Environment and Development Challenges: The Imperative to Act

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Table of Contents

10. Karl-Henrik Robèrt: The Policy-Science Nexus - An area for Improved Competence in Leadership;
11. Emil Salim: The Search of a Green Equitable Economy;
12. Gordon H. Sato: Seawater based Carbon sequestration- the key to climate change mitigation and adaptation;
13. Susan Solomon: Irreversibility of Climate Changes Due to Anthropogenic Carbon Dioxide Increases;
14. Nick Stern – Climate change, economics and a new energy-industrial revolution;
15. M S Swaminathan: Rio +20 : Green Economy with Inclusive Growth;
16. Robert Watson: Agriculture and Food Security;
17. Robert Watson: Current and Projected State of the Global and Regional Environment: Implications for Environmental, Economic and Social Sustainability;
18. Bunker Roy, Barefoot College: Innovation and Grass Root Action;
19. Saleem Huq, International Institute of Environment and Development: Adapting to Climate Change;
20. Camilla Toulmin, International Institute of Environment and Development: The Importance of Good Governance;
21. Will R. Turner, Russell A. Mittermeier, Julia Marton-Lefèvre, Simon N. Stuart, Jane Smart, Josephine M. Langley, Frank W. Larsen, and Elizabeth R. Selig, Conservation International and IUCN: Biodiversity: Conserving the foundation of sustainable development;
22. Will R. Turner[*], Russell A. Mittermeier, Julia Marton-Lefèvre, Simon N. Stuart, Jane Smart, David G. Hole, Elizabeth R. Selig, Conservation International and IUCN: Climate change: Protecting biodiversity and harnessing nature's climate solutions;
23. Will R. Turner, Russell A. Mittermeier, Rachel Neugarten, Julia Marton-Lefèvre, Simon N. Stuart, Jane Smart, Conservation International and IUCN: Ecosystem services: Accounting for the benefits that nature provides to humanity;

Preface

Part 1 of this paper is a synthesis of the key messages from the individual papers written by the Blue Planet Laureates (attached in Part 2), and discusses the current and projected state of the global and regional environment, and the implications for environmental, social and economic sustainability. It addresses the drivers for change, the implications for inaction, and what is needed to achieve economic development and growth among the poor, coupled with environmental and social sustainability, and the imperative of action now. The paper does not claim to address comprehensively all environment and development issues, but a sub-set that are deemed to be of particular importance.

In 1992, the year of the Rio Earth Summit, the Asahi Glass Foundation established the Blue Planet Prize, an award presented to individuals or organizations worldwide in recognition of outstanding achievements in scientific research and its application that have helped provide solutions to global environmental problems. The Prize is offered in the hopes of encouraging efforts to bring about the healing of the Earth's fragile environment.

The award's name was inspired by the remark "the Earth was blue," uttered by the first human in space, Russian cosmonaut Yuri Gagarin, upon viewing our planet. The Blue Planet Prize was so named in the hopes that our blue planet will be a shared asset capable of sustaining human life far into the future. 2012 is the 20th anniversary of the Blue Planet Prize. The Asahi Glass Foundation wishes to mark this anniversary with a fresh start in its efforts to help build an environmentally friendly society.

Key Messages

- We have a dream – a world without poverty – a world that is equitable – a world that respects human rights – a world with increased and improved ethical behavior regarding poverty and natural resources - a world that is environmentally, socially and economically sustainable, where the challenges such as climate change, loss of biodiversity and social inequity have been successfully addressed. This is an achievable dream, but the current system is deeply flawed and our current pathway will not realise it.
- Population size and growth and related consumption patterns are critical elements in the many environmental degradation and social problems we currently face. The population issue should be urgently addressed by education and empowerment of women, including in the work-force and in rights, ownership and inheritance; health care of children and the elderly; and making modern contraception accessible to all.
- There is an urgent need to break the link between production and consumption on the one hand and environmental destruction on the other. This can allow raising material living standards for a period that would allow us to overcome world poverty. Indefinite material growth on a planet with finite and often fragile natural resources will however, eventually be unsustainable. Unsustainable growth is promoted by environmentally-damaging subsidies in areas such as energy, transportation and agriculture and should be eliminated; external environmental and social costs should be internalized; and the market and non-market values of ecosystem goods and services should be taken into account in decision-making.
- The immense environmental, social and economic risks arising from our current path will be much harder to manage if we are unable to measure key aspects of the problem. For example, governments should recognise the serious limitations of GDP as a measure of economic activity and complement it with measures of the five forms of capital: built, financial, natural, human and social capital, i.e., a measure of wealth that integrates economic, environmental and social dimensions. Green taxes and the elimination of subsidies should ensure that the natural resources needed to protect poor people are available rather than via subsidies that often only benefit those that are better off.
- The present energy system, which is heavily dependent on fossil fuels, underlies many of the problems we face today: exhaustion of easily accessible physical resources, security of access to fuels, and degradation of health and environmental conditions. Universal access to clean energy services is vital for the poor, and a transition to a low carbon economy will require rapid technological evolution in the efficiency of energy use, environmentally sound low-carbon renewable energy sources and carbon capture and storage. The longer we wait to transition to a low carbon economy the more we are locked into a high carbon energy system with consequent environmental damage to ecological and socio-economic systems, including infrastructure.
- Emissions of GHG are one of the greatest threats to our future prosperity. World emissions (flows) are currently around 50 billion tonnes of carbon dioxide-equivalent (CO_2e) per annum and are growing rapidly. As the terrestrial and oceanic ecosystems are unable to absorb all of the world's annual emissions, concentrations (stocks) of GHG emissions in the atmosphere have increased, to over 400ppm of CO_2e today (even after taking the offsetting radiative effects of aerosols into account) and increasing at a rate of around 2.5ppm per year. Thus we have a flow-stock problem. Without strong action to reduce emissions, over the course of this century we would likely add at least 300 ppm CO_2e, taking concentrations to around 750 ppm CO_2e or higher at the end of the century or early in the next. The world's current commitments to reduce emissions are consistent with at least a 3^oC rise (50-50 chance) in temperature: a temperature not seen on the planet for around 3 million years, with serious risks of 5^oC rise: a temperature not seen on the planet for around 30 million years. Given there are some uncertainties present in all steps of the scientific chain (flows to stocks to temperatures to climate change and impacts), this is a problem of risk management and public action on a great scale.

- Biodiversity has essential social, economic, cultural, spiritual and scientific values and its protection is hugely important for human survival. The rapid loss of biodiversity, unprecedented in the last 65 million years, is jeopardising the provision of ecosystem services that underpin human well-being. The Millennium Ecosystem Assessment concluded that 15 of the 24 ecosystem services evaluated were in decline, 4 were improving, and 5 were improving in some regions of the world and in decline in other regions. Measures to conserve biodiversity and make a sustainable society possible need to be greatly enhanced and integrated with social, political and economic concerns. There is a need to value biodiversity and ecosystem services and create markets that can appropriate the value for these services as a basis for a 'green' economy.
- There are serious short-comings in the decision making systems at local, national and global levels on which we rely in government, business and society. The rules and institutions for decision making are influenced by vested interests, with each interest having very different access to how decisions are made. Effective change in governance demands action at many levels to establish transparent means for holding those in power to account. At the local level public hearings and social audits can bring the voices of marginalized groups into the forefront. At a national level, parliamentary and press oversight are key. Globally, we must find better means to agree and implement measures to achieve collective goals. Governance failures also occur because decisions are being made in sectoral compartments, with environmental, social and economic dimensions addressed by separate, competing structures.
- Decision makers should learn from ongoing grass-roots actions and knowledge in areas such as energy, food, water, natural resources, finance and governance. This is key, not the least in rural communities with a view to their management, control and ownership of these resources. There is a need to scale-up the grass roots actions by bringing together a complementary top-down and bottom-up approach to addressing these issues. Global cooperation can be improved by building on on-going regional cooperation to deal with common sustainable development issues.
- Effective training programs should be implemented to multiply the number of competent decision makers in business and government. They must learn how to integrate programmes and policies within sustainability constraints, to understand the business case thereof, and acquire the skills to strategically move towards such sustainability goals.
- All of the problems mentioned above demand we increase investments in education, research and assessments of knowledge. The goal of education for all must be realized. The Future Earth Program that is currently under development by ICSU and ISSC will provide the multi-disciplinary knowledge base (social science, humanities, economics, natural sciences, engineering and technologies) needed for sustainable development. Future Earth needs to be complemented by a web-based multi-disciplinary knowledge assessment system, which critically reviews, integrates and synthesizes new knowledge with previous information in as close to real time as possible to strengthen the science-policy interface.
- If we are to achieve our dream, the time to act is now, given the inertia in the socio-economic system, and that the adverse effects of climate change and loss of biodiversity cannot be reversed for centuries or are irreversible (for example, species loss). We know enough to act, but the current scientific uncertainties, means that we are facing a problem of risk management on an immense scale. Failure to act will impoverish current and future generations.

1.0 The Problem

1.1 Introduction

We have a dream – a world without poverty – a world that is equitable – a world that respects human rights – a world with increased and improved ethical behavior regarding poverty and natural resources - a world that is environmentally, socially and economically sustainable, and where economic growth is accomplished within the constraints of realising social objectives of poverty eradication and social equity and within the constraints of nature's life support carrying capacity, and a world where the challenges such as climate change, loss of biodiversity and social inequity have been successfully addressed. This is an achievable dream, but the system is broken and our current pathway will not realise it.

Unfortunately, humanity's behavior remains utterly inappropriate for dealing with the potentially lethal fallout from a combination of increasingly rapid technological evolution matched with very slow ethical-social evolution. The human ability to do has vastly outstripped the ability to understand. As a result civilization is faced with a perfect storm of problems driven by overpopulation, overconsumption by the rich, the use of environmentally malign technologies, and gross inequalities. They include loss of the biodiversity that runs human life-support systems, climate disruption, global toxification, alteration of critical biogeochemical cycles, increasing probability of vast epidemics, and the specter of a civilization-destroying nuclear war. These biophysical problems are interacting tightly with human governance systems, institutions, and civil societies that are now inadequate to deal with them.

The rapidly deteriorating biophysical situation is more than bad enough, but it is barely recognized by a global society infected by the irrational belief that physical economies can grow forever and disregarding the facts that the rich in developed and developing countries get richer and the poor are left behind. And the perpetual growth myth is enthusiastically embraced by politicians and economists as an excuse to avoid tough decisions facing humanity. This myth promotes the impossible idea that indiscriminate economic growth is the cure for all the world's problems, while it is actually (as currently practiced) the disease that is at the root cause of our unsustainable global practices.

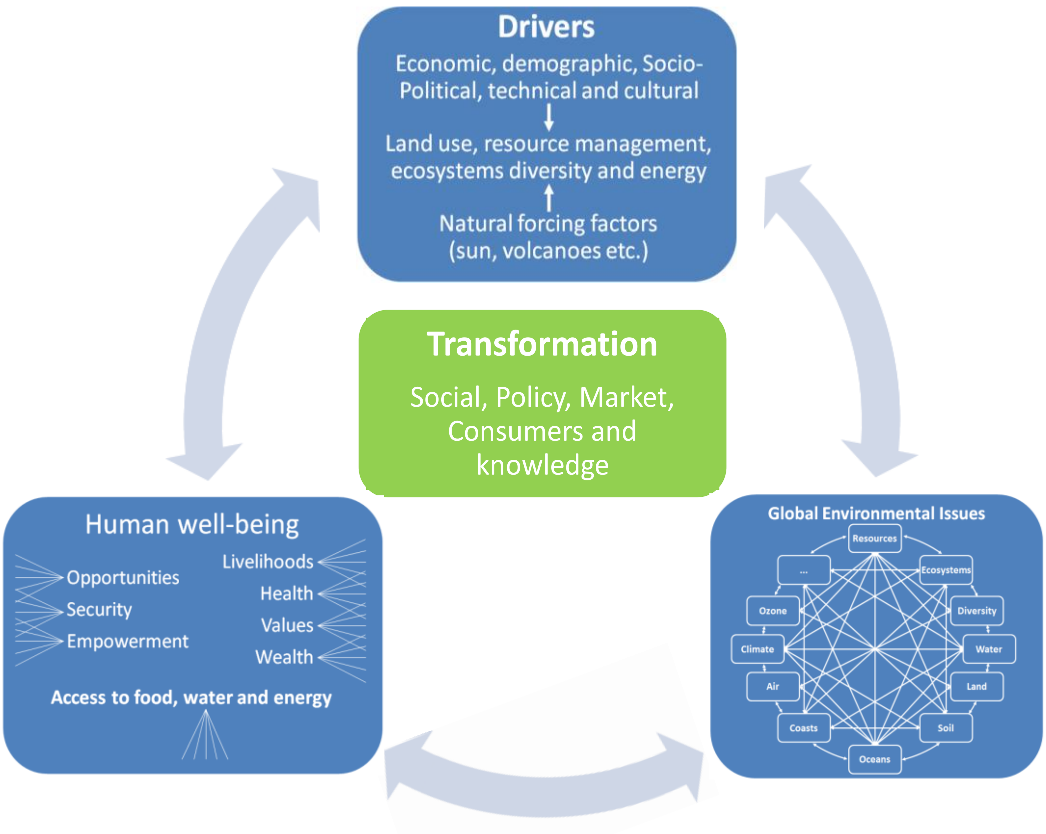
In the face of an absolutely unprecedented emergency, society has no choice but to take dramatic action to avert a collapse of civilization. Either we will change our ways and build an entirely new kind of global society, or they will be changed for us.

In order to realise our dream of a more sustainable world there is a need to understand the triple interdependence of economic, social and environmental factors and integrate them into decision-making in governments and the private sector. One challenge facing many countries is how to manage natural resources in order to contribute to poverty alleviation while maintaining the ecological life support system. In economics the main issue deals with what, where and how much of the natural resources are required to alleviate poverty, while social issues deal with for whom and how much are resources developed, and environmental issues address how natural resources can be managed with minimum negative impact on ecosystems. The interaction between economic, social and environment are enhanced and its coordination made more effective if their respective goals are translated into quantitative terms within a defined time scale. What is needed is to realize economic growth within the constraints of social and environmental sustainability.

1.2 Underlying Drivers of Change

The major indirect drivers of change are primarily demographic, economic, socio-political, technological, cultural and religious (Figure 1). These affect climate change and biodiversity loss somewhat differently, although the number of people and their ability to purchase and consume energy and natural resources are common to both issues. Human-induced climate change is primarily driven by the aggregate consumption and choice of technologies to produce and use energy, which is influenced by energy subsidies and unaccounted costs, hence the current over-reliance on burning fossil fuels. The loss of biodiversity and the degradation of ecosystems and their services are primarily due to the conversion of natural habitats, over-exploitation of resources, air, land and water pollution, introduction of exotic species and human-induced climate change.

FIGURE 1



1.2.1 Demographic:

The global population, which has now passed 7 billion people, and the average per capita energy consumption have both increased sevenfold over the past 150 years, for an overall fifty-fold increase in the emissions of carbon dioxide into the atmosphere. And both are still increasing. As a global average, total fertility rates (TFR) are decreasing, as a result of more females completing primary and secondary education, along with availability of fertility control. But this global average conceals many local difficulties. In some parts of the world fertility remains high and decline in these countries is by no means certain. More than 200 million women in developing countries still have unmet needs for family planning, and increased investment in reproductive health care and family planning programmes along with education programmes will be critical. Although the desire and the need are increasing, it is estimated that funding globally decreased by 30% between 1995 and 2008, not least as a result of legislative pressure from the religious right in the USA and elsewhere.

The ageing of populations in many countries around the world is also a relevant sustainable development issue. The economic, social and environmental implications are as yet unclear but this trend will undoubtedly have an impact. Whether it is positive or negative depends to a large extent on how countries prepare e.g., in evaluating what an ageing population will mean for economic productivity, consumption of goods and services, and in terms of urban planning, financial, health and social care systems etc.

Both culturally and genetically, human beings have always been small-group animals, evolved to deal with at most a few hundred other individuals. Humanity is suddenly, in ecological time, faced with an emergency requiring that it quickly design and implement a governance and economic system that is both more equitable and suitable for a global population of billions of people, and sustainable on a finite planet.

1.2.2 Economics:

Uncontrolled economic growth is unsustainable on a finite planet. Governments should recognise the serious limitations of GDP as a measure of economic growth and complement it with measures of the five forms of capital, built (produced), financial, natural, human and social capital: i.e., a measure of wealth that integrates economic, social and environmental dimensions and is a better method for determining a country's productive potential.

The failure of the economic system to internalize externalities leads to the continuation of environmentally damaging activities. If externalities are uncorrected then markets fail: they generate prices that do not reflect the true cost to society of our economic activities. Emissions of greenhouse gases represent a market failure as the damages caused by emissions from the burning of fossil fuels are not reflected in prices. The price of fossil fuels should reflect the true cost to society, resulting in a more level playing field for environmentally-sound renewable energy technologies and a stimulus to conserve energy. There are a range of economic instruments for correcting the emissions market failure from taxes and emissions trading schemes, to standards and other regulations. All are likely to be needed.

There are a number of other relevant market failures that must also be corrected if we are to manage the risks of climate change: correcting the emissions externality on its own will not be sufficient. For example, there are market failures around research and development (innovation), there are imperfections in capital markets that prevent financing for low-carbon infrastructure, there are network externalities, e.g. around electricity grids and public transport, there are failures in the provision of information, and there are failures in valuing ecosystems and biodiversity. In addition, environmentally-damaging subsidies in areas such as energy, transportation and agriculture, which total about $1 trillion per year, cause further market distortion and are in general leading to environmental degradation and should be eliminated. We must act strongly across all these dimensions.

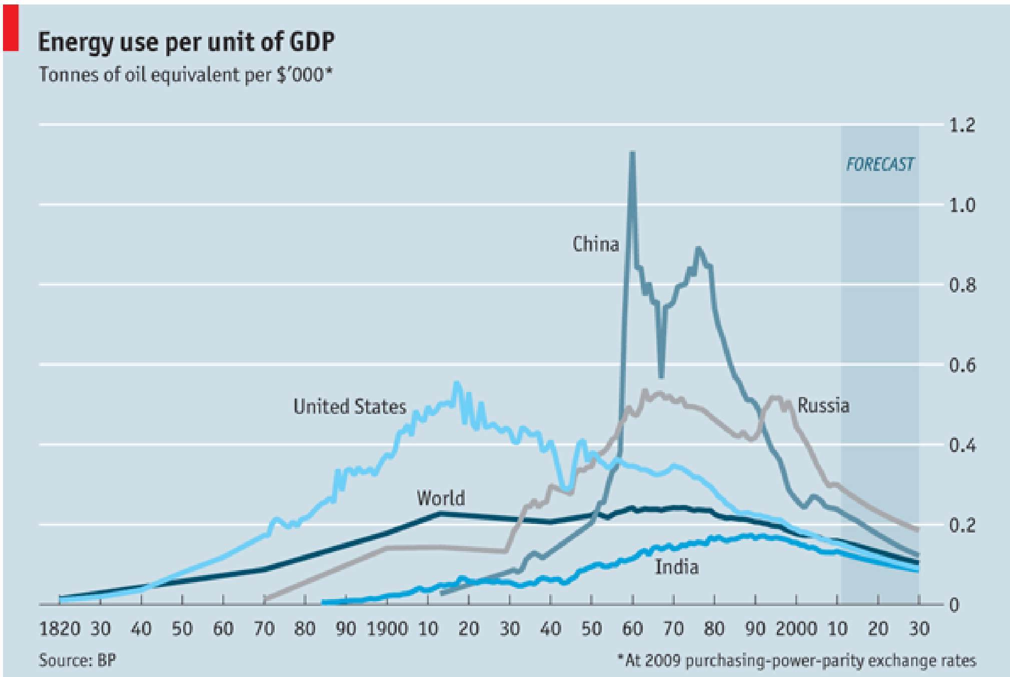
Correcting the biodiversity and ecosystem market failure is particularly urgent and important. The benefits that we derive from the natural world (biodiversity and ecosystem services) and its constituent ecosystems are critically important to human well-being and economic prosperity, but are consistently undervalued in economic analysis and decision making. Contemporary economic and participatory techniques allow us to take into account the monetary and non-monetary values of a wide range of ecosystem services. These techniques need to be adopted in everyday decision-making practice. Failure to include the valuation of non-market values in decision making results in a less efficient resource allocation, with negative consequences for social well-being. Recognising the value of ecosystem services would allow the world to move towards a more sustainable future, in which the benefits of ecosystem services are better realised and more equitably distributed.

Correcting these market failures is also important if developing countries are to continue to advance and improve their living standards. The economic emergence of the BRICS (Brazil, Russia, India, China, and South Africa) over recent decades has been a major success story. Their combined share of world GDP has increased from 23% to 32% over the last six decades. In contrast, over the same period the OECD share of world GDP has declined from 57% to 41%. This rapid economic growth has seen great improvements in health, literacy, and income. However, this rapid growth and development was achieved mostly through the increased use of fossil fuels (which in 2008 represented 90% of their energy consumption) and through the unsustainable exploitation of natural resources including oceans and forests. As a consequence of this energy intensive development, the emergence of the BRICS is associated with a significant increase in their GHG emissions (particularly CO_2), which have increased from 15% to 35% of global emissions over the last 60 years. This energy intensive development path is clearly unsustainable and impacts are already being felt, e.g. rapid increases in desertification in China and collapsing oceanic biodiversity. Failure to shift to a low-carbon development path, which will, among other actions, require correcting market failures and removing harmful energy subsidies, may result in damaging climate change and environmental damage. This would jeopardize future growth and put at risk these great advances in development over the past several decades. There are encouraging signs from BRIC countries. For example, in Brazil deforestation in the Amazon has been cut by around 80% in the last 7 years and in China their 12th 5-year plan (2011 to 2015) indicates a change in strategy to a more sustainable low-carbon economy. But much greater action is urgently needed.

1.2.3 Technology:

The over-reliance on fossil fuel energy (coal, oil and gas) and inefficient end-use technologies has significantly increased the atmospheric concentrations of carbon dioxide and other greenhouse gases. We are currently putting one million years worth of sequestered carbon into the atmosphere each year. Recent efforts to reduce the carbon intensity (CO_2/GDP) were made in a large number of countries, particularly in China and Russia where the carbon content has declined significantly in the last 30 years albeit from very high levels (Figure 2). However the carbon intensities of India, South Africa and Brazil (including deforestation) have not declined significantly in that period. It is therefore clear that all countries have to take serious measures to reduce their CO_2 emissions in the next few decades, recognizing the principle of differentiated responsibilities. OECD countries alone, despite their efforts to reduce their carbon intensity (and carbon emissions), will not be able to avoid the world's growth of carbon emissions.

FIGURE 2



1.2.4 Socio-Political:

There are serious shortcomings in the decision making systems on which we rely in government, business and society. This is true at local, national and global levels. The rules and institutions for decision making are influenced by vested interests, yet each interest has very different access to how decisions are made. Effective change in governance demands action at many levels to establish transparent means for holding those in power to account. Governance failures also occur because decisions are being made in sectoral compartments, with environmental, social and economic dimensions addressed by separate, competing structures.

The shift of many countries, and in particular the United States, towards corporate plutocracies, with wealth (and thus power) transferred in large quantities from the poor and middle-classes to the very rich, is clearly doing enormous environmental damage. The successful campaign of many of the fossil fuel companies to downplay the threat of climate disruption in order to maintain the profits of their industry is a prominent example.

1.2.5 Cultural:

The importance to reducing inequity in order to increase the chances of solving the human predicament is obvious just in the differences in access to food and other resources caused by the giant power gap between the rich and the poor. The lack of funding for issues such as the provision of family planning services and badly-needed agricultural research contrasts sharply with the expenditures by the United States and some other rich nations to try to assure that oil flows to themselves and the rest of the industrialized world are uninterrupted. The central geopolitical role of oil continues unabated despite the dangerous conflicts oil-seeking already has generated and the probable catastrophic consequences its continued burning portends for the climate.

1.3 Current and Projected State of the Global and Regional Environment: Implications of climate change and loss of biodiversity and ecosystem services for Environmental, Economic and Social Sustainability

The Earth's environment is changing on all scales from local to global, in large measure due to human activities. The stratospheric ozone layer has been damaged, the climate is warming at a rate faster than at any time during the last 10,000 years, biodiversity is being lost at an unprecedented rate, fisheries are in decline in most of the world's oceans, air pollution is an increasing problem in and around many major cities, large numbers of people live in water stressed or water scarce areas, and large areas of land are being degraded. Much of this environmental degradation is due to the unsustainable production and use of energy, water and food and other biological resources, and is already undermining efforts to alleviate poverty and stimulate sustainable development, and worse, the future projected changes in the environment are likely to have even more severe consequences.

1.3.1 Climate Change

There is no doubt that the composition of the atmosphere and the Earth's climate have changed since the industrial revolution predominantly due to human activities, and it is inevitable that if those activities do not shift markedly, these changes will continue regionally and globally. The atmospheric concentration of carbon dioxide has increased by over 30% since the pre-industrial era primarily due to the combustion of fossil fuels and deforestation. Global mean surface temperature, which had been relatively stable for over 1000 years, has already increased by about 0.75^{o}C since the pre-industrial era, and an additional 0.5^{o}C to 1.0^{o}C is inevitable due to past emissions. It is projected to increase by an additional 1.2-6.4^{o}C between 2000 and 2100, with land areas warming significantly more than the oceans and Arctic warming more than the tropics.

Precipitation is likely to increase at high and middle latitudes and in the tropics, but likely to decrease in the subtropical continents. At the same time, evaporation increases at all latitudes. Over continents water is likely to be more plentiful in those regions of the world that are already water-rich, increasing the rate of river discharge and the frequency of floods. On the other hand water stress will increase in the sub-tropics and other water-poor regions and seasons that are already relatively dry, increasing the frequency of drought. Therefore, it is quite likely that global warming magnifies the existing contrast between the water-rich and water-poor regions of the world. Observations suggest that the frequencies of both floods and droughts have been increasing as predicted by the climate models.

The Earth's climate is projected to change at a faster rate than during the past century. This will likely adversely affect freshwater, food and fiber, natural ecosystems, coastal systems and low-lying areas, human health and social systems. The impacts of climate change are likely to be extensive and primarily negative, and to cut across many sectors. For example, throughout the world, biodiversity at the genetic, species and landscape level is being lost, and ecosystems and their services are being degraded. Although climate change has been a relatively minor cause of the observed loss of biodiversity and degradation of ecosystems, it is projected to be a major threat in the coming decades.

There is a limit on the amount of fossil fuel carbon that we can pour into the atmosphere as carbon dioxide without guaranteeing climatic consequences for future generations and nature that are tragic and immoral. Given the decadal time scale required to phase out existing fossil fuel energy infrastructure in favor of carbon-neutral and carbon-negative energies, it is clear that we will soon pass the limit on carbon emissions. The inertia of the climate system, which delays full climate response to human-made changes of atmospheric composition, is simultaneously our friend and foe. The delay allows moderate overshoot of the sustainable carbon load but also brings the danger of passing a point of no return that sets in motion a series of catastrophic events. These could include melting of the Greenland and West Antarctic ice sheets leading to a sea level rise of many meters; melting of permafrost leading to significant emissions of methane, a potent greenhouse gas; and disruption of the ocean conveyor belt leading to significant regional climate changes. These impacts would largely be out of human control.

The risks from unmanaged climate change, as well as loss of biodiversity, are immense and action is urgent. Global warming due to human-induced increases in carbon dioxide is essentially irreversible on timescales of at least a thousand years, mainly due to the storage of heat in the ocean. Hence, decisions about anthropogenic carbon dioxide emissions being made today will determine the climate of the coming millennium. Even if emissions were to stop entirely in the 21st century, sea level would continue to rise. The level of carbon dioxide reached in this century will determine whether low lying areas are inundated by ice mass losses from Greenland and Antarctica, even if it occurs slowly over many centuries, because the warming will persist.

The world's current commitments to reduce emissions are consistent with at least a 3 degree C rise (50-50 chance) in temperature. Such a rise has not been seen on the planet for around 3 million years, much longer than *Homo sapiens* have existed. There is even a serious risk of a 5 degrees C increase, to an average temperature not seen on the planet for 30 million years. This is a problem for risk management and public action on a great scale. The fundamental market failure is the unpriced "externality" of the impact of emissions. Other crucial market failures exist including those associated with R&D and learning, networks/grids, information, and further market failures around co-benefits such as valuation of ecosystem services and biodiversity issues. Policy will fail to generate the scale and urgency of the response required if it considers only the emissions market failure.

The global community's attempts to address climate change have been hopelessly inadequate. The costs of climate change, already projected at 5% or more of global GDP, could one day exceed global economic output if action is not taken. The globe requires bold global leadership in governments, politics, business and civil society to implement the solutions, which have been scientifically demonstrated and supported by public awareness, to save humanity from climate change catastrophe.

1.3.2 Biodiversity, Ecosystems and their Services

Biodiversity – the variety of genes, populations, species, communities, ecosystems, and ecological processes that make up life on Earth – underpins ecosystem services, sustains humanity, is foundational to the resilience of life on Earth, and is integral to the fabric of all the world's cultures. Biodiversity provides a variety of ecosystem services that humankind relies on, including: provisioning (e.g. food, freshwater, wood and fiber, and fuel); regulating (e.g. of climate, flood, diseases); cultural (e.g. aesthetic, spiritual, educational, and recreational), and supporting (e.g. nutrient cycling, soil formation, and primary production). These ecosystem services contribute to human wellbeing, including our security, health, social relations, and freedom of choice and action, yet they are fragile and being diminished across the globe.

We are at risk of losing much of biodiversity and the benefits it provides humanity. As humankind's footprint has swelled, unsustainable use of land, ocean, and freshwater resources has produced extraordinary global changes, from increased habitat loss and invasive species to anthropogenic pollution and climate change. Threats to terrestrial and aquatic biodiversity are diverse, persistent, and, in some cases, increasing. The Millennium Ecosystem Assessment concluded that 15 of the 24 ecosystem services evaluated were in decline, 4 were improving, and 5 were improving in some regions of the world and in decline in other regions. Action is critical: without it, current high rates of species loss are projected to continue what is becoming the 6th mass extinction event in Earth's history. It has been estimated that for every 1^{o}C increase in global mean surface temperature, up to 5^{o}C, 10% of species are threatened with extinction. All species count, but some more than others at any given time and place. Losing one key species can have cascading effects on the delivery of ecosystem services.

Ecosystem services are ubiquitous, benefiting people in a variety of socioeconomic conditions, across virtually every economic sector, and over a range of spatial scales, now and in the future. The benefits that ecosystems contribute to human well-being have historically been provided free of charge, and demand for them is increasing. Although the global economic value of ecosystem services may be difficult to measure, it almost certainly rivals or exceeds aggregate global gross domestic product, and ecosystem benefits frequently outweigh costs of their conservation. Yet environmental benefits are seldom considered in conventional economic decision-making, and costs and benefits often don't accrue to the same community, or at the same time or place.

The value of these ecosystem services is being increasingly appreciated by a very large sector of society - extending from local stakeholders, the business community, agriculture, conservation, and governmental policy makers, including development agencies. Their economic value is enormous and a fundamental element of green economic development. However, we are degrading these services and squandering our natural capital for short-term gains. Two thirds of ecosystem services are currently being degraded globally, which will soon amount to an estimated loss of $500 billion annually in benefits. Green economic development will require technology development and technology transfer in order to increase value added from biological resources, especially in developing countries. This would help shift from the resource exploitative method of conventional development to the resource enrichment method of sustainable development.

1.3.3 Food security

Total food production has nearly trebled since 1960, per capita production has increased by 30%, and food prices and the percent of undernourished people have fallen, but the benefits have been uneven and more than one billion people still go to bed hungry each night. Furthermore, intensive and extensive food production has caused significant environmental degradation. Aside from the loss of much biodiversity through outright habitat destruction from land clearing, tillage and irrigation methods can lead to salinisation and erosion of soils; fertilizers, rice production and livestock contribute to greenhouse gas emissions; unwise use of pesticides adds to global toxification; and fertilizer runoff plays havoc with freshwater and nearshore saltwater habitats.

One of the key challenges facing the world is to increase agricultural productivity, while reducing its environmental footprint through sustainable intensification, given that the demand for food will likely double in the next 25 to 50 years, primarily in developing countries. Unfortunately, climate change is projected to significantly decrease agricultural productivity throughout much of the tropics and sub-tropics where hunger and poverty are endemic today.

The Right to Food should become a basic human right; a combination of political will, farmers' skill and scientists' commitment will be needed to achieve this goal.

1.3.4 Water Security

Projections show that by 2025 over half of the world's population will live in places that are subject to severe water stress, and by 2040 demand is projected to exceed supply. This is irrespective of climate change, which will likely exacerbate the situation. Water quality is declining in many parts of the world, and 50 to 60% of wetlands have been lost. Human-induced climate change is projected to decrease water quality and availability in many arid- and semi-arid regions and increase the threats posed by floods and droughts in most parts of the world. This will have far-reaching implications, including for agriculture: 70% of all freshwater withdrawn from rivers and aquifers is currently used for irrigation. Of all irrigation water use 15 to 35% of irrigation water use already exceeds supply and is thus unsustainable.

Freshwater availability is spatially variable and scarce, particularly in many regions of Africa and Asia. Numerous dry regions, including many of the world's major "food bowls," will likely become much drier even under medium levels of climate change. Glacier melt, which provides water for many developing countries, will likely decrease over time and exacerbate problems of water shortage over the long term. Runoff will decrease in many places due to increased evapotranspiration. In contrast, more precipitation is likely to fall in many of the world's wetter regions. Developed regions and countries will also be affected. For example, Southern Europe in summer is likely to be hotter and drier.

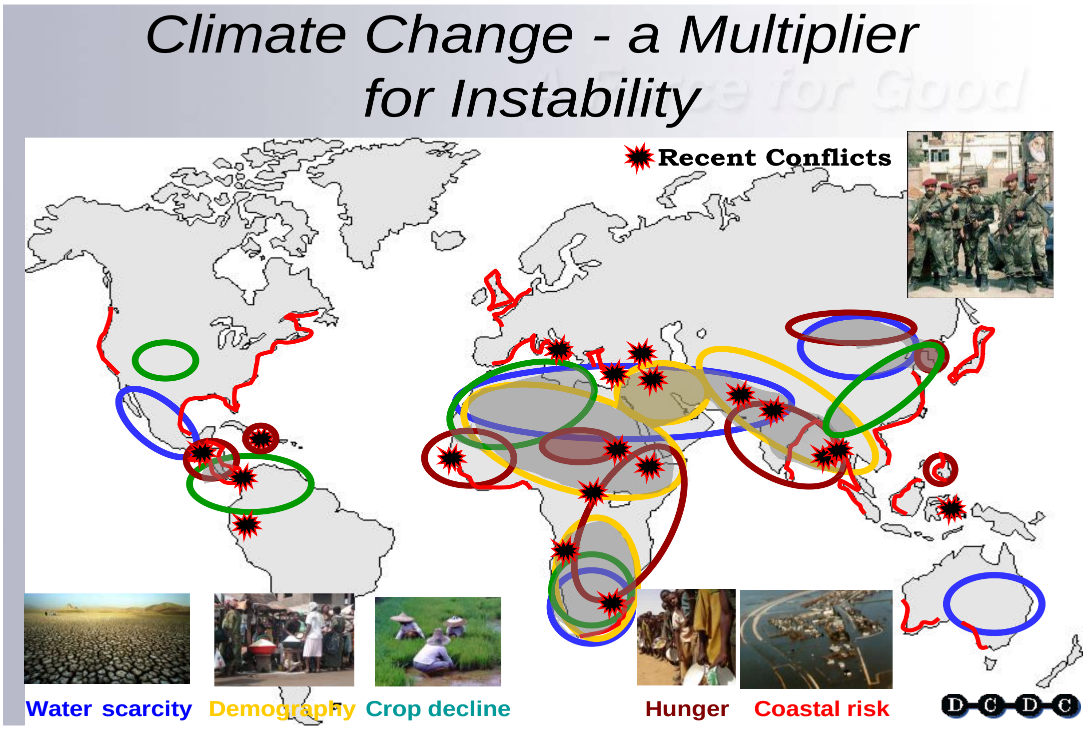
1.3.5 Human Security

Climate change and loss of ecosystem services, coupled with other stresses threatens human security in many parts of the world, potentially increasing the risk of conflict and in-country and out-of-country migration (Figure 3).

Climate change risks the spread of conflict by undermining the essentials of life for many poor people: (i) food shortages could increase where there is hunger and famine today; (ii) water shortages could become severe in areas where there are already water shortages; (iii) natural resources could be depleted with loss of ecological goods and services; (iv) tens of millions of people could be displaced in low-lying deltaic areas and Small Island States; (v) disease could increase; and (vi) severe weather events could be become more frequent or intense.

Many countries in sub-Saharan Africa have millions of people in abject poverty (per-capita incomes of less than $1 per day), lack access to adequate food, clean water and modern energy sources, and are particularly dependent on natural resources for their very existence. In some cases governments lack good governance and are faced with political instability, with some in conflict and others merging from conflict. Hence, climate change, coupled with other stresses, risks local and regional conflict and migration depending on the social, economic and political circumstances.

FIGURE 3



2.0 The Way Forward

2.1 Our Vision

The current global development model is unsustainable. We can no longer assume that our collective actions will not trigger tipping points, as environmental thresholds are breached, risking irreversible damage to both ecosystems and human communities. Therefore, our vision must be to eradicate poverty and reduce inequality, make growth more sustainable and inclusive, production and consumption more sustainable, combating climate change, and respecting other planetary boundaries, i.e., environmental limits. This will require recognizing, understanding and acting on interconnections between the economy, society and the natural environment.

Sustainable development is fundamentally a question of people's opportunities to influence their future, claim their rights and voice their concerns. Effective governance and respect for human rights are key prerequisites for empowering people to make sustainable choices. A serious shift towards sustainable development requires gender equality and an end to persistent discrimination against women. The next major increment of global well-being could well come from the full empowerment of women.

Since most goods and services sold today fail to bear the full environmental and social costs of production and consumption, we need to reach consensus on methodologies to price them properly. Costing environmental externalities could open new opportunities for green growth and green jobs. Another option is a way of doing business as if nature and people were properly valued, without needing to know or signal that value. The options are not mutually exclusive, and since the first may take longer than we have, the second provides a useful safety-net.

2.2 The Need to Act

We must act now to limit climate change and loss of biodiversity, and adapt to the inevitable changes that are already pre-ordained. To transition to a more sustainable future will require simultaneously redesigning the economic system, a technological revolution, and, above all, behavioral change.

To lower the risks of climate change to acceptable levels the world must reduce absolute emissions levels by at least a factor of 2.5 by 2050, which requires a reduction in emission per unit of output by around a factor of 8 if the world economy is 3 times larger in 2050 than today. We clearly need a new industrial revolution. In addition to mitigating climate change we must also be prepared to adapt since substantial changes in climate are unavoidable. Development, mitigation and adaptation are intertwined, e.g. irrigation and in urban design.

Now is the time to accelerate action. The world economy risks a prolonged slow-down as a consequence of the financial and economic crises of the past few years. Low-carbon growth is the only sound basis for a sustainable recovery. High-carbon growth would gravely imperil humanity's future and has no future.

Delay is dangerous and would be a profound mistake. The ratchet effect and technological lock-in increase the risks of dangerous climate change: delay could make stabilization of CO_2 concentrations at acceptable levels very difficult. If we act strongly and science is wrong, then we will still have new technologies, greater efficiency and more forests. If we fail to act and the science is right, then humanity is in deep trouble and it will be very difficult to extricate ourselves. Basic decision theory or common sense points to strong action, particularly since the science is very likely to be right. The Stern Review (2006) sets out the analytical case for early and strong action. The costs of action increase with delay.

The challenge is to generate substantial benefits simultaneously across multiple economic, environmental and social objectives. This synergy is advantageous and important, given that measures which lead to local and national benefits, e.g. improved local and immediate health and environment conditions, and support the local economy may be more easily adopted than measures mainly serving global and long-term goals, such as climate protection. An approach that emphasizes the local benefits of improved end-use efficiency and increased use of renewable energy would also help address global concerns.

In addition to addressing climate change it is of equal importance to reduce the loss of biodiversity and rate of deforestation and forest degradation. It is important that the 2020 Aichi targets to protect and conserve biodiversity are met.

2.3 Technology Options for a Transition to a Low-Carbon Economy

The world's ~78% reliance on fossil fuels (~90% excluding traditionally scavenged biomass) is at the root of many of the world's toughest problems. Economic, security, health, and environmental reasons all compel a vigorous transition beyond fossil fuels.

There are many combinations of energy resources, end-use, and supply technologies that can simultaneously address the multiple sustainability challenges. The different combinations share two common features: (i) radical improvements in energy end-use efficiency, and (ii) significant shifts toward energy supply systems with an emphasis on renewable energies and advanced fossil fuel systems with carbon capture and storage.

The effectiveness of such solutions depends very much on geography and the level of affluence of different countries. Generally, developing countries located in the tropical areas of the world can benefit most from solar energy technologies although cost-effectiveness is also becoming more common at higher latitudes. In industrialized countries with very high energy consumption per capita, energy efficiency measures can be very effective. Yet also in developing countries that have a low energy consumption per capita, economic progress can be achieved by adopting early in their growth trajectory energy efficient technologies rather than adopting obsolete technologies that will generate problems that will have to be fixed later. That is, though rich countries use a great deal of energy and waste much of it, poor people, despite using less energy, waste an even larger fraction of what they do use, and can ill-afford to.

Efficiency improvement is usually the most cost-effective option, and can generate benefits across multiple objectives, including alleviation of poverty, reduction in adverse environmental and health impacts, enhancing energy security, creation of net employment and economic opportunities, and increasing flexibility in selection of energy supply options.

The rate of decreased global energy and carbon intensity of around 3–4%/y needed to stabilize climate has not been achieved to date in most countries and is several times the global average. However, some private sector companies have greatly exceeded decreasing their energy intensity by 3–4%/y. Most global economic growth is in places like China and India that are building their infrastructure now, and can more easily build it right than fix it later. Poor people and countries most need energy efficiency, have the greatest potential for it (they're poor partly *because* their use is so inefficient), and can thereby win the most dramatic development gains. Universal access to electricity as well as cleaner cooking/heating stoves can be achieved by 2030; however, this will require innovative institutions and national enabling mechanisms such as appropriate subsidies and financing. Clean stoves would substantially reduce indoor air pollution, which causes millions of premature deaths per year, and should also lead to climate benefits due to avoidance of products of incomplete combustion.

The share of renewable energy in global primary energy could increase to 30% to 75%, and in some regions (especially but not limited to tropical regions) could exceed 90% by 2050. The main task is to achieve scale-up, reduce costs and integrate renewables in future energy systems. Carefully developed, renewable energies can provide multiple benefits, including employment, energy security, human health, environment, and mitigation of climate change.

Empirical evidence shows that switching from oil and coal to efficient use and diverse, climate-safe renewable supplies will not be costly but profitable. Saving fuel is almost always cheaper than buying fuel, and integrative design can often even make big savings cheaper than small ones (expanding returns). Scores of market failures block efficiency but can be turned into business opportunities. A number of renewable sources, as their costs plummet, now out-compete fossil fuels; most of the rest will very soon. Competitive clean energy has added half the world's new electric capacity since 2008, reaching a record $260 billion of private investment in 2011 and $1 trillion since 2004, and provides one-fifth of the world's electricity from one-fourth of its capacity. Fast-growing distributed resources add valuable resilience, and can bring electricity to the 1.6 billion people who now lack it.

Most components of Carbon Capture and Storage (CCS) systems are technically available, but the main task is to reduce costs and achieve rapid technology improvement. A number of pilot projects around the world will, we hope, soon demonstrate their viability. Many issues of cost and siting remain to be resolved, however. Efficiency and renewable energy technologies will be potent competitors.

These new energy realities should shift the climate conversation from cost, burden, and sacrifice to profits, jobs, and competitive advantage. Even if one rejects climate science, a transition to a low-carbon economy makes sense and makes money for many other compelling reasons. China, for example, is leading the global efficiency and clean-energy revolutions not because of international treaties and Conventions but to speed her own development and to improve public health and national security. Climate leadership is thus shifting from international negotiations to firms, national and subnational governments, and civil society—and from North to South.

2.4 Adapting to Climate Change

Climate change impacts are already occurring and further impacts are inevitable. While some of the impacts in certain parts of the world may have short-term benefits, most of the impacts, particularly in poorer developing countries in Asia, Africa and Latin America will damage poor countries, and poor communities.

All countries, developed as well as developing, will need to adapt to the impacts of climate change over the next few decades. However, there are limits to how effectively countries and communities can adapt. Adaptation becomes more difficult if temperatures rise more than 2 degrees, which is of significant concern since the world is on a pathway to becoming 3 to 5^{o}C warmer than pre-industrial.

The good news is that many countries, starting with the least developed countries, have already begun to take steps to plan adaptation to climate change and to try to mainstream them into development planning, e.g., Bangladesh which has developed a long-term Climate Change Strategy and Action Plan and has already begun to implement it.

All countries, rich as well as poor, will need to develop their own national adaptation plans. While many adaptation actions will be country and location specific, nevertheless there are opportunities for learning lessons across countries, south-south as well as south-north.

The most effective adaptation strategy is mitigation in order to limit the magnitude of climate change, especially given there are significant physical, financial, technological, and behavioral limits to adaptation.

2.5 Approaches to Conserve and Sustainably Use Biodiversity

The loss of biodiversity and degradation of ecosystem services can be stopped and reversed by concerted planning based on adequate data, a well-managed protected areas network, enhancement of the conservation value of agricultural areas supported by the new science of countryside biogeography, use of InVEST and other new tools for mapping and evaluating the services, and transformational shifts in the public and private sector that value the role of natural capital in economic development. The Convention on Biological Diversity (CBD) is the international umbrella for biodiversity, and its 2020 regional and global targets for protecting biodiversity, particularly targets on protected areas and preventing extinctions, are critically important.

To stop biodiversity loss and maintain the services humanity depends on, the value of ecosystem services and natural capital must be incorporated into national accounting and decision-making processes across all sectors of society, access to ecosystem benefits and costs of ecosystem conservation must be shared equitably, and biodiversity and ecosystem services must be seen as the most fundamental component of green economic development. Therefore there is a need to further develop and use tools such as InVEST, as well as the motivation, for nations to establish a national inclusive wealth accounting system, including accounting for ecosystem services imported and exported, which could stimulate further approaches to ecosystem service marketplace development. These tools can assist decision makers on how to balance the tradeoffs in choosing among ecosystem services in land use decisions at multiple spatial scales and include both economic and non-economic valuation. We also need to initiate a campaign to build societal awareness, including building the concept into secondary school education,

Biodiversity and natural ecosystems are foundational to solving the climate crisis, as conservation can slow climate change, increase the adaptive capacity of both people and ecosystems, save lives and sustain livelihoods in myriad ways as Earth's climate changes. Tropical forests, coastal marine habitats, and other ecosystems play major roles in global biogeochemical cycles, and are thus essential to mitigation. They are also widely available, and via protection and restoration can be deployed immediately to reduce atmospheric greenhouse gas concentrations without waiting for new technology. An effective mechanism for Reducing Emissions from Deforestation and forest Degradation (REDD+) must be implemented and financed to support countries in either reducing deforestation or, for some countries, maintaining already low deforestation rates.

