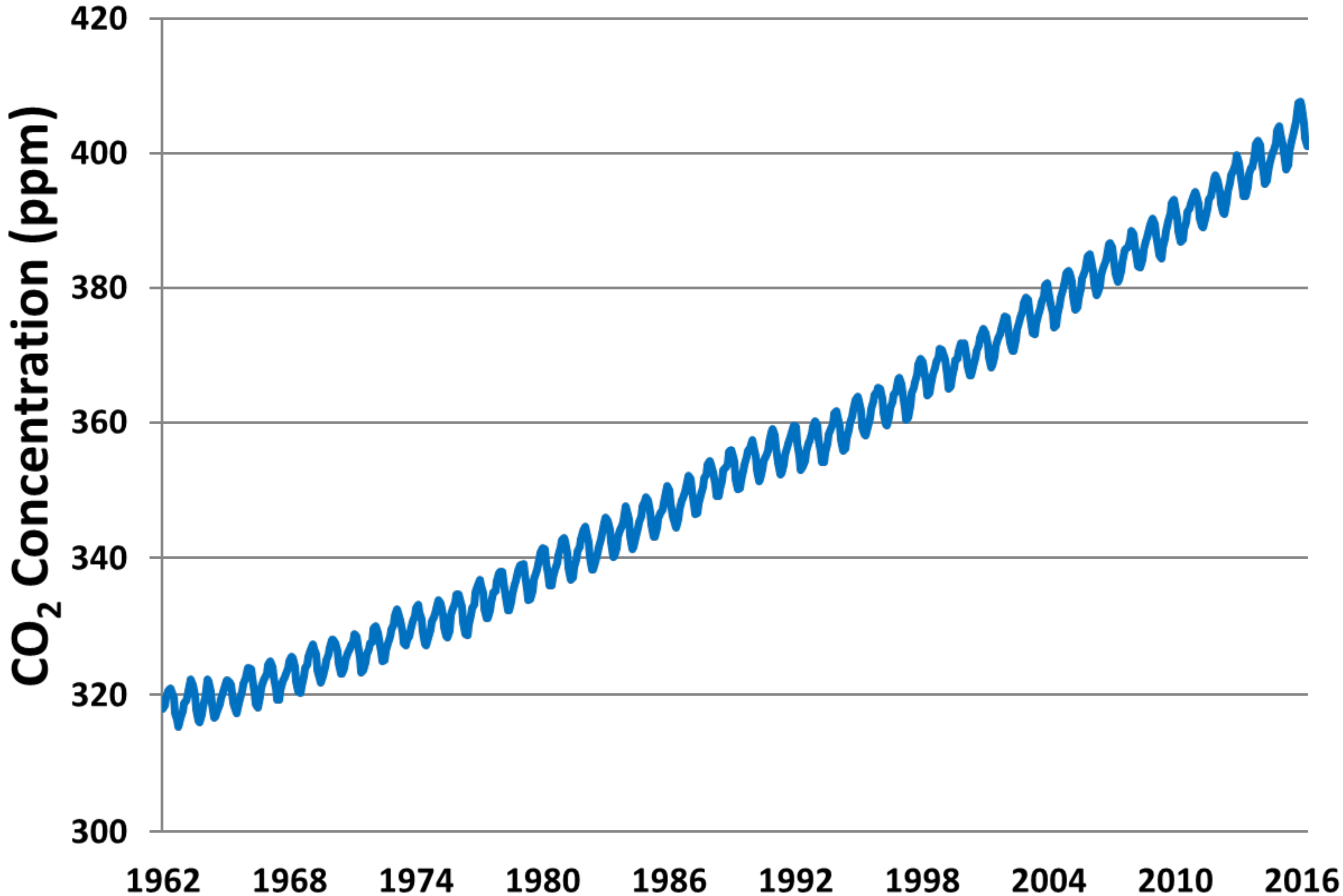
Mitigation measure, emission targets and carbon trading

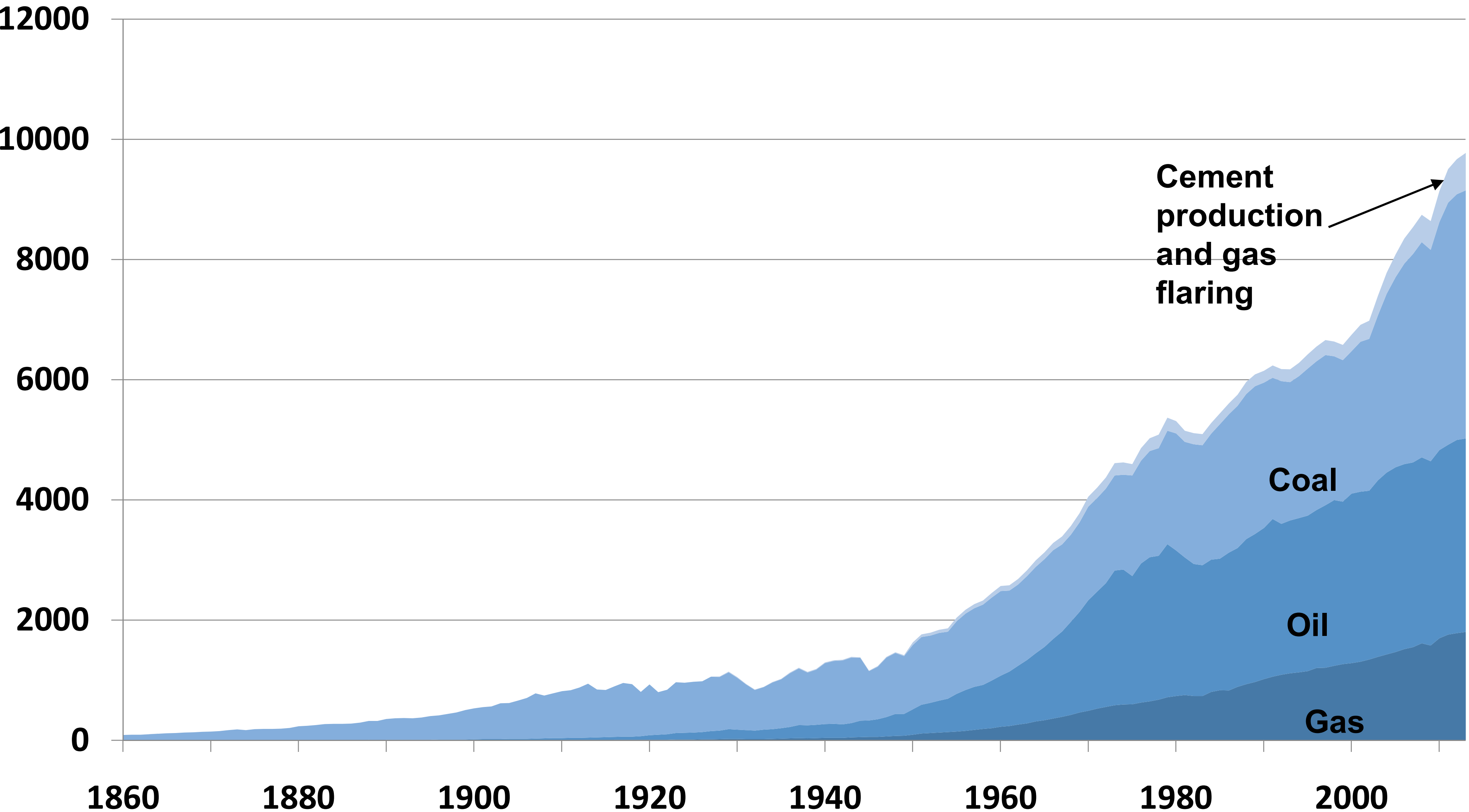
Figure 1: Atmospheric Carbon Dioxide Levels



Source: National Oceanic and Atmospheric Administration, Earth System Research laboratory, Global Monitoring Division http://www.esrl.noaa.gov/gmd/ccgg/trends/data.html

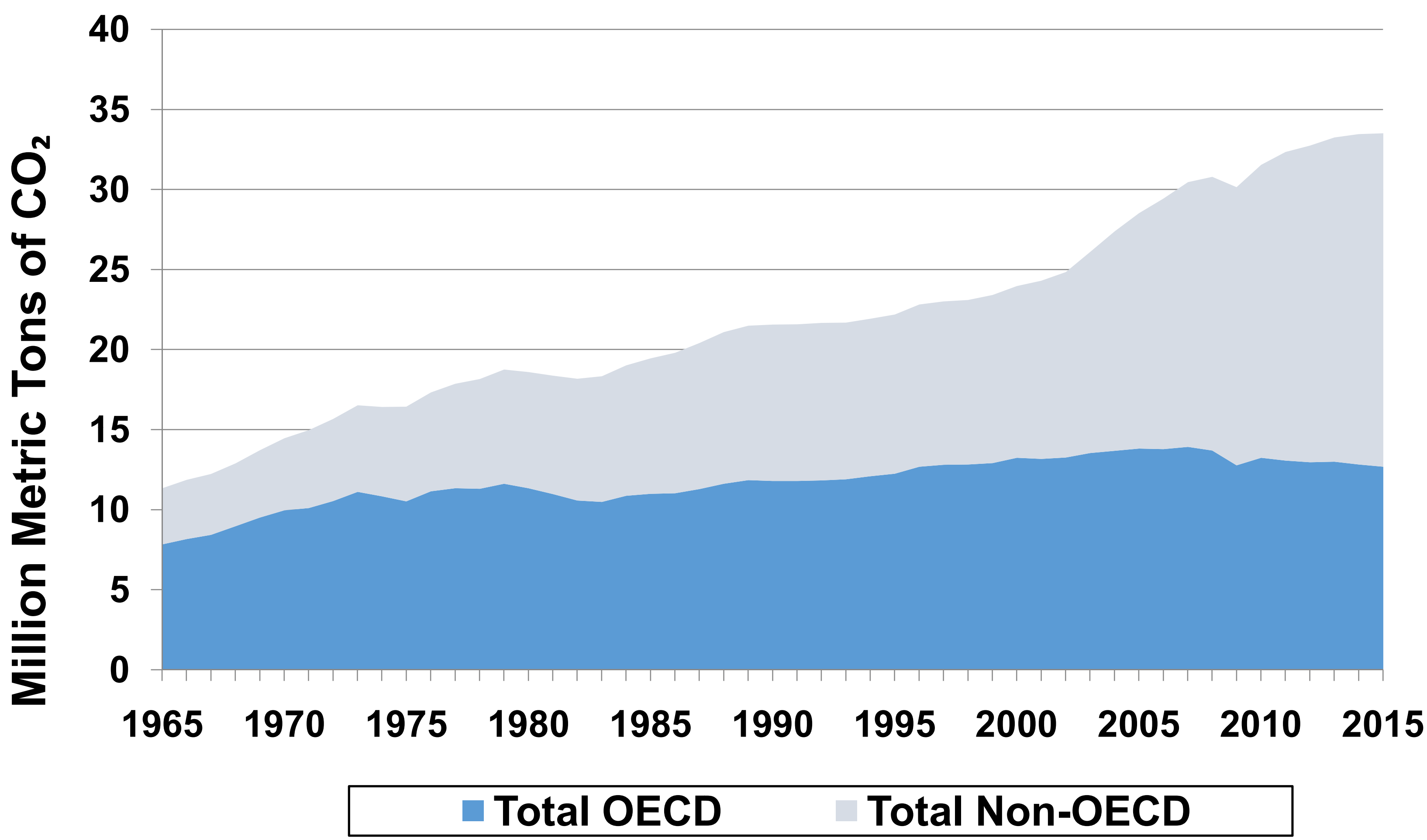
Note: Seasonal variations mean that CO_2 concentrations rise and fall each year with growth and decay of vegetation and other biological systems, but the long-term trend is a steady upward increase due to human emissions of CO_2.

Figure 2: Carbon Emissions from Fossil Fuel Consumption, 1860–2013



Dioxide Information Analysis Center (CDIAC)
.gov/ftp/ndp030/global.1751_2013.ems
016.
s in million tons (MMt) of carbon. To convert to MMt of CO_2, multiply by 3.67

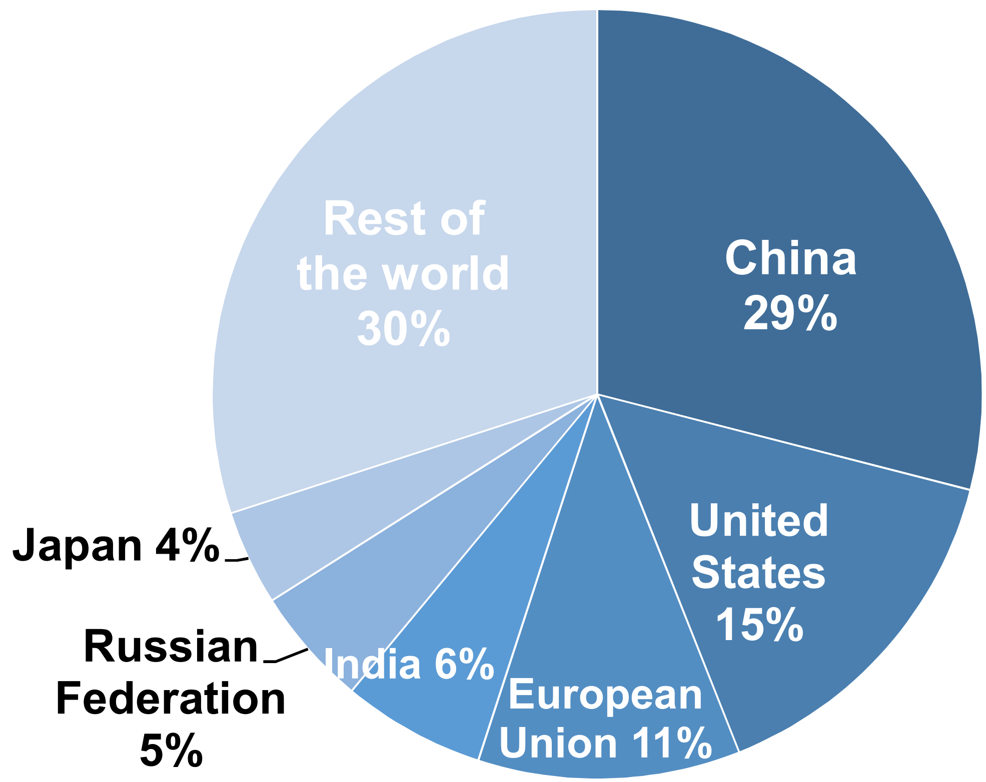
Figure 3: Carbon Dioxide Emissions, 1965-2015,
strialized and Developing Countries (Million Metric Tons of C



rgy Information Administration http://www.eia.gov/forecasts/aeo/data/browser/#/?id=10-IEO2016&sourcekey=0 accessed June

Organization for Economic Cooperation and Development (primarily industrialized countries, while non-OECD are developing
ertical axis in Figure 12.3 measures million metric tons of carbon dioxide. (the weight of a given amount of emissions measured
dioxide is about 3.67 times the total weight in carbon). The emissions estimates of the U.S. EIA shown here differ slightly from
AC shown in Figure 12.2.

