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I. Introduction—The Significance, the Challenges, the Opportunities

Energy and global warming are two of the most consequential challenges humanity will confront in the 21st century. Their significance cannot be understated—global demand for energy will continue to increase as the world population grows, billions of people gain access to electricity, and developing countries seek stable, available, and affordable energy sources to fuel economic growth. Meanwhile, the accumulation of greenhouse gasses in the atmosphere—primarily due to the consumption of fossil fuels—is raising global temperatures above anything experienced in the course of human history, with the potential to dramatically alter the ecological systems upon with civilization depends.

However, both of these phenomena—the rising demand for energy and the onset of global warming—are unfolding in a context where fossil fuels are becoming more expensive, more contentious, and more scarce. The world experienced a preview last year when oil briefly rose to $150 a barrel, with the severe economic ramifications felt across the globe. As a result of this temporary spike in world oil process, economic growth stalled, inflation rose, and consumer spending in other sectors decreased. In the future, this spike will be more than temporary—it will be the norm, as the rise in demand for oil outpaces new supply. To a similar but lesser extent, the same is true for the other fossil fuels, like coal and natural gas, which face their own supply and distribution constraints in a world hungry for cheap and dependable energy.

Energy and climate directly or indirectly affects nearly every other major global issue. Food production is heavily dependent on fossil fuels from the seed to the plate, and rising temperatures and shifting weather patterns from climate change threaten to dramatically alter the cultivation zones humanity has depended on since the dawn of agriculture. Freshwater sources are threatened by melting glaciers and changing levels of rainfall. Rising sea levels from polar ice-melt endanger billions of people populating coastal areas across the globe. Public health is affected as the range of many infections diseases expands as temperatures rise. The list goes on. And global security is jeopardized as conflicts are triggered or exacerbated by these environmental stresses.

Yet the energy and climate challenges outlined above (and presented in more depth in the sections below) also represent *an extraordinary opportunity to reinvigorate the global economy*—and lay the foundation for long-term sustainable growth—through investments in clean, renewable, low-carbon energy sources. Indeed, the transformation of our antiquated energy infrastructure around the platforms of efficiency and reduced carbon emissions represents *the* great potential driver of technological innovation, economic growth, and job creation in the coming decades.

Clean energy technology represents one sector of the global economy that has continued to flourish, despite the economic malaise of the past year. According to the market research firm Clean Edge, global revenues for solar, wind, and biofuels grew from $75.8 billion in 2007 to $115.9 billion in 2008, *an increase of 50%.* Clean Edge predicts revenues for these three benchmark technologies will grow to $325 billion within a decade.[i]

This transformation can also be structured to promote equitable economic development, providing opportunity and shared prosperity to—and within—all nations. There is the potential for hundreds of billions of dollars of clean energy investments to flow in the coming years; and these investments can serve as a catalyst for more vibrant and resilient cities, more prosperous rural areas, and better livelihoods for those countries and communities who have been left behind by the carbon-intensive economy of the past.

This is not an impossible vision. Today, in diverse localities across the globe, clean energy deployment strategies are making impressive strides in job creation, consumer energy savings, and environmental stewardship. Forward-thinking entrepreneurs, community activists, and elected officials are pursuing the promise of the clean energy economy to create good jobs and expanded opportunity for those who need it most, while reducing global warming emissions and investing in local people and places. The challenge is to take these successes from the margins to the mainstream.

The global community has arrived at a critical juncture, and the decisions we make now will affect the welfare of the planet for millennia to come. There is no longer such thing as the "status quo" or "business as usual," because the future under an unmitigated emissions scenario will be devastatingly different the world we know today. A lack of concerted action to reduce global warming emissions is in fact a decision to lock in this destructive future. On the other hand, a strong push to transition to a clean energy economy is a decision to avert a climate catastrophe and preserve a habitable planet for future generations. The choice if clear.

The scale of the change we need is daunting but achievable. In their well-known "wedges" analysis on how to stabilize atmospheric CO2 at non-dangerous levels, Stephen Pacala and Robert Socolow of Princeton University describe 15 major global energy initiatives, any 7 of which would allow us to bring emissions down to an acceptable level during the next 50 years. Each of these wedges is formidable, representing the avoidance of 1 billion tons of carbon emissions per year by 2054. The wedges include, for example, increasing the fuel efficiency of 2 billion cars from 30 miles per gallon to 60 mpg (the worldwide fleet of cars is currently 800 million, but that number is rapidly rising); improving the efficiency of buildings and appliances enough to cut their CO2 emissions by 25 percent; increasing the efficiency of coal-fired power plants by 50 percent; introducing so-called carbon capture-and-storage capabilities at the equivalent of 1,600 large (500 megawatt) power plants; and dramatically increasing the use of renewables like wind, solar, and biomass in producing electricity.[ii]

In sum, energy and climate challenge and opportunity can be summarized by four principal questions:

1. How will we provide clean and affordable energy for a global population expanding both in numbers and in wealth?

2. How will we decarbonize the global energy sector to reduce the threat of catastrophic global warming?

3. How can the growth of the global "clean energy economy" be structured to promote equitable economic development between and within nations, and to help democratize the energy sector?

4. What are the roles of the different stakeholders—individual countries, the international community (in particular the UN Framework Convention on Climate Change), and non-governmental organizations—in solving these challenges and laying the architecture for long-term international cooperation.

This paper attempts to answer these questions, drawing on the extensive body of work already in existence. It begins with an overview of the energy and climate challenges we confront, and explores the socioeconomic and environmental implications of the rapid industrialization of developing countries. Then, the focus is turned to the future of energy, and what is needed to transition to a clean energy future. Finally, the importance of the COP 15 meetings in Copenhagen is discussed, including what to expect from the negotiations.

II. Challenges: Energy Insecurity and Climate Change

Energy

Access to energy shapes the global economy and social development. Indeed, energy powers our daily lives; it runs our factories, fuels our vehicles, and heats and cools our homes and businesses. The stability and reliability of the energy system only becomes more important as society becomes more dependent on electronic data and services. The world cannot, however, take the continued availability of affordable energy for granted. Recent trends in energy markets suggest that the current trajectory is unsustainable and undesirable. Prices have become volatile and supplies tight. Before the global economic crisis, demand was growing while excess capacity was shrinking.

Yet the global economy will eventually recover, and the fundamental facts will not have changed. Conventional energy supplies are increasingly concentrated in volatile regions of the world. Investors see heightened geopolitical risks undermining efforts to ensure the uninterrupted production and delivery of energy supplies and to build and maintain infrastructure. And global energy markets are witnessing the emergence of important new players like China, India, and Russia.

