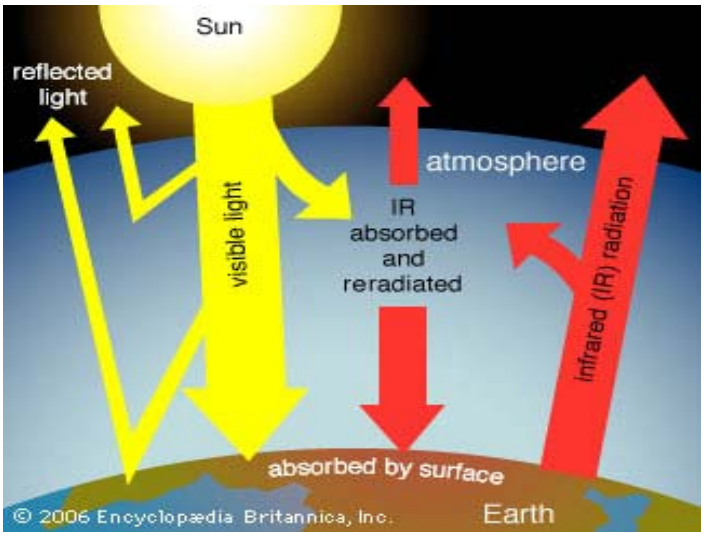
Greenhouse gases

Lecture 4

The greenhouse effect on Earth



Predicted effects of global warming

- Rising Sea Level due to melting of glaciers and ice. With the increase in sea level many cities will be under water in few decades.
- Extreme Weather. Global warming will heat up oceans causing more intense hurricanes, typhoons; more thunderstorms, tornadoes and droughts.
- Agricultural Changes. Change in weather pattern and temperature will affect the agricultural industry. Extreme rainfalls and droughts will change the soil fertility.
- Loss of Species. Extreme climatic changes impact the habitat of animals at a pace that's too rapid for them to naturally evolve to meet successfully and the result will be loss of certain animal species.
- Economic Effects. Rise in food price, need of electricity to cool the space, rise in insurance cost, re-building cost of destruction after damage caused by extreme weathers.
- Disease. Resurgence (revival) of infectious diseases associated with bacteria that thrive in warm temperatures.
- Water Scarcity. Another effect of the rising sea levels will be the contamination of fresh water by salt water affecting drinking eater supply systems as well as proper irrigation of crops. Possibility of wars over water rights to get fresh water supply.

D:\Bhakta Ale\MSc Program\ESPM\ESPM\Climate change and its impact on energy sector\Video clips\Global Warming 101.flv

Sources of greenhouse gas

GHG	Sources
CO_2	Natural: ocean, volcano, decomposition Anthropogenic: fossil fuel burning, exhaust
CH_4	Natural: aerobic decomposition (wetland, cows, etc.) Anthropogenic: fossil fuel burning, agriculture
N_2O	Natural: soil and ocean Anthropogenic: fertilizer (nitrification of ammonium)
CFC/ HCFCs	Natural: x Anthropogenic: refrigerant, aerosol propellent
O_3	Natural: photolysis Anthropogenic: NOx + VOC
SF_6	Natural: x Anthropogenic: insulator for high voltage equipment

D:\Bhakta Ale\MSc Program\ESPM\ESPM\Climate change and its impact on energy sector\Video clips\Global Warming 101 (1 of 5) - The Greenhouse Effect.flv

CO_2

- Carbon dioxide is the most important of the greenhouse gases that are increasing in atmospheric concentration because of human activities.
- The increase in carbon dioxide (CO_2) has contributed about 76% of the enhanced greenhouse effect to date, methane (CH_4) about 16% and nitrous oxide (N_2O) about 6.2% (AR5).

