Lecture 2A 2B & 2C

Energy Resources, Economics and Environment

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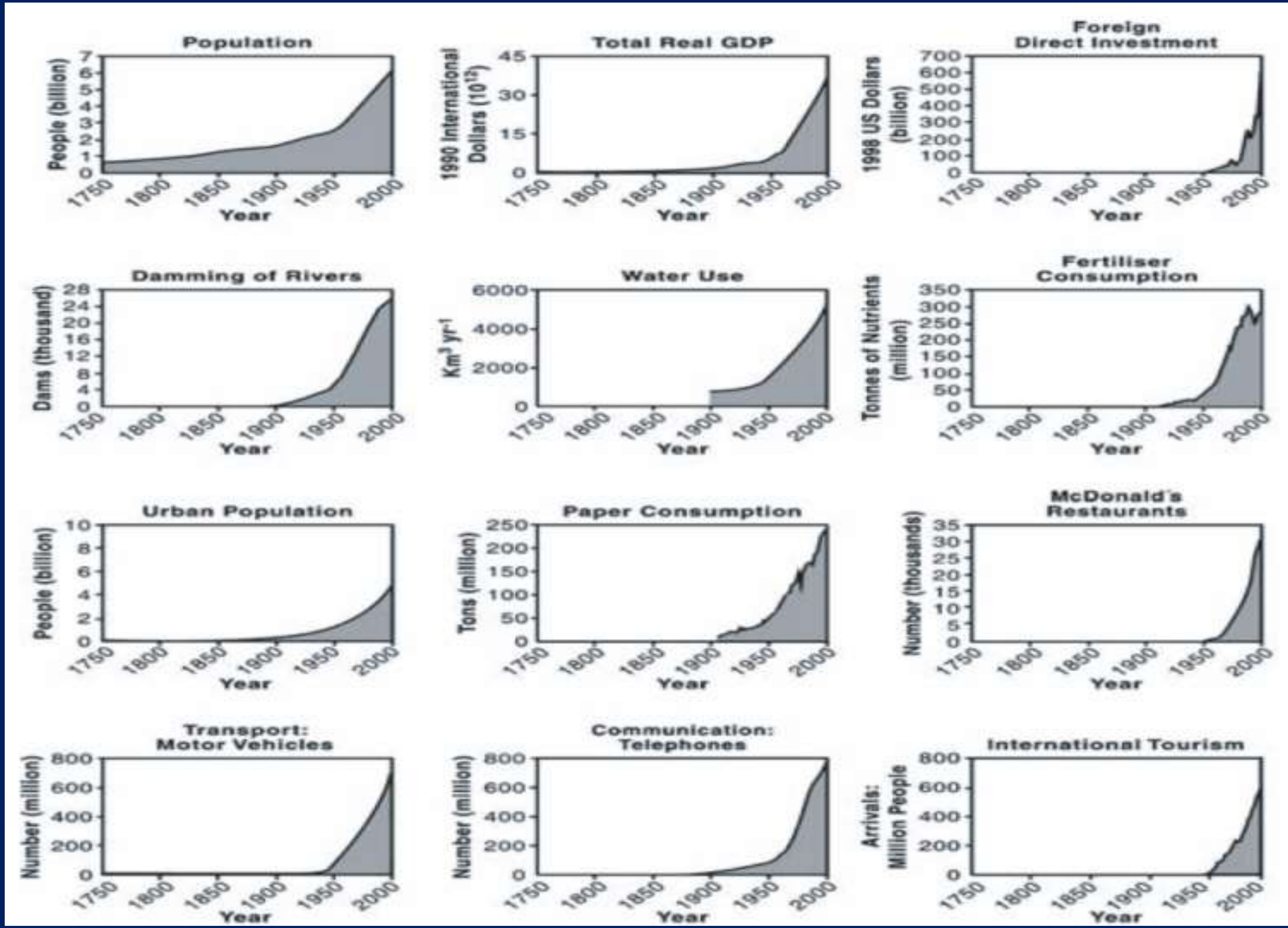
Energy Flow Diagram

PRIMARY ENERGY	COAL, OIL, SOLAR, GAS
↓ ENERGY CONVERSION FACILITY	POWER PLANT, REFINERIES
↓ SECONDARY ENERGY	REFINED OIL, ELECTRICITY
↓ TRANSMISSION & DISTRN. SYSTEM	RAILWAYS, TRUCKS, PIPELINES
↓ FINAL ENERGY	WHAT CONSUMERS BUY DELIVERED ENERGY
↓ ENERGY UTILISATION EQUIPMENT & SYSTEMS	AUTOMOBILE, LAMP, MOTOR, STOVE
↓ USEFUL ENERGY	MOTIVE POWER RADIANT ENERGY
↓ END USE ACTIVITIES (ENERGY SERVICES)	DISTANCE TRAVELLED, ILLUMINATION,COOKED FOOD etc..

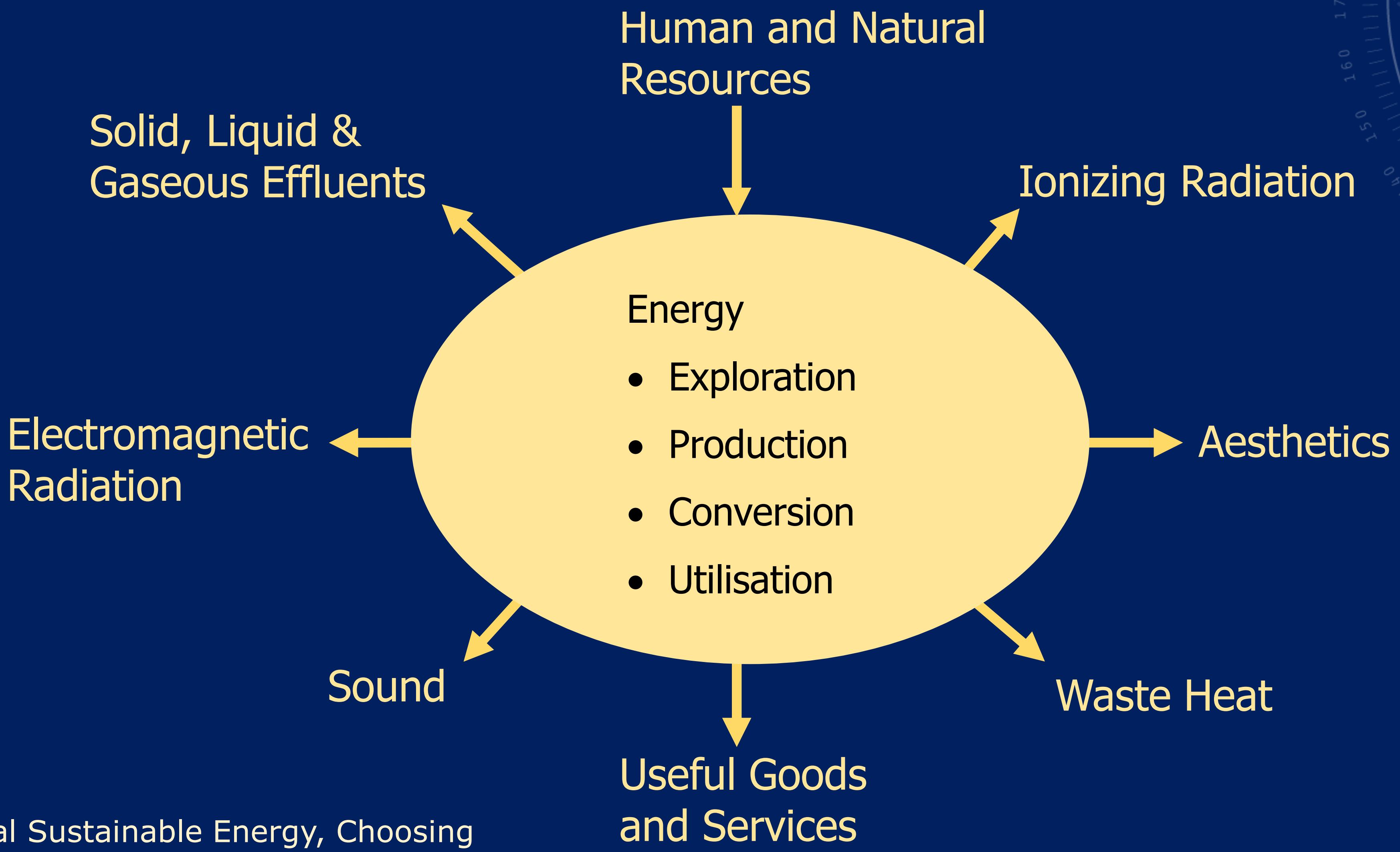
Global Trends – Unbounded Growth?



Issues

- Why is the environment important?
- How do energy systems impact the environment?
- Is there a trade-off between environment and economic development?
- What are the major impacts and causes?
- How can we quantify these impacts?
- How do we ensure a sustainable future?

Interactions of energy systems with the environment



Tester J.W. et al Sustainable Energy, Choosing Among Options, PHI, 2009

Energy Consumption and Air Pollution

- SO_2
- NOx
- CO
- SPM
- CO_2
- CFC

- Modification of Atmospheric properties/processes
- Photochemical Smog
- Precipitation Acidity
- Visibility
- Corrosion Potential
- Radiation Balance Alteration
- Ultraviolet energy absorption

Environmental Impacts

- Adverse Health Impacts- Local
- Local perturbations to Global Disruptions as human energy use increased
- Human Disruption Index (DI) = Ratio of Human generated flow of a given pollutant to the natural or baseline flow

Human Disruption Index

Insult	Baseline tonnes/yr	DI	
Lead Emissions	12000	18	41% C En
Oil to oceans	200000	10	44% Petr
Cadmium emiss	1400	5.4	13% CE, 5% Tr En
Sulphur emissions	31 million	2.7	85% CE
Methane	160million	2.3	18% CE