Figure 4: Percentage of Global CO_2 Emissions by Country/Region



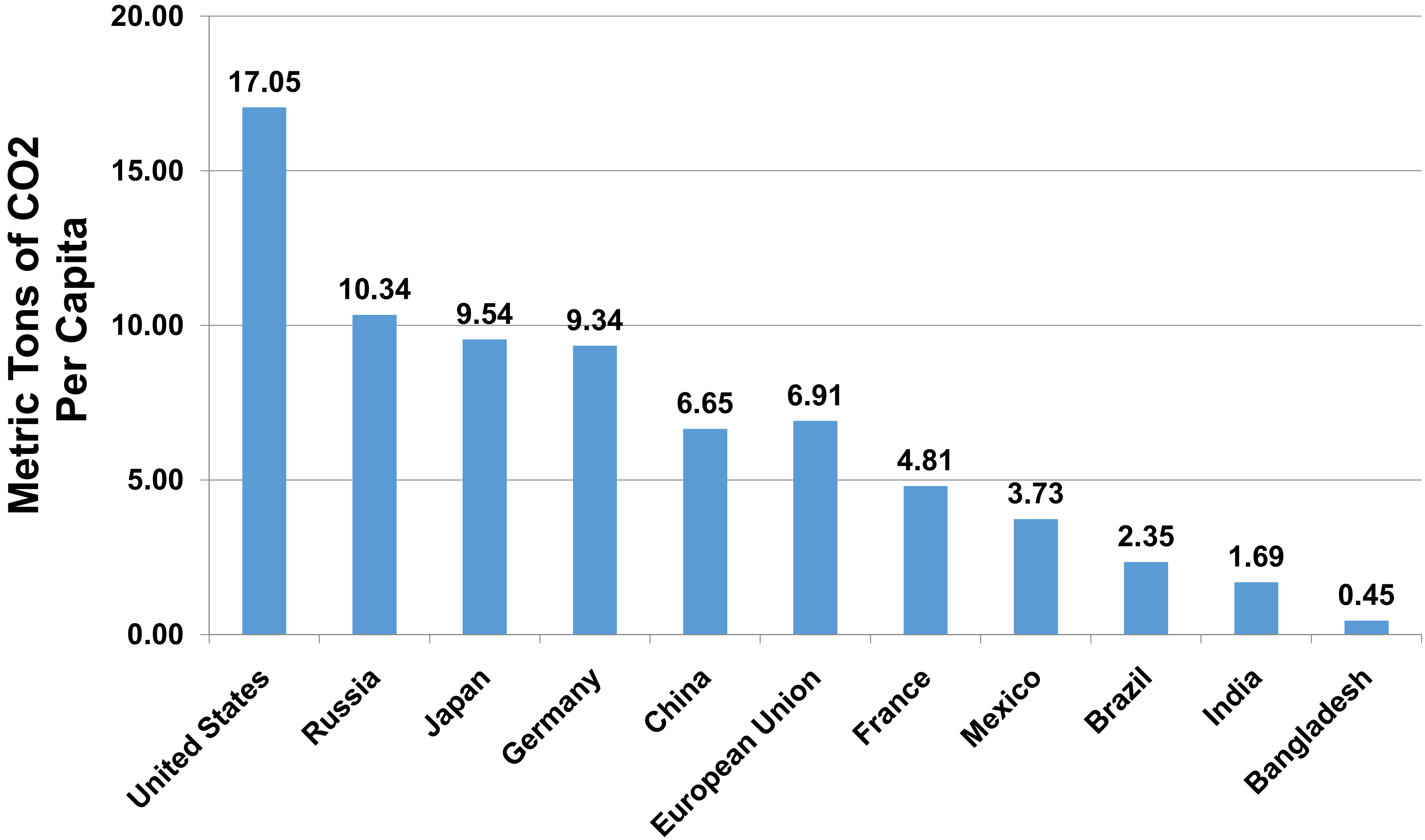
. Olivier et al., European Commission's Joint Research Centre, 2014. "Trends in global CO2 emissions: 2014 Report"
ec.europa.eu/news_docs/jrc-2014-trends-in-global-co2-emissions-2014-report-93171.pdf

Slide 5

AM2 Please change colors so that the legend is more clear - right now US and Rest of the world in the legend look alike. Maybe use white for rest of the world rather than black?

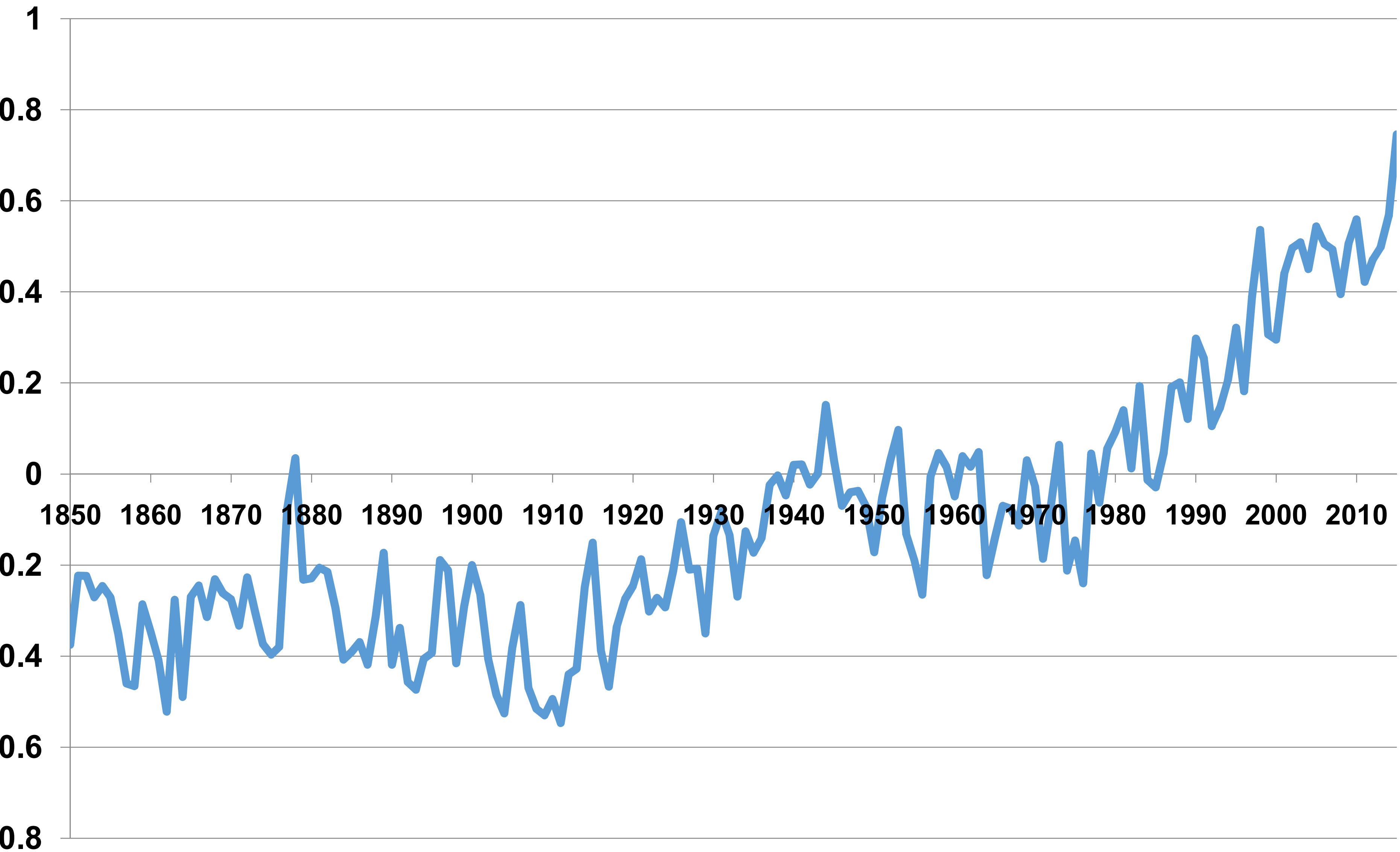
Anne Marie, 14-Jul-16

Figure 5: Per-Capita Carbon Dioxide Emissions, by Country



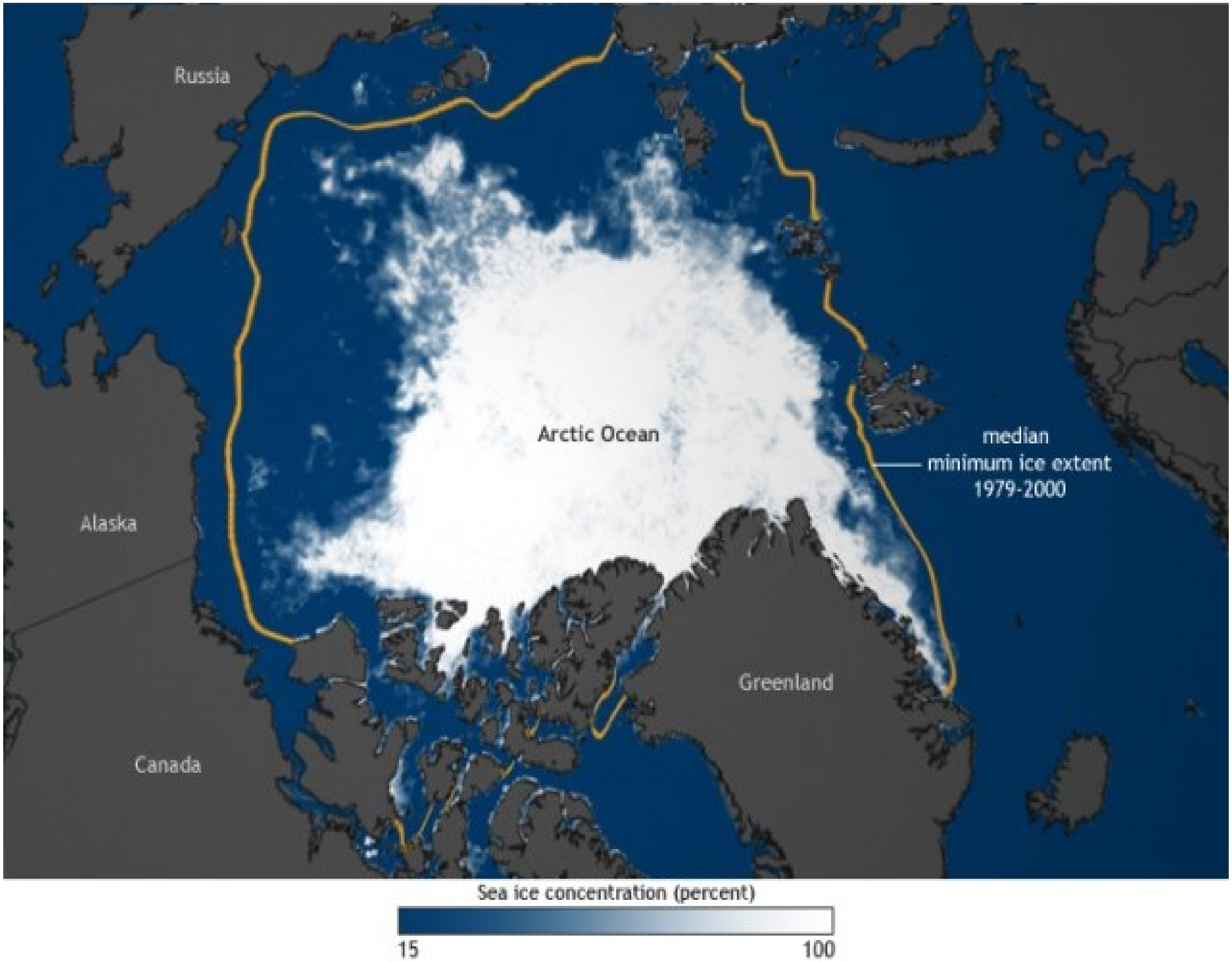
British Petroleum, Energy charting tool 2015.

Figure 6: Global Annual Temperature Anomalies (°C), 1850–2015



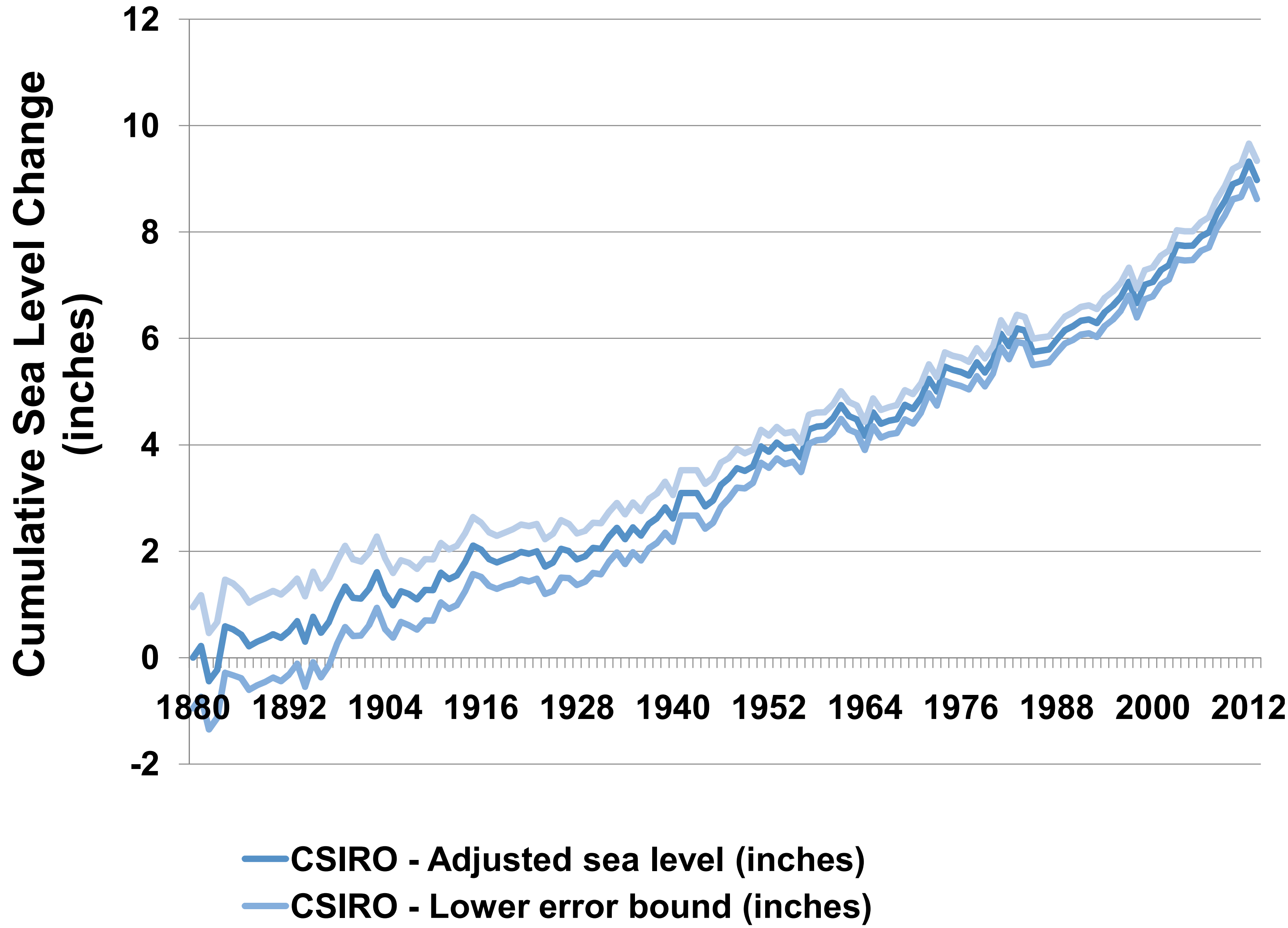
C, Global Monthly and Annual Temperature Anomalies (degrees C), 1850-2015, relative to the 1961-1990 mean, May 2016.
.gov/ftp/trends/temp/jonescru/global.txt *Note:* The zero baseline represents the average global temperature from 1961 to 1990.