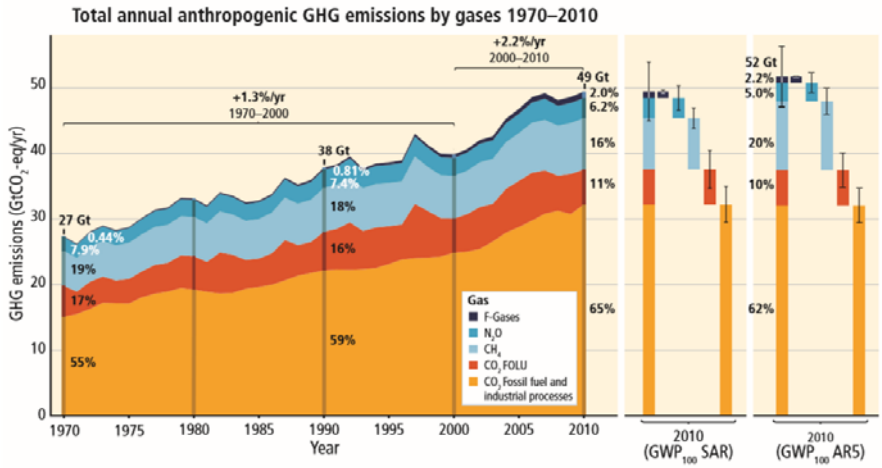


Figure SPM.2 | Total annual anthropogenic greenhouse gas (GHG) emissions (gigatonne of CO_2-equivalent per year, $GtCO_2$-eq/yr) for the period 1970 to 2010 by gases: CO_2 from fossil fuel combustion and industrial processes; CO_2 from Forestry and Other Land Use (FOLU); methane (CH_4); nitrous oxide (N_2O); fluorinated gases covered under the Kyoto Protocol (F-gases). Right hand side shows 2010 emissions, using alternatively CO_2-equivalent emission weightings based on IPCC Second Assessment Report (SAR) and AR5 values. Unless otherwise stated, CO_2-equivalent emissions in this report include the basket of Kyoto gases (CO_2, CH_4, N_2O as well as F-gases) calculated based on 100-year Global Warming Potential (GWP_{100}) values from the SAR (see Glossary). Using the most recent GWP_{100} values from the AR5 (right-hand bars) would result in higher total annual GHG emissions (52 $GtCO_2$-eq/yr) from an increased contribution of methane, but does not change the long-term trend significantly. *[Figure 1.6, Box 3.2]*

Source: AR5

GWP

- Global warming potentials (GWPs) are used to compare the abilities of different greenhouse gases to trap heat in the atmosphere. GWPs are based on the radiative efficiency (heat-absorbing ability) of each gas relative to that of carbon dioxide (CO_2), as well as the decay rate of each gas (the amount removed from the atmosphere over a given number of years) relative to that of CO_2.
- GWPs are an index for estimating relative global warming contribution due to atmospheric emission of a kg of a particular greenhouse gas compared to emission of a kg of carbon dioxide.

Global warming potentials

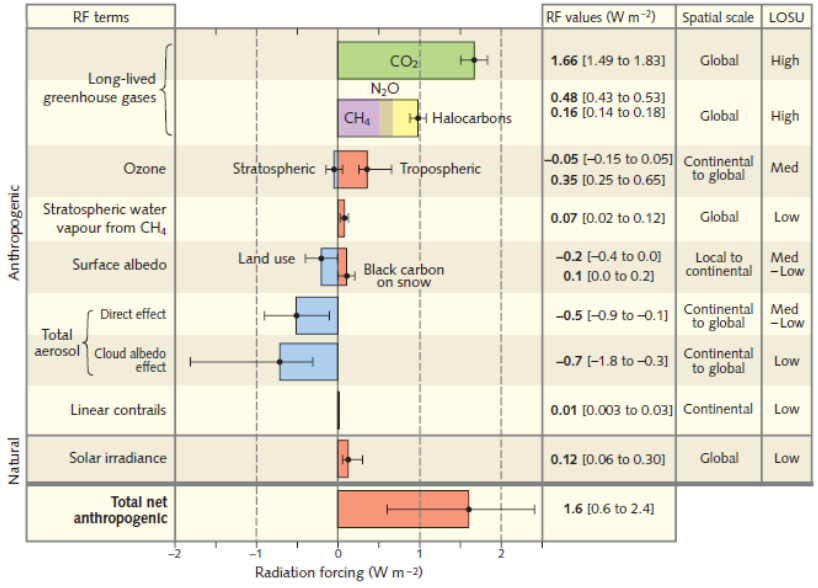
A ratio denoting the effect of a quantity of a greenhouse gas on climate change compared with an equal quantity of carbon dioxide.

- Usually expressed over a 100 year period
- Carbon dioxide always has a GWP of 1
- Results of applying a GWP expressed in Carbon Dioxide Equivalent (ex. t CO2e, lb CO2e)
- GWP values are periodically refined

