CLIMATE AND CLIMATE CHANGE

SCIENTIFIC BACKGROUND FOR INFORMED DECISION-MAKING

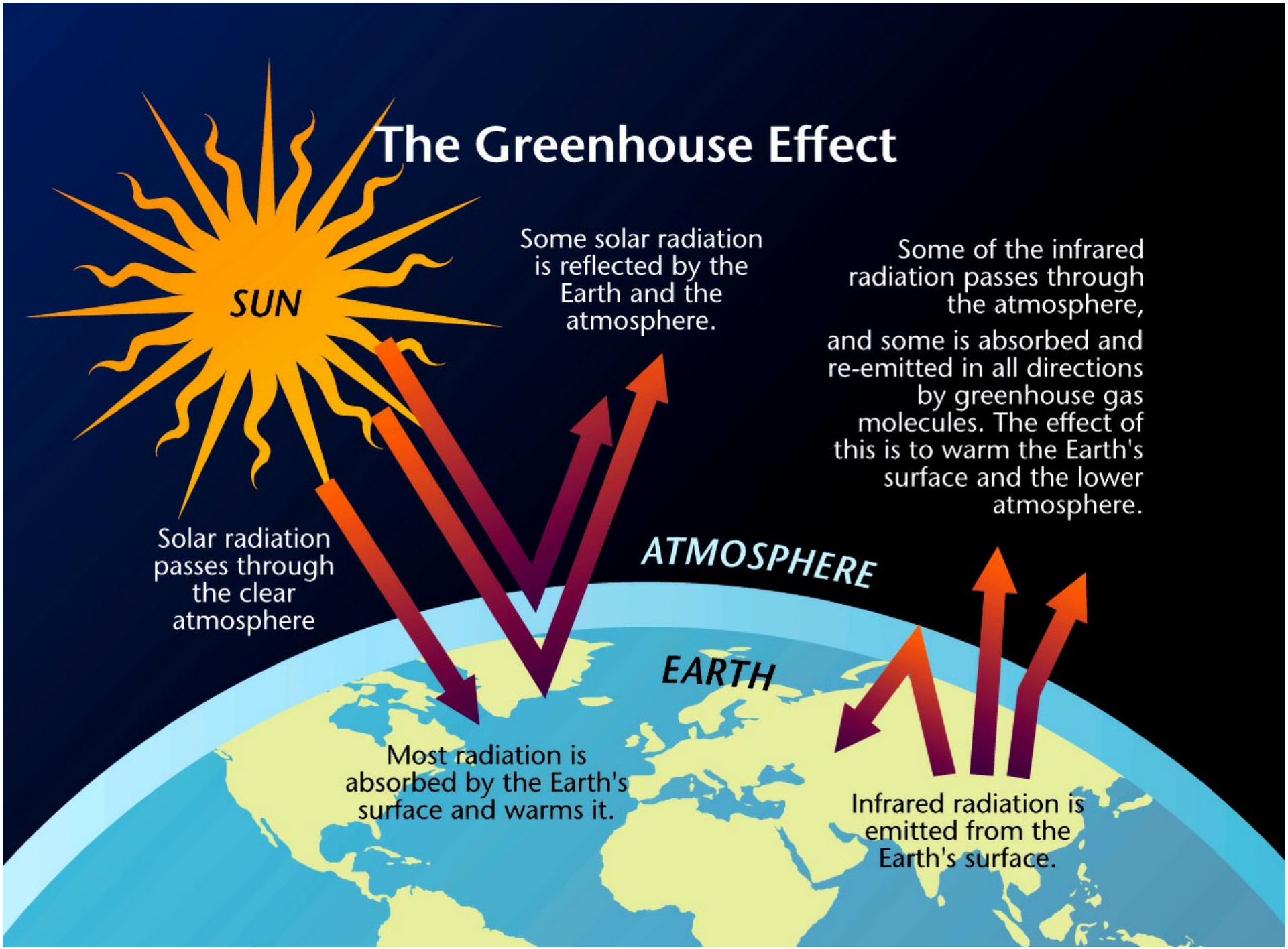
Stephen E. Schwartz

BROOKHAVEN NATIONAL LABORATORY

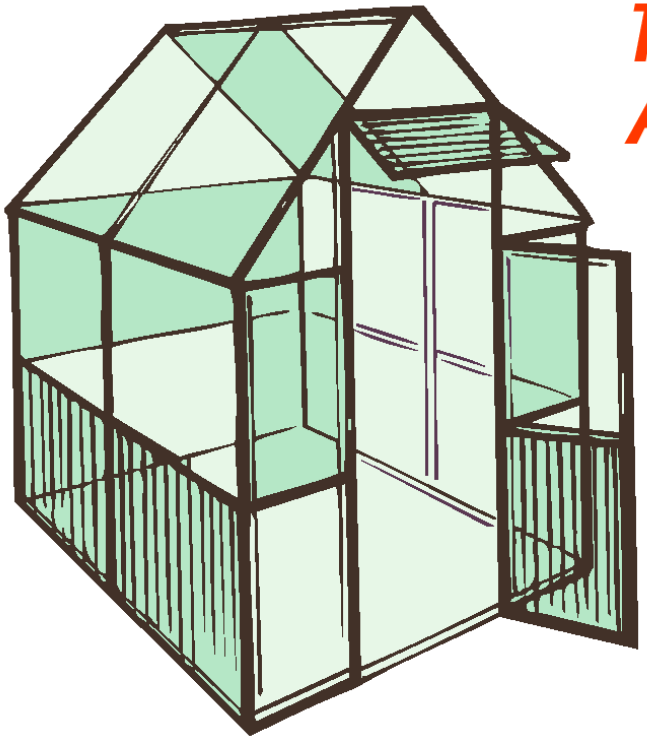
League of Women Voters of Brookhaven Town

Annual U.N. International Dinner
October 22, 2004

http://www.ecd.bnl.gov/steve/schwartz.html


The Greenhouse Effect
SUN
Some solar radiation is reflected by the Earth and the atmosphere.
Some of the infrared radiation passes through the atmosphere,
and some is absorbed and re-emitted in all directions by greenhouse gas molecules. The effect of this is to warm the Earth's surface and the lower atmosphere.
Solar radiation passes through the clear atmosphere
ATMOSPHERE
EARTH
Most radiation is absorbed by the Earth's surface and warms it.
Infrared radiation is emitted from the Earth's surface.

THE GREENHOUSE EFFECT



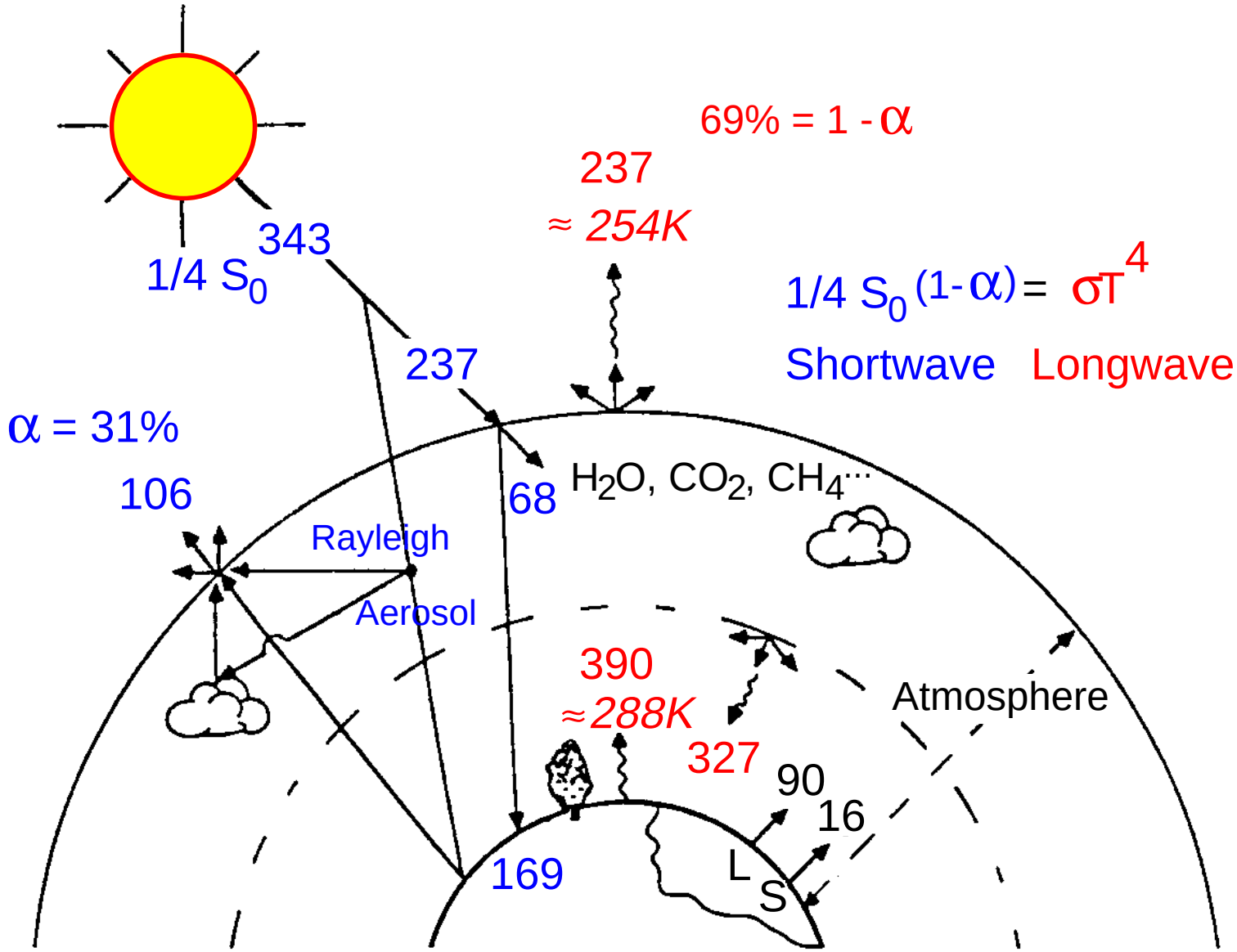
THE EARTH'S ENERGY BUDGET: A DELICATE BALANCE

- Sunlight heats the Earth.
- The warm Earth radiates energy (in the form of infrared radiation, or heat) back out to space.
- Some of this infrared radiation is trapped in the atmosphere, giving Earth its temperate climate.

This is the greenhouse effect. Without it, the Earth's climate would be like the moon's, harsh and severe.

GLOBAL ENERGY BALANCE

Global and annual average energy fluxes in watts per square meter



Schwartz, 1996, modified from Ramanathan, 1987

ATMOSPHERIC RADIATION

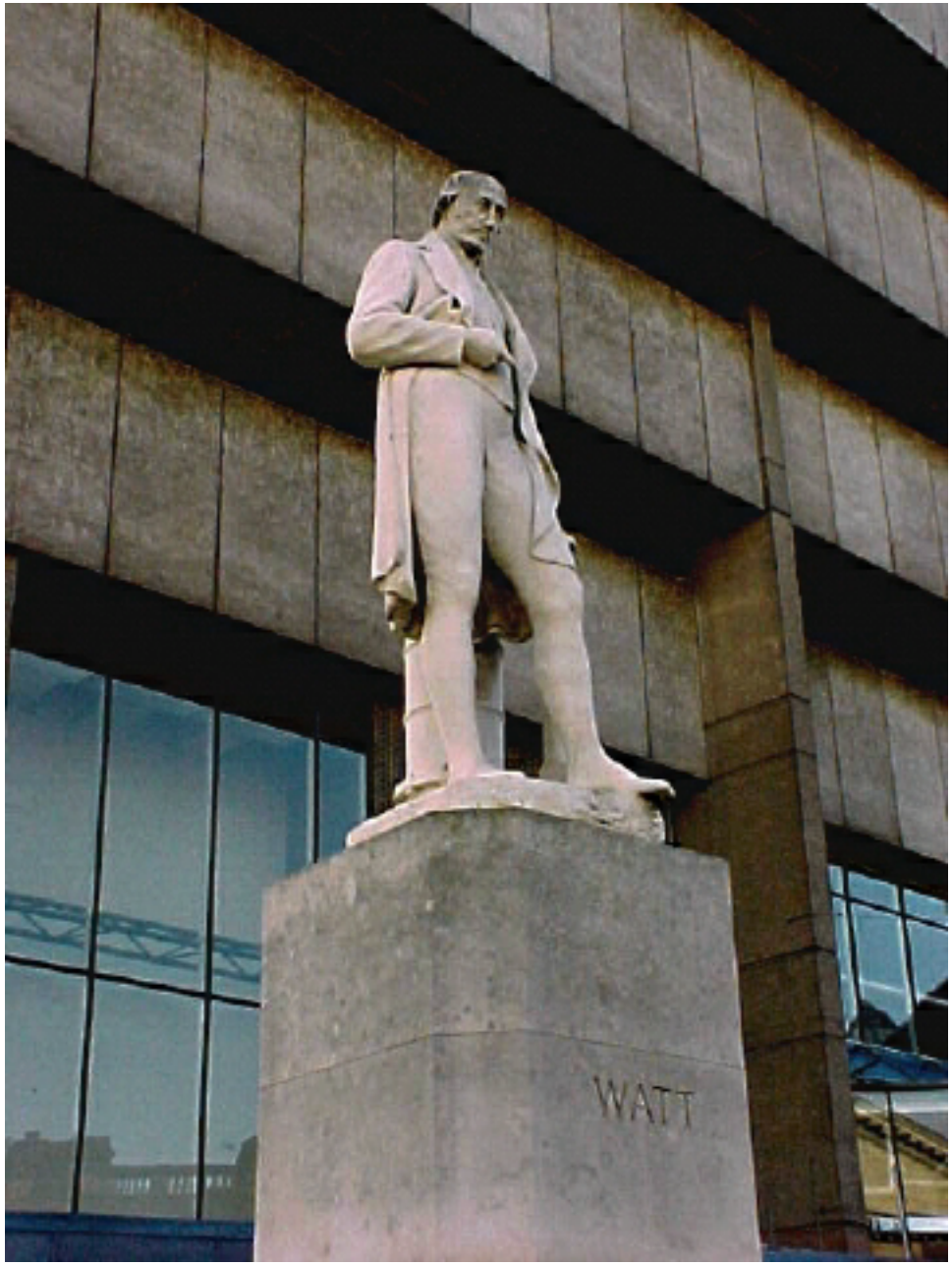
Energy per area per time

Power per area

Unit:

Watt per square meter

W m^{-2}



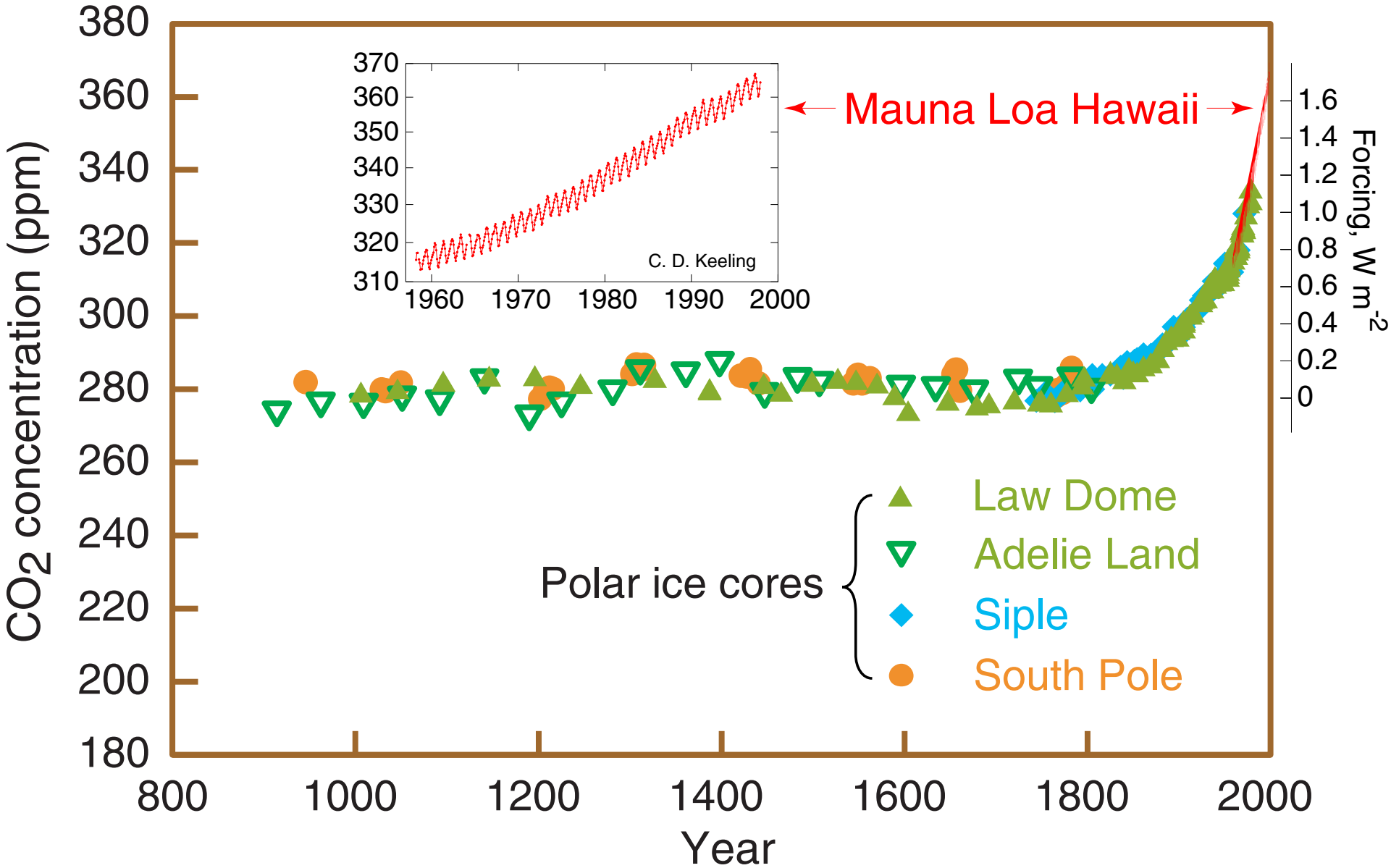
Everybody talks about the weather —

But nobody does anything about it.

– Mark Twain

Now with the greenhouse effect,
we ARE doing something about it.
What are we doing?

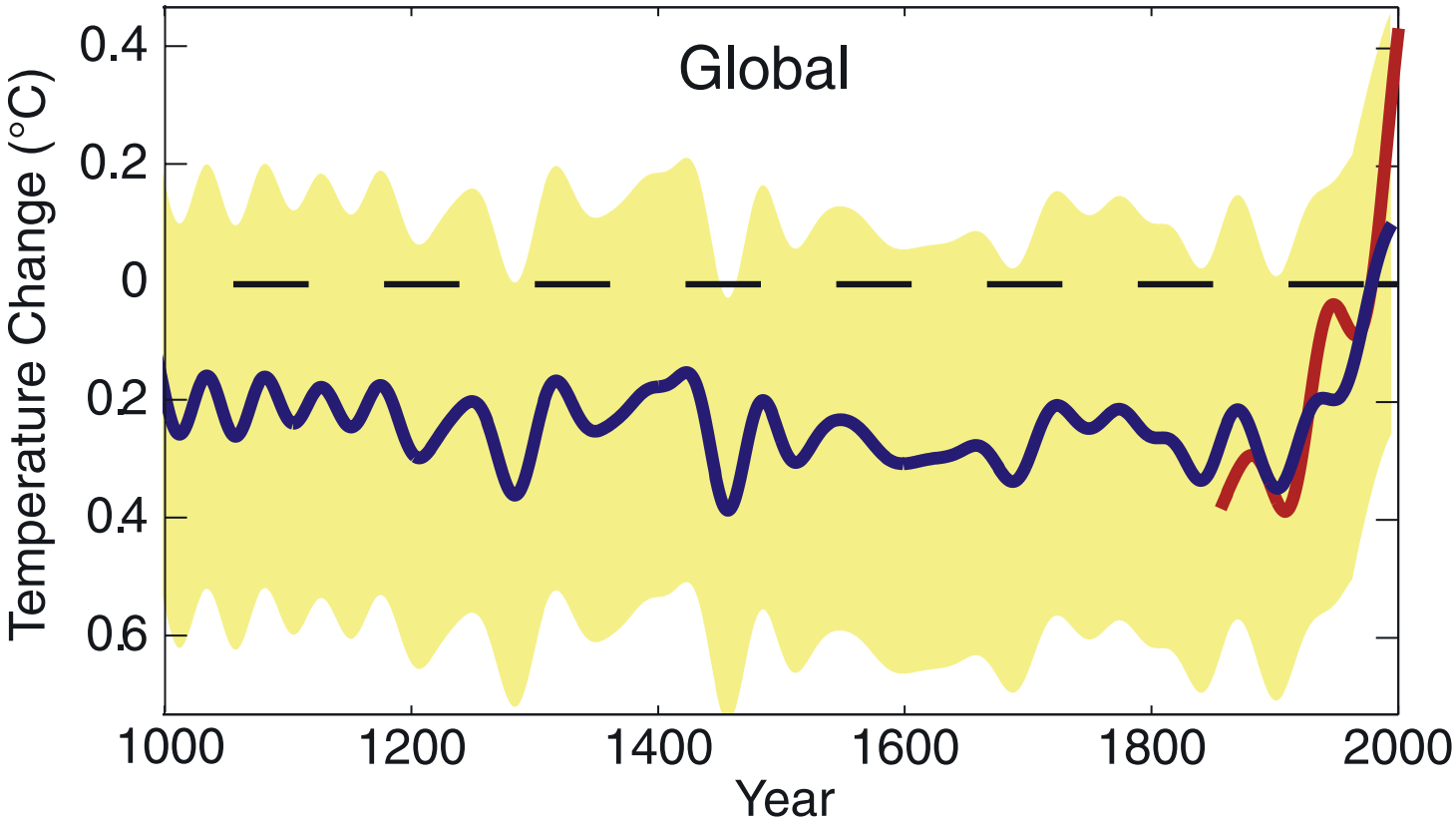
ATMOSPHERIC CARBON DIOXIDE IS INCREASING



Global carbon dioxide concentration and infrared radiative forcing over the last thousand years

GLOBAL TEMPERATURE TREND (1000-2000)

From tree-ring, coral, and ice-core proxy records
As calibrated by instrumental measurements



Instrumental record

Proxy reconstruction

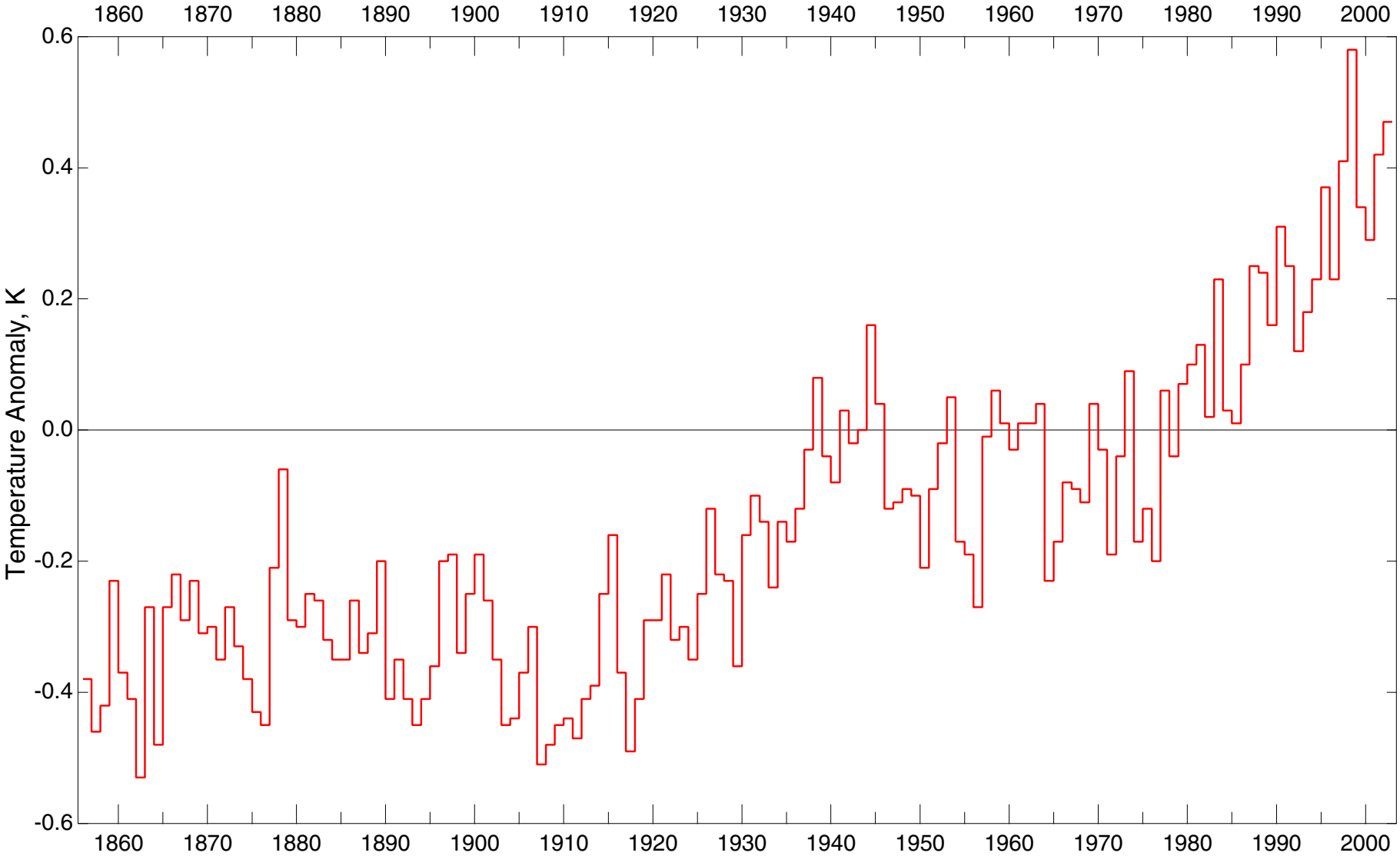
Uncertainty in proxy reconstruction

Jones & Mann, Revs. Geophys., 2004

GLOBAL AVERAGE TEMPERATURE TREND

1856-2002

Temperature Anomaly Relative to Base Period 1961-1990



Climate Research Unit, East Anglia UK

INDICATIONS OF SYSTEMATIC WARMING IN RECENT YEARS

The 1990s were the ***warmest decade*** in the instrumental record.

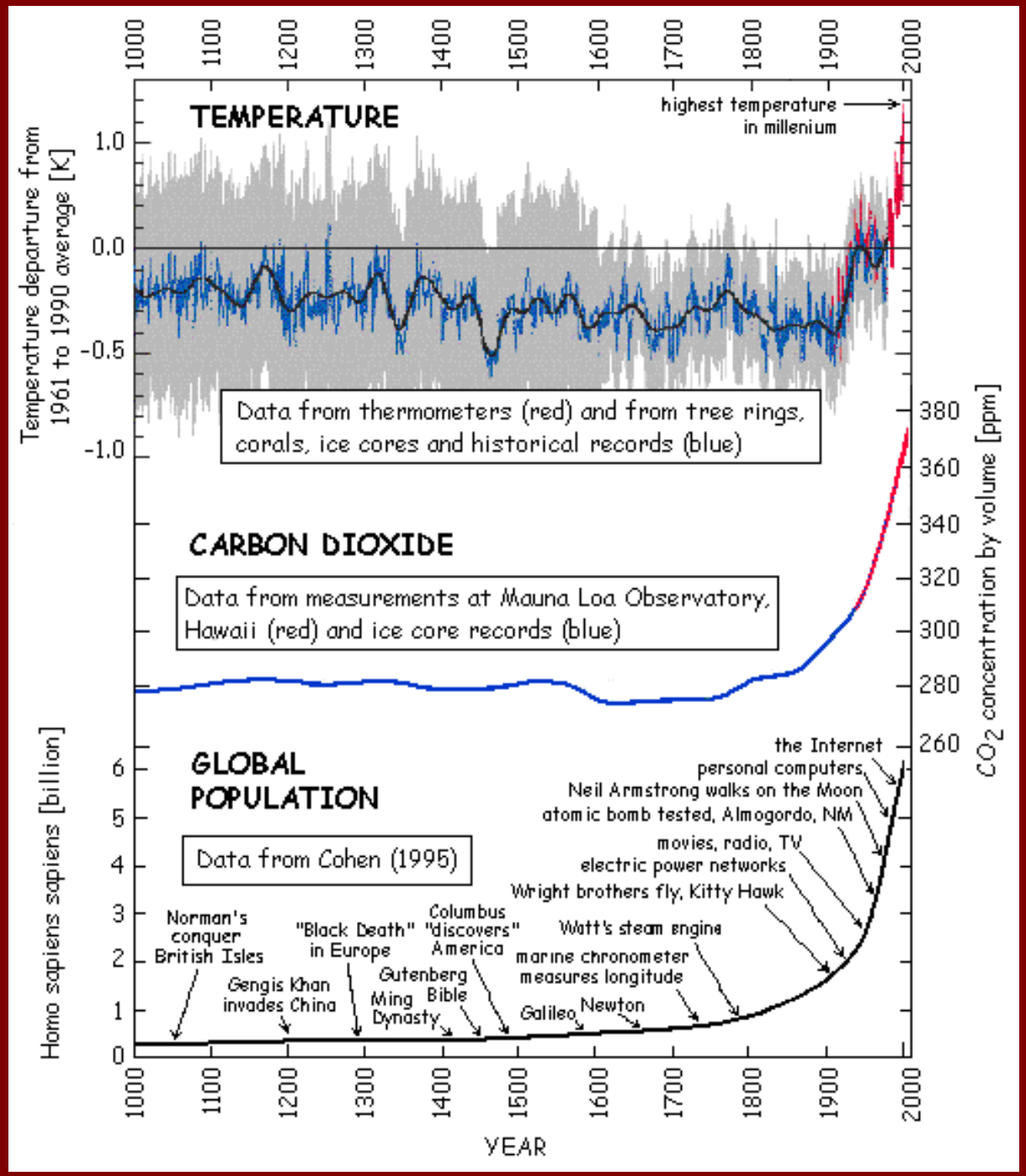
The ***warmest two years*** of the entire instrumental record have been 1998 and 2002.

The ***nine warmest years*** globally have now occurred in the 1990s and 2000s.

