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NANOTECHNOLOGY IN MITIGATING GLOBAL WARMING AND CLIMATE FORCING

From the Coordinator's Desk...

Today, Nanotechnology research and development is wide spread, although not high profile yet. Numerous Universities, such as University of Washington and Northwestern University have established centres and institutes to study nanotechnology and the US Government has created an organization, the National Initiative (NNI), to minor and guide research and development in this field. Defense Advances Research Projects Agency (DARPA) and the NSF are currently the two largest sources of funding for nanotechnology research and have an enormous influence on the direction of scientific research done in the United States. With so many resources dedicated to its development, nanotechnology will surely have an impact within our lifetime, so it is important to examine its ethical implications while it is still in its infancy.

Nanotechnology also called molecular manufacturing, is a branch of engineering that deals with the design and manufacture of extremely small electronic circuits and mechanical devices built at the molecular level of matter. Weapons are an obvious negative use of nanotechnology. Simply extending today's weapon capabilities by miniaturizing guns, explosives and electronic components of missles would be deadly enough.

However, with nanotechnology, armies could also develop disassemblers to attack physical structures or even biological organism at the molecular level. With such awesome dangers inherent in nanotechnology, we must seriously examine its potential consequences. Granted, nanotechnology may never become as powerful and profile as envisioned by its evangelists, but as with any potential, near horizon technology, we should go through the exercise of formulating solutions to the ethical issues before this technology is irreversibly adopted by the society. We must examine the ethics of developing nanotechnology and create policies that will aid in its development.

This newsletter focuses on **Nanotechnology in Mitigating Global Warming and Climate Forcing**. I hope this issue will be useful to readers.

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NANOTECHNOLOGY IN MITIGATING GLOBAL WARMING AND CLIMATE FORCING

Introduction

Global warming is affecting many parts of the world. Due to global warming, the glaciers are melting which are causing rise in sea level, thus causing danger to the people living in low lying areas. This causes a big problem for the Human being, Plants and Animals living on the earth. The whole chain will get affected if nothing is done on time to stop global warming from spreading it's wings.

Global Warming: Recent Scenario

Recently, Global warming dragged the world temperature to the maximum considered to that in past millennium. There is also a report saying that increase in global temperature associated with global warming is due to increase in the emission of anthropogenic Green House Gases. These Green House Gases (GHGs) lead to global climate forcing which means imposed perturbation of Earth's energy balance with space. The release or emission of these greenhouse gases help in reducing heat radiation that is getting escaped from the earth. This results in trapping of heat radiation within earth thus keeping it warmer always. This concept is referred as global warming. Though there are various climate forcing causes including natural and anthropogenic, Green House Gases are found to be the most important factor for global warming.

Climate models driven by "business-as-usual" Green House Gas scenarios for the 21st century yield a global warming of several degrees that would almost have detrimental effects on humans and wildlife. Such Green House Gas scenarios can leave the impression that curtails global warming is almost hopeless. The 1997 Kyoto Protocol, which calls for industrialized Nations to reduce their carbon dioxide emissions to 95% of 1990 levels by 2012, is itself considered a difficult target to achieve. Yet, the climate simulations lead to the conclusion that the Kyoto reductions will have little effect in 21st century and "thirty Kyotos" may be needed to reduce warming to an acceptable level.

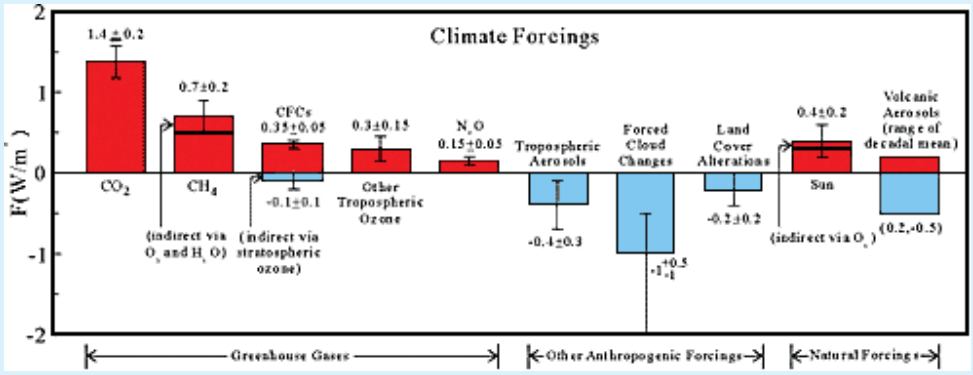
Scientists suggest equal emphasis on an alternative, more optimistic scenario that emphasizes reduction of non-carbon dioxide Green House Gases and black carbon during the next 50 years. This scenario, derives from our interpretation that observed global warming, has been caused mainly by non carbon dioxide greenhouse gases. Although this interpretation does not alter the desirability of slowing carbon dioxide emissions, it does suggest that it is more practical to slow global warming than is sometimes assumed.

Climate Forcing

Scientists separate carbon dioxide, methane, chlorofluorocarbons and ozone, because they are produced by different processes and have different growth rates. The association of Methane and its indirect effects on troposphere ozone and stratospheric hydrogen makes clear about its importance as a climate forcing.

Climate forcing by carbon dioxide is the largest forcing, but it does not dwarf the others. Climate forcing by methane is half as large as that of carbon dioxide and the total forcing by non-carbon dioxide green house gases equals to that of carbon dioxide. Moreover, in comparing forcing due to different activities, note that fossil fuels producing most of the carbon dioxide are also the main source of atmospheric aerosols, especially sulphates, black carbon, and organic aerosols.

Aerosols cause a climate forcing directly by reflecting Sunlight and indirectly by modifying



Climate Forcing betscientistsen 1850 & 2000

interpretation is that change of ocean heat content, and implied planetary energy imbalance, is a reflection of net global climate forcing. Observed heat storage is in good agreement with results in global climate models that use the forcing, provides empirical evidence for the sign and approximate magnitude of the net climate forcing.

cloud properties. Forcing by atmospheric aerosols is uncertain, but research of the past decade indicates that it is substantial. The aerosol forcing that scientists estimate has the same magnitude but become opposite sign of the carbon dioxide forcing. Fossil fuel use is the main source of both carbon dioxide and aerosols. Land conversion and biomass burning are also contributing to both forcing. Although fossil fuels contribute to growth of some of other Green House Gases, it follows that the net global climate forcing due to processes that produced carbon dioxide in the past century probably is much less than 1.4 W/m^2.

