

Testimony of Dr. Peter H. Gleick for
The Select Committee on Energy Independence & Global Warming Hearing
“Not Going Away: America’s Energy Security, Jobs and Climate Challenges.”
Wednesday, December 1, 2010

Chairman Markey, Ranking Member Sensenbrenner, and Select Committee members. Thank you for the opportunity to testify today on America’s ongoing struggle to deal with increasingly severe climate challenges and the risks and opportunity those challenges pose for the nation’s energy and economic security.

I am the co-founder and director of the Pacific Institute in Oakland, California, an independent, non-partisan research and policy center addressing the questions of environment, economic development, and international security. My background and training is in the fields of environmental science, engineering, hydrology, and climatology. I am an elected member of the U.S. National Academy of Science. My full biography has been provided to the Subcommittee staff. My research on climate issues is supported by foundations and state and local agencies; none of my climate work is funded by corporations or federal agencies.

I’d like to make the following six points:

1. The science of climate change is clear and convincing that climate change is happening, happening rapidly, and happening because of human activities.

Scientific conclusions derive from an understanding of basic laws supported by laboratory experiments, observations of nature, and mathematical and computer modeling. Based on these lines of evidence, the science of climate change is compelling and strong, and has been for over two decades. That science tells us that emissions of greenhouse gases from human activities not only *will* change the climate, but are *already* changing the climate. The evidence is now incontrovertible, even if a small minority cannot accept it.

Like all human beings, scientists make mistakes, but the scientific process is designed to find and correct them. This process is inherently adversarial — scientists build reputations and gain recognition not only for supporting conventional wisdom, but even more so for demonstrating that the scientific consensus is wrong and that there is a better explanation. That’s what Galileo, Pasteur, Darwin, and Einstein did. But no one who argues against the science of climate change has ever provided an alternative scientific theory that adequately satisfies the observable evidence or conforms to our understanding of physics, chemistry, and climate dynamics.

The science tells us – and has been telling us for over two decades – that:

- The planet is warming due to increased concentrations of heat-trapping gases in our atmosphere.
- Most of the increase in the concentration of these gases over the last century is due to human activities, especially the burning of fossil fuels and deforestation.

- Natural causes always play a role in changing Earth's climate, but are now being overwhelmed by human-induced changes.
- Warming the planet will cause many other climatic patterns to change at speeds unprecedented in modern times, including increasing rates of sea-level rise and alterations in the hydrologic cycle. Rising concentrations of carbon dioxide are making the oceans more acidic. And many other changes are seen to be happening.
- The combination of these complex climate changes threatens coastal communities and cities, human health, our food and water supplies, marine and freshwater ecosystems, forests, high mountain environments, and far more.

2. Despite continued efforts on the part of a small group of climate skeptics and deniers to mislead, misrepresent, and misuse the science, our understanding of human-caused climate change continues to strengthen and improve.

Here, in a nutshell, is **the best argument against global climate change**:

There isn't one.

There is nothing remotely identified in recent efforts to discredit climate science that changes these fundamental conclusions about climate change. Every recent independent review supports the message of my first point. A recent letter from 255 members of the U.S. National Academy of Sciences summarizes this issue and is attached as an addendum to this testimony.¹

Climate change deniers have been trying hard to confuse the public and policy makers about climate change. But their claims about climate science and what we see in the world around us are based on ideology and bad science, not reality. Those few extreme policy makers and pundits who continue to deny the realities of climate change often point to "uncertainty" in the observations, models, and climate system itself that make perfect predictions impossible. Of course, climate scientists also talk about uncertainty all of the time -- it is a characteristic of the science, not an excuse for politicians to avoid taking action. What those who deny the reality of climate change don't acknowledge, in an example of selective one-sided argumentation, is that uncertainty cuts both ways. While there is always a non-zero possibility that climate changes will fall on the less severe end of the scale, there is a comparable possibility that climate changes will be far worse than we expect, with far more serious consequences to the planet.

And that's what's happening.

There is growing evidence from the real world that climate changes are accelerating faster than we originally feared and that impacts -- already appearing -- will be more widespread and severe than expected. This makes the arguments against taking actions against climate change not just wrong, but dangerous.

It's too late to avoid serious, damaging, human-induced climate change. For a variety of reasons ranging from ignorance to political ideology to commercial self-interest to inertia to intentional

¹ This letter was published in [Science](#) magazine on May 7, 2010.

misrepresentations and misdirections on the part of a small number of committed climate deniers, the United States and the rest of the world have waited too long to act to cut the emissions of damaging greenhouse gas pollutants. We are now committed to irreversible long-term and inevitably damaging consequences ranging from rapidly rising sea levels, far greater heat stress and damages, disappearing glaciers and snowpack, more flooding and droughts, and far, far more. It is still not too late, however, to slow the rate of these changes and to reduce the ultimate cost to the U.S. economy and public health.

3. Every major international scientific organization working in the areas of geophysics, climate, geology, biology, chemistry, physics, ecology, atmospheric sciences, and meteorology agrees that humans are changing the climate.

This includes every single National Academy of Sciences, including of course, the US NAS. (See the attached list.) Conversely, no scientific body of national or international standing rejects the findings of human-induced effects on global warming. Ignoring the massive weight of this consensus is irresponsible.

4. The nation now faces only three options -- mitigation, adaptation, and suffering.

That is to say we can only (1) work to reduce the severity of future climate change through efforts to cut or mitigate emissions of greenhouse pollutants; (2) work to adapt to unavoidable climatic change already locked into the system; and (3) suffer the consequences of changing climate. The only question is how much of each option we do. We are now faced with unavoidable climate changes because we (the world) have delayed too long to implement policies to reduce greenhouse gas emission. The impacts of unavoidable climate change are going to be significant and will grow in extent and severity the longer we continue to delay efforts to reduce greenhouse gases. In fact, it appears that many of our estimates of the rate of climate change have been too *low*, not too *high*, and climate changes are happening *faster* than expected.

