Climate Mitigation
or
What Can We Do About Climate Change?

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Climate & Society Course

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Outline

Will discuss emission mitigation, which is reducing emissions in order to reduce future anthropogenic climate change.

- **What does the physical science of climate change imply for mitigation?**

  A century-scale problem that will ultimately require a global response.

- **Do we have to have an explicit climate policy?**

  If we want to reduce future climate change we do.

  This problem will not solve itself.

- **What does mitigation look like?**

  Large-scale transformation of the energy system, with multiple ways of getting to any specific goal.

- **What makes for cost effective mitigation?**

  Comprehensive (in space, sector and time), flexible, and predicable.

Climate: Key Points

- **Anthropogenic enhancement of the greenhouse effect is driving changes in climate**
  - Carbon Dioxide (CO_2) is the primary driver of anthropogenic climate change
- **Stabilizing CO_2 concentrations is a century+ scale endeavor**
  - This is because CO_2 accumulates in the atmosphere: some will be here 1000's of years from now.
  - **Stabilizing CO_2 concentrations requires that global CO_2 emissions must eventually go to zero.** This is unlike many other pollutants.
  - The climate system responds slowly to changes in emissions.
- **Climate response to emissions is uncertain**
  - The ***climate sensitivity*** is unlikely to be very low, but has a wide range.
- **We, therefore, cannot guarantee meeting any given climate target**
  - Emissions mitigation will, however, reduce future impacts.
  - The world without a climate policy is very likely to exceed 2°C, perhaps by a large amount.

What level of 'insurance' should society buy to avoid "dangerous interference" with the climate system?

What Can We Do?

We Cannot "Solve" the Climate Problem

Some amount of additional climate change is inevitable, although mitigation can limit the amount of additional climate change the world will experience.

Society's response will consist of some combination of:

- **We must adapt to some amount of change**

  Agriculture, for example, has continually changed to accommodate changing weather, climate, market demands, and technology.

  This takes social, financial, and institutional resources which may not be up to this task in some regions or sectors

- **We can (in principle) reduce the level of future changes (emissions mitigation)**

  The primary means to limit future climate change is to reduce greenhouse gas emissions, largely CO_2. This requires a price on carbon.

  Enhancing natural sinks, restoring forests, and so on can also play a role.

- **Geoengineering?**

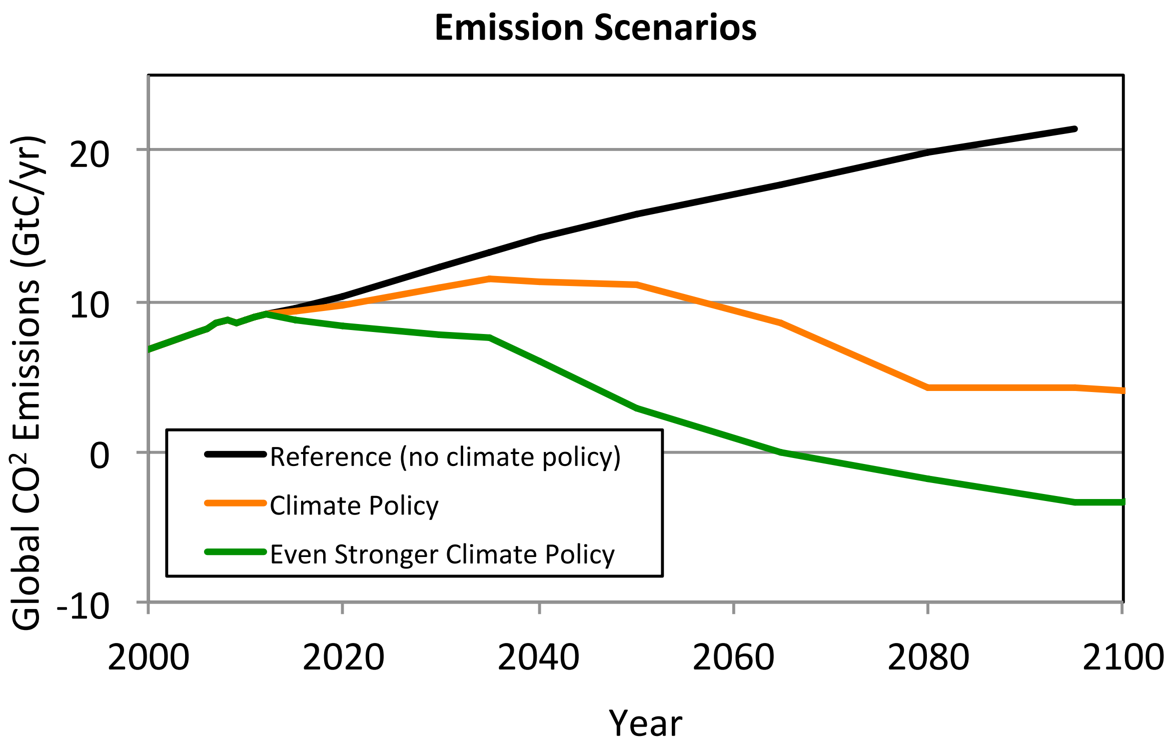
  That is another talk, but, in short, this will not solve the problem, nor reduce the need for emissions mitigation.

Big Picture: Emissions -> Climate Change

We can't predict the future, so we examine a number of scenarios.

Start with a "reference case" scenario with no climate policy (black line)

- Carbon dioxide (CO_2) emissions increase steadily over the century.

