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Future Energy Systems

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The world is not without limits...

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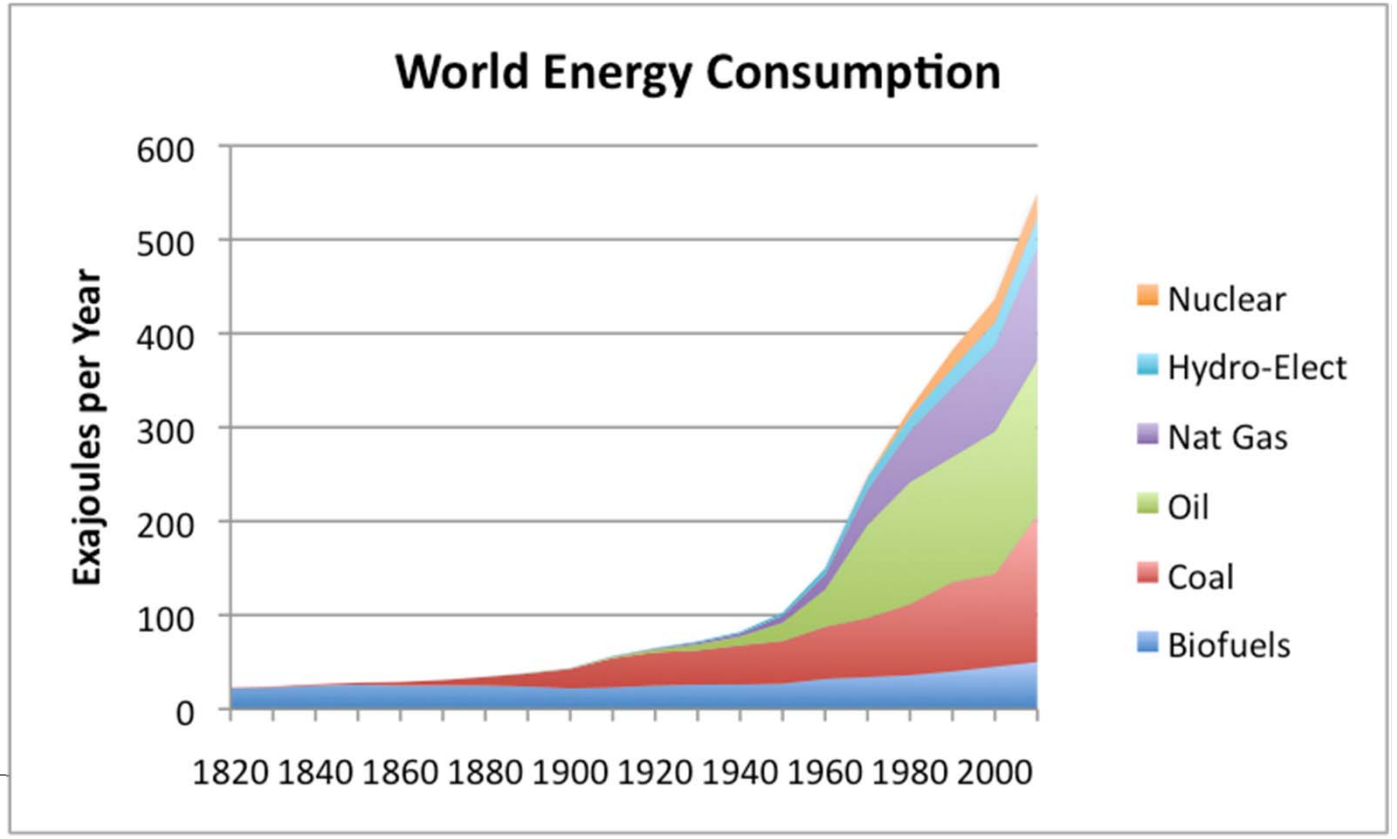
Energy use is increasing rapidly!
Is this sustainable?
And what are the reasons?



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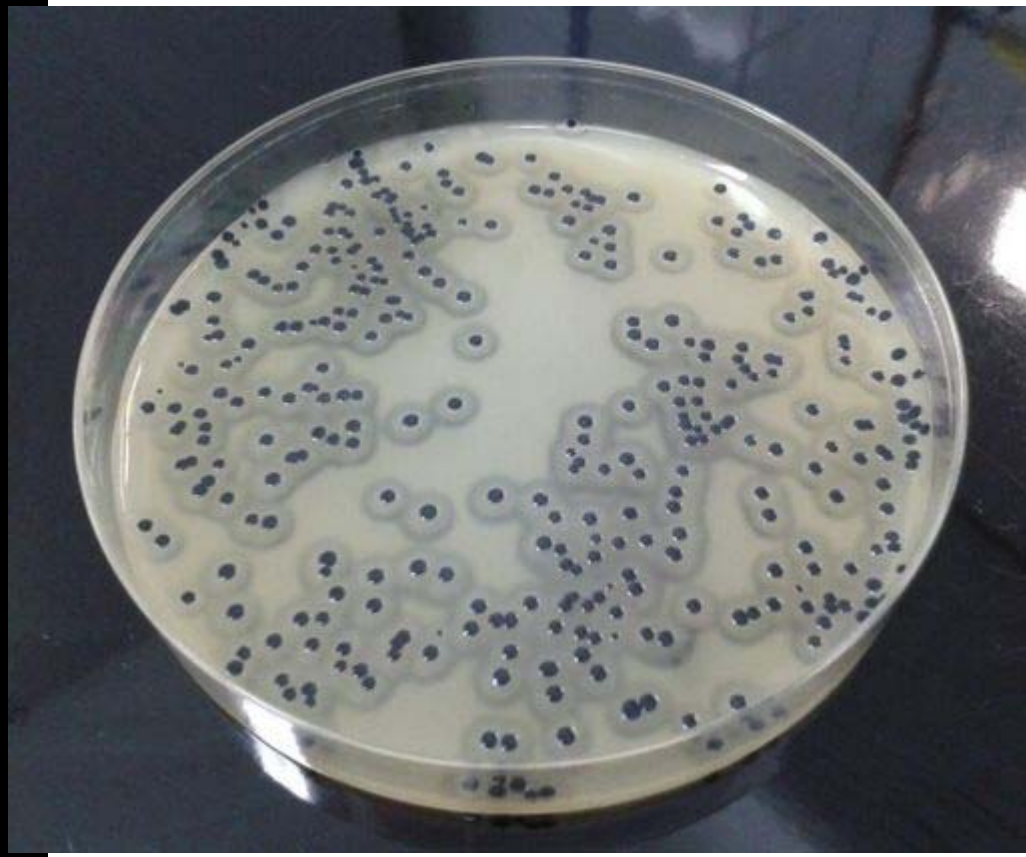
1. The world population is increasing...



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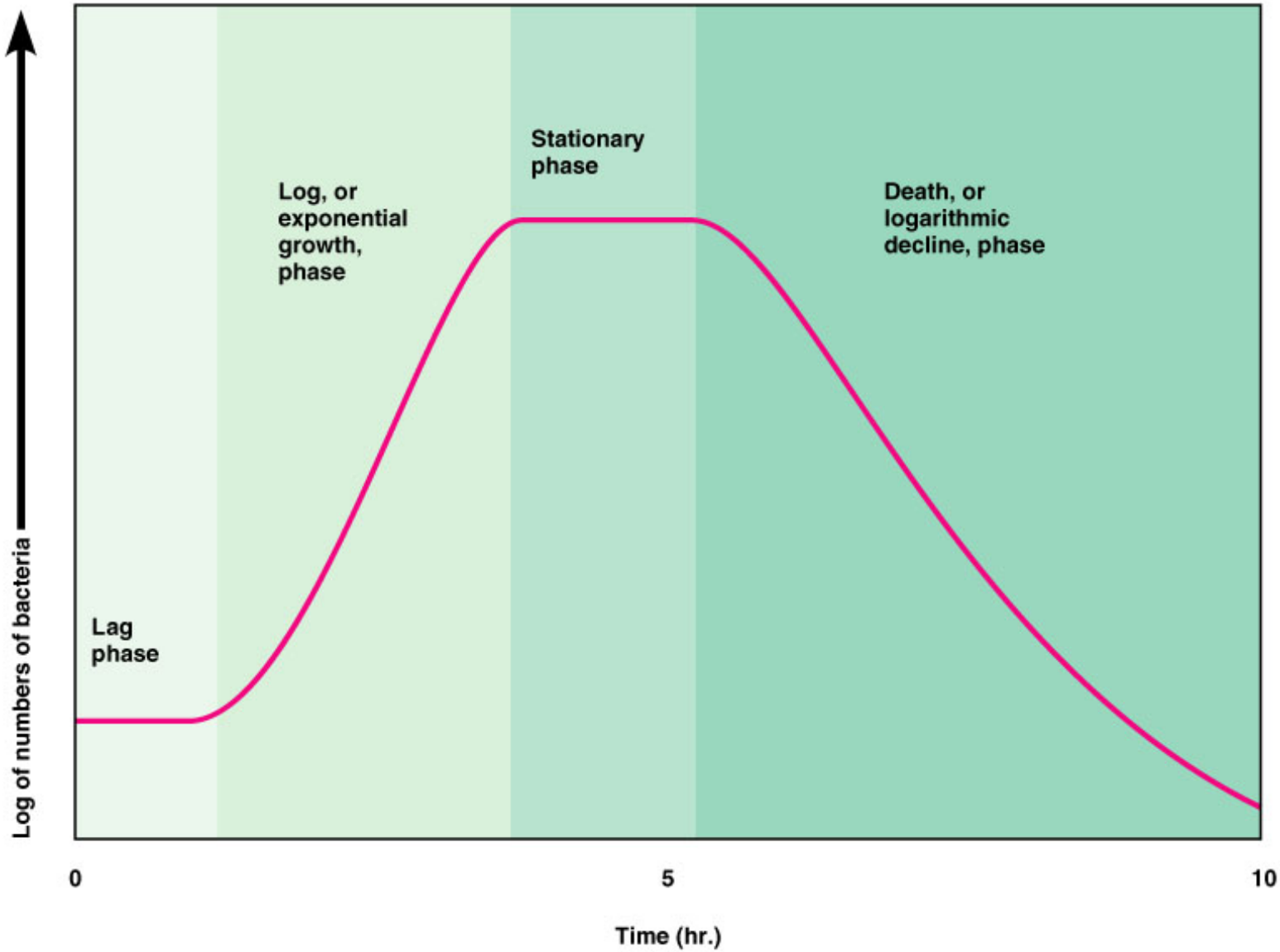
Population growth and decay of a species in a limited environment



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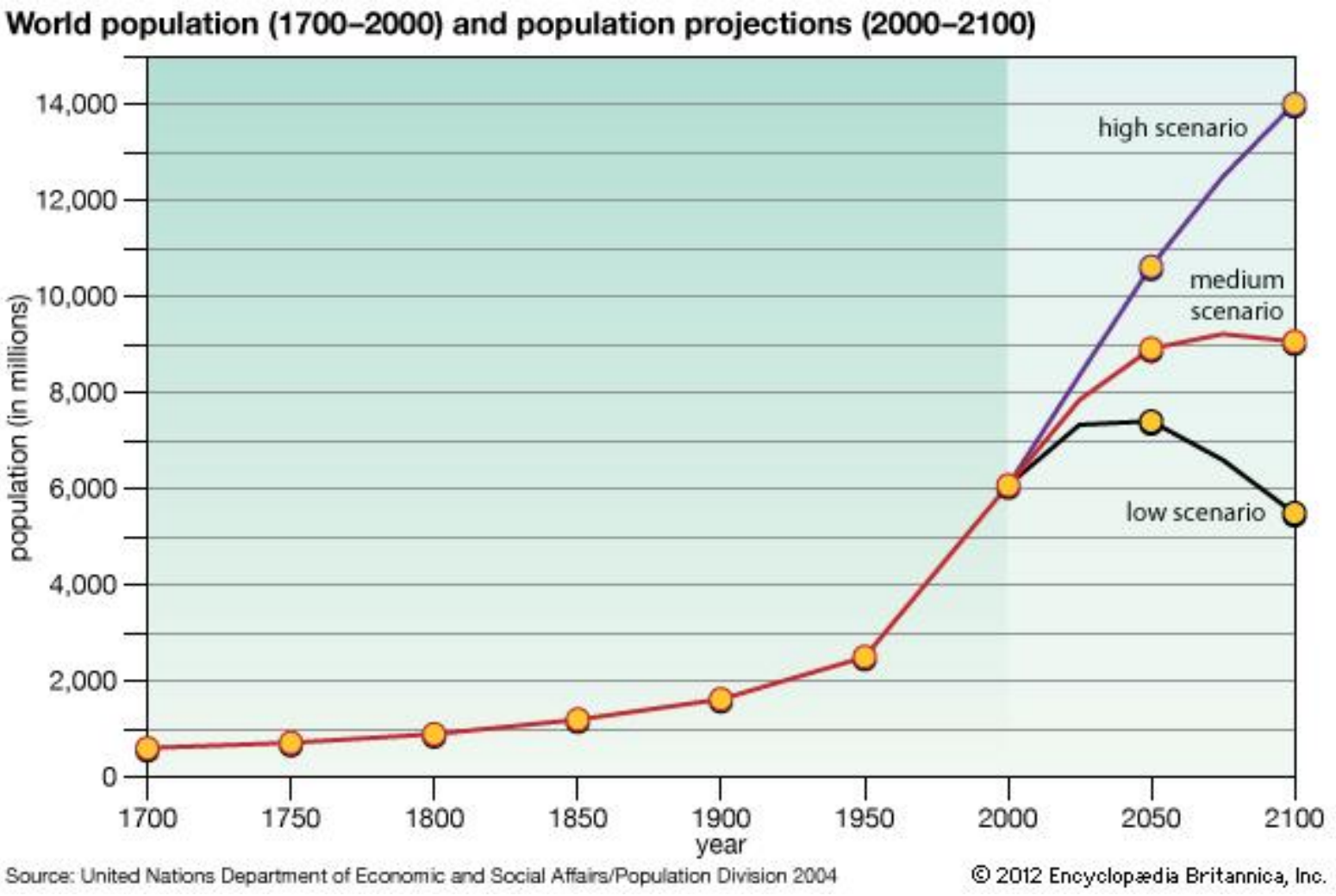
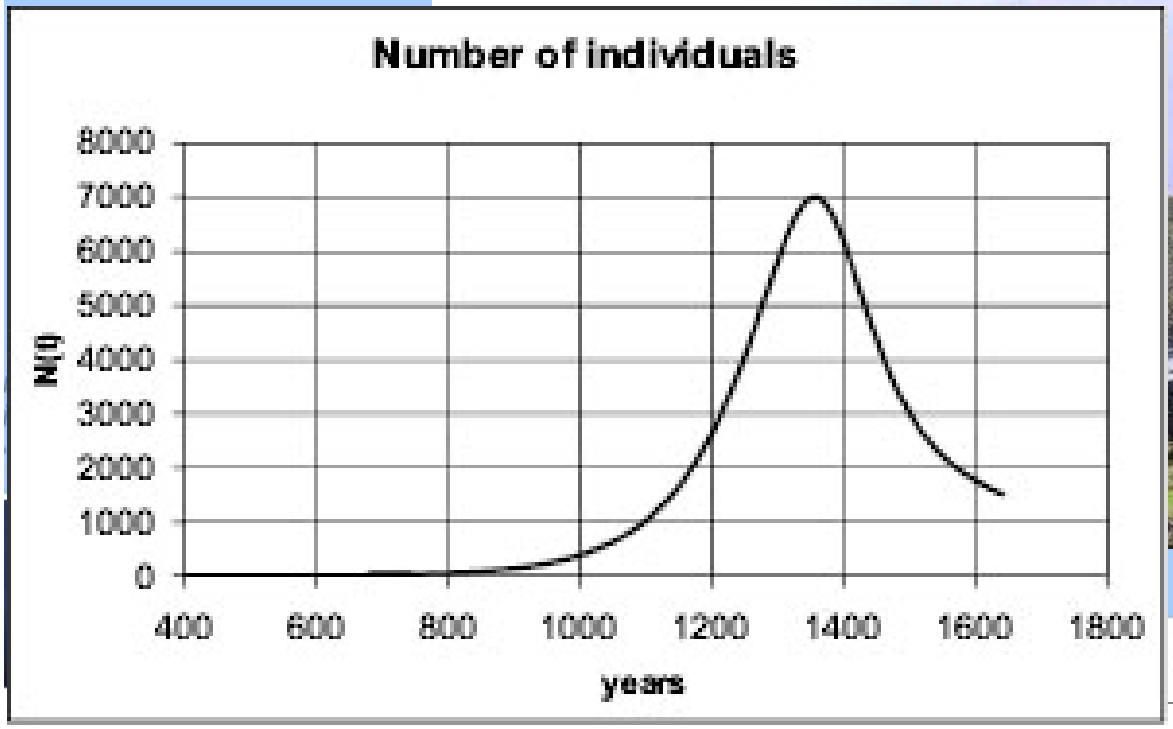
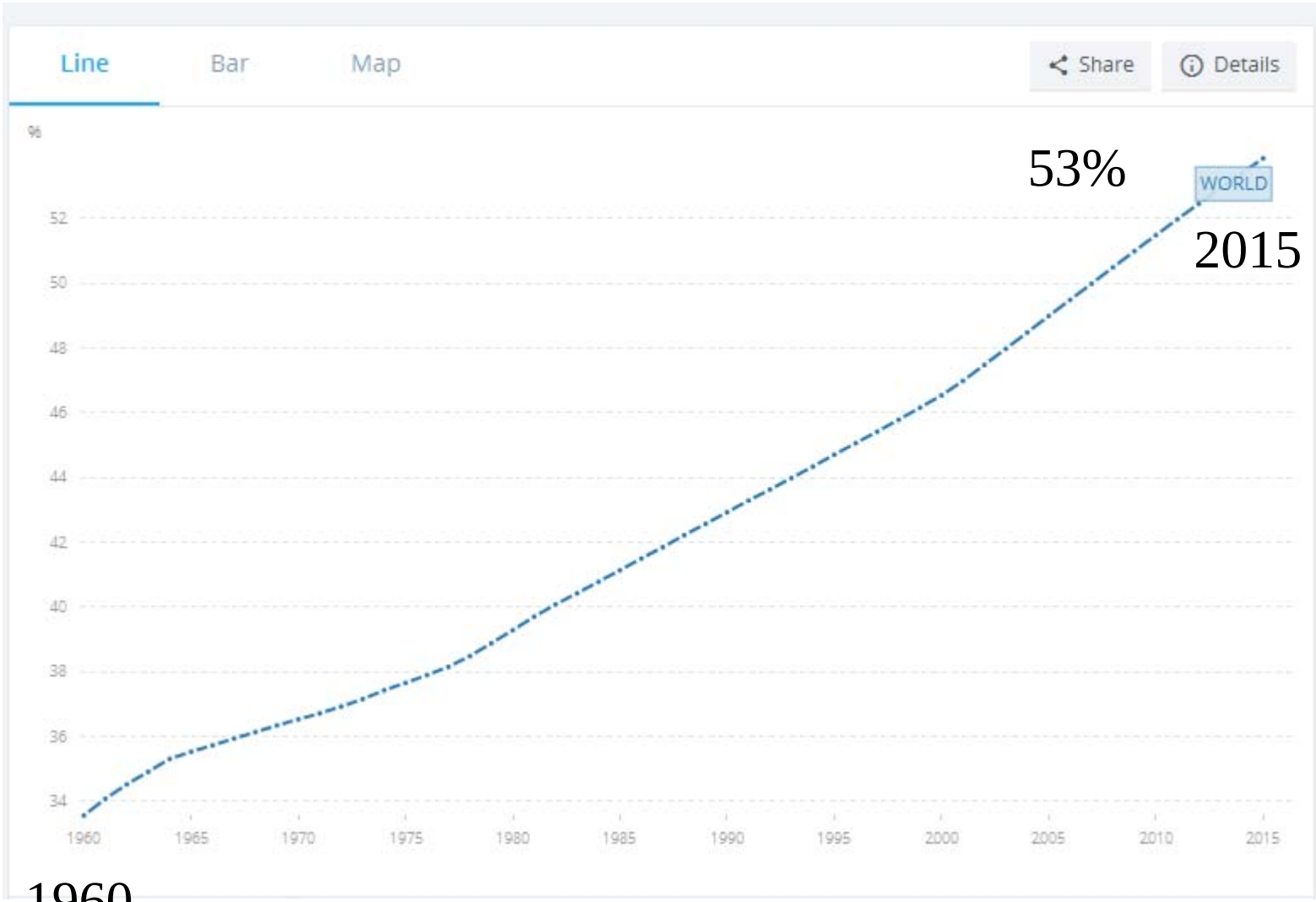
World population – how many can we be?