As a result, in twenty more years, the Earth will be even hotter, sea levels will be higher and rising faster, water and food resources will be increasingly stressed, extinction rates will accelerate, and our forced expenditures for climate adaptation will be far, far greater than they would otherwise have been if efforts to reduce greenhouse gas emissions had been implemented earlier.

5. A wide range of impacts (ranging from sea level rise to changing water availability to altered crop production to human health effects from heat and spreading tropical diseases, etc.) are already beginning to appear.

These impacts will be costly to society -- very costly. Indeed, probably far more costly than efforts to reduce emissions of greenhouse gases. But we tend to focus on the latter costs alone, not the costs of adaptation and suffering.

For example, at the request of three California state agencies, the Pacific Institute recently completed a [comprehensive assessment of the vulnerabilities of the California coast, population,](#)

[and infrastructure to accelerating sea-level rise](#). Over \$100 billion in infrastructure (including buildings, power plants, airports, roads, wastewater treatment plants, hospitals, schools, police stations, and much more) and a population of nearly 500,000 people are currently at risk of increased coastal flooding, and the research estimated that adaptation costs just to protect existing infrastructure will run around \$15 billion, plus high annual costs to maintain these protections. Other major areas and populations simply cannot be realistically protected and will have to be abandoned, with people forced to move over time. And this is just one small piece of the coming threats for one small part of the country. It is vital that efforts still be made to reduce greenhouse gas emissions, but we must also work to adapt to unavoidable impacts.

6. The good news is that there are smart and effective things that can be done immediately, with a focus on energy policy, land use policy, and water policy.

In particular, we need a national energy policy focused on renewable, non-carbon energy sources, with federal financing, tax credits, and loan guarantees for renewable energy and improved transmission. We need environmental standards for greenhouse gas emissions, including not just carbon dioxide but methane, hydrofluorocarbons (HFCs), and black carbon soot. And we need to begin the process of adapting to unavoidable impacts through smarter land-use and water-use planning.

If we act to slow climate change, and the impacts turn out to be less severe than we predict, we will still have reduced our emissions of pollutants, cut our economic dependence on fossil fuels from countries that fund extremism and terror, and boosted our economy with new green technologies and jobs. But if we do nothing, and climate changes are indeed more severe than we expect, we've made things far worse than they needed to be.

We've wasted more than two decades, passing the problem on to the next set of lawmakers and the next generations. Congress should take responsibility now and do its job.

Thank you for the opportunity to provide testimony to you today. I am happy to answer questions.

Addendum A to the Testimony of Dr. Peter H. Gleick for
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Statements of Major Scientific Organizations on Climate Change²

Every major international scientific organization working in the areas of geophysics, climate, geology, biology, health, chemistry, physics, ecology, atmospheric sciences, and meteorology agrees that humans are changing the climate. This includes every single National Academy of Sciences, including the US National Academies. The partial list below summarizes the findings of these organizations, along with selections from those scientific and policy statements.

Academies of Science

Since 2001, all of the world’s leading national science academies have issued declarations confirming anthropogenic global warming and urging the nations of the world act to reduce emissions of greenhouse gases. Signatories of such statements include the science academies of:

African Academy of Sciences
Australia
Belgium
Brazil
Cameroon
Royal Society of Canada
the Caribbean
China
Institut de France
Ghana
Leopoldina of Germany
Indonesia
Ireland
Accademia nazionale delle scienze of Italy
India
Japan
Kenya
Madagascar
Malaysia
Mexico
Nigeria
Royal Society of New Zealand

² Scientific organizations regularly issue updated and new science and policy statements. Check with each organization for the most current updates and for the complete text of each statement.

Russian Academy of Sciences
Senegal
South Africa
Sudan
Royal Swedish Academy of Sciences
Tanzania
Turkey
Uganda
The Royal Society of the United Kingdom
the United States
Zambia
Zimbabwe

Statements of The National Science Academies of the G8+5 nations (Brazil, Canada, China, France, Germany, Italy, India, Japan, Mexico, Russia, South Africa, the United Kingdom, and the United States).

It is unequivocal that the climate is changing, and it is very likely that this is predominantly caused by the increasing human interference with the atmosphere. These changes will transform the environmental conditions on Earth unless counter-measures are taken. (2007 Joint Academies Statement.)

The IPCC 2007 Fourth Assessment of climate change science concluded that large reductions in the emissions of greenhouse gases, principally CO₂, are needed soon to slow the increase of atmospheric concentrations, and avoid reaching unacceptable levels. However, climate change is happening even faster than previously estimated; global CO₂ emissions since 2000 have been higher than even the highest predictions, Arctic sea ice has been melting at rates much faster than predicted, and the rise in the sea level has become more rapid. Feedbacks in the climate system might lead to much more rapid climate changes. The need for urgent action to address climate change is now indisputable. (2009 Joint Academies Statement.)

Statement of the Network of African Science Academies

[The thirteen signatories were the science academies of Cameroon, Ghana, Kenya, Madagascar, Nigeria, Senegal, South Africa, Sudan, Tanzania, Uganda, Zambia, Zimbabwe, as well as the African Academy of Sciences.]

A consensus, based on current evidence, now exists within the global scientific community that human activities are the main source of climate change and that the burning of fossil fuels is largely responsible for driving this change.

Statements of Major Global Scientific Academies, Societies, and Associations

American Academy of Pediatrics

There is broad scientific consensus that Earth's climate is warming rapidly and at an accelerating rate. Human activities, primarily the burning of fossil fuels, are very likely (>90% probability) to be the main cause of this warming. Climate-sensitive changes in ecosystems are already being observed, and fundamental, potentially irreversible, ecological changes may occur in the coming decades. Conservative environmental estimates of the impact of climate changes that are already in process indicate that they will result in numerous health effects to children.