A corollary following from Figure 1 is that climate forcing by non-$C0_2$ GHGs (1.4 W/m^2) is nearly equal to the net value of all known forcing for the period 1850-2000 (1.6 W/m^2). Thus, assuming only that our estimates are approximately correct, scientists assert that the processes producing the non-$C0_2$ GHGs have been the primary drive for climate change in the past century.

Observed heat storage in the ocean provides a fundamental consistency check on the estimated climate forcing. The ocean is the only place that energy from a planetary radiation imbalance can accumulate, because of the low thermal conductivity of land and the limit on ice melting implicit in observed sea level rise. Global ocean data reveal that ocean heat content increased 2x10^{23} joules between the mid-1950s and mid-1990s. The simplest

Greenhouse Gas Growth Rates

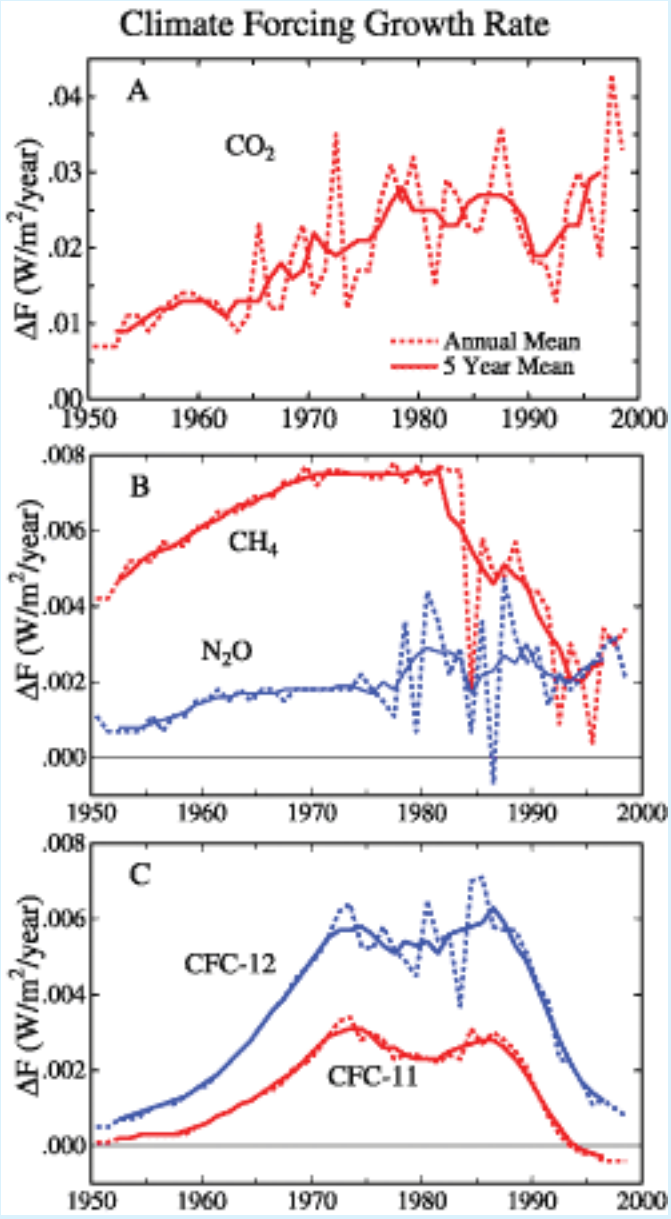
Atmospheric amount of the principal human-influenced GHGs have been monitored in recent years and extracted for earlier times from bubbles of air trapped in polar ice sheets. The growth rate of forcing by carbon dioxide doubled between 1950s and 1970s, but was flat from the late 1970s until late 1990s despite a 30% increase in fossil fuel use. This implies a recent increase of terrestrial and/or oceanic sinks for $C0_2$, which may be temporary. It is revealed that a dramatic growth rate change has occurred for methane. Factors that may have slowed the Methane growth rate are recognized, but most of them are not accurately quantified. The growth rate of two principal chlorofluorocarbons is near zero and will be negative in the future as a result of production restrictions imposed by the Montreal Protocol.

The Three Largest Climate Forcings

The largest anthropogenic climate forcings, by $C0_2$, CH_4 and aerosols, pose the greatest uncertainties in attempts to project future climate change. Coal and oil are now about equal sources of Carbon dioxide emissions. Coal is the source of potentially large future emissions, as its known resources are an order of magnitude greater than those of either oil or gas. The flat growth rate of $C0_2$ forcing, despite increased emissions, is at least in part a reflection of

increased terrestrial sequestration of carbon in the 1990s. The prognosis for future sequestration is uncertain, but it is unlikely that a flat growth rate of $C0_2$ forcing can be maintained without a flattening of the growth rate of fossil fuel emissions, which have grown 1.2% / year since 1975.

The decline of methane (CH_4) growth rate is due to some combination of changes in the sinks for methane and the sources of CH_4. The primary natural source of CH_4 is microbial decay of organic matter under anoxic conditions in wetlands. Anthropogenic sources, which in sum may be twice as great as the natural source, include rice cultivation, domestic ruminants, bacterial decay in landfills and sewage, leakage during the mining of fossil fuels, leakage from natural gas pipelines, and biomass burning. Global warming could cause natural wetland source to increase, but if warming causes a drying of wetlands, it might reduce the CH_4 source.



Climate Forcing by individual Green House Gases: a) Carbon dioxide, b) Methane and Nitrous oxide, c) CFC-11 and CFC-12 based on trace gas

Climate forcing by anthropogenic aerosols may be the largest source of uncertainty about future climate change. The approximate global balancing of aerosol and $C0_2$ forcing in the past cannot continue indefinitely as long-lived $C0_2$ accumulates, continued balancing requires a greater and greater aerosol load. Scientists have argued that would be a Faustian bargain. Detrimental effects of aerosols including acid rain and health impacts/will eventually limit aerosol amount and thus expose latent greenhouse warming. Scientists do not have observations that define even the sign of the current trend of aerosol forcing because it requires the trends of different aerosol compositions. The direct aerosol forcing depends on its absorption. The indirect aerosol forcing also depends on aerosol absorption, which affects both cloud cover and brightness.