The Easter island experience...



2. Urbanization, share of population living in urban areas is increasing



34%

1960

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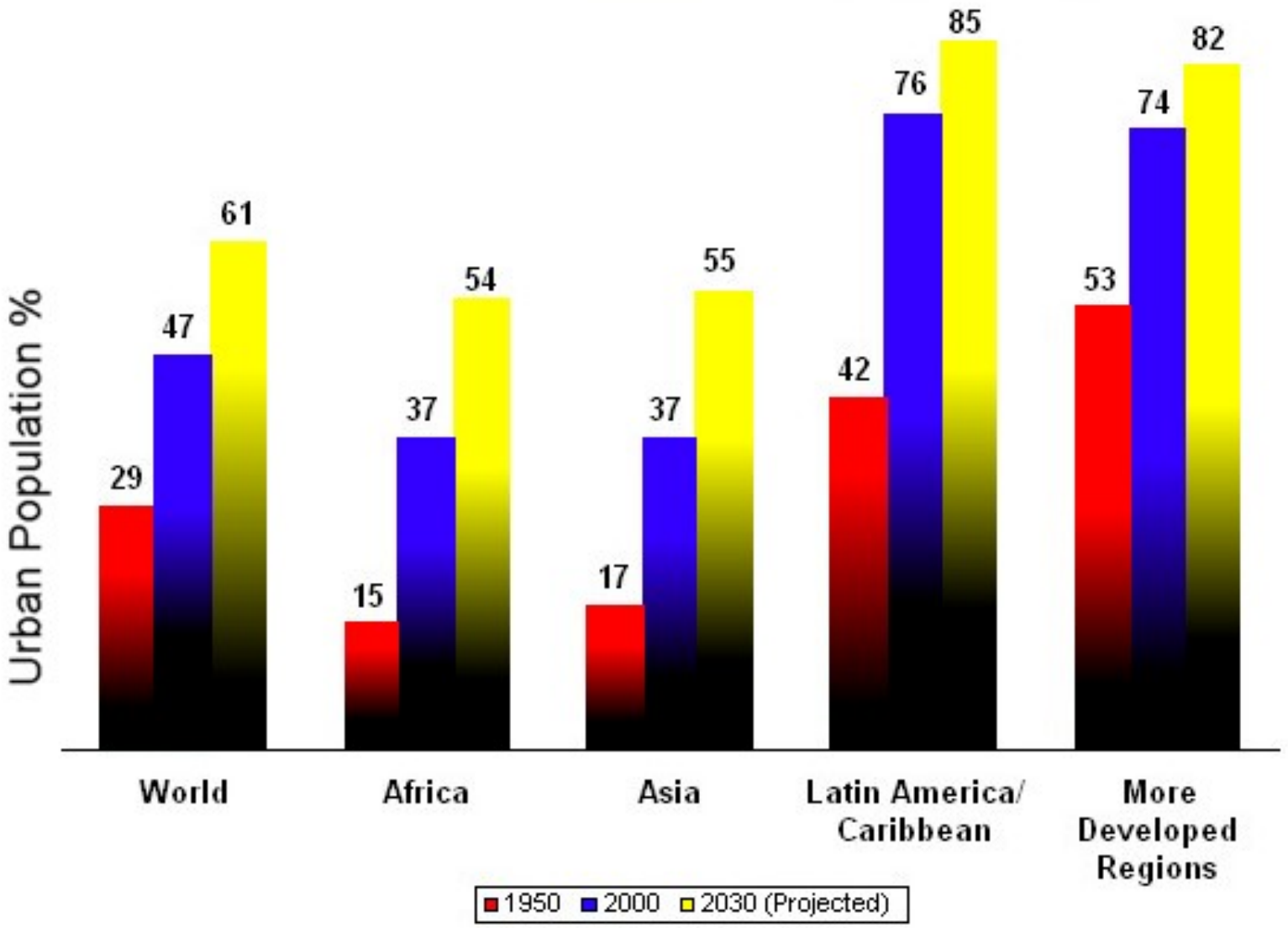
Trends in Urbanization by Region, 2003.



Source: United Nations, World Urbanization Prospects.

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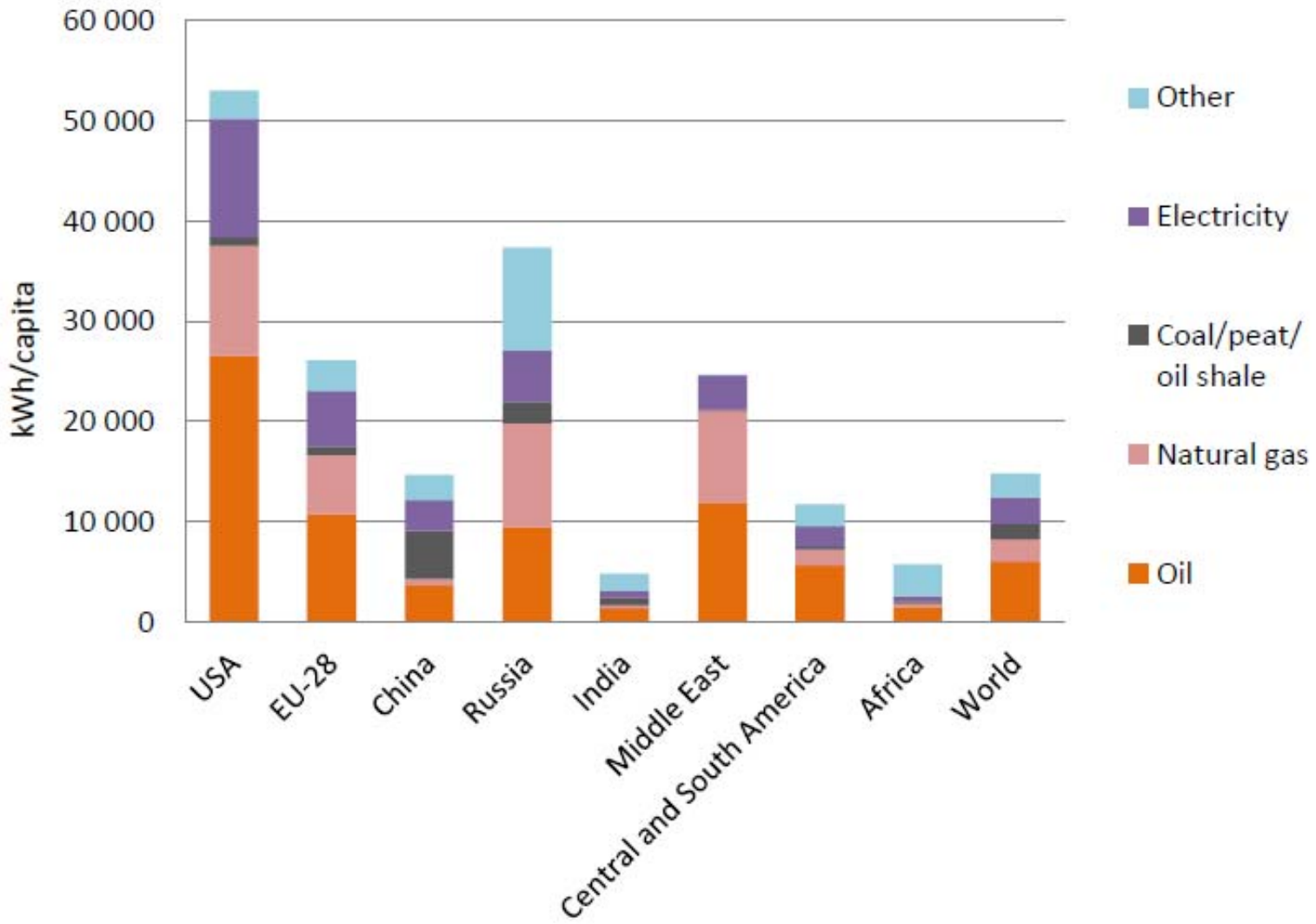
3. Uneven distribution of resources

- Energy use per capita



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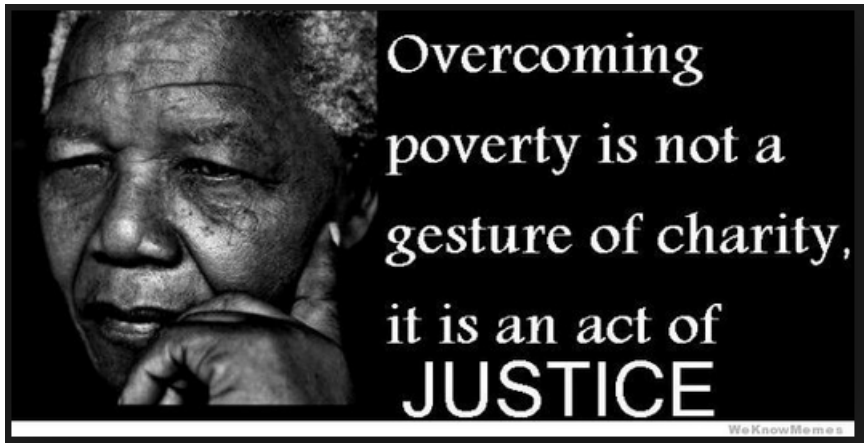

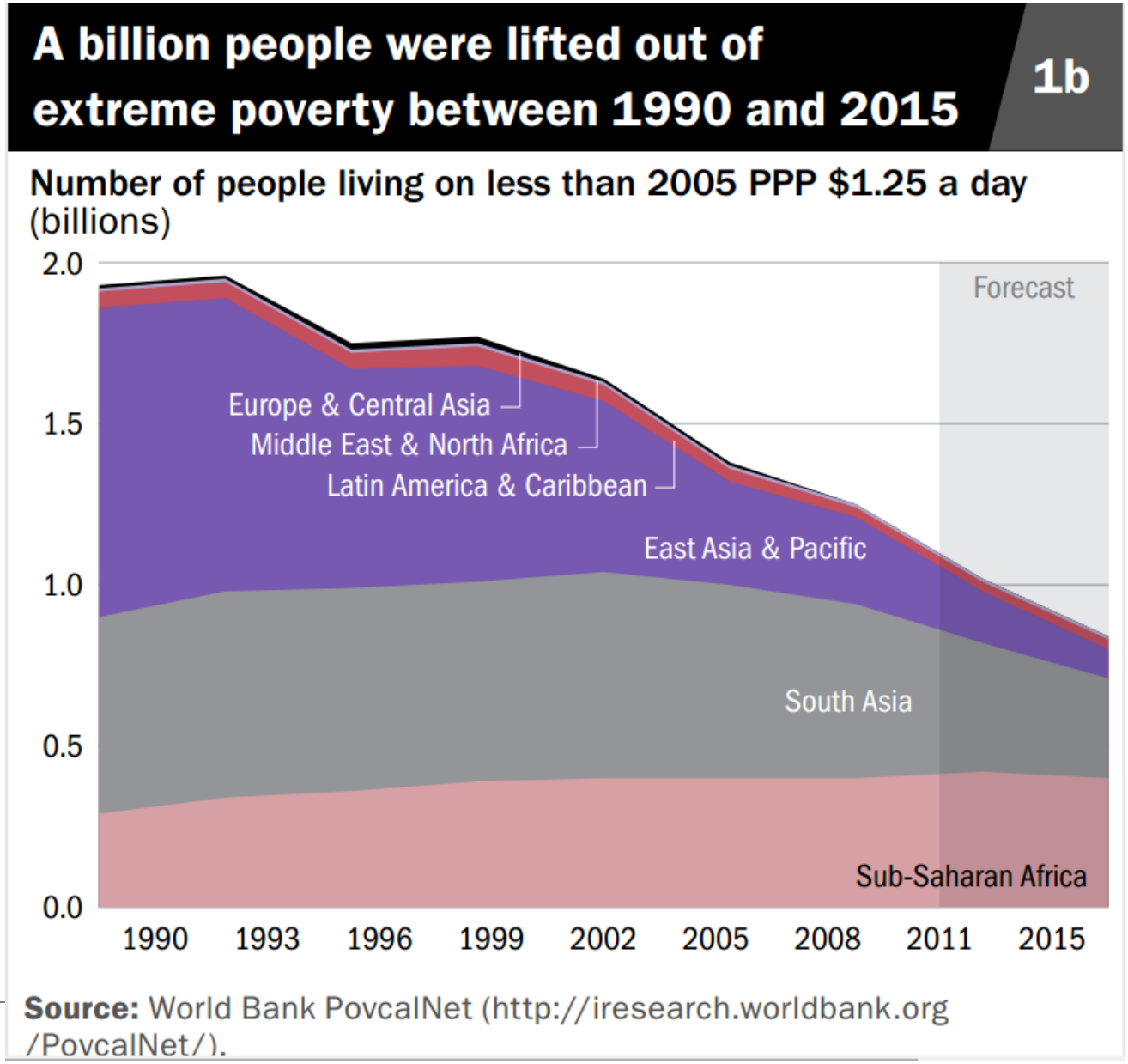

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Where does this lead?

