CHAPTER 8
ADAPTATION AND MITIGATION OF GLOBAL WARMING

8.1 Introduction

The past record and the present day emissions of carbon dioxide confirms the position that in this century and all around the world we are going to witness a significant change in climate. So the immediate concern is to adapt certain socio-economic measures and develop a good understanding for stabilizing the global emission seeing the current
progress and developmental activities of the developed and developing nations it is not that easy to go for sharper cuts in the emissions. The Inter-governmental Panel on Climate Change (IPCC) says that even if global emissions could be held at current level—an ambitious goal, considering present trends in energy use – the concentration of carbon dioxide in the atmosphere would not stabilize for several hundred years. For stabilizing carbon dioxide concentration the IPCC calculates that stabilization at today’s level would require that today’s carbon dioxide emissions be cut by 60 percent and the emissions be maintained at these reduced levels throughout the next century.

IPCC emphasizes that higher emissions today imply that much sharper cuts in emissions will be needed later on. And further, the longer those high emissions persist, the greater will be the required cuts in future emissions to stabilize carbon dioxide concentrations at a given level. This is because it is, to a great extent, the cumulative total of emissions over time that determines the level at which carbon dioxide stabilizes in the long run, not the particular year-by-year profile of emissions. The benefits of stabilizing carbon dioxide concentrations depend greatly on the level at which they are stabilized.

It is said stabilization even at today’s atmospheric concentration will not prevent additional greenhouse warming of the atmosphere. It could moderate the pace and magnitude of such warming. Stabilization at higher carbon dioxide levels are expected to lead to greater warming. Scientists who are active in this field believe that a failure to stabilize carbon dioxide concentrations will lead to progressively rapid and extensive climate change.

It is clear that if we go by present trends, the stabilization of global emissions is not that easy and it needs stronger commitments. Thus, given the difficulty of stabilizing global atmospheric carbon dioxide concentrations and the benefits of early planning in reducing eventual mitigation costs, many of the nations that signed the Framework Convention on Climate Change have begun to realize that a coordinated international course of action is urgently needed. At the first conference of the Parties convened in

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Berlin in 1995, the participants could not agree upon strict emissions limits, but they did adopt a procedure for negotiating such limits and set a deadline of 1997 for concluding these negotiations.  

Even as the negotiations for a carbon dioxide target and emissions cuts proceed, IPCC has stressed that many of the general outlines of a global carbon dioxide strategy have already begun to take shape, and there are many actions that nations can take immediately. These include:

(i) Encouraging the adoption of those energy-efficiency improvements that, apart from their greenhouse benefits, are cost-effective in their own right. This implies an active program of policy reforms to encourage full-cost pricing of energy, to create efficiency standards, and to implement rebate programs or other financial vehicles to encourage adoption of energy-efficient technologies.

(ii) Supporting expanded research and development of alternative energy sources and energy-efficient technologies and establishing incentives to encourage the penetration of these into energy markets.

(iii) Specifically promoting policies to encourage the replacement of long-lived energy, transportation, and industrial infrastructures at the end of their life cycles with efficient, low-emission technologies.

(iv) Supporting continued climate research and monitoring so that the mechanism and magnitude of climate change are better understood and so that the effect of climate can be better planned for.

However, it is clear that even if nations agree to take these actions and the international community is able to negotiate target for future emission cuts, there is little reason to believe that global action will be quick enough or effective enough in the short term to avoid a rise in atmospheric carbon dioxide concentrations from their present

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668 Ibid.
level. It is also no denying the fact that taking the present scenario, the global warming is a long term phenomenon whose mitigation must be seen in a long-term context.670

Adaptation to global warming is a response to climate change that seeks to reduce the vulnerability of biological systems to climate change effects.671 Even if emissions are stabilized relatively soon, climate change and its effects will last many years, and adaptation will be necessary.672 Climate change adaptation is especially important in developing countries since those countries are predicted to bear the brunt of the effects of climate change.673 That is, the capacity and potential for humans to adapt (called adaptive capacity) is unevenly distributed across different regions and populations, and developing countries generally have less capacity to adapt (Schneider et al., 2007).674 Adaptive capacity is closely linked to social and economic development (IPCC, 2007).675 The economic costs of adaptation to climate change are likely to cost billions of dollars annually for the next several decades, though the amount of money needed is unknown. Donor countries promised an annual $100 billion by 2020 through the Green Climate Fund for developing countries to adapt to climate change. However, while the fund was set up during COP16 in Cancun, concrete pledges by developed countries have not been forthcoming.676 The adaptation challenge grows with the magnitude and the rate of climate change. A theoretical, physiological limit to adaptation is that humans cannot survive mean temperatures of above 35 °C (95 °F).

Another policy response to climate change, known as climate change mitigation (Verbruggen, 2007) is to reduce greenhouse gas (GHG) emissions and/or enhance the removal of these gases from the atmosphere (through carbon sinks). Even the most effective reductions in emissions, however, would not prevent further climate change impacts, making the need for adaptation unavoidable (Klein et al., 2007). In a literature assessment, Klein et al. (2007) assessed options for adaptation. They concluded, with very high confidence, that in the absence of mitigation efforts, the effects of climate change would reach such a magnitude as to make adaptation impossible for some natural ecosystems. For human systems, the economic and social costs of unmitigated climate change would be very high.

**Conceptualizing adaptation**

Adaptation can be defined as adjustments of a system to reduce vulnerability and to increase the resilience of system to change, in this case in the climate system. Adaptation occurs at a range of inter-linking scales, and can either occur in anticipation of change (anticipatory adaptation), or be a response to those changes (reactive adaptation). Most adaptation being implemented at present is responding to current climate trends and variability, for example increased use of artificial snow-making in the European Alps. Some adaptation measures, however, are anticipating future climate change, such as the construction of the Confederation Bridge in Canada at a higher elevation to take into account the effect of future sea-level rise on ship clearance under the bridge.

Adaptive capacity and vulnerability are important concepts for understanding adaptation; vulnerability can be seen as the context in which adaptation takes place, and adaptive capacity is the ability or potential of a system to respond successfully to climate variability and change, in order to reduce adverse impacts and take advantage of new

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opportunities. Those societies that can respond to change quickly and successfully have a high adaptive capacity. High adaptive capacity does not necessarily translate into successful adaptation. For example the adaptive capacity in Western Europe is high, and the risks of warmer winters increasing the range of livestock diseases was well documented, but many parts of Europe were still badly affected by outbreaks of the Bluetongue virus in livestock in 2007.

Adaptive capacity is driven by factors operating at many different interlinked scales, and it is important to understand the ways in which the different drivers of adaptive capacity interact. Physical constraints are important, but in most cases it is social processes which increase or decrease adaptive capacity; it can be said that adaptive capacity is socially constructed. The social drivers of adaptive capacity are varied but may include broad structures such as economic and political processes, as well as processes which operate at a very local scale, such as access to decision-making and the structure of social networks and relationships within a community. Adaptive capacity at a local scale is constrained by larger scale processes. For example a farmer’s adaptive capacity will not only depend on access to resources (both physical and social) within the community which allow a crop to be grown successfully, but also the effect of macro-scale economic processes on the price received for the crop. Gender is another factor which is important in determining adaptive capacity constrain adaptive capacity and vulnerability, for example women may have participation in decision-making, or be constrained by lower levels of education.

The social construction of adaptive capacity is very important when thinking about the risks and impacts of a changing climate. It is not just the change in climate which will affect vulnerability and livelihoods, but the way that these changes are negotiated through complex social systems. A 10% decrease in rainfall may be acceptable and manageable to members of a community who have access to improved agricultural techniques, or whose livelihoods are in some way diversified, whereas marginalised members of the community may not be able to cope with these change.

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680 Ibid.
681 Ibid.
Adaptation can be seen as a social and institutional process that involves reflecting on and responding to current trends and projected changes in climate.

Both temporal and spatial scales are very important in thinking about adaptation, as is the frame of reference taken for looking at adaptation. Much adaptation takes place in relation to short-term climate variability; however this may cause maladaptation to longer-term climatic trends. For example, the expansion of irrigation in Egypt into the Western Sinai desert due to a period of higher river flows is a maladaptation when viewed in relation to the longer term projections of drying in the region. Adaptations at one scale can also create externalities at another by reducing the adaptive capacity of other actors. This is often the case when broad assessments of the costs and benefits of adaptation are examined at smaller scales and it is possible to see that whilst the adaptation may benefit some actors, it has a negative effect on others.

From the current literature on the subject, people have always adapted to a changing climate and that coping strategies already exist in many communities, for example changing sowing times or adopting new water-saving techniques. Traditional knowledge and coping strategies must be maintained and strengthened, otherwise adaptive capacity may be weakened as local knowledge of the environment is lost. Strengthening these indigenous techniques and building upon them also makes it more likely that adaptation strategies will be adopted, as it creates more community ownership and involvement in the process. In some cases however this will be not be enough to adapt to new conditions which are outside the range of those previously experienced, and new techniques will be needed.

8.2 Adaptation Mechanisms

Scheraga and Grambsch\textsuperscript{682} identify 9 fundamental principles to be considered when designing adaptation policy.

1. The effects of climate change vary by region.

2. The effects of climate change may vary across demographic groups.

\textsuperscript{682} http://www.epa.gov/eims/global/clim_res.pdf visited on 12/3/14 at 11:34
3. Climate change poses both risks and opportunities.

4. The effects of climate change must be considered in the context of multiple stressors and factors, which may be as important to the design of adaptive responses as the sensitivity of the change.

5. Adaptation comes at a cost.

6. Adaptive responses vary in effectiveness, as demonstrated by current efforts to cope with climate variability.

7. The systemic nature of climate impacts complicates the development of adaptation policy.

8. Maladaptation can result in negative effects that are as serious as the climate-induced effects that are being avoided.

9. Many opportunities for adaptation make sense whether or not the effects of climate change are realized.

8.3 Methods of Adaptation

Examples of adaptation include defending against rising sea levels through better flood defenses, and changing patterns of land use like avoiding more vulnerable areas for housing

Enhancing adaptive capacity

In a literature assessment, Smit et al. (2001) concluded that enhanced adaptive capacity would reduce vulnerability to climate change. In their view, activities that enhance adaptive capacity are essentially equivalent to activities that promote sustainable development. These activities include:

(i) improving access to resources

(ii) reducing poverty

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(iii) lowering inequities of resources and wealth among groups
(iv) improving education and information
(v) improving infrastructure
(vi) improving institutional capacity and efficiency
(vii) Promoting local indigenous practices, knowledge, and experiences

Researchers at the Overseas Development Institute found that development interventions to increase adaptive capacity have tended not to result in increased agency for local people. They argue that this should play a more prominent part in future intervention planning because agency is a central factor in all other aspects of adaptive capacity.

**Adaptation through local planning**

Local land use and municipal planning represent important avenues for adaptation to global warming. These forms of planning are recognised as central to avoiding the impacts of climate related hazards such as floods and heat stress, planning for demographic and consumption transition, and plans for ecosystem conservation. This type of planning is different from the National Adaptation Programs of Action (NAPAs) which are intended to be frameworks for prioritizing adaptation needs. At the local scale, municipalities are at the coal face of adaptation where impacts are experienced in the forms of inundation, bushfires, heat waves and rising sea levels.

Cities are planning for adapting to global warming and climate change. The New York Times began a series of articles on this subject with Chicago's adaptation initiatives being highlighted. Projects include changing to heat tolerant tree varieties, changing to water permeable pavements to absorb higher rainfalls and adding air conditioning in

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687 City Prepares for a Warm Long-Term Forecast New York Times May 22, 2011
public schools. New York and other cities are involved in similar planning. Carefully planned water storage could help urban areas adapt to increasingly severe storms by increasing rainwater storage (domestic water butts, unpaved gardens etc.) and increasing the capacity of storm water systems (and also separating storm water from black water, so that overflows in peak periods do not contaminate rivers). According to English Nature, gardeners can help mitigate the effects of climate change by providing habitats for the most threatened species, and/or saving water by changing gardens to use plants which require less.

Adaptation through local planning occurs in two distinct modes. The first is strategic planning, which is important but not unique to local governments. At the local scale it fosters community vision, aspirational goals and place-making, along with defining pathways to achieve these goals. The second form is land-use planning, and is focused on the allocation of space to balance economic prosperity with acceptable living standards and the conservation of natural resources. Although these two types of planning are quite different in practice, and in many cases are managed by different departments, we propose that both are highly important to climate change adaptation, and can contribute to achieving adaptation at the local scale. Significant constraints are recognised to hinder adaptation through planning, including limited resources, lack of information, competing planning agendas and complying with requirements from other levels of government. Examples of adaptation include defending against rising sea levels through better flood defenses, and changing patterns of land use like avoiding more vulnerable areas for housing.

Planning for rising sea levels is one of the key challenges for local planning in response to climate change. Many national governments around the world have attempted to address the problem of rising sea levels through policy and planning reforms designed

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to increase adaptive capacity. In the United States, many state and local governments are now assessing innovative, locality-specific options for sea-level rise adaptation.

**Adaptation in agricultural production**

A significant effect of global climate change is the altering of global rainfall patterns, with certain effects on agriculture. Rainfed agriculture constitutes 80% of global agriculture. Many of the 852 million poor people in the world live in parts of Asia and Africa that depend on rainfall to cultivate food crops. As the global population swells, more food will be needed, but climate variability is likely to make successful farming more difficult. Extended drought can cause the failure of small and marginal farms with resultant economic, political and social disruption. However, such events have previously occurred in human history independent of global climate change. In recent decades, global trade has created distribution networks capable of delivering surplus food to where it is needed, thus reducing local impact.  

a) **Drought tolerant crop varieties**

Agriculture of any kind is strongly influenced by the availability of water. Climate change will modify rainfall, evaporation runoff, and soil moisture storage. Changes in total seasonal precipitation or in its pattern of variability are both important. The occurrence of moisture stress during flowering, pollination, and grain-filling is harmful to most crops and particularly so to corn, soybeans, and wheat. Increased evaporation from the soil and accelerated transpiration in the plants themselves will cause moisture stress. As a result, there will be a need to develop crop varieties with greater drought tolerance.

b) **More spending on irrigation**

The demand for water for irrigation is projected to rise in a warmer climate, bringing increased competition between agriculture—already the largest consumer of water resources in semi-arid regions—and urban as well as industrial users. Falling water tables and the resulting increase in the energy needed to pump water will make the

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practice of irrigation more expensive, particularly when with drier conditions more water will be required per acre. Other strategies will be needed to make the most efficient use of water resources. For example, the International Water Management Institute has suggested five strategies that could help Asia feed its growing population in light of climate change. These are:

(i) modernising existing irrigation schemes to suit modern methods of farming
(ii) Supporting farmer's efforts to find their own water supplies, by tapping into groundwater in a sustainable way
(iii) Looking beyond conventional 'Participatory Irrigation Management' schemes, by engaging the private sector
(iv) Expanding capacity and knowledge
(v) Investing outside the irrigation sector.

