Climate change and implications for India

Mysore, October 2015

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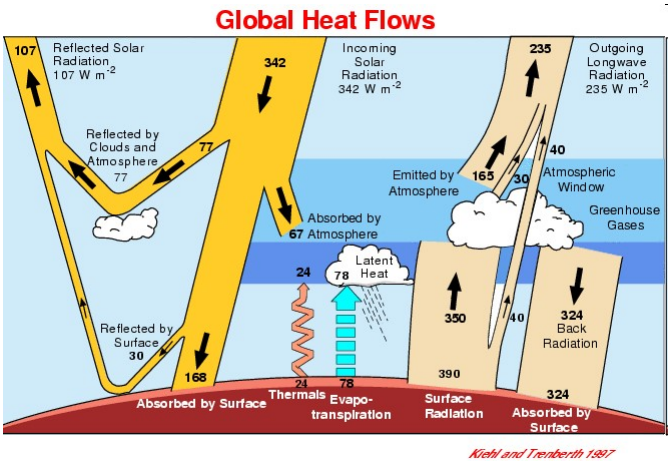
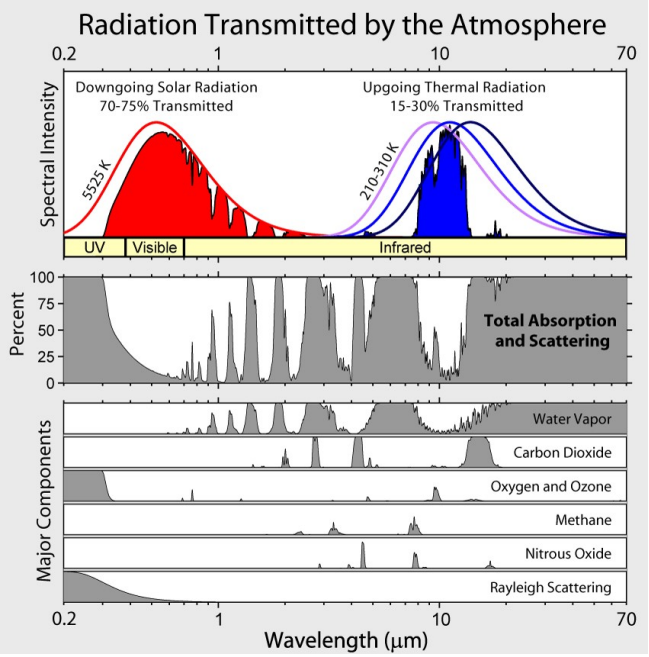
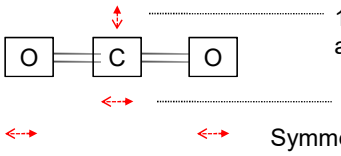
The Greenhouse effect



The atmosphere plays a key role in determining the earth's temperature through the greenhouse effect. The effect raises the average temperature of the earth by approx 33^0 C from -18^0 C.



Some complications



15.0 μm, most important for atmospheric absorption

4.26 μm

Symmetric mode, no IR activity

- 100 to1000 mtrs of air can absorb almost entire 15.0 μm IR radiation at present CO_2 levels; addition of CO_2 should not make a difference. "Saturation" effect.
- above 5-9 km the atmosphere thins out, so CO_2 absorption falls off and greater amounts of radiation escape into space.
- Atmosphere temperature drops by 7 deg C per km, pressure also falls. Hence less radiation out to space from upper layers.
- Dynamics of absorption of 15.0 μm radiation are complex, not clear how much addition of CO_2 will affect temperatures.

Greenhouse gases

- Greenhouse gases are those which absorb infrared (thermal) radiation. Most of the gases in the earth's atmosphere –Nitrogen, Oxygen, etc. are not greenhouse gases
- Percentage contributions to the greenhouse effect on Earth:
  - Water vapor, 36–70% [studies show that the heat-amplifying effect of water vapor is potent enough to double the climate warming caused by increased levels of carbon dioxide in the atmosphere.]
  - Carbon dioxide, 9–26%
  - Methane, 4–9%
  - Ozone, 3–7%
  - Nitrous oxide
  - The major non-gas contributor to the Earth's greenhouse effect, clouds
- If there was no atmosphere, the earth's average temperature would be –minus 18ºC. The atmospheric greenhouse effect accounts for a rise of 33ºC in temperature