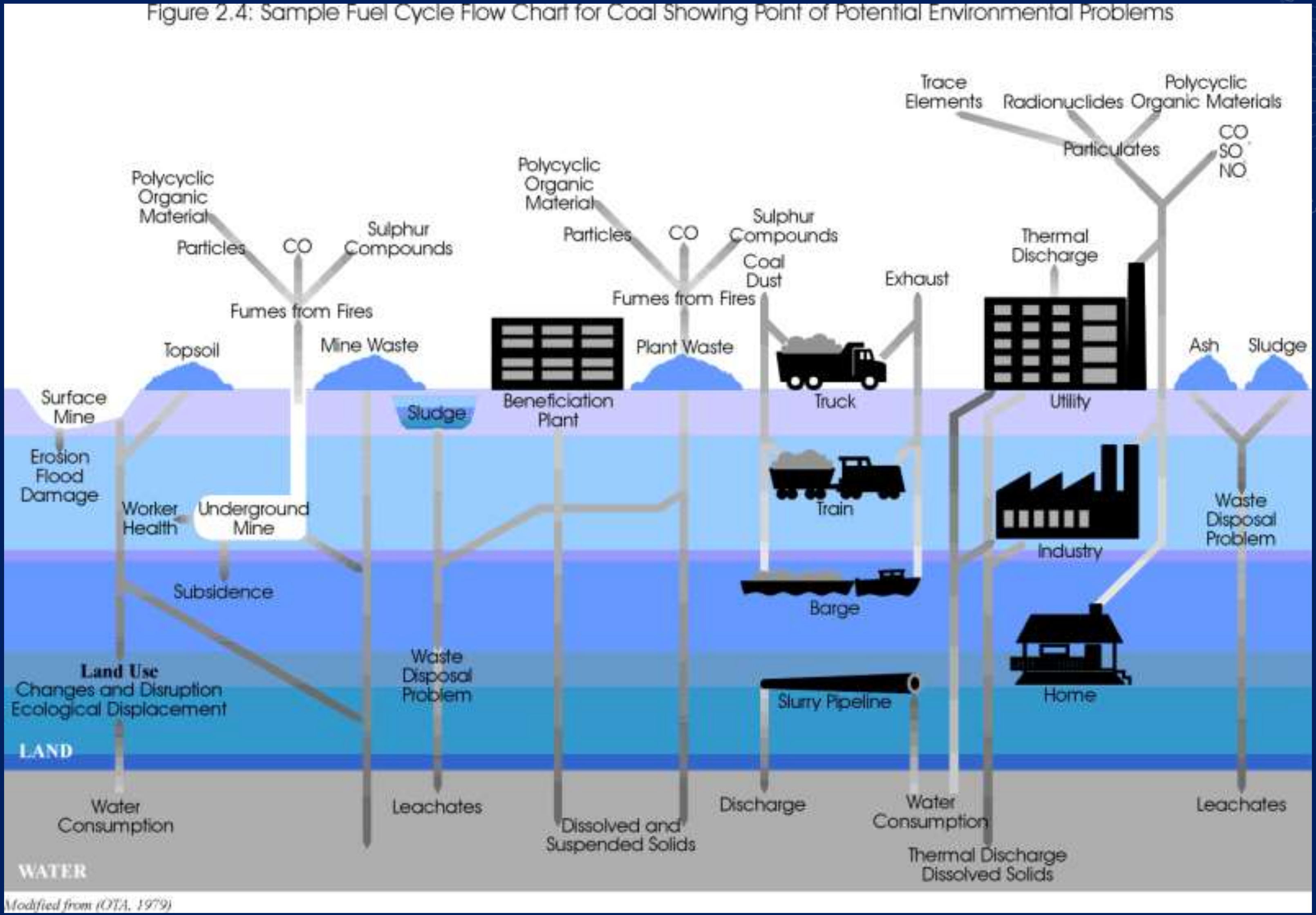
Human Disruption Index

Lead: 12000, Oil to Ocean: 200,000 Cd: 1400 Sulphur: 31Mi, CH4:160Mi

Particular Emisson, CH4, C02, N2, NOx, Sulphur, Oil to Ocean, Lead, Mercury, Cadmium

Insult	Baseline tonnes/yr	DI	
Nitrogen fixation	140million	1.5	30% C En
Mercury emission	2500	1.4	20% C En
NOx	33 million	0.5	12% CE, 8% Tr En
Particulate emiss	3100 million	2.7	35% CE 10% Tr En
Carbon Dioxide	150million	2.3	75% CE

Energy and Emissions



Energy After Rio: UNDP Publication

Planetary Boundaries

nature   Vol 461|24 September 2009

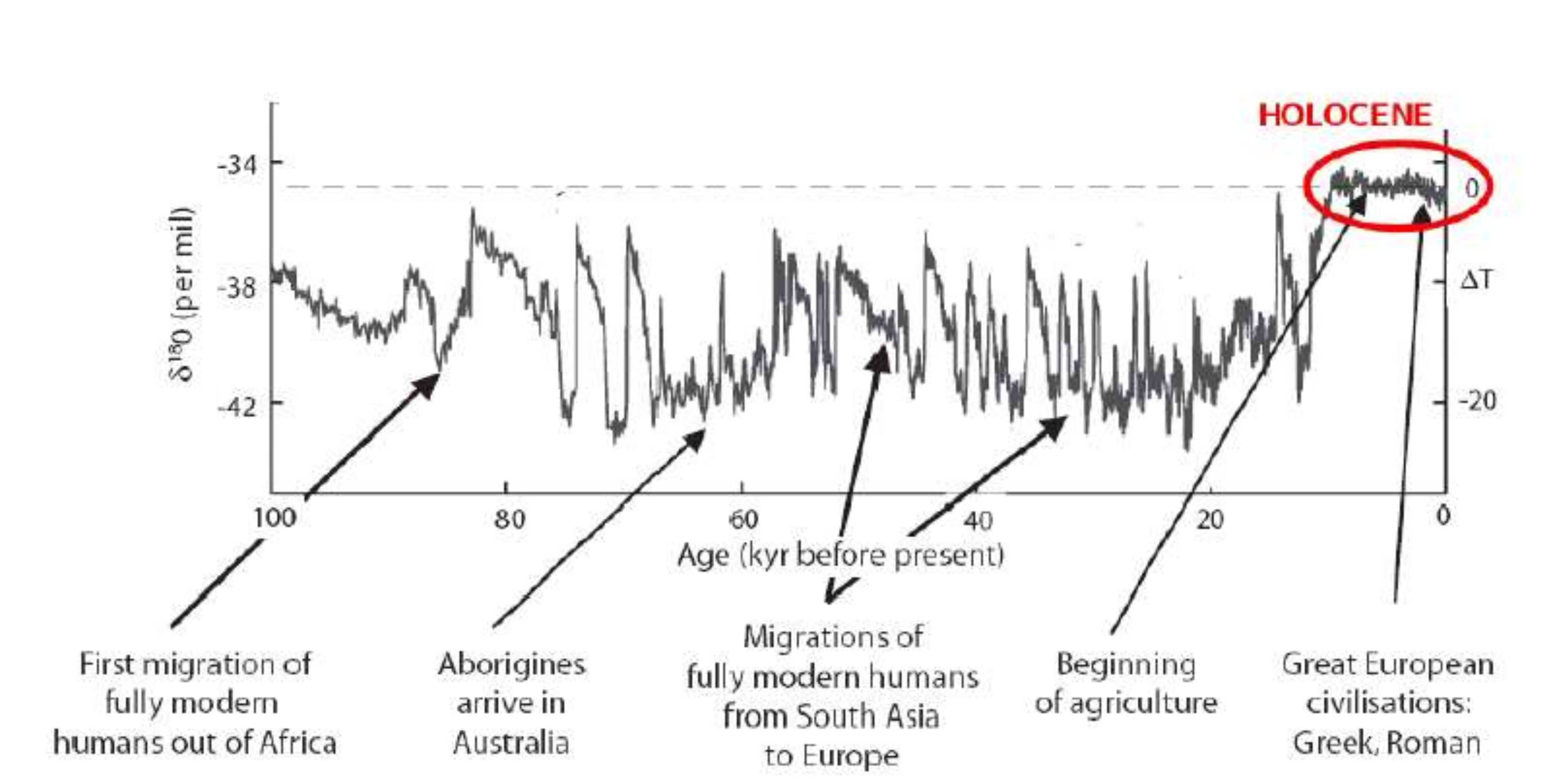
FEATURE

A safe operating space for humanity

Identifying and quantifying planetary boundaries that must not be transgressed could help prevent human activities from causing unacceptable environmental change, argue **Johan Rockström** and colleagues.

Rockstrom et al, Nature, 2009

Long term global temperature record



Rockstrom et al, Nature, 2009

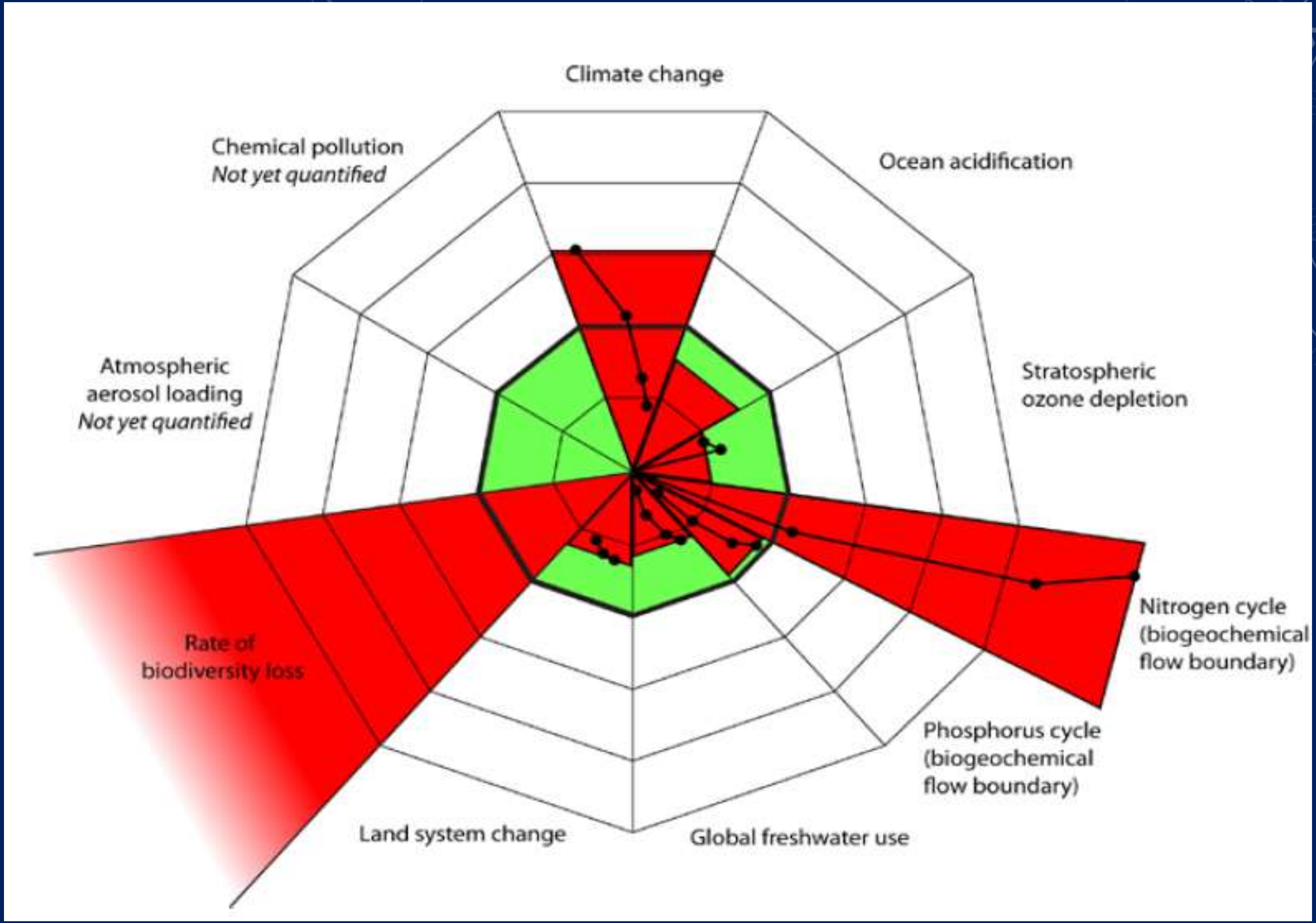
Boundary character / Scale of process	Processes with global scale thresholds	Slow processes without known global scale thresholds
Systemic processes at planetary scale	Climate Change	
	Ocean Acidification	
		Stratospheric Ozone
Aggregated processes from local/regional scale		Global P and N Cycles
		Atmospheric Aerosol Loading
		Freshwater Use
		Land Use Change
		Biodiversity Loss
		Chemical Pollution

