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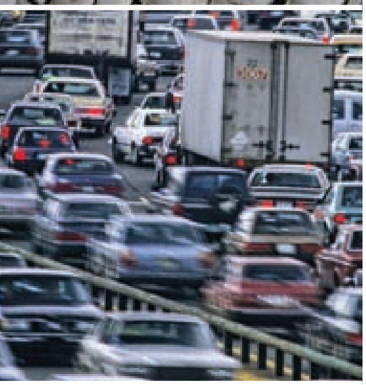

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Findings of the IPCC Fourth Assessment Report

Climate Change Mitigation

There are a variety of strategies available today that, if implemented quickly, can rein in global warming and avoid the most severe consequences. The impact of the more ambitious of these strategies on the world economy is expected to be a fraction of a percent reduction in the annual average growth rate of global gross domestic product (GDP). These are the conclusions of the Intergovernmental Panel on Climate Change (IPCC) Working Group III Fourth Assessment Report published in May 2007.[1]

The report further concludes that policies enacted to date have not been substantial enough to counteract the growth in global emissions driven by increasing fossil fuel consumption, forest clearing, and world population. Comprehensive public policies that bring clean technologies to the market are necessary to reduce emissions and limit the risks of climate change.

Findings: IPCC Working Groups I and II

Working Group I concluded that warming since the mid-20th century was unequivocal and was caused primarily by human activities (>90 percent probability), and that past emissions of heat-trapping gases make some continued warming unavoidable. Working Group II concluded that the consequences of recent warming were already apparent around the world, and that the severity of future impacts depends largely on the amount of heat-trapping gases emitted by current and future human activities. Working Group III was charged with assessing the potential for society to mitigate future warming by reducing emissions.

Increase in Heat-trapping Emissions

Emissions of heat-trapping gases rose 70 percent between 1970 and 2004, with carbon dioxide (CO_2) emissions accounting for three-quarters of total emissions from human activities in 2004. These emissions will continue to grow over the next few decades if current policies and development practices remain in effect.

Historic global trends: The combined effect of increased per capita income (up 77 percent) and population (up 69 percent) resulted in the dramatic rise in energy use and emissions between 1970 and 2004. Over the same time, progressive decoupling of income growth from carbon emissions also occurred with improvements in energy intensity (total energy used per unit of GDP; down 33 percent). However, the rate of improvement has not achieved global reductions in emissions of heat-trapping gases.

Regional differences: In 2004, developed countries[2] accounted for 20 percent of world population and 46 percent of global emissions. Developing countries generated one-fourth the per capita emissions of developed countries.[3]

Sector differences: The largest growth in emissions of heat-trapping gases resulted from energy supply (145 percent increase between 1970 and 2004). Direct emissions (i.e., excluding emissions from electricity consumed in these sectors) rose most rapidly in transportation (up 120 percent), followed by industry (up 65 percent), and land use and forestry (up 40 percent). Direct and indirect emissions (including electricity use) from buildings increased 75 percent.

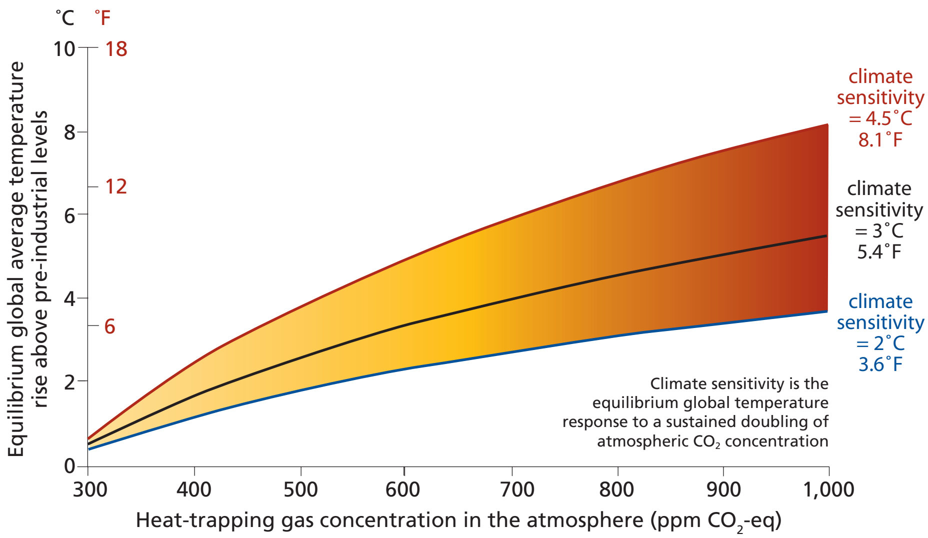
Future projections: CO_2 emissions from energy use are projected to increase 45 to 110 percent if fossil fuels continue to dominate energy production through 2030, with up to three-quarters of future emission increases coming from developing countries.