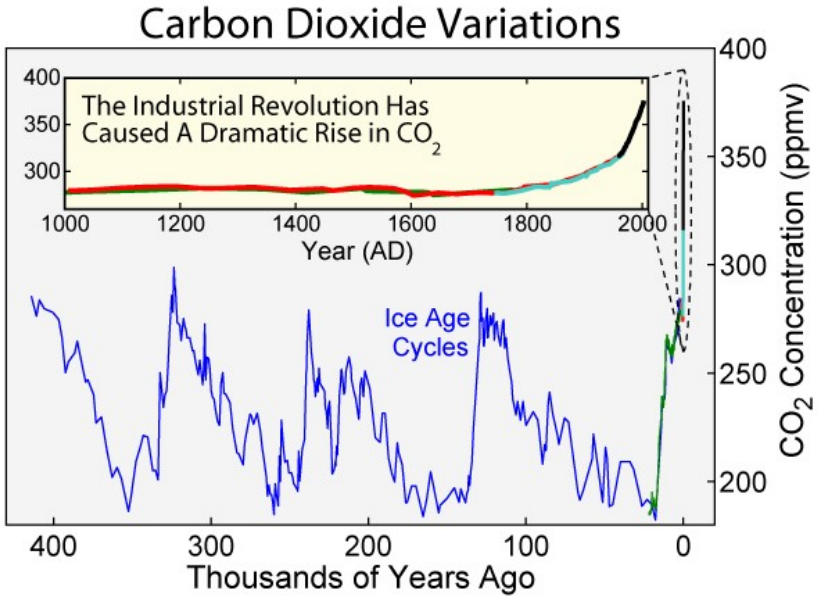
Global Warming Potential of greenhouse gases

Gas name	Chemical formula	Lifetime (years)	Global warming potential (GWP) for given time horizon		
			20-yr	100-yr	500-yr
Carbon dioxide	CO_2	30-95	1	1	1
Methane	CH_4	12	72	25	7.6
Nitrous oxide	N_2O	114	289	298	153
CFC-12	CCl_2F_2	100	11 000	10 900	5 200
HCFC-22	$CHClF_2$	12	5 160	1 810	549
Tetrafluoromethane	CF_4	50 000	5 210	7 390	11 200
Hexafluoroethane	C_2F_6	10 000	8 630	12 200	18 200
Sulfur hexafluoride	SF_6	3 200	16 300	22 800	32 600
Nitrogen trifluoride	NF_3	740	12 300	17 200	20 700

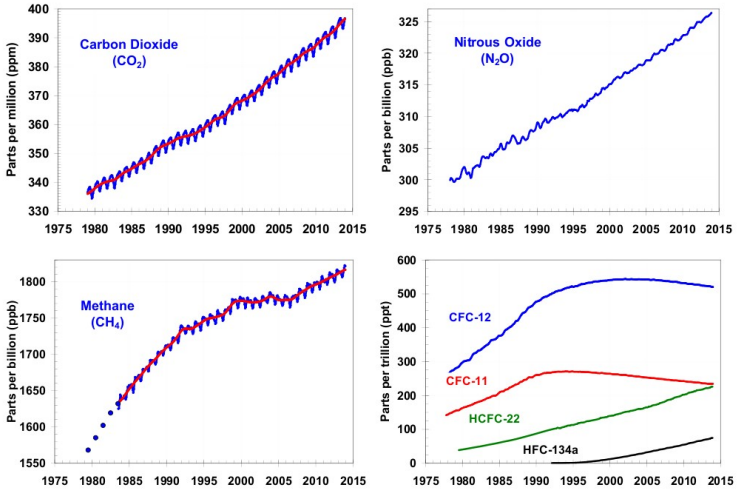
Current greenhouse gas concentrations, 2013

Gas	Pre-1750 tropospheric concentration	Recent tropospheric concentration	Absolute increase since 1750	Percentage increase since 1750	Rate of increase per yr
Carbon dioxide (CO_2)*	280 ppm	396.0 ppm	116 ppm	42%	2.07 ppm
Methane (CH_4)	700 ppb	1824 ppb	1124 ppb	153%	3.8 ppb
Nitrous oxide (N_2O)	270 ppb	326 ppb	56 ppb	21%	0.82 ppb
Ozone (O_3)	237 ppb	337 ppb	100 ppb	42%	

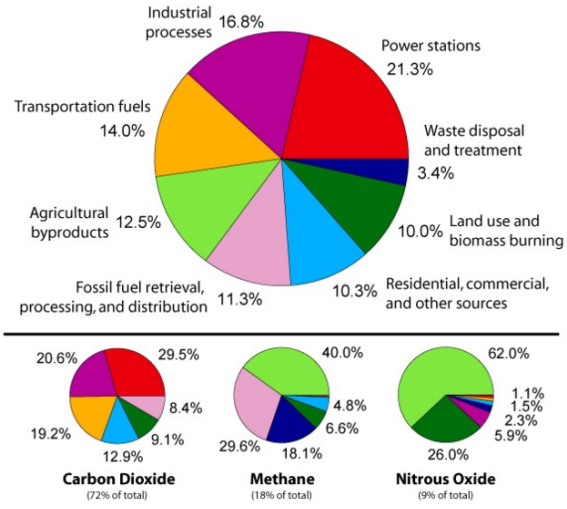
Source: WMO Greenhouse Gas Bulletin, Nov 2014
* increasing at 2.2ppmv per yr in 2012-13



Greenhouse Gas trends 1975-2015



Annual Greenhouse Gas Emissions by Sector



Relative fraction of man-made greenhouse gases coming from each of eight categories of sources, 2000.

The top shows all greenhouse gases, weighted by their global warming potential over the next 100 years. This consists of 72% carbon dioxide, 18% methane, 8% nitrous oxide and 1% other gases.

