



00:49

Module Objectives

1) Environmental change and planetary boundaries



2) Global Climate Change



2

02:10

Environment



3

- Biotic and abiotic components surrounding an organism or a population, thus influencing their survival, development and evolution.
- Vary from microscopic to global scale
- Environmental science = systematic study of human interactions with the environment

06:15

What is Environmental Change?

- Change or disturbance of the environment by either natural causes, anthropogenic factors, or even animal-environment interactions.
- Environmental degradation refers to the *"reduction of the capacity of the environment to meet social and ecological objectives, and needs"*
 - Depletion of resources
 - Reduced environmental quality
 - Habitat change

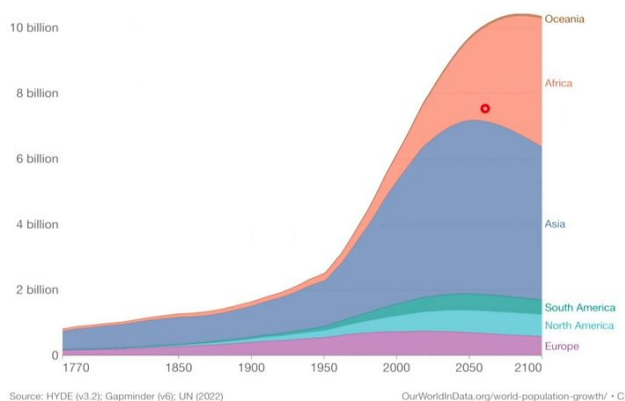


More information: <http://www.unisdr.org/eng/library/lib-terminology-eng%20home.htm>

4

11:02

Population and consumption drives environmental change



5

11:55

Planetary boundaries

- Planetary boundary representative of a "safe operating space for humanity"
 - Transgressing such a boundary has a deleterious or catastrophic risk to human and ecosystem health
 - Such change likely to be irreversible, non-linear and result in regional to planetary scale impacts

More information: <https://www.stockholmresilience.org/research/planetary-boundaries.html>

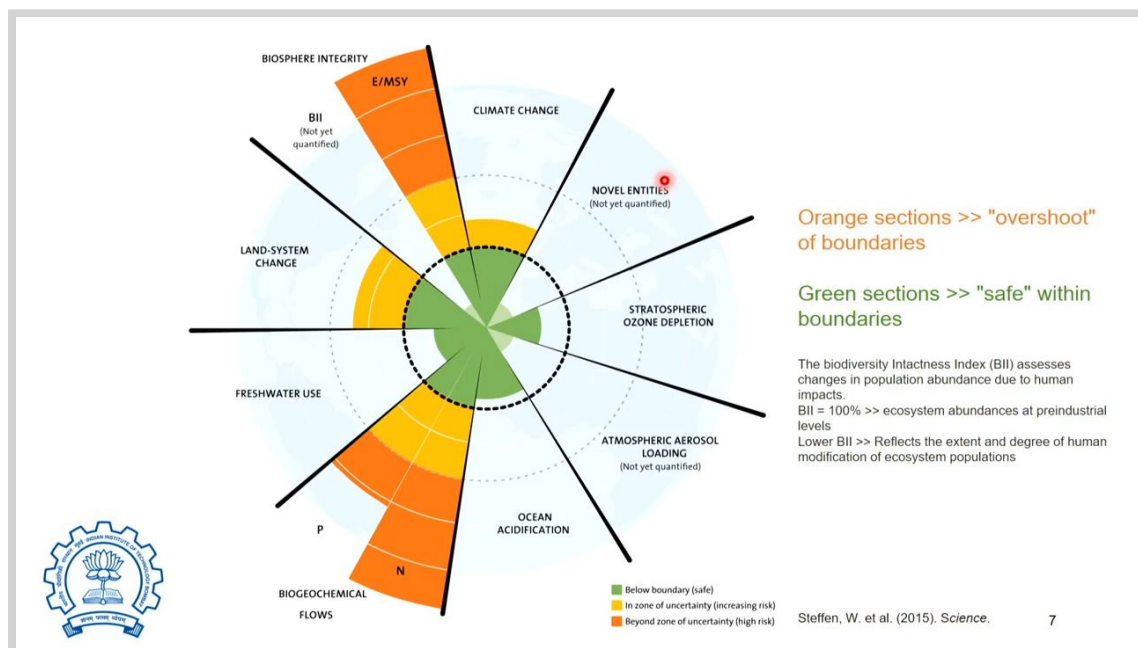
Podcast: <https://open.spotify.com/episode/69JCjeqnXpwkvKZmdl7OI6?si=9588e8645b4f08a>



6

"Transgressing" means violating a rule, law, or moral boundary. It refers to actions that go beyond accepted limits, whether in legal, ethical, or social contexts.

