City of Cambridge

O-17
ORIGINAL ORDER
IN CITY COUNCIL
May 11, 2009

COUNCILLOR DECKER
COUNCILLOR TOOMEY
COUNCILLOR DAVIS

WHEREAS: The City of Cambridge on May 24th, 1999, resolved to join the Cities for Climate Protection Campaign which commits the city to be an environmental leader; and

WHEREAS: In December 2002, the City of Cambridge adopted a Climate Protection Plan with the goal of reducing the emission of greenhouse gases (GHG) city-wide 20% below 1990 levels by 2010; and

WHEREAS: In April 2005, City of Cambridge joined the International Council for Local Environmental Initiatives (ICLEI) with the goal of leading by example; and

WHEREAS: Through the efforts of city staff and others, the City of Cambridge has successfully implemented much of the Climate Protection Plan, yet total city-wide GHG emissions, as measured by the City's Climate Protection Action Committee increased 27% from 1990 - 2003; and

WHEREAS: Since GHGs causing global warming accumulate and persist in the atmosphere, sharp reductions in GHG emissions are required immediately for there to be any possibility of forestalling the dangers of climate change; and

WHEREAS: In March 2009, more than 2,500 climate experts from 80 countries, assembled for an emergency meeting in Copenhagen to prepare for the UN Climate Change Conference in December, declared that "the climate system is already moving beyond patterns of natural variability within which our society and economy have developed and thrived;" that "the worst-case IPCC scenario projections (or even worse) are being realized;" that "there is a significant risk that many of the trends will accelerate, leading to a risk of abrupt or irreversible climatic shifts;" and that "there is no excuse for inaction"; and

WHEREAS: In March 2009, more than 2,500 climate experts from 80 countries, assembled for an emergency meeting in Copenhagen to prepare for the UN Climate Change Conference in December, declared that "the climate system is already moving beyond patterns of natural variability within which our society and economy have developed and thrived;" that "the worst-case IPCC scenario projections (or even worse) are being realized;" that "there is a significant risk that many of the trends will accelerate, leading to a risk of abrupt or irreversible climatic shifts;" and that "there is no excuse for inaction"; and

WHEREAS: The Administrator of the U.S. Environmental Agency on April 17, 2009 issued a proposed finding that says in part "the evidence points ineluctably to the conclusion that climate change is upon us as a result of greenhouse gas emissions, that climatic changes are already occurring that harm our health and welfare, and that the effects will only worsen over time in the absence of regulatory action. The effects of climate change on public health include sickness and death;" and

WHEREAS: As a preeminent center for scientific research with a well-educated population, Cambridge has the obligation to lead in responding to this critical situation; and

WHEREAS: This City Council recognizes that there is a climate emergency; now therefore be it

ORDERED: That the City Manager be and hereby is requested to direct the appropriate city departments to increase the City's responses to a scale proportionate to the emergency and consistent with the city's own Climate Protection goals for 2010 and beyond; and be it further

ORDERED: That this matter be referred to the Health and Environment Committee for a hearing.

In City Council May 11, 2009
Adopted as amended by the affirmative vote of nine members.

Attest:- D. Margaret Drury, City Clerk

A true copy; D. Margaret Drury

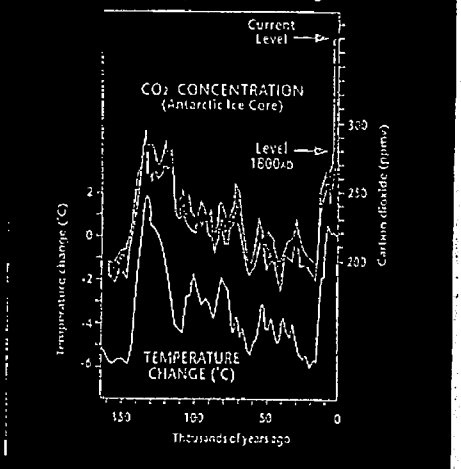
ATTEST:-

D. Margaret Drury, City Clerk

REFERRED TO THE HEALTH AND ENVIRONMENT COMMITTEE

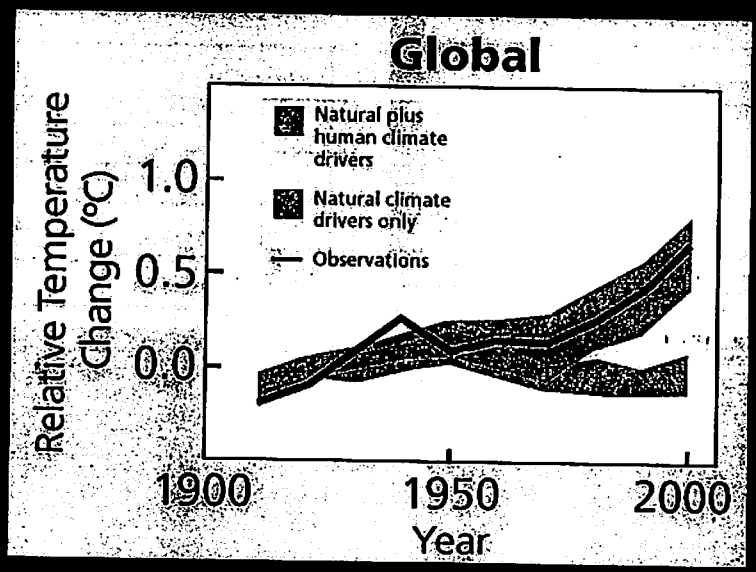
Current conditions are *unique*

- Concentration of carbon dioxide:
  - Ice age ~180 ppm
  - Interglacial warm period ~280 ppm
  - 2009 ~388 ppm
- Current rate of increase in emissions:
  - *Unprecedented* in geological history



OSTP / IPCC

Human Activity - Cause of Global Warming



Source: IPCC *Climate Change 2007: The Physical Science Basis*—Summary for Policymakers.

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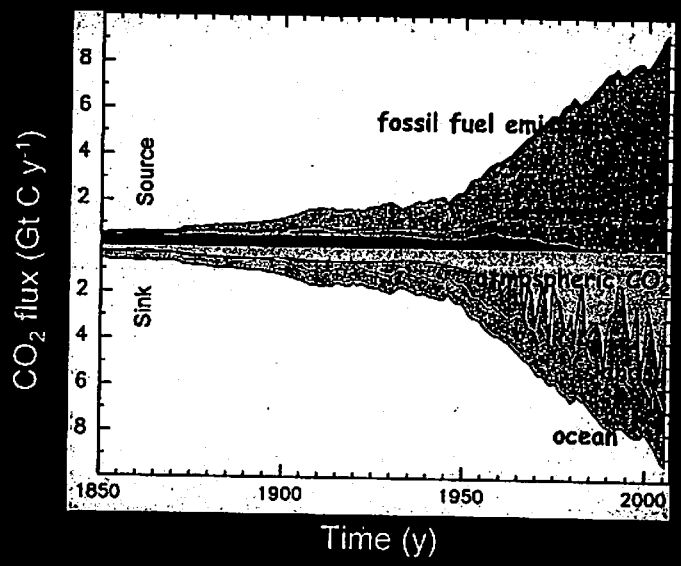
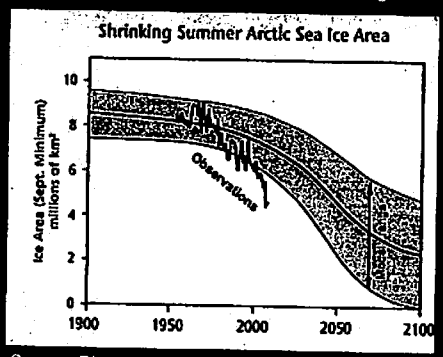
Perturbation of global CO_2

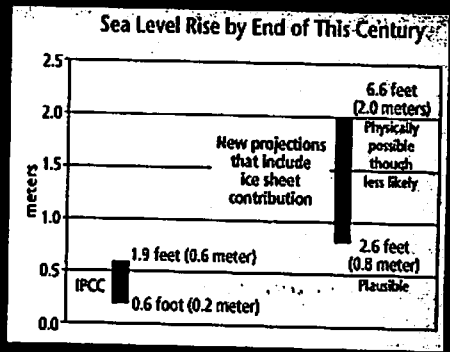


Source: Le Quere et al. 2007; Canadell et al. 2007, PNAS; Global Carbon Project 2008

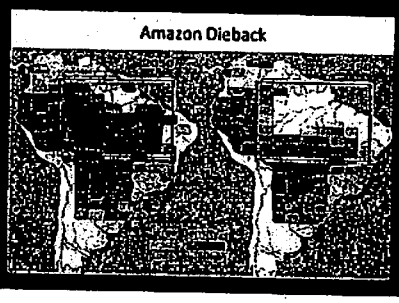
Revised projections since IPCC



Source: Dirk Notz / NSIDC



Source: Pfeffer et al. 2008



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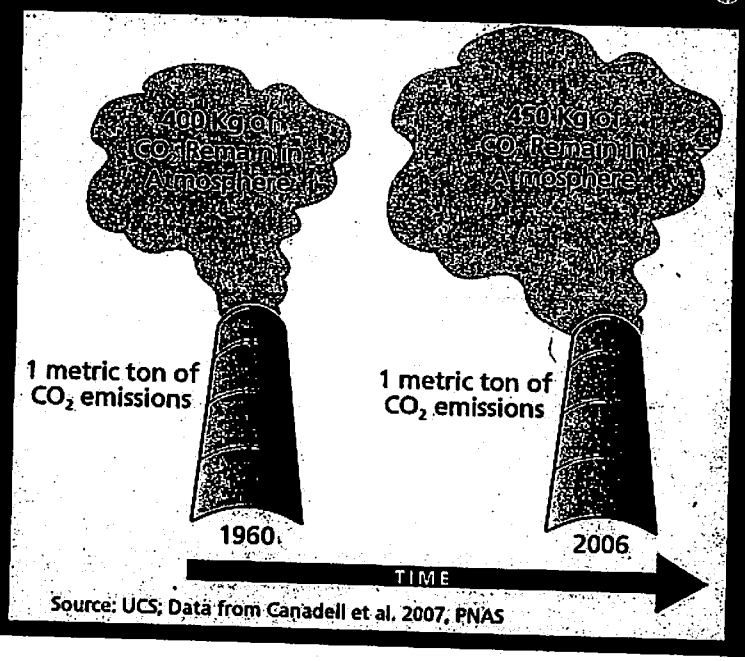
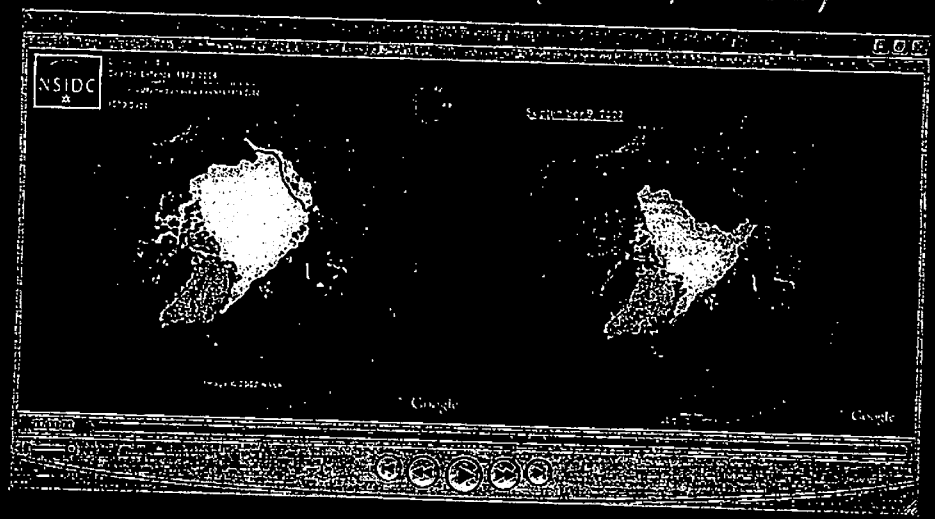
Natural "sinks" are declining



