Special Report: Climate Change

Examining the state of the science on climate change

How can we cope with global warming and the challenges it poses? The Intergovernmental Panel on Climate Change (IPCC) has just completed its fourth assessment of the science of climate change, its impacts and possible solutions. The panel of 2,500 scientists and other experts declared manmade warming "unequivocal" and wrote that it could lead to climate changes that are "abrupt and irreversible."

Next week the world's governments are set to gather in Bali to begin negotiating an international treaty to reduce greenhouse gas emissions that will succeed the much-debated Kyoto Protocol. The science is clear that the earth is heating up and will continue to do so－with potentially catastrophic consequences－unless we change our ways. What is unclear is how best to go about reining in our globe-warming pollution. Some argue for a fund for future clean technology while others prefer to focus on reducing globe-warming pollution from present sources.

This special report explores the latest findings on the impact of human activity on Earth's climate－from the melting of Arctic ice to the potential spread of disease. It also explores the more pertinent question of where we can go from here.

State of the Science: Beyond the Worst Case Climate Change Scenario

The IPCC has declared manmade climate change "unequivocal." The hard part: trying to stop it

STATE OF THE SCIENCE: Greenhouse gas emissions and sea levels continue to rise, outpacing previous predictions in the latest research.

Climate change is "unequivocal" and it is 90 percent certain that the "net effect of human activities since 1750 has been one of warming," the Intergovernmental Panel on Climate Change (IPCC) — a panel of more than 2,500 scientists and other experts — wrote in its first report on the physical science of global warming earlier this year. In its second assessment, the IPCC stated that human-induced warming is having a discernible influence on the planet, from species migration to thawing permafrost. Despite these findings, emissions of the greenhouse gases driving this process continue to rise thanks to increased burning of fossil fuels while cost-effective options for decreasing them have not been adopted, the panel found in its third report.

The IPCC's fourth and final assessment of the climate change problem — known as the Synthesis Report — combines all of these reports and adds that "warming could lead to some impacts that are abrupt or irreversible, depending upon the rate and magnitude of the climate change." Although countries continue to debate the best way to address this finding, 130 nations, including the U.S., China, Australia, Canada and even Saudi Arabia,

have concurred with it.

"The governments now require, in fact, that the authors report on risks that are high and 'key' because of their potentially very high consequence," says economist Gary Yohe, a lead author on the IPCC Synthesis Report. "They have, perhaps, given the planet a chance to save itself."

Among those risks:

Warming Temperatures—Continued global warming is virtually certain (or more than 99 percent likely to occur) at this point, leading to both good and bad impacts. On the positive side, fewer people will die from freezing temperatures and agricultural yield will increase in colder areas. The negatives include reduced crop production in the tropics and subtropics, increased insect outbreaks, diminished water supply caused by dwindling snowpack, and increasingly poor air quality in cities.

Heat Waves—Scientists are more than 90 percent certain that episodes of extreme heat will increase worldwide, leading to increased danger of wildfires, human deaths and water quality issues such as algal blooms.

Heavy Rains—Scientific estimates suggest that extreme precipitation events—from downpours to whiteouts—are more than 90 percent likely to become more common, resulting in diminished water quality and increased flooding, crop damage, soil erosion and disease risk.

Drought—Scientists estimate that there is a more than 66 percent chance that droughts will become more frequent and widespread, making water scarcer, upping the risk of starvation through failed crops and further increasing the risk of wildfires.

Stronger Storms—Warming ocean waters will likely increase the power of tropical cyclones (variously known as hurricanes and typhoons), raising the risk of human death, injury and disease as well as destroying coral reefs and property.

Biodiversity—As many as a third of the species known to science may be at risk of extinction if average temperatures rise by more than 1.5 degrees Celsius.

Sea Level Rise—The level of the world's oceans will rise, likely inundating low-lying land, turning freshwater brackish and potentially triggering widespread migration of human populations from affected areas.

"As temperatures rise, thermal expansion will lead to sea-level rise, independent of melting ice," says chemical engineer Lenny Bernstein, another lead author of the recent IPCC report. "The indications are that this factor alone could cause serious problems [and] ice-sheet melting would greatly accelerate [it]."

Such ice-sheet melting, which the IPCC explicitly did not include in its predictions of sea-level rise, has already been observed and may be speeding up, according to recent research that determined that the melting of Greenland's ice cap has accelerated to six times the average flow of the Colorado River. Research has also shown that the world has consistently emitted greenhouse gases at the highest projected levels examined and sea-level rise has also outpaced projections from the IPCC's last assessment in 2001.