Rockstrom et al, Nature, 2009

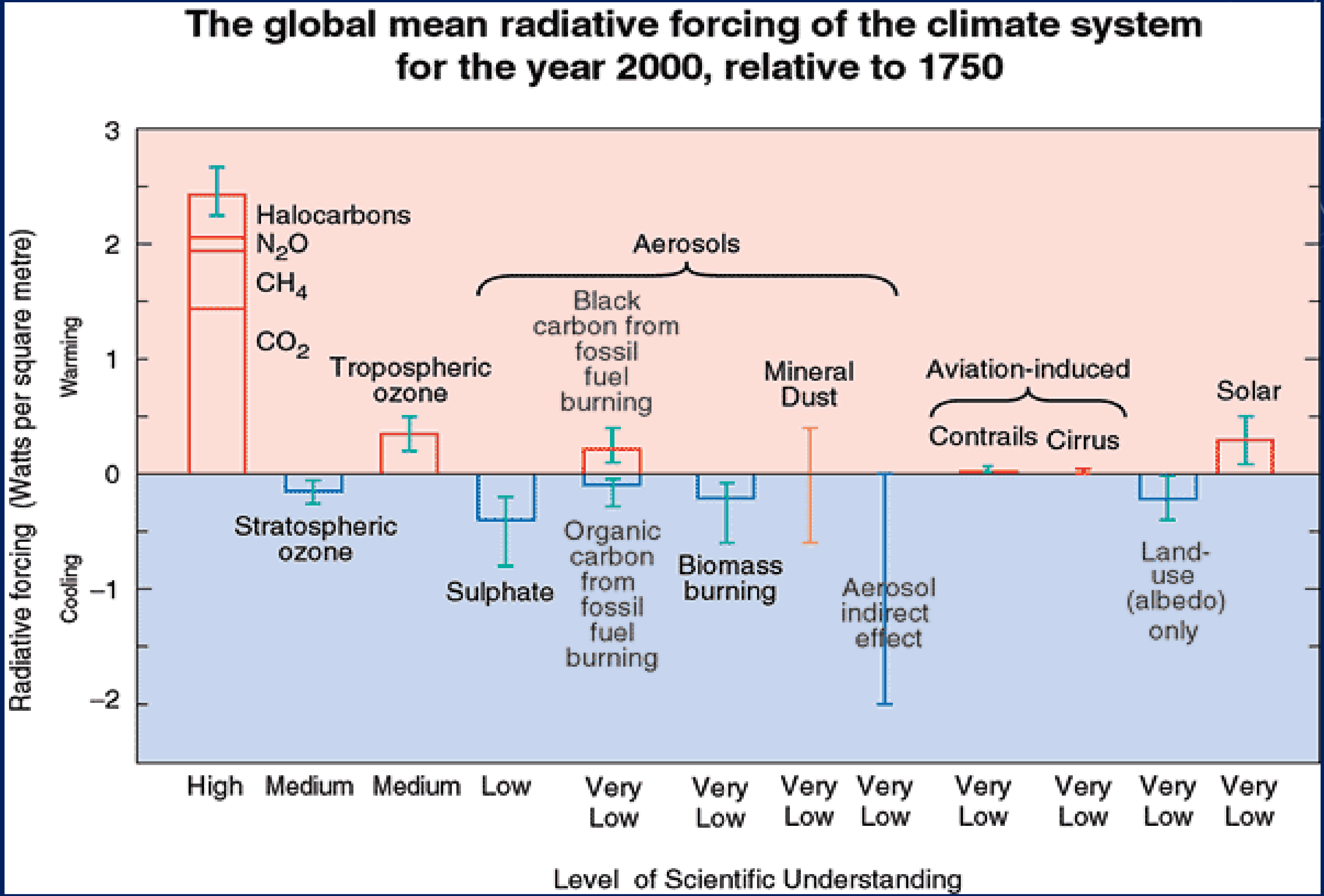
PLANETARY BOUNDARIES

Earth-system process	Parameters		Proposed boundary		Current status	Pre-industrial value
Climate change	(i) Atmospheric carbon dioxide concentration (parts per million by volume)	over	350	<	387	280
	(ii) Change in radiative forcing (watts per metre squared)	over	1	<	1.5	0
Rate of biodiversity loss	Extinction rate (number of species per million species per year)	high-over	10	<	>100	0.1–1
Nitrogen cycle (part of a boundary with the phosphorus cycle)	Amount of N_2 removed from the atmosphere for human use (millions of tonnes per year)	high over	35	<	121	0
Phosphorus cycle (part of a boundary with the nitrogen cycle)	Quantity of P flowing into the oceans (millions of tonnes per year)	low	11	>	8.5–9.5	~1
Stratospheric ozone depletion	Concentration of ozone (Dobson unit)	over	276	<	283	290
Ocean acidification	Global mean saturation state of aragonite in surface sea water	over	2.75	<	2.90	3.44
Global freshwater use	Consumption of freshwater by humans (km^3 per year)	low	4,000	>	2,600	415
Change in land use	Percentage of global land cover converted to cropland	low	15	>	11.7	Low
Atmospheric aerosol loading	Overall particulate concentration in the atmosphere, on a regional basis				To be determined	
Chemical pollution	For example, amount emitted to, or concentration of persistent organic pollutants, plastics, endocrine disrupters, heavy metals and nuclear waste in, the global environment, or the effects on ecosystem and functioning of Earth system thereof				To be determined	

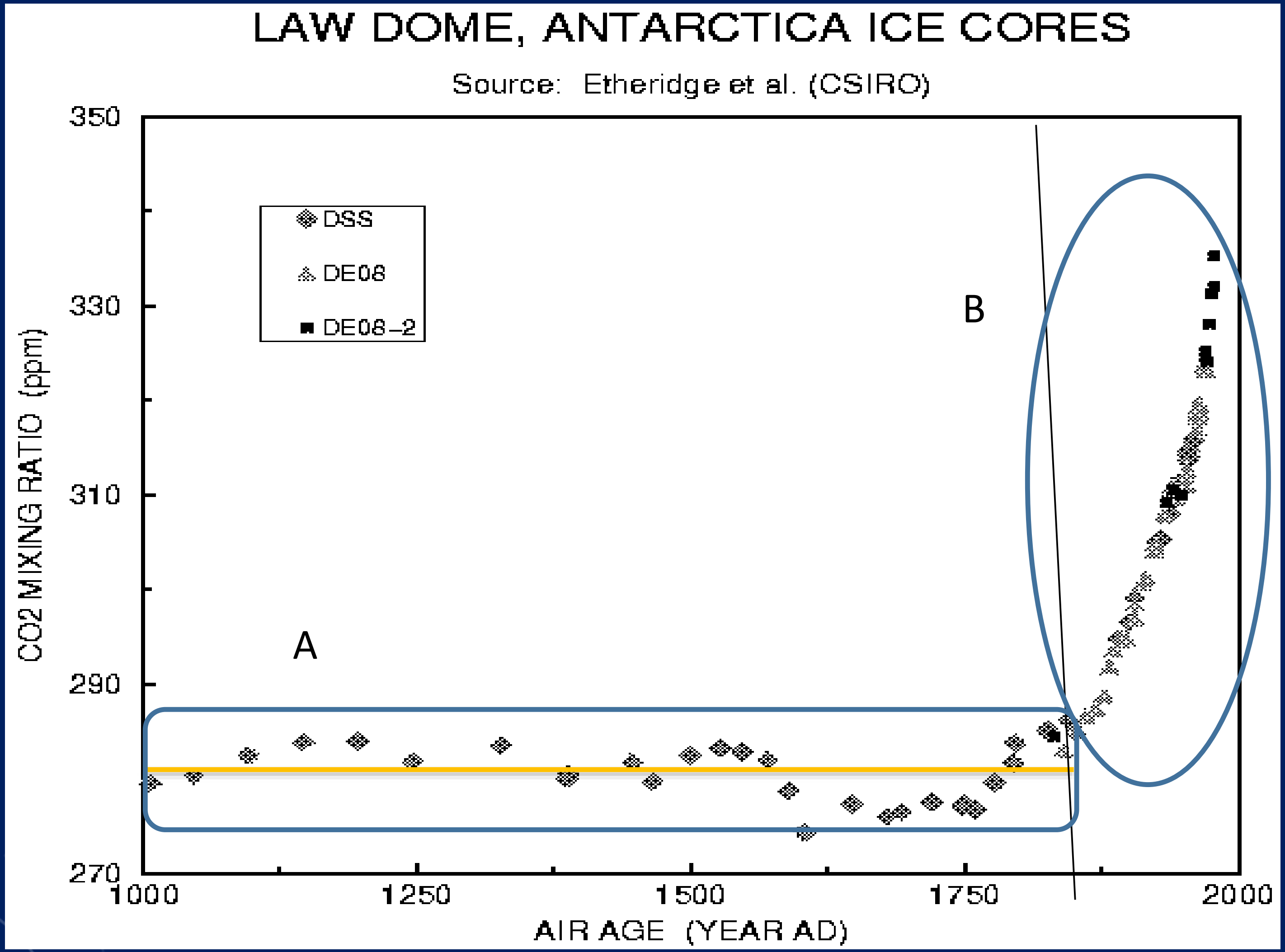
Rockstrom et al, Nature, 2009



Rockstrom et al, Nature 2009


The global mean radiative forcing of the climate system
for the year 2000, relative to 1750
Radiative forcing (Watts per square metre)
Warming
Cooling
3
2
1
0
−1
−2
Halocarbons
N_2O
CH_4
CO_2
Tropospheric ozone
Stratospheric ozone
Aerosols
Black carbon from fossil fuel burning
Mineral Dust
Sulphate
Organic carbon from fossil fuel burning
Biomass burning
Aerosol indirect effect
Aviation-induced
Contrails
Cirrus
Land-use (albedo) only
Solar
High
Medium
Medium
Low
Very Low
Very Low
Very Low
Very Low
Very Low
Very Low
Very Low
Very Low
Level of Scientific Understanding