Forest Resources

The forestry resources are most crucial means of adaptation to forest dependent people whose lives have been depending on it. If long duration of drought persist, definitely affect to rain-fed agricultural system. In this situation, people can collect the edible fruits, roots and leaves for their life survival. Similarly, forest resources provides not only goods but also services such as regulation of ecosystem, maintain linkage of upstream-downstream through watershed conservation, carbon sequestration and aesthetic value. These services become crucial part of life sustained through increased adaptive capacity of poor, vulnerable, women and socially excluded communities.

Rainwater storage

Providing farmers with access to a range of water stores could help them overcome dry spells that would otherwise cause their crops to fail. Field studies have shown the effectiveness of small-scale water storage. For example, according to the International Water Management Institute, using small planting basins to 'harvest' water in Zimbabwe

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692 Mukherji, A. Revitalising Asia’s Irrigation: To sustainably meet tomorrow’s food needs 2009, IWMI and FAO
has been shown to boost maize yields, whether rainfall is abundant or scarce. And in Niger, they have led to three or fourfold increases in millet yields.\footnote{Diverse water sources key to food security: report: Reuters, September 5, 2010.}

**Weather control**

Russian and American scientists have in the past tried to control the weather, for example by seeding clouds with chemicals to try to produce rain when and where it is needed. A new method being developed involves replicating the urban heat island effect, where cities are slightly hotter than the countryside because they are darker and absorb more heat. This creates 28% more rain 20–40 miles downwind from cities compared to upwind.\footnote{Fuchs, Dale (2005-06-28). “Spain goes hi-tech to beat drought”. The Guardian (London). Archived from the original on 30 May 2010. Retrieved 2010-04-23.} On the timescale of several decades, new weather control techniques may become feasible which would allow control of extreme weather such as hurricanes.\footnote{Lloyd de Vries (2004-10-29). “Sapping A Hurricane’s Strength, Research Under Way, But Actual Applications Still Decades Away”. CBS News. Retrieved 2010-08-29.}

The World Meteorological Organization (WMO) through its Commission for Atmospheric Sciences (CAS) has issued a "Statement on weather modification" as well as "Guidelines for the planning of weather modification activities" in 2007, stating among others that "Purposeful augmentation of precipitation, reduction of hail damage, dispersion of fog and other types of cloud and storm modifications by cloud seeding are developing technologies which are still striving to achieve a sound scientific foundation and which have to be adapted to enormously varied natural conditions."\footnote{WMO Documents On Weather Modification Approved By The Commission For Atmospheric Sciences Management Group, Second Session, Oslo, Norway, 24-26 September 2007 [1].}

**Migration**

Recent literature has also put forward the concept of migration as a climate change coping mechanism. Climate change push factors are weighed against economic or social pull factors: the role of climate change in migration is thus not a linear one of cause and effect. Migration frequently requires would-be migrants to have access to social and financial capital, such as support networks in the chosen destination, and the funds to be able to move. It is frequently the last adaptive response households will take

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\footnote{Diverse water sources key to food security: report: Reuters, September 5, 2010.}  
\footnote{WMO Documents On Weather Modification Approved By The Commission For Atmospheric Sciences Management Group, Second Session, Oslo, Norway, 24-26 September 2007 [1].}
when confronted with environmental factors that threaten their livelihoods, and mostly resorted to when other mechanisms to cope have proven unsuccessful. *Migration and Climate Change*, a UNESCO publication, explores the dynamics of environmental migration and the role of migration as an adaptive response to climate change.697

8.4 Policy Measures in India to Mitigate GHG Emissions

*Indian Policy and Planning*

Indian legislation relating to environment seems old but performing well in containing and controlling the pollution from the industries and trying maintain the Indian environment green. Low emission is one of the imperatives of green economics. On a per capita basis, India is one of the lowest Green House Gas (GHG) emitters in the world. Its emission of 1.18 tonnes of CO2 equivalent per capita in 2008 was nearly one-fourth of the corresponding global average of 4.38 tonnes. However India is highly vulnerable to climate change and has a strong interest in having a fair and equitable global agreement for minimizing the risk of climate change. India has already announced that it will reduce the emissions intensity of its GDP by 20-25 percent over the 2005 levels by the year 2020, through pursuit of proactive policies. India’s Twelfth Five Year Plan, to be launched on 1st April, 2012 will have as one of its key pillars, a low carbon inclusive growth. Various strategies have been evolved to the low carbon strategies for power, transport, industry, buildings and forestry sectors to the low carbon strategies for power, transport, industry, buildings and forestry sectors to achieve the target of GHG emission intensity reduction in 2020 for both 8 and 9 percent real GDP growth. These strategies includes (a) incentive strategy (b) The development and introduction of green technology is an essential element of any low-carbon strategy (c) Policies should facilitate coordination so to reduce transaction costs in the implementation of mitigation strategies (d) review of mitigation policies in pricing the fossil fuel. Laws relating to forests, industries, air pollution, and other developmental activities aim at to produce low

emission of carbon or greenhouse gases (GHGs). In other words GSHs are known as ‘carbon foot prints. The main influences on carbon footprints include population, economic output, and energy and carbon intensity of the economy.

It is to be noted that India has also evolved alternative strategies for the mitigation of carbon footprints through the development of alternative projects such as solar energy, wind energy, hydro-electric power, energy from municipal waste or goober, or reforestation for reducing carbon footprint and this is often known as ‘Carbon offsetting’. In Kyoto Protocol of 1997 the signatory nations agreed to bring their emission down to an average of 5.2 percent below the 1990 level under the Kyoto Protocol by the year 2012. Under the scheme entities in developed countries could sponsor projects in other countries projects that could absorb/reduce greenhouse gases and consequently obtain carbon credits, which they could then trade. This is being done by producing low GSHs emission. And low emission can be traded to one who is producing such gases but not meeting the required standards of low emission of these gases. Accordingly the Central Government constituted the National Clean Development Mechanisms (CDM) Authority for the purpose of protecting and improving the quality of environment in terms of the Kyoto Protocol. There are many instances where Indian institutions have traded their carbon credits to foreign institutions. It is expected by 2012 market of carbon trading will flourish and would reach to more than 40 billion Euros ($58 billion) from 22 billion Euros in 2006.

The Gujarat Fluorchemical Ltd is one such company duly permitted/approved under the CDM of the UN Framework for Climate Change Convention (UNFCCC) and involved in carbon trading. This company can trade internationally and can be used as a compliance tool under the Kyoto Protocol as well as several other trading markets like the EU Emissions Trading Scheme. According to World Bank estimates, India is expected to take in $ 100 million annually by trading in carbon credits and Indian companies are expected to corner at least 10 percent of the global market in the initial years.

Poverty eradication and population control are also concomitants of the green economics. These two have also been advocated by the Millennium Development Goals,
The Government of India has launched many programs to eradicate poverty which contributes to population explosion and pollution, such programmes include passing of the Mahatma Gandhi National Rural Employment Guarantee Act, 2005. Indian government has also come out with the National Population Policy in 2000 with an aim to stabilize the population. It consists of comprehensive and multisectoral coordination of planning and implementation between health and family welfare on the one hand, along with schemes for education, nutrition, women and child development, safe drinking water, sanitation rural roads, communications transportation housing, forestry development, environmental protection and urban development.

Thus, there is a clarion call to espouse the clean and green technology and to rigorously execute the imperatives of green economics in their true spirit. We have to act before it is too late. In recent years, the development planning in India has increasingly incorporated measurable goals for enhancement of human wellbeing, beyond mere expansion of production of goods and services and the consequent growth of per capita income. Many developmental targets\textsuperscript{698} are even more ambitious than the UN Millennium Development Goals\textsuperscript{699}; several of which are directly or indirectly linked to energy and therefore to GHG emissions. India’s share in global CO\textsubscript{2} emissions is still very small. The contribution of India to the cumulative global CO\textsubscript{2} emissions from 1980 to 2003 is only 3.11\%. Thus historically and at present India’s share in the carbon stock in the atmosphere is relatively very small when compared to the population. India’s carbon emissions per person are twentieth of those of the US and a tenth of most Western Europe and Japan.

The endogenous responses generated to achieve the ‘development goals’ are the key factors shaping the economic growth, endogenous technological change and consumption preferences that drive the energy and emissions trends. The goal of providing universal access to electricity has vital implications for development and greenhouse gas emissions. The policies to achieve ‘development goals’ could deliver double dividends for economies that are below the production frontier. In India’s case the

\textsuperscript{698} Tenth Plan Document, Planning Commission, New Delhi, 2002
recent history and the trends show that the economic reforms are enlarging choices that are delivering double dividends, as is evident from the declining trend of energy, electricity and carbon intensities of the Indian economy.

India has drawn up an ambitious National Action Plan and had set a goal of cutting emissions by 20 per cent in its 11th plan. In 2008, India transacted 15.8 million CERs and with 4% market share, India ranked second on the list of in terms of volumes transacted. In February and March 2009, buyers reported a greater willingness of Indian sellers to enter into forward sales with a combination of fixed and indexed pricing. Another reason that may help explain the large gap between the potential supply of CERs and actual transaction volumes in India relates to the challenges associated with obtaining financing for projects, especially in the energy sector. After renewable energy, energy efficiency projects are a strong component of India’s CDM pipeline.

Many energy efficiency projects in India originate in the SME cluster, where companies often lack strong balance sheets or creditworthiness. In tight credit markets, accessing financing through traditional routes (such as banks) has become more difficult and has had a strong negative impact on project origination and implementation. Alternative models such as Energy Service Companies (ESCOs) are still relatively new concepts in India, although several new WSCOs were formed in India and are, perhaps, a sign of things to come. Innovative financing mechanisms are needed to finance the deals that are being envisaged through India’s National Action Plan. India’s Prime Minister had released the National Action Plan on climate change. The plan focused on achieving a pattern of sustainable development while dealing comprehensively with the challenge of climate change.

In response to the threat of global climate change a wide variety of options are available but the option, which has received the greatest attention, is taking steps to slow or prevent global climate change due to accumulation of GHG in the atmosphere. India has for quite some time pursued policies conducive to the reduction of GHG emissions.

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700 Renewable energy, mostly through wind, hydro and biomass projects, accounts for the largest numbers of projects and annual emission reductions in India’s pipeline. While renewable projects were the most successful CDM projects from India last year, we have seen a slowdown in the number of biomass projects.

701 Relevant extract from The Hindu, a daily newspaper on 20 June, 2009.
8.4.1 Energy Conservation

In a broad sense energy conservation means economizing on the use of energy and therefore delimiting CO₂ emissions without adversely affecting or sacrificing economic growth and development. It includes improving the efficiency of energy extraction, reducing transmission and distribution losses and increasing the productivity of final energy use. It also includes changing the energy habits of the consumers thereby rationalizing the use of energy. Energy demand in the country is going to increase rapidly in future. Moreover, the energy resources that are indigenously available may not be sufficient to sustain the development process and dependence on imports for meeting the energy requirements would rise. Hence efforts must be made to conserve energy by enhancing the energy efficiency of the economy. India has enormous potential for conserving energy. Table 3 illustrates the potential of energy conservation in the various sectors and large energy intensive industries in the country. According to the Planning Commission, almost 5-10 per cent of the potential savings can be realised by adopting no or low cost housekeeping measures. A substantial portion of the balance potential can be realised with retrofitting or minor process or technology improvement measures. Apart from consumers, machinery and equipments should also be targeted to discourage inefficient and wasteful use of energy. This may require setting up of standards and norms for energy consumption and making it obligatory on part of the manufacturers to adhere to such norms and standards. In India a similar legislation to provide greater thrust to conserve energy is under consideration by the government, which would help in laying standards and norms for energy consumption in the country and prohibit manufacture of appliances, which do not adhere to such norms. There might be some costs associated with the conservation of energy, which may be a hindrance in the adoption of energy conservation techniques. Sometimes such costs may not be large in the developing countries but the problem remains due the scarcity of resources. Incentives in the form of lower rate/ exemption of excise and custom duties on energy efficient equipments and machinery or easy availability of finance at lower rates for installing energy efficiency equipment must be provided to consumers and producers for conserving energy. Such incentives alone with the legislation would be helpful in the promotion and adoption of energy conservation in developing countries like India.
Table 3
Energy Conservation Potential in India

<table>
<thead>
<tr>
<th>Sector</th>
<th>Potential (%)</th>
<th>Sector</th>
<th>Potential (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economy as a whole</td>
<td>Up to 23</td>
<td>Paper &amp; pulp</td>
<td>20-25</td>
</tr>
<tr>
<td>Agriculture</td>
<td>Up to 30</td>
<td>Ferrous Foundry</td>
<td>15-20</td>
</tr>
<tr>
<td>Industrial</td>
<td>Up to 25</td>
<td>Glass</td>
<td>15-20</td>
</tr>
<tr>
<td>Transport</td>
<td>Up to 20</td>
<td>Fertilizers</td>
<td>10-15</td>
</tr>
<tr>
<td>Domestic &amp; commercial</td>
<td>Up to 20</td>
<td>Cement</td>
<td>10-15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Chloro-Alkali</td>
<td>10-15</td>
</tr>
<tr>
<td>Industries</td>
<td></td>
<td>Aluminum</td>
<td>8-10</td>
</tr>
<tr>
<td>Textiles</td>
<td>20-25</td>
<td>Iron &amp; Steel</td>
<td>8-10</td>
</tr>
</tbody>
</table>

Source: Planning Commission, 2003

Note: The potential is with respect to housekeeping retrofitting and minor process modification measure sand does not include potential as a result of technology changes.

