



Greenhouse Gas and Climate Change Impact Analysis



Sacramento Metropolitan Air Quality
Management District Workshop
April 20, 2009
9 AM- 4 PM



Welcome!

Tim Taylor, Division Manager
Jeane Berry Borkenhagen
ICF Jones & Stokes

- Logistics
- Introductions
- District remarks
- Agenda

AGENDA

- Greenhouse Gas and Climate Change Basics
- Regulatory Framework
- GHG Quantification and Tools
- **Lunch & Robert Christopherson**
- Project GHG analysis
- Threshold and Impact Analysis



Unit 1 Introduction to Greenhouse Gas and Climate Change Impact Assessment

Tony Held, Ph.D.
ICF Jones & Stokes

Presented at the SMAQMD Climate Change Workshop
April 20, 2009

Science of Climate Change – An Overview

- Most people have varying Climate Change (CC) backgrounds
- Purpose of this presentation is to provide a common vocabulary and backdrop for the ensuing policy discussions

A Show of Hands – A Straw Poll

- CC a hoax and/or overstated?
- CC is not due to humans?
- You have seen a documentary about a PowerPoint presentation?



The Changing “Climate” for Climate Change

- “It is the sense of the scientific community that carbon dioxide from unrestrained combustion of fossil fuels potentially is the most important environmental issue facing mankind”
- Source: Department of Energy
- April 2, 1979

Climate Change – The Basics

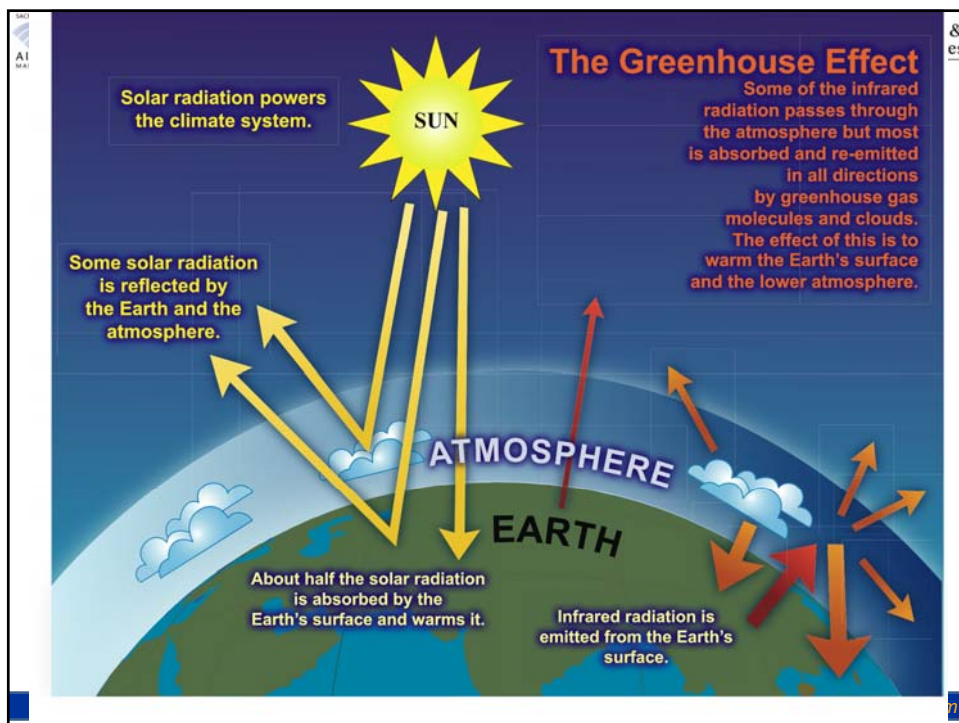
- Key definitions
 - Climate change
 - Global warming
 - Greenhouse effect
 - Greenhouse gases (GHG)
 - IPCC
 - Feedback loops
 - Tipping Point
 - Greenhouse Gas Inventories

Climate Change

- Global Warming – An increase in GHG emissions leads to an increase in average global temperature
- Climate Change – as a consequence of global warming, our climate is expected to change due to changes in weather patterns, average sea level, ocean acidification, changes chemical reaction rates, changes precipitation rates, etc.

Greenhouse Effect is due to Greenhouse Gasses

- Without the effect, our planet would not be inhabitable by humans
- GHG gasses are those that absorb infrared radiation in the spectrum emitted by our Earth
- GHG gasses can be emitted by natural processes (e.g. volcanoes) or from anthropogenic sources (those due to man)