Figure 7: Shrinking Arctic Ice in the Arctic



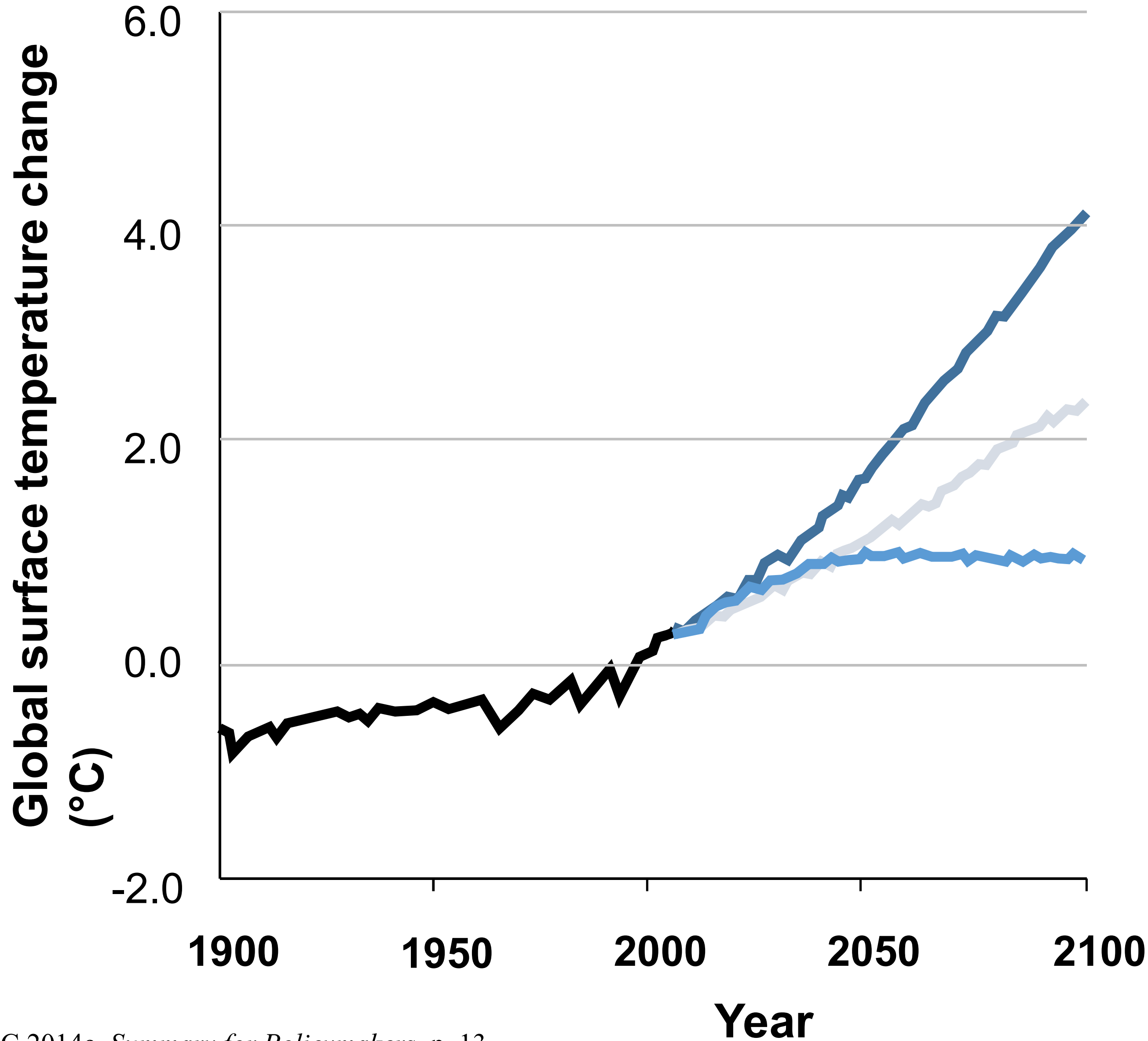
Source: http://thinkprogress.org/climate/2014/02/18/3302341/arctic-sea-ice-melt-ocean-absorbs-heat/.
Figure is based on data from the National Snow and Ice Data Center. Credit: Climate.gov.

Figure 8: Sea-Level Rise, 1880–2012



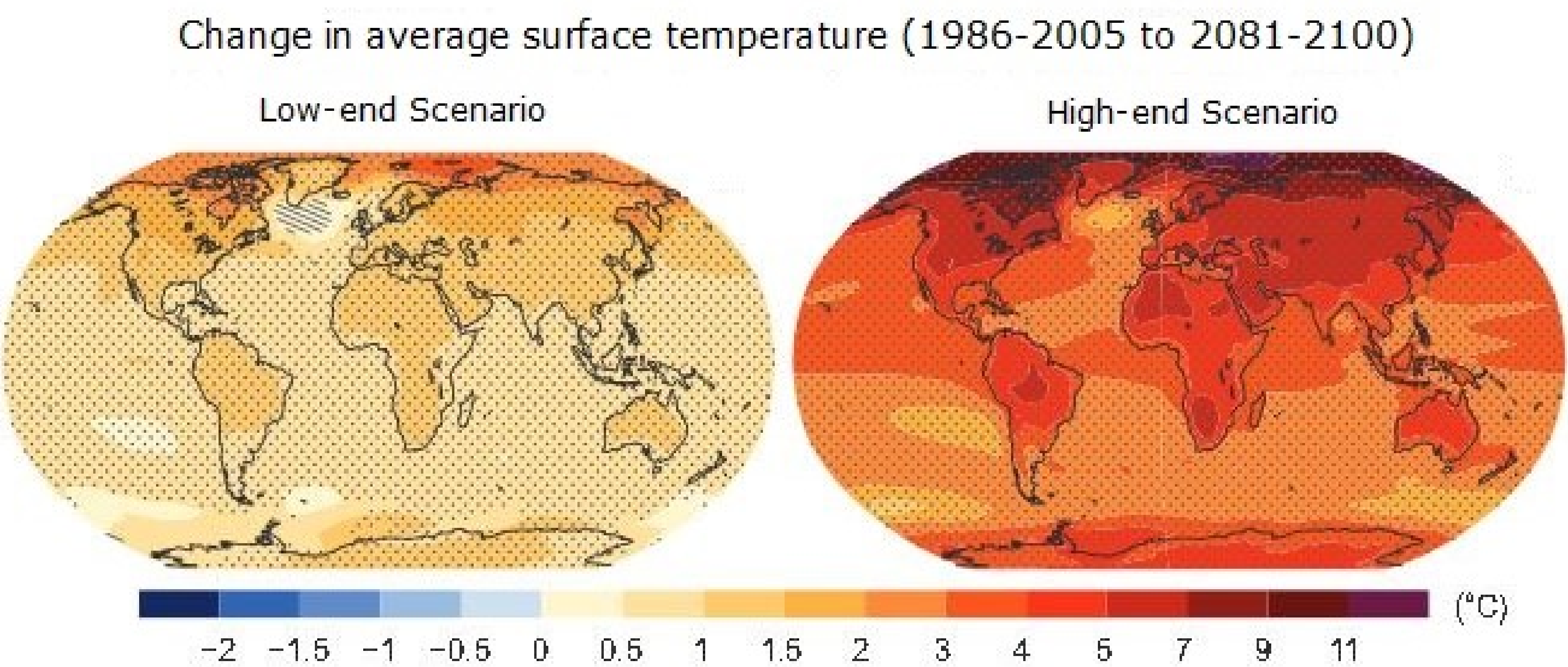
2014a
in the middle shows an average estimate based on a large number of data sources. Upper and lower lines represent high and low
f error (smaller for recent data).

Figure 9: Global Temperature Trends, 1900–2100



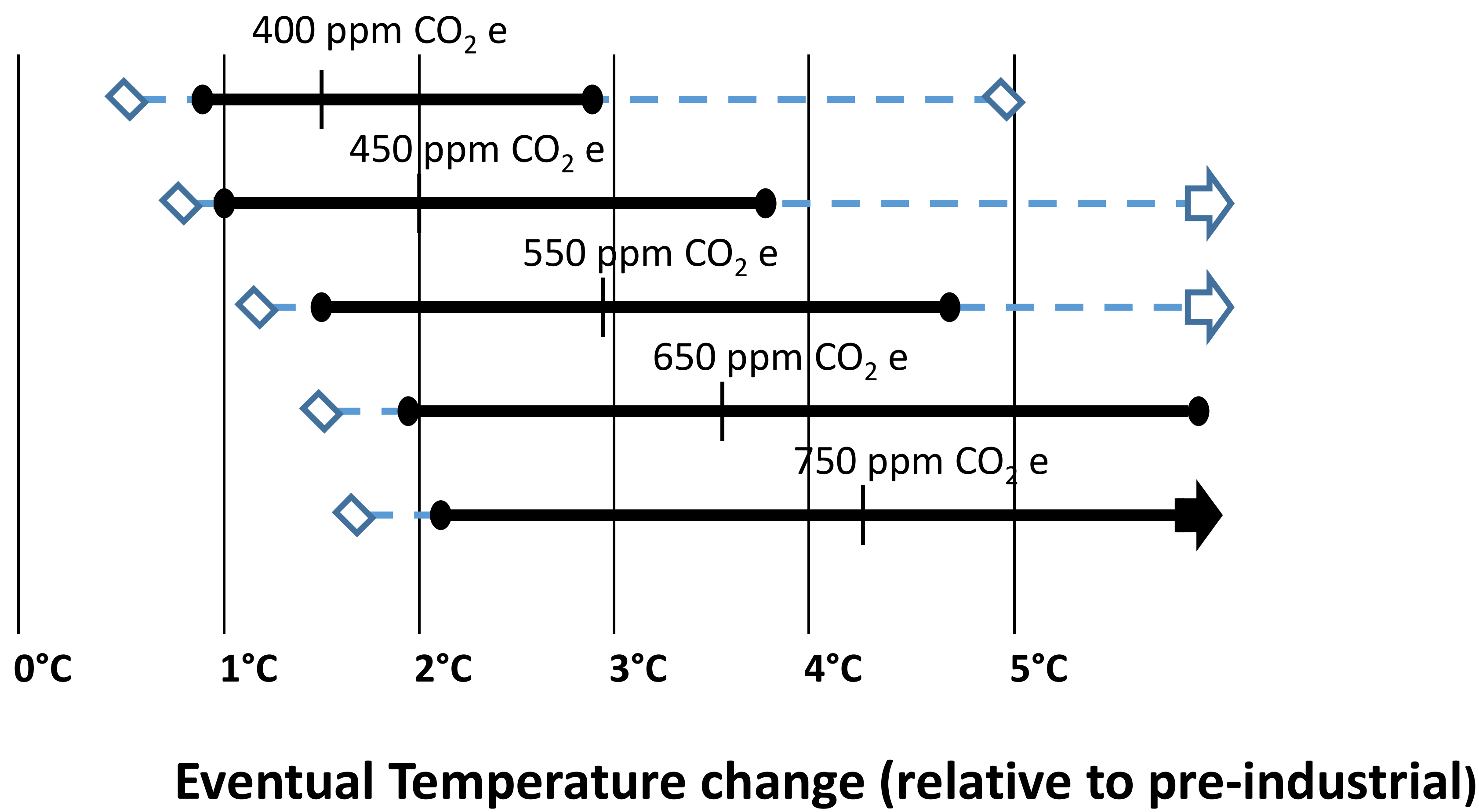
Source: IPCC 2014c, *Summary for Policymakers*, p. 13.

Figure 10: Global Temperature Trends Projected to 2100 – Two Scenarios



Source: IPCC, 2013

Figure 11: The Relationship Between the Level of Greenhouse Gas Stabilization and Eventual Temperature Change



.007.

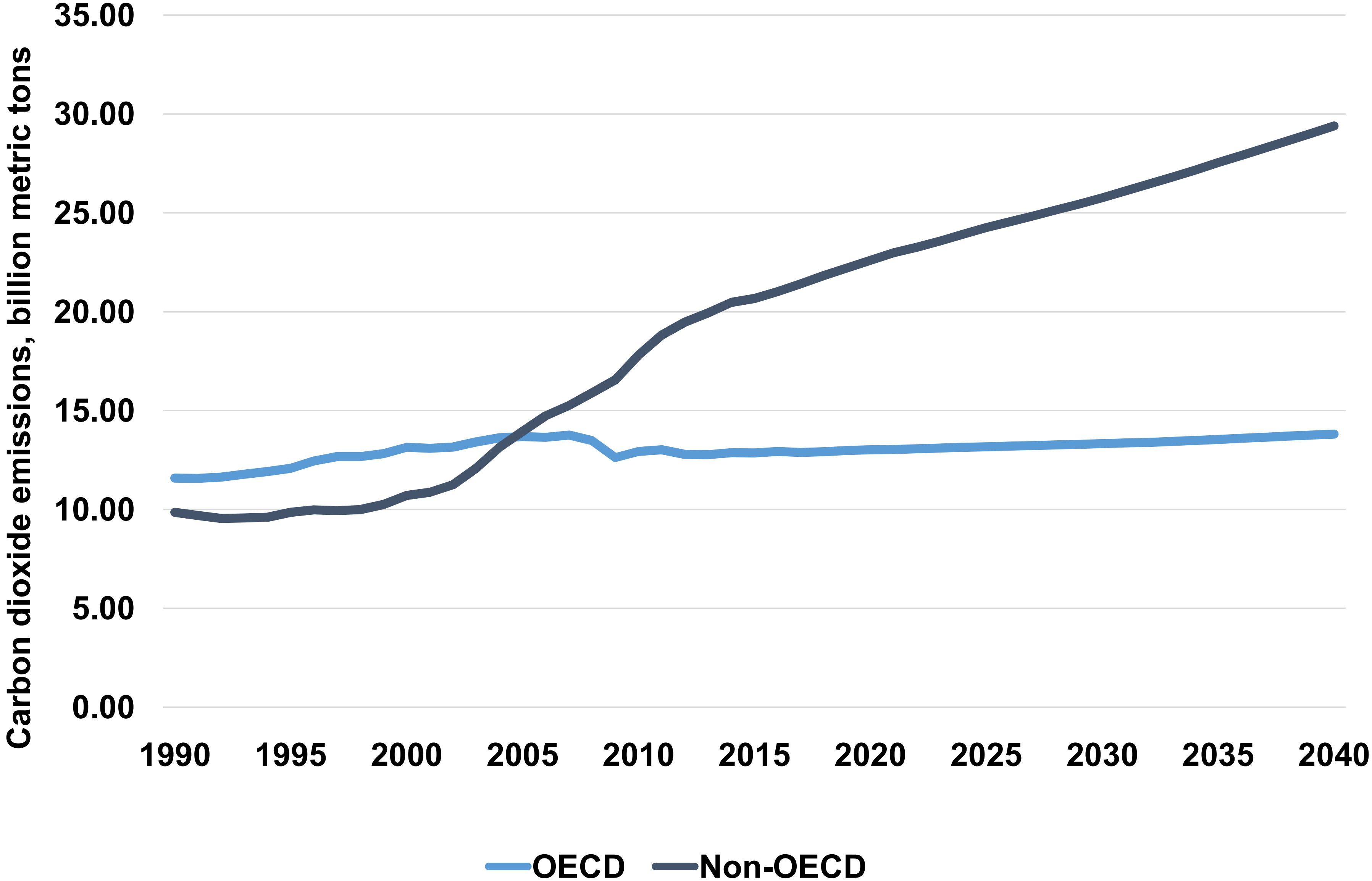
O_2 equivalent; ppm = parts per million.