A great advantage of ecosystems as a climate solution is that they play many roles at once. Beyond mitigation, the climate adaptation services provided by healthy, diverse ecosystems will become ever more important in the face of climate change since they can help deal with impacts such as changing freshwater flows, rising sea levels, and shifts in disease-carrying organisms and other pests. Mangroves, for example, store carbon, support fisheries, harbor diverse species, and can reduce storm impacts. Ecosystems also support human livelihoods by providing income and food alternatives that will be important where climate change disrupts current sources. Such diversification is helpful for all, but particularly the most vulnerable communities and countries, those with the least capacity to cope with climate change.

Climate mitigation and adaptation, for both nature and people, can no longer be thought of as separate problems, for they will not be solved in isolation. If human adaptation to climate change compromises forests or other ecosystems, this loss will speed climate change. If mitigation of climate change is sought for example via reforestation using single-species stands rather than ensembles of native species this will reduce biodiversity. These losses will increase the need for adaptation even as our capacity to accommodate it diminishes. An integrated approach makes this cycle virtuous: by conserving biodiversity, we decelerate climate change while increasing the adaptive capacity of people and ecosystems alike.

A comprehensive, integrated ecosystem approach is a powerful "tool" for identifying, analyzing and resolving complicated environmental problems, rather than the piecemeal approaches to multifaceted environmental problems that don't work. The inclusiveness of the ecosystem approach gives a powerful frame for identifying new environmental problems or re-shaping existing ones and then tackling their complexity, especially when ecosystem processes are coupled with social and economic considerations.

2.6 Food Security

We theoretically could feed the world today with affordable food while providing a viable income for the farmer, with appropriate distribution of what is harvested. But with business-as-usual this will not occur in the foreseeable future. Most of today's hunger problems can be addressed with the appropriate use of current technologies, particularly appropriate agro-ecological practices (e.g. no/low till, integrated pest management, and integrated natural resource management), but these must be coupled with decreased post-harvest losses, and broad-scale rural development. This will require recognizing the critical role of women and empower them through education, property rights, access to financing, and access to markets using improved roads. There is also a need to negotiate and implement global-scale trade policy reforms to stimulate local production in developing countries.

Emerging issues such as climate change and new plant and animal pests may increase our future need for higher productivity and may require advanced biotechnologies, where the risks and benefits need to be carefully evaluated.

To impart the dimension of economic and ecological sustainability in farming requires promotion of an integrated attention to conservation, cultivation, consumption and commerce. A country can become a knowledge and innovation super-power only if it pays attention to nutrition and education for all children, women and men from conception to cremation.

2.7 Water Security

Addressing the challenges associated with water scarcity will require: (i) river basin management (often transnational); multi-sectoral management (e.g. agriculture, industry, and households); and coupled land-and-water management; (ii) comprehensive stakeholder involvement (e.g. state, private sector, and civil society – especially women) with management action at the lowest level; and (iii) improved allocation and quality enhancement via incentives and economic principles. Cost recovery for water, at only 20%, poses a major problem for water management, hence it is crucial, yet controversial, to get water pricing right as well as reforming IMF and World Bank policies to ensure access to poor people.

2.8 Competence in Leadership

Sustainable development implies a major paradigm shift with unprecedented global implications. It is a trivial statement to say that big and effective international geopolitical decisions cannot be expected to be made from the blue. When major change is needed, new institutional and governmental models, with the competence needed for change at the appropriate scale, will rely on pioneering role models. In paradigm shifts, such demonstrate that the obsolete paradigm is less attractive, and that the new paradigm is not only more attractive but also feasible. Pioneering role models pave the way for the needed large-scale policies. Such role models are already up and running and you will find a number of examples in the paper by Karl-Henrik Robert. What is now needed is to empower and coach the pioneering role models that are already up and running to help them scale up enough to empower the needed policies. In that context, science can do more than to just demonstrate the need for change per se, and/or point at the complexity of the problems we encounter. On top of this, science can demonstrate ways to think and plan to exploit the opportunities that follow from the needed paradigm shift, not the least from the pioneer's own self-beneficial "enlightened" perspective, and to point at more robust ways of managing the complexity.

Policies and plans for sustainable development are currently often attempted through piecemeal ad-hoc driven agendas. To avoid this it is helpful but *not enough* to attempt a "holistic" systems perspective per se, recognizing that as more and more essential aspects from the system get added into models and then are related to all the others, complexity grows and eventually becomes unmanageable. What is needed is holistic thinking and action, not just holistic modeling. Each leader wanting to solve a problem typically is confronted with the fact that he or she has invented another problem elsewhere in the system, e.g., phasing out the irritating gas ammonic and replacing it with CFC's, only to run into an even larger problem risking the whole ozone layer. How can we learn how to *design* the sustainability problems out of the system? Would it be possible to find such principles for re-design, rather than running after reality and "fixing" more and worse problems as they keep surfacing?

We need a robust definition of sustainability that is possible to operationalise for any planning-topic/sector/region/organization. Such principles are frequently employed for all kinds of innovation also outside the domain of sustainable development. This is of particular importance when current trends are part of the problem and the temptation may be large to spend money on "fixing" problems instead of solving them. Such principles can then work as constraints, or to employ a more technical term, "boundary conditions for redesign". For adequate planning in complex systems, such a set of boundary conditions or constraints serve as a "lens" between the system and the strategic policies and plans, and build on an understanding of the basic mechanisms of destruction that underlie all the myriads of problems. Fixing problems one by one won't work. To employ such boundary conditions also for sustainability is mandatory to rationally (i) deal with system boundaries, (ii) deal with multi-dimensional trade-offs, (iii) make sustainable potentials for various technical systems calculable and (iv) cooperate between sectors and disciplines. People from different sectors and disciplines can now bring up problems as well as solutions in relation to the same set of boundary conditions, compare notes, and then find opportunities for synergies and cooperation.

A Framework for Strategic Sustainable Development (FSSD) has been developed during a 20 year peer-reviewed consensus process amongst scientists to empower and train leaders and policy makers to plan this way, and to provide them with the FSSD aligned tools and concepts they may need, e.g. tools for sustainability analyses, setting of goals, product/service development, modeling, simulation, monitoring etc. A growing network of universities across the globe is currently designing a joint research program to further this approach. In this, the FSSD is employed to structure the variety of research projects to help putting them in context of global sustainability and to enable more efficient interdisciplinary cooperation.

A growing number of executives in business and regions/cities across the globe are currently learning how to employ the FSSD, and the above mentioned FSSD aligned tools, in every-day business. They approach the sustainability principles systematically and step-wise while improving on bottom-line finances – "enlightened self-interest". They do not only employ forecasting, i.e. "improving" what they did before. They bridge their gap to sustainability (backcasting from the boundary conditions). And they empower, rather than discourage, proactive policy makers in legislation procedures and at international summits. This feeds into the next section. We need governance models that can empower the pioneering role models. To have shared mental models of boundary conditions for sustainability, will not suffice unless infrastructures for bringing people together to co-create solutions are established.

2.9 The Importance of Good Governance

There are serious shortcomings in the decision-making systems on which we rely in government, business, and society more broadly. Building more effective governance and institutions is central to achieving more sustainable patterns of development – globally, nationally, and locally. Yet the central importance of governance issues is often neglected. This is partly due to the differing definitions used of "governance", and the intangibility of these norms and structures. An analysis of governance needs to ask: How, where and by whom are decisions made? Who gets to write the rules by which decisions are made? What gets decided and who gets what? How are people able to monitor how decisions are made? Governance is more than just a question of the institutional architecture, and how different elements relate to each other. For each of these elements, there are issues of credibility and legitimacy concerning the processes by which rules are made and re-made, interpreted and re-interpreted.

The rules and institutions for decision-making are influenced by vested interests, yet each interest has very different access to the process. For example, lobbyists spend a large amount of time and money trying to influence the way that elected representatives vote in many legislatures. Governance must also be seen in a dynamic fashion, involving an ongoing process of negotiation between different interests, played out in a series of arenas and institutions, nationally and globally. The legitimacy of technical evidence marshaled within such negotiations is critical and often contested, as has been evident in the climate change talks.

Governance involves much more than the ensemble of government frameworks, and includes multiple and overlapping governance systems, with the private sector, civil society, sub-national and local levels all engaged in making decisions in relation to their interests. There is a widespread assumption that governments are the central actors in governance, but a deeper look shows that government is often an instrument both of its own and others' interests, rather than playing the role of objective arbiter. The existence of plural and overlapping systems of governance can lead to contest between competing structures, and institutional "shopping".

Transformation of governance systems needs to accommodate a far broader range of interests (both poor and rich, young and old, those of the future as well as of the present), and ensure access to information as regards the likely impacts of different pathways taken. Subsidiarity, control at the lowest possible level, should be a central principle for sustainable development governance, to assure that decisions over resource allocation and use are made at the correct level by the right authority for the resource in question. Shifting power down to lower levels is vital, to bring in local knowledge, increase accessibility to decision-making, and get a broader range of voices into the debate. Innovations are needed to ensure that the marginalized have a voice that counts, through for example coalition building, organization and mobilization to make those voices heard more effectively. Public hearings, social audits, and participatory budgeting can bring the voices of marginalized groups to the fore.

At national level, effective changes in governance require a transparent means for people to hold those in power to account. Parliamentary and press oversight are key alongside freedom of information, but in many countries, these mechanisms remain weak. The accountability challenge is compounded by alliances cemented between government officials and powerful individuals and corporations. The international nature of much of the corporate sector involved in natural resource use means that even the governments of the countries in which they are headquartered have limited ability to influence their actions and decisions.

Globally, we urgently need better means to agree and implement measures to achieve our collective goals. Given the large numbers of states and their separate jurisdictions, more effective and far-reaching international institutions and rules are necessary, yet nation states are unwilling to submit to collective agreements which constrain their freedom of manoeuvre. Equally, greater control over international financial and corporate actors is needed, to reduce their ability to escape fiscal and other responsibilities through freedom of movement between different jurisdictions. Global efforts to address climate change have resulted in a complex international governance architecture, which has largely replicated geopolitical and global economic power relations among nations. There has been little room in these evolving governance arrangements for the priorities of weaker countries and marginalized people to be heard and addressed. Growing reliance on the G20 as a forum for sorting out global problems runs the risk of disempowering the large number of smaller, less economically prominent nations.

Development policymakers and practitioners are increasingly turning to markets as a tool for addressing sustainability and alleviating poverty. Yet market governance also offers major challenges. Markets and business have the potential to generate new and decent jobs, and use natural assets more sustainably. But market signals and incentives must be set in ways that mobilise businesses and others to support sustainable growth, to create the "missing markets" for environmental goods and services and to ensure more equitable participation. They also need government to assure the institutional and regulatory infrastructure that allows markets to operate effectively, such as support to property rights. Another worry concerns the lack of accountability of market chains and transnational operations, which can evade national laws and regulatory frameworks. A third relates to finding the incentives for environmentally sustainable practices that pertain to the mainstream, as opposed to "niche" sustainable businesses.

Governance failures also occur because decisions are being made in sectoral compartments, with environmental, social and economic dimensions being addressed by separate competing structures. At government level, this means moving sustainable development concerns from beyond Ministries of Environment to focus on Ministries of Agriculture, Energy, Finance, Planning, Health, and Education as entry points. Cross-ministerial buy-in demands that sustainability be led by the head of government, and that environmental and social valuations are brought into decision-making. In business, environment and social issues need to move from corporate social responsibility (CSR) departments into core business operations, with companies required to report in terms of the triple bottom line. In society more generally, groups such as NGOs need to work together to bridge divides, and recognize both common interests, but also trade-offs between different objectives.

In policies for economic development, anti-corruption measures have received increased attention. It is now possible to speak of an international "good governance" regime supported by many national and international aid organizations and their research institutes.

The policy advice from this "regime" has previously to a large extent been geared towards incremental change by finding institutional solutions that will set in motion a "virtuous circle". It is very unlikely that small institutional devices can set in motion a process towards establishing good governance in countries were corruption is systemic. Based on an understanding of corruption as a "social trap", it is argued that what is needed to establish a new equilibrium of social and economic exchange is a "big-bang", i.e. sufficient financial resources needed to establish public institutions – schools, hospitals, police, courts etc – that can be characterized by two qualities: impartiality, competence and ethical behavior.

2.10 Regional Cooperation

Global cooperation along the conventional path of economic development has failed to be sustainable because of prevailing nation's self-centered economic interests in a world without politically viable global institutions for sustainable development. Hence, regional cooperation can play a key role in the transformation to a more sustainable world. Regional cooperation in ASEAN has through the years developed trust within its member-states that has grown into common vision and interests to pursue together regional developmental issues and created common interests to pursue together sustainable development.

It is of the utmost importance to forge an effective link between economic policies with their impacts on poverty eradication and enhancement of life supporting natural ecosystems at the sub-regional level with measurable indicators as the basis for geo-spatial natural resource management planning, superimposed on layers of social poverty location mapping and economic potentials of resource distribution. Indonesia's search for an implementable sustainable development model has demonstrated that macro-economic policies aimed at raising GDP, may well reach their economic objectives, while not necessary achieving the social development objective of reducing poverty or the environmental goal of sustaining natural resources.

Important lessons can be drawn from regional cooperation where efforts to pursue sustainable development on issues of common interest in the ASEAN region, like the Coral Reefs Triangle Cooperation, Forests Cooperation, Joint Efforts in Reducing Emissions of Deforestation and Degradation of Land, etc. These can grow into global building blocks, in spite of the fact that global cooperation is not advancing. It may be possible that similar regional cooperative efforts in East Asia, Africa, Latin America and others can be supported, providing a base that ultimately can lead toward global cooperation on sustainable development.

2.11 Innovation and Grass Root Action

"The Earth has enough for everyman's need but not for one man's greed"- Gandhi.

At the outset it must be said since Rio 1992 community based groups in the poorer most inaccessible rural areas around the world have demonstrated the power of grass roots action to change policy at regional and national levels. In consultation with communities, innovative methods and approaches have been put into practice and indeed been scaled up to cover thousands of individuals living in communities on less than $1/day.

But sadly they have not been collectively visible enough to catch the eyes of the policy makers and the movers and shakers who are formulating crucial global policies without engaging with them at the cutting edge levels.

Without devaluing the tremendous contribution of such grass roots action and while showing them the respect and recognition they deserve there is an urgency now to bring them into mainstream thinking, convey the belief all is not lost, and the planet and humanity can still be saved.

New ideas have been put into practice as a result of collective grass roots action where lessons can be learnt if only we have the humility and ability to listen. The main lessons learnt could be summarized:

- There is no urban solution to the basically rural problem of poverty. The simple solutions of how the rural poor have tackled the issues of climate change and water security (Box 1) already exist but we have yet to put a mechanism in place to learn from them. There are best practices with potential to scale up that needs to be highlighted.

Box 1

Traditional peoples practise of collecting rain water for drinking and irrigation needs to be revived. It has been used tested and proved over hundreds of years. But ever since the academic engineers turned up on the scene this practise has been devalued and the technology solution of exploiting (thus abusing) ground water through powerful polluting drilling rigs installing deep well pumps has seriously depleted groundwater. Thousands of open wells for irrigation and hand pumps for drinking water have gone dry. What needs to be done is to collect water from the roofs of public buildings (schools, dispensaries etc) into underground tanks and this could be used for drinking water and sanitation. Small dams need to be constructed to allow for ground water recharge thus revitalizing the dry open wells and hand pumps, reclaiming collective assets worth millions of dollars. What is needed is simple practical solutions multiplied over a large scale all over the world. This does not need much money but the long term impact will be tremendous.

- The answer to addressing the critical issues of poverty and climate change is not primarily technical but social. The problems of corruption, wastage of funds, poor technology choices and absent transparency or accountability are social problems for which there are innovative solutions emerging from the grass roots. For instance, the idea and practice of Public Hearings and Social Audits came from the people who were fed up with government inaction in India. Now it has been institutionalized and is benefitting nearly 600,000 villages in India.
- Grass roots groups have found the value and relevance of a South-South Partnership where the use and application of traditional knowledge, village skills and practical wisdom between communities across Continents have resulted in low cost community based solutions that have had an incredible impact in improving the quality of life. Migration from rural to the urban areas has decreased. Dependency on urban and technology skills has decreased.
- The empowerment of women is the ultimate sustainable rural solution. By improving their capacity and competence to provide basic services in the rural areas (for instance train them to be solar engineers – Box 2) they could be the new role models that the world is looking for.

Box 2

Without using the written or spoken word and only through sign language 300 illiterate rural grandmothers aged 35 to 50 have been trained as solar engineers. In 6 months they have solar electrified over 15,000 houses reaching more than 100 villages covering the whole continent of Africa (28 countries in 5 years) at a total cost of $ 2.5 million. This is what is spent on 1 Millennium Village in Africa. If a grandmother is selected from any part of the developing world the Government of India pays the air fare and 6 months training costs in India. The funds for the hardware has been provided by GEF Small Grants Programme, UNWOMEN, UNESCO, Skoll Foundation, and individual philanthropists.

- The long term answer is not a centralised system but a demystified and decentralized system where the management, control and ownership of the technology lie in the hands of the communities themselves and are not dependent on professionals, with little relevant experience, from outside the villages.

- Listen and learn how poor communities all over the world see the problems of energy, water, food and livelihoods as inter-dependent and integrated as part of a living eco system and not viewed separately.

2.12 Knowledge Generation and Assessment

Given the importance of credible peer-reviewed knowledge to inform national and international policy formulation and implementation, there is a need to support research and development, and national and international assessments.

National and international, coordinated, and interdisciplinary research is a critical underpinning for informed policy formulation and implementation. There is an urgent need for strengthening the scientific and technological infrastructure in most developing countries. The International Council (ICSU) and International Social Science Council (ISSC) are leading an effort to integrate the World Climate Research Programme (WCRP), the International Geosphere Biosphere Programme (IGPB), the International Human Dimensions Programme (IHDP), Diversitas, and the integrated Earth System Science Programmes (ESSP) into a prgramme called "Future Earth". Future Earth will provide the multi-disciplinary knowledge base (social science, humanities, economics, natural sciences, engineering and technologies) needed for sustainable development.

While there are uncertainties, knowledge gaps and controversies in our evidence base with respect to biodiversity and ecosystem services, we have sufficient information to manage our ecosystems, and the flows of services from them, more sustainably. In order to refine our understanding of the fundamental ecosystem processes underpinning the delivery of ecosystem services we need both to extend our observations and experimental manipulations, and also to improve our models of the key mechanisms. Better holistic ecosystem thinking and models offer a potential way forward for understanding some of the uncertainties and highlighting the sensitivities of multiple interacting drivers on ecosystems, the processes within them, and the flow of services and goods.

Quantifying and understanding the inputs and outputs of individual ecosystems are the functional connection among all ecosystems, constituting the "pulse" of the planet, and when measured quantitatively have major management relevance for understanding and resolving environmental problems. Long-term research and monitoring frequently provides new insights into the understanding of complicated environmental problems. Hence it is important to develop a global and comprehensive experimental and monitoring network that probes the nature of diversity and ecosystem processes and services under present as well as anticipated future environments as well accelerating capacity for future scenario work.

Improved high spatial resolution regional climate projections are needed to improve the quantification of extreme weather events and for assessing the impact of climate change on socio-economic sectors (e.g., food and water), ecological systems and human health.

Governments should support research and testing of new technologies such as low-loss smart electric grids, electrical vehicles interacting with the power grid, energy storage, improved nuclear power plant designs (in the view of some), and carbon capture and storage, as well as education and planning needed to foster and achieve a sustainable human population and lifestyles.

Independent, global expert assessments that encompass risk assessment and risk management, have proven to be a critical component of the science-policy interface. Such assessments must be policy-relevant rather than policy-prescriptive. International assessments such as the Stratospheric Ozone Depletion Assessments, Millennium Ecosystem Assessment (MA), the Intergovernmental Panel on Climate Change (IPCC) and the International Assessment of Agricultural Science and Technology for Development (IAASTD) have all contributed to providing national governments and the international negotiating processes with credible, multi-disciplinary peer-reviewed knowledge, acknowledging what is known, unknown and controversial. The development of the proposed Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) will provide vital information periodic assessments of the knowledge needed for ecosystem service delivery and the status of the delivery system.

However, there is a need for a web-based multi-disciplinary knowledge assessment system, which critically reviews, integrates and synthesizes new knowledge with previous information in as close to real time as possible, to produce the information needed to strengthen the science-policy interface and implement sustainable development nationally, regionally and globally.

The idea of an electronic, web-based system, for the critical, peer-reviewed integrated assessment and synthesis of multi-disciplinary knowledge for creating a world that enhances and sustains human security (economic, social and environmental) in the context of local, regional and global environmental change is gaining general acceptance through a series of formal and informal discussions. Peer reviewed and grey literature on all aspects of poverty alleviation, human well-being, food, water, energy, materials and human security, climate change, biodiversity loss and ecosystem degradation, land and water degradation, and air quality would be up-loaded into a web-based system, critically reviewed and synthesized with previous information.

3.0 Conclusion

Climate change and loss of biodiversity undermines sustainable development. However, there is no dichotomy between economic progress and protecting our environment by limiting climate change and loss of biodiversity. Indeed, the cost to mitigate climate change is less than the cost of inaction if one takes the ethical position of not discounting future generations, and delaying action can significantly increase costs. Efficient resource use (e.g., energy or water) saves money for businesses and households. Valuing and creating markets for ecosystem services can provide new economic opportunities. A green economy will be a source of future employment and innovation. Governments, the private sector, voluntary and civil society at large all have key roles to play in the transition to a low-carbon economy, adaptation to climate change and a more sustainable use of ecosystems.

If we are to achieve our dream, the time to act is now, given the inertia in the socio-economic system, and that the adverse effects of climate change and loss of biodiversity cannot be reversed for centuries or are irreversible (e.g., species loss). Failure to act will impoverish current and future generations.

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Resilient People; Resilient Planet: A future worth choosing
Gro Harlem Brundtland

This is the title chosen by the "High Level Panel on Global Sustainability", appointed by the UN Secretary General in 2010. It was presented to His Excellency Ban Ki Moon in Addis Ababa on January 30 – 2012, by one of its two co-chairs, President Jacob Zuma of South Africa.

In his terms of reference, the Secretary General made the following key observations: "Increasing strains and crises in recent years point to the deterioration of the natural environment. The changing climate is one key manifestation. We are reaching, and increasingly overstepping, planetary boundaries. Efforts to reach the Millennium Development Goals and other social and economic targets are hampered by the inability to agree on decisive and coordinated action in national and multilateral fora. This reveals the weaknesses of our governance structures and our outdated development models. It shows the limits of our current approach, which continues to deal with individual symptoms rather than the causes and their interrelationships. He called for us to "reflect on and formulate a new vision for sustainable growth and prosperity, along with mechanisms for achieving it."

Also co-chaired by President Tarjei Halonen of Finland, we have been 22 members from all continents of the world, including former and present Prime Ministers, Foreign Ministers, Ministers of Development Cooperation, and Environment Ministers, as well as people with experience from the private sector.

The Panel concluded that although the need to integrate the economic, social and environmental dimensions of development to achieve sustainability was clearly defined a quarter of a century ago, it is time to make it happen!

The report "Our Common Future" introduced the concept of sustainable development to the international community as a new paradigm for economic growth, social equality and environmental sustainability. It argued that this could be achieved by an integrated policy framework embracing all of those three pillars.

Since then, the world has gained a deeper understanding of the interconnected challenges we face, and the fact that sustainable development provides the best opportunity for people to choose their future.

The High Level Panel on Global Sustainability argues that by making transparent both the cost of action and inaction, the political process can summon both the arguments and the political will necessary to act for a sustainable future.

The long-term vision of the Panel is therefore 'to eradicate poverty and reduce inequality, make growth inclusive, and production and consumption more sustainable while combating climate change and respecting a range of other planetary boundaries'.

In light of this, the report makes a range of concrete recommendations to take forward its vision for a sustainable planet, a just society, and a growing economy.
Sustainable development is not a destination, but a dynamic process of adaptation, learning, and action. It is about recognizing, understanding and acting on

interconnections – above all those between the economy, society, and the natural environment. The world is still not on this path. Progress has been made, but it has been neither fast nor deep enough, and the need for farther-reaching action is growing ever more urgent.

At the same time, the status quo is increasingly being challenged by powerful drivers of change: the impacts of current production and consumption patterns and resource scarcity, innovation, demographic change, changes in the global economy, green growth, growing inequality, changing political dynamics and urbanization.

But what, then, is to be done if we are to make a real difference for the world's people and the planet? We must grasp the dimensions of the challenge.

We must recognize that the drivers of that challenge include unsustainable lifestyles, production and consumption patterns, and the impact of population growth.

As the global population grows from almost 7 billion to 9 billion by 2040, and with the emergence of 3 billion new middle class consumers over the next 20 years from today, the demand for resources is rising exponentially.

By 2030, the world will need at least 50 per cent more food, 45 per cent more energy and 30 per cent more water -- all at a time when environmental boundaries are throwing up new limits to supply. This is true not least for climate change, which affects all aspects of human and planetary health.

The current global development model is unsustainable. We can no longer assume that our collective actions will not trigger tipping points, as environmental thresholds are breached, risking irreversible damage to both ecosystems and human communities.

At the same time, such thresholds should not be used to impose arbitrary growth ceilings on developing countries seeking to lift their people out of poverty. Indeed, if we fail to resolve the sustainable development dilemma, we run the risk of condemning up to three billion members of our human family to a life of endemic poverty. Neither of these outcomes is acceptable, and we must find a new way forward.

Importantly, sustainable development is *not* a synonym for "environmental protection". Instead, sustainable development is fundamentally about recognising, understanding and acting on *interconnections* – above all those between the economy, society, and the natural environment. Sustainable development is about seeing the whole picture – such as the critical links between food, water, land and energy. And it is about ensuring that our actions today are consistent with where we want to go tomorrow.

It is time that genuine global action is taken to enable people, markets and governments to make sustainable choices. The more influence we have in society the greater is our potential impact on the Planet and our responsibility to behave sustainably – never more so than today, when globalization and the constraints of our natural resources mean that individual choices can have global consequences.

For too many of us, the problem is not unsustainable choices, but a lack of choices in the first place. Real choice is only possible once basic needs and human security are assured. They must include:

- International commitments to eradicate poverty, promote human rights and human security, and advance gender equality
- **education for sustainable development**, including secondary and vocational education, and building of skills to help ensure all of society can contribute to solutions that address today's challenges and capitalize on opportunities
- **employment opportunities** especially for women and youth to drive green and sustainable growth
- enabling consumers to make **sustainable choices** and advance responsible behaviour individually and collectively
- **managing resources** and enabling a 21st Century Green Revolution: agriculture, oceans and coastal systems, energy and technology
- **building resilience** through sound safety nets, disaster risk reduction and adaptation planning.

The opportunities for change are vast. We are not passive, helpless victims of the impersonal, determinist forces of history. The exciting prospect is that we can choose for the future.

The challenges we face are great, but so are the new possibilities that appear when we look at old problems with new and fresh eyes.

For example, unleashing technologies capable of pulling us back from the planetary brink; new markets, new growth and new jobs emanating from game-changing products and services; as well as new approaches to public and private finance that can truly lift people out of the poverty trap.

The truth is that sustainable development is fundamentally a question of people's opportunities to influence their future, claim their rights and voice their concerns.
Democratic governance and full respect for human rights are key prerequisites for empowering people to make sustainable choices.

The Panel calls for a new approach to the political economy of sustainable development to be implemented to address the sustainable development challenge in a fresh and operational way. That sustainable development is right is self-evident. Our challenge is to demonstrate that it is also rational -- and that the cost of inaction far outweighs the cost of action.

The Panel's report makes a range of concrete recommendations to take forward our vision for a sustainable planet, a just society, and a growing economy:

- It is critical that we embrace a new nexus between food, water, and energy rather than treating them in different silos. All three need to be fully integrated, not treated separately if we are to deal with the global food security crisis. It is time to embrace a second green revolution -- an ever-green revolution -- that doubles yields but builds on sustainability principles.
- It is time for bold global efforts, including launching a major global scientific initiative, to strengthen the interface between science and policy. We must define, through science, what scientists refer to as "planetary boundaries",

"environmental thresholds" and "tipping points". Priority should be given to challenges now facing the marine environment and the "blue economy".

- Most goods and services sold today fail to bear the full environmental and social cost of production and consumption. Based on the science, we need to reach consensus, over time, on methodologies to price them properly. Costing environmental externalities could open new opportunities for green growth and green jobs.

Addressing social exclusion and widening social inequity, too, requires measuring them, costing them and taking responsibility for them. The next step is exploring how we can deal with these critical issues to bring about better outcomes for all.

Equity needs to be at the forefront. Developing countries need time, as well as financial and technological support, to transition to sustainable development. All of society must be empowered -- especially women, young people, the unemployed, the most vulnerable and weakest sections of society. Properly reaping the demographic dividend calls on us to include young people in society, in politics, in the labour market and in business development.

Any serious shift towards sustainable development requires gender equality and an end to persistent discrimination against women. The next increment of global growth could well come from the full economic empowerment of women.

The scale of investment, innovation, technological development and employment creation required for sustainable development and poverty eradication is beyond the range of the public sector. The Panel therefore argues for using the power of the economy to forge inclusive and sustainable growth, and create value beyond narrow concepts of wealth. Markets and entrepreneurship will be a prime driver of decision-making and economic change.

So the Panel lays down a challenge for our governments and international institutions: to work better together in solving common problems and advancing shared interests.
Quantum change is possible when willing actors join hands in forward-looking coalitions and take the lead in contributing to sustainable development.

The Panel argues that by embracing a new approach to the political economy of sustainable development, we will bring the sustainable development paradigm from the margins to the mainstream of the global economic debate. Thus, both the cost of action and inaction would become transparent. Only then would the political process be able to summon both the arguments and the political will necessary to act for a sustainable future.

Achieving sustainability requires us to transform the global economy. Tinkering at the edges will not do the job. The current global economic crisis, which has led many to question the performance of existing global economic governance, offers an opportunity for root and branch reform. It gives us a chance to shift decisively towards green growth – not just in the financial system, but in the real economy. Policy action is needed in a number of key areas:

- **incorporating social and environmental costs** in regulating and pricing of goods and services, as well as addressing market failures

- creating an **incentive roadmap** that increasingly values long-term sustainable development criteria in investment and financial transactions
- increasing **finance for sustainable development**, including public and private funding and partnerships to mobilize large volumes of new financing
- changing **how we measure progress** in sustainable development by creating sustainable development indicators

To achieve sustainable development, we clearly need to build a more effective framework of institutions and decision-making processes at the local, national, regional and global level.

We must overcome the legacy of fragmented institutions established around single-issue 'silos'; deficits of both leadership and political space; lack of flexibility in adapting to new kinds of challenges and crises; and a failure to anticipate and plan for both challenges and opportunities – all of which undermine both policy-making and delivery on the ground.

To build better governance, coherence and accountability for sustainable development at the national and global level, these are priority areas:

- **coherence at sub-national, national and international** levels
- a set of **Sustainable Development Goals**
- a periodic **Global Sustainable Development Outlook report** that brings together information and assessments currently dispersed across institutions, and analyzes them in an integrated way

- a new commitment to revitalize and reform the international institutional framework, including considering the creation of a **Global Sustainable Development Council**

The Panel believes it is within the wit and will of our common humanity to choose for the future. We are on the side of hope.
All great achievements in human history began as a vision before becoming a reality. The vision for global sustainability, producing both a resilient people and resilient planet, is no different.

In the year 2030, a child born in 2012 - will turn 18. Will we have done enough in the intervening years to give her the sustainable, fair, and resilient future that all of our children deserve? We all must join forces to give her an answer.

OUR UNRECOGNIZED EMERGENCY
Paul R. Ehrlich and Anne H. Ehrlich

Humanity has stumbled into an unprecedented, yet scarcely recognized global emergency. Suddenly, in ecological time, the global community is faced with a desperate predicament, requiring it to quickly design and implement new global governance and economic systems that are at once more equitable and able to supply prosperity to billions more people. This task is more than daunting, but with the additional requirement that those systems must put humanity on track to become sustainable on a finite planet – in effect, to "resize" the entire human enterprise – the challenge becomes truly monumental.

Yet humanity's corporate behavior remains utterly inappropriate for dealing with a series of increasingly urgent problems such as resource constraints, environmental degradation, and climate disruption. The world community is facing the potentially lethal fallout from a combination of increasingly rapid technological evolution matched with very slow ethical-social evolution. The human ability to *do* has vastly outstripped the ability to *understand.* Both genetically and culturally, people have always been small-group animals; evolution shaped us to deal with at most a few hundred other individuals who were genetically closely related to us. Although, over centuries, we have progressed far enough to manage national entities with shared languages and cultures, contending successfully with a global population of billions has so far largely eluded us. As a result, humanity is faced with a perfect storm of problems driven by overpopulation, overconsumption by the rich, the use of environmentally damaging technologies, and gross inequalities.

Earth is now so overpopulated that it would require on the order of *five* additional planets to support permanently today's global population at the lifestyle of the average citizen of the United States. In fact, even with today's consumption patterns, leaving billions in poverty, Earth is insufficient to sustain the present population over the long term. Nonetheless, as many as two and a half billion more people are scheduled to be added to that population by mid-century.

Powerful technologies that benefit people in many ways have a dark side in that they have facilitated the rapid depletion of humanity's natural capital: deep agricultural soils, fossil groundwater, the biodiversity that runs its life-support systems, and natural sinks to absorb its dangerous effluents. Civilization is disrupting the global climate, spreading toxic chemicals from pole to pole, increasing the chances of vast epidemics, and risking nuclear war over resources, especially water, and nuclear terrorism over political and religious differences. A significant portion of the scientific community fears that at most a decade or two remain to undertake seriously revolutionizing our energy-mobilizing systems, which are still extremely dependent on fossil fuels, and make substantial progress in revising the global agriculture system to meet future needs flexibly. If leading climatologists are correct,[i] it is likely that Earth's temperature and precipitation patterns will be changing continually for a millennium or more. Any chance of maintaining a level of food production adequate to give a decent diet to all of *today's* population would require success in both increasing food production and upgrading water-handling systems as well as improving food distribution. Doing the same for 9.5 billion people by 2050 without further destruction of agriculture's underpinnings may prove impossible in the face of global change.

Today more than a billion people are inadequately nourished, even though enough food is produced to give everyone an adequate diet. The inequity of this is underlined by several hundred million other people being *over*weight in industrialized nations. That alone suggests that improving equity could make a major contribution to resolving the human predicament. For such improvement to occur in a world faced with the possible addition of 2-3 billion more people in the next half-century, equity of access to food supplies must be high on the global agenda – as must be assuring that food production per capita does not continue to fall.[ii]

On the demand side, more gender equity could help limit population growth and thus improve the chances of maintaining an adequate food supply. Total fertility rates are highly correlated with measures of women's rights and opportunities; as women gain autonomy, their fertility tends to fall. A more gender, racially, and economically equitable world could do more than greatly reduce both hunger and total fertility rates. It would also allow for a better educated global population, one where more people could focus on problems beyond those inherent in their personal situations. In turn, one hopes they would be able to deal in a more sensible and cooperative way with both the environmental aspects of the current emergency and with the need for further efforts to reduce inequities.

The importance of reducing inequity to increase the chances of resolving the human predicament is obvious just in the differences in access to food and other resources caused by the giant power gap between the rich and the poor. The lack of funds for such activities as provision of family planning services and badly-needed agricultural research contrasts sharply with the expenditures by the United States and other rich nations to try to assure the flow of oil to themselves. [iii] The central geopolitical role of oil continues unabated despite the dangerous conflicts oil-seeking already has generated and the probable catastrophic consequences its continued burning portend for climate disruption. The international wars associated with oil and other resources will doubtless continue to be accompanied by struggles within developing nations. Indeed, as long ago as 1993, a group of distinguished scientists warned, before Rwanda, Darfur, Somalia, and the Arab Spring, of coming violence "especially in poor countries where shortages of water, forests, and, especially, fertile land, coupled with rapidly expanding populations, already cause great hardship."[iv]

The recent shift of the United States and some other nations towards being a corporate plutocracy, with wealth transferred in large quantities from the poor and middle classes to the very rich, has clearly done enormous environmental damage. The Citizens United decision of the U.S. Supreme Court in 2010 essentially made corporations the legal equivalent of human beings with all their rights and privileges, in effect equating money with speech. It was only the latest step of the rich to increase their own power to buy the votes of lawmakers, control the media, and pursue campaigns designed to put their profits above the social good. [v]

This malign corporate influence is especially visible in the way the corporate-government complex in the United States and elsewhere promotes the impossible idea that economic growth is the cure for all the problems of the world. Actually, it is the disease. As economist Kenneth Boulding famously said in 1966, "Anyone who believes that exponential growth can go on forever in a finite world is either a madman or an economist."[vi]

Sadly, many people fail to realize that the "standard" economists' goal of 3.5 percent perpetual annual economic growth implies an impossibility – an economy more than 30 times as large as today's in a century. Even in the short term, it is a recipe for catastrophe; considering non-linearities, it would likely mean much more than doubling humanity's destructive impact on its life-support systems in just 20 years. It was pointed out long ago that population size and per-capita environmental impact are not independent variables.[vii]

Homo sapiens is a brilliant animal, greatly inclined to pick the low-hanging fruit first, and, especially in industrial societies, its activities are largely far past the point of diminishing marginal returns – one possible sign of impending social collapse.[viii] For instance, the history of oil has been one of exploiting resources that were ever more remote and difficult and dangerous to extract, a history that has included rising prices on the world market. One of the biggest recent environmental "events" was the Deepwater Horizon oil disaster that began in late April 2010. News coverage eventually explained that the wellhead was under a mile of ocean, the well itself was planned to extend almost another three miles beneath the sea floor, that the hi-tech devices protecting against disaster were faulty, and that the behavior of the main corporations involved was criminal. But little mention was ever made of the overall resource situation that needing to drill so deep indicated. The first commercial oil well was drilled in 1859 in Pennsylvania, and penetrated a mere 70 feet. That certainly suggests diminishing marginal returns.

Moreover, in the United States the "cost" of oil is not calculated to include the roughly 35 percent of the military budget dedicated to such things as invading other nations to get access to or control of oil fields. Nor does it include most of the gigantic external costs involved in the use of the oil, especially those associated with climate disruption – a risk that major oil interests have been prominent in trying to discredit.[ix]

One prominent analyst claims that international agreements for dealing with the latter costs are basically hopeless, and that instead carbon taxes within nations hold out the best hope of avoiding disaster.[x] But in the United States, such a course seems unlikely. The odds are low because of the successful corporate campaign preventing the United States government from taking any action on climate disruption.[xi] Given the important world position of the United States, that successful campaign may have been the most serious policy blow against global sustainability so far. It likely would have been impossible without the growing inequity in wealth and power within the nation, allowing money from corporations to block the necessary regulatory policies.

Diminishing returns in the global system of human support are now ubiquitous; the story of oil is being repeated for coal and natural gas, where the costs and environmental penalties of extraction are rising in the long term. Diminishing returns can also be seen in the fading ability of antibiotics to combat diseases and of pesticides to protect crops against insects and other pests. And efforts to develop new land for agriculture have long since been superseded by intensification of use of existing land, a process that itself is facing limits. Consequently, each one of the some 2.5 billion people expected to be added to the world population in the next 40 years will, on average, need to be fed from crops grown on more marginal land, supplied with water requiring more energy to transport and/or purify, and supported with materials won from ever-poorer ores.

It has become increasingly obvious that conventional economic/cultural systems, be they capitalist, socialist, or communist, simply have proven inadequate. They have not provided needed development among the poor. They have not encouraged the development of societies that understand the environmental constraints imposed by the biospheric complex adaptive system within which the human socio-economic complex adaptive system must function. As a result, the world community has not produced the sustainable redistribution and shrinkage of populations and material wealth that will be essential to create an environmentally sound and equitable global society.

Homo sapiens' negative impact on the planet's life-support systems can be approximated by the I = PAT equation, in which the size of the *population* (P) is multiplied by the average *affluence*, or consumption, per capita (A), and that in turn is multiplied by a measure of the impacts of *technology* and socio-political-economic arrangements (T) employed to supply the consumption. The product is *impact* (I), a rough index of how much humanity is assaulting its environment, threatening human health, and degrading the natural ecosystems whose services it depends upon. The factors in the equation, of course, are not independent; but that complication does not seriously lessen I = PAT's value as an heuristic tool.

The technological/economic/political dimensions of our predicament – such as the need to deploy alternatives to fossil fuel energy quickly – are frequently discussed in the academic community, but plainly are not well understood by decision makers in business, government, or the media. To the degree that environmental problems are recognized in those communities, it is widely believed that they can be solved by minor technological "fixes." As ecologist William Rees put it, "most sustainability campaigns, corporate responses, and government policies emphasize 'simple and painless' (read 'marginal and ineffective') actions that require only modest adjustments to personal lifestyles and none at all to the economic growth ethic or other key beliefs, values, and assumptions of technoindustrial society"[xii] That too many people view sustainability as involving only slight deviations from business as usual is suggested by the frequent use of the oxymoronic phrase "sustainable growth."

The complexity involved in revolutions such as converting from fossil fuels to wind, solar, and geothermal energy in industrial societies appears to be largely underappreciated by political leaders, leading to a lack of urgency or progress. Ironically, initiating the revolution in the poorest developing countries may be far easier than many leaders believe, stuck as they are in thinking that such countries must first create a 20th century energy infrastructure. But the wildfire spread of cell phones in Africa and India in the last decade shows another path, as the cell phones are now becoming the infrastructure and credit mechanism for the spread of small-scale solar power in rural villages far from any grid.

Any visitor to the climate negotiations in Cancun or Durban quickly became aware that it is the developing countries, not least the poorest, who most feel urgency about addressing climate disruption. They are keenly aware of their own vulnerability. And it is the richest and most powerful nations, the principal emitters of greenhouse gases, that are laggards in implementing their energy revolutions. The International Energy Agency (IEA) sent a message relevant to this to the participants at the 2011 climate negotiations in Durban by concluding that the world is "locking itself into an insecure, inefficient and high-carbon energy system. If bold policy actions are not put in place over the next several years, it will become increasingly difficult and costly to meet the goal set at last year's talks of limiting a global temperature increase to 2 degrees C."[xiii] They might have added to "costly" "and likely impossible."

Silence on the overconsumption (Affluence) factor in the I = PAT equation is readily explained. Consumption is still viewed as an unalloyed good by many economists, along with business leaders and politicians, who tend to see increasing consumption, even among the super-rich, as a cure-all for economic ills. Hardly a day goes by without the spectacle of some economic "expert" in the U.S. mass media discussing the degree of success in getting the economy growing. But most people do not realize that expanding consumption among the already rich is a recipe for drastic environmental deterioration. Yet it is a sad fact that giving today's 7 billion people the consumption patterns of western Europe is a biophysical impossibility – to say nothing of supplying such a lifestyle to more than 9 billion people by the middle of this century.

Indeed, the interactions among factors in our predicament are daunting. The need to expand agricultural production some 70 to 100% by 2050 to meet expected demand from a growing population, an increasing desire in emerging economies for meat-rich diets, and demand for biofuels will require further intensification of agricultural production and, among other things, increasing the oil subsidy to agriculture. If there is no significant progress in curbing greenhouse gas emissions, that in turn will raise oil prices and enlarge flows of greenhouse gases into the atmosphere on top of the increases traceable to the other activities of an additional 2.5 billion people. And that, of course, will almost certainly cause further disruption of the climate, altering precipitation patterns further, and likely make more problematic supplying the needed water to farms. Furthermore, the difficulties of increasing yields and total food production will be exacerbated by other likely ecological effects of moving to more intensive and extensive agriculture, such as loss of biodiversity, erosion of soils, and further toxification of both land and oceans. Even the normally conservative UN realizes that the situation is extremely serious,[xiv] and that "environmental damage will undermine food productivity growth." And the threat of famines is not, of course, the only negative effect of overpopulation – density-dependent factors range from the increased chances of epidemics and resource wars to higher death rates from violent climatic events.[xv]

The rapidly deteriorating biophysical situation we face today is more than bad enough, but it is still scarcely recognized by a global society afflicted by gross inequality and infected by the irrational belief that physical economies can grow forever – a myth enthusiastically embraced by politicians and economists as an excuse to avoid the tough decisions facing civilization.[xvi] Indeed, those who recognize the inequity portion of the human predicament usually call for more growth as a solution, unaware that growth demonstrably cannot do the job. Of course, focusing whatever physical growth we can afford on relieving the plight of the human beings most desperately in need must be one of the main tasks of a future social movement. But that is not enough unless we make certain that such growth is biophysically safe, in part by compensating for it by sustainable material shrinkage among the rich. There is no escaping the need for redistribution of access to resources; meeting the extraordinary global emergency requires it. The most immediate threats are to poor people and poor nations, but in the end – and possibly in the beginning – the rich will fall further.

Against a grim background of corruption and ignorance, can creating a just society, in which caring for each other and our life-support systems moves to the top of the political agenda? Given that the UN Rio+20 conference will be attended by representatives of present governments, whose leaders are apt to be happy with the status quo, it seems unlikely to us that it will stimulate the urgent action that is needed. The human future may instead depend on the success of social movements such as Occupy Wall Street, and its surrogates around the world, and the Millennium Alliance for Humanity and the Biosphere (MAHB -- http://mahb.stanford.edu/). Both require us to step back and ask “what are people for?” and consider whether the society we’ve built is indeed the one we want. In the face of an absolutely unprecedented emergency, the world community has no choice but to take dramatic action to avert a collapse of civilization. Either humanity will change its ways, or they will be changed for us.

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The emergence of the BRICS and climate change
José Goldemberg

One of the outstanding characteristic of the world's economic development of the last 60 years is the decline of the share of GDP (gross domestic product) of the OECD countries and the emergence of non-OECD countries and particularly the BRICS* as indicated in Table I.

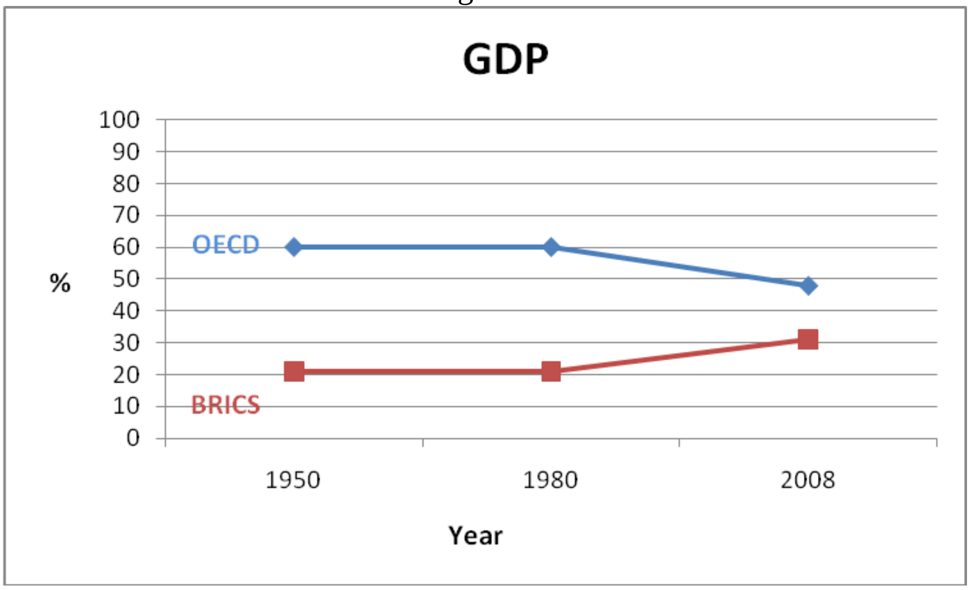
Table I
Fraction of GDP (%)

	1950	1980	2008
OECD	57	53	41
BRICS	21	21	31.5

Source: BRICS Policy Center[1]

The GDP share of OECD countries declined from 57 to 41% between 1950 and 2008 while the share of the BRICS increased almost from 21 to 31.5%.