Carbon Dioxide Concentrations

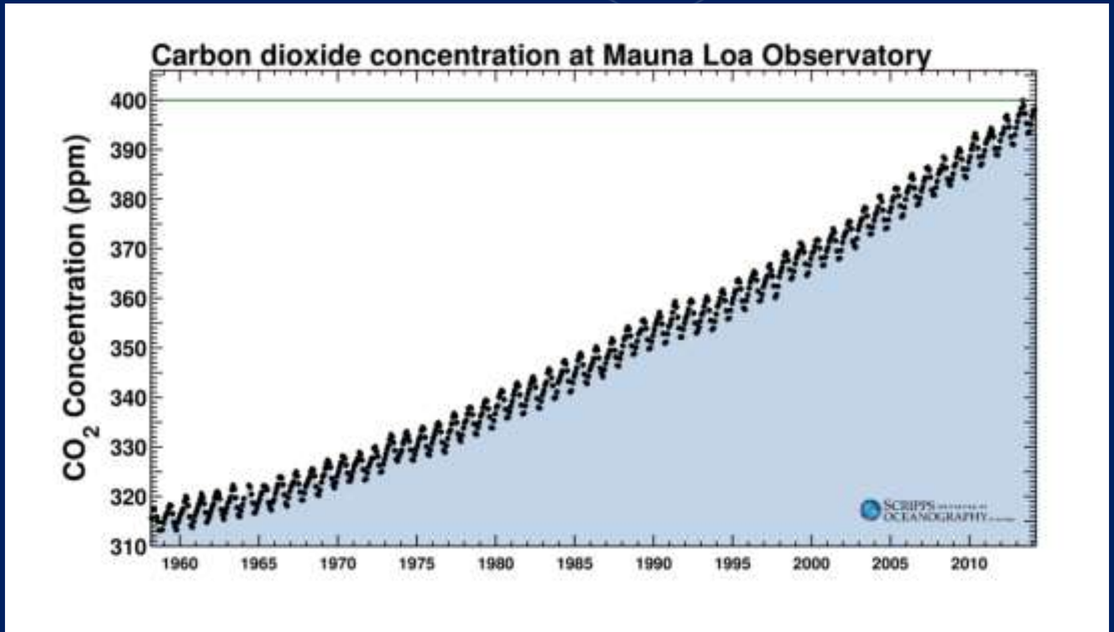


http://cdiac.ornl.gov/trends/co2/graphics/lawdome.gif

http://www.ei.lehigh.edu/learners/cc/paleoclimatology/iceCore.png

http://www.abc.net.au/radionational/image/7449688-3x2-700x467.jpg

https://www.usatoday.com/story/weather/2014/05/01/carbon-dioxide-400-ppm-april-mauna-loa/8575651/



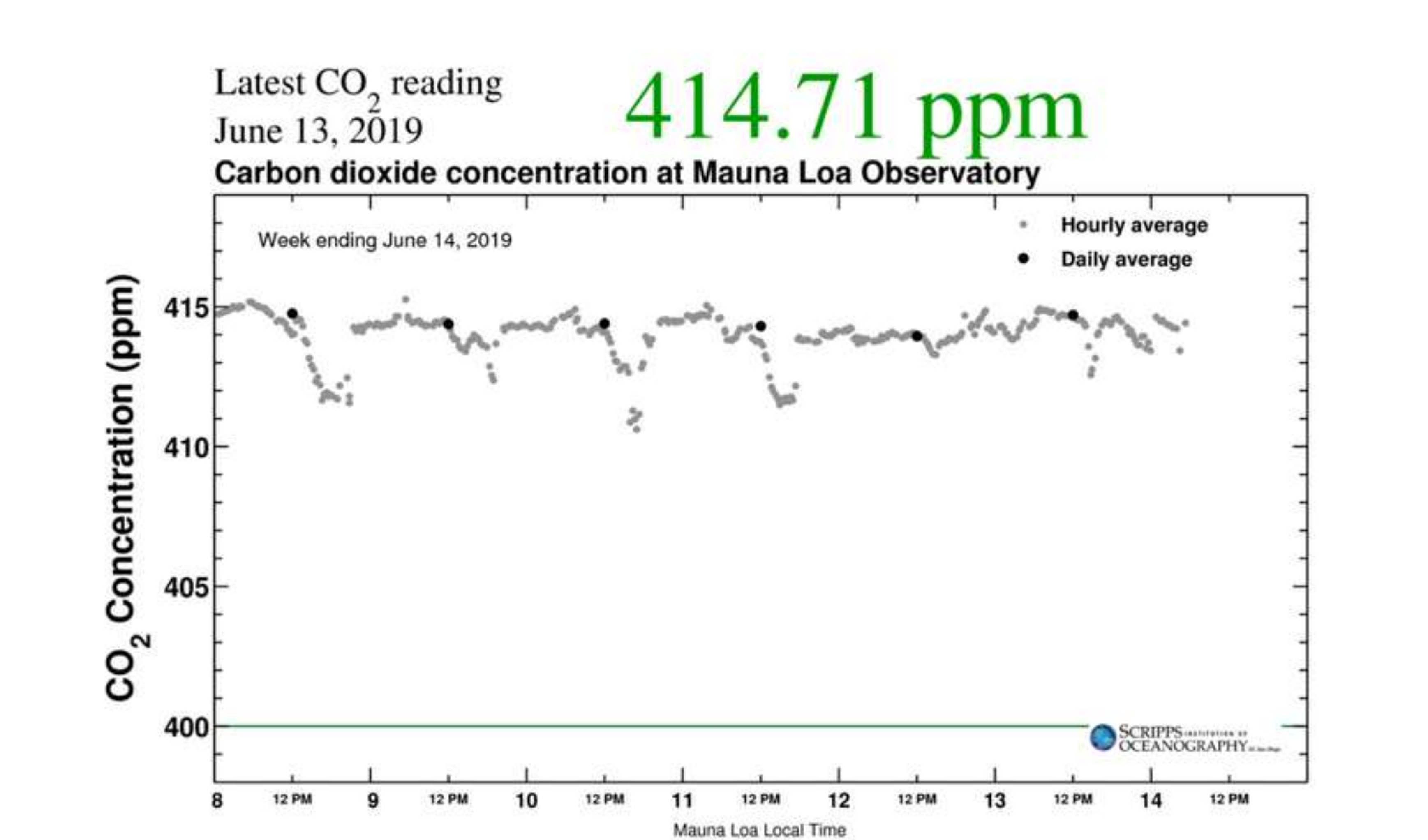
Examine the trend of CO2 shown here.

Which of the following is true:

i) CO_2 concentrations show an overall increase over several years but fluctuate randomly within the year
ii) The seasonal fluctuation in the CO2 concentration is due to seasonal fluctuations in the energy pattern
iii) The seasonal fluctuation is due to local fluctuations in Hawai
iv) The seasonal fluctuations are due to ice melting in summer
v) None of the above

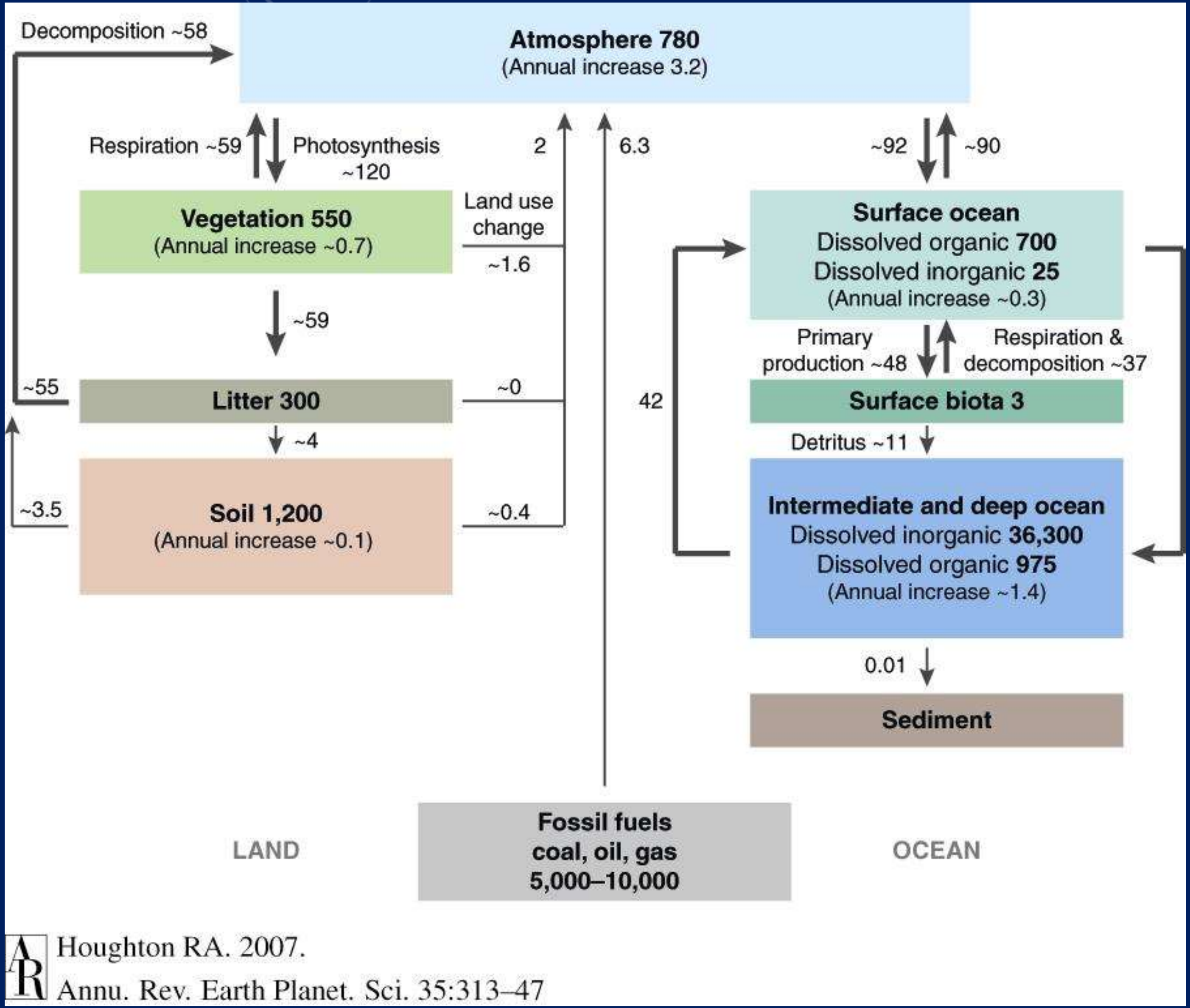
https://www.usatoday.com/story/weather/2014/05/01/carbon-dioxide-400-ppm-april-mauna-loa/8575651/