Source: UCS; Data from Canadell et al. 2007, PNAS

Observations: Arctic sea ice September 2007 (2008, 2009)



http://nsidc.org/news/press/2007_seaiceminimum/images/20070917_animation.mov

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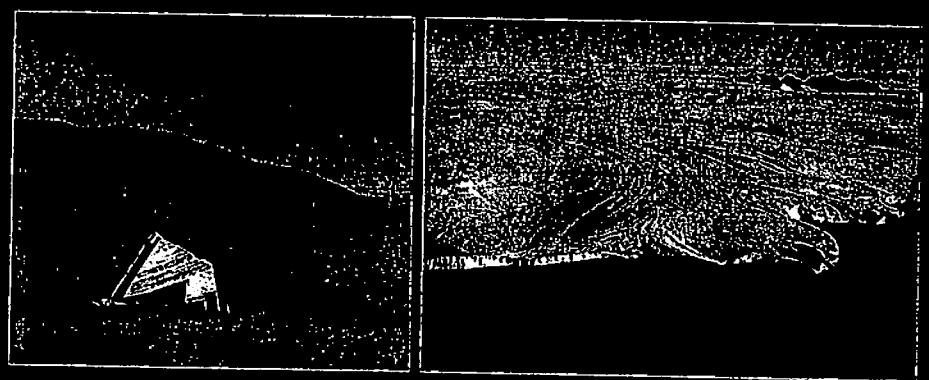
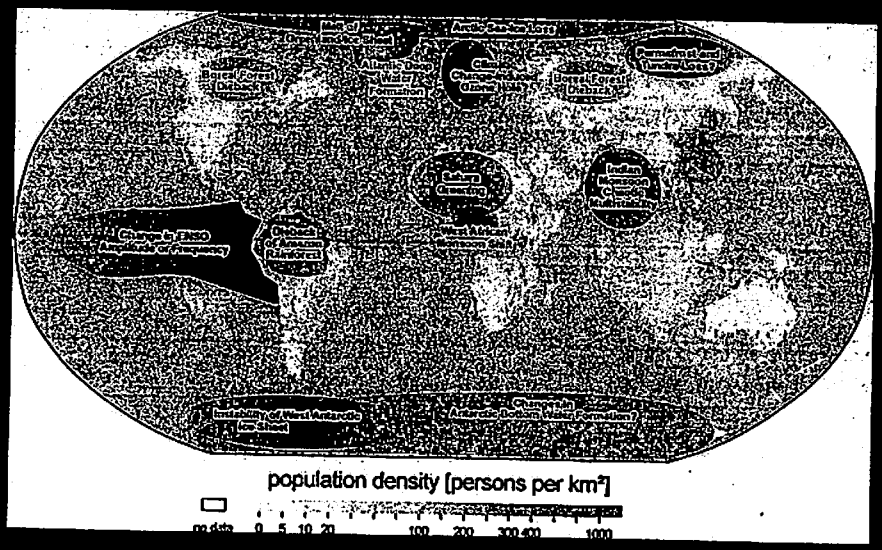
Surprises: Climate-ecosystem feedbacks

- Ice-albedo feedbacks
- Carbon-cycle feedbacks

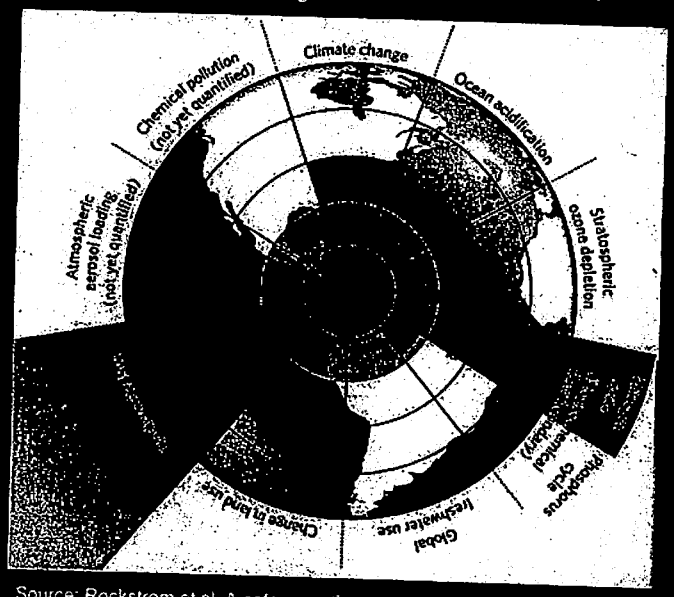


Climate tipping points



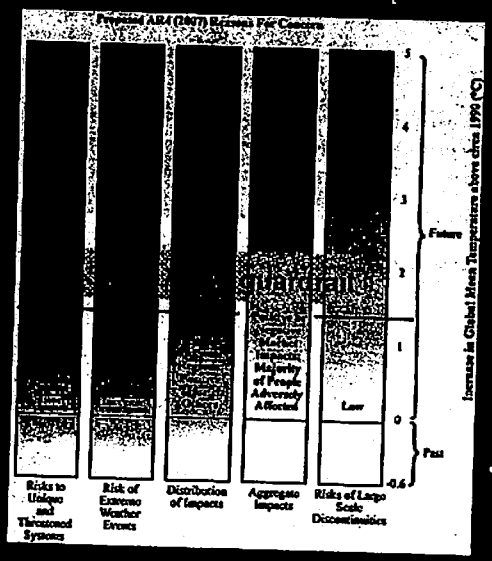
Lenton et al., Tipping elements in the Earth's climate system. *PNAS*, 2007

Planetary Boundaries



Source: Rockstrom et al. A safe operating space for humanity. *Nature*. 2009.

Risks with Temperature Increases



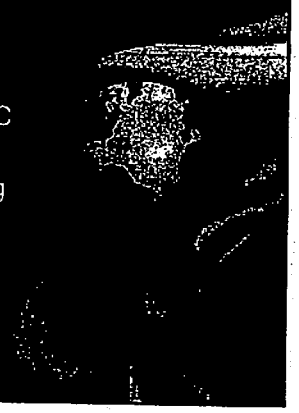
- An increase in global average temperature 3.6 deg F (2 deg C) above pre-industrial temperatures poses severe risks to natural systems and human health and well-being.
- In 2007 global average temperature was about 1.4 deg F above pre-industrial levels.
- We are committed to at least another 1.1 deg F from emissions to date.

Source: Smith et al, Assessing dangerous climate change through an update of the IPCC "reasons for concern". *PNAS*. 2009.

Reasons for concern

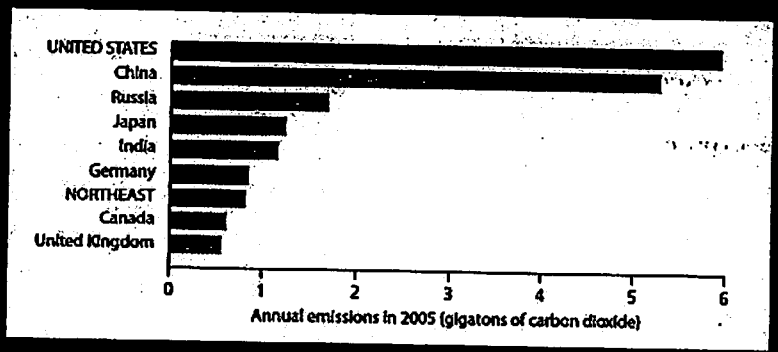
- Current global emissions (to end 2008) are higher than IPCC scenarios
- Atmospheric CO_2 concentrations greater than at any time in human history
- Record Arctic sea ice losses - decades earlier than projected by IPCC
- Accelerating glacier flows measured in Greenland and the Antarctic Peninsula
- Revised sea-level rise estimates greater than IPCC best estimate
- Capacity of land and ocean sinks may be declining
- Possible methane release from land and ocean

Some are low probability, but high consequence



2005 US emissions in a global context

- Per capita emissions in the US are 5 times higher than in China
- Emissions in the US ~ 20 metric tons per person



Source: Energy Information Administration, 2008.

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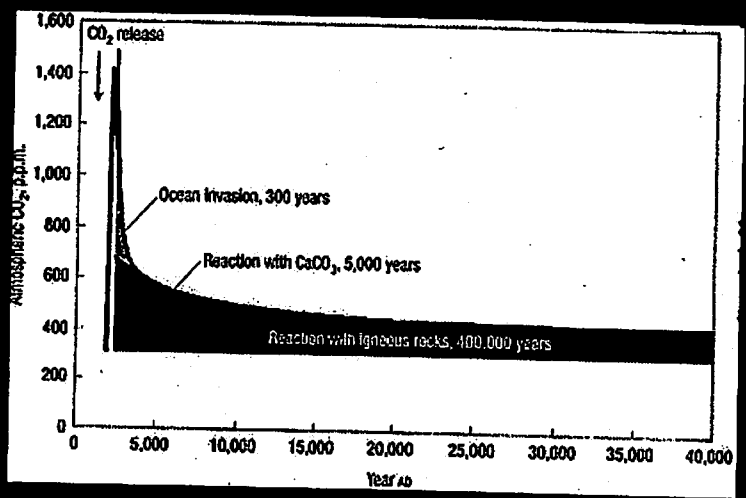
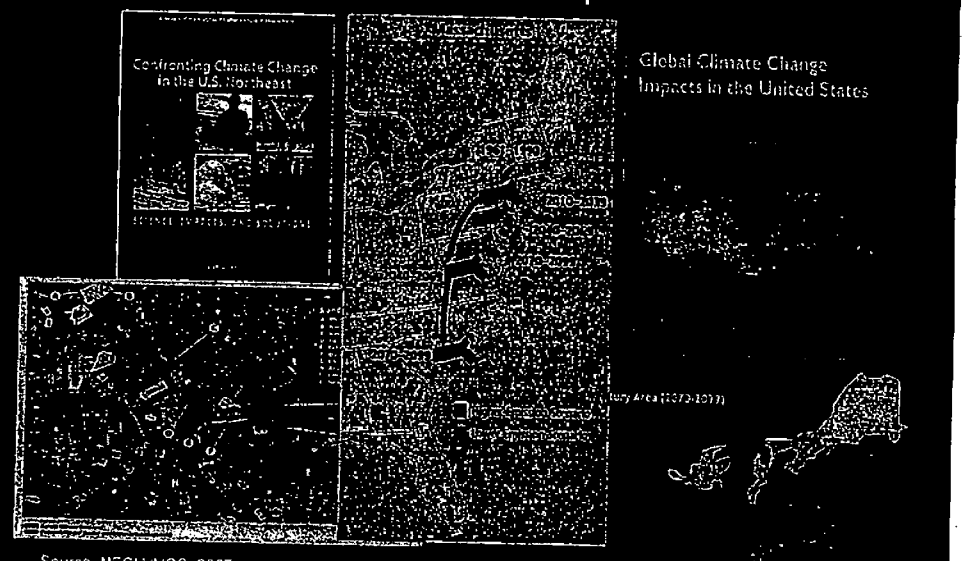
Carbon is forever



Model simulation of atmospheric CO2 concentration for 40,000 years following after a large CO2 release from combustion of fossil fuels. Different fractions of the released gas recover on different timescales. Reproduced from *The Long Thaw*, David Archer, 2008.

Local Climate Impacts



Source: NECIA/UCS, 2007 see www.climatechoices.org/ne/
Source: US Climate Impacts Report 2009 www.globalchange.gov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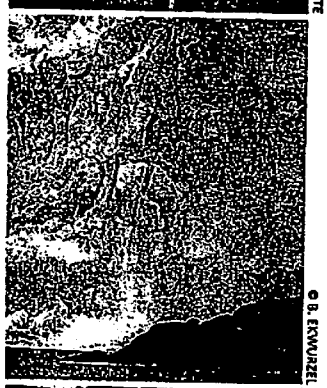
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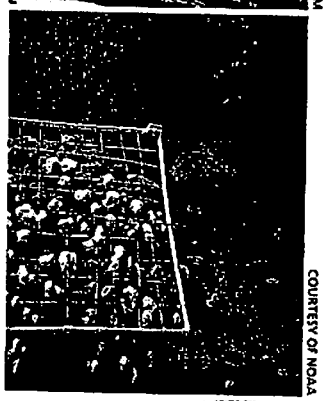
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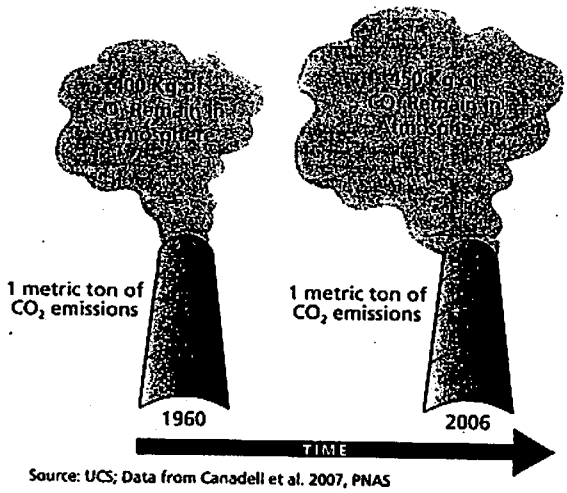
Latest Climate Science Underscores Urgent Need to Reduce Heat-trapping Emissions

Major developments in climate change science have been reported since the publication of the comprehensive 2007 Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC).[1] Recent publications indicate that the consequences of climate change are already occurring at a faster pace and are of greater magnitude than the climate models used by the IPCC projected. A few of the most compelling findings are summarized below.

More CO_2 Remains in the Atmosphere

Human activities have pumped excessive amounts of carbon dioxide (CO_2) into the atmosphere. Natural processes that absorb CO_2 cannot keep up. As the ocean absorbs carbon dioxide, it becomes more acidic. This combined with increasing ocean temperatures, diminishes its ability to continue absorbing CO_2. As a result, more CO_2 stays in the atmosphere. In 1960, a metric ton (1,000 kilograms; ~2,205 pounds) of CO_2 emissions resulted in around 400 kilograms (~881 pounds) of CO_2 remaining in the atmosphere (Figure 1). In 2006, a metric ton of CO_2 emissions results in around 450 kilograms (~992 pounds) remaining in the atmosphere.[2] Hence a ton of CO_2 emissions today results in more heat-trapping capacity in the atmosphere than the same ton emitted decades ago.

