INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY ADVANCED RESEARCH TRENDS
ISSN : 2349-7408
VOLUME II, ISSUE I, FEBRUARY 2015

GLOBAL CHANGE AND AIR POLLUTION

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ABSTRACT

This paper reviews and ranks major proposed energy-related solutions to global changes, air pollution mortality, and energy security while considering other impacts of the proposed solutions, such as on water supply, land use, resource availability, thermal pollution, nuclear proliferation, and under nutrition. Nine electric power sources and two liquid fuel options are considered. The electricity sources include solar-photovoltaics (PV), concentrated solar power (CSP), wind, hydroelectric, wave, tidal, nuclear energy. This paper gives information about global change and its causes like green house gases land use change, sulphate aerosols and black carbon, role of human activity and consequences like how the regions on the globe are effected due to global change it gives brief information about solutions to over come these global change like mitigations and adaptations, and energy innovations and acts of government. Among the atmospheric pollution air pollution and its causes, consequences and solutions are reviewed

Key Words: Global change, pollution, mitigation, air pollution, eutrophication, global warming

INTRODUCTION:

The term Earth System refers to the suite of interacting physical, chemical, and biological processes that transport and transform materials and energy and thus provide the conditions necessary for life on the planet. Climate refers to the aggregation of all components of weather – precipitation, temperature, cloudiness, for example – but the climate system includes processes involving ocean, land and sea ice in addition to the atmosphere. The Earth System encompasses the climate system, and many changes in Earth System functioning directly involve changes in climate. However, the Earth System includes other components and processes, bio-physical and human, important for its functioning. Some Earth System changes, natural or human-driven, can have significant consequences without involving any changes in climate. Global change should thus not be confused with climate change; it is significantly more.

Global Change

Over the past few decades, evidence has mounted that planetary-scale changes are occurring rapidly. These are, in turn, changing the patterns of forcings and feedbacks that characterise the internal dynamics of the Earth System. Key indicators, such as the concentration of CO2 in the atmosphere, are changing dramatically, and in many cases the linkages of these changes. Mean annual surface temperature variations over the northern hemisphere for the last 1000 years. It is increasingly clear that the Earth System is being subjected to a wide range of new planetary-scale forces that originate in human activities, ranging from the artificial fixation of nitrogen and the emission of greenhouse gases to the conversion and fragmentation of natural vegetation and the loss of biological species. It is these activities and others like them that give rise to the phenomenon of global change

CAUSES FOR GLOBAL CHANGE:

1. GREEN HOUSE GASES:

The presence of greenhouse gases in the atmosphere is a natural component of the climate system and helps to maintain the Earth as a habitable planet. Greenhouse gases are relatively transparent to incoming solar radiation, allowing the sun's energy to pass through the atmosphere to the surface of the Earth. The energy is then absorbed by the Earth's surface, used in processes like photosynthesis, or emitted back to space as infrared radiation. Some of the emitted radiation passes through the atmosphere and travels back to space, but some is absorbed by greenhouse gas molecules and then re-emitted in all directions. The effect of this is to warm the Earth's surface and the lower atmosphere. Water vapor (H2O) and carbon dioxide (CO2) are the two largest contributors to the greenhouse effect. Methane (CH4), nitrous oxide (N2O), chlorofluorocarbons (CFCs) and other greenhouse gases are present only in trace amounts, but can still have a powerful warming effect due to their heat-trapping abilities and their long residence time in the atmosphere. Without the greenhouse effect, Earth's average temperature would be -0.4°F (-18°C), rather than the present 59°F (15°C). Concentrations of greenhouse gases – and especially carbon dioxide have risen over the past two hundred and fifty years, largely due to the combustion of fossil fuels for energy production. Since the Industrial Revolution in the eighteenth century the concentration of carbon dioxide in the atmosphere has risen from about 270 parts per million (ppm) to about 370 ppm. Concentrations of methane have also risen due to cattle production, the cultivation of rice, and release from landfills. Nearly one-third of human-induced nitrous oxide emissions are a result of industrial processes and automobile emissions.