Recent Carbon dioxide concentrations



https://scripps.ucsd.edu/programs/keelingcurve/

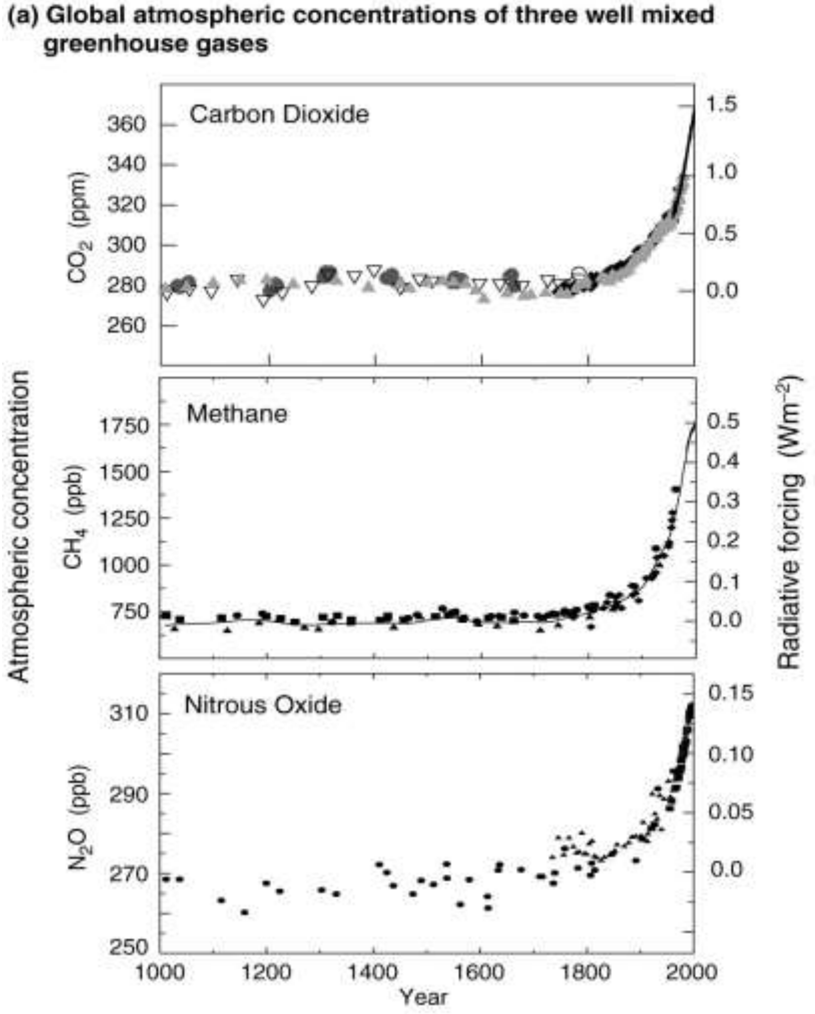
Last accessed June 16,2019

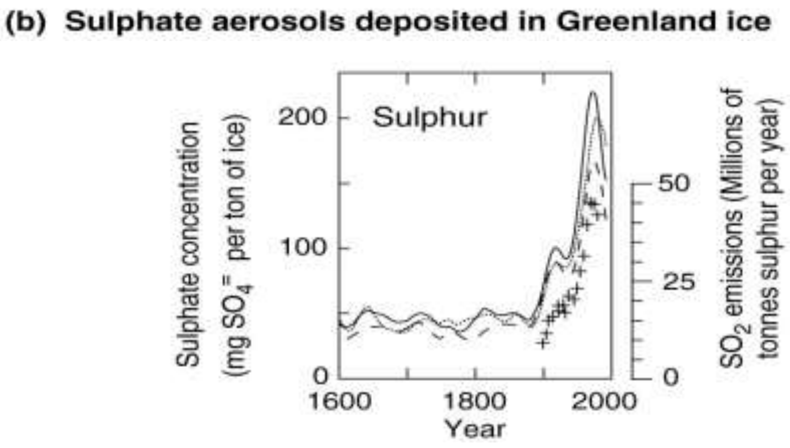


Source: Annual Reviews

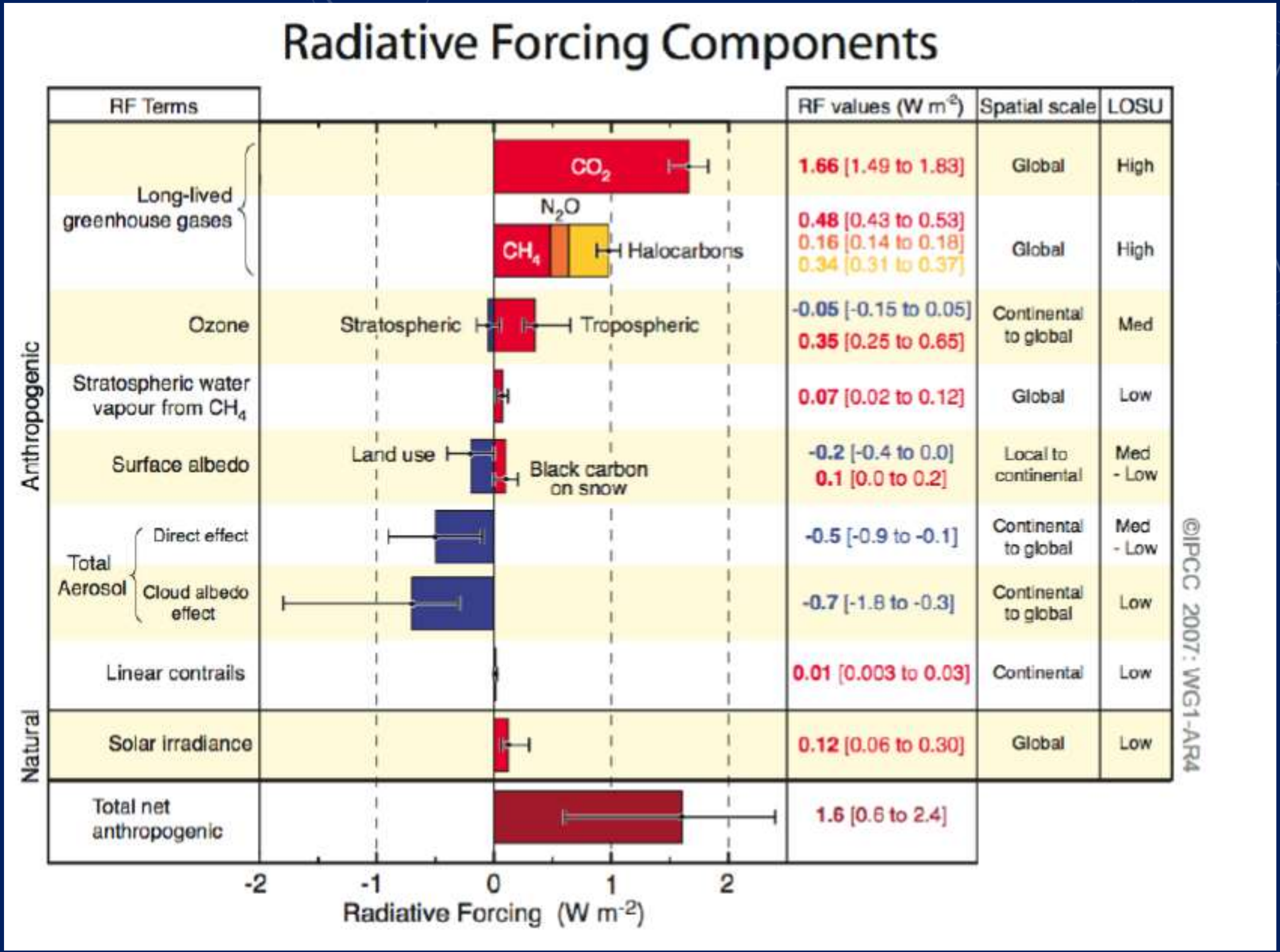
https://www.annualreviews.org/doi/pdf/10.1146/annurev.earth.35.031306.140057

Indicators of the Human Influence on the Atmosphere during the Industrial Era





www.ipcc.ch


Radiative Forcing Components
RF Terms
RF values (W m-2)
Spatial scale
LOSU
Long-lived greenhouse gases
CO2
1.66 [1.49 to 1.83]
Global
High
N2O
CH4
Halocarbons
0.48 [0.43 to 0.53]
0.16 [0.14 to 0.18]
0.34 [0.31 to 0.37]
Global
High
Ozone
Stratospheric
Tropospheric
-0.05 [-0.15 to 0.05]
0.35 [0.25 to 0.65]
Continental to global
Med
Stratospheric water vapour from CH4
0.07 [0.02 to 0.12]
Global
Low
Surface albedo
Land use
Black carbon on snow
-0.2 [-0.4 to 0.0]
0.1 [0.0 to 0.2]
Local to continental
Med - Low
Total Aerosol
Direct effect
-0.5 [-0.9 to -0.1]
Continental to global
Med - Low
Cloud albedo effect
-0.7 [-1.8 to -0.3]
Continental to global
Low
Linear contrails
0.01 [0.003 to 0.03]
Continental
Low
Solar irradiance
0.12 [0.06 to 0.30]
Global
Low
Total net anthropogenic
1.6 [0.6 to 2.4]
Anthropogenic
Natural
-2
-1
0
1
2
Radiative Forcing (W m-2)
©IPCC 2007: WG1-AR4

Global Warming Potential

Global Warming Potentials of Selected Greenhouse Gases

Gas	Lifetime (yr)	GWP		
		20 yr	100 yr	500 yr
CO2	~100	1	1	1
CH4	10	62	25	8
N2O	120	290	320	180
CFC-12	102	7900	8500	4200
HCFC-123	1.4	300	93	29
SF6	3200	16500	24900	36500

