In-house Sharing Session 2
The Basic of Climate Change (Part 1)

Lecture by: Dr. Chan Hoyyen
ACE HQ, Jakarta, 26 February 2020
What is Global Warming?

Survey:

“What’s the difference between climate change and global warming?”
Greenhouse Effect – natural phenomena to keep the earth warm

- **Absorbed at the earth surface**: 48%
- **Absorbed in the atmosphere**: 23%
- **Reflected**: 29%
- **Reemitted to the earth surface**: Net emission
- **GHGs**: Reemitted to the earth surface
- **Reabsorbed in the atmosphere**: 29%
- **Reabsorbed at the earth surface**: 29%
Global warming – Additional GHGs (esp. CO₂) by anthropogenic activities

Net emission

More heat is trapped

More heat is reemitted to the earth

Reflected as infrared

Long-term warming of the planet
Survey:

“Is the Sun causing global warming?”

No.

NASA: The Sun can influence Earth’s climate, but it isn’t responsible for the warming trend we’ve seen over the past few decades.
Greenhouse Gases (GHGs)

Survey: “Do you know water vapour is one of the primary greenhouse gases in the Earth's atmosphere?”

- Primary GHGs in the Earth’s atmosphere:
  Water vapour (H₂O), carbon dioxide (CO₂), nitrous oxide (N₂O), methane (CH₄) and ozone (O₃)
- Other human-made greenhouse gases in the atmosphere:
  The halocarbons and other chlorine- and bromine-containing substances
- Other greenhouse gases (from industries):
  Sulphur hexafluoride (SF₆), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs)

Survey: “Climate change could be caused by the human activities that produce emissions of heat-trapping greenhouse gases from fossil fuel combustion, deforestation, and land-use change. True or false?”
Sources of Anthropogenic GHGs

**Carbon dioxide (CO\textsubscript{2})**
- Primarily through the burning of fossil fuels (oil, natural gas, and coal), solid waste, and trees and wood products
- Changes in land use: Deforestation and soil degradation add carbon dioxide to the atmosphere, while forest regrowth takes it out of the atmosphere

**Methane (CH\textsubscript{4})**
- During the production and transport of oil, natural gas and coal
- Livestock and agricultural practices
- Anaerobic decay of organic waste in municipal solid waste landfills

**Nitrous oxide (N\textsubscript{2}O)**
- Combustion of fossil fuels and solid waste
- During agricultural and industrial activities

Fluorinated gases (do not occur naturally)
- Industrial processes; Commercial and household uses
Survey:
“Do you know energy sector is the largest contributor to global greenhouse gas emissions?”
Composition of the Atmosphere near Earth’s surface: Permanent gases

### Permanent Gases

<table>
<thead>
<tr>
<th>Gas</th>
<th>Symbol</th>
<th>Percent (by Volume) Dry Air</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>N₂</td>
<td>78.08</td>
</tr>
<tr>
<td>Oxygen</td>
<td>O₂</td>
<td>20.95</td>
</tr>
<tr>
<td>Argon</td>
<td>Ar</td>
<td>0.93</td>
</tr>
<tr>
<td>Neon</td>
<td>Ne</td>
<td>0.0018</td>
</tr>
<tr>
<td>Helium</td>
<td>He</td>
<td>0.0005</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>H₂</td>
<td>0.0006</td>
</tr>
<tr>
<td>Xenon</td>
<td>X₂</td>
<td>0.000009</td>
</tr>
</tbody>
</table>

### Atmospheric Lifetime (years)

- From a few years to thousands of years
- All of these gases remain in the atmosphere long enough to become well mixed
- The amount that is measured in the atmosphere is roughly the same all over the world, regardless of the source of the emissions.

- These gases constant in time and space
- Their input is balanced by their output
- The percent if the composition always the same
Composition of the Atmosphere near Earth’s surface: Variable gases

<table>
<thead>
<tr>
<th>Gas (and Particles)</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water vapor</td>
<td>H₂O</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>CO₂</td>
</tr>
<tr>
<td>Methane</td>
<td>CH₄</td>
</tr>
<tr>
<td>Nitrous oxide</td>
<td>N₂O</td>
</tr>
<tr>
<td>Ozone</td>
<td>O₃</td>
</tr>
<tr>
<td>Particles (dust, soot, etc.)</td>
<td></td>
</tr>
<tr>
<td>Chlorofluorocarbons</td>
<td></td>
</tr>
</tbody>
</table>

- Input and output are **not balanced**
- **Vary in time space**
- Changing of water vapour contents: sometimes clear sky, sometimes cloudy
- **How well** the gas **absorbs energy** (preventing it from immediately escaping to space)?
- **How long** the gas stays in the atmosphere?