An Alternative Scenario

Scientists propose a climate forcing scenario for the next 50 years that adds little forcing, less than or about 1 W/m^2. Next 50 years is the most difficult time to affect $C0_2$ emissions due to inertia of global energy systems. The essence of strategy is to halt and even reverse the growth of non-$C0_2$ GHGs and to reduce black carbon emissions. This will mitigate an inevitable, even if slowing, growth of $C0_2$. By mid-century improved energy efficiency and advanced technologies, perhaps including

hydrogen powered fuel cells, should allow policy options with reduced reliance on fossil fuels and, if necessary, $C0_2$ sequestration.

Carbon dioxide: The scenario calls for mean $C0_2$ growth rate in the next 50 years to be about the same as in past two decades. Is this plausible? Scientists note that $C0_2$ growth rate increased little in the past 20 years while much of developing world had rapid economic growth. The United States had strong growth with little emphasis on energy efficiency, indeed with increasing use of energy-inefficient sports utility vehicles. This suggests that there are opportunities to achieve reduced emissions consistent with strong economic growth. In the near term (2000-2025) this scenario can be achieved via improved energy efficiency and a continued trend toward decarbonization of energy sources, e.g., increased use of gas instead of coal. On the longer term (2025-2050) attainment of a decreasing C02 growth rate will require still greater use of energy sources that produce little or no $C0_2$. If renewable energy systems are to play a substantial role by second quarter of the century, it is important to foster research and development investments now on generic technologies at the interface between energy supply and end use, e.g., gas turbines, fuel cells, and photovoltaics.

Methane: Our scenario aims for a forcing of -0.2 W/m^2 for CH_4 change in the next 50 years. This requires reducing anthropogenic CR, sources by about 30%. Reduction of CH4 would have the added benefit of increasing atmospheric OH and reducing tropospheric 0_3, a pollutant that is harmful to human health and agriculture.

CH_4 produced by rice cultivation, perhaps the largest anthropogenic source, can be reduced by cultivar choice, fertilizer choice, and use of intermittent irrigation, which has the added advantage of reducing plant pests and malaria-carrying mosquitoes. Ruminants offer potential for emission reduction via dietary adjustments, as the farmer's objective is to produce meat, milk, or power from the carbon in their feed, not CH_4. CH_4 losses from leaky natural gas distribution lines could be reduced, especially in the former Soviet Union, which is served by an old system that was built without financial incentives to reduce losses. Similarly, CH_4 escaping at landfills, in coal and oil mining, and from anaerobic waste management lagoons, can be reduced or captured, with economic benefits that partially or totally offset the costs.

The pollutant carbon monoxide (CO) contributes to increased CH_4, and 0_3 through its effect on OH. A small downward trend of CO has occurred in recent years in many concerned countries. More widespread use of advanced technologies that reduce CO emissions will help achieve CH_4 and 0_3 reductions.

Chlorofluorocarbons (CFC): If CFCs are phased out according to the Montreal Protocol the forcing by controlled gases will be about 0.15 W/m^2 less in 2050 than at present. Uncontrolled gases, some of them substitutes for ozone-depleting chemicals, are likely to increase and cause a positive forcing of about that same magnitude, with the largest contributor being HFC-134a. The Protocol, which has been a model of international co-operation, recently approved $150M for China and $82M for India, the two largest remaining producers, for complete phase-out of their CFC production. This should make the net change in climate forcing by these gases over the next 50 years about zero. If the phase-out scientistsre extended to include additional gases, such as HFC-134a, and destruction of accessible bank of CFC-12, a negative forcing change of -0.1 W/m2 seems possible.

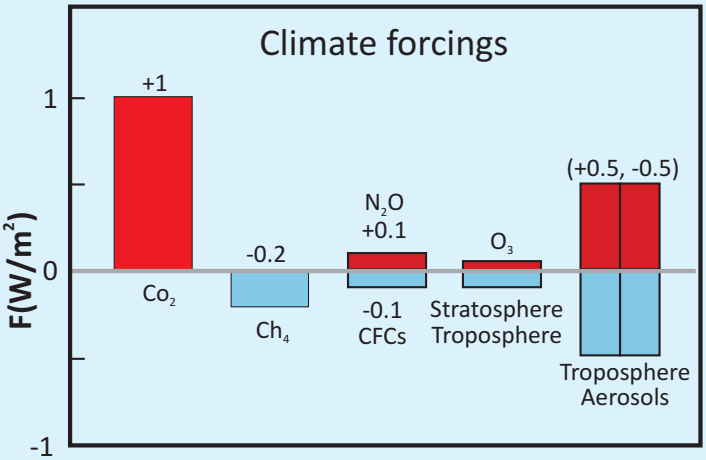
Tropospheric ozone: Principal precursor emissions of tropospheric 0_3 are volatile organic compounds and Nitrogen oxides (NOx). Primary sources of the precursors are transportation

vehicles and industrial processes. Business-as-usual scenarios have 0_3 continuing to increase in the future. Because 0_3 in the free troposphere can have a lifetime of scientistseks, tropospheric 0_3 is a global problem, e.g., emissions in Asia are projected to have a significant effect on air quality in the United States. High levels of 0_3 have adverse health and ecosystem effects. Annual costs of the impacts on human health and crop productivity are each estimated to be of the order of $10B/year in the United States alone.

The human and ecological costs of this pollutant suggest that it should be a target for international cooperation in the next half century. Air pollution in some Asian regions is already extreme, with high ecological and health costs. Unlike the Kyoto negotiations on $C0_2$ emissions, which cast the developed and developing worlds as adversaries, all parties should have congruent objectives regarding 0_3. Analogous to the approach for CFCs, sharing of technology may have mutual environmental and economic benefits.

