Global Climate Change: Impacts, Challenges and Opportunities

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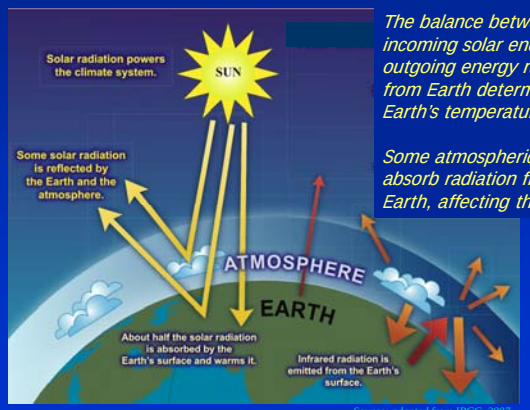
Fundamentals of global climate change

Motivating Questions

- What do we mean by "global climate change" and what are its causes?
- What are the current and future impacts of climate change that give us concern?
- What measures and policies can we pursue to reduce or avoid dangerous impacts?
- What is the outlook for actions to deal with climate change?

The Earth's Temperature is Set by a Global Energy Balance



The balance between incoming solar energy and outgoing energy radiated from Earth determines the Earth's temperature.

Some atmospheric gases absorb radiation from the Earth, affecting the balance.

Source: adapted from IPCC, 2007

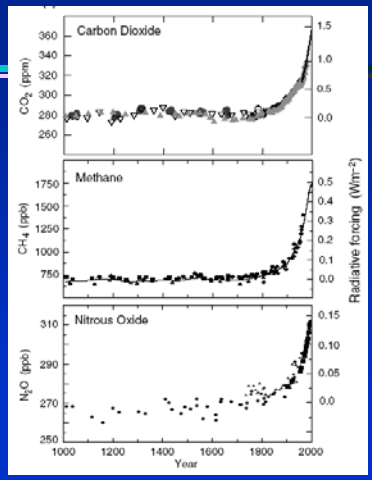
The "Greenhouse Effect"

- Atmospheric gases that absorb Earth's radiation, and warm the planet, are called greenhouse gases
- They include carbon dioxide, methane, nitrous oxide, other trace gases, and water vapor
- Without natural levels of these gases the average temperature of Earth would be –19°C (instead of the actual 15°C)
- The additional 34°C of warming due to these gases is called the "greenhouse effect"

Atmospheric GHG Levels

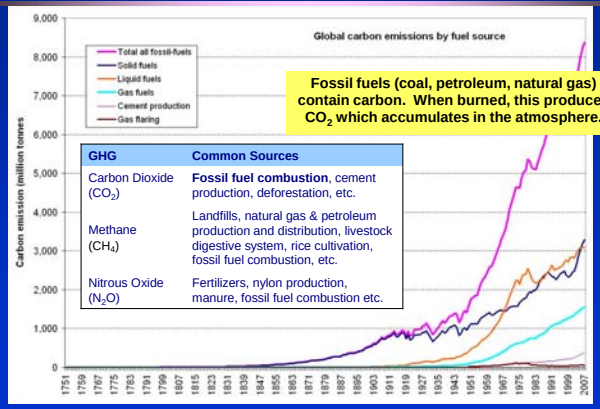
Greenhouse gas (GHG) concentrations in the atmosphere have been increasing rapidly as a result of human activities.

Once in the atmosphere, these gases are not easily or quickly removed.



Source: IPCC, 2001

We have been putting GHGs into the atmosphere at an increasing rate



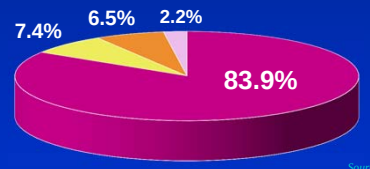
Fossil fuels (coal, petroleum, natural gas) contain carbon. When burned, this produces CO_2 which accumulates in the atmosphere.

GHG	Common Sources
Carbon Dioxide (CO_2)	**Fossil fuel combustion**, cement production, deforestation, etc.
Methane (CH_4)	Landfills, natural gas & petroleum production and distribution, livestock digestive system, rice cultivation, fossil fuel combustion, etc.
Nitrous Oxide (N_2O)	Fertilizers, nylon production, manure, fossil fuel combustion etc.