8.4.2 Promotion of Non-conventional and Renewable Energy Resources

In addition to the efforts to conserve energy there is a need to find, develop, and exploit non-conventional energy sources, many of which are clean and renewable in nature. India, recognizing the importance of such nonconventional energy resources initiated their development on a small scale following the energy crisis of 1973. Since then, as a result of the continued thrust on the part of the government, efforts were made for the commercial exploitation of these non-conventional energy resources. Table 4 shows the potential and the exploited potential of the non-conventional energy resources in India. As is evident from the table there exists enormous potential for generating power from these non-conventional sources in the country. Unfortunately even after so many years of action or inaction on the part of the government not much could be achieved, as the potential exploited is a very small fraction of the total potential of these resources. While the technologies for the development of wind energy, small hydro, biomass and tidal power already exists in the country, those for the exploitation of sea wave power and ocean thermal power have not been proven. Efforts must be made by means of increased research and development (R&D) activities in this sector to tap the enormous potential of these non-conventional energy resources.
### Table 4
Renewable Energy Potential in India  
(as on 31-03-2002)

<table>
<thead>
<tr>
<th></th>
<th>Potential</th>
<th>Potential Exploited</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biogas plants</td>
<td>12 million</td>
<td>3.52 million</td>
</tr>
<tr>
<td>Efficient Woodstoves</td>
<td>120 million</td>
<td>35 million</td>
</tr>
<tr>
<td>Solar Energy</td>
<td>120 MW/Sq.Km.</td>
<td>1.74MW.sq.Km.</td>
</tr>
<tr>
<td>Biomass-based power</td>
<td>19,500 MW</td>
<td>537.17 MW</td>
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<tr>
<td>Small hydro</td>
<td>15,000 MW</td>
<td>1,519 MW</td>
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<tr>
<td>Wind Energy</td>
<td>45,000 MW</td>
<td>1,870 MW</td>
</tr>
<tr>
<td>Energy Recovery from Waste</td>
<td>1,700 MW</td>
<td>25.25 MW</td>
</tr>
<tr>
<td>Ocean Thermal</td>
<td>50,000MW</td>
<td>-</td>
</tr>
<tr>
<td>Sea wave power</td>
<td>20,000MW</td>
<td>-</td>
</tr>
<tr>
<td>Tidal Power</td>
<td>9,000 MW</td>
<td>-</td>
</tr>
</tbody>
</table>

*Source: Government of India (2003) and Gupta (2005)*

#### 8.4.3 Fuel Substitution

Traditionally India is heavily reliant on coal for its energy requirements, which is the dominant source of commercial energy. It also uses some amount of oil and natural gas to meet its energy requirements. The major problem with the Indian coal, however, lies not in its quantitative availability, but in its low quality due to high ash content for both coking and non-coking coal and is therefore the major source of CO₂ emission in the country accounting for about 60.06 per cent of the total CO₂ emissions in 1997-98. Hence efforts should be made to substitute more polluting coal by less polluting fuels like oil and natural gas. In the post reforms period use of oil and gas has been permitted more freely as compared to the era of controlled planning. Sectors, which were earlier not permitted to use oil and gas, were now allowed switch to these cleaner fuels. Power sector is now permitted to use natural gas, steam-locos have been phased out by the railways and coal based fertilizer plants are no longer functional. All these have resulted in a gradual decline in the share of coal in the economy can be seen in Figure 2 which shows that the share of coal in the total energy requirement of the economy other than the power sector has gradually declined while that of oil and gas has risen over the years.
Power sector in India is heavily dependent on coal. Over the years the share of thermal power increased from 5.3 per cent to 81.7 per cent between 1980-81 and 2000-01, while that of hydro power decreased from 42 per cent to 14.9 per cent. Efforts must be made to exploit the enormous potential of hydro-based power in the country so that the share of hydro power, which is pollution free, in the total power generation can be increased. While natural gas is a relatively clean fossil fuel, its limited domestic availability has been a constraining factor. The other clean option of nuclear power has also seen slow progress due to indigenization and institutional failures.

8.4.4 Energy Sector Reforms

India's commercial energy is mainly based on fossil fuel and control of environmental externalities points to the importance of energy efficiency. Among the various policy options for achieving higher energy efficiency, liberalization of the
economy - both internal and external - for greater competitiveness in industry and trade has been supposed to restructure the technology and the institutions of the economy so as to induce efficient allocation of resources. India introduced a series of measures of economic reforms since 1991 for enforcing greater competitive efficiency in her economic system. The economic reforms process in the energy sector targeted particularly supply side efficiency through privatization, price reform, and globalization. On the demand side also it was assumed, that the reforms process would result in efficient use of energy. Sengupta and Gupta (2003) examined whether the measures of economic reforms both at the macro-economic and at the energy sector level have been able to make any significant impact on energy efficiency. Their results indicate that India's economic reforms programme at the macro level or in the energy sector has not as yet been able to make any significant impact on the energy efficiency of Indian economy. It is in fact the incompleteness of the price reforms, which is one of the major factors responsible for the insignificance of the impact of India's economic reforms on energy efficiency. Prevalence of low energy prices would discourage energy suppliers under the condition of privatization to expand supply by investment, as the marginal cost of supply under the normal rate of interest would exceed the given price. The consumers are also discouraged from energy saving resulting in energy inefficiency, as the cost of saving by upgrading appliances would be more than the price of the energy saved. They opined that either it is too early for assessing the impact of reforms or the reform measures themselves are hardly adequate for the achievement of energy efficiency and conservation in the non-energy sector of India.

8.4.5 Changing Product Mix

Changes in the lifestyle and consumption pattern of a society can also have a restraining effect on CO$_2$ emissions in the economy. By changes in the lifestyle and consumption pattern one refers to changes in the product mix in the consumption basket. By giving preference to less energy intensive products and reducing the consumption and therefore domestic production of more energy intensive commodities one can bring about a change in the product mix. This would mean a reduction in the overall energy intensity of the economy and therefore in its carbon emission intensity. Alternatively, a reduction
in the energy intensity of the economy can also be achieved by changing the basket of commodities that is traded i.e. by importing more energy intensive goods and exporting less energy intensive products. A country may continue to enjoy the benefits of the same level of consumption by changing the composition of trade and the pattern of production i.e., by importing products that are GHG emission intensive and reducing their domestic production thereby reducing the GHG emissions as calculated by the conventional approach. Any such reduction in emissions by a country does not result in the curtailment of global GHG emissions as in reality it amounts to shifting the emissions beyond ones national boundary. The global emission do not change unless the exporting country is more energy efficient in the production of the concerned products. The way out of this problem is to switch to more advanced and energy efficient technologies bring about a change in the lifestyle and consumption pattern by giving preference to less energy intensive commodities and import energy intensive commodities from countries which produces them more efficiently. Thus by restructuring people’s preferences in favor of eco-friendly products and technology one can contribute significantly to the abatement of global warming (Sengupta and Bhardawj, 2004).

8.4.6 Energy sector Research and Development

It is well known that energy sector plays a crucial role in any country’s economic development. India’s energy sector faces a daunting task of meeting the increasing demand for energy in an environmentally friendly manner. Unfortunately, over the years, all our efforts focused only on increasing the supply of energy and little attention was paid to the research and development (R&D) aspect of the energy system. The energy sector spans a range of activities: extraction of Primary energy sources, their conversion to usable forms through processes such as generation and refining, and eventually their use in the form of final energy in different sectors of the economy. R&D activities will facilitate development of new technologies which would increase the efficiency of the system right from the stage of extraction of primary energy resource, its conversion to usable forms and finally to the end-use technologies. Adequate attention should therefore be given to energy R&D activities in the country. As per the statistics provided by the Department of Science and Technology India had spent only Rs.83.4 billion on R&D
activities in the year 1996-97 and out of this only Rs.6.2 billion was allocated for R&D activities relating to production, conservation and distribution of energy which is just 7.6 per cent of the national expenditure on R&D (Sagar, 2002). As compared to the industrialised countries of the world this is a very small amount. Table 3 provides a comparison of India's national R&D budgets with other countries of the world. It is only recently that the Government has decided to raise the allocation to R&D to 2 per cent of GDP.

Table 6
Comparison of Selected National R&D Budgets (1996 Data)

<table>
<thead>
<tr>
<th></th>
<th>Total (Billion US$)</th>
<th>Percent of GDP</th>
<th>Per Capital (US$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>India (MER)</td>
<td>2.34</td>
<td>0.59</td>
<td>2.5</td>
</tr>
<tr>
<td>India (PPP$)</td>
<td>11.5</td>
<td>0.59</td>
<td>12.1</td>
</tr>
<tr>
<td>US</td>
<td>195.9</td>
<td>2.57</td>
<td>739.0</td>
</tr>
<tr>
<td>Japan</td>
<td>85.1</td>
<td>2.83</td>
<td>676.0</td>
</tr>
<tr>
<td>Germany</td>
<td>39.7</td>
<td>2.30</td>
<td>485.0</td>
</tr>
<tr>
<td>France</td>
<td>27.7</td>
<td>2.32</td>
<td>475.0</td>
</tr>
<tr>
<td>UK</td>
<td>22.3</td>
<td>1.95</td>
<td>380.0</td>
</tr>
<tr>
<td>Italy</td>
<td>12.0</td>
<td>1.02</td>
<td>209.0</td>
</tr>
<tr>
<td>Canada</td>
<td>10.8</td>
<td>1.60</td>
<td>365.0</td>
</tr>
</tbody>
</table>


8.4.7 Afforestation and Wasteland Development

It is estimated that land-use change in the developing countries could contribute to the global emission to the extent of 1.6 billion tonnes of carbon (Parikh, 2003). However, the satellite data for India shows that its share would be very small. According to Ministry of Environment and Forests (1995), the recent satellite data shows that deforestation in India has been considerably halted, if not marginally reversed. The green cover in the country has also registered an increase. Various agencies in the country spend as much as Rs.50 billion annually on wasteland development (Ministry of Rural
Areas and Employment, 1996). If all the efforts for afforestation were to succeed, India's net emission of CO$_2$ can come down substantially. Unfortunately CO$_2$ sequestered by these efforts is hard to estimate due to lack of systematic information and also because that is not the primary purpose for afforestation in the country.

Unchecked emission of various GHGs cannot be continued without any consideration for the future and efforts must be made at a global scale to restrict these emissions. Given the limited amount of emissions that is tolerated by the earth's environment there is a debate about who could emit how much in future. This will invariably have direct bearing on what development alternatives are feasible in future for the North and the South. The debate on climate change acquires a different dimension when disparities between the North and the South is considered in terms of responsibilities for emissions and vulnerabilities to the effects brought on by climate change. Table 4 shows the disparities in income and CO$_2$ emissions between some of the different regions and countries of the world. The developed countries, which account for about 25.9 per cent of the population of the world, emit 70.3 per cent of the total CO$_2$ emissions in 1998. Their per capita emissions are also much higher than the world's average of 3.87 tormes of CO$_2$. The developing countries, which are home to 74.1 per cent of the world population, contribute 29.7 per cent of the total CO$_2$ emissions and their per capita emissions are also much lower than the world average. India's contribution in 1998 was 908.2 mn tCO$_2$ accounting for about 4.1 per cent of the world CO$_2$ emissions and it had a per capita emission of 0.93 tCO$_2$. 

### Table 7
GDP and Patterns of CO₂ Emissions across Different Regions in 1998

<table>
<thead>
<tr>
<th>Regions</th>
<th>GDP (billion 1990US$ using PPPS)</th>
<th>Per Capita GDP (1990 US$ using PPP)</th>
<th>Emissions per unit of PPP$ GDP@</th>
<th>Total Emission world (mn t CO₂)</th>
<th>Percent of Emission CO₂</th>
<th>Per capita emission (tCO₂)</th>
</tr>
</thead>
<tbody>
<tr>
<td>OECD N. America</td>
<td>8412.0</td>
<td>21292.4</td>
<td>0.74</td>
<td>6243.30</td>
<td>28.24</td>
<td>15.80</td>
</tr>
<tr>
<td>OECD Europe</td>
<td>7802.0</td>
<td>15297.4</td>
<td>0.50</td>
<td>3933.70</td>
<td>17.80</td>
<td>7.71</td>
</tr>
<tr>
<td>OECD Pacific</td>
<td>3539.4</td>
<td>18108.1</td>
<td>0.52</td>
<td>1839.70</td>
<td>8.32</td>
<td>9.41</td>
</tr>
<tr>
<td>Africa</td>
<td>1235.4</td>
<td>1631.9</td>
<td>0.59</td>
<td>728.65</td>
<td>3.30</td>
<td>0.96</td>
</tr>
<tr>
<td>Middle East</td>
<td>608.69</td>
<td>3806.7</td>
<td>1.52</td>
<td>924.18</td>
<td>4.18</td>
<td>5.78</td>
</tr>
<tr>
<td>Non-OECD Europe</td>
<td>274.1</td>
<td>4314.5</td>
<td>1.07</td>
<td>393.73</td>
<td>1.78</td>
<td>6.20</td>
</tr>
<tr>
<td>Former USSR</td>
<td>1053.9</td>
<td>3613.3</td>
<td>2.09</td>
<td>2206.44</td>
<td>9.98</td>
<td>7.56</td>
</tr>
<tr>
<td>Latin America</td>
<td>2216.4</td>
<td>5498.8</td>
<td>0.39</td>
<td>866.43</td>
<td>3.92</td>
<td>2.15</td>
</tr>
<tr>
<td>Asia</td>
<td>8511.7</td>
<td>2755.3</td>
<td>0.58</td>
<td>4969.48</td>
<td>22.48</td>
<td>1.61</td>
</tr>
<tr>
<td>Mexico</td>
<td>758.0</td>
<td>7922.2</td>
<td>0.47</td>
<td>356.30</td>
<td>1.61</td>
<td>3.72</td>
</tr>
<tr>
<td>India</td>
<td>1487.0</td>
<td>1517.9</td>
<td>0.61</td>
<td>908.20</td>
<td>4.11</td>
<td>0.93</td>
</tr>
<tr>
<td>China</td>
<td>4292.4</td>
<td>3446.9</td>
<td>0.69</td>
<td>2893.15</td>
<td>13.09</td>
<td>2.32</td>
</tr>
<tr>
<td>US</td>
<td>7043.6</td>
<td>26175.6</td>
<td>0.77</td>
<td>5409.80</td>
<td>24.47</td>
<td>20.10</td>
</tr>
<tr>
<td>UK</td>
<td>1077.4</td>
<td>17187.0</td>
<td>0.51</td>
<td>549.50</td>
<td>2.49</td>
<td>9.28</td>
</tr>
<tr>
<td>Japan</td>
<td>2581.5</td>
<td>20408.7</td>
<td>0.44</td>
<td>1128.30</td>
<td>5.10</td>
<td>8.92</td>
</tr>
<tr>
<td>Developed Countries</td>
<td>20932.0</td>
<td>13771.4</td>
<td>0.77</td>
<td>15541.05</td>
<td>70.30</td>
<td>9.62</td>
</tr>
<tr>
<td>Developing Countries</td>
<td>12721.5</td>
<td>2927.8</td>
<td>0.54</td>
<td>6564.56</td>
<td>29.70</td>
<td>1.54</td>
</tr>
<tr>
<td>World #</td>
<td>33653.5</td>
<td>5738.0</td>
<td>0.66</td>
<td>22105.61</td>
<td>100.00</td>
<td>3.87</td>
</tr>
</tbody>
</table>

@ Kilograms of CO₂ per US$ using 1990 prices and purchasing power parities (PPPs)
# World emissions do not include emissions from international marine and aviation bunkers.