At the same time, the energy sector is a major contributor to global warming. Today, fossil fuels provide four-fifths of the energy that powers the global economy. Worldwide, 61 percent of greenhouse gas (GHG) emissions are linked to energy production, delivery, or use. In 2007, the combustion of fossil fuels released nearly 30 billion tons of carbon dioxide to the atmosphere—more than a million tons every hour—with coal and oil contributing roughly 40 percent each and natural gas accounting for the remaining 20 percent. Annual fossil-fuel carbon emissions have increased fivefold since 1950 and the rate of increase has accelerated since 2002.

To avoid catastrophic increases in global temperatures, these emissions must peak within a decade and then decline rapidly. The international community, however, still lacks a comprehensive multilateral framework for reducing global greenhouse gas emissions. Given these challenges, it is clear that our energy system—which evolved in a world very different from today's—must undergo a radical modernization. The market can no longer count on inexpensive and abundant supplies. Nor can the social and environmental costs of energy production, transport, and use continue to be ignored.

Transforming the energy system, however, cannot happen overnight. It will require new – and often disruptive – technologies. It will require taking steps to ensure that the energy system remains structurally sound and economically viable during potentially difficult transitions. And although modernization poses a significant economic challenge, it also offers a clear opportunity for the world economy to sustain economic growth while shifting energy priorities in favor of greater efficiency and low-carbon fuels. Seizing this opportunity will fundamentally alter the geopolitical, economic, and environmental dynamics of what appears to be an increasingly complex energy future.

Over the next 25 years, the world population is projected to grow to almost nine billion people. Living standards are expected to rise, and society will need more basic resources – including food, water, and energy – to fuel and sustain this expansion. Population growth and increasing levels of per capita resource consumption will drive energy demand in the 21st century. This growth will be significant, as developing nations even if other countries do not achieve U.S. or other developed country per-capita levels of consumption. Major sources of this growth will be in transportation (90% fueled by petroleum today and the world's fastest growing energy sector), and electrification, which increased dramatically in the 20th century and will continue to increase in the 21st century.

Global consumption of primary energy is projected to increase at a rate of approximately 1.6% per year. From 2006- 2030, the world's energy demand is expected to grow by 45%. Developing economies will account for nearly 87 percent of this growth, with just two nations – China and India – accounting for 51 percent.[iii] If current trends continue, it is projected that 86% of this new demand will be met by fossil fuels, 8.5% by renewables, and 5.4% by nuclear. Yet the planet cannot sustain such an outcome—this demand must be met in a much more sustainable manner.

Emissions from oil will most likely be limited by supply constraints. Production of conventional crude oil is expected to peak and begin declining within the next decade or two. By 2050, output could be a third or more below the current level. This will require that transportation fleets shift rapidly to other energy options, the most promising of which are electricity (produced from renewable energy), advanced biofuels, and compressed natural gas.

Unfortunately, the slowdown in the rate of discovery of oil and gas is pushing world energy markets toward dirtier, more carbon-intensive fossil fuels. The greatest problem for the world's climate is coal, which is both more abundant and more carbon-intensive than oil, and the "unconventional" fossil fuels such as tar sands and oil shale, which at recent oil prices have become economically viable. Unless the development of these dirty fossil fuels is deliberately curtailed in favor of renewable alternatives, it will be impossible to reach the declining emission trajectories that scientists say are needed to avoid a climate catastrophe.

"Energy Poverty" and Energy Security

If accurate, and energy prices stay level or increase as projected, energy poverty – i.e., limited supplies of energy that people can afford to buy - will be likely for many of the world's poorer countries. Combined with climate changes due to global warming we may be facing an increasingly unstable political situation in many developing economies over the next few decades. For example, increasingly limited water supplies due to changing precipitation patterns will lead to internal migrations within countries and across national borders. Even developed economies will be seriously impacted by increasing energy costs and climate change.

The term "energy poverty" is used to describe the lack of access to modern energy services. An estimated 2.4 billion people in developing countries lack modern fuels for cooking and heating and approximately 1.6 billion people—concentrated in sub-Saharan Africa and South Asia—do not have access to electricity.[iv] However, burning biomass for fuel poses significant health risks from indoor air pollution, including death. The dangerous particulates—commonly known as black carbon—are so concentrated and small that they travel deep into the lungs, causing chronic respiratory problems, lung cancer, pneumonia, and other health complications. Furthermore, recent research has revealed that that black carbon is the second major contributor to global warming after carbon dioxide emissions.[v]

Biomass also requires labor to collect, which prevents members of the household—primarily women and children—from engaging in income-generating activities or pursuing an education. This drawback reinforces a household's inability to escape the energy poverty cycle. Providing access to cleaner, more modern, and more dependable energy sources is a key component of Millenium Development Goals of alleviating poverty, improving public health, and reducing pollution in communities across the globe.

Meanwhile, nation-states face a different set and scale of energy-related concerns. "Energy security" is a term that encompasses a broad range of factors, including: a country's dependence on energy imports vs. domestic sources; susceptibility to supply disruptions, including price spikes; the vulnerability of the distribution system (pipelines, transmission wires, etc) to natural disasters or extremist attacks; and the overall diversity and resilience of a country's energy supply. Energy security is a key component of national security, economic development, and domestic political stability, yet each country faces a different set of circumstances and challenges surrounding their definition and pursuit of energy security, particularly as the global supply of fossil fuels struggles to keep up with ever-increasing demand.

The Economics and Geopolitics of Oil

Oil is vital to many industries, and is of importance to the maintenance of industrialized civilization itself, and thus is critical concern to many nations. Oil accounts constitutes the most commonly used energy fuel, at 35 percent of global primary energy use, ranging from a low of 32 percent for Europe and Asia, up to a high of 53 percent for the Middle East. Other geographic regions' consumption patterns are as follows: South and Central America (44 percent), Africa (41 percent), and North America (40 percent).[vi] Today, about 90 percent of vehicular fuel needs are met by oil. Oil's value as a portable, dense energy source powering the vast majority of vehicles and as the base of many industrial chemicals makes it one of the world's most important commodities.