15:11



16:31

Nine boundaries: some exceeded, some at risk

- 1) Climate change
- 2) Biodiversity loss
- 3) Biogeochemical flows of nitrogen and phosphorus
- 4) Land-system change
- 5) Ocean acidification
- 6) Stratospheric ozone depletion
- 7) Atmospheric aerosol pollution
- 8) Freshwater use
- 9) Release of novel chemicals



Humanity already exists outside the safe operating space for at least four of the nine boundaries

8

19:47

2) Loss of Biosphere Integrity

Animal populations experience average decline of almost 70% since 1970, report reveals

Huge scale of human-driven loss of species demands urgent action, say world's leading scientists



the guardian

Where have all the garden birds gone this year?

Mary Julian wonders if the hot summer has wiped out the birds. She would eventually write her own London garden in autumn.

Editors

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Unexpected patterns of fisheries collapse in the world's oceans

Matt L. Pinckney, Olaf P. Jensen, Daniel B. Riebel, and Stephen R. Palumbi | Authors Info & Affiliations

Edited by Daniel E. Schneider, University of Washington, Seattle, WA, and accepted by the Editorial Board March 30, 2011 (received for review October 12, 2010)

May 2, 2011 | 108 (20) 8317-8322 | <https://doi.org/10.1073/pnas.1015313108>



9

22:08

2) Loss of Biosphere Integrity

- **Problem:** Ecosystem changes due to human activities more rapid in the past 50 years than at any time in human history (The Millennium Ecosystem Assessment of 2005)
 - Increasing the risks of abrupt and irreversible changes in terms of biodiversity loss and extinctions.
- **Main drivers:** Demand for food, water, and natural resources.
- **Solutions:** Current high rates of ecosystem damage and extinction can be slowed by efforts to protect the integrity of living systems, enhance habitat, and improve connectivity between ecosystems while maintaining high agricultural productivity.



10

24:27

3) Biogeochemical Flows

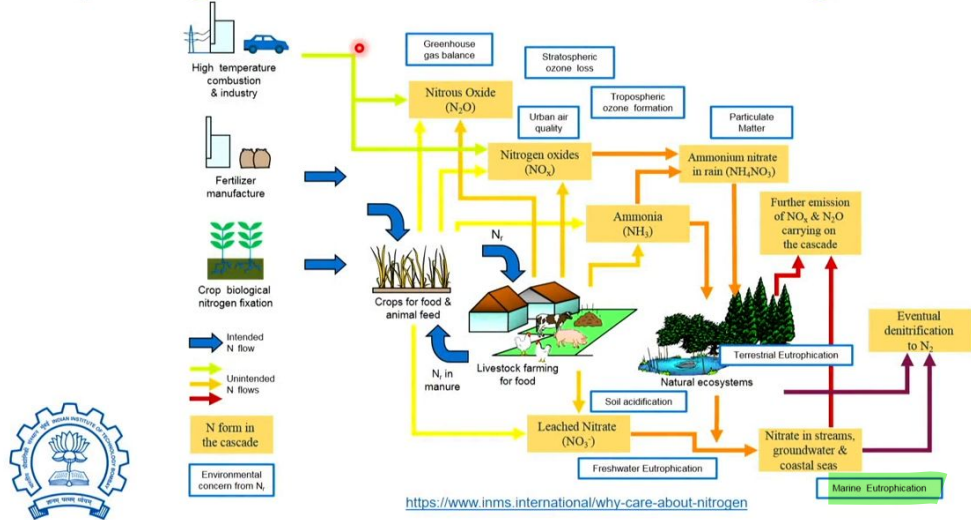
- **Problem:** Anthropogenic inputs of nitrogen and phosphorous for agricultural production, from mining and through smaller utilities such as detergent use.
 - Release and accumulation of reactive nitrogen (Nr includes NH_3 , N_2O , NO_x , and nitrates) and phosphorous in water, air, and soil.
 - Reactive nitrogen has local, regional and global scale impacts.
- **Main drivers:** Demand for food, fuel, and fibre.
- **Solutions:** Reduced reliance on N and P inputs by shifting farming practices and consumer demands of food and fuel. End-of-life treatment to reduce Nr and P discharge to air and water.