Preventing Severe Climate Change Impacts

The IPCC analyzed a range of policies, including ambitious but achievable measures that could bring about a 50 to 85 percent reduction in emissions of heat-trapping gases by 2050 (compared with 2000 levels). These paths involve emissions peaking by 2015 and heat-trapping gas concentrations in the atmosphere stabilizing around the end of the century at about 445 to 490 parts per million by volume (ppm) CO_2-eq.[4,5] Following this path could keep equilibrium global average temperature increases within 3.6 to 4.3 degrees Fahrenheit (°F), or 2 to 2.4 degrees Celsius (°C), above pre-industrial levels, thereby avoiding some of the most damaging and irreversible impacts (see figure).[5]

If, however, the current path of rapidly rising emissions continues, this could lead to elevated heat-trapping gas concentrations in the atmosphere

Higher Emissions Lead to Higher Temperatures



around 855 to 1,130 ppm CO_2-eq, which would be expected to cause equilibrium global average temperature increases of ~9 to ~11°F (5 to 6°C) above pre-industrial levels, bringing severe impacts. For example, IPCC Working Group II finds that up to 30 percent of plant and animal species could face increasing risk of extinction if temperatures rise more than ~3 to ~5°F (1.5 to 2.5°C).[6]

Benefits of Reducing Heat-trapping Emissions

In addition to avoiding the most severe effects of climate change over the long term, reducing emissions can result in lower energy use, saving consumers and industries money. These economic gains can offset a substantial portion of the expenditures made to reduce emissions. Many emissions reduction strategies also provide benefits for air quality, energy security, public health, agricultural production, balance of trade, employment, income generation, wealth creation, and poverty alleviation. For example, lower emissions results in reduced air pollution from power plants and factories, leading to substantial health benefits.

Emission Reduction Strategies

Various strategies are available for governments to mitigate climate change. A mix of well-designed policies can overcome economic, technological, informational, and behavioral barriers in the marketplace.

Policy makers have crucial roles in creating institutional, policy, legal, and regulatory frameworks that enable significant climate change emission reductions. Many mitigation strategies are at their disposal:

- ***Integrated policies*** that include climate change as a factor in broader policy development can ease implementation of mitigation mechanisms.
- ***Regulatory standards*** provide certainty and consistency on emission levels, and send a clear signal that discourages a business-as-usual approach.
- ***Taxes and fees*** are generally a cost-effective strategy; they send price signals that create incentives to reduce emissions, but cannot guarantee a specified level of reductions.
- ***Financial incentives*** such as rebates and tax breaks can be used to stimulate new markets for innovative technologies.
- ***Tradable permits*** establish a price for carbon and draw on the power of the marketplace to reduce emissions in a flexible manner. The volume of allowed emissions determines environmental effectiveness, while the distribution of allowances determines competitiveness.
- ***Voluntary agreements*** between industry and government raise awareness among stakeholders; however, the IPCC finds little evidence of their effectiveness.
- ***Voluntary actions*** (corporations, governments, nonprofits, and civil groups) can act to stimulate innovations, though the IPCC notes they tend to have limited impact beyond their immediate sphere of influence.

Many of these policies place a real or implicit price on carbon, which the IPCC finds would create significant incentives for producers and consumers to invest in lower carbon products, technologies, and processes. The IPCC analyses suggest that carbon prices of \$20 to \$80[7] per ton CO_2-eq, sustained or increased over decades, could eliminate most carbon emissions from power generation and make many mitigation strategies attractive. Setting a carbon price[8] in this range by 2030 would be consistent with stabilization levels around 550 ppm CO_2-eq by the end of the century.

According to the IPCC, carbon price strategies may be less effective at reducing emissions of heat trapping gases if they are set too low and/or applied in a limited scope to some sectors and not others. For example, a price

What Would It Cost to Reduce Emissions?

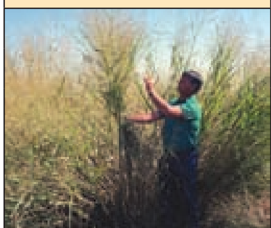
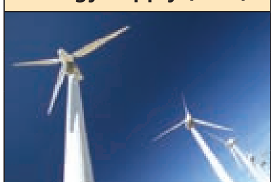
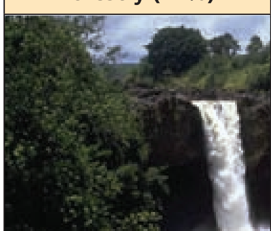
The IPCC evaluated the potential of various climate change mitigation strategies, and the impact these policies would have on the global economy. Stabilizing CO_2 concentrations at around 445 to 535 ppm, limiting the long-term temperature rise to about 3.6 to 5.4°F (2 to 3°C), is estimated to reduce the cumulative growth in global GDP 3 percent by 2030. This is equivalent to only a 0.12 percent reduction in *annual growth rate* of GDP.