2. Land-use Change:

The combustion of fossil fuels is not the only anthropogenic source of carbon dioxide. When ecosystems are altered and vegetation is either burned or removed, the carbon stored in them is released to the atmosphere as carbon dioxide. The principal reasons for deforestation are agriculture and urban growth, and harvesting timber for fuel, construction, and paper. Currently, up to a quarter of the carbon dioxide emissions to the atmosphere can be attributed to land-use change.

3. Sulfate Aerosols and Black Carbon

Sulfate aerosols and black carbon are two important additional examples of anthropogenic forcings. Sulfate aerosols, which enter the atmosphere naturally during volcanic eruptions, are tiny airborne particles that reflect sunlight back to space. Industrial activity has recently increased their concentration in the atmosphere primarily through the burning of fossil fuels containing sulfur. Anthropogenic emissions of sulfate aerosols have been associated with a net cooling effect. Black carbon is soot generated from industrial pollution, traffic, outdoor fires, and the burning of coal and biomass fuels. Black carbon is formed by incomplete combustion especially of coal, diesel fuels, biofuels and outdoor biomass burning. Soot particles absorb sunlight, both heating the air and reducing the amount of sunlight reaching the ground.

4. Global Climate Change in the Twentieth Century

The climate system includes a great deal of natural variability, and climate fluctuations have always been part of the Earth's 4.6 billion year history. However, over the past century changes in concentrations of greenhouse gases in the atmosphere are of an unprecedented rate and magnitude. Human population growth has led to increasing demands for energy and land resources. Through the burning of fossil fuels to produce energy for industrial use, transportation, and domestic power, and through land-use change for agriculture and forest products, humans have been altering the Earth's energy balance. Scientists believe that these changes may have already begun to alter the global climate.

5. **The role of human activity**

In its recently released Fourth Assessment Report, the Intergovernmental Panel on Climate Change, a group of 1,300 independent scientific experts from countries all over the world under the auspices of the

United Nations, concluded there's a more than 90 percent probability that human activities over the past 250 years have warmed our planet.

The industrial activities that our modern civilization depends upon have raised atmospheric carbon dioxide levels from 280 parts per million to 379 parts per million in the last 150 years. The panel also concluded there's a better than 90 percent probability that human-produced greenhouse gases such as carbon dioxide, methane and nitrous oxide have caused much of the observed increase in Earth's temperatures over the past 50 years. They said the rate of increase in global warming due to these gases is very likely to be unprecedented within the past 10,000 years or more.

6. Solar irradiance

It's reasonable to assume that changes in the sun's energy output would cause the climate to change, since the sun is the fundamental source of energy that drives our climate system. Indeed, studies show that solar variability has played a role in past climate changes. For example, a decrease in solar activity is thought to have triggered the Little Ice Age between approximately 1650 and 1850, when Greenland was largely cut off by ice from 1410 to the 1720s and glaciers advanced in the Alps. But several lines of evidence show that current global warming cannot be explained by changes in energy from the sun:

- Since 1750, the average amount of energy coming from the sun either remained constant or increased slightly.
- If the warming were caused by a more active sun, then scientists would expect to see warmer temperatures in all layers of the atmosphere. Instead, they have observed a cooling in the upper atmosphere, and a warming at the surface and in the lower parts of the atmosphere. That's because greenhouse gasses are trapping heat in the lower atmosphere.
- Climate models that include solar irradiance changes can’t reproduce the observed temperature trend over the past century or more without including a rise in greenhouse gases.

Current and Future Consequences of Global Change:

Scientists have high confidence that global temperatures will continue to rise for decades to come, largely due to greenhouse gasses produced by human activities. The Intergovernmental Panel on Climate Change (IPCC), which includes more than 1,300 scientists from the United States and other countries, forecasts a temperature rise of 2.5 to 10 degrees

Fahrenheit over the next century. According to the IPCC, the extent of climate change effects on individual regions will vary over time and with the ability of different societal and environmental systems to mitigate or adapt to change.

