Climate Change:
From Science to Action

Nevada Transportation Conference

May 7, 2019

Chas Macquarie, P.E.

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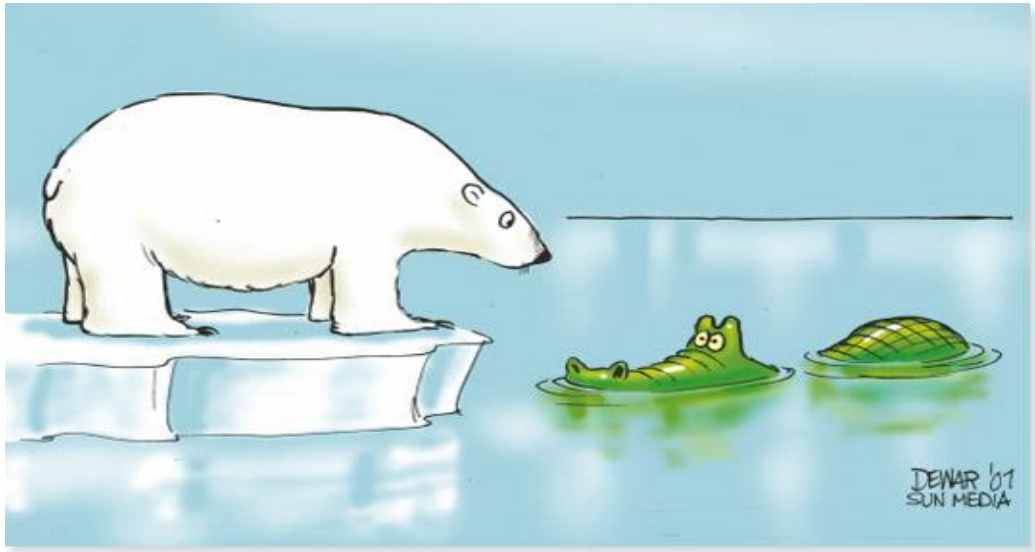
Tuolumne Meadows, Winter 1979

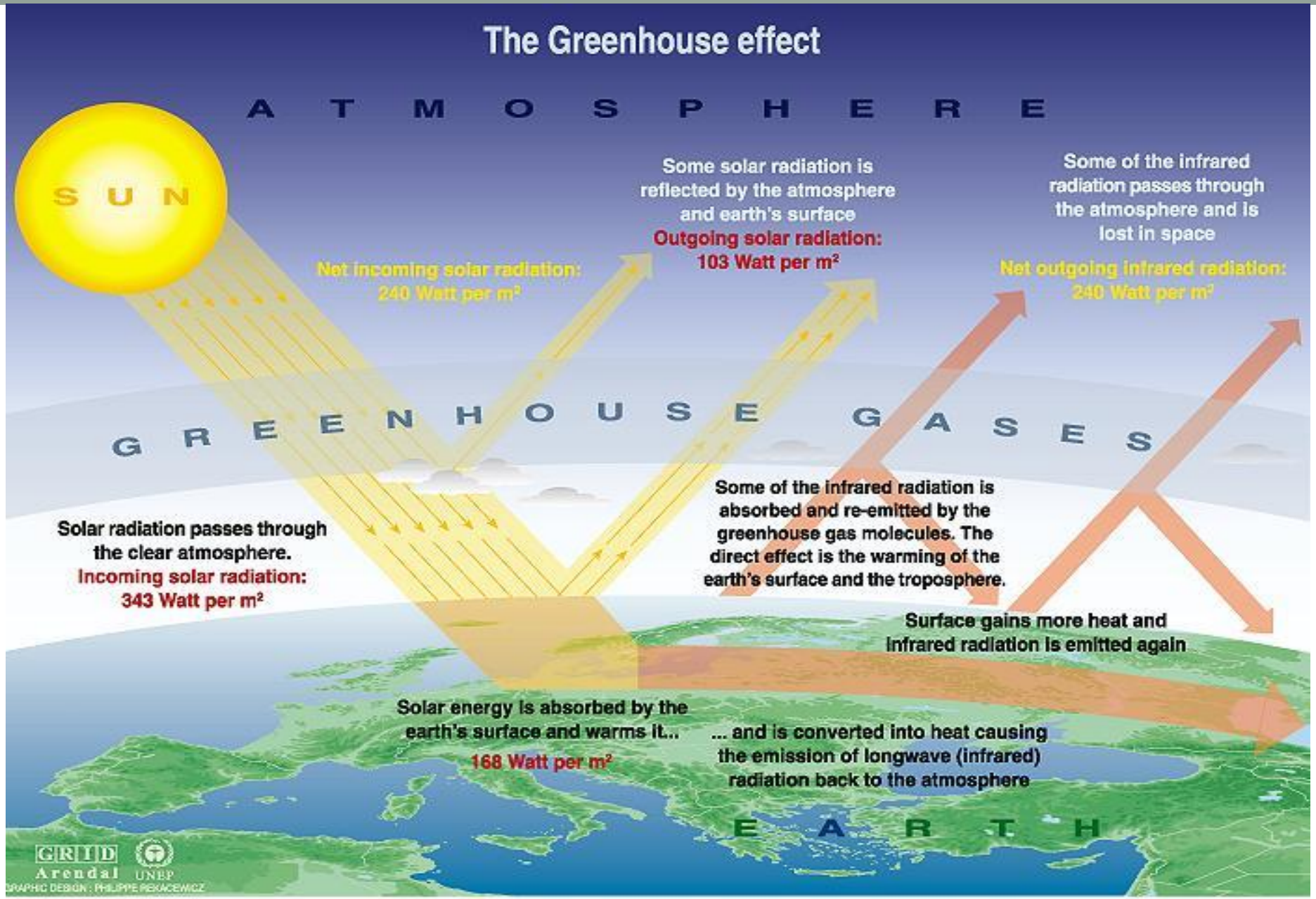
Why talk about science when 97% of climate scientists agree that:

- The earth is warming
- It is primarily due to an increase in Green House Gases
- We're responsible

Because there is a common misconception that scientists do not agree on these facts

- Science slides thanks to Dr. Alan Ferrenberg, PhD





Sources: Okanagan university college in Canada, Department of geography, University of Oxford, school of geography; United States Environmental Protection Agency (EPA), Washington; Climate change 1995, The science of climate change, contribution of working group 1 to the second assessment report of the intergovernmental panel on climate change, UNEP and WMO, Cambridge university press, 1996.

Green House Gases

- Most of the atmosphere is made up of Nitrogen (78%) and Oxygen (21%)
- GHGs account for only about 0.1% of total atmosphere
- Carbon Dioxide (CO_2) is about 83% (about 63% of warming)[1]
- Methane (CH_4) is about 12% (roughly 30 x as potent as CO_2)[2]
- Nitrous Oxide (N_20); Hydrofluorocarbons; Ozone
- Water Vapor
- Since CO2 is relatively easy to measure in ice cores it is used in historical data

1. NOAA – Earth Systems Research Lab, Boulder, CO
2. EPA, Understanding Global Warming Potentials

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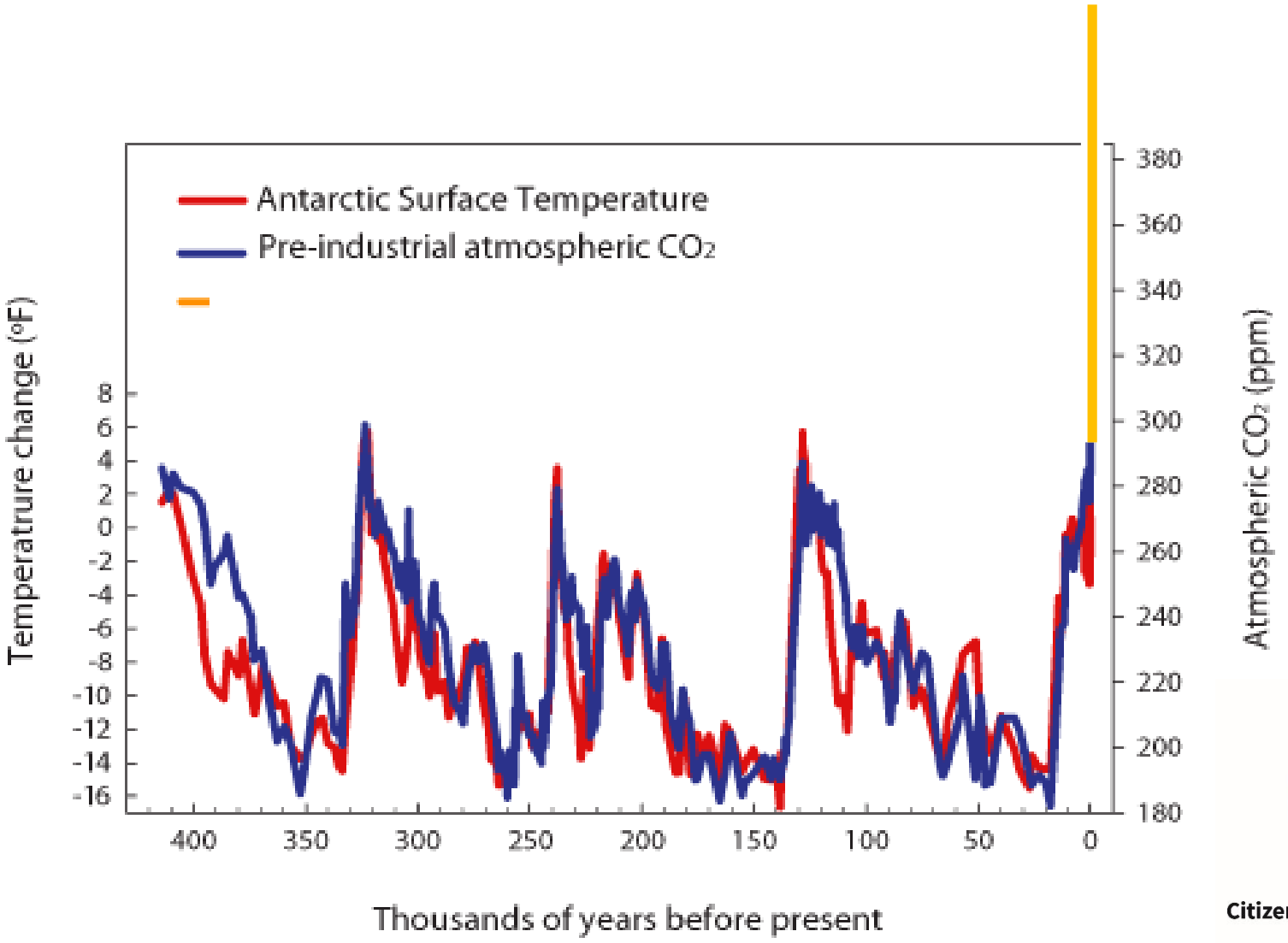
Atmospheric CO_2 & Global Surface Temperature for the Past 400,000 Years