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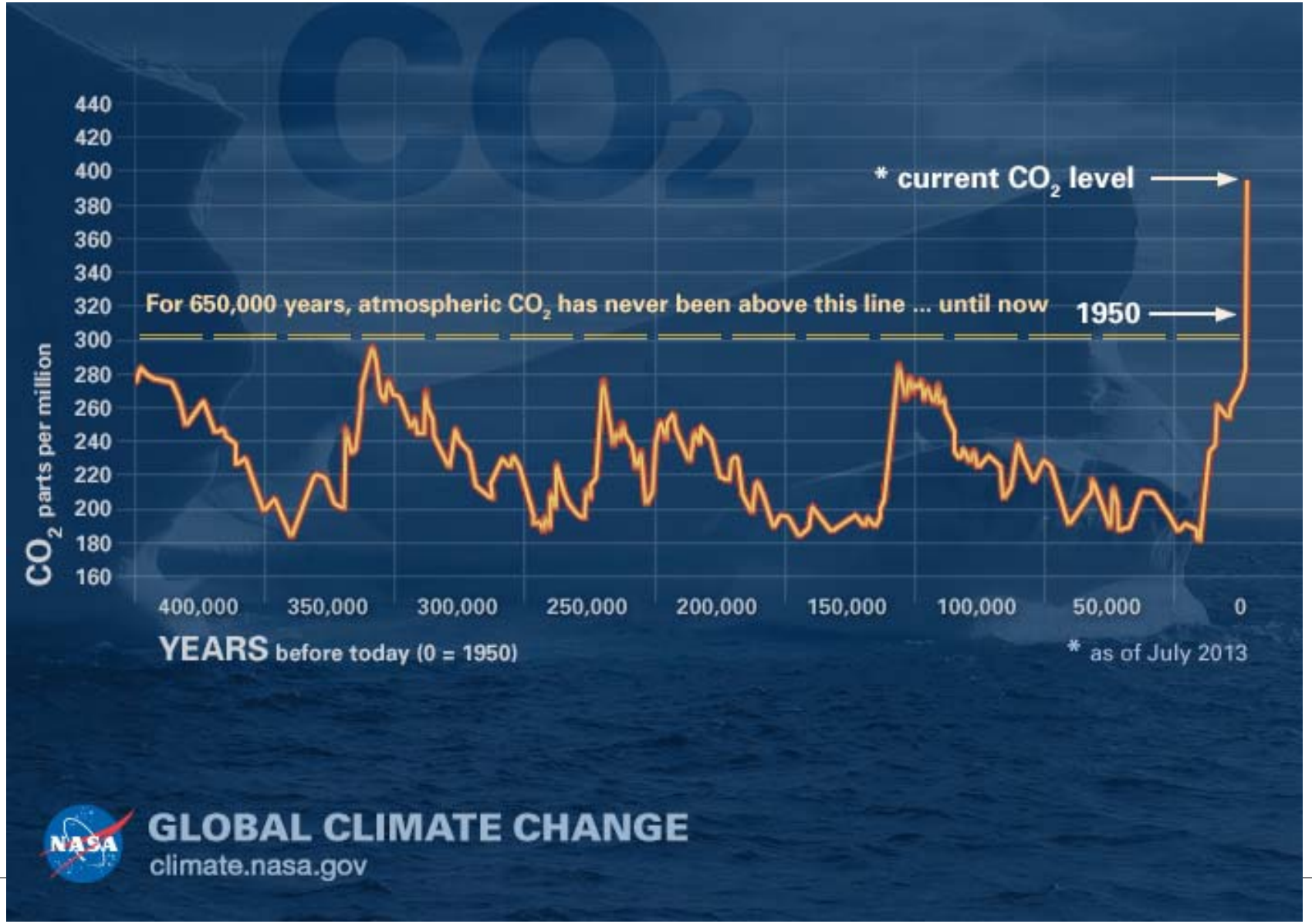
Increase of CO2 in the atmosphere



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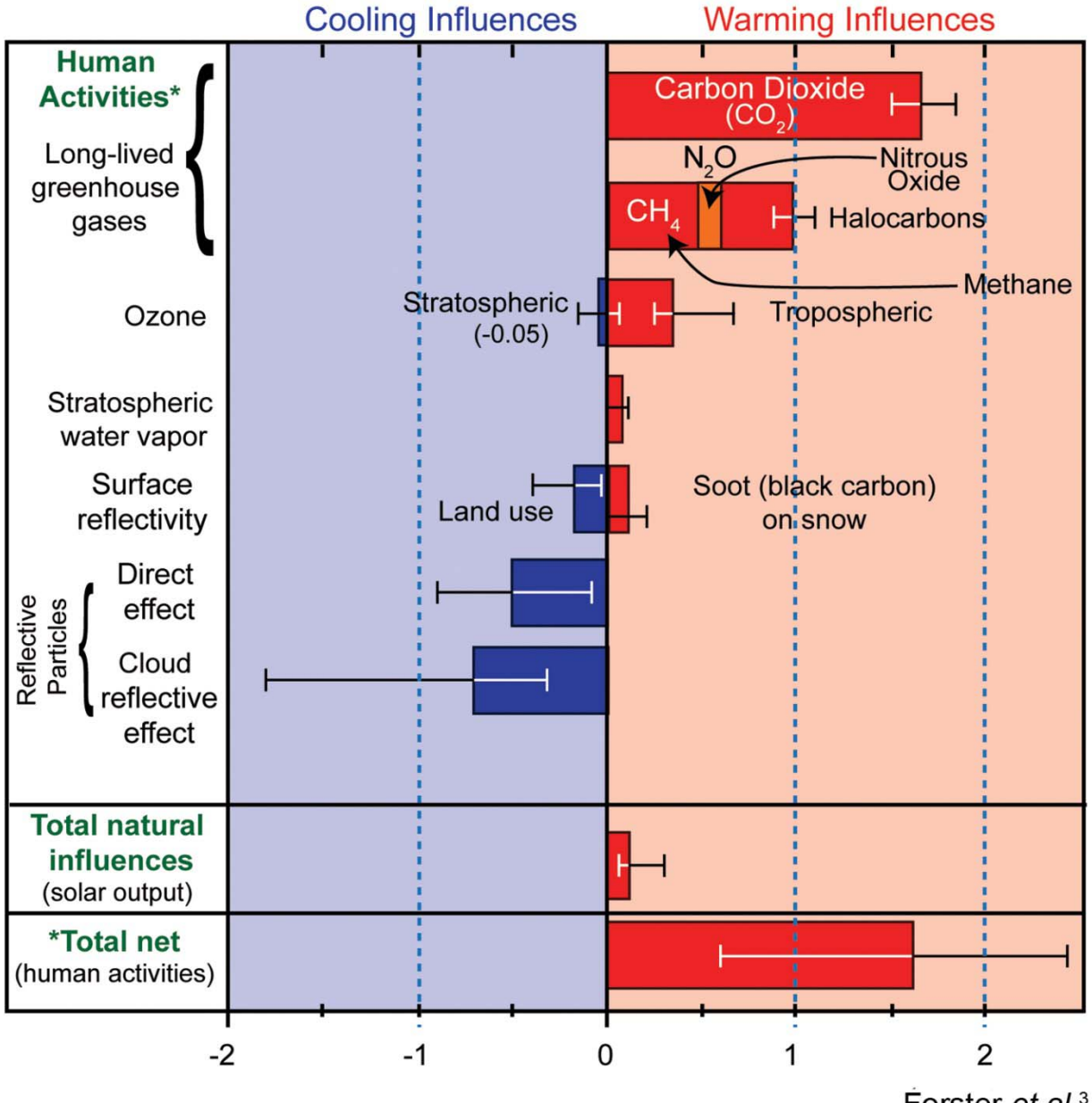
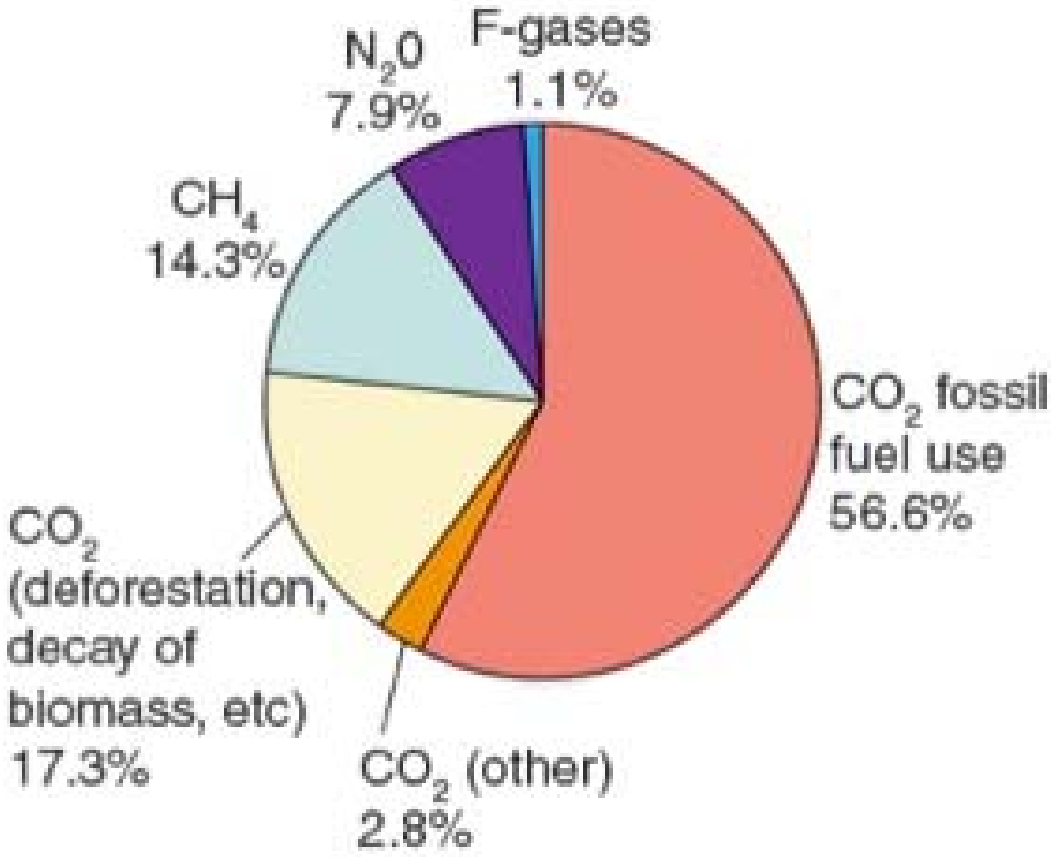
Contribution of different greenhouse gases to global warming, W/m^2



Contribution of different sources to global warming



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Effects of global warming

Toboggan Glacier
Alaska (USA)

Latitude: 61.0217, Longitude: -148.2769

Click on photographs to view the metadata.

Source: NSIDC's Glacier Photograph Collection

Photo Year: 1909
Photographer Name: "Paige, Sidney"
Photo Identifier: toboggan1909062901

Photo Year: 2000
Photographer Name: "Molnia, Bruce F."
Photo Identifier: toboggan2000090401

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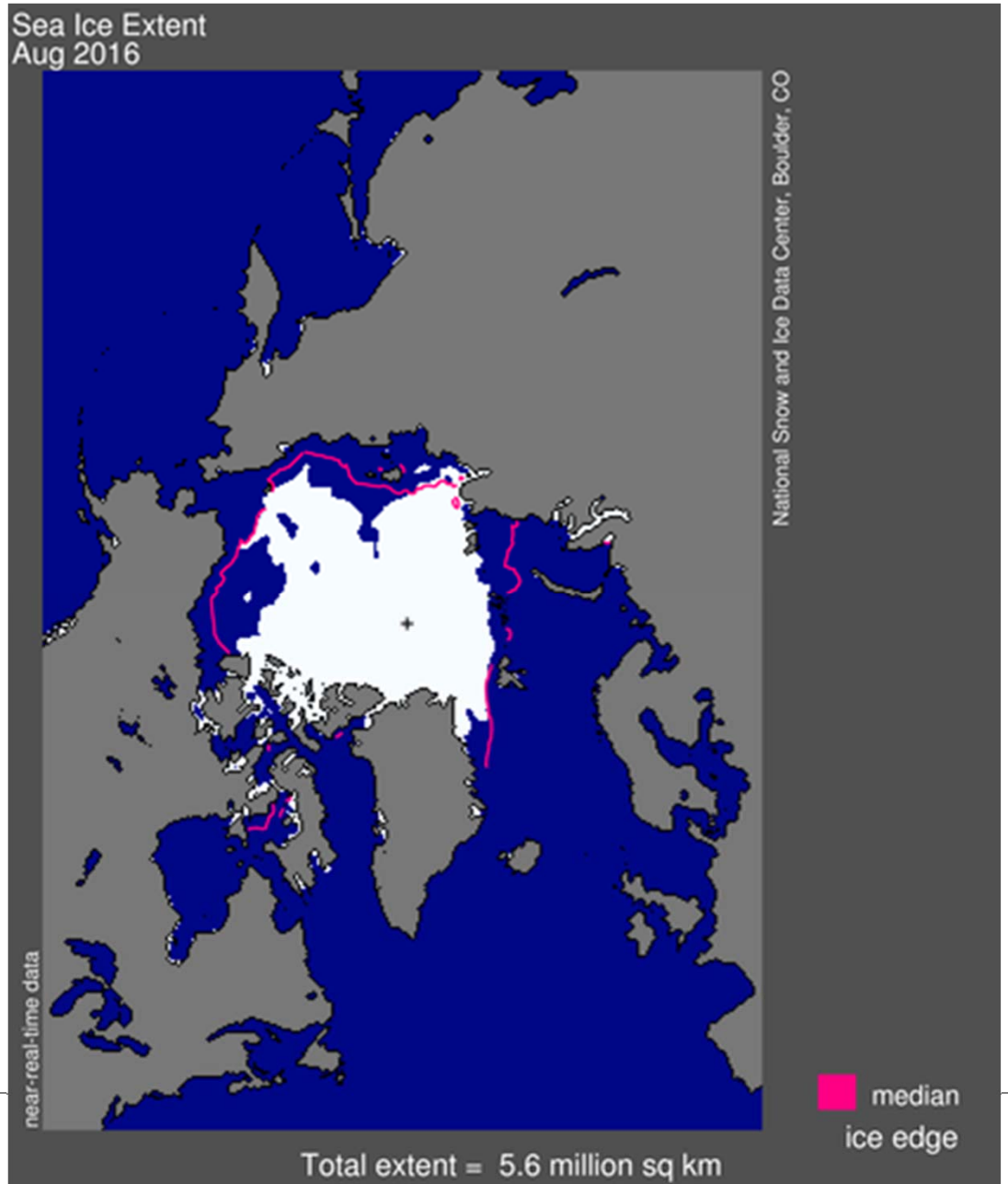
Effects of global warming