11

27:03

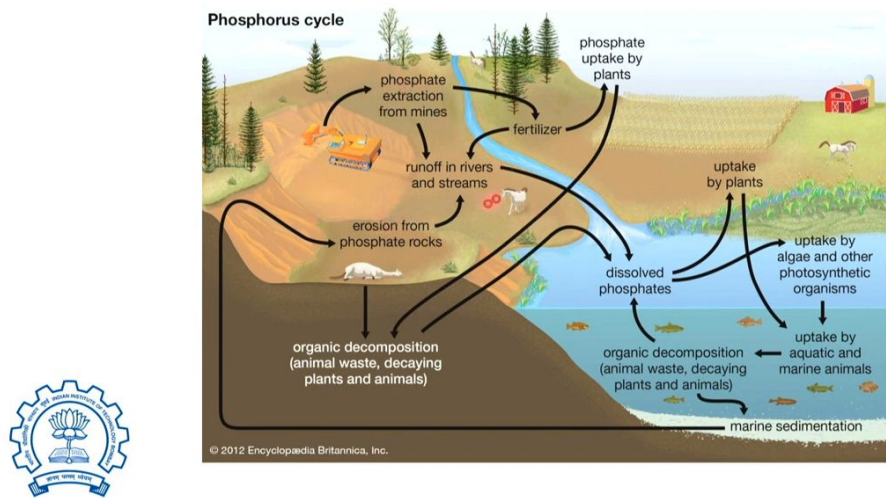
3) Biogeochemical Flows of Nitrogen



12

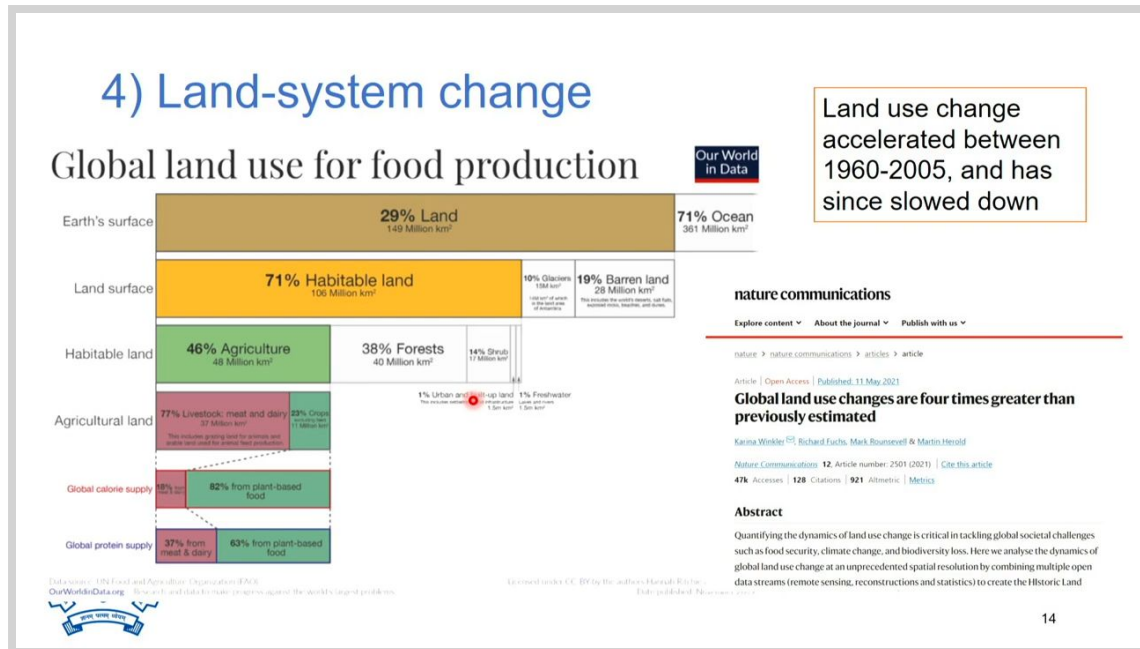
29:05

3) Biogeochemical Flows of Phosphorous



13

29:37



32:39

4) Land-system change

- **Problem:** Widespread conversion of forests, grasslands, wetlands and other vegetation types to agricultural land and for mining and logging.
- **Main drivers:** Demand for food (crops, grazing land, feed), biofuel, and natural resources (wood for paper products, precious metals, sand, etc.)
- **Solutions:** Afforestation, greener agricultural practices, reduced illegal mining and logging, and product and process improvement.