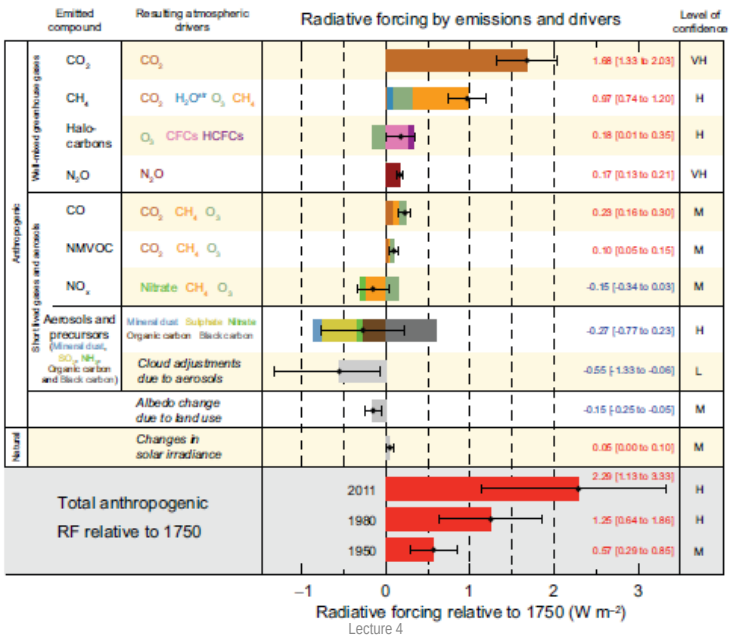
Comparison of 100-Year GWP Estimates from the IPCC's Second (1996),Third (2001) & Fourth (2007) Assessment Reports

Gas	1996 IPCC GWP[a]	2001 IPCC GWP[b]	2007 IPCC GWP[c]
Carbon Dioxide	1	1	1
Methane	21	23	25
Nitrous Oxide	310	296	298
HFC-23	11,700	12,000	14,800
HFC-125	2,800	3,400	3,500
HFC-134a	1,300	1,300	1,430
HFC-143a	3,800	4,300	4,470
HFC-152a	140	120	124
HFC-227ea	2,900	3,500	3,220
HFC-236fa	6,300	9,400	9,810
Perfluoromethane (CF_4)	6,500	5,700	7,390
Perfluoroethane (C_2F_6)	9,200	11,900	12,200
Sulfur Hexafluoride (SF_6)	23,900	22,200	22,800

Radiative forcing



Radiative forcing (AR5)



CO2 and carbon cycle

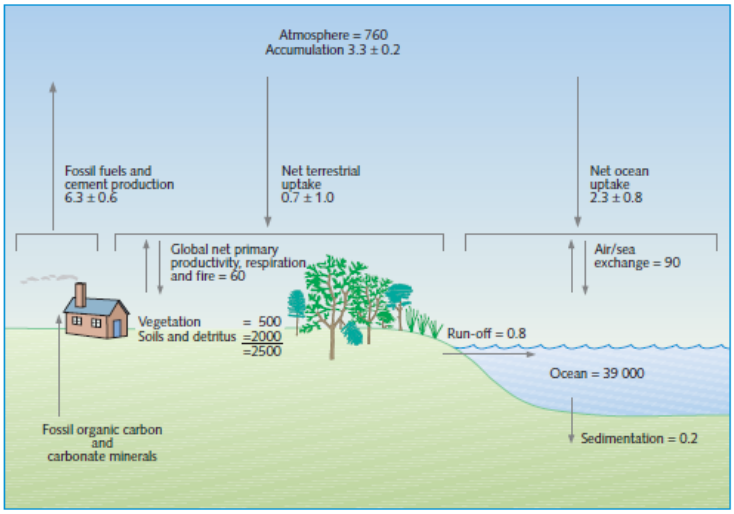
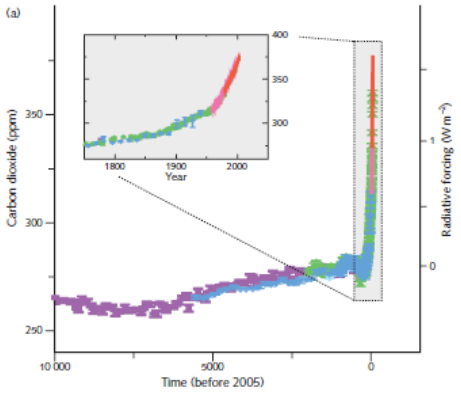


Figure 3.1 The global carbon cycle, showing the approximate carbon stocks in reservoirs (in Gt) and carbon flows (in Gt year^{-1}) relevant to the anthropogenic perturbation as annual averages over the decade from 1989 to 1998. Net ocean uptake of the anthropogenic perturbation equals the net air/sea input plus run-off minus sediment. The units are thousand millions of tonnes or gigatonnes (Gt). (More detail in Fig. 7.3 in Chapter 7 of IPCC AR4 WGI 2007.)

CO2 emissions



Over the last 10 000 years (inset since 1750) from various ice cores (symbols with different colours for different studies) and atmospheric samples (red lines). Corresponding radiative forcings shown on right-hand axis.