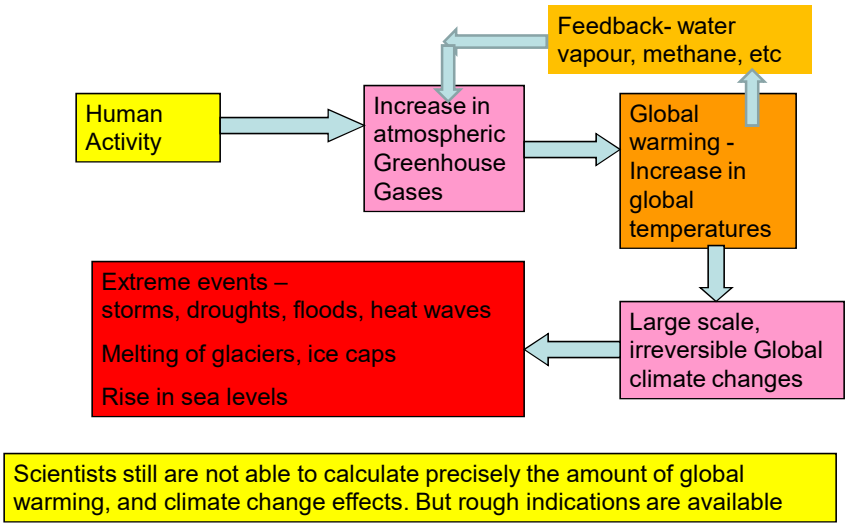
Lower panels show the comparable information for each of these three primary greenhouse gases, with the same coloring of sectors as used in the top chart. Segments with less than 1% fraction are not labeled.

Anesthesia gases

(Atmospheric lifetimes and GWP-20)

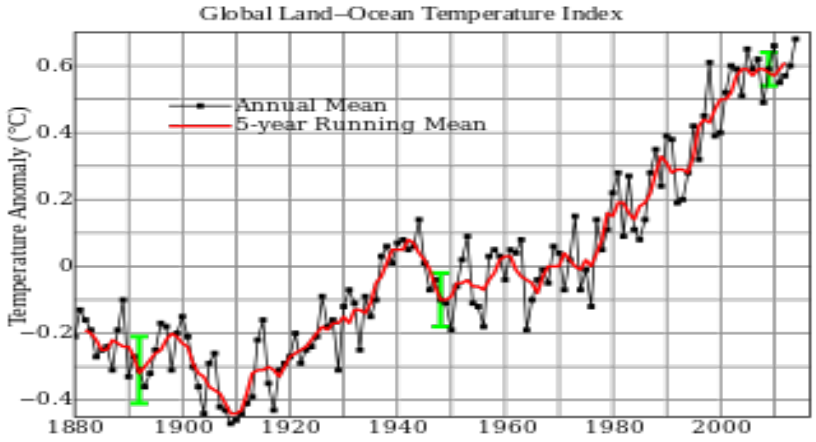
- Nitrous Oxide N_2O (114 yrs, 289)
- Isoflurane CHF_2-O-CHCl-CF_3 (3.6 yrs, 1401)
- Sevoflurane CH_2F-O-$CH(CF_3)_2$ (1.2 yrs, 349)
- Desflurane CHF_2-O-CHF-CH_3 (10 yrs, 3714)
- Halothane CF_3-CHClBr (7 yrs, 150) largely phased out.
- Discharged into the atmosphere in some systems.
- 2014 levels - Desflurane as 0.30 parts per trillion (ppt); isoflurane – 0.097 ppt; sevoflurane – 0.13 ppt; and halothane – 0.0092 ppt
- Measures- recovery and recycling, substitution with other gases (eg Xenon), etc.

Global warming and the climate change threat



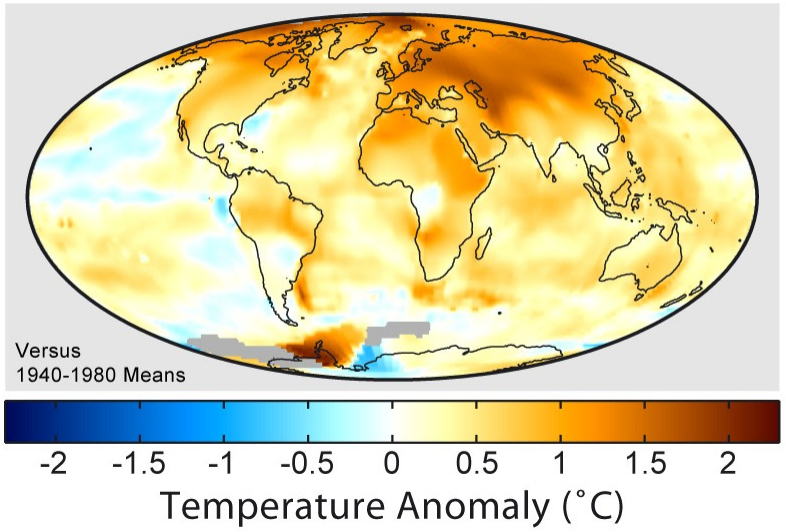
Scientists still are not able to calculate precisely the amount of global warming, and climate change effects. But rough indications are available