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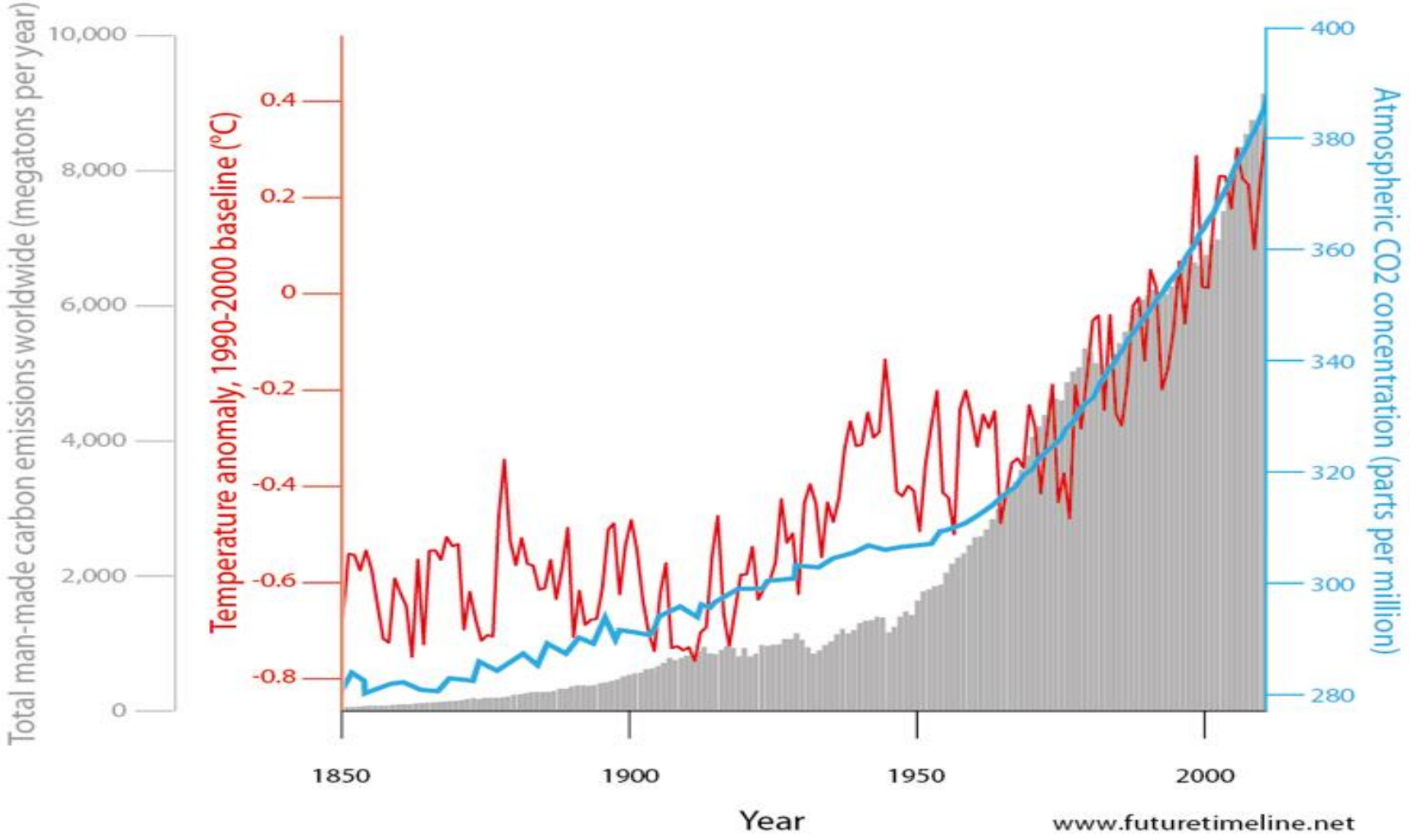
CO2 and Temperature, 1850 to 2010



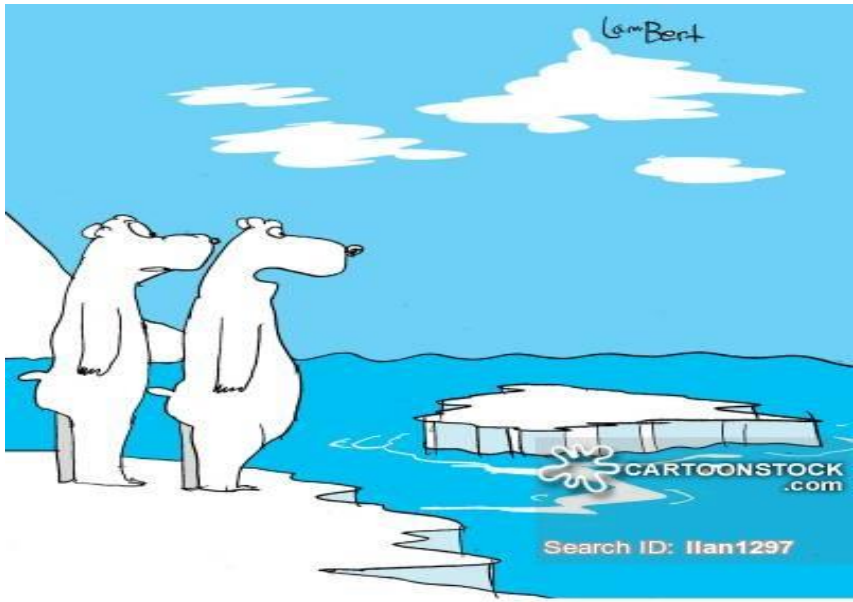
Global Warming

- There is a basic, simple theory that indicates increasing CO_2 will increase the Earth's temperature

- There is historic data that indicates that CO_2 and increasing temperature are correlated (rise and fall together).

- The temperature of the Earth

is rising and CO_2 levels are rising.



"There goes the neighborhood."

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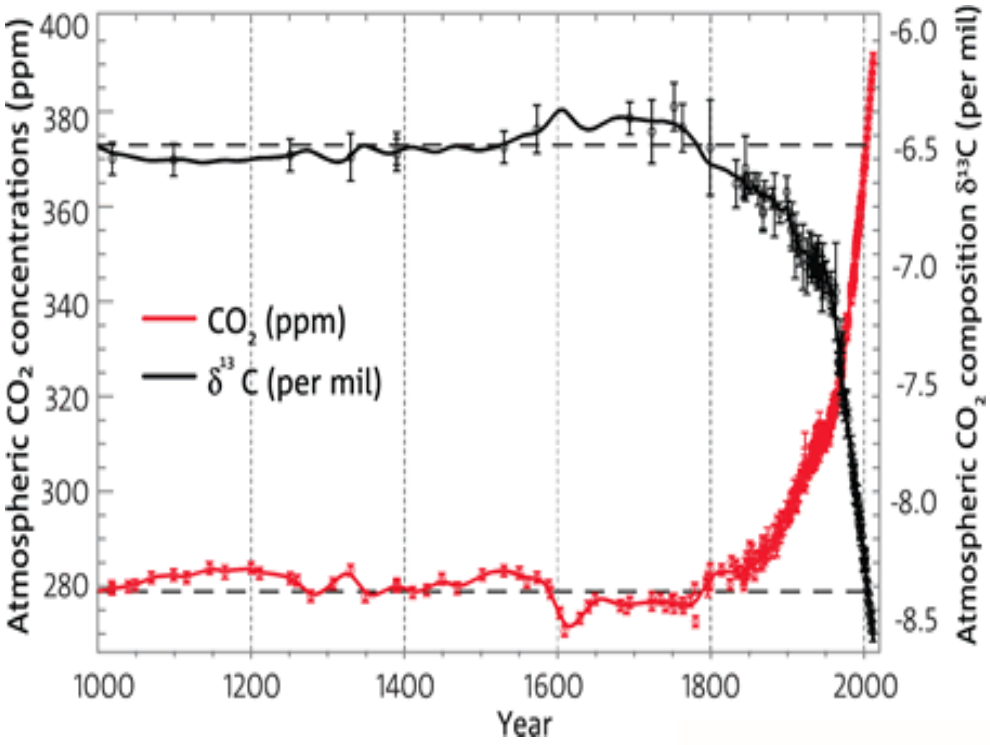
Are we responsible?