Global warming over the past millennium

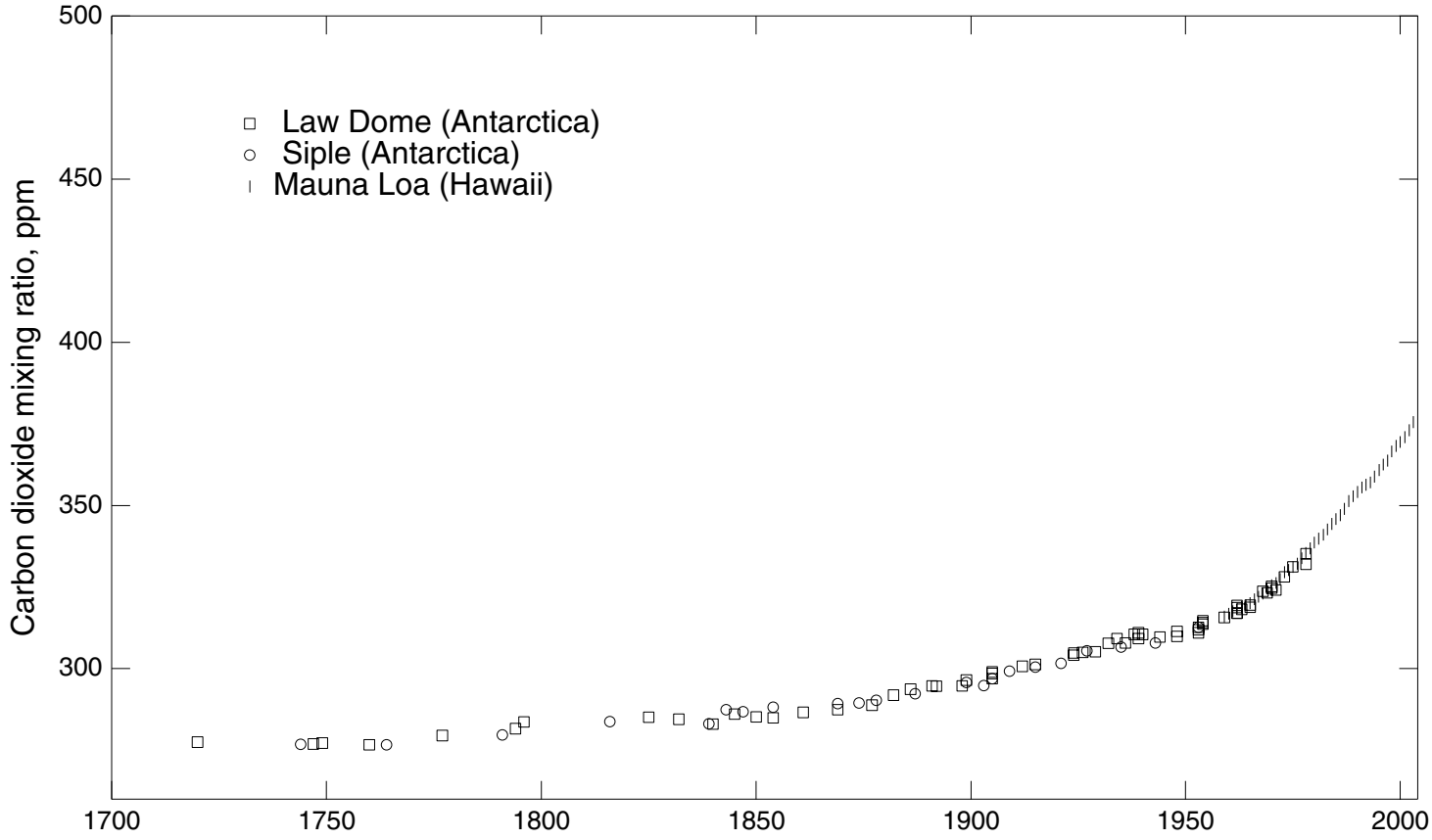
Very rapidly we have entered uncharted territory -– what some call the *anthropocene* climate regime. Over the 20th century, human population quadrupled and energy consumption increased sixteenfold. Near the end of the last century, we crossed a critical threshold, and global warming from the fossil fuel greenhouse became a major, and increasingly dominant, factor in climate change. Global mean surface temperature is higher today than it's been for at least a millennium.

Martin Hoffert, NYU



ATMOSPHERIC CARBON DIOXIDE

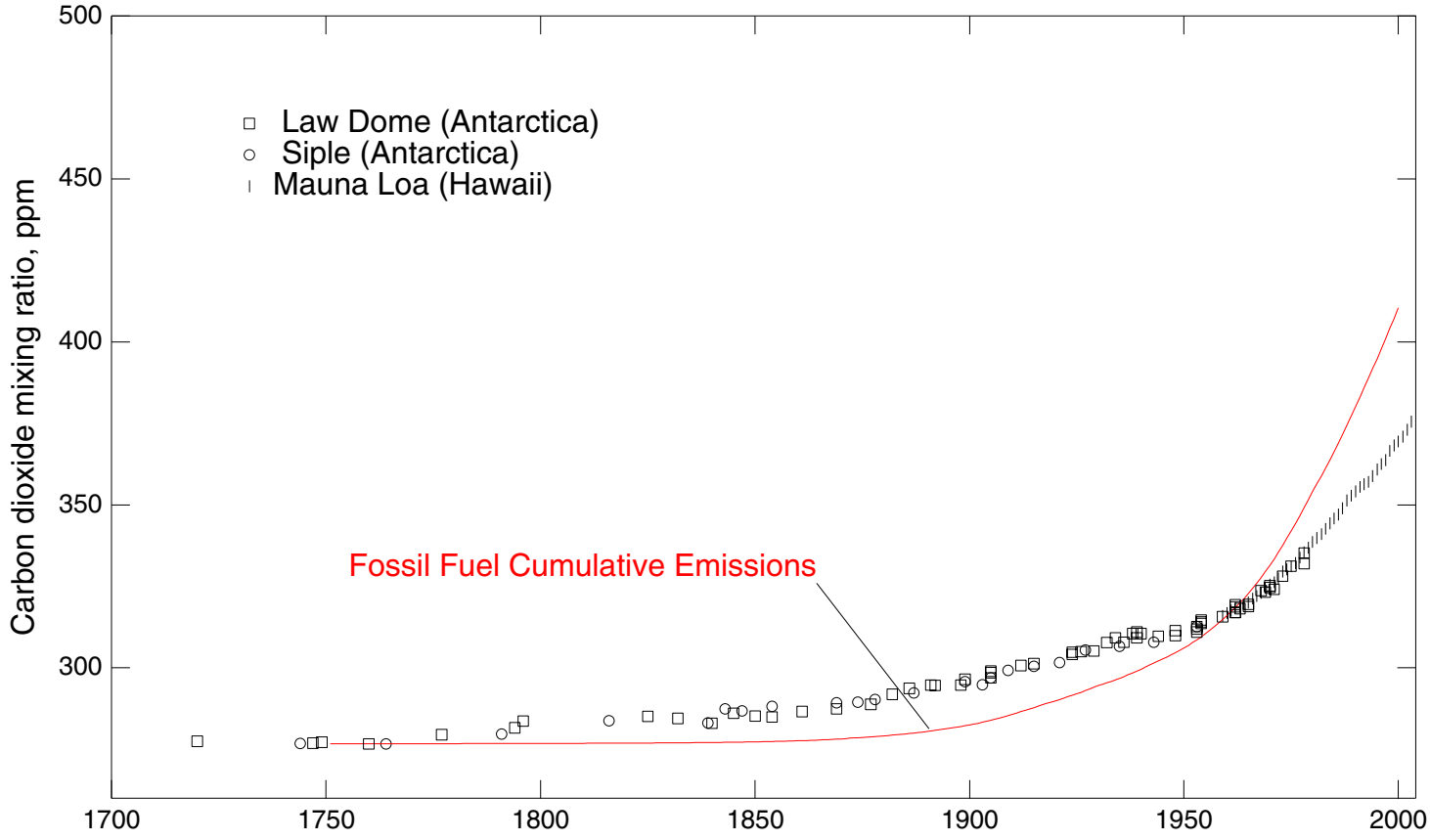
Time series 1700 - 2003



Law - Etheridge et al.
Siple - Friedli et al.
Mauna Loa - Keeling

ATMOSPHERIC CARBON DIOXIDE

Time series 1700 - 2003



Law - Etheridge et al.
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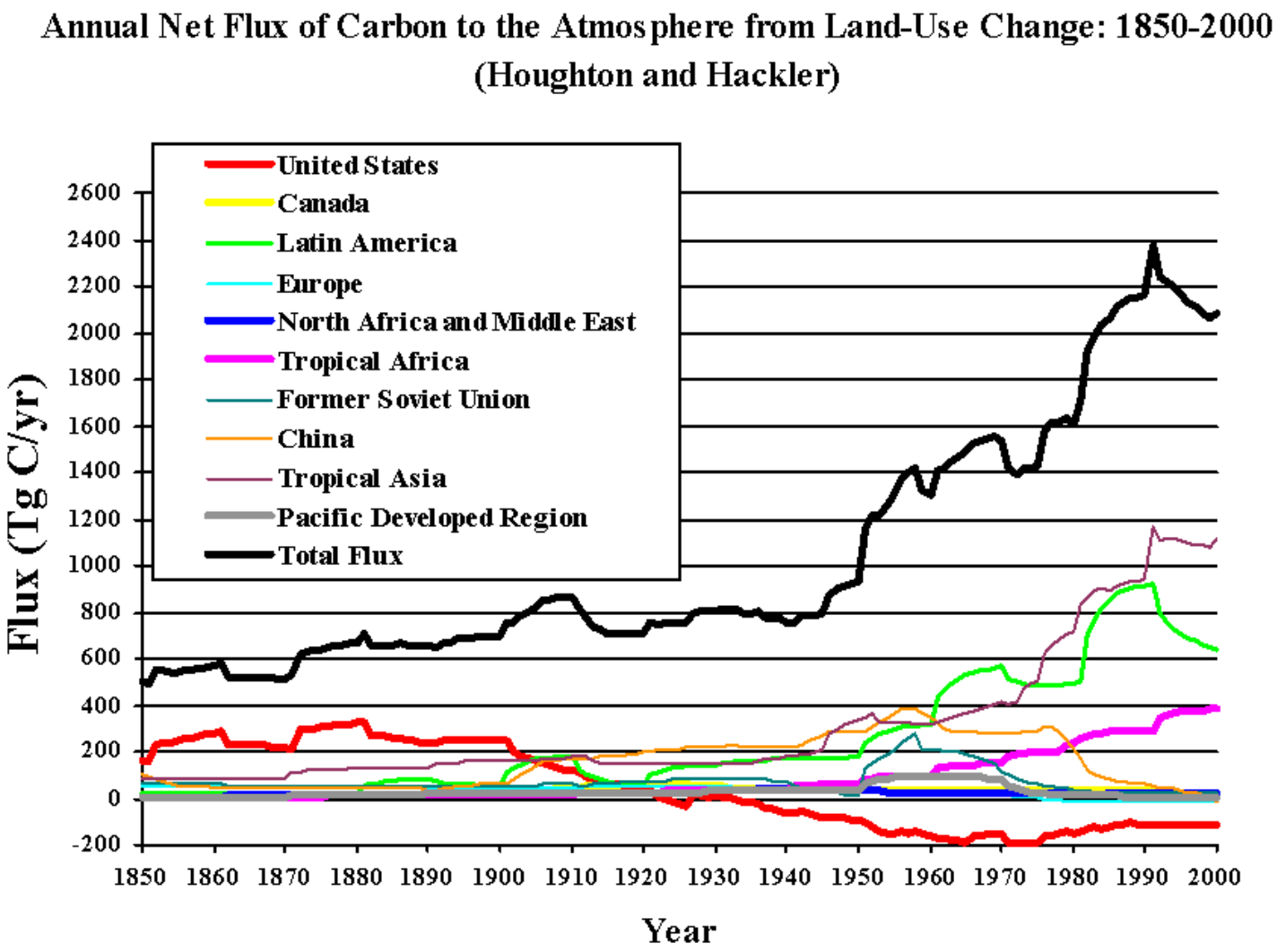
Mauna Loa - Keeling
Fossil Fuel - Marland

LAND USE CARBON EMISSIONS BY SOURCE REGION



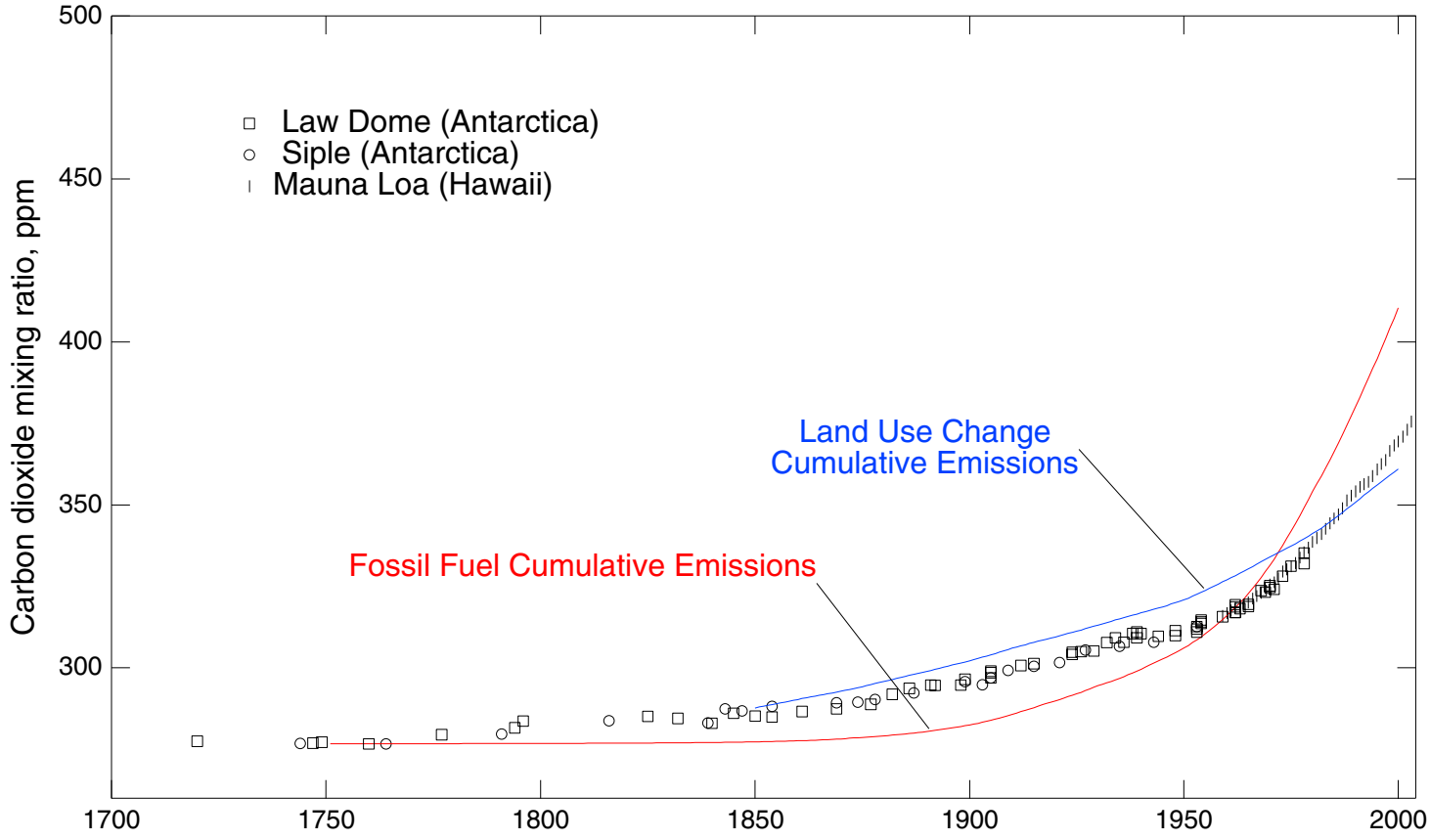
1000 Tg = 1 Pg
= 10^{15} g,
Equivalent to
0.47 ppm

Carbon flux estimated as land area times carbon emissions associated with land clearing or afforestation (uptake).

United States dominates emissions before 1900 and uptake after 1940.