Anticipated direct health consequences of climate change include injury and death from extreme weather events and natural disasters, increases in climate-sensitive infectious diseases, increases in air pollution-related illness, and more heat-related, potentially fatal, illness. Within all of these categories, children have increased vulnerability compared with other groups.

American Association for the Advancement of Science (AAAS)

The scientific evidence is clear: global climate change caused by human activities is occurring now, and it is a growing threat to society. Accumulating data from across the globe reveal a wide array of effects: rapidly melting glaciers, destabilization of major ice sheets, increases in extreme weather, rising sea level, shifts in species ranges, and more. The pace of change and the evidence of harm have increased markedly over the last five years. The time to control greenhouse gas emissions is now.

American Association of Wildlife Veterinarians

There is widespread scientific agreement that the world's climate is changing and that the weight of evidence demonstrates that anthropogenic factors have and will continue to contribute significantly to global warming and climate change. It is anticipated that continuing changes to the climate will have serious negative impacts on public, animal and ecosystem health due to extreme weather events, changing disease transmission dynamics, emerging and re-emerging diseases, and alterations to habitat and ecological systems that are essential to wildlife conservation. Furthermore, there is increasing recognition of the inter-relationships of human, domestic animal, wildlife, and ecosystem health as illustrated by the fact the majority of recent emerging diseases have a wildlife origin.

American Chemical Society

Careful and comprehensive scientific assessments have clearly demonstrated that the Earth's climate system is changing rapidly in response to growing atmospheric burdens of greenhouse gases and absorbing aerosol particles. There is very little room for doubt that observed climate trends are due to human activities. The threats are serious and action is urgently needed to mitigate the risks of climate change.

The reality of global warming, its current serious and potentially disastrous impacts on Earth system properties, and the key role emissions from human activities play in driving these phenomena have been recognized by earlier versions of this ACS policy statement, by other major scientific societies, including the American Geophysical Union, the American Meteorological Society, and the American Association for the Advancement of Science, and by the U. S. National Academies and ten other leading national academies of science.

American College of Preventive Medicine

The American College of Preventive Medicine (ACPM) accept the position that global warming and climate change is occurring, that there is potential for abrupt climate change, and that human practices that increase greenhouse gases exacerbate the problem, and that the public health consequences may be severe.

American Geophysical Union

The Earth's climate is now clearly out of balance and is warming. Many components of the climate system—including the temperatures of the atmosphere, land and ocean, the extent of sea ice and mountain glaciers, the sea level, the distribution of precipitation, and the length of seasons—are now changing at rates and in patterns that are not natural and are best explained by the increased atmospheric abundances of greenhouse gases and aerosols generated by human activity during the 20th century.

American Medical Association

The AMA states that they support “the findings of the latest Intergovernmental Panel on Climate Change report, which states that the Earth is undergoing adverse global climate change and that these changes will negatively affect public health...” and “educating the medical community on the potential adverse public health effects of global climate change, including topics such as population displacement, flooding, infectious and vector-borne diseases, and healthy water supplies.”

American Meteorological Society Council Statement

There will be inevitable climate changes from the greenhouse gases already added to the Earth system...there is adequate evidence from observations and interpretations of climate simulations to conclude that the atmosphere, ocean, and land surface are warming; that humans have significantly contributed to this change; and that further climate change will continue to have important impacts on human societies, on economies, on ecosystems, and on wildlife through the 21st century and beyond. Focusing on the next 30 years, convergence among emission scenarios and model results suggest strongly that increasing air temperatures will reduce snowpack, shift snowmelt timing, reduce crop production and rangeland fertility, and cause continued melting of the ice caps and sea level rise... Policy choices in the near future will determine the extent of the impacts of climate change. Policy decisions are seldom made in a context of absolute certainty. Some continued climate change is inevitable, and the policy debate should also consider the best

ways to adapt to climate change. Prudence dictates extreme care in managing our relationship with the only planet known to be capable of sustaining human life.

American Public Health Association Policy Statement

The long-term threat of global climate change to global health is extremely serious and the fourth IPCC report and other scientific literature demonstrate convincingly that anthropogenic GHG emissions are primarily responsible for this threat...US policy makers should immediately take necessary steps to reduce US emissions of GHGs, including carbon dioxide, to avert dangerous climate change.

American Physical Society

Emissions of greenhouse gases from human activities are changing the atmosphere in ways that affect the Earth's climate. Greenhouse gases include carbon dioxide as well as methane, nitrous oxide and other gases. They are emitted from fossil fuel combustion and a range of industrial and agricultural processes.

The evidence is incontrovertible: Global warming is occurring. If no mitigating actions are taken, significant disruptions in the Earth's physical and ecological systems, social systems, security and human health are likely to occur. We must reduce emissions of greenhouse gases beginning now.

American Quaternary Association

Few credible Scientists now doubt that humans have influenced the documented rise of global temperatures since the Industrial Revolution..." "the growing body of evidence that warming of the atmosphere, especially over the past 50 years, is directly impacted by human activity."

American Society for Microbiology

In 2003, the ASM issued a policy report in which they recommend "reducing net anthropogenic CO₂ emissions to the atmosphere" and "minimizing anthropogenic disturbances of" atmospheric gases:

Carbon dioxide concentrations were relatively stable for the past 10,000 years but then began to increase rapidly about 150 years ago...as a result of fossil fuel consumption and land use change. Of course, changes in atmospheric composition are but one component of global change, which also includes disturbances in the physical and chemical conditions of the oceans and land surface. Although global change has been a natural process throughout Earth's history, humans are responsible for substantially accelerating present-day changes. These changes may adversely affect human health and the biosphere on which we depend. Outbreaks of a number of diseases, including Lyme disease, hantavirus infections, dengue fever, bubonic plague, and cholera, have been linked to climate change.