FIGURE 1 Today's Ton Is Worse Than a Ton Emitted Decades Ago



Source: UCS; Data from Canadell et al. 2007, PNAS

The natural processes that have helped clean up the excess CO_2 pumped into the atmosphere by human activities have not been able to keep up at the same rate.

Increased Sea Level Rise

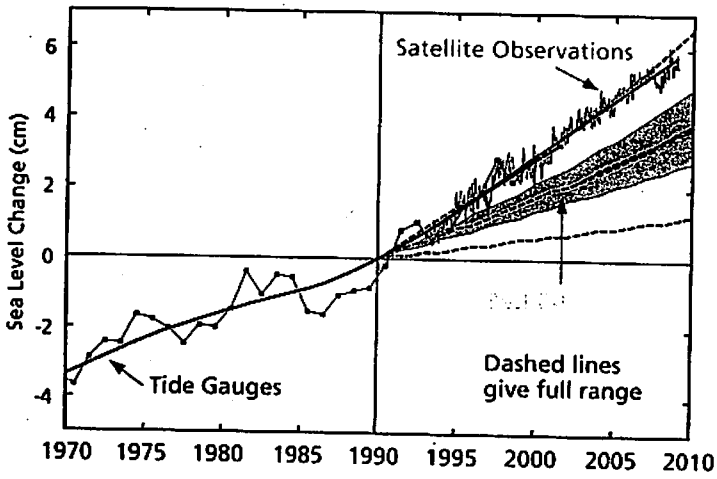
Increased contributions from melting mountain glaciers and ice sheets on land, as well as thermal expansion due to continued ocean warming, are resulting in higher sea level rise. The IPCC (AR4) noted that sea level has risen 50 percent faster than projected by models for the 1963–2001 period. Recent observations confirm that sea level rise is in the upper range projected by models used by the IPCC (Figure 2).[3]

The IPCC (AR4) estimated global average sea level rise for the end of this century (2090–2099) compared with the end of the last century (1980–1999) at between ~0.6–1.9 feet (~0.2–0.6 meter). These projections were based primarily on thermal expansion due to ocean warming with only modest contributions from mountain glaciers, leaving the potential contributions from ice sheets covering Greenland and Antarctica unclear.[4] Because understanding of ice sheet behavior is still evolving, future ice sheet disintegration was not included in models used by the IPCC at that time. Researchers have since examined plausible contributions from ice sheets given current understanding of accelerating ice sheet melt and other factors. New analysis indicates that meltwater from land ice could lead to sea level rise of ~2.6 feet (0.8 meter) by the end of the century; and although ~6.6 feet (2.0 meters) is less likely, it is still physically possible.[5] As depicted in Figure 3, when increased contributions from glaciers and ice sheets are taken into account, plausible twenty-first century sea level rise is higher than IPCC estimates.

Plummeting Arctic Sea Ice

Arctic sea ice models used by the IPCC are in general agreement with the observed decline over the last 50 years and indicate that heat-trapping gases are a major factor in the area decrease. Current observations show a much steeper drop in ice area than expected.[6] Global warming and natural cycles combine to create the observed Arctic sea-ice trend.

FIGURE 2 **Sea Level Rise in Line with Highest Projection**



Changes in sea level since 1973, compared with IPCC scenarios (dashed lines and gray ranges), based on tide gauges (red) and satellites (blue). From Rahmstorf et al. (2007) updated by Rahmstorf (personal communication).

FIGURE 3 **Sea Level Rise by End of This Century**

New analysis provides estimates for sea level rise by the end of this century between a plausible level and a physically possible though less likely level. Source (IPCC 2007 and Pfeffer et al. 2008).[4,5]

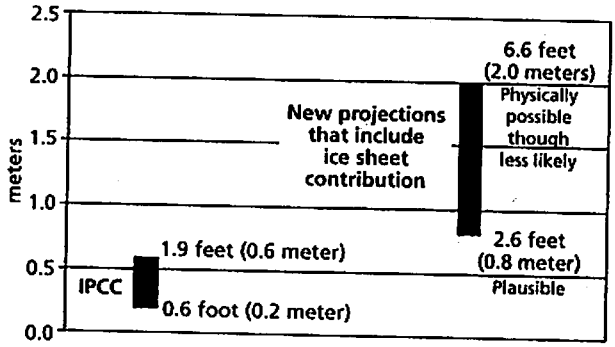
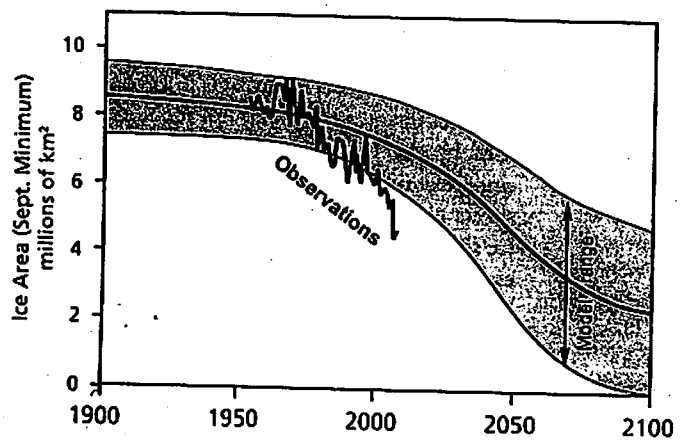


FIGURE 4 **Shrinking Summer Arctic Sea Ice Area**



Arctic models of September sea ice area underestimate the rate of observed sea ice retreat. Based on Stroeve et al. 2007.

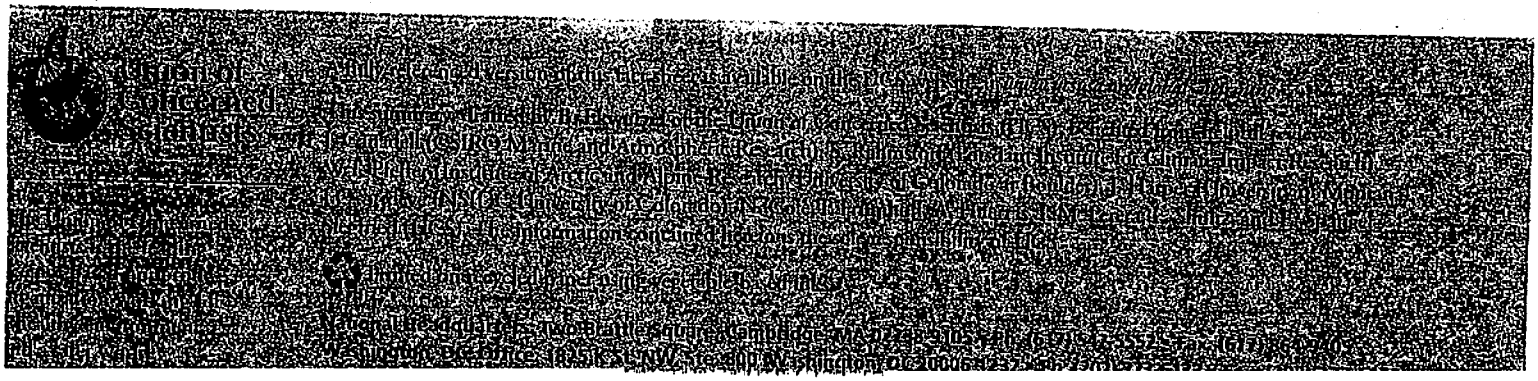
Source: Dirk Notz from Hamburg adapted figure from *http://www.nsidc.org/news/images/20070430Figure1.png.*

When sea ice would naturally rebound, global warming limits the full sea ice area achieved. When sea ice naturally would be less extensive in area, global warming exacerbates this natural tendency and contributes to sea ice plummeting. For example, the atmospheric pressure and wind patterns in 2007 have naturally ocurred in a similar fashion at various times in decades past. However, this type of weather pattern occurring after several decades of ice thinning combined to create a record breaking lowest summer sea ice area since satellite observations began.[7]

Recent evidence shows that periods of rapid Arctic sea ice loss lead to faster warming over land in the polar region.[8] As sea ice retreats it exposes dark ocean, which absorbs more of the sun's heat than white ice. Toward the end of summer this ocean heat dissipates to the atmopshere as the region enters winter and the ocean freezes again into sea ice. This warmer air extends over land and allows bacteria more time to decompose thawing plant and other organic matter that had been long frozen.[9] This process can lead to a release of heat-trapping gases (CO_2 and methane) into the atmosphere amplifying global warming.

CO_2 Effects Will Be Felt for Generations

Studies indicate that even after excess human-caused CO_2 emissions stop, the planet will experience the resulting warming for at least a thousand years. The higher the peak of atmospheric concentrations of CO_2, the greater is the level of irreversible consequences, such as species loss and sea level rise.[10] These and other peer-reviewed studies published since the release of the IPCC (AR4) provide ever more compelling evidence that swift and deep reductions of heat-trapping gasses are needed if we are to avoid catastrophic climate change. United States leadership is essential, and there is no time to waste.



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UNITED NATIONS ENVIRONMENT PROGRAMME

Programme des Nations Unies pour l'environnement | Programa de las Naciones Unidas para el Medio Ambiente
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UNEP

Embargoed:
Not for Publication or Broadcast Until After 15:00 HRS GMT 24 September 2009 (10:00 HRS EST)

From the Loss of Mountain Glaciers and Arctic Ice to the Acidification of Oceans—Impacts of Climate Change Coming Faster and Sooner

New UNEP Science Report Underlines Urgency for Governments to Seal the Deal in Copenhagen Says Executive Director Steiner

Washington/Nairobi, 24 September 2009 --The pace and scale of climate change may now be outstripping even the most sobering predictions of the last report of the Intergovernmental Panel of Climate Change (IPCC) including in North America..

An analysis of the very latest, peer-reviewed science indicates that many of predictions at the upper end of the IPCC's forecasts are becoming ever more likely.

Meanwhile the newly emerging science points to some events thought likely to occur in longer-term time horizons, as already happening or set to happen far sooner than had previously been thought.

Persistent drought crisis conditions for the southwestern United States and northern Mexico, unprecedented loss of sea ice in the Canadian archipelago and seasonal upwellings of acidic seawater off California are all being observed years or even decades ahead of earlier projections.

Losses from glaciers, ice-sheets and the polar regions appears to be happening faster with the Greenland ice sheet for example recently seeing melting some 60 per cent higher than the previous record of 1998.

- Some scientists are now warning that sea levels could rise by up to two metres by 2100 and five to ten times that over following centuries.

There is also growing concern among some scientists that thresholds or tipping points may now be reached in a matter of years or a few decades including dramatic changes to the Indian summer monsoon, the Sahara and West Africa monsoon and ones affecting a critical ecosystem like the Amazon rainforest.

The report also underlines concern by scientists that the planet is now committed to some damaging and perhaps irreversible impacts as a result of the greenhouse gases already in the atmosphere.

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- Losses of tropical and temperate mountain glaciers affecting perhaps 20 per cent to 25 per cent of the human population in terms of drinking water, irrigation and hydro-power.

- Shifts in the hydrological cycle resulting in the disappearance of regional climates with related losses of ecosystems, species and the spread of drylands northwards and southwards.

Recent science suggests that it may still be possible to avoid the most catastrophic impacts of climate change. However, this will only happen within the time span of the current civilization if there is immediate, cohesive and decisive action to both cut emissions and assist vulnerable countries adapt.

These are among the findings of a report released today by the United Nations Environment Programme (UNEP) entitled *Climate Change Science Compendium 2009*.

The report, compiled in association with scientists around the world, comes with less than 80 days to go to the crucial UN climate convention meeting in Copenhagen, Denmark.

In a foreword to the document, the United Nations Secretary-General, Ban Ki-moon, who this week hosted heads of state in New York, writes, "This Climate Change Science Compendium is a wake-up call. The time for hesitation is over".

"We need the world to realize, once and for all, that the time to act is now and we must work together to address this monumental challenge. This is the moral challenge of our generation."

The Compendium reviews some 400 major scientific contributions to our understanding of Earth Systems and climate change that have been released through peer-reviewed literature, or from research institutions, over the last three years.

Achim Steiner, UN Under-Secretary General and UNEP Executive Director, said, "The Compendium can never replace the painstaking rigour of an IPCC process—a shining example of how the United Nations can provide a path to consensus among the sometimes differing views of more than 190 nations".

"However, scientific knowledge on climate change and forecasting of the likely impacts has been advancing rapidly since the landmark 2007 IPCC report," he added.

"Many governments have asked to be kept abreast of the latest findings. I am sure that this report fulfils that request and will inform ministers' decisions when they meet in the Danish capital in only a few weeks time," said Mr. Steiner.