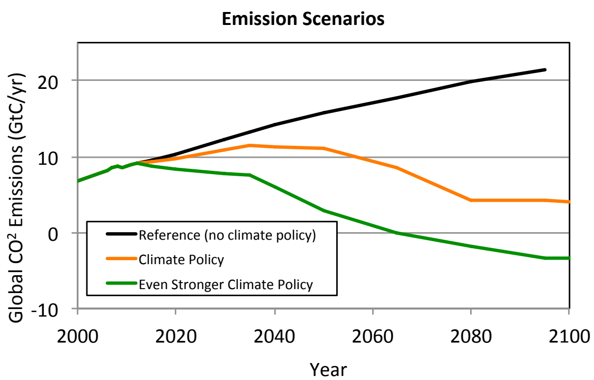


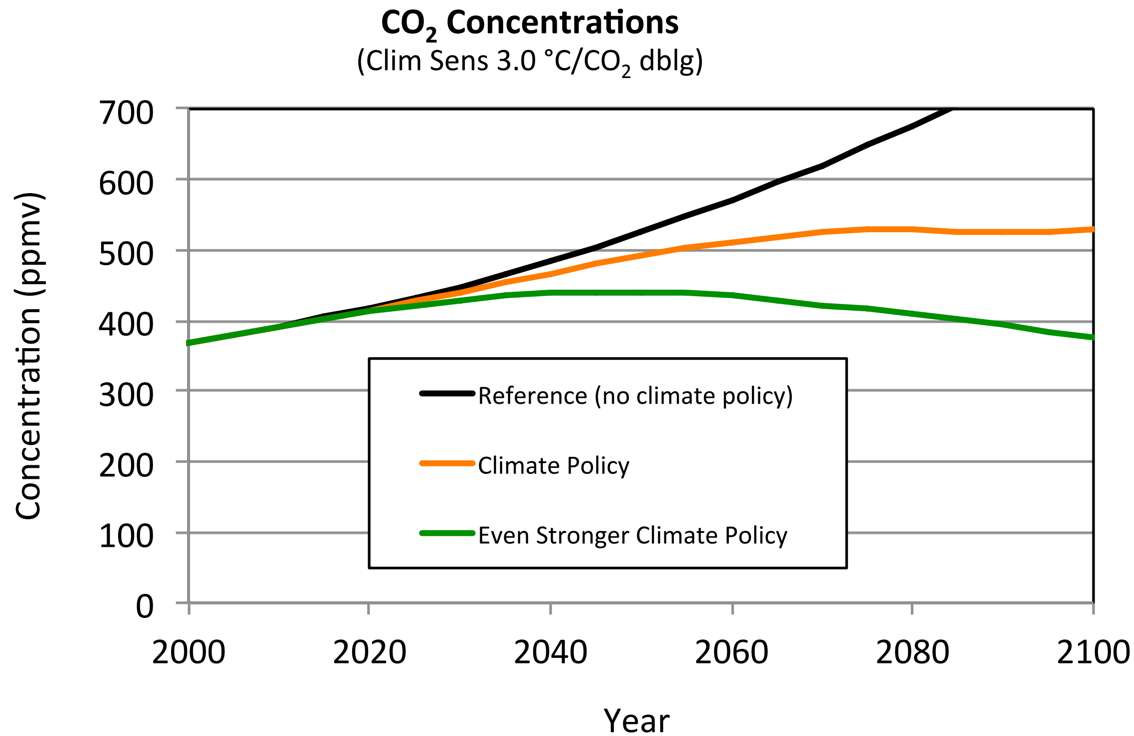
Under climate policy cases (colored lines), where actions are assumed to be taken to limit global greenhouse gas emissions:

- Carbon dioxide emissions might still increase for a limited time.
- But CO_2 emissions must eventually decrease

Big Picture: Emissions -> Climate Change

If CO_2 emissions keep increasing, the concentration of CO_2 in the atmosphere will also increase.



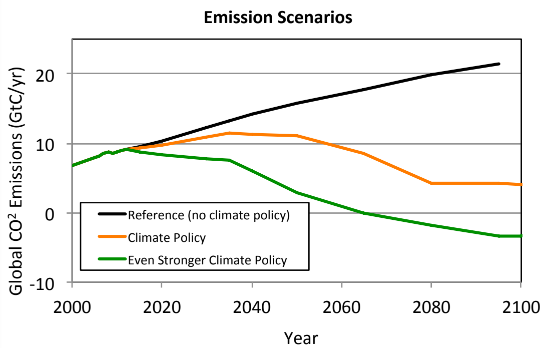


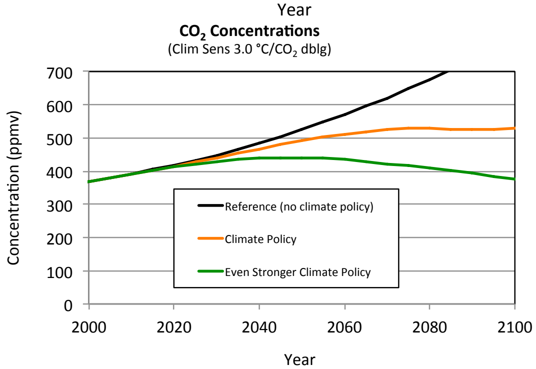
Under the climate policy cases (colored lines):

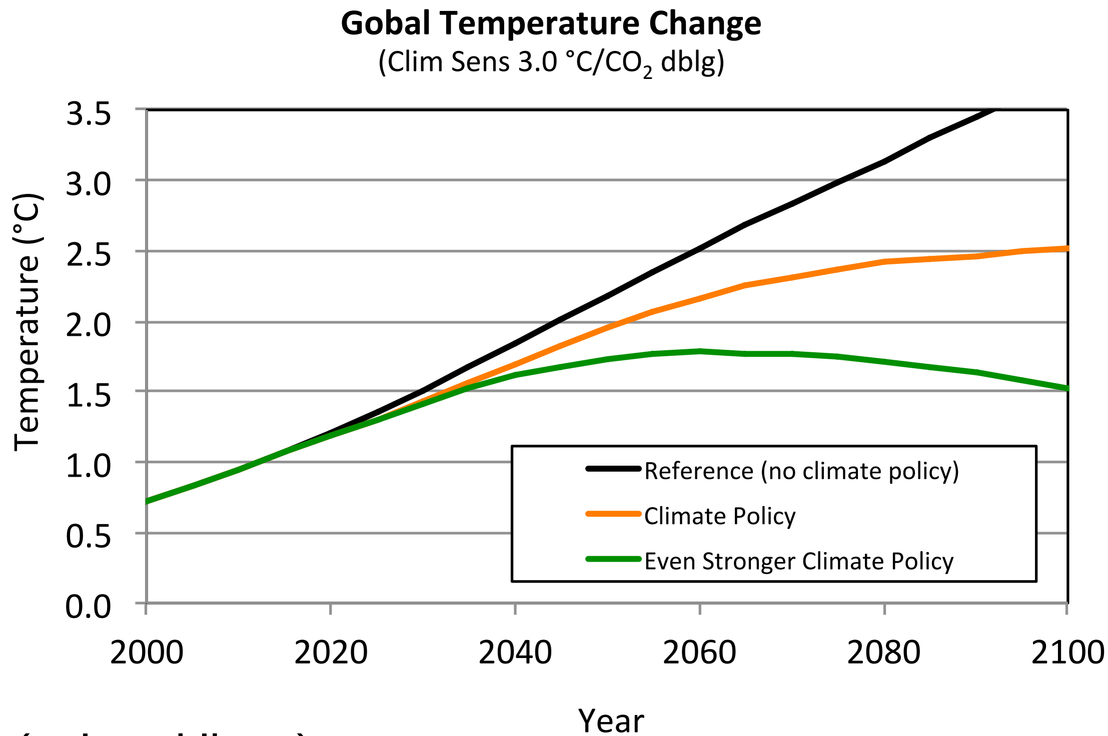
- CO_2 concentrations could stabilize, or even decrease.
- Decreasing CO_2 emissions by the end of the century at the level shown requires net negative CO_2 emissions!