Australian Coral Reef Society

There is almost total consensus among experts that the earth's climate is changing as a result of the build-up of greenhouse gases. The IPCC (involving over 3,000 of the world's experts) has come out with clear conclusions as to the reality of this phenomenon. One does not have to look further than the collective academy of scientists worldwide to see the string (of) statements on this worrying change to the earth's atmosphere.

There is broad scientific consensus that coral reefs are heavily affected by the activities of man and there are significant global influences that can make reefs more vulnerable such as global warming...It is highly likely that coral bleaching has been exacerbated by global warming.

Australian Institute of Physics

The AIP supports a reduction of the green house gas emissions that are leading to increased global temperatures, and encourages research that works towards this goal.

Research in Australia and overseas shows that an increase in global temperature will adversely affect the Earth's climate patterns. The melting of the polar ice caps, combined with thermal expansion, will lead to rises in sea levels that may impact adversely on our coastal cities. The impact of these changes on biodiversity will fundamentally change the ecology of Earth.

Australian Medical Association

The world's climate – our life-support system – is being altered in ways that are likely to pose significant direct and indirect challenges to health. While 'climate change' can be due to natural forces or human activity, there is now substantial evidence to indicate that human activity – and specifically increased greenhouse gas (GHGs) emissions – is a key factor in the pace and extent of global temperature increases.

Health impacts of climate change include the direct impacts of extreme events such as storms, floods, heatwaves and fires and the indirect effects of longer-term changes, such as drought, changes to the food and water supply, resource conflicts and population shifts.

Increases in average temperatures mean that alterations in the geographic range and seasonality of certain infections and diseases (including vector-borne diseases such as malaria, dengue fever, Ross River virus and food-borne infections such as Salmonellosis) may be among the first detectable impacts of climate change on human health.

Human health is ultimately dependent on the health of the planet and its ecosystem. The AMA believes that measures which mitigate climate change will also benefit public health. Reducing GHGs should therefore be seen as a public health priority.

Australian Meteorological and Oceanographic Society

Global climate change and global warming are real and observable ... It is highly likely that those human activities that have increased the concentration of greenhouse gases in the atmosphere have been largely responsible for the observed warming since 1950. The warming associated with increases in greenhouse gases originating from human activity is called the enhanced greenhouse effect. The atmospheric concentration of carbon dioxide has increased by more than 30% since the start of the industrial age and is higher now than at any time in at least the past 650,000 years. This increase is a direct result of burning fossil fuels, broad-scale deforestation and other human activity.

Canadian Foundation for Climate and Atmospheric Sciences

We concur with the climate science assessment of the Intergovernmental Panel on Climate Change (IPCC) in 2001 ... We endorse the conclusions of the IPCC assessment that “There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities” ... There is increasingly unambiguous evidence of changing climate in Canada and around the world. There will be increasing impacts of climate change on Canada’s natural ecosystems and on our socio-economic activities. Advances in climate science since the 2001 IPCC Assessment have provided more evidence supporting the need for action and development of a strategy for adaptation to projected changes.

Canadian Meteorological and Oceanographic Society

The CMOS: endorses the process of periodic climate science assessment carried out by the Intergovernmental Panel on Climate Change and supports the conclusion, in its Third Assessment Report, which states that the balance of evidence suggests a discernible human influence on global climate.

Ecological Society of America (2010)

The Earth is warming -- average global temperatures have increased by 0.74 deg. C (1.3 deg. F) in the past 100 years. The scientific community agrees that catastrophic and possibly irreversible environmental change will occur if average global temperatures rise an additional 2 deg. C. Warming to date has already had significant impacts on the Earth and its ecosystems including increased droughts, rising sea levels, disappearing glaciers, and changes in the distribution and seasonal activities of many species.... Most warming seen since the mid 1900s is very likely due to greenhouse gas emissions from human activities....Swift and significant emissions reductions will be vital in minimizing the impacts of warming.

Engineers Australia (The Institution of Engineers Australia)

"Engineers Australia believes that Australia must act swiftly and proactively in line with global expectations to address climate change as an economic, social and environmental risk... We believe that addressing the costs of atmospheric emissions will lead to increasing our competitive

advantage by minimising risks and creating new economic opportunities. Engineers Australia believes the Australian Government should ratify the Kyoto Protocol."

European Academy of Sciences and Arts

Human activity is most likely responsible for climate warming. Most of the climatic warming over the last 50 years is likely to have been caused by increased concentrations of greenhouse gases in the atmosphere. Documented long-term climate changes include changes in Arctic temperatures and ice, widespread changes in precipitation amounts, ocean salinity, wind patterns and extreme weather including droughts, heavy precipitation, heat waves and the intensity of tropical cyclones. The above development potentially has dramatic consequences for mankind's future.

European Federation of Geologists Position Paper

The EFG recognizes the work of the IPCC and other organizations, and subscribes to the major findings that climate change is happening, is predominantly caused by anthropogenic emissions of CO₂, and poses a significant threat to human civilization. It is clear that major efforts are necessary to quickly and strongly reduce CO₂ emissions.

European Geosciences Union

In 2008, the EGU issued a position statement on ocean acidification which states, "Ocean acidification is already occurring today and will continue to intensify, closely tracking atmospheric CO₂ increase. Given the potential threat to marine ecosystems and its ensuing impact on human society and economy, especially as it acts in conjunction with anthropogenic global warming, there is an urgent need for immediate action." The statement then advocates for strategies "to limit future release of CO₂ to the atmosphere and/or enhance removal of excess CO₂ from the atmosphere."