"We are above the high scenario now," says climatologist Stephen of Stanford University, an IPCC lead author. "This is not a safe world."

Other recent findings include:

Carbon Intensity Increasing—The amount of carbon dioxide per car built, burger served or widget sold had been consistently declining until the turn of the century. But since 2000, CO_2 emissions have grown by more than 3 percent annually. This is largely due to the economic booms in China and India, which rely on polluting coal to power production. But emissions in the developed world have started to rise as well, increasing by 2.6 percent since 2000, according to reports made by those countries to the United Nations Framework Convention on Climate Change. Researchers at the Massachusetts Institute of Technology also recently argued that U.S. emissions may continue to increase as a result of growing energy demand.

Carbon Sinks Slowing—The world's oceans and forests are absorbing less of the CO_2 released by human activity, resulting in a faster rise in atmospheric levels of greenhouse gases. All told, humanity released 9.9 billion metric tons (2.18×10^{13} pounds) of carbon in 2006 at the same time that the ability of the North Atlantic to take in such emissions, for example, dropped by 50 percent.

Impacts Accelerating—Warming temperatures have prompted earlier springs in the far north and have caused plant species to spread farther into formerly icy terrain. Meanwhile, sea ice in the Arctic reached a record low this year, covering just 1.59 million square miles and thus shattering the previous 2005 minimum of 2.05 million square miles.

"The observed rate of loss is faster than anything predicted," says senior research scientist Mark Serreze of the U.S. National Snow and Ice Data Center in Boulder, Colo. "We're already set up for another big loss next year. We've got so much open water in the Arctic now that has absorbed so much energy over the summer that the ocean has warmed. The ice that grows back this autumn will be thin."

The negative consequences of such reinforcing, positive feedbacks (white ice is replaced by dark water, which absorbs more energy and prevents the formation of more white ice) remain even when they seemingly work in our favor.

For example, scientists at the Leibniz Institute of Marine Sciences at the University of Kiel in Germany recently discovered that plankton consumes more carbon at higher atmospheric concentrations of CO_2. "The plankton were carbon-enriched," says marine biologist Ulf Riebesell, who conducted the study. "There weren't more of them, but each cell had more carbon."

This could mean that microscopic ocean plants may potentially absorb more of the carbon emitted into the atmosphere. Unfortunately, other research (from the Woods Hole Oceanographic Institution) has shown that such plankton does not make it to the seafloor in large enough amounts to sequester the carbon in the long term.

Further, such carbon-heavy plankton do not begin to appear until CO_2 concentrations reach twice present values—750 parts per million (ppm) in the atmosphere compared with roughly 380 ppm presently (a level at which catastrophic change may be a certainty)—and they are less nutritious to all the animals that rely on them for food. "This mechanism is both too small and too late," Riebesell says. "By becoming more carbon-rich, zooplankton have to eat more phytoplankton to achieve the same nutrition" and, therefore, "they grow and reproduce more slowly."

The IPCC notes that there are cost-effective solutions, such as retrofitting buildings for energy efficiency, but says they must be implemented in short order to stem further damage. "We are 25 years too late," Schneider says. "If the object is to avoid dangerous change, we've already had it. The object now is to avoid really dangerous change."

10 Solutions for Climate Change

Ten possibilities for staving off catastrophic climate change

EARTHWIDE EXPERIMENT: Climate change could turn catastrophic if efforts are not made to reduce the greenhouse gas emissions that cause it.

The enormity of global warming can be daunting and dispiriting. What can one person, or even one nation, do on their own to slow and reverse climate change? But just as ecologist Stephen Pacala and physicist Robert Socolow, both at Princeton University, came up with 15 so-called "wedges" for nations to utilize toward this goal—each of which is challenging but feasible and, in some combination, could reduce greenhouse gas emissions to safer levels—there are personal lifestyle changes that you can make too that, in some combination, can help reduce your carbon impact. Not all are right for everybody. Some you may already be doing or absolutely abhor. But implementing just a few of them could make a difference.

Forego Fossil Fuels—The first challenge is eliminating the burning of coal, oil and, eventually, natural gas. This is perhaps the most daunting challenge as denizens of richer nations literally eat, wear, work, play and even sleep on the products made from such fossilized sunshine. And citizens of developing nations want and arguably deserve the same comforts, which are largely thanks to the energy stored in such fuels.

Oil is the lubricant of the global economy, hidden inside such ubiquitous items as plastic and corn, and fundamental to the transportation of both consumers and goods. Coal is the substrate, supplying roughly half of the electricity used in the U.S. and nearly that

much worldwide—a percentage that is likely to grow, according to the International Energy Agency. There are no perfect solutions for reducing dependence on fossil fuels (for example, carbon neutral biofuels can drive up the price of food and lead to forest destruction, and while nuclear power does not emit greenhouse gases, it does produce radioactive waste), but every bit counts.