Source: http://climatechangeconnection.org

Contribution of GHGs to Total Global Warming Potential

CO_2 from Energy Use is the Dominant Greenhouse Gas



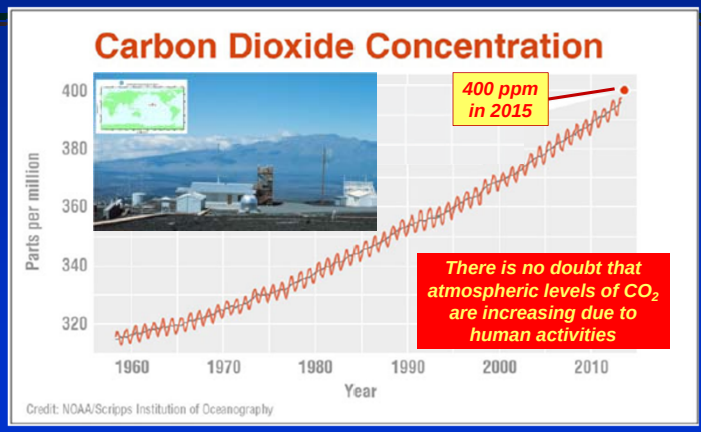
(values based on 100-year GWP)

Source: USEPA, 2007

Combined emissions commonly expressed as equivalent CO_2

Current trends

The Mauna Loa CO_2 Record



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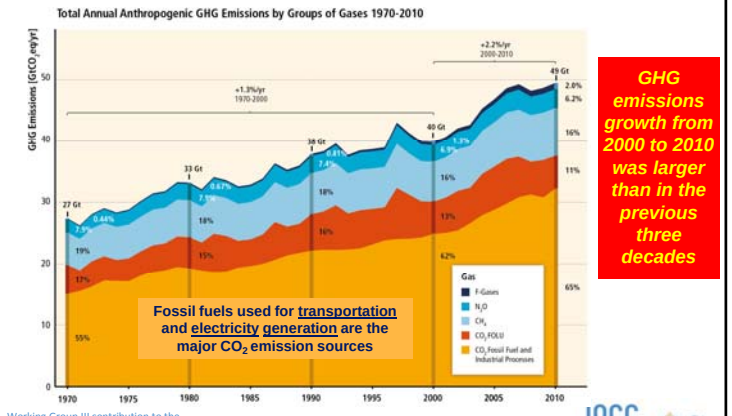
Global GHG emissions growth has accelerated despite reduction efforts



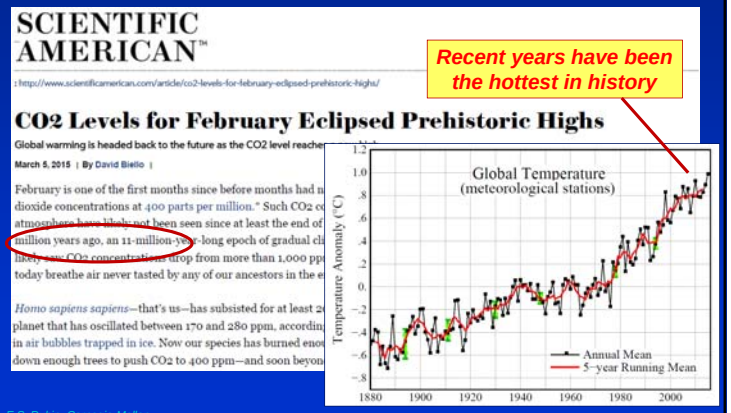
Fossil fuels used for transportation and electricity generation are the major CO_2 emission sources

GHG emissions growth from 2000 to 2010 was larger than in the previous three decades

Working Group III contribution to the IPCC Fifth Assessment Report

IPCC INTERGOVERNMENTAL PANEL ON climate change

Current CO_2 Levels and Global Temperature are at Historical Highs



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Global Climate Change Processes

Emissions of greenhouse gases from human activities → Increases in atmospheric concentration → Increases in global temperatures → **Changes in climate** → **Impacts on ecosystems and human welfare**

"Climate" is defined as the average weather over 30 years. It includes atmospheric temperature, pressure, humidity, wind and precipitation.