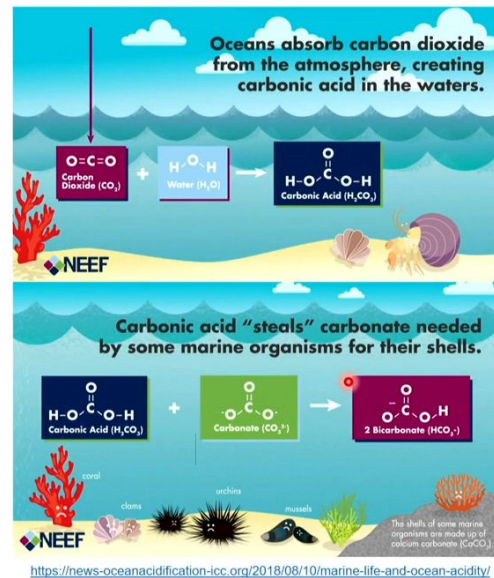
• Explore deforestation patterns and drivers: <https://www.globalforestwatch.org>

15

34:10

5) Ocean Acidification

- **Problem:** Quarter of emitted CO_2 dissolved in oceans >> reduces pH and alters biochemistry >> impacts shell and skeleton formation.
 - Ocean acidity has increased by 30% since pre-industrial times.
- **Main drivers:** Fossil fuel combustion
- **Solutions:** Climate change action, reduced dumping of illegal waste

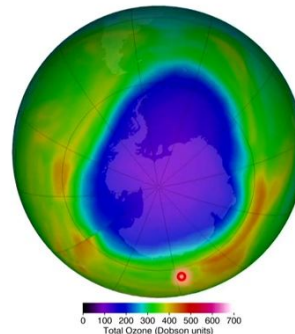


16

36:51

6) Stratospheric Ozone Depletion

- **Problem:** Release of ozone-depleting substances (ODS) that breakdown the protective stratospheric ozone layer >> increased cancer risk
- **Main drivers:** Release of ODS such as chlorofluorocarbons, halons, hydrochlorofluorocarbons that are present in solvents, refrigerants, degreasing agents, propellants, fire extinguishers and as agricultural pesticides.
- **Solutions:** Montreal Protocol helped reduce ODS!
- **NASA ozone watch:** <https://ozonewatch.gsfc.nasa.gov/>



Antarctic ozone hole occurs annually in September and October (Spring). Purples and deep blues indicate low ozone levels. Credit: NASA's Goddard Space Flight Center.

17

40:32

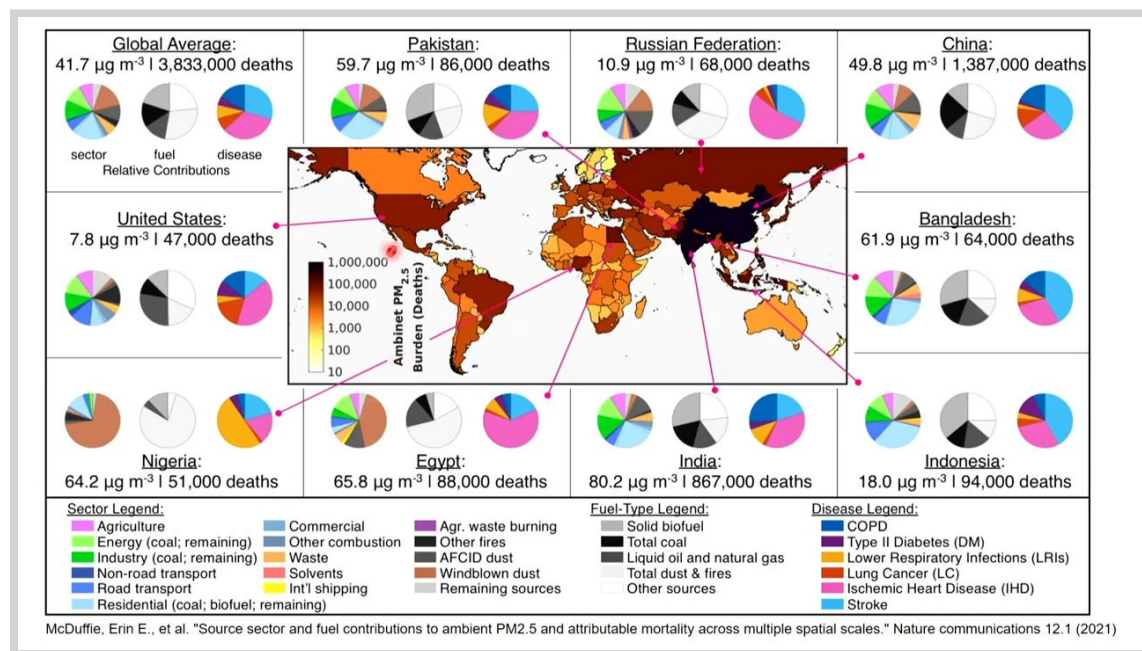
7) Atmospheric Aerosols

- **Problem:** Aerosols or particulate matter (PM₁₀ and PM_{2.5}, PM with diameters ≤ 10 and $2.5 \mu\text{m}$ respectively) emitted
- **Main drivers:** Industry, power generation, transportation, road dust, cookstoves, mining, construction, agriculture, and waste burning.
- **Solutions:** Low-carbon, clean and energy-efficient technologies, and improved waste management.
- **Satellite PM_{2.5} data:** <https://sedac.ciesin.columbia.edu/data/set/sdei-global-annual-gwr-pm2-5-modis-misr-seawifs-aod-v4-gl-03>



