, national, or regional levels. For example, adaptation actions by individuals and communities can be in the form of farmers shifting their agricultural production to more drought-resistant and less water-intensive crops to cope with the water scarcity imposed by climate change. Other examples include migration to new areas, building differently to protect against natural disasters or extreme weather events. However, the current rate of global climate change is unusually high compared to past changes, and global coordinated efforts and resources are needed to address the consequences of these changes. The main sectors that require adaptation actions include coastal regions, agriculture and food, building, water, energy, ecosystems, and public health.

1. **Coastal regions:** adaptation response strategies include coastal wetland restoration, and installation of protection barriers and/or open space preserves. These strategies respond to rising sea levels and changing rainfall and weather patterns, especially in low-lying areas. Improving emergency preparedness and management practices of low-lying coastal areas such as creating evacuation plans and routes is also an example of adaptation response measures for increased flash and coastal flooding events. Hundreds of years ago, the wall of Mohamed Ali was constructed on the western coast of the Nile Delta to achieve coastline stability, and to safeguard against potential inundations.

2. **Buildings:** response strategies include improving insulation and natural ventilation in buildings will protect against public health effects of heat waves, and provide cooling, and therefore save energy needed for air conditioning. In addition, responses include adopting innovative design in buildings to reduce demand for energy needed for cooling, heating, ventilation, and electricity such as using high-efficiency windows and double insulation in walls, ceilings, and floors, minimizing electric lighting and make better use of sunlight windows and sun roofs, and using windows or skylights that can be closed and opened to allow for hot air to escape during hot weather and hence reduce need for cooling in summer and are double glazed to allow for good insulation in winter.

3. Choosing safer locations for buildings and improve building materials and infrastructures to withstand extreme storms, hurricanes, or heavy downpours.

4. **Water Resources:** Responses to impacts of decreased precipitation and freshwater decline or degraded quality include improving water use efficiency and building additional water storage capacity, improving water retention and harvesting practices especially in agricultural areas, enhancing water recycling technologies to treat and re-use water/underground water, protecting and restoring streams and river banks to maintain water quality to safe drinking levels, and improving the efficiency of small-scale dikes and dams. Due to rising temperatures and increased evaporation and drought, adaptation measures include artificial recharge of underground water, desalinization of seawater to make up for declining freshwater resources and adopt technologies to improve stream run-off in lakes or river catchments to cope with streamflow reduction. Further, groundwater-based agricultural development will have to select high value cash crops with integrated industrial processing. For example; agricultural plantation of peanuts will need to be supplied by a unit for producing peanut butter, thus maximizing the return from the unit of water ($/m^3 of water). Further, irrigation method will have to ensure no losses by deep percolation in the soil, or by evaporation to the air. Furthermore, seedlings are preferably to be genetically checked or tissue cultural produced to ensure maximum tonnage per unit of water.

5. **Agriculture and Food Supply:** Adaptation measures include improving agricultural knowledge, adopting more efficient irrigation technology (irrigation capacity rehabilitation), increasing crop varieties that are more tolerant of heat, drought, and water logging from heavy rainfall or flooding, protecting livestock from higher summer temperatures by providing more shade and improving air flow in barns (i.e., improve livestock management, nutrition and health practices), changing crop rotation, and developing small scale rainwater harvesting or floodwater protection/capture techniques. All these measures address impacts such as crop failure, yield and livestock reduction or reduced quality of crops that result from decreased and changing precipitation and weather patterns, rising temperatures and droughts, and increasing extreme weather events.

6. **Energy:** Adaptation measures address climate change impacts on energy demand and supply. To improve supply side, response measures include improving energy efficiency practices such as improving energy transmission capacity to cope with increasing temperatures that leads to greater electricity losses and reduce the capacity of transmission lines. Increased floods, storms, and hurricanes cause shutdown of power plants, hence affecting energy supply. Adaptation measures include construction of sheds to protect fuel storage areas or equipment from storms or rainwater, construction of flood control systems within the production facilities, improving building structures for production facilities and cable lines, installation of water pumping equipment for water drainage during flood events, apply

segmentation of cable lines to avoid complete shutdown of entire lines, choosing secure high-elevation locations for new plants, and installation of lightning protection and monitoring systems. To reduce energy demand, response measures include adopting efficient technologies and processes that reduce need for cooling or electricity especially in industrial and buildings sectors.

7. **Ecosystems[104]:** Adaptation measures to changing migration patterns and declining species diversity within ecosystems include protecting and increasing migration corridors to allow species to migrate as the climate changes, and promoting land and wildlife management practices that enhance ecosystem resilience. Responses to deteriorating or damaged ecosystems include reforestation, wetlands, ponds and rivers restoration, adopting stormwater capture or management technologies to reduce water run-off into natural ecosystems (wetlands, agricultural lands, oceans etc), and maintenance of natural reserves and apply strict management practices to avoid further damage to natural ecosystems. For marine ecosystems, responses to climate-induced habitat destruction include restoration programs for fragmented ecosystems, bleached coral reefs, rehabilitation of mating environment and reproduction programs for endangered species (e.g., dolphins and tortoises), reducing human stressors on the marine systems to allow them to recover from tourism, pollution, destructive fishing practices, habitat destruction and unsustainable coastal development. Responses also include protection of natural buffers such as mangroves and wetlands at coastlines[105].

8. **Human Health:** Response measures include forecasting systems for climate impacts, assessing vulnerability levels, and projected magnitude of extreme events (i.e., early warning systems), developing emergency response plans to prepare for changes in the frequency, duration, and intensity of extreme weather events, improve knowledge and research on the healthcare burden needed for addressing climate-induced diseases and conditions, and expand trees, vegetation and green spaces in urban areas to cope with rising temperatures especially in densely populated areas.

In short, climate adaptation refers to the adjustments in ecological, social, or economic systems that are taken in response to actual or projected impacts of climate change. The main sectors that require adaptation actions include coastal regions, agriculture and food, building, water, energy, ecosystems, and public health.

[104] Wamsler, Christine et al. (2016). Operationalizing ecosystem-based adaptation: Harnessing ecosystem services to buffer communities against climate change. Ecology and Society. Vol 2(1).
[105] The Ocean and Climate Change. IUCN. Available at https://www.iucn.org/sites/dev/files/import/downloads/oceans_and_cc_brochure_final_1011.pdf (accessed: January 24th, 2021)

13.1.1 Self-check/quiz

Shifting agricultural production to less water-intensive crops is an adaptation measure to which climate change impact?

a. Rising temperature and droughts (correct answer)
b. Loss of habitats and biodiversity
c. Manifestation of vector-borne diseases
d. None of the above

Which of the following is not a priority sector for climate change adaptation?

a. Agriculture
b. Water
c. Public health
d. Manufacturing (correct answer)

13.2 Illustration of Concepts

Links to various material that can help engage the students and illustrate the concepts of climate adaptation are shown in Table 13-1.

Table 13-1: Various illustration aids for the concepts of climate adaptation

Concept	Short description of illustration, diagram, video, online course	Reference, link
Climate change adaptation	Example of how communities adapted to changing climate such as having floating homes in Netherlands in low rise cities. Also, in Copenhagen when heavy rainfall threatened to flood roads and hospitals, a new system was established to benefit from rain water and manage it better. (page 14)	https://ec.europa.eu/clima/sites/default/files/youth/docs/youth_magazine_en.pdf
Climate change adaptation	The video talk about how to take actions towards climate change adaptation Infographics presenting climate change adaptation strategies for different sectors including energy, tourism, health, and marine ecosystems.	https://www.youtube.com/watch?v=FO46sPwm4xk&ab_channel=GIZ https://www.desmogblog.com/2014/09/05/what-does-climate-adaptation-actually-look-check-out-awesome-new-infographic-series-cambridge
Adaptation responses in agriculture sector	Illustrations presenting more adaptation responses in the agriculture sector to address socio-economic impacts of climate change on the sector	https://www.researchgate.net/figure/Lowlands-Agricultural-Region-Priority-Adaptation-Measures-for-Armenia_fig4_300279696
Adaptation responses in energy sector	Academic article on the detailed impacts and vulnerabilities of the energy sector and potential adaptation response measures	https://www.mdpi.com/1996-1073/12/19/3640/htm

The ocean and climate change	Report on coastal and marine nature-based solutions to support mitigation and adaptation activities	https://www.iucn.org/sites/dev/files/import/downloads/oceans_and_cc_brochure_final_1011.pdf

13.3 Student Engagement Activities

13.3.1 Activity 1

1. Divide the class/persons into small groups and ask each group to list adaptation measures for different levels and/or sectors:
    - National level – the country or island, e.g. building sea defenses to protect valuable coastline infrastructure from rising sea levels (this contributes to adaptation by coping with rising sea levels)
    - Community level, e.g. starting a recycling program (this contributes to adaptation by reducing the solid waste dumped in rivers and on beaches, thereby keeping ecosystems healthier and resilient)
    - Individual level, e.g. conserving energy by turning out the lights when no one is in the room (this contributes to mitigation through reducing energy use and greenhouse gases)
2. After the groups have shared and discussed their lists, ask each person to select one activity from the individual level list, and to implement that activity in their home life for a week
3. After the week passes, ask students to report on their implementation success, problems encountered, and how their family members responded to the activity

14 MESSAGE 14: CLIMATE CHANGE MITIGATION

14.1 Background Information

Mitigation actions seek to control and limit factors resulting in climate change by reducing GHGs emissions[106] (prevent what you can't control)

Principal anthropogenic sources of emissions of greenhouse gas consist of:

- Burning of fossil fuels to produce energy (vehicles, electricity, and heating)
- Process emissions from different industries (ex. power to drive a fertilizer plant)
- Biodegradation of waste and manure
- Cutting down trees and forests (which act as a sink that absorbs excess CO_2 in the atmosphere)
- Using vegetated lands/soils for human activities (such as expanding cities and buildings, or roads, which reduces the lands' carbon sinking function)

There are different ways to reduce GHG emissions, including:

- **Reducing the sources of emissions** e.g. new technologies to utilize available energy sources/fuels more efficiently and switching to renewable energy
- **Increasing and improving the capacity of natural systems that absorb carbon from the atmosphere (carbon sinks)** e.g., increasing tree planting and vegetation)
- **Changing our behaviors and daily habits** e.g., avoid wasting energy and using products and services with lower carbon footprint

1. **Energy efficiency: doing more with less energy**

Energy efficient technologies help reduce emissions resulting from using fossil fuels for energy or optimizes the output from burning such fuels. They result in reduction of energy consumption by using less energy to perform a given activity such as switching to energy saving light bulbs[107] as shown in Figure 14-1.

[106] MRG Science. Available at https://www.mrgscience.com/ess-topic-73-climate-change-ndash-mitigation-and-adaptation.html (Accessed: 10 December, 2020)
[107] Energy Star Light Bulbs Efficiency Rating. Available at https://www.energystar.gov/products/lighting_fans/light_bulbs/learn_about_led_bulbs (accessed 10 December, 2020)

	INCANDESCENT	HALOGEN	COMPACT FLUORESCENT	LIGHT EMITTING DIODE
				
CONSUMPTION	100w	70w	20w	12w
EFFICIENCY	Low	Low	Medium	High
AVG. LIFETIME	1 year 1000 hours	1-2 years 2500 hours	10 years 10,000 hours	25+ years 50,000 hours
PRICE OF BULB	Low	Low	Medium	High
COST TO RUN	High	Medium	Low	Low

Figure 14-1: Comparison of energy consumption between different light bulb types[108]

Energy efficiency can be achieved by three possible approaches as shown in Figure 14-2.

[108] https://ledstuff.co.nz/led-lighting

Reduce/Avoid need for energy or wasted energy	Shift to efficient equipment/modes	Behavioral change
•Use more natural light •Unplug unused electronics •Turn water off when brushing teeth •Shutdown computer instead of sleep •Reduce time in shower with water running	•Use energy-saving light bulbs (LED) •Use mass transport modes such as metro, micro-mini buses • Use home appliances labelled as energy efficient using ratings systems such as the EU labels (Figure 14-3)	•Car pooling or using metro, bus (Figure 14-4) •Turn off TV, AC/fan and lights when leaving room •Use warm not hot water •Wash dishes while water is off and then rinse •Wash small items by hand not in machine
		

Figure 14-2: Approaches to energy efficiency

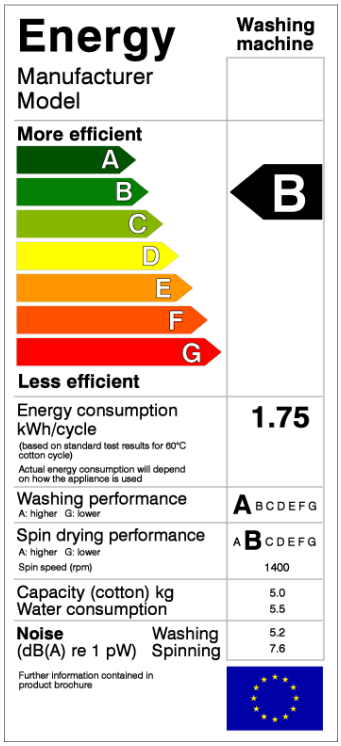


Figure 14-3: EU appliances Energy Efficiency rating system[109]

[109] EU Commission

Figure 14-4: Illustration of carpooling: 3 people in 1 car instead of 3 cars

2. **Renewable energy:** producing and using clean energy

Renewable energy is energy that is produced using renewable sources that are replenished by nature. Renewable resources include solar energy, wind, falling water, the heat of the earth (geothermal), or plant materials (biomass) as illustrated in Figure 14-5.

Figure 14-5: Renewable Energy

Renewable energy technologies produce electricity, heat or mechanical energy by converting the energy stored/created by these resources either to electricity or to motive power. The process does not involve burning fossils or extraction (e.g., oil or natural gas), which release GHGs; therefore, renewable energy is usually referred to as clean energy as it releases little to no GHG emissions.

Examples of renewable energy technologies include:

- **Hydroelectric power**[110]: producing electricity using the motion of water such as water flowing over a waterfall or flowing through a dam. A turbine converts the kinetic energy (or potential energy) of falling water into mechanical energy. Then a generator converts the mechanical energy from the turbine into electrical energy[111][112] as shown in Figure 14-6.

[110] Hydroelectric power explained in Video: https://www.youtube.com/watch?v=q8HmRLCgDAI

[111] Environment and Global Warming: Hydropower. National Geographic. Available at https://www.nationalgeographic.com/environment/global-warming/hydropower/ (accessed: 10 December, 2020)

[112] https://www.nationalgeographic.com/environment/global-warming/hydropower/

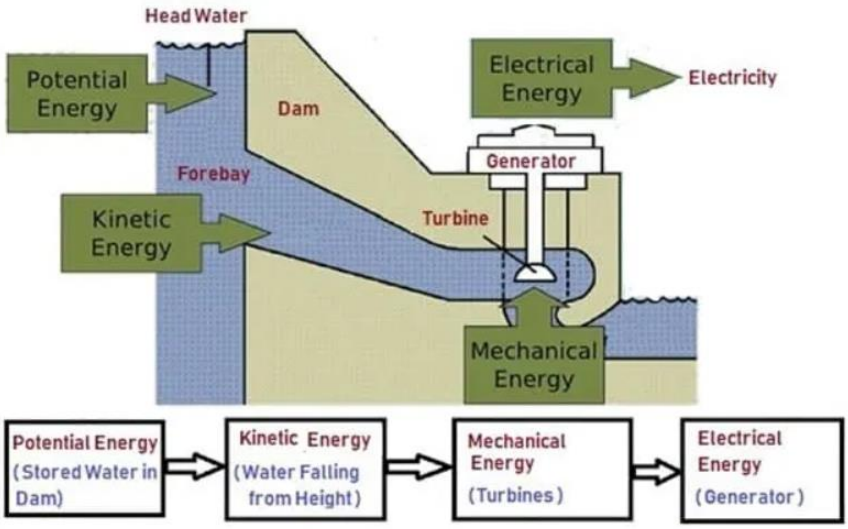


Figure 14-6: Hydroelectric power generation process diagram[113]

- **Solar energy:** using the light and heat that comes from the sun to generate electricity or heat as shown in Figure 14-7.
  Two common ways to generate electricity from solar energy are *photovoltaics (PV)* and *concentrated solar power (CSP).*

Photovoltaic (PV): comes from the words photo meaning "light" and Volt, a measurement of electricity. Solar cells/panels capture the energy that comes from the sun light and converts it into electricity.