Aerosols: It is often assumed that aerosol forcing will become more negative in the future, which would be true if all aerosols increased in present proportions. However, it is just as likely that aerosol forcing will become less negative, e.g., if sulfates decrease relative to black carbon. Black carbon reduces aerosol albedo, causes a semi-direct reduction of cloud cover, and reduces cloud particle albedo. All these effects cause warming. Conceivably a reduction of climate forcing by 0.5 W/m^2 or more could be obtained by reducing black carbon emissions from diesel fuel and coal. This might become easier in the future with more energy provided via electricity grids from power plants. But quantitative understanding of the absorbing aerosol role in climate change is required to permit reliable policy recommendations.

Aerosols, unlike GHGs, are not monitored to an accuracy defining their global forcing and its temporal change. They must be monitored

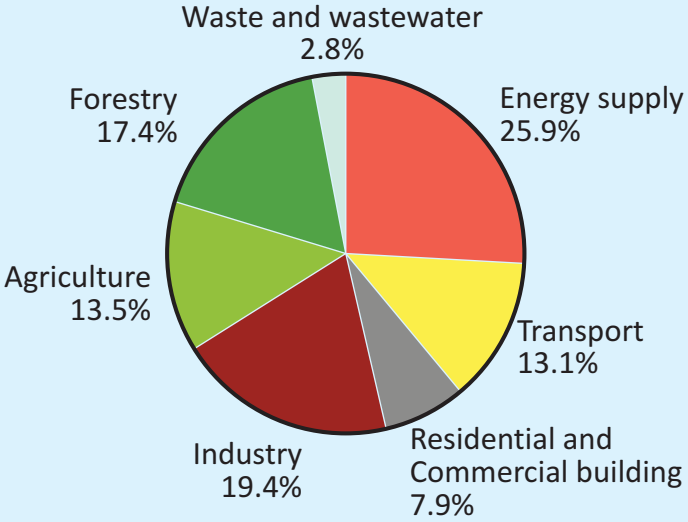


A Senario for additional climate forcing betescientistsen 2000 and 2050. Reduction of black carbon moves the aerosol forcing to losciientistsr values

globally because of their heterogeneity. Measurements must yield precise aerosol microphysics and composition information in order to define the direct forcing and provide data to analyze indirect effects.

Causes of Global Warming

Global warming is the greatest challenge facing by our planet. It is, in fact, the increase in the temperature of the earth's neon- surface air. It is one of the most current and widely discussed factors. It has far-reaching impact on



Pie Chart showing different causes of Global Warming

biodiversity and climatic conditions of the planet. Several current trends clearly demonstrate that global warming is directly impacting on rising sea levels, the melting of ice caps and significant worldwide climate changes. In short, global warming represents a fundamental threat to all living things on earth.

Global average temperature rose significantly during the past century. The prevailing scientific view is that most of the temperature increases since mid-20th century has been caused by increase in atmospheric Green House Gas concentrations produced by human activity. Most scientists agree that planet's temperature has risen 0.5 degree Celsius since 1900 and will continue-to increase at an increasing rate. As a result, the world is getting warmer. The year 1990 was the hottest year in the last century. Together with 1991, the years of 1983, 1987, 1988 and 1989 have been measured to be the warmest six years in the last hundred years. The year 1991 was the second warmest year of the past century. The consequences of rise in temperature is being felt all over the globe the findings of scientific research done in this field reveal that temperature of the earth is likely to rise from 1.4°C to 5.8°C within a period of 100 years.

Unfortunately, the imbalance which scientists have created between our life and earth is already showing the signs disasters in the form of flood, cyclones, landslides, tsunami, drought, etc. If the imbalance continues to rise, one day this will pose a question mark on existence of this planet. Carbon dioxide ($C0_2$), which is an important constituent of environment is causing a warming effect on earth's surface.

It increases evaporation of water into the atmosphere. Since water vapour itself is a greenhouse gas, this causes still more warming. The warming causes more water vapour to be evaporated. The C02 level is expected to rise in future due to ongoing burning of fossil fuels and land use change. The rate of rise will depend largely on uncertain economic, sociological, technological and natural developments. Other gases such as methane, CFCs, nitrous oxide, tropospheric ozone are also responsible for global warming. Increases in all these gases are due to explosive population growth, increased industrial expansion, technological advancement, deforestation and growing urbanization etc.

Trees play a significant role in the global carbon cycle. They are the largest land-based mechanism for removing carbon dioxide from the air. Deforestation is checking these positive processes. It is the second principal cause of atmospheric carbon dioxide. Deforestation is responsible for 25 per cent of all carbon emissions entering the atmosphere, by the burning and cutting of 34 million acres of trees each year. Every day over 5500 acres of rainforest are destroyed. As a consequence of massive loss of forests, global CO, levels rise approximately 0.4 per cent each year, the levels not experienced on this planet for millions of years. As scientists know forests are the great absorbers of CO.

There is a close relation between global warming and population growth. Today the large population on earth is using technologies which are destructive for the earth. Approximately, 80 per cent of atmospheric $C0_2$ increase is due to man's use of fossil fuels either in the form of coal, gas or oil. A large portion of carbon emission is attributed to the burning of gasoline in internal-combustion engine of vehicles. Vehicles with poor gas mileage contribute the most to global warming. Besides, Sulphur group gas is the most harmful for this. Its contribution is 30 per cent in global warming. This gas is also emitted from burning of fossil fuels. Increase in global temperatures will cause rise in sea level.

It will lead to melting of glaciers, changes in rainfall patterns, increased intensity and

frequency of extreme weather. As per the latest survey report, the rate of melting of glaciers has seen sharp increase in recent times. Even those glaciers are affected from global warming which have been considered permanent. The shrinking of glaciers is going to pose a major problem of drinking water. The sea levels as a result of melting of glaciers have risen from 0.35 mm to 0.4 mm. Scientists have warned in their reports that most of the glaciers will disappear within a period of 15 to 25 years. It will create problems of drinking water and food grains in most of the North American "countries. India is not unaffected from it. The Himalayan glaciers have shrunk about 30 per cent after 1970.

The rise in sea levels is a major cause of concern. A large number of cities located in coastal areas will submerge in the sea. Besides, many island countries will ultimately "lose their existence and will be washed away from the surface of earth. The damage of rising sea levels is diverse. Buildings and roads close to the water could be flooded and they could suffer damage from hurricanes and tropical storms. Experts believe that global warming could increase the intensity of hurricanes by over 50 per cent. In addition, as the sea rises, beach erosion takes place, particularly on steep banks.