- Carbon isotope ratio
- Climate models



It is <u>extremely likely</u> that human influence has been the dominant cause of the observed warming since the mid-20th century. (IPCC 2013 & 2018)

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Global Warming – A Recap

- It's real - Since 1950, the earth has warmed 0.9° C (1.6° F)[1]
- It's us - Since 1950, almost all the warming has been caused by human activities
  - Since 1950, other factors[2] have had an insignificant temp. impact (combined slight net cooling effect)
- Scientists agree - There's no scientific debate
  - All National Academies of Science 80 – 0
  - Scientific organizations 100's – 0
  - Peer-reviewed articles for 20 years 500 to 1
- Pentagon, NASA, NOAA, IPCC, DPWs Agree

1. http://climate.nasa.gov/vital-signs/global-temperature/
2. Solar flares, orbital changes, volcanos, land use changes, ozone, aerosol pollution

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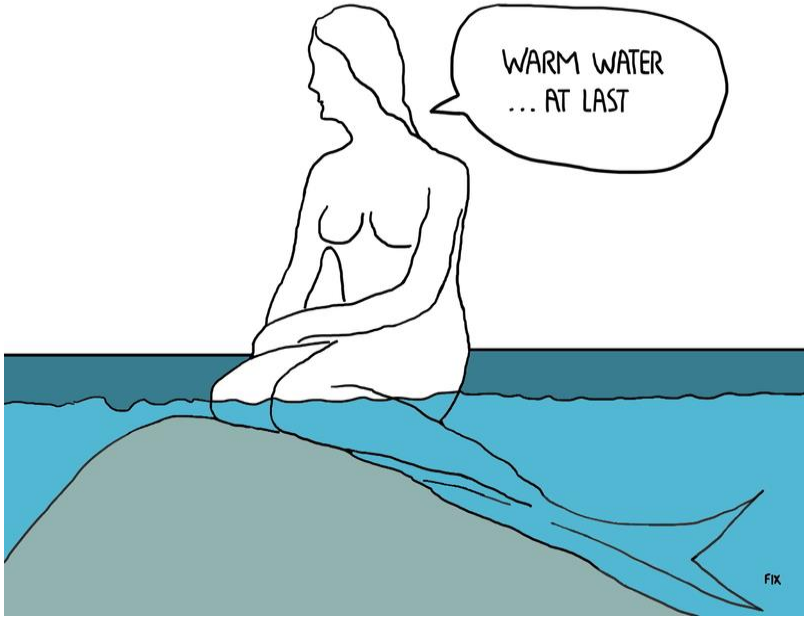
Reports predicting 7°F to 12°F warming by 2100 if we continue "Business as Usual"



- World Bank, 2012
- Price Waterhouse Coopers, 2012
- International Energy Agency, 2012
- Intergovernmental Panel on Climate Change (IPCC), 2014, 2018
- American Association for Advancement of Science (AAAS), 2014
- US Fourth National Climate Assessment, 2018

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Measured Effects of Climate Change

Some effects occurring now:

- 18 of the 19 warmest years have occurred in the 21st C.
- Plant and animal ranges have shifted and trees are flowering sooner
- Ice on rivers and lakes is breaking up earlier
- Arctic permafrost is melting
- Glaciers have shrunk; snow levels are rising
- Loss of sea ice
- Increased ocean temps & acidity
- Accelerated sea level rise
- Longer, more intense heat waves & wild fires
- More intense storms and flooding

Source: http://climate.nasa.gov/effects/

Potential Effects of Climate Change

Likely future effects:

- Change will continue through this century and beyond
- A continuation, and potential acceleration of the current effects
- Sea level rise of 1 ft. or more by 2050 (2-4 ft. by 2100)
- Arctic likely to become ice-free
- Species extinction
- Increased diseases
- Conflicts over resources
- Agricultural disruption
- Mass population migrations
- Starvation
- Wars

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What About Nevada?

- Increased heat and drought
- Health impacts in cities due to heat
- Increased wildfires, flooding and erosion
- Less snow and more rain in the mountains
- Changes in streamflow regimes
- Competing demands for available water
- Declining water supplies
- Reduced agricultural yields
- More dust at Burning Man
- Opportunity to expand solar and geothermal energy generation

Source:
U.S. Global Change Research Program: National Climate Assessment, Southwest.

Why Should we be Concerned?

- If we keep on a course of Business as Usual and don't take measures to slow the rate of global warming, the impacts of climate change will be more severe.
  - Greater sea level rise
  - More agricultural disruption
  - Increased fires and floods
  - Greater human suffering
  - Increased species extinction
  - Increased world-wide conflict
  - Hugely expensive

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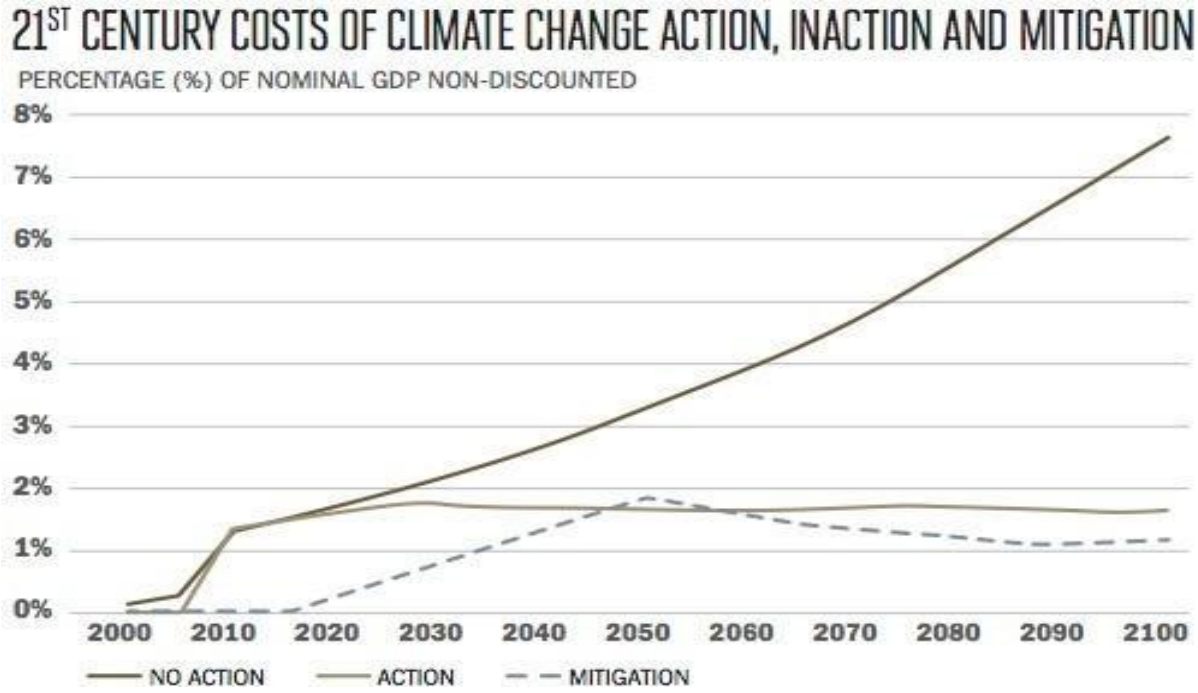
The Cost of Doing Nothing



The Economist Intelligence Unit: The Cost of Inaction, 2015

"Our estimates indicate that asset managers can expect present-day losses of US$4.2trn to the US$143trn of current manageable assets as a result of climate change by 2100 at a private-sector discount rate, equivalent to the entire GDP of Japan."

US Environmental Protection Agency Study, 2019

They found that taking action to reduce emissions could save us at least $200 billion *per year* by the end of the century.

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So how do we keep the warming to below 1.5ºC (2.7ºF)?

- Cut global emissions to 45 % below 2010 levels by 2030[1]
- Keep 80% of the carbon in the ground and reduce emissions to net zero by 2050
- Global GHG emissions need to peak by 2022. Then drop significantly (about 3% per year) to at least 2050
- Addressing climate change comes with a time limit…
  and we're running out of time.

1. IPCC Global Warming Special Report, 2018

- To avoid 1.5º C increase, global $C0_2$ emissions need to be limited to 1 Trillion tons. We have already used over 60% of this budget. Current global CO_2 emissions are 35 Billion tons/year.

1.5°C is Technically Feasible

"Delay and Pray" is not an option. We need to:

- Cut energy demand
  - Increase conservation
  - Efficiency innovations
- Increase renewable energy supply
  - Wind
  - Solar
  - Geothermal
  - Water
  - Nuclear (maybe)
- Make renewable energy cheaper
- Improve energy storage
- Develop non-fossil fuel transportation modes
- Take big actions not just small changes
- Streamline the vast array of Government regulations and incentives

56% of the energy in this country does no useful work – it's wasted in the system

1.5°C is Politically Viable

2019 Yale & George Mason Universities Poll:

- 69% Americans are “somewhat worried” about climate change
- 29% Americans are “very worried” about climate change

2019 University of Chicago Poll:

- 83% of Americans that are worried about climate change say the federal government should take action
- 80% say state government should take action
- 76% say local government should take action

Other Polls:

- 78% of Millennials think climate change is a serious problem

BUT: People’s willingness to support action is somewhat less than their concern

Economists see Climate Change as a Market Failure

The cost of energy does not include “Externalities”— it shifts a significant portion of the costs to non-users.