Figure 1



The BRICS represented half of the GDP of all non-OECD countries. China accounted in 2008 for 60% of the GDP of the BRICS. (Appendix I)

According to Gilpin[2] the emergence of the BRICS in the world economy is due to two conflicting pressures: on the one hand the development of industry and other economic activities in the advanced industrialized countries (the "center") and on the other hand the diffusion of such activities and wealth from the "center" to the "periphery" (developing countries).

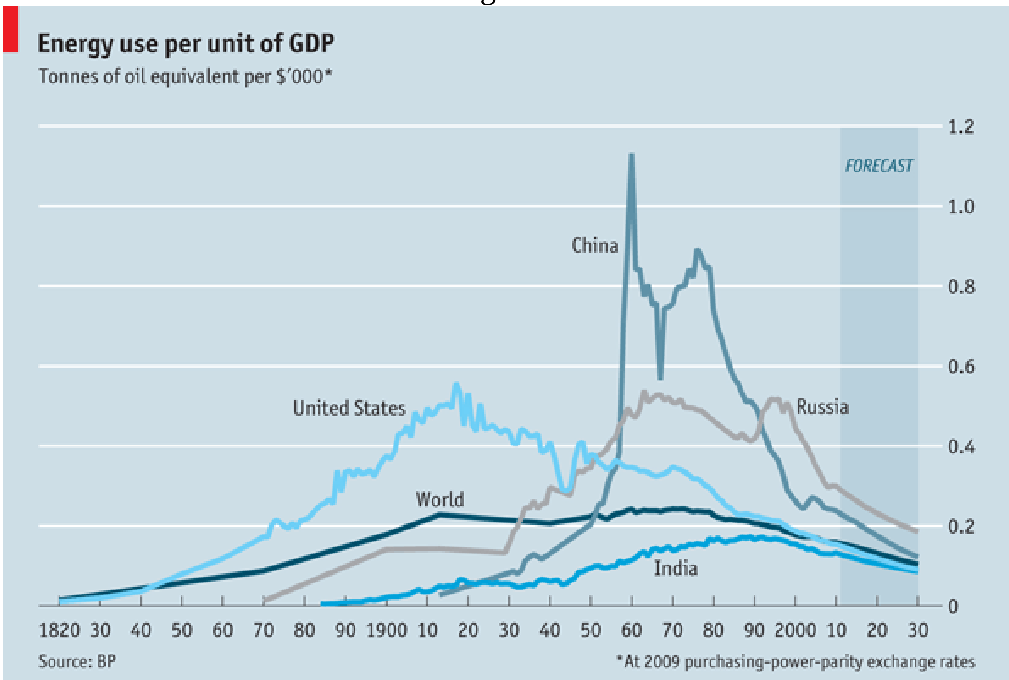
The initial advantage of the "center" over the "periphery" is the technical and organizational superiority. In the short term, innovation and increased efficiency, give to

* BRICS are Brazil, Russia, India, China and South Africa

the “center” greater profits and a faster growth. In the long term however the rate of growth of the “center” tends to decelerate and new economic activities migrate to the “periphery” which benefit, in the words of Gerschenkron[3], from the “advantages of the latecomers”. These countries initiate their industrialization process benefiting from the lessons learned from the advanced countries when they industrialized in the past and can therefore “leapfrog” over some stages of development[4].

Such behavior is illustrated in Figure 2 by the evolution of the energy intensity (E/GDP) of the economy which measures the amount of energy required to generate one unit of GDP measured in tons of oil equivalent per thousand dollars.

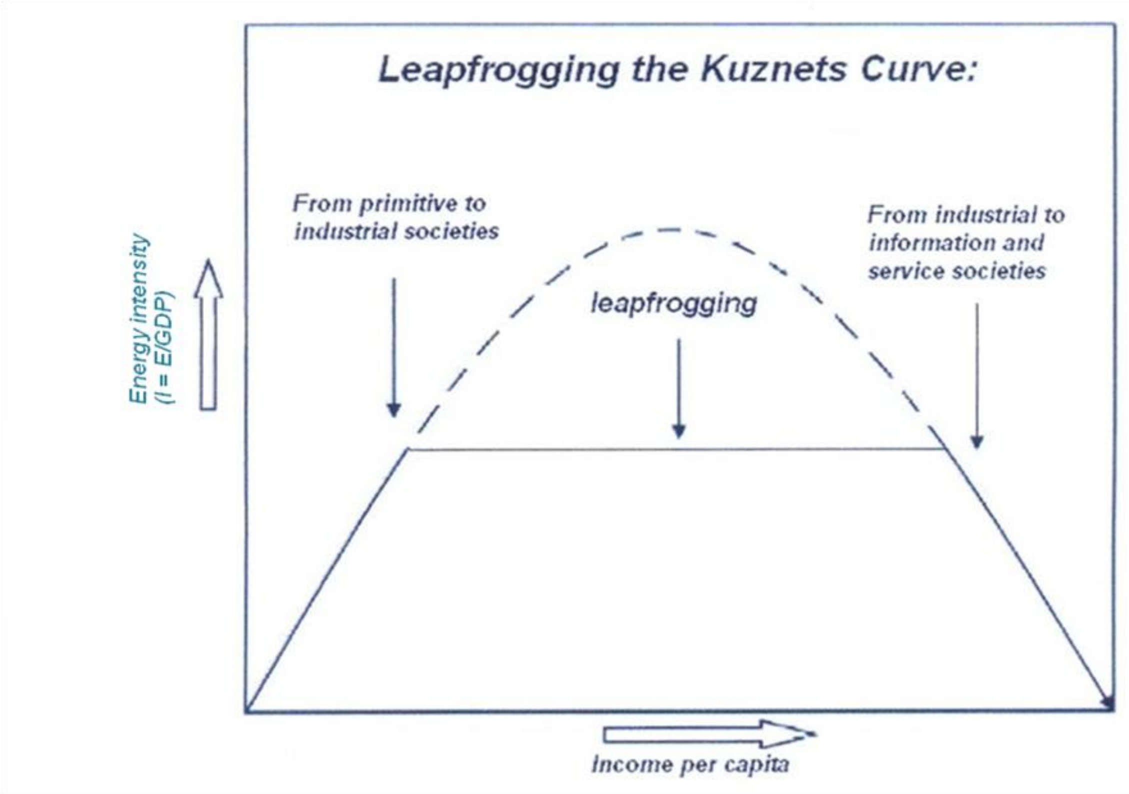
Figure 2



Source: BP Energy Outlook 2030 London 2011[5]

In the United States and other industrialized countries the energy intensity increased as the infrastructure and heavy industry developed, going through a peak and then a steady decline. Latecomers in the industrialization process, in other industrialized countries such as the United Kingdom and Germany as well as India peaked later and at lower energy intensities than their predecessors, indicating early adoption of modern, more energy-efficient industrial processes and technologies: a pictoric representation of such evolution is indicated in Figure 3.

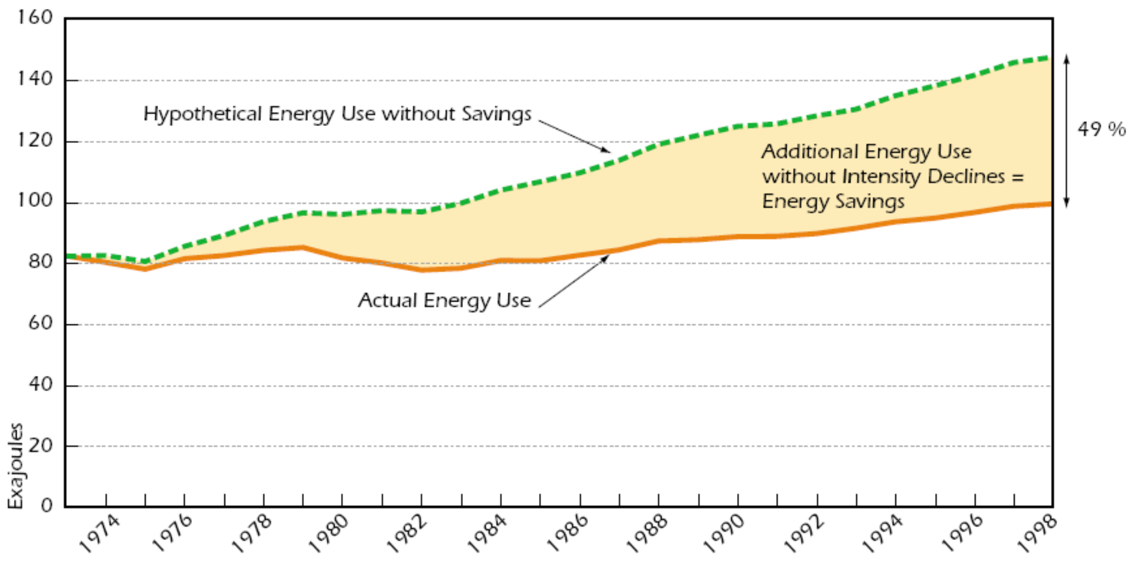
Figure 3



China and Russia industrialized very rapidly in the last century basically in a "brute force" pattern based on the use of less efficient technologies.

The observed decline of the energy intensity countries is due to the decoupling of energy consumption (E) – mostly originating in fossil fuels use – and GDP resulting from energy efficiency measures and shifts in the economic structure of these countries, from manufacturing sectors to services. As an example Figure 4 shows the evolution of energy consumption in the OECD between 1973 and 1998 demonstrate that without energy efficient measures energy consumption would be 49% higher than actually was.

Figure 4
Energy Savings in the OECD (1973 – 1998)

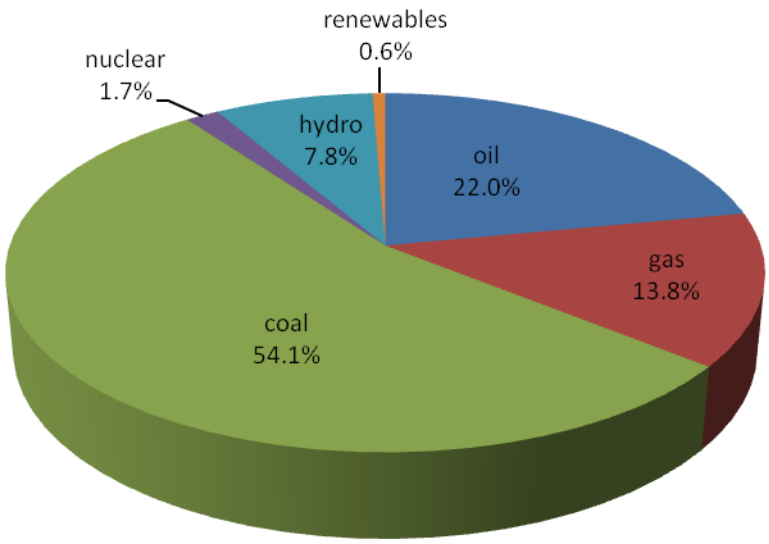


Source[6]

In developing countries, where consumption "per capita" is low and a large fraction of the population does not have yet access to many modern services energy efficiency "per se" might lead to deprivation and therefore is not easily be accepted. The rapid growth of industrialization in these countries particularly in China, Russia and the other BRICS countries – with the exception of Brazil – was made on the basis of using fossil fuels, particularly coal.

Figure 5 shows the present sources of energy (2010) in the BRICS countries.

Figure 5
BRICS (2008)



Fossil fuels represent 90% of the total; energy sources used in BRICS countries in the OECD they represent 83% due to the fact that renewables energy sources such as biomass, hydro, wind, geothermal and direct solar energy have grown in the aggregate at a higher rate than fossil fuel consumption which has remained practically constant in the last 30 years in OECD countries.

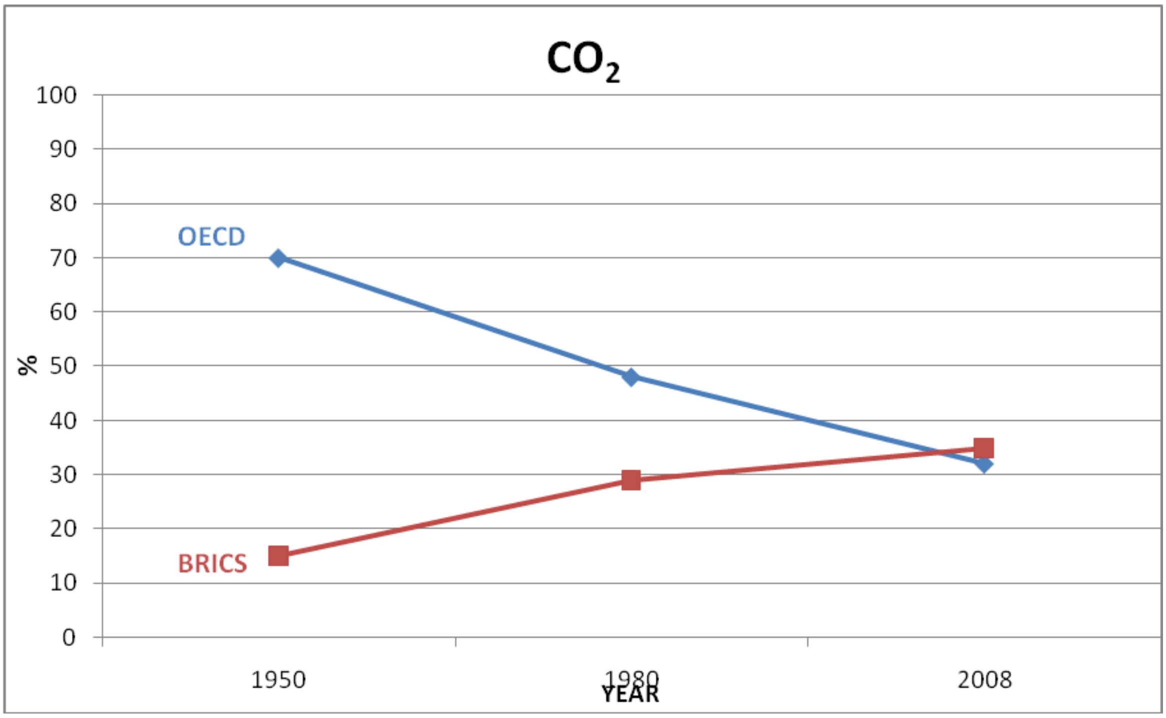
No wonder therefore that the emergence of the BRICS in terms of economic growth is reflected in an increase in their greenhouse gas emissions (particularly CO_2). (Table II) (Appendix II).

Table II
Fraction of CO_2 emissions (%)

	1950	1980	2008
OECD	70	48	32
BRICS	15	29	35

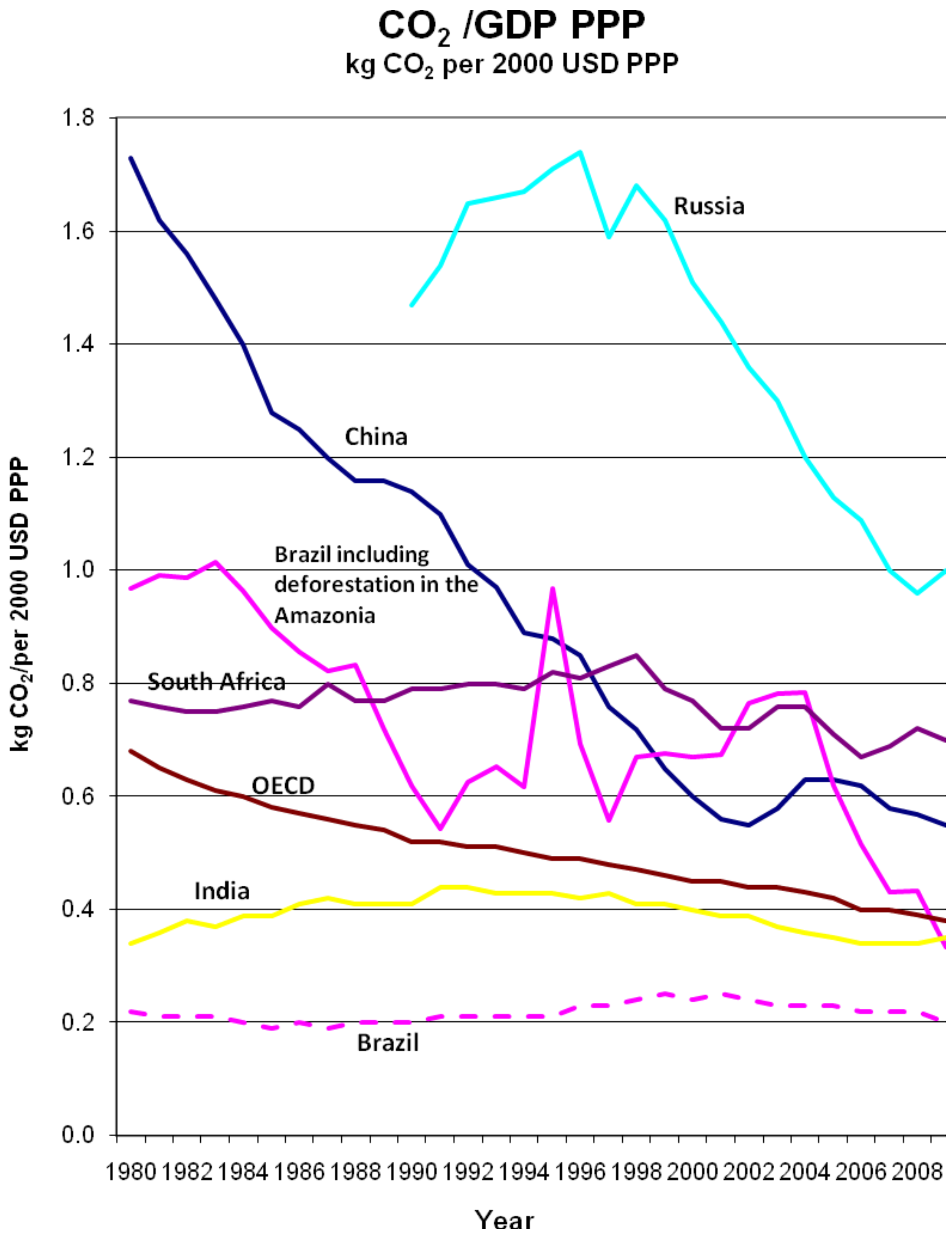
The OECD share of CO_2 emissions declined from 70% in 1950 to 32% in 2008 while BRICS increased their share from 15 to 35%. (Figure 6)

Figure 6



More recently however all the BRICS countries have made great efforts to decrease their energy intensity and consequently carbon intensity as shown in Figure 7.

Figure 7



China and Russia which are very dependent on coal are making great progress in reducing rapidly their carbon intensity (CO_2/GDP) although their carbon intensity is significantly higher than the one in OECD countries. South Africa is making small progress. India has a rather low carbon intensity being a less industrialized country. Brazil excluding deforestation in the Amazonia has a very low carbon intensity the main reason being the fact that electricity is produced almost entirely from hydroelectric plants. When the contribution to CO_2 emissions due to the deforestation in the

Amazonia is included its carbon intensity raises considerably although it has been decreasing significantly more in recent years.

The point has been made however that despite the significant growth of CO_2 emissions of the BRICS countries in recent years has not been translated yet in a large fraction of the accumulated emissions that occurred since the 19th century which has changed the composition of the atmosphere.

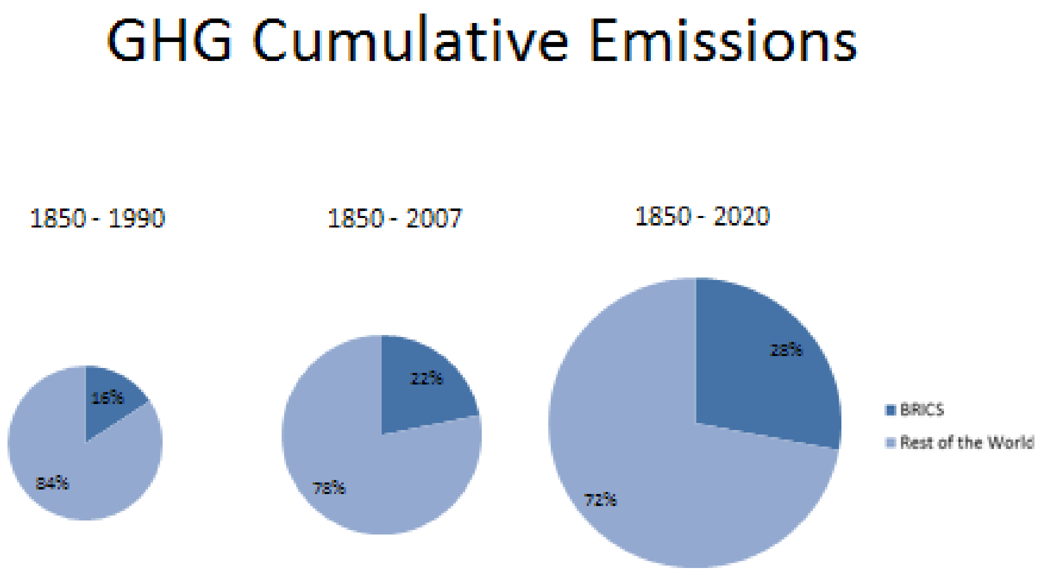
This is one of the strongest arguments used by the developing countries to refuse accepting limitations in their emissions in the Climate Convention and Kyoto Protocol. It is argued that to accept limitations in their emission was equivalent to accept a policy that will keep them poor and undeveloped now that it was their return to develop. Such reasoning is based on the false assumption that developing countries will grow and develop using the same fuels and technologies of the past.

Table III and Figure 8 shows the contribution of BRICS to the accumulated emissions since 1850

Table III
Accumulated CO_2 emissions (%)

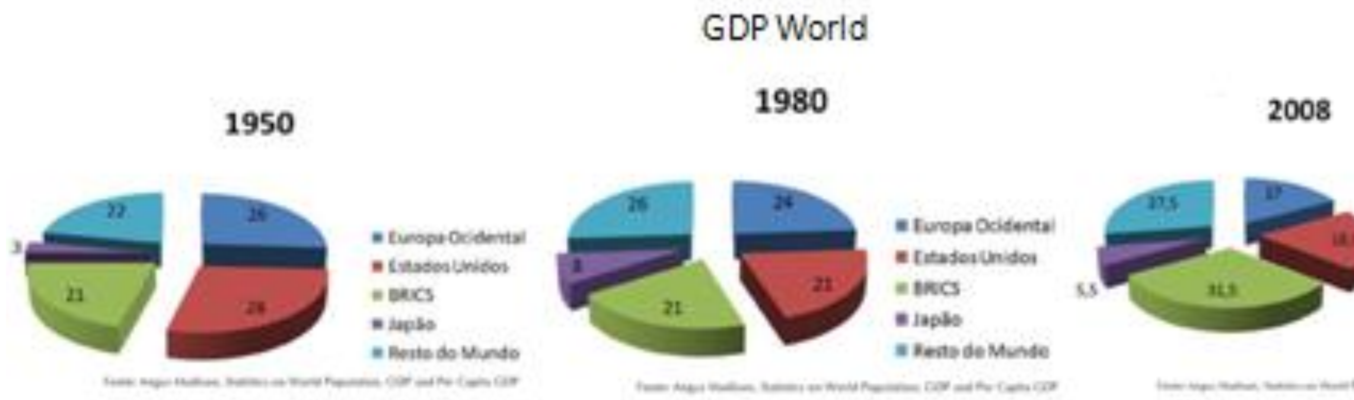
	1850-1950	1850-2007	1850-2020
BRICS	16	22	28
Rest of the world	84	78	72

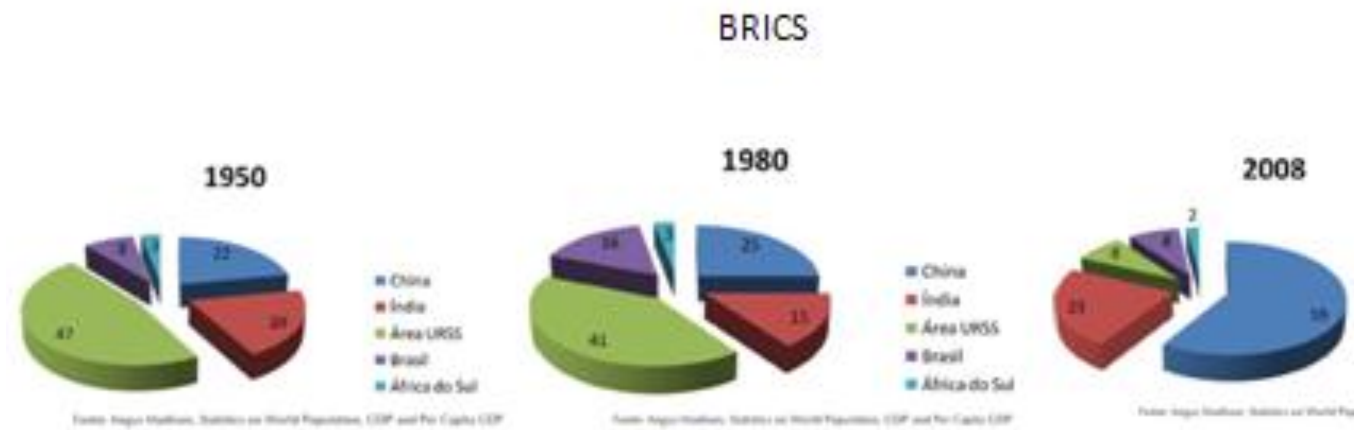
Figure 8



The contribution of the BRICS increased from 16% from 1850 to 1990 and 22% from 1850 up to 2007 and will likely represent 28% in 2020. Considering that a fraction of the CO_2 emissions that occurred more than a century ago (mainly from industrialized countries) have already been reabsorbed by the oceans the significance of recent emissions from the BRICS countries becomes more significant. This is the main reason why the 17th Conference of the Parties which met in Durban, South Africa in December 2011 decided to initiate a new negotiating process to be concluded by 2015 which will lead to mandatory reduction commitments of GHG for all countries which replace the Kyoto Protocol which established such mandatory reduction only for industrialized countries.

Appendix I

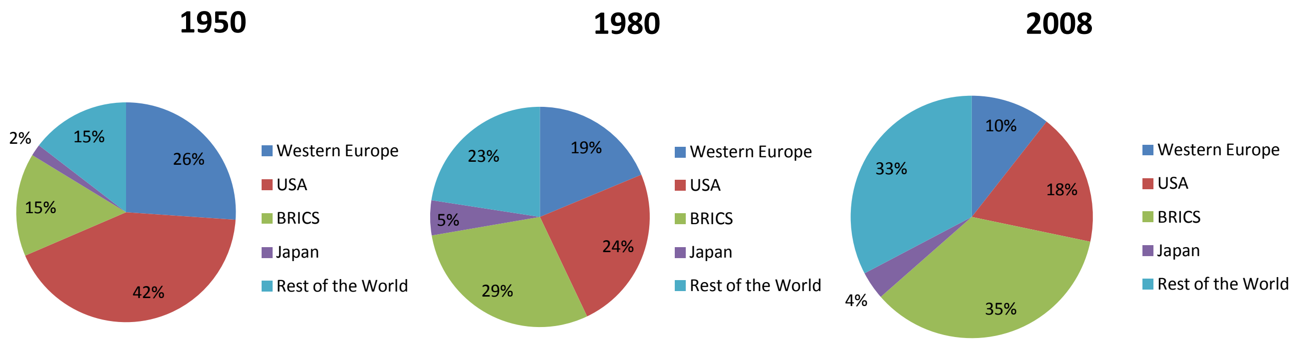




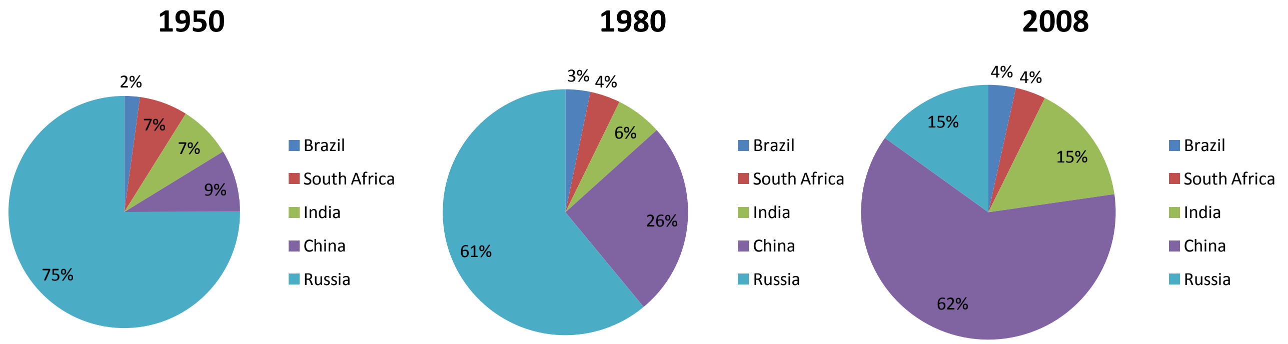
Appendix II

CO_2 emissions

World



BRICS



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Environment and Development Challenges: The Imperative of a Carbon Fee and Dividend

James E. Hansen

Most governments have paid little attention to the threat of human-made climate change. They have acknowledged its likely existence, notably in the Framework Convention on Climate Change (1), in which 195 nations agreed to avoid "dangerous anthropogenic interference" with climate. However, the instrument chosen to implement the Framework Convention, the Kyoto Protocol, is so ineffectual that global fossil fuel CO_2 emissions have increased by about 3 percent/year since its adoption in 1997, as opposed to a growth rate of 1.5 percent/year in the decades preceding the Kyoto Protocol [http://www.columbia.edu/~mhs119/Emissions/, which is an update of a graph in (2)].

This feckless path cannot continue much longer, if there is to be hope of preserving a planet resembling the one on which civilization developed, a world that avoids the economic devastation of continually receding shorelines and the moral nightmare of having exterminated a large fraction of the species on Earth. The science is clear enough: burning most fossil fuels would invoke such consequences (3).

At least a moderate overshoot of climate change into the dangerous zone is unavoidable now, but, fortunately, prompt actions initiating a change of directions this decade could minimize the impacts on humanity and nature. The policies needed to produce a rapid phase-out of fossil fuel emissions would have a wide range of other benefits for the public, especially in those nations that recognize the advantages in being early adoptors of effective policies. So there is some basis for optimism that the political will necessary to enact effective policies could be marshaled.

However, for this to happen it is essential that the next approach not repeat the fundamental mistakes that doomed the Kyoto Protocol. If another 15 years is wasted on an ineffectual approach, it will be too late to avoid catastrophic consequences for today's young people and future generations. Therefore it is important to clarify the principal flaws in the Kyoto approach from the standpoint of climate science.

Kyoto Protocol

A fundamental flaw of the Kyoto approach is that it was based on a "cap" mechanism. This approach embodies two ineluctable problems. First, it made it impossible to find a formula for emission caps that was equitable among nations and also reduced carbon emissions at the rate required to stabilize climate. Second, it failed to provide clear price signals that would reward businesses, individuals and nations that led the way in reducing emissions.

The validity of the first assertion can be proven by comparing national responsibilities for climate change, which are proportional to cumulative historical emissions (4, 5). The United Kingdom, United States, and Germany have per capita responsibilities exceeding the responsibilities of China and India by almost a factor of ten Hansen (4). Even if the UK, US and Germany terminated emissions tomorrow, by the time China, India and other developing nations reached comparable responsibility for climate change the world would be on a course headed to certain climate disasters.

Key Points: Why a Carbon Fee and Dividend is Imperative

1. There is a limit on fossil fuel carbon dioxide that we can pour into the atmosphere without guaranteeing unacceptably tragic, immoral climatic consequences for young people and nature.

2. It is clear that we will soon pass the limit on carbon emissions, because it requires decades to replace fossil fuel energy infrastructure with carbon-neutral and carbon-negative energies.

3. Climate system inertia, which delays full climate response to human-made changes of atmospheric composition, is both our friend and foe. The delay allows moderate overshoot of the sustainable carbon load, but it also brings the danger of passing a climatic point of no return that sets in motion a series of catastrophic events out of humanity's control.

4. The ineffectual paradigm of prior efforts to reign in carbon emissions must be replaced by one in which an across-the-board rising carbon fee is collected from fossil fuel companies at the place where the fossil fuel enters a domestic market, i.e., at the domestic mine or port-of-entry.

5. All funds collected from fossil fuel companies should be distributed to the public. This is needed for the public to endorse a substantial continually rising carbon price and to provide individuals the wherewithal to phase in needed changes in energy-use choices.

It is unrealistic to think that a "cap" approach can be made global or near-global. Nations less responsible for the world's climate predicament believe, with considerable justification, that they should not have to adhere to caps on CO_2 emissions (much less steadily shrinking caps) that are comparable to caps on industrialized countries. At the same time, some industrialized countries, including the United States, refuse to bind themselves to caps that are more stringent than those imposed on developing countries. This impasse cannot be resolved under a cap approach. Indeed, the targets adopted to date with a cap approach have been but a drop in the bucket compared to the reductions required to stabilize climate.

A secondary, but important, flaw of the Kyoto approach is its introduction of "offsets". Nations are allowed to limit reduction of fossil fuel emissions by means of alternative actions such as tree planting or reduced emissions of non-CO_2 climate forcings such as methane or chlorofluorocarbons. However, these offsets are not equivalent to fossil fuel emissions, because the fossil fuel carbon will stay in surface carbon reservoirs (atmosphere, ocean, soil, biosphere) for millennia. Rapid phase-out of fossil fuel emissions, as required to stabilize climate, becomes implausible if leakage is permitted via offsets. Leakage is avoided via the flat across-the-board carbon fee on fossil fuels in the fee-and-dividend approach. Incentives to reduce non-CO_2 climate forcings will be useful, but such programs should not be allowed to interfere with the more fundamental requirement of phasing out fossil fuel CO_2 emissions.

Fee and Dividend

Fee-and-dividend (5) has a flat fee (a single number specified in $ per ton of CO_2) collected from fossil fuel companies covering domestic sales of all fossil fuels. Collection cost is trivial, as there are only a small number of collection points: the first sale at domestic mines and at the port-of-entry for imported fossil fuels. All funds collected from the fee are distributed electronically (to bank account or debit card) monthly to legal residents of the country in equal per capita amounts. Citizens using less than average fossil fuels (more than sixty percent of the public with current distribution of energy use) will therefore receive more in their monthly dividend than they pay in increased prices. But all individuals will have a strong incentive to reduce their carbon footprint in order to stay on the positive side of the ledger or improve their position.

The carbon fee would start small and rise at a rate that sows benefits of economic stimulation while minimizing economic disruptions from sudden change. Economic efficiency requires the price of fossil fuels to rise toward a level that matches their cost to society. At present fossil fuels are the dominant energy only because the environmental and social costs are externalized onto society as a whole rather than being internalized into their prices (6). Human health costs due to air and water pollution from mining and burning of fossil fuels are borne by the public, as are costs of climate change that have been estimated at $100-1000/t$CO_2$ (7).

International Implementation

When the reality and consequences of the climate threat become clear enough the international community should recognize that all nations are in the same boat and that the fruitless cap-and-trade-with-offsets approach must be abandoned. The reality is that the Kyoto Protocol and proposed replacements are "indulgences" schemes Hansen (5), which allow aggressive development of fossil fuels to continue worldwide. Developing countries acquiesce if sufficient payments for offsets and adaptation are provided. This works fine for adults in developed and developing countries today, but this abuse of young people and future generations must eventually end as the facts become widely apparent.

A fundamental fact is that as long as fossil fuels are allowed to be cheap, via subsidies and failure to pay their costs to society, they will be burned. Even ostensibly successful caps have no significant benefit. They simply reduce demand for the fuel, thus lowering its price and creating incentives for it to be burned somewhere by somebody. What is required is an approach that results in economically efficient phase-out of fossil fuels, with replacement by energy efficiency and carbon-free energy sources such as renewable energy and nuclear power.

Specifically, there must be a flat (across-the-board) rising fee (tax) on carbon emissions. With such a flat fee, collected by the energy-using nation at its domestic mines and ports of entry, there is no need for trading carbon permits or financial derivatives based on them. Indeed the price oscillations inherent in carbon trading drown out the price signals. The required rapid phase-out of fossil fuels and phase-in of alternatives requires that businesses and consumers be confident that the fee will continue to rise. Another flaw of trading is that fact that it necessarily brings big banks into the matter – and all of the bank profits are extracted from the public via increased energy prices.

A carbon fee (tax) approach can be made global much more readily than cap-and-trade (8). For example, say a substantial economic block (e.g., Europe and the U.S. or Europe and China) agrees to have a carbon tax. They would place border duties on products from nations without an equivalent carbon tax, based on a standard estimates of fossil fuels used in production of the product. Such a border tax is allowed by rules of the World Trade Organization, with the proviso that exporters who can document that their production uses less fossil fuels than the standard will be assigned an appropriately adjusted border duty. Border duties will create a strong incentive for exporting nations to impose their own carbon tax, so they can collect the funds rather than have them collected by the importing country.

Once the inevitability of a rising carbon price is recognized, the economic advantages of being an early adopter of fee-and-dividend will spur its implementation. These include improved economic efficiency of honest energy pricing and a head-start in development of energy-efficient and low-carbon products. The potential economic gains to middle and lower income citizens who minimize their carbon footprint will address concerns of people in many nations where citizens are becoming restive about growing wealth disparities. Note that the effect of a carbon price on upper class citizens is modest and non-threatening except to a handful of fossil fuel moguls who extract obscene profits from the public's dependence on fossil fuels. An added social benefit of fee-and-dividend is its impact on illegal immigration – by providing a strong economic incentive for immigrants to become legal, it provides an approach for slowing and even reversing illegal immigration that will be more effective than border patrols.

National Implementation

The greatest barriers to solution of fossil fuel addiction in most nations are the influence of the fossil fuel industry on politicians and the media and the short-term view of politicians. Thus it is possible that leadership moving the world to sustainable energy policies may arise in China (9), where the leaders are rich in technical and scientific training and rule a nation that has a history of taking the long view. Although China's CO_2 emissions have skyrocketed above those of other nations, China has reasons to move off the fossil fuel track as rapidly as practical. China has several hundred million people living within 25 meter elevation of sea level, and the country stands to suffer grievously from intensification of droughts, floods, and storms that will accompany continued global warming (3, 5, 10). China also recognizes the merits of avoiding a fossil fuel addiction comparable to that of the United States. Thus China has already become the global leader in development of energy efficiency, renewable energies, and nuclear power.

Conceivably the threat of impending second-class economic status could stir the United States into action, but it is imperative that the action contain no remnant of prior cap-and-trade fiascos, which were loaded with giveaways to big banks, big utilities, big coal and big oil. The approach must be simple and clear, with the fee rising steadily and 100 percent of the collected revenue distributed to legal residents on a per capita basis.

The fee-and-dividend approach allows the market place to select technology winners. The government should not choose favorites, i.e., subsidies should be eliminated for all energies, not just fossil fuels. This approach will spur innovation, stimulating the economy as price signals encourage the public to adopt energy efficiency and clean energies. All materials and services will naturally incorporate fossil fuel costs. For example, sustainable food products from nearby farms will gain an advantage over highly fertilized products from halfway around the world.

The carbon price will need to start small, growing as the public gains confidence that they are receiving 100 percent of the proceeds. If the fee begins at \$15/tCO_2 and rises \$10 per year, the rate after 10 years would be equivalent to about \$1 per gallon of gasoline. Given today's fossil fuel use in the United States, that tax rate would generate about \$600B per year, thus providing dividends of about \$2000 per legal adult resident or about \$6000 per year for a family with two or more children, with half a share for each child up to two children per family.

The proposal for a gradually rising fee on carbon emissions collected from fossil fuel companies with proceeds fully distributed to the public was praised in the United States by the policy director of Republicans for Environmental Protection (11) as: "Transparent. Market-based. Does not enlarge government. Leaves energy decisions to individual choices… Sounds like a conservative climate plan."

A grassroots organization, Citizens Climate Lobby (12), has been formed in the United States and Canada with the objective of promoting fee-and-dividend. My advice to this organization is adoption of a motto "100 percent or fight", because politicians are certain to try to tap such a large revenue stream. Already there are suggestions that part of the proceeds should be used "to pay down the national debt", a euphemism for the fact that it would become just another tax thrown into the pot. Supporters of young people and climate stabilization will need to have the determination and discipline shown by the "Tea Party" movement if they are to successfully overcome the forces for fossil fuel business-as-usual.

Global Strategic Situation

Europe is the region where citizens and political leaders have been most aware of the urgency of slowing fossil fuel emissions. Given the stranglehold that the fossil fuel industry has achieved on energy policies in the United States, it is natural to look to Europe for leadership. Yet Europe, despite dismal experience with cap-and-trade-with-offsets, continues to push this feckless approach, perhaps because of bureaucratic inertia and vested interests of individuals. China, at least in the short run, likely would be only too happy to continue such a framework, as the "offsets" have proven to be a cash cow for China.

The cap-and-trade-with-offsets framework, set up with the best of intentions, fails to make fossil fuels pay their costs to society, thus allowing fossil fuel addiction to continue and encouraging "drill, baby, drill" policies to extract every fossil fuel that can be found. There is a desperate need for global political leaders who can see through special financial interests and understand the actions required to achieve a bright future for young people and the planet. Perhaps such leaders exist – the problem is really not <u>that</u> difficult.

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The global transition beyond fossil fuels
Amory B. Lovins and José Goldenberg

About 78% of the primary energy use by humans-nearly 90% excluding traditionally scavenged biomass such as wood and dung-comes from ancient sunlight concentrated into the rotted remains of primeval swamp goo. Burning this annual ~17 cubic kilometers of oil, gas, coal and related fossil fuels is the main threat to the Earth's climate. It is also costly, especially to poor people and nations; its extraction, transport, and combustion hazard public and environmental health; its uneven geological distribution fans tensions and inequities; its volatile prices (especially for oil) destabilize economies and political systems; its revenues (again especially for oil), with some notable exceptions, often promote unsound development patterns, corruption, and tyranny; and even without these side-effects, its gradual economic and physical depletion, despite stunning technological progress by the world's most powerful industries, makes a transition beyond fossil fuels inevitable (Fig. 1).

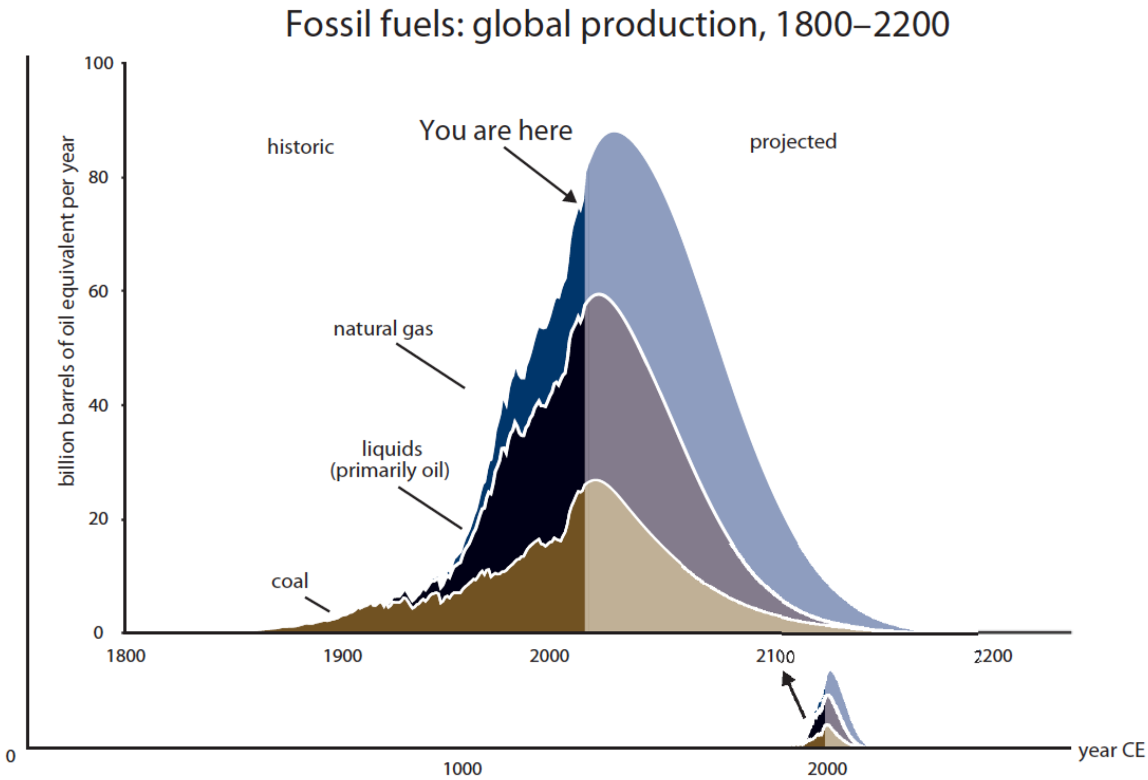

Fig. 1. Actual global output of the three major classes of hydrocarbons through 2010, then projections of the remaining amounts of each believed likely to be recovered if there are no aboveground constraints. The historic data are accurate but the smoothed illustrative projections are quite approximate, reflecting leading resource experts' knowledge in early 2011 but subject to many uncertainties. The projections include unconventional resources such as shale gas, heavy oil, tar sands, and shale oil, but not methane hydrates, potential Arctic and Antarctic resources, or Alaskan North Slope and central Siberian coal.[i]

Many numerical details of all these issues are disputed, but their general direction is clear: whether for reasons of economy (profits, jobs, competitive advantage, global development), security (dependence, reliable supplies, geopolitical stability, durability), or environmental stewardship, climate, and public health, the world has begun a gradual, historic, and immensely consequential shift from the anomalous few-centuries-long fossil-fuel "blip" shown at the bottom of Fig. 1 to an unbounded future of more-efficient use and durable supply. This transition is the "master-key" to solving or avoiding many of humanity's other most pressing problems.