The forecast for oil predicts tighter supplies, greater dependence on fewer suppliers, and higher prices over the long-term. Prior to the current economic crisis, projected growth in energy demand suggested an ever-tightening oil market, with some analysts forecasting a significant gap between global supply and demand. While the economic downturn has reduced oil prices and projections for near-term demand growth, lower prices will also decrease new supplies and investment, and lead to a resurgence in energy demand. In the future, the leveling off of Russian output, coupled with production declines in the North Sea, the U.S., and Mexico, will increase the leverage of a small number of major oil producers, most notably OPEC nations. Proven world oil reserves, as reported by the Oil & Gas Journal, are estimated at 1,342 billion barrels. Yet 56 percent of the world's proved oil reserves are in the Middle East, and just under 80 percent of the world's proved reserves are concentrated in eight countries, of which only Canada (with oil sands included) and Russia are not OPEC members.[vii]

Meanwhile, oil production will strain to keep up with demand in the coming years. The U.S. Energy Information Agency predicts that demand for liquid fuels and other petroleum derivatives will increase from 85.0 million barrels per day in 2006 to 106.6 million barrels per day in 2030, using their reference case scenario. More than 80 percent of this 22 million barrel increase in total liquids consumption is projected to occur in the nations of non-OECD Asia and the Middle East, where strong economic growth is expected. The transportation sector accounts for the largest increment in total liquids demand, at nearly 80 percent of the total world increase.[viii] The EIA estimates this increase will be met primarily with "unconventional" liquid fuels (including petroleum-based liquids from oil shale and tar sands, and biofuels like ethanol and biodiesel), which will increase from 3.1 million barrels to 13.4 million barrels per day. The economic viability of these unconventional fuels is made possible by oil prices projected to remain above $100 per barrel (in real 2007 dollars) from 2013 through 2030. Yet the implications of these unconventional liquid fuels for global warming pollution and land use change are significant.

Climate Change

According to the Intergovernmental Panel on Climate Change (IPCC)[ix], an international scientific body made up of hundreds of the world's top scientists and policy experts, there is no doubt that that the planet is warming. In their most recent report, the IPCC states, "Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level."[x]

Climate change, as defined by the IPCC, is "any change in climate over time, whether due to natural variability or as the result of human activity." The Earth's climate fluctuates naturally over time, as can be seen clearly in the geological record. Solar activity, the earth's orbit, ocean circulation, volcanic activity, and changes to the chemical composition of the atmosphere all influence Earth's climate. While past climate change undoubtedly occurred without human influence, there is little to no doubt among the world's top scientists that human activity is the *main cause* of the global warming evident in recent decades.

Carbon dioxide (CO2) comprises the majority of global greenhouse gas emissions, at about 77 percent of the worldwide total (measured in global warming potentials). The remainder comes mostly from methane (CH4) and nitrous oxide (N2O), with small shares coming from fluorinated gases (SF6, PFCs, and HFCs). The contributions of CH4 and N2O are significantly larger in developing countries, and in some cases are larger than energy-related CO2 emissions. Emission estimates of CH4 and N2O, however, are subject to higher measurement uncertainties than energy-related CO2 emissions.

Just in the past 100 years, atmospheric concentrations of carbon dioxide have increased from a pre-industrial level of 278 parts per million to 385 parts per million today. Atmospheric concentrations of methane (CH4), the second leading GHG, have more than doubled over the past two centuries. These and other GHG increases have led to an average global temperature increase of 0.74° C.[xi] This is the largest and fastest warming trend that scientists have been able to discern in the history of the Earth. This slight increase has already resulted in the rapid melting of the polar and glacial ice, the beginnings of ocean acidification, and a host of other foreboding ecological changes. If we continue on our current emissions track we can expect the consequences to be even more severe.

To keep the global average temperature from rising more than 2° C (3.6° F) above pre-industrial levels, worldwide emissions would need to peak around 2015 and subsequently decline by 40 to 45 percent by 2050 compared to 1990 levels. This corresponds to capping the concentration of CO2 in our atmosphere at 450 parts per million, and eventually reducing it down to 350 parts per million. However, over this century, the global population is expected to increase by 40 to 100 percent and economic growth is projected to climb exponentially. Reducing emissions and CO2 concentrations to levels that avoid dangerous human interference with the climate system will require substantial changes in energy use, including technological innovation plus advances in efficiency, conservation, and alternative energy sources.

The IPCC estimates that even under an optimistic future emissions scenario, global temperatures will rise 1.1—2.9 °C above current temperatures by the end of this century. Yet, according to the Copenhagen Climate Science Congress, attended by 2500 scientists, "Recent observations confirm that, given high rates of observed emissions, the worst-case IPCC scenario trajectories (or even worse) are being realized."[xii] The "worst-case" IPCC scenario predicts atmospheric concentrations of carbon dioxide of 1000 parts per million by 2100. Carbon dioxide concentrations of this level would correlate to global temperature increase of approximately 5° C, which would have devastating ecological, economic and social consequences. This grim outlook is substantiated by the International Energy Agency, in its *World Energy Outlook 2008*, which states: "Without a change in policy, the world is on a path for a rise in global temperature of up to 6°C."[xiii]

A global temperature increase of such magnitude would be catastrophic. Extreme weather events such as drought, floods, and severe storms, including hurricanes, would all become more intense and inflict enormous damage to life and infrastructure. Rising sea levels would threaten the megadelta regions of Asia, coastal cities in Europe, low-lying areas in North and

Latin America, and small islands. (The melting of the Greenland ice sheet alone could lead to a sea-level rise of seven meters). Other major impacts include:

- Melting of inland glaciers in the Himalayas and the Andes, which provide water to over a billion people
- Increased incidents of heat- and flood-related mortality and of water and food-borne diseases.
- Declining crop yields and increased hunger in many regions, including parts of Africa and Asia.
- Degrading fisheries.
- Declining coral reef systems.
- Extinction facing 20 percent to 30 percent of global plant and animal life.

The characteristics of climate change create unique policy challenges, and provide the foundation for appropriate policy responses. At the most basic level, climate change is a global problem, necessitating a coordinated international response. But countries do not have equal interests in reducing emissions, nor are they all equally significant. The problem is also long-term, since CO2 emissions, on average, remain in the atmosphere for about 100 years (some other gases persist for thousands of years). Left unchecked, some consequences of climate change, such as sea level rise, can be irreversible. Finally, responding to climate change implicates essential interests such as economic development and national security. Nearly the full range of human activities is associated with GHG emissions, including transport, industrial activities, and electric power usage. Collectively, these features create considerable challenges for the development of a concerted and cohesive international response.

Because of the nature and scale of the climate change problem, it is not surprising that the global agreements needed to adequately address climate change are only partially formed. Governments adopted the UN Framework Convention on Climate Change (UNFCCC, or "Climate Convention") in 1992. This agreement has nearly universal membership—including the United States and all major GHG emitting countries—and establishes the basic principles and preliminary steps for addressing climate change at a global level. Most importantly, the Climate Convention establishes an ultimate objective of stabilizing atmospheric concentrations of greenhouse gases at a level that avoids dangerous human interference with the climate system. Yet, the Convention established little in the area of firm governmental commitments. Recognizing this shortcoming, and responding to firmer scientific findings, governments agreed in 1997 to the Kyoto Protocol.