Annual changes in global mean and their five-year means from two different measurement networks (red and black stepped lines). The five-year means smooth out short-term perturbations associated with strong El Nino Southern Oscillation (ENSO) events in 1972, 1982, 1987 and 1997. The upper dark green line shows the annual increases that would occur if all fossil fuel emissions stayed in the atmosphere and there were no other emissions.

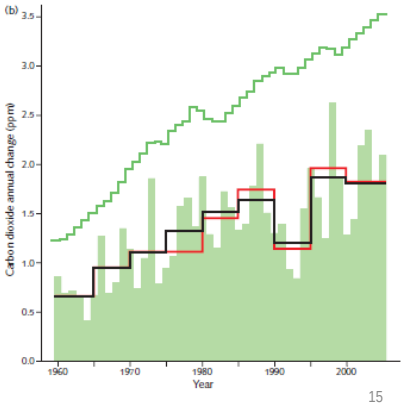


Table 3.1 Components of annual average global carbon budget for 1980s and 1990s in Gt of carbon per year (positive values are fluxes to the atmosphere, negative values represent uptake from the atmosphere)

	1980s	1990s	2000–2005
Emissions (fossil fuel, cement)	5.4 ± 0.3	6.4 ± 0.4	7.2 ± 0.3
Atmospheric increase	3.3 ± 0.1	3.2 ± 0.1	4.1 ± 0.1
Ocean–atmosphere flux	–1.8 ± 0.8	–2.2 ± 0.4	–2.2 ± 0.5
Land–atmosphere flux'	–0.3 ± 0.9	–1.0 ± 0.6	–0.9 ± 0.6
'partitioned as follows			
Land-use change	1.4 (0.6 to 2.3)	1.6 (0.5 to 2.7)	not available
Residual terrestrial sink	–1.7 (–3.4 to 0.2)	–2.6 (–4.3 to –0.9)	not available

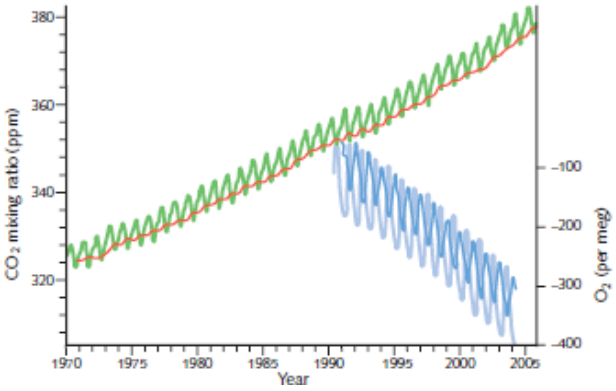


Figure 3.3 Carbon dioxide concentrations (monthly averages) observed from Mauna Loa, Hawaii, 19°N, green and from Baring Head, New Zealand, 41°S, red. Also shown are measurements of deviations in the O_2/N_2 ratio from an arbitrary reference multiplied by 10^6 from samples from Alert, Canada, 82°N, blue and from Cape Grim, Australia, 41°S, dark blue (after Manning and Keeling).

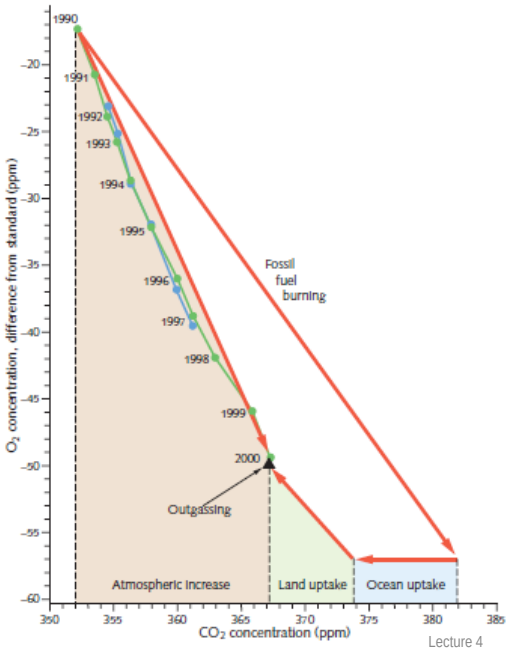


Figure 3.4 Partitioning of fossil fuel carbon dioxide uptake using oxygen measurements. Shown is the relationship between changes in carbon dioxide and oxygen concentrations. Observations are shown by solid circles. The arrow labelled 'fossil fuel burning' denotes the effect of the combustion of fossil fuels based on the O2 : CO2 stoichiometric relation of the different fuel types. Uptake by land and ocean is constrained by the stoichiometric ratio associated with these processes, defining the slopes of the respective arrows.