Most policymakers and analysts assert that this shift will raise costs, based on two theoretical assumptions: that markets govern transactions worldwide, and that markets are essentially perfect, so market failures are minor and unimportant. The first assumption is obviously wrong: though market mechanisms are important and widespread, many economies are actually planned or mixed. An enormous body of scholarship and practical experience also contradicts the second assumption-that if there were a cheaper way to meet the world's energy needs than burning fossil fuels, it would already have been fully adopted. Scores of well-known market failures[ii] often make it hard to use energy in a way that makes money, or prevent full and fair competition between savings and supply, or even between different sources of supply. (For example, only in a few countries and 13 of the United States are electricity savings allowed to bid against new supply; indeed, in 14 states and nearly all other countries, utilities are rewarded for selling more electricity and penalized for selling less.) Moreover, efficiency and renewable energy are getting rapidly cheaper, as their impressive market performance attests.

An important obstacle to economically efficient use of energy is that many users lack access to the cheap capital available to energy suppliers; most low-income users cannot get financing at all. But this capital gap can be bridged by such innovations as "feebates"[iii] (like the five European "bonus/malus" systems that enable automobile buyers to approach or apply societal discount rates) and long-term financing (like the U.S. PACE bonds, on-bill utility financing, and for renewable, long-term Power Purchase Agreements and residential photovoltaic financing packages).

Such proven policy and business innovations can unlock remarkable energy shifts. For example, an independent, detailed, documented, and peer-reviewed 2011 synthesis for the United States' vibrant and market-orientated economy[iv] found a practical potential to produce a 2.58-fold-bigger GDP in 2050 than in 2010 but using no oil, no coal no nuclear energy, and one-third less natural gas, all at $5-trillion *lower* net-present-valued cost than business-as-usual–valuing all externalities at zero. This transformation requires no new inventions and no Act of Congress; rather, it could be led by business for profit.

So important are current market failures that U.S. buildings could triple or quadruple their energy productivity with a 33% average Internal Rate of Return; industry could double its energy productivity with a 21% IRR[v]; and transportation could eliminate oil use through radical efficiency and supply substitutions averaging a 17% IRR. The average 14% IRR across all sectors for the resulting >80% fossil-carbon reduction includes an 80%-renewable electricity system, rearchitected to be so resilient that major failures would become impossible. All the same services as in the official forecasts would still be provided, often with higher quality. The investments assumed all meet commercial hurdle rates appropriate to each sector. These U.S.-specific findings suggest important analogies elsewhere, since the proposed shifts look highly fungible (many are already driven by global competition) and widely adaptable or adoptable in diverse locations, climates, and economic and social conditions.

These astonishing, even seemingly impossible, findings result from combining four kinds of linked innovations-in technology, policy, design, and strategy (the latter two normally omitted)-and from integrating all four energy-using sectors (transport, buildings, industry including primary production, and electricity), because, for example, the automotive and electricity problems are more easily solved together than separately. (Superefficient autos[vi] offering strong competitive advantage can be affordably electrified, like those entering volume production by 2013 from three German automakers; their intelligent linkage with smart buildings and smart grids, far from burdening the electricity system, adds to it valuable flexibility and integration resources that make wind and solar power easier to integrate. This approach shows promise in a wide range of societies.)

Those four kinds of widely transferable innovations can be adopted for any desired reason. Focusing on outcomes, not motives, thus bridges partisan fractures and makes the potential trans-ideological. In the United States, Congressional dysfunction currently blocks most actions on most issues, but can be end-run by the most effective institutions-private enterprise, coevolving with civil society sped by military innovation. The new policies needed to unlock or speed the transition can all be implemented administratively, or at a subnational level where gridlock is less serious and there are far more ways to evade it. Societies with more coherent, stable, and farsighted governance can of course adapt and adopt similar innovations in their own distinctive ways, perhaps even faster.

This is far from a uniquely U.S. finding. The European Climate Foundation presented a similarly ambitious EU transition in 2010[vii], as have many of its member nations. McKinsey and Company found in 2009[viii] that about 70% of projected global greenhouse gas (GHG) emissions in 2030 could be abated at an average cost of just \$6 per tonne of CO_2, without including many of the newer technologies nor any of the integrative designs[ix] that made the later U.S. findings so dramatic. McKinsey has also published similar GHG-abatement-potential supply curves for a dozen nations including Brazil, China, India and Russia.[x] Though the McKinsey studies are somewhat opaque in data sources (often based on proprietary client work) and sketchy on implementation, other detailed national analyses have been reporting such findings over the past three decades [xi], many of them deeply rooted in practical experience.

Practice is even overtaking theory. Energy energy, renewable supply, and smart energy technologies have attracted \$1 trillion of global investment since 2004.[xii] Some governments, from California (the world's #8 economy) to Denmark and from Germany (#4) to Sweden, are successfully implementing aggressive efficiency-and-renewables strategies. California in 1990-2006 shrank GHG emissions per dollar of GDP by 30% (and has now held per-capita electricity use flat for three decades while real income per capita grew by four-fifths). Denmark's GDP grew by two-thirds during 1980-2009 while energy use was returned to its 1980 level and carbon emissions fell 21%. All new Danish power plants are renewable or combined-heat-and-power (CHP)-categories able by 2010 to produce 36% of electricity in an average wind year. Of all 2010 Danish electricity, 53% was CHP and 30% renewable. The average Dane released 52% less fossil carbon than the average American, yet Danes have an excellent quality of life, with the most reliable electricity in Europe and at some of the lowest pretax prices.

Places as disparate as Sweden[xiii] and the Indian state of Karnataka[xiv] found in 1989 that renewable energy's modest extra cost could be repaid, or more, by savings from efficient end-use. Two decades later, renewables worldwide had actually achieved explosive growth and plummeting costs, each feeding on the other. China now leads the world in five renewable energy technologies and aims to do so in all.[xv] Portugal in 2005-10 soared from 17% to 45% renewable electricity (while the U.S. crawled from 9% to 10%). China in 2010 outinvested the United States by 60% in clean energy-139% per unit of GDP-and doubled its wind capacity for the fifth year running, blowing past its 2020 target, while Congressional wrangling halved U.S. windpower additions. India's clean-energy sector outinvested Japan's and Britain's. India just quadrupled its renewable target and aims to add 20 GW of coal-displacing solar power by 2022. China is rapidly forming the world's biggest carbon-trading zone and, unlike the U.S., has laid the foundation for stabilizing its carbon emissions before 2030, consistent with a 450-ppm world. China is still building coal plants, but at half it 2006 pace, and its 2010 net capacity additions were 38% renewable, only 59% coal-emphasizing the world's most efficient plants and thereby raising its average coal-plant efficiency past America's.

Half the world's new electric generating capacity added during 2008-10 was renewable, the majority now in developing countries. Global 2010 renewable capacity additions, *excluding* the $40-45 billion spent on big hydro dams, got $151 billion of private investment (by a broader measure, $195 billion[xvi]) and added ~66 GW, thereby overtaking nuclear power's total global installed capacity, and are projected to reach 34% of global power production by 2030 on a $5.4-trillion investment.[xvii] To be sure, the past century's total fossil-fuel and nuclear power investments (and subsidies) dwarf these figures, so total renewable power is only one-fifth of the world's total, mostly big hydro. (By early 2011, one-fourth of global installed capacity was renewable, often running fewer hours per year than traditional thermal power stations.) But in *new* orders, the shift from old to new technologies is unprecedented and exciting. For example, EU electric capacity additions have been over 40% renewable in the each year 2006-10; China ended 2010 with its electric capacity 26% and its generation 18% renewable.

The world can now manufacture 60 GW of photovoltaic capacity *each year*-a capability that averaged 65% annual growth during 2005-10. PVs, typically the costliest renewable, are at or near grid parity in many places, as windpower was years ago. In 2010, four German states got 43-52% of their electricity from windpower, and some regions of several European countries at some times were over 100% windpowered. Such local examples rely on embedding within a larger grid in flexible hydroelectric and fossil-fueled resources. But even in large countries or whole continents, generation coming 80+% from windpower and PVs (the two variable renewable sources) can sustain grid reliability with little or no bulk storage when a portfolio diversified by technology and location is properly forecasted, then integrated with flexible demand- and supply-side resources.[xviii]

Two-fifths of humanity lives in energy poverty. Yet in Kenya, more households get their first electricity from PVs sold by local entrepreneurs than from the grid. Across Africa and Asia, a social revolution driven by solar-powered lighting and telecommunications is underway as vital services start to reach 1.6 billion people who lack electricity.[xix]

These achievements reflect various mixtures of top-down policy, bottom-up entrepreneurship, and disaggregated market pull. They reflect a powerful trend towards decentralized electricity production. That is partly for economic reasons: 207 documented "distributed benefits" can often raise economic value by an order of magnitude.[xx] Also, led by the U.S. military, security concerns are important: diverse and renewable supplies linked by netted and islandable microgrids can make power grids inherently resilient.[xxi] Right-sized electricity production can include industrial or building-scale CHP as well as many renewable: in 2008, "micropower" (CHP plus renewables minus big hydro) produced about 91% of the world's *new* electricity. Distributed renewable can not only help create a decent life in rural villages, slowing urbanization, but also help poor urban and periurban dwellers get affordable and reliable energy services, using not just electricity generators but also thermal (like solar water heating) and sustainable biofuel technologies.

In short, the energy revolution now underway is making many policy and political debates moot or irrelevant. Since the Kyoto conference in 1977, most efforts to hedge climate risks have assumed that solutions will be costly rather than (at least mainly) profitable; insisted they be motivated by climate concerns rather than profit, economic development, or security; supposed they require a global treaty; and claimed little can be done without U.S. carbon pricing. These ideas look increasingly dubious and outmoded:

- Climate protection is generally not costly but profitable-a very convenient truth heretical to economic theorists but known to all practitioners-mainly because saving fuel costs less than buying fuel.[xxii] (Competitive renewables strengthen the point.) International climate discussions would become easier if focused on profits, jobs, and competitiveness rather than cost, burden, and sacrifice. While political leaders debate theoretical costs, smart corporate leaders are racing to pocket the profits before their rivals do: Dow Chemical Company, for example, has already earned a $19-billion return on a $1-billion efficiency investment. The U.S. synthesis cited at the start of this paper found a $5-trillion net *saving* from cutting U.S. fossil carbon emissions by 82-86% below their year-2000 level, consistent with a <450-ppm world.

- One can protect the climate without believing any of the climate science if one likes profit, development, or security. Any of those worthy motives, or several others, suffices, so accepting the climate-science consensus, though correct, is not essential for effective climate protection.

- China in 2005 made energy efficiency its top strategic priority for national development, not because a treaty made them do it, but because leaders like Wen Jiabao understood that otherwise China cannot afford to develop: energy's supply-side investments would devour the national budget. (That's why China's 1980-2001 growth in energy demand was already cut ~70% by deliberately reduced energy intensity.) Enlightened self-interest can thus supplant treaties.

- Though U.S. carbon pricing (now blocked by the political party that once favored market solutions and applied emissions trading to SO_x and NO_x with stunning success) would be appropriate and helpful, it's not essential or sufficient-nor probably, in the long run, very important, since efficient carbon markets will clear at low prices. Strategies that don't depend on carbon pricing, such as those in Ref. 1, are far more robust. Fortunately, since almost all major economies do price carbon or are moving to do so, most multinational firms price or shadow-price carbon in their investment and strategic choices. U.S. nonpricing thus distorts decisions mainly within U.S. or non-Annex-B-country firms that sell only or mainly in their home markets.

Climate protection is thus changing course:

It will be led more by countries and companies than by international treaties and organizations, more by the private sector and civil society than by governments, more by leading developing economies than by mature developed ones, and more by efficiency and clean energy's economic fundamentals than by possible future carbon pricing of unknown (but not zero) likelihood and price. These benefits will also be augmented by carbon and trace-gas savings from biologically informed agriculture, ranging from perennial polyculture to beef-system reforms to new ways to restore devastated tropical rainforests and their impoverished rural communities while reversing the huge greenhouse-gas emissions of countries like Indonesia and producing abundant biofuel. In short,…there's as much good news about advantageous ways to abate non-fossil [GHG]…emissions as fossil-fuel ones.[xxiii]

Cutting global carbon emissions quickly enough, without waiting for an elusive global agreement on vexing historical grievances and future divergent interests, is challenging but manageable. In 1977-85, for example, the U.S. cut its oil intensity by an average of 5.2% per year. (GDP rose 27%, oil use fell 17%, oil imports fell 50%, and oil imports from the Persian Gulf fell 87%; they'd have reached zero the following year had the policy continued.) Today, standard economic and decarbonization forecasts suggest, in rough numbers, that cutting global primary *energy* intensity by about 3-4%/y, *vs.* the historic ~1%/y, could more than offset secular net growth in carbon emissions and thus abate further climate damange.

This looks feasible: the U.S. has long achieved 2-4%/y lower primary energy intensity without national focus or concerted effort, while China beat 5%/y for a quarter-century through 2001 and returned to 4-5%/y in the past few years. Some firms have even achieved 6-16%/y. So why should 3-4%/y be hard-especially when most of the growth is in countries like China and India that are building most of their infrastructure in the next few decades, and building it right is easier than fixing it later? And since virtually everyone who invests in energy efficiency earns an attractive return at low risk, why should this activity be costly?

Profitable climate protection, economic growth and development, and energy security all require sustained effort, relentless patience, and meticulous attention to detail. They're not easy-only easier than not doing them.

Such a strategy is even more vital for developing countries[xxiv], which typically use severalfold more energy to deliver a given service (regardless of how deprived of services their poorer citizens may be). Poor people use little energy, but waste far more of what they do use and can afford the waste less: the poorest quintile can pay a sixfold or larger fraction of disposal income than do people in developed countries. Reversing that waste and its opportunity cost yields stunning results. When a South Indian village switched from kerosene to fluorescent lamps (let alone today's far better LEDs), illumination rose 19-fold, energy input fell ninefold, and household lighting costs were halved. The indirect benefits-of using saved kerosene costs to buy bednets, clean water, and drip irrigation, let alone of girls' learning to read at night-are incalculable.

Saving energy, especially electricity (the most capital-intensive sector), offers the biggest-yet unpulled and largely unnoticed-macroeconomic lever for development. For example, a standard Brazilian electric showerhead costing R$20 requires Eletrobras to invest about R$1,800-3,000, so extirpating those *chuveiros elétricos* would leverage huge capital savings. Or investing to make superwindows in Bangkok or LED lights in Mumbai, rather than building power plants and grids to deliver the same increased cooling and light, needs nearly a thousandfold less capital[xxv] and recycles it about tenfold faster. That roughly 10,000-fold lower capital need (intensity times velocity) could even turn the power sector, which devours one-fourth of global development capital, into a net *exporter* of capital for other development needs-and for even faster leapfrog development.[xxvi]

The first trillion-plus dollars' savings could come from the 2011 Super-Efficient Equipment and Appliance Deployment initiative. Its full execution could by 2030 save 1.8 PWh/y from 300 coal plants). The four appliances SEAD targets use ~60% of residential electricity in China and India (which together burn half the world's coal) as also in in the U.S. and EU. Together these four places use nearly three-fourths of those key appliances' electricity-and just 15 firms make three-fourths of them.

Though developing countires often lag in technical capabilities, their people are no less intelligent, entrepreneurial, hardworking, resourceful, and determined.[xxvii] Brains, as Gifford and Elizabeth Pinchot remind us, are evenly distributed, one per person, so they're mostly in the South and half in women. Thus the flow of innovation is already reversing from South to North, sped by the emerging global nervous system: Facebook has more members than America has people, political revolutions happen on Twitter and YouTube, and for each person on the planet there are more than a billion transistors.

As central institutions become gridlocked and even moribund, vitality emerging at the roots is starting to pervade business and civil society, even where governments may be the last to know. As this quiet bottom-up energy revolution continues and expands, its global flowering could create for the world a new fire that, efficiently used, can do our work without working our undoing.

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The Ecosystem Approach for Understanding and Resolving Environmental Problems

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The ecosystem approach, where complexity and inclusiveness are embraced rather than avoided, provides an important ecological "tool" for identifying, describing and addressing multifaceted environmental problems (e.g. Likens 1998, 2001). Using the required inclusiveness of the ecosystem approach gives a powerful frame for identifying new environmental problems or re-shaping existing ones and then tackling their complexity, especially when ecosystem processes are coupled with social and economic considerations (e.g. Currie 2011). In the upcoming decades we will need to deal with many existing environmental issues, but there will be new problems requiring new knowledge and the need for new and more innovative solutions to those problems at all levels of consideration (see, e.g. Likens 2001; http://ecohusky.uconn.edu/docs/news - Sustainability Newsletter Fall-Winter 2011-2012.pdf). We are indeed "shooting at a moving target" (Wiens 2011), and if we don't look into the future and attempt to anticipate problems and "surprises" (Lindenmayer, Likens, Krebs and Hobbs 2010), our chances of success will be dim. A comprehensive, integrated ecosystem approach provides an important window for doing that. Ecosystem scientists have helped to understand the ramifications of environmental deterioration by raising large-scale, realistic questions about impacts on Earth's systems from the outset of a problem's detection. This approach is crucial for finding management-relevant scientific results. Because of the magnitude and increased prevalence of environmental problems worldwide, Hobbs et al. (2011) have called for humans to intervene "…in ecosystems to restore ecosystem services and biodiversity." This time, however, our intervention must be positive, ethical, informed, broad-scaled, comprehensive and not just focused on restoration.

Environmental change is the result of a complex mix of powerful factors referred to as Human-Accelerated Environmental Change (Likens 1991). Human-Accelerated Environmental Change includes such problems as climate change, loss of stratospheric ozone, loss of species, invasion of alien species, toxification of the biosphere, infectious disease, and land-use changes caused and accelerated by humans (Figure 1). Even more important are the linkages and feedbacks among these various human-accelerated environmental changes, with their significant, incongruent legacies (e.g., Likens 1994, 2001, 2004). Ecosystem ecology is one of the best ways to get humans involved in more than just single-topic issues. Unless humans are united toward taking action that solves ecosystem-level problems, effort will always be piecemeal and ultimately ineffective. Even if humans choose to work on a single issue, they need to see clearly how that issue fits within the larger picture. Seeing how it all comes together is really the only way to resolve environmental issues. The complexity of ecosystems is daunting, but is the only way to know what is important in attempts to integrate the whole picture in resolving environmental problems.

Regardless of the misrepresentation and hype currently associated with the concept of ecosystem management - the holistic consideration and management of entire ecosystems are extremely valuable goals in attempts to make lasting progress on environmental problems. Specifically, the evaluation of ecosystem inputs and outputs are extremely critical measures in this regard for both defining and reducing the effects of pollution, for the conservation of habitat and biodiversity, and for quantitatively evaluating the effects of disturbances such as forestry and agriculture, or human development on watershed-ecosystems, and for intelligently managing Iandscapes or regions (e.g. Likens 1998). Resolving large-scale biogeochemical cycles quantitatively are critical, not only for understanding how ecosystems are changing due to factors like climate change, but also for managing these changes in the face of feedbacks between climate change and element cycles (e.g. Mitchell and Likens 2011; Mitchell et al. 2011; Likens et al. 2011; Fig. 1).

Delineation of ecosystem boundaries is critical for quantitative measures of input and output fluxes for ecosystems (Bormann and Likens 1967, Likens 1998). Ecosystem boundaries are usually determined for the convenience of the investigator, rather than on the basis of some known functional discontinuity with an adjacent ecosystem, in order to make quantitative measures of flux, and this has raised criticism in some quarters (e.g. Fitzsimmons 1996, Currie 2011). However, the theoretical and methodological constraints for boundary establishment are given in Bormann and Likens (1967), Likens (1972, 1975, 1992), Bormann and Likens (1979), Likens and Bormann (1985) and Wiens et al. (1985). Boundaries are required for quantitative measurements of flux (see e.g., Likens 1998, pp. 264-265), and indeed, such delineation of boundaries normally provides a powerful advantage in making the necessary quantitative analyses of ecosystems, such as mass-balances. Inputs and outputs for individual ecosystems are the functional connection among all ecosystems of the planet, comprising the “pulse” of the planet, and have major management relevance in resolving environmental problems.

Although ecosystem ecology is a relatively young science (Tansley 1935; Odum 1959), the ecosystem <u>approach</u> has become a powerful integrating tool for unraveling the complexity of major environmental problems, such as acid rain and eutrophication. Many exciting changes, such as the increased availability of large data sets, opportunities to study major regional and global-scale changes [“experiments”], longer-term financial support facilitating long-term research and monitoring, and powerful new tools such as isotopes and molecular/genetic approaches allow for a greater unraveling of the enormous complexity comprising diverse ecosystems and in turn, for guiding management solutions to vexing environmental problems (also see Pace and Groffman 1998).

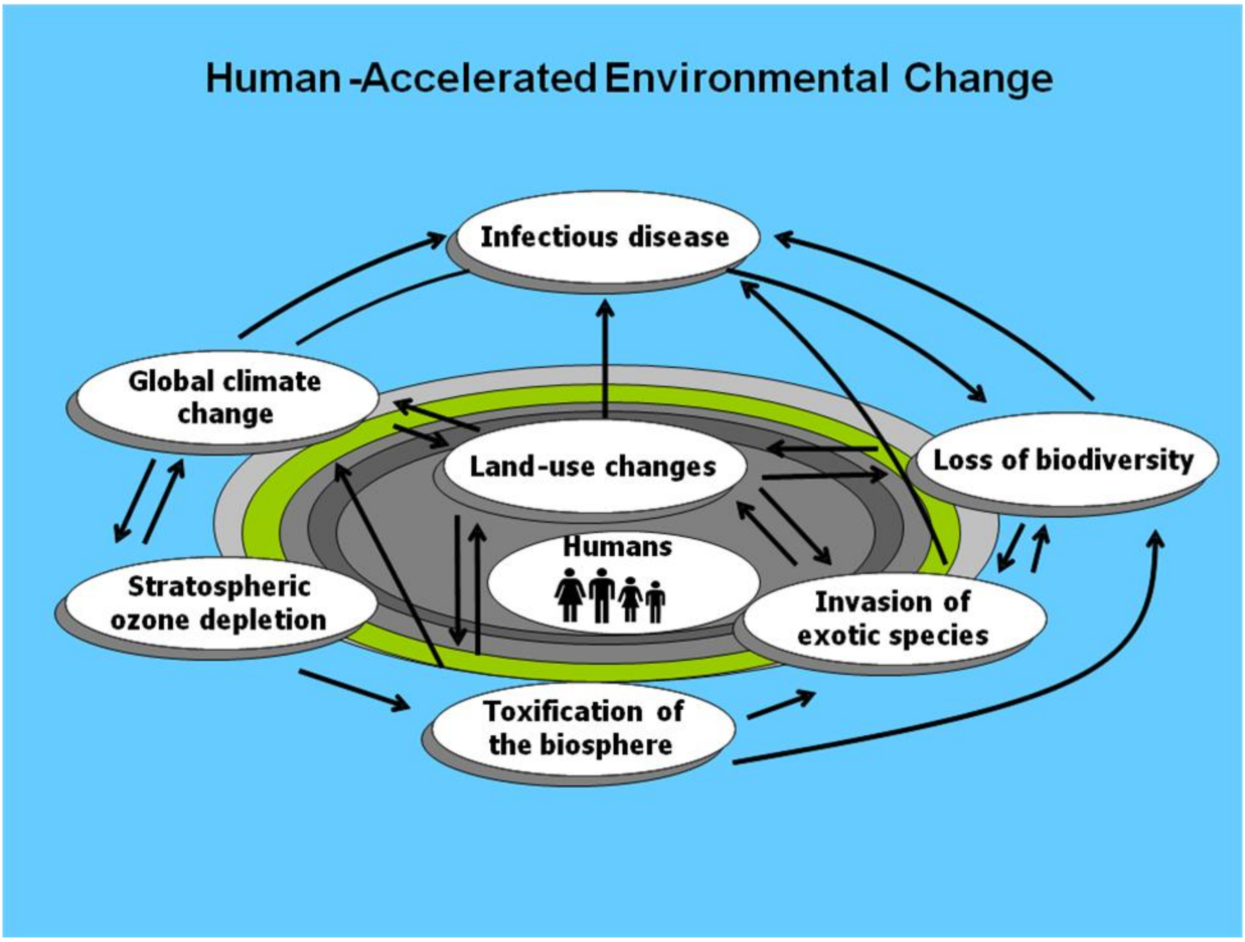
The environmental problem of acid rain gives one clear example of how the ecosystem approach can be effective throughout the continuum from problem detection, to comprehensive study and analysis, to management intervention (see, Likens 2010). This environmental problem continues to be one of the most urgent environmental issues related to long-term effects of human impacts on aquatic and terrestrial ecosystems (Likens et al. 2011).

Despite its ecological importance, the acid rain issue is very difficult to address experimentally, especially at small spatial scales, particularly with regional and international trans-boundary components regarding emission and transport of sulfur and nitrogen oxides. Short-term observations and experiments are relatively easy, but it is only through long-term observations and experiments at large scale (ecosystems) that it will be possible to understand and resolve the interaction with other drivers, such as the complex effects of changing climate. Identifying and interpreting the interactions among climate change and other human influences on targeted environmental problems, such as major disturbances in the global flux and cycling of nitrogen (e.g., Galloway et al. 2008; Vitousek et al. 1997; Tae-Wook Kim 2011; Bernal et al. 2012), remain extremely challenging. When long-term data from watershed-ecosystems are available, such as from the Hubbard Brook Experimental Forest (HBEF) in New Hampshire, USA [approaching 50 continuous years of the most complete, coordinated record in existence for precipitation and streamwater amount and chemistry (Likens 2004)], new insights into the workings of complicated ecosystems are possible (Lindenmayer and Likens 2010).

As argued previously (Likens 2001), never before have ecosystem ecologists needed to be as creative, innovative, proactive and aggressive to meet the environmental challenges of the next fifty years (e.g., Lubchenco 1998; Ayensu et al. 1999; Vörösmarty 2000; Estes et al. 2011; Tae-Wook Kim 2011). Likewise, never before has an holistic, comprehensive ecosystem approach (incorporating information from across the spectrum of Ecology from more biotic-centric evolutionary ecology to more abiotic-centric biogeochemistry) been more needed to address these challenges. Specifically, the need is for holistic, ecosystem thinking, not necessarily holistic modeling, which usually becomes excessively complex and thus unmanageable. Nevertheless, because of its integrative and comprehensive nature, the ecosystem approach offers hope in dealing with current and future large-scale environmental problems such as acidification of oceans and the widespread pollution following earthquake and tsunami damage during March 2011 in Japan (www.telegraph.co.uk/news/picture galleries). Not only are these problems catastrophic and profound for people in the local areas affected, but they involve the contamination and interaction of pollutants through air, land and water on massive scales (not just atmospheric transport of radioactive materials).

Hopefully, “ecosystem thinking” (Likens and Franklin 2009) will become the overriding paradigm as we struggle to resolve increasingly large and more complex environmental problems in the future. Piecemeal approaches, as have been used in the past, will no longer be appropriate in our densely populated planet, such as managing the environmental problems of a river, but not integrating this management approach with the management of the river’s airshed, drainage basin and the receiving estuary. Ecosystem thinking and a comprehensive, integrated ecosystem approach will be crucial for evaluating and reducing the ecological “footprints” of environmental problems in the future.

Figure 1. A conceptual model for Human-Accelerated Environmental Change



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Global Warming and Water Resources
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When we talk about global warming, we usually think about temperature. However, it has profound impact on the exchange of moisture between the Earth's surface and the atmosphere through evaporation and precipitation. The changes in precipitation and evaporation in turn result in the change in river discharge and soil moisture, affecting the availability of water at continental surface. Let me elaborates further the processes involved in these changes.

When the temperature increases at the Earth's surface, the saturation vapour pressure of air also increases, thereby enhancing evaporation. The increase in evaporation in turn results in the increase in precipitation. If both precipitation and evaporation increases uniformly everywhere by an equal magnitude, they have little impact on water availability at continental surface. However, [as you know,] water vapour circulates three-dimensionally in the atmosphere. Thus, precipitation increases in some place substantially, whereas it decreases in other place despite the increase in evaporation. For example, extra-tropical cyclones in middle latitudes bring warm, moist air pole-ward and cold dry air equator-ward, transporting moisture from subtropics towards middle and high latitudes, where it precipitates. On the other hand, trade-wind transports moisture-rich air from subtropics towards tropical rain-belt, where it converges, rises and precipitates.

As temperature increases due to global warming, the absolute humidity of air is expected to increase due to the increase in moisture-holding capacity (i.e., saturation vapour pressure) of air. The increase in absolute humidity in turn results in the increase in the export of moisture from the subtropics towards both high and low latitudes, where precipitation increases. On the other hand, because of the increased export of water vapour, precipitation fails to increase substantially or even decrease in subtropics despite the increase in evaporation from ocean. This is the main reason why river discharge is expected to increase in high latitudes and in certain regions of the tropics, accompanying global warming. In the subtropical latitudes, on the other hand, both river-discharge and soil moisture are likely to decrease in many semi-arid regions (e.g., Sahel and grassland of Africa, south-western part of North America, Australia) of the world.

Many modeling studies of global warming indicate that the large-scale change of water availability is likely to occur, accompanying global warming. On the one hand, water is going to be more plentiful in those regions of the world that are already "water-rich". On the other hand, water stresses will increase in "water-poor" regions and seasons that are already relatively dry. Observational studies suggest that the frequencies of both flood and drought have [been] increased in the world. As we know, we have already experienced serious water shortage in many semi-arid region of the world due to the rapidly increasing population, per capita consumption of water, demographic shift and so-on. Unfortunately, it is quite likely that global warming aggravate this situation, enhancing the existing contrast between the water-rich and water-poor region of the world.

In order to deal with the large-scale change in water availability described above, it is necessary to place increasing emphasis upon the management of water through

• Desalinization
• Filtering / Recycling
• Storage (Dam, Artificial Lake)
• Conservation
• Transport through Pipeline and Canal
• Changes in Agricultural Practice
• Application of biotechnology to agriculture

If we deal with the current problem of water satisfactorily, we are going a long way towards preparing for the future change in water availability.

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Underlying Drivers of Change and Their Inter-relationships - Demographic Changes
Robert May

The growth of the population of *Homo sapiens* has been far from simply exponential. For most of the roughly 200,000 year tenancy of our planet, we were bands of hunter-gatherers, whose total population has been estimated as around 5-20 million.

With the beginnings of settled agriculture, in several places around 10,000 years ago, things began to change. Towns and cities began to grow, and recorded history began. The first few thousand years of this growth are estimated to have seen numbers increase faster than in later millennia, as infectious diseases which could not be maintained within low-density populations were acquired from domestic animals, and began to bite. Some 300 such infections, including smallpox, measles and others, can be recognised; endemic measles, for example, requires population aggregations of 300,000 or more.

The next big acceleration in population growth rates, beginning in the seventeenth century mainly in Western Europe, was consequent upon the advent of more systematic understanding of how the natural world works, based on experimental science. Even so, mortality rates in industrial cities such as Liverpool in the mid-1800's were not much better than for hunter-gatherers, with roughly one of two dying before the age of five.

The past 70 years have been really different, as increasing basic scientific understanding of the transmission and treatment of infectious diseases has been achieved and applied in simple measures of primary health care. Also, these benefits have, to a degree, been more equitably distributed. Put briefly, global average life expectancy at birth 50 years ago was 46 years; today it is around 68. The main factor in this change is that the difference in life expectancy between developed and developing countries 50 years ago was 26 years; today it is a still-disgraceful 12 years. Even so, as a result of enlightenment science, the average child born in a poor country today is – at least in terms of life expectancy – better off than one born 150 years ago in the industralising centres of the Western World.

To summarise, it took a few hundred thousand years for human populations to reach one billion, around 1830. It took a century for that total to double, and only 40 years to double again to 4 billion in 1970. Forty years on, in 2011 the total is 7 billion. Recently, however, higher average living standards – in both developed and developing worlds – have seen fertility rates decrease to around replacement levels: around the globe, the average woman is having roughly one female child who will survive to adulthood. This "replacement rate" corresponds to a Total Fertility Rate (TFR) of roughly 2.3 children, allowing for non-survivors (or a little less than 2.1 otherwise; a boy baby is slightly more probable than a girl).

On average, today's women are having just half as many children as their mothers did. Overall, TFR has dropped from 4.9 children per woman in 1950 to around 2.5 in 2011 (consisting of 4.1 in the least developed countries, and 1.65 in more developed regions), and is expected to reach 2.2 by 2025. These trends are seen even in some of the poorest countries, such as Bangladesh, and in some of the more repressive Muslim countries (Iran had a TFR of 5.5 in 1988, which had reduced to 2.1 in 2000 and 1.9 in 2006; this figure of 1.9 comprises 1.7 for urban and 2.1 for rural regions).

Figure 1 gives a striking illustration of these changes in total population and in the annual increase, from 1750 and projected forward, assuming current trends continue, to 2050. The singularity of the past century is extraordinary.

These trends to smaller families of course vary somewhat among regions. They are highly correlated with education of women, along with availability of non-coercive fertility control. Recent studies in a variety of developing countries (Niger, Guatemala, Yemen, Haiti, Kenya, Philippines) show that girls completing primary education have on average 1.5 fewer children than those not so educated. Girls completing secondary education have an additional 2.0 fewer children (i.e. 3.5 fewer than those denied education). In Iran in recent decades more women are going on to higher education and marrying later, resulting in the odds of having only one child increasing by a factor of 2.64 with progression from school diploma to undergraduate degree. Additionally, investing in sexual and reproductive health and rights is cost effective, significantly improving individual lives and contributing to slowing population growth. Unfortunately, however, more than 200 million women in developing countries still have unmet needs for family planning. Although the need is increasing, it is estimated that funding decreased by 30% between 1995 and 2008 (not least as a result of legislative pressure from the religious right in the USA). In view of the correlation between education and TFR, Figure 2 is interesting in showing the proportion of the world's males and females, by age and level of educational attainment (none, primary, secondary, tertiary) in 1970, 2010, and projected to 2050.

Despite these encouraging trends, the world population continues to grow, albeit at a diminishing rate, as a result of the "momentum of population growth". This momentum is caused by there being many more young people than in older age classes in many, if not most, developing countries. Even though they seem very likely to have fewer children than their mothers, their number means populations will continue to increase. Populations will not attain steady levels until "age pyramids" change into "age rectangles". Looking ahead to 2050, and assuming current fertility trends continue, we expect 9.1 billion people. If each woman has 0.5 children fewer than the median projection, this number would be 7.7; with 0.5 children more, 10.6. And if we assumed that the already-diminished 2005 fertility levels simply persisted, we would have 11.7 billion.

Some, arguably many, of the problems of population growth are compounded by the fact that 95% of the "build-out" of human numbers will occur in the urban areas of developing countries. In 1700, fewer than 10% of the world's population lived in cities. By 1900 the proportion was 25%; today, 50%; and by 2050, 67%. In 1950 there were 86 cities with populations in excess of 1 million; today, well over 400; by 2015, at least 550.

The truly unprecedented nature of our current situation can be illustrated by deconstructing a phrase Walt Whitman once wrote: "row upon row rise the phantoms behind us". One dramatic way of conveying our present situation is to ask, if indeed all our predecessors were lined up behind the phalanx of those alive today, how deep would these rows be? Demographic guesstimates put this total in the range 80-100 billion, which roughly implies only 11-14 shadows – reaching back to the first humans in Africa – behind you.

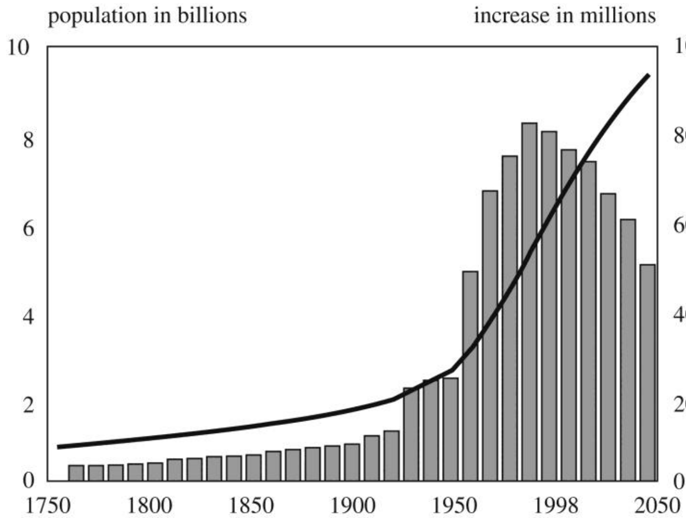
In summary, over the past 150 years human numbers have increased sevenfold. At the same time, the average *per capita* amount of energy subsidising daily activities (derived mostly from burning fossil fuels) has increased sevenfold. Our species' "ecological footprint" has thus grown by a factor of around 50 in this 150-year interval. This footprint is made up of demands for food, water, and a multitude of other resources. WWF has estimated the average *per capita* such footprint for each of the world's nations in 2009, along with the corresponding footprint each country could support on a sustainable basis, given its population size and resources. Fascinating ethical questions arise. For example, who are the more virtuous: Egyptians, who have an average footprint of 1.7 ha (hectares, but this is not important for the comparison) in a country whose corresponding biological capacity is 0.4, or Australians with a footprint of 7.8 but a biological capacity estimated at 15.4. The average Egyptian treads more lightly on the planet, but nevertheless exceeds the country's sustainable capacity; Australians are more profligate but arguably can live sustainably, given their greater resource base.

Broadly, today's growing populations require resources whose supplies are decreasing in relation to demands. More food requires both more water and more land. But demands for water (70% of it for agriculture) are estimated to exceed sustainable supplies around 2040. Our impacts on terrestrial ecosystems for food and other purposes have already caused plant and animal extinction rates to climb to rates last seen in the Big Five mass extinctions in the fossil record. And our understanding of the services that ecosystems deliver to us is still such that we cannot say how serious the impacts of such extinctions will be (never mind the ethical or aesthetic aspects of these questions).

Most importantly, our demand for energy is resulting in our burning fossil fuels at such a rate that one million years' deposits of such sequestered carbon is being put into the atmosphere each year, thickening the greenhouse gas blanket and changing the climate. Ultimately, of course, the problem is a product of both ever more people, and each one stamping a larger ecological footprint.

Figure 1

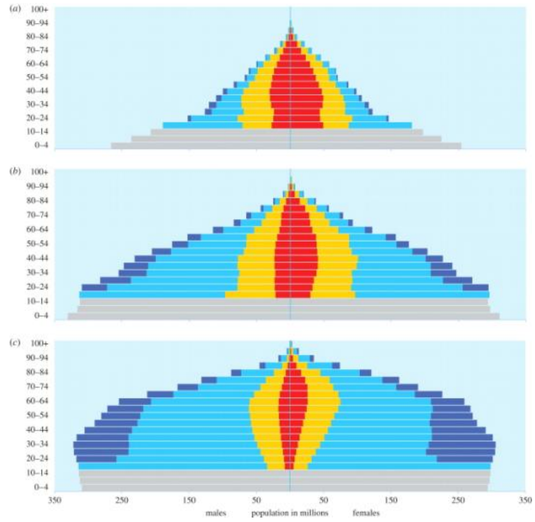
Estimated world population growth: 1750–2050 (McDevitt 1999).



Speidel J J et al. Phil. Trans. R. Soc. B 2009;364:3049-3065

Figure 2

World population by age, sex and four levels of educational attainment in (a) 1970, (b) 2010 and (c) projected to 2050 under the GET scenario.



Lutz W Phil. Trans. R. Soc. B 2009;364:3031-3047

Ecosystem Services: Protecting our heritage and life support system: some key issues and ways forward

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In a relatively short amount of time the concept of ecosystem services has penetrated deeply into research agendas and policy decisions at all levels from international agreements, to national and local priorities for agencies, both public and private. The term "ecosystem services" is beginning to appear in the popular press. Why is this so? Quite simply the concept resonates with so many sectors of society because ecosystem services provide benefits to people. Politicians serve society, so they are interested in protecting and enhancing these benefits. Conservationists are attracted to the concept since ecosystem services are built on the diversity of organisms in a habitat and thus speak to the preservation of diversity. Businesses are interested since some of these services are vital to their enterprises as is the case also with agriculturalists. Development agencies are embracing the concept since because of the strong links with ecosystem delivery and poverty alleviation (Barrett, Travis et al. 2011). All sectors of society benefit from the inspiration from nature and the clean water that vegetated watershed provide. Hence we are all beneficiaries of these services and indeed our very life depends on them.

What we can do? Although the ecosystem concept is penetrating many sectors it still needs a campaign to build societal awareness. Building the concept into secondary school education would be a good pathway to accomplish this along with a campaign for the general public.

A large number of the services that nature provides are abundant and are free to all. That is both the good and bad news. Since they are free, and have been so abundant, not much attention has been paid to protecting these resources. Consider the quote of the famous English biologist, Thomas Huxley, who stated in 1883 at the opening of a Fisheries Exhibition in London (Huxley 1883) "that I believe….that the cod fishery, the herring fishery, the pilchard fishery, the mackerel fishery, and probably all the great sea fisheries, are inexhaustible; that is to say, that nothing we do seriously affects the number of the fish. And any attempt to regulate these fisheries seems consequently, from the nature of the case, to be useless".

Since that optimistic statement, not so long ago in human history, we have seen the collapse of many of these fisheries due to overfishing,, made possible by technological advances in harvest technology, and the lack of a regulatory framework for the harvest of this "free" resource. More generally, a global survey involving over a thousand scientists concluded that in fact over 60% of these services had declined in availability to society, mostly during the past half century (MA 2005).

What we can do? We need to support the developing Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) that will provide periodic assessments of ecosystem service delivery and the status of the delivery system including the biophysical as well as social drivers of change.

There is a vast array of living things on Earth, no doubt numbering in the millions. But even these large numbers do not capture the true richness of our biological heritage. Each member of a population of virtually all species will be, to varying degrees, genetically distinct, possessing individual or combination of traits that determine their distinctive interaction with members of their own species as well as other interacting species (Whitham, Gehring et al. 2012). Yet there are species that act as keystone species that exert a predominant influence on the functioning of any ecosystem. These may be a tree species, or even a microbe (Power, Tilman et al. 1996). But these keystones in turn are dependent on other species for their survival. In nature there are apex species, such as top predators, that control the nature of the entire community or food chain. Throughout history humans have hunted these apex species both on the land and in the oceans. Their extinction has resulted in modification, and sometimes collapse of the entire ecosystem to a new state often less favorable to humans (Estes, Terborgh et al. 2011).

The breakdown of the historical barriers to intercontinental movement of species among continents has resulted in the movement of species into new environments where they are they generally free of the co-existing species that regulated their populations in their native habitats. Without such control the invader may have explosive growth and even occupy greater climatic limits than they had at home. In many cases those invaders that are successful will not provide benefits but rather can do great harm to the ecosystem that is invaded and to the benefits derived from it by society. Examples include diseases that can decimate crops and forests as well as directly affecting the health of humans. They can adversely affect water availability and increase ecosystem flammability. The numbers of invading species are increasing in all continents coincident with increased global trade (Mooney, Mack et al. 2005). Unwanted invaders are being transported by ships and airplanes in increasing numbers, generally inadvertently. Due to the ecosystem disruptions of rapid climate change this problem will be exacerbated (Mooney and Hobbs 2000).

Perrings et al. (Perrings, Mooney et al. 2010) point to a number of issues that can be addressed in particularly bring international agreements into conformity such as the International Health Regulations (IHR) and the World Trade Organization's Sanitary and Phytosanitary Agreement (SPS) into conformity. The WTO's mandate to foster global trade has to consider, and address, to a much greater extent the those potential negative impacts of global commerce. It is clear that the costs of adequate border protection from potential pests associated with imports are less than control of invaders once established. There is very uneven border inspection capacity globally and without this the invasive species problem will continue to grow.

What we can do? Align policy instruments regulating global trade and enhance national border inspection capacity.

We face an enormous challenge in the protection, management and design of ecosystem services that are critical for our well-being. Although the general features and broad results from our knowledge on the relationship between the multiple elements of the variety of life and ecosystem services are well articulated (MA 2005) (Leadley, Pereira et al. 2010) the details of the relationships between species diversity and ecosystem functioning and service provisioning is still rudimentary. We know a good deal about particular systems and places but this knowledge needs expansion built on experimentation more broadly practiced so this knowledge can be utilized more generally. Such information is invaluable in management for optimal utilization of resources but also for preparing for the changing nature of our ecosystems due multiple global changes including climate. There is no doubt that the structure and functioning of the ecosystems at any given location will change its character in the future. We will see the development of new climatic regimes and the corresponding disruption of what we see today as well as the development of new novel environments and ecosystem types (Hobbs, Higgs et al. 2009). We need more basic information in order to manage what we have now as well as predict the future in order to inform managers and policy makers of the challenges and opportunities of intervention versus restoration to some former state.

What we can do? Develop a global and comprehensive experimental network that probes the nature of diversity and ecosystem process and services under present as well as anticipated future environments as well accelerating our future scenario development capacity**.**

In recent years, there has been a flurry of research on the economic valuation of ecosystem services. These efforts provide decision makers the information needed to determine the economic consequences of any particular development decision. Many policy frameworks require a cost-benefit analysis for planning. In the past, the economic value of biodiversity and the related ecosystem services were not part of the process since there was little understanding that ecosystem services could be very high in monetary value. The Millennium Ecosystem Assessment (MA 2005) provided a stimulus for such analyses but the information base was slim at the time of the study in the early years of 2000. To remedy this lack UNEP launched TEEB (TEEB 2010)—and nations executed or stimulated their own assessments or built the capacity to do so (EPA 2009; UK 2011),. The Natural Capital Project led by a consortium of universities and NGO's has produced an array of software tools that can be used to develop spatially-explicit valuations of the services on a given landscapes. This information provides the base for understanding the full economic consequences of any particular development scenario (Kareiva, Tallis et al. 2011).

There are many services that are not amenable to economic valuation. Many of these are cultural services that are important locally. These non-economic services can be critical and should be evaluated since they can play an important role in final decision making.

What can we do? Provide the tools for decision makers on how to balance the tradeoffs in choosing among ecosystem services in land use decisions at multiple spatial scales and that include both economic and non-economic valuation.

Although progress is being made in economic valuation of ecosystem services the markets for these services have been slow to develop comprehensively over all ecosystem services. There are well-established markets for provisioning services, such as food, fiber and fuel. And there are developing markets for carbon sequestration and to a more limited extent, biological diversity. But much more is needed, and soon. As noted by Kinzig et al, (Kinzig, Perrings et al. 2011) "we get what we pay for" to illustrate that the losses we have seen in ecosystem service delivery globally is predominately on those services that are not in the market place--

-predominately public goods such a watershed protection, pest regulation, climate and erosion control..

To give an example of the urgency for a more comprehensive market development can be seen with the multi-use or “working landscapes” of the world that are storehouses of both natural and cultural diversity. These are the landscapes that have been highlighted in the recent adoption of the Satoyama Initiative of the Convention on Biological Diversity. As human populations shift to cities, landscapes that were utilized in a manner that provided multiple services are being abandoned, or developed to large-scale industrial agriculture. To give a single example, the oak woodlands of California have been traditionally utilized for cattle grazing. The grazing practices on these landscapes actually enhance biological diversity both directly and indirectly by preserving the oak trees a major habitat for a large host of species. The ranchers have become the guardians of the landscape beauty, its biological diversity, and its storehouse of carbon and the protection of the watersheds. The ranchers do not get rewarded by payment for protecting and maintaining these services. They get little economic return on their cattle operations although they do gain the amenity value of a traditional way of life enjoyed by their forebears. Inheritance taxes can result of the loss of the lands and a conversion to industrial agriculture or dispersed housing projects as a major development pathway today. A full payment for ecosystem service scheme could help maintain the traditional systems and the vital sources of ecosystem cultural and biotic services they provide.