Conclusions from the 2014 IPCC Fifth Assessment Report

Human influence on the climate system is clear

Worldwide Effects

- atmosphere, land, ocean
- extreme events
- water cycle
- sea ice, glaciers, ice sheets
- global mean sea level

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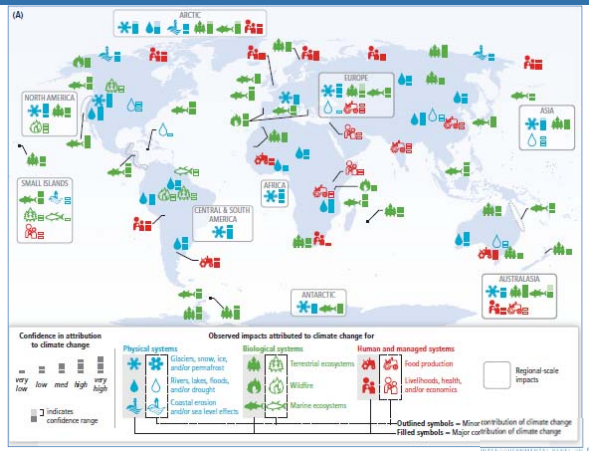
INTERGOVERNMENTAL PANEL ON climate change

The Intergovernmental Panel on Climate Change (IPCC) has been studying climate change impacts for over 25 years

Global pattern of impacts in recent decades attributed to climate change



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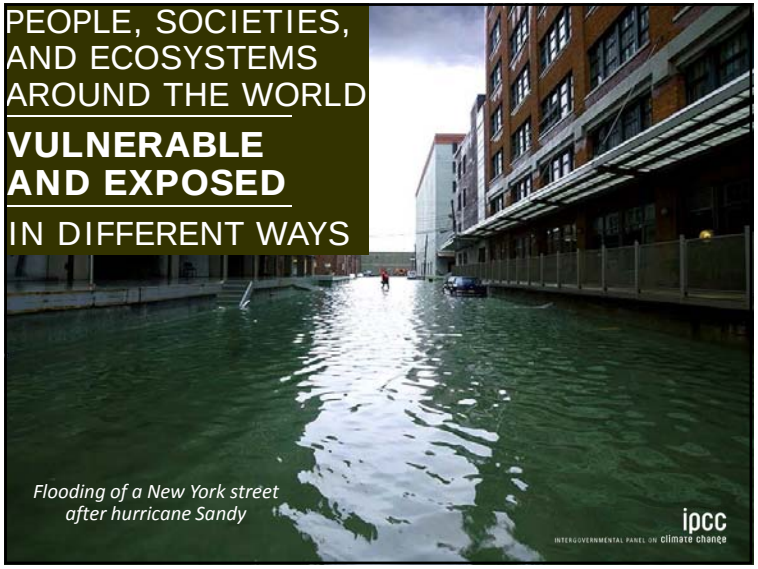
INTERGOVERNMENTAL PANEL ON climate change

PEOPLE, SOCIETIES, AND ECOSYSTEMS AROUND THE WORLD

VULNERABLE AND EXPOSED

IN DIFFERENT WAYS



Flooding of a New York street after hurricane Sandy

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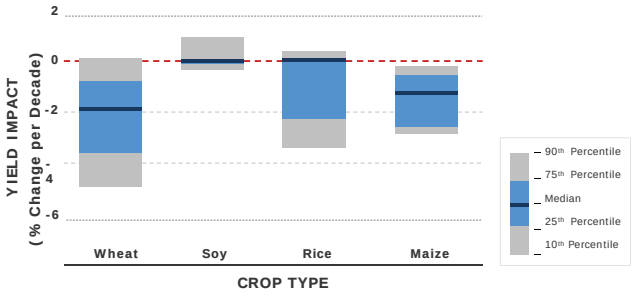
INTERGOVERNMENTAL PANEL ON climate change

Impact of climate change on yield of four major crops from 1960–2013



Includes tropical and temperate zones. Climate change is making it increasingly difficult to increase crop yields to meet growing demands for food and agricultural products.