"This is the most sobering assessment yet of how global warming is already affecting our climate and makes it very clear that we must take action," said Phyllis Cuttino, director, U.S. Global Warming Campaign, at the Pew Environment Group. "The U.S. Congress,

President Obama and other world leaders must act now to reduce the threat of global warming. Doing so will create a new clean energy economy, reduce dependence on fossil fuels and sustain our environment for future generations."

Key scientific observations and developments documented since the IPCC's Fourth Assessment Report in 2007 include:

NORTH AMERICA:

- Observation and modeling is pointing to an irreversible transition in the southwestern USA and Northern Mexico towards a sustained, drier climate. It may have been under way since 2000. "Dustbowl" conditions are projected to become the norm for the dry season in the region. This change, unprecedented in the instrumental record, is linked to global shifts of rainfall regimes as sub-tropical dry zones move towards the poles.

- Seawater acidic enough to corrode a shell-making carbonate substance called aragonite is already welling up during the summer along the California coast, decades earlier than models predict. It is an indication that oceans are becoming more acidic more quickly than expected, jeopardizing the ability of shellfish and corals to form their external skeletons.

- The average amount of sea ice within the Canadian Arctic Archipelago has decreased by an average of 8.7 per cent each decade since 1979. The melting season has lengthened by seven days per decade, with 2008 witnessing a record 129 days of melting.

- Vegetation surveys of California's Santa Rosa Mountains between 1977 and 2007 show that dominant plants have on average moved their range 65 metres (213 feet) higher in altitude. Research suggests this has been a response to warming, more variable precipitation and less snow cover, rather than other factors such as air pollution or fire.

The compendium also documents a number of significant recent climate anomalies for North America, including:

- The third-worst fire season and persistent drought in the western and southwestern USA in 2008.

- The worst drought in 70 years in Mexico, in August 2009, affecting about 3.5 million farmers, wiping out some 17 million acres of cropland and leaving 50,000 cows dead.

- The worst wildfire in 30 years in Southern California, in April 2009.

- Alaska's snowiest winter for 30 years in 2007-8, which also saw Toronto's third snowiest winter on record.

- Hurricane Gustav in August 2008, the worst storm to hit Cuba in five decades, with recorded gusts of 341 km per hour at one location, the strongest in the country's history.

GLOBAL:

- The growth in carbon dioxide emissions from energy and industry has exceeded even the most fossil-fuel intensive scenario developed by the IPCC in the late 1990s. Global emissions were growing by 1.1 per cent each year from 1990-1999 and this accelerated to 3.5 per cent per year from 2000-2007.

- Growth of the global economy in the early 2000s and an increase in its carbon intensity (emissions per unit of growth), combined with a decrease in the capacity of ecosystems on land and the oceans to act as carbon "sinks", have led to a rapid increase in the concentrations of carbon dioxide in the atmosphere. This has contributed to sooner-than-expected impacts including faster sea level rise, ocean acidification, melting Arctic sea ice, warming of polar land masses, freshening of ocean currents and shifts in the circulation patterns of the oceans and atmosphere.

- The observed increase in greenhouse gas concentrations are raising concern among some scientists that warming of between 1.4 and 4.3 degrees Centigrade above pre-industrial surface temperatures could occur. This exceeds the range of between 1 and 3 degrees perceived as the threshold for many "tipping points", including the end of summer Arctic sea ice, and the eventual melting of Himalayan glaciers and the Greenland ice sheet.

- In 2007, summer sea ice in the Arctic Ocean shrank to its smallest extent ever, 24 per cent less than the previous record in 2005, and 34 per cent less than the average minimum extent in the period 1970-2000. In 2008, the minimum ice extent was 9 per cent greater than in 2007, but still the second lowest on record.

- Until the summer of 2007, most models projected an ice-free September for the Arctic Ocean towards the end of the current century. Reconsideration based on current trends has led to speculation that this could occur as soon as 2030.

- Recent findings show that warming extends well to the south of the Antarctic Peninsula, to cover most of West Antarctica, an area of warming much larger than previously reported.

- The hole in the ozone layer has had a cooling effect on Antarctica, and is partly responsible for masking expected warming on the continent. Recovery of stratospheric ozone, thanks to the phasing out of ozone-depleting substances, is

projected to increase Antarctic temperatures in coming decades.

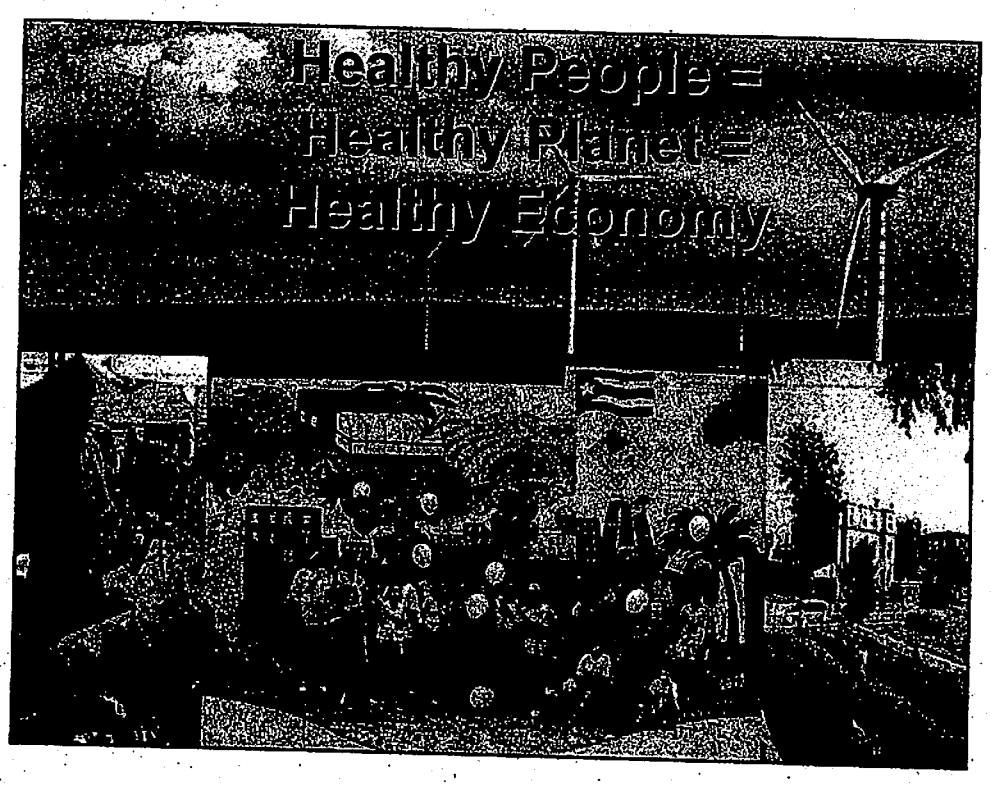
- Recent estimates of the combined impact of melting land-ice and thermal expansion of the oceans suggest a plausible average sea level rise of between 0.8 and 2.0 metres above the 1990 level by 2100. This compares with a projected rise of between 18 and 59 centimetres in the last IPCC report, which did not include an estimate of large-scale changes in ice-melt rates, due to lack of consensus.
- Under the IPCC scenario that most closely matches current trends – i.e. with the highest projected emissions – between 12 and 39 per cent of the Earth's land surface could experience previously unknown climate conditions by 2100. A similar proportion, between 10 and 48 per cent, will see existing climates disappear. Many of these "disappearing climates" coincide with biodiversity hotspots, and with the added problem of fragmented habitats and physical obstructions to migration, it is feared many species will struggle to adapt to the new conditions.

To download the full report, visit www.unep.org

For more information please contact:
Nick Nuttall, UNEP Spokesperson and Head of Media, on Mobile: +254 733 632755, or when traveling: +41 795965737, or Email: nick.nuttall@unep.org

Elisabeth Guilbaud-Cox, Senior Communications Officer, United Nations Environment Programme (UNEP) Regional Office for North America, Tel: 1 (202) 974-1307, Mobile: 1 (202) 812-2100, Email: elisabeth.guilbaud-cox@unep.org

B1


Healthy People =
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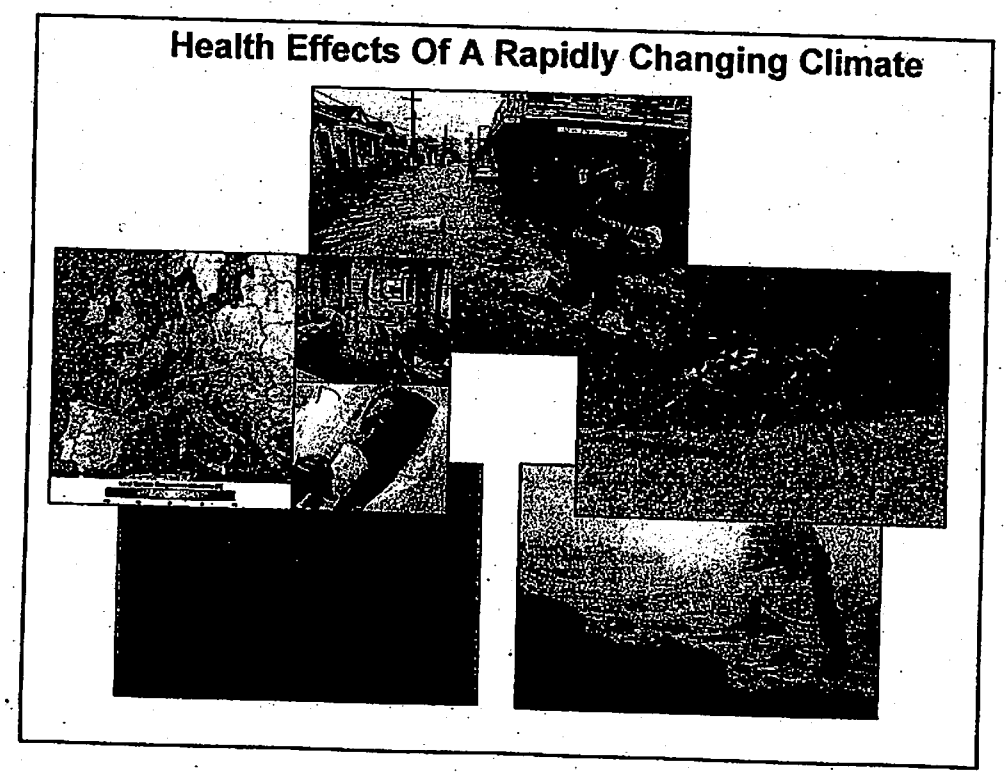
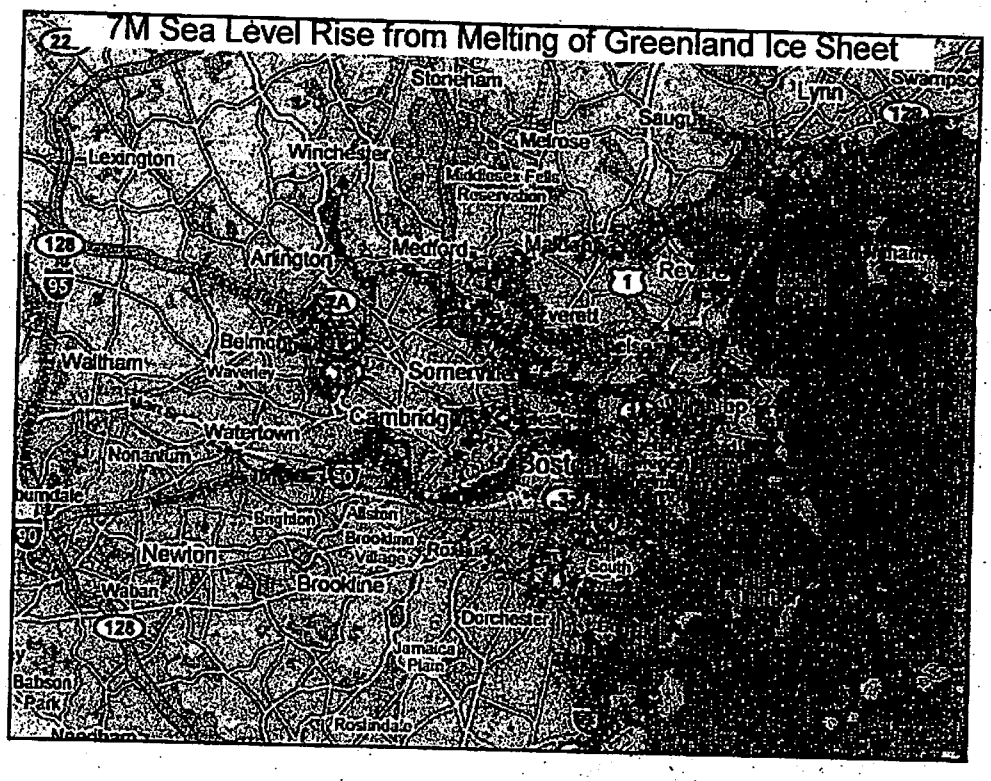

Health Effects Of A Rapidly Changing Climate



Environmental Factors Drive Chronic Disease & the Climate Crisis

Environmental Factors

- Industrial food system/diet
- Sedentary, built-environment, transportation
- Fossil fuel energy
- Socioeconomic stress/disparities