European Physical Society

The emission of anthropogenic greenhouse gases, among which carbon dioxide is the main contributor, has amplified the natural greenhouse effect and led to global warming. The main contribution stems from burning fossil fuels. A further increase will have decisive effects on life on earth. An energy cycle with the lowest possible CO₂ emission is called for wherever possible to combat climate change.

European Science Foundation

There is now convincing evidence that since the industrial revolution, human activities, resulting in increasing concentrations of greenhouse gases have become a major agent of climate change. These greenhouse gases affect the global climate by retaining heat in the troposphere, thus raising the average temperature of the planet and altering global atmospheric circulation and precipitation patterns.

While on-going national and international actions to curtail and reduce greenhouse gas emissions are essential, the levels of greenhouse gases currently in the atmosphere, and their impact, are likely to persist for several decades. On-going and increased efforts to mitigate climate change through reduction in greenhouse gases are therefore crucial.

Federation of Australian Scientific and Technological Societies

Global climate change is real and measurable. Since the start of the 20th century, the global mean surface temperature of the Earth has increased by more than 0.7°C and the rate of warming has been largest in the last 30 years... Key vulnerabilities arising from climate change include water resources, food supply, health, coastal settlements, biodiversity and some key ecosystems such as coral reefs and alpine regions. As the atmospheric concentration of greenhouse gases increases, impacts become more severe and widespread. To reduce the global net economic, environmental and social losses in the face of these impacts, the policy objective must remain squarely focused on returning greenhouse gas concentrations to near pre-industrial levels through the reduction of emissions... The spatial and temporal fingerprint of warming can be traced to increasing greenhouse gas concentrations in the atmosphere, which are a direct result of burning fossil fuels, broad-scale deforestation and other human activity.

Geological Society of America

Decades of scientific research have shown that climate can change from both natural and anthropogenic causes. The Geological Society of America (GSA) concurs with assessments by the National Academies of Science (2005), the National Research Council (2006), and the Intergovernmental Panel on Climate Change (IPCC, 2007) that global climate has warmed and that human activities (mainly greenhouse-gas emissions) account for most of the warming since the middle 1900s. If current trends continue, the projected increase in global temperature by the end of the twenty first century will result in large impacts on humans and other species. Addressing the challenges posed by climate change will require a combination of adaptation to the changes that are likely to occur and global reductions of CO₂ emissions from anthropogenic sources.

Geological Society of Australia

Human activities have increasing impact on Earth's environments. Of particular concern are the well-documented loading of carbon dioxide (CO₂) to the atmosphere, which has been linked unequivocally to burning of fossil fuels, and the corresponding increase in average global temperature. Risks associated with these large-scale perturbations of the Earth's fundamental life-support systems include rising sea level, harmful shifts in the acid balance of the oceans and long-term changes in local and regional climate and extreme weather events. GSA therefore recommends...strong action be taken at all levels, including government, industry, and individuals to substantially reduce the current levels of greenhouse gas emissions and mitigate the likely social and environmental effects of increasing atmospheric CO₂.

Geological Society of London

The last century has seen a rapidly growing global population and much more intensive use of resources, leading to greatly increased emissions of gases, such as carbon dioxide and methane, from the burning of fossil fuels (oil, gas and coal), and from agriculture, cement production and deforestation. Evidence from the geological record is consistent with the physics that shows that adding large amounts of carbon dioxide to the atmosphere warms the world and may lead to: higher sea levels and flooding of low-lying coasts; greatly changed patterns of rainfall; increased acidity of the oceans; and decreased oxygen levels in seawater.

There is now widespread concern that the Earth's climate will warm further, not only because of the lingering effects of the added carbon already in the system, but also because of further additions as human population continues to grow.

Institute of Biology (UK)

“There is scientific agreement that the rapid global warming that has occurred in recent years is mostly anthropogenic, *ie* due to human activity.” A “rise in sea levels due to melting of ice caps is expected to occur. Rises in temperature will have complex and frequently localised effects on weather, but an overall increase in extreme weather conditions and changes in precipitation patterns are probable, resulting in flooding and drought. The spread of [tropical diseases](#) is also expected.” The IB recommends policies to reduce “greenhouse gas emissions, as we feel that the consequences of climate change are likely to be severe.”

Institute of Professional Engineers (New Zealand)

Human activities have increased the concentration of these atmospheric greenhouse gases, and although the changes are relatively small, the equilibrium maintained by the atmosphere is delicate, and so the effect of these changes is significant. The world's most important greenhouse gas is carbon dioxide, a by-product of the burning of fossil fuels.

... Professional engineers commonly deal with risk, and frequently have to make judgments based on incomplete data. The available evidence suggests very strongly that human activities have already begun to make significant changes to the earth's climate, and that the longterm risk of delaying action is greater than the cost of avoiding/minimising the risk.

International Association for Great Lakes Research

While the Earth's climate has changed many times during the planet's history because of natural factors, including volcanic eruptions and changes in the Earth's orbit, never before have we observed the present rapid rise in temperature and carbon dioxide (CO₂).

Human activities resulting from the industrial revolution have changed the chemical composition of the atmosphere....Deforestation is now the second largest contributor to global warming, after the burning of fossil fuels. These human activities have significantly increased the concentration of “greenhouse gases” in the atmosphere.

As the Earth's climate warms, we are seeing many changes: stronger, more destructive hurricanes; heavier rainfall; more disastrous flooding; more areas of the world experiencing severe drought; and more heat waves.

International Council of Academies of Engineering and Technological Sciences

As reported by the Intergovernmental Panel on Climate Change (IPCC), most of the observed global warming since the mid-20th century is very likely due to human-produced emission of greenhouse gases and this warming will continue unabated if present anthropogenic emissions continue or, worse, expand without control. CAETS, therefore, endorses the many recent calls to decrease and control greenhouse gas emissions to an acceptable level as quickly as possible.