[113] electricalfundablog.com

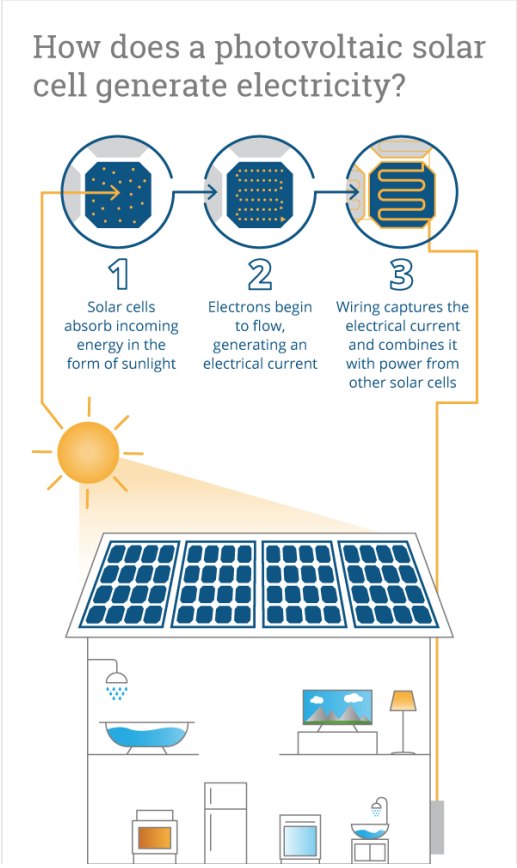


Figure 14-7: The way a photovoltaic solar cell generates electricity

Concentrated Solar Power (CSP): Electricity is generated by capturing the **heat** coming from sunlight onto a receiver using mirrors or lenses, then the concentrated light is converted to heat (solar thermal energy). This heat is used to run an engine that transforms the heat energy into electricity[114].

- **Wind energy:** wind is used to generate mechanical power or electricity using aerodynamic force (force created by the speed of wind). When the wind blows past a wind turbine with blades, the blades capture the wind's kinetic energy and rotate, turning it into mechanical energy. The rotational motion is then amplified by a shaft that is connected to a generator that produces electricity as shown in Figure 14-8.

[114] How CSP Works: Tower, Trough, Fresnel or Dish. SolarPACES. 12 June 2018. Available at https://www.solarpaces.org/how-csp-works/ (accessed: 30 November 2020).

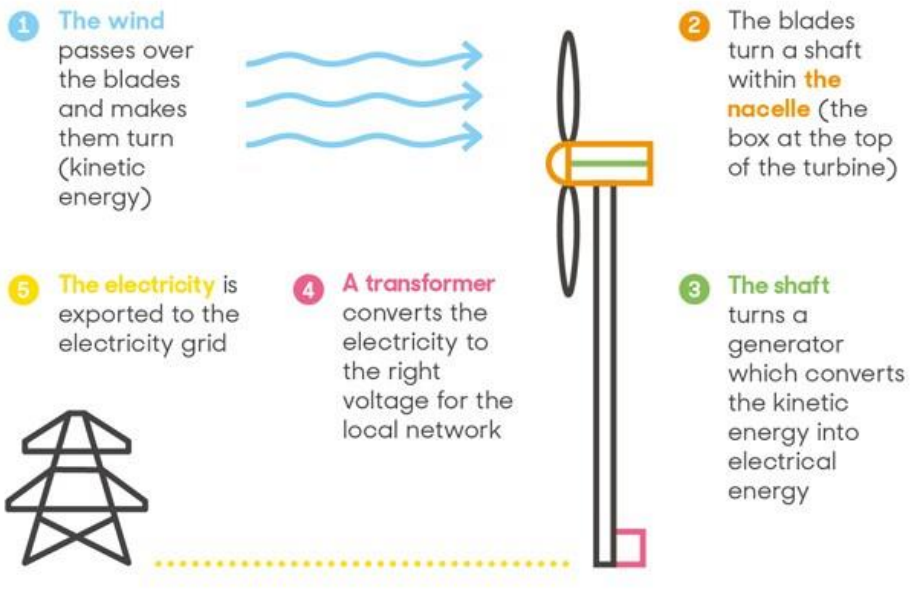


Figure 14-8: Wind energy process diagram[115]

3. **Enhancing carbon sinks**: improving the quality of carbon absorbing systems such as trees, forests, and marine ecosystems by increasing the amount of carbon they can retain/store as illustrated in Figure 14-9

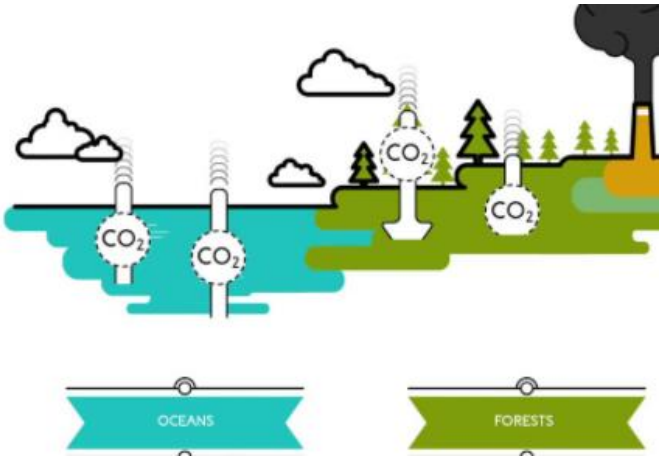


Figure 14-9: Carbon Sinks

Forests can absorb/uptake more than 30% of the CO_2 in the atmosphere[116]. Therefore, maintaining healthy forests, preventing deforestation, restoring damaged forests, and increasing tree coverage are considered important climate change mitigation strategies to improve their capacity to absorb more carbon. Similarly, marine ecosystems can play a

[115] Heatxperts
[116] Forests and Climate Change: Carbon and the Greenshouse effect. Food and Agricultural Organization (FAO). Available at http://www.fao.org/3/ac836e/AC836E03.htm (accessed: 30 November, 2020)

significant role in absorbing CO_2 in the atmosphere[117]. Activities to restore and increase the capacity of natural carbon sinks include:

a. Afforestation: conversion of non-forested or empty land to forest
b. Reforestation: conversion of previously or deteriorating forested land to healthy forest
c. Vegetation and planting: planting trees on cleared, deserted, and urban lands/areas.
d. Use sustainably harvested natural wood to make long-lasting products (e.g., flooring and furniture) that can provide carbon-absorbing abilities in areas beyond planted or forested areas (i.e., urban areas)[118]. Sustainable forest management work can improve carbon sink properties of forests by accelerating tree growth, maintaining optimum tree density levels (trees/hectare) and protecting it from fires, insects and disease or invasive weeds.
e. Marine ecosystems restoration: restoring damaged coral reefs, coastal management and reconstructing mangrove systems.

In short, mitigation actions seek to control and limit factors resulting in climate change by reducing GHGs emissions. The main approaches consist of developing renewable energy sources, increasing energy efficiency, and enhancing capacity of natural systems that absorb carbon from the atmosphere.

14.1.1 Self-check quiz

Mitigation seeks to control and limit factors resulting in climate change by reducing GHGs emissions

a. True (correct answer)
b. False

Deforestation is the conversion of previously or deteriorating forested land to healthy forest

a. True
b. False (correct answer: reforestation)

Energy efficiency and renewable energy are forms of clean energy technologies

a. True (correct answer)
b. False

[117] The Ocean and Climate Change. IUCN. Available at https://www.iucn.org/sites/dev/files/import/downloads/oceans_and_cc_brochure_final_1011.pdf (accessed: 1 December, 2020)
[118] Managed forests and climate change. Government of Ontario, Canada. Available at https://www.ontario.ca/page/managed-forests-and-climate-change (accessed: 30 November, 2020)

Using more renewable energy sources would increase the overall carbon emissions in the atmosphere

a. True
b. False (correct answer: renewable energy decrease carbon emissions)

Natural gas is a non-renewable energy source

a. True (correct answer)
b. False

14.2 Illustrations of Concepts

Links to information sources that can help engage the students and illustrate the concepts of the message are shown in Table 14-1.

Table 14-1: Resources illustrating concepts of climate change mitigation

Concept	Short description of illustration, diagram, video, online course	Reference, link
Energy Efficiency	Illustration of the rating scheme for energy efficiency of home appliances ranging from A(most efficient) to G(least efficient)	https://ec.europa.eu/info/energy-climate-change-environment/standards-tools-and-labels/products-labelling-rules-and-requirements/energy-label-and-ecodesign/about_en
Climate change mitigation	Video aimed for ***teachers*** to provide technical foundation on climate mitigation	https://www.youtube.com/watch?v=gDcGz1iVm6U&feature=emb_logo
Sustainable resource management	Case study highlighting the benefits of using natural wood that is sustainably sourced, instead of energy-intensive construction materials such as iron, steel, and concrete as a way to reduce emissions. Case study from Eldorado high school, Arkansas, USA The school used natural wood instead of iron and concrete. It was constructed with 153,265 cubic feet of lumber, panels and engineered wood, which can store 3,660 tons of carbon. By using wood instead of more fossil-fuel-intensive materials like steel and concrete, the building reduced 7,780 tons of carbon emissions, equivalent to reducing emissions from 2,100 cars for a year, or operating a small house for 970 years.	https://www.forestfoundation.org/wood--a-good-choice-for-energy-efficiency-and-the-environment#:~:text=Compared%20with%20concrete%20and%20steel,carbon%20dioxide%20as%20they%20grow.
Low carbon lifestyle	Illustration highlighting examples of personal choices to reduce contribution to climate change / carbon emissions grouped into low impact, moderate impact, and high impact activities	https://phys.org/news/2017-07-effective-individual-tackle-climate-discussed.html

Concept	Short description of illustration, diagram, video, online course	Reference, link
Sustainable forest management	Illustration of the elements of the carbon cycle for sustainable forest management	https://foresteurope.org/sfm-criteria-indicators2/
Carbon sinks	Simplified poster/illustration for carbon absorption by trees through photosynthesis and carbon storage through their wood	European Crop Protection Association https://www.ecpa.eu/media/reports_infographics
Reducing energy consumption	Poster promoting simple personal practices to reduce energy consumption referenced from Harvard Green Education	https://green.harvard.edu/tools-resources/poster/top-5-steps-reduce-your-energy-consumption

14.3 Student Engagement Activities

14.3.1 Activity 1

Concept: Energy efficiency: *Which light bulb is better?*[119]

Figure 14-10: Energy Efficiency

Activity: A teacher-guided experiment to highlight the concept of energy efficiency by using energy saving light bulbs such as LED lamps instead of traditional bulbs. The excess heat from the traditional bulbs demonstrate that more energy is consumed by the bulb in order to light up as opposed to LED lamps that do not heat up during operation. This means that LED lamps consumes less energy to perform, i.e. more energy efficient.

Materials: thermometer, Halogen lamp, LED lamp, and a lamp fixture with power outlet

[119] Energy Efficiency. Cambridge Energy Alliance Organization. Available at https://cambridgeenergyalliance.org/wp-content/uploads/Energy-efficiency-lesson-plans.pdf (accessed: 30 November, 2020)

Figure 14-11: Materials used (thermometer, Halogen lamp, LED lamp, lamp fixture with power outlet)

Procedure:

1. Students to prepare a table with the following layout:

Lamp type	Temperature at start	Temperature after 1 min	Temperature after 2 mins	Temperature after 4 mins	Temperature after 6 mins
Halogen lamp					
LED lamp					

2. Set up both lamps into the lamp fixture and turn them on
3. Students to bring the thermometer very close to the lamps to measure their temperature right the moment they are turned on and record it into their worksheet (table in step 1)

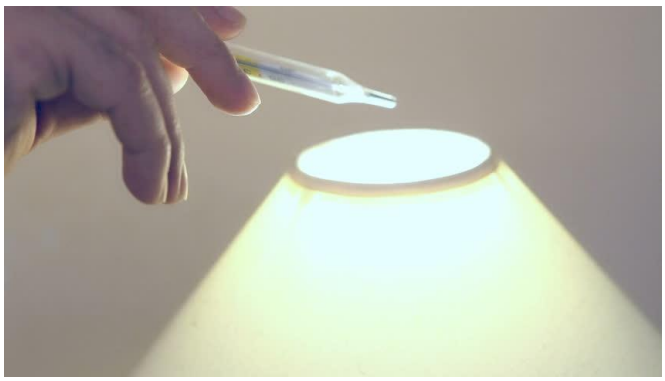


Figure 14-12: Thermometer close to a lamp

4. Record temperature measurements at 1 minute, 2 minutes, 4 minutes, and 6 minutes, and record the readings in the worksheet (table in step 1)
5. Students to plot a graph with the readings for the two lamps

Guide reporting of results:

1. What is the observation from the readings from both lamps? (halogen lamps will read increasing temperatures whereas LED lamps will read constant temperature that is much lower)

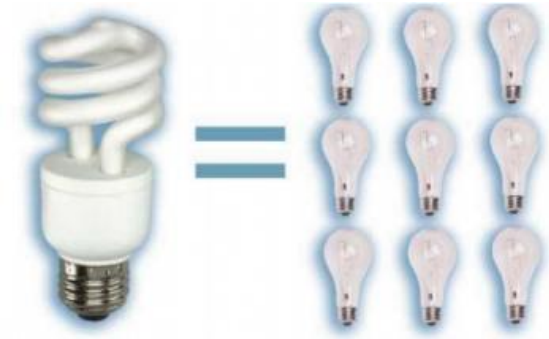


Figure 14-13: LED Lamp vs. halogen Lamps

2. Why did the halogen lamp read higher temperatures whereas the LED lamp read much lower and constant temperature at every time?

Reflection:

6. Higher temperatures (heat = more energy) mean that they use more energy to fulfill their purpose (lighting), whereas the LED lamps use less energy (no excess heat or energy) to fulfill the same purpose. Therefore, LED lamps are the more efficient choice of lamps (doing more with less energy).
7. Students to observe the types of lamps they have at home, and encourage the switching to LED lamps

14.3.2 Activity 2

Concept: Reducing energy consumption

Activity: Art project to promote energy saving practices in school and in students' daily life. Students to design and execute banners and posters with energy saving tips, slogans, and practices in order to hang them in class or in different areas at school[120]

Materials: Stationary: pens and markers, flipcharts, glue or tape, and/or decorative props

Procedure:

1. Organize a guided discussion for students to brainstorm ways to reduce energy consumption or energy wasted in the school
2. Students write down energy reducing practices or slogans
3. Using these slogans, students to be provided blank charts, posters, or banners to design or draw small picture banners to display the slogan (or practice), and the

[120] Energy Slogans and Posters. Green Education Foundtaion. Available at http://www.greeneducationfoundation.org/institute/lesson-clearinghouse/359-Energy-Slogan-Banners-and-Posters (accessed: 1 December, 2020)

associated energy saving facts. Banners should have a clear title and state the call to action

Sample banner:

Slogan: Turn Off the Light, We'll Be Alright Illustration: (drawing or illustration here in Figure 14-14) Call to action: Please turn off the lights/fan/AC/computer when not in use to save energy	

Figure 14-14: Illustration for Turning off the lights

4. Hang the banners and posters at appropriate places around the school to act as reminders for encouraging energy saving practices among students or staff (e.g., next to light or fan switches, hallways, etc)

Guide reporting of results:

1. What sources of energy are used at school? (electricity, heating, or cooling)
2. What activities contribute to wasted energy or use more energy?
3. What activities can reduce use of energy in and out of class?