Historically speaking the developed countries have been the major emitters of CO₂ in the atmosphere. The unsustainable consumption patterns of the industrialised North have led to the accumulation of greenhouse gases like CO₂ in the atmosphere. Thus, the prime responsibility of emission reduction lies with the developed nations. Even the Framework Convention on Climate Change (FCCC) recognising the right of the developing countries to develop calls for common but differentiated responsibilities for
all the countries and also expects the developed nations of the world to take lead in any global effort for mitigating GHG emissions. Accepting that, efforts should be made to restrict GHG emissions an important question which one face concerns with the distribution of abatement level among different countries of the world. In other words how should these abatement levels be distributed among countries taking into account their responsibilities for current concentrations and development needs? Who should bear the burden of emission abatement? What policies will achieve this desired reduction of GHG concentrations and therefore the desired emission reductions?

In order to answer these questions Smith et al., (1993) constructed an 'obligation to pay index' based on (i) the 'ability to pay', which is indicated by the present wealth and is completely separate from GHG emission, and (ii) a 'responsibility' index which is based on the historical contribution to climate change. These two address the question 'who can pay?' and 'who should pay?' respectively. From Table 4 it is evident that the developed countries have a much higher GDP vis-à-vis the developing countries. Thus, it is the developed countries, where most of the wealth is concentrated, that have the 'ability to pay' for abating GHG emissions. As regards the historical contributions it is the developed countries that have contributed to the emission of GHG in the past and are therefore, responsible for increased concentration of GHG in the atmosphere. Hence the developed countries, who are responsible for the problem of global climate change and have the ability to pay for restricting GHG emissions, must take the initiative in terms of controlling their emissions in order to address the problem of global climate change.

Having resolved the problem of 'who can pay' (or who has the ability to pay) and 'who should pay' (i.e. who is responsible) for abating GHG emissions, the next question that arises is where should the abatement be conducted? In other words one needs to know where are the best and cheapest projects located to carry out the abatement activities. Hayes (1993) calculated the marginal abatement costs for different countries to identify. The cheapest sites for abating GHG emissions. According to him the cheapest sites or projects are located in the developing countries where the marginal cost of abatement is much lower vis-à-vis the developed countries. Thus if we consider the distribution of opportunities for abating GHG emissions they are all located in the
developing countries. In order to minimize the global cost of mitigation most of the abatement activities should take place in the developing countries where the cheapest and best projects are concentrated.

The developing countries should complement the efforts of the developed countries to reduce their emissions by moving towards a system, which is more energy efficient and less carbon intensive. In reality many of the developing countries like India contributing to global efforts to restrict GHG emissions by adopting a path of development which is different from that of the developed countries and which is energy efficient. Such achievements of these countries needs to be highlighted so that it becomes a public knowledge that developing countries like India are in fact trying to address the problem of global climate change in their own possible way.

The FCCC, recognising both the historical responsibilities and the limited role that the developing countries could play in addressing the problem of global warming, called upon the developed countries to make efforts to reduce their GHG emissions. Recognising the need for development, the developing countries were exempted from any commitments towards emission reductions, but were asked to abstain from GHG emissions, which are not necessary for their development. The Convention also called upon the parties to protect the climate system for the benefit of the present and future generations on the basis of equity and in accordance with their common albeit differentiated responsibilities and capabilities.

Because of the current and projected climate disruption precipitated by high levels of greenhouse gas emissions by the industrialized nations, adaptation is a necessary strategy at all scales to complement climate change mitigation efforts because we cannot be sure that all climate change can be mitigated. And indeed the odds are quite high that in the long run more warming is inevitable, given the high level of GHGs in the atmosphere, and the (several decade) delay between emissions and impact.

Adaptation has the potential to reduce adverse impacts of climate change and to enhance beneficial impacts, but will incur costs and will not prevent all damages. Extremes, variability, and rates of change are all key features in addressing vulnerability and adaptation to climate change, not simply changes in average climate conditions.
Human and natural systems will to some degree adapt autonomously to climate change. Planned adaptation can supplement autonomous adaptation, though there are more options and greater possibility for offering incentives in the case of adaptation of human systems than in the case of adaptation to protect natural systems.\textsuperscript{702}

\textbf{National Programs}

The announcement of national level programs such as the Bachat Lamp Yojana, a programmatic national level project to replace incandescent lamps with CFLs using CDM as a project mechanism, showed the level of increased interest in energy efficiency marketing in India. Other examples of national programs recently announced include solar water heating in one million households, deployment of five million solar lanterns and two million home solar lighting systems. India is reportedly considering a trading scheme centered on energy efficiency certificates (that could expand to renewable energy) consistent with national climate change policy. The Government is setting up energy benchmarks for industry sectors and those companies that do not meet the benchmark could buy the certificates under a reward and penalty system. It hopes to reduce energy consumption by at least 25\% in energy-intensive sectors such as power and cement.\textsuperscript{703}

\textit{Setting up of NIRCE at Bangalore, India}\textsuperscript{704}

The Union of India is going to set up a world class institute to carry out research on climate change, global warming and its impact on the economy and environment. The “National Institute for Research on Climate and Environment” (NIRCE) would help build India’s own capacity for measuring, monitoring and modelling Climate change. The institute would use space-based and ground based observation system to create an indigenous “nucleus” for research into all issues relating to climate including the impact of climate change on aspects of the economy such as agriculture and water.

\textit{Satellite monitoring}\textsuperscript{705}

\textsuperscript{702} “Adaptation is a Necessary Strategy at All Scales to Complement Climate Change Mitigation Efforts”. \textit{Climate Change 2001: Working Group II: Impacts, Adaptation and Vulnerability}.

\textsuperscript{703} “India says readying energy efficiency trade policy”, Reuters, March 16,2009

\textsuperscript{704} The Hindu, a daily newspaper on 5 November,2009
By the Indian Space and Research Organization (ISRO) two satellites would be launched between 2010 and 2011 to measure and monitor greenhouse gases. While a micro satellite would be launched in 2010 to study aerosols, another dedicated satellite in 2011 would monitor greenhouse gases such as methane and trace gases.

*Green Bonus*\(^{706}\)

A new mechanism was being proposed by the G.O.I to provide incentives to States to retain and expand green cover. Towards this end a “green bonus” would be given to States along with funds from the Planning Commission or Finance Commission.

The Government of India, in cooperation with the Government of Mexico was the President of the 16th Conference of Parties to United Nations Framework Convention on Climate Change (UNFCCC) in Cancun, and the United Nations DESA has organized an Informal Ministerial Dialogue on 'Climate Change: Technology Mechanism' between Nov. 9 to 10, 2010 in New Delhi.

The Delhi Dialogue enabled the Ministers from about 50 countries to discuss and develop consensus on the design of a global technology mechanism for development, deployment and delivery of clean technologies in the context of climate change to developing countries.

Ministers and high-level representatives from Governments drawn from different regions and political groups as also the international organizations involved with the issue.

The agreement facilitate involvement of UNDESA (United Nations Department of Economic and Social Affairs) and GOI towards organising the Ministerial Dialogue which plays an important role in advancing the dialogue amongst the parties on technology related issues in the context of the upcoming climate change negotiations at Cancun in Dec., 2010.

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\(^{705}\) Ibid
\(^{706}\) Ibid
8.5 Climate Change Mitigation

Climate change mitigation is actions to limit the magnitude and/or rate of long-term climate change. Climate change mitigation generally involves reductions in human (anthropogenic) emissions of greenhouse gases (GHGs). Mitigation may also be achieved by increasing the capacity of carbon sinks, e.g., through reforestation. By contrast, adaptation to global warming are actions taken to manage the eventual (or unavoidable) impacts of global warming, e.g., by building dike in response to sea level rise.

Examples of mitigation include switching to low-carbon energy sources, such as renewable and nuclear energy, and expanding forests and other "sinks" to remove greater amounts of carbon dioxide from the atmosphere. Energy efficiency may also play a role, for example, through improving the insulation of buildings.

Another approach to climate change mitigation is geo-engineering (climate engineering). The main international treaty on climate change is the United Nations Framework Convention on Climate Change (UNFCCC). In 2010, Parties to the UNFCCC agreed that future global warming should be limited to below 2.0 °C (3.6 °F) relative to the pre-industrial level. Analysis suggests that meeting the 2 °C target would require annual global emissions of greenhouse gases to peak before the year

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708 IPCC, "Summary for policymakers" Table SPM.3, C. Mitigation in the short and medium term (until 2030), in IPCC AR4 WG3 2007
709 Ibid.
710 Ibid.
711 Nicholls, R.J., et al., "Ch 6: Coastal Systems and Low-Lying Areas", Table 6.11, in IPCC AR4 WG2 2007, p. 343
712 IPCC, "Summary for policymakers", Table SPM.3, C. Mitigation in the short and medium term (until 2030), in IPCC AR4 WG3 2007
713 "Synthesis report", Sec 5.5 Technology flows and development, in IPCC AR4 SYR 2007, p. 68
715 UK Royal Society 2009
716 UNFCCC (5 March 2013), Introduction to the Convention, UNFCCC
717 UNFCCC Conference of the Parties (COP) (15 March 2011), Report of the Conference of the Parties on its sixteenth session, held in Cancun from 29 November to 10 December 2010
718 UNEP 2012, pp. v, 25
2020, and decline significantly thereafter,\textsuperscript{719} with emissions in 2050 reduced by 30-50% compared to 1990 levels.\textsuperscript{720} Analyses by the United Nations Environment Programme\textsuperscript{721} and International Energy Agency\textsuperscript{722} suggest that current policies (as of 2013) are too weak to achieve the 2 °C target.

One of the issues often discussed in relation to climate change mitigation is the stabilization of greenhouse gas concentrations in the atmosphere. The United Nations Framework Convention on Climate Change (UNFCCC) has the ultimate objective of preventing "dangerous" anthropogenic (i.e., human) interference of the climate system. As is stated in Article 2 of the Convention, this requires that greenhouse gas (GHG) concentrations are stabilized in the atmosphere at a level where ecosystems can adapt naturally to climate change, food production is not threatened, and economic development can proceed in a sustainable fashion.\textsuperscript{723}

There are a number of anthropogenic greenhouse gases. These include carbon dioxide (chemical formula: CO$_2$), methane (CH$_4$), nitrous oxide (N$_2$O), and a group of gases referred to as halocarbons.\textsuperscript{724} The emissions reductions necessary to stabilize the atmospheric concentrations of these gases varies.\textsuperscript{725} CO$_2$ is the most important of the anthropogenic greenhouse gases.\textsuperscript{726}

There is a difference between stabilizing CO$_2$ emissions and stabilizing atmospheric concentrations of CO$_2$. Stabilizing emissions of CO$_2$ at current levels would not lead to a stabilization in the atmospheric concentration of CO$_2$. In fact, stabilizing emissions at current levels would result in the atmospheric concentration of CO$_2$ continuing to rise over the 21$^\text{st}$ century and beyond (see the graphs opposite).

\begin{itemize}
\item \textsuperscript{719} "Executive summary", \textit{in UNEP 2012}, p. 6
\item \textsuperscript{720} UNEP 2012, p. 25.
\item \textsuperscript{721} "Executive summary" \textit{in UNEP 2012}, p. 1.
\item \textsuperscript{723} \textit{Introduction}. \textit{Climate Change 2007: Mitigation}. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.
\item \textsuperscript{724} "Ch. 2: Changes in Atmospheric Constituents and in Radiative Forcing", FAQ 2.1 How do Human Activities Contribute to Climate Change and How do They Compare with Natural Influences?, \textit{in IPCC AR4 WG1 2007}, p. 135
\item \textsuperscript{725} "Ch. 10: Global Climate Projections", FAQ 10.3: If Emissions of Greenhouse Gases are Reduced, How Quickly do Their Concentrations in the Atmosphere Decrease?, \textit{in IPCC AR4 WG1 2007}, pp. 824–825
\item \textsuperscript{726} IPCC, "Summary for Policymakers", \textit{Human and Natural Drivers of Climate Change}, \textit{in IPCC AR4 WG1 2007}.
\end{itemize}
The reason for this is that human activities are adding CO\textsubscript{2} to the atmosphere far faster than natural processes can remove it (see carbon dioxide in Earth's atmosphere for a more complete explanation).\textsuperscript{727} This is analogous to a flow of water into a bathtub. So long as the tap runs water (analogous to the emission of carbon dioxide) into the tub faster than water escapes through the plug hole (the natural removal of carbon dioxide from the atmosphere), then the level of water in the tub (analogous to the concentration of carbon dioxide in the atmosphere) will continue to rise.

Stabilizing atmospheric CO\textsubscript{2} concentrations would require anthropogenic CO\textsubscript{2} emissions to be reduced by 80\% relative to the peak emissions level.\textsuperscript{728} An 80\% reduction in emissions would stabilize CO\textsubscript{2} concentrations for around a century, but even greater reductions would be required beyond this.\textsuperscript{729,730}

Stabilizing the atmospheric concentration of the other greenhouse gases humans emit also depends on how fast their emissions are added to the atmosphere, and how fast the GHGs are removed. Stabilization for these gases is described in the later section on non-CO\textsubscript{2} GHGs.