Table 1: Possible Effects of Climate Change

	Eventual Temperature Rise Relative to Pre-Industrial Temperatures				
Type of Impact	**1°C**	**2°C**	**3°C**	**4°C**	**5°C**
Freshwater Supplies	Small glaciers in the Andes disappear, threatening water supplies for 50 million people	Potential water supply decrease of 20–30% in some regions (Southern Africa and Mediterranean)	Serious droughts in southern Europe every 10 years 1–4 billion more people suffer water shortages	Potential water supply decrease of 30–50% in southern Africa and Mediterranean	Large glaciers in Himalayas possibly disappear, affecting ¼ of China's population
Food and Agriculture	Modest increase in yields in temperature regions	Declines in crop yields in tropical regions (5–10% in Africa)	150–550 million more people at risk of hunger Yields likely to peak at higher latitudes	Yields decline by 15–35% in Africa Some entire regions out of agricultural production	Increase in ocean acidity possibly reduces fish stocks
Human Health	At least 300,000 die each year from climate–related diseases Reduction in winter mortality in high latitudes	40–60 million more exposed to malaria in Africa	1–3 million more potentially people die annually from malnutrition	Up to 80 million more people exposed to malaria in Africa	Further disease increase and substantial burdens on health care services
Coastal Areas	Increased damage from coastal flooding	Up to 10 million more people exposed to coastal flooding	Up to 170 million more people exposed to coastal flooding	Up to 300 million more people exposed to coastal flooding	Sea-level rise threatens major cities such as New York, Tokyo, and London
Ecosystems	At least 10% of land species facing extinction Increased wildfire risk	15–40% of species potentially face extinction	20–50% of species potentially face extinction Possible onset of collapse of Amazon forest	Loss of half of Arctic tundra Widespread loss of coral reefs	Significant extinctions across the globe

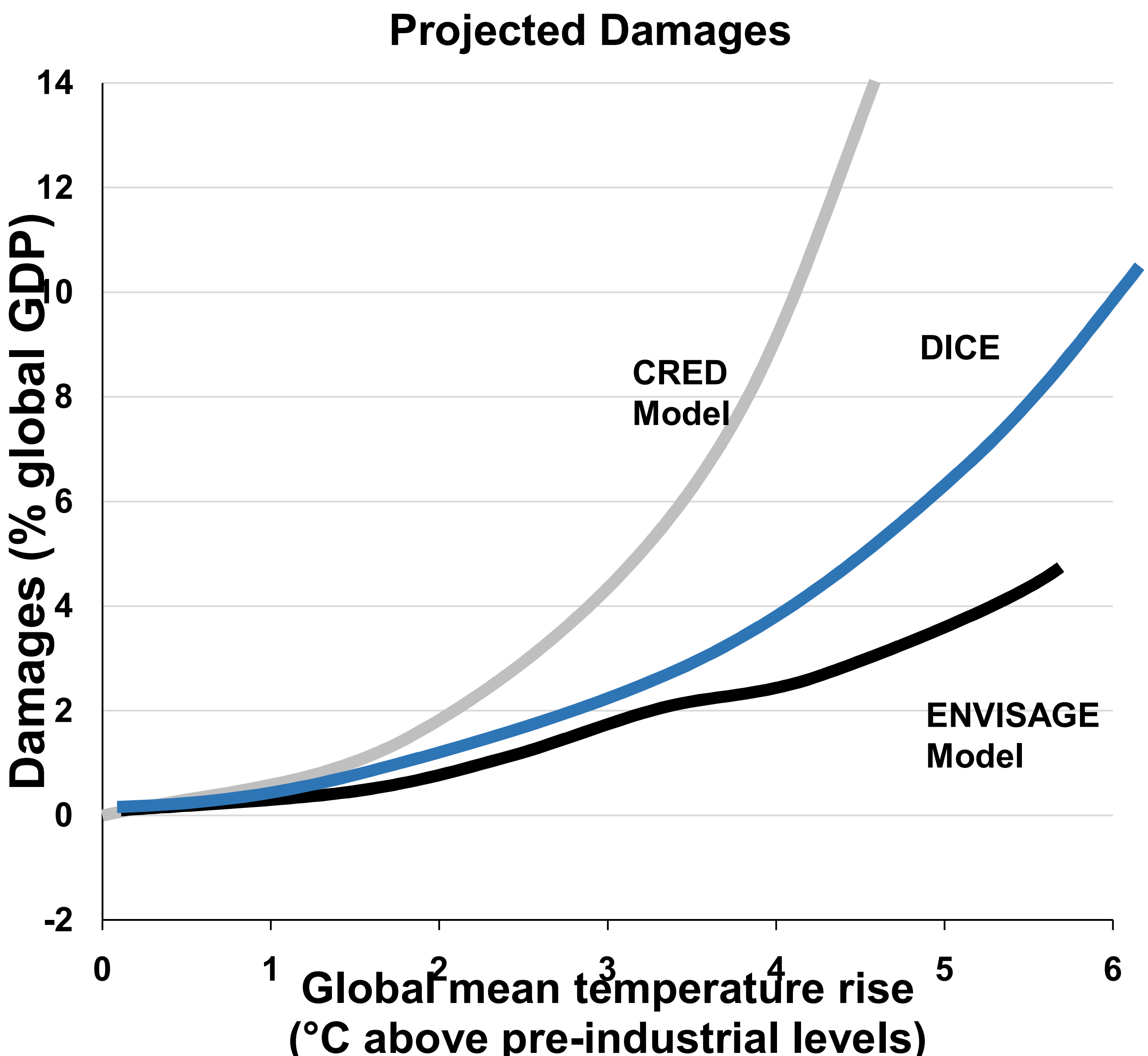
Sources: IPCC, 2007b; Stern, 2007.

Figure 12: Energy-Related Carbon Dioxide Emissions, Projected to 2040



016.
nization for Economic Cooperation and Development (OECD) includes primarily industrialized countries, and non-OECD
est of the world, including developing countries and including China.

Figure 13: Increasing Damages from Rising Global Temperatures



Source: R. Revesz, K. Arrow et al., 2014.
http://www.nature.com/news/global-warming-improve-economic-models-of-climate-change-1.14991
Note: The three different models (ENVISAGE, DICE, and CRED) shown in this figure give damage estimates that are similar at low to moderate levels of temperature change, but diverge at higher levels, reflecting different assumptions used in modeling.

Figure 14: Present Value of a Future $100 Cost or Benefit: The Effects of Different Discount Rates

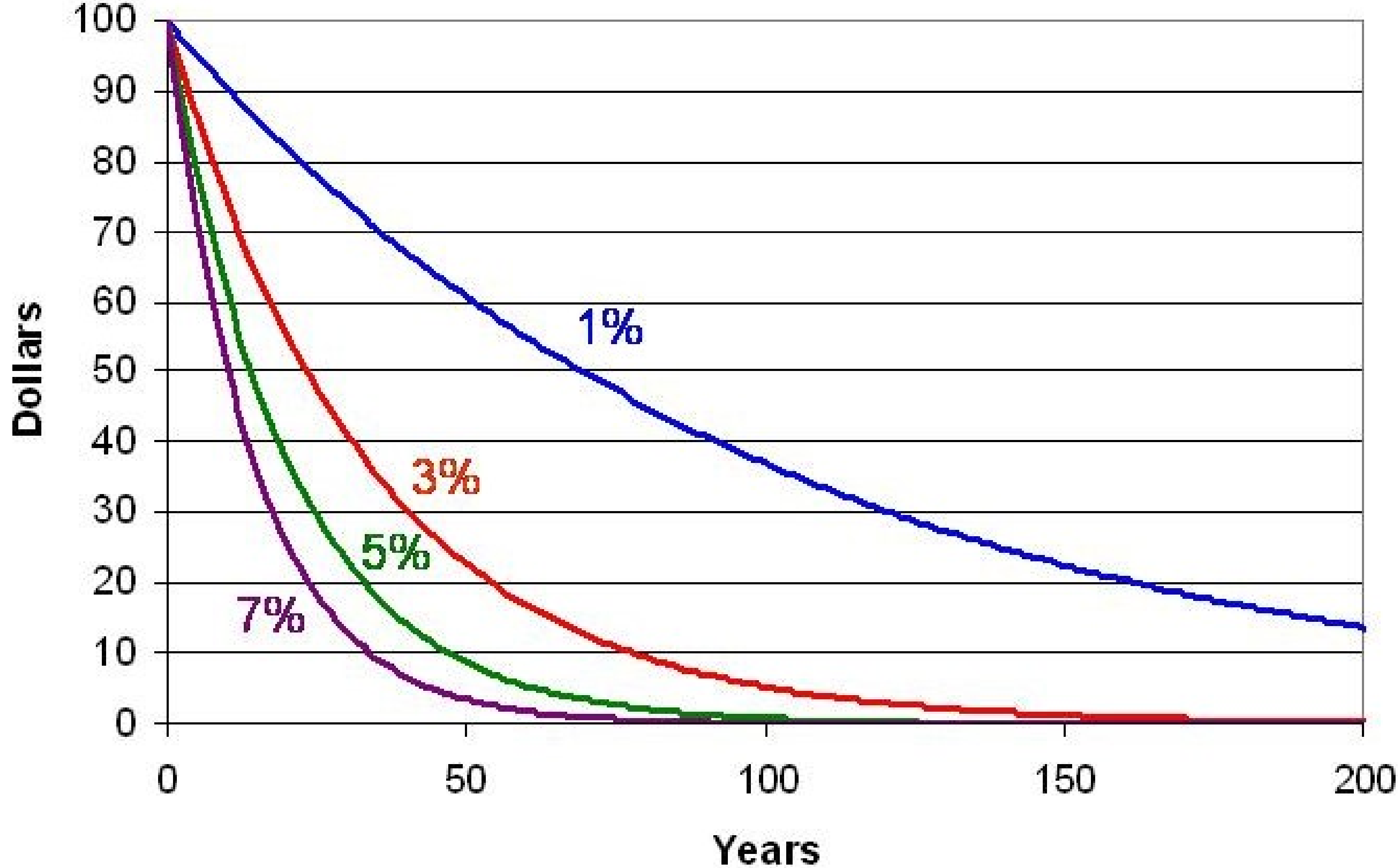


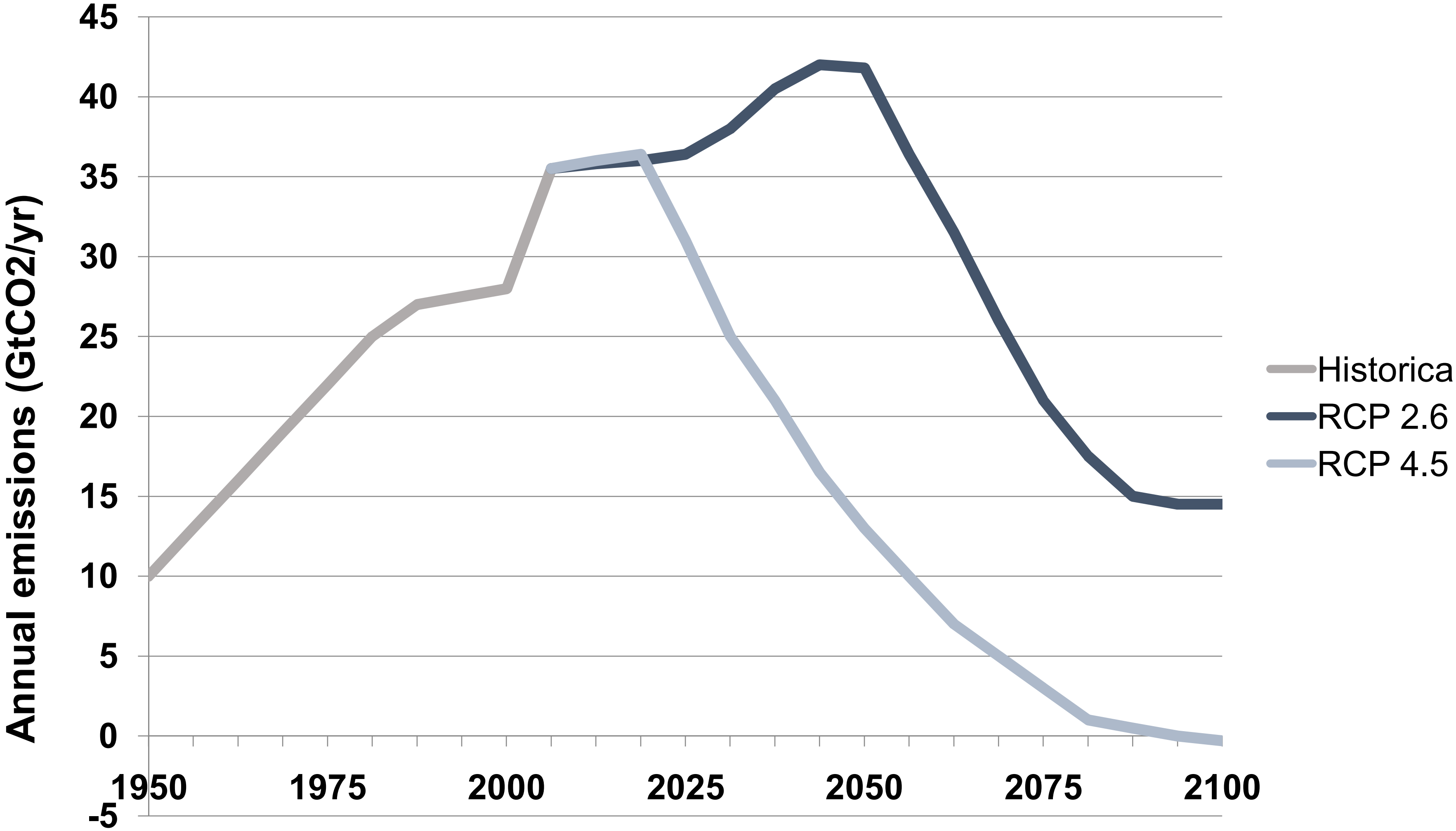
Table 2: Regional-Scale Impacts of Climate Change by 2080 (millions of people)

Region	Population living in watersheds with an increase in water-resources stress	Increase in average annual number of coastal flood victims	Additional population at risk of hunger (figures in parentheses assume maximum CO_2 enrichment effect)
Europe	382–493	0.3	0
Asia	892–1197	14.7	266 (–21)
North America	110–145	0.1	0
South America	430–469	0.4	85 (–4)
Africa	691–909	12.8	200 (–2)

Source: Adapted from IPCC, 2007b.

Note: These estimates are based on a business-as-usual scenario (IPCC A2 scenario). The CO_2 enrichment effect is increased plant productivity, which at maximum estimates could actually decrease the number at risk of hunger.

Figure 15: Carbon Stabilization Scenarios: Required Emissions Reductions



Source: IPCC, 2014d, p. 11.
Note: Upper line represents IPCC RCP 4.5 scenario (moderate stabilization in the range of 530 – 580 ppm CO_2 accumulation) and lower line represents IPCC RCP 2.6 scenario (stronger stabilization at 430 – 480 ppm CO_2 accumulation).

Table 3: Climate Change Adaptation Needs, by Sector

Sector	Adaptation strategies
Water	Expand water storage and desalination Improve watershed and reservoir management Increase water-use and irrigation efficiency and water re-use Urban and rural flood management
Agriculture	Adjust planting dates and crop locations Develop crop varieties adapted to drought, higher temperatures Improved land management to deal with floods/droughts Strengthen indigenous/traditional knowledge and practice
Infrastructure	Relocate vulnerable communities Build and strengthen seawalls and other barriers Create and restore wetlands for flood control Dune reinforcement
Human health	Health plans for extreme heat Increase tracking, early-warning systems for heat-related diseases Address threats to safe drinking water supplies Extend basic public health services

Source: IPCC, 2007; IPCC, 2014b.