So try to employ alternatives when possible—plant-derived plastics, biodiesel, wind power—and to invest in the change, be it by divesting from oil stocks or investing in companies practicing carbon capture and storage.

Infrastructure Upgrade—Buildings worldwide contribute around one third of all greenhouse gas emissions (43 percent in the U.S. alone), even though investing in thicker insulation and other cost-effective, temperature-regulating steps can save money in the long run. Electric grids are at capacity or overloaded, but power demands continue to rise. And bad roads can lower the fuel economy of even the most efficient vehicle. Investing in new infrastructure, or radically upgrading existing highways and transmission lines, would help cut greenhouse gas emissions and drive economic growth in developing countries.

Of course, it takes a lot of cement, a major source of greenhouse gas emissions, to construct new buildings and roads. The U.S. alone contributed 50.7 million metric tons of carbon dioxide to the atmosphere in 2005 from cement production, which requires heating limestone and other ingredients to 1,450 degrees Celsius (2,642 degrees Fahrenheit). Mining copper and other elements needed for electrical wiring and transmission also causes globe-warming pollution.

But energy-efficient buildings and improved cement-making processes (such as using alternative fuels to fire up the kiln) could reduce greenhouse gas emissions in the developed world and prevent them in the developing world.

Move Closer to Work—Transportation is the second leading source of greenhouse gas emissions in the U.S. (burning a single gallon of gasoline produces 20 pounds of CO_2). But it doesn't have to be that way.

One way to dramatically curtail transportation fuel needs is to move closer to work, use mass transit, or switch to walking, cycling or some other mode of transport that does not require anything other than human energy. There is also the option of working from home and telecommuting several days a week.

Cutting down on long-distance travel would also help, most notably airplane flights, which are one of the fastest growing sources of greenhouse gas emissions and a source that arguably releases such emissions in the worst possible spot (higher in the atmosphere). Flights are also one of the few sources of globe-warming pollution for which there isn't already a viable alternative: jets rely on kerosene, because it packs the most energy per pound, allowing them to travel far and fast, yet it takes roughly 10 gallons of oil to make one gallon of JetA fuel. Restricting flying to only critical, long-distance trips—in many parts of the world, trains can replace planes for short- to medium-distance trips—would help curb airplane emissions.

Consume Less—The easiest way to cut back on greenhouse gas emissions is simply to buy less stuff. Whether by forgoing an automobile or employing a reusable grocery sack, cutting back on consumption results in fewer fossil fuels being burned to extract, produce and ship products around the globe.

Think green when making purchases. For instance, if you are in the market for a new car, buy one that will last the longest and have the least impact on the environment. Thus, a used vehicle with a hybrid engine offers superior fuel efficiency over the long haul while saving the environmental impact of new car manufacture.

Paradoxically, when purchasing essentials, such as groceries, buying in bulk can reduce the amount of packaging—plastic wrapping, cardboard boxes and other unnecessary materials. Sometimes buying more means consuming less.

Be Efficient—A potentially simpler and even bigger impact can be made by doing more with less. Citizens of many developed countries are profligate wasters of energy, whether by speeding in a gas-guzzling sport-utility vehicle or leaving the lights on when not in a room.

Good driving—and good car maintenance, such as making sure tires are properly inflated—can limit the amount of greenhouse gas emissions from a vehicle and, perhaps more importantly, lower the frequency of payment at the pump.

Similarly, employing more efficient refrigerators, air conditioners and other appliances, such as those rated highly under the U.S. Environmental Protection Agency's Energy Star program, can cut electric bills while something as simple as weatherproofing the windows of a home can reduce heating and cooling bills. Such efforts can also be usefully employed at work, whether that means installing more efficient turbines at the

power plant or turning the lights off when you leave the office.

Eat Smart, Go Vegetarian?—Corn grown in the U.S. requires barrels of oil for the fertilizer to grow it and the diesel fuel to harvest and transport it. Some grocery stores stock organic produce that do not require such fertilizers, but it is often shipped from halfway across the globe. And meat, whether beef, chicken or pork, requires pounds of feed to produce a pound of protein.

Choosing food items that balance nutrition, taste and ecological impact is no easy task. Foodstuffs often bear some nutritional information, but there is little to reveal how far a head of lettuce, for example, has traveled.