Projections of future greenhouse gas emissions are highly uncertain.\textsuperscript{731} In the absence of policies to mitigate climate change, GHG emissions could rise significantly over the 21st century.\textsuperscript{732}

Numerous assessments have considered how atmospheric GHG concentrations could be stabilized.\textsuperscript{733} The lower the desired stabilization level, the sooner global GHG

\textsuperscript{727} "Ch. 10: Global Climate Projections", FAQ 10.3: If Emissions of Greenhouse Gases are Reduced, How Quickly do Their Concentrations in the Atmosphere Decrease?, in IPCC AR4 WG1 2007, pp. 824–825
\textsuperscript{728} Stabilization and Climate Change of the Next Few Decades and Next Several Centuries, p.21, in: Summary, in US NRC 2011
\textsuperscript{729} "Ch. 10: Global Climate Projections", FAQ 10.3: If Emissions of Greenhouse Gases are Reduced, How Quickly do Their Concentrations in the Atmosphere Decrease?, in IPCC AR4 WG1 2007, pp. 824–825
\textsuperscript{730} Stabilization and Climate Change of the Next Few Decades and Next Several Centuries, p.21, in: Summary, in US NRC 2011
\textsuperscript{731} "Ch 3: Issues related to mitigation in the long-term context", Sec 3.1 Emissions scenarios, in IPCC AR4 WG2007
\textsuperscript{732} "Ch 1: Introduction", Sec 1.3.2.4 Total GHG emissions, in IPCC AR4 WG3 2007, p. 111
\textsuperscript{733} "Ch 3: Issues related to mitigation in the long-term context” in IPCC AR4 WG3 2007
emissions must peak and decline.\textsuperscript{734} GHG concentrations are unlikely to stabilize this century without major policy changes.\textsuperscript{735}

To create lasting climate change mitigation, the replacement of high carbon emission intensity power sources, such as conventional fossil fuels - oil, coal and natural gas - with low-carbon power sources is required. Presently fossil fuels supply humanity with the vast majority of our energy demands, and at a growing rate. In 2012 the IEA noted that coal accounted for half the increased energy use of the prior decade, growing faster than all renewable energy sources.\textsuperscript{736} Both hydroelectricity and nuclear power together provide the majority of the generated low-carbon power fraction of global total power consumption.

8.6 Methods and Means of Mitigation

Assessments often suggest that GHG emissions can be reduced using a portfolio of low-carbon technologies.\textsuperscript{737} At the core of most proposals is the reduction of greenhouse gas (GHG) emissions through reducing energy waste and switching to low-carbon power sources of energy. As the cost of reducing GHG emissions in the electricity sector appears to be lower than in other sectors, such as in the transportation sector, the electricity sector may deliver the largest proportional carbon reductions under an economically efficient climate policy.

Other frequently discussed means include energy conservation, increasing fuel economy in automobiles (which includes the use of electric hybrids), charging plug-in hybrids and electric cars by low-carbon electricity, making individual-lifestyle changes\textsuperscript{738} (e.g., cycling instead of driving),\textsuperscript{739} and changing business practices.

A range of energy technologies may contribute to climate change mitigation.\textsuperscript{740} These include renewable energy sources such as solar power, tidal, ocean energy,
geothermal power, and wind power; nuclear power, the use of carbon sinks, and carbon capture and storage. For example, Pacala and Socolow of Princeton have proposed a 15 part program to reduce CO\textsubscript{2} emissions by 1 billion metric tons per year – or 25 billion tons over the 50-year period using today's technologies as a type of Global warming game.

Another consideration is how future socio-economic development proceeds. Development choices (or "pathways") can lead differences in GHG emissions.\textsuperscript{741} Political and social attitudes may affect how easy or difficult it is to implement effective policies to reduce emissions.\textsuperscript{742}

**Alternative Energy Sources**

**a) Renewable Energy**

Renewable energy flows involve natural phenomena such as sunlight, wind, tides, plant growth, and geothermal heat, as the International Energy Agency explains:\textsuperscript{743}

Renewable energy is derived from natural processes that are replenished constantly. In its various forms, it derives directly from the sun, or from heat generated deep within the earth. Included in the definition is electricity and heat generated from solar, wind, ocean, hydropower, biomass, geothermal resources, and biofuels and hydrogen derived from renewable resources.

Climate change concerns\textsuperscript{744} and the need to reduce carbon emissions are driving increasing growth in the renewable energy industries\textsuperscript{745} Low-carbon renewable energy replaces conventional fossil fuels in three main areas: power generation, hot water, space heating, and transport fuels.\textsuperscript{746}

\begin{itemize}
  \item \textsuperscript{741} "Ch 12: Sustainable Development and mitigation", Sec 12.2.1.1 Development paths as well as climate policies determine GHG emissions, in IPCC AR4 WG3 2007, pp. 701–703
  \item \textsuperscript{742} Greenhouse Gas Emission Mitigation Scenarios and Implications”, Sec 2.5.2.2 Storylines of Post-SRES Mitigation Scenarios, in IPCC TAR WG3 2001, pp. 149–150
  \item \textsuperscript{743} IEA Renewable Energy Working Party (2002)
  \item \textsuperscript{744} HM Treasury (2006). Stern Review on the Economics of Climate Change
  \item \textsuperscript{745} New UN report points to power of renewable energy to mitigate carbon emissions UN News Centre, 8 December 2007.
  \item \textsuperscript{746} REN21 (2010). Renewables 2010 Global Status Report p. 15.
\end{itemize}
Renewable energy use has grown much faster than anyone anticipated.\textsuperscript{747} The Intergovernmental Panel on Climate Change has said that there are few fundamental technological limits to integrating a portfolio of renewable energy technologies to meet most of total global energy demand.\textsuperscript{748} At the national level, at least 30 nations around the world already have renewable energy contributing more than 20\% of energy supply.

As of 2012, renewable energy accounts for almost half of new electricity capacity installed and costs are continuing to fall.\textsuperscript{749} Public policy and political leadership helps to "level the playing field" and drive the wider acceptance of renewable energy technologies.\textsuperscript{750} As of 2011, 118 countries have targets for their own renewable energy futures, and have enacted wide-ranging public policies to promote renewables.\textsuperscript{751,752} Leading renewable energy companies include BrightSource Energy, First Solar, Gamesa, GE Energy, Goldwind, Sinovel, Suntech, Trina Solar, Vestas and Yingli.\textsuperscript{753,754}

The incentive to use 100\% renewable energy has been created by global warming and other ecological as well as economic concerns.\textsuperscript{755} Mark Z. Jacobson says producing all new energy with wind power, solar power, and hydropower by 2030 is feasible and existing energy supply arrangements could be replaced by 2050. Barriers to implementing the renewable energy plan are seen to be "primarily social and political, not technological or economic". Jacobson says that energy costs with a wind, solar, water system should be similar to today's energy costs.\textsuperscript{756} According to a 2011 projection by the (IEA) International Energy Agency, solar power generators may produce most of the

\begin{thebibliography}{9}
\bibitem{747} Paul Gipe (4 April 2013). “100 Percent Renewable Vision Building” \textit{Renewable Energy World}.
\bibitem{748} IPCC (2011). "Special Report on Renewable Energy Sources and Climate Change Mitigation"
\bibitem{749} International Renewable Energy Agency (2012) "Renewable Power Generation Costs in 2012: An Overview"
\bibitem{751} REN21 (2012) Renewables Global Status Report 2012 p. 17
\bibitem{753} Renewable Energy World, 2 January 2006.
\bibitem{754} Keith Johnson, Wind Shear: GE Wins, Vestas Loses in Wind-Power Market Race, Wall Street Journal, March 25\textsuperscript{th} 2009, accessed on January 7\textsuperscript{th} 2010.
\bibitem{755} Paul Gipe (4 April 2013). “100 Percent Renewable Vision Building”. \textit{Renewable Energy World}
\end{thebibliography}
world's electricity within 50 years, dramatically reducing harmful greenhouse gas emissions.757

Economic analysts expect market gains for renewable energy (and efficient energy use) following the 2011 Japanese nuclear accidents.758 In his 2012 State of the Union address, President Barack Obama restated his commitment to renewable energy and mentioned the long-standing Interior Department commitment to permit 10,000 MW of renewable energy projects on public land in 2012.759 Globally, there are an estimated 3 million direct jobs in renewable energy industries, with about half of them in the biofuels industry.760

Some countries, with favorable geography, geology and weather well suited to an economic exploitation of renewable energy sources, already get most of their electricity from renewables, including from geothermal energy in Iceland (100 percent), and Hydroelectric Power in Brazil (85 percent), Austria (62 percent), New Zealand (65 percent), and Sweden (54 percent).761 Renewable power generators are spread across many countries, with wind power providing a significant share of electricity in some regional areas: for example, 14 percent in the U.S. state of Iowa, 40 percent in the northern German state of Schleswig-Holstein, and 20 percent in Denmark. Solar water heating makes an important and growing contribution in many countries, most notably in China, which now has 70 percent of the global total (180 GWth). Worldwide, total installed solar water heating systems meet a portion of the water heating needs of over 70 million households. The use of biomass for heating continues to grow as well. In Sweden, national use of biomass energy has surpassed that of oil. Direct geothermal heating is also growing rapidly.762 Renewable biofuels, for transportation, such as ethanol fuel and biodiesel, have contributed to a significant decline in oil consumption in the United States since 2006. The 93 billion liters of biofuels produced worldwide in 2009 displaced

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760 REN21 (2010), Renewagles 2010 Global Status Report p. 9 & 34.
762 Ibid.
the equivalent of an estimated 68 billion liters of gasoline, equal to about 5 percent of world gasoline production.\textsuperscript{763}

\textit{b) Nuclear power}

Since about 2001 the term “nuclear renaissance” has been used to refer to a possible nuclear power industry revival, driven by rising fossil fuel prices and new concerns about meeting greenhouse gas emission limits.\textsuperscript{764} However, in March 2011 the Fukushima nuclear disaster in Japan and associated shutdowns at other nuclear facilities raised questions among some commentators over the future of nuclear power.\textsuperscript{765,766,767} Platts has reported that “the crisis at Japan's Fukushima nuclear plants has prompted leading energy-consuming countries to review the safety of their existing reactors and cast doubt on the speed and scale of planned expansions around the world”.\textsuperscript{768}

The World Nuclear Association has reported that nuclear electricity generation in 2012 was at its lowest level since 1999.\textsuperscript{769} Several previous international studies and assessments,\textsuperscript{770,771,772} suggested that as part of the portfolio of other low-carbon energy technologies, nuclear power will continue to play a role in reducing greenhouse gas emissions. Historically, nuclear power usage is estimated to have prevented the atmospheric emission of 64 gigatonnes of CO$_2$-equivalent as of 2013.\textsuperscript{773} Public concerns about nuclear power include the fate if spent nuclear fuel, nuclear safety, and security risks which are considered unique among low-carbon energy sources.

\textsuperscript{764} The Nuclear Renaissance (by the World Nuclear Association).
\textsuperscript{765} Nuclear Renaissance Threatened as Japan’s Reactor Struggles Bloomberg, published March 2011, accessed 2011-03-14
\textsuperscript{766} Analysis: Nuclear renaissance could fizzle after Japan quake Reuters, published 2011-03-14, accessed 2011-03-14
\textsuperscript{767} Japan nuclear woes cast shadow over U.S. energy policy Reuters, published 2011-03-13, accessed 2011-03-14
\textsuperscript{768} “News Analysis : Japan crisis puts global nuclear expansion in doubt”. Platts. 21 March 2011.
\textsuperscript{769} WNA (20 June 2013). “Hyper power down in 2012”. World Nuclear News.
\textsuperscript{770} Sims, R.E.H., et al., “Ch. 4: Energy supply”, Executive Summary, in IPCC AR4 WG3 2007
\textsuperscript{771} IAEA 2008, p. 42
A Yale University review published in the Journal of Industrial Ecology analyzing CO₂ life cycle assessment emissions from nuclear power determined that: “The collective LCA literature indicates that life cycle GHG emissions from nuclear power are only a fraction of traditional fossil sources and comparable to renewable technologies.” Uncertainty surrounding the future GHG emissions of nuclear power have to do with the potential for a declining uranium ore grade without a corresponding increase in the efficiency of enrichment methods. In a scenario analysis of future global nuclear development, as it could be effected by a decreasing global uranium market of average ore grade, the analysis determined that depending on conditions, median life cycle nuclear power GHG emissions could be between 9 to 110 g CO₂-eq/kWh by 2050.

During his presidential campaign, Barack Obama stated, “Nuclear power represents more than 70% of our noncarbon generated electricity. It is unlikely that we can meet our aggressive climate goals if we eliminate nuclear power as an option.”

Nuclear power may be uncompetitive compared with fossil fuel energy sources in countries without a carbon tax program, and in comparison to a fossil fuel plant of the same power output, nuclear power plants take a longer amount of time to construct.

Two new, first of their kind, EPR reactors under construction in Finland and France have been delayed and are running over-budget. However learning from experience, two further EPR reactors under construction in China are on, and ahead, of schedule respectively. As of 2013, according to the IAEA and the European Nuclear

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775 http://www.barackobama.com/pdf/factsheet_energy_speech_080308.pdf
776 Ibid.
780 Ipsos, 2011, p. 3.
784 “China Builds Nuclear Reactor for 40% Less Than Cost in France, Areva Says”. Bloomberg
Society, worldwide there were 68 civil nuclear power reactors under construction in 15 countries.\textsuperscript{785} China has 29 of these nuclear power reactors under construction, as of 2013, with plans to build many more,\textsuperscript{786,787} while in the US the licenses of almost half its reactors have been extended to 60 years,\textsuperscript{788} and plans to build another dozen are under serious consideration.\textsuperscript{789} There are also a considerable number of new reactors being built in South Korea, India, and Russia. At least 100 older and smaller reactors will “most probably be closed over the next 10-15 years”.\textsuperscript{790} This is probable only if one does not factor in the ongoing Light Water Reactor Sustainability Program, created to permit the extension of the life span of the USA’s 104 nuclear reactors to 60 years. The licenses of almost half of the USA’s reactors have been extended to 60 years as of 2008.\textsuperscript{791} Two new AP1000 reactors are, as of 2013, being constructed at Vogtle Electric Generating Plant.