18

44:06

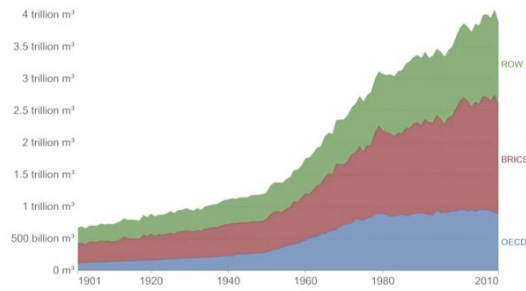


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8) Freshwater Use

Freshwater use by aggregated region, 1901 to 2010

Global freshwater withdrawals for agricultural, industrial and domestic uses by aggregated regional groupings. OECD members are defined as countries who were members in 2010 and their membership was carried back in time. BRICS countries are Brazil, Russia, India, China and South Africa. ROW refers to the Rest of the World, excluding OECD and BRICS countries.



- **Problem:** Human demand for freshwater has altered the functioning and distribution of global freshwater systems impacting the hydrological system.
 - Half-billion people are subject to water stress.
 - Changes in precipitation, soil acidification, habitat degradation, and crop yield impacts.
- **Main drivers:** Freshwater withdrawals for agriculture, industry and municipal uses have increased nearly six-fold since 1900.
- **Solutions:** Water-efficient technologies, water boundaries for consumptive freshwater use.

20

49:42

9) Release of Novel Chemicals

- **Problem:** Emissions of toxic and long-lived substances such as synthetic organic pollutants, heavy metal compounds, and radioactive materials have potentially irreversible impacts on health and the environment.
 - Reduced fertility, genetic damage, and bioaccumulation through the food chain.
- **Main drivers:** Demand for fuel, precious metals, pharmaceuticals, and agrochemicals.
- **Solutions:** Reduced demand for novel chemicals, redesign of products and processes, environmental labels.



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01:00:03

Is Climate changing?: Weather versus climate

- **Weather** >> short-term conditions of the lower atmosphere, such as precipitation, temperature, humidity, and wind.
- **Climate** >> long-term atmospheric change, usually defined as 30 years or more.

Weather-climate interlinked >> **changing climate** can impact short-term **weather** patterns

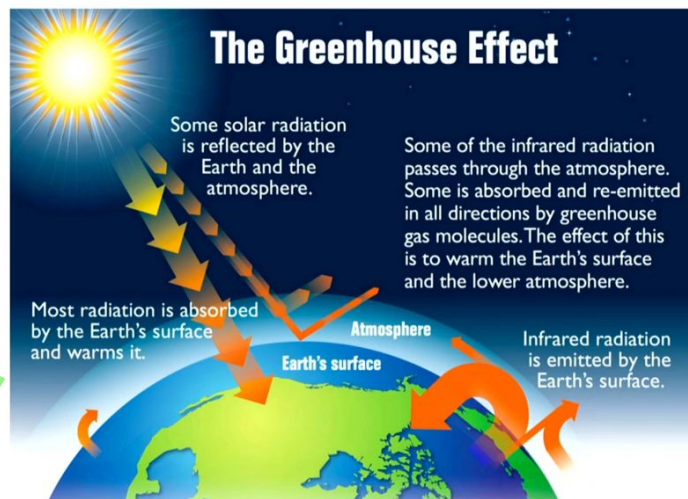
Is the **climate** changing? Is the change anthropogenic?



24

01:07:10

- **Global warming** refers to a steady rise in global temperatures as a result of the greenhouse effect.
- **Climate change** is the long-term change in the weather due to greenhouse gases.
 - **Net result of the interaction of GHGs and aerosols with the radiative balance >> net warming.**
 - **Some regions could get colder due to climate change!**



<https://onetreepanted.org/blogs/stories/difference-global-warming-climate-change>

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01:10:16

Greenhouse gas (GHG): Gas that absorbs and emits radiant energy within the thermal infrared range, causing the greenhouse effect.

Global warming potential (GWP): measure of how much energy emissions of 1 ton of a gas will absorb over a given period of time, relative to emissions of 1 ton of carbon dioxide (CO₂).

GHG	GWP for 100 years
CO ₂	1
CH ₄	23
N ₂ O	296
HFC - 23	12 000
HFC - 134a	1 300
SF ₆	22 200

Source: IPCC Third Assessment Report (2001).