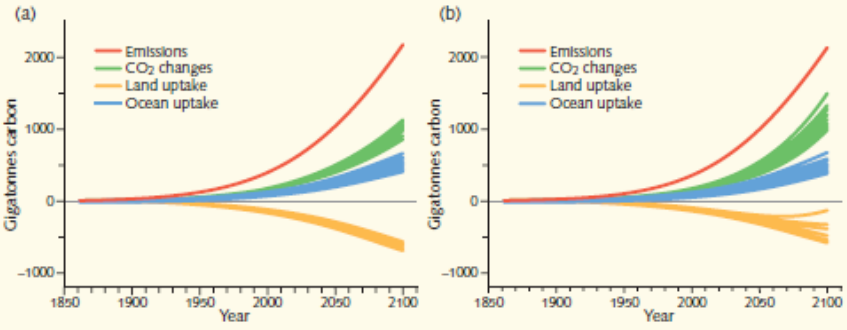
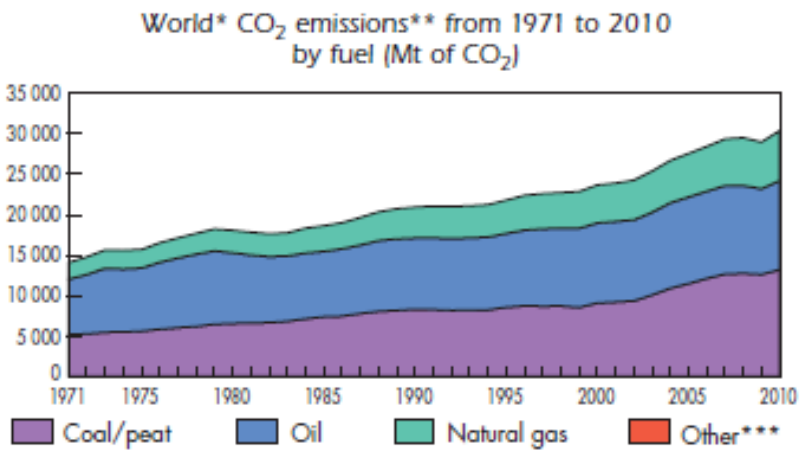


Figure 3.5 The possible effects of climate feedbacks on the carbon cycle. Shown are (1) accumulated fossil fuel CO_2 emissions from 1860 to the present and then projected to 2100 assuming the A2 SRES scenario (Figure 6.1) – in red (2) CO_2 from (1) absorbed into the ocean – in blue, (3) CO_2 taken up by the land (of the same sign as the other contributions but plotted below the axis for clarity) – in orange and (4) the residual CO_2 from (1) added to the atmosphere – in green. The nine different ocean and land budgets resulted from a study with nine coupled atmosphere–ocean general circulation climate models (AOGCMs – see chapter 5) organised internationally as part of a climate model intercomparison project (CMIP). (a) Shows results assuming no feedbacks from climate change into elements of the carbon cycle. (b) Shows results when climate feedbacks into the carbon cycle are included.

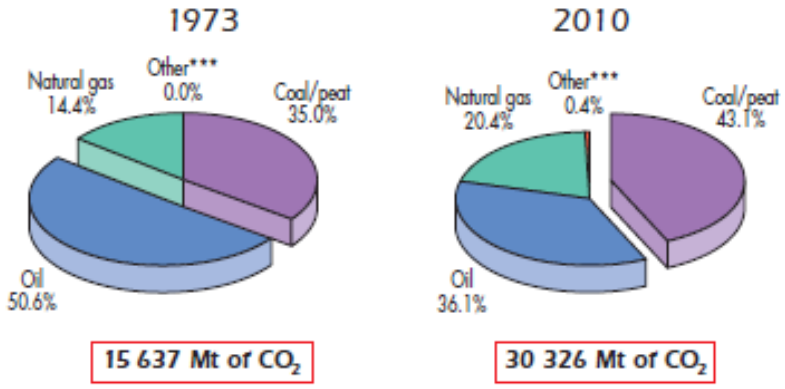
Source: 2012 and 2016 Key world energy statistics, IEA (www.iea.org)

CO2 emission by fuel



Source: 2012 Key world energy statistics, IEA (www.iea.org)