WGII Figure SPM 2

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INTERGOVERNMENTAL PANEL ON climate change

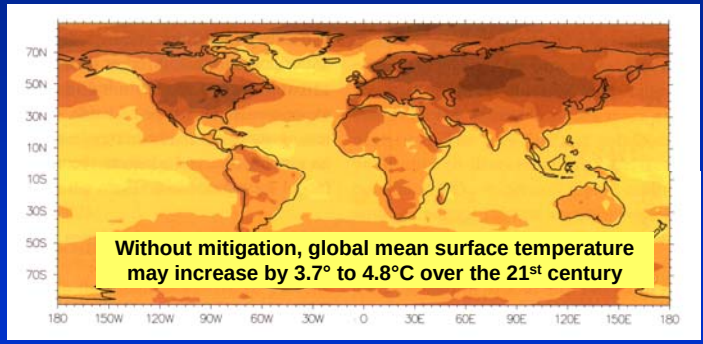
Another example of current impacts

Reeling From Effects of Climate Change, Alaskan Village Votes to Relocate

By CHRISTOPHER MELE and DANIEL VICTORAUG. 19, 2016

An abandoned house at the west end of Shishmaref, Alaska, that slid during a storm in 2005. Residents have voted in favor of relocating the community to the mainland.
CreditDiana Haecker/Associated Press

Predicted Temperature Changes for a Doubling of Atmospheric CO_2 Concentration



Source: *IPCC, 2014*

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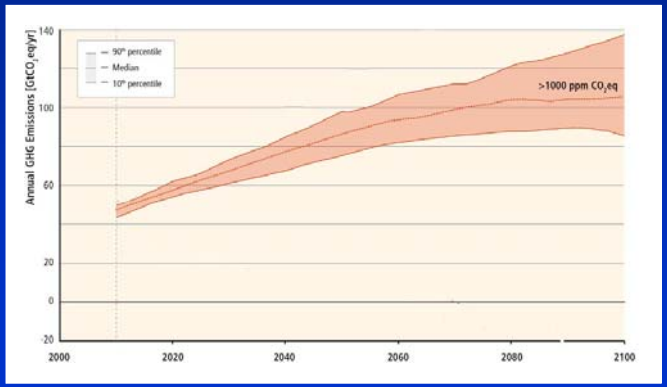
Baseline projections: Continued increases in GHG emissions and concentrations



Source: *IPCC, 2014*

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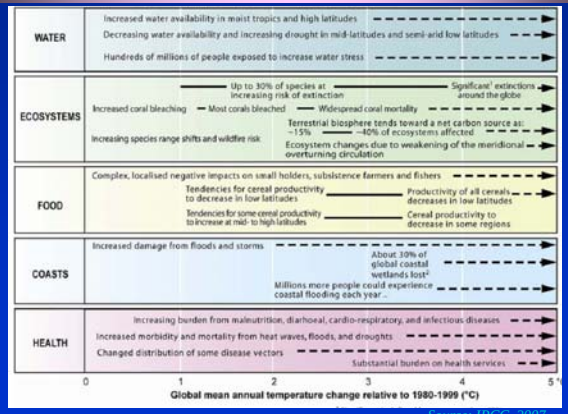
Dangers from climate change increase with higher global temperature



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Source: IPCC, 2007

Adaptation is Already Occurring

Example: **Flood barriers against rising waters**

Rotterdam, The Netherlands

Tuvalu, in the South Pacific

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What Options Do We Have ?

Option 1:

Adaptation

(adjust to changes)

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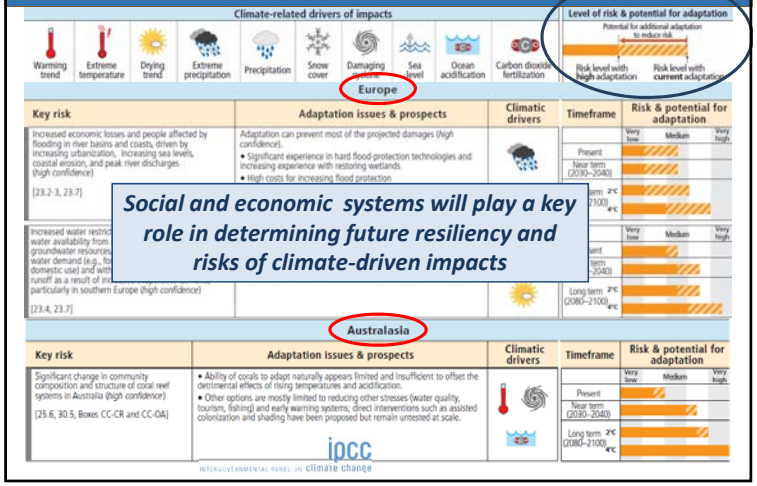
The potential for *future* adaptation also varies around the world



Social and economic systems will play a key role in determining future resiliency and risks of climate-driven impacts