ATMOSPHERIC CARBON DIOXIDE

Time series 1700 - 2003



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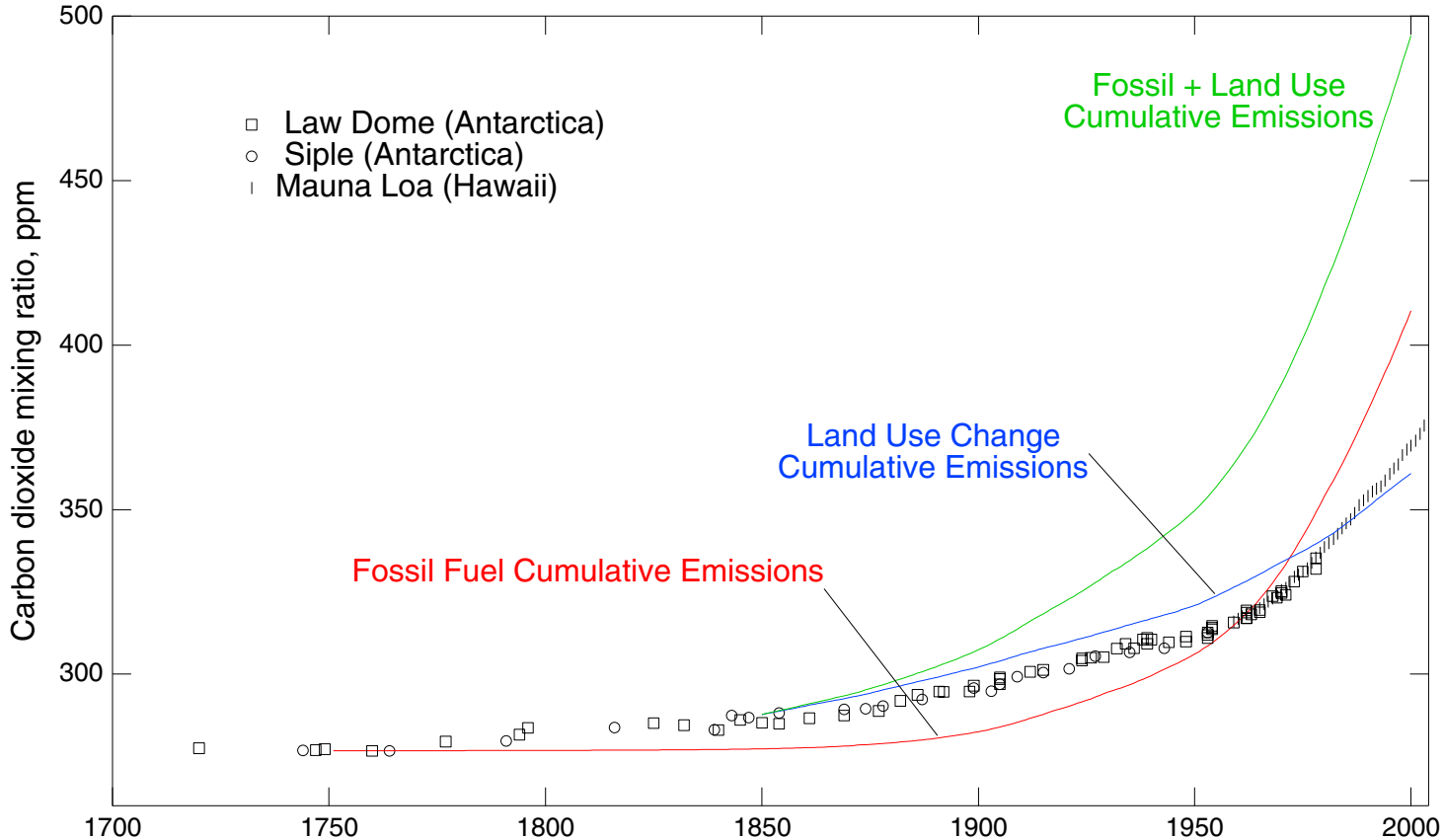

Law - Etheridge et al.
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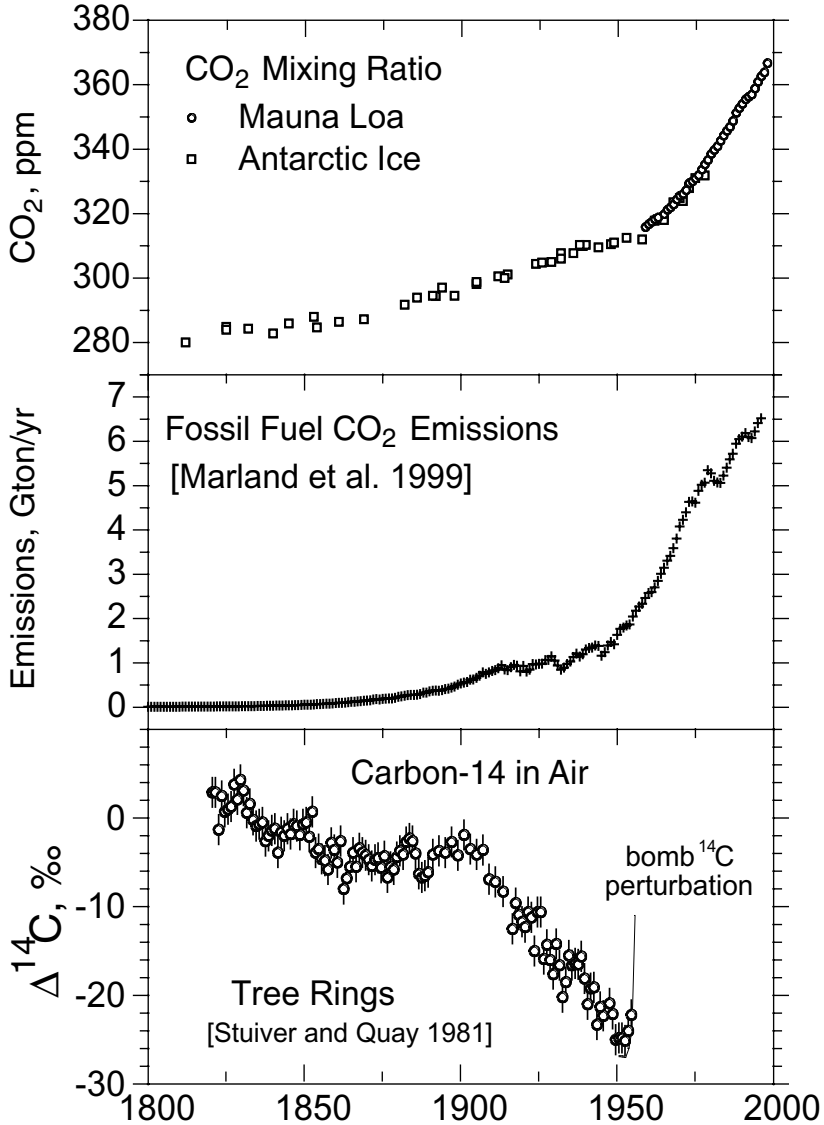
FOSSIL FUEL IMPACT ON ATMOSPHERIC CO_2 and ^{14}C



Levin and Hesshaimer, 2000

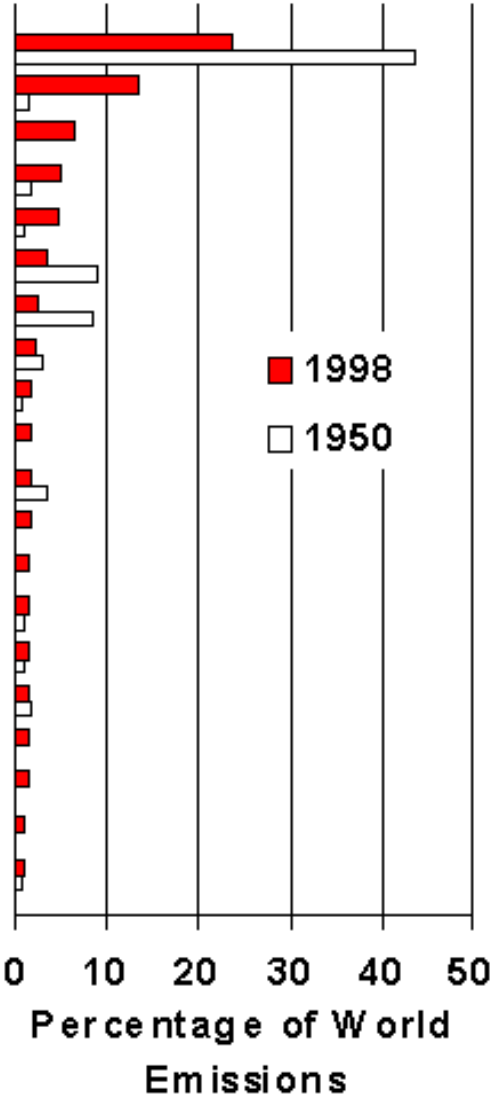
Atmospheric CO_2 increases with increasing fossil fuel CO_2 emissions.

Fraction of ^{14}C in atmospheric CO_2 decreases as fossil fuel CO_2 increases.

CARBON DIOXIDE EMISSIONS

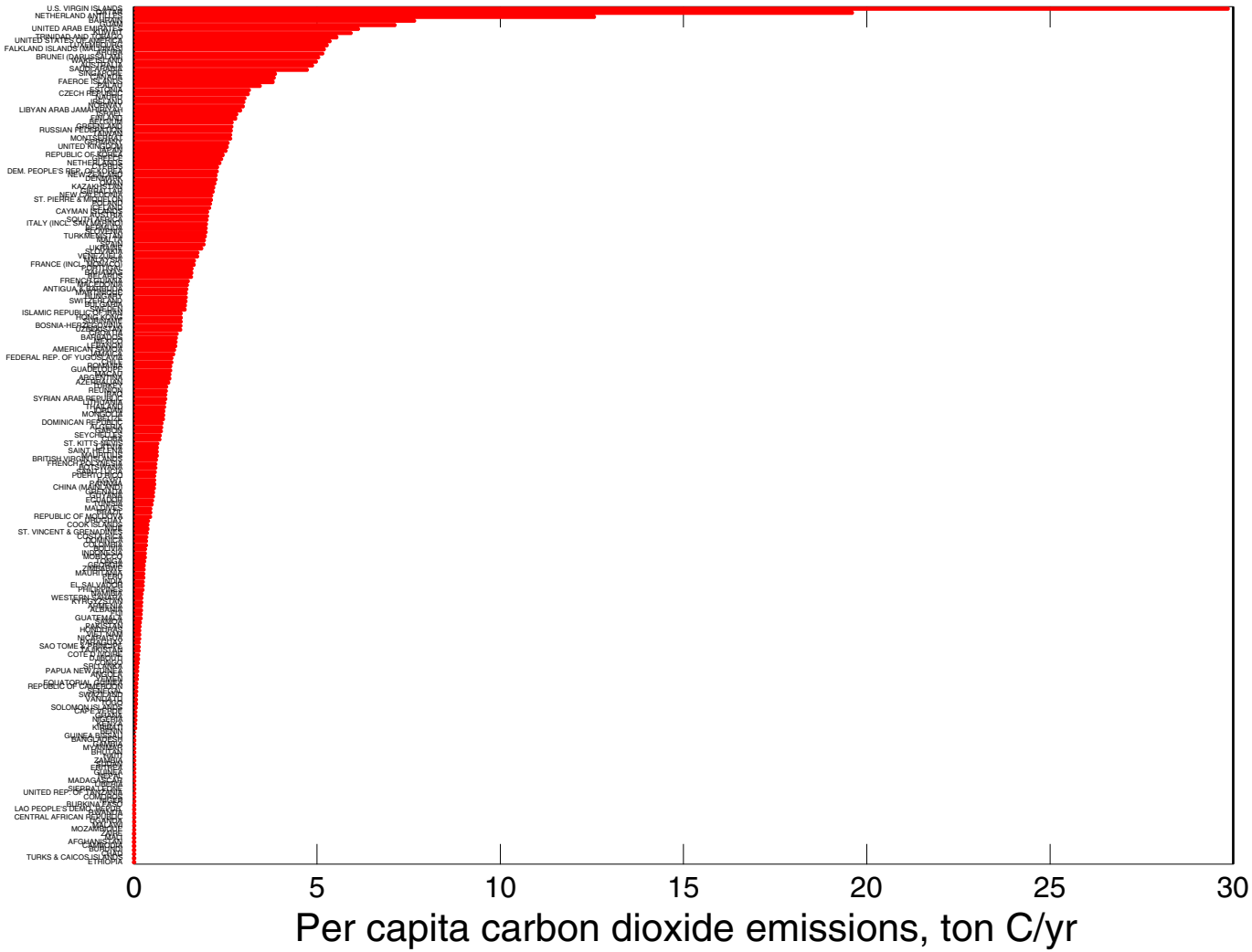
Percent of global fossil fuel emissions by country - 1998 and 1950

1998 Rank		1950 Rank
(1)	USA	(1)
(2)	China	(9)
(3)	Russia	(FSU=2)
(4)	Japan	(8)
(5)	India	(12)
(6)	Germany	(3)
(7)	UK	(4)
(8)	Canada	(6)
(9)	Italy	(16)
(10)	Mexico	(19)
(11)	France	(5)
(12)	South Korea	(58)
(13)	Ukraine	(FSU=2)
(14)	South Africa	(13)
(15)	Australia	(14)
(16)	Poland	(7)
(17)	Brazil	(24)
(18)	Iran	(28)
(19)	Saudi Arabia	(47)
(20)	Spain	(18)



Marland and Boden, Oak Ridge National Laboratory

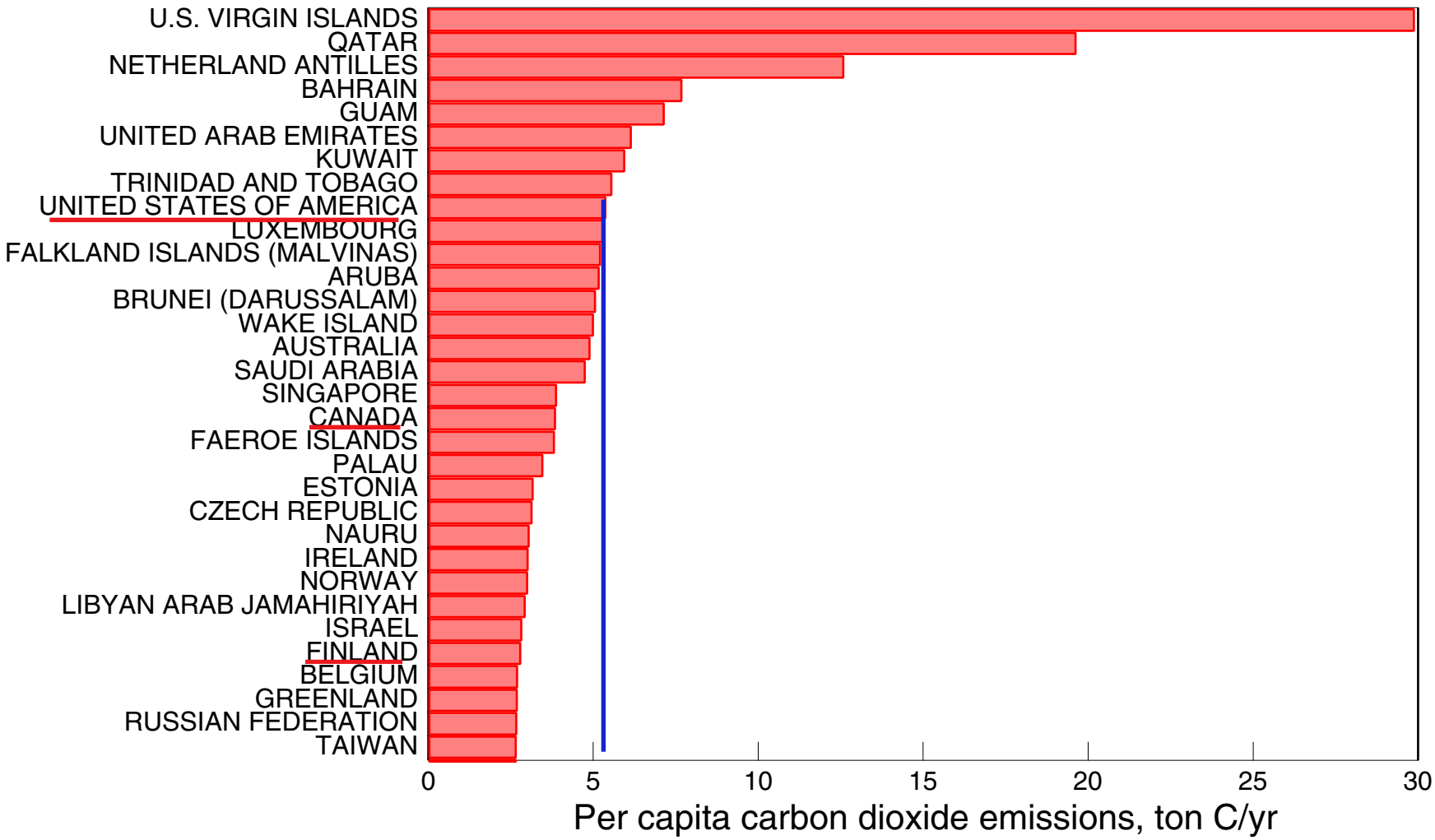
PER CAPITA FOSSIL FUEL CO_2 EMISSIONS



By country, year 2000.