Climate Change Consequences

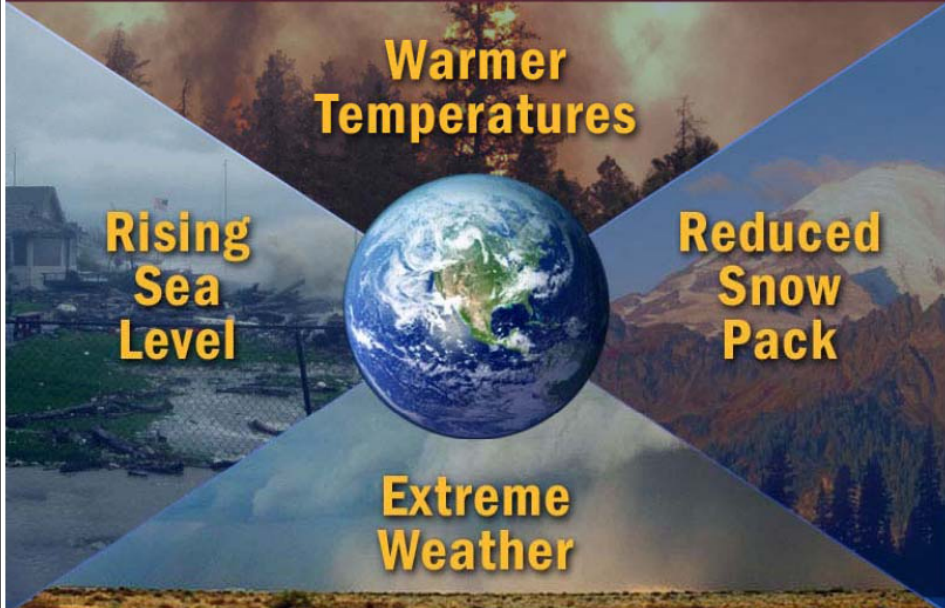
- Warmer Temperatures
- Drought and Wildfire
- More intense rainstorms
- Deadly heat waves & spread of disease
- More powerful hurricanes
- Melting glaciers, early ice thaw
- Sea-level rise
- Species extinction
- Mass human migration – political turmoil

Effect of Climate Change on California

Emissions Scenarios*	Summary of Projected Global Warming Impact, 2070 to 2099 (as compared with 1961–1990)	Statewide Temperature Rise
Higher Emissions: Rapid, fossil-fuel intensive growth	<ul style="list-style-type: none"> • 90% loss in Sierra snowpack • 22–30 inches of sea level rise • 3–4 times as many heat wave days in major urban centers • 4–6 times as many heat-related deaths for major urban centers • 2.5 times more critically dry years • 20% increase in energy demand 	Higher Warming Range: 8–10.5°F
Medium-High Emissions: Primarily fossil-fuel dependent growth with improvements in energy efficiency	<ul style="list-style-type: none"> • 70–80% loss in Sierra snowpack • 14–22 inches of sea level rise • 2.5–4 times as many heat wave days in major urban centers • 2–6 times as many heat-related deaths for major urban centers • 75–85% increase in days conducive to ozone formation • 2–2.5 times more critically dry years • 10% increase in electricity demand • 30% decrease in forest yields (pine) • 55% increase in the expected risk of large wildfires 	Medium Warming Range: 5.5–8°F
Lower Emissions: Less fossil-fuel dependent growth with heavy investment in cleaner technologies	<ul style="list-style-type: none"> • 30–60% loss in Sierra snowpack • 6–14 inches of sea level rise • 2–2.5 times as many heat wave days in major urban centers • 2–3 times as many heat-related deaths for major urban centers • 25–35% increase in days conducive to ozone formation • Up to 1.5 times more critically dry years • 3–6 % increase in electricity demand • 7–14% decrease in forest yields (pine) • 10–35% increase in the risk of large wildfires 	Lower Warming Range: 3.0–5.5°F

*Emissions scenarios defined by the Intergovernmental Panel on Climate Change.
Source: Curry, D., A. Lauen, M. Hazenmann, G. Frisso, and B. Croes, 2006. *Climate Change Scenario for California: an Overview*. California Climate Change Center report.

Climate Change Effects in Washington




Warmer Temperatures

Rising Sea Level

Reduced Snow Pack

Extreme Weather

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California with Warmer Temperatures

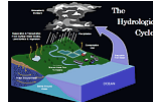
 <p>Milder winters hotter summers</p>	 <p>Salmon declines</p>
 <p>Decline in water supplies</p>	 <p>Native plant & animal populations decline</p>
 <p>Changing growing seasons</p>	 <p>Wetlands decline</p>
 <p>More human disease</p>	 <p>More pests in forests & crops</p>

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California with Reduced Snowpack