Big Picture: Emissions -> Climate Change - 3

Under the reference scenario, steadily increasing atmospheric CO_2 concentrations result in global temperature change of nearly 4°C by the end of the century *(using central climate response assumptions)*.





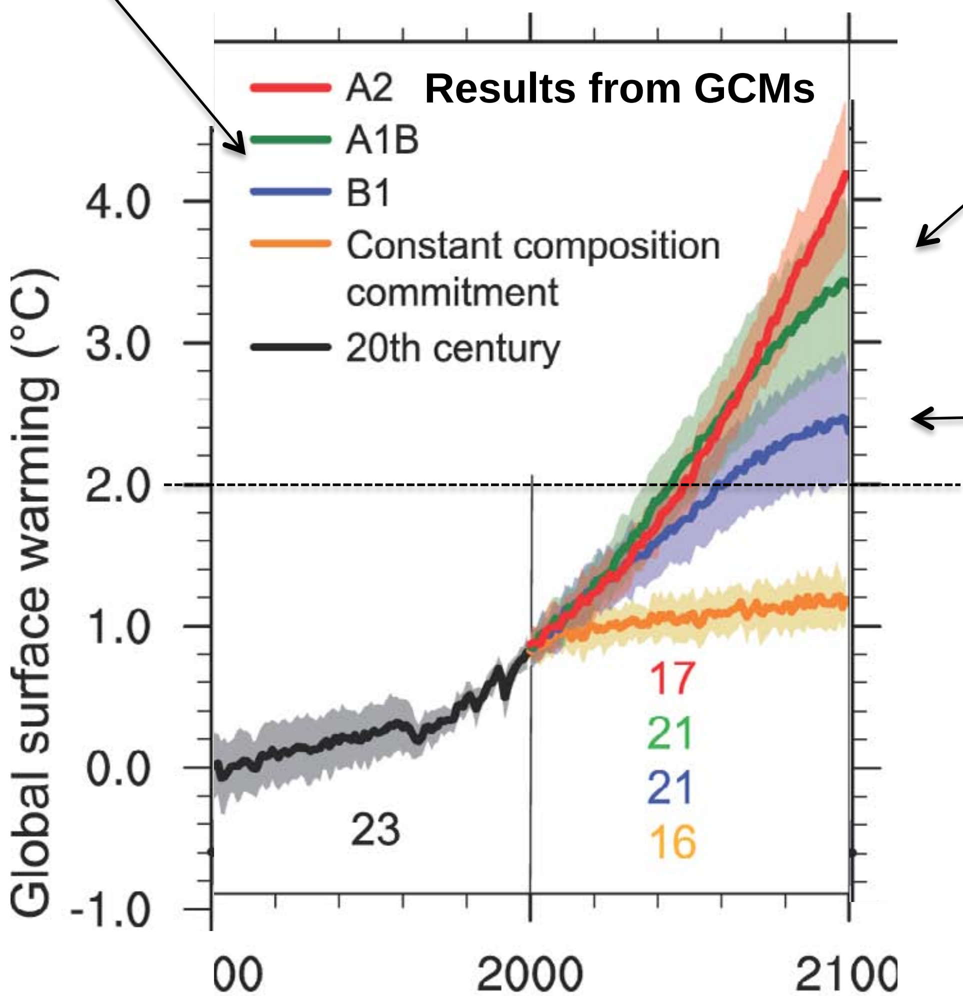


Under the climate policy cases (colored lines):

- Temperature increase can ultimately stabilize or even decrease in 100 years.
- Note there is little change in the near term even if emissions change dramatically!
- Climate change is more than temperature, but temperature is a convenient metric for the overall magnitude of the changes.

What Will It Take To Reduce Climate Change?

1 Three scenarios for future emissions and socio-economic developments without climate policy.



Temperature scale shifted to be relative to pre-industrial.

2 Under the A1B future scenario (no climate policy, substantial global economic growth), climate change is well above 2°C relative to preindustrial and still rising.

3 The B1 scenario is an example of a **global** emphasis on energy efficiency and environmental protection, but with no explicit climate policy.

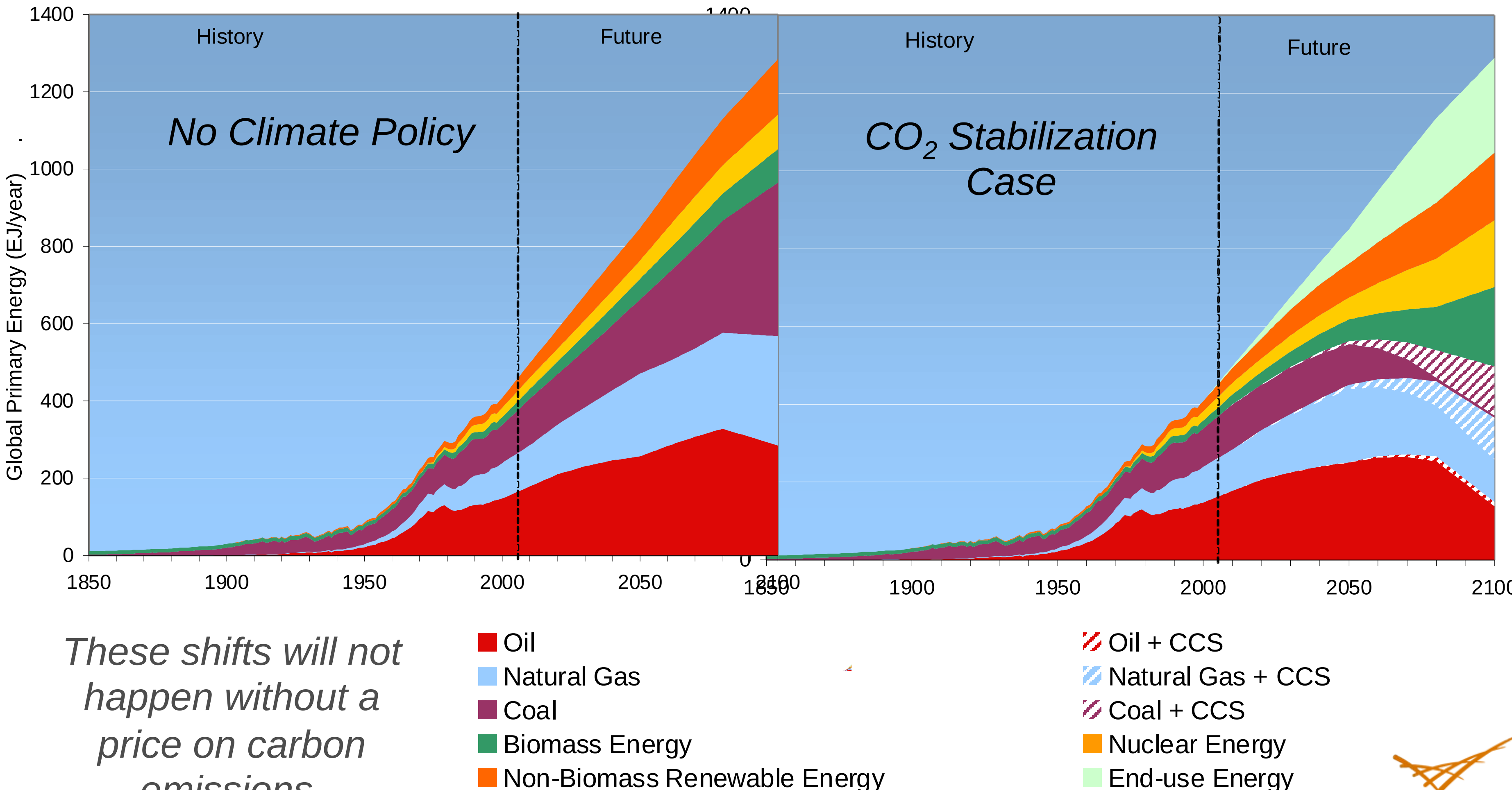
Temperature change is still very likely to be above 2°C above preindustrial levels.