Wetlands are lost as the level rises. Rise in atmospheric temperature will lead to outbreak of air-borne and water-borne diseases. It would also contribute to the rise in death caused by heat. The problem of drought would be frequent. Consequently, malnutrition and starvation will pose serious challenge before humanity. Global warming is a great threat to the flora and fauna of earth. A large number of species may become extinct.

The expand of desert would increase. Low rainfall and rising temperature could add to the intensity and frequency of dusty storm. This in turn will immensely affect the quality of agricultural land, ultimately causing adverse effect on agricultural produce. It would have far-reaching socio-economic impact. In Indian context, the impact of global warming is a matter of grave concern. As is well known, India is mainly an agricultural country and agriculture here is gamble of the monsoon, e.g. largely depending on rainfall. Though it is to affect the whole country, worst likely impact would be on central and northern India which is high-yielding parts of the country. These are the regions which produce the largest agricultural yield. The rise in atmospheric temperature and fall in rain would naturally result in decline in crop production. Moreover, it would have great effect on biodiversity as well.

The growing concerns over global temperatures have led to Nations, states, corporations and individuals to draw out a plan of action to avert the situation. As a result the world's primary international agreement on combating global warming was reached in Kyoto in 19-97 which came to be known as Kyoto Protocol. However, ten years have passed; the situation does not appear to be very changed. It seems that the member countries are not very serious about its devastating effects.

In addition, aforestation can be of great help in this regard. Planting more trees and reducing timber cuts worldwide will help restore the imbalance. Secondly, scientists must follow on environmental policy of 'reduce, reuse, recycle', i.e. promoting the reuse of anything. Thirdly, the use of fuel-efficient vehicles should be promoted as these vehicles have lower emissions of harmful gases. Fourthly, every individual should be aware of importance of protecting the environment. Besides, eco-friendly technologies must be promoted, and substituted with the technologies which cause great emission of global warming gases. Public awareness campaign can be of great help in this

regard because unless each and every individual is aware only Governments' effect cannot bring desired difference.

There are many causes of global warming, and scientists typically divide those causes into two primary groups: a) Natural causes and b) Man-made causes. While humans can do little to eradicate natural causes, it is possible to reduce or eliminate man-made causes.

Natural Causes of Global Warming

Natural causes have been contributing to global warming since before recorded history. Most experts do not believe that natural causes alone are substantial enough to result in climate changes currently taking place on the planet.

Sunspots

Increased solar activity changes the earth's solar radiation levels, thereby causing short-term warming cycles. Sunspots are dark patches on the Sun's surface that block hot solar plasma. Although this blocking action might appear to reduce solar radiation, the opposite is true. Surrounding sunspots are bright patches known as faculae. These patches give off greater than normal radiation, and they are more powerful than the darker, cooler patches. This means that the total average energy over a 30-day solar rotation increases.

Arctic Tundra

An estimated, 50 billion tons of carbon are frozen in the Tundra. Warmer global temperatures are causing the arctic Tundra to begin emitting carbon dioxide. As the average temperature on earth continues to rise due to global warming, increased carbon emissions will reach the atmosphere, resulting in a cycle that will significantly affect the planet.

Permafrost

Permafrost, which is solid, frozen soil, constitutes about 25 percent of the land area in Northern Hemisphere. Until recently, permafrost has locked carbon and methane beneath the surface of planet. In some areas, permafrost is now emitting carbon, which could potentially accelerate the Greenhouse effect and global warming.

Water Vapour

Water vapour is increasing in the atmosphere due to carbon dioxide-induced warming. Approximately two-third of the heat, trapped by greenhouses gases, is contained in water vapour, and as the average temperature on the planet continues to rise, the amount of water vapour rises in turn.

Man-made (Anthropogenic) Causes

Most man-made causes of global warming result from an increase in Green House Gases, which are gases that trap or absorb infrared radiation emitted from the planet.

Burning of Fossil Fuels

Carbon dioxide is the most significant cause of global warming, and most carbon dioxide emissions result from the burning of fossil fuels. Each time a fossil fuel burns, carbon dioxide levels in the atmosphere increase. Carbon dioxide absorbs infrared energy emitted from the earth, preventing it from returning to space.

- **Electricity Production:** Electricity generation through burning of fossil fuels accounts for 40 percent of carbon dioxide emissions in the United States. Coal is the largest producer of carbon dioxide emissions, giving off nearly twice as much carbon per energy unit as natural gas.

- **Automobiles:** Carbon emissions from the burning of gasoline to power cars, trucks, and other methods of transportation is one of the leading global warming causes in the United States. Pollution created by cars and light trucks accounts for nearly one-third of American carbon emission, and emissions of carbon dioxide from airplanes is responsible for an additional 3.5 percent of global warming.

Deforestation

All living plants are capable of storing carbon but as the number of plants on the planet declines, the amount of carbon dioxide free to build up in the atmosphere increases. Moreover, decaying plants give off stored carbon, thereby releasing a large abundance of carbon into the air during clearing of forests or grasslands for building purposes.

Fluorocarbons

Hydro-chlorofluorocarbons and Chlorofluorocarbons are used in refrigeration. While these gases occur in lower atmospheric concentrations than carbon dioxide, they are substantially more potent.

Fertilizer Use

Each time humans add fertilizer to soil, Nitrogen oxide escapes into the atmosphere. Nitrogen oxides trap 300 times more heat per volume than Carbon dioxide, making fertilizer use in farming which is the leading causes of global warming.

Mining

Mining oil and coal allows methane, a greenhouse gas, to escape from the earth. Any time the soil is disturbed, stored gases make their way into the environment.

Population Increase

As the population on earth increases, food and housing demands also increase. Manure from cattle, a primary food source worldwide, contributes to methane gas levels. The cutting down of forests for making room for housing and other buildings accounts for as much as 12 percent of carbon emissions.

Understanding Global Warming

Global warming is increase in average temperature of the oceans and atmosphere, both observed and predicted. The surface temperature of earth depends on a balance of incoming and outgoing heat. When outgoing heat, or energy, exceeds incoming energy, an ice age occurs. Global warming results when incoming energy levels are greater than outgoing energy levels.