Reduced snow pack



Lower groundwater tables



Receding glaciers



Hydropower loss



Lower summer stream flows



Recreational loss



Salmon declines



More water pollution

California with Rising Sea Level



Rising sea level



Seawater intrusion in wells



Coastal community flooding



Lost wetlands & estuaries



Coastal erosion & landslides

California with Extreme Weather



Extreme weather



More stormwater = more pollution



Droughts



Earlier river runoff



Floods more extreme & often



Changing growing season

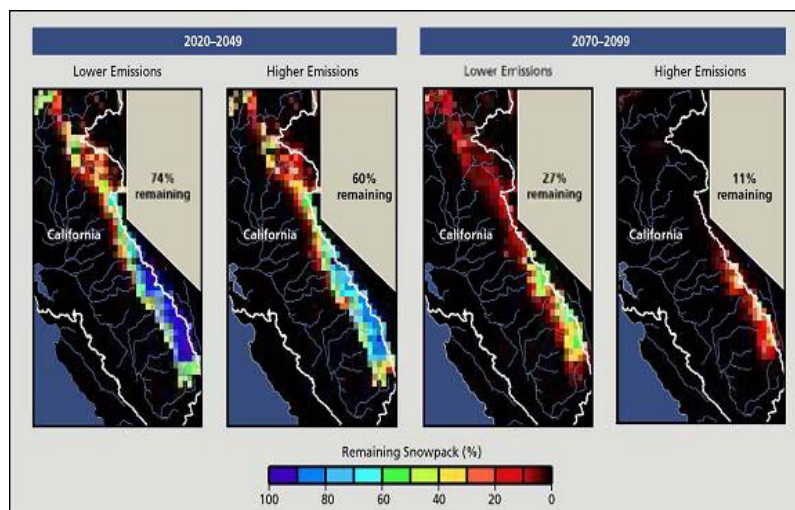


More Landslides



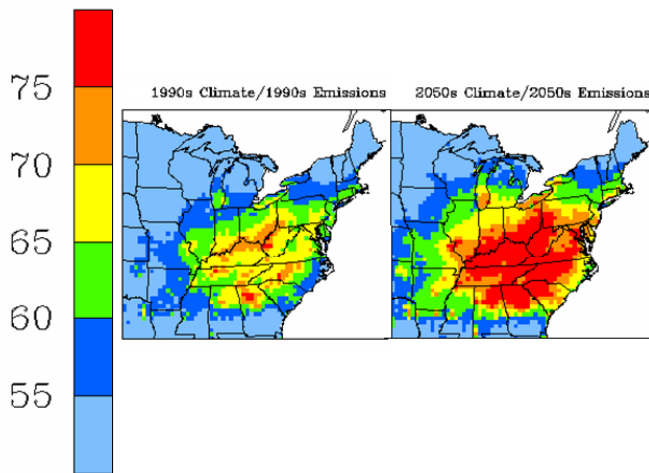
Multiple emergency response needs

California Snowpack Will Shrink

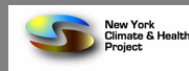


Linkage Between Climate and Air Quality

1 hour ozone (ppb)



Impact on
Ozone Formation
of
Changes in Climate
vs.
Changes in
Emissions



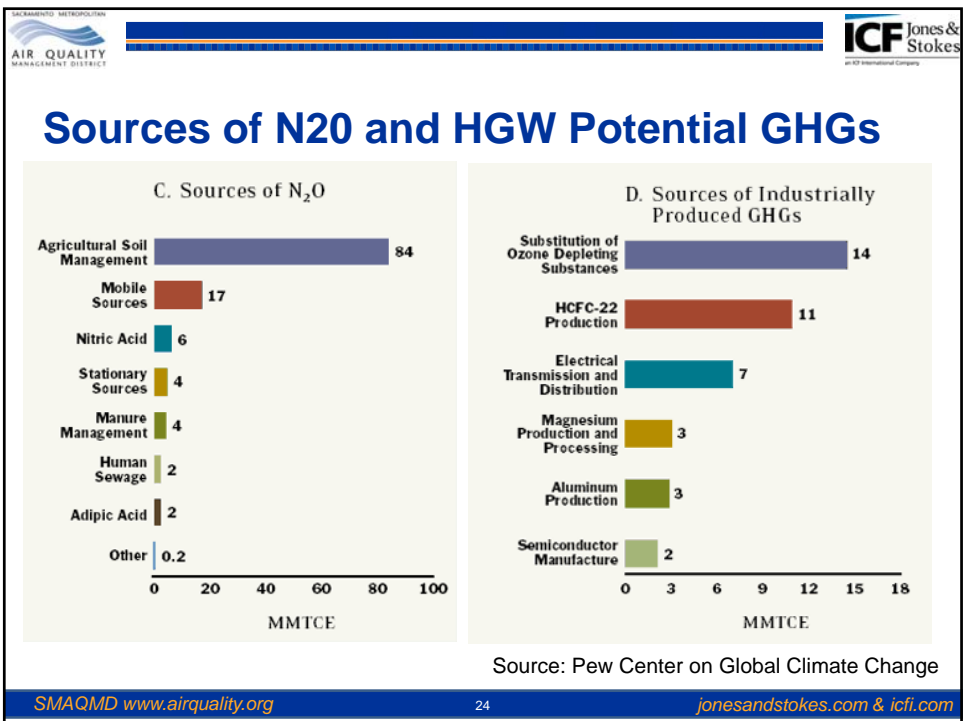
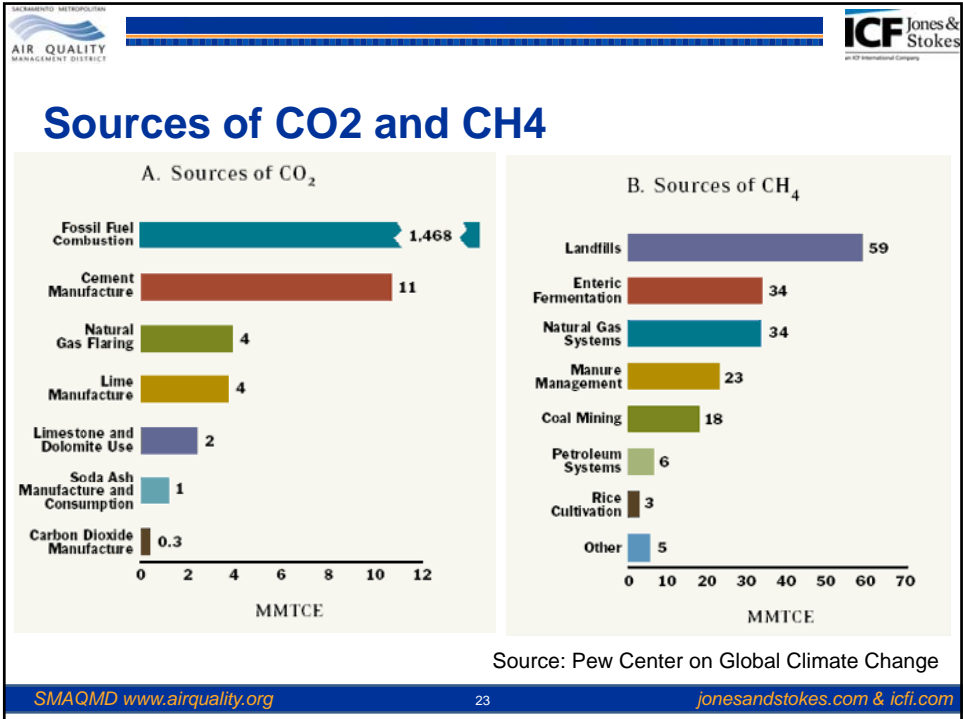
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The Most Important GHGs