Data: G. Marland, Oak Ridge National Laboratory

PER CAPITA FOSSIL FUEL CO_2 EMISSIONS



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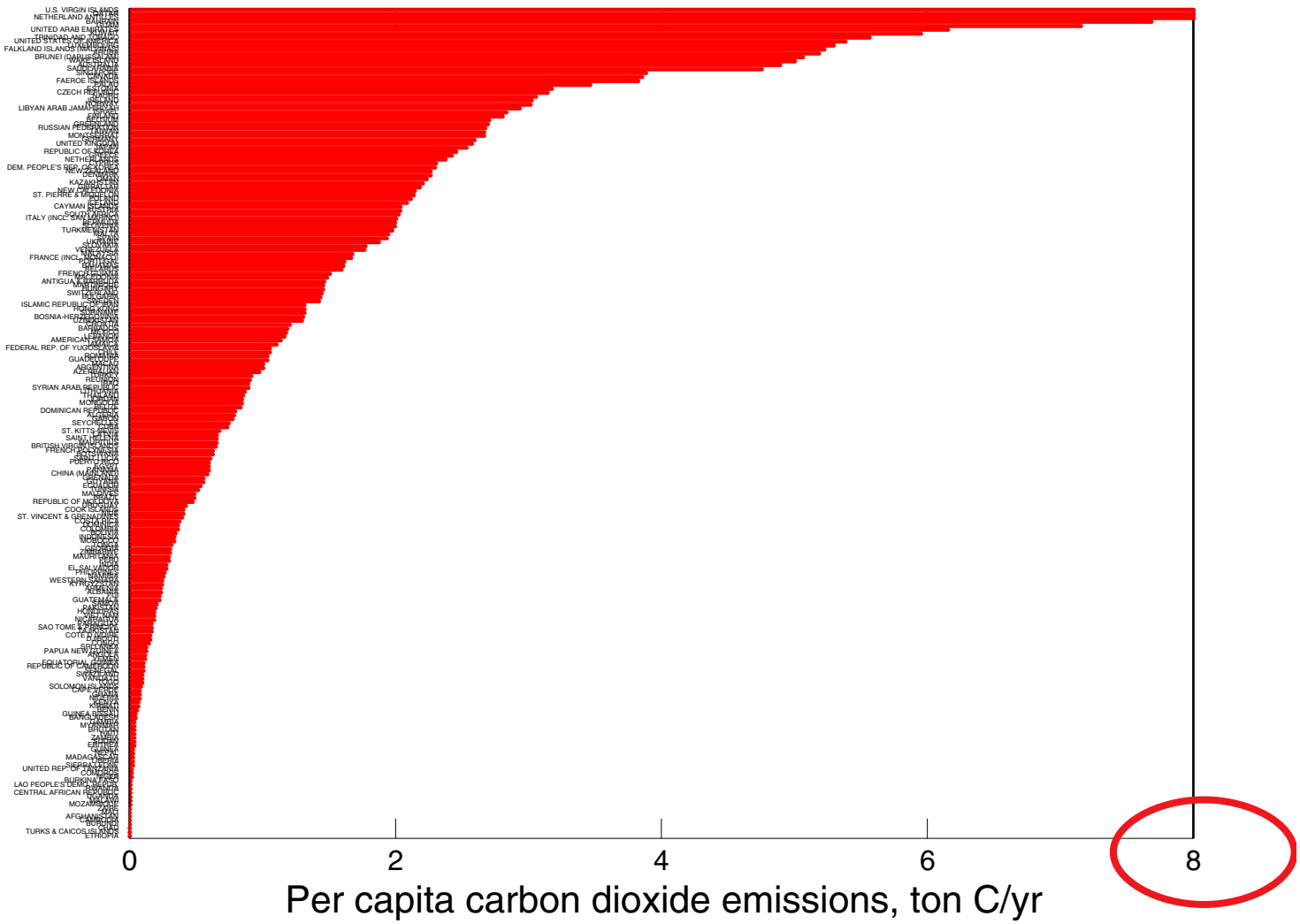

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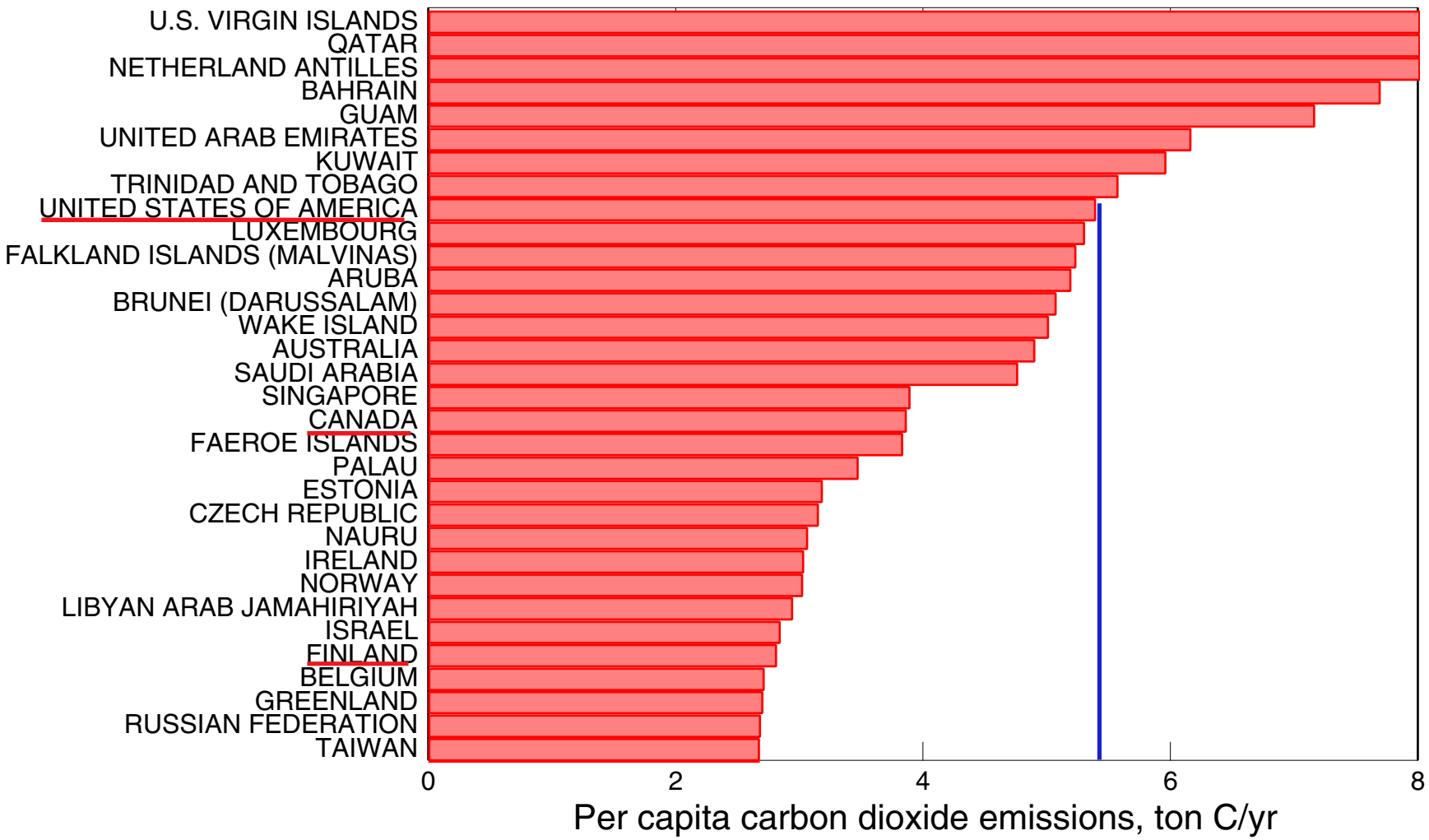

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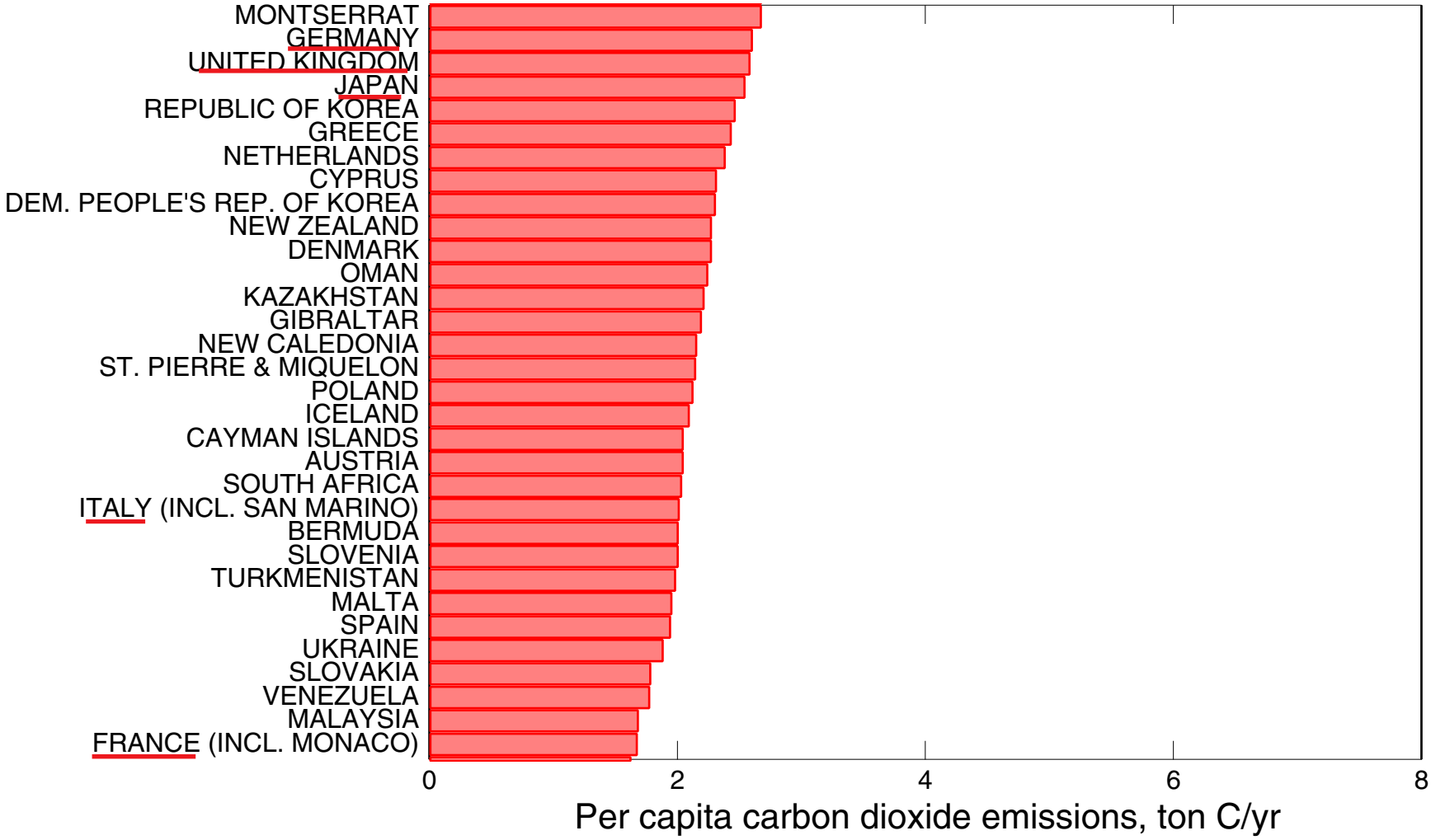

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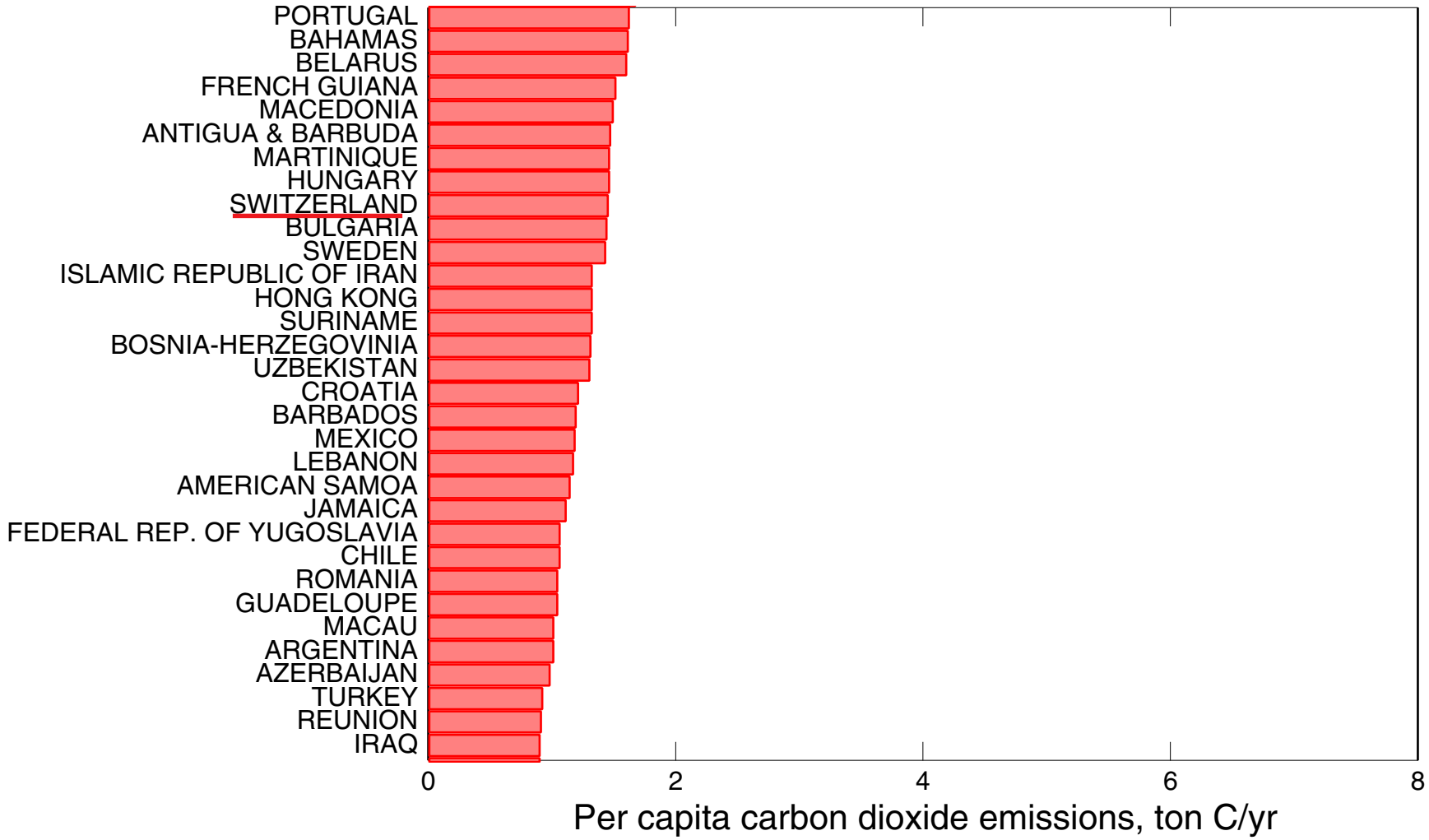