Under the Kyoto Protocol, industrialized and transition economies assumed legally binding emission caps to be achieved during the five-year period from 2008 to 2012. Targets ranged from a decrease of 8 percent relative to 1990 (European Union and others), to an increase of 10 percent (Iceland). However, developing countries, including major emitters such as China and India, have no emission limits under Kyoto. Furthermore, one industrialized country—the United States—has not yet ratified the Kyoto Protocol, and is therefore not bound by its emission controls.

Since the Protocol entered into force in February 2005, much of the international community has turned its attention to a successor agreement that builds on—or replaces—Kyoto by incorporating new features that attract the interest of the United States and key developing countries. Preliminary negotiations on this successor agreement are now underway, and the official negotiations will take place in December in Copenhagen, at the 15th Conference of the Parties of the UNFCCC.

Climate Change and Global Conflict

In April 2007, 55 delegations to the UN met at the Security Council to discuss the security implications of climate change. Led by the then UK Foreign Secretary, Margaret Beckett, states shared their concerns about the security implications of climate change. UN Secretary General Ban Ki-moon talked of scarce resources, fragile ecosystems and severe strains placed on the coping mechanisms of groups and individuals, potentially leading to "a breakdown of established codes of conduct, and even outright conflict".

There are at least four ways that climate change can contribute to global conflict. First, a changing climate will lead to large-scale displacement of people. This can occur either over the long-term (such as from rising sea levels or dwindling water supplies), or quite rapidly (such as a series of natural disasters). Displaced people eventually will eventually have to settle somewhere, and shifting demography and economy patterns due to climate change will force realignments in domestic, regional, and global power relations that may cause new frictions or exacerbate existing tensions.

Second, climate change may affect the availability of certain natural resources and cause scarcities that lead to conflict. Examples include freshwater shortages and reduced agricultural productivity due to changing weather and temperature patterns. Competition and conflict can increase over access to these resources as availability becomes scarce.

Third, climate change may also lead to conflict due to an increase in abundance. For example, the thawing of previously frozen polar areas may allow access to resources that were previously unreachable. Oil and gas fields in northern Canada, Alaska, and Siberia are likely to become accessible with warming and thus become economically viable. Competition over newly-available resources could lead to conflict, especially when these resources turn up in places where boundaries are not clearly set.

Finally, changing climate will expose new areas of national interests and new questions of sovereignty. Island states may become submerged under rising sea levels. Traditional geographic boundaries, such as rivers, may change course or disappear altogether. And large-scale human migrations may begin to strain our preconceived notions of national sovereignty.

Of course, these scenarios are all hypothetical—for now. Yet the reality of global warming is upon us, and without concerted global action to reduce greenhouse gas emissions, the potential for future conflict looms.

III. The Future of Energy

In 2007, the combustion of fossil fuels released nearly 30 billion tons of carbon dioxide to the atmosphere—more than a million tons every hour—with coal and oil contributing roughly 40 percent each and natural gas accounting for the rest. The manufacture of cement released nearly another 350 million tons, while deforestation and agriculture combined contributed roughly 1.6 billion tons. Annual fossil-fuel carbon emissions have increased fivefold since 1950 and the rate of increase has actually accelerated since 2002. Today, fossil fuels provide four-fifths of the energy that powers the global economy.[xiv]

To stabilize atmospheric concentrations of carbon dioxide at 450 parts-per-million (the very limit of what scientists predict is necessary to keep global warming below 2 °C), energy-related carbon dioxide emissions will have to level off at no more than 15 billion tons per year by 2050—down significantly from the current level of 30 billion tons. Bringing large quantities of low-carbon energy online is the only way to accomplish this reduction while allowing the global economy to continue to grow and support an expected population of 9 billion people.

Renewable Energy Potential

Renewable energy sources already supply nearly one-fifth of the world's electricity. While most of this comes from large hydropower, which is growing very slowly, wind capacity is expanding at 24 percent per year and solar at over 40 percent, rivaling the computer and mobile phone industries.

Wind

Since 2000, wind power has gone from a tiny niche electricity supplier to become a significant force in the global power business. Total generating capacity is estimated to have passed 100 gigawatts in early 2008, double the amount in 2004. In 2007, wind power represented 40 percent of new generating capacity installations in Europe and 35 percent in the United States. Further growth will come from offshore wind farms, which are expected to expand rapidly in the coming decade. And this torrid growth appears likely to continue as more and more governments follow the leaders and implement wind-friendly electricity laws.

In the case of wind power, the Pacific Northwest Laboratory found that the land-based wind resources of the U.S. states of Kansas, North Dakota, and Texas could meet all of the nation's electricity needs, even with large areas excluded for environmental reasons. The U.S. wind resource base is not limited to those states, however, and beyond the land-based resource, offshore wind offers enormous potential—enough in the case of northern European countries such as the Netherlands and the United Kingdom to in principle provide all of their electricity. China's wind resources alone are sufficient to provide more electricity than the country currently consumes

Solar

The solar industry is starting from a smaller base but is growing even more rapidly than wind power. Annual production of solar rose 41 percent in 2006 and 51 percent in 2007. Cumulative installations of solar cells have grown more than fivefold over the past five years, spurred by strong incentive programs in Germany, Japan, and Spain.

Even as solar cells enter the mainstream, attention has focused on using solar thermal energy through large concentrating solar power (CSP) plants. Built mainly in deserts, these plants provide wholesale electricity that is transmitted to cities and industries via high-voltage power grids, in the same way most power is today. A wide range of CSP plant designs are being pursued; most rely on mirrored parabolic troughs or dishes to concentrate the sun's heat, which is then transferred to water or another fluid, with the resulting steam used to spin a turbine and produce electricity. These plants produce power in much the way that conventional coal or nuclear plants do, but they operate at lower temperatures and pressures, which permits cost reduction.

A study by the National Renewable Energy Laboratory in the United States identified 159,000 square kilometers of land in seven southwest states that are suitable for CSP plants—representing nearly 7,000 GW of generating capacity, or nearly seven times the nation's existing capacity from all sources. One-fifth of U.S. electricity could be produced on a 1,500 square-kilometer plot of land slightly larger than the city of Phoenix. While some regions such as northern Europe do not have sufficient solar resources to meet more than a fraction of their energy needs, other areas could become major exporters of solar energy. North Africa, for example, has a vast solar resource, and plans are being laid to build solar power plants that would transmit electricity to Europe. An area covering less than 4 percent of the Sahara Desert could produce enough solar power to equal global electricity demand.