Result of melting permafrost

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Effects of global warming

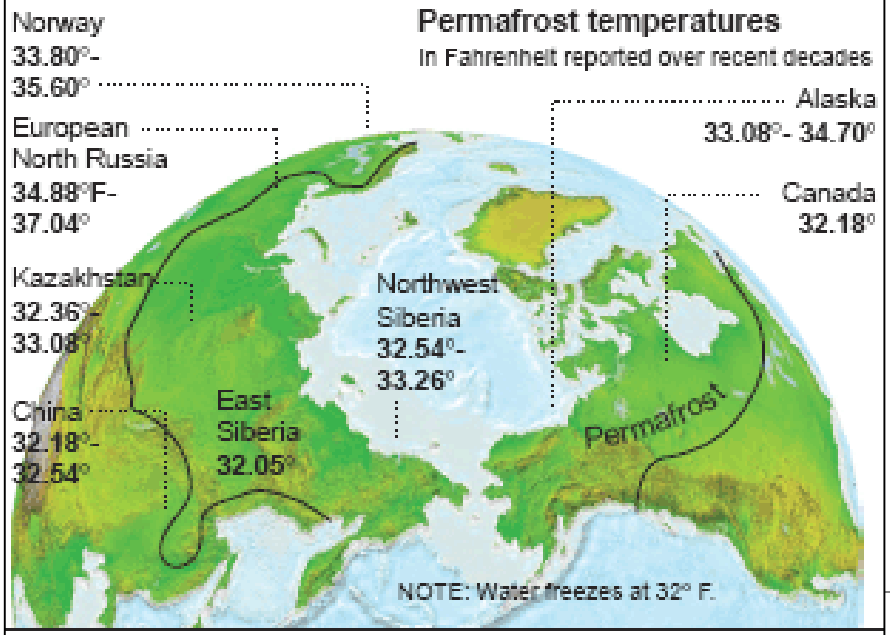
Effects of global warming

theguardian

Methane release from melting permafrost could trigger dangerous global warming

Arctic thaw releases greenhouse gas

As the Earth warms, greenhouse gases, once captive in the long-frozen soil, are bubbling into the atmosphere in much larger amounts than previously anticipated.



SOURCES: Nature; National Oceanic & Atmospheric Administration AP

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Effects of global warming

Morning Mix

Anthrax sickens 13 in western Siberia, and a thawed-out reindeer corpse may be to blame

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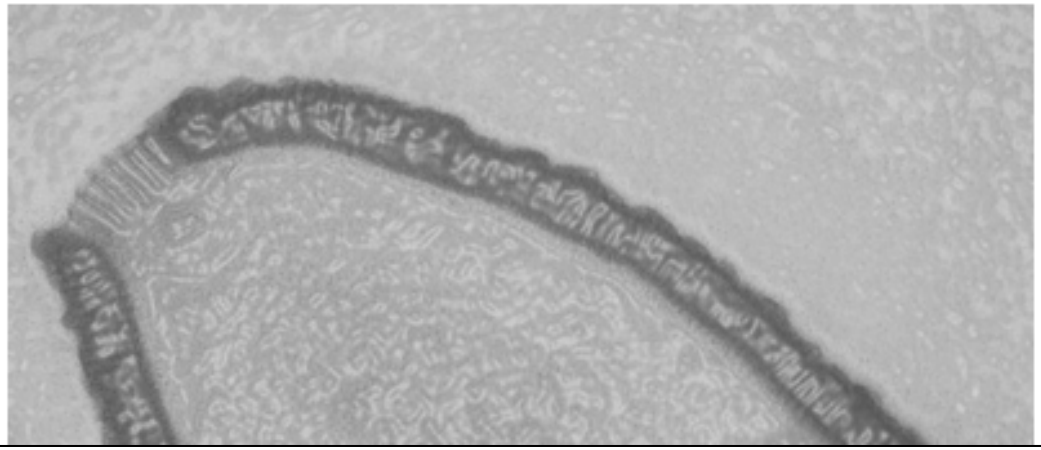
NATIONAL GEOGRAPHIC

Ancient "Giant Virus" Revived From Siberian Permafrost

Climate change could release more ancient viruses. Is there a risk to humans?

By **Stefan Sirucek**, for National Geographic

PUBLISHED MARCH 3, 2014



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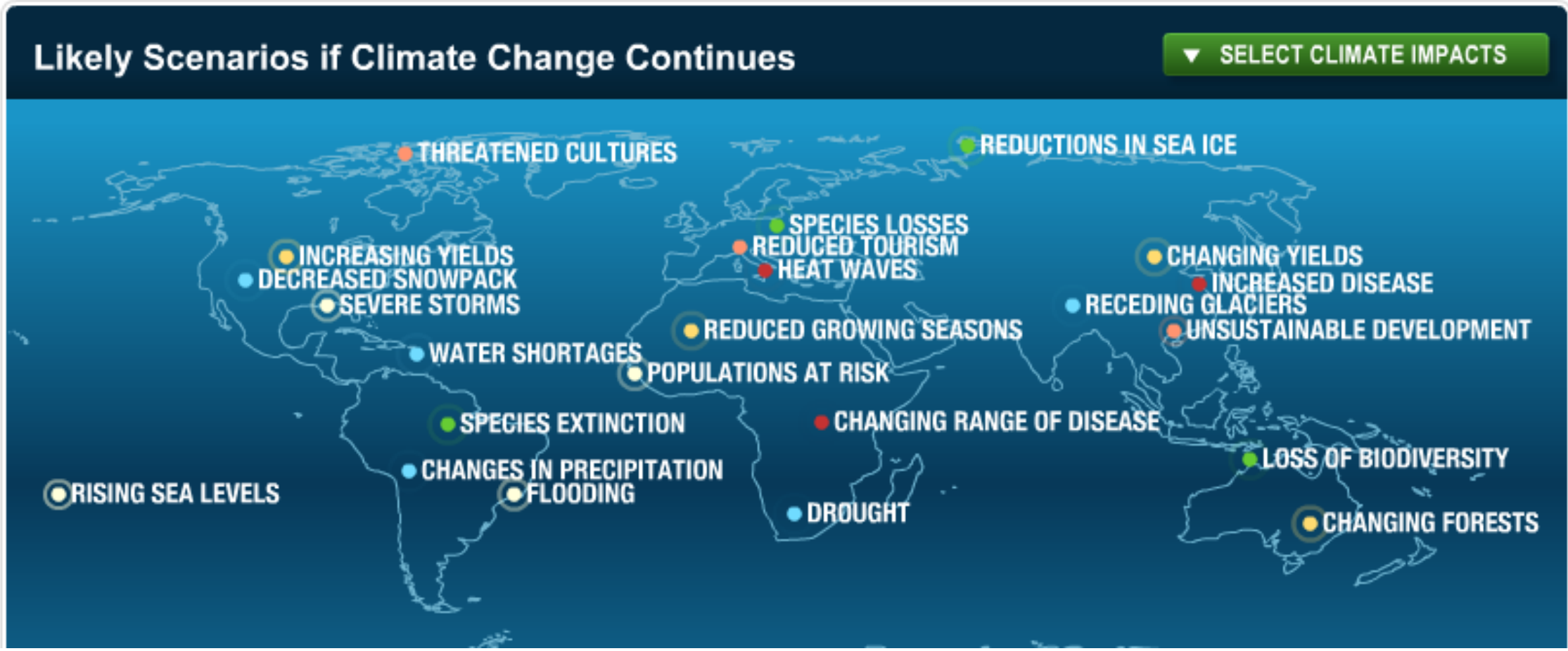
Effects of global warming



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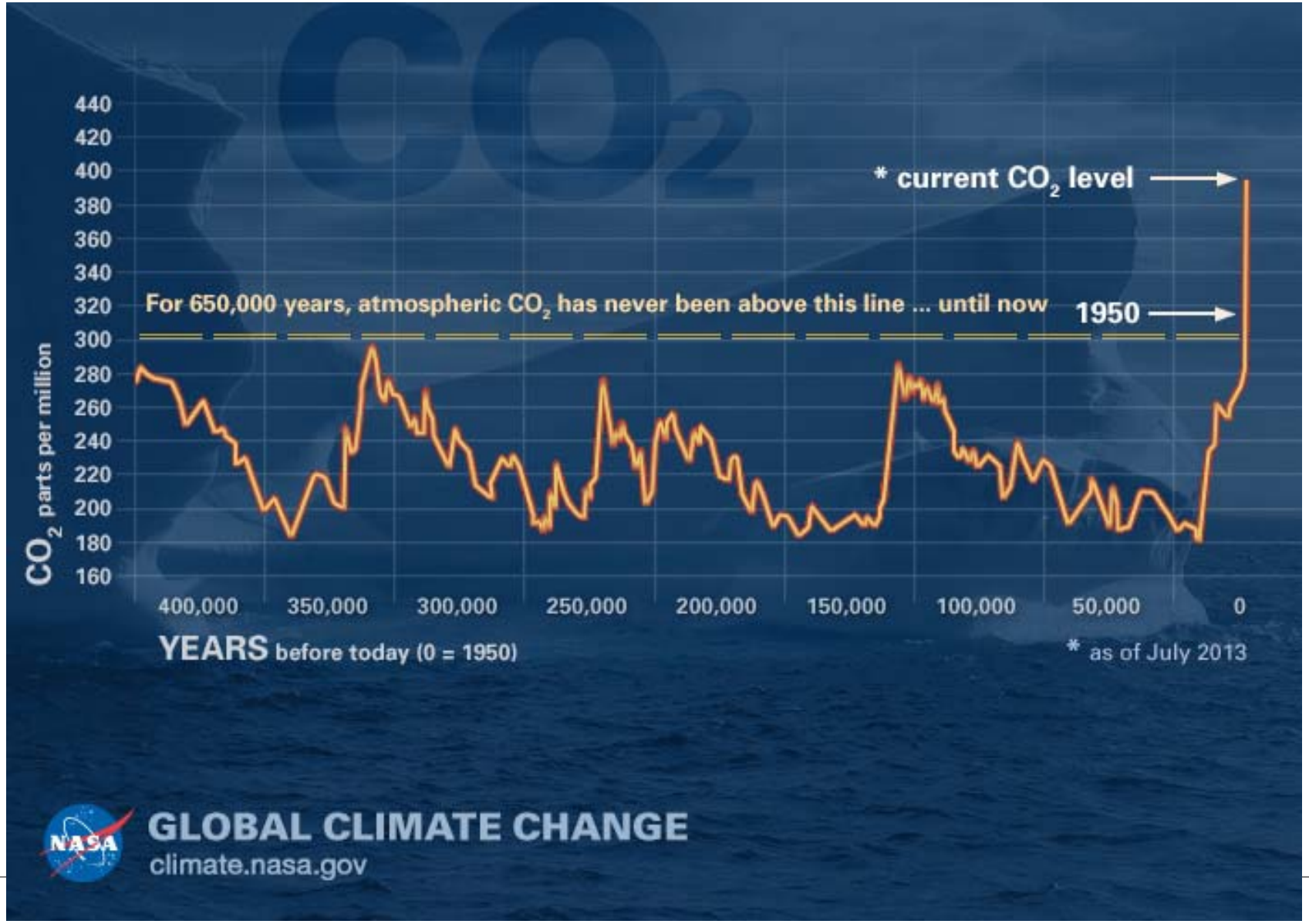
The evidence is convincing, climate change is for real, and we are causing it



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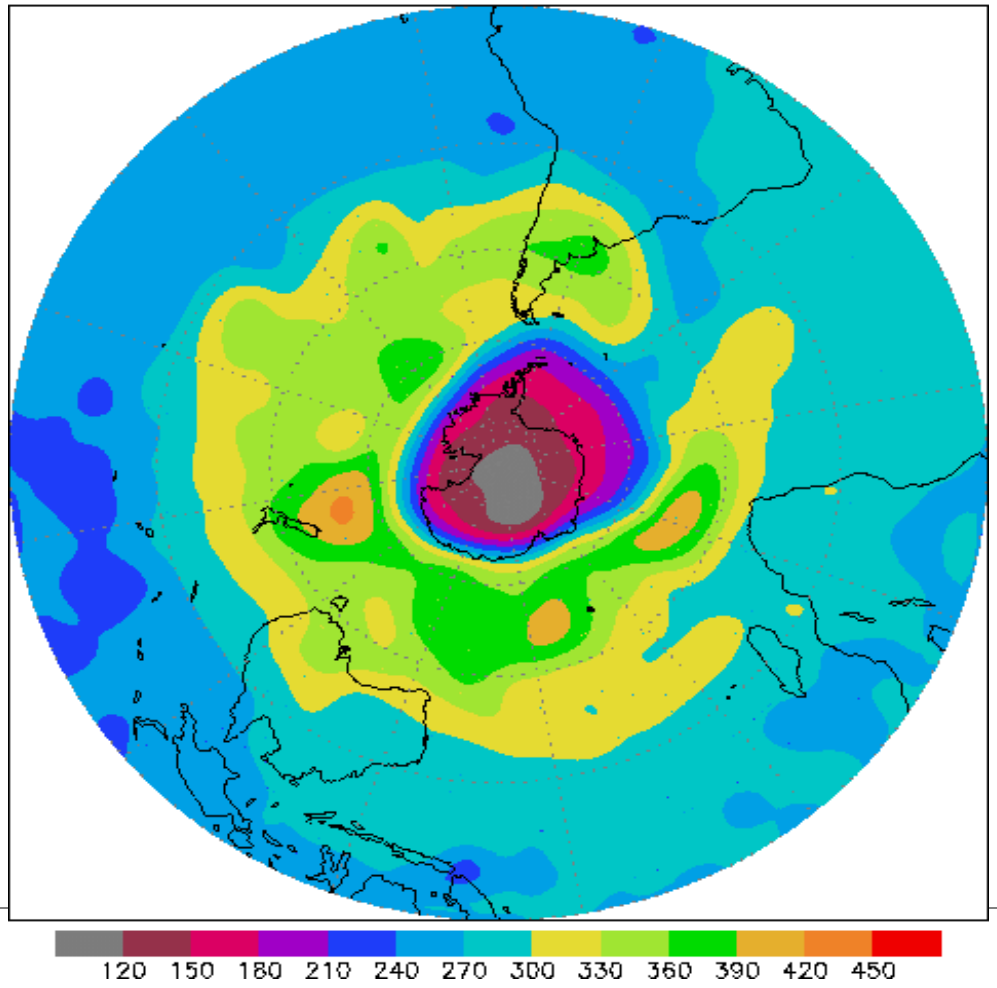
We have the power to change the world!