The models used in the IPCC's analysis incorporate the best information currently available to provide an estimate of the cost-effectiveness for reducing heat-trapping gases. Real-world mitigation costs, however, will depend on many variables such as how the existing tax system is structured, how revenues are spent, and whether a multi-gas reduction approach is taken. Investing revenues from carbon taxes or auctioned permits from a carbon trading system back into the economy would lower costs. A reduction in public health costs and other benefits would offset and thus lower mitigation costs. However, omitting some regions, sectors, heat-trapping gases, technologies, or policy options would raise costs. Regional and national costs could differ significantly from the global average.

Commercially Available Options for Mitigating Climate Change

Many opportunities exist for cost-effectively reducing emissions. Mitigation prospects differ in each sector, between regions, and there are advantages and/or barriers to each strategy.

Advantages
Barriers

Sector (Percent)*	Mitigation Strategies	Advantages‡/Barriers
Buildings (22%)	**Challenge for Sector: Up front cost barriers**	
 © ISTOCKPHOTO.COM	Energy-efficient lighting and appliances	Can lower energy costs
	Improved insulation and ventilation	Can lower energy costs (insulation) and improve indoor air quality (ventilation)
	Passive solar design	Can lower energy costs
	New refrigeration fluids/recycling fluorinated gases	Has the potential to reduce HFC emissions[4]
Agriculture (21%)	**Challenge for Sector: Successful application depends on region-specific response**	
 COURTESY OF ORNL	Improved land and livestock management	May reduce methane and nitrous oxide emissions
	Soil restoration	Can reduce soil carbon loss
	Improved rice cultivation techniques	Reduces methane and has synergies with sustainable agriculture
	Dedicated crops for liquid fuels and electricity	High transport energy demands (production and distribution), electricity demands, water availability
Industry (18%)	**Challenge for Sector: Many older, inefficient facilities remain worldwide**	
 © ISTOCKPHOTO.COM	Energy-efficient end-use electrical equipment	Sector-wide challenges include: slow rate of capital stock turnover, lack of financial and technical resources, limited ability of firms (particularly small- and medium-sized) to access and apply technical information
	Heat and power recovery	
	Material recycling and substitution	
	Improved non-CO_2 emission controls	
Energy Supply (15%)	**Challenge for Sector: Requires a large shift in the pattern of investments**	
 COURTESY OF NREL	Improved efficiency of supply and distribution	Can lower energy costs
	Increased renewable energy	Can increase energy security
	Increased nuclear power supply	Has safety, waste, and weapons proliferation problems that have not yet been resolved
	Combined heat and power (cogeneration)	Can lower energy costs
Forestry (14%)	**Challenge for Sector: Lack of investment capital**	
 COURTESY OF LLNL	Reduced tropical deforestation	Has greatest potential for emissions reduction in sector (50%); preserves biodiversity and carbon sinks
	Reforestation	Increases CO_2 removal by carbon sinks at low cost
	Improved forest and harvest management	Sequesters CO_2 and has synergies with sustainable development
	Using forest products for electricity and fuel	Displaces fossil fuels
Transportation (8%)	**Challenge for Sector: Growth counteracts mitigation; consumer choices trump best practices**	
 KRAEMER, INC.	Making vehicles more fuel efficient	Can save on fuel costs
		Lack of policy to influence market
	Increased production and use of biofuels	Benefits depend on source and production process
	Improved public and non-motorized transport	Successful application depends on local conditions
Waste[9] (2%)	**Challenge for Sector: Lack of local capital in developing countries**	
 JEAN E. BOGNER	Landfill methane recovery for energy use	Has a proven track record (used in commercial sector for more than 30 years)
	Waste incineration with energy recovery	Costly emission controls needed
	Composting of organic waste	Reduces need for landfill space; can improve soil quality
	Recycling and waste minimization	Conserves energy and raw materials

* Estimated share of mitigation potential based on high end of range for emissions reductions (31 $GtCO_2$-eq/year) at $100 per ton CO_2-eq in 2030.
‡ In addition to the illustrative advantages listed here, these strategies provide many public health, environmental protection, economic, energy, sustainable development, and/or other social and private benefits. Due to space constraints, these general "co-benefits" were not listed in the table.