- Healthcare cost of coal: $75 billion annually*.

- Disaster relief:

U.S. Taxpayers outspend insurers 3:1 on natural disasters (which will increase significantly with global warming)

October 2015 Flooding in South Carolina

* The Coal Study, Harvard Medical School, 2010.
(Does not include environmental cleanup)

How do we address the Market Failure?
There are four basic approaches

Technology	Good and essential, but long lead times
Subsidies	Expensive, and politically challenging
Regulation	Executive actions on fuel efficiency, power plants, methane, emissions limits
Taxes	"If you want less of something, tax it." *

*Arthur Pigou, 20th century economist

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Cap and Trade

- Total limit set on GHG emissions economy-wide, covering electric power generation, natural gas, and large manufacturers.
- Permits or “allowances” are distributed or auctioned to polluting entities: one allowance per ton of carbon dioxide, or CO_2 equivalent heat-trapping gases.
- The total amount of allowances will be equal to the cap. A company or utility may only emit as much carbon as it has allowances for.
- Each year, the cap is ratcheted down on a gradual and predictable schedule.
- Some companies will find it easy to reduce their pollution to match their number of permits; others may find it more difficult.
- Trading lets companies buy and sell allowances, leading to more cost-effective pollution cuts, and incentive to invest in cleaner technology.

Cap and Trade – Does it Work?

- Cap and Trade was initiated in several European countries in the 1990s. Since 2005 it has operated in 31 countries (all 28 EU countries plus Iceland, Liechtenstein and Norway)
  - Covers around 45% of the EU's GHG emissions (power gen., heavy industry, aviation)
  - Implemented in phases. Currently in Phase 3.
  - Emissions in covered sectors dropped 13% between 2005 & 2010 (9.2% overall)
  - GDP grew about 0.2% in same period. Cost Europe just 0.01 percent of GDP between 2005 through 2007
  - The EU handed out far too many pollution allowances between 2005 and 2007, which caused carbon prices to collapse, but later tightened the cap.
  - However, carbon process are still low and there is little incentive to invest in clean energy. There is the potential for fraud in carbon offsets.
- Cap and Trade program initiated in CA in 2011 as part of the state's compliance with AB32, the Global Warming Solutions Act of 2006
- Nine NE states participate in a joint C&T program
- China is in the process of implementing a nation-wide C&T program
- Does not address transportation

Carbon Pollution Pricing

- Economists see carbon pricing as the most cost-effective way to reduce GHG emissions. Tax something and people use less of it.
- There are many ways of structuring a carbon tax. Most proposals start off with an initial tax – say $15 per ton of CO_2 equivalent, then have annual increases for a period of time until carbon emissions decline sufficiently to limit the temperature rise to 1.5^{o}C.
- The main difference in the various carbon tax proposals is what to do with the money raised by the tax. There are real social justice issues with making something more expensive.
  - Reduce other taxes?
  - Subsidize clean energy alternatives until they are cost competitive?
  - Invest in clean energy research and development?
  - Pay for infrastructure improvements?
  - Give a distribution to all tax payers? All citizens?

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Carbon Pricing – Does it Work?

- A carbon tax was implemented in British Columbia in 2008. It started at $5/ton and rose to $30/ton.
  - Emissions have declined slightly
  - Fuel consumption has fallen by 17%, and 19% relative to the rest of Canada
  - The per capita GDP has grown slightly faster than the rest of Canada
  - It's popular because citizens get a tax credit
- In Sweden emissions declined 23% between 1990 and 2013, while GDP grew by 58% in the same period
- In Britain, a $25/ton carbon tax was implemented in 2013. Emissions are the lowest since 1890.
- Canada as a nation implemented a $15/ton tax in 2018 and is increasing it in increments to reach $38/ton in 2022

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The Energy Innovation and Carbon Dividend Act of 2019

- Introduced the House in January 2019. 32 Cosponsors
- Fee starts at $15/ton of CO_2e and increases by $10/yr. until GHG reduction targets are met.
- Revenue Neutral:
  - Money deposited in a Carbon Dividend Trust Fund.
  - All net revenue is returned to Americans in a monthly dividend.
  - All adults get one share. Children under 19 get a half share.
- Border Carbon Adjustment System:
  - Protects American business from unfair competition
  - Encourages other nations to adopt similar carbon pricing

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Projected Impacts *

- Jobs:
  - 2.1 million extra jobs in 10 years
  - 2.8 million extra jobs in 20 years. The fee adds over 1% to jobs.
- GDP:
  - GDP Increases $70-$85 billion annually after 5 years
  - Clean Energy is Cheaper than Carbon-based Energy
  - Cumulative GDP increase is $1.375 trillion in 20 years
- CO_2 emissions:
  - 40% below current levels in 12 years
  - 50% below 1990 levels in 20 years.
  - [Net Zero by 2050 is the target to keep under 1.5^{o} C]

* Source: Regional Economic Models, Inc. (REMI), 2014. REMI is a private econometric modeling firm used by the American Petroleum Inst. & labor unions

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And…there are other benefits.

- Health
  - 13,000 lives are saved annually after 10 years.
  - 227,000 American lives saved over 20 years.
- For most American families the dividend exceeds increased costs.
  - 10 yrs: Monthly dividend. Family of four. $288 ($3,500 per year)
  - 20 yrs: Monthly dividend. Family of four. $396 ($4,800 per year)
- Minimal Government Bureaucracy
  - Dept. of Energy sets the regulations
  - Treasury Dept. collects the money, puts it in a Trust Fund and hands it back out as a monthly dividend
  - Estimated cost of administration: 8% of receipts in years 1-5; 1.5% a year after that.
  - Could replace many of the existing subsidies & incentives

Carbon Dividend Supporters

THE WALL STREET JOURNAL.

THURSDAY, JANUARY 17, 2019

Original Co-Signatories Include (full list on reverse):

4 **Former Chairs of the Federal Reserve (All)**

27 **Nobel Laureate Economists**

15 **Former Chairs of the Council of Economic Advisers**

2 **Former Secretaries of the U.S. Department of Treasury**

Economists' Statement on Carbon Dividends

Global climate change is a serious problem calling for immediate national action. Guided by sound economic principles, we are united in the following policy recommendations.

I. A carbon tax offers the most cost-effective lever to reduce carbon emissions at the scale and speed that is necessary. By correcting a well-known market failure, a carbon tax will send a powerful price signal that harnesses the invisible hand of the marketplace to steer economic actors towards a low-carbon future.

Recent Climate Change Action

- The Energy Innovation and Carbon Dividend Act (HR 763) introduced in the House, 2019. 32 co-sponsors.
- Lots of talk about the Green New Deal
- Lots of pushback from the current administration
- Increased action at the state and local level
- Nevada passed a new RPS: 50% clean energy by 2030
- Other Nevada clean energy bills in progress
- NV Energy announces plan to add 1000 MW of solar
- Nevada becomes the 23rd state to join the US Climate Alliance, March 2019

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Nevada Opportunities

- Clean Energy Leader in production and technology
  - 32,000 Nevadans in all 17 counties work in clean energy
  - In 2018 clean energy jobs grew by about 8,000 (32%)
- Municipalities and Agencies can be proactive
  - Make climate change a core part of planning (not just adaptation)
  - Take advantage of GOE programs
  - Improve facility energy efficiency
  - Move to electric vehicles
  - Factor climate change into your designs
  - Talk to your legislators
  - Remember: It's going to cost a lot more later

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WHAT CAN I DO?

Exercise your political power!

- Meet, write and call your member of Congress
- Encourage others to do the same
- Create the political will for action

Exercise your personal power!

- Talk with your community
- Include science facts
- Reduce your carbon footprint

Join Citizens' Climate Lobby

- Over one hundred thousand supporters
- Hundreds of chapters

Citizens' Climate Lobby

Useful Links

- http://www.bloomberg.com/graphics/2015-whats-warming-the-world/
- https://www.edf.org/climate/climate-facts-dangers-and-what-you-can-do?
- http://climate.nasa.gov/ (good overview from NASA)
- http://www.ipcc.ch/ (Intergovernmental Panel on Climate Change)
- http://www.eia.gov/environment/emissions/ (US Energy Information Admn)
- https://www.noaa.gov/climate (many useful graphs and charts)
- http://www.skepticalscience.com/
- https://citizensclimatelobby.org/

Questions?