We have the power to change the world!

- Release of Ozone Depleting Substances as an example



Ozone concentrations over Antarctica, the ”Ozone Hole”

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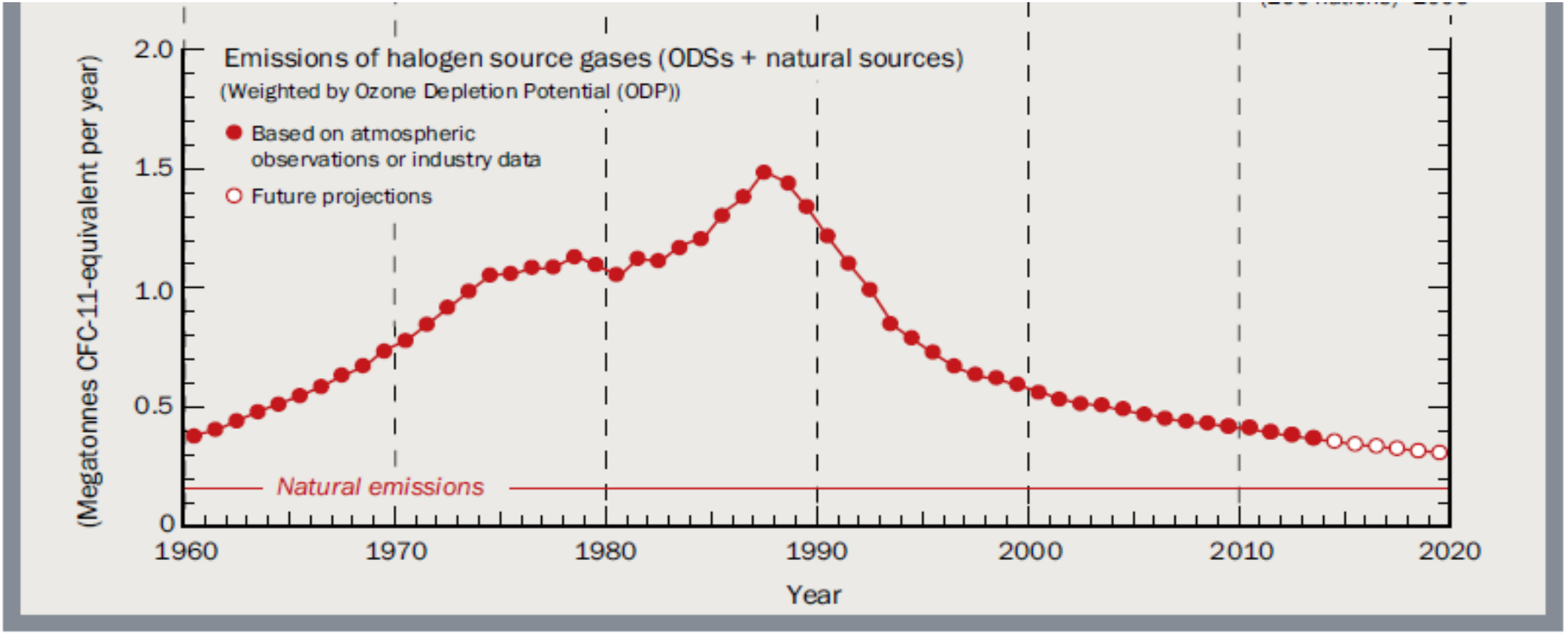
Emissions of Ozone Depleting Substances are down at the levels of 1960s



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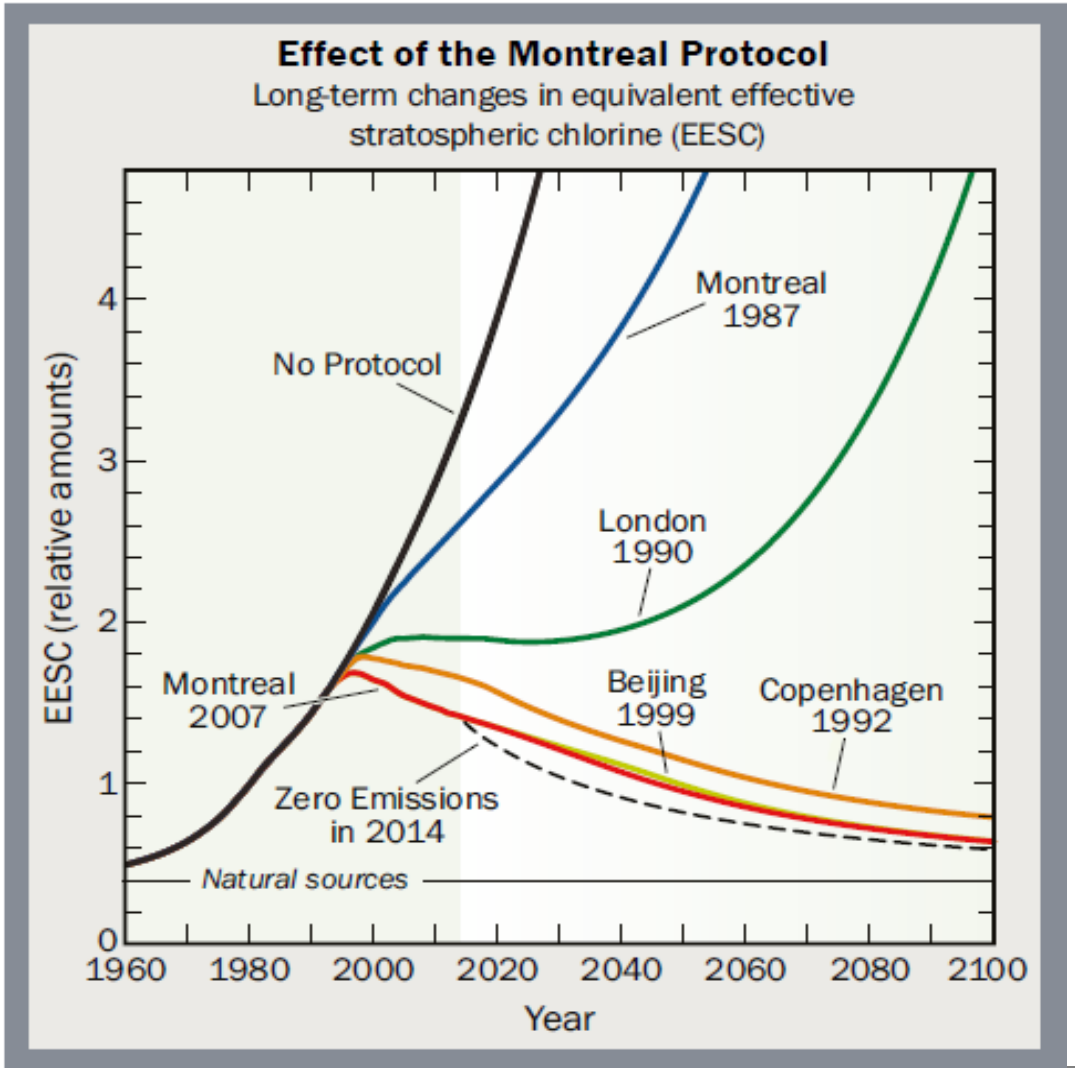
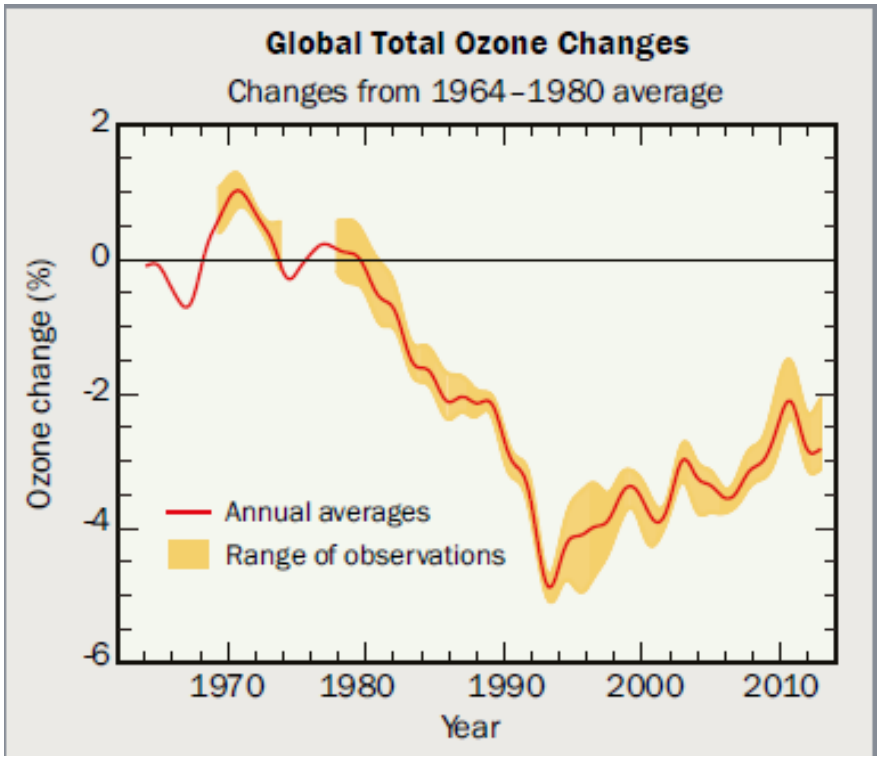
The decrease in ODS is a result of international agreements





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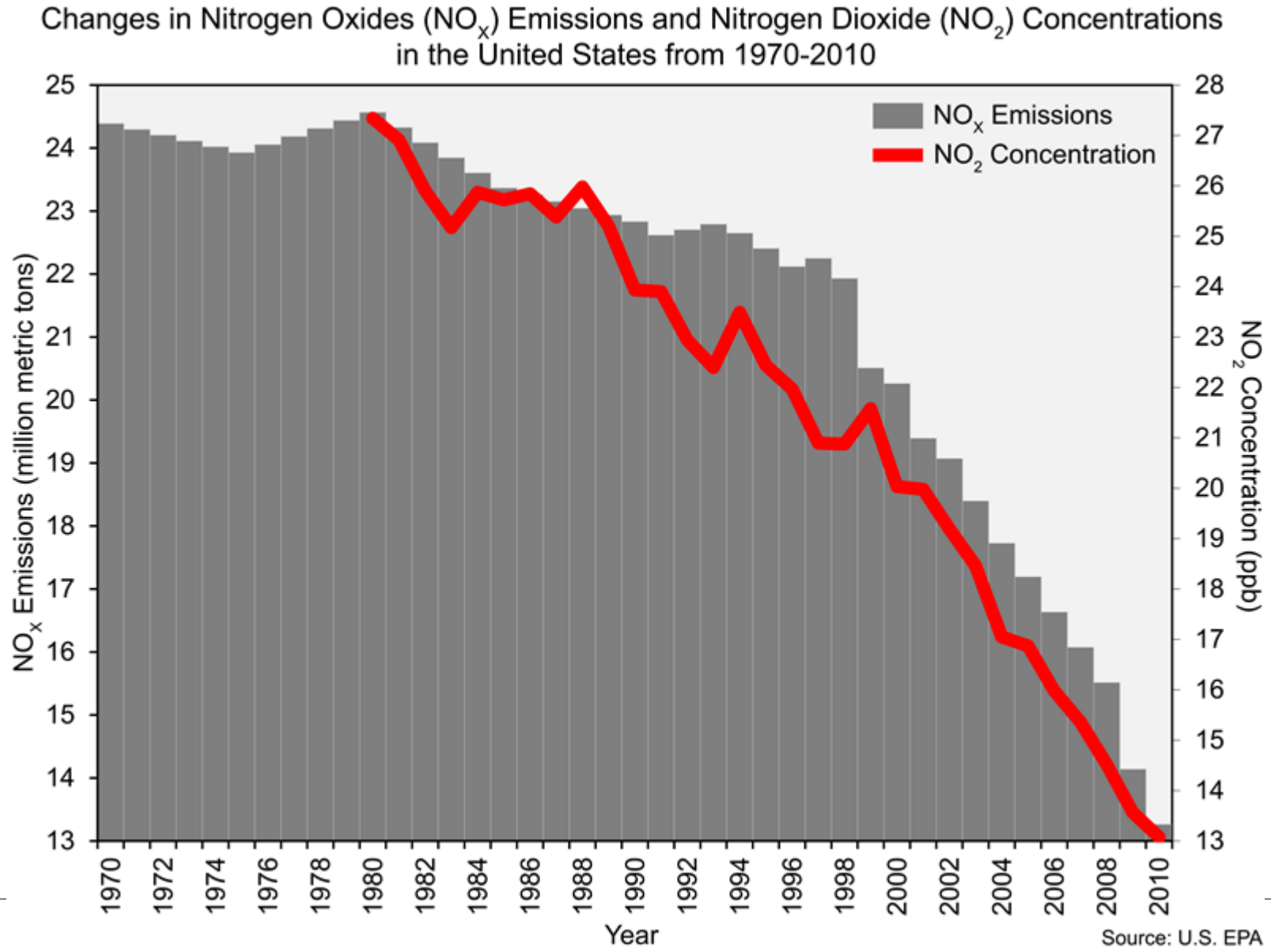
Ozone hole is not the only example



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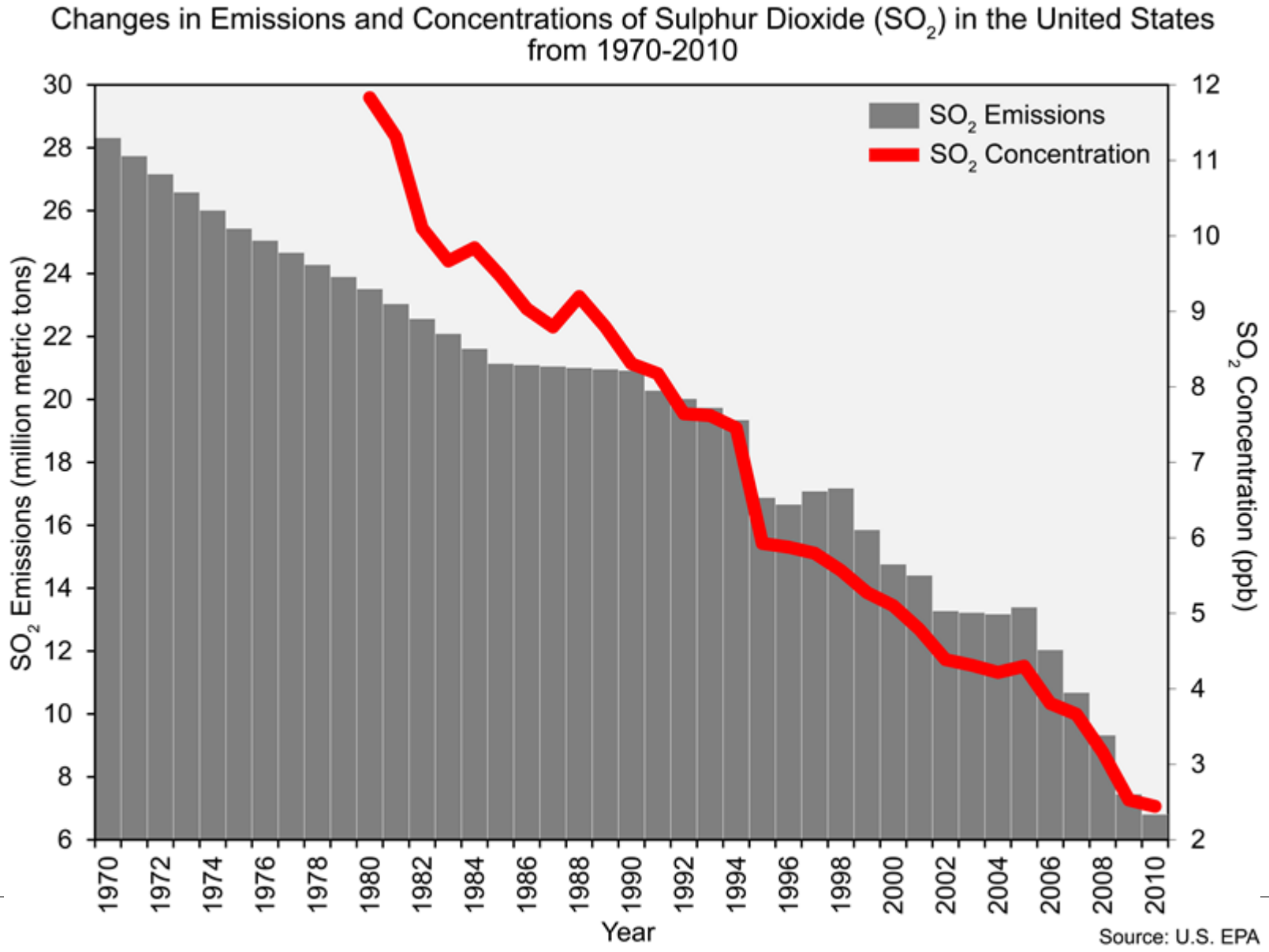
Ozone hole is not the only example



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What we do makes a difference!