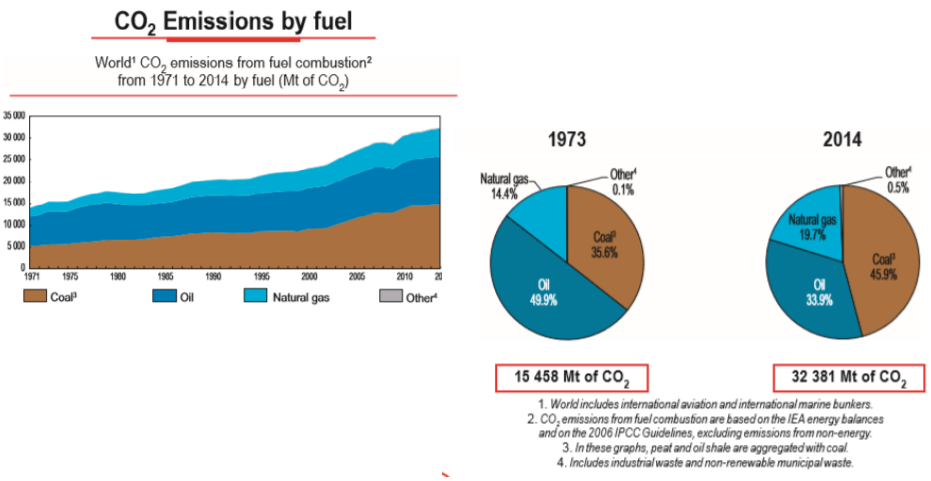
1973 1nd 2010 fuel shares of CO2 emissions **



*World includes international aviation and international marine bunkers.
**Calculated using the IEA's energy balances and the Revised 1996 IPCC Guidelines. CO_2 emissions are from fuel combustion only. ***Other includes industrial waste and non-renewable municipal waste.

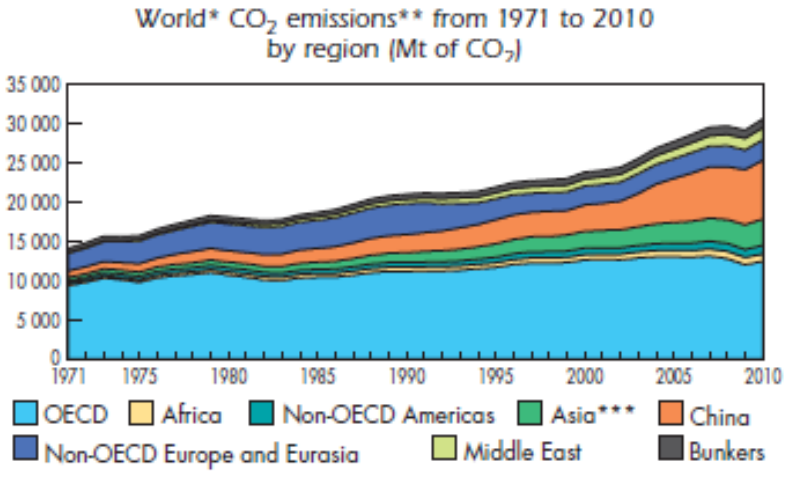
Source: 2012 Key world energy statistics, IEA (www.iea.org)

CO_2 emissions by fuel



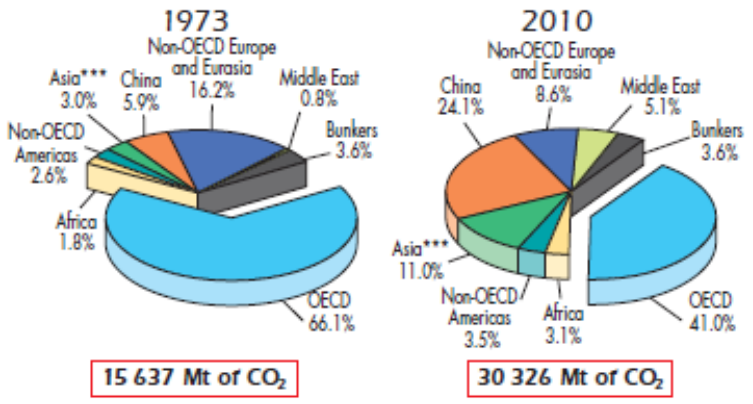
Source: 2016 Key world energy statistics, IEA (www.iea.org)

CO_2 emissions by Region



Source: 2012 Key world energy statistics, IEA (www.iea.org)