Slogan	Energy saving tip
Turn Off the Light, We'll Be Alright	Please turn off the lights/fan/AC/computer when not in use.
See It On, turn It Off	Please turn off the lights if you pass by an empty room
Daylight is just right	Use natural daylight as much as possible.
Water is life. Life is water	Turn off the water tap when brushing your teeth

14.3.3 Activity 3

Concept: Differentiate between adaptation and mitigation actions

What type of measure does each example below represent: adaptation or mitigation? Justify your answer.

Table 14-2: Differentiating between adaptation and mitigation actions

Action	Adaptation	Mitigation
 Designate more forests as protected areas		
 Improve roads, bridges and building design to resist weather damage.		
 Protect homes and buildings from flooding.		
 Invest in ways to absorb rainwater, like “green” roofs and porous driveways.		
 Promote water and energy conservation		
 Invest in or provide rebates for energy efficient fridges, furnaces, and appliances.		
 Promote cycling, walking and taking transit as alternatives to driving.		
 Increase sources of renewable energy like wind and solar		
 Improve industrial processes to use less energy and materials.		

Answer:

Action	Adaptation	Mitigation
 Designate more forests as protected areas		✓
 Improve roads, bridges and building design to resist weather damage.	✓	
 Protect homes and buildings from flooding.	✓	
 Invest in ways to absorb rainwater, like “green” roofs and porous driveways.	✓	
 Promote water and energy conservation		✓
 Invest in or provide rebates for energy efficient fridges, furnaces, and appliances.		✓
 Promote cycling, walking and taking transit as alternatives to driving.		✓
 Increase sources of renewable energy like wind and solar		✓
 Improve industrial processes to use less energy and materials.		✓

14.4 How to Change Student Behavior?

14.4.1 Activity 1

The art project suggested above can be an effective way to promote energy saving and energy efficiency practices in the student's schools and homes. In addition to the posters, banners, or reminders, a checklist could be distributed amongst students to encourage them to adopt more energy saving practices.

Create a list of energy saving practices and distribute it to students as illustrated in Figure 14-15.

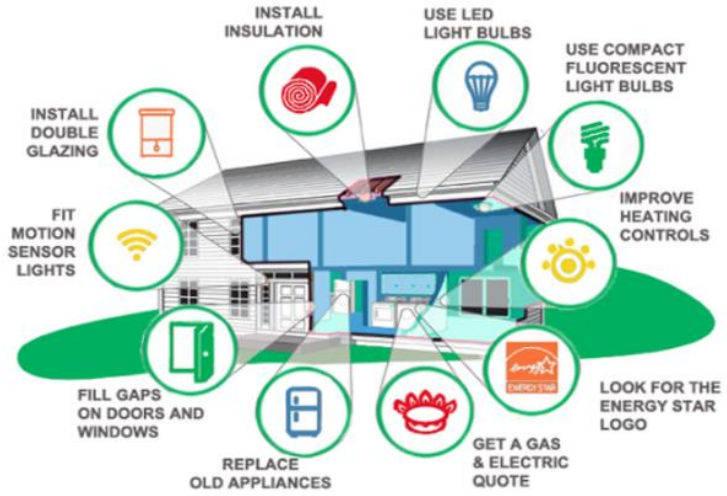
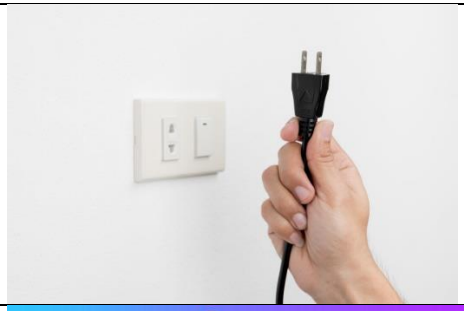


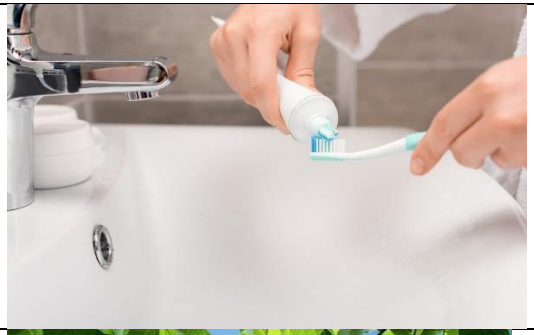
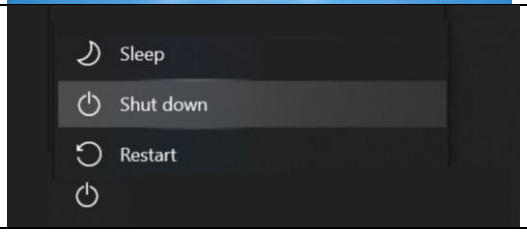
Figure 14-15: List of Energy saving practices

Each suggested practice will have 21 boxes next to it. It is believed that it takes 21 days to make a new habit. Therefore, students are asked to adopt as many practices as they can from the list on daily basis for 21 days and ticking the boxes accordingly. A reward could be offered for students with the most ticks. This activity could be done at the beginning of each semester or school year to encourage and promote awareness on efficient energy usage.

Sample checklist:

	Practice/Day	**Illustrative icon**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**
#	**Energy saving practice**																						
1	I turn off the lights every time I leave a room																						
2	I take shorter hot showers																						

3	I unplug unused electronics																							
4	I unplug battery chargers when not in use.																							
5	I don’t stand in front of an open refrigerator door.																							

6	I close the water tap while brushing my teeth																							
7	I use more natural light whenever possible in daytime																							
8	I shut down my computer after every use																							

9	I don’t use my phone while it’s charging																							

14.4.2 Activity 2

Which action is more energy efficient and why?

Action 1	Action 2
Using a car to go around places 	Using a metro to go around places 
Which one would you choose?	
Leave the fan turned on when you leave the room 	Turn off the fan when you leave the room 
Which one would you choose?	
Leave you unused phone charger plugged in 	Unplug your unused phone charger 
Which one would you choose?	

15 MESSAGE 15: THE CARBON FOOTPRINT

15.1 Background Information

A carbon footprint refers to the total greenhouse gas (GHG) emissions caused directly and indirectly by activities carried out by individuals, households, events, organizations, or products we use. It aims to identify the environmental performance of our activities or products when it comes to GHG emissions, thus assessing its impact on climate change[121].

Figure 15-1: Carbon Footprint

Carbon Footprint is calculated by summing the emissions resulting from performing an activity or using a product over a period of time. Burning of fossil fuels are the primary source of GHG emissions. Therefore, carbon footprint is usually calculated based on the amount of fuel burned or energy needed to perform an activity or produce and use a product or equipment.

Carbon Footprints look into different elements including energy consumption during the production and usage of products or performing an activity (e.g. electricity, transport, heating and cooling, water usage, food, etc.), as well as waste generated due to production or usage of product waste (e.g., packaging, plastic bags, throwing away products that are fit for use) as illustrated in Figure 15-2. Both **resource and energy consumption, and waste generation** are considered the primary variables governing carbon footprint calculations. There are currently numerous tools and online calculators available for individuals and organizations to calculate their carbon footprint.[122].

[121] Reducing your Carbon Footprint. Texas Coastal Exchange organization. Available at https://www.texascoastalexchange.org/reducing-your-carbon-footprint.html (accessed: 1 December, 2020)
[122] Calculating Carbon Footprint. The Open University. Available at https://www.open.edu/openlearncreate/mod/oucontent/view.php?id=22692&printable=1 (accessed: 1 December, 2020)

Figure 15-2: Components included in estimating carbon footprints [123]

The average person's carbon footprint is measured in tons of carbon, and it depends on factors such as country, income level, lifestyle, and consumption habits. The **annual global carbon footprint average per person is approximately 4 tons of carbon**, whereas in many wealthy countries such as **USA it reaches up to 16 tons**[124]. **In Egypt**, the national average footprint per person is **around 2.5 tons of carbon as of 2019**, and it is growing at an annual rate of 2.7%[125]. The primary activities contributing to individual carbon footprint in Egypt are electricity and energy use for heating, cooling, and other household energy use, food and beverage consumption, clothing and other consumer goods, transportation, and miscellaneous goods and services (including health, recreation and culture) as shown in Figure 15-3. Food and beverages make up the largest contribution to individual footprint at around 35%, followed by household energy use and miscellaneous goods and services at 20%, then transportation and clothing and consumer goods at 15% and 10% respectively[126].

[123] https://mahb.stanford.edu/blog/carbon-footprint/attachment/carbonfootprint/
[124] Calculate your carbon footprint. The Nature Conservancy. Available at https://www.nature.org/en-us/get-involved/how-to-help/carbon-footprint-calculator (accessed: 30 November, 2020)
[125] Egypt- CO2 emissions per Capita. Knoema. Available at https://knoema.com/atlas/Egypt/CO2-emissions-per-capita (accessed: 30 November, 2020)
[126] https://www.iamm.ciheam.org/publications/190/010_-_Galli.pdf

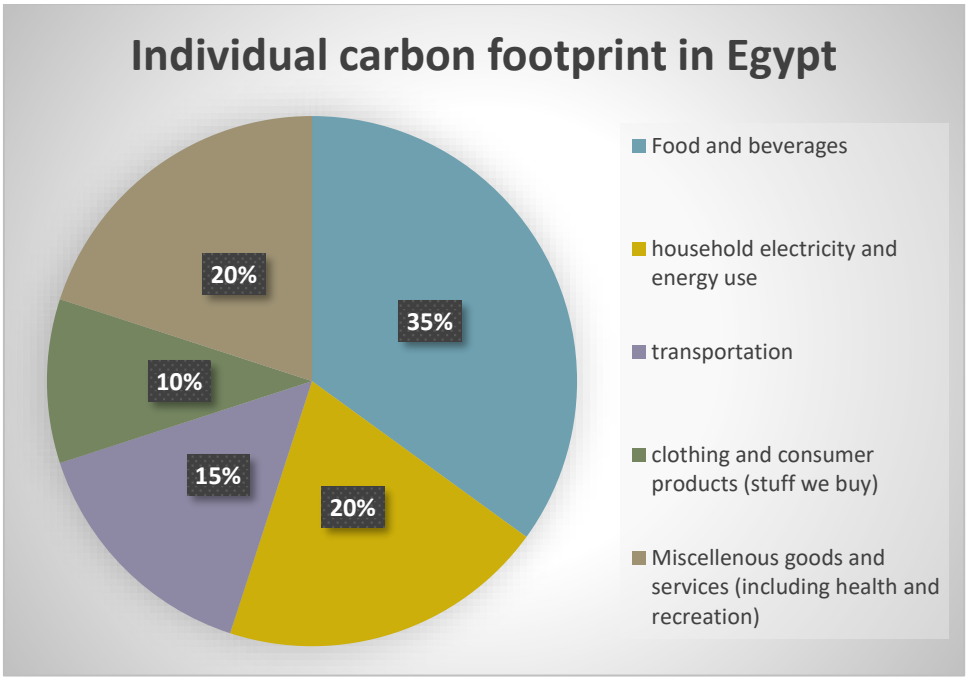


Figure 15-3: Primary activities contributing to individual carbon footprint in Egypt [127]

Ways to reduce carbon footprint on food, transport, energy use, heating and cooling, and products we consume[128]:

- Reduce Energy use:
  - Reducing energy consumption (energy efficiency)
  - Using more energy efficient products (e.g., LED lamps)
  - Using renewable energy
  - Reducing energy consumption by behavior such as unplugging unused electronics
  - Use AC only when necessary (with curtains shut in summer to avoid over heating from the sun which need more energy from the AC to cool the room)
  - Hanging clothes out to dry instead of using drying machine which consumes electricity
  - Use refrigerators responsibly (avoiding unnecessary opening and closing)
  - Switch off unnecessary lighting at daytime and when leaving home
  - Try to use cars when full and not only with one or two people (i.e. carpooling). This would be relaxed under COVID19 conditions.
  - Substituting activities needing fossil energy with non-fossil energy (e.g., using bike or walking for short distance travel)

127

128 Carbon Dioxide Emissions and Carbon Footprint. Standford University MAHB blog. Available at https://mahb.stanford.edu/blog/carbon-footprint/ (accessed: 1 December, 2020)

Figure 15-4: Reducing energy use

- Reduce Waste:
  - Minimize purchases of new products (buy what you need not what you want)
  - Buy locally sourced food from local shops instead of heavily packaged products
  - Reduce usage of plastic bags and boxes and bottles
  - Consume less packaged products to reduce your waste
  - Use a reusable cloth bag when you go shopping
  - Use less water and especially hot water. Don’t take very long hot showers
  - Recycle as much as possible
  - Shift to a more greenish diet.

Figure 15-5: Ideas for reducing waste

In short, a carbon footprint refers to the total greenhouse gas (GHG) emissions caused directly and indirectly by activities carried out by individuals, households, events, organizations, or products we use. The average person's carbon footprint is measured in tons of carbon, and it depends on factors such as country, income level, lifestyle, and consumption habits. Calculation and knowledge of one's footprint can help guide efforts and changes in behavior to reduce GHG emissions.

15.1.1 Self-check quiz

The main human activity that adds to an individual's carbon footprint:

a. Use of renewable energy
b. Photosynthesis by plants
c. Using energy (electricity, heating, and car fuel) from fossil fuels (correct answer)
d. Respiration and growth

Why should you be concerned with your carbon footprint?

a. To contribute to reducing carbon emissions and global warming (correct answer)
b. To save money

c. To know the size of your foot
d. To learn about carbon dioxide formation in the atmosphere

What is an action to reduce your carbon footprint?

a. Using more products than needed
b. Reduce your waste (e.g., reduce usage of plastic bags and boxes and bottles) (correct answer)
c. Using private cars instead of mass transport (both fossil-based)
d. Eating packaged food instead of home-cooked food

Which activity does not add to your personal carbon footprint?

a. Cooking meals
b. Taking long hot showers
c. Riding a bike (correct answer)
d. Playing computer games

15.2 Illustrations of Concepts

Links to various material that can help engage the students and illustrate the concepts of the message are shown in Table 15-1.

Table 15-1: Resources illustrating the concept of carbon footprint

Concept	Short description of illustration, diagram, video, online course	Reference, link
Carbon Footprint	Simple videos explaining carbon footprint using illustrations and age-appropriate language:	https://www.youtube.com/watch?v=8q7_aV8eLUE https://www.youtube.com/watch?v=DKDq1RMHscQ https://www.youtube.com/watch?v=Xdl5Vht0sO8
Carbon footprint	Poster providing 10 tips to reduce carbon footprint	https://www.texascoastalexchange.org/reducing-your-carbon-footprint.html

15.3 Student Engagement Activities

15.3.1 Activity 1

Concept: Personal carbon footprint for younger students (simple version)

Activity: Personal carbon footprint estimation.