University of Chicago researchers estimate that each meat-eating American produces 1.5 tons more greenhouse gases through their food choice than do their vegetarian peers. It would also take far less land to grow the crops necessary to feed humans than livestock, allowing more room for planting trees.

Stop Cutting Down Trees—Every year, 33 million acres of forests are cut down. Timber harvesting in the tropics alone contributes 1.5 billion metric tons of carbon to the atmosphere. That represents 20 percent of human-made greenhouse gas emissions and a source that could be avoided relatively easily.

Improved agricultural practices along with paper recycling and forest management—balancing the amount of wood taken out with the amount of new trees growing—could quickly eliminate this significant chunk of emissions.

And when purchasing wood products, such as furniture or flooring, buy used goods or, failing that, wood certified to have been sustainably harvested. The Amazon and other forests are not just the lungs of the earth, they may also be humanity's best short-term hope for limiting climate change.

Unplug—Believe it or not, U.S. citizens spend more money on electricity to power devices when off than when on. Televisions, stereo equipment, computers, battery chargers and a host of other gadgets and appliances consume more energy when seemingly switched off, so unplug them instead.

Purchasing energy-efficient gadgets can also save both energy and money—and thus prevent more greenhouse gas emissions. To take but one example, efficient battery chargers could save more than one billion kilowatt-hours of electricity—$100 million at

today's electricity prices—and thus prevent the release of more than one million metric tons of greenhouse gases.

Swapping old incandescent lightbulbs for more efficient replacements, such as compact fluorescents (warning: these lightbulbs contain mercury and must be properly disposed of at the end of their long life), would save billions of kilowatt-hours. In fact, according to the EPA, replacing just one incandescent lightbulb in every American home would save enough energy to provide electricity to three million American homes.

One Child—There are at least 6.6 billion people living today, a number that is predicted by the United Nations to grow to at least nine billion by mid-century. The U.N. Environmental Program estimates that it requires 54 acres to sustain an average human being today—food, clothing and other resources extracted from the planet. Continuing such population growth seems unsustainable.

Falling birth rates in some developed and developing countries (a significant portion of which are due to government-imposed limits on the number of children a couple can have) have begun to reduce or reverse the population explosion. It remains unclear how many people the planet can comfortably sustain, but it is clear that per capita energy consumption must go down if climate change is to be controlled.

Ultimately, a one child per couple rule is not sustainable either and there is no perfect number for human population. But it is clear that more humans means more greenhouse gas emissions.

Future Fuels—Replacing fossil fuels may prove the great challenge of the 21st century. Many contenders exist, ranging from ethanol derived from crops to hydrogen electrolyzed out of water, but all of them have some drawbacks, too, and none are immediately available at the scale needed.

Biofuels can have a host of negative impacts, from driving up food prices to sucking up more energy than they produce. Hydrogen must be created, requiring either reforming natural gas or electricity to crack water molecules. Biodiesel hybrid electric vehicles (that can plug into the grid overnight) may offer the best transportation solution in the short term, given the energy density of diesel and the carbon neutral ramifications of fuel from plants as well as the emissions of electric engines. A recent study found that the present amount of electricity generation in the U.S. could provide enough energy for the country's entire fleet of automobiles to switch to plug-in hybrids, reducing greenhouse gas emissions in the process.

But plug-in hybrids would still rely on electricity, now predominantly generated by burning dirty coal. Massive investment in low-emission energy generation, whether solar-thermal power or nuclear fission, would be required to radically reduce greenhouse gas emissions. And even more speculative energy sources — hyperefficient photovoltaic cells, solar energy stations in orbit or even fusion — may ultimately be required.

The solutions above offer the outline of a plan to personally avoid contributing to global warming. But should such individual and national efforts fail, there is another, potentially desperate solution:

Experiment Earth — Climate change represents humanity's first planetwide experiment. But, if all else fails, it may not be the last. So-called geoengineering, radical interventions to either block sunlight or reduce greenhouse gases, is a potential last resort for addressing the challenge of climate change.

Among the ideas: releasing sulfate particles in the air to mimic the cooling effects of a massive volcanic eruption; placing millions of small mirrors or lenses in space to deflect sunlight; covering portions of the planet with reflective films to bounce sunlight back into space; fertilizing the oceans with iron or other nutrients to enable plankton to absorb more carbon; and increasing cloud cover or the reflectivity of clouds that already form.

All may have unintended consequences, making the solution worse than the original problem. But it is clear that at least some form of geoengineering will likely be required: capturing carbon dioxide before it is released and storing it in some fashion, either deep beneath the earth, at the bottom of the ocean or in carbonate minerals. Such carbon capture and storage is critical to any serious effort to combat climate change.