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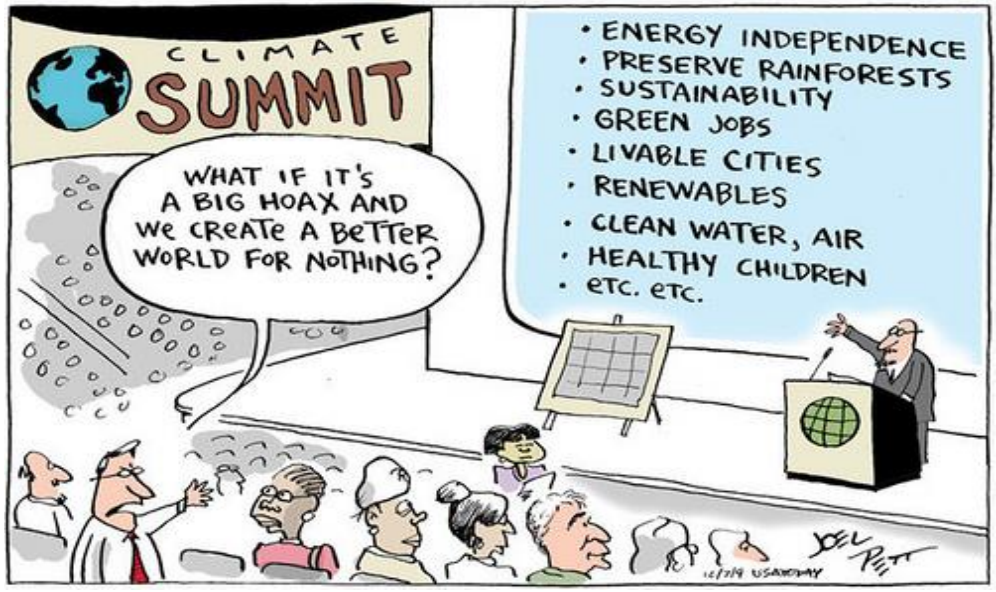
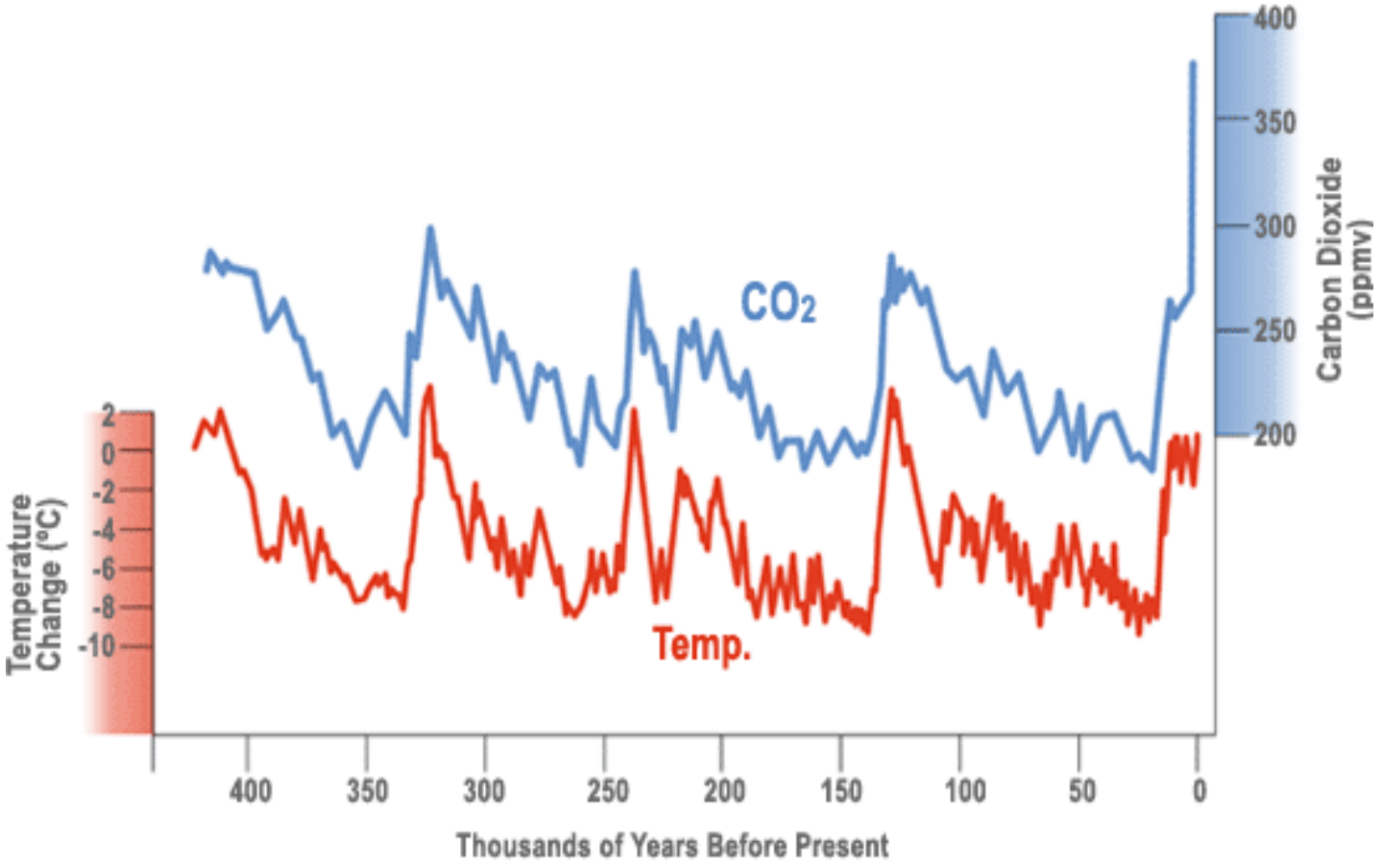


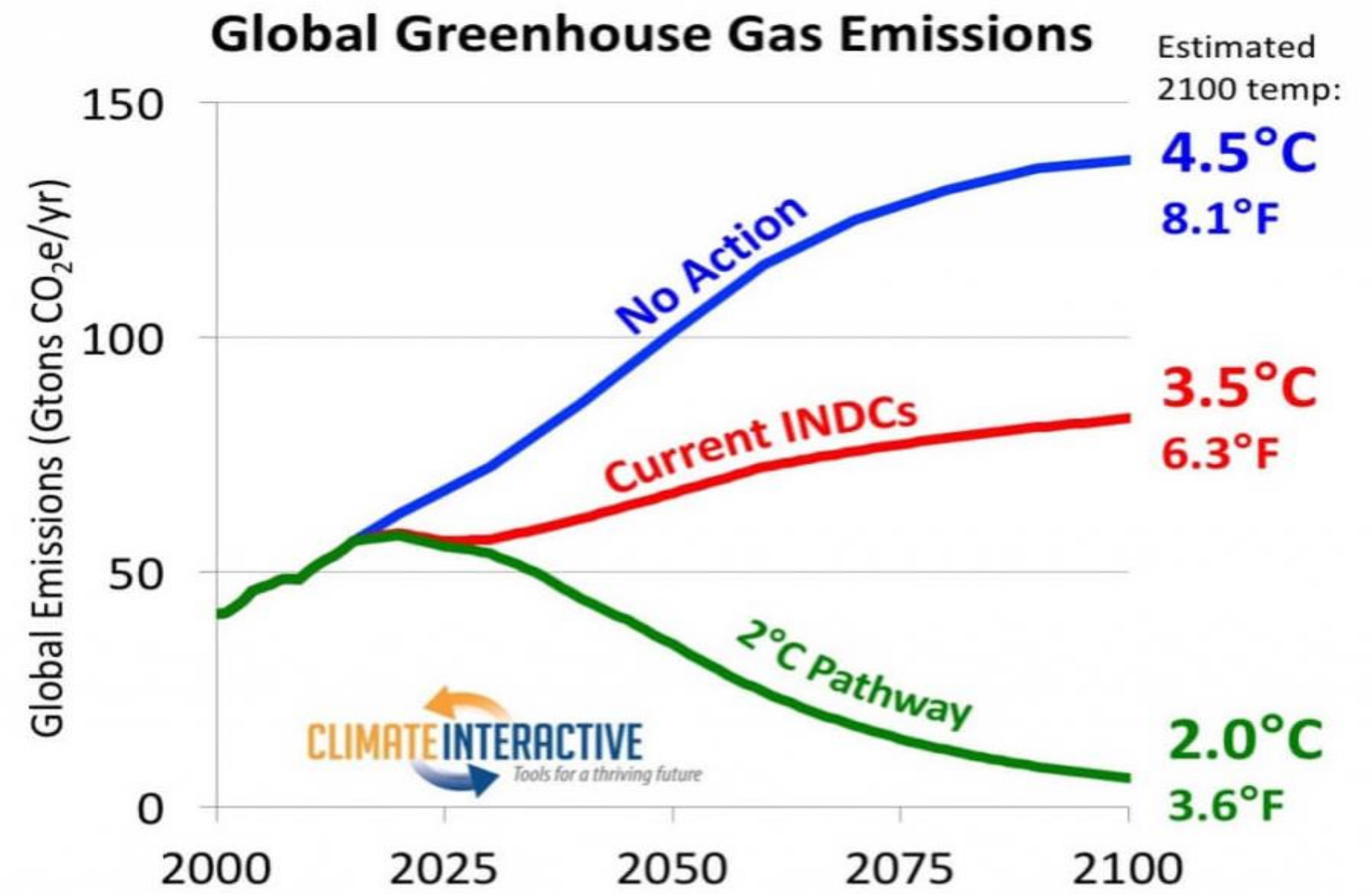
Climate Science Sceptics

"*Everyone is entitled to his own opinion but not this own facts*" Daniel Patrick Moynihan