Table 3 continued: Climate Change Adaptation Needs, by Sector

Sector	Adaptation strategies
Transport	Relocation or adapt transport infrastructure New design standards to cope with climate change
Energy	Strengthen distribution infrastructure Address increased demand for cooling Increase efficiency, increase use of renewables
Ecosystems	Reduce other ecosystem stresses and human use pressures Improve scientific understanding, enhanced monitoring Reduce deforestation, increase reforestation Increase mangrove, coral reef, and seagrass protection

Source: IPCC, 2007; IPCC, 2014b.

Table 4: Alternative Carbon Taxes on Fossil Fuels

Impact of Carbon Price on Retail Price of Gasoline

kg CO_2 per gallon	8.89
tonnes CO_2 per gallon	0.00889
$/gal., $50/tonne tax	$0.45
$/gal., $100/tonne tax	$0.88
Retail price (2016) per gallon	$2.20
% increase, $50/tonne tax	20.2
% increase, $100/tonne tax	40.4

Impact of Carbon Price on Retail Price of Coal

kg CO_2 per short ton	2100
tonnes CO_2 per short ton	2.1
$/short ton, $50/tonne tax	$105
$/short ton, $100/tonne tax	$210
Retail price (2016) per short ton	$40
% increase, $50/tonne tax	262.5
% increase, $100/tonne tax	525.0

emissions calculated from carbon coefficients and thermal conversion factors available from the U.S.
Energy. All price data from the U.S. Energy Information Administration.

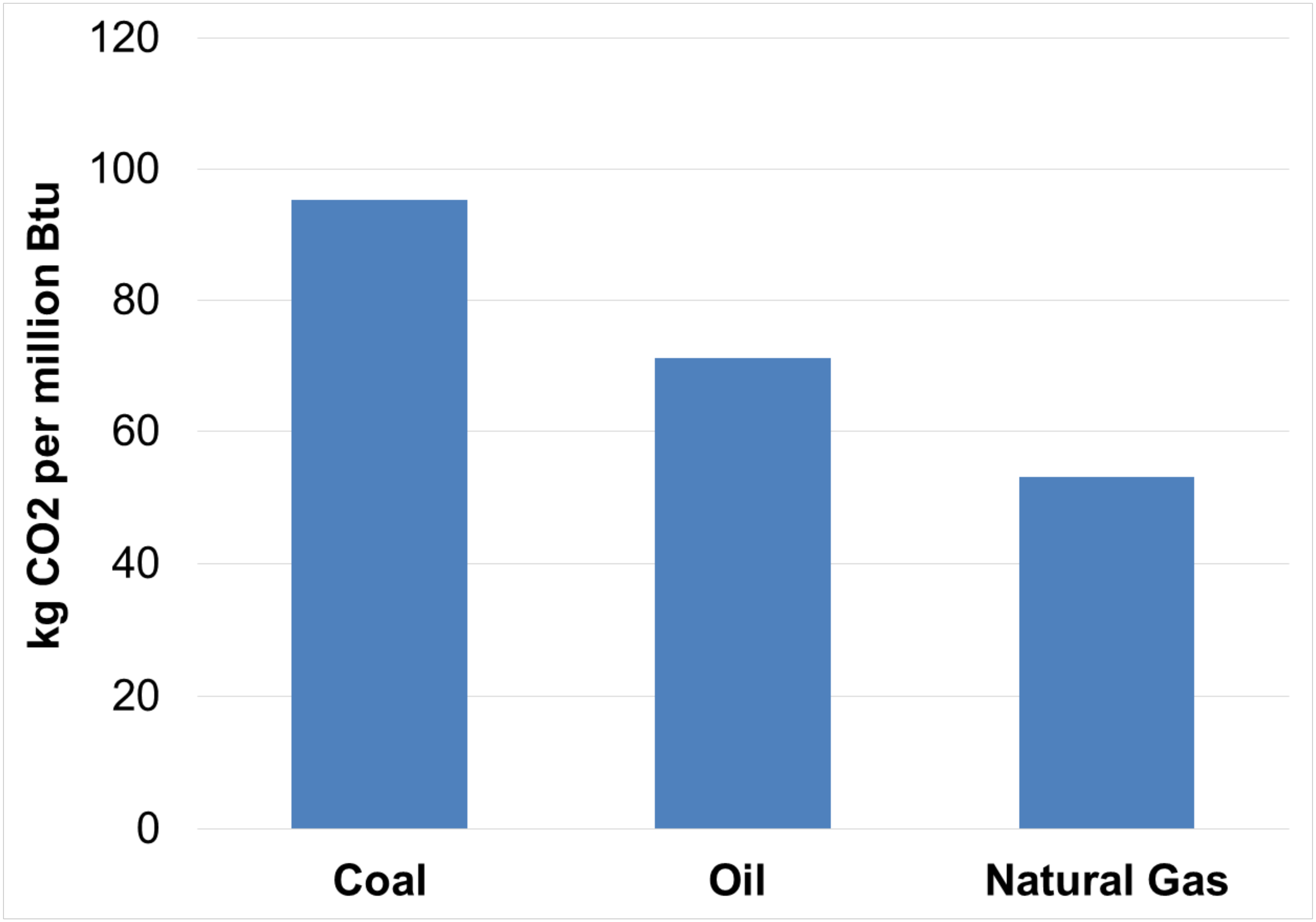
Table 4: Alternative Carbon Taxes on Fossil Fuels

Impact of Carbon Price on Retail Price of Natural Gas

kg CO_2 per 1000 cu. ft.		53.12
tonnes CO_2 per 1000 cu. ft.		0.05312
$/1000 cu. ft., $50/tonne tax		$2.66
$/1000 cu. ft., $100/tonne tax	$5.31	
Retail price (2016)	$12	
% increase from $50/tonne tax	22.1	
% increase from $100/tonne tax		44.2

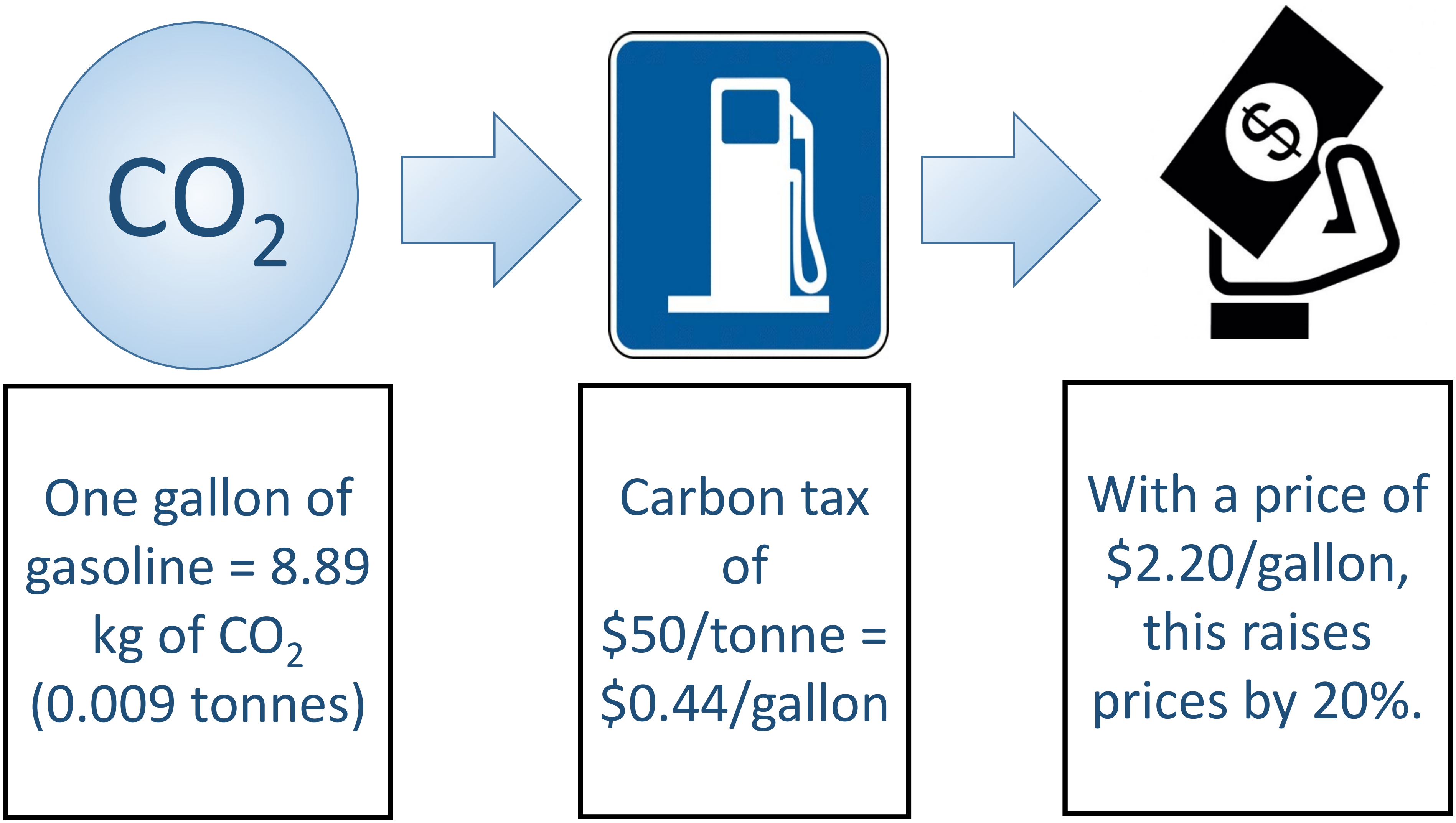
emissions calculated from carbon coefficients and thermal conversion factors available from the U.S. Department of Energy.
om the U.S. Energy Information Administration.

Figure 16: Carbon Content of Fuels



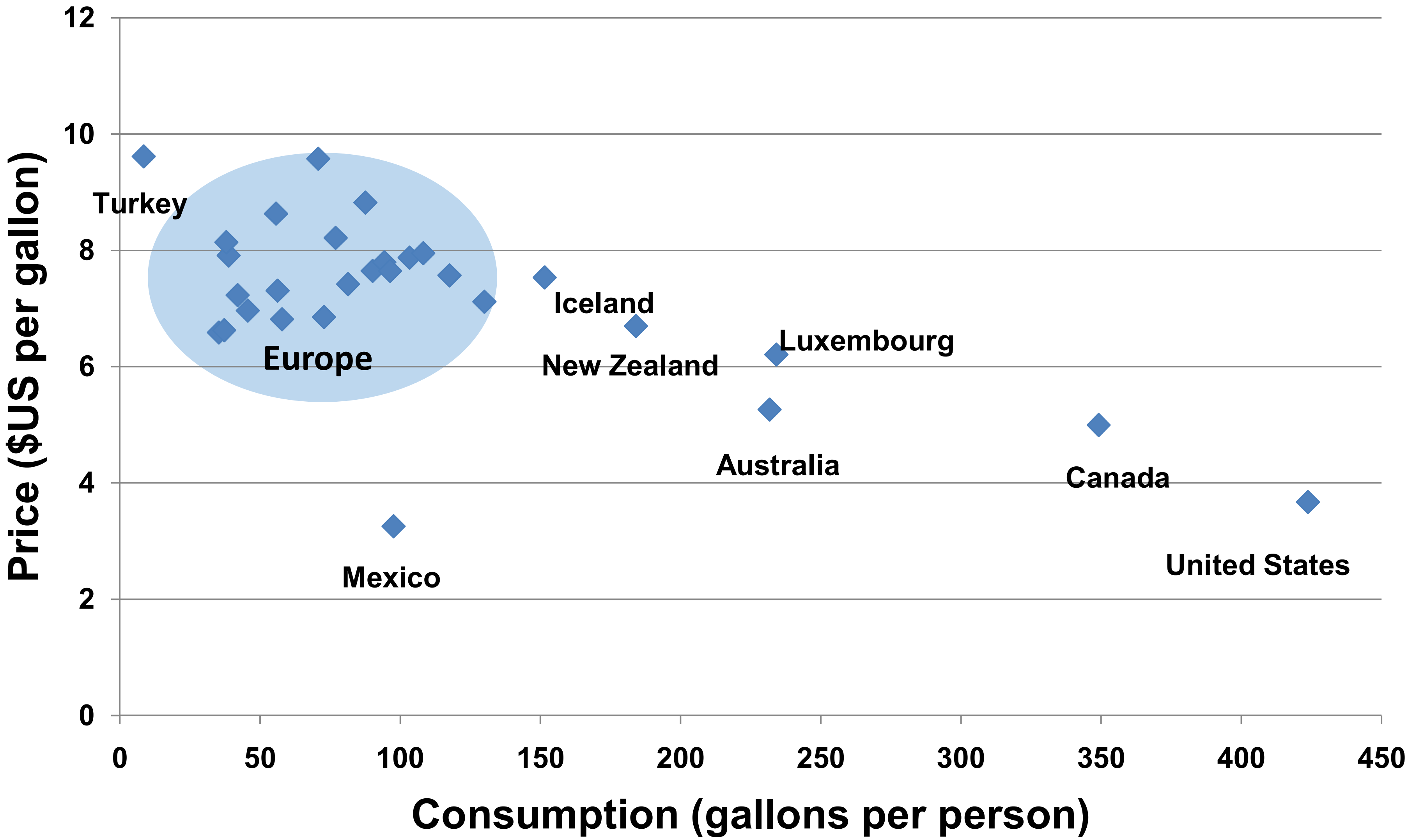
ated from U.S. Department of Energy data.

