Climate Change is Here:
Tipping Points & Rays of Hope

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The Scientific Consensus

1300 Authors; 1100 Reviewers
Unanimously adopted by 100+ nations (including U.S.)
Federal Government

“By increasing the levels of greenhouse gases in the atmosphere, human activities are strengthening Earth's natural greenhouse effect.”

- U.S. Environmental Protection Agency
Local Governments

The mayors of more than 200 cities in 38 states have signed the “U.S. Mayors Climate Protection Agreement,” urging Congress to pass federal climate legislation and pledging to meet or better Kyoto targets in their own communities.
The Business World

In a survey completed by 354 of the Financial Times Global 500 companies, more than 90 percent cited climate change as posing commercial risks and/or opportunities.
Insurance Industry

“We'd be out of our minds if we wrote weather insurance on the opinion global warming would have no effect at all.”

- Warren Buffett
2006 annual Shareholder meeting
• **James Woolsey** - Former CIA Director
  Prius’ bumper sticker reads:  
  “*Osama bin laden hates this car.*”

• **Richard Cizik** - National Assoc. of Evangelicals
  “Pollution from cars and power plants is destroying God's creation… it violates sanctity of life.”
Climate Change Views by Party Association (2004)

- Republicans
  - Wait and see
  - Go Slow
  - Urgent

- Democrats
  - Wait and see
  - Go Slow
  - Urgent
**Public Opinion on Climate Change**
*(June 2004)*

- Would approve of tightened CAFÉ standards: 85%
- Approve of McCain-Lieberman (CO2 reductions; cap and trade): 80%
- Would pay $15/month to see this happen: 65%
- Responding will hurt the US Economy: 35%
- Responding will make US economic more efficient and competitive: 70%
- There is near complete scientific consensus: 50%
The Greenhouse effect

Solar radiation passes through the clear atmosphere.
Incoming solar radiation: 343 Watt per m²

Not incoming solar radiation: 240 Watt per m²
Outgoing solar radiation: 103 Watt per m²
Some solar radiation is reflected by the atmosphere and earth’s surface

Some of the infrared radiation passes through the atmosphere and is lost in space
Net outgoing infrared radiation: 240 Watt per m²

Some of the infrared radiation is absorbed and re-emitted by the greenhouse gas molecules. The direct effect is the warming of the earth’s surface and the troposphere.
Surface gains more heat and infrared radiation is emitted again

Solar energy is absorbed by the earth’s surface and warms it...
168 Watt per m²

... and is converted into heat causing the emission of longwave (infrared) radiation back to the atmosphere
The cooling factors

- Volcanic eruptions
- Biomass burning (forest fires)
- Burning of coal and oil
- Deserts, and dust from sandstorms
- Ice and snow
- Barren lands

AEROSOLS

Albedo: ability of a surface to reflect light.

Aerosols: tiny particles of liquid or dust suspended in the atmosphere (most important anthropogenic aerosols is sulphate produced from SO₂)

Sources: Radiative forcing of climate change, the 1994 report of the scientific assessment working group of IPCC, summary for policymakers, WMO, UNEP; L.D. Danny Harvey, Climate and global environmental change, Prentice Hall, Pearson Education, Harlow, United Kingdom, 2000.

Source: United Nations - Intergovernmental Panel on Climate Change
Vostok Ice Cores:

150,000 years of carbon and temperature
The Primary Human Influence is Fossil Fuels Combustion

(Second is Deforestation)
Future energy policy will determine this

This warming has already occurred
We’ll pass the 2xCO\textsubscript{2} Milestone ~2050

**Air Temperatures**

- 2x CO\textsubscript{2}
- 4x CO\textsubscript{2}

**Soil Moisture**

- 2x CO\textsubscript{2}
- 4x CO\textsubscript{2}

With increased warming, net impacts become increasingly negative

Source: NOAA (Geophysical Fluid Dynamics Laboratory)
Climate change affects all aspects of life

Physical Processes
- Air & water temperatures
- Ice
- Precipitation
- Soil moisture
- Ocean currents
- Sea level
- Permafrost
- Weather

Human Relevance

Health Impacts
- Weather-related mortality/heat stress
- Infectious diseases
- Air quality-induced respiratory effects

Agriculture Impacts
- Crop yields and commodity prices
- Irrigation demands
- Pests and weed

Forest Impacts
- Change in forest composition
- Shift geographic range of forests
- Forest health and productivity

Water Resource Impacts
- Changes in water supply and timing
- Water quality
- Increased competition for water

Coastal Area Impacts
- Erosion of beaches
- Inundation of coastal wetlands
- Costs to defend coastal communities

Ecosystem Impacts
- Shifts in ecological zones
- Loss of habitat and species
- Coral reefs threatened
Fingerprint: Rise in Number and Change in Mix of Weather/Climate Disasters