The IPCC predicts that increases in global mean temperature of less than 1.8 to 5.4 degrees Fahrenheit (1 to 3 degrees Celsius) above 1990 levels will produce beneficial impacts in some regions and harmful ones in others. Net annual costs will increase over time as global temperatures increase. "Taken as a whole," the IPCC states, "the range of published evidence indicates that the net damage costs of climate change are likely to be significant and to increase over time." Below are some of the impacts that are currently visible throughout the U.S. and will continue to affect these regions, according to the Third National Climate Assessment Report, released by the U.S. Global Change Research Program:

Northeast. Heat waves, heavy downpours, and sea level rise pose growing challenges to many aspects of life in the Northeast. Infrastructure, agriculture, fisheries, and ecosystems will be increasingly compromised. Many states and cities are beginning to incorporate climate change into their planning.

Northwest. Changes in the timing of streamflow reduce water supplies for competing demands. Sea level rise, erosion, inundation, risks to infrastructure, and increasing ocean acidity pose major threats. Increasing wildfire, insect outbreaks, and tree diseases are causing widespread tree die-off.

Southeast. Sea level rise poses widespread and continuing threats to the region's economy and environment. Extreme heat will affect health, energy, agriculture, and more. Decreased water availability will have economic and environmental impacts.

Midwest. Extreme heat, heavy downpours, and flooding will affect infrastructure, health, agriculture, forestry, transportation, air and water quality, and more. Climate change will also exacerbate a range of risks to the Great Lakes.

Southwest. Increased heat, drought, and insect outbreaks, all linked to climate change, have increased wildfires. Declining water supplies, reduced

agricultural yields, health impacts in cities due to heat, and flooding and erosion in coastal areas are additional concerns.

Solutions for Globle Changes:

NASA is a world leader in climate studies and Earth science. While its role is not to set climate policy or prescribe particular responses or solutions to climate change, its purview does include providing the robust scientific data needed to understand climate change. NASA then makes this information available to the global community – the public, policy- and decision-makers and scientific and planning agencies around the world.

Climate change is one of the most complex issues facing us today. It involves many dimensions – science, economics, society, politics and moral and ethical questions – and is a global problem, felt on local scales, that will be around for decades and centuries to come. Carbon dioxide, the heat-trapping greenhouse gas that has driven recent global warming, lingers in the atmosphere for hundreds of years, and the planet (especially the oceans) takes a while to respond to warming. So even if we stopped emitting all greenhouse gases today, global warming and climate change will continue to affect future generations. In this way, humanity is "committed" to some level of climate change.

How much climate change? That will be determined by how our emissions continue and also exactly how our climate system responds to those emissions. Despite increasing awareness of climate change, our emissions of greenhouse gases continue on a relentless rise. In 2013, the daily level of carbon dioxide in the atmosphere surpassed 400 parts per million for the first time in human history. The last time levels were that high was about three to five million years ago, during the Pliocene era. Because we are already committed to some level of climate change, responding to climate change involves a two-pronged approach:

1. Reducing emissions of and stabilizing the levels of heat-trapping greenhouse gases in the atmosphere ("mitigation");
2. Adapting to the climate change already in the pipeline ("adaptation").

Mitigation and adaptation:

Mitigation – reducing climate change – involves reducing the flow of heat-trapping greenhouse gases into the atmosphere, either by reducing sources of these gases (for example, the burning of fossil fuels for electricity, heat or transport) or enhancing the "sinks" that accumulate and

store these gases (such as the oceans, forests and soil). The goal of mitigation is to avoid dangerous human interference with the climate system, and "stabilize greenhouse gas levels in a timeframe sufficient to allow ecosystems to adapt naturally to climate change, ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner"

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Adaptation – adapting to life in a changing climate – involves adjusting to actual or expected future climate. The goal is to reduce our vulnerability to the harmful effects of climate change (like sea-level encroachment, more intense extreme weather events or food insecurity). It also encompasses making the most of any potential beneficial opportunities associated with climate change (for example, longer growing seasons or increased yields in some regions).