We will likely need to have an explicit climate policy in order to shift the global energy system away from greenhouse gas emissions in order to limit climate change below 2°C.

JGCRI **IPCC AR4 WG1 fig 10-4**

Climate Stabilization: Global Energy

Substantial changes in the global energy system will be needed to stabilize climate.

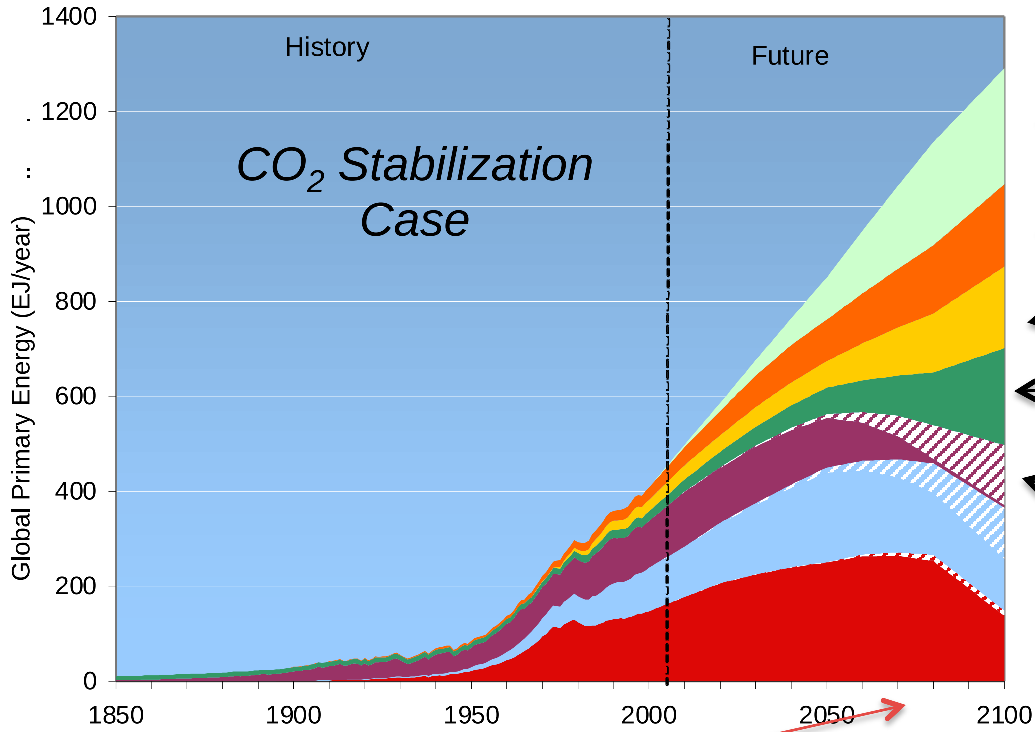


These shifts will not happen without a price on carbon emissions.

CCSP Scenarios

Climate Stabilization: Many Options Needed

A gradual shift away from technologies that vent CO_2 to the atmosphere over the century.



Energy Efficiency & Demand Reduction

Nuclear

Wind, Solar, Geothermal, …

Biomass

Carbon Dioxide Capture and Geologic Storage (CCS)

Remaining Carbon Dioxide Emitting Fuel consumption.

- Oil
- Natural Gas
- Coal
- Biomass Energy
- Non-Biomass Renewable Energy
- Oil + CCS
- Natural Gas + CCS
- Coal + CCS
- Nuclear Energy
- End-use Energy

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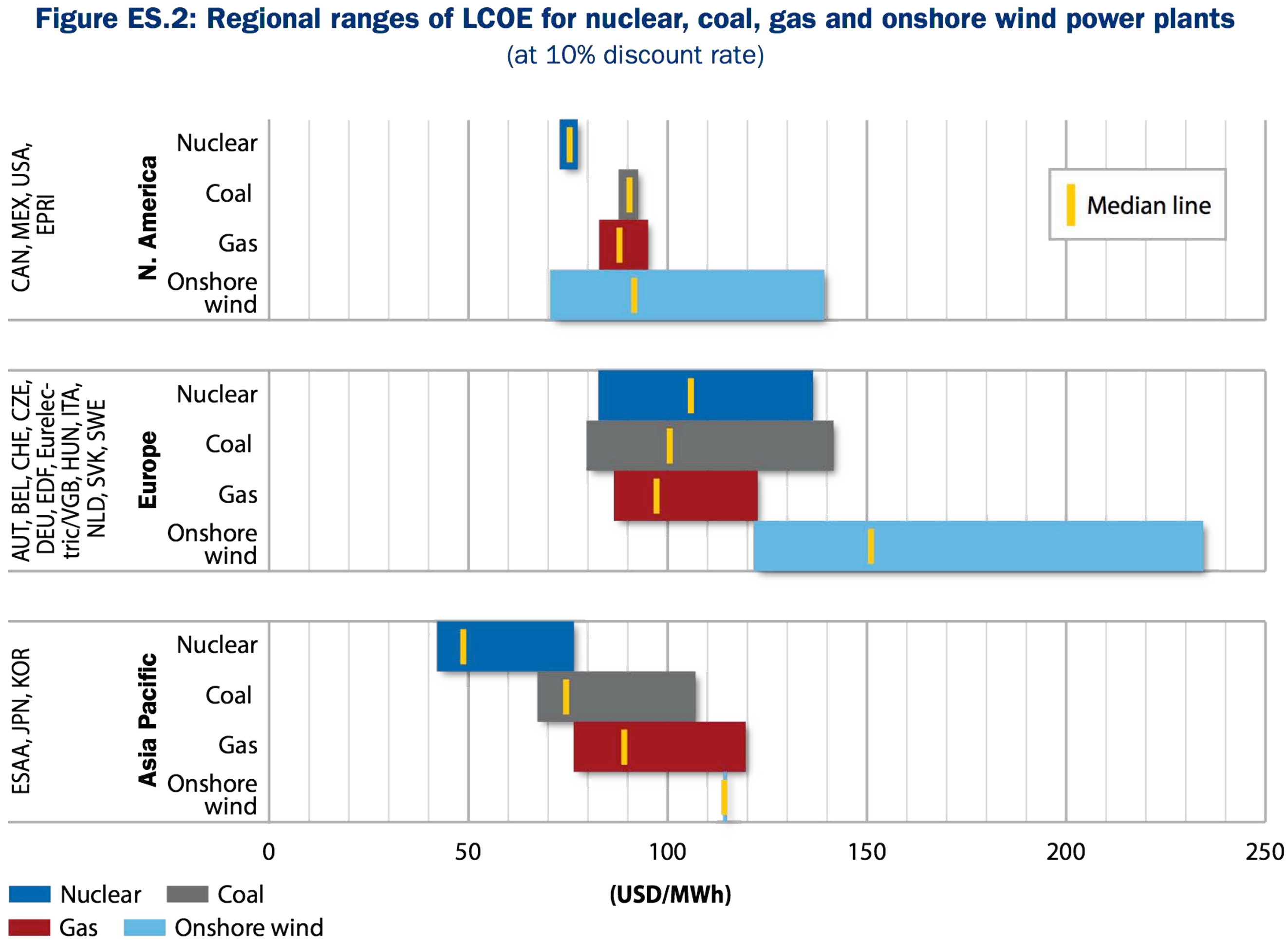
Mitigation: Key Points