Conduct a guided session in the school outdoor space, or during a school trip (any outdoor space where students can observe and identify activities and products they use or waste)

Materials: Sample questionnaire to estimate carbon footprint[129] [130]:

Activity	Ranking	My performance
Food and drinks and entertainment		
I eat at home food that is produced locally	a. Once a week b. Three times per week c. Almost everyday	
I eat packaged processed/junk/snack food	a. Everyday b. Three times per week c. Less often or rarely	
Of the food you buy how much is wasted and thrown away?	a. I don't eat half of my food b. I leave out some food because I buy more than I need c. I rarely/never waste food. I only buy what I need	
How often do you buy locally produced food	a. I don't buy locally produced food. b. Sometimes c. I always buy locally produced food	
I drink bottled water	a. Everyday b. Sometimes c. I always have my own reusable bottle (flask)	
I use my own bottles and boxes for my food and drink at school	a. I always use disposable boxes and bottles b. Sometimes I have my own lunchbox c. I always use my own food box and food at school/club	
I eat my food in one plate	a. Rarely/never. I like using 2-3 plates b. Sometimes depending on my food c. I always use one plate and eat food one by one	
Transport and travel		
How often do you use cars?	a. Everyday b. Three times per week c. Once or twice a week/never	
How often do you walk/use bikes	a. Rarely/never b. Once or twice a week c. More than three times per week	
Share car rides with other people	a. Rarely b. Sometimes c. Always	
Energy use (electricity and heating)		

[129] Carbon Footprint calculator. World Wildlife Foundation. Available at https://footprint.wwf.org.uk/#/questionnaire (accessed: 1 December, 2020)
[130] Ways to reduce your carbon footprint. Ovo Energy blog. Available at https://www.ovoenergy.com/blog/green/ways-to-reduce-your-carbon-footprint.html (Accessed: 1 December, 2020)

Shut Down/unplug Electronics	a. Rarely b. Sometimes c. Always	
I switch off lights when leaving home/room/class	a. Rarely b. Sometimes c. Always	
I use AC/fan only when necessary, and I turn it off when I leave a room	a. Rarely b. Sometimes c. Always	
I use natural daylight in the day	a. Rarely b. Sometimes c. Always	
I take long hot showers	a. Everyday b. 2-3 times per week c. All my showers are under 4-5 minutes	
I use cold water when washing my face and brushing teeth	a. Rarely b. Sometimes c. Always	
I close water taps when brushing my teeth	a. Rarely b. Sometimes c. Always	
Resources we consume and waste		
I use both sides of paper, and I use recycled paper	a. Rarely b. Sometimes c. Always	
I buy new products regularly (electronics, clothes, furniture, toys and games)	a. Everyday b. 3-4 times per month c. Once or twice per month	
I buy packaged products	a. Everyday b. 3-4 times per week c. Once or twice per week	
I consume disposable products (juice boxes, water bottles, toys, cans, plates, cutlery, straws)	a. Everyday b. 3-4 times per week c. Once or twice per week	
I use my own bag instead of plastic bags to carry stuff	a. Rarely b. Sometimes c. Always	
I use discarded products to create useful items from them (upcycling or re-use instead of throwing away)	a. Rarely b. Sometimes c. Always	
I try to fix my stuff first before I throw them away	a. Rarely b. Sometimes c. Always	
I use water filters or dispensers instead of plastic bottled water	a. Rarely b. Sometimes c. Always	

Procedure:

1. Provide explanation on how to fill in the checklist: checklist consists of four categories of activities. each category includes some activities that contribute to the

personal carbon footprint. For each activity, students should choose the answer that best describes their lifestyle: either A, B, or C

2. After filling out their checklists, each student should count the number of A answers, B answers, and C answers
3. Choices C are considered the most environmentally friendly, so students with the most C answers have lower personal carbon footprint
4. Students with the greatest number of C answers to be called out or rewarded as "Environmental champions"

15.3.2 Activity 2

Concept: Personal carbon footprint for older or more advanced students (advanced version)

Activity[131]: For each question below, choose the option that best describes you or your family most of the time. Then write the number (which represents how many kilograms (kgs) of carbon per year you emit). Only fill in one line for each question. After you answer all the questions, add up all the numbers to find your carbon footprint**.**

Please answer the following question by selecting the appropriate answer and associated emissions of kg CO_2eq per year

1. How do you get to school? …….

a. Walk	a. 0 kg CO_2 eq /year
b. bike	b. 0 kg CO_2 eq/year
c. car	c. 506 kg CO_2 eq/year
d. bus	d. 59 kg CO_2 eq/year
e. carpool	e. 208 kg CO_2 eq/year

2. How do you get to most evening/ weekend activities? …….

a. car with just you (and your parents)	a. 383 kg CO_2 eq/year
b. carpool	b. 52 kg CO_2 eq/year

3. How often do you eat out/ get take-out? ……..……..

a. NEVER	a. 57 kg CO_2 eq/year
b. Once per week	b. 298 kg CO_2 eq/year

[131] This activity was adapted from this source: https://www.teacherspayteachers.com/Product/Carbon-Footprint-Calculator-designed-for-middle-school-students-6522682 and https://www.teachengineering.org/content/cub_/lessons/cub_whatkindoffootprint/cub_footprint_lesson01_worksheet_v3_tedl_dwc.pdf (accessed 20 May, 2021)

c. 2-3 times per week	c. 893 kg CO_2 eq/year
d. 4 or more times per week	d. 1451 kgCO_2 eq/year

4. How often do you eat RED MEAT (hamburger, ground beef)? …….

a. NEVER	a. 69 kg CO_2 eq/year
b. Once per week	b. 292 kg CO_2 eq/year
c. 2-3 times per week	c. 793 kg CO_2 eq/year
d. 4 or more times per week	d. 1451 kgCO_2 eq/year

5. Do you eat mostly……...

a. Vegetables/fruits	a. 69 kg CO_2 eq/year
b. Meat	b. 292 kg CO_2 eq/year
c. Bread	c. 165 kg CO_2 eq/year

6. How often do you eat food package in single serve containers? ..……

a. NEVER	a. 124 kg CO_2 eq/year
b. Once per week	b. 442 kg CO_2 eq/year
c. 2-3 times per week	c. 974 kg CO_2 eq/year
d. 4 or more times per week	d. 1732 kgCO_2 eq/year

7. Do you drink (most often) ……...

a. Water from a bottle filled by the tap or from the fridge	a. -136 kg CO_2 eq/year
b. Bottled water from individual bottle once per day.	b. 227 kg CO_2 eq/year
c. Bottled water from individual bottle several times per day.	c. 454 kg CO_2 eq/year
d. Some of both	d. 113 kg CO_2 eq/year

8. How do you bring/ get lunch at school? ……..……

a. Buy it from school	a. 68 kg CO_2 eq/year
b. Bring it using reusable containers	b. 91 kg CO_2 eq/year
c. Bring it with disposable bags (zip lock, pre-packaged snacks)	c. 295 kg CO_2 eq/year

9. Do you turn off lights when you leave a room? ……..……..

a. Yes	a. 60 kg CO_2 eq/year

b. No	b. 122 kg CO_2 eq/year

10. Do you unplug phone/ ipad/ etc. chargers when not in use?.....

a. Yes	a. 9 kg CO_2 eq /year
b. No	b. 54 kg CO_2 eq/year

11. Do you turn off the water when brushing your teeth?.....

a. Yes	a. 15 kg CO_2 eq/year
b. No	b. 124kg CO_2eq/year

12. How long of a shower do you take? ……

a. 1-3 minutes	a. 57 kg CO_2 eq/year
b. 4-9 minutes	b. 191 kg CO_2 eq/year
c. 10+ minutes	c. 283 kg CO_2 eq/year
d. 20 + minutes	d. 565 kg CO_2 eq/year

13. How many hours of TV/ computer/ video games per day? ……..…

a. 1-2	a. 91 kg CO_2 eq/year
b. 3-4	b. 204 kg CO_2 eq/year
c. 5+	c. 295 kg CO_2 eq/year

14. Do you turn off the TV when you're not watching it or does it stay on as background noise? …….

a. Yes	a. 21 kg CO_2 eq/year
b. No	b. 64 kg CO_2 eq/year

15. How many pencils do you go through in a week? ……

a. 1-2	a. -23 kg CO_2 eq/year
b. 3+	b. 68 kg CO_2 eq/year

16. How many rooms (bedrooms, living room, kitchen, etc) are there in your house?

a. 3-4	a. 522 kg CO_2 eq/year
b. 5-9	b. 658 kg CO_2 eq/year

17. How often do you run the air conditioners in your house in the summer? …….

a. Rarely	a. 68 kg CO_2 eq/year
b. Sometimes (we turn it on and off depending on how hot it is)	b. 271 kg CO_2 eq/year
c. All day and night (you have central air)	c. 692 kg CO_2 eq/year

18. How often does your family fly for a vacation? ……

a. Never- we only drive	a. 163 kg CO_2 eq/year
b. 2-3 times a year	b. 1761kgCO_2eq/year
c. 1 time every 2 years or so	c. 798 kg CO_2 eq/year
d. We do not go on vacation	d. 0 kg CO_2 eq/year

19. How often do you buy new clothes or shoes? ……..……

a. Weekly	a. 848 kg CO_2 eq/year
b. Monthly	b. 419 kg CO_2 eq/year
c. Yearly	c. 233 kg CO_2 eq/year

20. Do you recycle? (for this question, select all that apply) ……..……...

a. Paper	a. -107 kg CO_2 eq/year
b. Newspapers or magazines	b. -41 kg CO_2 eq/year
c. Glass	c. -3 kg CO_2 eq/year
d. Plastic	d. -33 kg CO_2 eq/year
e. Aluminum and steel cans	e. -39 kg CO_2 eq/year

21. Do you use any renewable energy sources strategies? ……..……

a. We have solar panels	a. -340 kg CO_2 eq/year
b. We drive an electric or hybrid car	b. -340 kg CO_2eq/year
c. We use re-useable bags when shopping	c. -45 kg CO_2 eq/year
d. None	d. 0 kg CO_2 eq/year

Add together all the values and report here …… kg CO_2 eq/year

Convert this number to tons by dividing it by 1,000. Round to the nearest whole number and record it below.

My carbon foot print in tons is…… CO_{2eq} per year

- The lower the number the fewer greenhouse gases emitted to the atmosphere

- The average person in Egypt generates about 2.52 tons of CO_{2eq} each year.
- The global average is about 4 tons of CO_{2eq} each year.

Is your footprint over Egypt's average or under?.....

15.3.3 Activity 3

15.3.3.1 Example 1

Ahmed wakes up at 6 AM to go to school. First he takes a shower for about 10 minutes then he brushes his teeth. He doesn't turn off the water while he brushes his teeth. Most of the time, his mom prepares his lunch in disposable bags. He takes bottled water once per day. Ahmed goes to school with his dad in a car. Ahmed doesn't turn off the light when he leaves the room. After school, Ahmed is allowed to watch TV or play video game for 3-4 hours. Ahmed doesn't unplug charger when not in use. He loves to eat meat 4 or more times per week and doesn't like fruits nor vegetables.

Answer the following questions:

1. How does Ahmed get to school? …….

a. Walk	a. 0 kg CO_{2eq}/year
b. bike	b. 0 kg CO_{2eq}/year
c. car	c. 506 kg CO_{2eq}/year
d. bus	d. 59 kg CO_{2eq}/year
e. carpool	e. 208 kg CO_{2eq}/year

2. How long of a shower does Ahmed take? ……

a. 1-3 minutes	a. 57 kg CO_{2eq}/year
b. 4-9 minutes	b. 191 kg CO_{2eq}/year
c. 10+ minutes	c. 283 kg CO_{2eq}/year
d. 20 + minutes	d. 565 kg CO_{2eq}/year

3. Does Ahmed turn off the water when brushing his teeth?.....

a. yes	a. 15 kg CO_{2eq}/year
b. no	b. 124 kg CO_{2eq}/year

4. How does Ahmed bring/ get lunch at school? ……

a. Buy it from school	a. 68 kg CO_{2eq}/year
b. Bring it using reusable containers	b. 91 kg CO_{2eq}/year
c. Bring it with disposable bags (zip lock, pre-packaged snacks)	c. 295 kg CO_{2eq}/year

5. Does Ahmed drink (most often) …….…….

a. Water from a bottle filled by the tap or from the fridge	a. -136 kg CO_{2eq}/year
b. Bottled water from individual bottle once per day.	b. 227 kg CO_{2eq}/year
c. Bottled water from individual bottle several times per day.	c. 454 kg CO_{2eq}/year
d. Some of both	d. 113 kg CO_{2eq}/year

6. Does Ahmed turn off lights when he leaves a room? ……..

a. yes	a. 60 kg CO_{2eq}/year
b. no	b. 122 kg CO_{2eq}/year

7. How many hours of TV/ computer/ video games per day? …….

a. 1-2	a. 91 kg CO_{2eq}/year
b. 3-4	b. 204 kg CO_{2eq}/year
c. 5+	c. 295 kg CO_{2eq}/year

8. Does Ahmed unplug phone/ ipad/ etc. chargers when not in use?.....

a. yes	a. 9 kg CO_{2eq}/year
b. no	b. 54 kg CO_{2eq}/year

9. How often does Ahmed eat RED MEAT (hamburger, steak, ground beef)?...

a. NEVER	a. 69 kg CO_{2eq}/year
b. Once per week	b. 292 kg CO_{2eq}/year
c. 2-3 times per week	c. 793 kg CO_{2eq}/year
d. 4 or more times per week	d. 1451 kg CO_{2eq}/year

10. Does Ahmed eat mostly ……

a. Vegetables/fruits	a. 69 kg CO_{2eq}/year
b. Meat	b. 292 kg CO_{2eq}/year
c. Bread	c. 165 kg CO_{2eq}/year

Add the numbers from each question then divide it by 1000 to calculate Ahmed's carbon foot print.

Ahmed's foot print is…….. ton CO_{2eq} per year

Answer:

506+283+124+295+227+122+204+54+1451+292 = 3558 kg CO_2eq per year

Ahmed's foot print is = 3558/1000 = 3.558 ton CO_{2eq} per year

15.3.3.2 Example 2

Samar wakes up at 6 AM to go to school. First she takes a shower for about 2 minutes then she brushes her teeth. She turns off the water while she brushes her teeth. Most of the time, her mom prepares her lunch in reusable container. She takes water filled by the tap. Samar goes to school with her neighbor as they carpool. Samar turns off the light when she leaves the room. After school, Samar is allowed to watch TV or play video game for 1-2 hours. Samar unplugs charger when not in use. She loves to eat meat 2-3 times per week and loves fruits and vegetables.

Answer the following questions:

1. How does Samar get to school? …….

a. Walk	a. 0 kg CO_{2eq}/year
b. bike	b. 0 kg CO_{2eq}/year
c. car	c. 506 kg CO_{2eq}/year
d. bus	d. 59 kg CO_{2eq}/year
e. carpool	e. 208 kg CO_{2eq}/year

2. How long of a shower does Samar take? ……

a. 1-3 minutes	a. 57 kg CO_{2eq}/year
b. 4-9 minutes	b. 191 kg CO_{2eq}/year
c. 10+ minutes	c. 283 kg CO_{2eq}/year
d. 20 + minutes	d. 565 kg CO_{2eq}/year

3. Does Samar turn off the water when brushing his teeth?.....

a. yes	a. 15 kg CO_{2eq}/year
b. no	b. 124 kg CO_{2eq}/year

4. How does Samar bring/ get lunch at school? ……

a. Buy it from school	a. 68 kg CO_{2eq}/year
b. Bring it using reusable containers	b. 91 kg CO_{2eq}/year
c. Bring it with disposable bags (zip lock, pre-packaged snacks)	c. 295 kg CO_{2eq}/year

5. Does Samar drink (most often) ……

a. Water from a bottle filled by the tap or from the fridge	a. -136 kg CO_{2eq}/year
b. Bottled water from individual bottle once per day.	b. 227 kg CO_{2eq}/year
c. Bottled water from individual bottle several times per day.	c. 454 kg CO_{2eq}/year
d. Some of both	d. 113 kg CO_{2eq}/year

6. Does Samar turn off lights when he leaves a room? ……..

a. yes	a. 60 kg CO_{2eq}/year
b. no	b. 122 kg CO_{2eq}/year

7. How many hours of TV/ computer/ video games per day? …….

a. 1-2	a. 91 kg CO_{2eq}/year
b. 3-4	b. 204 kg CO_{2eq}/year
c. 5+	c. 295 kg CO_{2eq}/year

8. Does Samar unplug phone/ ipad/ etc. chargers when not in use?.....

a. yes	a. 9 kg CO_{2eq}/year
b. no	b. 54 kg CO_{2eq}/year

9. How often does Samar eat RED MEAT (hamburger, steak, ground beef)?...

a. NEVER	a. 69 kg CO_{2eq}/year
b. Once per week	b. 292 kg CO_{2eq}/year
c. 2-3 times per week	c. 793 kg CO_{2eq}/year
d. 4 or more times per week	d. 1451 kg CO_{2eq}/year

10. Does Samar eat mostly ……

a. Vegetables/fruits	a. 69 kg CO_{2eq}/year
b. Meat	b. 292 kg CO_{2eq}/year
c. Bread	c. 165 kg CO_{2eq}/year

Add the numbers from each question then divide it by 1000 to calculate Samar's carbon foot print.