The Climate Policy Framework

- 1992 U.N. Framework Convention on Climate Change called for "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system"

**192 countries are parties to the convention*

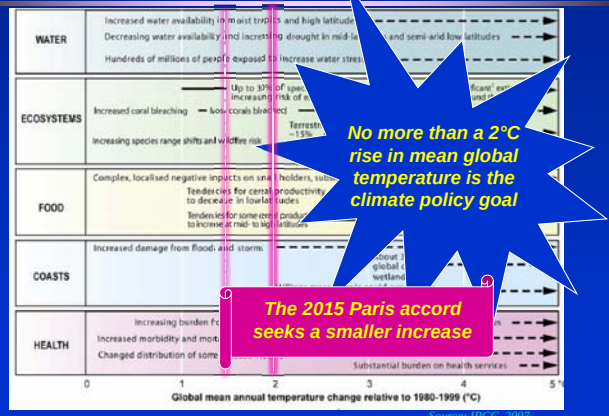
What Options Do We Have ?

Option 2:

Mitigation

(reduce GHG emissions)

How do we define "dangerous anthropogenic interference" ?

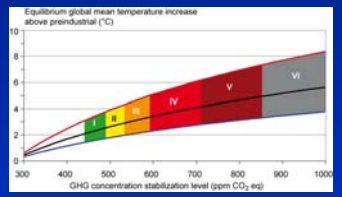


No more than a 2°C rise in mean global temperature is the climate policy goal

The 2015 Paris accord seeks a smaller increase

Source: IPCC, 2007

What does it take to limit the increase in global temperature to 2°C ?



Atmospheric concentration of GHGs must be stabilized at about 450 ppm CO_2, equiv

This requires LARGE REDUCTIONS in GHG EMISSIONS …. Quickly!

Required reduction in global GHG emissions from 2000 to 2050:
50% to 85%

Source: IPCC, 2007, 2014

How can we get big reductions in GHG emissions ?

Why are such large emission reductions needed for stabilization?

- Unlike conventional air pollutants, most GHGs are not quickly removed by natural processes —so they remain in the atmosphere for centuries or more
- So, to stabilize atmospheric *concentrations*, GHG emissions must be reduced dramatically

Analogy: To stabilize the water level in a slow-draining bathtub, the faucets must be tightened to a trickle or the water level will continue to rise

General Strategies for Reducing Emissions

$$\frac{\text{CO}_2 \text{ emissions}}{\text{per year}} = \left(\frac{\text{Population}}{\text{per year}}\right) \times \left(\frac{\text{GDP}}{\text{per capita}}\right) \times \left(\frac{\text{Energy use}}{\text{per GDP}}\right) \times \left(\frac{\text{CO}_2 \text{ emissions}}{\text{per unit energy}}\right)$$

The Kaya Identity

These two factors depend strongly on technology

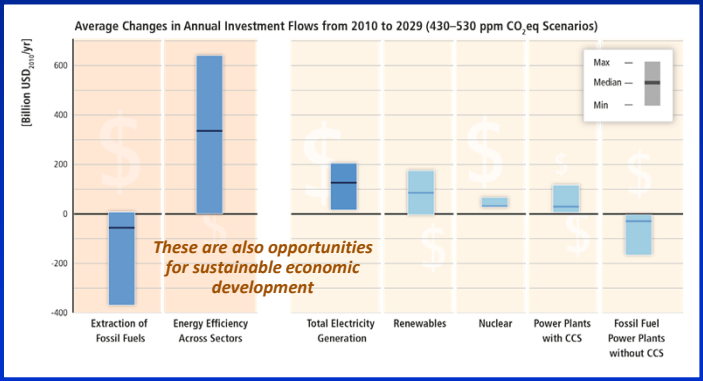
Computer models of global and national energy systems are used to find the combination of measures that can achieve emission reduction goals at the lowest cost to society

Technologies Needed to Mitigate CO_2 Emissions

- Technologies and social systems that reduce the demands for energy in all sectors of the economy
- Technologies that use energy more efficiently
- Technologies to produce and use energy sources with low or no GHG emissions (e.g., renewables)
- Technologies for CO_2 capture and sequestration at power plants and other large industrial facilities

How do government actions influence technology deployment and innovation?