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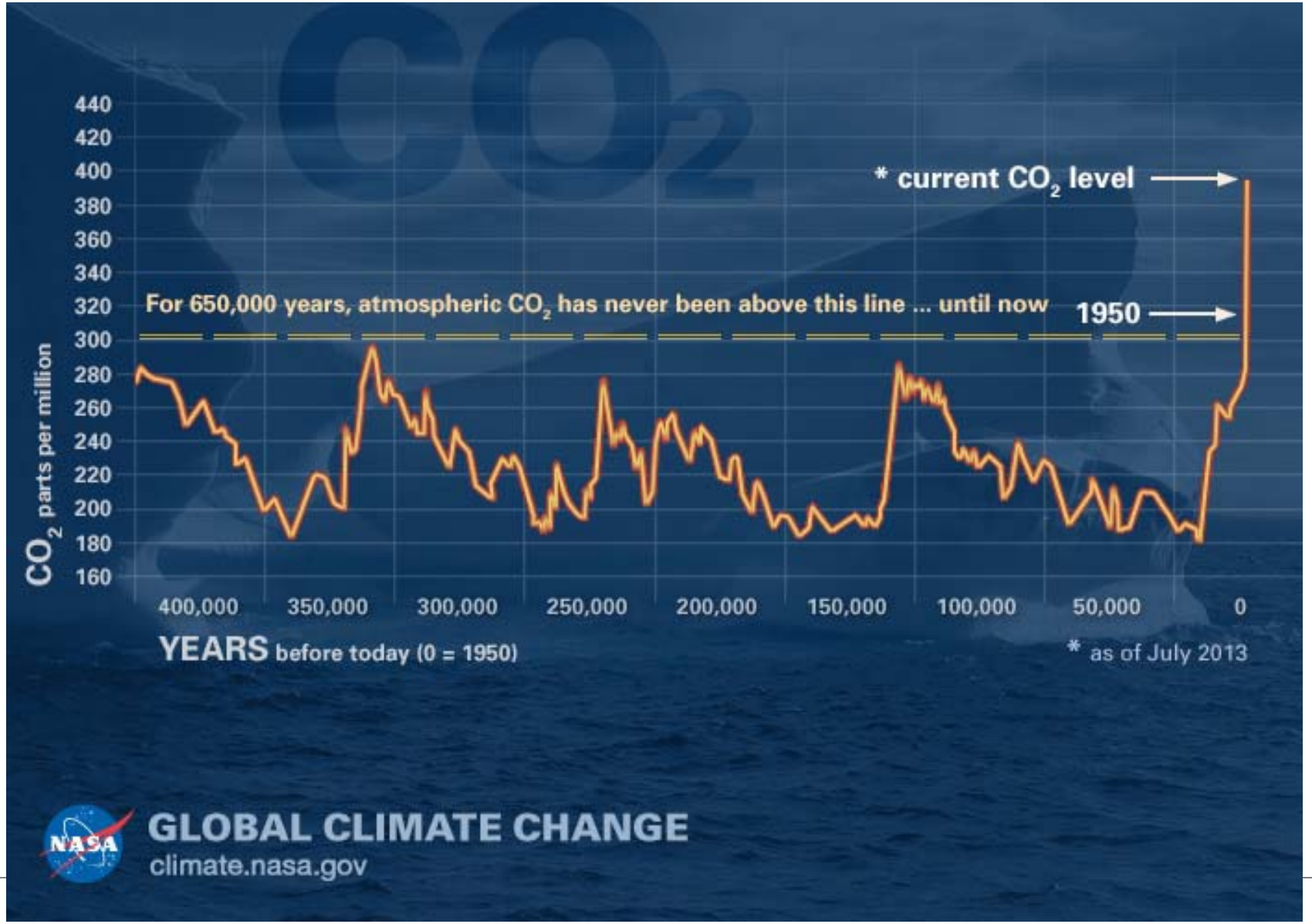
Will we be able to change this curve in a similar way?



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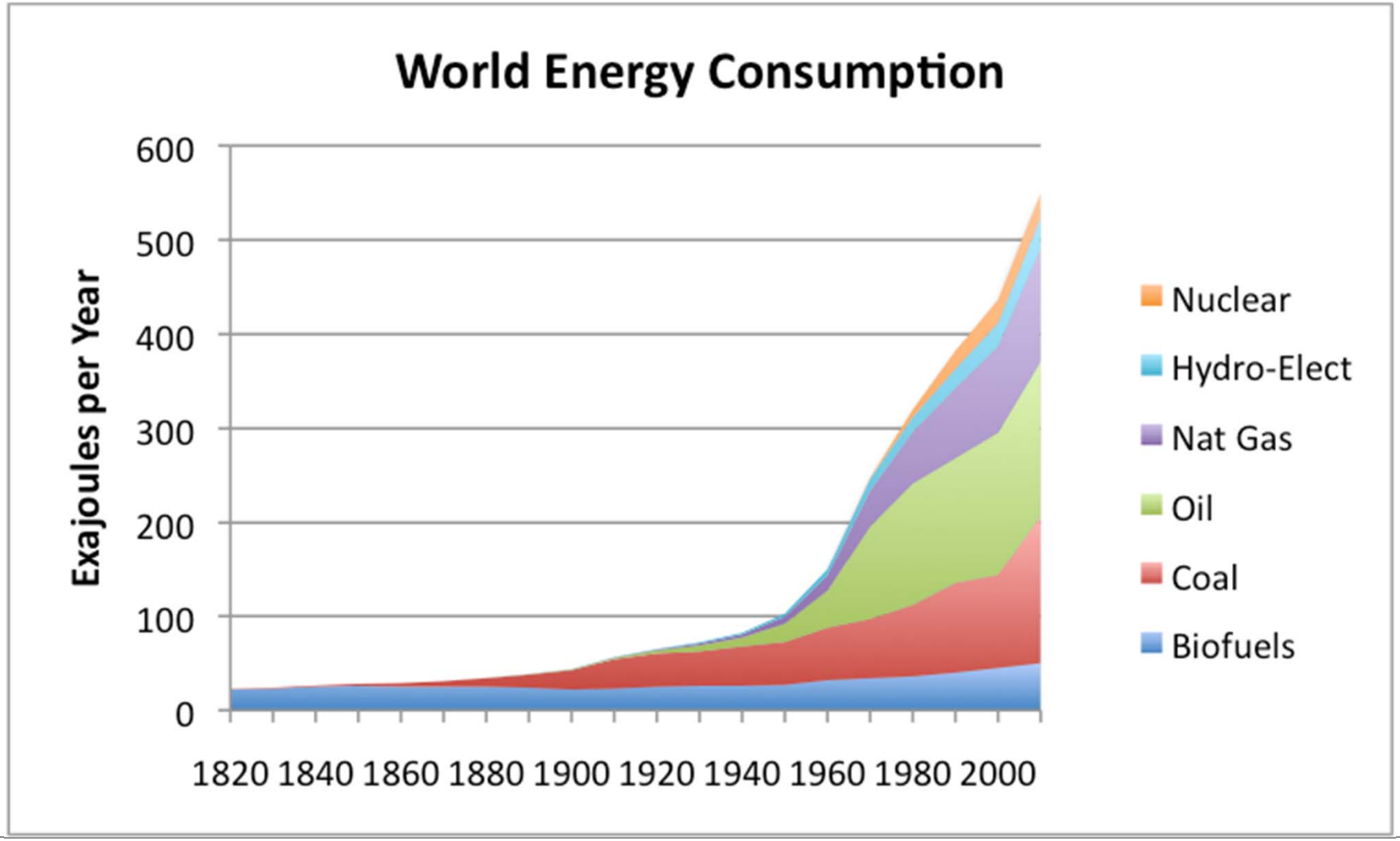
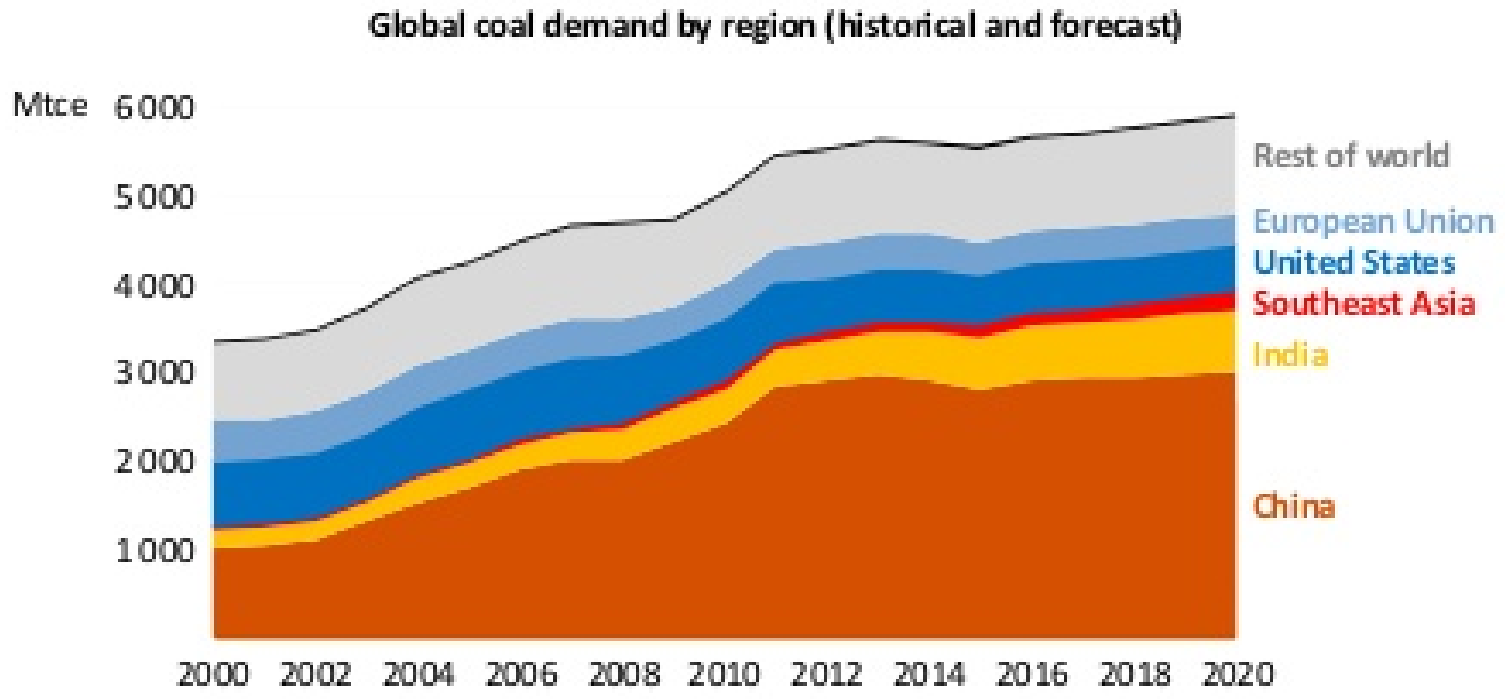
A formidable task to reduce use of fossil fuels! But necessary!



Demand for coal is still increasing, but not so much as before

- Source: IEA



Strong growth in coal use in India & Southeast Asia offset declines in the EU & the US, but does not match the rise seen over last decade in China

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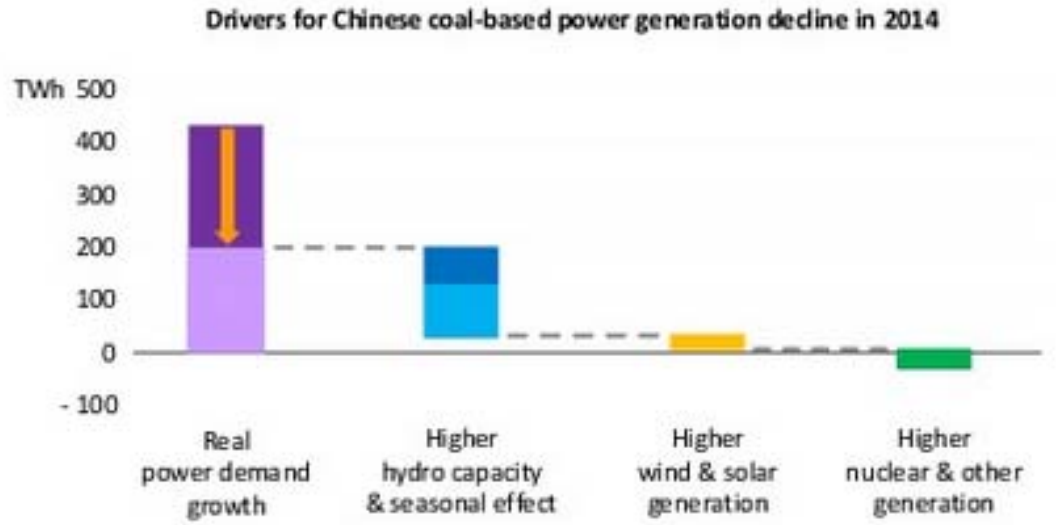
Steps are taken to decrease coal use

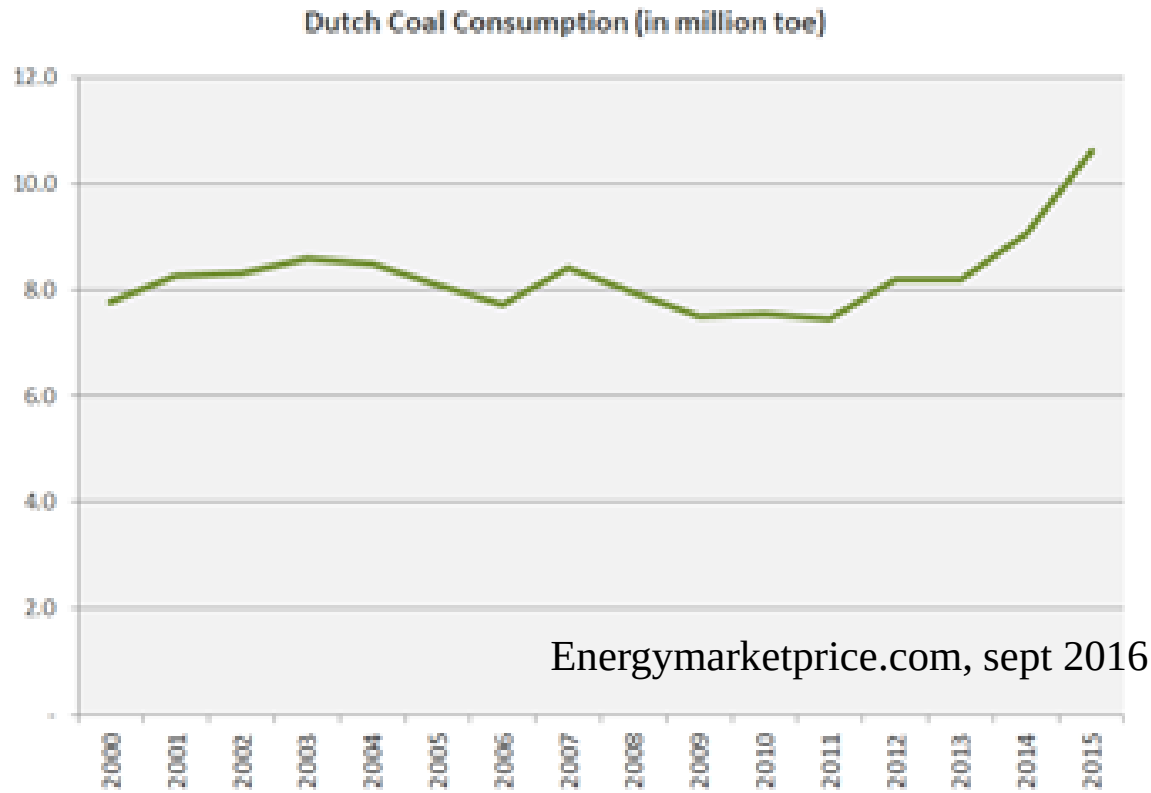
Has coal use in China already peaked?