- **Emissions are not likely to go down because we run out of fossil fuels**
  - There is a large amount of fossil resources on the planet.
  - We keep finding new and cheaper ways of tapping into these resources.
- **Stabilizing CO_2 concentrations at low levels will require a price on carbon**
  - Putting a value on emissions of carbon dioxide, and other greenhouse gases, provides an incentive to reduce these emissions.
  - There is a **big difference** between a price of zero as compared to anything > 0.
- **The most economically efficient policy covers all sectors of the economy, including carbon in trees and soils.**
  - Under an optimal policy the carbon price increases steadily over time (approximately at the long-term interest rate), which allows planning.
  - A flexible policy, and flexible energy system, is important for keeping costs down. (*For example, SO_2 trading system in the US*).
  - Costs are not necessarily large, for example as a fraction of total income.
  - Increased efficiency makes any policy target easier to obtain.
- **The cost of a climate policy increases as:**
  - Technology options are "taken off the table".
  - Less than comprehensive policies, i.e., economic sectors are exempted
  - Fewer countries participate (however, not all are willing or able)

Electricity Generation Costs



- Fossil fuels are a dominant energy source because they are relatively inexpensive to use, in part due to a high energy density.
- Wind is currently one of the most competitive renewable resources, but high quality wind is not available everywhere.

Research and development will be needed to bring down the costs of lower carbon energy sources.

Source: Projected Costs of Generating Electricity, 2010 Ed. International Energy Agency, ISBN 978-92-64-08430-8

Mitigation Costs

How much will it cost to reduce emissions?

Table SPM.7. Estimated global macro-economic costs in 2030 and 2050. Costs are relative to the baseline for least-cost trajectories towards different long-term stabilisation levels. {Table 5.2}

Stabilisation levels (ppm CO_2-eq)	Median GDP reduction [a] (%)		Range of GDP reduction [b] (%)		Reduction of average annual GDP growth rates (percentage points) [c], [e]	
	2030	2050	2030	2050	2030	2050
445 – 535 [d]	Not available		< 3	< 5.5	< 0.12	< 0.12
535 – 590	0.6	1.3	0.2 to 2.5	slightly negative to 4	< 0.1	< 0.1
590 – 710	0.2	0.5	-0.6 to 1.2	-1 to 2	< 0.06	< 0.05

- Costs are often expressed as a carbon price (\$/tC or \$/tCO_2).
- The cost of reducing emissions (i.e., mitigation) increases as the climate policy gets stronger (lower concentration target).
- Costs are very uncertain and depend on numerous assumptions.
- Costs can also be expressed in terms of changes in aggregate economic activity (GDP).

More Mitigation Points

- **There is no "silver bullet"**

  No one technology is going to "solve" climate change. The problem is big and multi-faceted (electricity generation, cars, freight trucks, airplanes, deforestation).

  A broad portfolio of changes in our system and new technologies will be required to cost-effectively reduce greenhouse gas emissions.

- **Carbon dioxide with geologic capture and storage (CCS) is an important option.**

  This allows continued use of fossil fuels where other options are not affordable.

  Coupled with biomass this can provide net negative emissions!

  Nuclear, renewables (wind, solar, etc.) and energy efficiency are also important.

- **The electric sector is one of the first to largely decarbonize**

  This is because this is relatively less costly relative to other sectors, and there are many low-carbon options. This is not the end of the process (*e.g.*, transportation).