Global greenhouse gas emissions by sector

This is shown for the year 2016 – global greenhouse gas emissions were 49.4 billion tonnes CO₂eq.

Sector	Percentage
Energy	73.2%
Agriculture, Forestry & Land Use	18.4%
Industry	5.2%
Waste	3.2%
Landfill	1.9%
Wastewater	1.3%
Chemicals	2.2%
Cement	3%
Energy in Agriculture & Fishing	1.7%
Fugitive emissions from energy production	5%
Unallocated fuel combustion	7.8%
Energy use in buildings	17.5%
Commercial buildings	6.4%
Residential buildings	10.9%
Transport	16.2%
Road Transport	11.9%
Aviation	3.4%
Shipping	1.2%
Other industry	10.6%
Iron and steel	7.2%
Chemical & petrochemical	4.4%
Food & beverages	3.1%
Textiles & leather goods	2.1%
Machinery & equipment	1.4%

OurWorldinData.org – Research and data to make progress against the world's largest problems.
Source: Climate Watch, the World Resources Institute (2020).
Licensed under CC-BY by the author Hannah Ritchie (2020).

01:12:17

Global demand for energy, transportation, and industrial products is the key driver of GHG emissions

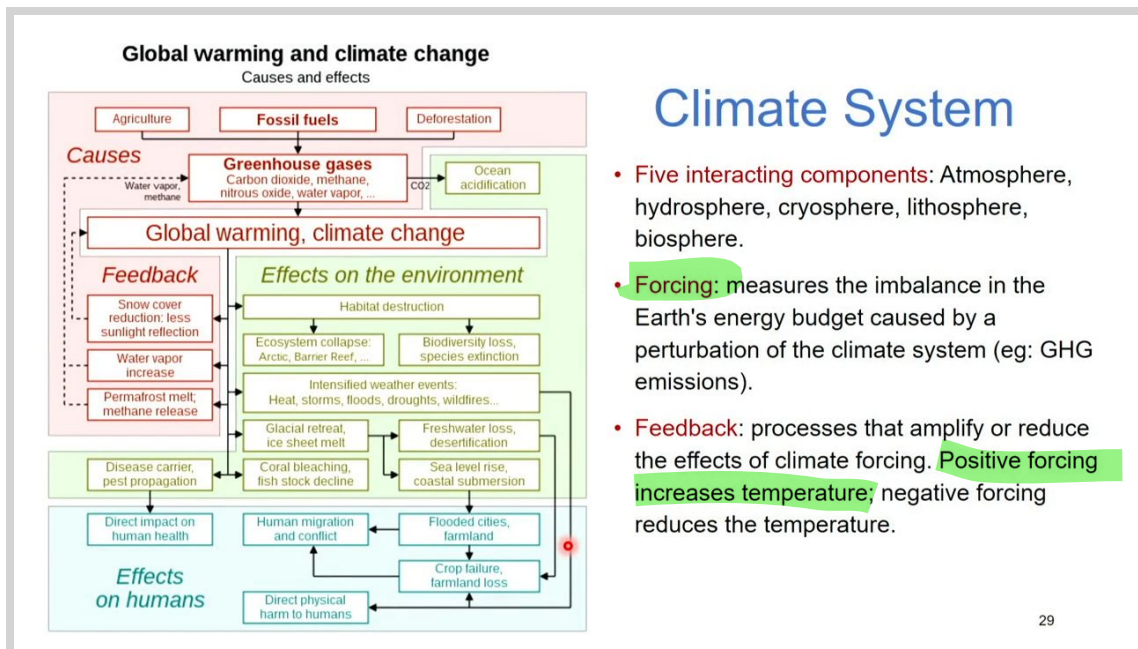
Change in greenhouse gas emissions by sector, World

Emissions are measured in carbon dioxide equivalents (CO₂eq). This means non-CO₂ gases are weighted by the amount of warming they cause over a 100-year timescale.