Global warming is a fact

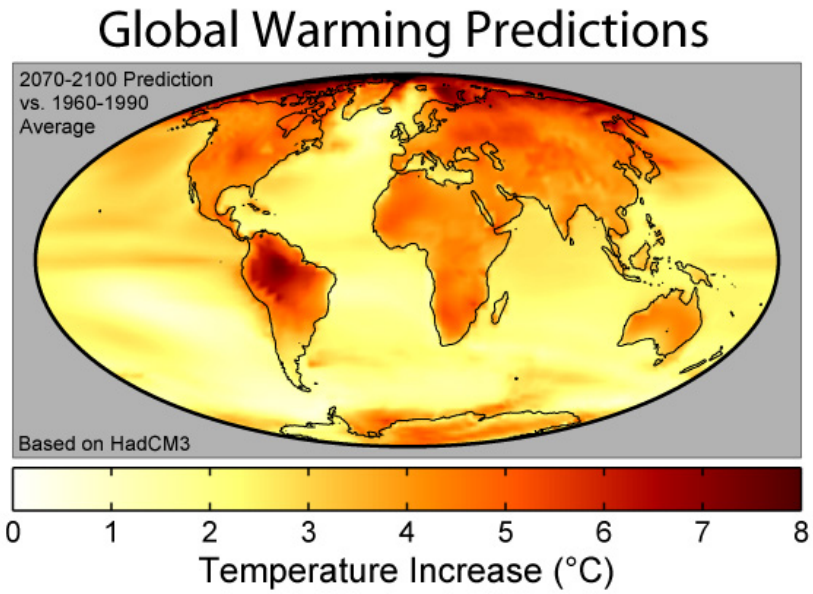


Global mean surface temperature difference from the average for 1961–1990

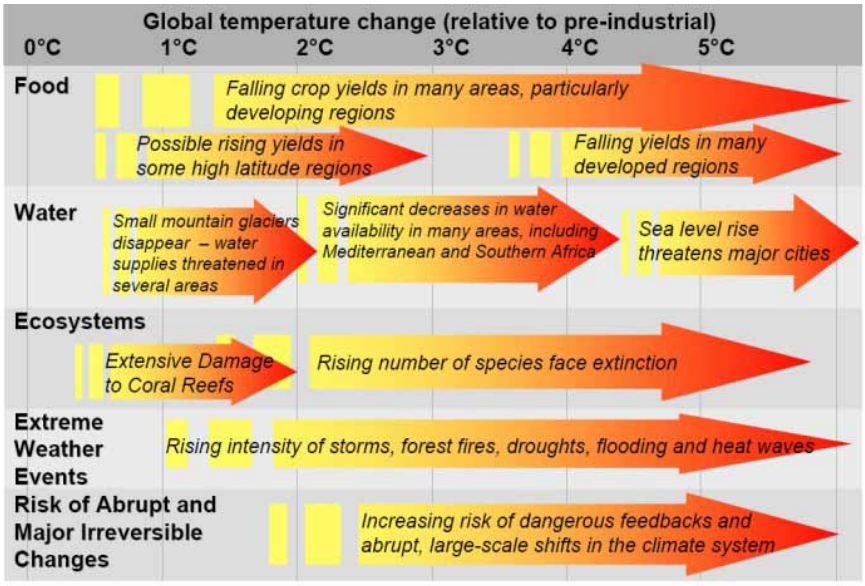
1999-2008 Mean Temperatures

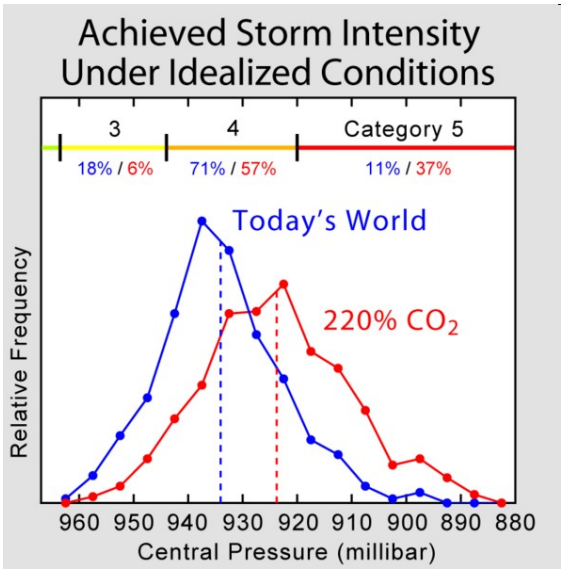


Predictions if no action is taken to limit emissions



Climate Change Impact





Sustained wind speeds:

Cat 5: >250 kph

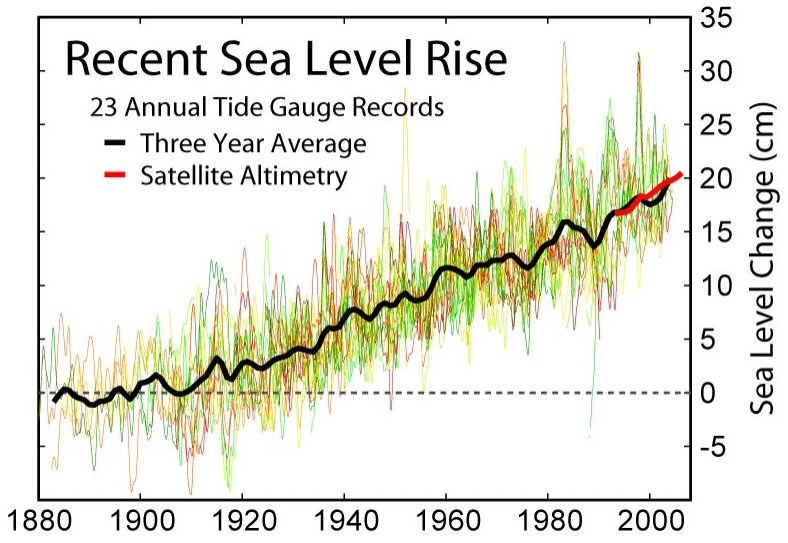
Cat 4: 210-250 kph

Cat 3: 178-210 kph

Cat 2: 154-177 kph

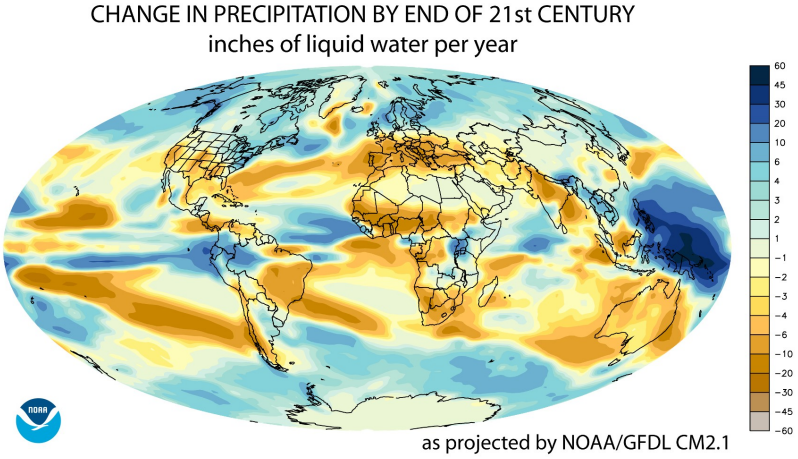
Cat 1: 119-153 kph

Prediction for how hurricanes and other tropical cyclones may intensify as a result of global warming, assuming ocean warming ranging from 0.8 to 2.4 °C.



Impact of sea level rise

- Values for predicted sea level rise over the course of this century typically range from 90 to 880 mm.
- Increased coastal erosion, higher storm-surge flooding, more extensive coastal inundation, increased loss of property and coastal habitats, increased flood risk and potential loss of life.
- About 630 million people live in coastal areas within 30 feet (9.1 m) of sea level. About two thirds of the world's cities with over five million people are located in these low-lying coastal areas.
- Sea-level rise of just 400 mm in the Bay of Bengal would put 11 percent of the Bangladesh's coastal land underwater, creating 7 to 10 million climate refugees
- Deltas and small island states are particularly vulnerable to sea level rise.



India - impact of climate change

- Agriculture – Reduction in yields of maize and rice
- Water resources – High variability predicted in water yields (from 50% increase to 40-50% fall) – 10-30% increased risk of floods; increased risks of droughts .
- Forests and natural ecosystems – Shifting forest borders; species mix; negative impact on livelihoods and biodiversity .
- Melting of Himalayan glaciers, increase in floods.
- Sea level rise, increase in vulnerability of coastal areas. Increase in storm surges and cyclones.

Health sector effects

- Changes in insect and rodent vector populations, spread to new areas.
- Possibility of new vector species emerging as well as new diseases.
- Incidence and spread of vector borne and zoonotic diseases such as malaria, dengue, filariasis, JE, chikungunya, avian and swine flu, plague, etc.
- Additional burden on already overstretched heath care systems.
- Climate change affects determinants of health such as clean air, safe drinking water, sufficient food and secure shelter.
- Between 2030 and 2050, climate change is expected to cause approximately 250 000 additional deaths per year, from malnutrition, malaria, diarrhoea and heat stress.

Predicted changes in Malaria incidence due to climate change

Transmission windows (TWs) for malaria are predicted to increase with climate change.

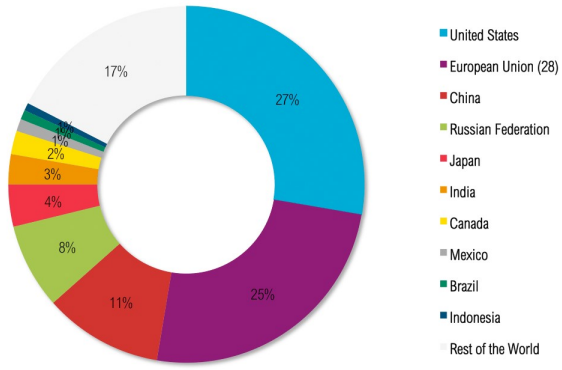
For most vectors of malaria, the temperature range of 20°C – 30°C is optimal for development and transmission.

A relative humidity higher than 55% is optimal for vector longevity, enabling the successful completion of sporogeny.

Analysis of average temperature, humidity, precipitation and incidences indicate that the maximum incidence occurs in the months of June, July and August when the relative humidity is in the range of >60% and <80%, at temperatures ranging between 25°C to 30°C.