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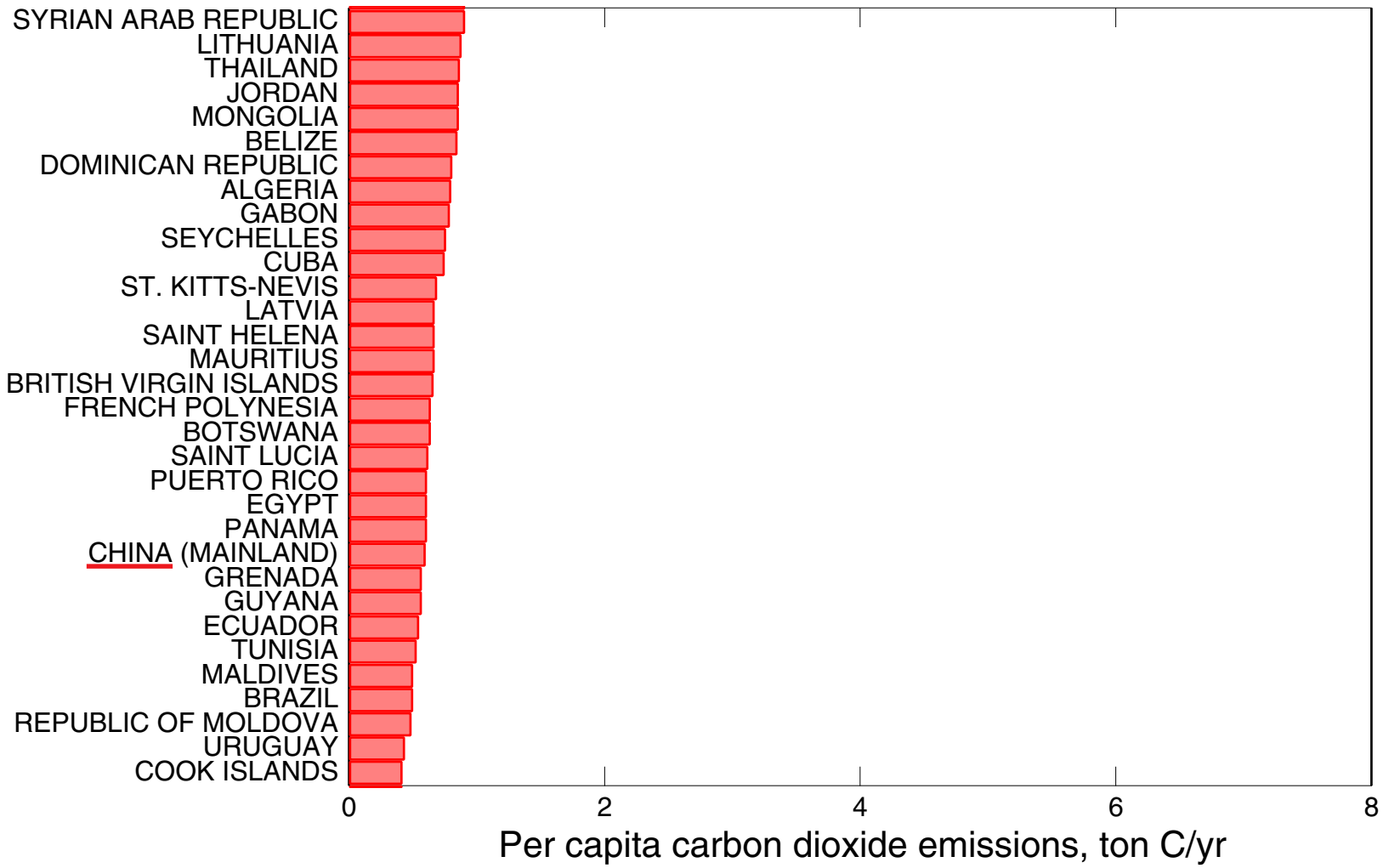

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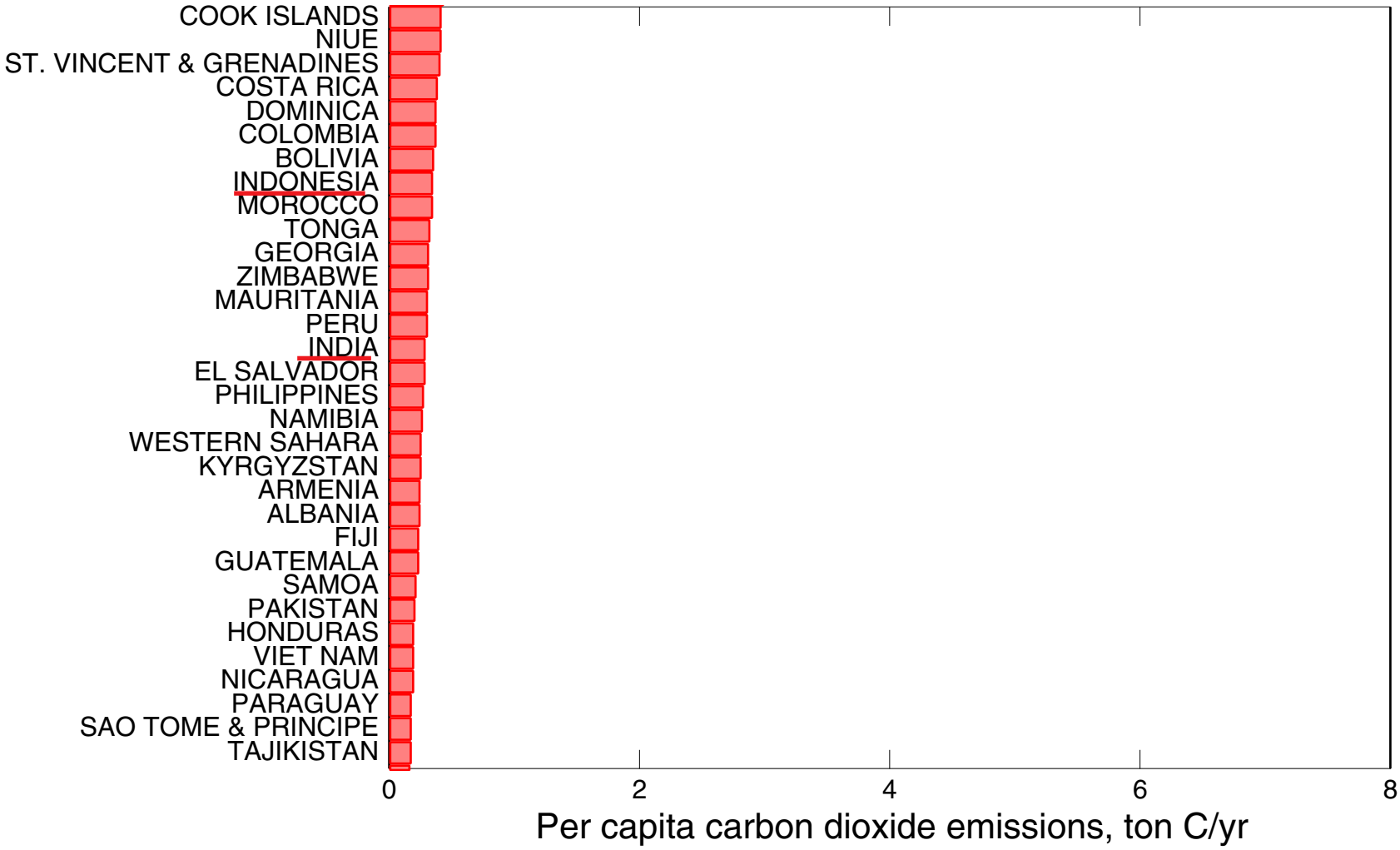

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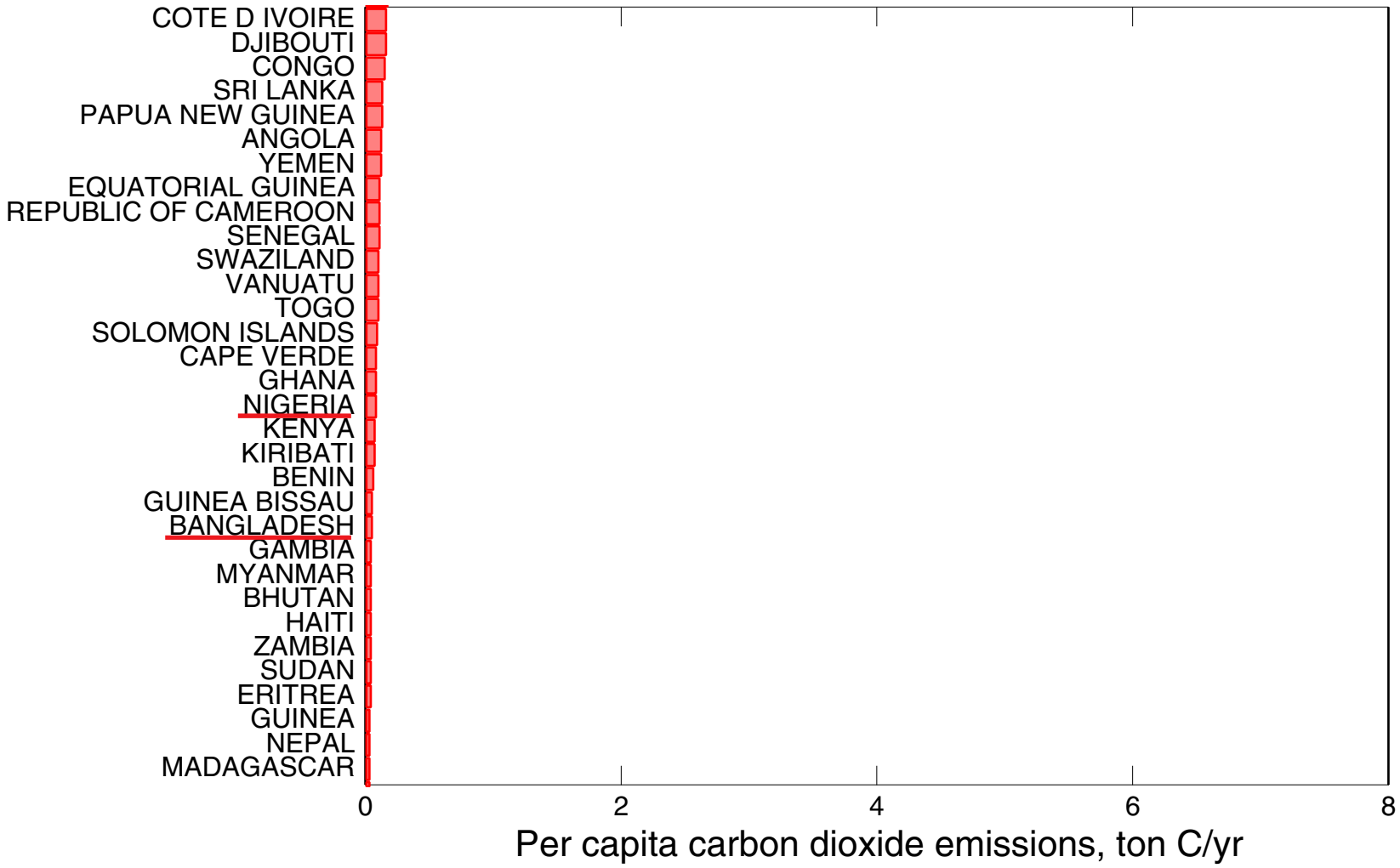

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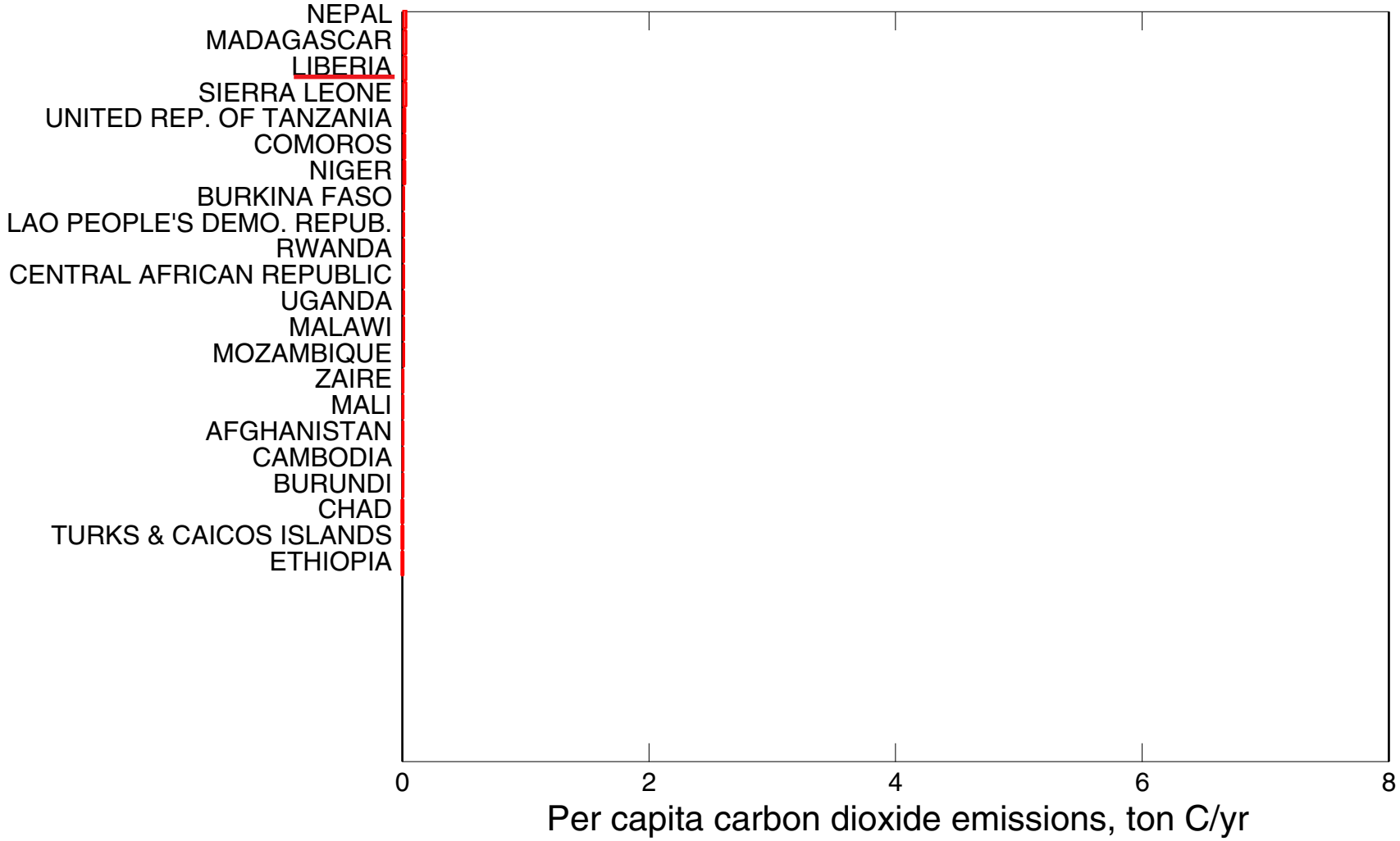
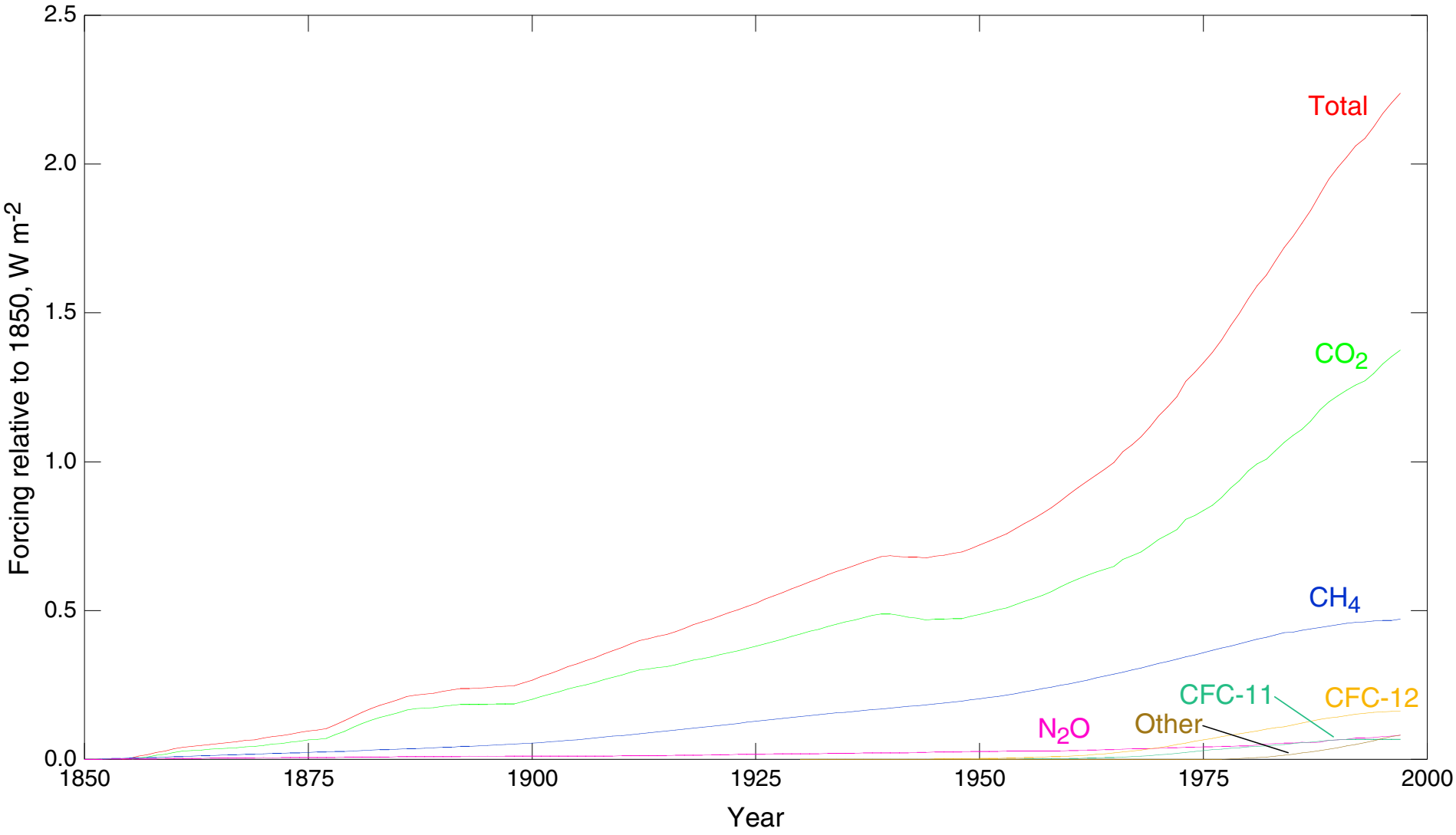