Throughout history, people and societies have adjusted to and coped with changes in climate and extremes with varying degrees of success. Climate change (drought in particular) has been at least partly responsible for the rise and fall of civilizations. Earth's climate has been relatively stable for the past 12,000 years and this stability has been crucial for the development of our modern civilization and life as we know it. Modern life is tailored to the stable climate we have become accustomed to. As our climate changes, we will have to learn to adapt. The faster the climate changes, the harder it could be.

While climate change is a global issue, it is felt on a local scale. Cities and municipalities are therefore at the frontline of adaptation. In the absence of national or international climate policy direction, cities and local communities around the world have been focusing on solving their own climate problems. They are working to build flood defenses, plan for heatwaves and higher temperatures, install water-permeable pavements to better deal with floods and stormwater and improve water storage and use.

According to the 2014 report on Climate Change Impacts, Adaptation and Vulnerability from the United Nations Intergovernmental Panel on Climate Change, governments at various levels are also getting better at adaptation. Climate change is starting to be factored into a variety of development plans: how to manage the increasingly extreme disasters we are seeing and their associated risks, how to protect coastlines and deal with sea-level encroachment, how to best manage land and forests, how to deal with

and plan for reduced water availability, how to develop resilient crop varieties and how to protect energy and public infrastructure.

Government Resources

NASA is an expert in climate and Earth science. While its role is not to set climate policy or prescribe particular responses or solutions to climate change, its purview does include providing the robust scientific data needed to understand climate change and evaluating the impact of efforts to combat it. NASA then makes this information available to the global community – the public, policy- and decision-makers and scientific and planning agencies around the world.

Energy innovations:

- Satellite shed light on solar system-the one on your roof top.
- NASA test revolutionary shape changing air craft flap for the first time
- Turning the tide to energy
- Alternative energy craft in space
- Wind forms can store and deliver surplus energy
- Generating electricity from 20 suns
- Artificial photosynthesis to make plants green with envy
- Nuclear reactor in your basement
- Electricity in air
- Getting a change of automobile heat

Pollution is now a common place term, that our ears are attuned to. We hear about the various forms of pollution and read about it through the mass media. Air pollution is one such form that refers to the contamination of the air, irrespective of indoors or outside. A physical, biological or chemical alteration to the air in the atmosphere can be termed as pollution. It occurs when any harmful gases, dust, smoke enters into the atmosphere and makes it difficult for plants, animals and humans to survive as the air becomes dirty.

Air Pollution:

Air pollution can further be classified into two sections- Visible air pollution and invisible air pollution. Another way of looking at Air pollution could be any substance that holds the potential to hinder the atmosphere or

the well being of the living beings surviving in it. The sustainment of all things living is due to a combination of gases that collectively form the atmosphere; the imbalance caused by the increase or decrease of the percentage of these gases can be harmful for survival. The Ozone layer considered crucial for the existence of the ecosystems on the planet is depleting due to increased pollution. Global warming, a direct result of the increased imbalance of gases in the atmosphere has come to be known as the biggest threat and challenge that the contemporary world has to overcome in a bid for survival.

Types of Pollutants

In order to understand the causes of Air pollution, several divisions can be made. **Primarily air pollutants** can be caused by primary sources or secondary sources. The pollutants that are a direct result of the process can be called primary pollutants. A classic example of a primary pollutant would be the sulfur-dioxide emitted from factories. **Secondary pollutants** are the ones that are caused by the inter mingling and reactions of primary pollutants. Smog created by the interactions of several primary pollutants is known to be as secondary pollutant.

Causes of Air pollution

1. Burning of Fossil Fuels:

Sulfur dioxide emitted from the combustion of fossil fuels like coal, petroleum and other factory combustibles is one the major cause of air pollution. Pollution emitting from vehicles including trucks, jeeps, cars, trains, airplanes cause immense amount of pollution. We rely on them to fulfill our daily basic needs of transportation. But, there overuse is killing our environment as dangerous gases are polluting the environment. Carbon Monooxide caused by improper or incomplete combustion and generally emitted from vehicles is another major pollutant along with Nitrogen Oxides, that is produced from both natural and man made processes.

2. Agricultural activities:

Ammonia is a very common by product from agriculture related activities and is one of the most hazardous gases in the atmosphere. Use of insecticides, pesticides and fertilizers in agricultural activities has grown quite a lot. They emit harmful chemicals into the air and can also cause water pollution.