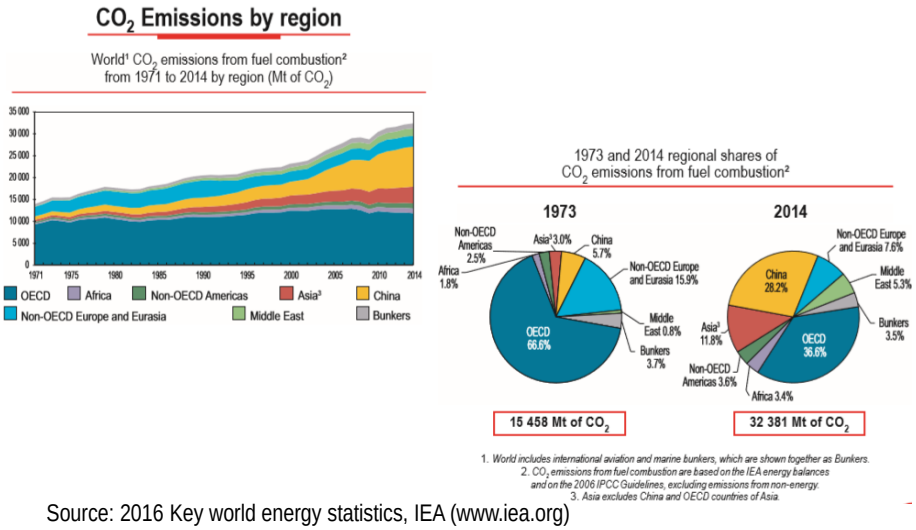
1973 1nd 2010 regional shares of CO2 emissions **



*World includes international aviation and international marine bunkers, which are shown together as Bunkers. **Calculated using the IEA's energy balances and the Revised 1996 IPCC Guidelines. CO_2 emissions are from fuel combustion only. ***Asia excludes China.

Source: 2012 Key world energy statistics, IEA (www.iea.org)

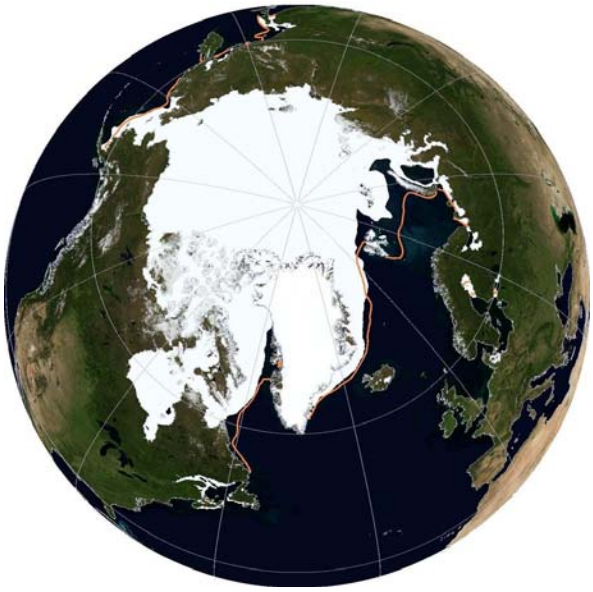
CO_2 emission by region

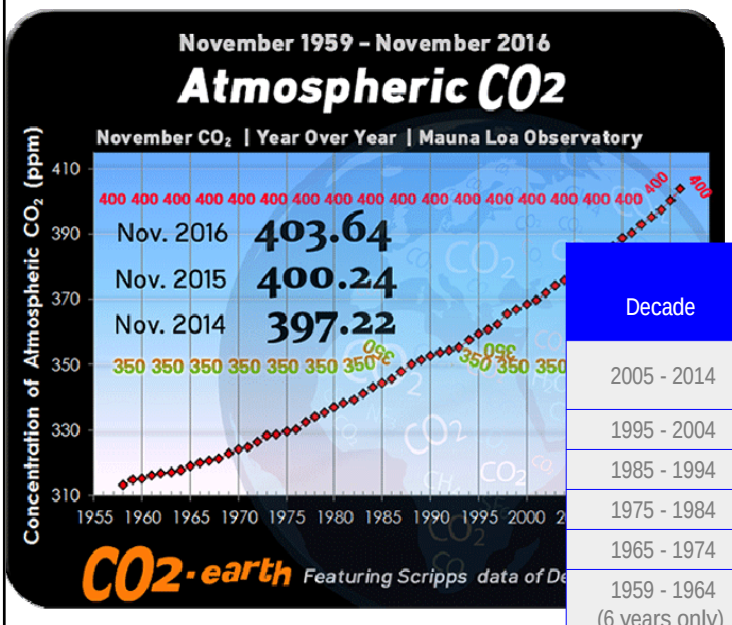


Source: 2016 Key world energy statistics, IEA (www.iea.org)

22 Dec 2012
This visualization shows Saturday's extent of Arctic sea ice, as charted by the National Snow and Ice Data Center. The readings have been overlaid on NASA imagery of the Northern Hemisphere. The orange line indicates the median extent of sea ice on the same calendar date for the 1979-2000 time period.