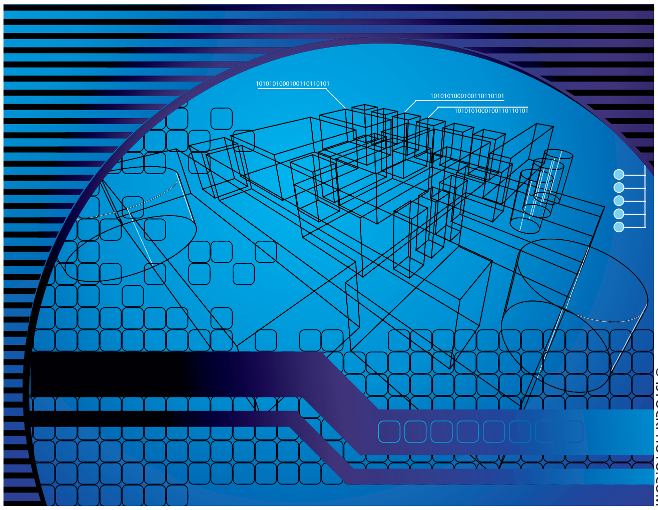
under \$20 per ton CO_2-eq may only reduce emissions by 20 percent below 2000 levels by 2030.

Evolving Technologies

In addition to the options available now, there are more technologies in all sectors that will be available before 2030 that could lead to even greater emissions reductions. For example, energy efficiency is expected to play a key role. Future deployment of carbon capture and storage (CCS) for coal-, natural gas-, and biomass-fired electricity generation and for other industries with high levels of direct emissions (cement, ammonia, and iron manufacturing) has potential to reduce emissions substantially. In order to stimulate deployment of these and other technological advances, larger investment in research and development is necessary during the next few decades. As fossil fuel prices increase, more of these low-carbon alternatives will become competitive. However, high fossil fuel prices can spur the extraction of oil from oil sands and shales, as well as the development of synthetic fuels derived from coal and natural gas, all of which would lead to increased emissions of heat-trapping gases.[10]

Global Action Is Needed

Countries can use different strategies to reduce heat-trapping emissions, but early action increases the likelihood of avoiding the most severe consequences of global climate change. Setting effective carbon prices, strengthening regulations such as efficiency standards, and increasing government funding for research, development, and demonstration of carbon-free energy sources could encourage climate solutions.



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Delaying the implementation of these mitigation strategies and continuing on a business-as-usual path may lock us into a more emissions-intensive future, greatly increasing the risk of more severe and irreversible climate change impacts. The longer we wait to act, the more costly it becomes to limit climate change and to adapt to those consequences that cannot be avoided.[11]

ENDNOTES

1. Whenever practical, the language from the Working Group III Summary for Policymakers titled *Climate Change 2007: Mitigation of Climate Change* is used throughout this document. To enhance clarity, modifications were made that maintain the intended meaning of the report. The full IPCC Fourth Assessment Report includes the input of more than 1,200 authors and 2,500 scientific expert reviewers from more than 130 countries. The full text of this report is available online at *www.ipcc.ch*.
2. A list of Annex I (developed) and Non-Annex I (developing) regions is available online at *www.unfccc.int/parties_and_observers/items/2704.php*.
3. Developing countries average 4 tons CO_2-eq per person, and developed countries average 16 tons CO_2-eq per person.
4. Carbon dioxide equivalent takes into account the different time period each gas remains in the atmosphere and its respective heat-trapping properties. The heat-trapping "greenhouse" gases covered by the Kyoto Protocol include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6). To calculate CO_2-eq see *www.epa.gov/climatechange/emissions/downloads/2007GHGFastFacts.pdf*.
5. For most studies assessed, stabilization of heat-trapping gas concentrations in the atmosphere occurs between 2100 and 2150. Equilibrium global average temperature refers to the temperature achieved once atmospheric concentrations of climate change gases have been stabilized. "Climate sensitivity" is the surface warming response to a sustained doubling of carbon dioxide concentrations. The temperature ranges reported in this document are based on the best estimate of "climate sensitivity" (3°C); the full range of "likely" estimates takes into account a wider range of "climate sensitivity" estimates (2 to 4.5°C).
6. The species extinction risk is reported as temperature rise relative to the 1980–1999 global average. The 1980–1999 average is 0.5°C above the 1850–1899 average.
7. All costs are expressed in U.S. dollars.
8. Lower carbon price ranges (\$5 to \$65 per ton CO_2-eq in 2030, and \$15 to \$130 per ton CO_2-eq in 2050) may achieve the same stabilization levels if policies that induce technological advances are implemented.
9. "Waste" includes post-consumer waste and wastewater only; industrial, energy, agricultural, and forestry waste are covered in those sectors.
10. According to the U.S. Environmental Protection Agency (EPA420-F-07-035), even if CCS technology were able to capture almost all of the CO_2 from the process of converting coal to liquid fuel, the remaining CO_2 emissions from vehicles' tailpipes would be similar to today's vehicles burning gasoline or diesel fuel (including petroleum refining emissions). Thus, even under the most optimistic assumptions, coal-based liquid fuels would increase emissions.
11. For more background on IPCC history and process, visit *www.ucsusa.org/global_warming/science/the-ipcc.html*.

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