3. Exhaust from factories and industries:

Manufacturing industries release large amount of carbon monoxide, hydrocarbons, organic compounds, and chemicals into the air thereby depleting the quality of air. Manufacturing industries can be found at every corner of the earth and there is no area that has not been affected by it. Petroleum refineries also release hydrocarbons and various other chemicals that pollute the air and also cause land pollution.

4. Mining operations:

Mining is a process wherein minerals below the earth are extracted using large equipments. During the process dust and chemicals are released in the air causing massive air pollution. This is one of the reason which is responsible for the deteriorating health conditions of workers and nearby residents.

5. Indoor air pollution:

Household cleaning products, painting supplies emit toxic chemicals in the air and cause air pollution. Have you ever noticed that once you paint walls of your house, it creates some sort of smell which makes it literally impossible for you to breathe. Suspended particulate matter popular by its acronym SPM, is another cause of pollution. Referring to the particles afloat in the air, SPM is usually caused by dust, combustion etc.

Effects of Air pollution

1. Respiratory and heart problems:

The effects of Air pollution are alarming. They are known to create several respiratory and heart conditions along with Cancer, among other threats to the body. Several millions are known to have died due to direct or indirect effects of Air pollution. Children in areas exposed to air pollutants are said to commonly suffer from pneumonia and asthma.

2. Global warming:

Another direct effect is the immediate alterations that the world is witnessing due to Global warming. With increased temperatures world wide, increase in sea levels and melting of ice from colder regions and icebergs, displacement and loss of habitat have already signaled an impending disaster if actions for preservation and normalization aren't undertaken soon.

3. Acid Rain:

Harmful gases like nitrogen oxides and sulfur oxides are released into the atmosphere during the burning of fossil fuels. When it rains, the

water droplets combines with these air pollutants, becomes acidic and then falls on the ground in the form of acid rain. Acid rain can cause great damage to human, animals and crops.

4. Eutrophication:

Eutrophication is a condition where high amount of nitrogen present in some pollutants gets developed on sea's surface and turns itself into algae and and adversely affect fish, plants and animal species. The green colored algae that is present on lakes and ponds is due to presence of this chemical only.

5. Effect on Wildlife:

Just like humans, animals also face some devastating affects of air pollution. Toxic chemicals present in the air can force wildlife species to move to new place and change their habitat. The toxic pollutants deposit over the surface of the water and can also affect sea animals.

6. Depletion of Ozone layer:

Ozone exists in earth's stratosphere and is responsible for protecting humans from harmful ultraviolet (UV) rays. Earth's ozone layer is depleting due to the presence of chlorofluorocarbons, hydro chlorofluorocarbons in the atmosphere. As ozone layer will go thin, it will emit harmful rays back on earth and can cause skin and eye related problems. UV rays also have the capability to affect crops. There are two types of sources: **Natural sources and Man-made sources.**

Natural sources of pollution include dust carried by the wind from locations with very little or no green cover, gases released from the body processes of living beings (Carbon dioxide from humans during respiration, Methane from cattle during digestion, Oxygen from plants during Photosynthesis). Smoke from the combustion of various inflammable objects, volcanic eruptions etc along with the emission of polluted gases also make it to the list of Natural sources of Pollution.

While looking at the man-made contributions towards air pollution, smoke again features as a prominent component. The smoke emitted from various forms of combustion like in bio mass, factories, vehicles, furnaces etc. Waste used to create landfills generate methane, that is harmful in several ways. The reactions of certain gases and chemicals also form harmful fumes that can be dangerous to the well being of living creatures.

Solutions for Air Pollution

1. Use public mode of transportation:

Encourage people to use more and more public modes of transportation to reduce pollution. Also, try to make use of car pooling. If you and your colleagues come from the same locality and have same timings you can explore this option to save energy and money.

2. Conserve energy:

Switch off fans and lights when you are going out. Large amount of fossil fuels are burnt to produce electricity. You can save the environment from degradation by reducing the amount of fossil fuels to be burned.