Source: http://photoblog.nbcnews.com/_news/2012/12/23/16109972-satellites-check-in-on-the-north-pole?lite



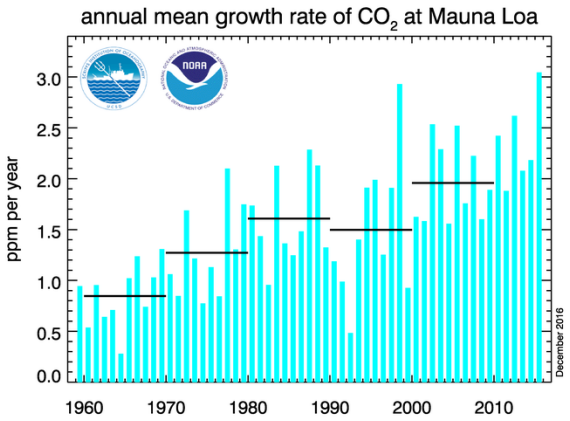


Keeling curve monthly

Decade	Atmospheric CO_2 Growth Rate
2005 - 2014	2.11 ppm per year
1995 - 2004	1.87 ppm per year
1985 - 1994	1.42 ppm per year
1975 - 1984	1.44 ppm per year
1965 - 1974	1.06 ppm per year
1959 - 1964 (6 years only)	0.73 ppm per year

https://www.co2.earth/

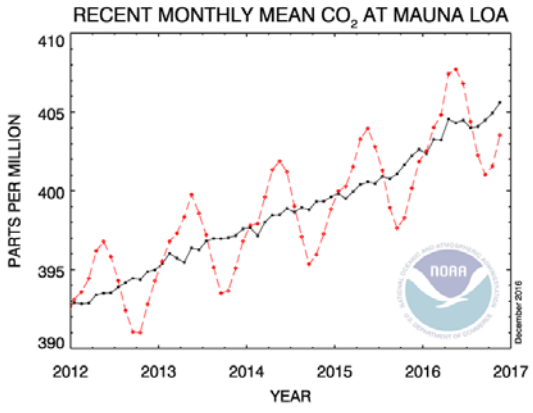
Annual CO_2 Growth Rates



- Atmospheric CO_2 is rising at an unprecedented rates. Consequences are profound for earth's temperatures, climates, ecosystems and species, both on land and in the oceans.
- To see whether the speeding rise of atmospheric CO2 is slowing or speeding up, take a look at the bend in the iconic Keeling Curve. Or, is the rate of change speeding up or slowing down? The answer can be seen in the direction of the bend in the Keeling Curve. And it can be seen in the data that produces the Keeling Curve.
- NOAA-ESRL charts the annual growth rate for atmospheric CO_2 at Mauna Loa. The table below shows the average annual increase (blue bars) and the average for each decade (black horizontal bars).

https://www.co2.earth/co2-acceleration

Recent Monthly Average Mauna Loa CO_2



- In the above figure, the dashed red line with diamond symbols represents the monthly mean values, centered on the middle of each month.
- The **black line** with the square symbols represents the same, after correction for the average seasonal cycle.

https://www.esrl.noaa.gov/gmd/ccgg/trends/index.html

CO2 measured at Mauna Loa Observatory, Hawaii

S.N.	Year	CO_2 ppm
1	November 2012	392.95
2	November 2013	395.19
3	November 2014	397.22
4	November 2015	400.24
5	November 2016	403.64

Station Name	Station Code	Latitude	Longitude	Elevation (m)
Mauna Loa Observatory, Hawaii	MLO	19.5 °N	155.6 °W	3397

Home works

- Calculate the positive and negative impact of following fuels at local, regional and global level
  - Petrol, coal, natural gas, LPG
- Estimate the annual CO2 injection into the atmosphere from the combustion of petrol used by one billion cars consuming 5 liters per day.
- What are the predicted effect of global warming? Describe with examples.

Videos in youtube

Global warming 101

- https://www.youtube.com/watch?v=oJAbATJCugs
- https://www.youtube.com/watch?v=QL3ED6aXrks
- https://www.youtube.com/watch?v=5iT83MIAcxQ
- https://www.youtube.com/watch?v=dQC-S0UGJZA
- https://www.youtube.com/watch?v=WheKvRTbysw
- https://www.youtube.com/watch?v=zGOqfmvt_fo