Source: Center for Research in the Epidemiology of Disasters (CRED)
Fingerprints
Hurricane destructiveness increasing in lockstep with ocean temperatures

2005 broke most records
- Number
- Strongest storm
- Physical size
- Storm duration
- Season duration
- Southernmost landfall

Source: Kerry Emanuel, MIT *Nature* (former “climate skeptic”)
A

Number of Intense Hurricanes

Maximum Wind Speed

m/s

Number of Hurricanes/Category

70/74  75/79  80/84  85/89  90/94  94/99  00/04

pentad

cat: 1
cats: 2+3
cats: 4+5

COLOR IR CH. 4 - SEP 23 05 03:15 UTC
Disasters Not Just a “Coastal” Issue

~99% Weather Related

Mitigation Strategies for the Next Millennium
More Frequent Extremes: For a 1.5 °F temperature increase, the 1-in-300 year heatwave comes every 10 years.
Fingerprint: the 2003 European Heat Wave
(hottest summer since 1500 AD)

Multiple correlated, impacts:
- 22,000-35,000 human fatalities (+unhealthy air masses)
- $13.6B in crop/livestock losses
- 25,000 fires; 1.2 million acres. $1.7B in wildfires in Portugal alone + respiratory illness
- Nuclear power plant curtailment (insufficient cooling water)
- Electricity prices 20x US average
- Avalanches (melting permafrost)
- Unhealthy air masses (smog, particulate)

Source: Schar 2004 (Nature)
Small-scale, Gradual, Diffuse, and Indirect Events Often Overlooked

- Blackouts
- Crop damages
- Equipment breakdown
- Eroded air quality
- Eroded water quality
- Hail
- Ice Storms
- Infectious diseases
- Lightning
- Mudslides
- Permafrost melt
- Sea-level rise & coastal erosion
- Sinkholes
- Subsidence
- Thunderstorms
- Tornados
- Vehicle damages/injuries
- Wildfire
- Winterstorms

Greater combined impacts than CATs in an average year
Precipitation changes: trend over land from 1900 to 1994

Precipitation decreasing by:
- 20%
- 10% between 1900 and 1994
- 5% between 1900 and 1994
- 2%

Precipitation increasing by:
- 2%
- 5% between 1900 and 1994
- 10% between 1900 and 1994
- 20%

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, 1996; Hulme et al., 1991 and 1994; Global Historical Climate Network (GHCN), Vose et al., 1995 and Eischedt et al., 1995.
Mudslide in El Salvador (2001)
Fingerprint: Lightning

Lightning-related damages accelerate with temperature

Examples of Losses:
- State Farm: $330M/year in claims
- Factory Mutual: 3-4% of claims
- 50% wildfires in western US
- >3000/year: structural, vehicle fires
- 30% of power outages
- 80% of petroleum storage accidents
- 346 incidents, 81 nuclear sites: 1990s
- $2B/year: airline operating costs
- 100,000/y: desktop computer losses
- Traffic signal outages

Source: Hartford Steam Boiler Inspection and Insurance Co.

Source: www.lightningsafety.com
Fingerprint: Sea Level Rise

South Bethany, Delaware -- 3 rows of homes to be lost. Source: FEMA

Increase: 10-20 cm (4-8 inches) in 20th Century

3 feet displaces 200 million people globally
Fingerprint: Loss of Ice & Snow Cover

- Loss of land ice --> sea-level rise
- “Darkens” Earth’s surface
- “Freshens” oceans

Since 1979, more than 20% of the Polar Ice Cap has melted away.
Harvard Expedition to North Pole

7 August 2004
90 deg N
Polar Bears are the Canaries in the Mineshaft

- Polar bears drowning in unprecedented numbers
- Reduced birth rates
- Extinction projected this century
- (Inuit hunters also impacted)
Fingerprint: Systematic Worldwide Glacier Retreat

- Americas
- Europe
- Asia
- Africa
- Australasia

Loss of world’s glaciers = 1 1/2 foot sea level rise
The Greening of Greenland: 50 cubic miles of ice lost each year


Already enough climate change to melt Greenland

= 10 feet sea level rise
Glacial Earthquakes on the Rise
Sea-level Rise for Half of Greenland Melting: ~2100
(Source: Harvard University)
Harvard University
Sea-level Rise for Half of Greenland Melting: ~2100
Mt. Kilimanjaro (Tanzania)

1990  
1990

2000  
2000
The snows will be gone in 15 years
Permafrost Disintegration
Rapid Antarctic Warming

- First Antarctica-wide warming picture
- 1 degree Warming per Decade over past 30 years
- Warming 3x faster than world average

Source: Trends (degrees C per decade) in the winter season 500-hPa temperatures from 1979 to 2001
Abrupt Climate Change

In the largest single ice sheet disintegration event in recorded history, approximately 3,250 square kilometers of the Larsen B ice sheet shattered in a five-week period in 2002.