- Carbon Dioxide (CO₂)
- Methane (CH₄)
- Nitrous Oxide (N₂O)
- Hydrofluorocarbons (HFC)
- Perfluorocarbons (PFC)
- Sulfur hexafluoride (SF₆)
- Water (H₂O)
- Ozone (O₃)

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Describing the Complex Soup of GHGs

- Each GHG has different chemical reactivity & lifetimes
- Commonly combine all GHG emissions into the equivalent emissions of carbon dioxide (CO_{2E})
- Normalization process requires the specification of the Global Warming Potential (GWP) of each gas and the evaluation timeframe (use 100 years in general)

Global Warming Potentials

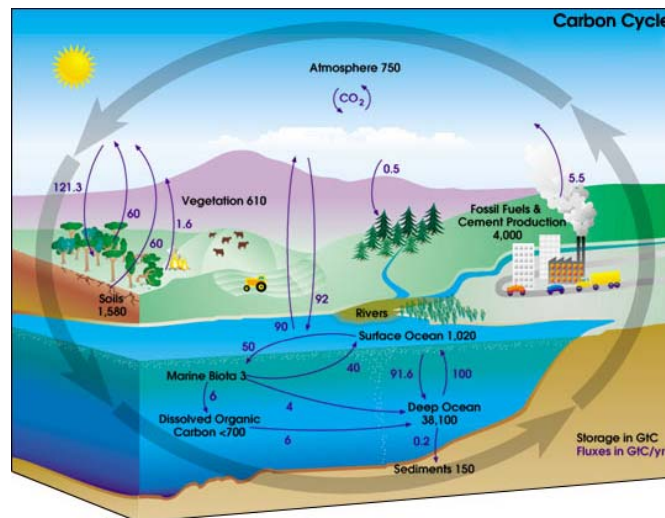
GWP values and lifetimes from IPCC TAR

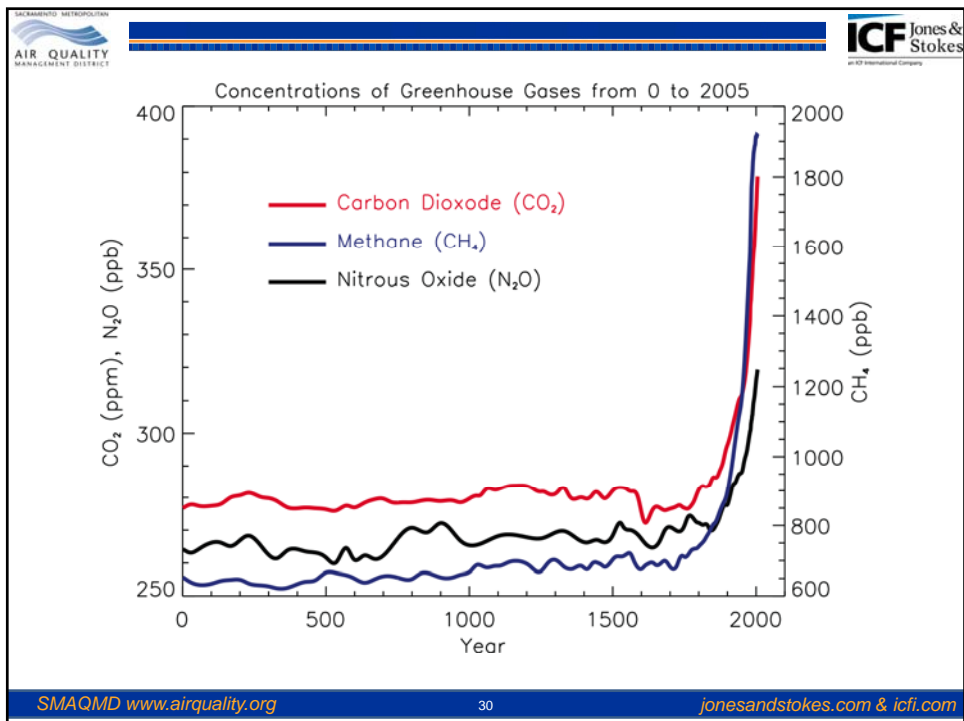
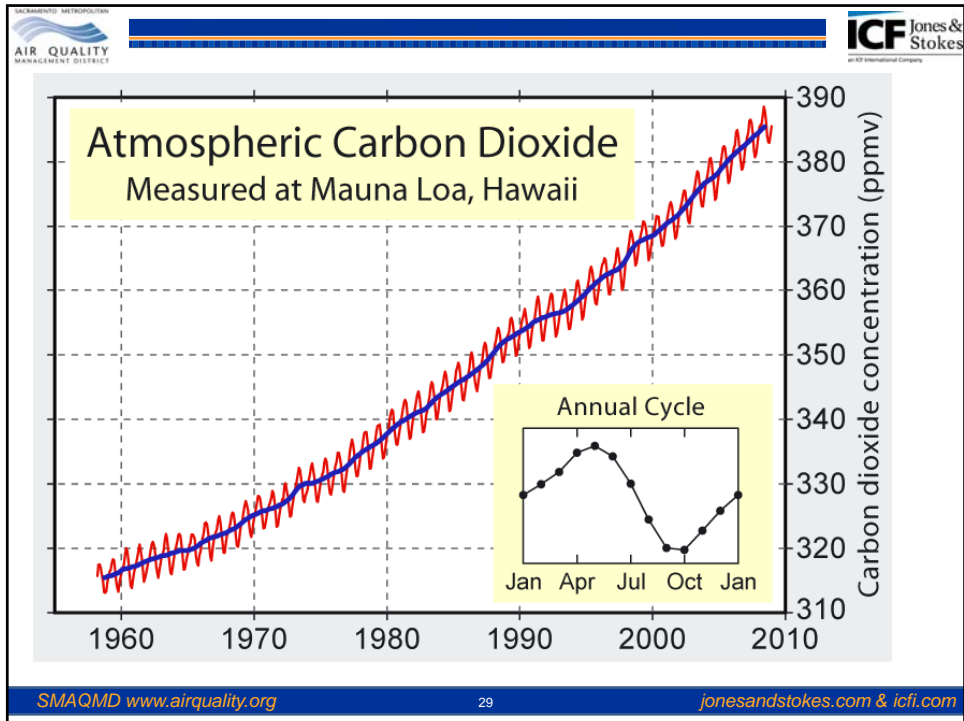
Gas	Lifetime (years)	GWP Time horizon		
		20 years	100 years	500 year
<u>Methane</u>	12	62	23	7
<u>Nitrous oxide</u>	114	275	296	156
<u>HFC -134a (hydrofluorocarbon)</u>	13.8	3,300	1300	400
<u>HFC -23 (hydrofluorocarbon)</u>	260	9,400	12,000	10,000
<u>sulfur hexafluoride</u>	3,200	15,100	22,200	32,400
Carbon Dioxide	50-200	1	1	1