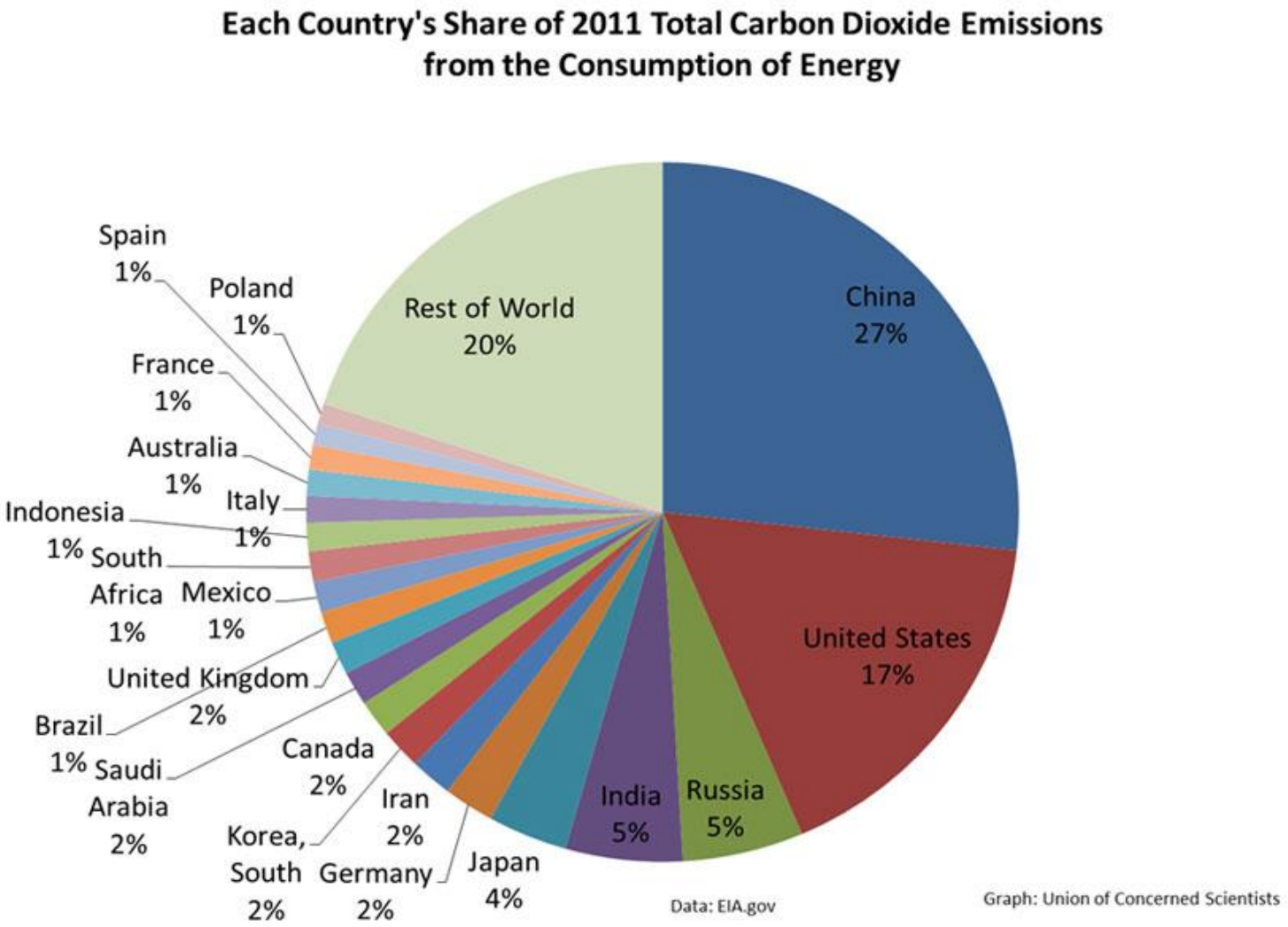
CO2 and Temperature, last 430,000 years



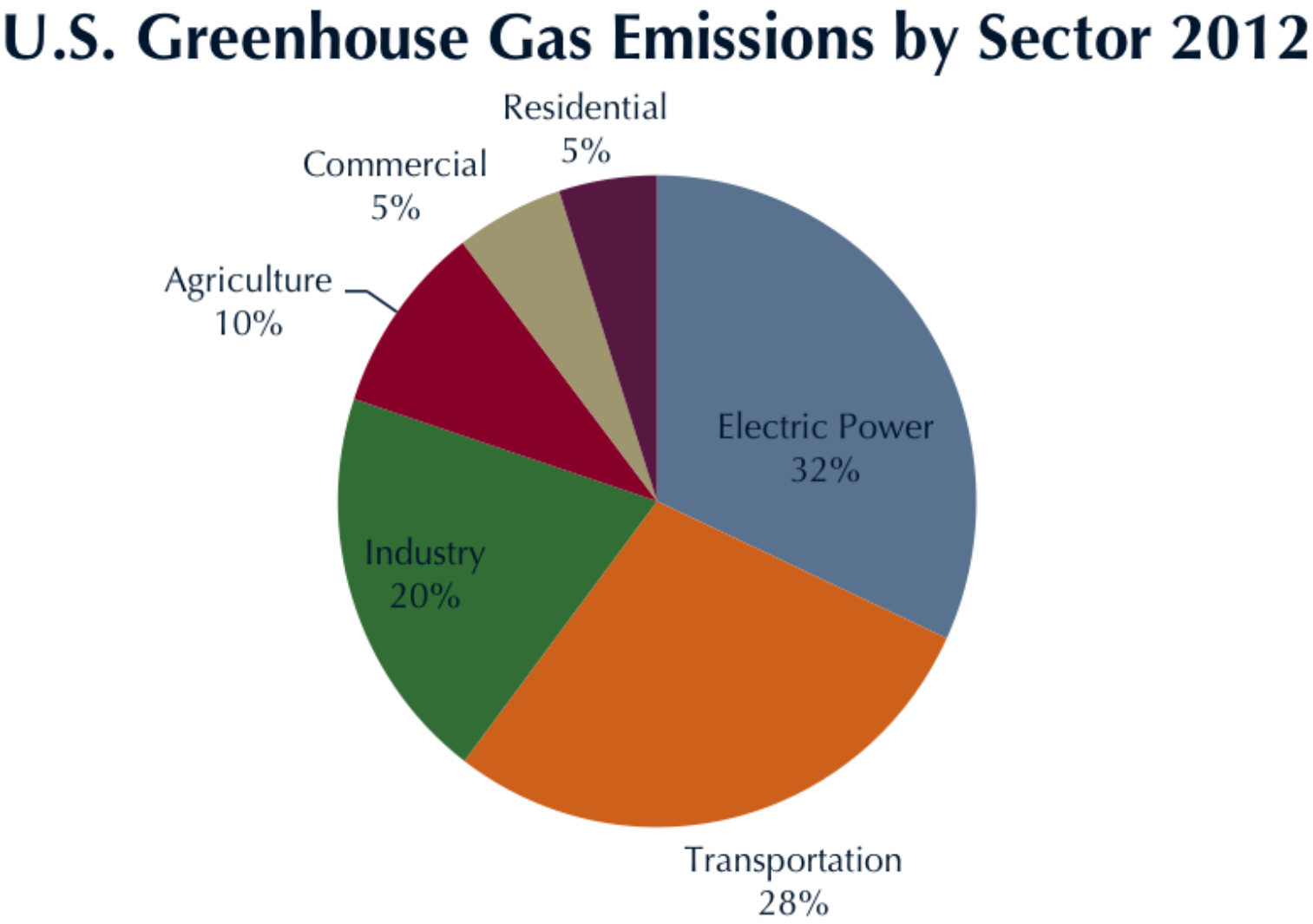
GHG Action and Temperature



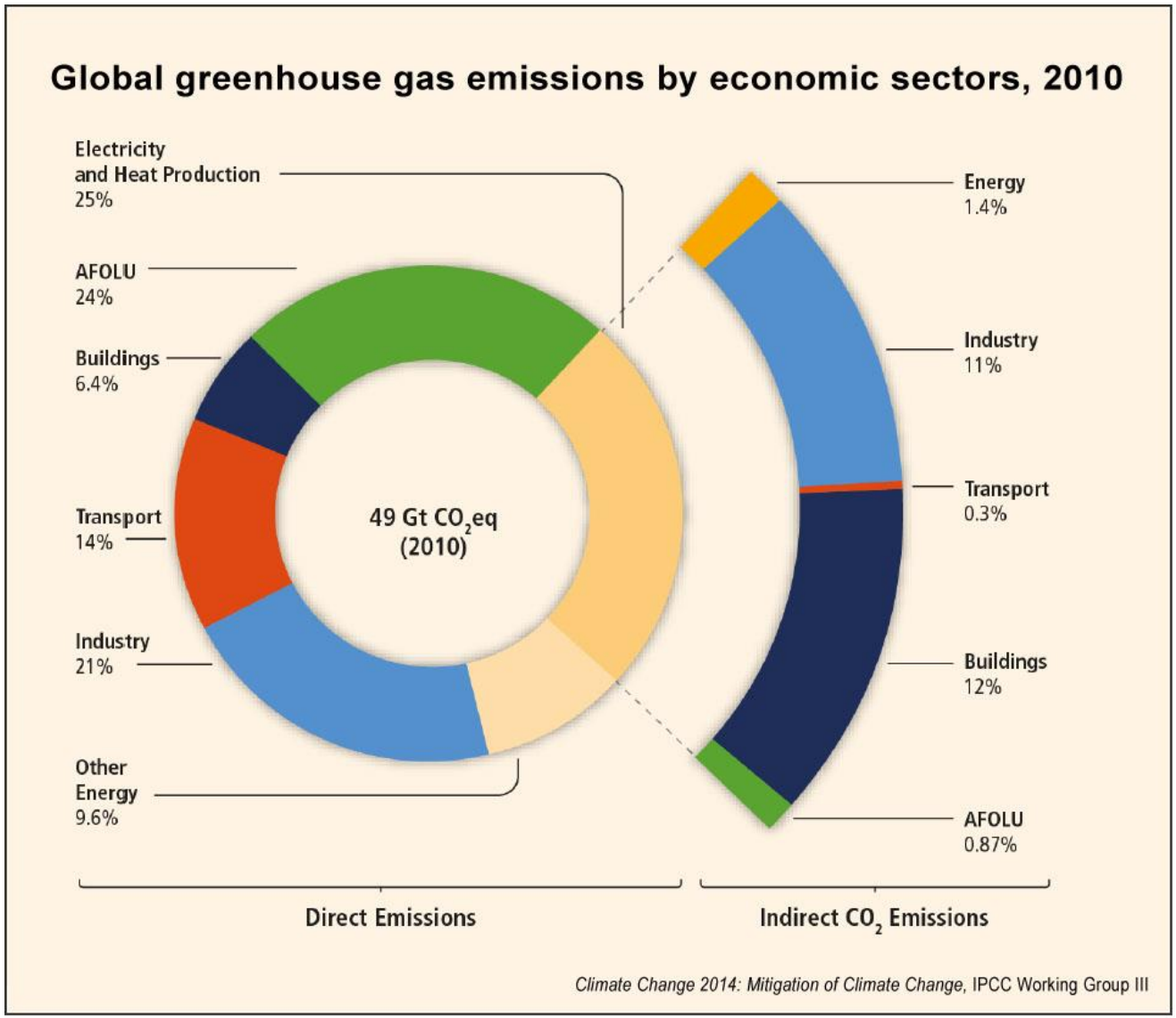
CO2 Emissions by Country



U.S. GHG Emissions by Sector

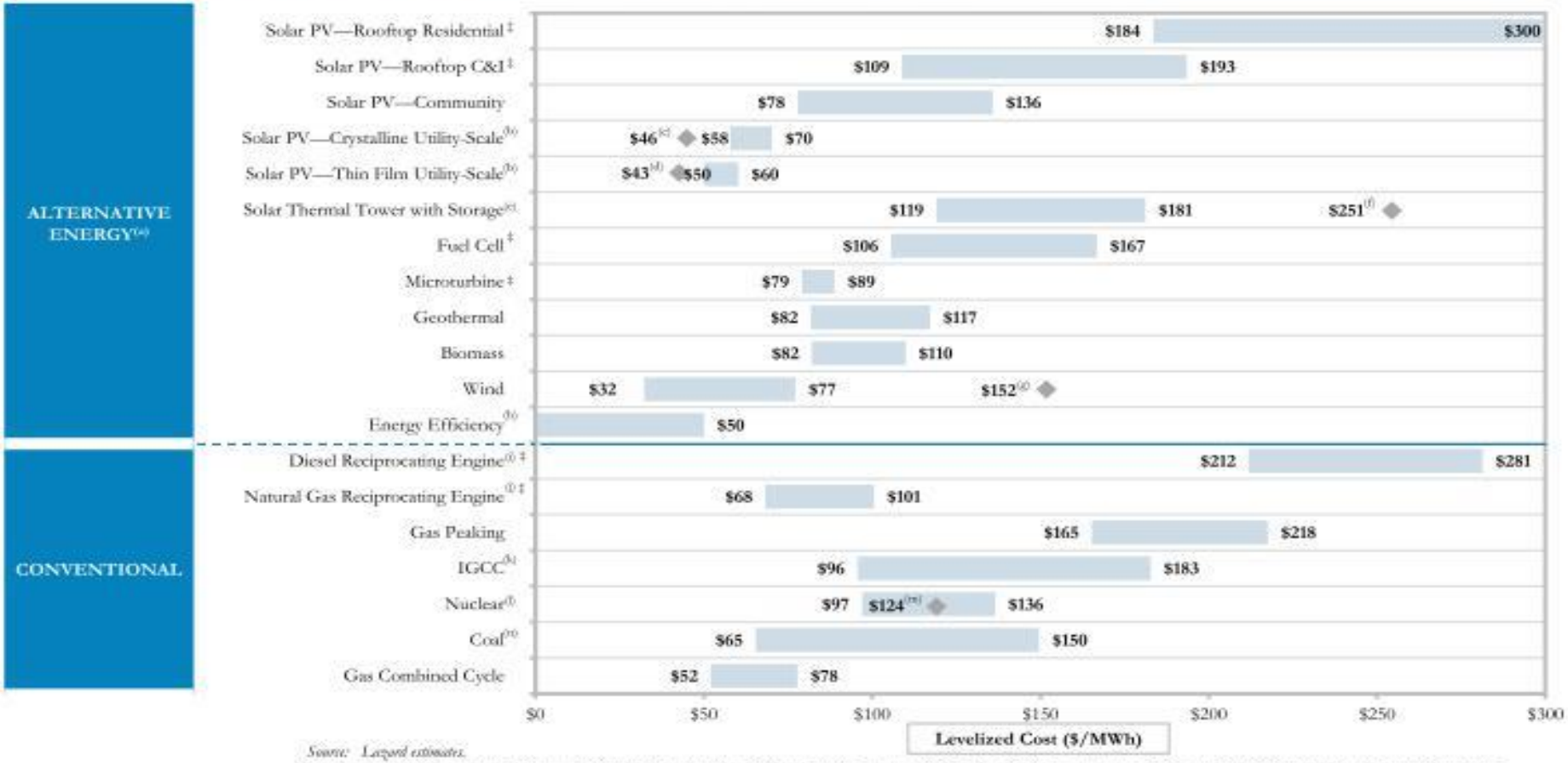


Global GHG Emissions by Sector



Unsubsidized Levelized Cost of Energy Comparison

Certain Alternative Energy generation technologies are cost-competitive with conventional generation