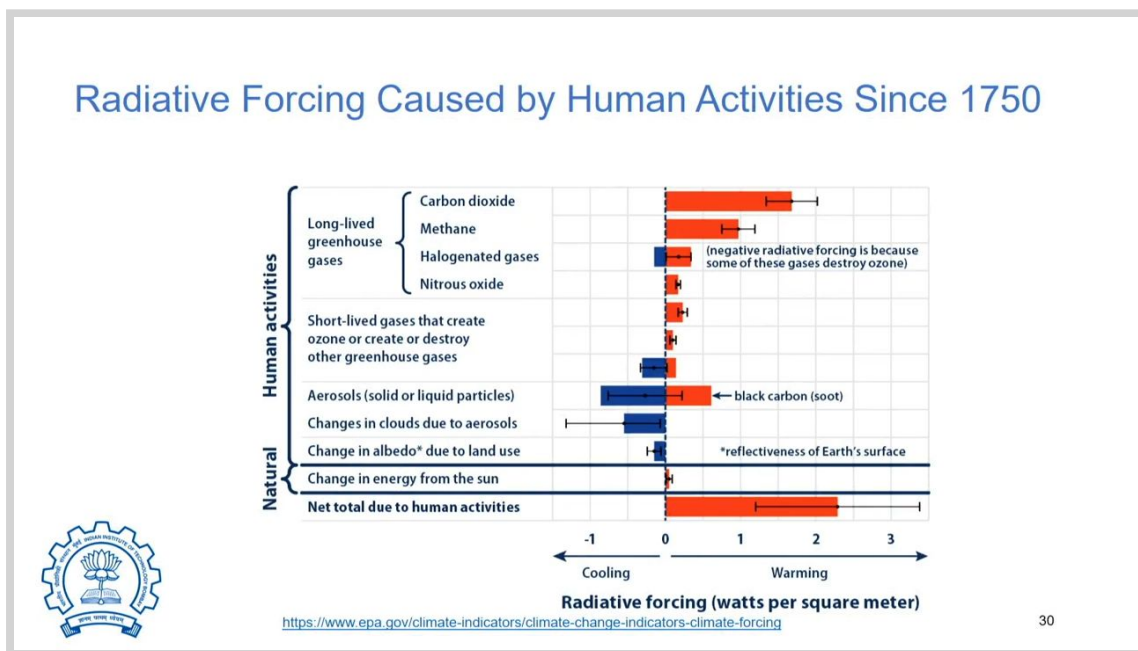
Sector	Approximate % Change (2019 vs 1990)
Industry	+200%
Aviation and shipping	+100%
Electricity and heat	+80%
Transport	+70%
Manufacturing & Construction	+50%
Fugitive emissions	+40%
Waste	+20%
Agriculture	+10%
Buildings	+5%
Land-use change and forestry	-10%
Other fuel combustion	-5%

Source: Our World in Data based on Climate Analysis Indicators Tool (CAIT).
OurWorldinData.org/co2-and-other-greenhouse-gas-emissions • CC BY

01:18:13

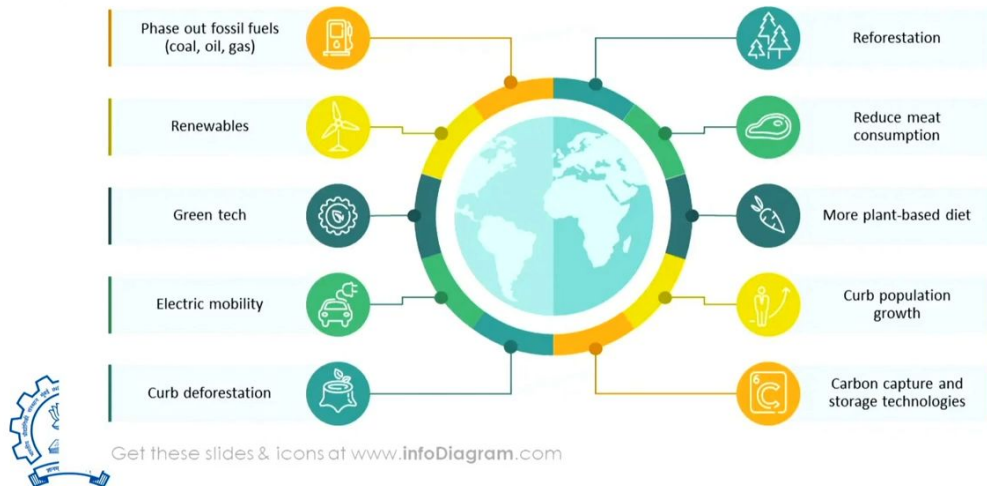


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01:20:53

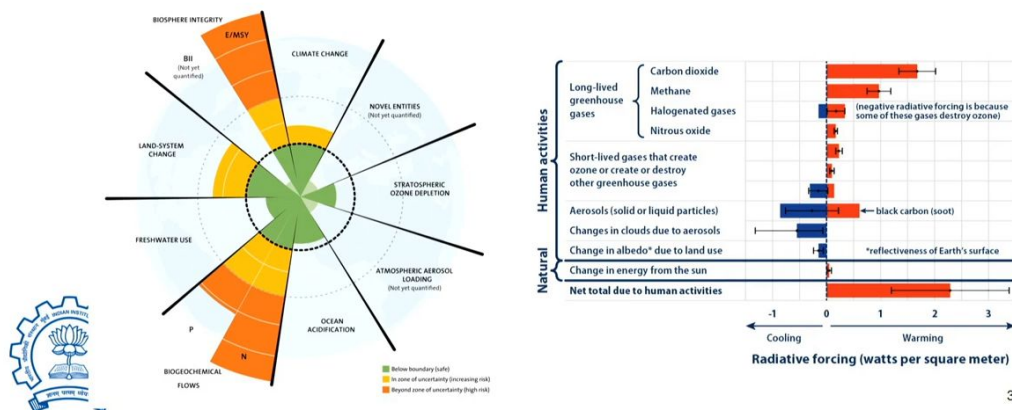
Mitigating Climate Change is a Multi-Sector Challenge