Samar's foot print is…….. ton CO_{2eq} per year

Answer:

208+57+15+91-136+60+91+9+793+69 = 1257 kg CO2eq per

Samar's foot print is = 1257/1000 = 1.257 ton CO_{2eq} per year

15.3.4 Activity 4

Concept: Personal carbon footprint calculator**.** This activity can be done as a home assignment, if there is no access to internet. The results of the students are then discussed in class.

Activity: There is an online tool to calculate personal carbon footprint. To achieve accurate calculation, students will need to collect data related to their energy use at home and other behaviors. Students are encouraged to talk to their family and look around in their homes

to collect the data listed in the below questionnaire (Table 15-2 and Table 15-3) and then fill it in. Tools like Google Earth or Google Maps can help with some of the transportation distances.

Materials: Sample questionnaire to estimate carbon footprint[132]

Link to the online carbon foot print calculator:
https://depts.washington.edu/i2sea/iscfc/calculate.php

Table 15-2: Data collection guiding questions to facilitate the use of the online calculator

I. Transportation	
A. Distance traveled going out with friends per week *(km)*	
B. Distance traveled for shopping, sports, extracurricular activities per week	
C. Distance between your home and school *(km)*	
D. If a personal vehicle is used for A, B, and/or C, what is the fuel efficiency of that vehicle *(in liters/100km)*	
E. Flight information for the last year	
i. # of flights taken in the last year ***please note:* * a round-trip is counted as TWO flights** *** you'll be asked below how many stops there were on each flight**	
a) Flight #1	
• **number of stops on the way to your destination**	
• **Approximate total distance traveled *(km)* or time *(hours) note: if you had one or more stops on route, add up the total flying distance or flying time for each portion of the journey combined. (do not include time spent in an airport between***	
Total distance traveled for vacations last year (i.e., non-airplane modes of transportation)	
II. Home and appliances	
A. Size of your home in square feet or square meters	
B. Number of months per year the air conditioning is used in your home	
C. Average temperature *(°C)* you keep your home at in summer	
D. Number of incandescent, LED and fluorescent light bulbs in your home and the approximate number of hours used per day.	***(see chart at the bottom to calculate these values)***

[132] https://depts.washington.edu/i2sea/docs/wwwfootprint/CalculatorPrep.pdf (Accessed on 19 May, 2021)

E. Type of water heating system in your home (e.g., gas, electric, solar, etc.)	
F. How many minutes is your average shower time?	
G. Approximate volume of trash generated in your home per week	
III. Food	
A. Approximate caloric intake perday	
B. Amount of each of the following that you eat per week:	
i. Eggs *(number /week)*	
ii. Dairy	
a) liters of milk/week	
b) Grams of cheese/week	
iii. Vegetarian meals *(number of meals/week)*	
iv. Fish or chicken *(number of meals/week)*	
v. Beef *(number of meals/week)*	
C. What proportion of your food is locally grown? ***(most / some / none / I don't know)***	
D. What proportion of your food is organic? ***(most / some / none / I don't know)***	

Table 15-3: Data collection to use the online calculator

Room	Number of incandescent bulbs in this room	Total number of hours these incandescent bulbs are on per day (add up the time for each bulb)	Number of fluorescent bulbs in this room	Total number of hours these fluorescent bulbs are on per day (add up the time for each bulb)	Number of LED bulbs in this room	Total number of hours these LED bulbs are on per day (add

						up the time for each bulb)
Your bedroom						
Kitchen						
Your parents' bedroom						
Bathroom						
Living room						
Dining room						
Lights on exterior of home						
Hallway						
Closets						
Please continue to add rooms below if you have additional rooms in your house not included above						
Total (add up your totals in each						

Procedures:

1. **Register into the online calculator to record and remember your results**
2. **Choose Egypt's time zone, which is (+2 Eastern Europe)**
3. **Follow the steps such as choosing Egypt and Cairo as your city**
4. **Answer the questions to calculate your carbon foot print**

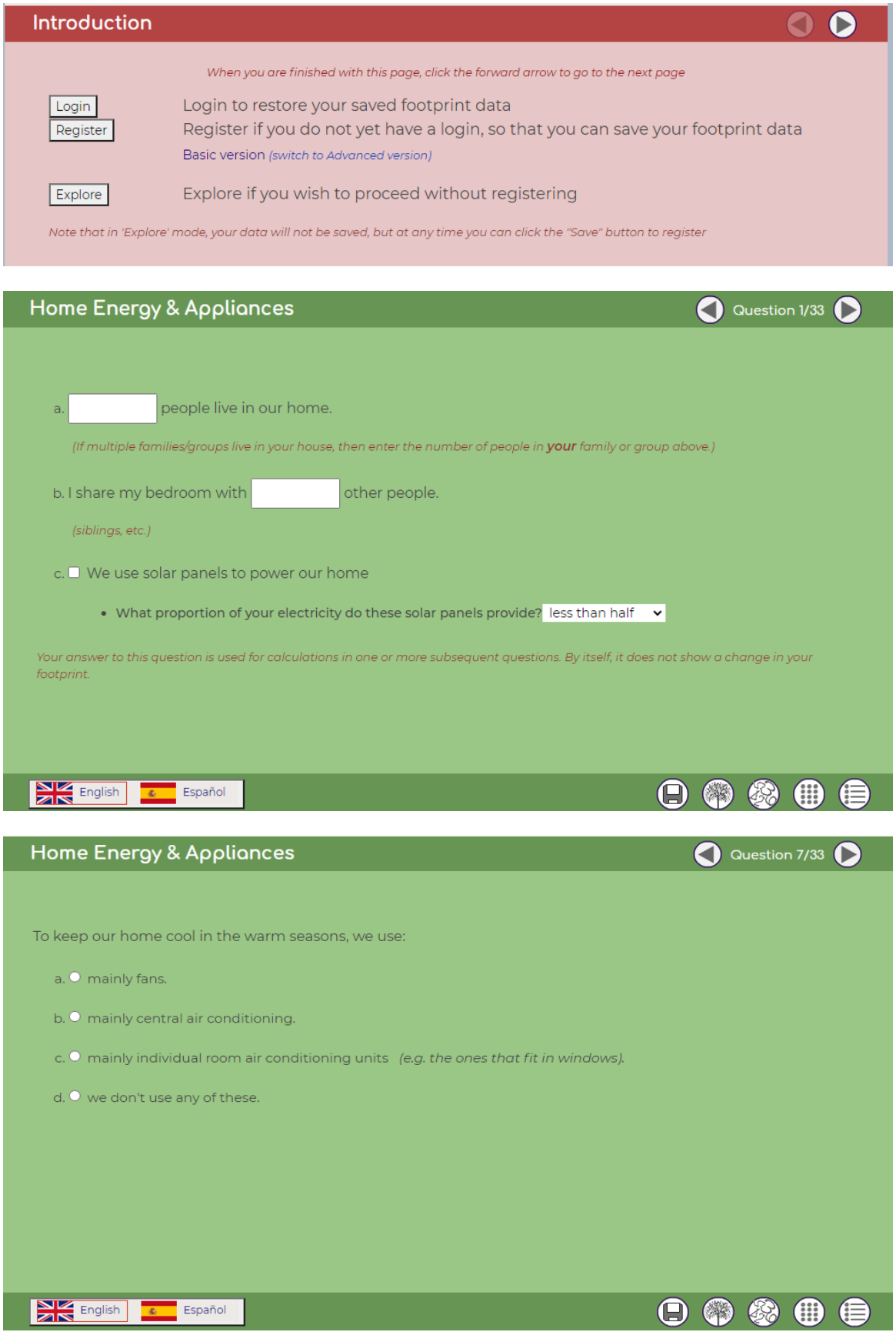


Figure 15-6: Screenshots from the online calculator

Discussion questions

What is your carbon footprint?

Is your footprint over Egypt's average or under?

What can you do to reduce your CO_2 emission?

15.4 How to Change Student Behavior?

15.4.1 Activity 1

Concept: Reducing personal carbon footprint

Procedure:

1. Building on the abovementioned extracurricular activity, students are asked to identify two A answers and two B answers from the footprint calculation activity

   Example:

Activity	Ranking	My performance
Food and drinks and entertainment		
I eat at home food that is produced locally	a. Once a week b. Three times per week c. Almost everyday	A
I eat packaged processed/junk/snack food	a. Everyday b. Three times per week c. Less often or rarely	B
Resources we consume and waste		
I use both sides of paper, and I use recycled paper	a. Rarely b. Sometimes c. Always	A
Energy use (electricity and heating)		
I switch off lights when leaving home/room/class	a. Rarely b. Sometimes c. Always	B

2. In a guided session, students are asked to brainstorm different ways or behaviors that could help them change their habits and become more environmentally friendly (changing their A and B answers to become a C)

   Example:

Activity	Ranking	Proposed way to change behavior	Expected outcome

I switch off lights when leaving home/room/class	b. Sometimes	Put reminders or banners above the light switches or in school hallway	Reminders will help students ***always*** remember to switch off the lights when leaving an empty room/class (instead of sometimes) and hence reduce their carbon footprint from the energy consumption category

3. Set a timeline with the students (e.g., one month or a semester), and then, in a guided session, follow up and discuss the challenges they faced when trying to implement different ways to change their A and B answers

Activity	**Ranking**	**Proposed way to change behavior**	**Challenges faced during implementation**	**Proposed measure to overcome challenges**
I switch off lights when leaving home/room/class	b. Sometimes	Put reminder signs or banners above the light switches or in school hallway	Reminders are removed or vandalized (torn, fall off, covered)	Assign one of the "environmental champions" to be responsible for maintaining the signs or reporting vandalized signs, and remind their peers verbally when needed

15.4.2 Activity 2, 3 and 4

Review your selections on the above questions. Answer the questions below.

1. For which choices you collect the most amount of CO_2 *(List your top 4)*?
   a. ……
   b. ……
   c. ……
   d. ……

2. What can you do to reduce the CO_2 emission of 2 of those selections? *(For example, if you don't turn off the light when you leave the room, try to put notes to help you remember to do so).*
   a. ……

b. ……

Do you want to reduce your carbon footprint? You can make a plan to change some of your habits. Test the plan for a week and see if it was hard for you or it was easy and you can continue on these habits. It is important that you choose habits that you can actually change to make a difference. If you won't do it – don't plan it. Try to get your family to participate with you. Use the space below to help you implement your plan.

Activity	**Today**	**Did I do my plan (Yes/No)**	**One week later**
	Plan		How hard was it? Will I continue?
Things I will turn off/unplug			
How I will change my transportation			
What I will eat differently			
How long I will use electronics			
What I will recycle			
Other things I will do			

16 MESSAGE 16: ACTIONS TO REDUCE CLIMATE CHANGE IMPACTS

16.1 Background Information

Climate change impacts affect all levels: country level, economy level, community level, as well as individual level. Therefore, actions (adaptation and mitigation actions) on all levels are needed in order to effectively address all impacts resulting from climate change and build resilience for human and natural systems towards climate shocks in the future (the intersection part in Figure 16-1 below). Changes in individuals' behaviors on energy use e.g., transport, waste generation, food consumption, energy use can help reduce climate change impacts, save natural resources, and drive economies to grow in an environmentally friendly manner.

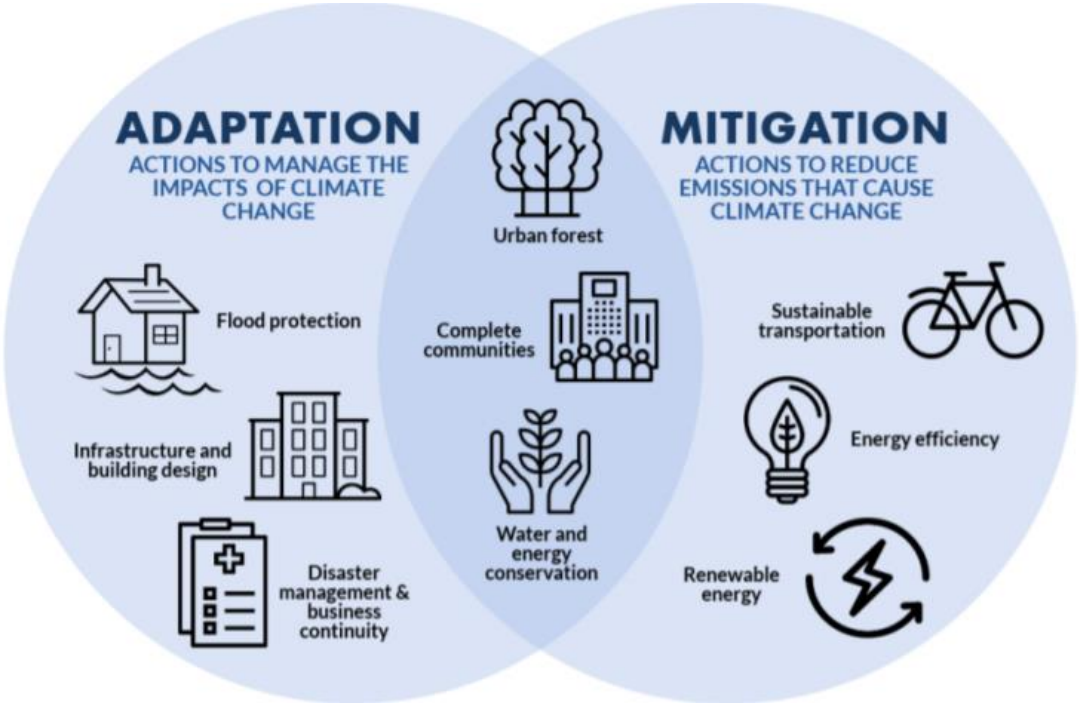


Figure 16-1: Climate change mitigation vs. adaptation (source: Waterloo City Council[133])

Energy Use/Transport

Reducing climate change impacts from transport can be achieved by adopting practices that use energy more efficiently, reduce wasted energy, and reduce overall energy consumption on transport. Examples of these practices are shown in Figure 16-2.

133 https://www.waterloo.ca/en/government/resources/Documents/Cityadministration/Corporate-Climate-Change-Adaptation-Plan.pdf

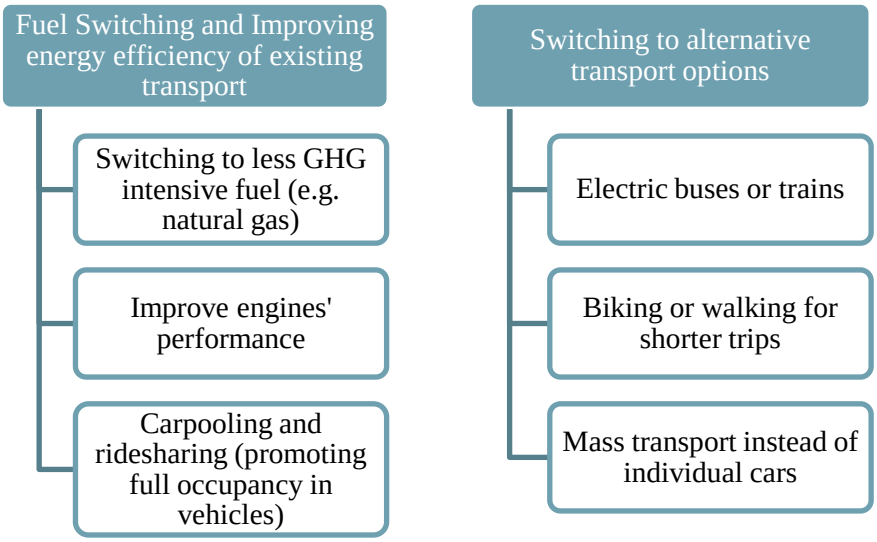


Figure 16-2: Approaches to reduce carbon emissions from transport

Using mass transport instead of single cars (e.g., buses, metro, or trains) can reduce emissions by saving energy as illustrated in **Error! Reference source not found.**3. It a lso reduces traffic jams. **Average global emissions from petrol-run private cars and diesel run buses are 104 and 158 grams of CO_2 per kilometer**, respectively[134] .

- Average emissions from a 30-passenger bus: 158 g CO_2/km
- Average emissions from 30 cars: 104 x 30 = 3120 g CO_2/km

Figure 16-3: Average emissions resulting from bus versus 30 private cars[135]

Different transport options ranked from most favorable to least favorable for low carbon transportation are illustrated in Figure 16-4 [136].