→ Toxic chemicals

↑ Greenhouse Gases → **Climate Crisis**
Heat, drought, fires, storms, ice sheet instability, sea level rise, loss of glacial irrigation, food insecurity/starvation, tropical diseases

Altered Biological Pathways → **Chronic Disease**
Western Disease Cluster: Diabetes, Obesity, CVD, Metabolic syndrome, AD

Magnitude of Western Disease Cluster

- Obesity/overweight – 2/3 US adults
- Diabetes - 40% US adults diabetic or pre-diabetic. # with DM ~x2 over 20 yrs Cowie 09 CDC. http://apps.nccd.cdc.gov/DDTSTRS/default.aspx
- Cardiovascular disease – still leading cause of death. Hypertension increasing.
- Metabolic syndrome = early signs of other cluster diseases; 60% adults>65 yrs old.
- Alzheimer's disease – ½ >84 yrs old, 5.3M

Mediterranean Diet

- ↓ risks for diabetes, vascular disease, **recurrent heart attacks, CV** and cancer mortality, **metabolic syndrome,** chronic **inflammation, prediabetes**, Alzheimer's, Parkinson's disease, asthma. Gao, Sofi 06, Dai 06, DeLogeril 99, Trichopoulou 03
- **Eliminated the metabolic syndrome in ~50%** of subjects over 2 years. Also ↓ inflammatory mediators and insulin resistance, and improved endothelial function. Esposito 04
- Risk of developing AD was ↓ >30% in elderly following Med. diet. Another study showed a 70% ↓ in mortality in AD subjects eating Med. diet → 4 year ↑ lifespan. Scarmeas 06,07

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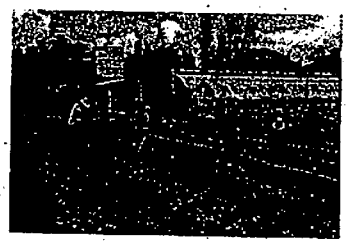
Advance Access publication September 18, 2007

Impact of Energy Intake, Physical Activity, and Population-wide Weight Loss on Cardiovascular Disease and Diabetes Mortality in Cuba, 1980–2005

Manuel Franco[1], Pedro Orduñez[2], Benjamín Caballero[3], José A. Tapia Granados[4], Mariana Lazo[1], José Luis Bernal[5], Eliseo Guallar[1,3], and Richard S. Cooper[6]



Cuba- lost fossil fuels→
↑ biking, walking, local plant-based food
↑ physical activity 50%
↓ obesity 50%
↓ mortality: DM 51%, CVD 35%, stroke 20%, all cause 18%

Solutions for Both
Chronic Disease & Climate Crisis

Environmental Factor	Health Impact	Climate Impact	Intervention-> Effects
Globalized food system	Inflammatory diet → chronic disease	↑ GHGs (19%) Land, chemicals, machines, CFOs, food transport	Local organic food systems
Car-centered built environment, transportation	Inadequate exercise → chronic disease	↑ GHGs (13% transport)	Public trans., bike paths, sidewalks.
Fossil fuel energy	Chronic disease air pollution, toxics	↑ GHGs	Green energy
Socioeconomic stressors	Chronic disease	Deforestation, desertification	Green jobs, health care, housing, equity
Open Space Loss	Chronic disease	↑ GHGs	Ecosystem restoration
Chemicals	Chronic disease	fossil fuel byproduct	safe chemicals

B5

The Mass. Health Dividend Waiting to Happen!

Up to $56 Billion per year*

Diabetes

Obesity

Asthma

Heart Disease

Alzheimer's

Metabolic Syndrome

*Estimated Annual Cost of Chronic Disease in Massachusetts

The investments needed for the health dividend:

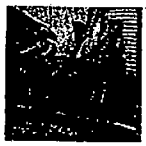
[redacted]

- Weatherization
- Conservation, Efficiency
- Solar, Wind

[redacted]

- Agricultural preservation
- Incentives for CSA's, Farmer's Markets, organic farms

[redacted]

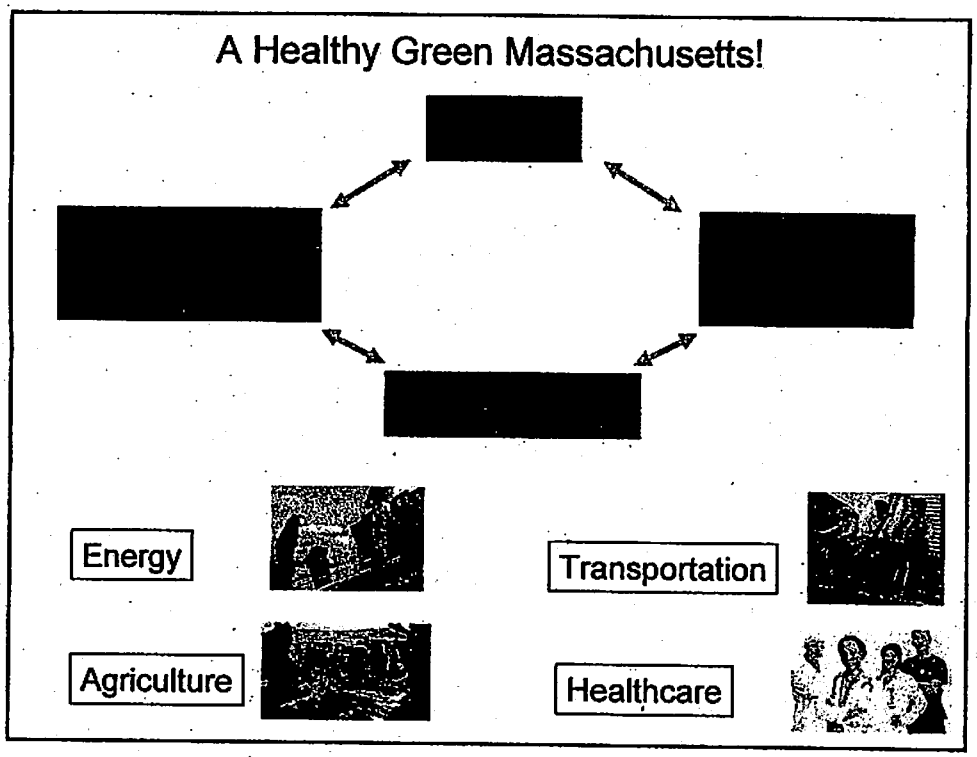


- Safe streets to school
- Walkable communities
- Bike paths
- Public transit

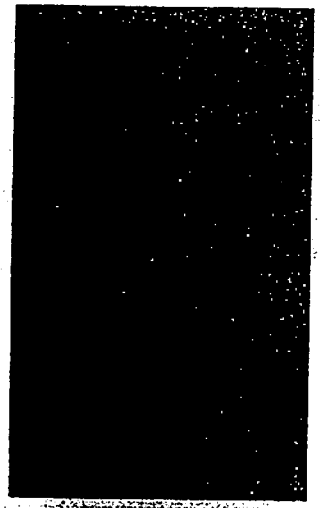
[redacted]

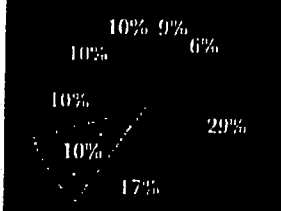
- Affordable, accessible care for all

B6


A Healthy Green Massachusetts!
Energy
Transportation
Agriculture
Healthcare

B7





U.S. Greenhouse Gases from Food

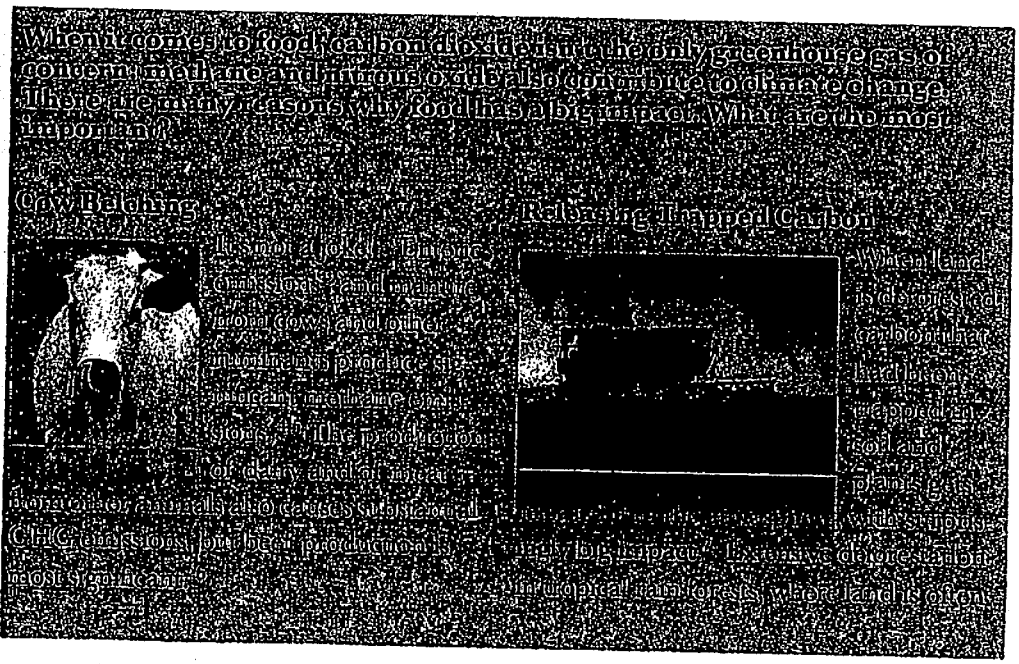
Red meat and dairy are responsible for nearly half of all greenhouse gas emissions from food for an average U.S. household. (Christopher Weber/Rhonda Saunders)

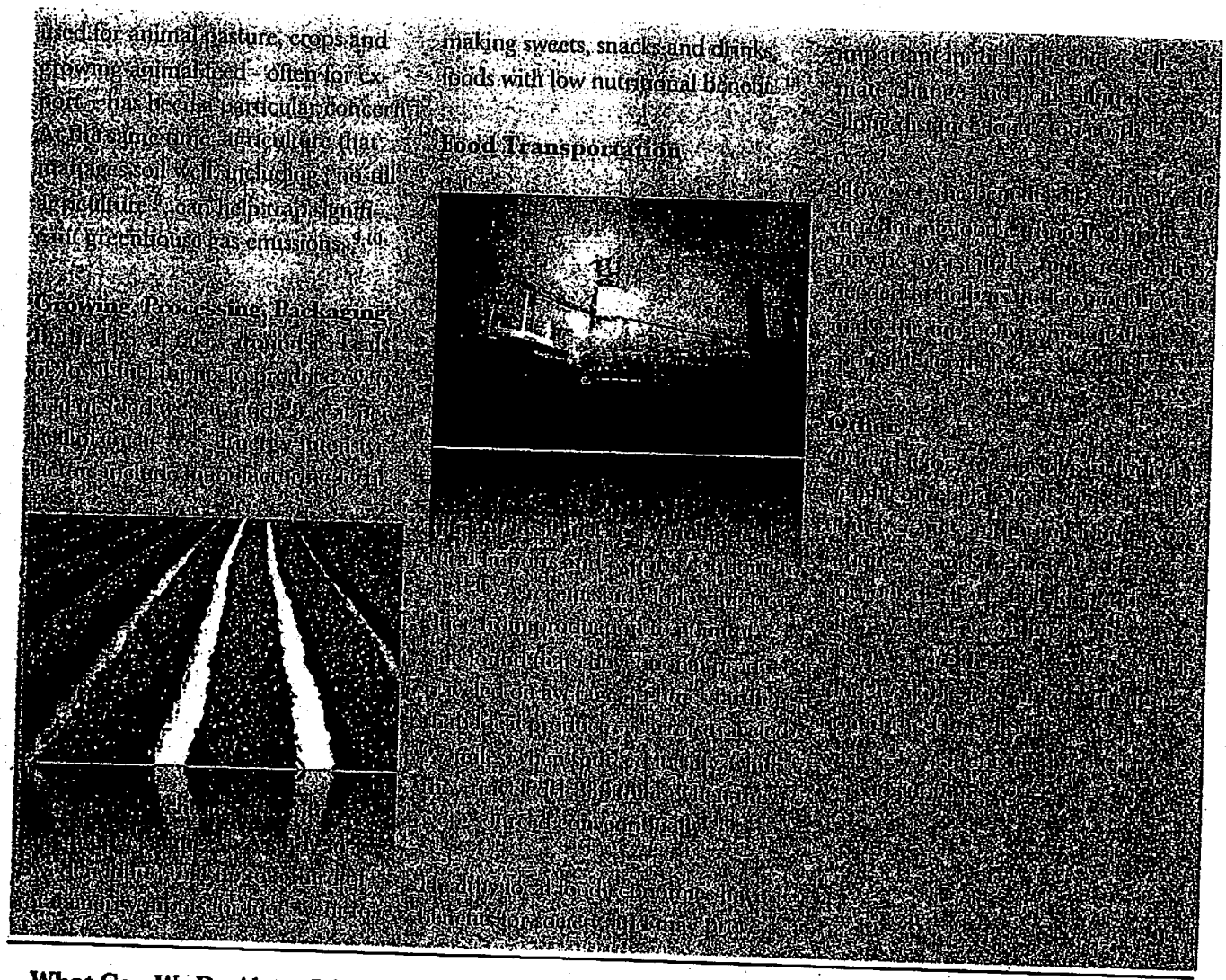
Livable Future

WHAT YOU EAT
AFFECTS CLIMATE CHANGE

Understanding causes and impacts of greenhouse gas emissions from food and agriculture can help you make choices to protect the environment. And what's better for the environment is often better for your own health. The following numbers give a sense of the impact of agriculture and livestock on climate change:

- Almost 1/3 of world human-caused GHGs are estimated to come from agriculture and forestry.[1]
- Livestock production alone is responsible for an estimated 18% of world GHGs, more than the contribution of transportation, according to the U.N. Food and Agriculture Organization.[2]
- The E.U. food system as a whole may cause 31% of E.U. consumption-related GHGs[3].