This window shifts from state to state depending on the arrival of the monsoon.

Cumulative CO_2 Emissions 1850–2011 (% of World Total)



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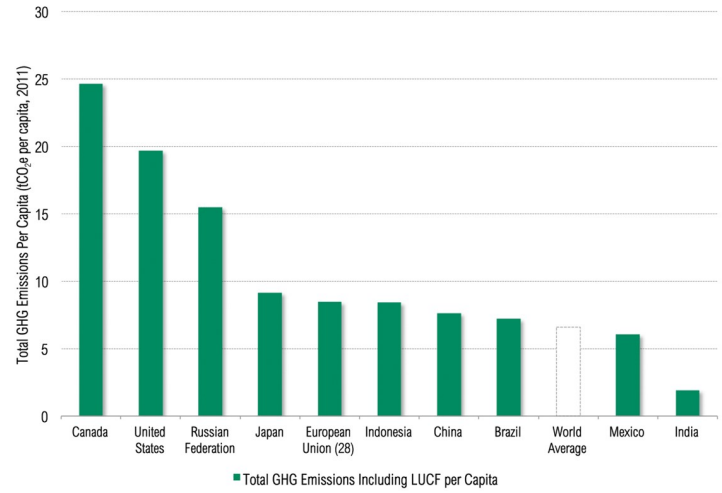
Total emissions up to 2011 = 515 GT; Limit for 2 deg C rise = 1000 GT; Annual emissions in 2014= 11 GT

Per Capita Emissions for Top 10 Emitters



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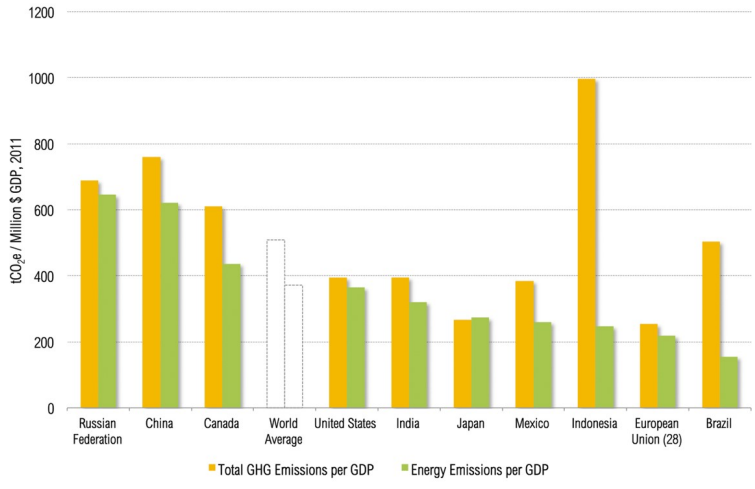
Emissions Intensity of Top 10 Emitters



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Responding to the challenge

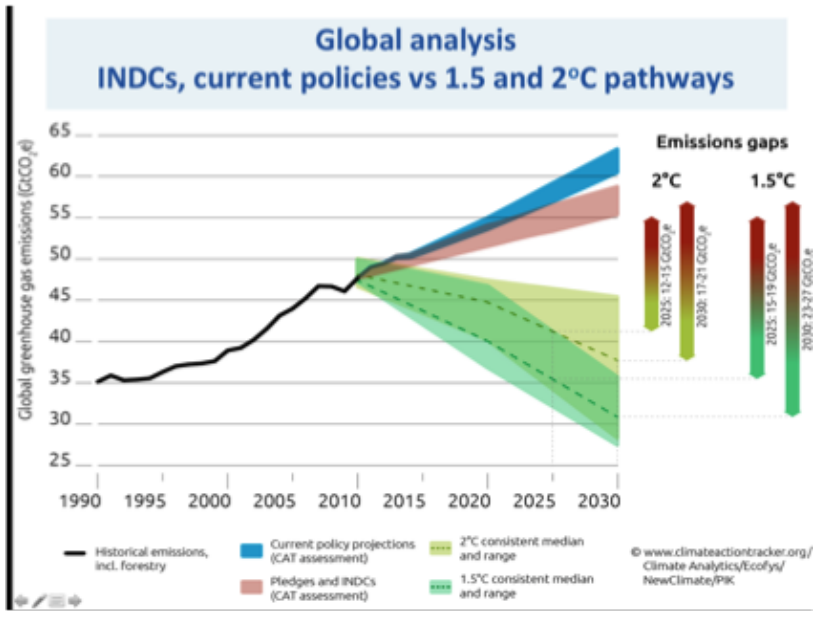
- Mitigation – reducing global warming, mainly by reducing emissions of GHGs.
- Adaptation – activities to reduce adverse impact of climate change.
- Increasing public awareness of climate change issues.
- Most scientists now agree that global warming is a real phenomenon, and needs to be faced.
- International consensus on limiting global warming to within 2 ºC, and CO2 levels to 450 ppmv.
- Uncertainty over how increased CO2 levels affect extreme climate events. But precautionary principle dictates that we should take action even if there is scientific uncertainty.
- Wide differences on how this should be achieved, keeping in mind economic development needs.