At the scale of nations it has been noted that such metrics as GDP is not a full measure of human well-being and national wealth (Dasgupta 2002). Countries that appear by traditional metrics to be gaining wealth can be in fact losing wealth since their natural capital, and its depletion, is not taken into account. There are now efforts to utilize metrics of inclusive wealth that not only incorporates manufactured and human capital but also natural capital (World Bank 2006). This will be a very large step forward in correcting society’s perception of the value of the services that we are losing by essentially faulty or at least incomplete accounting systems.

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The Policy-Science Nexus - An area for Improved Competence in Leadership

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Abstract

It is a fantastic experience to understand basic principles for worthy goals together — across disciplinary, professional and ideological boundaries — and to realize that we need each other in order to attain those goals. Conversely, it is sobering that so few of our leaders know how to build full sustainability into their decision-making, and to shape their analyses, debates, action programs, stakeholder alliances, economies and summit meetings accordingly. That deficiency is reflected in the questions put to scientists, who are often caught in the middle of conflicting policy proposals. On such occasions, empirical facts may be presented out of context and applied as arguments for alternative solutions: for or against the rapid phase-out of fossil fuels, for or against nuclear power, etc. This results in attempts to deal with one issue at a time, often creating a new sustainability problem while "solving" another. Strategic planning towards sustainability is not something that you simply pick up as you go along, if only you are sufficiently engaged in public debate, have a certain field of expertise, or remain faithful to a certain ideology. What is needed today are decision-makers who are open to learning the crucial competence of strategic planning and the language that goes with it — a language which makes multi-sectoral collaboration possible at the scale required for success. Only then can leaders make their leadership relevant, co-operate effectively across discipline and sector boundaries; and only then can they ask the relevant questions of scientists and other experts. This is not incompatible with a strong economy nor with "competitiveness". It is just the opposite: We are now experiencing increasing costs and lost opportunities due to lack of competence in strategic sustainable development. Such competence is not incompatible with the freedom to embrace different values and ideologies, nor with the creative tensions that may arise from the confrontation of such values and ideologies with each other. On the contrary, the potential value of creative tensions increases when they are not rooted in lack of knowledge and misunderstandings.

* * *

There is a major problem with the current sustainability discourse between scientists and policymakers. Examples of this are the summit meetings in Rio, Kyoto, Copenhagen and most recently in Durban, which nearly always involve attempts to move directly from scientific data to policy making without any agreed framework for sustainable decision making in the process. First-rate natural and social scientists in the fields of climatology, ecology, chemistry, economy etc., typically provide data on negative developments in the socio-ecological system, as well as on various possible means to deal with each of those. Policymakers are expected to devise strategies and agreements directly from this information. This chapter describes how this results in lost opportunities, and outlines some basic constituents of a framework which makes it possible to make better use of empirical science.

Absent a generic framework to organize data in a comprehensive way for decision-making, complexity increases as more problems are inevitably added and models become unmanageable. This leads to serious risks of misunderstanding each other's individual frameworks for organizing data, with corresponding risks of also failing to satisfy both common and individual interests relating to sustainable development *(1)*. Examples of the resulting shortcomings include the following:

1. Failing to see the individual benefits of sustainable development, over and above the collective benefits.

2. Failing to deal effectively with system boundaries and trade-offs.

3. Failing to estimate sustainable resource potentials.

4. Creating a new problem in attempting to solve another.

5. Sub-optimizations.

6. Running into expensive blind alleys i.e. employing expensive measures to improve the current situation without ensuring that the chosen measures can serve as platforms for further progress later on.

The question thus becomes: Is it possible to link sciences to policy in a more effective manner, so that policymakers can make better use of empirical data in arriving at their decisions?

There are two key missing elements in the current discourse on sustainable development. First, there is a poor grasp of the obvious self-benefits of taking the initiative rather than waiting for others to act *(2)*. Second, once the benefits of being ahead of the game are understood, there is a lack of competence on how to act strategically so as to exploit opportunities in a spirit of enlightened self-interest (for references see *(3)*).

A new framework for leadership and decision-making for sustainability

The aim of this chapter is to supply those two missing elements by outlining a framework for making policy decisions based on the valuable empirical data provided in the other chapters of this book. It is a framework that has been developed in a scientific consensus process that has continued for over 20 years. The process is peer-reviewed and has been applied in practice by political and business leaders in a variety of real-life situations in many different parts of the world.

First missing element:
The benefits of strategic sustainable development in a dynamically changing world

The benefits to an organization, region or country in moving gradually towards sustainable practices and lifestyles are typically not understood. Heads of state, mayors and business executives act as though a competitive edge would be lost if all entities involved do not share the initial costs of developing new and sustainable paradigms and technologies. But has this ever been a winning strategy in a changing world? Who wins — the last to abandon obsolete paradigms and practices, or those who proactively take the lead in adapting to the inevitable needs of change?

Many leaders may feel intuitively that the assumption of lost competitive edge may be flawed, and that it might be a good idea instead to be a bit ahead of the game and part of the solution — to act in a spirit of enlightened self-interest. That would be the optimal approach for any business or political entity, i.e. acting as a role model for others, not only saying the right things and taking the right actions, but improving on bottom-line financial success in the process. The benefits occur at two levels:

Common good. The benefits of Sustainable Development now seem to be gradually becoming better appreciated, and lack of understanding is perhaps a declining obstacle to international agreements. As noted in other chapters of this book, there will be a shared cost to everyone if we continue to lose biodiversity, natural resources, purity of ecosystems and climate stability; the same applies to loss of trust between people and their leaders and institutions. That part of the discourse is more or less complete, especially in the European Union and China. Clearly, it is to everyone's benefit to develop technologies and policies for the inevitably and abruptly changing conditions in global markets that can already be foreseen. By the same token, it is essential to find ways of financing the transfer of clean technology to developing countries in order to help them avoid repeating our mistakes.

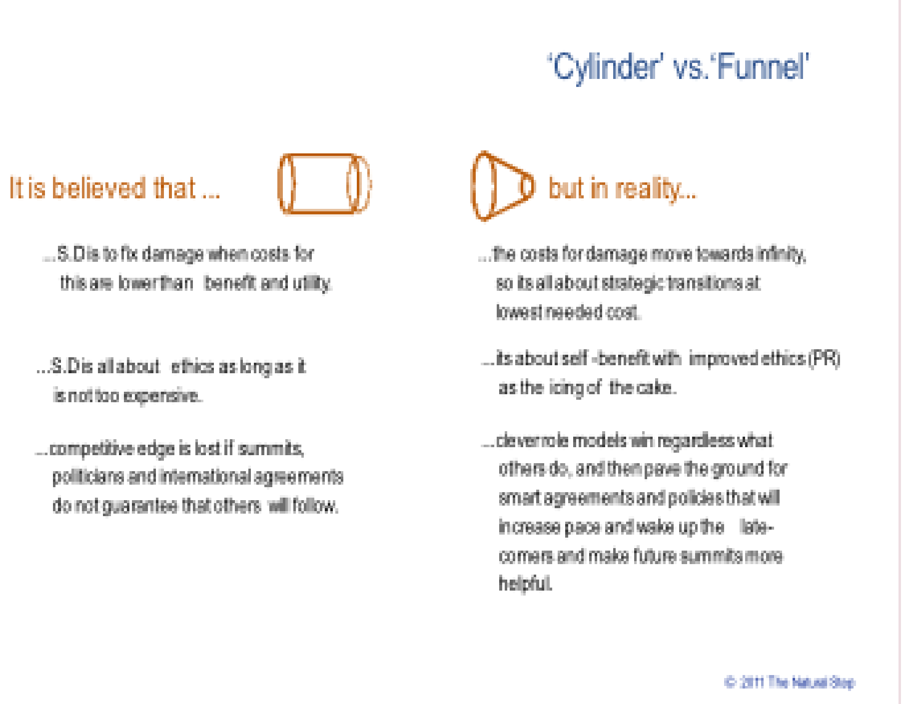
Self-interest. However, the corollary as regards self-interest is not as widely appreciated or understood. It is still the case that leaders are anxiously watching "competitors", including other nations, to ensure that the "costs" for sustainable practices are shared by all. This ignores the fact that the declining resource potential to sustain civilization means that it is a good idea for the bottom line of individual organizations or actors to be *comparatively* proactive *(2)*.

The gradual loss of social and environmental systems' capacity can be conceptualized as those systems moving deeper and deeper into a funnel whose narrowing circumference represents increasingly harsher constraints and smaller degrees of freedom. It follows that the risk of being hit financially by the narrowing walls of the funnel are relatively higher for those organizations whose contribution to the global problem is relatively large, and that the risk is accelerating for those organizations.

Any organization which requires more resources and/or creates more toxic waste per added value, or relies more on unsustainable energy systems with fuel-cycles based on larger resource flows (fossil, nuclear and biofuels), thereby becoming increasingly irrelevant in markets that evolve as a consequence of the funnel, is subject to increasingly larger financial risks than its competitors. Such organizations will increasingly, and in abrupt ways that will be increasingly difficult to foresee, experience harsh financial impacts due to the narrowing "funnel". They will encounter higher and higher relative costs for resources, waste management and insurance, as well as lost market opportunities, lower creativity, etc. The opposite is true for those organizations that are skilfully and gradually becoming part of the solution, developing their practices so that they are moving toward the opening of the funnel i.e. being ahead of the game.

This emphasis on dynamic aspects is quite different from the traditional approach of sustainable development proponents, who typically stress the public relations value of sustainable development messages for return on investments. But gains from improved PR are merely the icing on the cake. In purely financial terms it corresponds merely to how much extra customers are prepared to pay for products or services provided by "nice" organizations.

Again, the major benefits result from adapting at an early stage to future markets by providing products and services that are sustainably produced, and that will help others to be sustainable, while decreasing waste production and saving resources, the costs of which will skyrocket as the "funnel" narrows.



Unfortunately, top executives in business and government around the world (not least in the U.S. Congress) have been labouring under the flawed assumption of a "cylinder paradigm" (see figure). That view of the world, one that assumes a basically unchanged system potential, is a crucial barrier to sustainable development, and to relevant international policies and agreements at summits. It has resulted in steadily deteriorating consequences for the world at large; and what is typically neglected is that the deterioration is greatest for those individual organizations, regions and nations that are relatively larger parts of the problem. How much of the current financial problems confronting many nations are in fact due to previous decisions leading towards the narrow outlet of the funnel rather than to its opening?

For decision-makers to get stuck in the "cylinder" paradigm, or be obligated to congresses or parliaments back home that are stuck in the cylinder, is counter-productive. It backfires collectively, and it backfires in particular on those organizations and nations that hold fast to obsolete mindsets, policies, technologies, and practices. The further civilization moves into the funnel, the less "free" it will be. To both Democrats and Republicans in the U.S. for instance, the idea of freedom is a key policy component. But to neglect the consequences of the "funnel", while waiting for others to take a lead to avoid its imperatives, does not promote freedom.

Most likely, the problem is not a result of poor values. It is not about inferior intelligence. It is about incompetence in the face of a paradigm shift, even among very talented people.

Second missing element:
A framework to strategically exploit the opportunities of Sustainable Development.

The next hurdle to overcome is how to strategically manage the complex transition, i.e. to gradually prepare for new demands in the dynamically changing markets, and to avoid skyrocketing costs for poor resource management or dependencies on inherently unsustainable technical systems for energy, forestry, fisheries, agriculture, transport, etc.

From the individual organization's point of view, it is necessary to strike a balance so that the transition is, first of all, not so slow that it misses the opportunities offered by the constraining funnel-dynamics outlined above. Secondly it must not be too fast for maintaining adequate return on investment. It's about surfing on the cutting edge. To do this systematically requires a very clear view of the endgame, as well as logical guidelines to get there.

We cannot keep sidestepping the key element of strategic planning, which is to define what we want to be heading towards, the goal, i.e. towards the opening of the funnel. If sustainability is what we want, then a powerful concept of what that looks like must be on the table. Every leader responsible for investments must be able to clearly visualize sustainability, be free to improve upon it, and be engaged to "own" it as a personal and societal mission.

Further, it must be a comprehensive vision. By piling up *ad hoc* projects piecemeal, each addressing a separate sustainability thread, we have not been weaving a tapestry that can inspire people everywhere. There should be a clear differentiation between studies of the system within which we act, our definition of the objective of the planning, and the process by which we approach the objective. This has long been known to both military *(4)* and civil *(5)* strategic planners. However, the dominant planning method is "forecasting" in many decision-making settings. Forecasting extrapolates current trends into the future as means to predict and fix problems *(6-9)*. This method leads to 'path-dependencies' *(10,11)* and is insufficient to proactively plan toward a novel future objective.

A way to deal with these problems, and approach the more "military" way of heading towards clear objectives, is called "backcasting". It is generally applied in the context of scenario planning, i.e. envisioning a simplified picture of the desired future and then plan – "backwards in time" – to make it possible to get there. Scenario planning has at least four potential shortcomings *(3):* First, it may be difficult for large groups to agree on relatively detailed descriptions of a desirable distant future. Second, given technological and cultural evolution, it is unwise to lock into overly specific assumptions about the future. Third, if basic principles for sustainability are not explicit, it is difficult to know whether any given scenario is really sustainable or not.

And fourth, a lack of common principles for success also makes it difficult to relate one planning endeavour with another; the process may need to be reinvented from scratch each time.

Unifying Framework

A unifying sustainability framework is already being developed to take the above obstacles into consideration (for references see www.alliance-ssd.com). Through an ongoing consensus process between pioneering scientists of many sustainability related methods/tools and concepts *(2, 3, 6, 12-24)*, policy makers *(25-29)*, and business leaders *(30-38)* an overarching framework for strategic sustainable development is emerging. A rapidly growing group of decision-makers including hundreds of mayors, CEOs and other high-level managers across the world are using it to tackle the sustainability challenge.

The framework has been developed first in theoretical science, then improved in action research with business and municipalities. It is designed to be unifying, by placing any organization or planning endeavour (regardless of scale) within a context of global sustainability. It also has a unifying effect by making better use of various tools and concepts for sustainable development. Examples of this include ecological footprinting, management systems, life-cycle assessments, product service systems, value-chain management, modelling and simulation, development of indicators, etc.

To serve such a unifying role, the framework had to comply with the following logical sequence:

1. If you want to be strategic, you must at least know what the objective is.

2. The objective can generally not be defined in detail when it comes to complex systems. “Nobody can look into the future”. For complex endeavours in complex systems we need basic principles as constraints for the design.

3. If a set of principles is to serve as a basic and operational definition of an objective, e.g. sustainability, the principles must be:
   - Necessary, but not more than that, to avoid imposing unnecessary restrictions and to avoid confusion over elements that may be debatable.
   - Sufficient, to avoid gaps in the thinking, i.e. to allow elaboration into second and higher orders of principles from a complete base.
   - General, to be applicable in any arena, at any scale, by any member in a team and all stakeholders, regardless of field of expertise, to allow for cross-disciplinary and cross-sector collaboration.
   - Concrete, to actually guide problem solving and re-design and a step-by-step approach in real-life planning.
   - Non-overlapping, to enable comprehension and facilitate development of indicators for monitoring progress.

4. When you have defined a goal by a set of principles that fulfil such criteria, and only then, can you attain the following benefits:
   - The resource potential becomes calculable. If you do not know how to define the objective, you cannot even attempt to calculate the resource potential and

determine the degrees of freedom within the constraints of the objective. But if you do, your planning and decision-making can be supported by a scientific estimate of the resource potential (using physics and ecology, for example), rather than being based only on the constraints of current technologies and cultures.

• Trade-offs can be rationally managed. Advantages and disadvantages often relate to different variables and parameters, and come in different units. "Is it better to risk polluting with mercury than to waste energy (as in the case of low-energy light bulbs)?" Analyzing the either/or of "snapshots" in the short term has limited strategic value. However, if you know the end goal, you can evaluate various options for their capacity to serve as stepping-stones to bringing the process to a stage where the trade-off does not exist. You model optional routes to complete success, rather than evaluating snapshots at this moment as good vs. bad. If you frame a choice as between plague or cholera, you are likely to get one or the other.

• System-boundaries setting can be guided by the objectives. Science puts demands on clear and adequate boundaries when systems are studied. Sustainability discourses in an organization often come with debates around where to draw the system boundaries. Trained scholars tend to ask: "Do you mean the factory with its walls, or do you include clients… supply chains… other stakeholders… the whole world?" The last alternative is often proposed with a little smile, to demonstrate how unimaginable that would be. Yet, the truth is that, when it comes to sustainability, the whole world does count to some extent. Again, basic principles of objectives provide a way forward. You put yourself in the shoes of the CEO or project manager and ask yourself what, in the whole world, needs to be taken into account to make the respective organization/planning region/region support societal compliance with sustainability principles and you let this inform your decision on system boundaries, from geography to disciplines and beyond.

• Interdisciplinary cross-sector co-operation can be better facilitated. With a principled definition of the objective, each expert group becomes better in drawing the relevant knowledge from their respective silos. Again, each sector that needs to be taken into account to comply with the sustainability principles, and the relevant data from each following the same principles, are brought to the table.

• Unknown problems can be avoided. You can do much better than just fixing the impacts you already know. If you redesign your respective area of responsibility by basic principles that are robust for success, you will not need to learn all the detailed consequences from not doing so. For instance, you can avoid contributing to increasing zinc or silver levels in natural systems, without knowing exactly what further increases in such concentrations may imply at certain (unknown) ecotoxic thresholds — just as we should have done, for example, with CFCs from their very introduction, before we learnt what they do to the ozone layer. They are relatively very persistent and foreign to nature; so it was inevitable that they would gradually increase in concentrations in the biosphere for as long as they were used in consumer goods. It was clear from the beginning that they did not belong as such in a sustainable society.

• Selection, use and development of other concepts, methods and tools can be guided. A principled definition of the objective, fulfilling the listed criteria, makes it possible to make better use of other existing concepts, methods and tools for sustainable development, by guiding the selection of such concepts, methods and tools that are necessary for reaching the objective. The framework is applied to display the gap of an organization to comply with the basic sustainability principles, action plans are put forward to bridge it, and the appropriate tools and concepts to monitor the bridging are chosen. It can also help identify a need for development, and it can guide such development, of new concepts, methods and tools.

A framework for strategic sustainable development (FSSD) — including sustainability principles fulfilling the above criteria and thus with the ability of providing the above unique benefits (se point 4) — has been developed, scrutinized, tested in reality, refined and scrutinized again in peer-reviewed scientific consensus process that has continued for over 20 years. The FSSD helps to merge seemingly impossible-to-merge polarities into unity: big picture with small picture, long term with short term, ethics with money, and sectors and disciplines with each other.

The FSSD is structured in five levels, each of which is "cut" along the dimension of what we want in the system, i.e. the second level of the framework, the principled vision (including the sustainability principles). The five levels are described briefly as follows:

1. System. The global socio-ecological system (society within the biosphere) including laws of nature, the biogeochemical cycles of nature and, integrated in this system, the global social system, and, integrated in this system, the respective organization, region or planning activity.

2. Success. Basic principles of sustainability for all of civilization, plus the organization/region/topic reaching its goals without contributing to violation of the basic sustainability principles.

3. Strategic Guidelines. Backcasting from the above image of success, i.e. envisioning it, and then drawing the right strategic conclusions *backwards* in time from this image; logical guidelines for step-wise transitions between current challenges and future opportunities.

4. Actions. Actions put into a plan that help move the organization/region/topic towards its sustainable vision.

5. Tools. Tools used to help planners explore actions (4) to be strategic (3) to arrive at the objectives (2) within the system (1).

The current formulation of the sustainability principles (level 2) is as follows:

In the sustainable society, nature is not subject to systematically increasing
1. concentrations of substances extracted from the Earth's crust
2. concentrations of substances produced by society
3. degradation by physical means, and
4. in that society, people are not subject to conditions that systematically undermine their capacity to meet their needs.

Furthermore, an organization can 'translate' the sustainability principles to its own ultimate objectives in order to eliminate its contribution to
1. systematic increases in concentrations of substances from the Earth's crust
2. systematic increases in concentrations of substances produced by society
3. systematic physical degradation of nature, and
4. conditions that systematically undermine people's capacity to meet their needs.

Guidelines on how to put each of the basic principles into operational practice include:

1. Certain minerals that are scarce in nature can often be substituted by others that are more

abundant. And it includes using all mined materials efficiently, and systematically reducing dependence on fossil fuels and nuclear power.

2. Certain persistent and unnatural compounds can often be substituted by others that are normally abundant or break down more easily in nature. All substances produced by society should be used efficiently.

3. Resources should be drawn only from well-managed ecosystems. The most productive and efficient use of both those resources and land should be systematically pursued. Caution should be exercised in all modifications of nature, including the introduction of new species.

4. Thought should be given to how our behaviour has consequences for people, now and in the future, how it can restrict their opportunities to lead fulfilling lives. The key question is whether we would like to be subjected to the conditions we create.

The major intellectual contribution of FSSD is not only the sustainability principles; those are under continuous scrutiny and refinement in peer-review. The major contribution is the concept of "Backcasting from Principles". Since there are myriad possible sustainable designs of human society, sustainability must be defined by principles. Once that idea is understood, that is, the rationale for "Backcasting from Principles", we need principles that are necessary, sufficient, general, concrete and non-overlapping. It may be theoretically possible to create other principles that carry those characteristics; but thus far, the above-noted sustainability principles are the only ones that are designed for this purpose.

The economic imperative and the lack of clear visions

The most urgent challenge is to arrive at a critical mass of leaders in line with the above, who master the logistics of putting basic principles of sustainability on the table and then asking questions about alternative routes toward that goal, including relevant economic questions.

This is opposed to believing that fixing the myriad problems one by one, e.g. climate change, outside the realm of all the other sustainability-related problems would be a feasible solution. Or to believe that if only knowledgeable people enough meet and share knowledge, collected from their respective "silos", the big systems perspective will take care of itself. Beyond a robust framework for sustainable decision-making, large enough in time (backcasting) and scale (all of civilization) the big picture of sustainability and sustainable development has not, and will not, take care of itself.

One example of what may otherwise happen is that biofuels sourced from cropland to help curb fossil CO_2 emissions (first sustainability principle) may lead to increased food prices with serious implications for social sustainability (fourth principle), thereby delaying adequate system-level solutions to climate change. Another well-known example is the change from ammonia to CFCs to get rid of a highly irritating gas, only to discover that we had developed a life-threatening problem at the global level (violating the second sustainability principle). Or to believe that some "silver bullet" modification of the economy would possibly lead to sustainability, over and above effective leadership with its demands for adequate means, of which the economic system is but one.

The common discourse of searching for silver bullets in the economic system is in itself evidence of our era's lack of competent leadership. We have become so accustomed to the lack of clear and robust sustainability visions amongst our leaders, who have focused too strongly and too long on the short-term economy with its growth imperative that the current costs for this are already exploding, still without the right systems-derived conclusions being drawn.

"Economic growth", i.e. increased GNP, could be a nice means for achieving some worthy goal, but is certainly not a goal in itself. Scientific research and actions for completing/modifying our economic system are needed. Relevant questions to ask are: How can our present economic system be used more effectively to bridge the gap to sustainability? How could we complete/modify the economic system such that it would even more effectively empower the proactive leaders to harvest all the sustainability driven opportunities, and to wake up the latecomers?

A research alliance for strategic sustainable development

A research alliance has been established for more effective co-operation across silo-boundaries. The objective of a new research alliance will be all about inspiring change with examples set by competent and successful role models, and to help them co-operate effectively across value chains and sectors and regions and nations (see www.alliance-ssd.com).

A model for such systematic cooperation has already been tested in cooperation with five Swedish agencies in a three-year research program called Real Change (see three year report on www.alliance-ssd.org). The programme is based on all scientists and practitioners sharing the framework for the approach outlined above, the FSSD. We have seen, and published reports on, several examples of how leaders inspired by their acquired competences first begin developing step-wise industrial and governance models towards the full scope of sustainability, and then turn to politicians to suggest higher taxes (e.g. Electrolux concerning heavy metals in batteries, and OK petroleum asking for higher tax on petroleum), tougher legislation (e.g. IKEA asking for harsher legislation than the EU Reach protocol on chemicals), or develop CO2 labelling of their consumer goods and suggesting that this become the norm (e.g. Max Hamburgers).

The objective of the alliance is to scale up this model, i.e. to increase the number of leaders in business and municipalities across the globe who share the FSSD, and to empower them with the research they need to: (a) create an arena for active modelling and problem-solving across borders of disciplines, sectors, value-chains, regions and nations, (b) develop and test FSSD tools that are adequate for analyses, envisioning, planning, decision-support, monitoring, modelling, simulation and communication in relation to global sustainability, (c) create a growing database of case studies of best practices, and (d) widely disseminate the results of those efforts in order to influence change through successful role models.

It is a fantastic experience to understand basic principles for worthy goals together — across disciplinary, professional and ideological boundaries — and to realize that we need each other in order to attain those goals. To make that happen, we must first understand that unsustainability is the greatest challenge that humanity has ever faced.

Second, we must fully grasp the benefits to ourselves of being proactive. Third, the leaders of our era need to learn the competence of how to move strategically towards sustainability — step by step, while ensuring that each step moves in the right direction, can be further developed later on, and will generate enough income to sustain the transition. Effective policies, adaptations of the economic system, and constructive decisions made at summits – all these rely on a build-up of sufficient numbers of leaders with this competence in policy and business.

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THE SEARCH OF A GREEN EQUITABLE ECONOMY

Emil Salim

Global cooperation along the conventional pattern of development has failed to reach the objectives of sustainable development. New modalities through building regional blocks have emerged to search for more effective cooperation. Established since 1968, the Association of South East Asia Nations (ASEAN) has become a vibrant force of regional cooperation between Brunei Darussalam, Cambodia, Indonesia, Lao PDR, Malaysia, Myanmar, Philippines, Singapore, Thailand and Vietnam. Except for Singapore, all are developing economies. ASEAN cooperation has grown since 1968 till now into "ASEAN plus Three" (Japan, People's Republic of China and Republic of Korea) and "East Asia Summit", which includes Australia, India and New Zealand. These regional cooperative arrangements with ASEAN as its core have proven to be helpful to overcome the recent turbulent years of global crises[1]

Asia, especially China, India and ASEAN, has strategic potentials for rapid development: *first*, because of having large domestic market supported by large labor force with rising incomes; *second*, the revolution in information-communication technologies has strengthened regional integration within Asia; *third*, Asia with untapped natural resources has ample potentials for growth; *fourth*, most Asian countries still abide to a life style of "man in harmony with God the Creator, nature and society," as revealed in *"Tri Hita Karana"* (Bali) and "*Hamemayu Hayuning Bawana"* (Java). In Bhutan, His Majesty the King has set "Gross National Happiness" as the goal of development to balance tradition and modernity on the basis of resource development with environmental and cultural preservation guided by good governance; *fifth*, all Asian nations have to cope with poverty as the overiding goal of Asian development while maintaining Asian nations need to ensure the resiliency of the global common to cope with climate change and biodiversity erosion.

To accomplish this growth, Asia has to encounter the most serious challenges of poverty eradication and social inequality, which in countries with wide social diversities in ethnicity, culture, religion and race have serious implications to forge social cohesion in building one nation. During the last decade of development, income inequality as revealed by *"Gini Coefficient",* in Indonesia, has been increasing[2] Similarly disparities in economic capabilities between Asian countries have also widen.

Past processes of current industrialized countries have followed a path of natural resource exploitation along a single linear track of economic growth and have been succesful to raise material wealth to an unprecedented high level. Its negative impacts on social equity and poverty eradication however, has been huge. And most disturbing, past development models have wrecked the equilibrium of ecological systems and have eroded biological diversity combined with rising global warming that affect climate change.

Such an experience of "creative destructive" approach of development has raised the need in Asia to abandon this conventional economic single linear model of development with its over-emphasis on material wealth. And to explore different venues of growth, which are more keen to the "Asian values", to search for equilibrium in life between man with God, man with nature and man with society.

There is an implicit recognition of interdependent relationship between man, society and nature in a "web of life" created by Almighty God. It causes that in many Asian society the meaning of development has a triple content, namely material wealth creation in economic terms, enhancing social cohesion in social terms, and preserving ecological equilibrium in environmental terms.

In pursuing such a development today however, Asia is already confronted with the grim reality that the air, as the global common, is heavily polluted by "green-house gas" emissions caused by burning of fossil-fuel mainly by industrialized economies, with its wide repecussions on global warming and climate change. This will affect changing monsoons, with negative impacts on agricultural and food production. Sea level is expected to rise that raise the frequency of floods hitting coastal population. It increases weather related diseases that affect especially the vulnerable poor. Asia needs therefore to conducts its development while conserving precious natural life supporting system, to preserve biological diversity, to control "green-house gas" emissions and to strive for ecological sustainability. It is with these considerations that Asia needs to pursue a different model of development which is more green and more equitable along a triple track of economic, social and environmental development. Many models have already been developed since the concept of sustainable development was launched at the Rio-Summit, Brazil, June 1992, such as the "Framework for Strategic Sustainable Development (FSSD). It is now time, 20 years later that Asia pursues more effective policies to meet the challenges of sustainable development.

TRIPPLE FUNDAMENTALS OF ASIAN DEVELOPMENT

Based on the lessons learned from most countries in crises, Asian development must first firmly set basic *economic* fundamentals as prerequisites of development. It needs to keep up society's stable purchasing power by controling inflation, maintaining a stable national currency properly managed by a viable financial and banking institutions with foreign exchange reserves sufficient to support economic resiliency internationally, backed up by the nation's productivity level able to support its competitivenes.

Asia must also set firmly basic *social* fundamentals. Most Asian nations have to build a united nation based on diverse ethnic, cultural and religious social groupings. The enhancement of social equity and poverty eradication are most strategic to unite nation with diverse race, ethnicities and social entities. Poverty in Asia is not only valid in monetary value but also in non monetary value as revealed in terms of poor physical connectivity due to inadequate infrastructure for transportation and communication services, lack of electricity, clean drinking water, sanitation and human settlement facilities and others. Poverty is also caused by inadequate human resource development due to poor education, and by lack of accesibility to banking and other financial services. The poor requires equal access to obtain productive natural reources and effective protection under the rule of law. Without all these multi-facet shortages of accesibilties, the poor are trapped in the "holes-of-poverty". And by ignoring those poor stucked in these "holes-of-poverty", social equity will not be reached through development.[3]

Asia must also set basic *ecological* fundamentals recognizing that development is conducted in a "web of life" that interconnects man and society with natural ecological systems, which functions as life support system. In many parts of Asia, terrestrial and marine eco-systems are habitats for unique biological natural resource that are important for human's survival. Many Asian countries close to the sea are vulnerable to sea level rise and tsunamis. Surounded by the "Ring of Fire" these countries are also vulnerable to natural disasters. Asian developmental policies need therefore explicitly include these ecological considerations.

Asian Development Bank has predicted that Asia growing in its recent trajectory, could by 2050 produce more than half of global Gross Domestic Product with per capita, income potentential rise of sixfold reaching the global average similar to European levels of today. This optimistic outcome however, is fraught with multiple risks and challenges, such as growing inequality within countries, the risk of falling into the "Middle Income Trap", the impacts of global warming, climate change, erosion of biodiversity and poor governance.

Based on past economic performances of Asia since 1970, Asian Development Bank has classified Asia region's 49 economies into three groups of economic performance: (1)"High-Income developed economies", like Japan, Brunei Darussalam, Hongkong, Singapore and 3 other similar highly developed economies; (2)"Fast growing converging economies", such as People's Republic of China, India, Indonesia and 8 other economies; (3) "Slow or modest growth aspiring countries", like the Philippines, Sri Lanka and 29 other countries.

From these three groupings, the "fast growing converging countries" are producing today 52% of Asian GDP and comprises 77% of Asian population.

As a representative of the "fast growing converging countries" it is useful to explore Indonesian sub-national development as a proxy of Asian countries to pursue sustainable development.

From the macro economic point of view, the Indonesian national economic growth rate has performed well, in spite of the economic crisis of last years. From the sub-national regional development point of view however, economic growth rate is unequally distributed among the islands. The 2010 national GDP has been contributed by Java (58%), Sumatera (23.1%), Borneo (9.2%), Celebes (4.6%), Bali and the Nusa Tenggara Islands (2.7%), Moluccas and Papua (2.4%).

The archipelego of Indonesia can be divided into two major islands areas: West-Indonesia covering islands of Sumatra, Java and Bali, and East-Indonesia covering Borneo, Celebes, Nusa-Tenggara Islands, Moluccas and Papua. The distance between the most western and the most eastern tip of Indonesia is equal to London-Teheran, with wide variations in climate, ecosystems and ethnic, religious, culture of social communities.

During 1980-2010 West-Indonesia contributed approximately80% of GDP by roughly 80% numbers of Indonesia's total population. West-Indonesian economy is more advanced than East-Indonesia. Although the total numbers of population living in poverty in East-Indonesia is less than West-Indonesia, in percentage however, East-

Indonesia has much higher poor people than in West-Indonesia.This deviation of poverty percentage distribution is also vivid in many Asian countries, such as between Eastern (rich) and Western area of China (poor), between South (rich) and North India (poor), South (rich) and North (poor) Vietnam, North (rich) and South (poor) Thailand, West (rich) and East (poor) Malaysia, North (rich) and South (poor) Philippine, North (rich) and South Thailand (poor), East (poor) and West Malaysia (rich).

Regional distribution of poverty in these countries shares the same fate like in Indonesia, of suffering poor physical connectivity of sea, river and land transportation, poor accessibility to education, lack of facilities for rising human capabilities, lack of acces to financial facilities, lack of access to productive natural resources, to the rule of law and government services – are all essential prerequisites in getting the poor out of the "poverty hole"[4]

Indonesian efforts in meeting the goals of “Pro Growth, Pro Job, Pro Poor and Pro Environment” has taught us that macro-economic policies are necessary but not sufficient. The high rate of growth at the national macro-economy level may well be biased in favor of growth only for those already advanced sub-national regions and for social groupings, living mainly in Java (58%). These national macro targets must be translated into sub-national targets in terms of: (a) economic sector targets with the required job absorbtion investments; (b) taking into account its impacts on raising the income of the poor; (c) through the use of resources that sustain natural’s life support system.

Sub-national spatial planning opens the opportunity to link in real terms economic investments with job creation, poverty alleviation and sustained natural resource management. The appropriate direct investment in resource sector must not only sustain economic growth but must also affect positively social development[5]

Development at sub-national and district level can practically apply the principles of: (1) acquiring Total Factor Production, raising more output-per-unit-of-input; (2) raising value added per unit of natural (especially biologial) resources through the application of innovative technology; (3) renewable energy based decentralized grid-system and wide spread public transportation inducing th creation of better managable sized cities; (4) scientific aqua-culture fisheries; (5) hydrophonic agriculture, among others on building roofs to optimize urban space and reduce heat along the “Singaporean Model”; (6) to merge economic with social and ecological considerations in the field, through the involvement of NGO’s as revealed by development of markets for watershed services and improved livelihoods by NGO as honest broker in devising “peudo-market” to substitute for “market failures”[6]

Environmental impact analysis, the requirements of obtaining “social licenses”, especially for extractive industries, and the preferences for biological resource value added enrichment though science and technology as well as post-mining non-renewable resource recovery requirements are useful tools to link economic with social andenvironmental considerations.

To establish the link between economic macro policies and poverty alleviation, it is important to trace the impacts of these policies on components of the “poverty line” and its impact on the size of income of the poor. In this context, macro economic policies have to operate within the constraints of reducing values of components affecting the poverty line and to increase income of the poor as well.[7]

To cope with this unequal areal distribution of growth, Indonesia deems it necessary to complement the macro-model with layers of economic resource mapping, sub national poverty mapping and sustained natural resource mapping. As the *first layer,* the sub-national regional economic development plan in Indonesia is divided into six major corridors as location for major growth centers in each main islands, to be linked with networks of transportation and communication covering the whole country. This is superimposed on the *second layer,* the sub-national regional social development plan revealing the location of the poor and to strive for social coheson among communities spread over all islands, districts and provinces.A *third layer* is the sub-national regional natural resource management plan that identifies location of unique natural resources with the potentials to be developed in conjunction with the economic and poverty eradication plan.

These triple layers of sub regional national development plans provide significant inputs in drawing the “dynamic general equilibrium model”. It is also useful to convey a simplified three-factor matrix, consisting of economic growth, social development and environmental development as the main factors and to trace with relevant stakeholders the possible intensity of interdependency and linkages that this triple sector development may encounter.

Economic growth traces its impact on GDP (eonomic factor), jobs creation (social factor) and CO2 emissions (environmental factors). Social development affects growth factor through education, health, capacity building, poverty eradication (social factor) and local wisdom for resource enrichment (environmental factor). And environmental development has its impact on growth through resource efficiency (economic factor), on provision of resources for job creation (social factor) and sustaining life support system (environmental factor). Through iteration between various stakeholders in the field, the interdependency between economic, social and environment makes possible the creation of a conducive working arrangement in implementing sustainable development.

There may be no “one size fits all” type of solution. And Asian nations are not growing simultaneuosly at once but moving in waves of different stages of development. The “low income nations” can learn and avoid the mistakes made by the “middle income nations”, who can also learn from the experiences of the “high income economies.”

It is recognized that the market is not fully efficient and has a built-in failure to capture social and environmental costs and benefits. It is hence necessary to apply *social and environmental impact analysis* to recognize and to make possible internalization of social and environmental external costs into economic costs and benefits calculation. In this context the approach of *social accounting matrix* can be useful to develop multi-sector approach covering economic, social and environmental sectors within an extended input-output analysis.

To follow effectively these multiple inter-active impacts of economic, social and environmental development, it will be useful to superimpose these various development layers in geo-spatial mapping. On a sub-regional scale it is hence possible to trace the various interependent linkages between economic growth factors, with the poor in specific location with clear natural resource endowments information.

When economic development overshoots the constraints of environment, it feeds back the need to device a *different pattern* of growth. When palm-oil plantation extensification hits the arable land constraints it requires that palm-oil plantation must shift towards resources enrichment, raising the value of palm oil into new products through the use of science and technology along the vertical value chain. Products development need to be discovered to combine natural resource enrichments and raising its value added. The developments of rattan in numerous products through creative industries raise its value and by the same token *rattans* that grow on trees are saving the forests.

Bio-mimicry, the knowledge of mimicking nature and behavior of biological natural resources open the frontiers for applying nature’s behavior in raising value added through science and techology. Local ethnic communities, like in Indonesia, have and can developed local medicine, cosmetics, food, horticulture and others, can provide their ethnic local wisdom to be enhanced by modern science and technology. This approach enables shifting the orientation of development from *resource exploitation* to *resource enrichment,* while maintaining the existence of natural resources and raise its value added. Development and conservation needs not be considered as an either-or choice of policies, they can go hand in hand together through the use of science, technology and local wisdom.

Economic policies needto take explicitly poverty eradication as an inhaerent goal of its development. It can be most influential in reducing factors affecting non-income-poverty, such as improving accessibility of the poor into the market by physically build infrastructure, Improving financial infrastructure, such as village banks, cooperatives, credit unions. Raising human capacity through education, health, social insurance schemes, etc. A poverty eradication focus model of development can be both economic and socially sound.

If this model is implementable on national scale, to what extent can this be developed on regional scale of Asia? In theory the answer must be affirmative. It needs however relevant and correct data to draw the building blocks for a workable sustainable development model of Asia.

The experiences thus far have indicated that it is a cumbersome and painful process. It is however possible to draw an ASEAN Regional Sustainable Development model. And by the same token also possible for Asia, Africa, Latin America and other regions. Regional cooperation are already on the rise currently driven by the common interests to face the same economic, social and environmental challenges. In spite of the fact that global cooperation has proven not to be effective thusfar, it is perhaps more realistic to strive for regional cooperation that is driven from below by the nations' respective interests that can become the pillars for future global cooperation to meet the challenges of sustainable development in this twenty-first century.

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Seawater based Carbon sequestration- the key to climate change mitigation and adaptation

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The only hope solving CO2 problem is to use photosynthetic organisms that can use seawater. Seawater contains all the elements of Zarrouk algae medium except for Nitrogen, phosphorous and Iron. The elements of Zarrouk algae medium are required for the growth of all plants including algae, various seaweeds and giant red wood trees. Plants do not need any element not found in the Zarrouk algae medium. Exceptions to these generalisations are rare and reside only in plants that survive in extreme and rare environments. Therefore adding Nitrogen, phosphorous and iron in seawater permits the growth of plants that can grow in seawater. Mangrove trees would be grown in the Sahara desert with irrigation with seawater supplemented with Nitrogen, phosphorous and iron.

A mature mangrove forest which may only take up to 4 years to fully grow should fix up to 10 ton CO2 per hectare per year. If the entire Sahara desert were planted with mangrove forest, they should be able to fix all the CO2 produced by the activities of man. There are many deserts that can be used to grow mangrove trees, for instance the deserts in Saudi Arabia, Iraq, Iran and Mexico.

We also believe fertilising the sea bottom across coastal waters could drastically reduce world poverty. The difficulty of fertilising coastal waters is that eutrophication and the growth of toxic algae would be encouraged. Therefore, man has refrained from fertilising coastal waters. Plants beneficial to coastal waters such as eelgrass and kelp have the same nutritional requirement of red tide algae. We have devised ways of fertilising that encourage the growth of beneficial plants but not algae. We incorporate urea and di-ammonium phosphate in bricks (balls) of gypsum and small amount of cement. Pieces of iron are also distributed in the soil. These are spread over the soil of coastal waters from the balls sinking to the mud and the plants will have access to these fertiliser imbedded in the soil. In this way we have seen great increase in the growth of eel grass and kelp with no visible growth of algae. These methods can be used to regenerate lost underwater vegetation such as seagrass and enhance convenient environments. Considering the size of convenient shallow continental shelf it is not difficult to imagine the impact of such initiatives in tackling climate change mitigation and adaptation issues. In this way we strongly believe we can greatly increase the wealth of coastal countries.

Seawater irrigation in barren coastal deserts could also contribute to solve global food security challenges that are being exacerbated by the quest for alternative renewable energy resources using biofuels. Marine algae and halophytes such as salicornia bigelovii (that can be cultivated by seawater irrigation) are more sustainable biofuel sources unlike conventional crops based biofuels that compete with food, land use and pressurise other resources including freshwater, rain forests and in some cases political stability.
Likewise, promoting mangrove forest and seagrass rehabilitation in degraded mangrove forests and seagrass beds and planting in new sites can deliver greater CO2 reduction, positive ecological and sustainability outcomes in existing carbon market mechanisms.

Irreversibility of Climate Changes Due to Anthropogenic Carbon Dioxide Increases

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As the world considers next steps in the United Nations Framework Convention on Climate Change (UNFCCC) on the occasion of the 20th anniversary of the Rio conference, the breadth, depth, and role of inputs from scientific advances should be considered. The text of the convention includes Article 2, setting out the "ultimate objective" of "stabilization of greenhouse gas concentrations" that would "prevent dangerous interference with the climate system." Much has been written regarding the definition of what is dangerous, and the ways in which this represents intersection of science, policy, economics, etc. Article 3 of the convention states the Parties should be guided by factors including "threats of serious or irreversible damage."

The identification of what is likely to be irreversible is purely a scientific matter, quite different from the complexities of Article 2. In this contribution I wish to highlight the substantially improved scientific understanding of the irreversibility of changes in climate driven by anthropogenic carbon dioxide increases that has resulted from research of the past several years. I will restrict my attention here to the Earth's climate system, and will not consider human actions that may be proposed to "geoengineer" that system and reduce future warming.

As carbon dioxide increases, the Earth's energy budget is altered in such a way as to warm the planet. That warming is nearly irreversible (within about ±0.5°C) over time scales of at least a thousand years, even if emissions of carbon dioxide were to cease entirely. This result was first identified in one model of intermediate complexity (Matthews and Caldeira, 2008), subsequently confirmed in many different models of intermediate complexity (Plattner et al., 2008; Solomon et al., 2009), and has now also been simulated in a number of more detailed ocean-atmosphere general circulation models (Lowe et al., 2009; Gillett et al., 2011). This broad range of studies has demonstrated that the irreversibility of the warming due to anthropogenic increases in carbon dioxide is a fundamental property of the climate system.

The persistence of warming arises largely from ocean heat uptake (Solomon et al., 2010). The deep ocean can be thought of as a bath that can keep the entire planet warm over a long time, so the amount of anthropogenic heat transported to the deep ocean is important. In addition, carbon dioxide is a unique gas that does not have a single atmospheric decay process over time. If human emissions of carbon dioxide were to stop, the human increase in this gas to the atmosphere would decay over several different time scales, and while some added carbon would be removed by the surface ocean on a time scale of a few decades, some would remain in the atmosphere for many millennia, due again to the slow timescales of the deep ocean (Archer et al., 1997). The timescales for the removal of carbon and for the warming from the deep ocean combine to produce the near-irreversibility of the carbon dioxide-induced warming. Warming that persists for a long time will lead to a broad range of climate impacts, including rising sea levels through thermal expansion of the ocean. Persistent warming could also slowly erode the mass of the Greenland or Antarctic ice sheets. Because the warming is nearly irreversible, the anthropogenic carbon dioxide added to the atmosphere in the 21st century will set the amount of sea level that should be expected in a thousand years, even if emissions were to cease. Therefore, the decisions made at this conference will be critical for determining how much the Earth's climate system will be altered, including whether low-lying regions continue to exist in the far future on planet Earth.

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Climate change, economics and a new energy-industrial revolution Nicholas Stern[2]

Why is there a problem?

Science tells us that the problems created by the accumulation of emissions of greenhouse gases (GHGs) are potentially immense. Under anything approximating business-as-usual (BAU) there is a substantial probability (perhaps as high as 50%) that in a century or so global average temperatures could reach 5°C above the 19th century, temperatures not seen on the planet for around 30 million years (see below). The potential climate change associated with such temperatures would likely transform the lives and livelihoods of billions of people, including where hundreds of millions could live. Resulting population movements could lead to extended, severe and widespread conflict. These are the scale of the stakes that follow from the science.

The potential effects are subject to major uncertainties, they appear with long lags, and the effect of a kilogram of GHG emissions is independent of whom or where are the emitters (emissions are "public bads" in the language of economics). The combination of the magnitude, the uncertainty, the lags in the consequences, and the 'publicness' of the causes, all of which follow from the science, makes the politics and economics of policy supremely difficult.

It is hard for people to understand the scale of risk from climate change. More generally, misunderstanding of the meaning of uncertainty and how to respond are pervasive in both public and private decision-making. And the lags are compounded by ratchet effects and irreversibilities: once carbon-dioxide, the most important of the GHGs, is in the atmosphere, it is likely to stay for many decades. Further, capital equipment and infrastructure can last for a few decades, locking in high-carbon structures. Thus if decisions are postponed until the effects are very clear and the scale is demonstrated, it may be difficult, extremely costly, or impossible to extricate ourselves. Or we may have to consider very risky and badly understood alternatives such as geoengineering, which themselves may carry immense and potentially damaging consequences. The publicness of the cause may tempt people to leave action to others on the articulated grounds that each individual contribution is small or they may decline to act because they do not have confidence that others will act.