Figure 17: Impact of a Carbon Tax on Gasoline Price



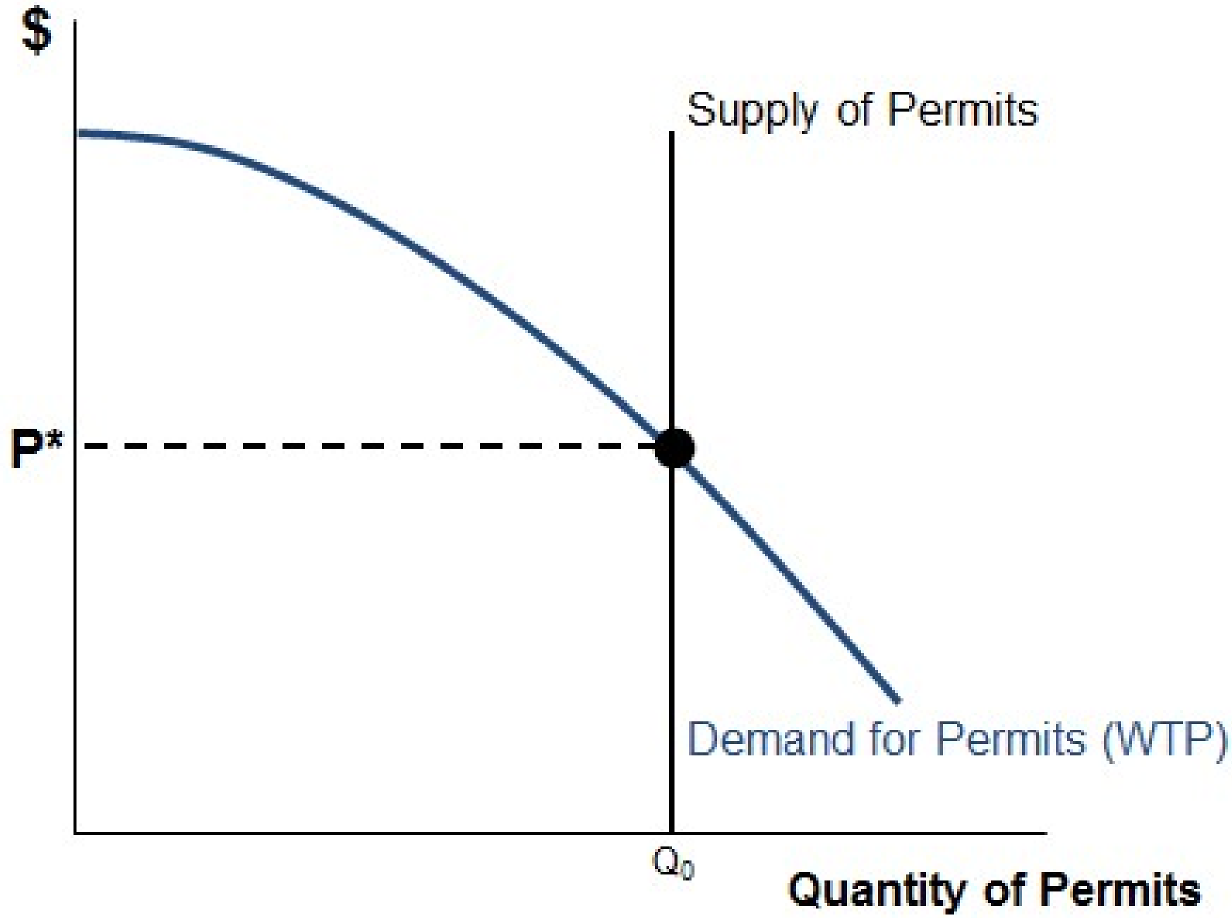
ted from U.S. Department of Energy data.

gure 18: Gasoline Price Versus Consumption in Industrial Countries, 2



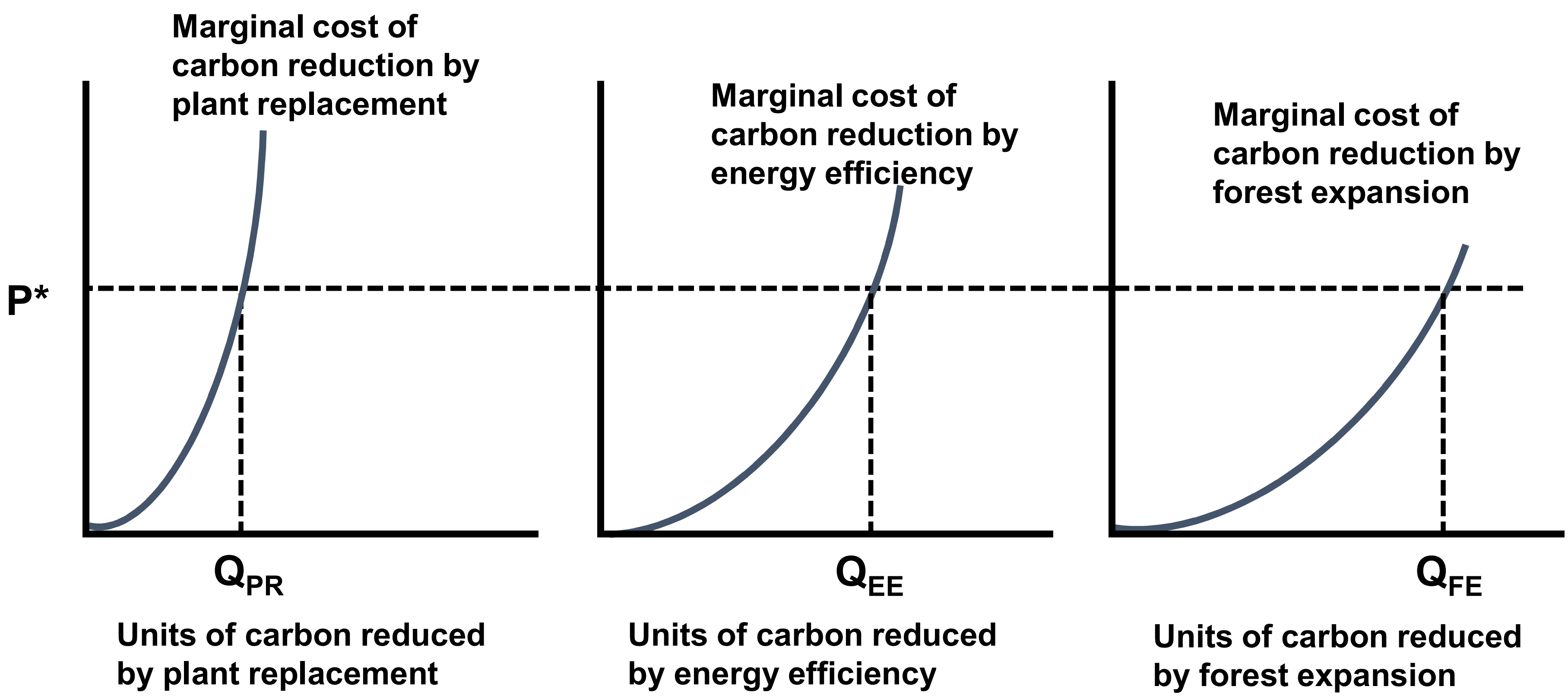
nergy Information Administration database, *International Energy Statistics; GIZ,* International Fuel Prices 2012/2013;
orld Development Indicators (Population).
rea represents price/consumption range typical of West European countries.

Figure 19: Determination of Carbon Permit Price



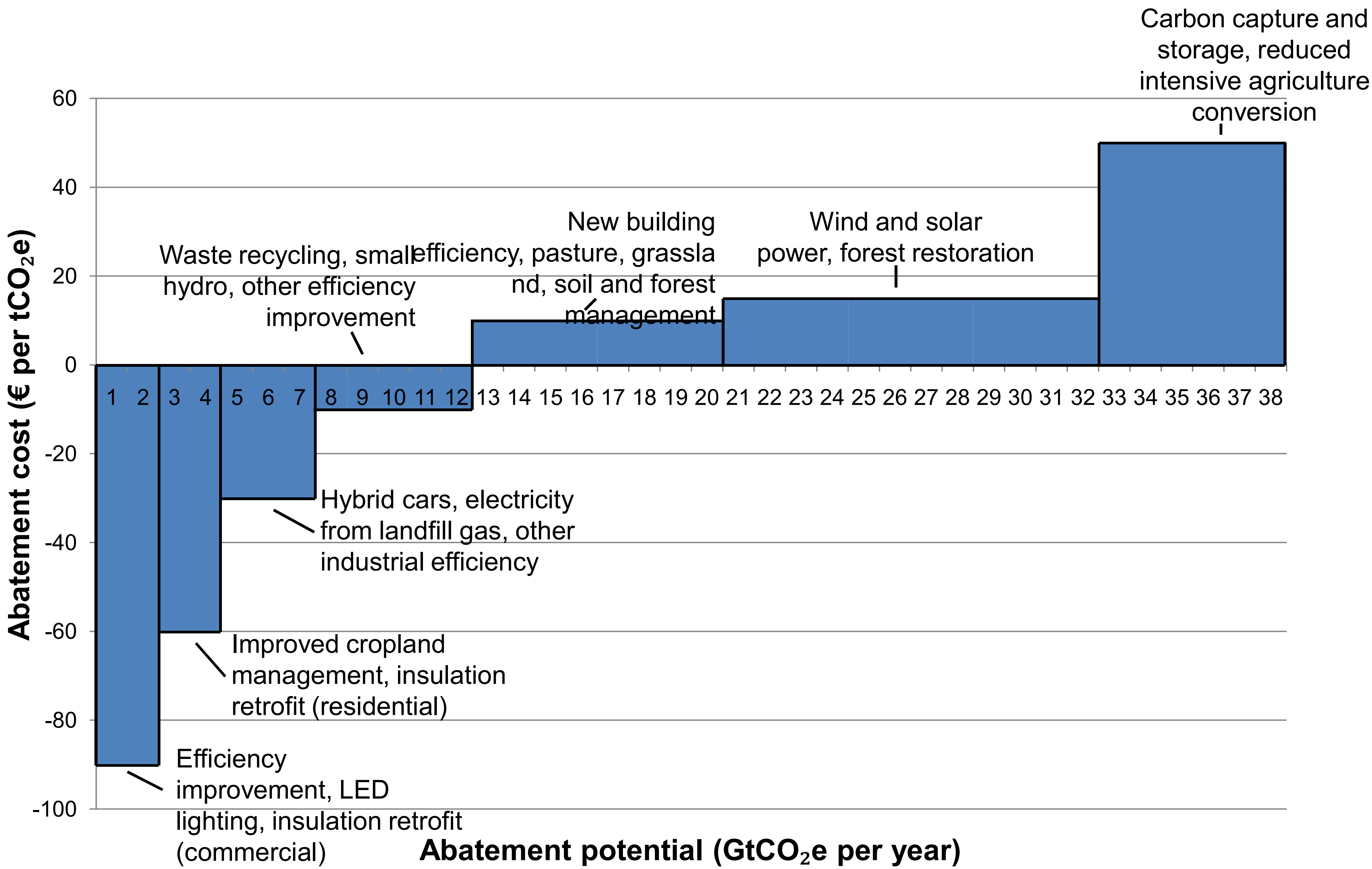
= Willingness to pay.

Figure 20: Carbon Reduction Options with a Permit System



inal costs shown here are hypothetical.

Figure 21: Global Greenhouse Gas Abatement Cost Curve for 2030

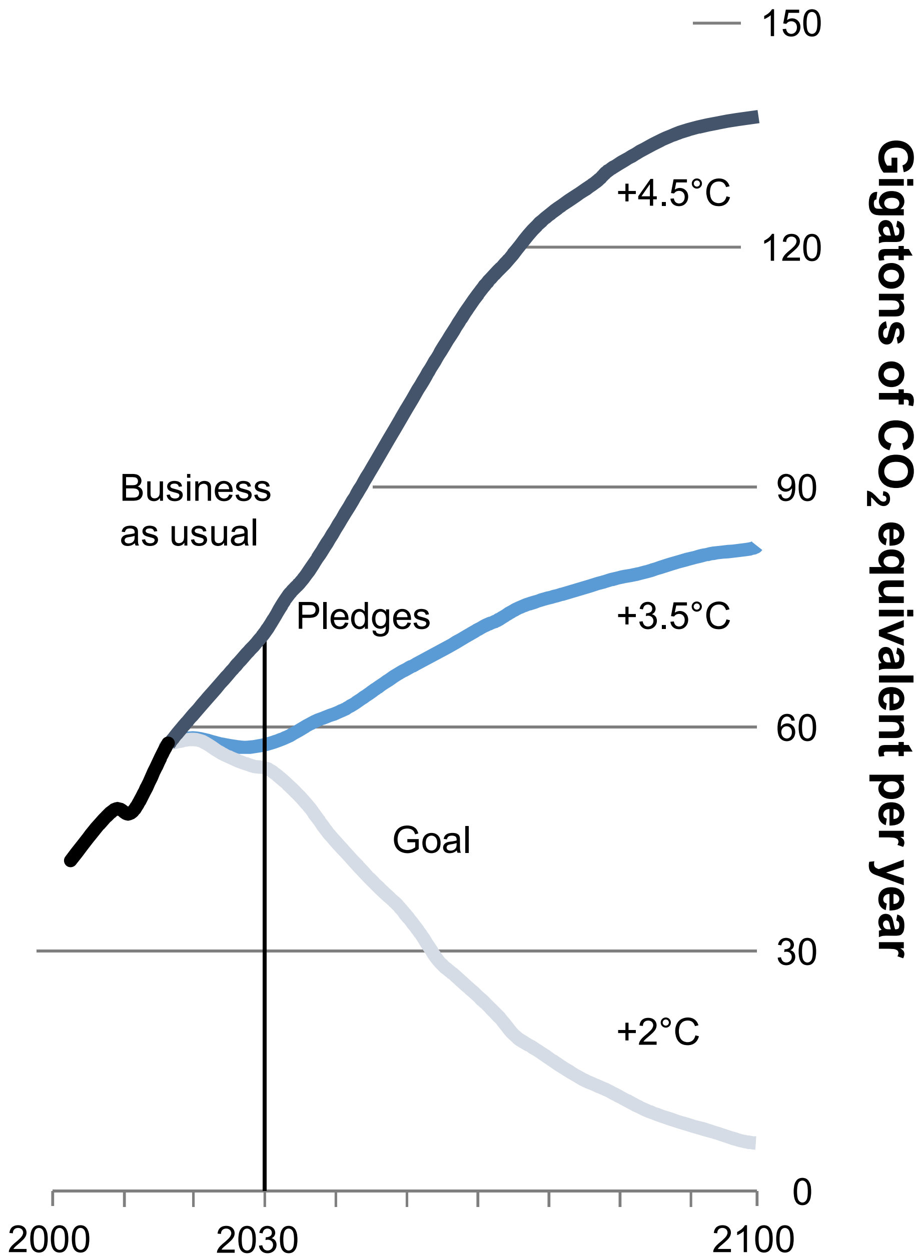


ed from McKinsey & Company, 2009.

Table 5: Important Events in International Climate Change Negotiations

Year, Location	Outcome
1992, Rio de Janeiro	UN Framework Convention on Climate Change (UNFCCC). Countries agree to reduce emissions with "common but differentiated responsibilities."
1995, Berlin	The first annual Conference of the Parties to the framework, known as a COP. U.S. agrees to exempt developing countries from binding obligations.
1997, Kyoto	At the third Conference of the Parties (COP-3) the Kyoto Protocol is approved, mandating developed countries to cut greenhouse gas emissions relative to baseline emissions by 2008-2012 period.
2001, Bonn	(COP-6) reaches agreement on terms for compliance and financing. Bush administration rejects the Kyoto Protocol; U.S.is only an observer at the talks.
2009, Copenhagen	COP-15 fails to produce a binding post-Kyoto agreement, but declares the importance of limiting warming to under 2°C. Developed countries pledge $100 billion in climate aid to developing countries.
2011, Durban	(COP-17) participating countries agreed to adopt a universal legal agreement on climate change as soon as possible, and no later than 2015, to take effect by 2020.
2015, Paris	COP-21 195 nations sign the Paris Agreement, providing for worldwide voluntary actions (INDC's) by individual countries.