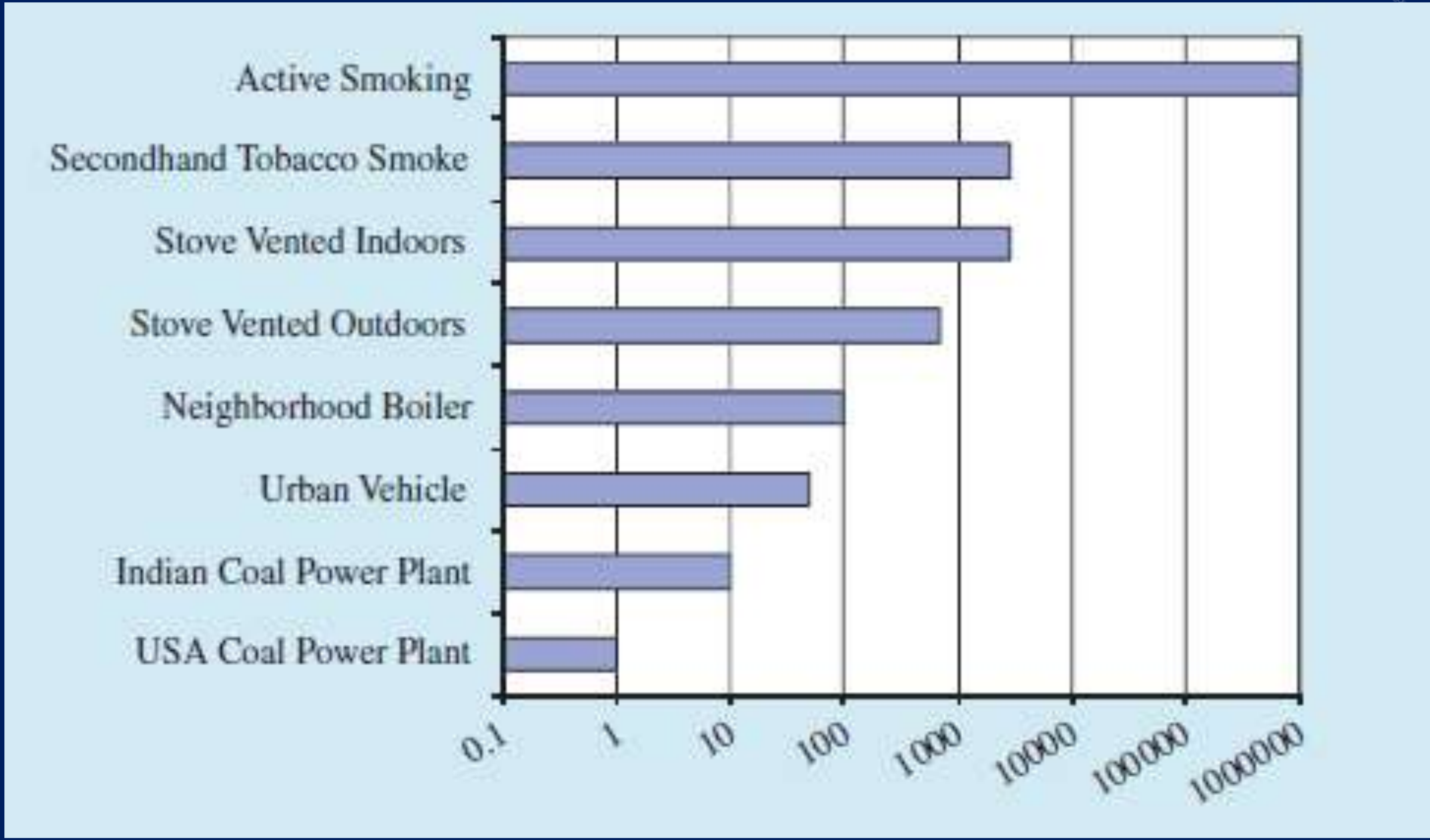
Figure 2.5: Example Environmental Pathway for Combustion-derived, Health-damaging Air Pollution

SOURCE	EMISSIONS	CONCENTRATION	EXPOSURE	DOSE	HEALTH EFFECTS
Quantity and quality of fuel gives some idea of	Emissions of air pollutants depend on how much of which type is burned in	The concentra-tion of air pollutants in the air depends not only on the emis-sions but also on the atmospheric condi- tions (or ventilation conditions inside	Exposure depends on how many people breathe certain concentra-tions	Dose measures how much pollutant is actually deposited in the body and depends not only on exposure but also factors such	Health effects depend not only on dose but also on factors such as age, sex, whether the person smokes, and the

Measurement and control can be initiated at any stage.

Source: Energy after Rio UNDP

Intake Fraction



Gms of pollutant inhaled per tonne emitted

GEA Chap 4

Disability Adjusted Lost Years

- One DALY can be thought of as one lost year of "healthy" life. The sum of these DALYs across the population, or the burden of disease, can be thought of as a measurement of the gap between current health status and an ideal health situation where the entire population lives to an advanced age, free of disease and disability. (Source: WHO)
- DALY = YLL +YLD

Carbon Dioxide Emissions

Kaya identity:
Total CO_2 Emissions
$= (CO_2/E)(E/GDP)(GDP/Pop)Pop$

CO_2/E – Carbon Intensity

E/GDP- Energy Intensity of Economy

Kaya Identity

Total CO_2 Emissions =

$(CO_2/E)(E/GDP)(GDP/Pop)Pop$

CO_2/E – Carbon Intensity

E/GDP- Energy Intensity of Economy

Does a country that has a lower energy intensity per unit GDP imply that it is more efficient?

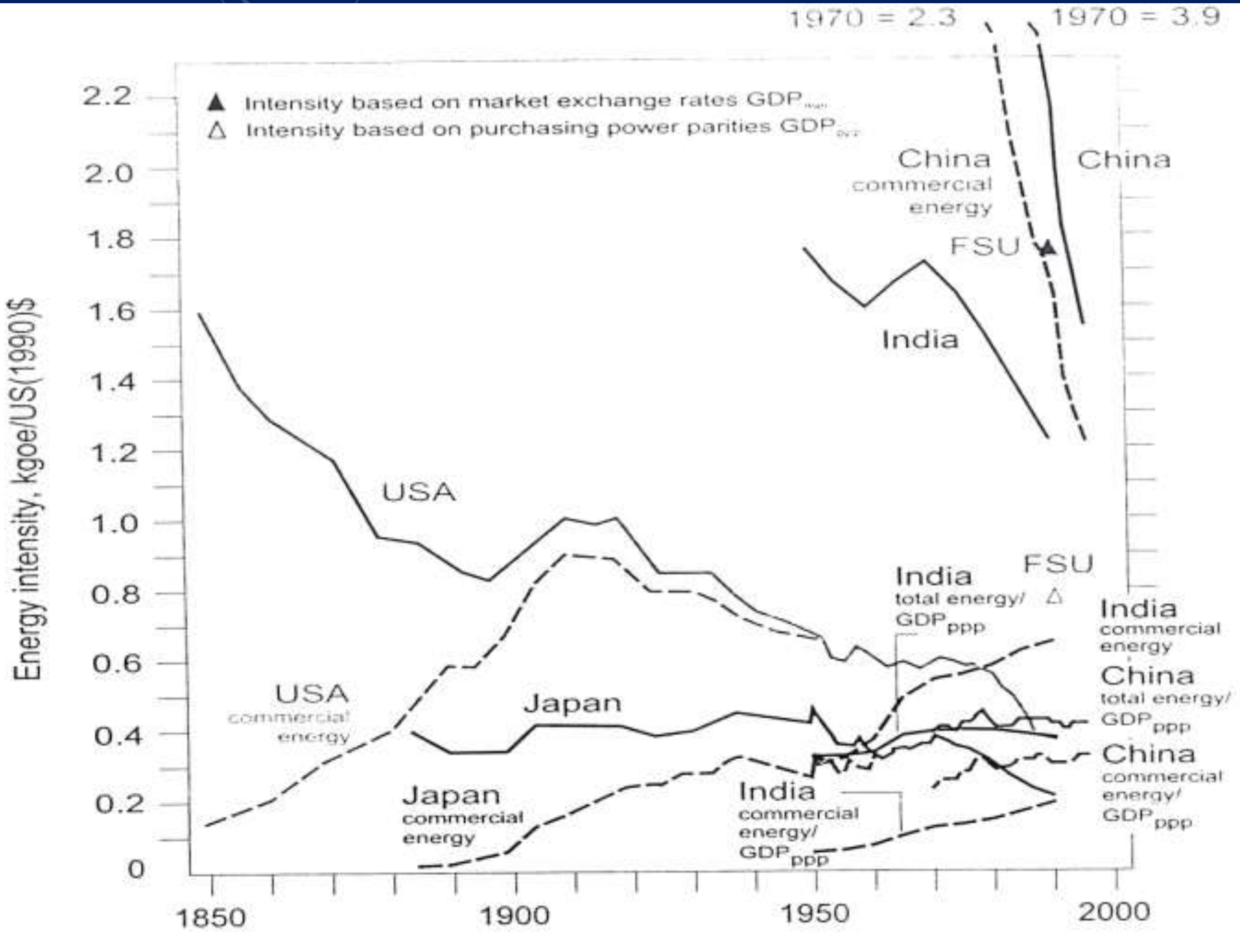
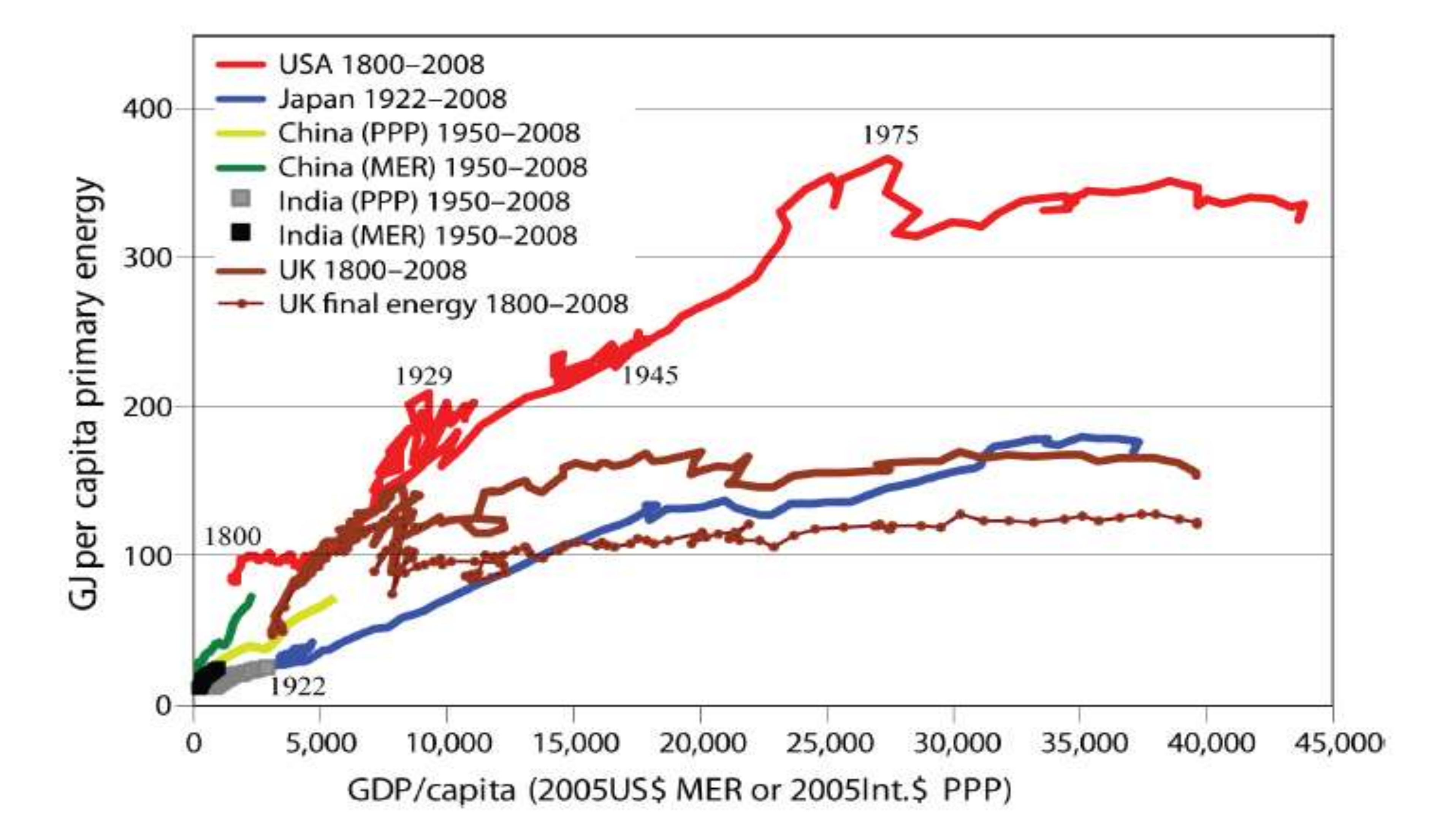