We have a problem of risk management and public action of immense importance whose scientific logic makes the formulation, decision-making, and implementation of policy extremely difficult. The policy challenge is, however, far from insoluble; indeed if it were, it is likely that the future for our children and grandchildren would be dire.

The building of the political will to take the radical decisions necessary will require the widespread and shared understanding of two fundamental propositions. So far, we as scientists, social scientists, and communicators have not made sufficient progress in explaining and demonstrating these propositions. The two propositions concern first, the scale of the risks and the urgency of action and second, the nature and attractiveness of the new energy-industrial revolution which is required. They are the subject of the second and third sections of this brief paper. The remainder of this first section is devoted

[2] I am very grateful to James Rydge for his guidance and support.

to the key elements of economic policy for the management of climate change and broader issues of sustainability beyond climate change.

Emissions of GHGs are not the only market failure relevant to the management of climate change. There are crucial market failures concerning: research, development and deployment; networks and grids; long-term risk and capital markets; property markets; and information more generally. Further, there are failures in the valuing and understanding of co-benefits of action on climate change (beyond the fundamental benefits of reducing the risks of climate change) and embedding these in policy. These arise especially around the valuation of ecosystem services and biodiversity issues which require close attention in their own right as well as being profoundly affected by action or inaction on climate change.

Each of these requires careful attention: thus the problems of market failure associated with promoting action on GHGs go beyond the fundamental market failure of the unpriced "externality" of emissions. That market failure is indeed fundamental and is a first and crucial element of any policy foundation, but policy will fail to generate the scale and urgency of the response required if it stops there. The demonstration of ideas and new techniques helps others and thus should be fostered; networks depend on interaction and require government policy to work effectively and so on. Policy in relation to each of the failures described should be based on careful analysis of the origins of the failure itself and thus how it can best be tackled.

Markets generally fail to recognise the economic and social value of much of the services of ecosystems and biodiversity which are affected by the associated activities. There is an urgent need to deepen our understanding and strengthen our practice for methods for valuing ecosystems and biodiversity. In many cases we need methods that allow us to calculate the social value of the services required, which can require some care and subtlety both in understanding the physical and biological effects of the ecosystem on say, rainfall water supply or the spread of disease or pests, as well as how to value those effects in terms of impacts on well-being. It is clear that there are great challenges in attempting to place a value on such a wide array of diverse and often only partially understood natural systems, many of which are public goods with no prices or markets. It would be a gross error, however, to suppose that because the challenges of valuation are difficult that we might as well suppose the costs are small or zero. Internalising these costs into prices or regulations would change our economic and social relationship with the natural world. Currently in all too many cases we behave as though ecosystem services and biodiversity have an economic value of zero. Consequently their critical role in maintaining our well-being, economic activity and environmental, natural and social assets, remains unaccounted for leading to severe overuse, degradation and destruction.

The benefits and uses of ecosystems and biodiversity are large and wide-ranging and are discussed elsewhere in this set of papers. Our purpose here is to emphasise the intimate links with climate change and the importance of measurement. It is a great mistake to try to separate climate change and ecosystems/biodiversity into distinct boxes and to set them as priorities one against the other. For example, the degradation of ocean ecosystems, such as the observed rapid decline in phytoplankton biomass that produces around half of all atmospheric oxygen and absorbs large amounts of CO_2 from the atmosphere, may severely weaken the carbon cycle; and the loss of forests can lead to greater flooding and a greater need for costly adaptation.

Crucial here is an urgent need to develop more widely accepted metrics for measurement of ecosystem services and biodiversity. Without these tools it will be difficult to develop more effective methods for valuing natural assets and engaging more constructively with policy makers. Costs of damage from neglect and the value of the use of these services can be examined by looking at costs of damage prevention or repairs (e.g. flood control or recovery) or at the costs of being forced to find different ways of doing things or at the potential costs of forgoing options which might become available (what do we fail to learn because we destroy the book of life before reading it?)

The implications of such degradation and loss are uncertain. There may be complex feedback loops between ecosystem services, biodiversity and climate change, and it could take a long time, perhaps millennia, for ecosystems and biodiversity to recover, if at all. The valuation of the emissions market failure, complex though it is, perhaps embodies a more straightforward set of measurement questions than those for some of our natural assets, although given how closely they are intertwined we must be wary of this type of comparison. The potential magnitude of the value of ecosystems and their intimate relationship with the effects of climate change imply that we should not make the mistake of focusing exclusively on climate change when we examine the challenges and importance of sustainability more generally.

Scale of the risks and the dangers of delay

Global GHG emissions are currently around 50 billion tonnes of carbon dioxide-equivalent (CO_2e) per annum and are growing strongly, mainly due to carbon intensive growth in the developing world. As the carbon cycle is unable to absorb all of the world's annual emissions, concentrations (stocks) of GHG emissions in the atmosphere have increased, to around 440ppm of CO_2e today. We are currently adding at a rate of around 2.5ppm per year. This rate is rising. Thus if we continue with something like BAU over the course of this century we would likely add at least 300 ppm, taking concentrations to around 750 ppm CO_2e or higher at the end of the century or early in the next. Such a path could bring somewhere in the region of a 50-50 chance of an eventual warming of more than 5^{o}C relative to mid-19th century levels[3]. A rise of 5^{o}C is immense: the planet has not seen these temperatures for more than 30 million years.

The world's current commitments to reduce emissions, as pledged in the Appendices to the Copenhagen Accord and confirmed in the Cancun agreement and recently at Durban, are consistent with at least a 3^{o}C rise (again with roughly a 50-50 chance of above or below). The world has not seen 3^{o}C for around 3 million years. *Homo sapiens* has experienced nothing like this, being present for only around 200,000-250,000 years, and our civilisations, in terms of arable farming, villages, towns and so on, have been here for only 8,000 or 9,000 years, since the emergence from the last ice age, i.e. during the

[3] See, for example, Bowen, A. & N. Ranger, 2009, *Mitigating Climate Change Through Reductions in Greenhouse Gas Emissions: The Science and Economics of Future Paths for Global Annual Emissions*, Policy Brief, December, Centre for Climate Change Economics and Policy, and Grantham Research Institute on Climate Change and the Environment.
www2.lse.ac.uk/GranthamInstitute/publications/Policy/docs/PBMitigatingBowenRangerDec09.pdf

Holocene period, during which time average temperatures have fluctuated in a quite narrow range of between ±1ºC.

Such warming would likely cause disruption on a huge scale to local habitats and climates, for example through flooding, desertification, and water scarcity. Hundreds of millions of people, perhaps billions, would probably have to move, with the associated risks of severe and extended conflict. The great advances in development of the last few decades, which have seen hundreds of millions of people in developing countries rise out of income poverty, substantial improvements in health and life expectancy, large reductions in fertility rates, and major advances in education and literacy, would likely be put at risk.

The scale of the risks and the inherent uncertainty around these projections clearly imply that policy analysis of climate change must be framed in terms of risk-management. The potential risks are huge and the associated probabilities are not small.

The uncertainty present in these projections may suggest to some that delay whilst we learn more is the best response, rather than early and strong action to reduce emissions. That would be a profound mistake. First, the flow-stock process, from emissions to increasing concentrations of GHGs in the atmosphere, with CO_2, in particular, very long-lasting in the atmosphere, implies that we have a ratchet effect. Processes to remove emissions from the atmosphere or prevent solar energy reaching the earth, known as geoengineering, are undeveloped, largely untested and are also likely to involve significant risks. Second, much of infrastructure and capital investment can result in technological "lock-in". With little action the long life times of much of the relevant high-carbon infrastructure and network investment could imply that the lock-in could last for many decades to come. Delay is clearly very dangerous: we are already at a difficult starting point in terms of concentrations of GHGs and weak action or inaction for a decade could make stabilisation of concentrations at levels that reduce the risks to acceptable levels, in particular 2^oC, very difficult.

To embark on strong action now, if the science turns out to be wrong and the risks are small, would leave us with a more energy efficient and bio-diverse economy and new technologies, even though ex post we might have wished there had been somewhat smaller investment in these areas. On the other hand, if the science turns out to be right, and we ignore the risks, we would be in an extremely difficult position from which it would be very hard to extricate ourselves. Given this logic, basic decision theory or common sense points to strong action, particularly since the science is very likely to be right. To argue for weak or delayed action involves claiming to be pretty sure the risks are small – an extraordinary position given 200 years of cumulative scientific analysis – and/or that delay has only modest downside.

The Stern Review (2006) sets out the case for early action. Strong action, starting now, with the aim of stablising GHGs concentrations, as it suggested, at between 500ppm and 550ppm would require, as it estimated, extra global investments of around 1 (-1 to 3) percent of world GDP per annum. Given rapidly rising emissions, advances in our knowledge of climate change science, which make inaction look ever more worrying, and rapid technological advance since the Stern Review, I and many others would now suggest a target of around 450ppm. That means acting more strongly, particularly given delays since 2006, and the extra global investment necessary may now be around 2% of world GDP. The Stern Review estimated that the costs and risks of unmanaged climate change may be equivalent to damages, in welfare terms, of between 5-20% of GDP per annum, averaged appropriately over space, time and possible outcomes. The likely damages from inaction do indeed appear very large but one does not have to follow the kind of approach of formal cost-benefit analysis and all the attendant particular assumptions to make the case for strong and urgent world action. As we have argued it follows from a fairly basic approach to an analysis of risk.

Size of the response and the new energy-industrial revolution

Most nations now agree, as expressed in the current global negotiations (the agreement at Cancun at the UNFCCC meeting of December 2010), that limiting the rise in global temperature to 2°C is necessary in the sense that levels above this are (sensibly) regarded as dangerous. To achieve this goal, with a 50-50 probability, global emissions would need to fall from current levels to pass well below 35 billion tonnes of CO_2e in 2030, and well below 20 billion tonnes of CO_2e in 2050. These "global constraints" should be at the heart of discussions and of the understanding of action.

Reducing absolute emissions levels by a factor of at least 2.5 in 40 years would require a reduction in emissions per unit of output by a factor of around 8 if the world economy grows over 40 years by a factor of around 3 (equivalent to an annual world GDP growth rate of around 2.8%). Emissions reductions on this scale should surely be regarded as a new energy-industrial revolution. The transition to low-carbon growth and the energy-industrial revolution represent a far more attractive path than the high-carbon, dirty and environmentally destructive path that has gone before. The transition is likely to be a period of innovation, creativity and growth, and will involve substantial investment across the economy. And low-carbon growth is likely to be cleaner, safer, quieter, more energy secure and more bio-diverse. Low-carbon growth is the genuine growth option; an attempt at high-carbon growth will self-destruct.

The study of past periods of economic/technological transformation has much to teach us here. Past industrial revolutions, e.g. steam and the railways, and much more recently the information, communications and technology (ICT) revolution, which continues, involved a transformation that saw two or more decades of strong innovation and growth, with investment flowing to those pioneer countries and businesses that showed leadership and embraced the transition. Such transformations involve periods of 'creative destruction' (in the tradition of the economist Joseph Schumpeter), where new firms and ideas drive out the old, generating a dynamic period of innovation, opportunity, employment and economic growth. Countries and states such as China, Korea, Germany, the Scandinavian countries, and California are leading the transition with the size of their low-carbon markets growing strongly. The costs of low-carbon technologies, such as solar PV and off-shore wind power have declined rapidly over recent years and similar cost reductions are expected in the future as their deployment accelerates.

The transition will require strong action to reduce emissions across all countries and all economic sectors. Energy efficiency will be central to the response, as will the introduction of new low-carbon technologies and strong and determined action to slow and halt deforestation. This will involve the implementation of transparent, long-term and credible public policies (to address the market failures) and public investments that create a positive environment for innovation and change. They should take careful account of and be integrated with policies to protect ecosystems and biodiversity.

As this transformation progresses the world must also be prepared to adapt to the climate change to which we are already committed from past and future emissions. We have to manage the unavoidable as well as avoiding the unmanageable. We are already outside the temperature range of the Holocene period when our societies developed. Another 1-1.5^{o}C which appears very likely will require major adaptation to changing weather and climate patterns. There should be close intertwining with mitigation and development – indeed it is a mistake to separate them excessively in terms of organization and implementation. Much of irrigation and water management should combine mitigation, adaptation and development, similarly buildings, city management, power and so on. The stronger the emissions reduction, the less the necessary scale of adaptation but given what we have already done and are doing on emissions the scale of adaptation will have to be large.

We are already starting to see emissions reduction policies introduced in many countries. But action will have to be stronger and more rapid, more coordinated, and extend more broadly across the many relevant market failures if the level of investment and pace of change necessary to avoid dangerous climate change are to be achieved. Delay is dangerous and now is the time to accelerate. The world economy risks a prolonged slow down as a consequence of the financial and economic crises of the last few years. Low-carbon growth is the only sound basis for a sustainable recovery.

Rio +20 : Green Economy with Inclusive Growth
M S Swaminathan

The Blue Planet Prize, first awarded at Rio-de-Janeiro in 1992 is a landmark in human efforts to keep our planet ever blue. Twenty years after Rio, we are struggling to find a pathway of development which concurrently integrates the principles of ecology, economics, equity, ethics and employment. Green Economy can be defined as, *"Enhancing economic growth in perpetuity without associated ecological and/or social harm."*

Green Economy ensures both economic growth and ecological and social sustainability. Since agriculture is the predominant occupation of a vast majority of the population of developing countries, I would like to deal with methods of achieving a paradigm shift from green to ever-green revolution. Ever-green revolution involves the enhancement of crop productivity in perpetuity without associated ecological harm. India has been chosen as a case study for understanding how green economy and inclusive growth can become mutually reinforcing.

While visiting the National Dairy Research Institute, Bangalore, on 27 June, 1927 Mahatma Gandhi wrote in the Visitors' Book "**Farmer**" against the column titled "occupation", thus emphasizing that farming is the most dignified profession of our country. He also used to emphasise that **Gram Swaraj** is the pathway to **Poorna Swaraj**. Lal Bahadur Shastri later gave the slogan "Jai Jawan, Jai Kisan" to stress that Jawans and Kisans are the two pillars of our freedom. **The extreme volatility of the price of food grains in the international market emphasizes that the future belongs to nations with grains and not guns**.

For young people to take to agriculture, farming must be both intellectually satisfying and economically rewarding. This will call for a technological and managerial upgradation of farm operations. We have to harness the best in frontier science and marry it with the best in traditional knowledge and ecological prudence. Such a blend leads to the science of ecotechnology. In addition to ecotechnology, our Agricultural Universities should become leaders in biotechnology, information technology, space technology, nuclear technology, nanotechnology, renewable energy and management technology. **The University should enable every scholar to become an entrepreneur** and help to achieve the technological transformation of agriculture.

During visit to India in 2010, US President Barack Obama pointed out that India is fortunate to have over half of its total population of 1.2 billion under the age of 30. Out of the 600 million young persons, over 60 per cent live in villages. Most of them are educated. Mahatma Gandhi considered the migration of educated youth from villages to towns and cities as the most serious form of brain drain adversely affecting rural India's development. He, therefore, stressed that we should take steps to end the divorce between intellect and labour in rural professions.

The National Commission on Farmers (2004-06)stressed the need for attracting and retaining educated youth in farming. The National Policy for Farmers, placed in Parliament in November 2007, includes the following goal — "to introduce measures which can help to attract and retain youth in farming and processing of farm products for higher value addition, by making farming intellectually stimulating and economically rewarding". **At present, we are deriving very little demographic dividend in agriculture**. On the other hand, the pressure of population on land is increasing and the average size of a farm holding is going down to below one hectare. Farmers are getting indebted and the temptation to sell prime farmland for non-farm purposes is growing. Over 45 per cent of farmers interviewed by the National Sample Survey Organisation wanted to quit farming. Under these conditions, how are we going to persuade educated youth, including farm graduates, to stay in villages and take to agriculture as a profession? How can youth earn a decent living in villages and help shape the future of our agriculture? Also, women scholars are out-numbering men in many Agricultural and Veterinary Colleges. How are we going to benefit from the large number of qualified women in crop and animal husbandry, fisheries and forestry? This will require a four-pronged strategy.

(a) Improve the productivity and profitability of small holdings through appropriate land use policies, technologies and market linkages; develop for this purpose a "4C approach", i.e., Conservation, Cultivation, Consumption and Commerce as an integrated system.
(b) Enlarge the scope for the growth of agro-processing, agro-industries and agri-business and establish a "Farm to Home" chain in production, processing and marketing.
(c) Promote opportunities for the services sector to expand in a manner that will trigger the technological and economic upgradation of farm operations.
(d) Create opportunities for women professionals to take to a career of self-employment, based on a flexi-time, flexi-duration and flexi-place approach to job creation (eg. Women's Biotechnology Park in Chennai).

A few years ago, the Government of India launched a programme to enable farm graduates to start agri-clinics and agri-business centres. This programme is yet to attract the interest of educated youth to the degree originally expected. It is hence time that the programme is restructured based on the lessons learnt. Ideally, a group of four to five farm graduates, who have specialised in agriculture, animal husbandry, fisheries, agri-business and home science, could jointly launch an agri-clinic-cum-agri-business centre in every block of the State. Agri-clinics will provide the services needed during the production phase of farming, while the agri-business centre will cater to the needs of farm families during the post-harvest phase of agriculture. Thus, farm women and men can be assisted during the entire crop cycle, starting with sowing and extending up to value addition and marketing. The multi-disciplinary expertise available within the group of young entrepreneurs will help them to serve farm families in a holistic manner. The home science graduate can pay particular attention to nutrition and food safety and processing and help a group of farm women to start a food processing park. The group should also assist farm families to achieve economy and power of scale both during the production and post-harvest phases of farming. Such as integrated centre can be named "**Agricultural Transformation Centre**".

Opportunities for young entrepreuners are several. Climate resilient agriculture is another area that needs attention. In dry farming areas, methods of rainwater harvesting and storage, aquifer recharge and watershed management as well as the improvement of soil physics, chemistry and microbiology, need to be spread widely. The cultivation of fertiliser trees which can enrich soil fertility and help to improve soil carbon sequestration and storage, can be promoted under the Green India Mission as well as the Mahatma Gandhi National Rural Employment Guarantee programme. **A few fertiliser trees, a *jal kund* (water harvesting pond) and a biogas plant in every farm will help to improve enormously the productivity and profitability of dryland farming**. In addition, they will contribute to climate change mitigation.

The "yuva kisans" or young farmers can also help women's self-help groups to manufacture and sell the biological software essential for sustainable agriculture. These will include biofertilisers, biopesticides and vermiculture. The Fisheries graduate can promote both inland and marine aquaculture, using low external input sustainable aquaculture (Leisa) techniques. Feed and seed are the important requirements for successful aquaculture and trained youth can promote their production at the local level. They can train rural families in induced breeding of fish and spread quality and food safety literacy.

Similar opportunities exist in the fields of animal husbandary. Improved technologies of small-scale poultry and dairy farming can be introduced. Codex alimentarius standards of food safety can be popularised in the case of perishable commodities. For this purpose, the young farmers should establish Gyan Chaupals or Village Knowledge Centres. Such centres will be based on the integrated use of the internet, FM Radio and mobile telephony.

In the services sector designed to meet the demand driven needs of farming families, an important one is soil and water quality testing. Young farmers can organise mobile soil-cum-water quality testing work and go from village to village in the area of their operation and issue a **Farm Health Passbook** to every family. Farm Health Passbook will contain information on soil health, water quality, and crop and animal diseases, so that the farm family has access to integrated information on all aspects of Farm Health. Very effective and reliable soil and water quality testing kits are now available. This will help rural families to utilise in an effective manner the nutrient based subsidy introduced by the government from April 1, 2010. Similarly educated youth could help rural communities to organise gene-seed-grain-water banks, thereby linking conservation, cultivation, consumption and commerce in a mutually reinforcing manner.

Young farmers can also operate climate risk management centres, which will help farmers to maximise the benefits of a good monsoon and minimise the adverse impact of unfavourable weather. Educated youth can help to introduce the benefits of information, space, nuclear, bio- and eco-technologies. Ecotechnology involves the blend of traditional wisdom and frontier technology. This is the pathway to sustainable agriculture and food security, as well as agrarian prosperity. **If educated youth choose to live in villages and launch the new agriculture movement, based on the integrated application of science and social wisdom, our untapped demographic dividend will become our greatest strength**.

Mahila Kisans (Women Famers) and Yuva Kisans (Young Farmers) will determine the future of our agrarian and rural economy. In the central budget of 2010-11, a *Mahila Kisan Shasaktikaran Pariojana* was introduced by the Finance Minister on my suggestion. The Home Science graduates participating in the Agricultural Transformation Centre movement should also organise a "Feeding Minds – First 1000 Days" programme to ensure that there is no maternal and foetal undernutrition and that every new born child has an opportunity for realising its innate genetic potential for mental and physical development. Babies with low birth weight, as a result of foetal undernutrition suffer from handicaps in brain development and cognitive ability. **Our desire to become a Knowledge and Innovation Super-power can be realised only by paying attention to nutrition and education on a life cycle basis, i.e., from conception to cremation**.

Addressing the World Climate Conference held in Geneva in 1989 on the theme, "Climate Change and Agriculture" (Swaminathan, M.S (1990) "Agriculture and food systems" in Proceedings of the Second World Climate Conference, Geneva, World Meteorological Organisation), I pointed out the serious implications of a rise of 1 to 2 deg C in mean temperature on crop productivity in South Asia and Sub-saharan Africa. An Expert Team constituted by FAO in its report submitted in September 2009, also concluded that for each 1 deg. C rise in mean temperature, wheat yield losses in India are likely to be around 6 million tonnes per year, or around $ 1.5 billion at current prices. There will be similar losses in other crops and our impoverished farmers could lose the equivalent of over US $ 20 billion in income each year. Rural women will suffer more since they look after animals, fodder, feed and water.

We are now in the midst of a steep rise in the price of essential food items like pulses, vegetables and milk. The gap between demand and supply is high in pulses, oilseeds, sugar and several vegetable crops including onion, tomato and potato. Production and market intelligence as well as a demand – supply balance based an integrated import and export policy are lacking. The absence of a farmer-centric market system aggravates both food inflation and rural poverty. FAO estimates that a primary cause for the increase in the number of hungry persons, now exceeding over a billion, is the high cost of basic staples. **India has unfortunately the unenviable reputation of being the home for the largest number of undernourished children, women and men in the world**. The task of ensuring food security will be quite formidable in an era of increasing climate risks and diminishing farm productivity.

China has already built strong defences against the adverse impact of climate change. During 2010, China produced over 500 million tonnes of food grains in a cultivated area similar to that of India. Chinese farm land is however mostly irrigated unlike us where 60% of the area still remains rainfed. Food and drinking water are the first among our hierarchical needs. Hence while assessing the common and differentiated impact of a 2 deg. rise in temperature, priority should go to agriculture and rural livelihoods.

2010 was the International Year of Biodiversity. We can classify our crops into those which are climate resilient and those which are climate sensitive. For example, wheat is a climate sensitive crop, while rice shows a wide range of adaptation in terms of growing conditions. We will have problems with reference to crops like potato since a higher temperature will render raising disease free seed potatoes in the plains of North-west India difficult. We will have to shift from planting tubers to cultivating potato from true sexual seed. The relative importance of different diseases and pests will get altered. The wheat crop may suffer more from stem rust which normally remains important only in Peninsular India. A search for new genes conferring climate resilience is therefore urgent. **We have to build gene banks for a warming India**.

Anticipatory analysis and action hold the key to climate risk management. The major components of an Action Plan for achieving a Climate Resilient National Food Security System will be the following:

- Establish in each of the 127 Agro-climatic Sub-zones, identified by the Indian Council of Agricultural Research based on cropping systems and weather patterns of the country, a **Climate Risk Management Research and Extension Centre**.
- Organise a Content Consortium for each centre consisting of experts in different fields to provide guidance on alternative cropping patterns, contingency plans and compensatory production programmes, when the area witnesses natural calamities like drought, flood, higher temperature and in case of coastal areas, a rise in sea-level.
- Establish with the help of the Indian Space Research Organisation (ISRO) a Village Resource Centre (VRC) with satellite connection at each of the 127 locations.
- Link the 127 Agro-climate Centres with the National Monsoon Mission, in order to ensure better climate, crop and market intelligence.
- Establish with the help of the Ministry of Earth Sciences and the India Meteorological Department an Agro-Meteorological Station at each Research and Extension Centre to initiate a "Weather Information for All" programme.
- Organise Seed and Grain Banks based on Computer Simulation Models of different weather probabilities and their impact on the normal crops and crop seasons of the area.
- Develop Drought and Flood Codes indicating the anticipatory steps necessary to adapt to the impact of global warming.
- Strengthen the coastal defences against rise in sea level as well as the more frequent occurrence of storms and tsunamis through the establishment of bio-shields of mangroves and non-mangrove species. Also, develop sea water farming and below sea level farming techniques. Establish major Research Centres for Sea- Water Farming and Below Sea-Level Farming. Agri-aqua farms will have to be promoted along the coast. 2010 marked the 80th anniversary of Gandhiji's salt satyagraha. Gandhiji emphasized that sea water, which forms 97% of the global water resources, is a social resource. We should have a large programme to convert sea water into fresh water through halophytes.
- Train one woman and one male member of every Panchayat to become **Climate Risk Managers**. They should become well versed in the art and science of Climate Risk Management and should help to blend traditional wisdom with modern science. The Climate Risk Managers should be supported with an internet connected Village Knowledge Centre.

A Climate Literacy Movement as well as anticipatory action to safeguard the lives and livelihoods of all living in coastal areas and islands will have to be initiated. Integrated coastal zone management procedures involving concurrent attention to both the landward and seaward site of the ocean and to coastal forestry and agro-forestry as well as capture and culture fisheries are urgently needed. A Genetic Garden for Halophytes is being established at Vedaranyam in Tamil Nadu. Biodiversity is the feedstock for a climate resilient agriculture and food security system.

Gandhiji pointed out long ago that the future of rural enterprises will depend upon our ability to marry intellect will labour. The Mahatma Gandhi National Rural Employment Guarantee Programme, which accords priority to water harvesting, aquifer recharge and watershed management, provides a unique opportunity for integrating brain and brawn. MGNREGA workers should feel that they are working for the important cause of water security. Government should institute on **“Environment Saviour Award**” to recognise and reward the best MGNREGA Team in the areas of water harvesting and Watershed Management.

The challenging economic, environmental and social problems facing our country can be solved only with the help of science and technology. Technology is the prime mover of change, as will be evident from the impact of mobile telephony in our day-to-day life. Jawaharlal Nehru with his characteristic vision, said over 60 years ago, “the future belong to science and to those who make friendship with science”. I therefore wish to cite for the benefit of young scientists a few examples from the work of the M S Swaminathan Research Foundation (MSSRF), Chennai, on the translation of vision to impact.

From Vision to Impact

During the last 21 years, the scientists and scholars of MSSRF have been working on the design and implementation of projects which could have a large extrapolation domain in respect of imparting a pro-nature, pro-poor, pro-women and pro-sustainable livelihood orientation to technology development and dissemination. I would like to talk about a few of the MSSRF initiatives, which have now become State, national and global programmes.

Mahila Kisan Sashaktikaran Pariyojana: Strengthening the role of women in agriculture

MSSRF initiated the Mahila Kisan Sashaktikaran Pariyojana in the Vidarbha region of Maharashtra in 2007 for empowering women farmers, including the widows of farmers who had committed suicide, in areas related to enhancing the productivity, profitability and sustainability of small-scale rain-fed farming. The empowerment measures incorporated access to technology, credit, inputs and market. Separately, an education programme was introduced for the children who had lost their fathers due to the agrarian crisis. Encouraged by the results of this small programme, Finance Minister Shri Pranab Mukherji included funds in the Union Budget for 2010-11 for initiating a national *Mahila Kisan Sashaktikaran Pariyojana*. The Ministry of Rural Development, Government of India, which is in charge of administering this programme, has made it an integral part of its Rural Livelihood Mission. Recently, MSSRF was invited to undertake the Mahila Kisan programme in the Wardha and Yavatmal districts of Vidarbha from 2011 to 2014. This will include both technological and organisational empowerment. It is anticipated that by 2014, a well-organised Mahila Kisan Federation with a membership of over 3000 women farmers will emerge. There is a growing feminisation of agriculture in India, and it is hoped that the Wardha-Yavatmal Mahila Kisan Federation will be a forerunner to others at State and national level, capable of securing women farmers their entitlements. In addition to technology, inputs and market, women farmers also need services like crèches and day care centres. The gender-specific needs of mahila kisans, both as women and as farmers, will have to be met, if women are to play their rightful role in India’s agricultural progress.

In addition to action at the grass-roots, MSSRF organised several consultations to prepare a draft Women Farmers' Entitlements Bill to be introduced in Parliament as a Private Member's Bill. The draft Bill is ready and is currently under circulation among women parliamentarians and gender specialists for their scrutiny and advice. It is hoped that this two pronged action — one at the village level, and the other, at the national policy level — will help the over 350 million women engaged in farming to contribute more effectively to agrarian prosperity and sustainable food security.

Pulses Villages: Bridging the demand-supply gap

To illustrate how the gap between demand and supply in pulses, which is one of the contributory factors to food inflation in the country, can be speedily bridged, MSSRF organised Pulses Villages in the Pudukottai and Ramanathapuram districts of Tamil Nadu over 15 years ago. In these Pulses Villages located in low rainfall areas, farmers undertook to harvest rainwater in farm ponds and cultivate pulses with appropriate varieties and soil fertility and agronomic management. Based on the success of this approach to accelerating progress in the production of pulses, a national programme for the establishment of Pulses Villages was recommended to the Union Finance Minister, who announced financial provision for starting 60,000 Pulses Villages in the country. A sum of Rs. 300 crore has been provided in the Union Budget for 2011-12 for organising 60,000 Pulses Villages. Already, the impact of this integrated and concentrated approach is becoming evident from the increase observed in pulses production from 14.66 million tonnes in 2009-10 to 16.51 million tonnes in 2010-11. Under the umbrella of the Pulses Village programme, special *Arhar* Villages (pigeon pea; *Cajanus cajan*) are being developed based on hybrid *arhar* strains. High-yielding *arhar* hybrids have been developed at the International Crops Research Institute for the Semi-arid Tropics (ICRISAT) located in Hyderabad. Women's Self-help Groups will be trained to become hybrid-seed producers and some of the pulses villages will be developed into Pulses Seed Villages for this purpose. This will enable the rapid spread of a yield revolution in pulses.

Nutri-cereals: Role in strengthening food security and climate-resilient farming

Almost from the early years of its establishment, MSSRF started working on underutilised or orphan crops such as a whole range of millets belonging to *Panicum, Pennisetum, Paspalum, Setaria, Eleucine* and other genera. These crops, normally classified as coarse cereals, are very nutritious and are rich both in macro- and micro nutrients. In fact, a combination of millet and *Moringa* (drumstick) provides most of the macro- and micro-nutrients needed by the body. The widespread hidden hunger now prevailing in the country as a result of a deficiency of iron, iodine, zinc, vitamin A, vitamin B_{12} and other needed micronutrients in the diet can be overcome at low cost through the consumption of millets and vegetables.

In 1992, MSSRF initiated in Kolli Hills in Tamil Nadu a programme for the revitalisation of culinary traditions involving a wide range of millets. A four-pronged strategy involving concurrent attention to conservation, cultivation, consumption and commerce was initiated. Commercialisation proved to be a trigger in the area of conservation, since farmers generally prefer to grow crops like rice, wheat or tapioca, for which there is a ready market. Similarly, in the Wayanad district of Kerala, tribal families were enabled to continue the conservation and consumption of tuber crops like *Dioscorea*. There is now a revival of interest in millets and other underutilised crops, both because of their ability to help in overcoming chronic and hidden hunger and their role in the design of climate-resilient farming systems.

In partnership with Bioversity International and the Agricultural Universities of Bangalore and Dharwar, and with financial support from the International Fund for Agricultural Development (IFAD) and the Swiss Agency for Development Cooperation (SDC), MSSRF has succeeded in introducing appropriate milling machines as well as markets for value-added products in a wide range of millets. Through several Policy Makers' Workshops and efforts in nutritional literacy, an understanding of the role of millets, tubers and other underutilised crops in improving rural nutrition and income in an era of climate change was promoted. Finance Minister Shri Pranab Mukherjee thus referred to *jowar* (sorghum), *bajra* (pearl millet), *ragi* (*Eleucine*) and minor millets as "nutri-cereals" and provided an allocation of Rs 300 crore in the Union Budget for 2011-12 for their popularisation.

In its draft National Food Security Bill, The National Advisory Council, headed by Shrimati Sonia Gandhi, has included millets among the staple grains that should be made available to food-insecure families, both in rural and urban India, at a highly concessional price through the public distribution system. If this Bill is approved and implemented, there will be a revival of interest in the cultivation and consumption of these nutrition-rich and climate-resilient crops. Agro-biodiversity hot spots can then become happy spots and will witness the dawn of an era of biohappiness where rural and tribal families are able to convert bioresources into jobs and income in an environmentally-sustainable and socially-equitable basis.

Another significant recent development is the initiation of a project on "Alleviating Poverty and Malnutrition in Agro-biodiversity Hotspots" with financial support from the Canadian International Food Security Research Fund (CIFSRF). The project is administered by the Canadian International Development Agency (CIDA) and the International Development Research Centre of Canada (IDRC) and involves partnerships with MSSRF, the University of Alberta, Canada, Bioversity International, the World Agroforestry Centre (ICRAF) and the World Food Programme (WFP). This five-year project (2011-16) will help to revitalise the *in situ* on-farm conservation traditions of tribal and rural families in the Kolli Hills area of Tamil Nadu, the Wayanad district of Kerala and the Koraput district of Orissa. MSSRF has been working with them for over 15 years. The contributions of the tribal families of Koraput have been recognised through the Equator Initiative Award at the UN Conference on Sustainable Development held at Johannesburg in 2002, and the Genome Savior Award by the Plant Variety Protection and Farmers' Rights Authority of the Government of India in 2011. Thus, two decades of research and education carried out by MSSRF in the area of orphan crops have led to important research investment and public policy initiatives at the national and international level. The expansion of the food basket by increasing the number of crops which go into the daily diet will also impart stability to food security systems.

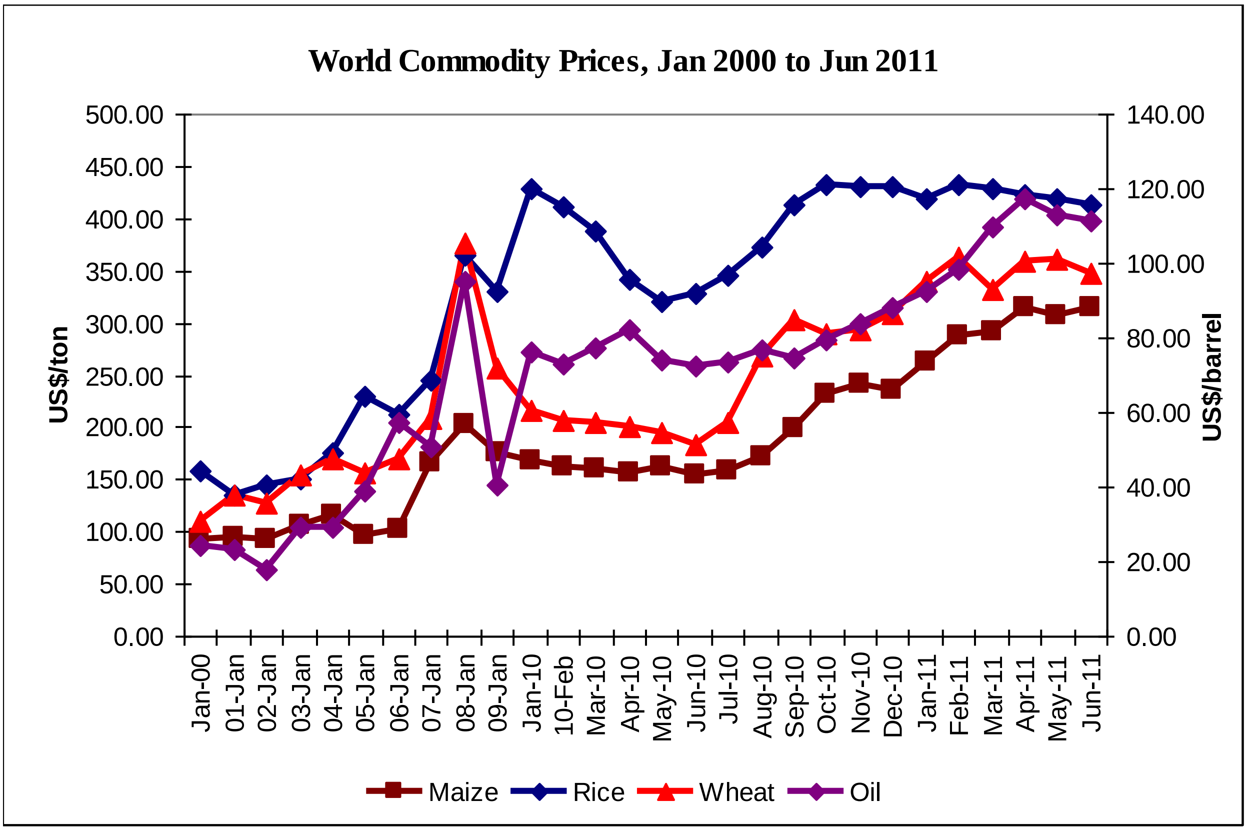
IDRC through CIFSRF is also supporting another project on strengthening rural food security through the production, processing and value-addition of nutritious millets. This project is being implemented in collaboration with McGill University, Canada and the University of Agricultural Sciences, Dharwad. MSSRF also coordinates the project activities assigned to the Himalayan Environmental Studies and Conservation Orgnisation (HESCO), Dehradun. This project capitalises on the progress earlier made by

MSSRF in these crops with support received from the International Fund for Agricultural Development and Bioversity International.

Price Volatility and Hunger: Operation 2015

Nearly 70 per cent of the income of the poor goes to buy food. High prices therefore tend to reduce food intake by the poor, thus leading to the persistence of hunger. The extent of price volatility in recent years with reference to rice, wheat, maize and oil (petroleum products) is indicated in **Figure 1**.

Figure 1



Source: FAO and US Energy Information Administration (data updated as on 29/06/2011)

The Agriculture Ministers of the G-20 Nations who met in Paris on 22-23 June 2011 have emphasised that "small scale agricultural producers represent the majority of the food insecure in developing countries. Increasing their production and income would directly improve access to food among the most vulnerable and improve supply for local and domestic markets." The Ministers also decided to establish an Agricultural Market Information System, to start with in wheat, rice, maize and soybean, in order to improve agricultural market outlook and forecasts at the national and global levels.

MSSRF's work in this area has three major dimensions. The first is the development of village-level food security systems based on community Gene, Seed, Grain and Water

Banks, which will help to store and distribute local nutritious grains like millets and pulses; the second encompasses the training of a cadre of “Community Hunger Fighters” who will be well versed in the science and art of overcoming both chronic and hidden hunger. The third dimension of MSSRF’s work in the management of price volatility is a dynamic and location-specific market information system through Gyan Chaupals or Village Knowledge Centres. Many of these centres, now operating for over 15 years, provide timely information on the monsoon and the market. The bahaviour of the monsoon and the market determines farmers’ well-being. Hence, the Gyan Chaupals operated by local women and men give priority to empowering farm women and men with timely information on weather and market behaviour. Also, they provide information on food quality and safety, as well as on the entitlements of farm households to various government schemes.

The tribal areas where MSSRF is working in Tamil Nadu, Kerala and Odisha, as well as the Vidharba region of Maharashtra, are yet to achieve the progress necessary in the reduction of hunger and poverty to reach by 2015 the target set under the first among the UN Millennium Development Goals. Therefore, MSSRF in association with other partners has launched a programme titled “Operation 2015” to help these areas achieve UNMDG 1 by 2015. The programme consists of the following features:

- Adoption of a lifecycle approach in nutrition support programmes
- Promotion of a “deliver as one” method with reference to nutrition, clean drinking water, sanitation, environmental hygiene, and primary health care
- Payment of concurrent attention to small farm productivity improvement and producer-oriented marketing
- Encouragement of a food-cum-fortification approach (especially fortification of salt with iron and iodine) in respect of fighting chronic calorie deprivation and micronutrient deficiencies
- Establishment of a cadre (at least one woman and one man in every village) trained as Climate Risk Managers and Community Hunger Fighters

Thus, MSSRF hopes that the challenge of price volatility can be fought at the local community level as well as at national and global levels.

Seawater Farming

From 1990 onwards, MSSRF has been working on integrated coastal zone management, involving concurrent attention to the seaward and landward sides of the shoreline. The aim has been to strengthen both the ecological security of coastal areas and the livelihood security of coastal communities. A Coastal Systems Research (CSR) methodology was thus developed. The research activities included the conservation and restoration of mangrove wetlands, development of a Participatory Mangrove Forest Management System, generation of awareness of the importance of mangrove and non-mangrove bioshields in reducing the fury of coastal storms and tsunamis, and the breeding of salinity-tolerant rice, pulses and other crops of importance to coastal agriculture by transferring genes for salinity tolerance from mangrove species through marker-assisted selection of recombinant DNA technology. Eighteen years of sustained research in this field led to international patents being granted for the novel genetic combinations produced by MSSRF scientists for tolerance to abiotic stresses like salinity and drought. These include:

- US patent for the Dehydrin gene from *Avicennia marina* responsible for conferring salt tolerance in plants (Dr. Ajay Parida, Dr.Preeti Mehta and Dr. Gayatri Venkataraman)
- US patent for the Glutathione-S-transferase gene from *Prosopis juliflora* conferring drought tolerance in plants (Dr. Ajay Parida and Dr. Suja George)

Three more patents — for Phytosulfokine-ά precursor sequence from *Avicienna marina* conferring stress tolerance, Antiporter gene from *Porteresia coarctata* conferring stress tolerance and Superoxidase dismutase gene for conferring abiotic stress tolerance in plants — have been filed and are in the process of being granted.

Marker-assisted breeding has resulted in developing location-specific transgenic lines in popular *indica* varieties (IR64, IR20, Ponni and ADT 43) showing 99.5 percent purity and enhanced salinity tolerance of 400mM of NaCl.

MSSRF's work led to the rehabilitation and replanting of 2400 ha of mangroves in Tamil Nadu, Andhra Pradesh and Odisha. The 2011 Coastal Regulation Zone Notification (6 January 2011) by the Government of India derives its scientific basis from MSSRF's research during the past 20 years and from two reports submitted by committees chaired by me.

On the basis of the projects proposed by MSSRF, both the Ministry of Environment and Forests (MoEF) and the Department of Science and Technology (DST) of the Government of India sanctioned funds for making effective use of seawater not only to raise bioshields, but also to initiate seawater farming projects involving integrated agro-forestry and mariculture techniques. The support from MoEF is through the Society of Integrated Coastal Management (SICOM). Seawater constitutes nearly 97 per cent of global water resources and Mahatma Gandhi rightly emphasised that it is a very important social resource. In 1930, Gandhiji's salt march was to manufacture salt in the Dandi beach in violation of the then prevailing government regulations. In the same year, C Rajagopalachari and Sardar Vedaratnam Pillai organised a salt satyagraha at Vedaranyam in Tamil Nadu. MSSRF organised a workshop at Vedaranyam on 26 December 2010 to highlight the need for undertaking the conversion of seawater into fresh water through halophytes possessing food and other economic value. The seawater farming project was included by DST under its WAR for Water Mission (Winning, Augmentation and Renovation). Steps have been initiated for establishing a genetic garden of halophytes in Vedaranyam, both to conserve the genetic resources of halophytes and to spread economically-attractive and environmentally-sustainable seawater farming methods. Under conditions of a potential rise in sea level, halophytes will become crops of the future in coastal areas.

Preserving Agricultural and Biodiversity Heritage Sites

During 2010-11, two important initiatives of MSSRF achieved wider impact. First, the Government of Tamil Nadu established genetic heritage gardens based on the description of ecosystems in the classical Sangam literature. These were set up at:

Kurinji (hill) – Yercaud, Salem District
Mullai (forest) – Sirumalai, Dindigul District

Marudham (wetland) – Maruthanallur, Kumbakonam, Thanjavur District
Neithal (coastal area) – Thirukadaiyur, Nagapattinam District
Palai (arid land) – Achadipirambu, Ramanathapuram District

In such genetic heritage gardens, the flora and fauna characteristic of each ecosystem will be preserved, which will help to spread the understanding of the value of such ecosystems. The garden in the Taramani campus of MSSRF also contains a replica of these five ecosystems described 2000 years ago.

The other important initiative relates to getting recognition for two Globally Important Agricultural Heritage Sites (GIAHS) under FAO's GIAHS programme. The project proposal seeking recognition for the Koraput rice genetic heritage site in Odisha has been prepared and forwarded to FAO. Here, tribal families have conserved a veritable mine of valuable genes in rice for hundreds of years. Recognition under FAO's GIAHS programme will help to give prestige to those conserving vanishing varieties and dying wisdom.

Another globally important agricultural heritage site is the Kuttanad area of Kerala where, for over a century, farmers have been practising farming below sea level. This system developed by farm families through practical experience involves the cultivation of rice during the monsoon season and fish during the non-rainy season. Unlike in the Netherlands, the Kuttanad farmers only put up low-cost temporary dykes. The GIAHS designation for the below sea level farming system developed by the farm families of Kuttanad will help to give recognition to the pioneers of this technology as well as refine it further. This will be particularly useful in the event of a rise in sea level as a result of global warming, as it now seems very likely. It is proposed to establish a Regional Training Centre for Below Sea Level Farming in Kuttanad, for the benefit of countries in this region — like the Maldives, Sri Lanka, Bangladesh and Thailand — which may have to undertake farming below sea level during this century.

Land and Water Care: Role of Global Soil Partnership

Since 2000, MSSRF, with financial support from the Tata Trusts and in association with the Punjab Agricultural University, Ludhiana and the Jawaharlal Nehru Krishi Vishwavidyalaya, Jabalpur, has been carrying out detailed studies on rainwater harvesting and efficient use, and watershed development and management. The emphasis in the current phase of this project is on maximising employment and income-generation opportunities for the watershed community through both on-farm and non-farm enterprises. The programme is hence known as "Bio-industrial Watershed" development. Small-scale market-linked enterprises supported by micro credit are promoted. Land-use decisions are also water-use decisions, and hence an integrated approach to land and water care is necessary to achieve an ever-green revolution leading to enhancement in productivity in perpetuity without associated ecological harm. Since land is a shrinking resource for agriculture and since there is a growing tendency to 'grab' prime farmland for non-farm purposes, such as for real estate and biofuel production, I proposed in October 2009, in my capacity as Chairman of the FAO's High Level External Committee (HLEC) on the UN Millennium Development Goals, the establishment of a Global Soil Partnership (GSP) for Food Security and Climate Change Adaptation and Mitigation. Both HLEC and the Director General of FAO have accepted this suggestion The Ministry of Environment and Forests has invited MSSRF to assist in developing strategies for sustainable food and nutrition security within the framework of a green economy. Obviously, a National Soil and Water Care programme involving all stakeholders, particularly farmers' associations, has to be an integral component of India's Rio +20 programme.