[134] https://www.eea.europa.eu/
[135] EEA
[136] Sustainable Transport and Walkable Cities. Newcastle University. Available at https://2016-2017.nclurbandesign.org/2017/01/sustainable-transport-walkable-cities/ (accessed: 10 December, 2020)

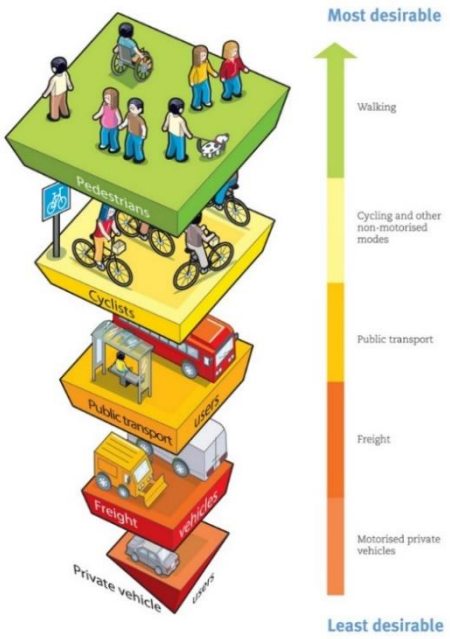


Figure 16-4: Least desirable to most desirable transport options for low carbon mobility[137]

Waste[138]:

Reducing waste is effectively linked to emissions reduction. By consuming more products, more waste is produced. More waste requires disposal in landfills, which results in methane emissions from biodegradation of organic waste e.g., food, paper, and textiles. In addition to the GHG emissions produced from waste disposal, other environmental problems are associated with waste generation e.g., disposal in streets and water bodies. The sustainable

[137] Newcastle University
[138] Waste Hierarchy Guidance. UK Department for Environment, Food & Rural Affairs. Available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/69403/pb13530-waste-hierarchy-guidance.pdf (Accessed: 1 December, 2020)

waste management hierarchy outlined in Figure 16-5 is an effective approach to tackle the environmental problems related to waste.

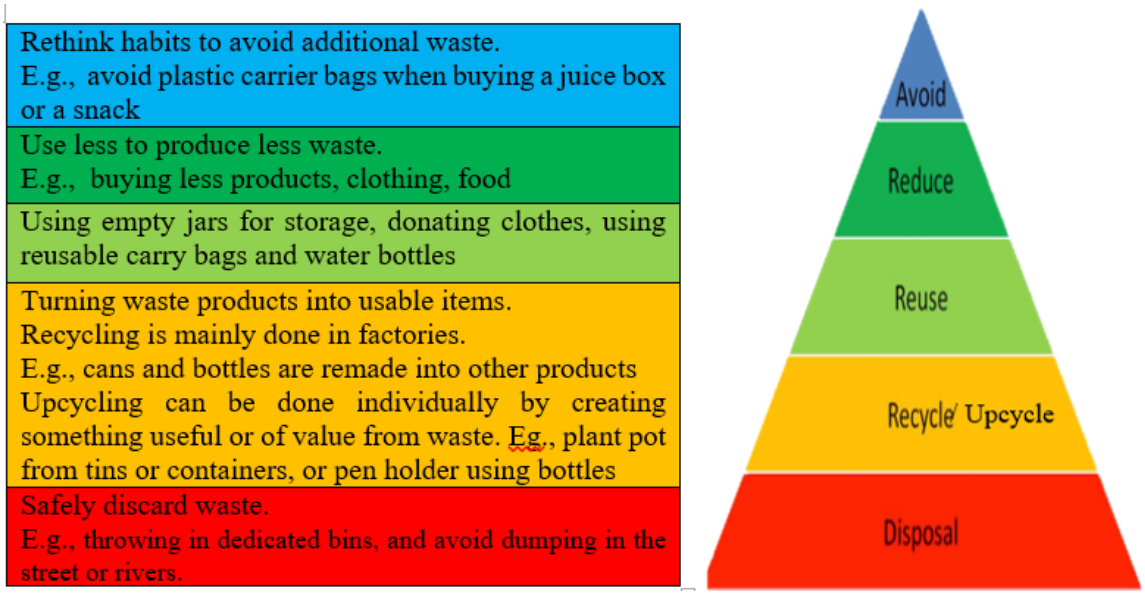


Figure 16-5: Sustainable waste management hierarchy

The types and quantities of waste vary widely according to geographical locations, lifestyles and consumption habits, as well as income level. In Egypt, the Ministry of Environment estimates that we produce around 20 million tons of waste each year[139]. Municipal solid waste (MSW) (e.g., household waste) produced in Egypt by type of waste and region is highlighted in Figure 16-6[140].

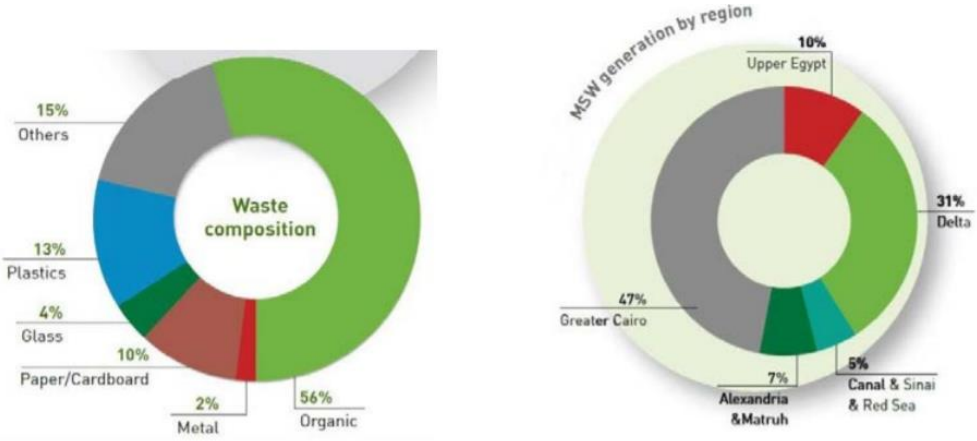


Figure 16-6: Waste type and region distribution in Egypt

Food consumption:

[139] Egypt state of the environment report. 2016. Egyptian Environmental Affairs Agency. Available at http://www.eeaa.gov.eg/en-us/mediacenter/reports/soereports.aspx (accessed: 10 December, 2020)
[140] Ibrahim, Mohamed. (2016).Towards Sustainable Management of Solid Waste in Egypt. Procedia Environmental Sciences. 1(34). pp 336-347.

The production and consumption of food contributes about a quarter of the emissions causing global warming and climate change. Similar to other types of waste, food waste generation varies depending on location, consumption habits, income level, and state of the economy[141] . Due to these variables, food is wasted in different stages of the food production chain[142], which is shown in Figure 16-7.

The Food and Agriculture Organization of the UN (FAO) estimates that, **each year, one-third of all food produced for human consumption in the world (around 1.3 billion tons) is lost or wasted**. This includes 45% of all fruit and vegetables, 35% of fish and seafood, 30% of cereals, 20% of dairy products and 20% of meat.

Not surprisingly, **most of this wastage occurs in the developed world**; per capita food waste by consumers (not including the production process) in Europe and North America is around 95-115kg per year, compared to just 6-11kg in sub-Saharan Africa and South/South-East Asia.

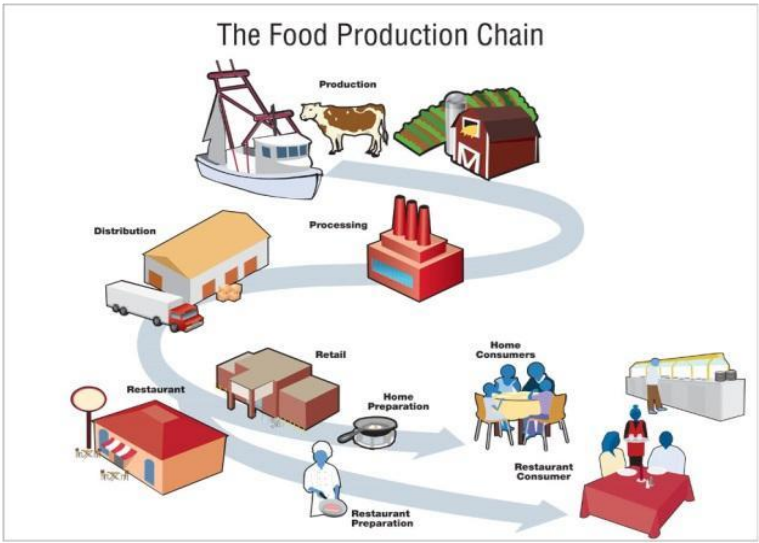


Figure 16-7: Food production supply chain (source: Local Nexus Network)[143]

In medium to high income countries, food is wasted more at consumer level (homes, restaurants, supermarkets, grocers, etc.) due to over consumption of food, throwing away food that is still suitable for human consumption, and the increasing demand on food products beyond needs, especially processed and packaged food. In middle or low income countries, such as Egypt, approximately 40% of food is primarily lost or wasted during the early and middle stages rather than the consumer level (i.e. harvesting, production, transporting and storage). All steps of the food production chain require energy, which usually comes from combustion of fossil fuels. Therefore, increased food waste results in increase in emissions in our atmosphere [144] [145] [146]. Changing food consumption habits and reducing the amount of food wasted or thrown away can have positive contribution to

[141] Which regions waste the most food?. Food and Agricultural Organization. Available at https://www.weforum.org/agenda/2015/08/which-countries-waste-the-most-food/ (accessed: 10 December, 2020)
[142] Driving the supply chain to more local food production. Local Nexus Network. Available at https://localnexus.org/driving-the-supply-chain-to-more-local-food-production/ (accessed: 10 December, 2020)
[143] Local Nexus Network
[144] Food Wastage and Climate Change. Food and Agriculture Organization. Available at http://www.fao.org/3/a-bb144e.pdf (accessed: 10 December, 2020)
[145] Fight climate change by preventing food waste. World Wildlife Foundation. Available at https://www.worldwildlife.org/stories/fight-climate-change-by-preventing-food-waste (accessed: 10 December, 2020)
[146] Foodwaste, the environment + climate change. 2020. Commission for Environmental Cooperation. Available at http://www.cec.org/flwy/food-waste-climate-change/ (accessed: 10 December, 2020)

reduce the impacts of climate change. The food recovery hierarchy shown in Figure 16-8 is an effective approach to reduce food waste and the associated environmental problems.

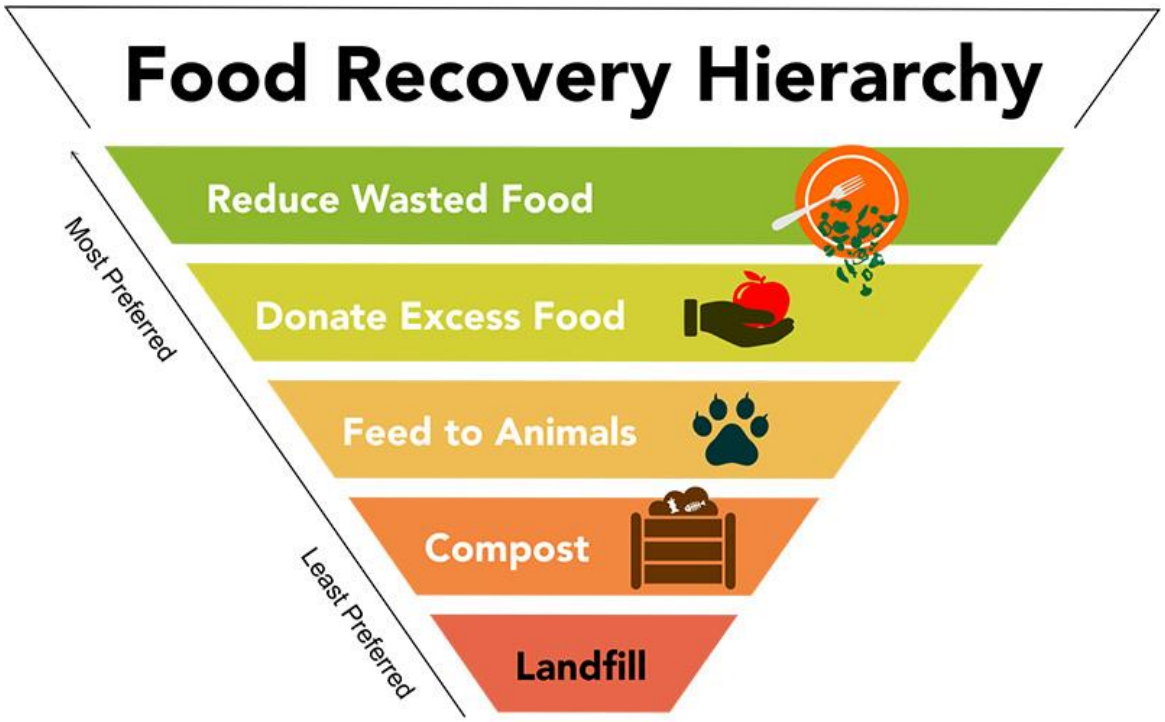


Figure 16-8: Food recovery hierarchy to reduce to food waste[147]

Knowing the carbon foot print for different agricultural products can help us make better choices on the food we consume. The more resource-intensive (primarily energy and water) it is to produce certain foods, the higher their carbon footprint and their contribution to the adversities of climate change. The list of foods shown in Figure 16-9 below show the GHG emissions associated with producing one kilogram of each. Beef has the highest carbon footprint of more than 40 $KgCO_2$ per kilogram of beef produced, followed by other animal proteins such as lamb at 20 $KgCO_2$/kg. Most foods with much lower carbon footprint are vegetables and grains as illustrated in the figure including oranges, pasta, onions, cereals, and apples.

[147] Edmonton Council, Canada

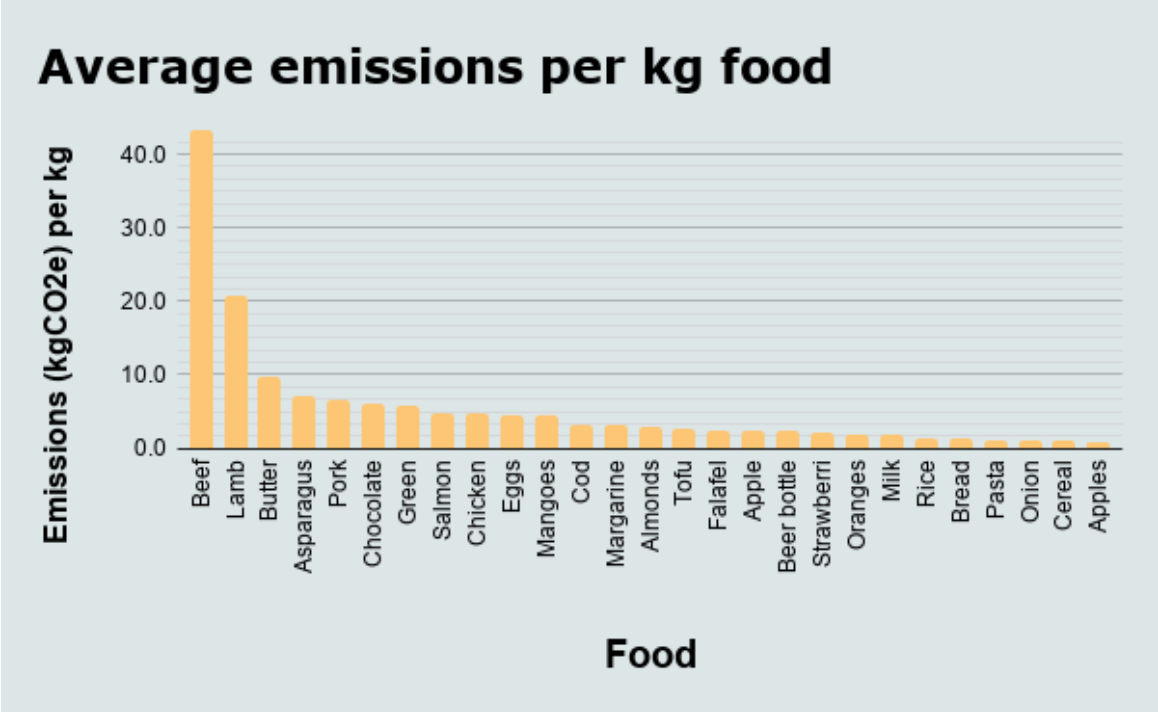


Figure 16-9 Average emissions released per one kilograms of food produced (source: My Emissions[148])

Volunteering and Awareness Campaigns:

Protecting the environment is a shared responsibility for all individuals. Volunteering and campaigning for solving environmental issues is one of the ways to promote awareness and induce change in the community. Benefits of volunteering include:

- Offering time and effort to an important cause
- Helps students learn new practical skills, become a part of like-minded community that have similar motives towards helping our planet
- Provide students with sense of achievement, ownership and real contribution to society and the environment.