China's coal use may have already peaked, reflecting the gradual economic rebalancing & further growth in low-carbon sources of power

Steps are taken to decrease coal use

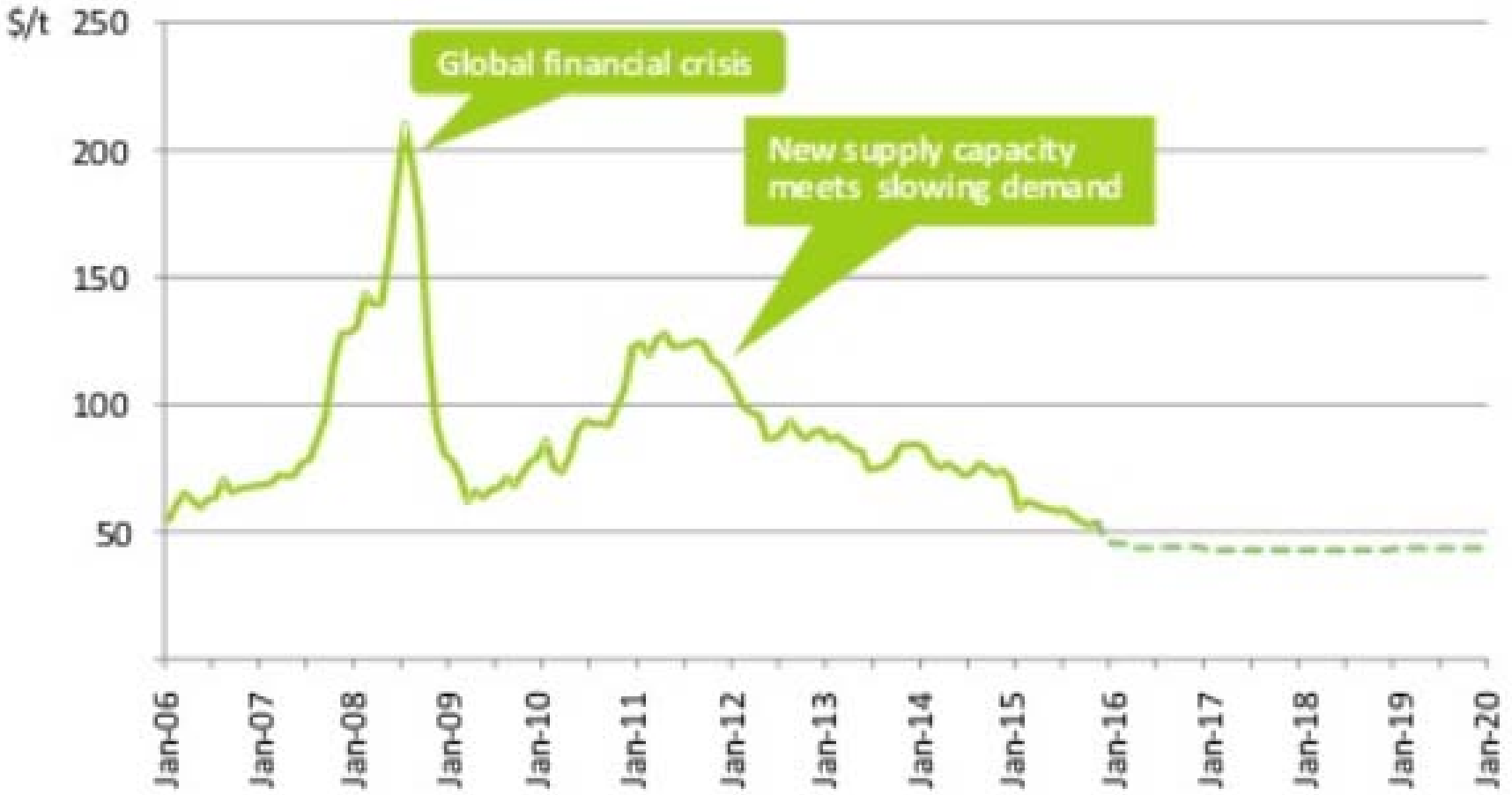
Dutch parliament has decided to close all its coal-fired power plants



Energymarketprice.com, sept 2016

Are energy prizes too low?

- Coal price 2006 - 2016



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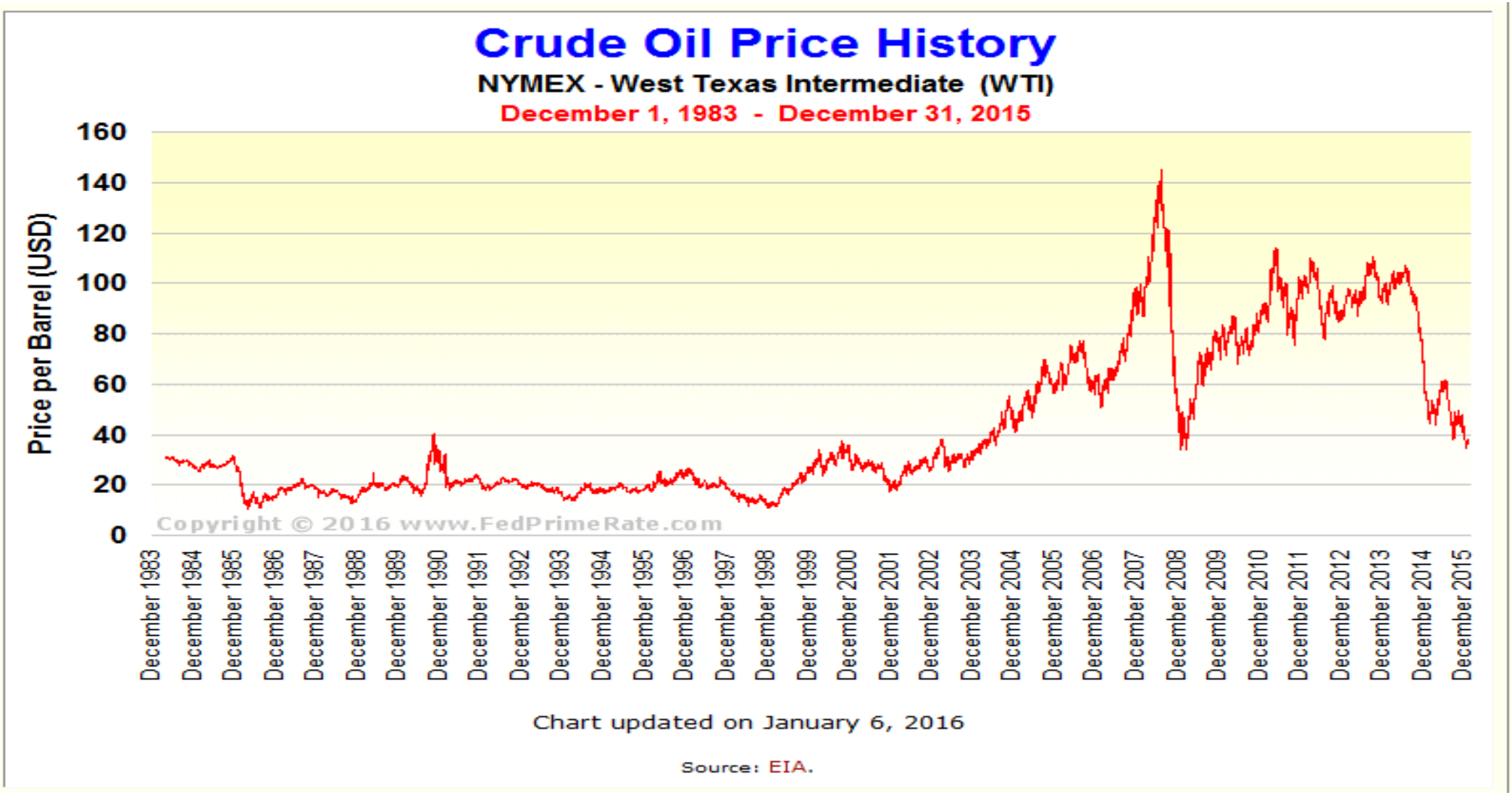
Are energy prizes too low?



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The Paris Agreement, COP21

Key elements

- The Paris Agreement is a bridge between today's policies and climate-neutrality before the end of the century.

Mitigation: reducing emissions

Governments agreed

- a long-term goal of keeping the increase in global average temperature to **well below 2°C** above pre-industrial levels;
- to aim to limit the increase to **1.5°C**, since this would significantly reduce risks and the impacts of climate change;
- on the need for **global emissions to peak as soon as possible**, recognising that this will take longer for developing countries;
- to undertake **rapid reductions thereafter** in accordance with the best available science.

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Is a global carbon tax the solution?

The Economic Journal, **101** (*July* 1991), 938–948
Printed in Great Britain

THE ROLE OF CARBON TAXES IN ADJUSTING TO GLOBAL WARMING

David Pearce

I. INTRODUCTION

In August 1990, Working Group 1 of the United Nations Intergovernmental Panel on Climate Change (IPCC) published its assessment of the scientific evidence on global warming (Houghton, Jenkins and Ephraums, 1990). Referring to the greenhouse effect as a natural phenomenon, the Working Group was none the less of the opinion that:

> emissions resulting from human activities are substantially increasing the atmospheric concentrations of the greenhouse gases: carbon dioxide, methane, chlorofluorocarbons (CFCs) and nitrous oxide. These emissions will enhance the greenhouse effect, resulting on average in an additional warming of the Earth's surface. The main greenhouse gas, water vapour, will increase in response to global warming and further enhance it.

Scientific opinion continues to differ on the extent to which global warming is

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Arguments for a global carbon tax!

- Emission of CO_2 is causing society immense costs which are not borne by those responsible for the release.
- A global CO_2 tax would shift the costs from society as a whole to those who benefit from the release.
- A CO_2 tax would benefit developing countries and low income groups.

- A CO_2-tax is not a punishment, it should be seen as a fair distribution of costs!

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Technologies needed

- Energy efficient products to reduce demand
- Efficient products for electricity production from renewables
- Efficient energy storage
- Strong electric grids
- Smart systems/smart control to manage all

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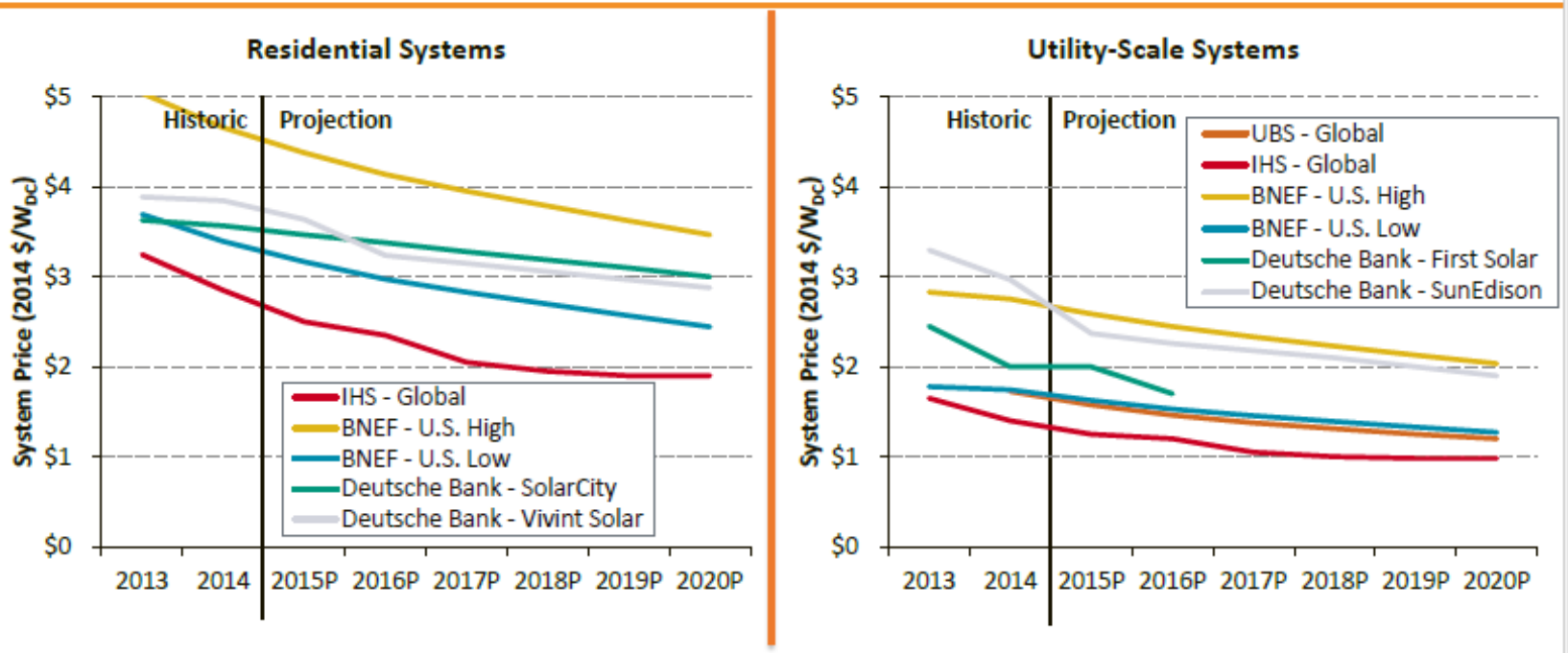
Technology needed

- PV price expected to continue to decrease

Analyst Estimates (2013-14) and Projections (2015–2020) of Average System Price



- Analysts expect the system prices of both utility-scale and distributed systems to continue to fall in the near future
  - Residential systems are expected to reach $1.5/W - $3.0/W and utility-scale systems are expected to reach $1.00/W - $1.75/W by 2020
  - Analysts project that from 2014-2020, system prices will fall 16%-33% for residential systems and 26%-36% for utility-scale systems, or between 3%-12% per year.