Human Resource Development

MSSRF's institution building philosophy has always been to concentrate on brains and not bricks. The sustained growth of MSSRF's Gyan Chaupal movement is a good example of the value of this approach. It is equally important that initiatives like Village Knowledge Centres are based on the principle of dynamic and location- specific information delivered in the local languages, based on a demand-driven approach. Local communities should also have a sense of ownership, as otherwise it will not be sustainable. The Jamsetji Tata National Virtual Academy, which now has nearly 1500 rural women and men as Fellows as well as 35 foreign Fellows, has become a valuable institutional device to build the self-esteem and capability of rural women and men belonging to socially- and economically-underprivileged families. In a recent review of the project, the reviewers concluded that the Academy has helped to convert ordinary people into extraordinary individuals.

Research Strategies for Social Impact

It will be clear from the foregoing that the bottom line of the programmes undertaken by MSSRF during the last twenty years has been the wellbeing of rural and tribal families in an environmentally and socially sustainable manner. Unless we place faces before figures in our programmes dealing with humanbeings, we will not know whether the steps we have taken are really beneficial to those for whose welfare they are intended. Greatest emphasis has to be placed on anticipatory research for meeting the challenges of climate change and participatory research with rural and tribal families to ensure economic, environmental and social sustainability.

Food Security in an Era of Climate Change

On the basis of a proposal I had made three years ago, the Food and Agriculture Organisation of the UN (FAO) launched a **Global Soil Partnership for Food Security and Climate Change Adaptation and Mitigation** at a Multi-stakeholder Conference held in Rome from 7 to 9 September 2011. Even with all the advances made in capture and culture fisheries, nearly 90% of human food requirements will have to come from the soil. Land is becoming a diminishing resource for agriculture, inspite of the growing understanding that the future of food security will depend upon the sustainable management of land resources as well as the conservation of prime farm land for agriculture. The National Commission on Farmers emphasized in its report submitted in 2006 the urgent need for replacing the 1894 Land Acquisition Law with a 21st century legislation that safeguards the interests of farmers and farming. Shri Jairam Ramesh is to be complemented for introducing in Parliament a National Land Acquisition and Rehabilitation and Resettlement Bill which pays attention not only to acquisition, but also to the rehabilitation and resettlement of the affected families.

A High Level Panel of Experts (HLPE) set up under my Chairmanship in 2010 by the UN Committee on Food Security (CFS) has recently submitted to CFS a Report on Land

Tenure and International Investments in Agriculture. The Report analyses the potential impact of land acquisitions, particularly in Africa, on food security. It has been estimated that about 50 to 80 million hectares of farm land in developing countries have been the subject of negotiations by international investors in recent years, two thirds of them in sub-saharan Africa, widely recognized as a "hot spot" for endemic hunger. We found little evidence that such large scale land acquisitions have helped to provide food and jobs to the local population. More than three quarters of the land deals are yet to demonstrate improvements in agricultural output. The HLPE identified several steps that governments should take towards more effective and equitable land tenure systems, starting with creating more transparent systems for registering, tracking and protecting land rights, in particular of women, tribal families and other vulnerable groups who depend on common property resources for the security of their livelihoods. The satellite and aerial imagery used in biophysical surveys are blind to the rights and institutions that govern how land is actually used on the ground. **According to the World Bank the "land rush" is not likely to slow in the future**. As a result, the landless labour population will grow leading to greater social unrest in the rural areas of developing countries.

The loss of land for food security has to be measured not only in quantitative terms, but also in respect of land use. According to the US Department of Agriculture, American farmers for the first time will harvest during 2011 more maize for ethanol production than for food or feed. In Europe, about 50% of the rapeseed crop is likely to be used for biofuel production. The plant-animal-man food chain (particularly beef and poultry products) will need several times more land for producing a calorie of meat, as compared to a calorie of cereal or vegetable.

The sudden escalation in the price of rice and wheat observed in 2008 was largely due to a steep increase in the price of fossil fuels leading to a rise in input costs. The growing diversion of farm land for fuel production in industrialized countries, increasing consumption of meat on the part of the affluent sections of the society, and loss of farm land for other uses such as roads, houses and industries are likely to lead to acute food scarcity, severe price volatility and high food inflation by the end of this decade. Several experts have pointed out that "the Arab Spring" had its genesis in high food inflation. This is why I have been stressing that the future belongs to Nations with grains and not guns.

On the basis of widespread consultations, FAO has recently prepared "Voluntary guidelines on the responsible governance of tenure of land, fisheries and forests in the context of national food security". These voluntary guidelines will be considered at the next meeting of CFS scheduled to be held in October, 2011. There are elements in these guidelines which are worthy of consideration by the Committee of Parliament, which will go into the provisions of our National Land Acquisition Bill. For example, one provision states, "subject to their national law and legislations and in accordance with national context, **States should expropriate only where rights to land (including associated buildings and other structures), fisheries or forests are required for a public purpose. In no way, should expropriation or forced eviction be made for private purposes"**. The Voluntary Guidelines also recommend that "states should ensure that women and girls have equal tenure rights and access to land, fisheries and forests, independent of their civil or marital status". Business models should involve steps which will help to generate employment opportunities and strengthen the livelihood security of the poor. “Food security first” should be the motto of our Land Acquisition Bill. Large scale investment for biofuels is a risk and must be avoided, unless there are situations, as for example in Brazil, where such investments provide a win-win situation for both food and energy security. Land tenure is key to protect land rights. Central and State Governments should have accessible systems for registering, tracking and protecting land rights, including customary rights and common property resources.

In 1981, Member-States of FAO adopted a World Soil Charter, containing a set of principles for the optimum use of world’s land resources and for the improvement of their productivity as well as their conservation for future generations. The World Soil Charter called for a commitment on the part of governments and land users to manage the land for long term advantage rather than a short term expediency.

International interest in the conservation and management of soil resources for food security and climate change adaptation and mitigation has grown in recent years, because of increasing diversion of farm land for non-farm uses. In May, 2011 a Global Soil Forum was formed at a Conference held at the Institute for Advanced Sustainability Studies, Potsdam, Germany for enhancing investment on soil resources assessment and management. The Global Soil Forum, with financial support from Germany and a few other donors, with help to identify some key technological options to enhance and sustain soil-based ecosystem services, in order to safeguard food security in the long term. To emphasise the need to conserve soil biodiversity, the European Union has prepared a comprehensive European Soil Biodiversity Atlas.

Over 15 years ago, a Global Water Partnership (GWP) was formed to stimulate attention and action at the national, regional and global levels in the area of sustainable water security. The GWP was conferred the status of an international organization by the Government of Sweden in 2002. India is also a partner in the activities of GWP. Land use decisions are also water use decisions and hence the organization of a GSP to work closely with GWP is a timely initiative. GSP will specifically address urgent problems such as soil degradation, conservation of soil biodiversity, gender and social equity, climate change and soil health management for an ever-green revolution in agriculture. GSP will provide a multi-disciplinary and multi-institutional platform for mobilizing the power of partnership in managing threats to food security arising from climate change and “land rush”.

Soil anemia also breeds human anemia. Deficiency of micronutrients in the soil results in micronutrient malnutrition in children, women and men, since the crops grown on such soils tend to be deficient in the nutrients needed to fight hidden hunger. With the addition of GSP to the already existing GWP, and with the likely adoption of the Voluntary Guidelines on the Responsible Governance of Tenure of Land and other Natural Resources, we have the global instruments which can assist nations to safeguard and strengthen the ecological foundations of sustainable agriculture and for overcoming endemic, hidden and transient hunger. What is needed is the conversion of global instruments and guidelines into socially sustainable and equitable national regulations, on the lines recommended in the HLPE report on Land Tenure. The National Land Acquisition and Rehabilitation and Resettlement Bill, now under the consideration of Parliament, has a much wider significance, than just preventing land grab. The critical role soil plays in food security and climate change adaptation and mitigation have to be widely understood.

Along with Oceans, soils offer opportunities for storing carbon. For example, it is estimated that global net primary productivity (NPP) may be about 120 Gt/c/year. Most of it is returned to the atmosphere through plant and soil respiration. If 10% of NPP can be retained in the terrestrial biosphere like wetlands and mangrove ecosystems, 12 Gt/c/year can become a part of a terrestrial carbon bank. Increasing soil C pool by 1 t/c/ha/year in the root zone can increase food production by 30 to 50 million tonnes. Thus, soil carbon banks represent a win-win situation for both food security and climate change mitigation.

Managing our soil and water resources in a sustainable and equitable manner needs a new political vision, which can be expressed through the proposed Land Acquisition Bill. 2012 marks the 20th anniversary of the Rio Earth Summit and 40th anniversary of the Stockholm Conference on the Human Environment. This will be an appropriate occasion to launch a Soil and Water Security Movement through education, social mobilization through *Gram Sabhas*, and legislation like the Land Acquisition Bill.

Mahatma Gandhi's articulation of the role of food in a humanbeing's life in his speech at Naokhali, now in Bangladesh, in 1946 is the most powerful expression of the importance of making access to food a basic human right. Gandhiji also wanted that the pathway to ending hunger should be opportunities for everyone to earn their daily bread, since the process of ending hunger should not lead to the erosion of human dignity. Unfortunately, this message was forgotten after the country became independent in 1947, and Government Departments started referring to those being provided some form of social support as "beneficiaries". The designation, "beneficiary" is also being applied to the women and men who toil for 8 hours in sun and rain under the Mahatma Gandhi National Rural Employment Guarantee Programme (MGNREGA). Sixty five years after Gandhiji's Naokhali speech, we find that India is the home for the largest number of under- and malnourished children, women and men in the world. There are more persons going to bed partially hungry now, than the entire population of India in 1947.

Recent articles of P Sainath in the Hindu (September 26 and 27, 2011) bring out vividly the extent of deprivation and destitution prevalent in rural India. Rural deprivation and agrarian distress lead to the growth of urban slums and suffering. The recent submission of the Union Planning Commission to the Supreme Court on the amount needed per day per person in urban and rural India for meeting his/her needs in the areas of nutrition, education and health care (ie. Rs.35 per person per day in Urban India and Rs.26 in rural India) has shown how divorced this important organization has become from the real life of the poor. It is in this context that there is atleast a ray of hope in the draft National Food Security Bill, 2011 placed on the website of the Ministry of Consumer Affairs, Food and Public Distribution, now the under the charge of the humanist, Prof K V Thomas. This draft will ultimately go through a Select Committee of Parliament and I hope the final version designed to make access to food a legal right, rather than remain a token of political patronage, will help to erase India's current image as the land of the malnourished. The stated aim of the draft bill is "to provide for food and nutritional security, in human life cycle approach, by ensuring access to adequate quantity of quality food at affordable prices, for people to live a life with dignity". To realize this goal, we must ensure that every child, woman and man has physical, economic and social (in terms of gender) access to balanced diet (ie, the needed calories and protein), micronutrients (iron, iodine, zinc, Vitamin A, Vitamin B 12, etc) as well as clean drinking water, sanitation and primary health care.

A life cycle approach to food security will imply attention to the nutritional needs of a humanbeing, from conception to cremation. The most vulnerable but most neglected segment is the first 1000 days in a child's life. This covers the period from conception to the first two years in the life of the child. This is the period when much of the brain development takes place. Obviously the child during this period can be reached only through the mother. The life cycle approach to food security, hence starts with pregnant women. The high incidence of children with low birth weight (ie, less than 2.5 kg. at birth) is the result of maternal and foetal under-nutrition. Such children suffer from several handicaps in later life including impaired cognitive ability. Denying a child even at birth an opportunity for the full expression of its innate genetic potential for physical and mental development is the cruelest form of inequity. The Integrated Child Development Service (ICDS) will have to be redesigned and implemented in two time frames (0-2 and 3 to 6 years).

From the view point of legal rights, the draft bill addresses only the issue of economic access to food. The other two components of food security, namely availability of food, which is a function of production, and absorption of food in the body, which is a function of clean drinking water, sanitation and primary health care, cannot easily be made into legal entitlements. To make food for all a legal right, it will be necessary to adopt a Universal Public Distribution System (PDS) with common but differentiated entitlements with reference to the cost and quantity of food grains. The draft bill adopts the nomenclature suggested by the National Advisory Council (NAC) and divides the population into *priority*, ie, those who need adequate social support, and *general*, ie those who can afford to pay a higher price for food grains. The initial prices proposed are Rs.3, 2 and 1 per kg for rice, wheat and millet respectively for the priority group, and 50% of the Minimum Support Price for the general group. In a Universal PDS system, both self selection and well defined exclusion criteria operated by elected local bodies will help to eliminate those who are not in need of social support for their daily bread. In fact, it is the general group that should be supporting financially the provision of highly subsidized food to the economically and socially under-privileged sections of our Society. In the case of the well-to-do, the aim of the Universal PDS should be to ensure physical access to food.

The widening of the food basket by including a wide range of nutri-cereals (normally referred to as "coarse cereals"), along with wheat and rice in a very important feature of the Food Security Bill. Nutri-cereals like *bajra, ragi, jowar, maize,* etc, constitute "health foods" and their inclusion in PDS, along with wheat and rice, will help to increase their production by farmers. Nutri-cereals are usually cultivated in rainfed areas and they are also more climate resilient. Hence in an era of climate change, they will play an increasingly important role in human nutrition security. During 2010-11, our farm women and men produced 86 million tonnes of wheat, 95 million tonnes of rice and 42 million tonnes of nutri-cereals or coarse cereals. The production of nutri-cereals, grown in dry farming areas, will go up if procurement and consumption go up. Thus, the addition of these grains will help to strengthen concurrently food grain availability and nutrition security.

The other components of the Bill, which do not involve legal commitments, refer to agricultural production, procurement and safe storage of grains, clean drinking water and sanitation. The temptation to provide cash instead of grains to the Priority Group should be avoided. Currency notes can be printed, but grains can be produced only by farmers, who constitute nearly two thirds of our population. Giving cash will reduce interest in procurement and safe storage. This in turn will affect production. The "Crop Holiday" declared by farmers in the East Godavari District of Andhra Pradesh is a wake up call. A Committee chaired by Dr Mohan Kanda, set up by the Government of Andhra Pradesh has pointed out that the following are some of the factors which formed the basis of the decision of a large number of farm families not to grow rice this *Kharif* season. First, the MSP presently offered does not cover the cost of production; the MSP fixed by the Government of India was Rs.1080 per quintal for common varieties, while the cost of production was Rs.1270 per quintal. Secondly, procurement is sluggish since it is largely being done by the Rice Mills. Third, late release of canal water, non-availability of credit and other essential inputs and delayed settlement of crop insurance dues are also affecting the morale and interest of farm families. Thus farmers are facing serious economic, ecological and farm management difficulties. Government should seriously consider adopting as a general policy the formula suggested by the National Commission on Farmers that MSP should be C2 plus 50% (ie, total cost of production plus 50%).

Finally, the Bill provides for the setting up of Food Security Commissions at the State and Central level. **The two essential ingredients of success in implementing the legal right to food are political will and farmers' skill**. Hence, it will be appropriate if the State level Food Security Commissions are chaired by farmers with outstanding record of successful farming. They will then help to ensure adequate food supply to feed the PDS. At the National Level, the following composition proposed by the National Commission on Farmers (NCF) in their final report submitted in October, 2006 would help to ensure adequate political will and oversight. NCF's suggestion was to set up a National Food Security and Sovereignty Board at the central level, with the Prime Minister as Chair. The other Members could be the concerned Ministers of the Central Government, Leaders of Political Parties in Parliament, a few Chief Ministers of surplus and deficit States and a few leading farmers and experts. Unless we develop and introduce methods of ensuring effective political and farmers' participation in implementing successfully the Food Security Bill, we will not be able to overcome the problems currently faced by PDS at some places arising from corruption in the distribution of entitlements.

The National Food Security Bill, 2011, provides the last chance for making a frontal attack on poverty-induced hunger and for realizing Mahatma Gandhi's desire that the God of Bread should be present in every home and hut in our country. Gandhi's message for achieving green economy with inclusive growth is the following:

"Unsustainable lifestyles and unacceptable poverty should become problems of the past, to achieve harmony with nature and with each other."

This is the pathway to achieve the goal of the Blue Planet Prize namely, to keep our planet ever blue.

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Agriculture and Food Security

Robert Watson, Strategic Director of the Tyndall Center, University of East Anglia and Chief Scientific Adviser, Defra

There is no doubt that the Earth's environment is changing on all scales from local to global, in large measure due to human activities,. The climate is warming at a rate faster than at any time during the last 10,000 years, biodiversity is being lost at an unprecedented rate, fisheries are in decline in most of the world's oceans, and soils and water are degrading in many parts of the world. Much of this environmental degradation is due to the unsustainable production and use of energy, water, food and other biological resources, but in turn environmental degradation is undermining poverty alleviation, the livelihoods of the poor, human health, and food, water and human security.

Understanding the interconnections among these environmental and development issues is essential in order to develop and implement informed cost-effective and socially acceptable policies, practices and technologies at the local, regional and global scale. Given these environmental and development issues are closely inter-linked we must ensure that policies and technologies to address one issue, positively, and not negatively, impact on other aspects of the environment and human well-being. Cost-effective and equitable approaches to address these issues exist or can be developed, but will require political will and moral leadership.

The major indirect drivers of change are primarily demographic, economic, sociopolitical, technological, and cultural. These drivers are clearly changing: the world's population and the global economy are growing, the world is becoming more interdependent, and there are major changes in information technology and biotechnology. Increases in population and wealth will place increasing demands for food, water, energy and other biological resources.

Total food production has nearly trebled since 1960, per capita production has increased by 30%, and food prices and the percent of undernourished people have fallen, but the benefits have been uneven and more than one billion people still go to bed hungry each night. Furthermore, intensive and extensive food production has caused environmental degradation.

The major challenges facing agriculture and food security, as identified by the UK Go-Science Foresight report – The Future of Food and Farming, include; (i) balancing future demand and supply sustainably; (ii) addressing the threat of future volatility in the food system; (iii) ending hunger; (iv) meeting the challenges of a low emissions world; and (v) maintaining biodiversity and ecosystem services while feeding the world.

It is clear that to achieve food security for all in an environmentally sustainable manner will require a radical redesign of the global food system. Business-as-usual will not work, and no action/change is not an option. It must also be recognized that policies and decisions outside of the food system are also critical, e.g., climate change policy.

A key issue is price volatility. Food prices have shown significant volatility during the last several years with prices for some commodities doubling for periods of time. There are a variety of reasons for these increases that are unlikely to disappear in the coming decades, possibly including: (i) poor harvests due to variable weather that could possibly be related to human-induced climate change; (ii) low food stocks; (iii) increased use of biofuels; (iv) increased demand in rapidly growing economies; (v) high energy prices, increasing the cost of mechanization and fertilizers; (vi) speculation on the commodity markets at a time of low stocks; and (vii) export bans from some large exporting countries to protect domestic supplies.

Agriculture affects the environment; for example, tillage and irrigation methods can lead to salinisation and erosion of soils, fertilizers, rice production and livestock contribute to greenhouse gas emissions, and extensification into grasslands and forests leads to loss of biodiversity at the genetic, species and landscape level. One of the key challenges facing the world is to increase agricultural productivity, while reducing its environmental footprint through sustainable intensification. As noted earlier, environmental degradation in turns reduces agricultural productivity.

The demand for food will likely double in the next 25-50 years, primarily in developing countries. Furthermore, the type and nutritional quality of food demanded will change, e.g., an increased demand for meat. We need sustained growth in the agricultural sector to feed the world, enhance rural livelihoods, and stimulate economic growth. Yet these new demands are arising at a time when – in addition to the challenges highlighted above – the world will have less labour due to disease and rural-urban migration, less water due to competition from other sectors, distorted trade policies due to OECD subsidies, land policy conflicts, loss of genetic, species, and ecosystem biodiversity, increasing levels of air and water pollution, and human-induced climate change.

We can feed the world today with affordable food while providing a viable income for the farmer, but business-as-usual will not work. Most of today's hunger problems can be addressed with the appropriate use of current technologies, particularly appropriate agro-ecological practices (e.g. no/low till, integrated pest management, and integrated natural resource management), but these must be coupled with decreased post-harvest losses.

Emerging issues such as climate change and new plant and animal pests may increase our future need for higher productivity and may require advanced biotechnologies, including genetic modification, to address future food demands. However, the risks and benefits of these technologies must be fully understood on a case-by-case basis. The public and private sectors should increase their investments in research and development, extension services, and weather and market information.

Farmers must be central to all initiatives taken; local and traditional knowledge must be integrated with agricultural knowledge, science, and technology developed in universities and government laboratories. Innovation that involves all relevant stakeholders along the complete food chain is essential. As such, we must recognize the critical role of women and empower them through education, property rights, and access to financing.

We will also need to employ global-scale policy reforms. This will include eliminating both OECD production subsidies and tariff escalation on processed products, and recognizing the special needs of the least developed countries through non-reciprocal market access. Governments should pay farmers to maintain and enhance ecosystem services, e.g., the agri-environment schemes of the EU Common Agricultural Policy.

Current and Projected State of the Global and Regional Environment: Implications for Environmental, Economic and Social Sustainability

Robert Watson, Strategic Director of the Tyndall Center, University of East Anglia and Chief Scientific Adviser, Defra

Most countries are attempting to achieve environmentally and socially sustainable economic growth, coupled with food, water, energy and human security at a time of enormous global changes, including environmental degradation at the local, regional and global scale. Key issues include climate change, loss of biodiversity and ecosystem services (provisioning, regulating, cultural and supporting), local and regional air pollution, and land and water degradation.

There is no doubt that the Earth's environment is changing on all scales from local to global, in large measure due to human activities,. The stratospheric ozone layer has been depleted, the climate is warming at a rate faster than at any time during the last 10,000 years, biodiversity is being lost at an unprecedented rate, fisheries are in decline in most of the world's oceans, air pollution is an increasing problem in and around many of the major cities in the world, large numbers of people live in water stressed or water scarce areas, and large areas of land are being degraded. Much of this environmental degradation is due to the unsustainable production and use of energy, water, food and other biological resources and is already undermining efforts to alleviate poverty and stimulate sustainable development, and worse, the future projected changes in the environment are likely to have even more severe consequences.

Understanding the interconnections among these environmental issues is essential in order to develop and implement informed cost-effective and socially acceptable policies, practices and technologies at the local, regional and global scale. Given these environmental issues are closely inter-linked we must ensure that policies and technologies to address one environmental issue, positively, and not negatively, impact on other aspects of the environment or human well-being, i.e., it is important to identify climate change response measures that are also beneficial to biodiversity and do not adversely affect biodiversity. Cost-effective and equitable approaches to address these issues exist or can be developed, but will require political will and moral leadership. While the substantial measures needed to prevent environmental degradation from undermining growth and poverty alleviation are not yet in place, a combination of technological and behavioral changes, coupled with pricing and effective policies (including regulatory policies), are needed to address these global challenges at all spatial scales, and across all sectors.

The major indirect drivers of change are primarily demographic, economic, socio-political, technological, and cultural and religious. These drivers are clearly changing: the world's population and the global economy are growing, the world is becoming more interdependent, and there are major changes in information technology and biotechnology. The world's population will likely increase from about 6.5 billion people today to 9 to10 billion people by 2050. This increase in population will be accompanied by an increase in GDP globally of a factor of 3-4, with developing countries increasingly driving global economic growth. By 2030, about half or more of the purchasing power of the global economy will stem from developing countries. Broad-based growth in developing countries sustained over the next 25 years could significantly reduce global poverty. At the same time, it must be recognized that the benefits from growth and globalization could be undermined by a failure to properly manage global environmental issues, especially mitigating and adapting to climate change, and reducing the loss of biodiversity and degradation of ecosystem services.

Climate change

There is no doubt that the composition of the atmosphere and the Earth's climate have changed since the industrial revolution predominantly due to human activities, and it is inevitable that these changes will continue regionally and globally. The atmospheric concentration of carbon dioxide has increased by over 30% since the pre-industrial era primarily due to the combustion of fossil fuels and deforestation. Global mean surface temperatures have already increased by about 0.75^{o}C, an additional 0.5^{o}C to 1.0^{o}C is inevitable due to past emissions, and are projected to increase by an additional 1.2-6.4^{o}C between 2000 and 2100, with land areas warming more than the oceans and high latitudes warming more than the tropics. Precipitation is more difficult to predict, but is likely to increase at high latitudes and in the tropics, and decrease significantly in the sub-tropics, with an increase in heavy precipitation events and a decrease in light precipitation events, leading to more floods and droughts.

Changes in temperature and precipitation are causing, and will continue to cause, other environmental changes, including, rising sea levels, retreating mountain glaciers, melting of the Greenland ice cap, shrinking Arctic Sea ice, especially in summer, increasing frequency of extreme weather events, such as heat waves, floods, and droughts, and intensification of cyclonic events, such as hurricanes in the Atlantic.

The Earth's climate, which is projected to change at a faster rate than during the last century, is projected to adversely affect freshwater, food and fiber, natural ecosystems, coastal systems and low-lying areas, human health and social systems. The impacts of climate change are likely to be extensive, primarily negative, and cut across many sectors. Temperature increases, which will increase the thermal growing season at temperate latitudes, including in the US and Europe, are likely lead to increased agricultural productivity for temperature changes below 2-3°C, but decrease with larger changes. However, agricultural productivity will likely be negatively impacted for almost any changes in climate throughout the tropics and sub-tropics, areas with high levels of hunger and malnutrition. Water quality and availability in many arid- and semi-arid regions will likely decrease, while the risk of floods and droughts in many regions of the world will increase. Vector- and water-borne diseases, heat stress mortality and extreme weather-event deaths, and threats to nutrition in developing countries, will likely increase. Millions of people could be trapped in areas of abject poverty or displaced due to sea-level rise and flooding. These climate change impacts are most likely to adversely affect populations in developing countries. Climate change, coupled with other stresses, can lead to local and regional conflict and migration depending on the social, economic, and political circumstances.

The goal, agreed at the Ministerial session of the UNFCCC in Copenhagen in 2009, and endorsed in Cancun and Durban, to limit global temperature changes to 2^{o}C above pre-industrial levels is appropriate if the most severe consequences of human-induced climate change are to be avoided, but it must be recognized to be a stretch target and, unless political will changes drastically in the near future, it will not be met. Therefore, we should be prepared to adapt to global temperature changes of 4-5^oC. In addition, we must recognize that we cannot address mitigation and adaptation separately.

Mitigating climate change will require getting the price right, an evolution of low-carbon technologies (production and use of energy), and behavior change by individuals, communities, private sector and the public sectors (see paper by Goldemberg and Lovins). In addition to transitioning to a low carbon energy system, it is critical to reduce emissions from forests by reducing forest degradation and deforestation; and sequestering carbon through reforestation; afforestation; and agroforestry, and from agricultural systems through conservation tillage, reducing emissions from the use of fertilizers, and from livestock and rice production.

In addition, to mitigating the emissions of greenhouse gases, it will be essential to adapt to climate change. However, mitigation is essential because there are physical, technological, behavioural and financial limits to the amount of adaptation that we can achieve: there are physical limits to adaptation on small, low-lying islands, technological limits to flood defences, behavioural limits to where people live and why, and financial limits for adaptation activities. The more we mitigate, the less we will have to adapt. Nevertheless, we know that adaptation is essential and must be mainstreamed, particularly into sectoral and national economic planning in developing countries due to their heightened vulnerability to climate change impacts.

Loss of biodiversity and degradation of ecosystem services

Throughout the world, biodiversity at the genetic, species and landscape level is being lost, and ecosystems and their eservices are being degraded, because of conversion of natural habitats, over-exploitation, pollution, introduction of exotic species and climate change, which are in many instances causing tremendous harm to both people and the environment. In particular, the emphasis placed on provisioning services to meet the increased need for food (crops and livestock), and to a lesser extent fibre, water and energy, for an increasing population has resulted in a decline in biodiversity and degradation of many ecosystems. The Millennium Ecosystem Assessment reported that 15 of the 24 services evaluated were in decline, 4 were improving and 5 were improving in some regions of the world and declining in other regions. The UK National Ecosystem Assessment reported that between 30-35% of the ecosystem services evaluated were in decline, 20% were improving and 45-50% were relatively stable. While climate change has not been a major cause of biodiversity loss over the last 100 years it is likely to be a major threat in all biomes during the next 100 years. Climate change will likely exacerbate biodiversity loss and adversely affect most ecological systems, especially coral reefs, mountainous and polar ecosystems, potentially resulting in significant adverse changes in ecosystem goods and services. A recent assessment estimated that every 1^oC increase in global mean surface temperature up to 5^oC would eventually result in a 10% loss of species.

Biodiversity is central to human wellbeing, providing a variety of ecosystem services that humankind relies on, including: provisioning (e.g. food, freshwater, wood and fiber, and fuel); regulating (e.g. of climate, flood, diseases); culture (e.g. aesthetic, spiritual, educational, and recreational), and supporting (e.g. nutrient cycling, soil formation, and primary production). These ecosystem services, which contribute to human wellbeing, including our security, health, social relations, and freedom of choice and action, are being diminished.

The benefits that we derive from the natural world and its constituent ecosystems are critically important to human well-being and economic prosperity, but are consistently undervalued in economic analysis and decision-making. Effective conservation and sustainable use of ecosystems are critical for human well-being and a future thriving and sustainable green economy. Failure to include the valuation of non-market values in decision making results in a less efficient resource allocation; however, a major challenge is to develop systems to appropriate the values of non-market ecosystem services to land managers.

Therefore, addressing the issue of biodiversity and ecosystem services requires changing the economic background to decision-making. There is a need to: (i) make sure that the value of all ecosystem services, not just those bought and sold in the market, are taken into account when making decisions; (ii) remove subsidies to agriculture, fisheries, and energy that cause harm to people and the environment; (iii) introduce payments to landowners in return for managing their lands in ways that protect ecosystem services, such as water quality and carbon storage, that are of value to society; and (iv) establish market mechanisms to reduce nutrient releases and carbon emissions in the most cost-effective way.

There is also a need to improve policy, planning, and management by integrating decision-making between different departments and sectors, as well as international institutions, to ensure that policies are focused on protection and sustainable use of ecosystems. It will require: (i) empowering marginalized groups to influence decisions affecting ecosystem services, and recognize in law local communities' ownership of natural resources; (ii) restoring degraded ecosystems and establishing additional protected areas, particularly in marine systems and providing greater financial and management support to those that already exist; and (iii) using all relevant forms of knowledge and information about ecosystems in decision-making, including the knowledge of local and indigenous groups.

Success will also require influencing individual and community behavior. Thus it will be critical to provide access to information about ecosystems and decisions affecting their services, provide public education on why and how to reduce consumption of threatened ecosystem services, and by establishing reliable certification systems to give people the choice to buy sustainably harvested products. It will also be important to develop and use environment-friendly technologies, thus requiring investments in agricultural science and technology aimed at increasing food production with minimal harmful trade-offs

INNOVATION AND GRASS ROOT ACTION
Bunker Roy, Barefoot College

“The Earth has enough for everyman’s need but not for one man’s greed”-Gandhi

At the outset it must be said since Rio 1992 community based groups in the poorer most inaccessible rural areas around the world have demonstrated the power of grass root action to change policy at regional and national levels. In consultation with communities innovative methods and approached have been put into practice and indeed been scaled up to cover thousands of communities living on less than $ 1/day.

But sadly they have not been collectively visible enough to catch the eyes of the policy makers and the movers and shakers who are formulating crucial and serious global policies without engaging with them at the cutting edge levels.

Without devaluing the tremendous contribution of such grass root action and while showing them the respect and recognition they deserve there is an urgency now to bring them into mainstream thinking, convey the belief all is not lost and the planet can still be saved thus exposing the doom and gloom skeptics.

New ideas have been put into practice as a result of collective grass root action that have lessons we can learn from if only we have the humility and ability to listen. Broadly speaking the lessons learnt could be summarized to mention a few:

1.There is no urban solution to basically a rural problem of poverty. The simple solutions of how the rural poor have tackled the issues of climate change already exist but we have yet to put a mechanism in place to learn from them. There are best practices with potential to scale up that needs to be highlighted.

2. The answer to addressing the critical issues of poverty and climate change is NOT Technical but Social. The problems of corruption, wastage of funds, poor technology choices, no transparency or accountability are social problems for which they are innovative solutions emerging from the grass roots. For instance the idea and practice of Public Hearings and Social Audits came from the people who were fed up with government inaction in India. Now it has been institutionalized and benefitting nearly 600,000 villages in India.

3.Grass root groups have found the value and relevance of a South-South Partnership where the use and application of traditional knowledge, village skills and practical wisdom between communities across Continents have resulted in low cost community based solutions that have had an incredible impact in improving the quality of life. Migration from the rural to the urban has decreased. Dependency on urban and technology skills have decreased.

4. The empowerment of women is the ultimate sustainable rural solution. By improving their capacity and competence to provide basic services in the rural areas(for instance train them to be solar engineers) they could be the new role models that the world is looking for.

5. The long term answer is NOT a Centralised system but a demystified and decentralized system where the management, control and ownership of the technology lies in the hands of the communities themselves and not dependent on paper qualified professionals from outside the villages.

6. Listen and learn how poor communities all over the world see the problems of energy, water, food and livelihoods as inter-dependent and integrated as part of a living eco system and not viewed separately.

Without using the written or spoken word and only through sign language 300 illiterate rural grandmothers between ages 35 to 50 have been trained as solar engineers in 6 months have solar electrified over 15,000 houses reaching more than 100 villages covering the whole continent of Africa(28 countries in 5 years) at a total cost of $ 2.5 million. This is what is spent on 1 Millennium Village in Africa.

If a grandmother is selected from any part of the developing world the Government of India pays the air fare and 6 months training costs in India. The funds for the hardware has been provided by GEF Small Grants Programme, UNWOMEN, UNESCO, Skoll Foundation. Individual philanthropists.

The traditional and peoples practice of collecting rain water for drinking and irrigation needs to be revived. It has been used tested and proved over hundreds of years. But ever since the “paper” qualified engineer turned up on the scene this practice has been devalued and the technology solution of exploiting(thus abusing)ground water through powerful polluting drilling rigs installing deep well pumps have seriously depleted groundwater. Thousands of open wells for irrigation and hand pumps for drinking water have gone dry.

What needs to be done on a war footing is to collect water from the roofs of public buildings(schools, dispensaries etc) into underground tanksand this could be used for drinking water and sanitation.

Small dams need to be constructed to allow for ground water recharge thus revitalizing the dry open wells and hand pumps. Reclaiming collective assets worth millions of dollars.

What is needed is simple practical solutions multiplied over a large scale all over the world that does not need much money but the long term impact will be tremendous.

Adapting to climate change
Saleem Huq, International Institute of Environment and Development

Climate change impacts are already occurring and further impacts are inevitable. While some of the impacts in certain parts of the world may have short term benefits, most of the impacts, particularly in poorer countries in Asia, Africa and Latin America will damage poor countries and poor communities.

All countries, both developed as well as developing, will need to adapt to the impacts of climate change over the next few decades. However, there are limits to how effectively countries and communities can adapt. Adaptation becomes more difficult if temperatures rise more than 2 degrees, which is of significant concern since the world is on a pathway to becoming 3-5 degrees warmer than pre-industrial.

The good news is that many countries, starting with the least developed countries, have already begun to take steps to plan adaptation to climate change and try to mainstream them into development planning, e.g. Bangladesh which has developed a long-term Climate Change Strategy and Action Plan and has already begun to implement it.

All countries, both rich as well as poor, will need to develop their own national adaptation plans. While many adaptation actions will be country and location specific, nevertheless there are opportunities for learning lessons across countries, south-south as well as south-north.

The most effective adaptation strategy is mitigation in order to limit the magnitude of climate change, especially given there are significant physical, financial, technological and behavioural limits to adaptation.

Adaptation is essential

For the next two, or even three, decades the amount of warming of nearly 1 degree Centigrade due to human induced climate change is now inevitable due to past emissions of greenhouse gases and the time lags in the atmospheric system. This is now unavoidable and no amount of mitigation of greenhouse gases will prevent this. Hence the world can expect a certain amount of climate change impacts and all countries will need to deal with them. While there may be some beneficial impacts in some parts of the world, most of the impacts will be adverse and will fall disproportionately on poorer countries and poor communities (in all countries).

Therefore adapting to climate change needs to be a part of all national development plans, both in developing as well as developed countries, and also at the global level. As the poorer countries, already have difficulty coping with the current climate impacts, they will need financial and technical assistance to be able to adapt to the additional burden of climate change impacts.

While most of the adaptation actions will be at the local and nation al level, there are few that transcend national boundaries, for which global solutions will need to be developed. These include transboundary water systems which will possibly dry up as well as transboundary migration of populations beyond their national borders due to environmental degradation in their current locations.

Limits to adaptation

While adaptation to climate change is now unavoidable, there are limits to how much can be achieved. Unlike mitigation, which avoids climate change (a tonne of greenhouse gas not emitted means that the impacts of that tonne have been reduced to zero), with adaptation, while it can bring down the amount of impacts does not bring them down to zero. There are always going to be some residual impacts even after adaptation.

Furthermore, as the temperatures rises above two degrees to three and even four degrees Centigrade the residual impacts will become bigger and bigger. In other words there are limits to how effective adaptation can be at higher temperatures. Hence mitigation remains the best form of adaptation and must remain the first strategy to tackle climate change.

This is significant as the current emission trajectory will lead to a 3.5 to 4 degree Centigrade rise in global temperatures.

Least developed countries taking the lead

The good news is that many countries have already taken significant steps to start planning and implementing adaptation to climate change. The first countries to have carried out a National Adaptation Programme of Action (NAPA) have been the forty-eight least developed countries (LDCs) who were the first countries in the world to do so. These exercises identified the vulnerable sectors and communities and prioritised urgent and immediate adaptation actions. Many of them have gone on to implement many of the adaptation actions.

A few of the countries have gone beyond the NAPAs to develop longer term strategic climate change plans. One such country is Bangladesh which was one of the first LDCs to develop its NAPA and then went beyond it to develop a longer-term Climate Change Strategy and Action Plan which the government of Bangladesh is now implementing with a Climate Change Trust Fund of 300 million US Dollars of its own money.

Another example is Nepal which was one of the last LDCs to finish its NAPA, but was able to gain from the experience of other LDCs, and have developed an adaptation plan that allocated 80% of all climate change resources to the most vulnerable communities, to use themselves through the development of Local Adaptation Plans of Action (LAPAs).

International cooperation on adaptation

While most of the adaptation plans and actions will remain location and country specific, nevertheless there are many lessons that can be shared across countries. One of the first lessons about adaptation planning that has come out of the NAPA by nearly fifty LDCs, is that adaptation is less about making technical interventions and much more about societal and institutional capacities to deal with a changing environment. These institutional issues are similar in all countries, regardless of level of development hence what the poorest countries are learning can be applicable even in the rich countries.

Thus when it comes to adaptation to climate change, international cooperation and lesson sharing across countries is likely to be most likely south-to-south as well as south-to-north.

Focus on most vulnerable countries and communities

While the impacts of climate change will affect all countries sooner or later, those impacted first are the poorest countries and communities. Hence financial and technical assistance from the global level need to focus on assisting the efforts of the poorest countries and poorest communities in all countries (even the rich countries).

This requires working with those communities and enhancing their adaptive capacities as well as empowering tem to adapt themselves. This will mean supporting the growing numbers of communities around the world who are already practicing Community Based Adaptation to climate change.

Conclusion

In the end the most effective adaptation strategy is mitigation in order to limit the magnitude of climate change, especially given there are significant physical, financial, technological and behavioural limits to adaptation

The Importance of Good Governance

Camilla Toulmin, International Institute of Environment and Development

There are serious shortcomings in the decision-making systems on which we rely in government, business, and society more broadly. Building more effective governance and institutions is central to achieving more sustainable patterns of development – globally, nationally, and locally. Yet the central importance of governance issues is often neglected. This is partly due to the differing definitions used of "governance", and the intangibility of these norms and structures. An analysis of governance needs to ask: How, where and by whom are decisions made? Who gets to write the rules by which decisions are made? What gets decided and who gets what? How are people able to monitor how decisions are made? Governance is more than just a question of the institutional architecture, and how different elements relate to each other. For each of these elements, there are issues of credibility and legitimacy concerning the processes by which rules are made and re-made, interpreted and re-interpreted.

The rules and institutions for decision-making are influenced by vested interests, yet each interest has very different access to the process. For example, lobbyists spend a large amount of time and money trying to influence the way that elected representatives vote in many legislatures. Governance must also be seen in a dynamic fashion, involving an ongoing process of negotiation between different interests, played out in a series of arenas and institutions, nationally and globally. The legitimacy of technical evidence marshaled within such negotiations is critical and often contested, as has been evident in the climate change talks.

Governance involves much more than the ensemble of government frameworks, and includes multiple and overlapping governance systems, with the private sector, civil society, sub-national and local levels all engaged in making decisions in relation to their interests. There is a widespread assumption that governments are the central actors in governance, but a deeper look shows that government is often an instrument both of its own and others' interests, rather than playing the role of objective arbiter. The existence of plural and overlapping systems of governance can lead to contest between competing structures, and institutional "shopping".

Transformation of governance systems needs to accommodate a far broader range of interests (both poor and rich, young and old, those of the future as well as of the present), and ensure access to better information as regards the likely impacts of different pathways taken. Subsidiarity should be a central principle for sustainable development governance, to assure that decisions over resource allocation and use are made at the correct level by the right authority for the resource in question. Shifting power down to lower levels is vital, to bring in local knowledge, increase accessibility to decision-making, and get a broader range of voices into the debate. Innovations are needed to ensure that the marginalized have a voice that counts, through for example coalition building, organization and mobilization to make those voices heard more effectively. Public hearings, social audits, and participatory budgeting can bring the voices of marginalized groups to the fore.

At national level, effective changes in governance require a transparent means for people to hold those in power to account. Parliamentary and press oversight are key alongside freedom of information, but in many countries, these mechanisms remain weak. The accountability challenge is compounded by alliances cemented between government officials and powerful individuals and corporations. The international nature of much of the corporate sector involved in natural resource use means that even the governments of the countries in which they are headquartered have limited ability to influence their actions and decisions.

Globally, we urgently need better means to agree and implement measures to achieve our collective goals. Given the large numbers of states and their separate jurisdictions, more effective and far-reaching international institutions and rules are necessary, yet nation states are unwilling to submit to collective agreements which constrain their freedom of manoeuvre. Equally, greater control over international financial and corporate actors is needed, to reduce their ability to escape fiscal and other responsibilities through freedom of movement between different jurisdictions. Global efforts to address climate change have resulted in a complex international governance architecture, which has largely replicated geopolitical and global economic power relations among nations. There has been little room in these evolving governance arrangements for the priorities of weaker countries and marginalized people to be heard and addressed. Growing reliance on the G20 as a forum for sorting out global problems runs the risk of disempowering the large number of smaller, less economically prominent nations.

Development policymakers and practitioners are increasingly turning to markets as a tool for addressing sustainability and alleviating poverty. Yet market governance also offers major challenges. Markets and business have the potential to generate new and decent jobs, and use natural assets more sustainably. But market signals and incentives must be set in ways that mobilise businesses and others to support sustainable growth, to create the 'missing markets' for environmental goods and services and to ensure more equitable participation. They also need government to assure the institutional and regulatory infrastructure that allows markets to operate effectively, such as support to property rights. Another worry concerns the lack of accountability of market chains and transnational operations, which can evade national laws and regulatory frameworks. A third relates to finding the incentives for environmentally sustainable practices that pertain to the mainstream, as opposed to 'niche' sustainable businesses.

Governance failures also occur because decisions are being made in sectoral compartments, with environmental, social and economic dimensions being addressed by separate competing structures. At government level, this means moving sustainable development concerns from beyond Ministries of Environment to focus on Ministries of Finance, Planning, Health, and Education as entry points. Cross-ministerial buy-in demands that sustainability be led by the head of government, and that environmental and social valuations are brought into decision-making. In business, environment and social issues need to move from CSR departments into core business operations, with companies required to report in terms of the triple bottom line. In society more generally, groups such as NGOs need to work together to bridge divides, and recognize both common interests, but also trade-offs between different objectives.

Biodiversity: Conserving the foundation of sustainable development

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Biodiversity – the variety of species, genes, ecosystems, and ecological processes that make up life on Earth – is integral to the fabric of all the world's cultures. Biodiversity underpins ecosystem services, sustains humanity, and is foundational to the resilience of life on Earth. It is also the source of benefits, often immeasurable, that sustain human lives, livelihoods, communities, and economies. The economic value of biodiversity is enormous. Yet we are at risk of losing much of biodiversity and the benefits it provides humanity. As humankind's footprint has swelled, unsustainable use of land, ocean, and freshwater resources has produced extraordinary global changes, from habitat loss and invasive species to anthropogenic climate change. Threats to terrestrial and aquatic biodiversity are diverse, persistent, and, in some cases, increasing. Action is critical: without it, current high rates of species loss are projected to continue what is becoming the 6th mass extinction event in Earth's history, while losses in 2/3 of ecosystem services already will soon amount to an estimated \$500 billion annually in lost benefits. But action is also possible: biodiversity losses can be stopped and reversed by concerted planning based on adequate data, a well-managed protected areas network, and transformational shifts in the public and private sector that value the role of natural capital in economic development.

Introduction. *Biodiversity, the variability among living organisms and ecosystems, is foundational to the resilience of life on Earth.*

Biodiversity, or biological diversity, is defined by the Convention on Biological Diversity (CBD) as 'the variability among living organisms', including 'diversity within species, between species and of ecosystems'[4]. Biodiversity often serves as a measure of the health of biological systems. Ecosystems are distinguished from each other by the composition and interactions of species within and between these systems. A healthy population of organisms, community of species, or ecosystem is able to recover from disturbance and threat, provides sufficient opportunity for feeding, growth and reproduction. Loss of species, declining populations or size of organisms, and changing dynamics between species can represent reduced health of the system. Within species, genetic diversity influences the ability to respond to threats, adapt to a changing environment, and evolve in the face of long-term changes.

Benefits of biodiversity. *Biodiversity underpins ecosystem services and sustains humanity; its economic value is enormous; biodiversity is the most fundamental element of green economic development.*

[4] http://www.cbd.int/doc/legal/cbd-en.pdf

Biodiversity is the source of the benefits, or ecosystem services, that humans receive from nature. It is thus a fundamental component of natural capital, which along with produced capital and human capital, underpins human communities and economies. Fish, for example, are among the most important food sources (FAO Fisheries and Aquaculture Department 2010) and the fishing industry contributes USD 225-240 billion/yr to the global economy (Dyck & Sumaila 2010). Plant pollination by insect, bird, and other animal pollinators is essential for about one in three food crops worldwide (Daily & Ellison 2002). Species are a storehouse of genetic material that has provided more than half of all commercial medicines – even more in developing nations (Chivian & Bernstein 2008) – and may harbor undiscovered cures for cancer, malaria, or the next infectious disease to emerge. Natural patterns and processes inspire a vast array of novel materials, energy sources, technological devices, and other innovations (Benyus 2009). Biodiversity loss has been compared to burning down all the world's libraries with the content of 90% of the books unknown. As species vanish, so too do the source of our crops and the genes we use to improve agricultural resilience, the inspiration for products, and the structure and function of the ecosystems that support human communities and all life on Earth (McNeely et al. 2009). Beyond material goods and livelihoods, biodiversity contributes to security, resiliency, and freedom of choices and actions (Millennium Ecosystem Assessment 2005). Species extinctions inflict cultural, spiritual, and moral costs – perhaps less tangible, but no less important, than direct economic costs. All societies value plants and animals for their own sake, and wild species are integral to the fabric of all of the world's cultures (Wilson 1984).