**Global Warming Potential (100 year)**
- a measure of the total energy that a gas absorbs over a particular period of time (usually 100 years), compared to carbon dioxide
- The larger the GWP, the more warming the gas causes
Global Anthropogenic GHG Emissions by Gas, 2010

<table>
<thead>
<tr>
<th>GHGs</th>
<th>How well (100 GWP)</th>
<th>How long</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO2 (Fossil fuels &amp; industrial processes)</td>
<td>65%</td>
<td>Lifetime cannot be represented with a single value because the gas is not destroyed over time, carbon is transferred to ocean sediments (slow process): thousands of years</td>
</tr>
<tr>
<td>CO2 (Forestry &amp; other land use)</td>
<td>11%</td>
<td></td>
</tr>
<tr>
<td>CH4</td>
<td>16%</td>
<td>12.4 years</td>
</tr>
<tr>
<td>N2O</td>
<td>6%</td>
<td>121 years</td>
</tr>
<tr>
<td>F-gases</td>
<td>2%</td>
<td></td>
</tr>
</tbody>
</table>

Source: IPCC, 2014
Global energy-related CO₂ emissions by sector, 2017

Survey: “Which sector is the largest emitter of global energy-related CO₂ emissions for the past 5 years?”

Source: IEA, 2019
Survey:

“Do you know burning different types of fossil fuels emit different amounts of carbon dioxide ($CO_2$)?”

“Which fossil fuel emits the most carbon dioxide ($CO_2$) when it is burned?”
World primary energy supply and CO2 emissions: Share by fuels in 2017

Which is the **dominant** fuel in the Total Primary Energy Supply (TPES)?

Which is the **dominant** fuel in CO$_2$ emission?

Coal – the “Dirtiest”

RE – the “cleanest”

Source: IEA, 2019
Historical data:
Temperature is increasing with CO$_2$ emissions

Below 2°C by 2100:
➢ Low emission scenario

Below 1.5°C by 2100:
➢ Lower than low emission scenario

Source: IPCC, 2013
Source: IPCC, 2018
What is Climate Change?

Survey:
“What’s the difference between climate change and global warming?”
Weather Vs. Climate (NASA)

Survey: “What is the difference between weather and climate?”

- The difference between weather and climate is a measure of time.

Weather
- Conditions of the atmosphere are over a short period of time (minutes to months)
- Temperature, humidity, precipitation, cloudiness, brightness, visibility, wind, and atmospheric pressure

Climate
- How the atmosphere "behaves" over relatively long periods of time (months to million years)
- A statistical description of the mean and variability of weather characteristics

Climate Change
- A change in the state of the mean and/or variability of these elements that can be identified statistically and that persists over a longer period, typically decades or longer

“Climate is what you expect; weather is what you get”
Indicators of Global Warming

- Air Temperature in the lowest few km (troposphere)
- Water Vapor
- Sea Ice Area
- Marine Air Temperature
- Sea Surface Temperature
- Sea Level
- Ocean Heat Content
- Glacier Volume
- Temperature Over Land
- Snow Cover
Global mean energy budget under present-day climate conditions

- Warming climate leads to an increased evaporation rate
- More water vapor in the atmosphere
- Water vapor is a greenhouse gas so causes even more warming.
The Ocean and Cryosphere
The ocean

What we know..

Excess heat been trapped ➔ global warming

Do you know ocean absorbs how much of heat?

About 93% of the excess heat energy stored by the Earth over the last 50 years is found in the ocean
As the ocean warms

Thermal expansion of seawater

Expansion:
- higher in volume
- occupying more space
- Sea level rise

Cryosphere

- Refers to frozen components of the Earth system that are at or below the land and ocean surface
- Include snow, glaciers, ice sheets, ice shelves, icebergs, sea ice, lake ice, river ice, permafrost and seasonally frozen ground

When the earth is warmed,
- Melting of glaciers and continental ice sheets
- Transfer of water stored on land to the ocean
- **Sea level rise**