Geothermal

Geothermal power currently provides just 10 GW of power worldwide, with much of it in the United States, the Philippines, and Mexico. But a new generation of enhanced geothermal technologies is now being developed that makes it possible to tap a much larger geothermal resource base. Advanced geological sensing and drilling techniques developed by the oil industry are being combined with new heat exchanger materials and systems. The Massachusetts Institute of Technology has estimated that the United States alone has at least 100 GW of geothermal potential, mainly in the Western states, and similar potential undoubtedly exists in many other countries.

Energy efficiency

From the earliest stages of the Industrial Revolution, energy productivity has advanced steadily, a trend that accelerated dramatically when energy prices soared in the 1970s. In the United States, the economy has grown 165 percent since 1973, while energy use rose just 34 percent, allowing the nation's energy productivity to double during the period. But even today, well over half of the energy harnessed worldwide is converted to waste heat rather than being used to meet energy needs.

This suggests enormous potential to improve energy productivity in the decades ahead, and broader trends will boost that effort. Many technologies are becoming more and more efficient—from steelmaking to automobiles— and in recent decades, the economies of most industrial countries have centered the bulk of their economic growth on light industry and the service sector, with energy-intensive industries such as smelting metals and manufacturing petrochemicals falling as a share of the total economy. Even larger opportunities are found in developing nations, where energy productivity tends to be lower and much of the basic infrastructure is still being built. However, this potential will be offset in some countries in the short term by the fact that they are entering an infrastructure- and energy-intensive stage of economic development.

Lighting

Compact florescent light bulbs (CFLs) represent a remarkable advance in energy efficiency – producing nearly four times as much light for each watt of power consumed. Until recently, CFLs were expensive and did not meet the needs of many lighting applications, but two decades of miniaturization of components, improvements in the quality of light produced, and reductions in manufacturing costs have largely closed the gap with incandescents, and sales are soaring.

Although CFL technology was developed in the United States and has been dominated by European and U.S. firms, most of the bulbs are now manufactured in China where they have become nearly ubiquitous. Chinese production of CFLs tripled from 750 million units in 2001 to 2.4 billion in 2006. In the United States, sales rose from 21 million units in 2000 to 397 million in 2007. The CFL share of the lighting market varies widely, from 80 percent in Japan, to 50 percent in Germany, to 20 percent in the United States. Around the world, the use of CFLs will continue to rise as governments implement lighting efficiency standards that promote their use and in some cases virtually prohibit the sale of incandescent bulbs.

In the meantime, several other new lighting technologies are under development, including a semi-conductor device known as a light emitting diode (LED) that is as much as 90 percent more efficient than an incandescent. Currently deployed for a range of specialized forms of lighting, including stoplights and electronic devices, LEDs are still too expensive for widespread use. However, costs are falling, and engineers are developing a range of new LEDs that will have much wider application.

Buildings

The greatest potential for energy savings lies in the most basic element of the energy economy— buildings—which consume about 40 percent of global energy and emit a comparable share of CO_2 emissions. About half of this energy use is for space and water heating, and the rest is associated with the production of electricity for lighting, space cooling, and powering appliances and office equipment. With technologies available today, such as better insulation, more-efficient lighting and appliances, improved doors and windows, and heat recovery ventilators, the fossil energy needs of buildings can be reduced by 70 percent or more, with the additional investment paid for via lower energy bills. Further gains can be achieved by designing and orienting buildings so that they can benefit from natural heating, cooling, and day lighting.

Even greater savings can come from "zero energy" or "zero-carbon" buildings that produce all of their energy on site with renewable energy, emitting no CO_2. (Most buildings will need to have an energy supply from outside to meet peak demands at particular times of the day and year, but are considered zero net energy if they produce as much energy as they consume over the course of a year.) The United Kingdom has mandated that all new homes built after 2016 and all commercial buildings built after 2019 be zero-carbon.

The advent of cheap energy enabled modern buildings to work in spite of nature rather than with it. But it is possible to reduce demand in existing buildings by insulating them appropriately, controlling unwanted air infiltration, and improving performance for space and water heating, lighting, ventilation, and air conditioning. There is a substantial gap between economic potential and commercial reality in the buildings sector, and since the 1970s, national, state, and local governments have imposed energy building codes to close that gap. But in recent years, those codes have themselves fallen short of driving the kind of advances that are possible.

Studies show that for new construction, the integration of design with multiple energy efficiency measures can reduce energy use substantially compared to conventional building, as new offices from New York City to London to Berlin have demonstrated. Potential savings in India, China, and elsewhere could be even greater. India, for example, has no mandatory efficiency codes for commercial buildings, and most building contractors have not been trained to install insulation. But greener buildings are on the way in India as well. One of the largest green commercial developments in the world is under construction outside of Delhi; it is expected to exceed international energy performance standards. “Green buildings” that minimize the use of energy as well as other environmental impacts have attracted growing attention around the globe in recent years. In the United States, green certification is now highly sought by builders of new commercial buildings, setting off a wave of advances by architects, engineers, and builders. The U.S. Green Building Council, which developed a popular set of voluntary standards, now includes more than 15,000 member organizations.

In developing countries, energy use in buildings is growing particularly rapidly as people move into improved homes and acquire amenities such as heating, cooling, and refrigeration. In China, buildings already account for 23 percent of energy use, and with 300 million people—equivalent to the entire U.S. population—expected to move to cities in the next decade, the largest construction boom in history will unfold in the coming years. How these buildings are constructed will profoundly shape CO2 emissions in China for decades to come.[xv]

Cogeneration

In most power plants today, two-thirds of the energy contained in the plant’s fuel is converted into waste heat or lost in the transmission process. In the United States, just the waste heat from power plants is equivalent to all of the energy consumed in Japan. By integrating power generation with factories and buildings, high-temperature waste heat can be used to produce electricity, or, in another configuration, the waste heat from power generation can be used for industrial and building heat, increasing total energy efficiency from 33 percent to as high as 80–90 percent.

It is estimated that concentrated heat and power (CHP) in Europe reduced annual CO2 emissions by 57 million tons between 1990 and 2005, accounting for 15 percent of European emissions reductions. If most industrial countries were to aggressively pursue CHP, it would eliminate the need for new coal plants and allow many older plants to be gradually shut down.

At today's energy prices, much of the investment can be justified in energy savings alone. The United States could get 150 gigawatts, or 15 percent of its power, from the unused waste heat from heavy industry as well as from manure, food industry waste, landfill gas, wastewater, steam, gas pipeline pressure differentials, fuel pipeline leakages, and flaring. This is as much power as the entire U.S. nuclear industry produces.