technologies under some scenarios; such observation does not take into account potential social and environmental externalities (e.g., social costs of distributed generation, environmental consequences of certain conventional generation technologies, etc.) or reliability-related considerations (e.g., transmission and back-up generation costs associated with certain Alternative Energy technologies)

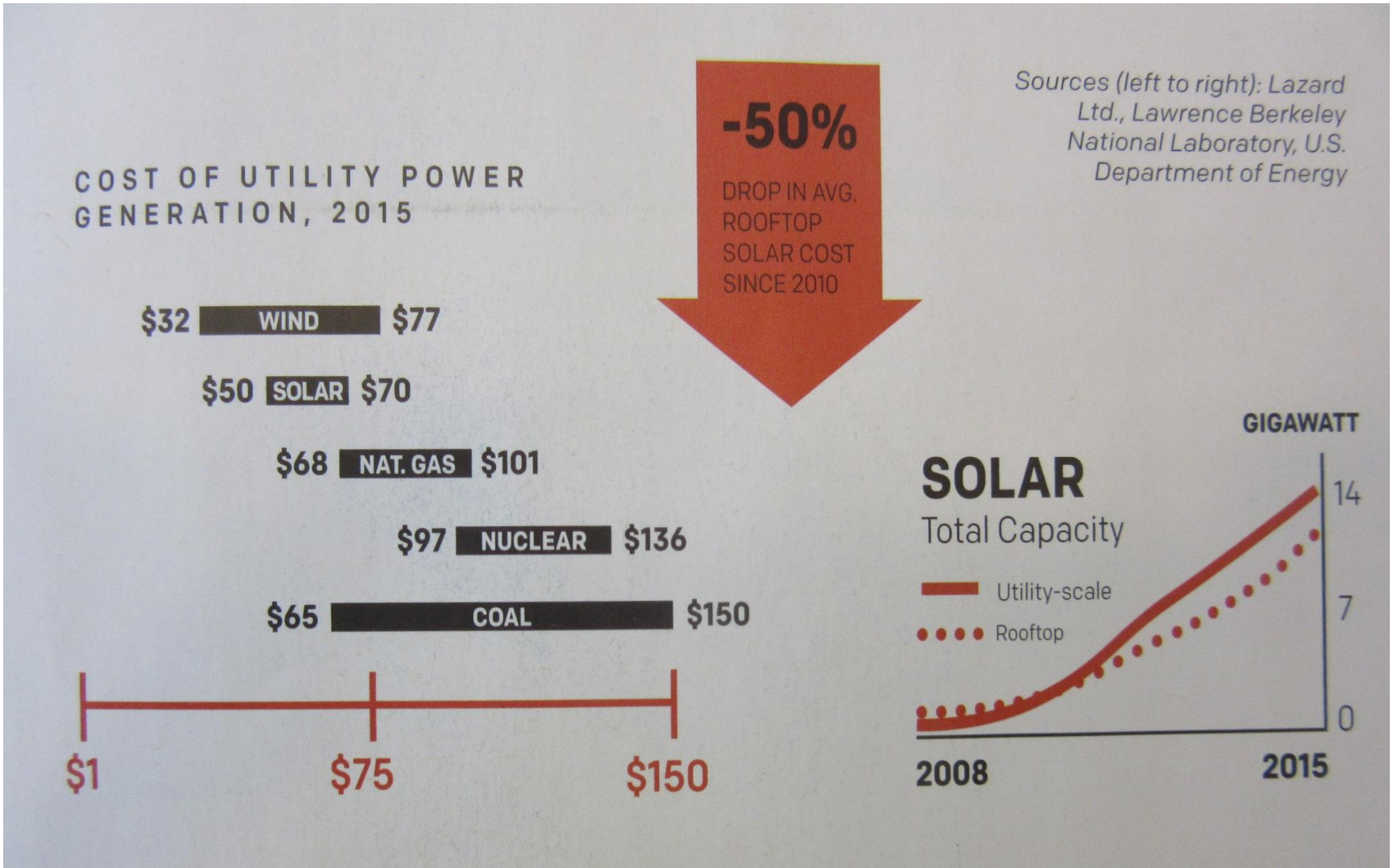


Source: Lazard estimates.