Effects of Global Warming

Global warming can potentially affect every aspect of life on Earth. Higher average temperatures will cause changes in plant and crop life, which can decrease worldwide food supplies. Warmer polar winters will result in melting sea ice, which will cause a rise in sea level. Warmer temperatures will also increase evaporation from large water bodies, which in turn will increase cloud formation and rainfall amounts. Other potential effects of global warming include more frequent hurricanes and higher rates of some diseases, such as malaria.

Solutions offered by Nanotechnology

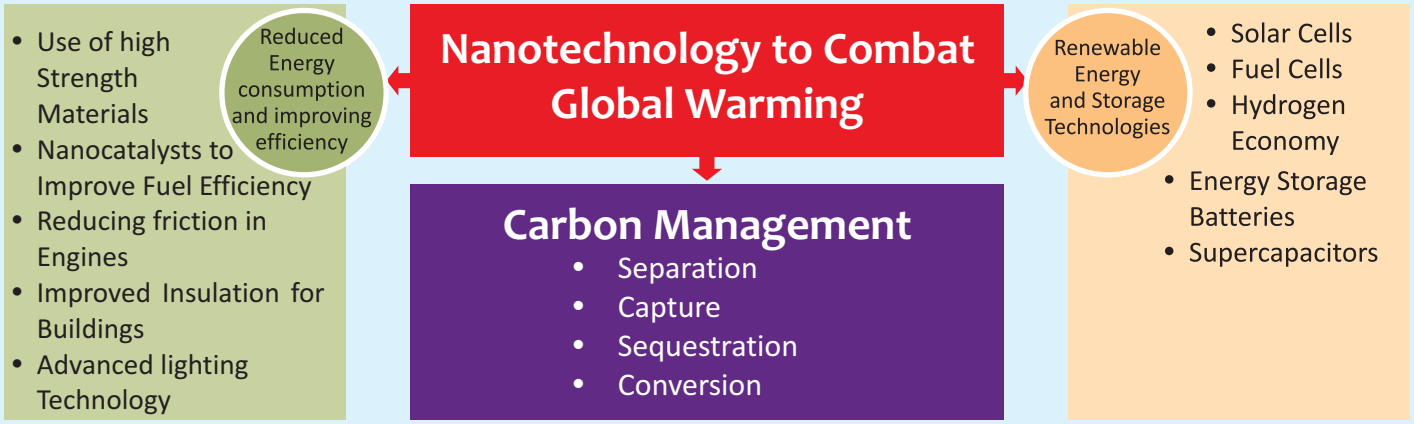
One of the greatest current environmental concerns both for the near term as well as for the future is global warming caused by man-made carbon emissions and its well-recognized impact on climate change. There has been a dramatic increase in Green House Gases, particularly carbon dioxide ($C0_2$), in recent times. According to the US National Oceanic and Atmospheric Administration (NOAA), $C0_2$ levels in the atmosphere now stand at 387 parts per million (ppm), up almost 40% since the industrial revolution. The largest source of $C0_2$ emissions globally is the combustion of fossil fuels such as coal, oil and gas in power plants, automobiles, industrial facilities and other sources.

These greenhouse gases have been known to inflict irreparable damage to ozone layer, equality of life, environment and health. In recent times, there has been growing awareness and concern among people about this phenomenon and it has become a global issue, prompting governments to look at diverse approaches to reduce $C0_2$ emissions. Strategies

are adopted to combat global warming are classified three categories:

1) Reducing energy consumption by employing more efficient technologies that minimize use of fossil fuels;
2) Adopting technologies that utilize renewable energy and energy storage technologies;
3) Addressing carbon management issues that involve separation, capture, sequestration and conversion to useful products.

Challenges and Technological Prospectus relating to Carbon management.



Strategies to combat global warming

Reduced Energy Consumption and Improving Efficiency

There are number of approaches to reduce energy consumption in many major applications and thereby have a direct influence on decreasing Green House Gas emissions. The major impact of nanotechnology on the energy sector is likely to be by way of improving the efficiency of present day technologies to minimize usage of fossil fuels. The transportation sector is one of the major contributors to $C0_2$ emissions (about 28% according to a report by the Environmental Protection Agency, USA). Therefore, any effort to reduce emissions in vehicles by reducing their weight and, in turn, decreasing fuel consumption can have an immediate and significant global impact. It is estimated that a 10% reduction in weight of the vehicle corresponds to a 10% reduction in fuel consumption leading to a proportionate fall in emissions.

In recognition of the above, there is growing interest worldwide in exploring means of achieving weight reduction in automobiles through use of novel materials. For example, use of lighter, stronger and stiffer nano-composite materials is considered to have the potential to significantly reduce weight. Polymers like thermostats, thermoplastics and elastomers reinforced with colloidal silica, nanoclay and nanotubes are promising candidate materials. Employing nanocomposites can lead to reduced energy consumption in cars, with the impact of their use being likely to be even more dramatic in the aerospace sector. It is estimated by the Mitre Corp that use of CNT reinforced polymer composite airframes in place of aluminium airframes would result in 14.05% decrease in structural mass of the aircraft, and as a consequence, likely to reduce fuel consumption by about 9.8%.

Another strategy to improve fuel efficiency is by incorporation of nanocatalysts. Enercat, a third generation nanocatalyst developed by Energenics, uses the Oxygen storing cerium oxide nanoparticles to promote complete fuel combustion, which helps in reducing fuel consumption. Recently, the same company has

demonstrated fuel savings of about 8-10% on a mixed fleet of diesel vehicles in Italy.