International Union of Geodesy and Geophysics

The IUGG concurs with the “comprehensive and widely accepted and endorsed scientific assessments carried out by the Intergovernmental Panel on Climate Change and regional and national bodies, which have firmly established, on the basis of scientific evidence, that human activities are the primary cause of recent climate change.” The “continuing reliance on combustion of fossil fuels as the world's primary source of energy will lead to much higher atmospheric concentrations of greenhouse gasses, which will, in turn, cause significant increases in surface temperature, sea level, ocean acidification, and their related consequences to the environment and society.”

International Union for Quaternary Research

Human activities are now causing atmospheric concentrations of greenhouse gasses - including carbon dioxide, methane, tropospheric ozone, and nitrous oxide - to rise well above pre-industrial levels....Increases in greenhouse gasses are causing temperatures to rise...The scientific understanding of climate change is now sufficiently clear to justify nations taking prompt action....Minimizing the amount of this carbon dioxide reaching the atmosphere presents a huge challenge but must be a global priority.

National Association of Geoscience Teachers

The National Association of Geoscience Teachers (NAGT) adopted a statement on climate change in which they acknowledge that "Earth's climate is changing [and] that present warming trends are largely the result of human activities"

NAGT strongly supports and will work to promote education in the science of climate change, the causes and effects of current global warming, and the immediate need for policies and actions that reduce the emission of greenhouse gases.

National Research Council (US) (2008)

There is a growing concern about global warming and the impact it will have on people and the ecosystems on which they depend. Temperatures have already risen 1.4°F since the start of the

20th century—with much of this warming occurring in just the last 30 years—and temperatures will likely rise at least another 2°F, and possibly more than 11°F, over the next 100 years. This warming will cause significant changes in sea level, ecosystems, and ice cover, among other impacts. In the Arctic, where temperatures have increased almost twice as much as the global average, the landscape and ecosystems are already changing rapidly.

Most scientists agree that the warming in recent decades has been caused primarily by human activities that have increased the amount of greenhouse gases in the atmosphere. Greenhouse gases, such as carbon dioxide, have increased significantly since the Industrial Revolution, mostly from the burning of fossil fuels for energy, industrial processes, and transportation. Carbon dioxide levels are at their highest in at least 650,000 years and continue to rise.

There is no doubt that climate will continue to change throughout the 21st century and beyond, but there are still important questions regarding how large and how fast these changes will be, and what effects they will have in different regions. In some parts of the world, global warming could bring positive effects such as longer growing seasons and milder winters. Unfortunately, it is likely to bring harmful effects to a much higher percentage of the world's people. For example, people in coastal communities will likely experience increased flooding due to rising sea levels. The scientific understanding of climate change is now sufficiently clear to begin taking steps to prepare for climate change and to slow it.

Royal Meteorological Society (UK)

The Fourth Assessment Report (AR4) of the Inter-Governmental Panel on Climate Change (IPCC) is unequivocal in its conclusion that climate change is happening and that humans are contributing significantly to these changes. The evidence, from not just one source but a number of different measurements, is now far greater and the tools we have to model climate change contain much more of our scientific knowledge within them. The world's best climate scientists are telling us it's time to do something about it.

Carbon Dioxide is such an important greenhouse gas because there is an increasing amount of it in the atmosphere from the burning of fossil fuels and it stays in the atmosphere for such a long time; a hundred years or so. The changes we are seeing now in our climate are the result of emissions since industrialisation and we have already set in motion the next 50 years of global warming – what we do from now on will determine how worse it will get.

Royal Society of New Zealand

The globe is warming because of increasing greenhouse gas emissions. Measurements show that greenhouse gas concentrations in the atmosphere are well above levels seen for many thousands of years. Further global climate changes are predicted, with impacts expected to become more costly as time progresses. Reducing future impacts of climate change will require substantial reductions of greenhouse gas emissions.

Royal Society of the United Kingdom

There is strong evidence that changes in greenhouse gas concentrations due to human activity are the dominant cause of the global warming that has taken place over the last half century. This warming trend is expected to continue as are changes in precipitation over the long term in many regions. Further and more rapid increases in sea level are likely which will have profound implications for coastal communities and ecosystems.

There is strong evidence that the warming of the Earth over the last half-century has been caused largely by human activity, such as the burning of fossil fuels and changes in land use, including agriculture and deforestation. The size of future temperature increases and other aspects of climate change, especially at the regional scale, are still subject to uncertainty. Nevertheless, the risks associated with some of these changes are substantial.

Society of American Foresters

Forests are shaped by climate....Changes in temperature and precipitation regimes therefore have the potential to dramatically affect forests nationwide. There is growing evidence that our climate is changing. The changes in temperature have been associated with increasing concentrations of atmospheric carbon dioxide (CO₂) and other GHGs in the atmosphere.

The Wildlife Society (international)

Scientists throughout the world have concluded that climate research conducted in the past two decades definitively shows that rapid worldwide climate change occurred in the 20th century, and will likely continue to occur for decades to come. Although climates have varied dramatically since the earth was formed, few scientists question the role of humans in exacerbating recent climate change through the emission of greenhouse gases. The critical issue is no longer “if” climate change is occurring, but rather how to address its effects on [wildlife](#) and wildlife habitats... “evidence is accumulating that wildlife and wildlife habitats have been and will continue to be significantly affected by ongoing large-scale rapid climate change.” The WS statement calls for “reduction in anthropogenic (human-caused) sources of carbon dioxide and other greenhouse gas emissions contributing to global climate change and the conservation of CO₂- consuming photosynthesizers (i.e., plants).”