Note: Here and throughout this presentation, unless otherwise indicated, analysis assumes 60% debt at 8% interest rate and 40% equity at 12% cost for both conventional and Alternative Energy generation technologies. Assumes diesel price of ~$2.50 per gallon, Northern Appalachian bituminous coal price of ~$2.00 per MMBtu and a natural gas price of ~$3.50 per MMBtu for all applicable technologies other than Natural Gas Reciprocating Engine, which assumes ~$5.50 per MMBtu. Analysis does not reflect potential impact of evolving regulations/rules promulgated pursuant to the EPA's Clean Power Plan. **See following page for footnotes.**

‡ Denotes distributed generation technology.

Power Generation Costs & Capacity



Global Warming – the Basics

- **Greenhouse effect**: Glass allows the solar radiation to enter freely but blocks the infrared radiation emitted by the interior surfaces. This causes a rise in the interior temperature.

- **Carbon dioxide (CO_2),** water vapor, and trace amounts of some other gases such as methane and nitrogen oxides act like a blanket and keep the earth warm by blocking the heat radiated from the earth. The result is **global warming**.

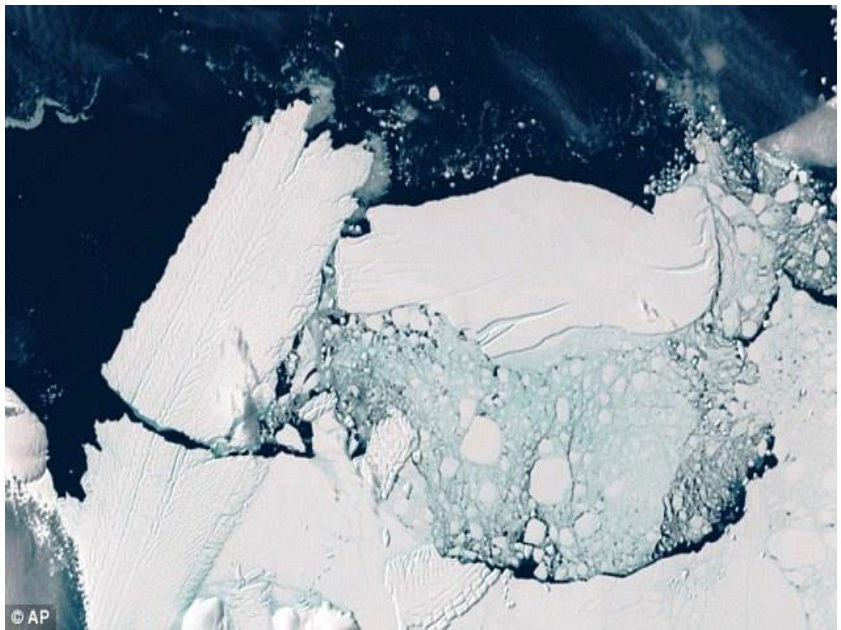
- These gases are called "**greenhouse gases**," (GHG) with CO_2 being the primary component.

- CO_2 is produced by the burning of fossil fuels such as **coal, oil, and natural gas**, as well as natural processes.

The Tipping Point Scenario

- The “Tipping Point” is when human actions are irrelevant. The earth’s physics and chemistry keep warming us in a feedback loop. (melting deep ocean clathrates, ice sheets, permafrost)
- When might we reach the Tipping Point? – We don’t know exactly
  - We’ve already warmed almost 1° C (1.8°F)
    - We now know humans can’t stop the West Antarctic Ice Sheet from melting. WAIS will melt. Sea levels will rise 1 to 4 feet.
    - Almost half the “permanent” Arctic ice cap has melted.
- At 2°C (3.6°F), the tipping point scenario is possible, but not likely
- At 4-7°C (7-12°F), the tipping point scenario is almost a certainty

2°C is considered the maximum rise before dangerous warming occurs [1]



1. Intergovernmental Panel on Climate Change (IPCC)

Weather, Global Warming, and Climate Change

Weather: Atmospheric conditions that occur locally over short periods of time—from minutes to hours or days. Familiar examples include rain, snow, clouds, winds, floods or thunderstorms. Weather is local and short-term.

Climate: Long-term regional or even global average of temperature, humidity and rainfall patterns over seasons, years or decades. Climate is global and long-term.

"Climate is what you expect: Weather is what you get." - Mark Twain

Global Warming: Global warming refers to the upward temperature trend across the entire Earth since the early 20th century, and most notably since the late 1970s, due to the increase in fossil fuel emissions since the industrial revolution.

Climate Change: Climate change refers to a broad range of global phenomena created predominantly by burning fossil fuels, which add heat-trapping gases to Earth's atmosphere. These phenomena include the increased temperature trends described by global warming, but also encompass changes such as sea level rise; ice mass loss in Greenland, Antarctica, the Arctic and mountain glaciers worldwide; shifts in flower/plant blooming; and extreme weather events.

Source: http://climate.nasa.gov/resources/global-warming/

“Risky Business” Study

- The three billionaires
  - Hank Paulson, Treasury Secretary, George W. Bush
  - Michael Bloomberg, ex-NY City mayor
  - Tom Steyer, ex-hedge-fund manager

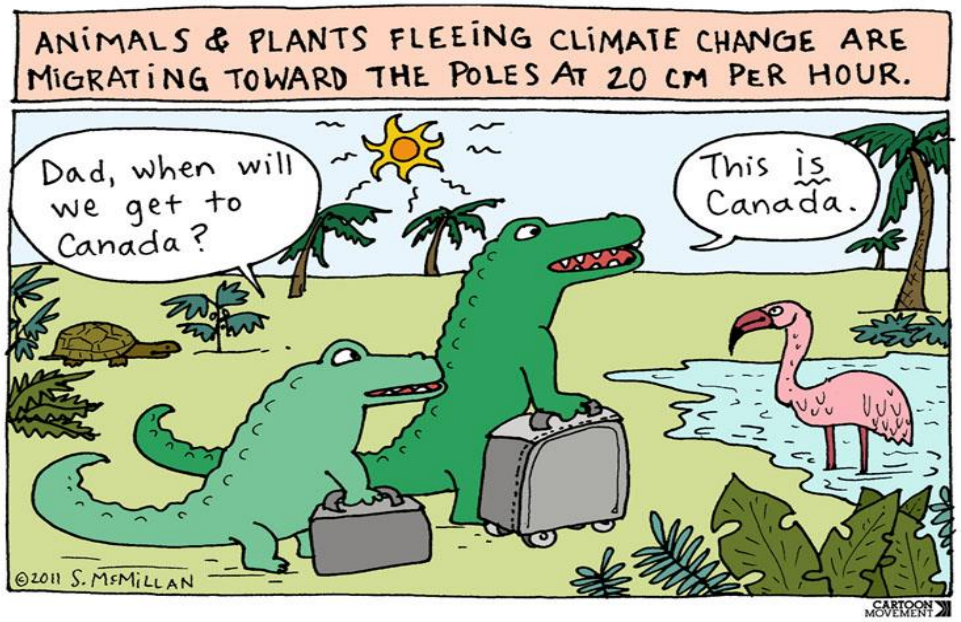
Instead of asking, what’s the cost to business of government ACTION on climate change, the study asks, what’s the cost to business, if government does NOTHING about climate change? They focused on sea level rise and agriculture.

- $66B to $106B coastal property below sea level by 2050; $238B to $507B by 2100.
- Ave. annual losses from hurricanes grows by up to $42B by 2100
- Lower crop yields in SE, lower GP and MW; increased yields in upper GP and northern states.

American Climate Prospectus, Economic Risks in the United States, Risky Business Project, 2014

Citi Global Perspectives & Solutions Study

- Global study on costs of Inaction vs. Action over next 25 years
- Considered increased energy use in developing nations
- Inaction Scenario:
  - Total Energy cost: $192 trillion
  - 0.7% to 2.5% negative impact on GDP (1.5% to 5% after 2060)
  - Major environmental and economic impacts for more than a century
- Action Scenario:
  - Total Energy cost: $190 trillion
  - ROI of 1% to 4% in 2021, rising to 3% to10% by 2035



Citi – Citigroup "*Why a Low Carbon Future Doesn't have to Cost the Earth"*, August 2015

Who's not on Board?

- The current administration
- Coal companies and their political supporters
  - The inevitable decline in coal production will be a major economic impact in some states
- Major oil & gas companies send mixed messages:
  - In May 2015, six oil companies wrote to the UN to argue that "a price on carbon should be a key element" of inter-governmental action to address climate change.
  - Major oil companies have already factored in an $80/ton carbon fee in their long term strategic planning.
  - BUT – behind the scenes they work to delay any action on climate change
- They know it is coming eventually – and they want some certainty for planning