Reducing friction and improving wear resistance in engine and drive train components is of vital importance in the automotive sector. Reducing friction can lower the fuel consumption by about 2% and result in cutting down carbon dioxide emissions by 500 million tons per year from trucks and other heavy vehicles in Sweden alone, based on the estimates made by a Swedish company, Applied Nano Surfaces. Nano based lubricants and nanocoatings can significantly reduce coefficient of friction and are being increasingly introduced in the market. ApNano, Israel has developed NanoLubTM lubricant based on inorganic fullerenes like WS2, MoS2, NbS2, etc. NanoLub reduces friction and wear significantly and to a much greater extent than conventional lubricants, especially at higher loads. The company claims that NanoLub saves money, reduces pollution, is cost effective, safe and environmentally-friendly. Similarly, NanoBoron, UK has developed BOR Power(R) to reduce fuel consumption and extend the lifetime of engines. This is achieved by reducing friction and abrasion during motion via the hard-coating and miniaturized bearing-ball effect. BORPower(R) contains two active ingredients, namely Mono Crystal Diamond Powder (MCDP) and Nano Boron. According to the company, use of BORPower(R) results in lower fuel consumption (8-15%), improved engine power (7-9%) and correspondingly lower $C0_2$ emissions (8-15%).

Residential and commercial buildings contribute to 11% of total Green House Gas emissions. Space heating and cooling of residential buildings account for 40% of the total residential energy use. Nanostructured materials, such as aerogels, have potential to greatly reduce heat transfer through building elements and assist in reducing heating loads placed on air-conditioning or heating systems. Aerogel lis a Nanoporous super-insulating material having extremely low density (90-95% air). Silica aerogel is the lightest solid material known (density is less than 0.05 g/cm3) with excellent thermal insulating properties, high temperature stability, very low dielectric constant and high surface area. Aerogel is a breakthrough material technology for energy conserving buildings. Use of aerogel interior wall insulation can reduce U-values. U value is a measure of the flow of heat through an insulating or building material; the lower the U value is the better insulating ability) by 44%, lower energy consumption by 900kW,hr/yr with attendant reduction in carbon emission of 400kg/yr for apartment buildings. Although, aerogels can make significant contributions to reduce energy consumption for heating and cooling of buildings, their high cost is one of the inhibiting factors in their widespread adoption.

Dr. Halimaton Hamdan and her team from the Universiti Teknologi in Malaysia have developed a method of producing aerogels, using rice husks (agricultural waste) as the feedstock that could reduce the production cost of aerogel by 80%. Rice husk has high silica content, which is the main constituent of aerogel. In addition to potentially being able to produce aerogels at one-fifth the current cost, the above method also addresses the problem of rice husk waste disposal.

Aerogel, being a translucent material, also finds architectural applications as daylighting panels with excellent insulating characteristics. Advanced Glazings Ltd. And Cabot Aerogel have recently introduced a new line of their Solera(R) daylighting insulated glass units that, for the first time ever, will now be available with Nanogel (R) aerogel (a product of Cabot Corp), which is a translucent form of silica aerogel. These systems will allow architects to design buildings with glass exteriors having an insulation value

ranging from traditional R-2 to unprecedented R-12 (R value represents the resistance to heat flow through a building material. The higher the R value, the greater is the resistance to heat flow and the insulating value).

Artificial lighting fritters away a significant portion of all electrical energy consumed worldwide, which represents 20-40% of the primary energy consumption of residential and commercial buildings. The common incandescent light bulbs and fluorescent lamps are highly inefficient, with luminous efficiencies of 10-35 lm/W(5% efficiency) and 50-100 lm/W (20-25% efficiency), respectively. In recent years, new lighting devices based on white-light-emitting diodes (WLEDs) are being introduced in the market. These devices exhibit high luminous efficiency of up to 150 lm/W and long lifetimes (several thousand hours). Inorganic solid-state lighting is partly based on quantum dots while Organic LEDs (OLEDs) rely on nano-scale thin film technology. The LOMOX company of UK is developing OLED lighting technology, which promises to be 2.5 times more efficient than standard energy saving bulbs. This revolutionary technology has a wide variety of applications and, when coated onto a film, could be used to cover walls creating light-emitting wallpaper which replaces the need for traditional light builbs. RTI International has developed a technology for high efficiency lighting devices by combining nanofiber based reflectors and photoluminescent nanofibres (PLN). These devices are at least 5 times more efficient than traditional incandescent bulbs and are environmentally safer than the compact fluorescent light bulbs as they do not contain mercury.

While decreasing energy consumption and improving efficiency is a near term solution, in order to meet the challenges posed by the looming crisis, disruptive technologies based on renewable energy sources will have to be developed. Some promising approaches are briefly discussed below.

Renewable Energy Generation

Thin Film Solar Cells or Photovoltaic Cells: A Solar Cell is a device which converts the energy of the sun into electricity. This technology has a huge potential, as sunlight is a non-exhaustible source of energy without contributing greenhouse gases to the atmosphere. It is also one of the most attractive solutions, because the amount of solar energy reaching the earth every day is 10,000 times greater than the present world energy consumption. Current solar cell technologies are mainly based on silicon (single or polycrystalline silicon). However, they are expensive to manufacture and have limited efficiency. The high cost of silicon-based solar cells has been the greatest barrier to their widespread adoption. Organic or plastic thin film solar cells are a low cost alternative, mainly based on nanoparticles and polymers, and are now being used to manufacture flexible solar panels. The thin film technology is also cost effective, and uses a cheap polymer substrate coated by a thin film of an active component. The active component comprises either amorphous silicon or nanoscaled CdS, CIS, CdTe, Ti02, SnO, Quantum Dots, Organic materials, etc. The material requirement is much less than that in case of silicon wafers and, hence, the costs are further reduced. Flexible substrate technology also enables use of continuous roll processing technique, rather than the step processing technique being use in a semiconductor plant, thereby resulting in dramatic cost reductions. Some of the recent key developmental activities and breakthroughs in the area of solar cells applying nanotechnology are summarized below.

Recent Developmental Activities and Breakthroughs in Nanotech Solar Cells

a) Stanford University - Activity: Based on silicon nanowires, a solar cell which has achieved efficient absorption of sunlight while using only 1% of the active material used in conventional designs has been designed.

b) University of Texas at Austin — Activity: Spray-on nano-ink of copper-indium-gallium selenide (CIGS) that would allow the rooftops and sides of buildings to be spray painted with nanoparticles and do away with massive solar panels has been developed.

c) IBM Corp. - Activity: Low-cost, efficient (9.6%) solar cells using abundant elements (Cu, Zn, Sn, S or Se) and employing thin film technology based on a nano-ink method have been developed.

d) Stanford University - Activity: Nanodome solar cells using nano-coating of amorphous silica have been developed. Nanodome structure captures the reflected light and improves the efficiency of a solar cell by 25%.

e) Lawrence Berkley National Lab - Activity: Thin films fabricated from an array of vertical silicon nanowires are able to increase the light trapping of solar cells by a factor of over 70. This approach represents an economically viable path towards high-efficiency, low-cost thin film solar cells.

f) New Energy Technologies - Activity: A technology to spray a solar coating directly onto "glass by replacing visibility-blocking metal with environmentally-friendly see-through compounds marks an advance in the development of see-through glass windows capable of generating electricity.