By country, year 2000.

Data: G. Marland, Oak Ridge National Laboratory

GREENHOUSE GAS FORCINGS OVER THE INDUSTRIAL PERIOD



Data: GISS

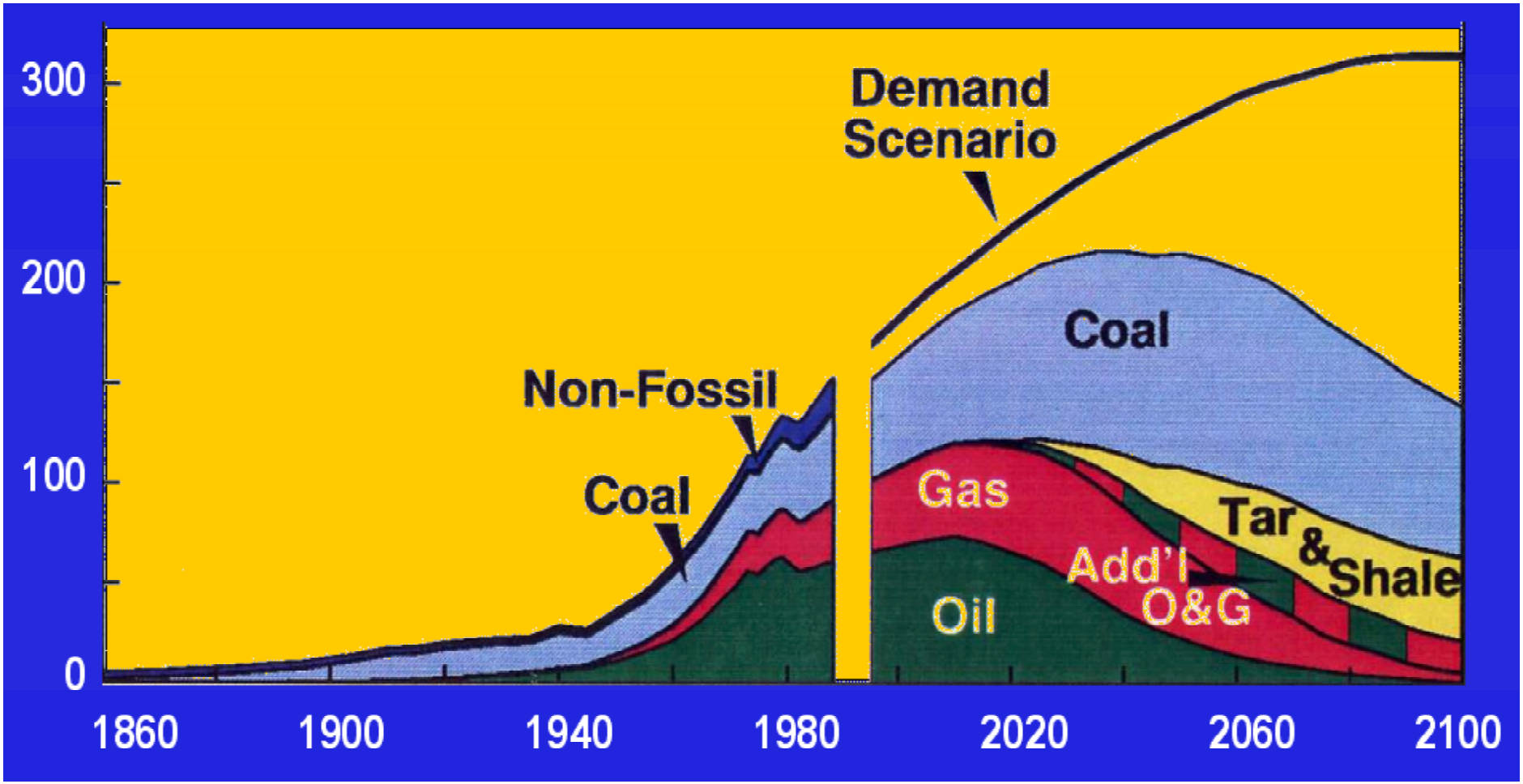
Looking to the Future . . .

In the long run we're all dead

– John Maynard Keynes

WORLD ENERGY

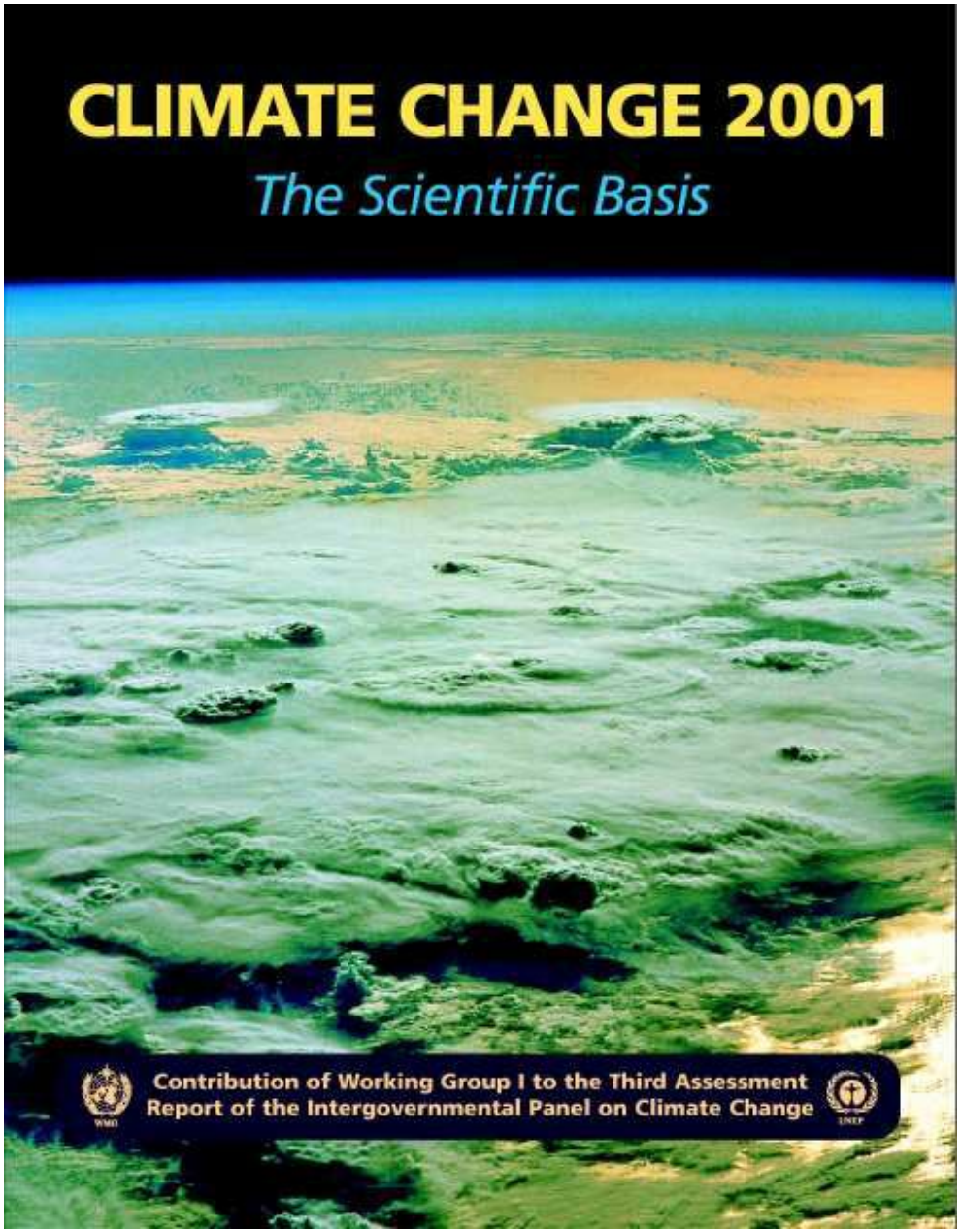
Millions of Barrels per Day (Oil Equivalent)



J. Bookout (President of Shell USA, 1985)

THE “BIBLE” OF CLIMATE CHANGE RESEARCH

WMO

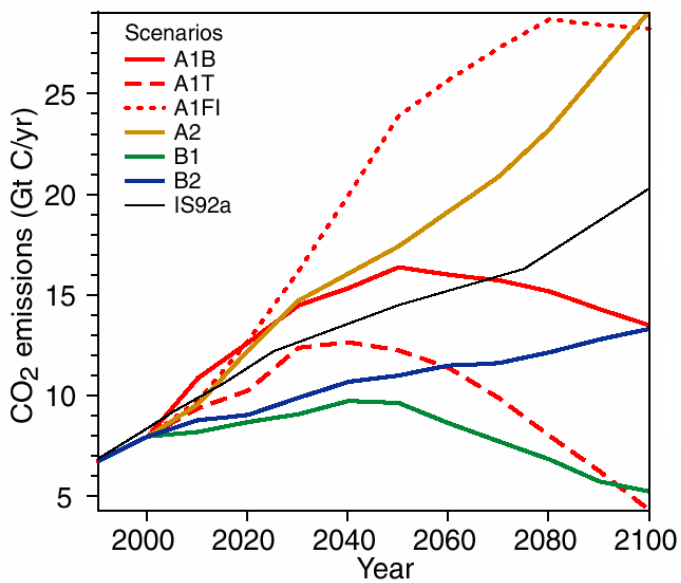


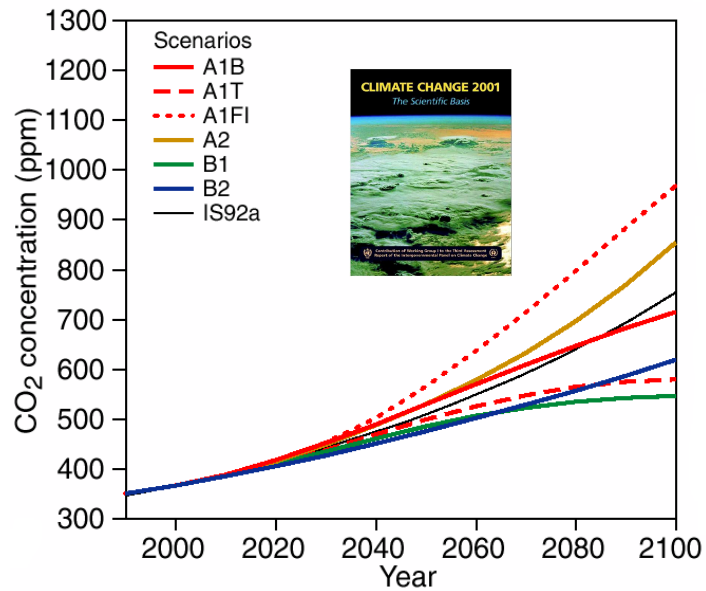
UNEP

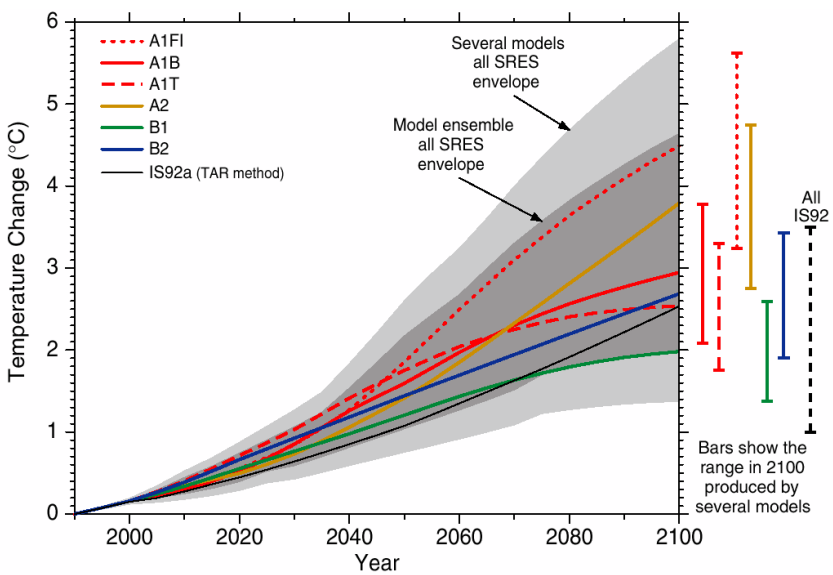
Cambridge University Press, 2001

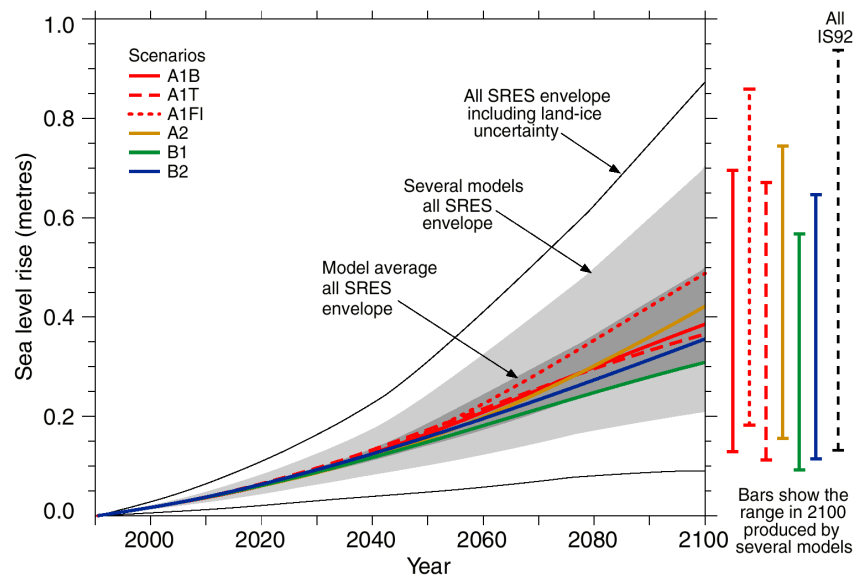
http://www.grida.no/climate/ipcc_tar/wg1/

FUTURE CLIMATE IS HIGHLY UNCERTAIN









Contributors to uncertainty in future temperature include ***emissions***, ***concentrations***, and Earth's ***climate sensitivity***.