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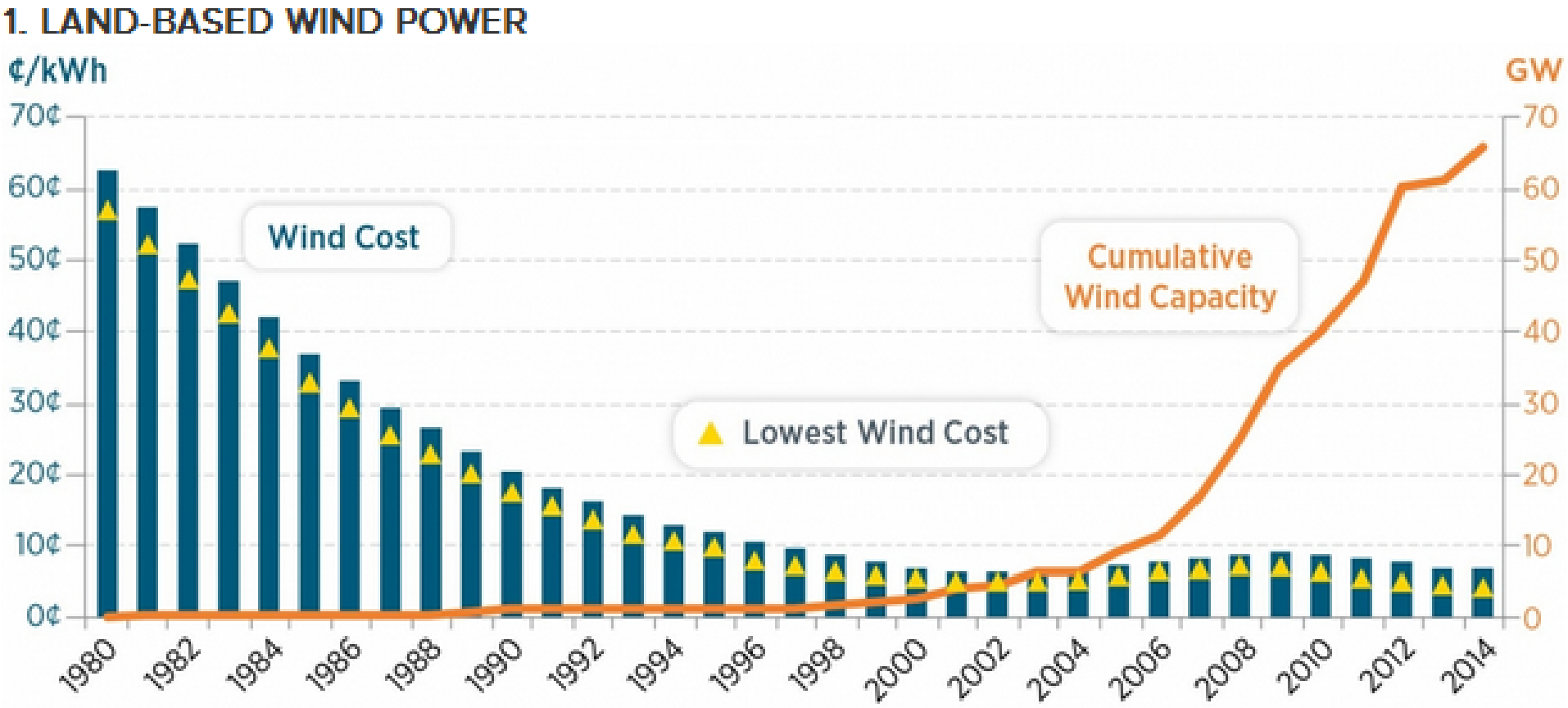
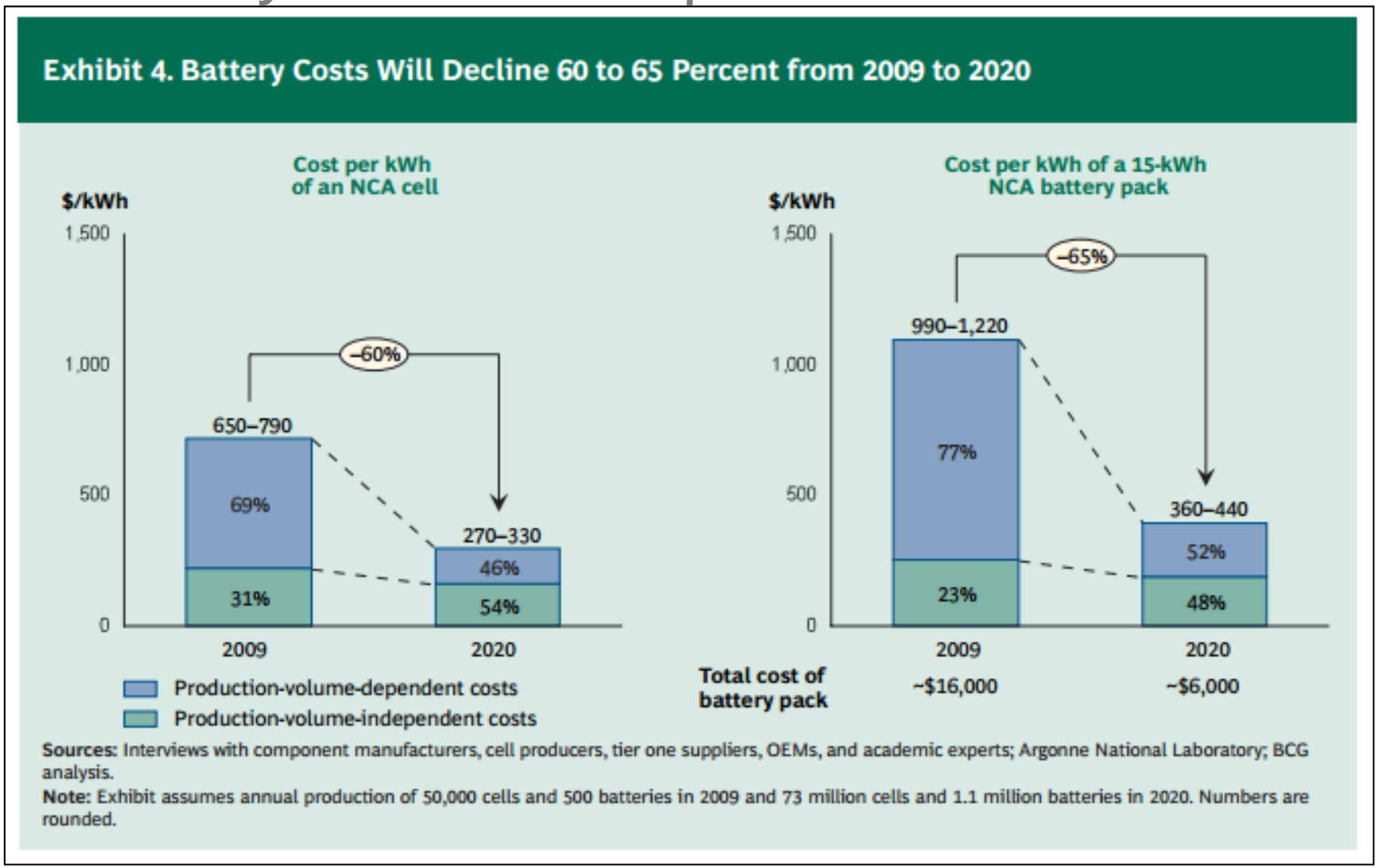
Technology needed

- Price of electricity from wind, 5 – 10 US cent/kWh



Breakingenergy.com

Battery cost development



Source: Boston Consulting Group
http://www.electricdrive.org/index.php?ht=a/GetDocumentAction/id/27906

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Is pumped hydro the solution to energy storage?

ENERGY STORAGE

Norway Could Provide 20,000MW of Energy Storage to Europe

Modifying existing infrastructure could add 20 GW of pumped hydro storage in just seven years.

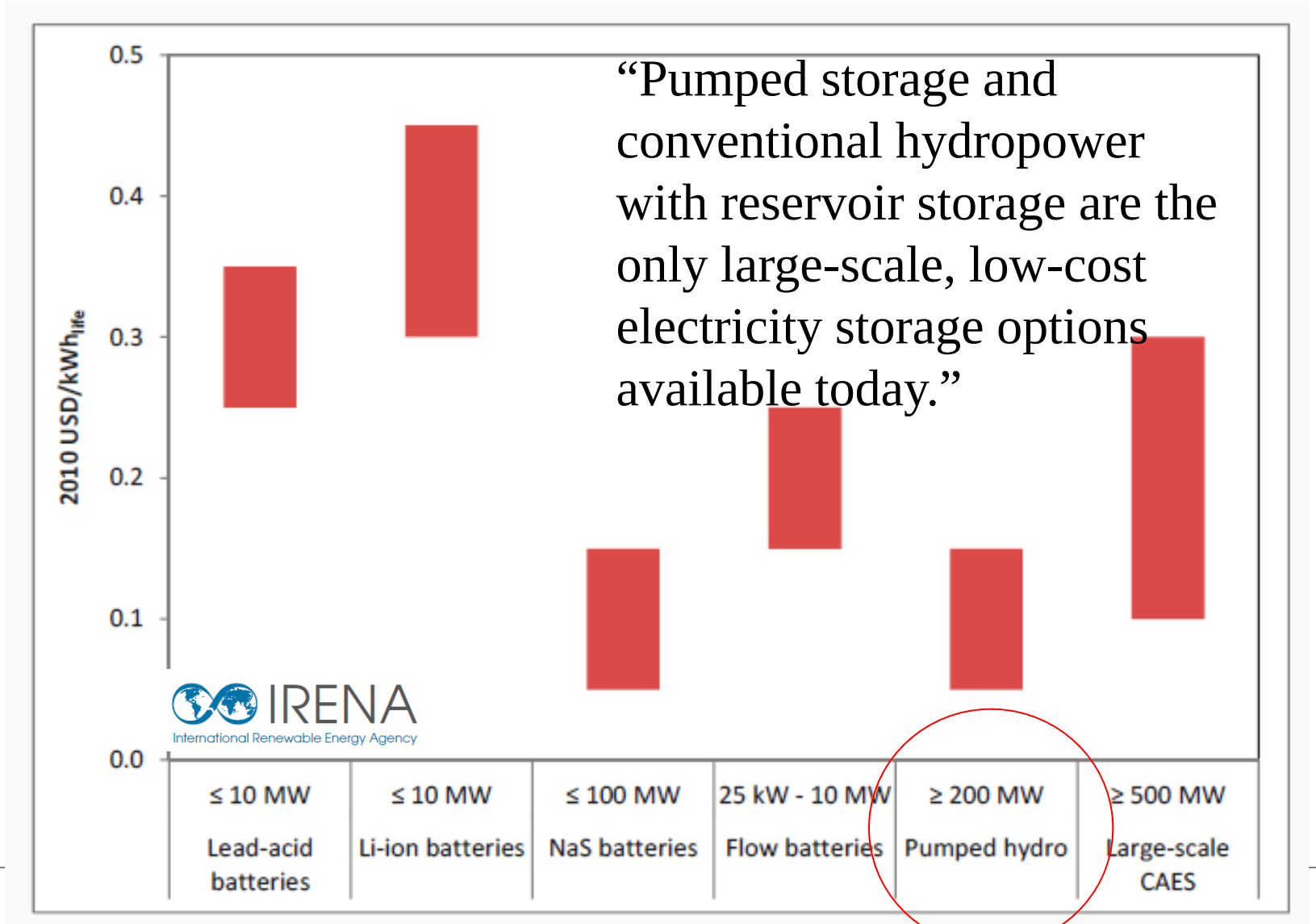
by Mike Stone

August 10, 2015

Norway has a lot of hydroelectric plants: a total of 937 of them, which provide a population of 5 million with around 98 percent of its electricity. In fact, the

Global Solar Demand Monitor:

Comparison of life cycle cost of electricity storage systems



"Pumped storage and conventional hydropower with reservoir storage are the only large-scale, low-cost electricity storage options available today."

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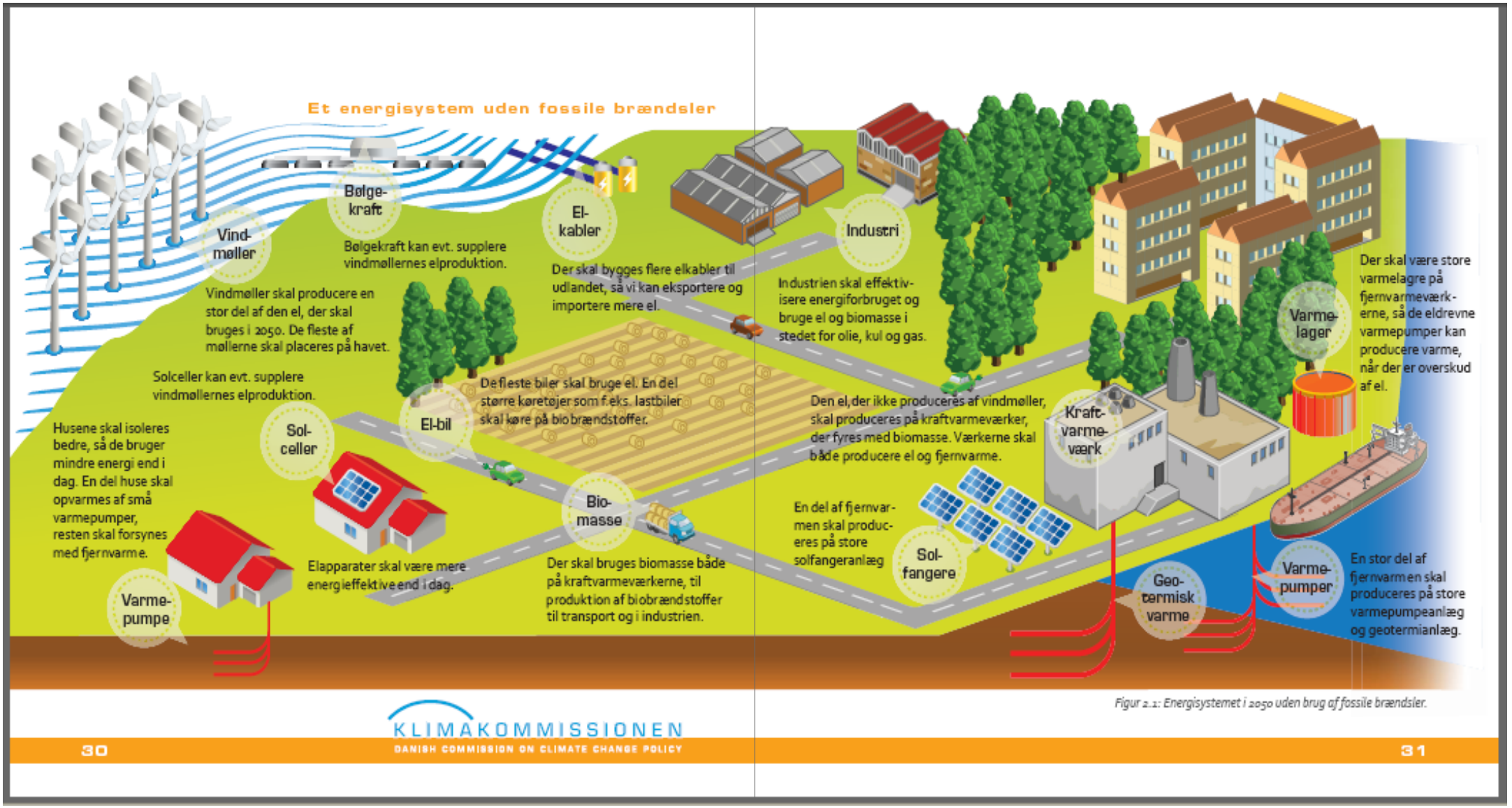
The energy future according to the Danish Klima commission



Figur 2.1: Energisystemet i 2050 uden brug af fossile brændsler.