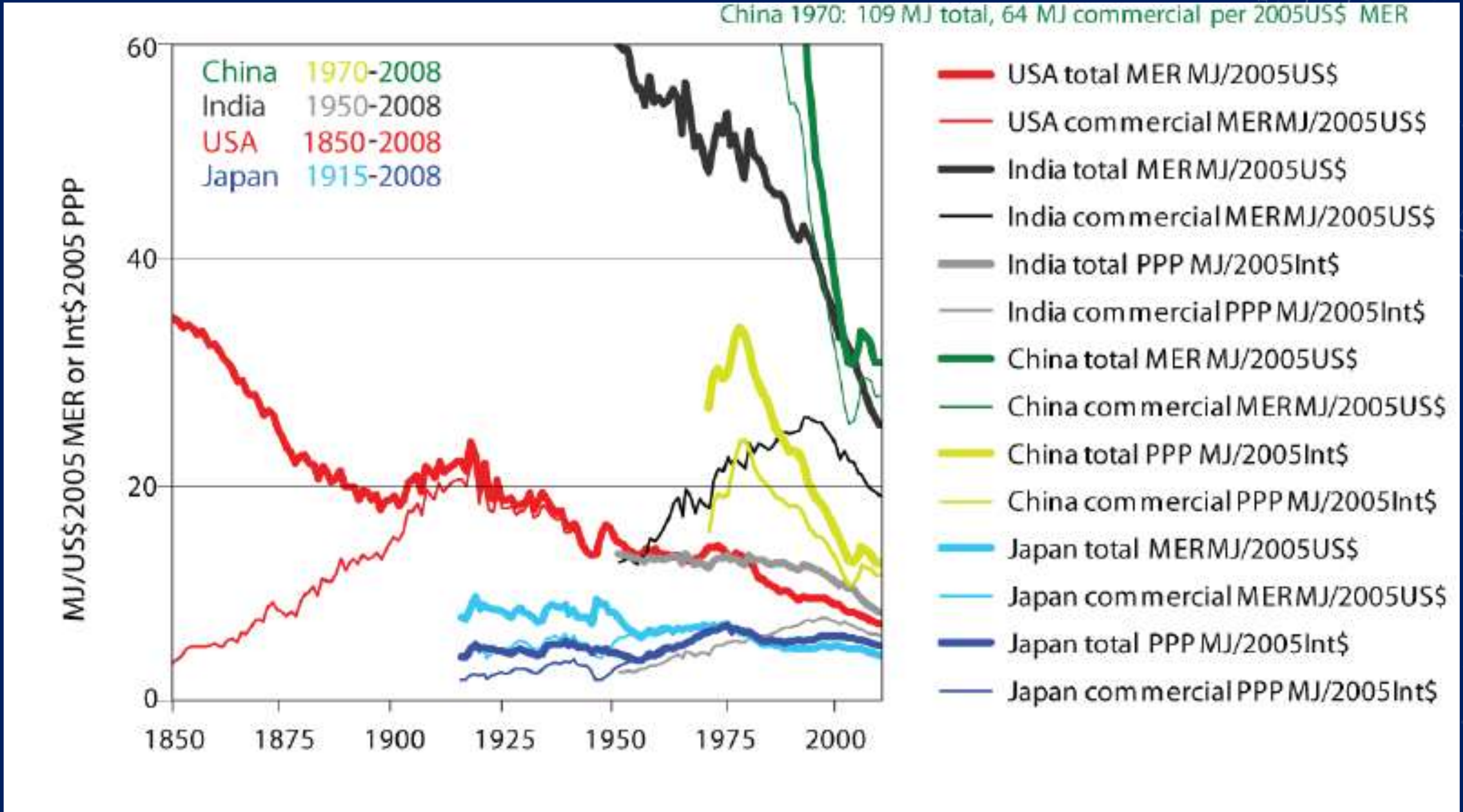
Figure 4.5: Primary energy intensity for four selected countries and FSU, total (solid lines) and commercial energy (dashed lines), in kgoe, per GDP, in US(1990)\$. Unless otherwise specified, GDP refers to GDP_{mer}. For China, India, and FSU intensities based on GDP_{ppp} are also given. Data sources: Nakićenović, 1987; Martin, 1988; TERI, 1994.