Public opinion about nuclear power varies widely between countries.\textsuperscript{792,793} A poll by Gallup International (2011)\textsuperscript{794} assessed public opinion in 47 countries. The poll was conducted following a tsunami and earthquake which caused an accident at the Fukushima nuclear power plant in Japan. 49% stated that they held favourable views about nuclear energy, while 43% held an unfavourable view.\textsuperscript{795} Another global survey by Ipsos (2011)\textsuperscript{796} assessed public opinion in 24 countries. Respondents to this survey showed a clear preference for renewable energy sources over coal and nuclear energy (refer to graph opposite).\textsuperscript{797} Ipsos (2012)\textsuperscript{798} found that solar and wind were viewed by the public as being more environmentally friendly and more viable long-term energy sources relative to nuclear power and natural gas. However, solar and wind were viewed as being

\begin{footnotes}
\footnotemark[]{http://www.euronuclear.org/info/encyclopedia/n/nuclear-power-plant-world-wide.htm}
\footnotemark[96]{Ibid.}
\footnotemark[97]{World Nuclear Association (December 10, 2010). Nuclear Power in China.}
\footnotemark[98]{Ibid.}
\footnotemark[100]{Matthew L. Wald (December 7, 2010). Nuclear ‘Renaissance’ Is Short on Largess The New York Times.}
\footnotemark[101]{Ibid.}
\footnotemark[102]{Michael Dittmar. Taking stock of nuclear renaissance that never was Sydney Morning Herald, August 18, 2010.}
\footnotemark[103]{Ibid.}
\footnotemark[105]{Gallup International 2011, pp. 9–10}
\footnotemark[106]{Ipsos 2011, p. 4}
\footnotemark[107]{Gallup International 2011.}
\footnotemark[108]{Ibid.}
\footnotemark[109]{Ipsos 2011.}
\footnotemark[110]{Ibid.}
\end{footnotes}
less reliable relative to nuclear power and natural gas. In 2012 a poll done in the UK found that 63% of those surveyed support nuclear power, and with opposition to nuclear power at 11%. In Germany, strong anti-nuclear sentiment led to eight of the seventeen operating reactors being permanently shut down following the March 2011 Fukushima nuclear disaster.

Nuclear fusion research, in the form of the International Thermonuclear Experimental Reactor is underway. Fusion powered electricity generation was initially believed to be readily achievable, as fission power had been. However, the extreme requirements for continuous reactions and plasma containment led to projections being extended by several decades. In 2010, more than 60 years after the first attempts, commercial power production was still believed to be unlikely before 2050.

**Carbon intensity of fossil fuels**

Most mitigation proposals imply – rather than directly state – an eventual reduction in global fossil fuel production. Also proposed are direct quotas on global fossil fuel production.

**Fuel switching**

Natural gas emits far fewer greenhouse gases (i.e. CO₂ and Methane - CH₄) than coal when burned at power plants, but evidence has been emerging that this benefit could be completely negated by methane leakage at gas drilling fields and other earlier points in the production lifecycle.

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799 http://www.reuters.com/article/2012/07/02/britain-nuclear-poll-id.AFL6E812E4G20120702. UK popular support for nuclear power rises -poll. 63 pct Britons support nuclear as part of energy mix.
A study performed by the Environmental Protection Agency (EPA) and the Gas Research Institute (GRI) in 1997 sought to discover whether the reduction in carbon dioxide emissions from increased natural gas (predominantly methane) use would be offset by a possible increased level of methane emissions from sources such as leaks and emissions. The study concluded that the reduction in emissions from increased natural gas use outweighs the detrimental effects of increased methane emissions. More recent peer-reviewed studies have challenged the findings of this study, with researchers from the National Oceanic and Atmospheric Administration (NOAA) reconfirming findings of high rates of methane (CH\textsubscript{4}) leakage from natural gas fields.

A 2011 study\textsuperscript{804} by noted climate research scientist, Tom Wigley found that while carbon dioxide (CO\textsubscript{2}) emissions from fossil fuel combustion may be reduced by using natural gas rather than coal to produce energy, it also found that additional methane (CH\textsubscript{4}) from leakage adds to the radiative forcing of the climate system, offsetting the reduction in CO\textsubscript{2} forcing that accompanies the transition from coal to gas. The study looked at methane leakage from coal mining; changes in radioactive forcing due to changes in the emissions of sulfur dioxide and carbonaceous aerosols; and differences in the efficiency of electricity production between coal- and gas-fired power generation. On balance, these factors more than offset the reduction in warming due to reduced CO\textsubscript{2} emissions. When gas replaces coal there is additional warming out to 2,050 with an assumed leakage rate of 0%, and out to 2,140 if the leakage rate is as high as 10%. The overall effects on global-mean temperature over the 21\textsuperscript{st} century, however, are small. Petron et al. (2013)\textsuperscript{805} and Alvarez et al. (2012)\textsuperscript{806} note that estimated that leakage from gas infrastructure is likely to be underestimated. These studies indicate that the exploitation of natural gas as a “cleaner” fuel is questionable.

**Carbon Capture and Storage**

Carbon capture and storage (CCS) is a method to mitigate climate change by capturing carbon dioxide (CO\textsubscript{2}) from large point sources such as power plants and subsequently storing it away safely instead of releasing it into the atmosphere. The

\textsuperscript{805} http://www.epa.gov/ttnchie/conference/ei20/session6/gpetron.pdf
\textsuperscript{806} http://www.pnas.org/content/early/2012/04/02/120247109.abstract
Intergovernmental Panel on Climate Change says CCS could contribute between 10% and 55% of the cumulative worldwide carbon-mitigation effort over the next 90 years. The International Energy Agency says CCS is “the most important single new technology for CO₂ savings” in power generation and industry.⁸⁰⁷ Though it requires up to 40% more energy to run a CCS coal power plant than a regular coal plant, CCS could potentially capture about 90% of all the carbon emitted by the plant.⁸⁰⁸ Norway, which first began storing CO₂, has cut its emissions by almost a million tons a year, or about 3% of the country’s 1990 levels.⁸⁰⁹ As of late 2011, the total CO₂ storage capacity of all 14 projects in operation or under construction is over 33 million tonnes a year. This is broadly equivalent to preventing the emissions from more than six million cars from entering the atmosphere each year.⁸¹⁰

**Energy efficiency and conservation**

Efficient energy use, sometimes simply called “energy efficiency”, is the goal of efforts to reduce the amount of energy required to provide products and services. For example, insulating a home allows a building to use less heating and cooling energy to achieve and maintain a comfortable temperature. Installing fluorescent lights or natural skylights reduces the amount of energy required to attain the same level of illumination compared to using traditional incandescent light bulbs. Compact fluorescent lights use two-thirds less energy and may last 6 to 10 times longer than incandescent lights.⁸¹¹

Energy efficiency has proved to be a cost-effective strategy for building economies without necessarily growing energy consumption. For example, the state of California began implementing energy-efficiency measures in the mid-1970s, including building code and appliance standards with strict efficiency requirements. During the following years, California’s energy consumption has remained approximately flat on a per capita basis while national U.S. consumption doubled. As part of its strategy, California implemented a “loading order” for new energy resources that puts energy

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⁸⁰⁸ Ibid.
⁸⁰⁹ Ibid.
efficiency first, renewable electricity supplies second, and new fossil-fired power plants last.\textsuperscript{812}

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Energy conservation is broader than energy efficiency in that it encompasses using less energy to achieve a lesser energy service, for example through behavioural change, as well as encompassing energy efficiency. Examples of conservation without efficiency improvements would be heating a room less in winter, driving less, or working in a less brightly lit room. As with other definitions, the boundary between efficient energy use and energy conservation can be fuzzy, but both are important in environmental and economic terms. This is especially the case when actions are directed at the saving of fossil fuels.\textsuperscript{817}

\textsuperscript{812}“Loading Order White Paper” (PDF). Retrieved 2010-07-16.
\textsuperscript{814}Ibid.
\textsuperscript{815}Ibid.
Reducing energy use is seen as a key solution to the problem of reducing greenhouse gas emissions. According to the International Energy Agency, improved energy efficiency in buildings, industrial processes and transportation could reduce the world's energy needs in 2050 by one third, and help control global emissions of greenhouse gases.\textsuperscript{818}

Modern energy-efficient technologies, such as plug-in hybrid electric vehicles, and development of new technologies, such as hydrogen cars, may reduce the consumption of petroleum and emissions of carbon dioxide. A shift from air transport and truck transport to electric rail transport would reduce emissions significantly. For electric vehicles, the reduction of carbon emissions will improve further if the way the required electricity is generated is low-carbon power in origin.

Effective urban planning to reduce sprawl would decrease Vehicle Miles Travelled (VMT), lowering emissions from transportation. Increased use of public transport can also reduce greenhouse gas emissions per passenger kilometer.

*Urban planning*

Urban planning also has an effect on energy use. Between 1982 and 1997, the amount of land consumed for urban development in the United States increased by 47 percent while the nation's population grew by only 17 percent. Inefficient land use development practices have increased infrastructure costs as well as the amount of energy needed for transportation, community services, and buildings.

At the same time, a growing number of citizens and government officials have begun advocating a smarter approach to land use planning. These smart growth practices include compact community development, multiple transportation choices, mixed land uses, and practices to conserve green space. These programs offer environmental, economic, and quality-of-life benefits; and they also serve to reduce energy usage and greenhouse gas emissions.

Approaches such as New Urbanism and Transit-oriented development seek to reduce distances travelled, especially by private vehicles, encourage public transit and make walking and cycling more attractive options. This is achieved through "medium-density", mixed-use planning and the concentration of housing within walking distance of town centers and transport nodes.

Smarter growth land use policies have both a direct and indirect effect on energy consuming behavior. For example, transportation energy usage, the number one user of petroleum fuels, could be significantly reduced through more compact and mixed use land development patterns, which in turn could be served by a greater variety of non-automotive based transportation choices.

**Building design**

Emissions from housing are substantial, and government-supported energy efficiency programmes can make a difference.

For institutions of higher learning in the United States, greenhouse gas emissions depend primarily on total area of buildings and secondarily on climate. If climate is not taken into account, annual greenhouse gas emissions due to energy consumed on campuses plus purchased electricity can be estimated with the formula, $E=aS^b$, where $a =0.001621$ metric tonnes of CO$_2$ equivalent/square foot or $0.0241$ metric tonnes of CO$_2$ equivalent/square meter and $b = 1.1354$.

New buildings can be constructed using passive solar building design, low-energy building, or zero-energy building techniques, using renewable heat sources. Existing buildings can be made more efficient through the use of insulation, high-efficiency appliances (particularly hot water heaters and furnaces), double-or triple-glazed gas-filled windows, external window shades, and building orientation and sitting. Renewable heat sources such as shallow geothermal and passive solar energy reduce the amount of

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greenhouse gasses emitted. In addition to designing buildings which are more energy-efficient to heat, it is possible to design buildings that are more energy-efficient to cool by using lighter-coloured, more reflective materials in the development of urban areas (e.g. by painting roofs white) and planting trees. \textsuperscript{823,824} This saves energy because it cools buildings and reduces the urban heat island effect thus reducing the use of air conditioning.

**Sinks and negative emissions**

A carbon sink is a natural or artificial reservoir that accumulates and stores some carbon-containing chemical compound for an indefinite period, such as a growing forest. A negative carbon dioxide emission on the other hand is a permanent removal of carbon dioxide out of the atmosphere, such as directly capturing carbon dioxide in the atmosphere and storing it in geologic formations underground.

The Antarctic Climate and Ecosystems Cooperative Research Centre (ACE-CRC) notes that currently one third of humankind’s current present annual emissions of CO\textsubscript{2} are absorbed by the oceans. The oceans act as a carbon sink, that is, a reservoir that accumulates and stores carbon via its physicochemical and biological processes.\textsuperscript{825} Unfortunately, this, “vital service comes with the cost of ocean acidification”. The ecological effects of ocean acidification are still largely unknown. Research so far has focussed on how acidification lowers pH and the level of carbonate ions available for calcifying organisms to form their shells. These organisms include plankton species that contribute to the foundation of the Southern Ocean food web. However acidification may impact on a broad range of other physiological and ecological processes, such as fish respiration, larval development and changes in the solubility of both nutrients and toxins.\textsuperscript{826} According to the CSIRO\textsuperscript{827} the Southern Ocean is absorbing increasing amounts of carbon dioxide, with potentially significant impacts on marine life.\textsuperscript{828}

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\textsuperscript{826} http://www.acecrc.org.au/Research/Ocean%20Acidification.
Reforestation and avoided deforestation

Almost 20% (8 GtCO₂/year) of total greenhouse-gas emissions were from deforestation in 2007. The Stern Review found that, based on the opportunity costs of the land use that would no longer be available for agriculture if deforestation were avoided, emission savings from avoided deforestation could potentially reduce CO₂ emissions for under $5/tCO₂, possibly as little as $1/tCO₂. Afforestation and reforestation could save at least another 1 GtCO₂/year, at an estimated cost of $5/tCO₂ to $15/tCO₂. The Review determined these figures by assessing 8 countries responsible for 70% of global deforestation emissions. Pristine temperate forest has been shown to store three times more carbon than IPCC estimates took into account, and 60% more carbon than plantation forest. Preventing these forests from being logged would have significant effects. Further significant savings from other non-energy-related-emissions could be gained through cuts to agricultural emissions, fugitive emissions, waste emissions, and emissions from various industrial processes. Using evidence from Mozambique, a typical low income country where agriculture is the dominant provider of income for most citizens, researchers from the overseas Development Institute found a positive correlation between increased production intensification and reduced land conversion, and crop returns, economic growth and food security.

Restoring grasslands store CO₂ from the air into plant material. Grazing livestock, usually not left to wander, would eat the grass and would minimize any grass growth while grass left alone would eventually grow to cover its own growing buds, preventing them from photosynthesizing and killing the plant. A method proposed to restore grasslands uses fences with many small paddocks and moving herds from one paddock to another after a day a two in order to mimick natural grazers and allowing the grass to grow optimally. It is estimated that increasing the carbon content of the soils in the world's 3.5 billion hectares of agricultural grassland by 1% would offset nearly 12 years

827 Commonwealth Scientific and Industrial Research Organisation.
of CO₂ emissions. Allan Savory, as part of holistic management, claims that while large herds are often blamed for desertification, prehistoric lands used to support large or larger herds and areas where herds were removed in the United States are still desertifying.

**Negative carbon dioxide emissions**

Creating negative carbon dioxide emissions literally removes carbon from the atmosphere. Examples are direct air capture, biochar, bio-energy with carbon capture and storage and enhanced weathering technologies. These processes are sometimes considered as variations of sinks or mitigation, and sometimes as geoengineering.