A global assessment by the McKinsey Global Institute of the potential to improve energy productivity concluded that the rate of annual improvement between now and 2020 could be increased from 1 percent to 2 percent, which would slow the rate of global energy demand growth to just 1 percent a year. If these gains are extended to 2050, the growth in world energy use could be held to roughly 50 percent above current levels, rather than the doubling that is projected under most business-as-usual scenarios. This large difference is equivalent to the combined current energy consumption of the European Union, Japan, and North America. By fully exploiting all of the opportunities described above, the world could likely do even better than that.[xvi]

The Role of Coal in a Low-Carbon Future

Coal-fired power plants currently supply more than 40 percent of the world's electricity, and their large contribution to CO2 emissions has led policymakers and industrialists to focus on carbon capture and storage (CCS) so that coal can be compatible with a low-carbon economy. Such plants would be equipped with devices that capture carbon either before or after the combustion of fossil fuels, and then pipe the CO2 into underground geological reservoirs or into the deep ocean, where it could in principle remain for millions of years.

Coal can either be gasified (as it already is in some advanced power plants), with the carbon dioxide then separated from the other gases, or it can be burned directly in a super-critical pulverized plant that also allows the capture of as much as 90 percent of the CO2. Four CCS projects are in operation in Algeria, Canada, Germany, and Norway. The facilities in Algeria and Norway simply capture carbon dioxide that is extracted together with natural gas. The small project in Weyburn, Canada, on the other hand, gasifies coal, extracting CO2 and injecting it underground. While these technologies are advancing, together with advances in modeling and monitoring of geological sites, full-scale commercial CCS systems are still a long way off. And a vast physical infrastructure will be needed to capture, move, and store the emissions from even a fraction of today's fossil fuel combustion. The United States, European Union, Japan, and China have all launched government funded CCS programs in the last few years, but the pace of these efforts is surprisingly lethargic given the urgency of the climate problem and the fact that much of the power industry is counting on CCS to allow them to continue burning massive amounts of coal.

A 2007 study by the Massachusetts Institute of Technology concluded that the U.S. Department of Energy's main program to demonstrate the feasibility of large-scale CCS is not on track to achieve rapid commercialization of key technologies. Locating, testing, and licensing large-scale reservoirs where CO2 can be stored is a particularly urgent task. Also problematic is the fact that CCS will be water- and energy intensive, which will limit its attractiveness in many regions. It will take at least a decade to develop and test large-scale CCS technology, which means that it will be the 2020s or 2030s at the earliest before significant numbers of low-carbon coal plants can begin to be built. How large a role CCS ultimately plays in a low-carbon economy will depend on how rapidly the technology develops, how much it costs, and whether governments and industries are able to successfully mobilize the massive infrastructure investment that will be required. In the meantime, many scientists and environmental activists have called for a moratorium on building new coal-fired power plants until CCS can be included.

IV. Transitioning to the Clean Energy Future

Social and Economic Considerations

Many scientists expect that developing countries with little responsibility for today's climate instability will be the hardest hit by climate change. This asymmetry of circumstance prompts a pressing question: Can climate treaties be built on strong principles of fairness? In truth, equity already plays a role, albeit a limited one, in climate agreements. The Kyoto Protocol, for example, is based on the principle of "common but differentiated responsibilities," which recognizes different obligations for parties in different economic and emissions positions. And the Kyoto negotiating positions of many countries incorporated specific equity dimensions.

But fairness concerns are likely to assume a higher profile in future climate negotiations as the demands of climate stabilization become more burdensome. Two nagging questions in particular have equity at their core: How should rights to emit greenhouse gases be allocated? And who should bear the costs of emissions reductions and adaptation to climate change? A broad range of answers is given to these questions—each grounded in one or more climate equity principles. On emissions rights, for example, two very different principles are often cited by proponents of allocation schemes:

- The Egalitarian Principle states that every person worldwide should have the same emission allowance. This principle gives populous countries the greatest number of emissions rights. India, for example, with 3.8 times as many people as the United States, would be entitled to 3.8 times the emissions allowance available to the United States.

- The Sovereignty Principle argues that all nations should reduce their emissions by the same percentage amount. Large emitters would make large absolute reductions of greenhouse gases, while low-volume emitters would make smaller absolute reductions. Thus under an agreement to reduce emissions of carbon dioxide by, say, 10 percent, the United States would cut output by some 579 million tons of CO2,while India would reduce its emissions by 141 million tons.

Two other principles are often invoked to determine the economic burden of curbing climate change for different nations:

- The Polluter Pays Principle asserts that climate related economic burdens should be borne by nations according to their contribution of greenhouse gases over the years. Since 1950 the United States has emitted about 10 times as much CO2 as India; using this historical baseline suggests that the U.S. bill for dealing with climate costs should be about 10 times greater than India's. (The difference would be greater still if the baseline were set at 1750, roughly the start of the Industrial Revolution.)

- The Ability to Pay Principle argues that the burden should be borne by nations according to their level of wealth. If gross domestic product figures are used to determine how much each country pays, the U.S. responsibility would be some 12 times greater than that of India. A 2006 survey of climate negotiators from a broad range of nations revealed that the vast majority believe equity considerations should figure in climate negotiations. The survey found a relatively high degree of support for the Polluter Pays and the Ability to Pay Principles, and a relatively low degree of support for the Sovereignty Principle, consistent with a general sense in the international community that wealthy historical emitters should pay more and poor countries should pay less.

In the end, agreement on emissions allocations may require a mixture of different principles. Some analysts, for example, see egalitarianism as a desirable long-term equity goal, with other principles used to transition to an egalitarian outcome. These four equity principles address only the distributional dimension of climate equity concerns. Other principles are used to assess the equity of outcomes (how fair is the result of climate negotiations?) and of process (how fair is the procedure by which deals are negotiated?). The result is a thicket of principles, often conflicting, that will compete for policymakers' attention as climate negotiations unfold in the years ahead.

Origin of UNFCCC

The United Nations Framework Convention on Climate Change (UNFCCC or FCCC) is an international environmental treaty that was produced at the United Nations Conference on Environment and Development (UNCED) (informally known as the Earth Summit) in Rio de Janeiro, in 1992. The UNFCCC is also the name of the United Nations Secretariat charged with supporting the operation of the Convention. Since 2006 the head of the secretariat has been Yvo de Boer.

The treaty as originally framed set no mandatory limits on greenhouse gas emissions for individual nations and contained no enforcement provisions; it is therefore considered legally non-binding. Rather, the treaty included provisions for updates (called "protocols") that would set mandatory emission limits. The principal update is the Kyoto Protocol, which has become much better known than the UNFCCC itself.