Energy Intensity vs Per capita GDP



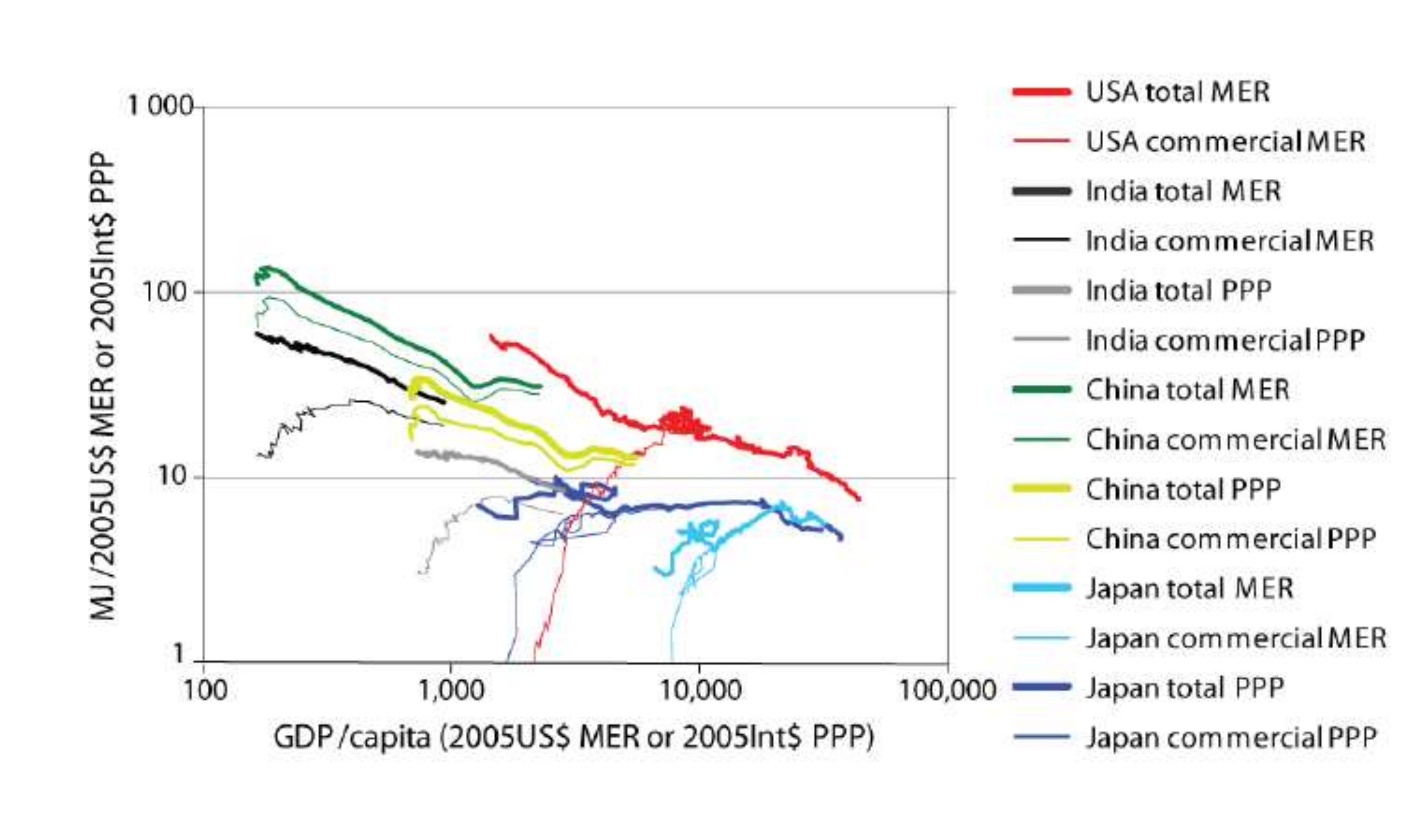
Source: GEA, 2012

Energy Intensity Improvements



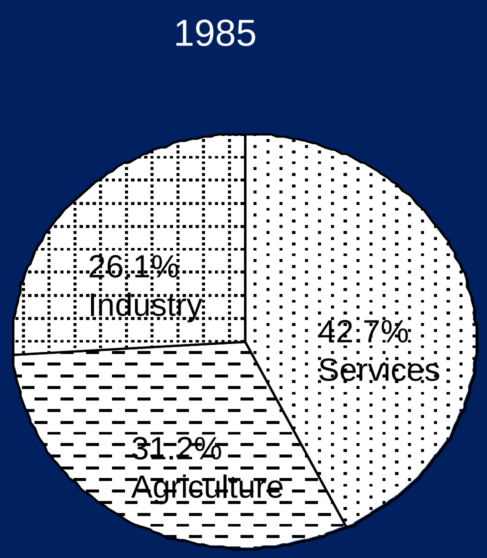
Source: GEA, 2012

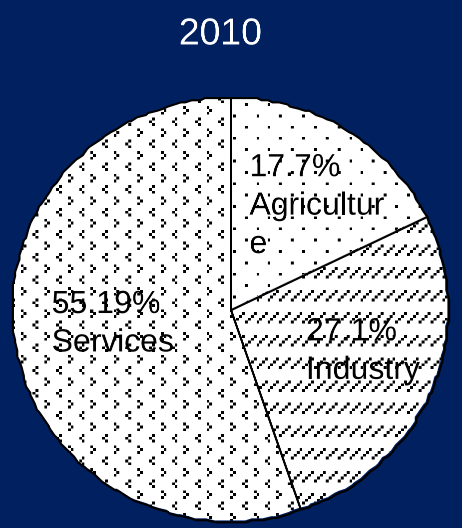
Energy Intensity vs per capita use



Source: GEA, 2012

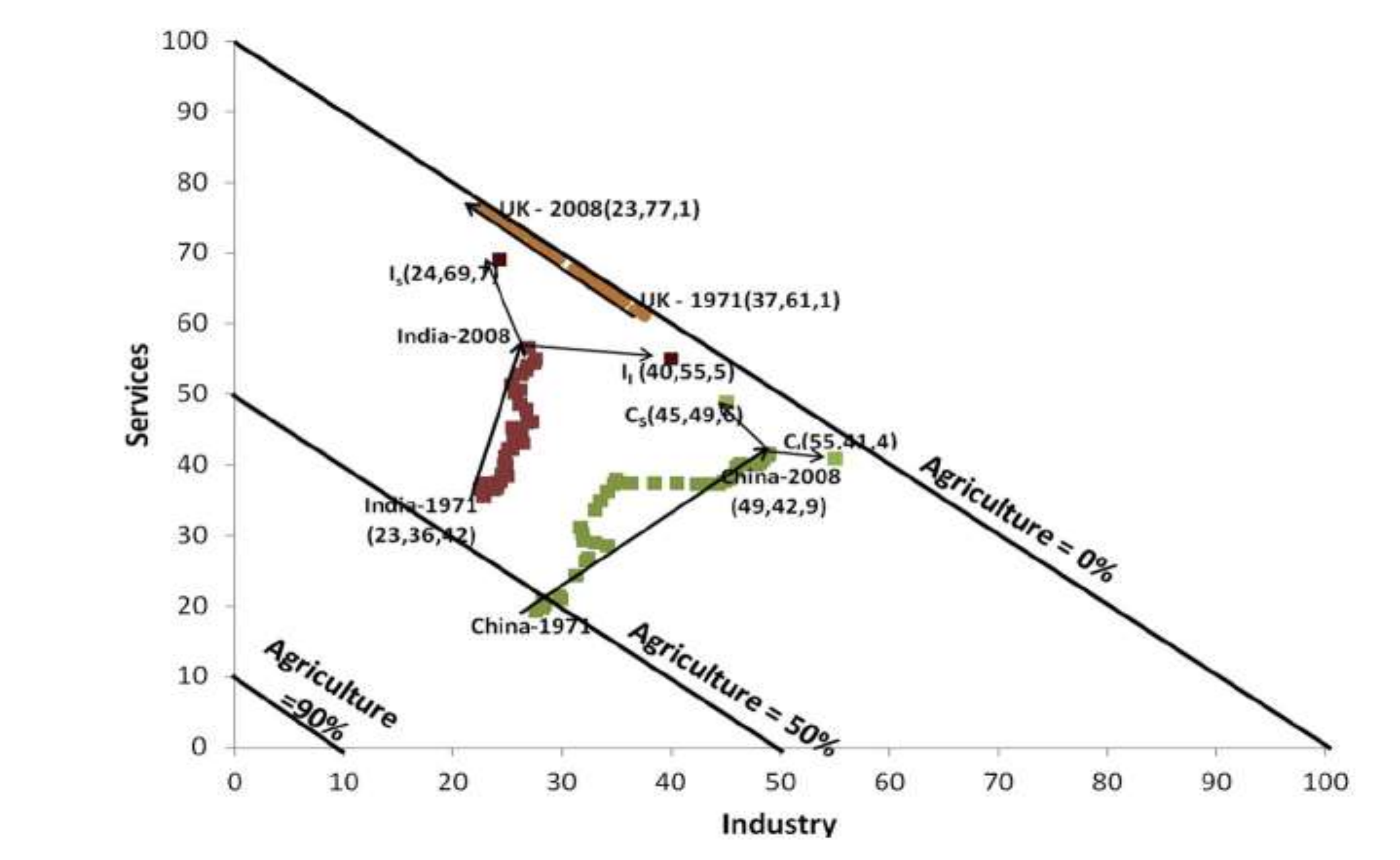
Sectoral Shares of GDP in 1985 and 2010





	1971	1981	1991	2001	2008	2011
Industry	23%	25%	26%	25%	27%	27%
Services	36%	39%	44%	51%	57%	59%
Agriculture	42%	36%	30%	23%	16%	13.9%

Composition of GDP



Source: Kanitkar, T. et al ESD, 2015

Emission Factor

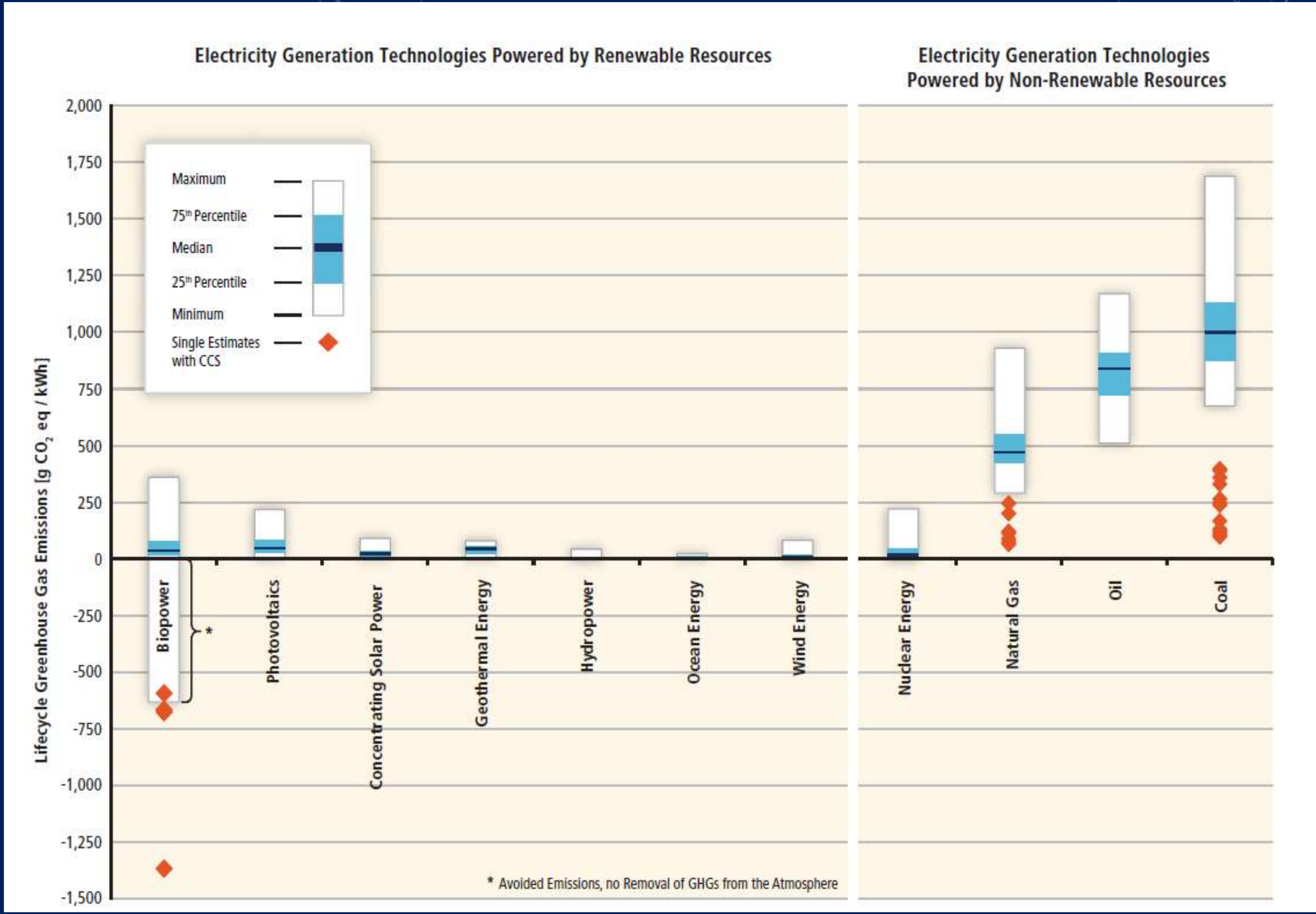
- Emissions per unit of output
  e.g. CO_2 / kWh for a power plant
  Depends on composition of fuel
  Efficiency, characteristics of conversion device
  Can be done for all pollutants
- Calculations possible from basic stoichiometry

Power plant calculation (Previous lecture)

- A thermal power plant is rated at 500 MW (gross), has 9% auxiliary consumption, has an annual PLF of 80%. Calculate the annual generation in MWh and Million units and in GJ.
- If the plant has an efficiency of 38% calculate the amount of input energy supplied to the plant. If the input energy used is coal (NCV 4500 kcal/kg) calculate the annual amount pf coal used

Power plant calculation (Previous lecture)

- If the power plant has an efficiency of 38% calculate the emission factor of the plant. The input energy used is coal (NCV 4500 kcal/kg) and the percentage of carbon in the coal is 50% by weight



Source: IPCC, 2011

Options for Low Carbon

Mitigation options
increase sinks,
reduce sources- aforestation,fuel mix,
energy efficiency,
renewables,
nuclear,
carbon sequestration (CCS)
Adaptation

Homework

- Check the IEA statistics for India for 2005 and 2015
- Calculate the terms of the Kaya identity for both these years.
- How do you think these factors will change in 2025?
- What are possible future scenarios?
- What interventions can we make to reduce the carbon intensity?

India’s NDC

#1 Reduce Emissions Intensity of GDP by 33-35% of 2005 level in 2030

#2 Create 40% cumulative non fossil power by installed capacity by 2030 (using finance from Green Climate Fund)

#3 Create an additional carbon sink of 2.5 to 3 billion tonnes of CO_2 equivalent through additional tree cover and forest

Summing up

- Environment- key driver for future energy systems
- Focus is on future sustainability
- Climate change, local emissions,, urban air quality
- Quantification – Kaya identity, Emission factors
- Future classes we will explore the interaction between energy, economics and environment

References

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Thank you