International action

- Kyoto Protocol, to the UNFCCC, signed 1997, entered into force in 2005.
- Industrialized countries commit to reduce greenhouse gas emissions by 5.2 % over 1990 levels during 2008-12. They have the primary responsibility to reduce emissions.
- Developing countries have no limits on emissions, as they were not the main contributors to greenhouse gases during the past.
- Includes mechanisms such as Joint Implementation, Emissions Trading, and Clean Development Mechanism – to enable industrialized countries to reduce emissions by activities in developing countries, or by buying carbon credits from developing countries.
- US, the largest emitter did not ratify the Protocol. They wanted developing countries also to have reduction targets.
- Based on principle of “common but differentiated responsibility.” and climate justice.

Post 2012 period

- Kyoto Protocol commitment period ended in 2012. Efforts to renew it are facing difficulties.
- Copenhagen Accord, 2009; 114 countries agree to limit global warming to below 2 deg C.
- COP21, Paris, planned date Dec 2015. Serious differences remain.
- Developed countries seeking to move away from the basic principles of the Kyoto Protocol.
- They want only voluntary reduction pledges , and also for developing countries.
- Countries asked to submit their pledges (Intended National Contributions INDCs) by October 2015. These will not be legally binding.
- Total of all INDCs will not be sufficient to reach global emission targets.



COP 21 Paris, 30 Nov-11 Dec 2015

- Will an agreement be reached ? Major issues are-
- Submission of intended National Determined Contributions (INDC), wide variation in pledges. 121 countries given pledges so far. These are voluntary and non-binding.
- Differentiation between developed and developing countries challenged.
- Financing for Green initiatives is not sufficient.
- More attention and resources needed for adaptation measures.
- Legal character of the agreement is in doubt.
- Transparency- reporting and verification measures.
- Ambition – present cuts will not limit warming to 2 deg C

Challenges in climate change

- Scientific consensus that CO2 levels of 450 ppmv will cause 2 C rise and irreversible changes- the “danger level” . However scientific basis is still incomplete.
- CO2 emissions up to 2050 should be limited to 1000 GT to limit temperature rise below 2 C. If no action is taken, the limit will be reached by 2030
- Technology to sequester or remove CO2 is not yet economically feasible.
- World population to rise from 6.7 bn in 2008 to 8.9 bn in 2050. This translated into a target of per capita emissions of 1.42 T by 2050. The present world average is 4.2 T .

Policy challenges

- Total CO2 emissions must be limited.
- Developed countries have a larger responsibility to cut emissions.
- Development in developing countries must not be constrained.
- Carbon intensity in GDP must be reduced.
- Energy efficiency and conservation must be integrated into economy.
- Green technology must be adopted, to reduce emissions.
- Forests and land use must contribute to emission reductions.
- Access to technology and finance is needed.
- There must be economic incentives for reducing carbon footprints. Carbon tax - would it help ?
- Special problems of small island states, coastal states, and mountain states need to be addressed.
- Rich elites produce more CO2 than poor people because of life style.

Mitigation actions

- World economic energy efficiency is presently improving at only half the rate of world economic growth.
- Renewable energy - currently provides 18 percent of total electricity generation worldwide.
- Nuclear power - currently produces 13-14% of the world's electricity.
- Shift to increased natural gas use.
- Energy efficiency and conservation.
- Transport – use of energy efficient technologies, biofuels, urban transport systems.
- Urban planning and building design.
- Reforestation, GHG removal.

Nuclear vs Renewables

- Nuclear power plants produce electricity with about 66 g equivalent lifecycle carbon dioxide emissions per kWh.
- There are problems of public concern, radioactive waste management, and safety and security of installations.
- Renewable power generators produce electricity with 9.5-38 g carbon dioxide per kWh. Renewable electricity technologies are thus "two to seven times more effective than nuclear power plants on a per kWh basis at fighting climate change.
- Nuclear power plants require heavy initial investment and at least 6-7 years to build.

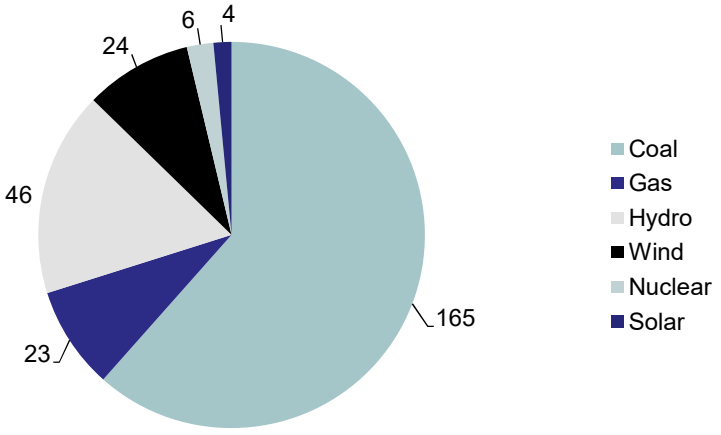
Technology development

- Carbon dioxide capture and storage.
- Biofuels – biogas, bioalcohols and ethers, vegetable oils, cellulose, biowaste(municipal waste), algae, biomass gasification, etc.
- Nuclear power generation on large scale.
- Wind power on large scale.
- Solar thermal (ST) power, Solar Photovoltaic (SPV) power (research for lower costs and increased efficiency),
- Better energy storage systems.
- Hydrogen energy – from coal, biomass, solar, genomics, etc. Storage of hydrogen, fuel cells.
- Electric powered vehicles.
- Genomics research to produce clean energy, bio-chemicals and other high value products directly from carbon dioxide, plant biomass and coal.