The disintegration released 720 billion tons of ice into the Weddell Sea.

Equal to area of Los Angeles Basin

Source: National Snow and Ice Data Center
Abrupt Climate Change

The Ocean Conveyor Belt

Labrador and South England are same latitude

1998-2004 30% reduction in observed flow @ 25°NL
= Heat equivalent of 500,000 power plants

(Source: Bryden et al. *Nature*)
Human Health Impacts

- **Human Systems**
  - Heat stress
  - Respiratory disease
    - Pollen
    - Mold
    - Smoke and particulates
    - Urban air pollution
  - Infectious diseases
  - Food poisoning
  - Water quality
  - Injury/death from disasters
  - Environmental contamination

*WHO estimates 150,000 human mortalities each year due to current climate change*
Correlation of Disease Clusters with the 1997-1998 El Niño Weather Extremes

El Niño expected to become more frequent under climate change

Source: Harvard Medical School, Center for Health and the Global Environment (Science)
Malaria in Florida (2003)
Spread of West Nile Virus in North America: 1999-2002

Drought-Mosquito-Bird Vector chain

Human Impacts:
2001: 66 cases; 9 deaths
2002: 4161 cases; 284 deaths


233 Other species

Sources: U.S. Army Environmental Programs Directorate, from Centers for Disease Control, Health Canada, USGS, and ProMED-mail as of 14 May 2003)
Health Impacts on Non-Human Systems Are Economically Important

Pine beetle super-infestations: wildfire, lumber products, tourism/recreation, mudslides

Crop Diseases: e.g. Expanding range of soybean rust: 1971-1998

Coral bleaching: loss of pharmaceutical resources; coastal protection; freshwater salinization; fisheries
Crop

$ Millions

Fingerprints: North America wildfire - area burned has doubled since 1970
Alaska: Summer 2004

Unhealthful air conditions over most of state

800 miles
Wildfire & Air-Quality Links: Alaska: Summer 2004

Fairbanks June 28, 2004

2.5 Micron Airborne Particulate Matter - 24 hour Daily Average Values
Downtown Fairbanks, Alaska: June 15 - September 20, 2004

Date, 2004
Notes: 24 hr. average is from midnight to midnight, Alaska Standard Time, using available hours of data.
Average summertime particulate value for the Fairbanks area is 10 μg/m³.
• October was dry, hot. 85-100°F
• Fierce Santa Ana winds, up to 70 mph
• Humidity below 10-15% in many places

• 14 fires
• Over 750,000 acres
• 24 deaths, 246 injured
• 3600 houses burned
• Cost over $2 billion
• 15,000 firefighters
Idyllwild is More Vulnerable to Climate Change Impacts than Most Places

- Water quality/quantity
- Wildfire
- Power outages
- Forest loss/change
- Air pollution
- Loss of tourism
- Sensitive species
Climate Skeptics are an Endangered Species
• Variability is a fact of life; but the dice are loaded

• No better alternative theory has been advanced

• Models predict past climate very well

• Risk management is the appropriate response
Satellite data controversy resolved (May 2006)

Source: Kerr, Science v312:825 (12 May 2006)
Cutting U.S. Emissions in Half

After Pacala and Socolow (Science)
Energy Efficiency is Mainstream

 Increased fuel economy will “save jobs, save lives and save fuel.”

 Bush Administration: April 27, 2006
The Molecular Foundry -- High-tech can be green
Scorecard:
- 37% energy savings
- 92% of electricity purchased from renewables
- 85% greenhouse-gas reduction [Kyoto = 5%]
- 35% indoor water savings and 65% outdoor savings
- Renewably grown bamboo floors
- Low-emission building materials
- LEED Silver (pending)
Light Emitting Diodes

Source: Hewlett-Packard
Stable Technology Learning over three decades and four orders of magnitude in spite of a deployment roller-coaster.

PV Power Modules 1976-2001

Global Average Price (USD(2001)/Wp)

$\rightarrow$ Technology Learning System

Wp $\rightarrow$ M

Learning Rate: 20%

Oil crises
Solar vision
Growth 84%

Commercial off-grid
Growth 12%

"Roof-top" programmes
Growth 35%

Cumulative Global Shipments (MWp)
Fuel-based Lighting

India: street vendor

India: propane lamp

Ghana: lamp

Bhutan: merchant

India: sweat shop
Tanzania: night market

China: kerosene porter

China: kitchen
• **Kenya:** classroom light levels as low as 2% of western standards

• **Tanzania:** teachers grading homework with light levels 1% of western standards
million points of light
Kenya: vegetable stand in Kibera slum

Tanzania: shoe seller - flame [left]; white LED [right]
http://HomeEnergySaver.lbl.gov
Thank You

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Thank You

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