Carbon Equivalent/ CO_{2E} – Units

- Inventories are based on annual emissions
- State GHG inventories are in MMT/year (million metric tons of CO_{2E}) (1 metric ton=1000 kg)
- 1 MMT = ~ 215,000 passenger cars
- 1 car at 20 miles/gal @ 10,000 miles/year = ~5 tons CO_{2E} /year

Carbon Cycle – Biogenic and Anthropogenic

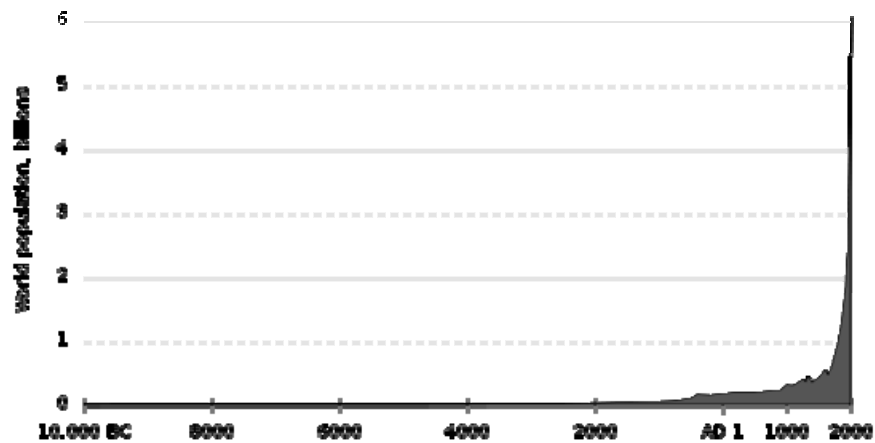




Temperature are Hitting Historic Highs

- 10 hottest years on record have occurred in the last 15 years
- 2007 data is not in yet – but it is project to be the hottest year on record
- Official hottest year on record – 2006
- Previous hottest year on record – 2005

World Population (Post Cylon Era)



Intergovernmental Panel on Climate Change (IPCC)

- IPCC is the scientific body tasked to evaluate the risk of climate change caused by human activity.
- Created in 1988 by two UN organizations
 - World Meteorological Organization (WMO) & the
 - United Nations Environment Programme (UNEP)
- Does not carry out research or monitoring, rather it distills peer reviewed literature on CC and periodically creates special reports
- Widely considered the authoritative body on CC
- Creates summaries for policymakers and scientists

IPCC Report Release Dates

- 1990 – First Assessment
 - 1992 – Supplementary Assessment
- 1995 Second Assessment Report (SAR)
- 2001 – Third Assessment Report (TAR)
- 2007 – Fourth Assessment Report (AR4)

IPCC 2007 Findings

- Warming of the climate system is unequivocal.
- The probability that this is caused by natural climatic processes alone is less than 5%.
- World temperatures could rise by between 1.1 and 6.4 °C (2.0 and 11.5 °F) during the 21st century (table 3) and that:
- Sea levels will probably rise by 18 to 59 cm (7.08 to 23.22 in)

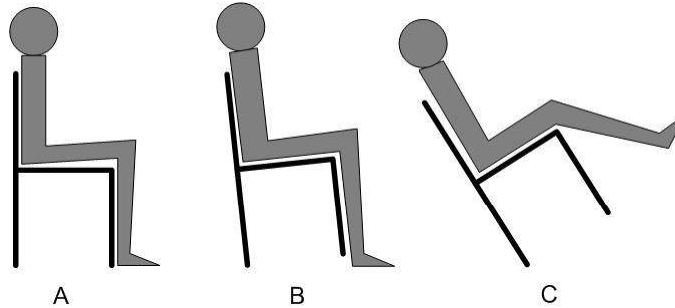
Feedback loops

- Feedback loop – output of process is fed back into the input. Can be negative or positive.
- Negative feedback is self regulating
 - more heat -> more cloud cover
- Positive feedback can go out of control
 - Ice melting will reduce reflectivity of earth increasing