Threats. *Biodiversity is being lost at alarming rates; threats to terrestrial and aquatic biodiversity are diverse, persistent, and, in some cases, increasing.*

Earth's species and the benefits they provide humanity are in trouble. As human populations have increased from a few hundred million 1000 years ago to 7 billion in 2011, unsustainable consumption in developed nations and dire poverty in developing countries are together destroying the natural world. Agricultural expansion, urbanization, and industrial development have spread significantly through wild lands, overexploitation threatens the viability of populations, invasive species degrade and alter the structure of ecosystems, chemical pollution impairs biochemical processes in the soil, air, and water, and rapidly spreading diseases put entire branches of the tree of life at risk (Millennium Ecosystem Assessment 2005; Vitousek et al. 1997; Wake & Vredenburg 2008). The higher density of people in some areas puts particular strain on ecosystems to provide food and fuel and also to clean the water, break down the waste and control the spread of disease.

Extinction, irreversible, may be the gravest consequence of the biodiversity crisis. Human activities have elevated the rate of species extinctions to a thousand or more times the background rate (Pimm et al. 1995). Habitat destruction, which even in an era of climate change may remain the dominant threat to biodiversity (Sala et al. 2000), is driving extinctions around the world (Brooks et al. 2002). Growing impacts of climate change will be felt worldwide, as modified precipitation and temperature, rising oceans, and climate-driven habitat loss threaten a substantial fraction of species with extinction (Thomas et al. 2004) and drive desperate human populations to additional environmental degradation (Turner et al. 2010). Other threats, even if less widespread, are felt severely in particular regions. Introduced predators have devastated island biodiversity, where species evolved in the absence of domestic cats and rats and other invasive predators

(Steadman 1995). Introduced plants are having massive impacts on hydrology and biodiversity in many ecosystems, particularly those having Mediterranean vegetation (Groves & di Castri 1991). Exploitation for macro- and micronutrients (e.g., bushmeat), for medicine, and for the pet trade threatens species in several regions, particularly in sub-Saharan Africa and Southeast Asia (van Dijk et al. 2000). Chitridiomycosis, a fungal disease, is recognized as dominant driver of amphibian decline and extinction worldwide (Stuart et al. 2004; Wake & Vredenburg 2008).

There are multiple indications of continuing decline in biodiversity in all three of its components – ecosystems, species and genes. The Millennium Ecosystem Assessment (2005) concluded that 60% of ecosystem services worldwide have become degraded in the past 50 years, primarily due to unsustainable use of land, freshwater and ocean resources. Most major habitats have declined in this time and at the species level, The IUCN Red List of Threatened Species (IUCN 2008) tells us that 22% of the world's mammals are threatened and at risk of extinction worldwide, as well as nearly one third of amphibians, one in eight birds, and 28% of conifers.

Marine ecosystems and species have experienced substantial declines in the last several decades as well (Butchart et al. 2010), with populations of exploited marine species declining an average 84% in abundance (Lotze & Worm 2009). Globally, 35% of mangrove area (Valiela et al. 2001) and 15% of seagrass area has been lost (Waycott et al. 2009), and an estimated 32% of coral species are threatened (Carpenter et al. 2008). The loss of foundation species or top-level predators can cause shifts from highly productive ecosystems to less complex ones with reduced ecosystem services (Estes et al. 2011; Springer et al. 2003). Human activities now threaten every part of the oceans, with 41% of the ocean strongly impacted by multiple human activities (Halpern et al. 2008). Climate-related threats currently have the highest cumulative impact on marine ecosystems (Halpern et al. 2008), with increased ocean temperatures, ocean acidification, sea level rise, increased ultraviolet radiation, and increased storm frequency and intensity (Harley et al. 2006; IPCC 2007) producing shifts in species' ranges, ocean productivity, species composition, and population dynamics (Hoegh-Guldberg & Bruno 2010). Open ocean and coastal regions are also highly impacted by fishing, as vast new areas of the ocean have been opened to commercial fishing (Swartz et al. 2010) and technology has facilitated an unprecedented level of exploitation, leading to collapse of several major fisheries (Myers & Worm 2003). Land-based activities can cause direct habitat destruction and result in run-off of sediments and nutrients to sensitive coastal habitats (Mcculloch et al. 2003). Population density and growth are very high in coastal regions around the world, with roughly half of all humans living within 200 km of the coast, with the result that the most highly impacted marine regions in the world are in coastal areas, because they experience the full set of coastal and open ocean threats (Halpern et al. 2008). Although some large areas of the ocean remain comparatively unaffected, particularly near the poles, even these areas will likely be at future risk if climate change continues at current rates and illegal, unregulated, and unreported fishing in these areas remains relatively uncontrolled.

Responses. *Arresting biodiversity loss depends critically on sufficient data, effective planning, a well managed protected areas network, and transformational shifts in the public and private sectors to green economic development. The CBD is our international umbrella for biodiversity, and its 2020 Aichi targets – particularly targets 11 and 12 – are critically important.*

To end global biodiversity loss, limited available resources must be guided to conservation and green economic development in those regions that need it most. Biodiversity is not evenly distributed on our planet. It is heavily concentrated in certain areas, these areas have exceptionally high concentrations of endemic species found nowhere else, and many (but not all) of these areas are those at greatest risk of disappearing because of heavy human impact. The biodiversity hotspots, for example, are a set of 35 regions of high endemism that collectively has lost more than 85% of its original habitat extent (Mittermeier et al. 2011; Myers 1988; Myers et al. 2000). Though their combined remnant natural vegetation comprises a scant 2.3% of the world's land area (3.4 million km^2), these regions harbor more than 50% of all plant species and 43% of all terrestrial vertebrates as endemics. Considering threatened species only – those that are assessed as critically endangered, endangered, or vulnerable on the IUCN Red List of Threatened Species (IUCN 2008) – 60% of threatened mammals, 63% of threatened birds, and 79% of threatened amphibians are found exclusively within the hotspots. These regions harbor an irreplaceable concentration of biodiversity in a very small and highly threatened portion of our planet. While conservation in these areas is more difficult due to ongoing threats, scarce information, and limited local financial capacity, action in these places is not optional. Indeed, failure in the hotspots will translate to loss of nearly half of all terrestrial species even if we are successful everywhere else, not to mention an almost unthinkably large contribution to greenhouse gas emissions and extensive human suffering resulting from the loss of ecosystem services upon which the human populations of the hotspots ultimately depend. A few highly diverse regions remain largely intact, including the high-biodiversity wilderness areas of Amazonia, Congo, and the island New Guinea (Mittermeier et al. 2003). What is more, some 18 'megadiversity' countries (Mittermeier et al. 1997) account for more than 2/3 of all biodiversity – terrestrial, freshwater and marine – a concept that led to the creation of the Like-minded Group of Megadiverse Countries in the CBD.

Understanding the natural and human dimensions of biodiversity conservation requires good data. The Global Mammal Assessment (Schipper et al. 2008) and related efforts provide updated data on the status and distribution of species, while population, poverty, and other data sets provide important socioeconomic context. Successful conservation requires accurate, timely data on biodiversity, threats, and benefits to humanity at finer scales. Data on marine regions remains sparse compared with information on terrestrial systems (Sala & Knowlton 2006), and our lack of knowledge about freshwater systems is even more pronounced. However, substantial strides are being made on knowledge of aquatic biodiversity, for example with efforts such as the Global Freshwater Biodiversity Assessment (Darwall et al. 2005) and the Global Marine Species Assessment, which includes comprehensive status assessments completed for reef-forming corals (Carpenter et al. 2008), and similar work under way for thousands of other species.

The establishment and effective management of a comprehensive set of protected areas (Bruner et al. 2001) must continue to be the cornerstone of efforts to halt the loss of biodiversity. These areas may be in the form of national parks or strict biological reserves, or may come in a variety of other forms, depending on local context, including indigenous reserves, private protected areas, and community conservation agreements. Efforts must focus on ensuring long-term persistence and equitable management of the areas already protected, and strategically add new protected areas in the highest priority intact, unprotected habitats as indicated by systematic efforts to identify gaps in protected areas networks (e.g., Rodrigues et al. 2004).

Maintaining the resilience of biodiversity in the face of climate change is another major challenge for planning and policy. Changing temperature and precipitation have begun forcing species to follow their preferred environmental conditions, yet these movements will often be both difficult for species to undertake and complex for researchers to predict (Loarie et al. 2009; Tewksbury et al. 2008), and further climate change will likely produce a complex mosaic of climates shifted in space, climates that disappear, and entirely novel climates (Williams et al. 2007). Thus, to be successful, conservation planning must begin to systematically plan actions in both space and time. Protecting the sites where species currently exist is essential, particularly sites where species are at greatest current risk, including key biodiversity areas (Eken et al. 2004) and Alliance for Zero Extinction sites – locations harboring the sole remaining populations of the most threatened species (Ricketts et al. 2005). If we lose these sites now, we will not be granted another chance to save the species they contain later. But this is only the beginning. We must also protect habitats where species will be in the future, as well as 'stepping stones' to facilitate movement to these new ranges. Biologists are increasing their ability to anticipate and plan for these needs (Hannah et al. 2007). To be successful, conservation in a changing climate will require a very strong focus on ending further habitat destruction as quickly as possible.

In 2002 World leaders committed through the UN Convention on Biological Diversity (CBD) "to achieve by 2010 a significant reduction of the current rate of biodiversity loss…" (Balmford & Bond 2005). This target was not met: most indicators of the state of biodiversity (e.g. population trends, extinction risk) showed declines, with no significant recent reductions in rate, whereas indicators of pressures on biodiversity (e.g. resource consumption, invasive alien species, climate change impacts) showed increases (Butchart et al. 2010; CBD 2010b). In October 2010 World leaders met in Nagoya in Japan at the Conference of the Parties (COP10) of the CBD, and adopted a strategic plan for biodiversity and 20 biodiversity targets—the so-called Aichi Biodiversity Targets—for the 2011-2020 period. The Aichi targets (CBD 2010a) now articulate much of what needs to be done to secure the life support systems of the planet. In the Aichi targets, countries settled on a target for the global coverage of protected areas, comprising 17% of land and 10% of oceans by 2020. Currently, the global network of protected areas (PAs) covers 12.9% of Earth's land surface (IUCN & UNEP-WCMC 2010) and only about 1.17% of the total ocean area (CBD 2010b). Thus, on land a fulfillment of this global target would expand the global coverage of PAs by about 4% by 2020, while for the oceans the agreed target represents more than a ten-fold increase over what is currently protected. CBD parties—and indeed the world—together need to maintain the sense of urgency and level of ambition of the targets to ensure the necessary change in our investment and action towards achieving the targets we have set.

Nevertheless, the agreement on the CBD policy target of global coverage of 17% of land as PAs by 2020 is based on perceptions of political feasibility rather than science-based understanding of PA needs to sustain planetary health. The question of how much nature needs to be protected to prevent biodiversity loss and ensure important ecosystem services is critical and holds many challenges. First, little is still known about Earth's biodiversity: only 2.5% of known species have been assessed for their conservation status (Stuart et al. 2010), and only a small fraction of the estimated total number of species have been described by science. Second, the understanding of ecosystem services is still poor for a range of important issues such as the ecological underpinnings of ecosystem services (Kremen & Ostfeld 2005). Finally, we face limited understanding of tipping points in ecological systems and cannot yet predict the potential threshold effects of climate change and other anthropogenic pressures on biodiversity and ecosystem services.

The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES, www.ipbes.net) – patterned after the influential IPCC for climate change – is in the process of being established. IPBES will be an interface between the scientific community and policy makers and will conduct regular and timely assessments of knowledge on biodiversity and ecosystem services and their interconnections (Perrings et al. 2011). IPBES must catalyze the effort to set science-driven targets for protection of biodiversity and ecosystem services and create the necessary understanding of societal dependence on natural ecosystems to decision-makers.

The Millennium Development Goals (MDGs) constitute a set of goals and targets by 2015 designed to inspire efforts to improve people's lives, i.e. halving extreme poverty[5]. The people for whom the benefits from protecting biodiversity matter most are the world's poor, who depend disproportionately on nature for critical services such as clean water, for livelihoods, and for insurance against hard times, making biodiversity conservation and development two intertwined challenges (Sachs et al. 2009; TEEB 2009; Turner et al. 2012). Therefore, the development and environmental sustainability agenda needs to be integrated in order to address these two linked issues in a meaningful way. The upcoming UN Conference on Sustainable Development in 2012 (Rio+20) will provide an opportunity for the international community to address this challenge.

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Climate change: Protecting biodiversity and harnessing nature's climate solutions

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Earth's climate continues to change at unprecedented rates, with dramatic global, regional, and local changes that will with increasing severity undermine food security and freshwater security, particularly in the developing world, and produce severe changes in the ecosystems that support all life. The loss of biodiversity and natural ecosystems from dangerous levels of climate change portend a serious threat to human communities via the loss of ecosystem services. Ecosystems are critical for mitigating climate change. Tropical forests, coastal marine ecosystems, and others play large roles in global biochemical cycles, are widely available, and can be deployed immediately to reduce atmospheric greenhouse gas concentrations without waiting for new technology. An effective mechanism for Reducing Emissions from Deforestation and forest Degradation must be implemented, financed, and recognize the role of traditionally high-forest, low-deforestation countries. Natural ecosystems will save lives and sustain livelihoods in myriad ways as Earth's climate changes, and the services provided by healthy, diverse ecosystems will become ever more crucial in the face of climate change. Yet the global community's attempts to address climate change have been inadequate. The costs of climate change, already projected at 5% or more of global GDP, could one day exceed global economic output if action is not taken. We have the ability to reduce or avoid many of these impacts. Biodiversity, in particular, is foundational to solving the climate crisis, as conservation can decelerate climate change while increasing the adaptive capacity of people and ecosystems alike. The opportunities to harness nature's climate change solutions are essential, immediate, and fleeting. We must act now.

Introduction.

Earth's climate continues to change at an unprecedented rate (Kiehl 2011). Emissions from fossil fuels have accelerated over the past decade (Raupach et al. 2007), with the fleeting reduction during the financial crisis of 08-09 being followed by further rapid growth (Peters et al. 2012), and our planet is steadily heading towards a concentration of greenhouse gases in the atmosphere that is unprecedented during the past 20 million years (Beerling & Royer 2011). The implications of this trend for dramatic global, regional and local changes in, among others, temperature, precipitation patterns, sea-level rise, ice-sheet and glacier loss, and the frequency of extreme climatic events, are underscored by a review of research covering the period since the IPCC's 2007 assessment report (Good et al. 2010). Indeed, analyses now suggest there is now little or no chance of maintaining the global mean surface temperature at or below 2^0C (Anderson & Bows 2011). The impacts of a 2^0C rise on human societies and the natural world that supports them will likely be severe and pervasive (Solomon et al. 2007), and the impacts of exceeding this value are dire (New et al. 2011). Among the greatest risks, even at increases in global mean temperature well below 4^0C, is the potential for exceeding one or more tipping points in the Earth-system – from irreversible melt of the Greenland ice sheet to dieback of the Amazon rainforest (Lenton 2011). Slower-onset, chronic changes meanwhile will have equally profound impacts, with reductions in food security (Lobell et al. 2008) and freshwater security (McDonald et al. 2011), particularly in the developing world, amplified by equally severe changes in the natural world – from likely significant numbers of species committed to extinction (Thomas et al. 2004), to many of the world's coral reefs in terminal decline (Veron et al. 2009). The magnitude and severity of such impacts underscore the urgent need for rapid and substantive progress to mitigate climate change and help the world adapt to its impacts.

Climate change impacts on biodiversity and ecosystem services. *The loss of biodiversity and natural ecosystems from dangerous levels of climate change portend a serious threat to human communities via the loss of ecosystem services.*

Anthropogenic climate change has the potential to dramatically disrupt biodiversity at all levels of organization, from individuals to populations to entire ecosystems. Organisms are already displaying a range of responses to contemporary climate change, including changes in phenology (Parmesan 2006), abundance (Moritz et al. 2008) and evolutionary processes (Karell et al. 2011). These changes are paralleled by shifts in species' ranges as they attempt to track shifting climatic niches. Indeed, evidence from the paleoecological record of past climate change (Graham & Grimm 1990), together with recent documented changes in species' distributions (Chen et al. 2011) and modeled simulations of future range shifts (Hole et al. 2009), indicate that species' responses to projected climate change over the coming decades could substantially alter present-day patterns of biodiversity. Species responses are also highly individualistic, dependent on factors such as individual dispersal capability and the responses of interacting species such as competitors, predators or prey (Traill et al. 2010). Furthermore, projected rates of climate change in both terrestrial (Loarie et al. 2009) and marine (Burrows et al. 2011) environments are likely to be of such magnitude that many species will be unable to keep pace with their shifting envelope – an outcome that is already becoming apparent (Devictor et al. 2008). As a result, changes in community composition and structure, and the emergence of novel species' assemblages are likely to characterize the future as they did the past (Williams & Jackson 2007). This disassembly and reassembly of ecosystems, together with inevitable extinctions, will affect ecosystem function and resulting service provision (Traill et al. 2010). This era of uncertainty and rapid change will pose unprecedented challenges to our ability to achieve global goals for sustaining biodiversity and the communities that depend upon it.

Climate change impacts on ecosystem services are still relatively poorly characterized in large part because of our lack of understanding of the complex web of interacting species that comprise any ecosystem, each of which will be responding to climate change in its own individual manner. Yet accumulating evidence suggests the implications of climate change for the provision of ecosystem services are profound (Millennium Ecosystem Assessment 2005; Schroter et al. 2005; Traill et al. 2010). Ecosystems that are most susceptible to climate change impacts will be those whose sustained provision of services is likely most at risk. For example, montane cloud forests are highly susceptible to a climate change-driven lifting of the cloud base (Still et al. 1999), with consequent ramifications for future downstream provision of freshwater services (Bruijnzeel 2004). The nature and magnitude of changes in service provision will potentially be greatest, but also most uncertain, in ecosystems whose biota disassemble and reassemble as a result of climate change, to such a degree that no-analog communities form (Harborne & Mumby 2011; Hoegh-Guldberg & Bruno 2010). The impacts of such changes in ecosystem structure and function will have significant consequences for realized service provision to human communities across spatial scales (Millennium Ecosystem Assessment 2005). For example, at local scales, shifts in pollinator abundance and distribution will impact pollination services (Traill et al. 2010). Indeed, a wide range of negative impacts across the panoply of provisioning, regulating, cultural and supporting services can be expected, as climate change reshuffles the web of life.

Climate change effects on the ocean will be diverse and profound. Rising ocean temperatures have led to widespread die-offs on coral reefs from bleaching events (Veron et al. 2009) and ocean acidification slowed coral growth (Lesser & Farrell 2004). Ocean acidification—a decrease in ocean pH—can have similarly devastating consequences for other ecosystems and species. Many species need particular levels of chemicals in the ocean to build their shells; as these levels change, populations must shift their energy and resources from reproduction to simply keeping up their individual growth rates, a shift that can lead to considerable declines in the number of individuals in a population. Over the next few decades, ocean acidification is predicted to affect corals and many shell-builders of commercial importance including crabs, lobsters, mussels and clams. Furthermore, sea-level rise threatens several coastal ecosystems like mangroves and seagrass beds, particularly where development inhibits their ability to migrate inland with rising seas. Meanwhile at regional to global scales significant changes in global fisheries catch potential – both positive and negative – are projected under climate change (Cheung et al. 2010). The combination of all these climate change impacts leads to a pernicious and global reach of climate change that can affect every marine ecosystem in the world including relatively pristine areas of the ocean.

Nature is essential for mitigating climate change. *Ecosystems are critical for mitigating climate change. Tropical forests, coastal marine ecosystems, and others play large roles in global biochemical cycles, are widely available, and can be deployed immediately to reduce atmospheric greenhouse gas concentrations without waiting for new technology. An effective mechanism for Reducing Emissions from Deforestation and forest Degradation must be implemented, financed, and recognize the role of traditionally high-forest, low-deforestation countries.*

Natural ecosystems are a major force in mitigating global warming. First, forests, peatlands, oceans and other ecosystems play major roles in carbon and other global biogeochemical cycles. The oceans sequester about two gigatonnes of carbon a year, while reducing deforestation and forest degradation rates by half would cut global emissions by about a gigatonne of carbon a year—substantially more than the emissions of all passenger cars combined. Restoring marginal and degraded lands to natural habitats could sequester an additional 0.65 gigatonnes annually (McKinsey & Company 2009). Second, the maintenance and restoration of natural habitats are among the most cost-effective, widely accessible solutions available in the effort to reduce greenhouse gas concentrations. Ecosystem restoration (e.g., replanting forest on previously degraded land) may remain for several decades the only realistic large-scale mechanism for removing CO_2 already in the atmosphere (Hansen et al. 2008).

Ecosystem-based adaptation. *Natural ecosystems will save lives and sustain livelihoods in myriad ways as Earth's climate changes. The services provided by healthy, diverse* *ecosystems will become ever more crucial in the face of climate change since they can help us deal with impacts such as changing hydrology, rising sea levels, and changes in the range of disease-carrying organisms and other pests.*

While it is critical that the world mitigates aggressively in order to 'avoid the unmanageable', it is equally crucial that we address the impacts that are already with us, and those we are committed to, in order to 'manage the unavoidable'. Adaptation to climate change comprises a wide range of approaches in response to experienced or expected climate change exposures. It is becoming clear that the maintenance and restoration of natural ecosystems are among the cheapest, safest, and most readily implemented solutions at our disposal to lessen the impacts of climate change on people (Turner et al. 2009). Ecosystem-based approaches to adaptation (EbA) harness the capacity of nature to buffer human communities against the adverse impacts of climate change through the sustainable delivery of ecosystem services. They are generally deployed in the form of targeted management, conservation and restoration activities and are often focused on specific ecosystem services with the potential to reduce climate change exposures. For example, mangrove forests and coastal marshes can help dissipate the energy of storm surges along exposed coastlines (Costanza et al. 2008; Das & Vincent 2009; Shepard et al. 2011). Restoring or conserving mangrove ecosystems can therefore help protect coastal communities from the projected rise in the number of powerful tropical storms under climate change (Emanuel 2005). The potential scope of EbA to help reduce vulnerability to a range of climate change impacts is broad. Ecosystems deliver services that can help meet adaptation needs across multiple human development sectors (Andrade et al. 2010; World Bank 2009), including disaster risk reduction (through flood regulation and storm surge protection), food security (from fisheries to agro-forestry), sustainable water management (via water purification and flow regulation) and livelihoods diversification (through increasing resource-use options or tourism). While people have used the natural environment to cope with climatic variability for millennia, the potential for natural infrastructure to provide adaptation services is gaining increasing attention at all levels because of the urgent need to find tractable, flexible, cost-effective adaptation interventions that reduce vulnerability under rapid anthropogenic climate change.

A great advantage of ecosystems as a climate solution is that they play many roles at once. Beyond mitigation, the climate adaptation services provided by healthy, diverse ecosystems will become ever more important in the face of climate change since they can help us deal with impacts such as changing freshwater flows, rising sea levels, and shifts in disease-carrying organisms and other pests. Mangroves, for example, store carbon, support fisheries, harbor diverse species, and can reduce storm impacts. Ecosystems also support livelihoods by providing income and food alternatives that will be important where climate change disrupts current sources. Such diversification is helpful for all, but particularly the most vulnerable communities and countries, those with the least capacity to cope with climate change.

Although the known value of nature in reducing climate change and its impacts is high, there may be more value in what remains to be discovered. Few imagined a few decades ago that the carbon stored in natural ecosystems would become critical for combating climate change. What breadth of untapped innovation for addressing climate change – the 'option value' of biodiversity – might lie in the diverse wildlands of the world? Agriculture is one area in which this untapped innovation could prove particularly valuable. When changes in patterns of precipitation and temperature start to test the physiological limits of current crops, farmers may benefit greatly from wild relatives and novel cultivars better suited to the new conditions (Sheehy et al. 2005).

Harnessing nature to fight climate change impacts, and the costs of inaction. *The global community's attempts to address climate change have been inadequate. The costs of climate change, already estimated at 5% or more of global GDP, could one day exceed global economic output if action is not taken. Biodiversity is foundational to solving the climate crises, as conservation can decelerate climate change while increasing the adaptive capacity of people and ecosystems alike. The opportunities to harness nature's climate change solutions are essential, immediate, and fleeting. We must act now.*

The global community's attempts to address climate change thus far have been entirely inadequate. There is now little chance of avoiding global mean temperature increases of 2^0C or more (Anderson & Bows 2011), the so-called 'guard-rail' recognized by the Copenhagen Accord in 2009 as the limit necessary to avoid 'dangerous' climate change, despite the growing view that this limit might itself be too high (New et al. 2009). It is true that individual ecosystems and regions will likely exhibit high variability in their responses to continued climatic change, depending on their degree of exposure to climatic perturbations and specific tolerances of their component species. For example, under the combined pressures of increasing ocean temperatures, ocean acidification, and other environmental impacts, coral reefs could face rapid and terminal decline world-wide by mid-century if CO_2 levels exceed 450ppm (Veron et al. 2009). Meanwhile other ecosystems, such as the humid tropical forests of South and insular Asia, could be relatively unaffected (Zelazowski et al. 2011), although evidence suggests tropical biodiversity may be more affected by climate change than previously thought (Tewksbury et al. 2008). Overall, the direct impacts of climate change on people and ecosystems are likely to be substantial and primarily negative, particularly in the developing world where exposure to climatic changes are likely to be highest and the potential to adapt lowest (Parry et al. 2007). For example, food security is likely to be reduced in many regions of the developing world as the yields of many agricultural staples fall (Lobell et al. 2008; Thornton et al. 2011) and fisheries productivity declines (Cheung et al. 2010), while exposure to climatic extremes (e.g. droughts, floods and storms) increases.

Without concerted action, the costs of climate change will exceed 5%, and perhaps 20%, of global GDP (Stern 2007). The consequences of continued inaction are ominous. The risk of breaching one or more 'tipping points' in the Earth system – including shifts in the West African monsoon, West Antarctic ice-sheet collapse, Amazon forest dieback, and shutdown of the Atlantic thermohaline circulation – increases with increasing climatic change, with estimates of threshold levels for tipping points at global mean temperature change from $0.5\text{-}6^0$C of warming (Lenton et al. 2008). Under such circumstances, total costs may approach and exceed global GDP. Continued failure to implement substantive mitigation actions will also result in significant adaptation costs. Current estimates of global adaptation need range from $49 to 171 billion per year, although these are recognized as gross underestimates (Parry et al. 2009). Similarly, reactive conservation actions will cost substantially more than proactive ones (Hannah et al. 2007). Even if strong mitigation measures are taken now, together with the actions required to adapt to the climatic changes already locked into the system, care must be taken to minimize the unintended, harmful consequences for biodiversity and people of inadequately planned or inappropriate responses to climate change (Turner et al. 2010).

Our responses to climate change must harness nature as a solution if we are to avoid further compromising the integrity of the planet upon which we depend. We cannot restrict our actions to engineered fixes, such as constructing sea walls to protect against sea level rise or desalination facilities to address water scarcity. Since human responses will be diverse, addressing the threats of climate change will require coordination across various sectors, including conservation and development. By focusing on ecosystems and their benefits to people, we can improve resilience and ensure that we and other species will be around for generations to come. We must proactively identify and secure key intact ecosystems and the climate services they provide, restore lost or degraded ones, and limit future losses, all in partnership with the communities who need those services most.

Climate mitigation and adaptation, for both nature and people, can no longer be thought of as separate problems, for they will not be solved in isolation. If human adaptation to climate change compromises forests or other ecosystems, this loss will speed climate change. If mitigation of climate change -- for example via reforestation using single-species stands -- this will reduce biodiversity. It is important that ensembles of native species are used for reforestation activities. These losses will increase the need for adaptation even as our capacity to accommodate it diminishes. An integrated approach makes this cycle virtuous: by conserving biodiversity, we decelerate climate change while increasing the adaptive capacity of people and ecosystems alike. Achieving such an integrated approach will pose challenges: the broad interest of humanity is up against powerful short-term political and economic interests. Yet these are challenges we must conquer. The opportunities to harness nature's climate change solutions are essential, immediate, and fleeting. We must act now.

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Ecosystem services: Accounting for the benefits that nature provides to humanity

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Ecosystem services—the benefits that ecosystems contribute to human well-being—have historically been provided free of charge, and demand for them is increasing. With biodiversity as their foundation, ecosystem services are provided both directly and indirectly by species from all branches of the tree of life and a variety of habitats around the globe. Ecosystem services are pervasive, benefiting people in a variety of socioeconomic conditions, across virtually every economic sector, and over a range of spatial scales, now and in the future. Although the global economic value of ecosystem services may be impossible to measure, it almost certainly rivals or exceeds aggregate global gross domestic product, and ecosystem benefits frequently outweigh costs of their conservation. Yet environmental benefits are seldom considered in conventional economic decisionmaking, and costs and benefits often don't accrue to the same community, or at the same time or place. Thus a range of ecosystem services are vanishing rapidly, with enormous consequences for current and future human well-being. To stop biodiversity loss and maintain the services humanity depends on, the value of ecosystem services and natural capital must be incorporated into national accounting and decisionmaking processes across all sectors of society, access to ecosystem benefits and costs of ecosystem conservation must be shared equitably, and biodiversity and ecosystem services must be seen as the most fundamental component of green economic development.

Introduction. *Ecosystem services are the benefits that ecosystems contribute to human well-being.*

Ecosystem services are "the benefits people obtain from ecosystems" (Millennium Ecosystem Assessment 2005) or "the direct and indirect contributions of ecosystems to human well-being" (TEEB 2009). Humans are fundamentally dependent on the flow of ecosystem services for food provision, water purification, waste and nutrient cycling, climate stabilization, recreational and spiritual fulfillment, and other needs. In economic terms, ecosystems should be considered capital assets worthy of careful valuation and investment, because they sustain both lives and livelihoods (Turner & Daily 2007). This 'natural capital', along with human and produced capital, is one of the cornerstones of societies and economies. Natural capital plays a large role in supporting human communities, and a disproportionate role in supporting the rural poor.

Between 1960 and 2000, the demand for ecosystem services grew significantly as world population doubled to 6 billion people and the global economy increased more than sixfold. To meet this demand, food production increased by roughly two-and-a-half times, water use doubled, wood harvests for pulp and paper production tripled, installed hydropower capacity doubled, and timber production increased by more than half (Millennium Ecosystem Assessment 2005).

Biodiversity and ecosystem services. *Biodiversity is the foundation of the ecosystem services humanity depends on; these services are provided both directly and indirectly by all branches of the tree of life and a variety of habitats around the globe.*

Ecosystem services are produced by all branches of the tree of life—the many species of plants, insects, microbes, and mammals that populate the planet. For example, fish are among the most important sources of food for much of the world's population. The fishing industry contributes between US$ 225-240 billion per year to the global economy (Dyck & Sumaila 2010). In coastal and island communities, reef-based resources are the primary source of income and food for 30 million people (TEEB 2010).

Many other species provide valuable services to humanity. Birds act as pollinators, scavengers, seed dispersers, seed predators, and ecosystem engineers (Whelan et al. 2008) as well as providing an important global food source and significant recreational and economic values in the form of nature-based tourism.

Mammals, both wild and domesticated, also provide a significant source of food to the global population, as well as significant recreational values in the form of hunting, wildlife tourism, and the pet trade. Bats and many other mammals provide services such as seed dispersal, pollination, pest control, and fertilization (Kunz et al. 2011). Collectively, insects, birds, and bats reduce agricultural crop losses due to pests as well as costs of pesticide use, services that are estimated to range between $54 billion and $1 trillion globally (Kunz et al. 2011). Migratory mammals, birds, and fish also transport energy and nutrients between ecosystems (de Groot et al. 2002).

Amphibians also help cycle nutrients (VanCompernolle et al. 2005), and like many mammal, birds, and fish species, can serve as cultural symbols. For example, the Wet'suwet'en peoples in British Columbia are organized into frog, beaver, wolf, and fireweed clans.

Invertebrates such as insects, prawns and crabs play an important role in nutrient cycling, breaking down waste and making it available directly as food or as nutrients in soil. Invertebrates also pollinate crops, control pests, and provide food for fish and wildlife. Pollinators are necessary for producing about one in three of the world's food crops (Daily & Ellison 2002). Wild insects provide services estimated to be worth at least US $57 billion per year in the U.S. alone (Losey & Vaughan 2006). Commercial bee keeping generates US $213 million per year in Switzerland (TEEB 2010). Invertebrates also provide raw ingredients for many medicines. For example, chemicals derived from molluscs such as cone snails have been turned into powerful painkillers (Becker & Terlau 2008).

Many species of trees are used for timber and fuel wood. Forests also provide protection from floods and landslides, erosion control, climate stabilization, food crops, and habitat for wildlife. Worldwide, forests are estimated to provide US $4.7 trillion in total ecosystem services (Costanza et al. 1997). The value of living trees has been recognized in some cities. For example, 400,000 trees were planted in Canberra, Australia, in order to improve urban air quality, reduce energy costs for air conditioning, sequester and store

carbon, and regulate microclimate. In total, these services are estimated to be worth US $20-67 in value provided or savings to the city for the period 2008-2012 (TEEB 2010). Trees also provide significant aesthetic, recreational, and cultural values. Hospital patients that looked out on a modest stand of trees fared much better than those that had a view of a building wall (Daily & Ellison 2002). Other flowering and non-flowering plants make up a significant portion of the world's food crops, help clean water, cycle nutrients, prevent soil erosion, and absorb heat-trapping atmospheric gases and other pollutants. Like animals, plants can also be the source of life-saving medicines. For example, substances extracted from the Madagascar periwinkle, an endangered flowering plant, are used to treat leukemia.
Microorganisms, the most abundant life form by far, provide countless services: they purify groundwater, detoxify and decompose wastes, regulate of climate, and improve soil fertility (Lavelle et al. 2006).

The ocean provides a range of important ecosystem services including food provision, recreational and tourism opportunities, coastal protection, climate regulation, and a source of livelihoods. Marine ecosystems provide the majority of all ecosystem service value (Costanza et al. 1997). More than 1.5 billion people rely on the oceans for 20% of their animal protein (FAO Fisheries and Aquaculture Department 2010). Beyond fishing, the world's oceans also play a critical role in regulating global climate change (Levitus et al. 2005; Turner et al. 2009). Although the ocean's vegetated habitats (mangroves, seagrasses, and salt marshes) only have 0.05% of the total biomass of terrestrial plants, they store a disproportionate amount of carbon globally per year – so are amongst the most efficient carbon sinks on the planet (Laffoley & Grimsditch 2009).

Variation itself – within or among species – often underpins ecosystem services. Agricultural crops that have higher genetic diversity are better able to adapt to changing environmental conditions, and therefore more likely to survive pest or pathogen outbreaks or climate fluctuations. The functioning of forest ecosystems, and therefore their ability to sequester and store carbon, is influenced by the diversity of animals that eat fruit and disperse seeds (Brodie & Gibbs 2009; Howe & Smallwood 1982; Kone et al. 2008). Nutrient cycling, carbon sequestration, and other services are also influenced by plant species richness (Maestre et al. 2012).

The breadth of services. *Ecosystem services benefit people in a variety of socioeconomic conditions, across virtually every economic sector, and over a range of spatial scales, now and in the future.*

The Millennium Ecosystem Assessment (2005) grouped ecosystem services into four categories: *provisioning* services that produce food, water, timber and fiber; *regulating* services that mitigate climate and flooding, purify water and process wastes; *supporting* services that underpin photosynthesis, nutrient cycling and soil formation; and *cultural* services such as spiritual, aesthetic, and recreational benefits.
Primary production, the process by which organisms such as plants, algae, or bacteria transform energy and carbon dioxide into biomass, is considered the most fundamental supporting service (McNeely et al. 2009). Nutrient cycling of carbon, nitrogen, phosphorus, and sulfur is also a critical supporting service as it both maintains ecosystem productivity and reduces the dangerous accumulation of nutrients that can threaten ecological and human health.

Important regulating services provided by ecosystems include the sequestration and cycling of greenhouse gases such as carbon dioxide and methane, and other pollutants such as sulfur dioxide that cause climate change and affect air quality. These pollutants are released by human activities including burning fossil fuels, growing crops and livestock, and clearing forests, and have negative impacts on ecosystem and human health. Ecosystems also help process wastes, protecting soil and water quality. Intact and functioning ecosystems can also reduce the frequency, intensity, and damage resulting from natural disasters such as floods, tropical storms, and landslides. Natural habitats provide refuges for people and animals fleeing natural and human-caused disasters, and can provide emergency supplies of food, water, shelter and fuel. Many species provide regulating services in the form of pollination and the control of insects and other pests, which directly affects food production and the spread of disease.

Provisioning services are the most direct form of benefits from nature. They include the direct harvest of food from fishing, hunting, and gathering as well as the harvest of timber, fuel and fiber. Grazing of livestock and crop cultivation are also supported by provisioning services, as are the production of fuel and energy from firewood and charcoal, biomass fuel, grain ethanol, or animal dung. Natural products are also used in medicine, biomimicry, and genetic resources. Nature provides a 'library' of genetic material with values for medical, industrial, and agricultural products (Daily & Ellison 2002). At least half of the medicines in use have natural components (Chivian & Bernstein 2008). Genetic resources that offer or inspire important drugs arise from taxa as disparate as reptiles, flowering plants, and microbes. For example, a drug derived from Gila monster saliva is used to treat diabetes (Triplitt & Chiquette 2006), while a chemical from the Madagascar periwinkle is used to fight cancer (Gentry 1993).

Biodiversity also provides many non-material benefits to humanity, including recreation, tourism, aesthetic and spiritual values, cultural identity, and opportunities for education and scientific research. It is difficult to quantify these values, but in many cases the value of cultural services may outweigh the market value of converting or exploiting ecosystems, providing one of the strongest arguments for conserving biodiversity to sustain human well-being.

All of the ecosystem services described above are supported, directly or indirectly, by the diversity of life on Earth – its genes, species, populations, and ecosystems. Diverse life forms provide the basic materials for the production of food and medicine, biological control of pests and pathogens, genetic material for crops and cures, and experiences that heal the body and soothe the soul. As valuable as the known benefits of biodiversity may be, there may be even greater value in what we have yet to discover. Indeed, humanity remains every bit as dependent on nature in solving 21st century problems such as climate change (Turner et al. 2009) and multiple-drug-resistant pathogens (e.g., vancomycin, a powerful antibiotic, originated in bacteria from interior Borneo; Moellering 2006) as it has always been for more basic services such as food and water provision. As these and many other examples demonstrate (McNeely et al. 2009), time and again biodiversity offers solutions to challenges we could not have anticipated. If we succeed in protecting only the biodiversity we can put a price on in today's markets, then we will fail. Our failure will not only be measured by the intrinsic value of nature and our ethical responsibilities to it. Nor will it be measured only by the 'existence' value of nature—its value to the identities of local communities, as well as people around the globe who benefit from nature's existence, whether experienced directly or from afar. If we fail to protect biodiversity beyond what can be immediately priced, we will also fail in retaining the benefits of nature for human well-being in the long term. Thus any discussion of 'tradeoffs' between biodiversity and human well-being presents a false choice; the real tradeoff is between short-term benefits to a limited set of people and the long-term well-being of humanity.

The value of nature. *The global economic value of ecosystem services may be impossible to measure, but almost certainly rivals or exceeds aggregate global gross domestic product; these benefits of ecosystems frequently outweigh costs of their conservation.*

By 1997, the total economic value of ecosystem services globally was estimated to be US $33 trillion per year (Costanza et al. 1997), nearly twice the global aggregate gross domestic product.

The global protected area network is a critical core of our efforts to preserve our collective natural capital. Nearly a third (33 out of 105) of the World's largest cities, for example, obtain a substantial portion of their drinking water directly from PAs (Dudley & Stolton 2003). The value of maintaining natural ecosystems and their wide range of services frequently far outweighs the value of converting them to supply a limited range of provisioning services, with global estimates of benefits relative to costs ranging from 3:1 (Turner et al. 2012) to 100:1 (Balmford et al. 2002).

The broken economic compass and the cost of inaction. *Environmental benefits are seldom considered in conventional economic decisionmaking, and costs and benefits often don't accrue to the same community, or the same time or place. Thus a range of ecosystem services are vanishing rapidly, with enormous consequences for current and future human well-being.*

Although the benefits of ecosystems are substantial, the value of ecosystem services and natural capital are seldom considered in economic decision making, with the result that the actions of our governments, banks, corporations, and other institutions are guided by what economist Pavan Sukhdev calls a 'broken economic compass' (Sukhdev 2011). The value of ecosystem services – and the costs of losing them – are treated merely as externalities in convential decisionmaking.

The result of this disconnect is that ecosystems and their services continue to be lost rapidly. More than half of the services studied during the Millennium Ecosystem Assessment (2005), including freshwater, fisheries, pest control, air and water purification, climate regulation, and natural hazards were either degraded or being used at unsustainable levels. Water from overpumped aquifers is used to produce much of the world's grain (Brown 2001). Globally, deforestation claims over 9 million hectares of land every year. Nearly a fifth of the planet's coral reefs have been lost, and another fifth have been degraded in the past few decades. Two thirds of oceanic fisheries are being fished at or beyond their sustainable yield (Millennium Ecosystem Assessment 2005). The loss of marine biodiversity affects the ocean's ability to provide food and maintain water quality (Worm et al. 2006). Lower marine diversity was also associated with decreased stability, increasing rates of resource collapse, and decreased recovery potential. Between 10-30% of the world's mammals, birds, and amphibians are at risk of going extinct (Millennium Ecosystem Assessment 2005). Due to the burning of fossil fuels, deforestation, and other changes in land use, the amount of carbon in the atmosphere has increased by about a third (from 280 to 376 parts per million in 2003).

Changes in ecosystem extent, function, or species abundances can have major impacts on the delivery of critical services. Population growth is expected to slow and level off in mid-century, nonetheless global GDP is predicted to multiply three to six-fold, driving ever higher levels of demand for ecosystem services (Millennium Ecosystem Assessment 2005).

It is challenging to quantify the costs of lost or degraded ecosystem services, but the evidence suggests that such costs are substantial and growing. The single greatest cost might be in terms of lost future opportunities. Fewer than 10%, or perhaps even 1%, of the Earth's species have been described, much less studied (Novotny et al. 2002). The opportunity to learn from, enjoy, or discover new sources of food and medicine dwindles with every species that disappears. Due to the complexity of interactions between many species, a single extinction can cause cascading effects on other species that are important to humans, as well as the functioning of ecosystems that provide many other services.

Exploitation of species or destruction of ecosystems can have severe consequences for human well-being. The destruction of coastal wetlands and mangrove forests results in increased human mortality and economic damage from tropical cyclones (Costanza et al. 2008; Das & Vincent 2009). Trade in wildlife for human consumption contributes to the spread of diseases, such as the 2003 outbreak of Severe Acute Respiratory Syndrome (SARS) in East Asia (Guan et al. 2003). In Africa, the degradation of rangeland has caused a decrease in livestock production with an estimated cost of $7 billion per year, nearly the gross domestic product of Ethiopia (Brown 2001). Declining soil fertility and erosion has resulted in the abandonment of nearly half of Kazakhstan's cropland between 1980-2000, resulting in declining wheat harvests and an annual economic loss of $900 million.

In the early 1990s, the Newfoundland cod fishery collapsed due to overfishing, resulting in the loss of tens of thousands of jobs and at least $2 billion in income support and retraining (Millennium Ecosystem Assessment 2005). Globally, fisheries are estimated to underperform by US$ 50 billion annually (TEEB 2010). Terrestrial biodiversity losses over the last decade are estimated to have cost the global economy $500 billion per year (TEEB 2009). Economic losses from natural catastrophes (fires, floods, storms, droughts and earthquakes) totaled approximately $70 billion in 2003, a tenfold increase since the 1950s (Millennium Ecosystem Assessment 2005). In coming decades, the effects of a changing climate, including increased frequency and intensity of natural disasters, will increase the importance of, and demand for, the services provided by species and ecosystems (Turner et al. 2009).

The costs of losing ecosystems are borne disproportionately by the poor, who are more directly dependent on nature for the provision of food, water, shelter, energy and livelihoods. Thus the destruction of ecosystems exacerbates existing inequality, resulting in increased poverty and conflict (Millennium Ecosystem Assessment 2005). This complicates efforts to improve human well-being, such as global efforts to achieve the Millennium Development Goals agreed upon by the UN General Assembly in 2000.

Fixing the broken economic compass. *The value of ecosystem services and natural capital must be incorporated into national accounting and decisionmaking processes across all sectors of society; biodiversity and ecosystem services must be seen as the most fundamental component of green economic development; and access to ecosystem benefits and costs of ecosystem conservation must be shared equitably*.

Incorporating the value of nature in decisionmaking is complicated by a series of disconnects between those who receive the benefits of ecosystems and those who incur the costs of their conservation. Whereas the costs of conserving ecosystems are most often incurred by those nearby, many benefits can accrue over large distances—for example, in the cases of water provision, climate regulation, and recreation. There is also a temporal disconnect: whereas costs are often felt immediately and acutely, benefits are often not realized until the future. And different services are of greater or lesser importance to different people, communities, and institutions (Kremen et al. 2000).

These disconnects will not resolve themselves, but understanding them can point the way to solutions. Among these are ‘payments for ecosystem services’, which are financial transfers from service beneficiaries to would-be resource stewards or those whose behavior must be altered to secure ecosystems (Wunder et al. 2008).

Mechanisms such as payments for ecosystem services can create incentives for conserving or enhancing services. In some cases, the conservation of certain services (such as carbon sequestration) results in synergistic production of other services (such as freshwater and other biodiversity benefits; Larsen et al. 2011). Such mechanisms can also alleviate poverty and promote sustainable development if they are carefully designed and implemented (Turner et al. 2012). Understanding synergies and tradeoffs between services requires knowing the value and location of services. Efforts to map the costs and benefits of ecosystem services are beginning at scales ranging from global (TEEB 2010), national (Moilanen et al. 2011, the World Bank's Wealth Accounting and Valuation of Ecosystem Services initiative, and others), to local (Beier et al. 2008; O'Farrell et al. 2010). Mechanisms such as payments for ecosystem services and Reducing Emissions from Deforestation and forest Degradation (REDD) are just beginning to reconcile the disconnects between costs and benefits of services, to develop markets and institutions for previously unvalued services, and to share benefits equitably. Nonetheless, sweeping changes in policies, institutions, and practices will be necessary to fix the broken compass and reverse degradation of ecosystems while meeting increasing demand for services in coming decades.

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