WHERE IS ALL THIS CO_2 COMING FROM?

WHO IS RESPONSIBLE?

HOW MUCH CARBON IS IN A GALLON OF GASOLINE?

1 lb?

2 lbs?

3 lbs!?

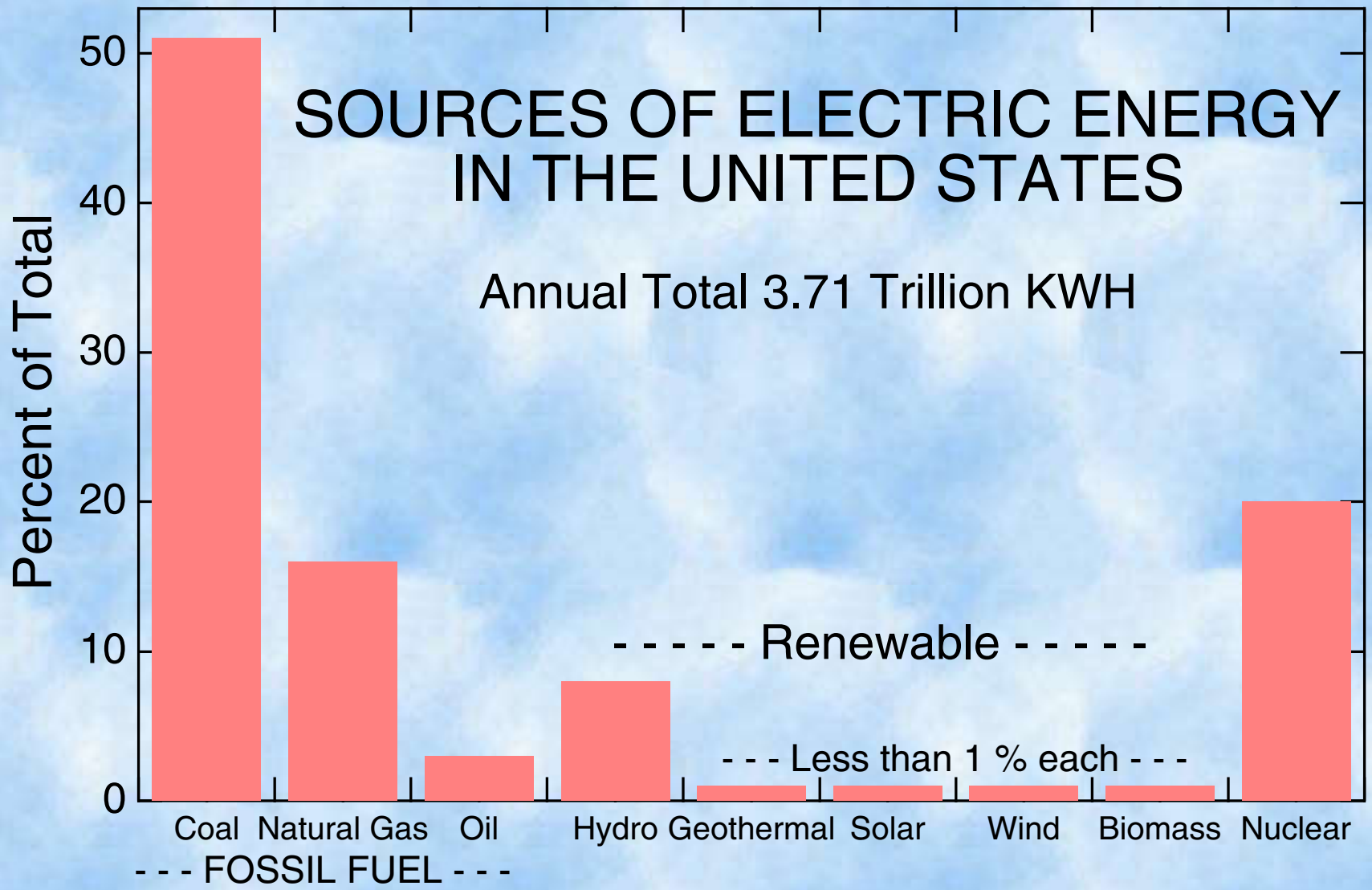
5 lbs!?!

All of this carbon goes into the atmosphere as carbon dioxide when you burn the gasoline in your car.

THE MOST EFFECTIVE WAY TO DOUBLE THE FUEL ECONOMY OF A CAR . . .

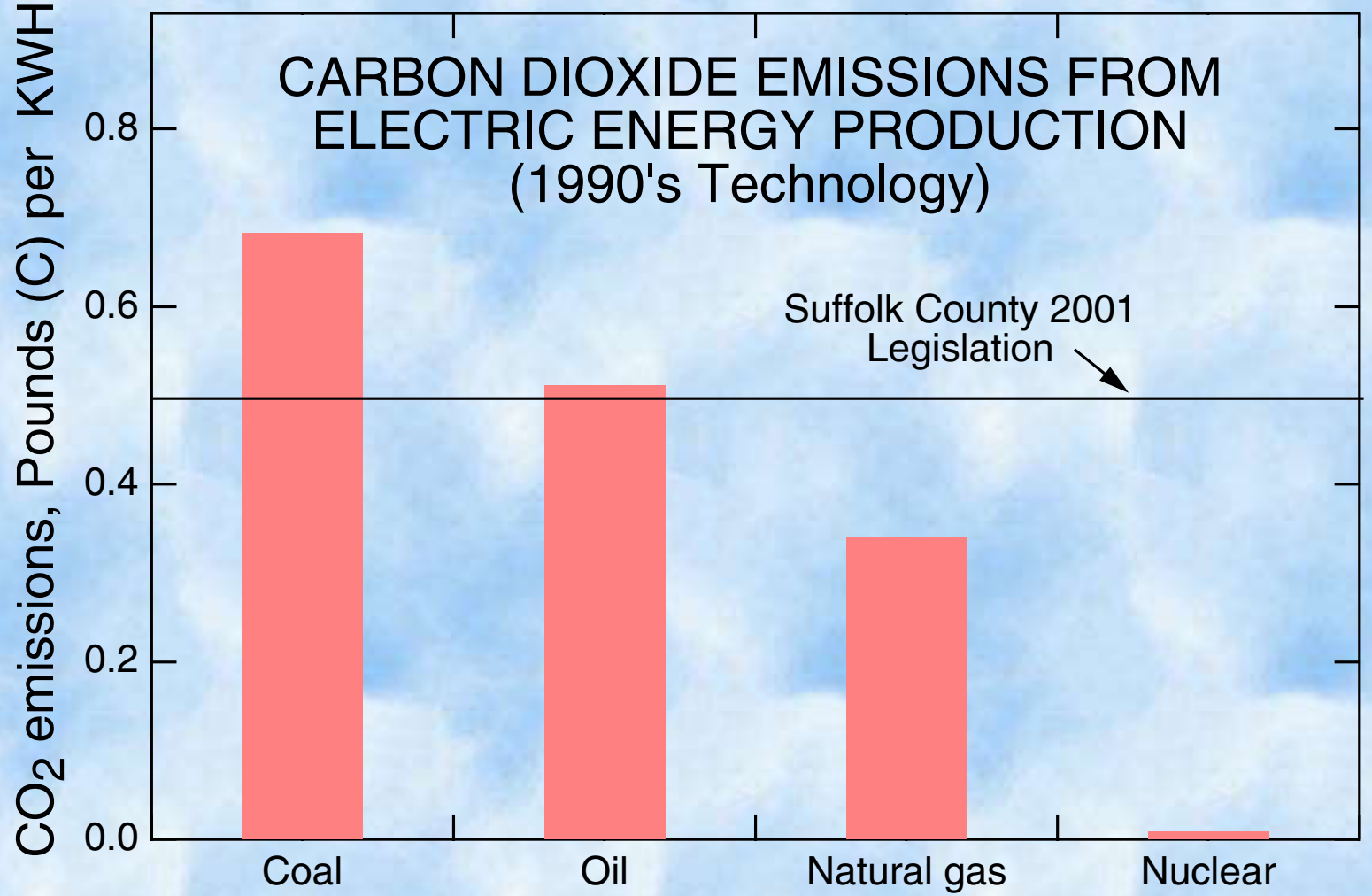
IS TO PUT TWO PEOPLE IN IT!

WHERE DOES YOUR ELECTRIC ENERGY COME FROM?



On Long Island most electric energy derives from combustion of oil.

YOUR FAMILY'S CONTRIBUTION TO THE GREENHOUSE EFFECT



A typical household using 1000 kilowatt hours of electricity per month is responsible for emission of 3 tons of carbon a year in the form of carbon dioxide.

How much does your household contribute?

YOUR CONTRIBUTION TO THE GREENHOUSE EFFECT

ELECTRIC SUPPLY AND DELIVERY FROM LIPA

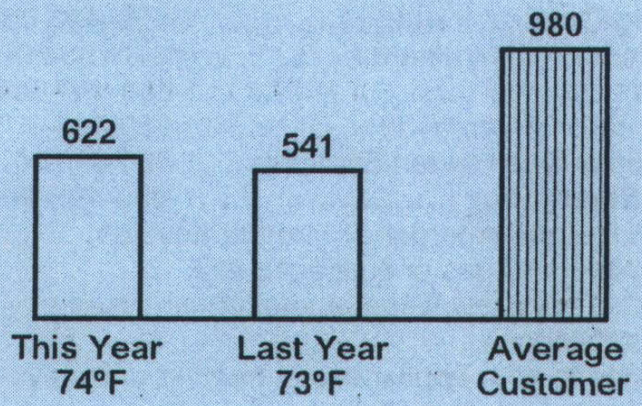
Meter Readings Meter # 15790134

	Jul 24	93155	Actual
	Jun 26	92533	Actual
Use	28 **Days**	622	**KWH**

Cost Rate 880 - Water and Home Heating

Basic Service: 28 Days @ 17.90¢	$5.01
Use: 233 KWH @ 12.49¢	29.10
140 KWH @ 13.67¢	19.14
249 KWH @ 9.78¢	24.35
Excess Fuel Price Surcharge	4.28
PILOTs and Credits	1.40
Shoreham Credit	-.59
Sales Tax: @ 1%	.83
Total	$83.52

Comparisons KWH



500 pounds of carbon per month
3 tons of carbon per year

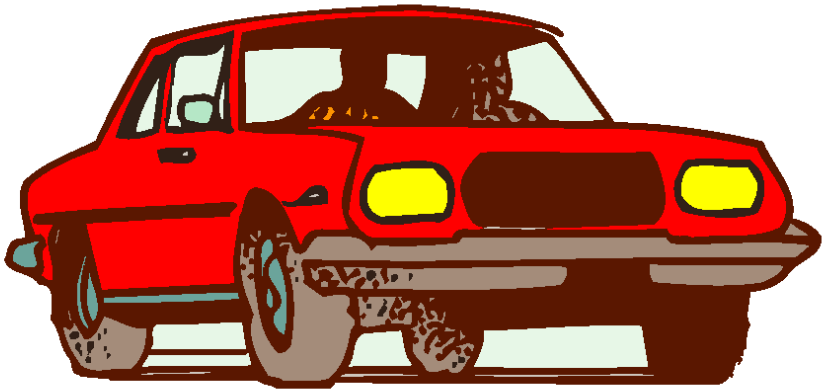
LIPA Long Island Power Authority

Jul 25, 2001	927 20 1805 3 5	1-800-490-0025	See Back Of Bill
Date	Account Number	Any Questions?	Service Problems

At half a pound of carbon per KWH, the average household is responsible for emission of 500 pounds of carbon a month .

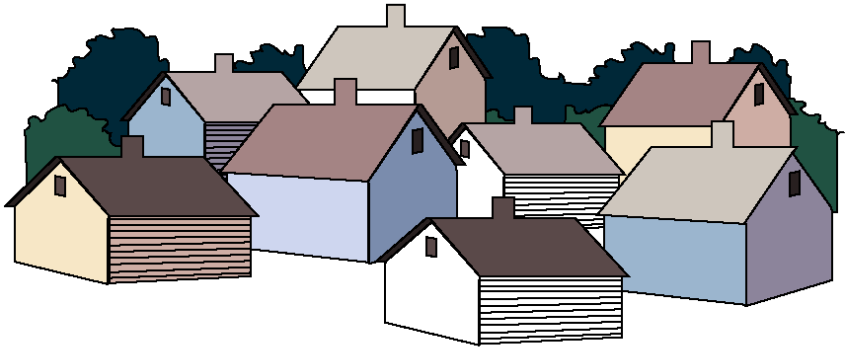
WHERE IS THIS CARBON DIOXIDE COMING FROM?

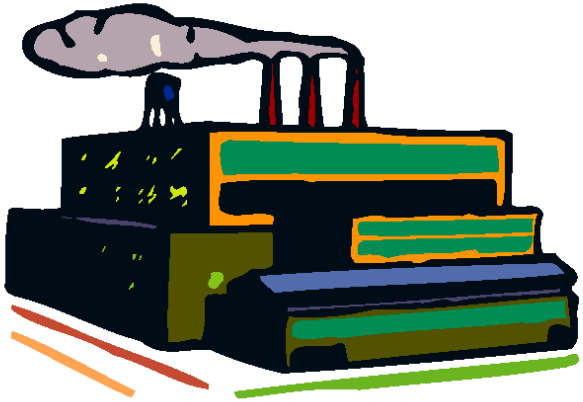
WE ARE ALL RESPONSIBLE.



Burning a gallon of gasoline in your car puts 5 pounds of carbon in the atmosphere as carbon dioxide (CO_2), and it will stay there for decades — maybe a century!

Other sources are home heating and electric power production.





KYOTO PROTOCOLS

The 38 “developed” countries are required to reduce emissions (of CO_2 and non-CO_2 greenhouse gases) for the period 2008 to 2012 to an average of ***5.3% less*** (in CO_2 equivalents) than comparable emissions in 1990.

Global Atmosphere, Global Warming

QUESTIONS ABOUT GLOBAL WARMING

- IS IT REAL?
- IS IT IMPORTANT?
- WHAT IS IT DUE TO?
- HOW MUCH MORE CAN WE EXPECT?
- ARE WE SEEING JUST THE TIP OF THE ICEBERG?

RESEARCH AT BROOKHAVEN NATIONAL LABORATORY IS HELPING TO ANSWER THESE QUESTIONS.