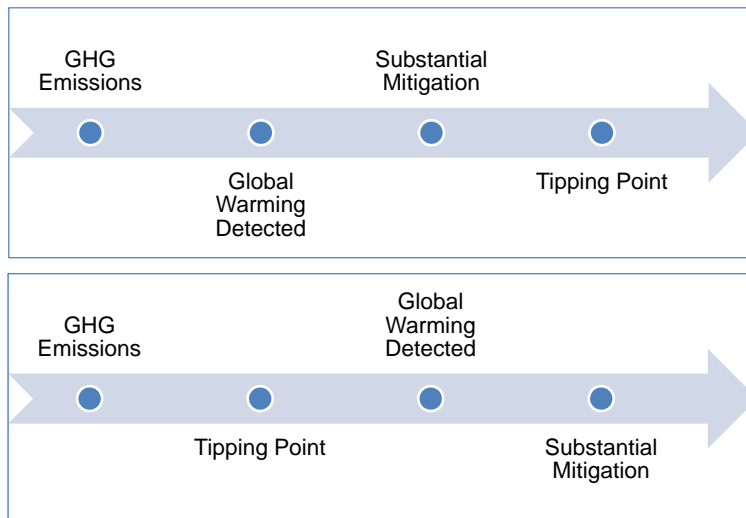


Tipping Points

- Tipping Point - the levels at which the momentum for change becomes unstoppable



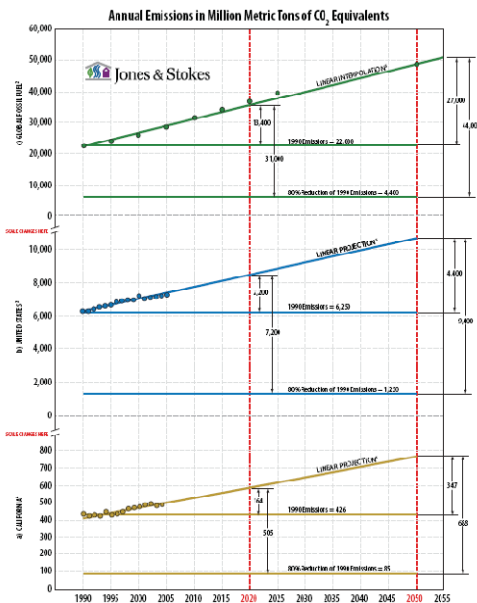
Tipping Points Scenarios



Stabilization Goal

- The scientific community is not envisioning a future without climate change
- In fact, almost all predictions and policy goals anticipate some climate changes as a consequence of GHG emissions
- The current goal is to have global temperatures raise by less than 2 degrees Celsius (4⁰ F) to avoid the catastrophic consequences of climate change
- It is currently thought that the industrialized countries will have to reduce emissions 80% below their 1990 to meet the stabilization goal.

CA, US, & Global GHG Projections



2020 and 2050 milestones
If CA meets goals but rest of
the world is business-as-usual

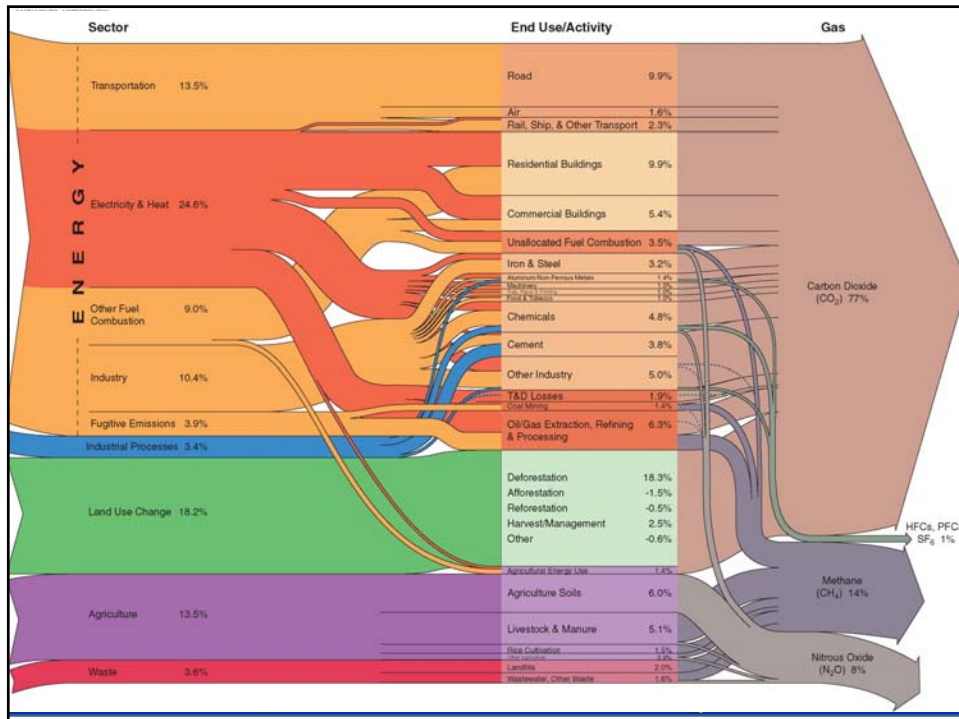
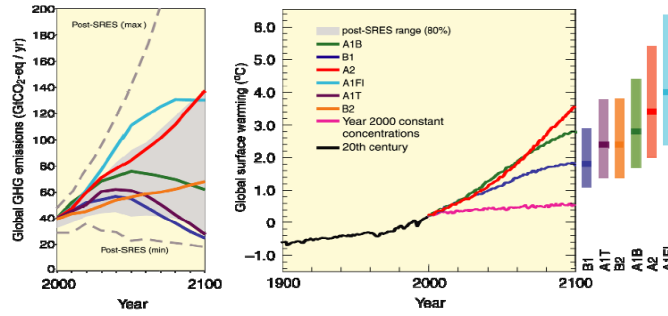
2020 World Up 13,000 MMT
2050 World Up 26,000 MMT