What Can We Do About It?

There is a great need for more life cycle analysis of U.S. food products to help clarify the impacts of various foods and production/distribution methods. But even after that research is done, the "best" answer will often depend on factors including where you live, the time of year, local conditions, weather, species/breed, energy efficiency of equipment, and so on, even down to exactly what was in a cow's feed.

Individuals, Food Businesses

- Eat less ruminant (cow) meat. This is probably the most important step you can take. One estimate suggests that U.S. meat consumption would need to drop by nearly 2/3 by 2050 to stabilize livestock-related greenhouse gas emissions. [25] While you may not be ready for such significant cuts, as a start, consider joining the *Meatless Monday* campaign to reduce your meat consumption by 15%,[26] and try to minimize using dairy as a protein substitute. Reducing meat consumption also benefits health in numerous ways. [27]
- Eat food that is seasonal, local, relatively unprocessed, and produced with fewer chemicals, to the extent feasible. Such foods tend to have lower carbon footprints, although the relationship is not consistent. Eating lower-chemical and less-

processed foods also has health benefits. [28]

- Reduce home food-related energy use: Get an Energy Star refrigerator, buy more long shelf-life foods and fewer frozen foods. Reduce your trips to the store. Cook in bulk.

- Reduce food packaging and plastic bags. Buy food with less packaging and bring your own bags to the store. Bring your own mug, water bottle, and utensils. Eat take-out less often.
- Eat less and waste less. Food waste and per capita food consumption continue to rise, with each unnecessary calorie contributing unnecessary greenhouse gas emissions.

Government

Support research on:

- How to produce food more sustainably
- How to adapt our agriculture and food systems to climate change
- Life cycle analysis that details greenhouse gas emissions from different foods
- Food carbon footprint labels

Promote "green" policy:

- Support local and sustainable food production through incentives such as grants, tax rebates, support programs, etc. Make it less cost-effective to produce unsustainably. Change policies including the farm bill to require agribusinesses to pay more of the costs of the greenhouse gas emissions and environmental damage they incur.
- Encourage less energy use, including by mandating energy efficiency in equipment, facilities and vehicles used in the food system, and by regulating reduced food packaging and use of plastic bags.
- Raise awareness about the climate change consequences of various diet choices.
- Promote National Conservation Reserve Program lands including those through farm bill policy, and increase disincentives for sourcing food and feed from previously forested lands.
- Better incorporate food and agriculture needs into national climate change mitigation policy.

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[1] Intergovernmental Panel on Climate Change (2007) Climate Change 2007: Synthesis Report. New York, NY: Cambridge Univ. Press.

[2] Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M, de Haan C. 2006. Livestock's long shadow: Environmental issues and options. Rome: Food and Agriculture Organization of the United Nations.

[3] Environmental impact of products (EIPRO): Analysis of the life cycle environmental impacts related to the total fintal consumption of the EU25, European Science and Technology Observatory and Institute for Prospective Technological studies, full report, May 2006.

[4] See footnote 2.

[5] Koneswaran G, Nierenberg D. Global Farm Animal Production and Global Warming: Impacting and Mitigating Climate Change. Environmental Health Perspectives. Jan. 31, 2008

[6] Garnett T. Meat and dairy production & consumption: Exploring the livestock sector's contribution to the UK's greenhouse gas emissions and assessing what less greenhouse gas intensive systems of production and consumption might look like. Nov. 2007.

[7] Nabuurs GJ; Masera O, K A, Benitez-Ponce P, Boer R, Dutschke M, et al. (2007) Forestry. In: Climate Change 2007: Mitigation Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. [B Metz, OR Davidson, PR Bosch, R Dave and LA Meyer, editors]. New York, NY: Cambridge Univ. Press.

[8] Reganold JP, Huggins DR. No-Till: How Farmers Are Saving the Soil by Parking Their Plows. Scientific American. June 30, 2008.

[9] U.S. Environmental Protection Agency (2008) Draft Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006.

[10] Paustian K, Antle JM, Sheehan J & Paul EA (2006) Agriculture's Role in Greenhouse Gas Mitigation. Arlington, VA: Pew Center on Global Climate Change.

[11] Pimentel D, Pleasant A, Barron J, Gaudioso J, Pollock N, Chae E, Kim Y, Lassiter A, Schiavoni C, Jackson A, Lee M, Eaton A. 2004. U.S. Energy Conservation and Efficiency: Benefits and Costs. Environment, Development and Sustainability 6: 279–305.

[12] Pimentel D and Pimentel M. Sustainability of meat-based and plant-based diets and the environment. American Journal of Clinical Nutrition. Sept. 2003; 78(3):660S-663S.

[13] See footnote 11.

[14] Carlsson-Kanyama A, Pipping Ekström M, Shanahan H. Food and life cycle energy inputs: consequences of diet and ways to increase efficiency. Ecological Economics. Volume 44, Issues 2-3, March 2003, 293-307

[15] USDA. Value of U.S. trade—agricultural, nonagricultural, and total—and trade balance, by calendar year. Available at: http://www.ers.usda.gov/Data/FATUS/. Accessed: March 24, 2008.

[16] Pirog, R, and Benjamin A. Checking the food odometer: Comparing food miles for local versus conventional produce sales to Iowa institutions. Leopold Center for Sustainable Agriculture, 2003.

[17] Collins A & Fairchild R (2007) Sustainable food consumption at a sub-national level: An ecological footprint, nutritional and economic analysis. J Environ Pol Plann 9, 5-30.

[18] Pretty JN, Ball AS, Lang T & Morison JIL (2005) Farm costs and food miles: An assessment of the full cost of the UK weekly food basket. Food Pol 1, 1-19.

[19] Saunders C, Barber A & Taylor G (2006) Food miles – Comparative energy/emissions performance of New Zealand's agriculture industry. Report No.: 285. Lincoln, NZ: Agribusiness and Economics Research Unit, Lincoln Univ.

[20] Brodt S (2007) Assessment of Energy Use and Greenhouse Gas Emissions in the Food System: A Literature Review. Agricultural Sustainability Institute, Univ. of California, Davis.

[21] Carlsson-Kanyama A. Climate change and dietary choices — how can emissions of greenhouse gases from food consumption be reduced? Food Policy, Vol. 23, No. 3/4, pp. 277–293, 1998

[22] Garnett T. Food refrigeration: What is the contribution to greenhouse gas emissions and how might emissions be reduced? Food & Climate Research Network Working Paper. At: http://www.fcrn.org.uk/frcnResearch/publications/PDFs/FCRN%20refrigeration%20paper%20final.pdf. Accessed March 24, 2008.

[23] Heller MC, Keoleian GA. Assessing the sustainability of the US food system: a life cycle perspective. Agricultural Systems. Volume 76, Issue 3, June 2003, Pages 1007-1041

[24] Kantor LS, Lipton K, Manchester A, Oliveira V. Estimating and Addressing America's Food Losses. Food and Consumer Economics Division, Economics Research Service, USDA. FoodReview, Vol. 20, No. 1, Jan-Apr, 1997.

[25] McMichael A, Powles J, Butler C, Uauy R. 2007. Food, food production, energy, climate change, and health. (Series on Energy and Health #5). The Lancet 370:55-65. Calculated based on US meat consumption data from: U.S. Department of Agriculture, Economic Research Service. Briefing Room: Food Consumption. Available: http://www.ers.usda.gov/Briefing/Consumption/ [accessed September 24, 2007.

[26] http://www.meatlessmonday.com

[27] Walker P, Rhubart-Berg P, McKenzie S, Kelling K, Lawrence RS. Public health implications of meat production and consumption. Public Health Nutr. 2005 Jun;8(4):348-56.

[28] Cordain L, Eaton SB, Sebastian A, Mann N, Lindeberg S, Watkins BA, O'Keefe JH, Brand-Miller J. Origins and evolution of the Western diet: health implications for the 21st century. Am J Clin Nutr 2005;81:341–54.

C1

Excerpt from "Can We Afford the Future? The Economics of a Warming World"
by Frank Ackerman

The problem of climate change is too important to leave to the experts. A sustainable low-emissions future must be built on a foundation of scientific and economic knowledge--but the challenge facing us is not only the development if new technologies. More immediately, we need to make much greater use of the technologies we already have. Our decisions about climate policy are, above all, ethical and political judgments about what we can and should do for each other today, and for the generations that will follow us....

A better understanding of climate economics rests on the four "bumper stickers...
Your grandchildren's lives are important. Climate change is a long-term problem, with impacts of current decisions extending over centuries to come. any economic analysis over such spans of time is dominated by the discount rate, expressing our political and ethical judgments about the well-being of future generations. The judgment that the future matters to us today implies a low discount rate, which endorses a broad range of climate policy initiatives. In contrast, a high discount rate, whatever its justification, endorses doing almost nothing about climate policy.

We need to buy insurance for the planet. We don't know exactly how bad the earth's climate will get -- and we don't know whether or when we will pass the tipping point for a catastrophic, irreversible event such as the loss of the Greenland ice sheet. the most likely outcomes of climate change look bad enough; the credible worst cases could involve the end of much of the human and other life on the planet. In this context, the details of the most likely outcomes are virtually irrelevant.; all that matters is preventing the worst cases from occurring. These worst cases appear to be more likely than the individual losses for which people routinely buy insurance. thus, climate policy can be thought of as life insurance for the planet.

Climate damages are too valuable to have prices. The cost-benefit approach stumbles when measuring and monetizing benefits; many of the most important benefits of climate protection are priceless. As a result, those benefits are either ignored or are valued with incoherent, partial approximations for the purpose of cost-benefit calculations. To make these calculations complete and meaningful, it would be necessary to put prices on human lives, endangered species, ecosystems and much more. The attempts to invent such prices have produced ludicrous results.

Some costs are better than others. On the other side of the ledger, , orthodox economic theory exaggerates the costs of emissions reduction by rejecting the possibility of costless ("no-regrets") emissions savings, ignoring the jobs and incomes crated by clean energy and efficiency expenditures, and assuming that the pace and direction of technological progress cannot be altered. In the imperfect real-world economy, the "good costs" of expenditures on climate mitigation are entirely preferable to the "bad costs" of physical damages caused by a worsening climate.

Turning toward policy solutions, the standard cost-benefit framework overlooks the question of equity. Some of the poorest countries of the world will be the first and hardest hit by the changing climate; they are among the least responsible for climate change, and the least able to pay for emissions reductions. Based on either historical emissions or current ability to pay, the

developed countries should pay the bulk of the global costs of climate protection--in particular, they should pay more than their current share of worldwide emissions. Suppose, then, that a formerly recalcitrant country experiences a miraculous change of heart and steps forward to do its part to solve the global problem. What should it do?

Climate policy includes a complex mixture of technology, economics, and politics.....
three errors to avoid:

* Don't expect to find a simple technical fix - there are good reasons for skepticism about the leading proposals [e.g ethanol, nuclear power, geoengineering.]
* Don't exaggerate the benefits of setting a price for carbon -- market mechanisms may facilitate other policy changes, but will not solve the problem alone.
* Don't doubt that we can ultimately change fast enough -- the first half of this century can and must, see a total transformation in the way we produce and use energy.

...Environmental advocates of previous years would be surprised at the extent to which public policy, especially in the U.S., now takes for granted the centrality of the market. The high points of environmental improvement in the late twentieth century were chieved by the Clean Air Act, the Clean Water Act, and other laws that would now be disparaged as "command and control" regulation. In contrast, twenty-first century climate policy seems sure to involve a leading role for either a carbon tax or a "cap and trade" system of tradable carbon emissions permits. Either one will result in a higher price for anything that causes carbon emissions, creating an incentive to seek alternatives with lower emissions.....