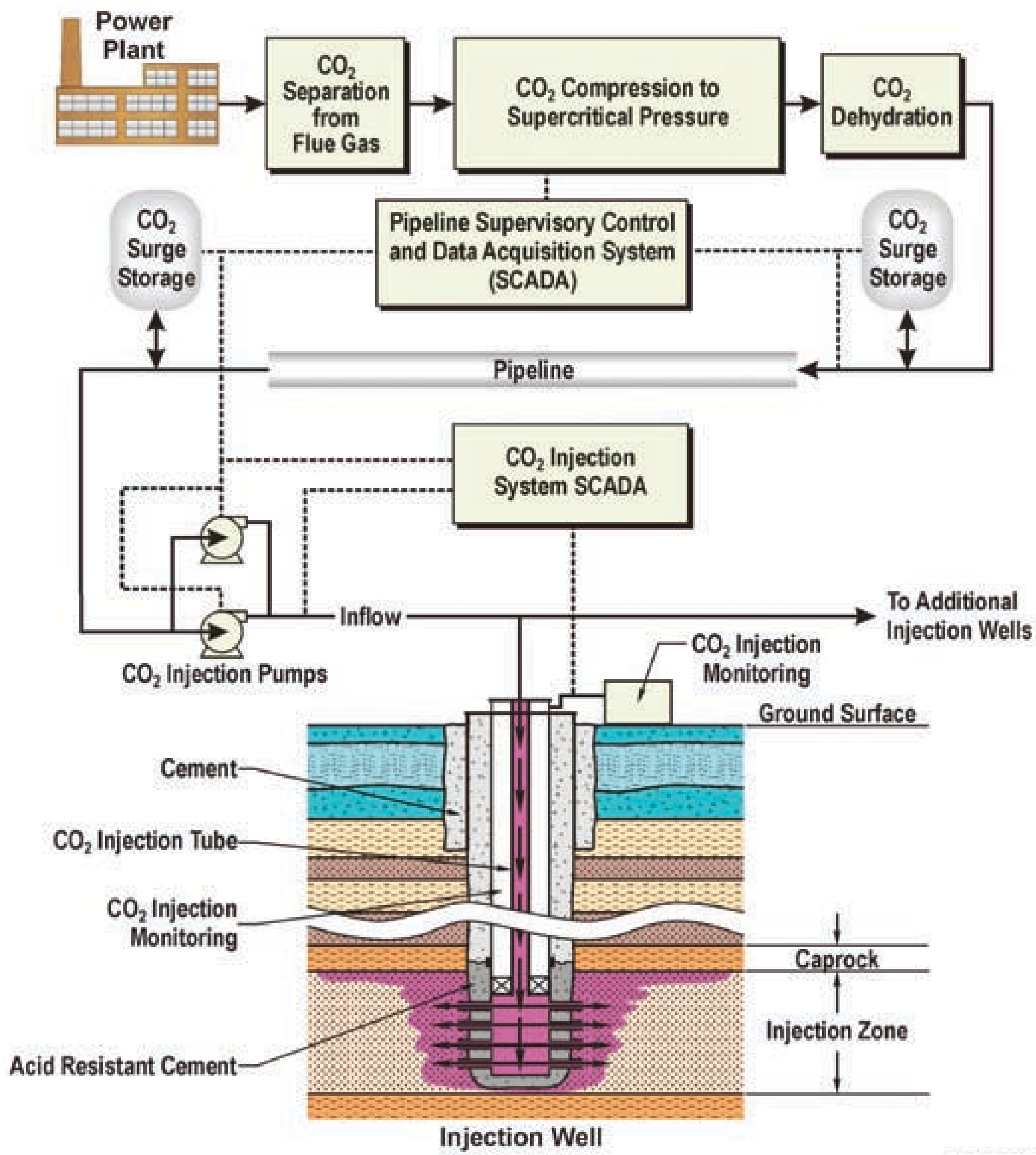
  End-use sectors (transport, buildings, industry) shift to electricity as a means of lowering net emissions.

- **There are multiple paths to any given goal.**

  Less than theoretically "ideal" strategies are often employed in the real world.

  Best if these are not too far from ideal (otherwise, either costs will high or policy might not achieve goals).

Carbon Dioxide Capture and Storage (CCS)



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Summary Points

- **A price on carbon will be needed to reduce emissions sufficiently to stabilize the climate**
  - This is a policy choice. A societal choice.
- **A broad array of technologies will be needed**
- **Improving efficiency makes any climate goal more achievable**
- **Flexible policies and a flexible energy system are valuable**
  - We will need to learn, adjust, and learn some more
  - Society will need to adapt to changes (hopefully technology can assist with this)
- **Research and development are essential**
  - New and improved technologies will be needed to facilitate the needed transformations

Further Reading

Emissions Mitigation and The Role Of Technology

GTSP Phase 2 Capstone Report

http://www.globalchange.umd.edu/gtsp/publications/

Broadly accessible material written for policymakers

Future Emissions Scenarios

CCSP Emissions Scenarios

http://www.climatescience.gov/Library/sap/sap2-1/finalreport/default.htm

(a bit more technical detail)

IPCC 4th Assessment Report

Source of some graphics used here

http://www.ipcc.ch/publications_and_data/publications_and_data_reports.shtml

National Academy of Sciences: America's Climate Choices

http://americasclimatechoices.org/panelmitigation.shtml

THE END

Additional Slides

What is Climate and Climate Change?

Climate can be considered the long-term average of weather

Weather: daily and weekly variations in temperature, rainfall, snow, etc.

Climate: conditions considered over some longer time period

~ average temperature

~ precipitation frequency and amount

We have weather because the Sun shines on the Earth

Complicated by a spinning planet, atmospheric and ocean dynamics, water cycle, carbon-cycle, and so on.

The climate we experience can change due to:

Decadal changes in the climate system are caused by internal couplings and cycles (El Nino, North Atlantic Oscillation)

Changes in Earth’s distance from and degree of tilt toward the Sun

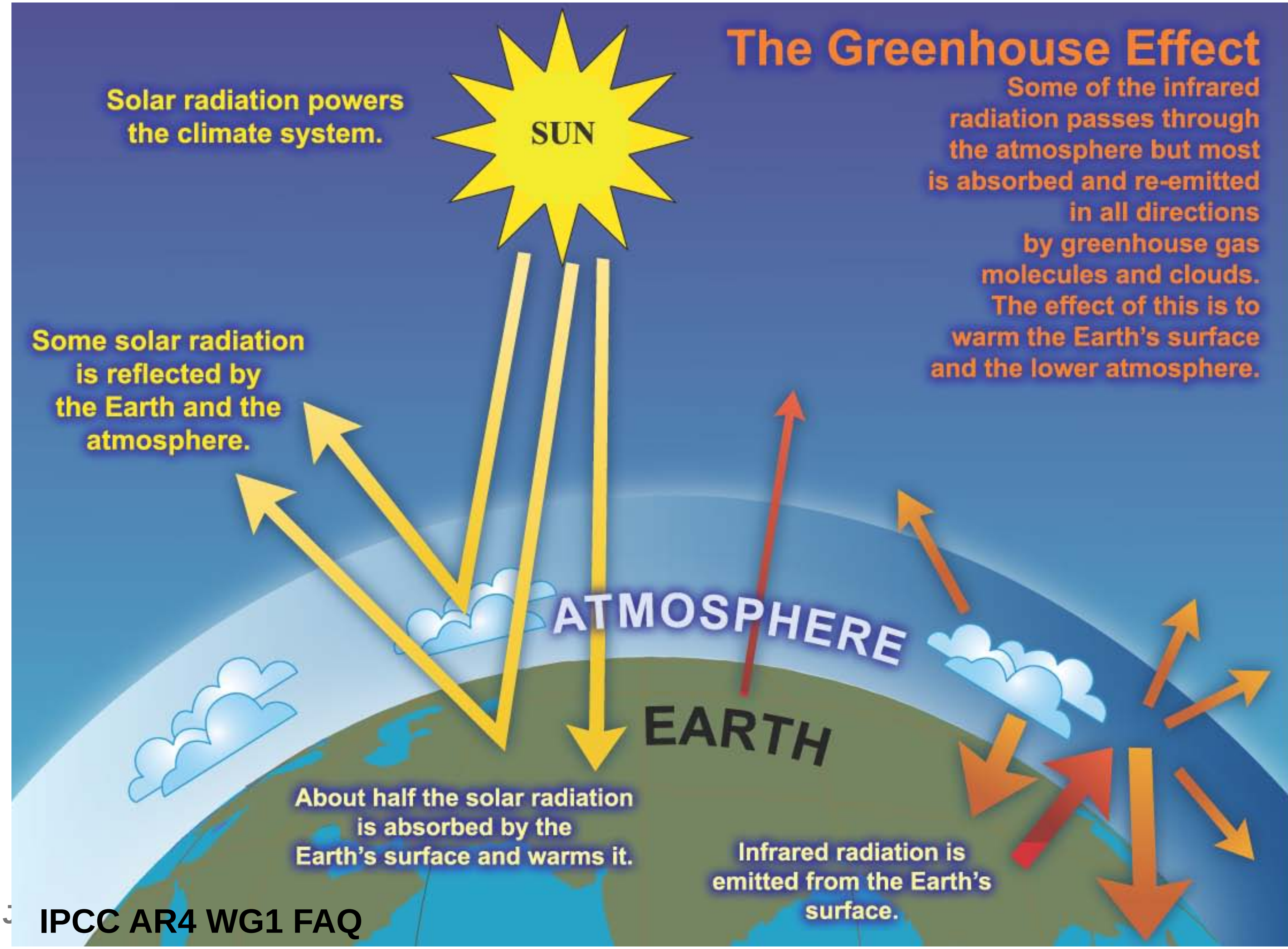
which sometimes have resulted in ice ages