01:24:09

Recap:

- 1) Global environmental change is largely driven by anthropogenic activities
- 2) Impacts are multi-fold as shown through nine interconnected planetary boundaries
- 3) Climate change refers to long-term changes in the weather and is largely attributed to emissions of greenhouse gases.



01:27:36

Recommended resources

Textbook:

- Ela, Wendell, and Masters, Gilbert M.. Introduction to Environmental Engineering and Science. United Kingdom, Prentice Hall, 2008.
- IPCC Fifth Assessment Report: <https://www.ipcc.ch/assessment-report/ar5/>

Publications:

- Johnson, D.L., Ambrose, S.H., Bassett, T.J., Bowen, M.L., Crummey, D.E., Isaacson, J.S., Johnson, D.N., Lamb, P., Saul, M. and Winter-Nelson, A.E., 1997. Meanings of environmental terms. *Journal of environmental quality*, 26(3), pp.581-589.
- Steffen, W., Richardson, K., Rockström, J., Cornell, S.E., Fetzer, I., Bennett, E.M., Biggs, R., Carpenter, S.R., De Vries, W., De Wit, C.A. and Folke, C., 2015. Planetary boundaries: Guiding human development on a changing planet. *Science*, 347(6223), p.1259855.



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01:27:52

Explore trends in Global Environmental Change

Global environmental change is an expansive, interdisciplinary subject. Multiple institutional repositories help provide insight into the ever-changing world around us. Select datasets are listed here. Explore these datasets and make at least three observations:

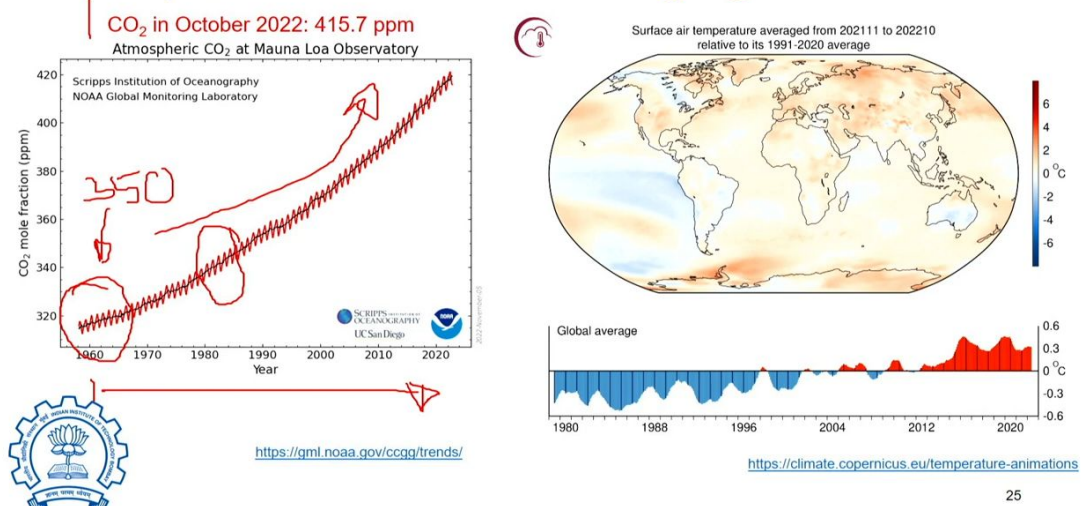
- Global Forest Watch: <https://www.globalforestwatch.org/map/>
- GHG from Energy Use: <https://www.iea.org/data-and-statistics/data-tools/greenhouse-gas-emissions-from-energy-data-explorer>
- Agriculture and Environment: <https://www.fao.org/faostat/en/#data> >> Select "climate"
- Climate Interactive Viewer: <https://climate.nasa.gov/explore/interactives>
- Food and footprints: <https://www.bbc.com/news/science-environment-46459714>



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01:01:52

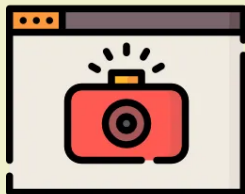
Atmospheric Trends in a Changing Climate



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