Reducing GHG emissions will require major new investments



Source: IPCC, 2014

"Technology Policy" Options

Direct Government Funding of Research and Development (R&D)

- R&D contracts with private firms
- R&D grants and contracts with universities
- Intramural R&D conducted at gov't laboratories
- R&D contracts with consortia (2 or more of the actors above)

Direct or Indirect Support for Commercialization and Production; Indirect Support for Development

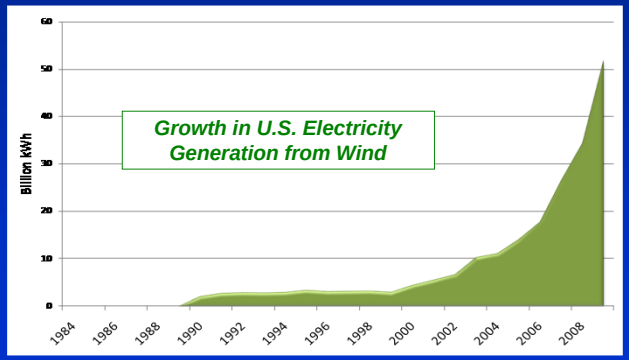
- Patent protection
- R&D tax credits
- Production subsidies or tax credits to firms bringing new technologies to market
- Tax credits or rebates for new technology buyers
- Government procurement
- Demonstration projects

Support for Learning and Diffusion of Knowledge and Technology

- Education and training
- Codification and transfer of knowledge
- Technical standard-setting (non-regulatory)
- Technology and/or industrial extension services
- Publicity and consumer information

- ***Provide "carrots" to incentivize innovation & technological change***
- ***Policies influence different phases of the innovation process***

Government incentives have played a key role in growth of renewables



Source: EIA, 2010

Regulatory policies have had a major impact on energy efficiency and emissions

Energy Demand Sectors and Technologies	
BUILDINGS (Residential & Commercial)	***TRANSPORTATION SYSTEMS***
Lighting	Light-duty vehicles
Water heating	Trucks, buses, locomotives
Cooking	Aircraft
Refrigeration	Marine vessels
Space heating	***INDUSTRIAL PROCESSES***
Air conditioning	Electricity use (motors, drives, etc.)
Ventilation	Process heat and fuel use
Appliances	Cogeneration systems
Building structures	New process technology

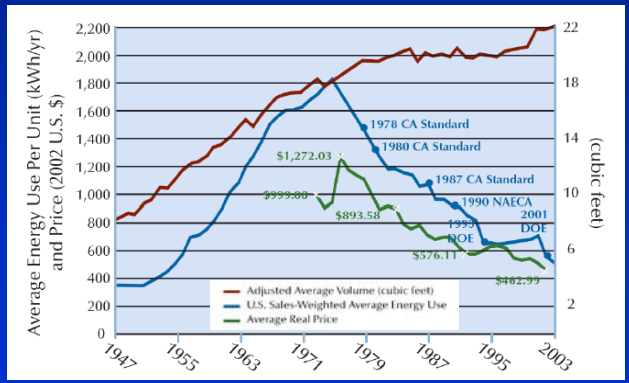
Regulatory Policy Options

Includes Economy-wide or Sector-wide Measures, plus Technology-specific Regulations and Standards; e.g.,

- Emissions tax
- Fuels tax
- Cap-and-trade program
- Technology portfolio standards
- Technology performance standards (for pollutant emission rates, efficiency, or other measures)

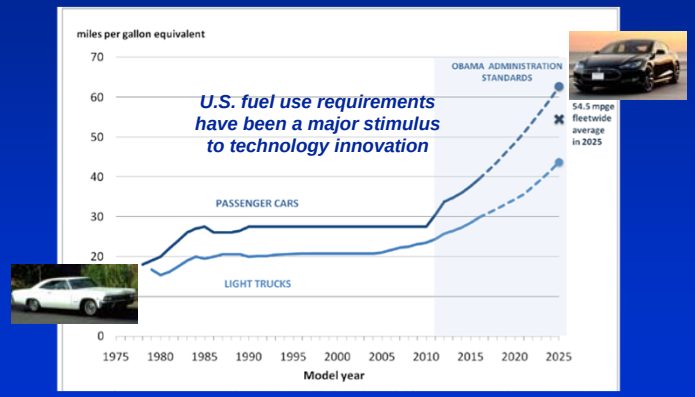
- ***Provide "sticks" to incentivize innovation & technological change***
- ***Also influence different phases of the innovation process***