Changes in the arrangement of continents

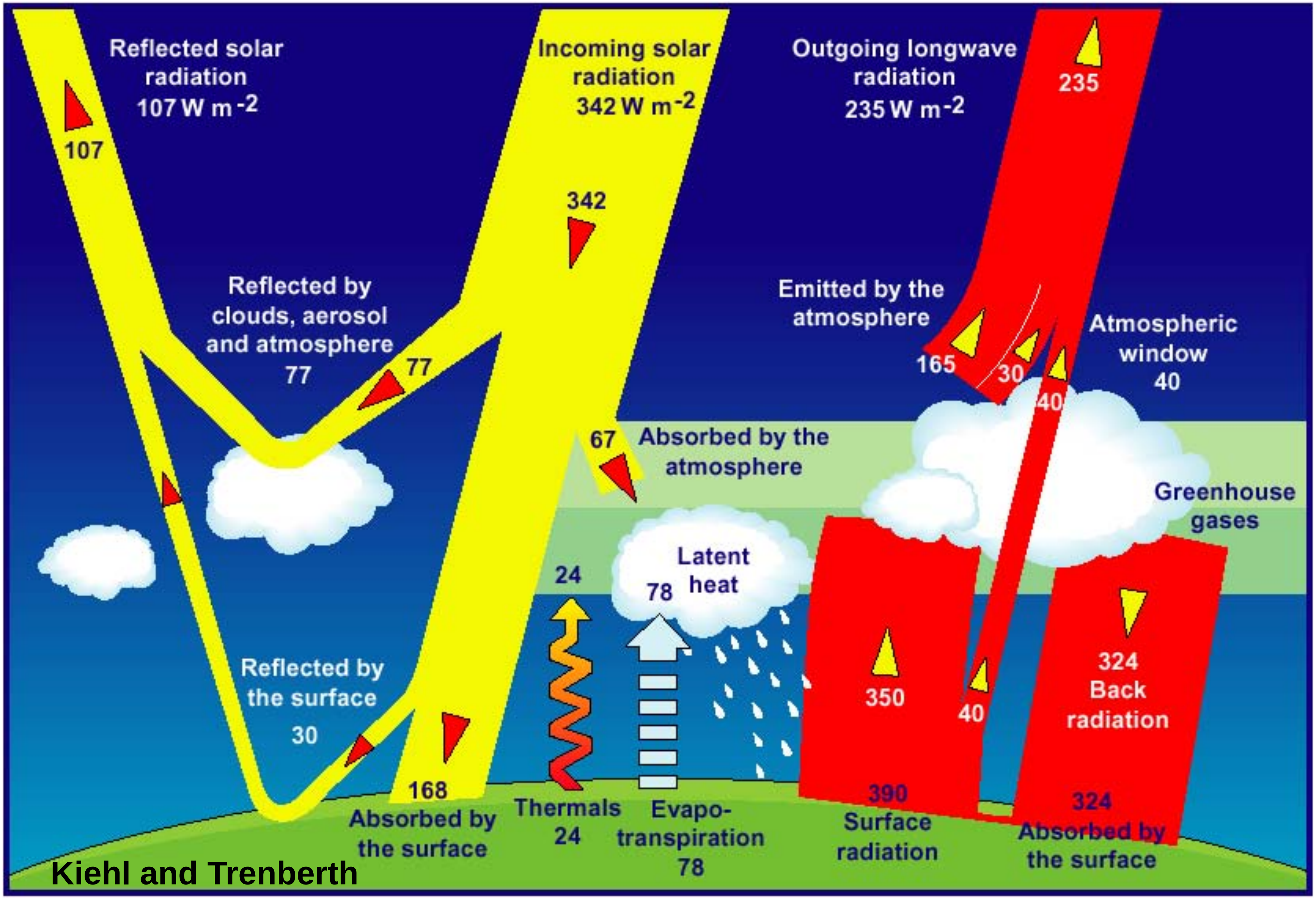
Changes in concentrations of greenhouse gas and aerosols