Photovoltaics development

- Costs of installation per watt are declining.
- Solar panel efficiency (measured by energy conversion ratio) is increasing.
- Grid-connected solar power likely to become cost-competitive with electricity generated by conventional sources by 2015 in parts of Europe and by 2020 in many regions of the world.
- Fuel cells and new batteries could be combined with solar PVs into a self contained energy system.
- Electric and hybrid vehicle technology development

Power by source GW India 2015



Total 276 GW

India – energy resources

- Present power generation capacity total – 276 GW in 2015; target 360 GW in 2017. Power deficit in South and NE India.
- Solar potential 600,000 GW ; Present capacity is 4 GW; Target of 100 GW by 2022
- Wind energy potential 60 GW (present capacity 24 GW)
- Nuclear energy (based on Uranium and ample Thorium reserves); actual 5.8 GW. Target of 20 GW by 2020.
- Hydro Power 148 GW; actual capacity 46 GW – zero CO2 output
- Coal and gas based thermal plants; actual 188 GW , of which coal is 165 GW – high CO2 output
- Geothermal potential 10 GW
- Tidal energy potential 15 GW
- Challenge of energy policy is to stimulate development of all these areas, with incentives for lower carbon processes, and disincentives for higher carbon processes.

India – the challenges

- Green technology is essential if total emissions for India are limited as development proceeds.
- India's population is 1.17 bn in 2009, expected to stabilize around 1.7 bn by 2060.
- India rejects attempts to impose reduction in emissions on it. Only commits not to exceed present per capita emission levels of developed countries. This cannot be reconciled with solving the global warming problem.
- India has limited resources of coal, oil, and gas, and cannot afford large imports of these.
- The only long term solution is solar, hydro, wind, biomass energy. Nuclear energy has problems of radioactive waste storage for 100,000 years

India's pledges to combat climate change

- 40% or more of energy from non-fossil fuel sources by 2030. Presently it is 30%.
- 175 GW of renewable energy by 2022.
- Emission intensity of GDP to be cut by 33% of 2005 levels by 2030. Decreased already by 12 % during 2005-10
- Energy efficiency measures – lighting, appliances, buildings, industries, transportation.
- Reforestation of 0.8 mn ha/yr, to remove 3 GT/yr of carbon and create jobs.
- Waste to Energy conversion plants.
- Above mitigation measures will require $ 834 bn during 2015-30.
- Measures to adapt to climate change in agriculture, water, health, and disasters. Requirement $236 bn during 2015-30

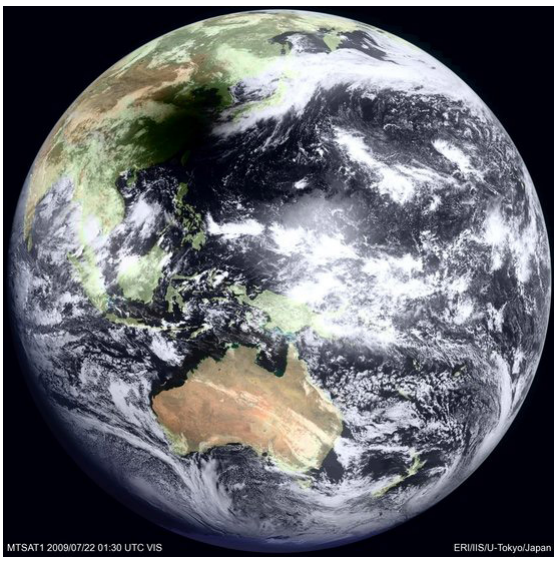
Solar energy in India

- India's theoretical solar power received, just on its land area, is about 5,000,000 GWh/year. Enormous potential exists.
- The daily average solar energy incident over India varies from 4 to 7 kWh/m2 with about 2,300–3,200 sunshine hours per year, depending upon location.
- India's Solar Mission target is to reach 100 GW by 2022 and 200 GW of solar power by 2050. Grid-interactive solar power as of 2015 was 4 GW.
- Solar-generation costs here have dropped from around Rs18 (27¢ US) a kWh to about Rs 7 (11¢ US) a kWh, an is coming down as technology develops, whereas power from imported coal and domestically-produced natural gas currently costs around Rs. 4.5(6.8¢ US) a kWh and it is increasing with time.
- India provides incentives for solar power, such as depreciation, capital subsidy, renewable energy certificates and net metering.

What we can do

- Install LED lighting, phase out incandescent, fluorescent, mercury and sodium vapour lighting.
- Install solar PV generating units on rooftops.
- Evaluate and improve energy efficiency of buildings, industries.
- Use biomass for power generation.
- Reduce emissions of Greenhouse gases from airconditioning, anesthesia, solvents, etc.
- Use more electric vehicles.

Our beautiful home !



Thank you