Fuel Cells and Hydrogen Economy

Fuel cells represent a key enabling technology for renewable energy systems. A fuel cell is an electrochemical device generating power by directly converting hydrogen into electricity at an efficiency that can approach 60% (compared to 25% efficiency for the best gasoline engines), with the sole exhaust product being non-polluting water. The fuel cells and hydrogen energy market was estimated to be US$ 8.8 billion in 2009 and expected to grow to US$ 14 billion by 2014, with a compound average growth rate of 9.6%. The key application of fuel cells is expected to be in automobiles, and limited mass production of fuel cell vehicles is expected to begin after 2015. Hydrogen fuel vehicles are capable of eliminating all toxic pollutants from road transport. However, there are a number of challenges to be overcome before the fuel cell car becomes a reality. The high cost of fuel cells is a major obstacle for their widespread adoption. Other challenges include safe and solid storage of hydrogen, and methods of producing and purifying hydrogen. Nanotechnology will play an important role in the efficient storage of hydrogen. A number of nanostructured material systems like CNTs, alanates, nano-Mg based hydrides, complex hydride/carbon nanocomposites, BN nanotubes, TiS2/MoS2 nanotubes and polymer nanocomposites are promising candidates for storage of large quantities of hydrogen. A noteworthy development in this area is metal-organic framework (MOF) compounds comprising metal-oxide clusters connected by organic linkages for hydrogen storage applications because of their tunable pore size and functionality. In addition, they offer advantages such as high surface area, low density, and both thermal and mechanical stability.

Currently, the most economical way to produce hydrogen is from natural gas; however, it leads to Green House Gas emissions. The best "clean" approach to generate hydrogen is by photocatalytic splitting of water molecules into Hydrogen and Oxygen atoms using Sunlight. Thomas Nann and Christopher J.Pickett at the University of East Anglia, UK have successfully demonstrated the photo-electrocatalytic

splitting of water to produce hydrogen with an efficiency of 60%, employing a new system consisting of a gold electrode covered with layers of InP nanoparticles and including an iron sulfur complex introduced into the layered structure to produce hydrogen via the photo-electrocatalytic reaction.

Another "clean" process for hydrogen production involves electrolysis of water. Recently, QuantumSphere Inc. (QSI) has made a breakthrough in the above area using electrodes coated with nano Ni-Fe alloy. These nano-structured electrodes increase hydrogen gas output by 300% at 85% efficiency, making it a commercially viable process for industrial and transportation applications. QSI has also developed a palladium based nanocatalyst which reduces the cost of direct methanol fuel cells (DMFC) by reducing platinum usage by 30 to 50%. The nanocatalyst significantly increases the catalytic surface area, resulting in enhanced durability, extended life cycles, and a reduction in device size of DMFCs. Other key players in the domain of fuel cell nanocatalysts are Nanostellar, Catalytic Solution and Nanophase Technologies Corporation.

The membrane is an important component of a fuel cell which allows only positively charged ions (like hydrogen ions) to pass through towards cathode. Nano-engineered membranes in fuel cells are more efficient and enable building of lighter weight and longer lasting fuel cells. PolyFuel Inc., USA has introduced in the market nano-architectured hydrocarbon membranes for both portable direct methanol fuel cells and for automotive hydrogen fuel cells. These are more durable and less expensive than the state-of-the-art fluorocarbon membranes. Recently, researches from the University of Calgary in Canada have developed a new membrane based on MOFs that enables a polymer electrolyte membrane (PEM) fuel cell to operate at higher temperatures - an important step in terms of increasing the efficiency and decreasing the cost of PEM fuel cells.

Energy Storage

Batteries and Supercapacitors: Plug-in electric and plug-in hybrid cars have the potential to dramatically reduce emissions that cause global warming and air pollution, and would also curb our dependence on oil. According to estimates made by the Argonne National Laboratory in USA, electric vehicles would reduce Green House Gas emissions by 26% over gasoline-powered vehicles and transform the automotive industry. Advanced battery technology is at the heart of this transformation because it determines how far an electric car can travel on a charge and how long it takes to recharge. Currently, the automotive battery market is dominated by Nickel-Metal Hydride (NiMH) or lead acid batteries but experts predict that lithium-ion/lithium-sulfur batteries would capture- the market in the near future.

Nanotechnology holds great promise for improving the performance and life-times of the Li-ion batteries. It also has the potential to enhance the energy and power density, shorten the recharge time, as well as decrease the size and weight while improving safety and stability of the batteries. A large number of companies such as Altair Nanotechnologies, mPhase Technologies, A123 Systems, Li-Tec Battery GmbH, NanoEner Technologies, Next Alternative Inc., Nexeon Ltd, etc are actively pursuing ' the development of nano-enabled batteries while some others are already producing them as summarized below.

Conclusion

Although Nano-technology has significant potential to mitigate the problem of Global Warming, the economics application needs to be examined thoroughly.

Reviewed : Ashutosh Debata

Release of 49th issue of ENVIS Newsletter by the Vice Chancellor of Utkal University, Prof. Dr. Soumendra Mohan Patnaik during Observation of World Ozone Week at Utkal University on 14.09.2017

Observation of World Ozone Day at Capital High School, Unit-III, Bhubaneswar on 16th September 2017.

Observation of Coastal Clean-up Day at Puri on 16th September 2017.

Meeting with District Collector and Officials of Khurda on 08.09.2017 for strengthening Eco-Club activities, Swachh Bharat and Plastic free campaign.

Meeting on 13.10.2017 to sensitize the Commissioner & Officials of Cuttack Municipal Corporation (CMC) for making pollution and plastic free Baliyatra at Cuttack.

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