Since the UNFCCC entered into force, the parties have been meeting annually in Conferences of the Parties (COP) to assess progress in dealing with climate change, and beginning in the mid-1990s, to negotiate the Kyoto Protocol to establish legally binding obligations for developed countries to reduce their greenhouse gas emissions.

A key element of the UNFCCC is that parties should act to protect the climate system "on the basis of equality and in accordance with their "common but differentiated responsibilities" and respective capabilities." The principle of 'common but differentiated responsibility' includes two fundamental elements. The first is the common responsibility of Parties to protect the environment, or parts of it, at the national, regional and global levels. The second is the need to take into account the different circumstances, particularly each Party's contribution to the problem and its ability to prevent, reduce and control the threat. Another element underpinning the UNFCCC is the "polluter pays principle." This means that the party responsible for producing pollution is responsible for paying for the damage done to the natural environment.

Kyoto Protocol

The protocol negotiations were completed in Kyoto in 1997. Flowing ratification by countries responsible for at least 55% of the world's emissions, the Protocol entered legal force on February 16, 2005. The Protocol is a first step, and initial emissions cuts are modest. However, Kyoto is the only binding international agreement that has established a legal framework for more ambitious cuts to prevent dangerous climate change.

The Protocol is legally binding, and has been ratified by 175 countries and the EU (the US is a notable exception). The agreement requires industrialized Annex I countries to limit their emissions of six key greenhouse gases (carbon dioxide, methane, nitrous oxide, sulfur hexafluoride, hydroflurorocarbons and perfluorocarbons) relative to their emissions in the base year of 1990. These Annex 1 countries are responsible for the large majority of the world's greenhouse emissions in the 19th and 20th century.

Specific targets differ from country to country, but the goal of the "first commitment period" (2008-2012) is to reduce climate change pollution by 5% by 2012. Some developed countries are required to reduce emissions, some to keep their emissions constant, and some to increase emissions by a defined amount.

The Protocol includes developing countries through a program called the Clean Development Mechanism, which allows developed countries to invest in clean energy and emissions reduction projects in the developing world, and use the emissions reductions to help meet their domestic reduction targets.

Bali

In December 2007, climate negotiators agreed at a major conference in Bali, Indonesia, on a plan and timetable for working toward a protocol to succeed Kyoto when its first commitment period ends in 2012. One resolution of the "Bali Action Plan" was to continue the focus of global climate negotiations on four main areas:

- **Mitigation**, a term covering efforts to reduce emissions below what they would otherwise be, especially through energy efficiency and a transition to low-carbon energy production, as well as avoiding deforestation in developing countries;
- **Adaptation** to the climate change that is already on the way, bringing rising sea levels and more severe weather patterns;

- **Technology** transfer from industrial to developing countries to facilitate and help pay for these efforts in countries that otherwise may not be able to afford them, or in some cases transfers between developing countries; and
- **Financing** for poorer countries provided by wealthier ones and potentially a pool of all nations, for the three activities agreed upon.

Some analysts add “Vision” to this list, an overarching statement about what the negotiations are designed to achieve and how they will do so.

The conference also clarified that major departures from the overall architecture of the climate change convention and the Kyoto Protocol were unlikely. Thus the major division of responsibilities to act between industrial and developing countries would remain. Yet the Bali Action Plan also for the first time expressed the objective that all parties— indeed, all human beings—will reduce emissions.

Discussion moved forward on the idea of emissions cuts negotiated within important industrial sectors—electric utilities, steel and aluminum production, aviation, shipping, or even land transportation. Helped by governments, companies in these sectors would pledge an overall emissions cap for their industry and then work together across national borders to invest in and secure the needed reductions where they could be achieved most cheaply—most often, probably, in less wealthy countries, where the industrial infrastructure is less modern and efficient.

The development that provided the most excitement at Bali was a new willingness by developing countries to consider reductions in the destruction of forests and land degradation if these could be financed by industrial countries. An estimated 23 percent of all global carbon dioxide emissions come from deforestation and other changes in land use, a proportion just a bit larger than the CO2 emissions of the United States or China (which account for about 20 percent of the world total each).

Towards Copenhagen

The world is rapidly approaching the U.N. climate change negotiations in Copenhagen, which are intended to hammer out a successor treaty to the Kyoto protocol that expires in 2012. COP15 is the fifteenth Conference of the Parties (COP) under the United Nations Framework Convention on Climate Change (UNFCCC). The conference will take place from December 7 to December 18, 2009 in Copenhagen, Denmark. The overall goal for the COP15 is to establish an ambitious global climate agreement for the period from 2012 when the first commitment period under the Kyoto Protocol expires.

Key issues which will be under discussion in the lead up to and at COP15 will include:

- The baseline year that specified reduction targets will be measured against and the duration of the second commitment period.
- The proposed greenhouse gas reduction targets for both the second commitment period and beyond.

- Whether the agreement will be expanded to include greenhouse gases that are currently excluded from the Kyoto Protocol.
- Whether a new agreement will be expanded to include Greenhouse gas emissions from the international maritime industry and Greenhouse gas emissions from the international aviation industry, both of which are currently omitted from the Kyoto Protocol.
- Whether the rules governing the Clean Development Mechanism (CDM) will be tightened to ensure the environmental integrity and avoidance of greenhouse gas emissions or whether they will be relaxed.
- Whether the CDM will include the as yet unproved Carbon Capture and Storage technology being promoted as a way of allowing coal-fired power stations to continue operating and new ones to be built.
- Whether the agreement will include measures to curb the rate of deforestation, especially of tropical rainforests in developing countries – otherwise known as Reducing Emissions from Deforestation and Degradation (REDD).

A successful post-2012 climate agreement must engage all the world's major economies through a "multi-track" framework allowing different types of commitments for developed and developing countries. The 25 major economies accounting for 84 percent of global emissions are extremely diverse, with per capita incomes and per capita emissions ranging by a factor of 18. Strategies for integrating climate action with broader economic and development agendas will vary with national circumstance.

Accommodating these differences requires a flexible but binding international framework integrating different types of commitments, such as economy-wide emission targets, policy-based commitments, and sectoral agreements. Incentives for developing countries, including both market-based schemes and direct assistance, also must be provided. A post-2012 agreement might advance adaptation on two fronts: proactively, by facilitating comprehensive national planning; and reactively, by helping countries cope with the risks that remain. Given the time it will take a new U.S. administration and Congress to establish a domestic climate policy, a detailed post- 2012 agreement is unlikely when governments meet in late 2009 in Copenhagen. Instead, governments should aim for consensus on a broad framework and continue negotiating toward specific commitments.