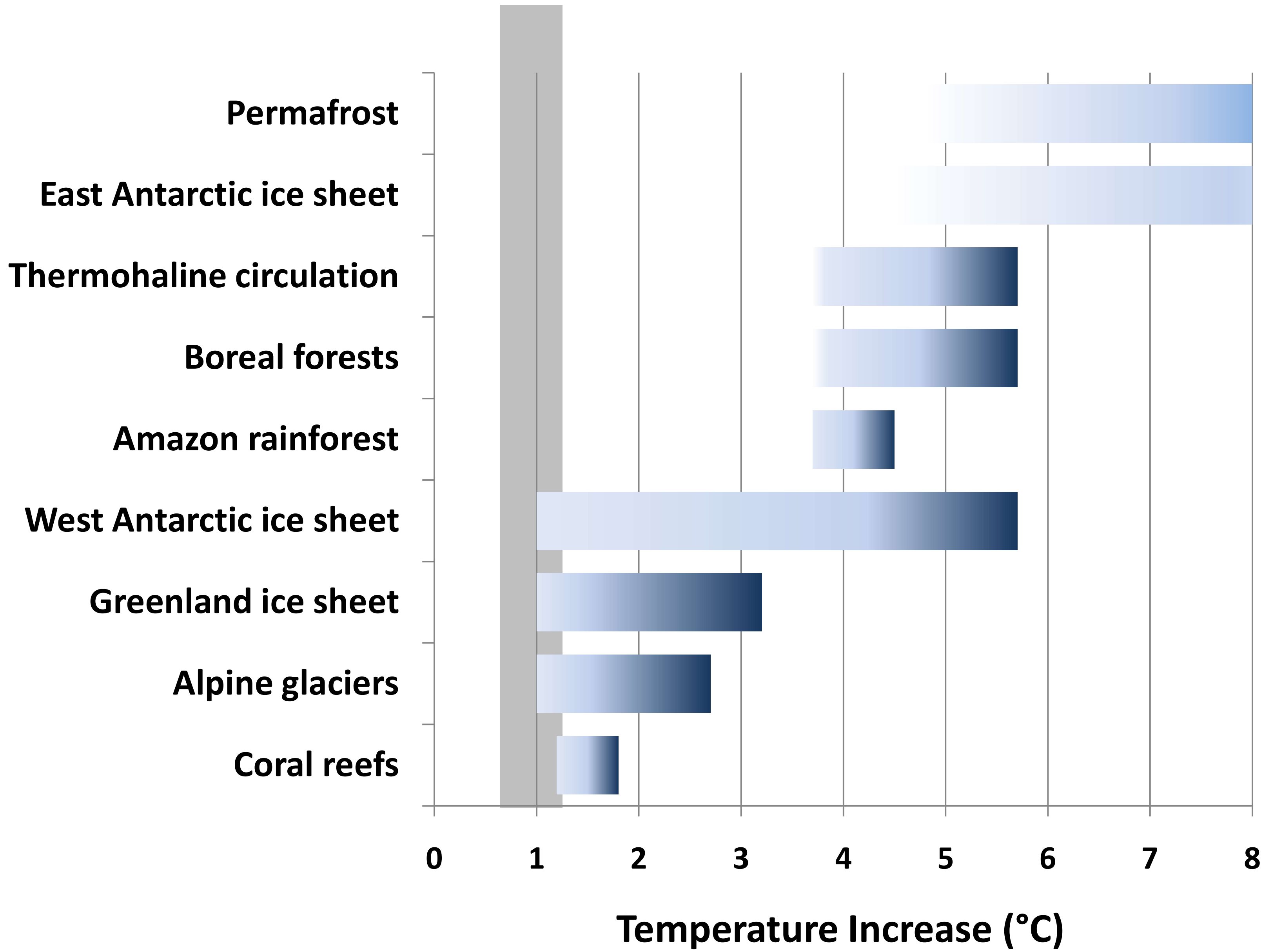
Figure 22: Business as Usual, Paris Pledges, and 2°C Path



mes.com/interactive/2015/11/23/world/carb
l?_r=1

; 3.5°C = 6.3°F; 2 4.5°C = 8.1°F.

Figure 23: Paris Climate Targets and Catastrophic Impacts



huber et al, 2016.
cal bar represents the range of the Paris climate targets, from 1.5°C to 2.0°C

MITIGATING CLIMATE CHANGE

LONG-TERM MITIGATION OBJECTIVE

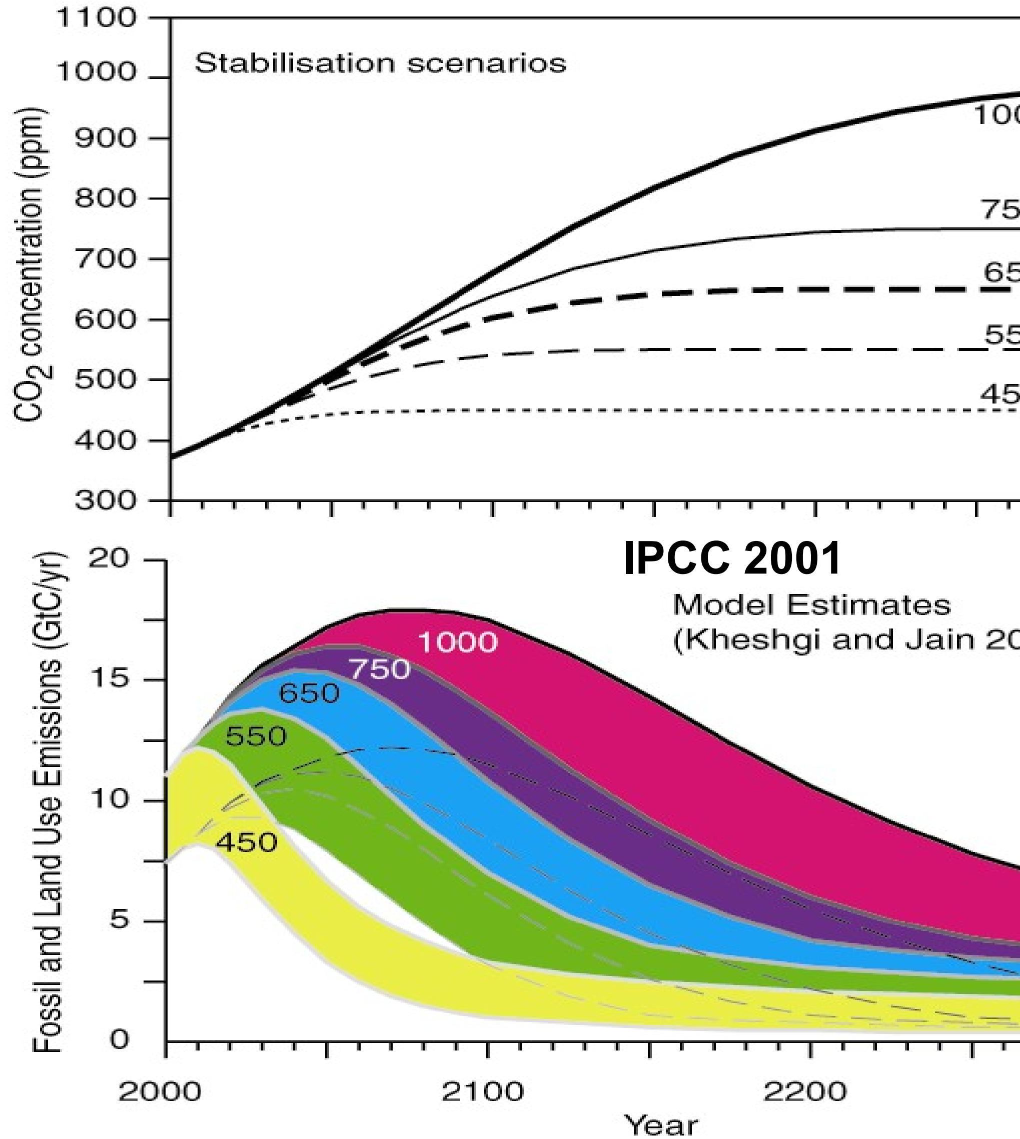
"...stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system."
UNFCCC(1992)

ern for long-
ccumulation of
n the
sphere

SPECIFIED, ARBITRARY CONCENTRATION

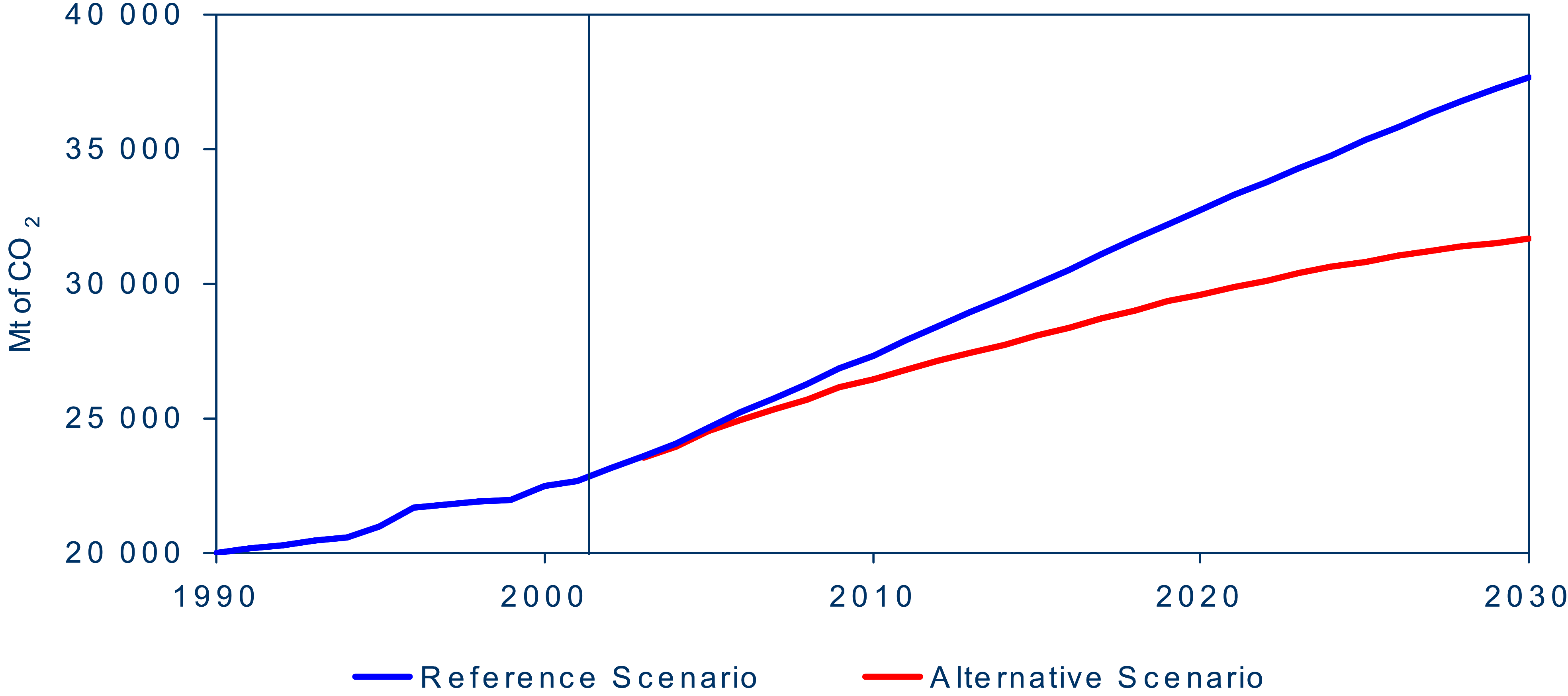
IMPLIED EMISSIONS

CO_2 emissions approach zero for all stabilization levels



What can be done in the near term?

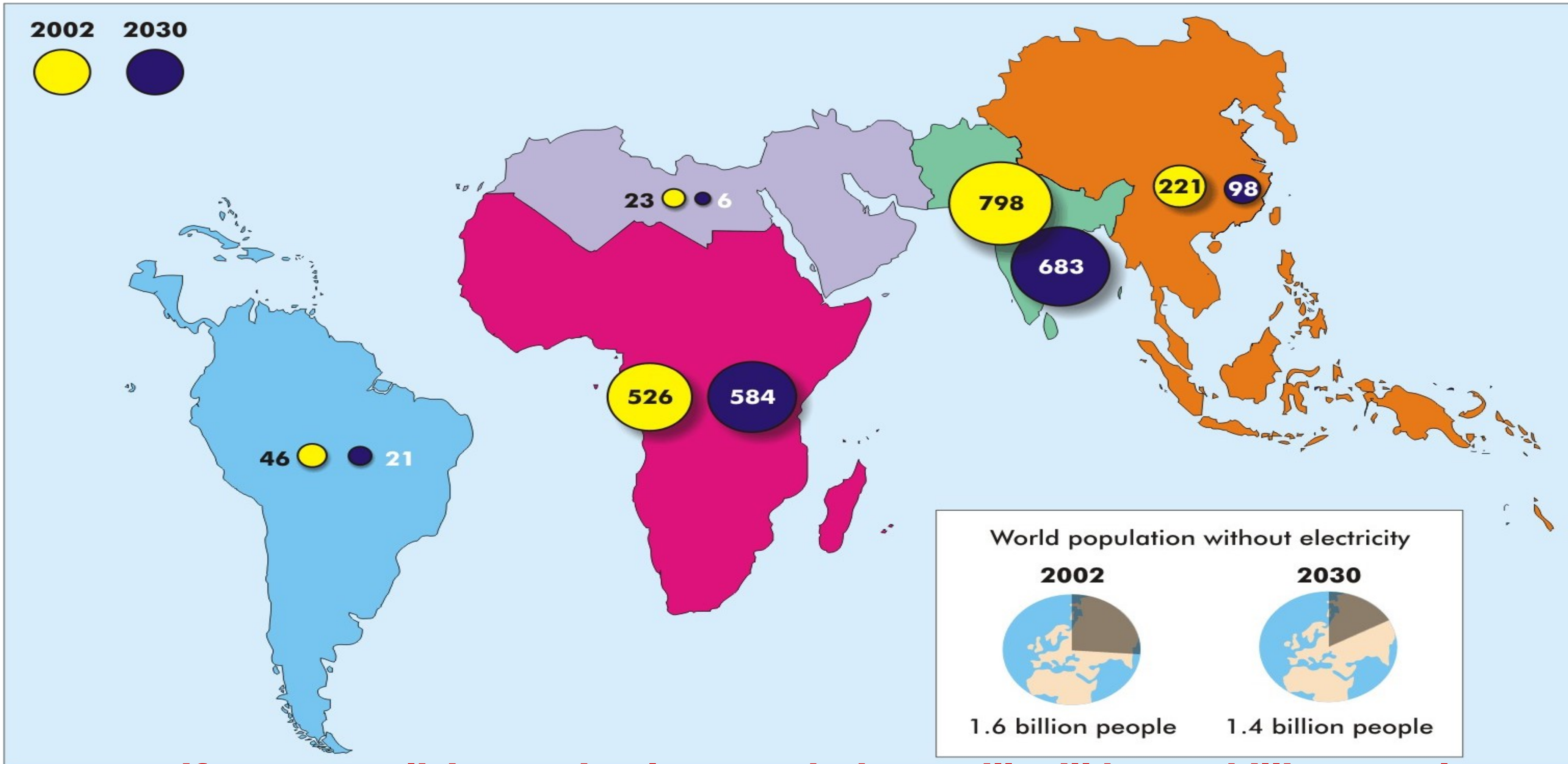
Global CO2 Emissions in the Reference & Alternative Scenarios



CO_2 emissions are 16% less in the AS in 2030, a reduction of about 6 Gt of CO_2

: WEO 2004

Electricity Deprivation



In 2030, if no new policies are implemented, there will still be 1.4 billion people without electricity

Avoiding 1 billion tons of CO_2 per year

oal	Replace 300 conventional, 500-MW coal power plants with "zero-emission" power plants, or ...
O_2 Sequestration	Install 1000 Sleipner CO_2 sequestration plants
Vind	Install 200 x current US wind generation in lieu of unsequestered coal
olar PV	Install 1300 x current US solar generation in lieu of unsequestered coal
luclear	Build 140 1-GW power plants in lieu of unsequestered coal plants