In combination with other mitigation measures, sinks in combination with negative carbon emissions are considered crucial for meeting the 350 ppm target, and even the less conservative 450 ppm target.\(^{831}\)

**Geoengineering**

Geoengineering is seen by some as an alternative to mitigation and adaptation, but by others as an entirely separate response to climate change. In a literature assessment, Barker et al. (2007) described geoengineering as a type of mitigation policy.\(^{832}\) IPCC (2007) concluded that geoengineering options, such as ocean fertilization to remove CO₂ from the atmosphere, remained largely unproven.\(^{833}\) It was judged that reliable cost estimates for geoengineering had not yet been published.

Chapter 28 of the National Academy of Science report *Policy Implications of Greenhouse Warming: Mitigation, Adaptation, and the Science Base* (1992) defined geoengineering as “options that would involve large-scale engineering of our environment in order to combat or counteract the effects of changes in atmospheric

\(^{831}\) “OECD Environmental Outlook to 2050, Climate Change Chapter, pre-release version”. OECD. 2011.


chemistry." They evaluated a range of options to try to give preliminary answers to two questions: can these options work and could they be carried out with a reasonable cost. They also sought to encourage discussion of a third question — what adverse side effects might there be. The following types of option were examined: reforestation, increasing ocean absorption of carbon dioxide (carbon sequestration) and screening out some sunlight. NAS also argued "Engineered countermeasures need to be evaluated but should not be implemented without broad understanding of the direct effects and the potential side effects, the ethical issues, and the risks." In July 2011 a report by the United States Government Accountability Office on geoengineering found that "climate engineering technologies do not now offer a viable response to global climate change."

**Carbon dioxide removal**

Carbon dioxide removal has been proposed as a method of reducing the amount of radiative forcing. A variety of means of artificially capturing and storing carbon, as well as of enhancing natural sequestration processes, are being explored. The main natural process is photosynthesis by plants and single-celled organisms. Artificial processes vary, and concerns have been expressed about the long-term effects of some of these processes.

It is notable that the availability of cheap energy and appropriate sites for geological storage of carbon may make carbon dioxide air capture viable commercially. It is, however, generally expected that carbon dioxide air capture may be uneconomic when compared to carbon capture and storage from major sources – in particular, fossil fuel powered power stations, refineries, etc. In such cases, costs of energy produced will grow significantly. However, captured CO₂ can be used to force more crude oil out of oil fields, as Statoil and Shell have made plans to do. CO₂ can also be used in commercial greenhouses, giving an opportunity to kick-start the technology. Some attempts have

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been made to use algae to capture smokestack emissions, notably the Green Fuel Technologies Corporation, who have now shut down operations.

**Solar radiation management**

The main purpose of solar radiation management seek to reflect sunlight and thus reduce global warming. The ability of stratospheric sulfate aerosols to create a global dimming effect has made them a possible candidate for use in geoengineering projects.

**Societal controls**

Another method being examined is to make carbon a new currency by introducing tradeable "Personal Carbon Credits". The idea being it will encourage and motivate individuals to reduce their 'carbon footprint' by the way they live. Each citizen will receive a free annual quota of carbon that they can use to travel, buy food, and go about their business. It has been suggested that by using this concept it could actually solve two problems; pollution and poverty, old age pensioners will actually be better off because they fly less often, so they can cash in their quota at the end of the year to pay heating bills, etc.

**Population**

Various organizations promote population control as a means for mitigating global warming. Proposed measures include improving access to family planning and reproductive health care and information, reducing natalistic politics, public education about the consequences of continued population growth, and improving access of women to education and economic opportunities.

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841 Facing a changing world: women, population and climate, United Nations Population Fund.
842 Population and Global Warming Factsheet from Sierra Club.
843 Ibid., National Wild Life Federation
844 Population and the Environment Fact Sheet, Population Connection.
845 Population Connection Statement of Policy
Population control efforts are impeded by there being somewhat of a taboo in some countries against considering any such efforts.\textsuperscript{846} Also, various religions discourage or prohibit some or all forms of birth control.

Population size has a different per capita effect on global warming in different countries, since the per capita production of anthropogenic greenhouse gases varies greatly by country.

\textit{Non-CO}_2 \textit{greenhouse gases}

CO\textsubscript{2} is not the only GHG relevant to mitigation, and governments have acted to regulate the emissions of other GHGs emitted by human activities (anthropogenic GHGs). The emissions caps agreed to by most developed countries under the Kyoto Protocol regulate the emissions of almost all the anthropogenic GHGs. These gases are CO\textsubscript{2}, methane (chemical formula: CH\textsubscript{4}), nitrous oxide (N\textsubscript{2}O), the hydrofluorocarbons (abbreviated HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF\textsubscript{6}).

Stabilizing the atmospheric concentrations of the different anthropogenic GHGs requires an understanding of their different physical properties. Stabilization depends both on how quickly GHGs are added to the atmosphere and how fast they are removed. The rate of removal is measured by the atmospheric lifetime of the GHG in question (see the main GHG article for a list). Here, the lifetime is defined as the time required for a given perturbation of the GHG in the atmosphere to be reduced to 37\% of its initial amount.\textsuperscript{847} Methane has a relatively short atmospheric lifetime of about 12 years, while N\textsubscript{2}O's lifetime is about 110 years. For methane, a reduction of about 30\% below current emission levels would lead to stabilization in its atmospheric concentration, while for N\textsubscript{2}O, an emissions reduction of more than 50\% would be required.

Methane is a significantly more powerful greenhouse gas than carbon dioxide. Burning one molecule of methane generates one molecule of carbon dioxide, indicating there may be no net benefit in using gas as a fuel source. Reducing the amount of waste

\textsuperscript{846} To the point of farce: a martian view of hardinian taboo – the silence that surrounds population control. Maurice King, Charles Elliott BMJ
methane produced in the first place and moving away from use of gas as a fuel source will have a greater beneficial impact, as might other approaches to productive use of otherwise-wasted methane. In terms of prevention, vaccines are in the works in Australia to reduce significant global warming contributions from methane released by livestock via flatulence and eructation.

Another physical property of the anthropogenic GHGs relevant to mitigation is the different abilities of the gases to trap heat (in the form of infrared radiation). Some gases are more effective at trapping heat than others, e.g., SF₆ is 22,200 times more effective a GHG than CO₂ on a per-kilogram basis. A measure for this physical property is the Global Warming Potential (GWP), and is used in the Kyoto Protocol.

Although not designed for this purpose, the Montreal Protocol has probably benefitted climate change mitigation efforts. The Montreal Protocol is an international treaty that has successfully reduced emissions of ozone-depleting substances (e.g., CFCs), which are also greenhouse gases.

8.7 Costs and Benefits

Costs

The Stern Review proposes stabilising the concentration of greenhouse-gas emissions in the atmosphere at a maximum of 550ppm CO₂e by 2050. The Review estimates that this would mean cutting total greenhouse-gas emissions to three quarters of 2007 levels. The Review further estimates that the cost of these cuts would be in the range −1.0 to +3.5% of World GDP, (i.e. GWP), with an average estimate of approximately 1%. Stern has since revised his estimate to 2% of GWP. For comparison, the Gross


World Product (GWP) at PPP was estimated at $74.5 trillion in 2010, thus 2% is approximately $1.5 trillion. The Review emphasises that these costs are contingent on steady reductions in the cost of low-carbon technologies. Mitigation costs will also vary according to how and when emissions are cut: early, well-planned action will minimise the costs.\(^\text{852}\)

One way of estimating the cost of reducing emissions is by considering the likely costs of potential technological and output changes. Policy makers can compare the marginal abatement costs of different methods to assess the cost and amount of possible abatement over time. The marginal abatement costs of the various measures will differ by country, by sector, and over time.\(^\text{853}\)

Yohe et al. (2007) assessed the literature on sustainability and climate change.\(^\text{854}\) With high confidence, they suggested that up to the year 2050, an effort to cap greenhouse gas (GHG) emissions at 550 ppm would benefit developing countries significantly. This was judged to be especially the case when combined with enhanced adaptation. By 2100, however, it was still judged likely that there would be significant effects of global warming. This was judged to be the case even with aggressive mitigation and significantly enhanced adaptive capacity.

**Sharing**

One of the aspects of mitigation is how to share the costs and benefits of mitigation policies. There is no scientific consensus over how to share these costs and benefits (Toth et al., 2001).\(^\text{855}\) In terms of the politics of mitigation, the UNFCCC's

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\(^\text{853}\) Ibid.


ultimate objective is to stabilize concentrations of GHG in the atmosphere at a level that would prevent "dangerous" climate change (Rogner et al., 2007). There is, however, no widespread agreement on how to define "dangerous" climate change.

GHG emissions are an important correlate of wealth, at least at present (Banuri et al., 1996, pp. 91–92). Wealth, as measured by per capita income (i.e., income per head of population), varies widely between different countries. Activities of the poor that involve emissions of GHGs are often associated with basic needs, such as heating to stay tolerably warm. In richer countries, emissions tend to be associated with things like cars, central heating, etc. The impacts of cutting emissions could therefore have different impacts on human welfare according to wealth.

**Distributing emissions abatement costs**

There have been different proposals on how to allocate responsibility for cutting emissions (Banuri et al., 1996, pp. 103–105):

- **Egalitarianism**: this system interprets the problem as one where each person has equal rights to a global resource, i.e., polluting the atmosphere.

- **Basic needs and Rawlsian criteria**: this system would have emissions allocated according to basic needs, as defined according to a minimum level of consumption. Consumption above basic needs would require countries to buy more emission rights. This can be related to Rawlsian philosophy. From this viewpoint, developing countries would need to be at least as well off under an emissions control regime as they would be outside the regime.

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858 Ibid.
• **Proportionality and polluter-pays principle**: Proportionality reflects the ancient Aristotelian principle that people should receive in proportion to what they put in, and pay in proportion to the damages they cause. This has a potential relationship with the "polluter-pays principle", which can be interpreted in a number of ways:

  o **Historical responsibilities**: this asserts that allocation of emission rights should be based on patterns of past emissions. Two-thirds of the stock of GHGs in the atmosphere at present is due to the past actions of developed countries (Goldemberg *et al*., 1996, p. 29).\(^{859}\)

  o **Comparable burdens and ability to pay**: with this approach, countries would reduce emissions based on comparable burdens and their ability to take on the costs of reduction. Ways to assess burdens include monetary costs per head of population, as well as other, more complex measures, like the UNDP's Human Development Index.

  o **Willingness to pay**: with this approach, countries take on emission reductions based on their ability to pay along with how much they benefit from reducing their emissions.

**Specific proposals**

• **Ad hoc**: Lashof (1992) and Cline (1992) (referred to by Banuri *et al*., 1996, p. 106),\(^{860}\) for example, suggested that allocations based partly on GNP could be a way of sharing the burdens of emission reductions. This is because GNP and economic activity are partially tied to carbon emissions.

• **Equal per capita entitlements**: this is the most widely cited method of distributing abatement costs, and is derived from egalitarianism (Banuri *et al*., 1996, pp. 106–107).

  This approach can be divided into two categories. In the first category, emissions are


allocated according to national population. In the second category, emissions are allocated in a way that attempts to account for historical (cumulative) emissions.

- **Status quo**: with this approach, historical emissions are ignored, and current emission levels are taken as a status quo right to emit (Banuri *et al.*, 1996, p. 107). An analogy for this approach can be made with fisheries, which is a common, limited resource. The analogy would be with the atmosphere, which can be viewed as an exhaustible natural resource (Goldemberg *et al.*, 1996, p. 27). In International Law, one state recognized the long-established use of another state's use of the fisheries resource. It was also recognized by the state that part of the other state's economy was dependent on that resource.

### 8.8 Governmental and Intergovernmental Action

Many countries, both developing and developed, are aiming to use cleaner technologies (World Bank, 2010, p. 192). Use of these technologies aids mitigation and could result in substantial reductions in CO₂ emissions. Policies include targets for emissions reductions, increased use of renewable energy, and increased energy efficiency. It is often argued that the results of climate change are more damaging in poor nations, where infrastructures are weak and few social services exist. The Commitment to Development Index is one attempt to analyze rich country policies taken to reduce their disproportionate use of the global commons. Countries do well if their greenhouse gas emissions are falling, if their gas taxes are high, if they do not subsidize the fishing industry, if they have a low fossil fuel rate per capita, and if they control imports of illegally cut tropical timber.

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Kyoto Protocol

The main current international agreement on combating climate change is the Kyoto Protocol, which came into force on 16 February 2005. The Kyoto Protocol is an amendment to the United Nations Framework Convention on Climate Change (UNFCCC). Countries that have ratified this protocol have committed to reduce their emissions of carbon dioxide and five other greenhouse gases, or engage in emissions trading if they maintain or increase emissions of these gases.

Temperature targets

Actions to mitigate climate change are sometimes based on the goal of achieving a particular temperature target. One of the targets that has been suggested is to limit the future increase in global mean temperature (global warming) to below 2 °C, relative to the pre-industrial level. The 2 °C target was adopted in 2010 by Parties to the United Nations Framework Convention on Climate Change. Most countries of the world are Parties to the UNFCCC. The target had been adopted in 1996 by the European Union Council.

Temperatures have increased by 0.8 °C compared to the pre-industrial level, and another 0.5–0.7 °C is already committed. The 2 °C rise is typically associated in climate models with a carbon dioxide equivalent concentration of 400–500 ppm by volume; the current (April 2011) level of carbon dioxide alone is 393 ppm by volume, and rising at 1-3 ppm annually. Hence, to avoid a very likely breach of the 2 °C target, CO₂ levels would have to be stabilised very soon; this is generally regarded as unlikely, based on current programs in place to date. The importance of change is illustrated by the fact that

866 UNFCCC (3 May 2012), Essential Background, UNFCCC
867 Oliver Geden (2013), Modifying the 2°C Target, Climate Policy Objectives in the Contested Terrain of Scientific Policy Advice, Political Preferences, and Rising Emissions, SWP Research Paper 5/13
world economic energy efficiency is presently improving at only half the rate of world economic growth.\textsuperscript{869}

\textbf{Encouraging use changes}

\textbf{Emissions tax}

An emissions tax on greenhouse gas emissions requires individual emitters to pay a fee, charge or tax for every ton of greenhouse gas released into the atmosphere.\textsuperscript{870} Most environmentally related taxes with implications for greenhouse gas emissions in OECD countries are levied on energy products and motor vehicles, rather than on CO\textsubscript{2} emissions directly.\textsuperscript{871}

Emission taxes can be both cost-effective and environmentally effective.\textsuperscript{872} Difficulties with emission taxes include their potential unpopularity, and the fact that they cannot guarantee a particular level of emissions reduction.\textsuperscript{873} Emissions or energy taxes also often fall disproportionately on lower income classes. In developing countries, institutions may be insufficiently developed for the collection of emissions fees from a wide variety of sources.\textsuperscript{874}

\textbf{Making the emitting of CO\textsubscript{2} illegal}

Another option is to replace the emission reduction-positive approach proposed with the Kyoto protocol and its successor with an emitted GHG-negative approach.