Performance Standards Reduced Refrigerator Energy Use Significantly



Source: A.Rosenfeld, CEC, 2007

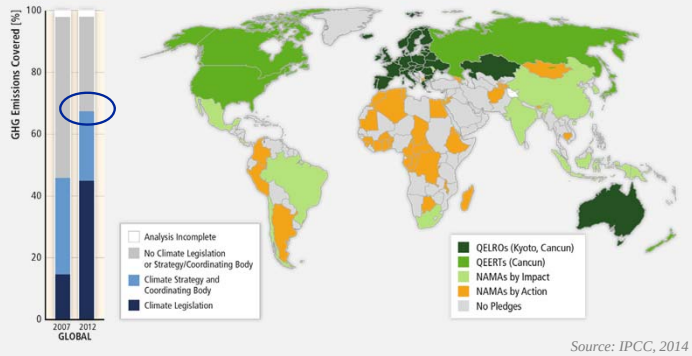
Corporate Average Fuel Economy (CAFE) Standards for New Light-Duty Vehicles



U.S. fuel use requirements have been a major stimulus to technology innovation

Increasing percentage of global emissions are covered by mitigation plans and strategies …

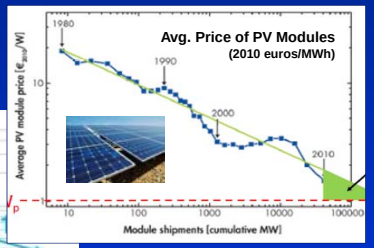
… but commitments to large emission reductions are still lacking



Source: IPCC, 2014

Renewable Portfolio Standards for Electric Power Systems

Power generation costs for wind and solar energy systems have fallen dramatically as these technologies were deployed in response to requirements



Source: Kleiburg, ECN, 2011

Source: Bloomberg New Energy Finance

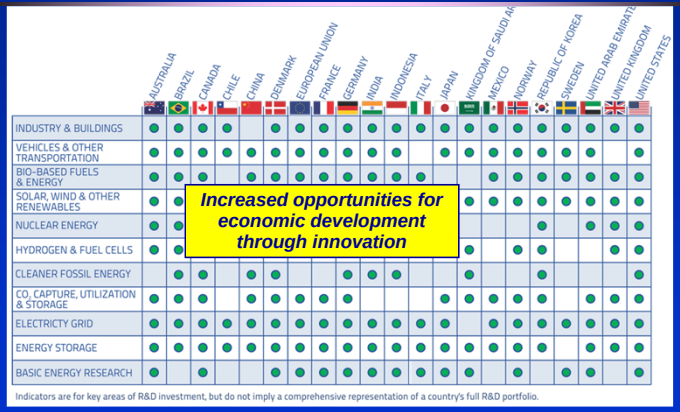
Two Promising New Developments

Key Elements of the Paris Accord

(COP 21, December 2015)

- World nations agreed to binding commitments for "nationally determined contributions" to GHG emission reductions and measures to achieve them
- New plans every five years to cut emissions beyond previous levels
- Rich countries to help developing nations by providing $100 billion/yr in "climate finance" by 2020, and more after 2025
- Between 2050 and 2100, limit GHGs emitted by human activities to what can be absorbed naturally

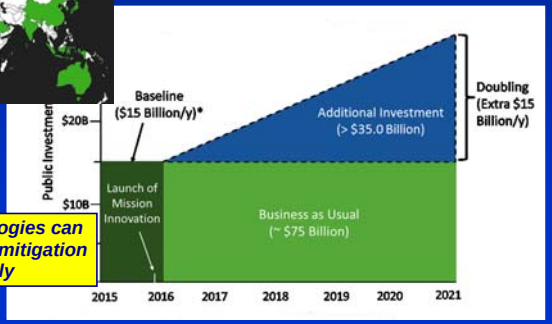
Mission Innovation R&D Areas



Increased opportunities for economic development through innovation

"Mission Innovation" Plans

21 countries pledge to double public spending on energy R&D over 5 years



Advanced technologies can reduce the cost of mitigation significantly

So What Will the Future Bring ?

- The Paris Agreement is an important step in the effort to mitigate climate change
- Need for strong policy drivers to spur innovation and deployment of clean and sustainable technologies
- Adaptation and effective social-economic systems also are needed to reduce climate change impacts
- **WATCH THIS SPACE FOR FUTURE UPDATES**

Thank You !

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