There are many .. more questions about the design of taxes and trading system. International coordination,,, verification of reported emissions and reductions is a formidable challenge, especially when one country pays for reductions in another country. Sequestration--storing carbon in forests, soils, or other places that keep it out of the atmosphere--poses its own set of additional difficulties for record-keeping and verification.
...how do we know that reliance on the market is the right way to organize an economy? [not as invisible hand]... the market does a credible job of decentralized processing of gigantic amounts of information... This is essential when ... there is a great variation on one side of the market or the other: consumers want diverse and changing products, and companies have differing cost structures and production capabilities. ... The success of the market depends on the existence of variability. ... Uniformity among producers or consumers is not going to happen spontaneously. But something closely related does happen at times if a society mobilizes all its resources for a single goal, the variation in individual objectives disappears--and so does the superior efficiency of the market. The mobilization of World War 2 is a case in point. Lester Brown has evoked the image of U.S. wartime mobilization as a model of what need to be done to address the environmental crisis, in fact, the mobilization was impressive on both sides of the Atlantic. soviet central planning, as bad as it was in meeting consumer demands in peacetime, was spectacularly good at rapidly shifting the nation's resources into military production--a fact that played no small part in determining the war's outcome. The U.S> economy ran in a more planned command and control mode during World War 2 than at any time before or since; automobile production was suspended for several years in order to produce more military vehicles, while gasoline and other goods were rationed.

D1

ECONOMICS

Risk Communication on Climate: Mental Models and Mass Balance

Public confusion about the urgency of reductions in greenhouse gas emissions results from a basic misconception.

John D. Sterman

The strong scientific consensus on the causes and risks of climate change stands in stark contrast to widespread confusion and complacency among the public (*1*, *2*). Why does this gulf exist, and why does it matter? Policies to manage complex natural and technical systems should be based on the best available scientific knowledge, and the Intergovernmental Panel on Climate Change (IPCC) provides rigorously vetted information to policy-makers. In democracies, however, the beliefs of the public, not only those of experts, affect government policy.

Effective risk communication is grounded in deep understanding of the mental models of policy-makers and citizens (*3*). What, then, are the principal mental models shaping people's beliefs about climate change? Studies show an apparent contradiction: Majorities in the United States and other nations have heard of climate change and say they support action to address it, yet climate change ranks far behind the economy, war, and terrorism among people's greatest concerns, and large majorities oppose policies that would cut greenhouse gas (GHG) emissions by raising fossil fuel prices (*1*, *2*).

More telling, a 2007 survey found a majority of U.S. respondents (54%) advocated a "wait-and-see" or "go slow" approach to emissions reductions. Larger majorities favored wait-and-see or go slow in Russia, China, and India (*1*, *2*). For most people, uncertainty about the risks of climate change means costly actions to reduce emissions should be deferred; if climate change begins to harm the economy, mitigation policies can then be implemented. However, long delays in the climate's response to anthropogenic forcing mean such reasoning is erroneous.

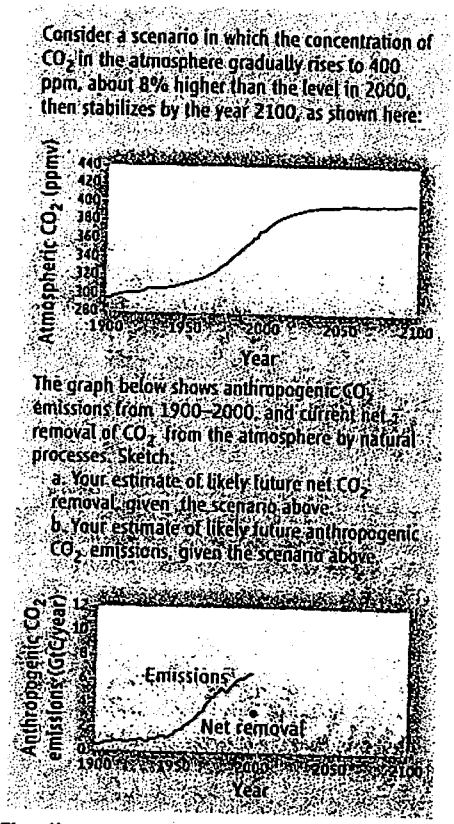
Wait-and-see works well in simple systems with short lags. We can wait until the teakettle whistles before removing it from the flame because there is little lag between the boil, the whistle, and our response. Similarly, wait-and-see would be a prudent response to climate change if there were short delays in the response of the climate system to intervention. However, there are substantial delays in every link of a long causal chain stretching from the implementation of emissions abatement policies to emissions reductions to changes in atmospheric GHG concentrations to surface warming to changes in ice sheets, sea level, agricultural productivity, extinction rates, and other impacts (*4*–*6*). Mitigating the risks therefore requires emissions reductions long before additional harm is evident. Wait-and-see policies implicitly presume the climate is roughly a first-order linear system with a short time constant, rather than a complex dynamical system with long delays, multiple positive feedbacks, and nonlinearities that may cause abrupt, costly, and irreversible regime changes (*7*, *8*).

Obviously, few people are trained in climatology or nonlinear dynamics, and public understanding of these topics is poor (*9*–*11*). But there is a deeper problem: poor understanding of stocks and flows—the concept of accumulation. Accumulation is pervasive in everyday experience: Our bathtubs accumulate the inflow of water through the faucet less the outflow through the drain, our bank accounts accumulate deposits less withdrawals, and we all struggle to control our weight by managing the inflows and outflows of calories through diet and exercise. Yet, despite their ubiquity, research shows that people have difficulty relating the flows into and out of a stock to the level of the stock, even in simple, familiar contexts such as bank accounts and bathtubs. Instead, people often assess system dynamics using a pattern-matching heuristic, assuming that the output of a system should "look like"—be positively correlated with—its inputs (*12*, *13*).

Although sometimes useful, correlational reasoning fails in systems with important accumulations. Since 1950, the U.S. federal budget deficit and national debt have risen dramatically and are highly correlated ($r = 0.84$, $P < 0.0001$). Correlational reasoning predicts that cutting the deficit would also cut the debt. However, because the national debt is a stock that accumulates the deficit, it keeps rising even if the deficit falls; debt falls only if the government runs a surplus.

Poor understanding of accumulation leads to serious errors in reasoning about climate change (see charts, left, and on page 533). Sterman and Booth Sweeney (*14*) gave 212 graduate students at the Massachusetts Institute of Technology (MIT) a description of the relationships among GHG emissions, atmospheric concentrations, and global mean temperature. The description was excerpted from the IPCC's "Summary for Policymakers" (SPM), a document intended for nonspecialists (*4*). Participants were then asked to sketch the emissions trajectory required to stabilize atmospheric CO_2. To highlight the stock-flow structure, participants were first directed to estimate future net removal of CO_2 from the atmosphere (net CO_2 taken up by the oceans and biomass), then draw the emissions path needed to stabilize atmospheric CO_2 [the SOM (*2*) provides details].

Knowledge of climatology or calculus is not needed to respond correctly. The dynamics are easily understood using a bathtub analogy in



The climate stabilization task. Subjects were first given an excerpt from the IPCC SPM explicitly describing the accumulation of CO_2 in the atmosphere [see (*2*)].

MIT Sloan School of Management, 30 Wadsworth Street, Cambridge, MA 02142, USA. E-mail: jsterman@mit.edu

which the water level represents the stock of atmospheric CO_2. Like any stock, atmospheric CO_2 rises when the inflow to the tub (emissions) exceeds the outflow (net removal), is unchanging when inflow equals outflow, and falls when outflow exceeds inflow. Participants were informed that anthropogenic CO_2 emissions are now roughly double net removal, so the tub is filling.

Yet, 84% drew patterns that violated the principles of accumulation. If emissions followed the path in the typical example shown, atmospheric CO_2 would continue to rise. Nearly two-thirds of the participants asserted that atmospheric GHGs can stabilize even though emissions continuously exceed removal—analogous to arguing a bathtub continuously filled faster than it drains will never overflow. Most believe that stopping the growth of emissions stops the growth of GHG concentrations. The erroneous belief that stabilizing emissions would quickly stabilize the climate supports wait-and-see policies but violates basic laws of physics.

Training in science does not prevent these errors. Three-fifths of the participants have degrees in science, technology, engineering, or mathematics (STEM); most others were trained in economics. Over 30% hold a prior graduate degree, 70% of these in STEM. These individuals are demographically similar to influential leaders in business, government, and the media, though with more STEM training than most.

It is tempting to respond to these discouraging results by arguing that poor public understanding of climate change is unimportant because policy should be informed by scientific expertise. Many call for a new Manhattan Project to address the challenge (*15*, *16*). The desire for such technical solutions is understandable. In 1939, scientists directly alerted the nation's leaders to developments in atomic physics, then, by focusing enough money and genius in the deserts of New Mexico, created nuclear weapons in just 6 years. Science has arguably never affected geopolitical outcomes more decisively.

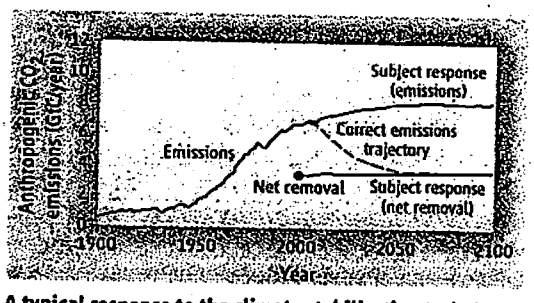
But a Manhattan Project cannot solve the climate problem (*17*). The bomb was developed in secret, with no role for the public. In contrast, reducing GHG emissions requires billions of individuals to cut their carbon footprints by, e.g., buying efficient vehicles, insulating their homes, using public transit, and, crucially, supporting legislation implementing emissions abatement policies. Changes in people's views and votes create the political support elected leaders require to act on the science. Changes in buying behavior create incentives for businesses to transform their products and operations. The public cannot be ignored.

The civil rights movement provides a better analogy for the climate challenge. Then, as now, entrenched interests vigorously opposed change. Political leadership and legislation often lagged public opinion and grass-roots action. Success required dramatic changes in people's beliefs and behavior, changes both causing and caused by the courageous actions of those who spoke out, registered voters, and marched in Washington and Selma (*18*).

Building public support for action on climate change is in many ways more challenging than the struggle for civil rights. Science is not needed to recognize the immorality of racism but is critical in understanding how GHG emissions can harm future generations. The damage caused by segregation was apparent to anyone who looked, but the damage caused by GHG emissions manifests only after long delays.

The scientific community has a vital role to play in building public understanding. First, the SPM is far too technical to change people's mental models. The IPCC should issue its findings in plain language. Second, clarity, while necessary, is not sufficient. When "common sense" and science conflict, people often reject the science (*3*). Even if people sincerely wish to mitigate the risks of climate change, wait-and-see will seem prudent if they misunderstand basic concepts of accumulation and erroneously believe that stopping the growth of emissions will quickly stabilize the climate. The implications go beyond the failure to understand accumulation. People's intuitive understanding of dynamics, including stocks and flows, time delays, and feedbacks, is poor (*11*). Analogous to common biases and errors in probabilistic reasoning (*19*), these errors are unlikely to be corrected merely by providing more information (*13*). We need new methods for people to develop their intuitive systems thinking capabilities. Bathtub analogies and interactive "management flight simulators" through which people can discover, for themselves, the dynamics of accumulation and impact of policies have proven effective in other settings (*20*) and may help here (*21*). Third, climate scientists should partner with psychologists, sociologists, and other social scientists to communicate the science in ways that foster hope and action rather than denial and despair. Doing so does not require scientists to abandon rigor or objectivity. People of good faith can debate the costs and benefits of policies to mitigate the risks of climate change, but policy should not be based on mental models that violate fundamental physical principles.

Of course, we need more research and technical innovation—money and genius are always in short supply. But there is no purely technical solution for climate change. For public policy to be grounded in the hard-won results of climate science, we must now turn our attention to the dynamics of social and political change.



A typical response to the climate stabilization task. Future emissions are erroneously correlated with atmospheric CO_2. Gold dashed line indicates the correct emissions path to stabilize CO_2 given the subject's estimate of net removal.

References and Notes

1. A. Leiserowitz, *Public Perception, Opinion and Understanding of Climate Change—Current Patterns, Trends and Limitations* (United Nations Development Programme, New York, 2007); http://hdr.undp.org/en/reports/global/hdr2007-2008/papers/leiserowitz_anthony.pdf.
2. Materials and methods are available as supporting material on *Science* Online.
3. M. G. Morgan, B. Fischhoff, A. Bostrom, C. J. Atman, *Risk Communication: A Mental Models Approach* (Cambridge Univ. Press, New York, 2002).
4. IPCC, *Climate Change 2007: The Physical Science Basis: Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, S. Solomon *et al.*, Eds. (Cambridge Univ. Press, Cambridge, 2007).
5. T. M. Wigley, *Science* 307, 1766 (2005).
6. G. A. Meehl *et al.*, *Science* 307, 1769 (2005).
7. R. B. Alley *et al.*, *Science* 299, 2005 (2003).
8. M. Scheffer *et al.*, *Nature* 413, 591 (2001).
9. B. Kasemir *et al.*, *Glob. Environ. Change* 10, 169 (2000).
10. W. Kempton, *Environment* 39, 12 (1997).
11. J. D. Sterman, *Syst. Dyn. Rev.* 10, 291 (1994).
12. L. Booth Sweeney, J. D. Sterman, *Syst. Dyn. Rev.* 16, 249 (2000).
13. M. A. Cronin *et al.*, *Org. Behav. Hum. Decis. Process.* 21 May 2008, 10.1016/j.obhdp.2008.03.003.
14. J. D. Sterman, L. Booth Sweeney, *Clim. Change* 80, 213 (2007).
15. G. Prins, S. Rayner, *Nature* 449, 973 (2007).
16. Searching Google for "Manhattan Project" AND "climate change" yields 164,000 hits (accessed 23 June 2008).
17. C.-J. Yang, M. Oppenheimer, *Clim. Change* 80, 199 (2007).
18. J. Williams, *Eyes on the Prize: America's Civil Rights Years, 1954–1965* (Viking, New York, 1987).
19. A. Tversky, D. Kahneman, *Science* 185, 1124 (1974).
20. J. D. Sterman, *Business Dynamics:* (Irwin/McGraw-Hill, New York, 2000).
21. Management Flight Simulators, http://scripts.mit.edu/~jsterman/Management_Flight_Simulators_(MFS).html.