World Federation of Public Health Associations

Noting the conclusions of the United Nations' Intergovernmental Panel on Climate Change (IPCC) and other climatologists that anthropogenic greenhouse gases, which contribute to global climate change, have substantially increased in atmospheric concentration beyond natural processes and have increased by 28 percent since the industrial revolution....Realizing that subsequent health effects from such perturbations in the climate system would likely include an increase in: heat-related mortality and morbidity; vector-borne infectious diseases,... water-borne diseases...(and) malnutrition from threatened agriculture....the World Federation of Public Health Associations...recommends precautionary primary preventive measures to avert climate change, including reduction of greenhouse gas emissions and preservation of greenhouse gas

sinks through appropriate energy and land use policies, in view of the scale of potential health impacts...

World Health Organization

There is now widespread agreement that the earth is warming, due to emissions of greenhouse gases caused by human activity. It is also clear that current trends in energy use, development, and population growth will lead to continuing – and more severe – climate change... The changing climate will inevitably affect the basic requirements for maintaining health: clean air and water, sufficient food and adequate shelter.

World Meteorological Organization

The WMO confirms the need to “prevent dangerous anthropogenic interference with the climate system.” The WMO states that “scientific assessments have increasingly reaffirmed that human activities are indeed changing the composition of the atmosphere, in particular through the burning of fossil fuels for energy production and transportation...” “the present atmospheric concentration of CO₂ was never exceeded over the past 420,000 years...” and the IPCC “assessments provide the most authoritative, up-to-date scientific advice.”

Letter sent to the US Senate in October 2009 from:

American Association for the Advancement of Science
American Chemical Society
American Geophysical Union
American Institute of Biological Sciences
American Meteorological Society
American Society of Agronomy
American Society of Plant Biologists
American Statistical Association
Association of Ecosystem Research Centers
Botanical Society of America
Crop Science Society of America
Ecological Society of America
Natural Science Collections Alliance
Organization of Biological Field Stations
Society for Industrial and Applied Mathematics
Society of Systematic Biologists
Soil Science Society of America
University Corporation for Atmospheric Research

“Observations throughout the world make it clear that climate change is occurring, and rigorous scientific research demonstrates that the greenhouse gases emitted by human activities are the primary driver. These conclusions are based on multiple independent lines of evidence and contrary assertions are inconsistent with an objective assessment of the vast body of peer-reviewed science. Moreover, there is strong evidence that ongoing climate change will have broad impacts on society, including the global economy and on the environment. For the United

States, climate change impacts include sea level rise for coastal states, greater threats of extreme weather events, and increased risk of regional water scarcity, urban heat waves, western wildfires, and the disturbance of biological systems throughout the country. The severity of climate change impacts is expected to increase substantially in the coming decades.

If we are to avoid the most severe impacts of climate change, emissions of greenhouse gases must be dramatically reduced. In addition, adaptation will be necessary to address those impacts that are already unavoidable.”

Addendum B to the Testimony of Dr. Peter H. Gleick for
The Select Committee on Energy Independence & Global Warming Hearing
“Not Going Away: America’s Energy Security, Jobs and Climate Challenges.”

**Open Letter from 255 Members of the U.S. National Academy of
Sciences
Science Magazine, May 7, 2010
“Climate Change and the Integrity of Science”**

[See attached]

Evidence
ignored

692

Building trust in
climate science

695

Supplying tellurium
for photovoltaics

699



LETTERS | BOOKS | POLICY FORUM | EDUCATION FORUM | PERSPECTIVES

LETTERS

edited by Jennifer Sills

Climate Change and the Integrity of Science

WE ARE DEEPLY DISTURBED BY THE RECENT ESCALATION OF POLITICAL ASSAULTS ON SCIENTISTS in general and on climate scientists in particular. All citizens should understand some basic scientific facts. There is always some uncertainty associated with scientific conclusions; science never absolutely proves anything. When someone says that society should wait until scientists are absolutely certain before taking any action, it is the same as saying society should never take action. For a problem as potentially catastrophic as climate change, taking no action poses a dangerous risk for our planet.

Scientific conclusions derive from an understanding of basic laws supported by laboratory experiments, observations of nature, and mathematical and computer modeling. Like all human beings, scientists make mistakes, but the scientific process is designed to find and correct them. This process is inherently adversarial—scientists build reputations and gain recognition not only for supporting conventional wisdom, but even more so for demonstrating that the scientific consensus is wrong and that there is a better explanation. That's what Galileo, Pasteur, Darwin, and Einstein did. But when some conclusions have been thoroughly and deeply tested, questioned, and examined, they gain the status of “well-established theories” and are often spoken of as “facts.”



For instance, there is compelling scientific evidence that our planet is about 4.5 billion years old (the theory of the origin of Earth), that our universe was born from a single event about 14 billion years ago (the Big Bang theory), and that today's organisms evolved from ones living in the past (the theory of evolution). Even as these are overwhelmingly

accepted by the scientific community, fame still awaits anyone who could show these theories to be wrong. Climate change now falls into this category: There is compelling, comprehensive, and consistent objective evidence that humans are changing the climate in ways that threaten our societies and the ecosystems on which we depend.

Many recent assaults on climate science and, more disturbingly, on climate scientists by climate change deniers are typically driven by special interests or dogma, not by an honest effort to provide an alternative theory that credibly satisfies the evidence. The Intergovernmental Panel on Climate Change (IPCC) and other scientific assessments of climate change, which involve thousands of scientists producing massive and comprehensive reports, have, quite expectedly and normally, made some mistakes. When errors are pointed out, they are corrected. But there

is nothing remotely identified in the recent events that changes the fundamental conclusions about climate change:

(i) The planet is warming due to increased concentrations of heat-trapping gases in our atmosphere. A snowy winter in Washington does not alter this fact.

(ii) Most of the increase in the concentration of these gases over the last century is due to human activities, especially the burning of fossil fuels and deforestation.

(iii) Natural causes always play a role in changing Earth's climate, but are now being overwhelmed by human-induced changes.