3. Understand the concept of Reduce, Reuse and Recycle:

Do not throw away items that are of no use to you. In-fact reuse them for some other purpose. For e.g. you can use old jars to store cereals or pulses.

4. Emphasis on clean energy resources:

Clean energy technologies like solar, wind and geothermal are on high these days. Governments of various countries have been providing grants to consumers who are interested in installing solar panels for their home. This will go a long way to curb air pollution.

5. Use energy efficient devices:

CFL lights consume less electricity as against their counterparts. They live longer, consume less electricity, lower electricity bills and also help you to reduce pollution by consuming less energy. Several attempts are being made world wide on a personal, industrial and governmental levels to curb the intensity at which Air Pollution is rising and regain a balance as far as the proportions of the foundation gases are concerned. This is a direct attempt at slacking Global warming. We are seeing a series of innovations and experiments aimed at alternate and unconventional options to reduce pollutants. Air Pollution is one of the larger mirrors of man’s follies, and a challenge we need to overcome to see a tomorrow.

Conclusion:

The ozone (O3) layer in the stratosphere protects life on earth by filtering out harmful ultraviolet radiation (UV) from the sun. When CFCs and other ozone-degrading chemicals are emitted, they mix with the atmosphere and eventually rise to the stratosphere. There, the chlorine and the bromine they contain initiate chemical reactions that destroy ozone. This

destruction has occurred at a more rapid rate than ozone can be created through natural processes, depleting the ozone layer. Higher levels of ultraviolet radiation reaching Earth's surface lead to health and environmental effects such as a greater incidence of skin cancer, cataracts, and impaired immune systems. Higher levels of ultraviolet radiation also reduce crop yields, diminish the productivity of the oceans, and possibly contribute to the decline of amphibious populations that is occurring around the world. Countries around the world are phasing out the production of chemicals that destroy ozone in the Earth's upper atmosphere under an international treaty known as the Montreal Protocol. Using a flexible and innovative regulatory approach, the United States already has phased out production of those substances having the greatest potential to deplete the ozone layer under Clean Air Act provisions enacted to implement the Montreal Protocol. These chemicals include chlorofluorocarbons (CFCs), halons, methyl chloroform and carbon tetrachloride. The United States and other countries are currently phasing out production of hydrochlorofluorocarbons (HCFCs), chemicals being used globally in refrigeration and air-conditioning equipment and in making foams. Phasing out CFCs and HCFCs is also beneficial in protecting the earth's climate, as these substances are also very damaging greenhouse gases. Also under the Clean Air Act, EPA implements regulatory programs to ensure that refrigerants and halon fire extinguishing agents are recycled properly. Ensure that alternatives to ozone-depleting substances are evaluated for their impacts on human health and the environment. Ban the release of ozone-depleting refrigerants during the service, maintenance, and disposal of air conditioners and other refrigeration equipment. Require that manufacturers label products either containing or made with the most harmful ODS. These vital measures are helping to protect human health and the global environment.The work of protecting the ozone layer is not finished. EPA plans to complete the phase-out of ozone-depleting substances that continue to be produced, and continue efforts to minimize releases of chemicals in use. Since ozone-depleting substances persist in the air for long periods of time, the past use of these substances continues to affect the ozone layer today. In our work to expedite the recovery of the ozone layer, EPA plans to augment CAA implementation by Continuing to educate the public, especially children, on how to protect themselves from excess exposure to UV radiation through the SunWise program. Continuing to foster domestic and international partnerships to protect the ozone layer. Encouraging the development of products, technologies, and initiatives that reap co-benefits in climate change and energy efficiency.