2020 U.S. Up 2,000 MMT
2050 U.S. Up 4,000 MMT

2020 CA Down 164 MMT
2050 CA Down 347 MMT

Uncertainty in Future Predictions

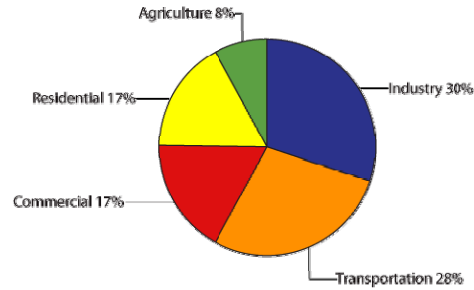
Scenarios for GHG emissions from 2000 to 2100 (In the absence of additional climate policies) and projections of surface temperatures



U.S. GHG Inventory

Greenhouse Gas Emissions by Sector

United States, 2004

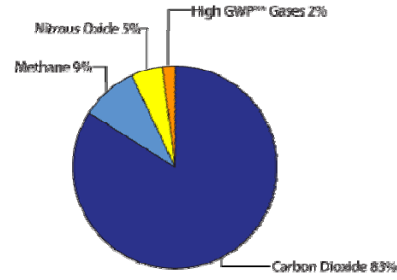


Total Emissions* = 7,074 MMT CO₂E

* Net Emissions (Sources + Sinks) = 6,204 MMT CO₂E
 ** High GWP Gases include: HFCs, PFCs, and SF₆
 Data expressed in Million Metric Tons of Carbon Dioxide Equivalents (MMT CO₂E)
 Source: US EPA Inventory of Greenhouse Gas Emissions and Sinks, 2006.