(iv) Warming the planet will cause many other climatic patterns to change at speeds unprecedented in modern times, including increasing rates of sea-level rise and alterations in the hydrologic cycle. Rising concentrations of carbon dioxide are making the oceans more acidic.

(v) The combination of these complex climate changes threatens coastal communities and cities, our food and water supplies, marine and freshwater ecosystems, forests, high mountain environments, and far more.

Much more can be, and has been, said by the world's scientific societies, national academies, and individuals, but these conclusions should be enough to indicate why scientists are concerned about what future generations will face from business-as-usual practices. We urge our policy-makers and the public to move forward immediately to address the causes of climate change, including the unrestrained burning of fossil fuels.

We also call for an end to McCarthy-like threats of criminal prosecution against our colleagues based on innuendo and guilt by association, the harassment of scientists by politicians seeking distractions to avoid taking action, and the outright lies being spread about them. Society has two choices: We can ignore the science and hide our heads in the sand and hope we are lucky, or we can act in the public interest to reduce the threat of global climate change quickly and substantively. The good news is that smart and

effective actions are possible. But delay must not be an option.

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Notes

1. The signatories are all members of the U.S. National Academy of Sciences but are not speaking on its behalf.
2. Signatory affiliations are available as supporting material at www.sciencemag.org/cgi/content/full/328/5979/689/DC1.

Shifting the Debate on Geoengineering

AS DISCUSSED IN THE RECENT POLICY FORUM “The politics of geoengineering” (J. J. Blackstock and J. C. S. Long, 29 January, p. 527), there is growing recognition that avoiding dangerous climate change during the 21st century may require society to adopt geoengineering technologies to supplement CO₂ emission reduction efforts. Unfortunately, despite the essential role

that CO₂ removal (CDR) and solar radiation management (SRM) technologies may play in reducing the risks of dangerous climate change, discussions of the necessary research and development [including the Policy Forum and others (1, 2)] frequently turn into debates about the environmental costs and benefits of SRM. A more productive approach would shift the debate to comparing the relative costs and benefits of CDR and SRM.

CDR approaches are frequently discounted because, as Blackstock and Long explain, “technical challenges and large uncertainties [surround] large-scale CDR deployment.” Although this may be true for human-built systems that capture CO₂ from air at ambient concentrations, there are other technologies based on biological carbon fixation that could be fast-tracked for rapid deployment during the next few decades (3). Most major international energy corporations are investing in algal-based biofuel technologies because of the tremendous production potential of algae relative to terrestrial energy crops (4). Commercial-scale production of algal biofuels will begin during the next 5 years, and rapid scaling up can be expected afterward if the economic incentives are favorable. However, becoming carbon negative will require society to develop plans for retrofitting existing coal-fired power plants and building future ones so that they can burn algal biomass and capture the emitted CO₂ for subsequent sequestration. The basic technologies described here are not novel; rather, I am proposing a conceptual rearrangement that may enable society to transition more gracefully

CORRECTIONS AND CLARIFICATIONS

Research Articles: “Doc2b is a high-affinity Ca²⁺ sensor for spontaneous neurotransmitter release” by A. J. Groffen *et al.* (26 March, p. 1614). Several author affiliations were not footnoted properly; three corrected affiliations follow. Y. Takai, Department of Biochemistry and Molecular Biology, Kobe University Graduate School of Medicine, Kobe 650-0017, Japan. J. G. Borst, Department of Neuroscience, Erasmus MC, University Medical Center, Rotterdam, 3000 CA, Netherlands. N. Brose, Max-Planck-Institut für Experimentelle Medizin, Abteilung Molekulare Neurobiologie, 37075 Göttingen, Germany.

Letters: “Oil and water do mix” by J. L. Kavanau (19 February, p. 958). Due to an editorial error, the title was incorrect. It should have been “Opposites attract.”

Reports: “100-million-year dynasty of giant planktivorous bony fishes in the Mesozoic seas” by M. Friedman *et al.* (19 February, p. 990). The author Matt Friedman’s affiliation should have been “Committee on Evolutionary Biology, University of Chicago, 1025 East 57th Street, Chicago, IL 60637, USA.” The affiliation that was listed is his present address.

News of the Week: “DSM-V at a glance” by G. Miller and C. Holden (12 February, p. 770). In the sidebar, it was reported that the term “gender identity disorder” has been retained. In fact, a different term—“gender incongruence”—has been proposed.

Research Articles: “PRDM9 is a major determinant of meiotic recombination hotspots in humans and mice” by F. Baudat *et al.* (12 February, p. 836). M. Lichten was incorrectly listed as an author in references 18 and 19. The correct authors for reference 18 are C. Grey, F. Baudat, and B. de Massy; for reference 19, the correct authors are E. D. Parvanov, S. H. Ng, P. M. Petkov, and K. Paigen.

Reports: “Epigenetic transgenerational actions of endocrine disruptors and male fertility” by M. D. Anway *et al.* (3 June 2005, p. 1466). As clarification of the abstract to Anway *et al.*, the F₁ to F₄ generations were examined after vinclozolin treatment, and F₁ and F₂ generations were examined after methoxychlor treatment. To clarify data referred to in the last paragraph of the Report, serum testosterone measurements after vinclozolin treatment were shown in reference 21 (Uzumcu *et al.*) for the F₁ generation. Data for the F₁ to F₄ generations were subsequently published in Anway *et al.*, *J. Androl.* **27**, 868 (2006). Serum testosterone measurements after methoxychlor treatment were shown in reference 20 (Cupp *et al.*) for the F₁ generation, but measurements of the F₂ generation have not been published. The *Science* Anway *et al.* manuscript showed DNA methylation analysis after vinclozolin treatment, but the DNA methylation data after methoxychlor treatment have not been published.