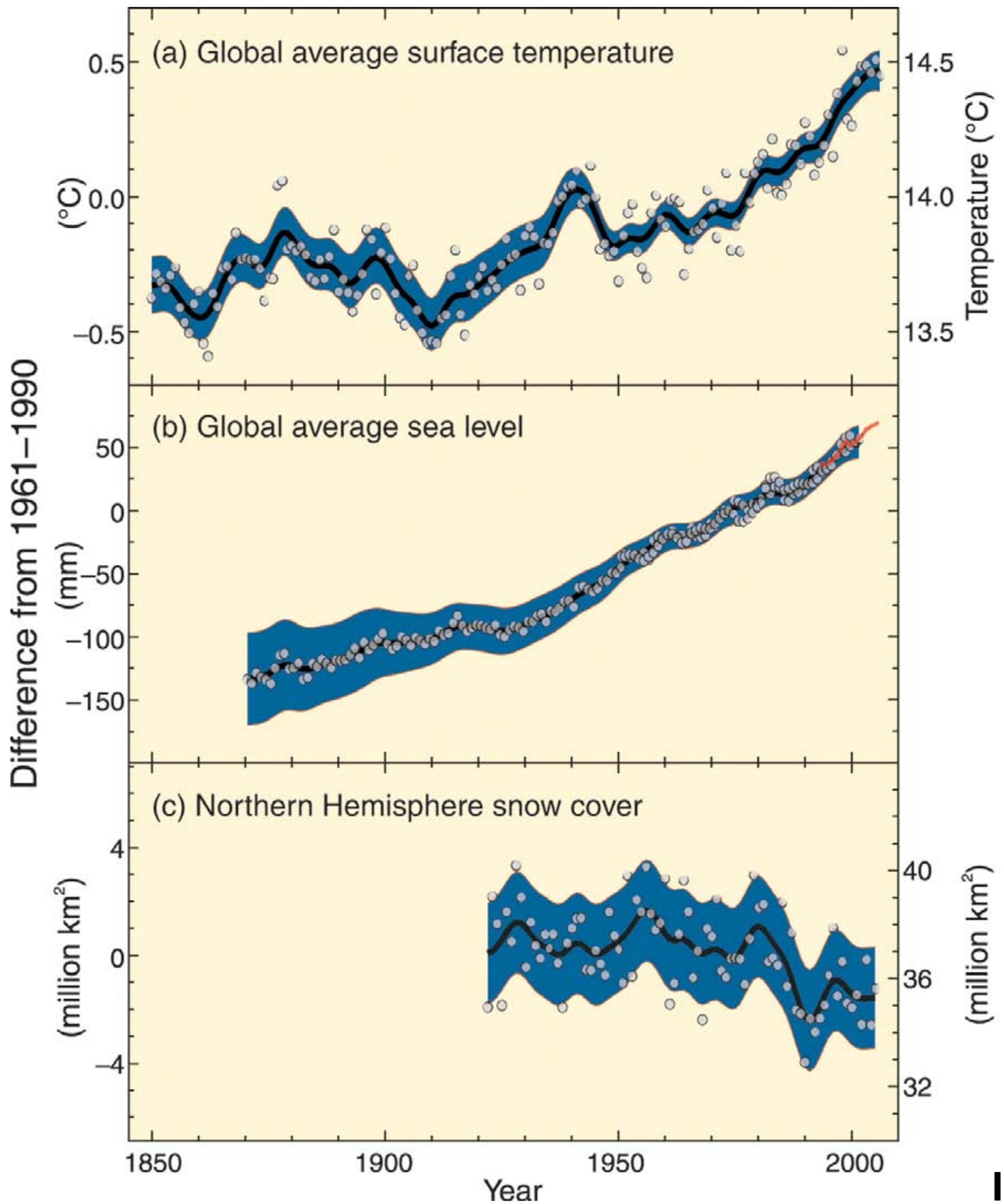
The rate and magnitude of human-caused increases in GHG concentrations is pushing the system outside the range of natural variability.

The “Greenhouse” Effect



We Have Changed the Planetary Radiation Balance





Observed Changes are Above Background Variations

- Climate change means many aspects of the system can change (temperature, rainfall frequency and intensity, etc.)
- Conclusions about the reality of anthropogenic-driven climate change are drawn from multiple lines of evidence (observational, theoretical, modeled)

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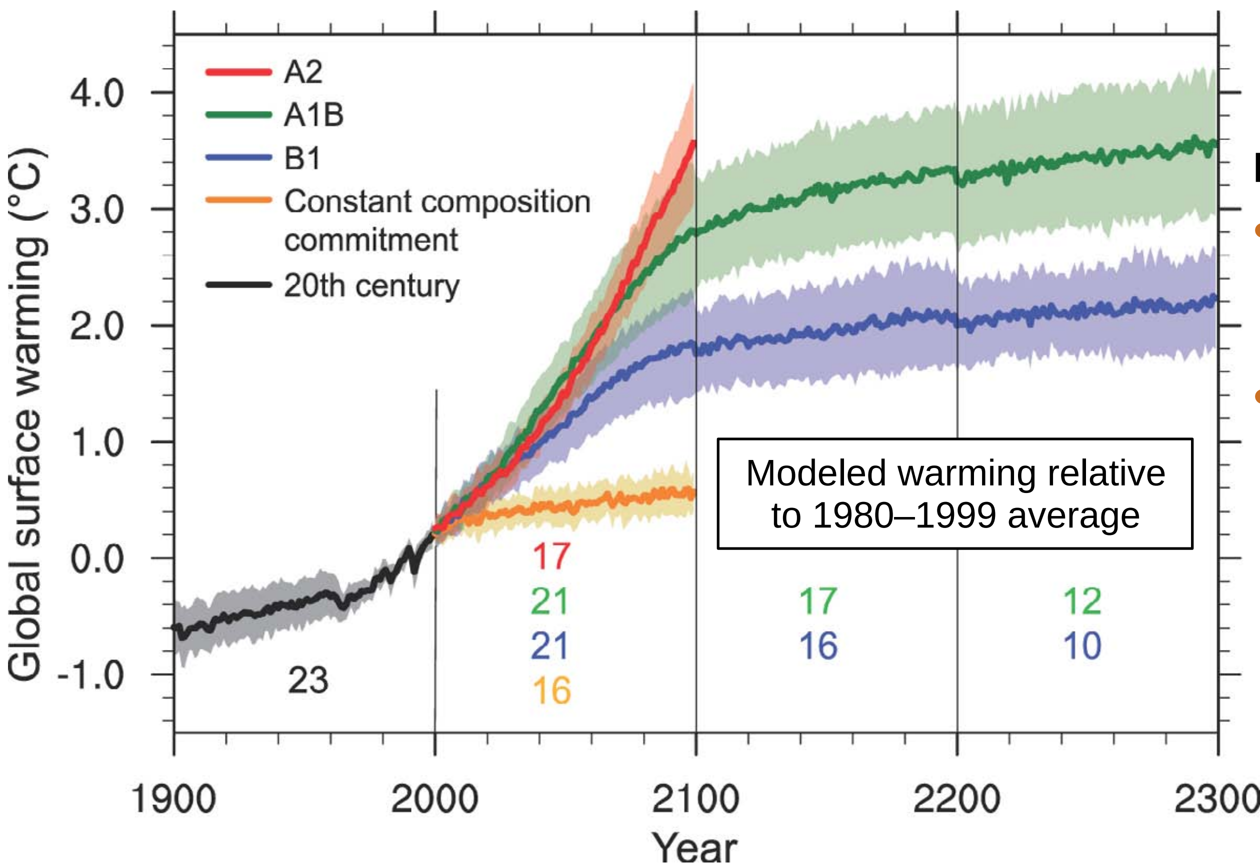
Climate Changes Are Going to Continue

We have already committed to some amount of future climate changes due to:

- Warming of the ocean to date
- "Unmasking" of current forcing due to future air pollution controls
- Inertia in technological and social systems that results in continued GHG emissions



Range in future results due to:

- Uncertainty in system response (within colored ranges)
- Uncertainty in human influences and action (between colored ranges)

Both extend beyond the ranges shown in this figure!

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IPCC AR4 WG1 fig 10-4

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