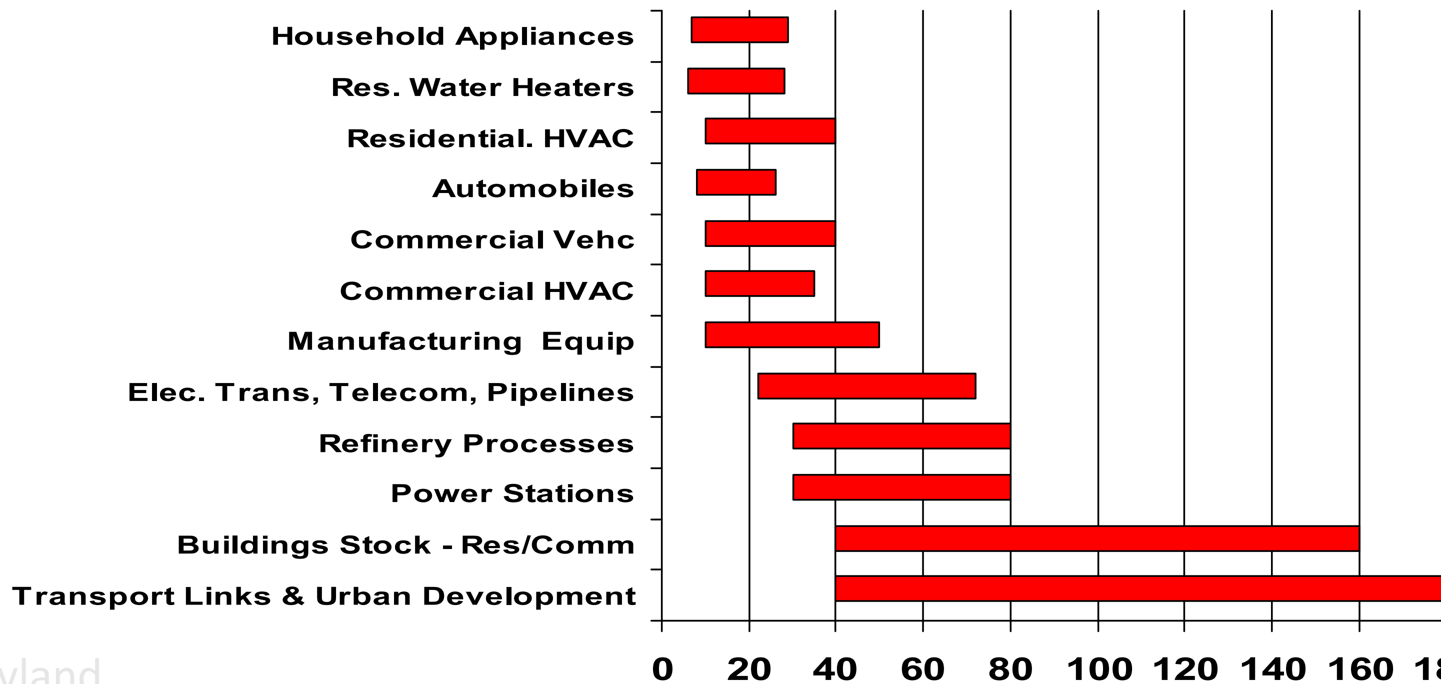
To meet the energy demand & stabilize CO_2 concentrations unprecedented technology changes must occur in this century

Mitigation Policy & Technology

apital stock turnover—*You on't kill the "cash cow." pportunities for learning e only in new capital stock*

creasing marginal cost of pid deployment.

Capital Stock Turnover Rates

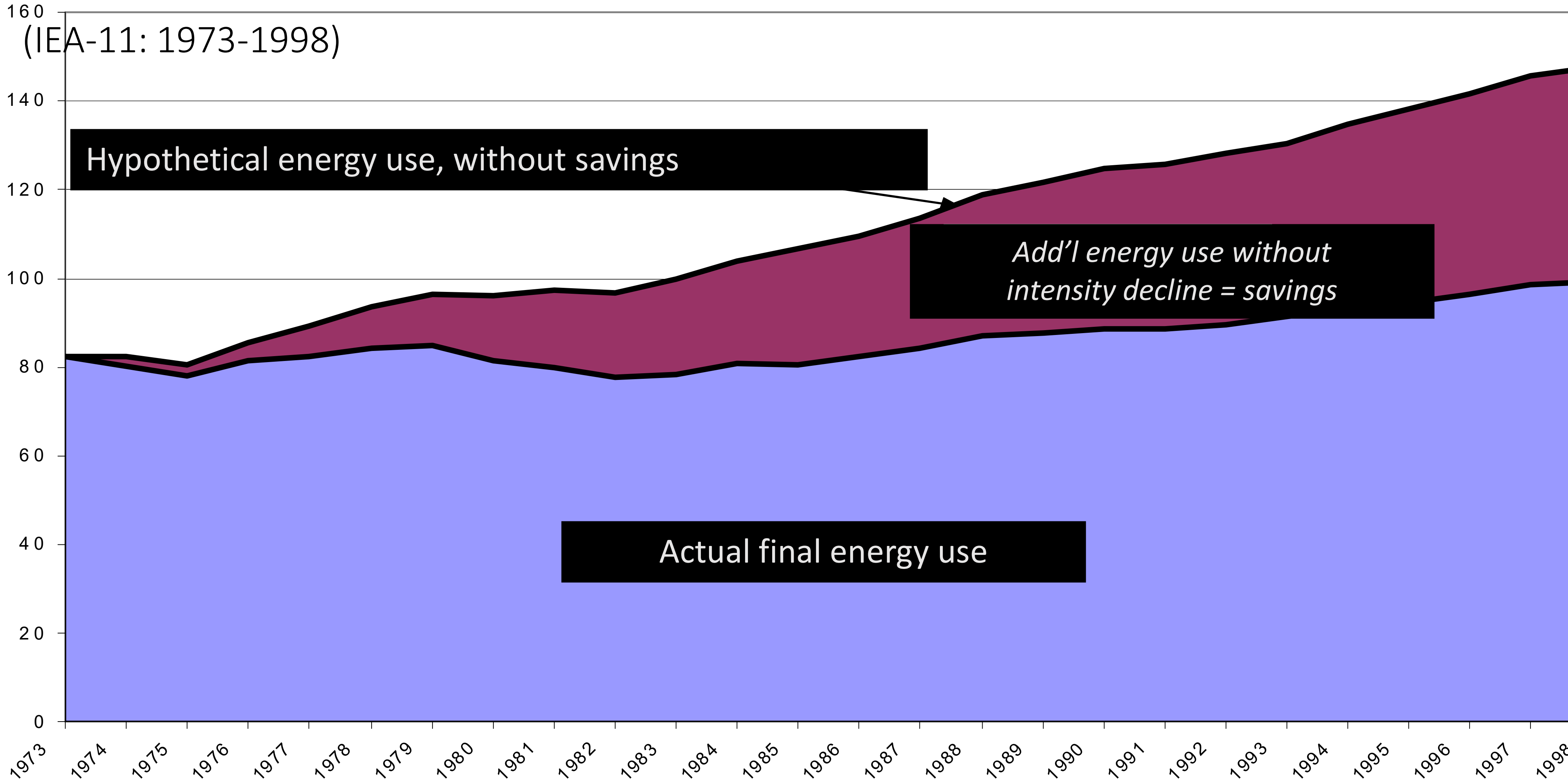


rce: Adapted from PNL/Un. of Maryland

Early market signals and technology R&D can ork together to assist the market transition – Market oriented policies and R&D are inseparabl

In the near term, energy efficiency!

Without 25 Years of Energy Savings, Consumption Would Be 49% High



ource: Oil Crises and Climate Challenges: 30 Years of Energy Use in IEA Countries IEA/OECD 2004

There is an important role for cooperation

- Some are cooperating within the Kyoto Protocol.
- But to promote energy efficiency specifically
  - Standards, labeling, and barrier removal
  - Private-public partnerships
  - Government procurement and market transformation activities on a regional basis.

n the Longer Term
New Technologies

- Two categories of action
  - Cooperative R&D
  - Cooperative Deployment Activities

Cooperative RD&D

We cooperate because the scope and range of technologies exceed the reach of any countries R&D programme

IEA Implementing Agreements

Consultative Group on International Agricultural Research

Newer models

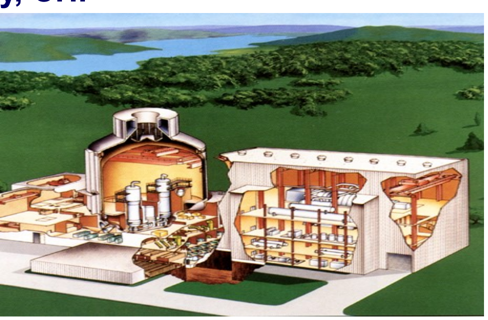
- International Partnership for a Hydrogen Economy
- Carbon Capture Leadership Forum

The Technology Challenge

Stabilising Greenhouse Gas Concentrations in the Atmosphere

: Efficiency, Bio-
drogen Fuel Cells

Emission Bldgs., Industrial
y, CHP

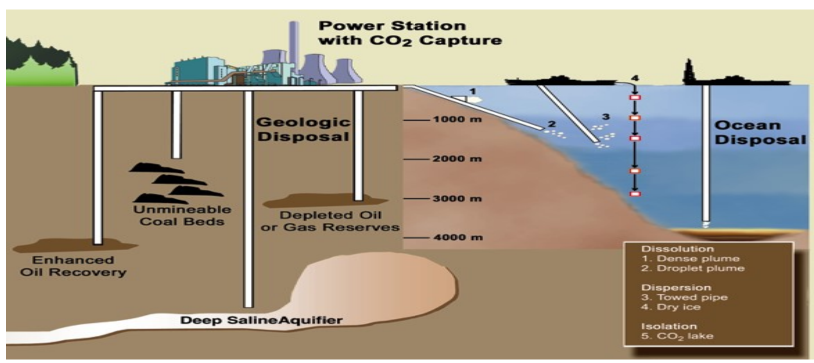


uclear Power Generation IV

No single technology or policy can do it all

Different

- regions
- markets
- scale-up requirements
- resources
- preferences
- technology timing
- infrastructures



Carbon (CO_2) Sequestration

Renewable Energy Techn

Bio-Fuels and Pow

Advanced Power G

Accelerated Deployment

- EGTT Report on Enabling Environments
  - Recommendations included:
    - Focus on barrier removal
    - Engagement of broad range of stakeholders
    - Important role for private-public partnerships

Barriers

- rriers to technology transfer exist at every stage of transfer and take a iety of forms including technical, economic, political, cultural, social, havioral, and/or institutional
- "green" international investment patterns through:
  - capacity building, incentives, and international barrier removal so as to promote "learning investments.
  - Technology agreements to work on testing methods, standards, labeling schemes, etc.

Barriers Exist in Both Transferring and Host Countries

- Recognizing that national circumstances differ widely, opportunities exist for facilitating technology transfer through the appropriate enabling environments in transferring and recipient countries

Opportunities for Improving Institutional Environments Exist at Many Levels

- us levels at which institutional onments influence technology er
- cal, national, regional and global vels.

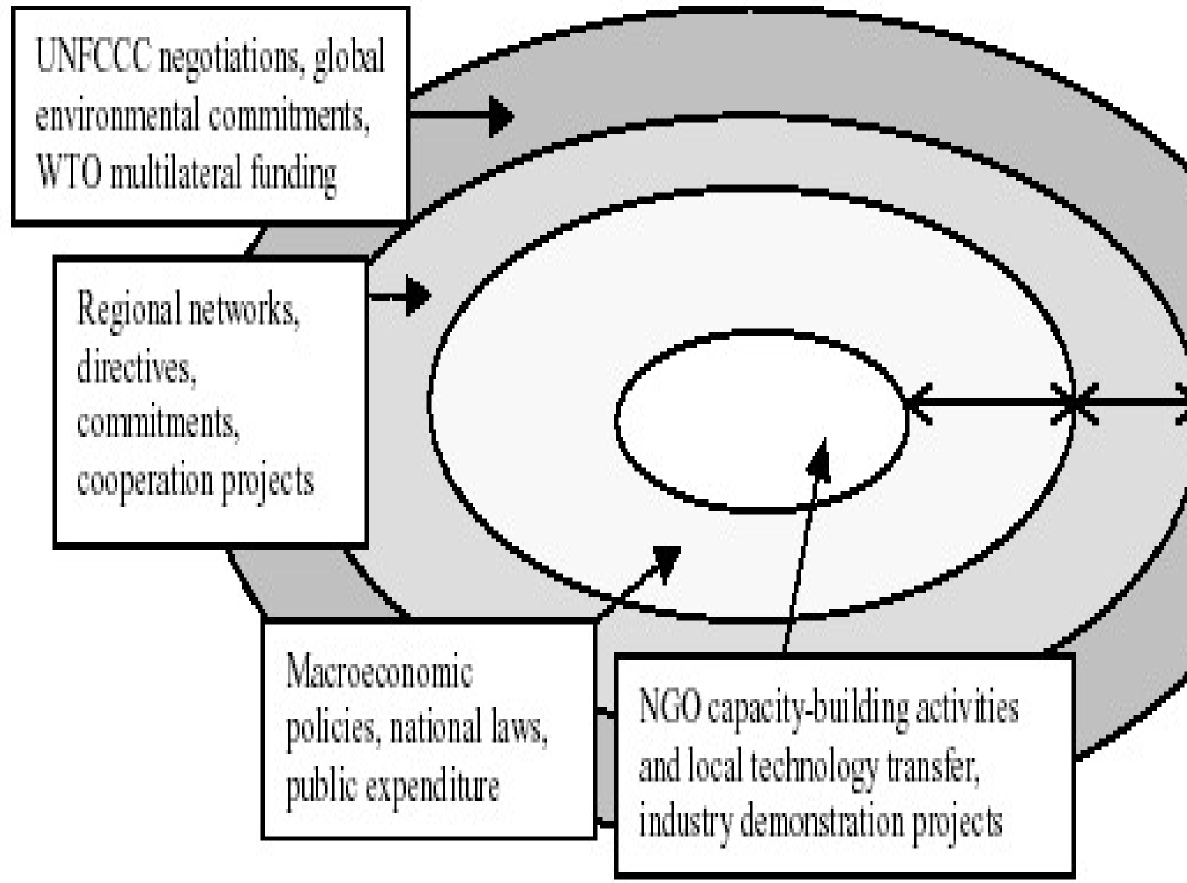


Figure 1: Different and interacting levels of enabling environments

International Partnerships Important

There is agreement that international cooperation and partnerships can enhance the transfer of technology between countries and thus help

- Success stories
  - WBCSD sector projects
  - Climate Technology Initiative assistance for Technology Needs Assessment's
  - Swiss Agency for Development Cooperation assistance for adaptive R&D

WHAT WE KNOW

The level of greenhouse gases in the atmosphere have increased, causing the Earth’s temperature to rise.

One greenhouse gas in particular, carbon dioxide (CO_2) has steadily increased over the past century largely due to human activity (anthropogenic).

We know that emissions have a significant impact on the world around us. How can we reduce the amount of carbon that is emitted?

What is mitigation?

To decrease force or intensity. To lower risk.

Earthquake mitigation

Flood mitigation

Climate change mitigation

How can we reduce carbon emissions?

Work in pairs to talk about ways in which we could reduce (mitigate) carbon emissions in the following areas. Feel free to write your answers in the appropriate column on the board:

- Transportation
- Heating and Cooling Buildings
- Industry Carbon Output
- Electricity Use

Mitigation Strategy #1: Transportation Efficiency

1Gallon = 3.78541L

- A car that gets 30 mpg releases 1 ton of carbon into the air for every 10,000 miles of driving
- Fuel efficient cars get more miles per gallon (mpg)
- Increasing the fuel efficiency of cars will reduce the amount of CO_2 emitted into the atmosphere

Mitigation Strategy #2: Transport Conservation

- With more cars on the road, the amount of CO_2 emitted steadily increases.
- Reducing the time and number of cars on the road will reduce emissions.
- Increasing the use of public transportation would reduce the amount of individual driving time.

Mitigation Strategy #3:
Building Efficiency

- Providing electricity, transportation, and heat for buildings produces high levels of CO_2 emission.

- Reducing heating and energy use would reduce the amount of carbon released into the atmosphere.

- nsulating buildings, using alternative energy sources, and solar water heating are ways to reduce emissions.

Mitigation Strategy #4:
Efficient Electricity Production

- 25% of the world's carbon emissions come from the production of electricity at coal plants.

- Since nearly 50% of electricity comes from coal combustion, improving coal plant efficiency will significantly reduce carbon emission.

- To do this requires alternative ways of using coal to produce electricity.