Scientist Ken Caldeira has proposed making greenhouse gas-emitting devices illegal.\textsuperscript{875}

\textsuperscript{869} United States Department of Energy World Trends
\textsuperscript{871} Ibid.
\textsuperscript{872} Ibid.
\textsuperscript{873} Ibid.
\textsuperscript{874} Ibid.
\textsuperscript{875} The terms “global climate change” and “global warming” are used interchangeably throughout this dissertation. Global climate change is the term most often used by the scientific community, while global warming is the term most often used by the media and the lay public.
**Subsidies**

According to Mark Z. Jacobson, a program of subsidization balanced against expected flood costs could pay for conversion to 100% renewable power by 2030.\footnote{Jacobson, M.Z. (2009) “Review of solutions of global warming, air pollution, and energy security” \textit{Energy and Environmental Science} 2:148-73.} Jacobson, and his colleague Mark Delucchi, suggest that the cost to generate and transmit power in 2020 will be less than 4 cents per kilowatt hour (in 2007 dollars) for wind, about 4 cents for wave and hydroelectric, from 4 to 7 cents for geothermal, and 8 cents per kwh for solar, fossil, and nuclear power.\footnote{Ibid.}

**Carbon emissions trading**

With the creation of a market for trading carbon dioxide emissions within the Kyoto Protocol, it is likely that London financial markets will be the centre for this potentially highly lucrative business; the New York and Chicago Stock markets may have a lower trade volume than expected as long as the US maintains its rejection of the Kyoto.\footnote{How high-pressure politics threatens action on climate. The Observer June 2005.}

However, emissions trading may delay the phase-out of fossil fuels.\footnote{StoryOfStuff.com (2009) “The Story of Cap and Trade”.
}

The European Union Emission Trading Scheme (EU ETS)\footnote{Emission Trading Scheme (EU ETS) from ec.europa.eu} is the largest multinational, greenhouse gas emissions trading scheme in the world. It commenced operation on 1 January 2005, and all 25 member states of the European Unions participate in the scheme which has created a new market in carbon dioxide allowances estimated at 35 billion Euros (US$43 billion) per year. The Chicago Climate Exchange was the first (voluntary) emissions market, and is soon to be followed by Asia's first market (Asia Carbon Exchange). A total of 107 million metric tonnes of carbon dioxide equivalent have been exchanged through projects in 2004, a 38% increase relative to 2003 (78 Mt CO$_2$e).\footnote{State and Trends of the Carbon Market International Emissions Trading Association 2005.}
Twenty three multinational corporations have come together in the G8 Climate Change Roundtable, a business group formed at the January 2005 World Economic Forum. The group includes Ford, Toyota, British Airways and BP. On 9 June 2005 the Group published a statement stating that there was a need to act on climate change and claiming that market-based solutions can help. It called on governments to establish "clear, transparent, and consistent price signals" through "creation of a long-term policy framework" that would include all major producers of greenhouse gases.

The Regional Greenhouse Gas Initiative is a proposed carbon trading scheme being created by nine North-eastern and Mid-Atlantic American states; Connecticut, Delaware, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island and Vermont. The scheme was due to be developed by April 2005 but has not yet been completed.

Implementation

Implementation puts into effect climate change mitigation strategies and targets. These can be targets set by international bodies or voluntary action by individuals or institutions. This is the most important, expensive and least appealing aspect of environmental governance.

Funding

Implementation requires funding sources but is often beset by disputes over who should provide funds and under what conditions. A lack of funding can be a barrier to successful strategies as there are no formal arrangements to finance climate change development and implementation. Funding is often provided by nations, groups of nations and increasingly NGO and private sources. These funds are often channelled through the Global Environmental Facility (GEF). This is an environmental funding mechanism in the World Bank which is designed to deal with global environmental

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882 Statement of G8 Climate Change Roundtable Convened by the World Economic Forum June 2005
884 Ibid.
The GEF was originally designed to tackle four main areas: biological diversity, climate change, international waters and ozone layer depletion, to which land degradation and persistent organic pollutant were added. The GEF funds projects that are agreed to achieve global environmental benefits that are endorsed by governments and screened by one of the GEF’s implementing agencies.

**Occurrence**

Despite a perceived lack of occurrence, evidence of implementation is emerging internationally. Some examples of this are the initiation of NAPA’s and of joint implementation. Many developing nations have made National Adaptation Programs of Action (NAPAs) which are frameworks to prioritize adaptation needs. The implementation of many of these is supported by GEF agencies. Many developed countries are implementing ‘first generation’ institutional adaptation plans particularly at the state and local government scale. There has also been a push towards joint implementation between countries by the UNFCCC as this has been suggested as a cost-effective way for objectives to be achieved.

### 8.9 Role of United States in Mitigation

Efforts to reduce greenhouse gas emissions by the United States include energy policies which encourage efficiency through programs like Energy Star, Commercial Building Integration, and the Industrial Technologies Program. On 12 November 1998, Vice President Al Gore symbolically signed the Kyoto Protocol, but he indicated

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886 Evans, J (forthcoming 2012) Environmental Governance, Routledge, Oxon
891 UNFCCC (2011) Annual report of the Joint Implementation Supervisory Committee to the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol, United Nations Framework Convention on Climate Change.
participation by the developing nations was necessary prior its being submitted for ratification by the United States Senate.\footnote{How the White House Worked to Scuttle California’s Climate Law, San Francisco Chronicle, September 25, 2007}

In 2007, Transportation Secretary Mary Peters, with White House approval, urged governors and dozens of members of the House of Representatives to block California’s first-in-the-nation limits on greenhouse gases from cars and trucks, according to e-mails obtained by Congress.\footnote{Reuters, January 30, 2007, free archived version at http://www.commonderams.org/headlines.htm, last visited Jan. 30, ’13} The U.S. Climate Change Science Program is a group of about twenty federal agencies and US Cabinet Departments, all working together to address global warming.

The Bush administration pressured American scientists to suppress discussion of global warming, according to the testimony of the Union of Concerned Scientists to the Oversight and Government Reform Committee of the U.S. House of Representatives.\footnote{Ibid.}\footnote{Written testimony of Dr. Grifo before the Committee on Oversight and Government Reform of the U.S. House of Representatives on January 30, 2007, archived at http://oversight.house.gov/Documents/20070130113153-55829.pdf.} “High-quality science" was "struggling to get out,” as the Bush administration pressured scientists to tailor their writings on global warming to fit the Bush administration's skepticism, in some cases at the behest of an ex-oil industry lobbyist. “Nearly half of all respondents perceived or personally experienced pressure to eliminate the words 'climate change,' 'global warming' or other similar terms from a variety of communications.” Similarly, according to the testimony of senior officers of the Government Accountability Project, the White House attempted to bury the report “National Assessment of the Potential Consequences of Climate Variability and Change,” produced by U.S. scientists pursuant to U.S. law.\footnote{Written testimony of Rick Piltz before the Committee on Oversight and Government Reform of the U.S. House of Representatives on January 30, 2007, archived at http://oversight.house.gov/Documents/20070130113813-92288.pdf last visited Jan. 30, 13} Some U.S. scientists resigned their jobs rather than give in to White House pressure to underreport global warming.\footnote{Reuters, January 30, 2007, free archived version at http://www.commondereams.org/headlines 07/0130-10.htm, last visited Jan. 30, ’13}
In the absence of substantial federal action, state governments have adopted emissions-control laws such as the Regional Greenhouse Gas Initiative in the Northeast and the Global Warming Solutions Act of 2006 in California.\textsuperscript{899}

\textbf{8.10 Scenario in Developing Countries}

In order to reconcile economic development with mitigating carbon emissions, developing countries need particular support, both financial and technical. One of the means of achieving this is the Kyoto Protocol’s Clean Development Mechanism (CDM). The World Bank’s Prototype Carbon Fund\textsuperscript{900} is a public private partnership that operates within the CDM.

An important point of contention, however, is how overseas development assistance not directly related to climate change mitigation is affected by funds provided to climate change mitigation.\textsuperscript{901} One of the outcomes of the UNFCC Copenhagen Climate Conference was the Copenhagen Accord, in which developed countries promised to provide US $30 million between 2010 and 2012 of new and additional resources.\textsuperscript{902} Yet it remains unclear what exactly the definition of additional is and the European Commission has requested its member states to define what they understand to be additional, and researchers at the Overseas Development Institute have found 4 main understandings:\textsuperscript{903}

1. Climate finance classified as aid, but additional to (over and above) the ‘0.7%’ ODA target;

2. Increase on previous year's Official Development Assistance (ODA) spent on climate change mitigation;

3. Rising ODA levels that include climate change finance but where it is limited to a specified percentage; and

4. Increase in climate finance not connected to ODA.


\textsuperscript{900} Prototype Carbon Fund from the World Bank Carbon Finance Unit.

\textsuperscript{901} Jessica Brown, Neil Bird and Liane Schalatek (2010) Climate finance additionality : emerging definitions and their implications Overseas Development Institute..

\textsuperscript{902} Ibid.

\textsuperscript{903} Ibid.
The main point being that there is a conflict between the OECD states budget deficit cuts, the need to help developing countries adapt to develop sustainably and the need to ensure that funding does not come from cutting aid to other important Millennium Development Goals.\textsuperscript{904}

However, none of these initiatives suggest a quantitative cap on the emissions from developing countries. This is considered as a particularly difficult policy proposal as the economic growth of developing countries are proportionally reflected in the growth of greenhouse emissions. Critics of mitigation often argue that, the developing countries' drive to attain a comparable living standard to the developed countries would doom the attempt at mitigation of global warming. Critics also argue that holding down emissions would shift the human cost of global warming from a general one to one that was borne most heavily by the poorest populations on the planet.

In an attempt to provide more opportunities for developing countries to adapt clean technologies, UNEP and WTO urged the international community to reduce trade barriers and to conclude the Doha trade round "which includes opening trade in environmental goods and services".\textsuperscript{905}

Actions to mitigate climate change are sometimes based on the goal of achieving a particular temperature target. One of the targets that has been suggested is to limit the future increase in global mean temperature (global warming) to below 2 dc, relative to the pre-industrial level.\textsuperscript{906} The 2 dc target was adopted in 2010 by Parties to the United Nations Framework Convention on Climate Change.\textsuperscript{907} Most countries of the world are Parties to the UNFCCC.\textsuperscript{908} The target had been adopted in 1996 by the European Union Council.\textsuperscript{909}

\subsection*{8.11 Non-Governmental Approaches}

\begin{footnotesize}
\textsuperscript{904} Ibid.
\textsuperscript{905} Free trade can help combat global warming, finds UN report UN News Centre, 26 June 2009
\textsuperscript{908} UNFCCC (3 May 2012), Essential Background, UNFCCC
\textsuperscript{909} European Union Council (1996), Community strategy on climate change – Council conclusions, Paragraph 6. In: 1939\textsuperscript{th} council meting environment, document Nr. 8518/96.
\end{footnotesize}
While many of the proposed methods of mitigating global warming require governmental funding, legislation and regulatory action, individuals and businesses can also play a part in the mitigation effort.

**Choices in personal actions and business operations**

Environmental groups encourage individual action against global warming, often aimed at the consumer. Common recommendations include lowering home heating and cooling usage, burning less gasoline, supporting renewable energy sources, buying local products to reduce transportation, turning off unused devices, and various others.

A geophysicist at Utrecht University has urged similar institutions to hold the vanguard in voluntary mitigation, suggesting the use of communications technologies such as videoconferencing to reduce their dependence on long-haul flights.910

**Air travel and shipment**

In 2008, climate scientist Kevin Anderson raised concern about the growing effect of rapidly increasing global air transport on the climate in a paper,911 and a presentation,912 suggesting that reversing this trend is necessary to reduce emissions.

Part of the difficulty is that when aviation emissions are made at high altitude, the climate impacts are much greater than otherwise. Others have been raising the related concerns of the increasing hypermobility of individuals, whether traveling for business or pleasure, involving frequent and often long distance air travel, as well as air shipment of goods.913

**Business opportunities and risks**

On 9 May 2005 Jeff Immelt, the chief executive of General Electric (GE), announced plans to reduce GE’s global warming related emissions by one percent by

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912 Anderson, K (June 17, 2008). “Reframing climate change: from long-term targets to emission pathways”, "(esp. slide 24 onward)"
2012. "GE said that given its projected growth, those emissions would have risen by 40 percent without such action."

On 21 June 2005 a group of leading airlines, airports and aerospace manufacturers pledged to work together to reduce the negative environmental impact of aviation, including limiting the impact of air travel on climate change by improving fuel efficiency and reducing carbon dioxide emissions of new aircraft by fifty percent per seat kilometre by 2020 from 2000 levels. The group aims to develop a common reporting system for carbon dioxide emissions per aircraft by the end of 2005, and pressed for the early inclusion of aviation in the European Union's carbon emission trading scheme.

There are numerous issues which result in a current perceived lack of implementation. It has been suggested that the main barriers to implementation are, Uncertainty, Fragmentation, Institutional void, Short time horizon of policies and politicians and Missing motives and willingness to start adapting. The relationships between many climatic processes can cause large levels of uncertainty as they are not fully understood and can be a barrier to implementation. When information on climate change is held between the large numbers of actors involved it can be highly dispersed, context specific or difficult to access causing fragmentation to be a barrier. Institutional void is the lack of commonly accepted rules and norms for policy processes to take place, calling into question the legitimacy and efficacy of policy processes. The Short time horizon of policies and politicians often means that climate change policies are not implemented in favour of socially favoured societal issues. Statements are often posed to keep the illusion of political action to prevent or postpone decisions being made. Missing motives and willingness to start adapting is a large barrier as it prevents any implementation.

914 “Green Electric? GE unveils eco-strategy publisher=MSNBC”.  
915 “Aviation groups set targets to limit their environmental impact publisher=FT.com”.  