References

- National Research Council (2010), *Advancing the Science of Climate Change*, National Academy Press, Washington, D.C., p. 3.
- National Research Council (2010), *Advancing the Science of Climate Change*, National Academy Press, Washington, D.C., p. 286.
- USGCRP (2009). *Global Climate Change Impacts in the United States*. Karl, T.R., J.M. Melillo, and T.C. Peterson (eds.). United States Global Change Research Program. Cambridge University Press, New York, NY, USA.
- CCSP (2008). *Analyses of the effects of global change on human health and welfare and human systems*. A Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. Gamble, J.L. (ed.), K.L. Ebi, F.G. Sussman, T.J. Wilbanks, (Authors). U.S. Environmental Protection Agency, Washington, DC, USA.
- Confalonieri, U., B. Menne, R. Akhtar, K.L. Ebi, M. Hauengue, R.S. Kovats, B. Revich and A. Woodward (2007). Human health. In: *Climate Change 2007: Impacts, Adaptation and Vulnerability . Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* Parry, M.L., O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, (eds.), Cambridge University Press, Cambridge, United Kingdom
- An explanation of observed and projected climate change and its associated impacts on health, society, and the environment is included in the EPA's Endangerment Finding and associated technical support document (TSD). See EPA, "Endangerment and Cause or Contribute Findings for Greenhouse Gases under Section 202(a) of the Clean Air Act," 74 FR 66496, Dec. 15, 2009. Both the Federal Register Notice and the Technical Support Document (TSD) for Endangerment and Cause or Contribute Findings are found in the public docket, Docket No. EPA-OAR-2009-0171 and at http://epa.gov/climatechange/endangerment.html.
- EPA, *Endangerment Finding*, 74 FR 66535.
- EPA, *Endangerment Finding*, 74 FR 66498.

- National Research Council (2011) *America's Climate Choices: Report in Brief*, Committee on America's Climate Choices, Board on Atmospheric Sciences and Climate, Division on Earth and Life Studies, The National Academies Press, Washington, D.C., p. 2.
- Greenough G, McGeehin M, Bernard SM, Trtanj J, Riad J, Engelberg D. The potential impacts of climate variability and change on health impacts of extreme weather events in the United States. Environ Health Perspect. 2001;109 (Suppl 2):191–8. "International Geosphere- Biosphere Programme the Earth as a System". Retrieved 2010-03-25. International Geosphere-Biosphere Programme
- "The Achilles Heel of the Earth System". International Institute for Applied Systems Analysis. Retrieved 2010-03-25.
- "The Amsterdam Declaration". Earth System Science Partnership. Retrieved 2010-03-25.
- "Global Change and the Earth System". Retrieved 2010-03-25.
- "2008 Global Carbon Budget". Global Carbon Project. Retrieved 2010-03-25. NASA Earth Observatory. 2011. Retrieved 8 July 2011. Climate System: The five physical components (atmosphere, hydrosphere, cryosphere, lithosphere, and biosphere) that are responsible for the climate and its variations.
- IPCC (2007). "What are Climate Change and Climate Variability?". IPCC.
- Kirk Bryan, Geophysical Fluid Dynamics Laboratory. Man's Great Geophysical Experiment. U.S. National Oceanic and Atmospheric Administration.
- Spracklen, D. V; Bonn, B.; Carslaw, K. S (2008). "Boreal forests, aerosols and the impacts on clouds and climate". *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* **366** (1885): 4613–26. doi:10.1098/rsta.2008.0201. PMID 18826917.
- Christner, B. C.; Morris, C. E.; Foreman, C. M.; Cai, R.; Sands, D. C. (2008). "Ubiquity of Biological Ice Nucleators in Snowfall". *Science* **319** (5867): 1214. doi:10.1126/science.1149757. PMID 18309078.
- Schwartzman, David W.; Volk, Tyler (1989). "Biotic enhancement of weathering and the habitability of Earth". *Nature* **340** (6233): 457. doi:10.1038/340457a0.

- Kopp, R. E.; Kirschvink, J. L.; Hilburn, I. A.; Nash, C. Z. (2005). "The Paleoproterozoic snowball Earth: A climate disaster triggered by the evolution of oxygenic photosynthesis". *Proceedings of the National Academy of Sciences* **102** (32): 11131–6. doi:10.1073/pnas.0504878102. PMC 1183582. PMID 16061801.
- Kasting, J. F.; Siefert, JL (2002). "Life and the Evolution of Earth's Atmosphere". *Science* **296** (5570): 1066–8. doi:10.1126/science.1071184. PMID 12004117.