22. Financial support from the Project on Innovation in Markets and Organizations at the MIT Sloan School.

Supporting Online Material
www.sciencemag.org/cgi/content/full/322/5901/532/DC1

10.1126/science.1162574

E1

Testimony to Cambridge City Council
Special meeting on Science and the Climate Emergency
Sept. 24, 2009

As Rajendra Pachauri, chairman of the Intergovernmental Panel on Climate Change said on Tuesday, "Science leaves us no room for inaction." Yet science can offer us no guide or blueprint for action. This we must somehow figure out through the messy processes of politics, producing goods and services, earning a living, and living our lives.

The forces and causes of climate change are global, to build a movement we must each start by understanding why it matters to us. If you're old enough to draw Social Security, as I am, you might think of a grandchild, as I do. If you're younger, you might be concerned for your children's future, and if you're just starting out in life yourself, you may see climate change as a direct threat to yourself. We need to take the climate emergency *personally*.

We need to understand that the CO2 emissions that cause most climate change are also very personal, which I want to illustrate with this 4 kg. bag of hardwood charcoal – fairly pure carbon -- that I bought yesterday at a market. The point is not that grilling with charcoal is somehow any more harmful than any of hundreds of other things we do in our lives. It is to show more concretely what we are doing when we "emit CO2." Every year the U.S. emits an average of about 20 tons of CO2 per person. When you take that down to the daily level and count just the carbon part of the CO2, it amounts to almost three bags of this stuff per person every day that we pump into the atmosphere, along with a larger weight of oxygen, and most of it stays there for many years, warming the earth.

Even if most of us in Cambridge are responsible for less than average because we live in a city and may be environmentally conscious, we need to understand this as a problem similar to that of second-hand smoke. Directly and indirectly we are all puffing out much more than the climate can handle.

With motivation and a sense of personal responsibility for the future, we can make changes in the way we live, work, and play, in our way of life, to respond to the emergency we have, so far unknowingly, created. These changes will much easier and more congenial if we make them together as a community.

For this reason, Joanna Herlihy, Steve Wineman, and I, with input from a dozen other activists, have prepared a Climate Emergency Awareness and Mobilization Plan for consideration by the City Council.

This plan proposes three initiatives to be taken by the City Council to build on and broaden the work of City staff, the Climate Protection Action Committee and the City's Climate Protection Plan,

1. to greatly increase local awareness by all Cambridge residents of the Climate Emergency, its causes, and the local contribution,
2. to mobilize new support for a citywide goal for reducing CO2 emissions, as called for in the City's 2002 Climate Protection Plan, in a special two-month conference to be convened by the Mayor and to include the widest possible diversity of constituencies and

interests, including the full range of voluntary membership organizations, the CPAC, faith-based organizations, neighborhood and community groups, environmental organizations and climate advocacy groups, small and large businesses, condo associations, landlords, tenants, labor unions, educational institutions, school parents, teachers, and students, as well as artists.

This proposal recognizes that a citywide emission goal cannot be met without a much more inclusive process than we have had so far. and

3. to take local leadership by making continued and rapid reductions in greenhouse gas emissions from municipal facilities and activities.

Of course, because the scale of the climate emergency and the need for action is global, no amount of local action by itself will be enough to turn back the forces of climate change. Actions at the state, national, and international level are needed just as urgently, so se need to do everything we can to encourage and demand these actions as well.

As a center of scientific knowledge and progress, Cambridge is a natural center from which to start a regional, national, and international movement of grass-roots awareness and mobilization to meet the global scale of the problem.

F1

Open Letter to the Cambridge City Council for the Special Hearing on the Climate Emergency, September 24, 2009

We have been working for several months to organize speakers and coordinate plans for the City Council's September 24th special meeting and hearing on the climate emergency. We anticipate that the speakers, Dr. Melanie Fitzpatrick of the Union of Concerned Scientists, Dr. Jill Stein of Physicians for Social Responsibility, Dr. Frank Ackerman of the Stockholm Environmental Institute at Tufts University and Dr. John Sterman of MIT Sloan School of Management, will address the nature of the emergency and the urgency of a local response to it. We expect the Council and the public will want to respond to their testimony in an appropriate manner. *Our group has therefore prepared a draft "Climate Emergency Awareness and Mobilization Plan," which we offer for consideration by the City Council.*

This plan proposes three major initiatives to be taken by the City Council to build on and broaden the work of City staff, the Climate Protection Action Committee and the City's Climate Protection Plan,

1. to greatly increase local **awareness** by Cambridge residents of the Climate Emergency, its causes, and the local contribution,
2. to **mobilize** broad support for and participation in a citywide goal for reducing locally measured CO2 emissions, as called for in the City's Climate Protection Plan, in a two-month conference, and
3. to take leadership by **acting** to ensure rapid reductions in CO2 emissions from municipal facilities and activities.

The proposals recognize and build on the efforts of City staff, the City's Climate Protection Action Committee, and the Cambridge Energy Alliance. They envision an important continuing role for the CPAC, and the programs of the CEA will provide a foundation to achieve rapid reductions in local CO2 emissions.

At the same time the proposals recognize that a citywide emission goal cannot be met without a much broader, more diverse and inclusive process than the CPAC has created. In fact, this need is recognized by the CPAC in its recent report "Interim Recommendations on Moving Cambridge Forward on Climate Protection":

> **Broad support for bold action is missing.** To be successful, there must be a critical mass of public support across Cambridge for bold action related to the climate crisis.

With broad participation, good leadership – by a former mayor or person of similar stature – and adequate technical support, this conference could both accomplish a review and revision of the Climate Plan and build the consensus and commitment that are essential to achieve a new community-wide goal.

Even if this extraordinary conference succeeds and ultimately achieves locally measurable reductions in CO2 emissions in future years, this must not be considered a sufficient

response to the emergency. We cannot afford to delay urgently needed initiatives in other arenas to respond to the climate emergency – to reduce the substantial amount of emissions that are locally generated but *not* readily measured (e.g., to produce goods and services that are consumed in Cambridge), to build a more ecologically sustainable regional economy, to start a movement of climate action that will spread across the Commonwealth and beyond, and to lobby for state and federal legislation to enable and support these efforts.

We urge the Council itself to take leadership by integrating sustainability and resilience into its own goals, enacting wise ordinances, policies, and regulations to support these goals, and lobbying Congress and the state for strong climate legislation that will enable and amplify our local efforts. At the same time, it will be important for the Council and the City to recognize and support the initiatives of community organizations and the growing climate action movement that are also essential for an effective local response to the climate emergency.

Respectfully submitted,

Climate Emergency Awareness and Mobilization Working Group
Joanna Herlihy <joanna_herlihy@yahoo.com>
John Pitkin <john_pitkin@earthlink.net> and
Steve Wineman swineman@gis.net

Proposed Climate Emergency Awareness and Mobilization Plan for Cambridge

For consideration by the Cambridge City Council, September 24, 2009

1. Promote **awareness** of the Climate Emergency, its causes, and the local contribution to the problem among Cambridge residents of all ages, those who work or study in Cambridge, and city employees by all means at the City's disposal.

    - Conduct a public education campaign about climate change, humans' role in causing it, the risks to humanity, the carbon cycle, and Cambridge's response.
    - Support and facilitate public dialogue about the climate emergency and community response.
    - Encourage preparedness to respond to expected near and longer term impacts of the Climate Emergency

2. Convene a two-month citywide Mayor's conference to propose and endorse revised citywide goals for rapid, sustained reductions in 2012 and following years for CO2 and other greenhouse gas emissions due to local use of local electricity, natural gas, and fuel oil, transportation and solid waste disposal. This goal is to replace the

goals in the City's 2002 Climate Protection Plan which is now obsolete due to the projected *increase* of 29 % from 1990 to 2010 while a 20% *decrease* was called for in the 2002 Plan. The conference shall also propose new measures and municipal regulations, fees, and policies necessary and appropriate to attain these goals, including

- Organization, staffing, and funding for the City to support and administer the community-wide effort to meet the goals, and
- Provisions for collection and timely, transparent reporting of data to measure progress toward the municipal emissions reduction goals and the contributions of households, landlords, businesses, and institutions.

- The Climate Emergency conference is to be convened by the Mayor with members appointed to include members of the Climate Protection Action Committee as well as representatives of the widest possible diversity of constituencies and interests, including the full range of voluntary membership organizations, including faith-based organizations, neighborhood and community organizations, environmental organizations and climate advocacy groups, small and large businesses, condo associations, landlords, tenants, public housing tenants, labor unions, educational institutions, school parents, teachers, students, and artists.
- It is to be supported by staff from the Mayor's office, City Council staff, and the Community Development Department.

- The new goals and other recommendations, to be adopted and endorsed by majority vote of the conference members, will be delivered to the City Council by the end of 2009 for consideration by the City Council in 2010. Goals and other recommendations that are not adopted by the City Council within three months of submittal will be submitted to the voters of Cambridge as ballot questions no later than the General Election in November 2010.

3. Adopt and promote **municipal policies**, practices, and regulations, and enter into cooperative agreements with other governments, businesses, institutions and other private entities to achieve speedy, substantial reduction in emissions of CO2 and other greenhouse gases. The effect of these policies, practices, regulations and agreements must be to rapidly and progressively reduce net emissions from municipal facilities and operations *as well as* those beyond the City's borders that are directly linked to facilities located in Cambridge, including but not limited to
    i. generation and distribution of electric power,
    ii. sales of fuels for local use,
    iii. solid waste management,
    iv. movement of people and goods,
    v. water supply, sewerage, and storm water management,
    vi. food supply,
    vii. construction, and
    viii. operation of existing structures.

F4

- Re-evaluate City Council goals in view of the climate emergency and with reference to the Climate Protection Plan of 2002 to promote values of sustainability and community resilience in all sectors of Cambridge.

- Reduce CO2 emissions due to municipal operations in 2010 to 20% below the 2005 benchmark, as called for in a 2005 Policy Order.

- Achieve reductions in CO2 emissions due to energy use by the Cambridge School Department facilities and operations beginning in the 2010-2011 school year and attain a 20 % reduction by 2013-2014.

- Set limits on municipal and School Department CO2 emissions for future years to ensure continued annual reductions.

- Extend and improve municipal tracking and reporting of municipal greenhouse gas emissions, include achievement of CO2 emissions targets as criterion for evaluating the performance of the City Manager and Superintendent of Schools, and consider instituting a municipal CO2 emission budget.

- Advocate for climate protection policies and targets at state and national level that are consistent with the scientific findings showing a need for prompt, substantial reduction in emissions of CO2 and other greenhouse gases.

- Institute a program to systematically improve preparedness for anticipated near and longer term impacts of climate change.

We make these recommendations in the belief that we can make large and rapid enough reductions in CO2 emissions to make a difference only if we are willing to make some changes in the way we live, work, and play and in our lifestyle that reduce our consumption and use of natural resources. These changes will easier and more congenial if we make them together as a community and recognize that they will also offer many new opportunities for strengthening and building our local economy.

F5

Some links for further reading on climate change and response:

Cambridge City Climate website
http://www.cambridgema.gov/climate

Climate Science
http://data.giss.nasa.gov/ (hard science)
http://www.realclimate.org

Local Impacts of Global Warming
http://environment.tufts.edu/?pid=41
http://www.psr.org/assets/pdfs/more-extreme-heat-waves.pdf

Environmental Esonomics
http://www.grist.org/article/harris-economists
http://www.neweconomics.org
http://www.grist.org/article/harris-economists
http://www.sei-us.org/climate-and-energy/climate-economics.html

Simulations for understanding CO2 accumulation in the atmosphere
http://www.sustainer.org/tools_resources/climatebathtubsim.html
http://sustainer.org/climate_change/simulations.html
http://www.climateinteractive.org/simulations/bathtub

Local projects
http://www.heetma.com/index.php
http://www.gogreenstreets.org/
http://www.greencambridge.org
http://www.citysprouts.org
http://cambridge-climate.ning.com
http://ecoethics.net/hsev/2001-2002/index.htm