Greenhouse Gas Emissions

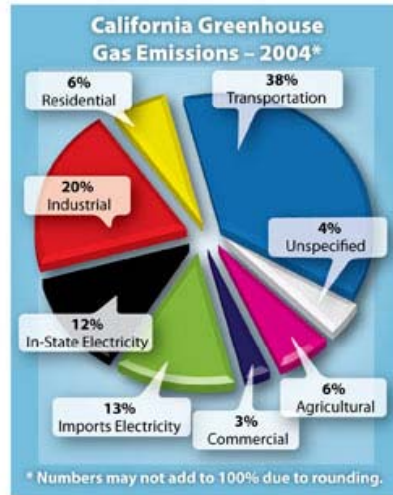
United States, 2004



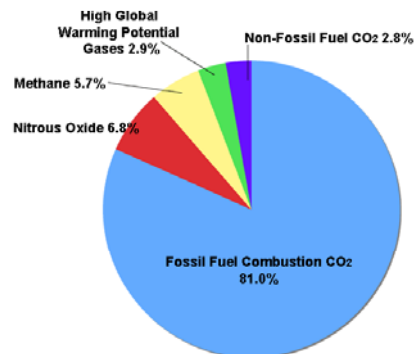
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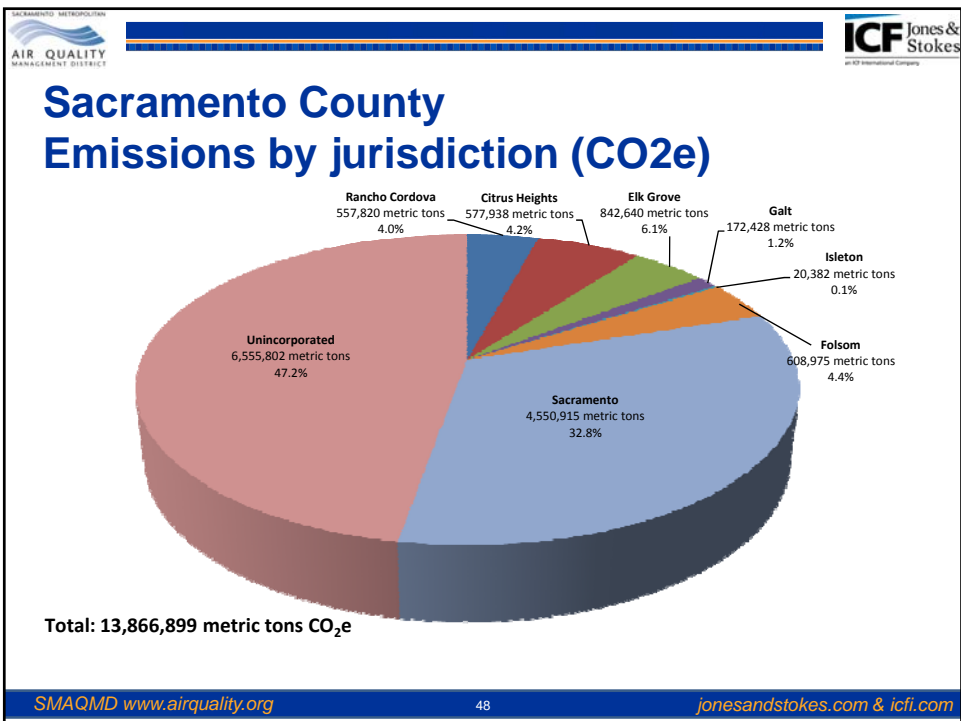
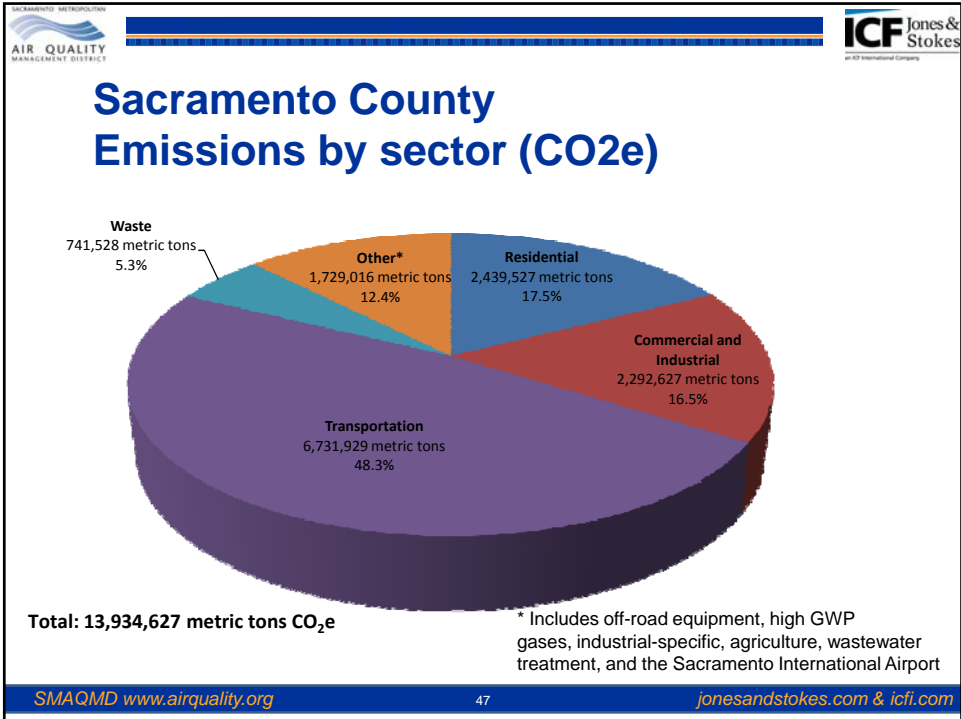
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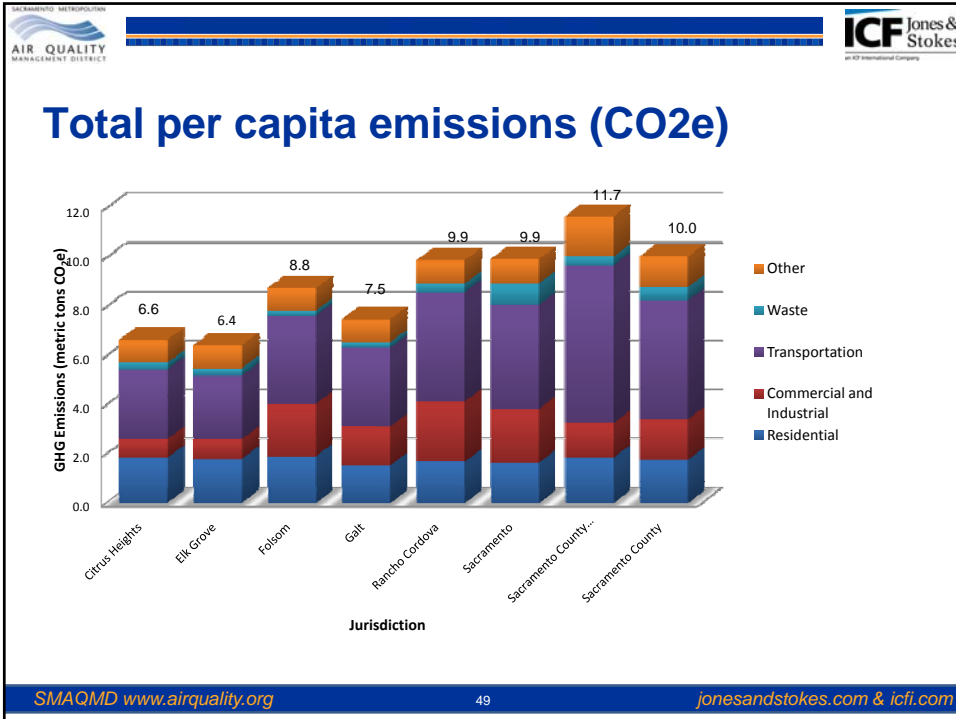
California GHG Inventory



California Greenhouse Gas
Composition by Type of Gas in 2004
(includes electricity imports and includes international bunker fuels)







What is the point of climate change policy?

- Perform a GHG inventory because they create interesting graphics?
- Create an inventory to avoid a AG lawsuit
- Perform a GHG inventory to allow decision makers to make the best and most cost effective strategies to help mitigate a global catastrophe?

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Always Remember

- **An inventory for the sake of an inventory is not nearly as useful as an inventory created from the outset help craft a GHG reduction plan!**