When the earth is warmed,
- Melting of sea ice
- Changing the surface albedo
- Changing the exchange rate of water vapour and CO$_2$ between the ocean and atmosphere
- Salt is ejected, altering the density structure and modifies the circulation of the ocean
Albedo
• In the context of climate change, albedo is the fraction of solar energy that is reflected from the Earth into space
• If Earth was completely covered in ice, its albedo would be about 0.84, meaning it would reflect most (84%) of the sunlight that hit it.
• On the other hand, if Earth was covered by a dark green forest canopy, the albedo would be about 0.14 (most of the sunlight would get absorbed)
• Changes in ice cover, cloudiness, airborne pollution, or land cover (from forest to farmland, for instance) all have subtle effects on global albedo
• Using satellite measurements accumulated since the late 1970s, scientists estimate Earth’s average albedo is about 0.30

“How much extra heat are the dark waters of Arctic Ocean in summer adding to the planet? One recent study estimates that it’s equivalent to adding another 25 percent to global greenhouse emissions.”
– Peter Wadhams, professor of ocean physics at Cambridge University
Contribution of Glaciers and Ice Sheets to Sea Level Change

Cumulative ice mass loss from glacier and ice sheets (in sea level equivalent) is 1.0 to 1.4 mm yr$^{-1}$ for 1993-2009 and 1.2 to 2.2 mm yr$^{-1}$ for 2005-2009.
Climate Change-related Effects in the Ocean

- Glacier mass
- Snow cover
- Permafrost temperature
- Sea ice
- Ocean heat content
- Ocean pH
- Ocean oxygen
- Marine heatwaves
- Sea level
- Ice sheet mass (Greenland & Antarctica)

Source: IPCC 2013
Global mean air temperature
Global mean surface temperature
Marine heatwave days
Ocean heat content
Greenland ice sheet mass loss
Antarctic ice sheet mass loss
Glacier mass loss
Surface ocean pH
Ocean oxygen
Artic sea ice extent
Artic snow cover extent
Near-surface permafrost area
Global mean sea level
How hot will it get in your lifetime?

Before and after satellite images show that nearly a quarter of the snow cover on Antarctica's Eagle Island has melted after a heat wave earlier this month, an increasingly common symptom of the climate crisis. In just over a week, 4 inches of Eagle Island's snowpack melted — that's about 20% of the island's total seasonal snow accumulation, NASA's Earth Observatory said. Even during the summer, melting like this is rare for Antarctica, one of the coldest places on Earth.

(📸: NASA)
Antarctica has exceeded 20°C for the first time, after researchers logged a temperature of 20.75°C on Seymour Island off the coast at the northernmost point of the continent.

(BBCnews)
Does it matter with the temperature increases?

Real Evidences: Artic

In 2018, the Arctic’s oldest and thickest sea ice was observed breaking up for the first time in recorded history.

Feb 14, 2016 at Arctic
(source: paulnicklen@Natgeo Instagram)
Does it matter with the temperature increases?

Waterfall made by the melting glacier ice under the heat of the Arctic summer

(source: Paul Nicklen)
“I am always trying to explain the difference between multiyear and annual sea ice. This mother walrus and her newborn pup are resting on a piece of multiyear ice. This is ice that lives for many years. It is much thicker and much more dense and is crucial to many species that use it as a floating home. Annual ice comes and goes with each season. So, when scientists say that the Arctic will be completely void of sea ice in the next 20 to 30 years during the summer months, that means that there will be absolutely no sea ice left anywhere in the Arctic for several months each year. What will happen to the walrus, the polar bears the bearded seals, the harp seals and the birds that all rely on some form of ice throughout the summer.” – Paul Nicklen
Sea ice as floating home
Which Mountain Is the Tallest in the World?

Studies of increased vegetation in the Arctic found that they delivered a warming effect in the surrounding landscape, with the plants absorbing more light and warming the soil.
Further Reading

Earth Energy Balance

• https://earthobservatory.nasa.gov/features/EnergyBalance
• https://www.youtube.com/watch?v=sTvqlijqvTg
• https://earthobservatory.nasa.gov/images/84499/measuring-earths-albedo

Lifetimes & GWP

• https://www.epa.gov/climate-indicators/greenhouse-gases
• https://www.epa.gov/climateleadership/atmospheric-lifetime-and-global-warming-potential-defined
• https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_Chapter08_FINAL.pdf
Basic of Climate Change Part II:

• Global warming and sea level change
• How climate risk matters in Southeast Asia: the Past and Future