There are many ways students can do volunteer work to help protect the environment. It could either be individually or through schools or communities. Examples of volunteer projects and campaigns include[149]:

- Tree planting campaign/activities
- Gardening and growing food (i.e., urban gardening)
- Awareness posters for the school on energy conservation, waste reduction, promoting healthy lifestyle and riding bikes
- Clean-up campaigns to clean the school yard

[148] https://myemissions.green/reduce-the-carbon-footprint-of-your-diet/

[149] Hands on ways you can volunteer to help the environment. Available at https://www.onegreenplanet.org/environment/awesome-hands-on-ways-you-can-volunteer-to-help-the-environment/ (accessed: 10 December, 2020)

- Biking and running/walking events to promote alternative transport options and healthier lifestyle
- Promoting locally produced food (e.g., Organize a local farmer market)

Figure 16-10: Clean Up Campaigns

Another way to contribute to protecting the environment is by studying to become a professional in the environmental field. Environmental studies are a vast field and numerous study disciplines can help students build a career in the environment, including:

- Environmental science
- Environmental engineering
- Biology (with focus on conservation)
- Agriculture and zoology
- Natural science
- Urban planning and design
- Environmental Law
- Ecology
- Food Science
- Environmental researcher
- Software and computer science (for environmental modelling)

In short, approaches to reduce climate change at the country level, economy level, community level, as well as individual level aim to reduce energy consumption. The main sectors where changes are needed are the transport sector, where practices such as carpooling and using fuel efficient cars or mass transit help reduce emissions. In the waste sector, reducing waste generation reduces the amount requiring disposal and hence emission. With respect to food consumption, reducing wasted food and making changes in the selection of food, which have different carbon footprints, can reduce emissions. A final approach is raising awareness and involving the community in volunteer work related to reducing emissions from daily activities and habits.

16.1.1 Self-check Quiz

Wasting less food is a way to reduce greenhouse gas emissions

a. True (correct answer)
b. False

Carpooling and ridesharing are ways to reduce climate change impacts from waste

a. True
b. False (correct answer: transport)

Using empty glass jars for storage is a way to reuse waste

a. True (correct answer)
b. False

The first step in sustainable waste management is recycling

a. True
b. False (correct answer: avoid)

Composting is a preferred way to manage food waste than consuming less to reduce wasted food

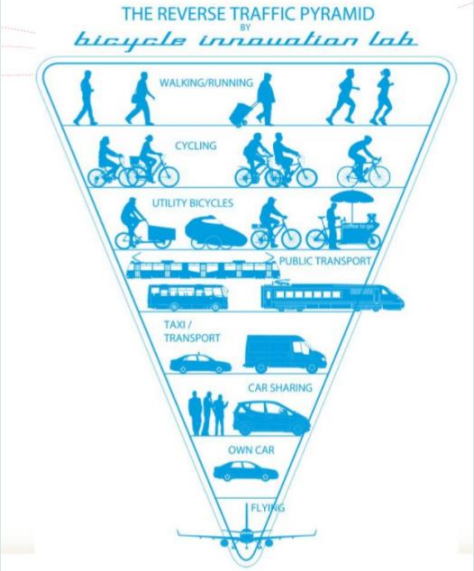
a. True
b. False (correct answer)

16.2 Illustrations of Concepts

Links to various material that can help engage the students and illustrate the concepts of the message are shown in Table 16-1.

Table 16-1: Various links to materials that illustrate the concept of actions to reduce climate change impacts

Concept	Short description of illustration, diagram, video, online course	Link / references
Waste	Material and infographs on different types of plastic waste and their suitability for recycling	https://www.sewdynamic.com/pages/plastic-pollution https://possibility.teledyneimaging.com/planet-earth-or-planet-plastic/ https://renewelp.co.uk/news/plastic-production-and-pollution-an-infographic/
Waste	Material and videos on Plastic waste	https://kids.niehs.nih.gov/topics/reduce/plastics/index.htm
Waste	Illustration of different types of waste and global compositions	http://Worldbank.org/what-a-waste

Concept	Short description of illustration, diagram, video, online course	Link / references
Waste reduction	Tips on waste reduction by National Geographic Kids	https://kids.nationalgeographic.com/explore/nature/reduce-your-waste/
Sustainable Transport	Poster describing hierarchy of transport options from most sustainable to least sustainable	GIZ: https://www.slideshare.net/deespacio/giz-mobility-asapublicgoodmanfredbreithaupt 
Reducing food waste	Educational videos on food waste	Simpleshow foundation: https://www.youtube.com/watch?v=RL_NYVxe8uY Foodwaste EU: https://www.youtube.com/watch?v=0eqxgvZNn0I Food waste presentation for schools by Food Rescue organization (in the US): this video is more suited to older students (grades 10+) https://www.youtube.com/watch?v=7xBzAqnXZJc Awareness video on food waste in Arabic (suited for younger ages) https://www.youtube.com/watch?v=BVarma3qH-I Egyptian food bank awareness video in Arabic (suited for all ages) https://www.youtube.com/watch?v=raH9yzzgGXI

Concept	Short description of illustration, diagram, video, online course	Link / references
Food waste	Poster on the amount of food wasted globally each year	
Food waste	10 facts about food waste and tips to reduce food waste	https://earthbound.report/2010/09/27/10-facts-about-food-waste/ https://www.edmonton.ca/programs_services/garbage_waste/how-to-reduce-food-waste.aspx

16.3 Student Engagement Activities

16.3.1 Activity 1

Concept: Waste management

Activity: experiment on monitoring personal waste generation

Students are asked to monitor the amount and type of waste they produce at home, by storing their waste in separate trash bags from the rest of their household members for a week. They are asked to segregate their waste into three bags: plastics, paper and cardboard, and other waste. After one week of monitoring, each student should fill out a monitoring checklist, and compare it in class with their peers.

Materials needed: trash bags and monitoring checklist

Figure 16-11: Trash bags (left) and Monitoring checklist (right)

Procedure:

1. Ask students to use three separate trash bags at home for a week, where they are required to collect their personal waste. Each bag will be used to collect different type of waste: one bag for plastic waste, one for paper and cardboard waste, and one for all other waste types
2. Each student should prepare a monitoring checklist at the beginning of the week in order to record how much waste they are producing from each category. By the end of the week, they should add up the total from each category, and record the total number of trash bags filled for each category

Sample checklist:

Waste category	Waste product	1	2	3	4	5	6	7	Total
Plastic	Bottles	5 bottles	2	3					
	Plastic bags	15	9	6					
	Packaging	4 snacks/chips bags							
TOTAL									Number of bags?
Paper and cardboard	Juice boxes	5	8	7					
	Paper	30	24	10					
TOTAL									Number of bags?
Others	Stationary	2	1	3					
	Soft drink cans and tins	6	2	4					
	Glass bottles	3	2	1					
TOTAL									Number of bags

3. After one week, each student will discuss their personal checklist in class, and compare it with their peers in teacher-guided discussion.

Questions/pointers to guide reporting of results:

1. Which type of waste do you produce the most at home? How to reduce it?
2. What do you do with plastic bottles? Do you reuse them?
3. Is there any waste you produce that can be upcycled?
4. How can you change your habits to reduce food packaging waste? Do you eat a lot of packaged snacks at home?
5. Where can you send your plastic and paper/cardboard waste for recycling?

16.3.2 Activity 2

Concept: Reuse and Upcycling of waste:

Activity: Arts and crafts workshop to promote (reuse and upcycling):

Ask students to collect different waste (carton boxes, bottles) either from home (in the previous extracurricular activity proposed, the teacher could ask them to store the bottles and cartons) or from the school yard (after a clean-up event for example). Example of upcycling:

1. Creating plant pots out of plastic bottles

2. Creating artwork from bottle caps, to be hanged in class, in school, or home

3. Using bottles and/or cardboard boxes or bottles for organization

Examples of reuse:

1. Glass bottles to store water

Figure 16-12: Glass bottle storing water

2. Using reusable cloth bags instead of plastic bags

Figure 16-13: Reusable cloth bag

3. Using reusable bottles instead of buying bottled water

Figure 16-14: Reusable bottles

Materials: paint, glue, used cardboard boxes, bottles, paper, bottle caps

Procedure: Group the class into 3-4 groups, and assign each group materials to create useful product, or an artwork. The aforementioned examples could be used, or each group can think of other creative re-use/upcycle options using the material they are provided (bottle caps, cardboard boxes, bottles, and/or paper).

16.4 How to Change Student Behavior?

16.4.1 Activity 1

Concept: Reduce/reuse waste

Activity: Event to collect and donate used stuff that are still fit for use

Figure 16-15: Donation stuff

Procedure:

1. Ask students to bring toys, clothes, or anything old they don't use anymore that can still be used by someone else
2. Two possible options are proposed:
    - Have them do a mini market open day (or during break time) where they could buy from each other using fake 5-10 EGP notes (like monopoly money or they could design their own notes or tokens). This is to help them understand that

unused or old stuff that are considered waste can still have value even if they stopped using them

Figure 16-16: Waste reused

- Organize an event to collect the stuff they brought from home and send them to charity as a donation

16.4.2 Activity 2

International volunteering day event (December 5): organize a school clean-up day and have students sort out the bottles, glasses, and cartons and store them for arts and crafts reuse and upcycling workshops (extracurricular activity #2). In preparation of the event, providing equipment for the clean-up such as gloves and aprons is necessary to maintain hygiene and safety of students

Figure 16-17: School clean-up day

16.4.3 Activity 3

Research project on local initiatives, shops, or NGOs offering environmentally friendly alternatives.

- Each student to conduct brief research that includes information on actual programs, initiatives, NGOs, or shops within their community (or in Egypt in general) that offers environmentally friendly solutions/products as an alternative to mainstream consumer products. Each student is required to search for the following categories:
- Cloth or paper bags (e.g., https://elbadeel.co/)
- Plastic and carton recycling services (e.g., http://www.gocleaneg.com/)
- Clothing and papers donation (e.g., https://resala.org/)
- Waste clean-up initiatives to reduce waste in streets and water (e.g., http://verynile.org/)
- Any other initiatives using recycled material to make new products/projects or crafts
- Multiple examples can be found on Greenish Foundation's (local NGO) website (https://www.green-ish.org/en/trust-by greenish?category=1&sub_category=19)

Information that should be included in the research:

- Name of the initiative, shop, or organization
- Its objective
- Which environmental problem are they addressing?
- What alternative/solution/service are they offering?

17 MESSAGE 17: GLOBAL AGREEMENTS AND RESPONSIBILITIES

17.1 Background Information

Climate change has no physical boundaries; an increase of emissions in one country will contribute to a global accumulation of emissions in the Earth's atmosphere, resulting in global warming. Therefore, global collaboration between countries have been taking place for many years, aiming at reducing the negative impacts of climate change (i.e., reduce emissions)[150].

The Intergovernmental Panel on Climate Change (IPCC) (1988)[151]: it is an organization consisting of 195 countries, established in 1988 by the United Nations as the main provider of scientific knowledge and basis for climate change and its impacts, and how to address them (through adaptation and mitigation). It produces comprehensive assessment reports on the most contributing sectors to climate change, primarily classified into 4 sectors: Energy, Industry, Waste, and Agriculture, Forestry, and Other Land Uses. These reports help countries understand the physical basis of climate change and develop better strategies to address climate change impacts. These reports are also used as basis for the negotiations between countries to establish global agreements and frameworks on climate change.

The United Nations Framework Convention on Climate Change (UNFCC) (1992) was established as part of the UN system in 1992 in Rio for the "Earth Summit" in order to support and promote global collaboration and efforts to address the stressing impacts of climate change. The convention is joined by 197 countries, all of which agree to take collective action towards solving the climate change problem, yet with different responsibilities between them, depending on the UNFCCC classification of countries into four groups[152] as illustrated in Figure 17-1.

- Annex I countries representing the wealthier industrial countries
- Annex II countries representing developed countries required to provide financial assistance to address climate change globally
- Non-Annex countries or developing countries: that are more vulnerable to the negative impacts of climate change, despite their little contribution to these impacts. Egypt is included in this category.
- Least developed countries (LDCs): they are part of the Non-Annex countries, but are given special consideration due to their limited capacity to respond to climate change (Figure 17-2)

[150] Joyeeta Gupta , Kim van der Leeuw & Hans de Moel (2007) Climate change: a 'glocal' problem requiring 'glocal' action, Environmental Sciences, 4(3), pp 139-148 (https://www.tandfonline.com/doi/pdf/10.1080/15693430701742677)
[151] About the Intergovernmental Panel on Climate Change. IPCC. Available at https://www.ipcc.ch/about/ (accessed: 1 December, 2020)
[152] UNFCCC International Solutions. Climate Change Connection Organization. Available at https://climatechangeconnection.org/solutions/international-solutions/unfccc/ (accessed: 1 December, 2020)

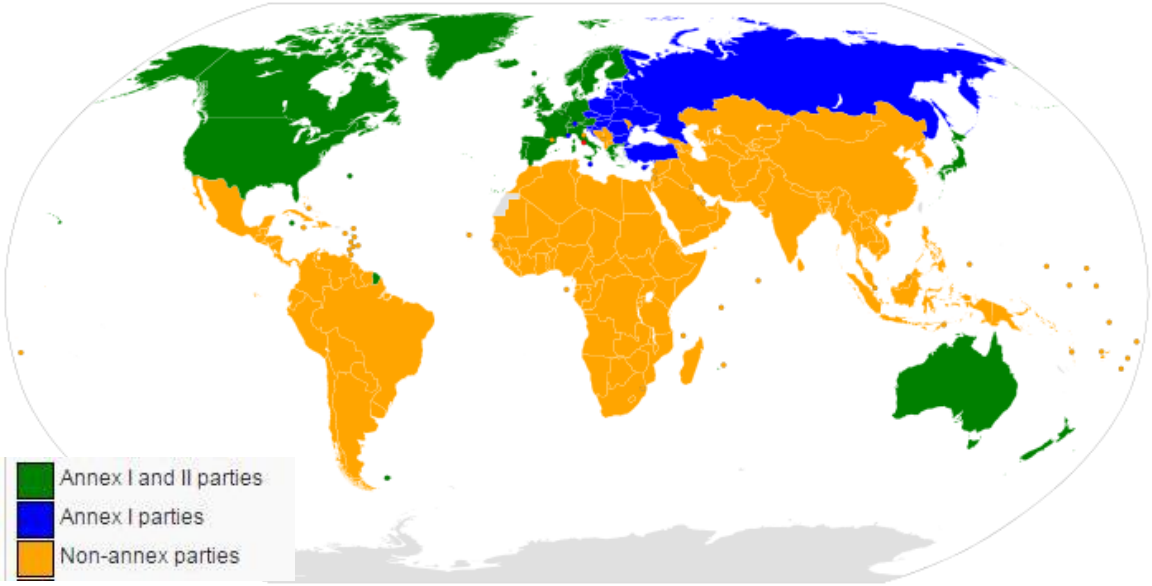


Figure 17-1: UNFCCC country classification

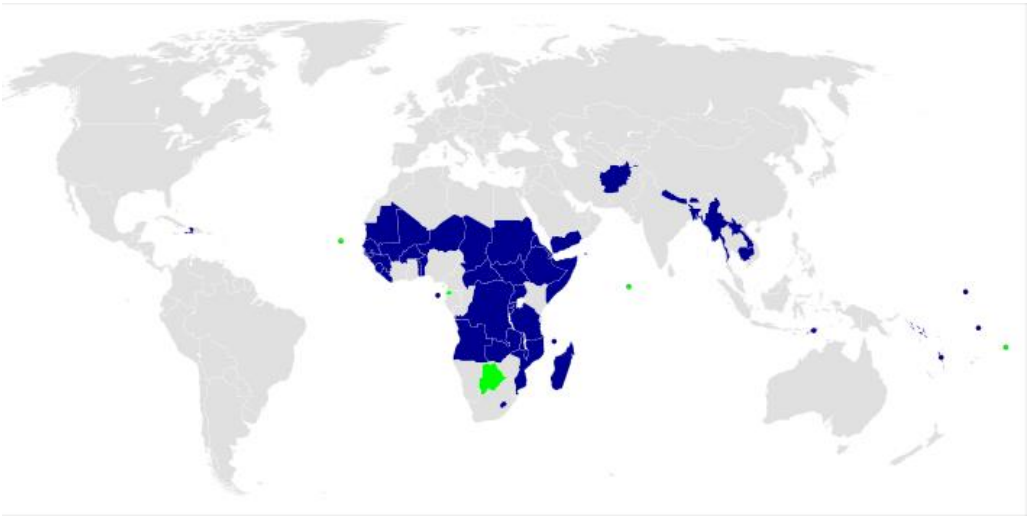


Figure 17-2: Least Developed Countries (part of Non-annex countries)

Conference of Parties (COP): it is the decision-making body of the UNFCCC, and it includes all countries of the convention. Every year since 1992, the COP takes place in one of the member countries to discuss and review the implementation of the Convention and make policy decisions and recommendations accordingly to ensure its effectiveness. 25 COPs have taken place so far. Prior to each COP, each country is required to submit relevant information to the UNFCCC in order to provide basis for the annual discussion and review. These submissions include various reports[153] as illustrated in Figure 17-3.

[153]Nationally Determined Contributions. UNFCCC. Available at https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement/nationally-determined-contributions-ndcs (accessed: 2 December, 2020)

National Communications (NC)	Nationally Determined Contributions (NDC)	Biennial Update Report (BUR) Biennial Report (BR)
•Country report on status of climate change impacts •GHG emissions released by the country •Efforts taken to address climate change • Required support to address climate change •NC reports should be submitted every four years by all countries	•Country level information on capacities and abilities to reduce climate change impacts via mitigation and adaptation actions •Country's ambition for reducing emissions •Each party shall communicate a nationally determined contribution every 5 years	•Progress report on actions in NDC every two years •Updated estimations of GHG emissions •Non Annex I: Updates on support needed and received •Annex I and II: Updates on support provided

Figure 17-3: Reports required by the UNFCCC from member countries[154]

Kyoto Protocol (1997): It is a global agreement derived from the UNFCCC COP negotiations. It is the first agreement to put restrictions on some of the largest contributors to GHG emissions due to their industrial activities. The agreement, established in 1997, set reduction targets to achieve such targets over the period (2008-2012). 168 countries were part of this agreement. The agreement entered its implementation phase in 2005. Many of the targets were not met, so countries agreed to extend its implementation for a second period from 2013-2020. The implementation was still not as effective as needed and not much progress was achieved. However, many lessons and improvement plans were learned and a new comprehensive legally binding agreement was promised by 2015.

Paris Agreement (2015): This agreement built upon the lessons learned from the Kyoto Protocol, making it the most updated and comprehensive agreement on global climate action. One of the key differences to Kyoto Protocol is that it distributes the responsibility of addressing climate change on all countries, and not just the large economies that release the largest amounts of emissions. However, the contribution of each country towards the global solutions is based on each country's capabilities and resources (which are communicated through the NDCs), and the level of support needed to improve such contribution. Paris Agreement includes 195 countries, and it entered its implementation phase in 2016, and the key elements of the agreement include:

- The Paris Agreement is legally binding, and each country should establish national targets consistent with their circumstances and capacities
- Limit the **global average temperature[155]** to 2 degrees Celsius by 2100 and strive to reduce it to no more than 1.5 degrees.

[154] Biennial Update Reports. UNFCCC. Available at https://unfccc.int/process/transparency-and-reporting/reporting-and-review-under-the-convention/biennial-update-reports-and-international-consultation-and-analysis-non-annex-i-parties/biennial-update-reports (accessed: 2 December, 2020)
[155] Global Average Temperature. NOAA. Available at https://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature (accessed: 2 December, 2020)

- Support shall be provided from developed countries to developing countries to implement the climate actions in their NDCs.
- Capacity building and technical assistance to be provided to developing and LDC countries
- Common framework for reporting to ensure transparency of the provided information from all countries

Carbon Market: Emissions trading between countries: Based on the carbon credit system (carbon credit is a permit that provides its buyer with emission allowance), which was launched in line with the Kyoto Protocol, a trading system for emissions was established. The system aims to help countries balance their excess emissions by purchasing additional allowance (carbon credits) from countries with lower emissions level (i.e., have surplus emission allowance), as illustrated in Figure 17-4.

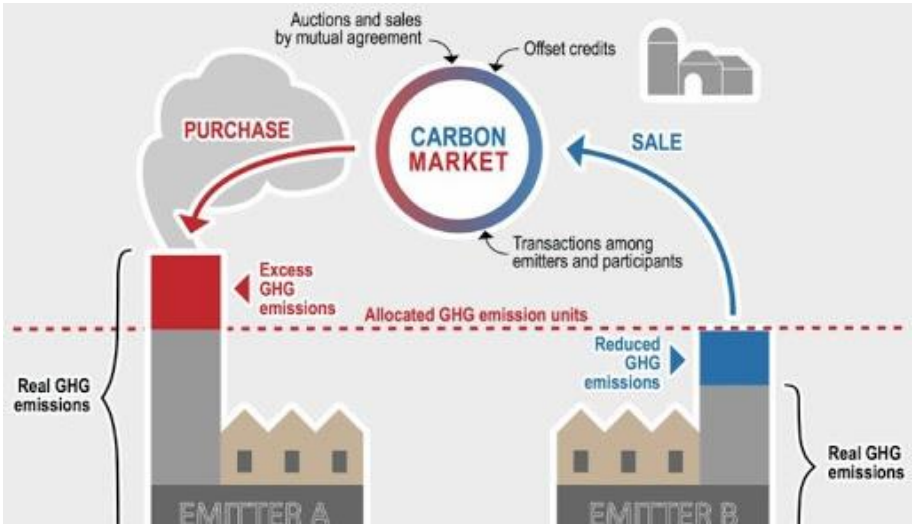


Figure 17-4: Emissions trading system[156]

In short, climate change has no physical boundaries; an increase of emissions in one country will contribute to a global accumulation of emissions in the Earth's atmosphere, resulting in global warming. Global collaborations and efforts started in the 1988 with the establishment of the IPCC. Today, the Paris Agreement is the most recent obligation destined to limit surface temperature below 2◦C. To this end, countries have to report on their emissions and determine their contributions depending on their capabilities and resources to address climate change. Other global

[156] Norwegian Energy and Environment Consotrium

efforts include developing a carbon market, where carbon emissions are priced and traded (e.g., emissions trading system ETS.)

17.1.1 Self-check quiz

Which treaty provides the global framework for international cooperation to combat climate change?

a. UNHCR
b. UNFCCC (correct answer)
c. ICRC
d. UNDP

The scientific body regarding climate change in the UN is called:

a. ICRC
b. UNEP
c. IPCC (correct answer)
d. COP

What is the name of the protocol launched in 1997 which set emission reduction targets for developed countries?

a. New York protocol
b. Berlin protocol
c. Kyoto protocol (correct answer)
d. Paris protocol

The decision-making body of the UNFCCC is called:

a. COP (correct answer)
b. POC
c. IPCC
d. NDC

Why do countries submit National Communication reports to the UNFCCC?

a. To provide the status quo on impacts, emissions, and efforts taken or planned, in order to serve as basis for annual global negotiations (correct answer)
b. To promote their work on climate change
c. To provide scientific knowledge to the UNFCCC
d. To avoid paying fines

What did countries agree to in the “Paris Agreement” in 2015?

a. Protect biodiversity and end deforestation of the world's rainforests
b. To keep global average temperature rise below 2℃, and pursue to reach a maximum of 1.5℃ increase (correct answer)
c. To increase sea level by 2 feet
d. To increase fossil fuel-based energy sources

In the UNFCCC, developing countries including Egypt are referred to as:

a. Annex 1 countries
b. Non-Annex I countries (correct answer)
c. Middle income countries
d. Non-developed countries

17.2 Illustrations of Concepts

Links to various material that can help engage the students and illustrate the concepts of the message are shown in Table 17-1.

Table 17-1: Various links to materials that illustrate the concepts of global agreements and responsibilities

Concept	Short description of illustration, diagram, video, online course	Link / reference
Kyoto Protocol	Powerpoint presentation aimed for teachers, providing more information on the Kyoto protocol	https://slideplayer.com/slide/14267273/
Climate negotiation history	Video on the global climate negotiations prior to the Paris Agreement	https://www.youtube.com/watch?v=B11kASPfYxY
Kyoto Protocol	Background information on the challenges of Kyoto Protocol	https://www.britannica.com/event/Kyoto-Protocol
Paris Agreement	Video explaining the Paris Agreement in simplified form	https://www.youtube.com/watch?v=1DdfNU5iATU&t=12s
Paris Agreement	Poster summarizing key elements of PA	https://www.activesustainability.com/climate-change/paris-agreement-what-is-it/
Latest IPCC reports	These reports were the basis upon which Paris Agreement temperature increase limits were set.	Assessment Report 5: The Synthesis Report https://www.ipcc.ch/report/ar5/syr/ Special Report on Global Warming of 1.5 degrees: https://www.ipcc.ch/sr15/
UNFCCC reporting	Reporting requirements and guidelines for Non-Annex countries	https://unfccc.int/national-reports-from-non-annex-i-parties
Sustainable Development Goals	The 2030 Global Agenda for Sustainable Development to improve human lives and protect the environment	https://sdgs.un.org/goals

17.3 Student Engagement activities

17.3.1 Activity 1

Concept: Global negotiations and conflict resolution

Activity: Simulation conference of the COP:
Organize an in-class simulation of the COP conference (1-2 hours long), where students are assigned a country to represent, and then they are asked to discuss a problem related to climate change (by moderating a guided discussion with questions) and work as a group to find a solution to the issue and prepare a poster explaining the solution (in drawing or writing). All of them must agree to the solution, sign the poster (to mimic the actual signing of agreements), and assign at least one responsibility to each of them (i.e., each country).

Figure 17-5: COP meeting

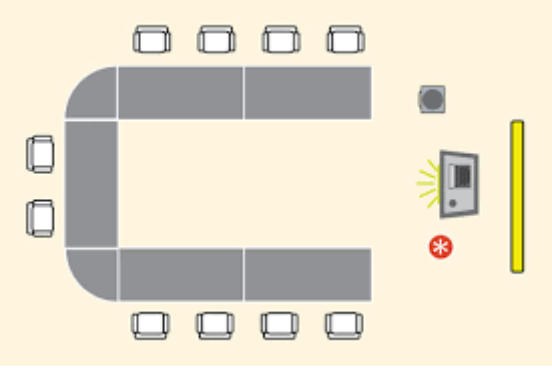
Materials: placards with names of different countries on them. Diversity of countries from developing and developed are encouraged.

Figure 17-6: Placards with names of different countries

Procedure:

- Assign each student (or in pairs) a country to represent in the simulation conference (10-15 countries depending on class size). Each student (or pair) will discuss the topic from the point of view or perspective of the countries they are representing

- Choose a topic: impacts of climate change due to transport, waste, energy consumption, or other topic covered in this course/package
- Each student (or pair) needs to do research, prior to the conference day, about the country they are assigned to, and the topic of discussion. The research could be done using the internet, using the material covered in this course, or with help of teachers. Research should answer the following questions:
    - How does (waste, transport, energy, etc) affect climate change?
    - What are examples of solutions found in (assigned country) to solve this problem (one or more of the above) related to climate change?
    - Is the country a member of UNFCCC and Paris Agreement?
    - Is the country considered a developed/developing country?
    - Is the country suffering from climate change?
    - Is the country contributing to climate change?
    - How can (Assigned country) collaborate with other countries to solve climate change?
- On the conference day, prepare the country placards and set the classroom to a U setting as shown in the below figure. Explain the rules of the conference to the students:
    - The teacher/moderator will ask one question, then each student (or pair) need to raise their placards if they wish to speak and answer the question
    - When a student is speaking, no other placards should be raised and other students should not speak
    - Each country should only address the moderator/teacher and not other students
    - Each student should speak on behalf of the country they are representing, and not their own country
    - Students should not move around or talk to each other during the discussion session



- The conference will start by a moderated discussion for 20 minutes, asking the following questions:
    - What are the main problems of (waste, transport, energy, etc) related to climate change?
    - Why is it important to be solved in collaboration with all countries?

- Is your country considered developed or developing? did it sign the UNFCCC and Paris Agreement?
- What are the possible "mitigation" and "adaptation" options we can implement?
- What could be the responsibility of your assigned country in addressing the problem? (provide support, reduce emissions, collaborate with other countries, share knowledge, etc)
- How can we solve these problems and work together as countries?

- After the discussion, the moderator will hand in the students a flipchart, and allow them to move around the room and discuss and work together to come up with solutions together for 15-20 minutes (here it's important to remind them again to think from the perspective of the country they are representing). The solutions should include the responsibilities of each country in the implementation process (e.g., Japan will provide technology, USA will provide funding/money, Jordan will supervise implementation, etc). The solutions sheet must be signed by all countries after they all agree on the proposed solution(s)
- After the solutions sheet have been signed by all countries, it should be submitted to the moderator. The moderator will then ask each country to read out one of the solutions and explain it. Then the moderator will explain each country's responsibility. After presenting the solutions, the moderator will carry out a roll call, and ask each country to cast a confirmation vote on the solutions by responding with "yes we agree"
- e.g., Moderator asks "does China agree on the proposed solutions and responsibilities" and the student/country should respond "yes we agree"
- After all countries have responded, the moderator declares that the discussions yielded a successful solution, and all countries should start working on the responsibilities they are assigned

17.4 How to Change Student Behavior?

17.4.1 Activity 1

Concept: Pro-activity, negotiation, and public speaking skills

Activity: Start a monthly debate club and select a group of 10 students each month to have a debate session to discuss one topic or problem (either an environmental topic covered in this course/package, or any problem relevant to the school or the students such as class/yard cleanliness), and work together on a solution:

Procedure: The debate session should be guided by the teacher (with questions)

Figure 17-7: Debate session guided by teacher

Sample questions:

- What is the problem?
- Why do you think the problem exists?
- What are the different factors affecting the problem?
- How can the problem be solved?
- Who should be involved in solving the problem? What is the responsibility of each of them?
- What resources are needed to implement the solution?
    - Allow time for teamwork in order to come up with a solution
    - Using a flipchart, ask the student to prepare a poster outlining the solution
    - Ask the debate club members of the month to present their solution to their class peers

Together we protect our environment and save our lives with our own hands

Enhancing National Capacities for Improved Public Participation for Implementing Rio Conventions Project – CB3

CB3 project is initiated to address the critical priority capacity needs required to increase the participation of stake-holders in fulfilling the obligations of multi-lateral environmental agreements (MEAs) as committed by the govern-ment of Egypt (GoE). Three main agree-ments are of prime concern, these are:
i) The UNFCCC (related to climate change),
ii) The CBD (related to conservation of biodiversity), and
iii) The UNCCD (related to combating desertification).

The objective of the project is "to strengthen the participation of Stake-holders in the implementation of MEAs in Egypt". The CB3 Project will engage a large number of government officials, universities, representatives of line ministries, and registered NGOs to build partnerships to ensure mutual knowl-edge transfer and learning.

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