The core international challenge in addressing climate mitigation—and, by extension, climate adaptation—is arriving at fair and effective commitments among the world's major economies. They are ones whose actions are needed to reduce global emissions, and the ones best able to help poor, vulnerable countries cope with climate impacts.

The world's major economies are also the ones most responsible for the greenhouse gas pollution already accumulated in the atmosphere. Between 1900 and 1999 the currently industrialized countries have emitted the vast majority of the total emissions. Though no longer the number one emitter, the United States still accounts for 30.3% of all emissions since the industrial revolution. The EU (22.1%), Russia (8.9%), China (7.0%), and Japan (3.7%) follow distantly.

Twenty-five economies (counting the European Union as one) currently account for 84 percent of global emissions. These same countries account for 74 percent of global population, and 90 percent of global GDP. It is obvious enough why the engagement of the major economies is an environmental imperative—steep cuts in global emissions are not possible without them. But it is imperative politically as well. There are costs to reducing emissions and when only some bear them—because they are the only ones acting—these countries may risk harm to their industrial competitiveness. For any to sustain ambitious climate efforts, they must therefore be confident that their counterparts (and competitors) are also contributing their fair share. The best way to instill this confidence is through a balanced set of commitments that are clear, verifiable, and in some way binding.

Mitigation commitments by all major economies may only be feasible, however, with some flexibility in the *form* of their commitments. In their stages of development, economic structures, policy cultures, resource bases, etc., the 25 largest emitters are extremely diverse. Their per capita incomes and per capita emissions range by a factor of 18. The kinds of policies that can successfully integrate climate action into broader economic and development agendas vary from country to country. To accommodate these differences in circumstance and strategy, a new agreement will have to allow for different types of mitigation commitments.

On adaptation, it is for the most part not the major economies, but a different set of countries, that have the most at stake: small island and low-lying nations losing ground to rising seas, and poor African countries facing greater risk of drought, disease, and famine. Yet here, too, an effective response hinges on agreement among the major economies. It is the major developed countries that have the resources—and, in the eyes of many, the responsibility—to help these countries absorb the impacts of warming. And they are only likely to commit substantial resources as part of a deal in which the major emerging economies commit to reduce their emissions.

The type of architecture that would most effectively marshal the major economies on both mitigation and adaptation could be described as an "integrated multi-track" framework: "multi-track" because it contains multiple commitment types, or tracks, and countries have some choice among them; "integrated" because these varied efforts are linked in a single, unifying structure.

Elements of an Equitable Climate Agreement

The ultimate configuration of a post-2012 climate framework can emerge only through the negotiations themselves. But the essential elements are reasonably clear. A comprehensive agreement must include mitigation commitments by the major emitting countries, technology assistance and other incentives for developing country action, and support for climate adaptation in poor, vulnerable countries.

Mitigation

Effective mitigation commitments can take three basic forms: emission targets, policy-based commitments, and sectoral agreements. From the standpoint of environmental effectiveness and economic efficiency, absolute economy-wide emission targets, like those set by the Kyoto

Protocol, are the clear favorite. They establish clear and verifiable environmental endpoints. And they provide a foundation for emissions trading—the buying and selling of emission allowances—which harnesses market forces to achieve reductions at the lowest possible cost. On pure policy grounds, environmental effectiveness and economic efficiency would argue for extending this approach globally, with all the major economies committing to binding absolute targets. Indeed, this may be the long-term ideal towards which the climate regime should evolve. But it is not feasible now. China, India, and other developing countries have made clear that they will not accept economy-wide emission limits.

An alternative approach for developing countries is "policy-based commitments"— making an international commitment to implement specific nationally defined policies that will reduce emissions. Such commitments could be readily tailored to national circumstance, and could flow directly from domestic policies that are driven by other priorities, such as energy security, economic growth, or cleaner air, but simultaneously deliver climate co-benefits. China, for example, has domestic energy efficiency targets, renewable energy goals, and automobile fuel economy standards; some version of these could be put forward as international commitments. Tropical forest countries such as Brazil or Indonesia could commit to policies to reduce deforestation. Others might put forward policies to reduce industrial emissions.

A third form of mitigation commitment—in addition to targets and policy commitments—is sectoral agreements. Countries, both developed and developing, could commit to targets, standards, or other measures to reduce emissions from one or more given sectors. The case for sectoral agreements is strongest in the case of energy-intensive, globally traded industries, such as iron, aluminum, and cement, where uneven carbon regulation poses the greatest risk of competitive imbalances. Sectoral agreements could also help to target efforts in key sectors such as electric power, where international technology cooperation is perhaps most critical, and transportation, where commitments among a handful of countries on fuel and efficiency standards could effectively transform the global automotive market. For a developing country, a sectoral agreement might be in addition to, or in lieu of, a policy-based commitment. For a developed country, a sectoral commitment would be parallel to its economy-wide target, and one means of achieving it.

Incentives for Developing Country Action

In the case of developing countries, commitments will come only in exchange for incentives. These can take two forms—market-based incentives, in which countries earn tradable emission credits for reducing their emissions, and official development assistance from developed countries. Many developing countries are earning emission credits now under Kyoto's Clean Development Mechanism, which has demonstrated both the weaknesses and the promise of the crediting approach. A post-2012 agreement will almost certainly include a redesigned crediting mechanism that moves beyond a project-by-project approach to reward reductions on a broader scale. One possibility is to complement policy based commitments with "policy crediting"—allowing a country to earn credits for a portion of the reductions achieved under a committed policy. This creates a market incentive to assume, and to fulfill, a policy-based commitment. A crediting approach works, however, only if there is demand for the credits developing countries are generating, which in turn necessitates strong absolute targets for developed countries.

Developed countries also must be prepared to provide more direct assistance. As an interim step, the United States, Britain and Japan recently led an effort to establish a new Clean Technology Fund at the World Bank projected to deliver $5 billion or more for technology deployment over five years. As with past climate-related assistance, the fund relies entirely on voluntary contributions by donor countries. One issue for post-2012 is whether to establish a more predictable flow through firm funding commitments or through a mechanism such as a levy on international emissions trading. Another issue is how to give developing countries greater access to state-of-the-art technology while safeguarding intellectual property rights.

Adaptation

From its inception, the international climate effort has focused predominately on the mitigation side of the equation. There is broad recognition, however, that a post-2012 agreement must deliver stronger action on adaptation as well. The issue is in part the willingness of better-off countries to commit steady, substantial support. But the real challenge is how best to deploy those resources to facilitate climate resilience and response on the ground.

One complicating issue in crafting the international response is the impossibility in most cases of clearly distinguishing the effects of global warming from the effects of natural climate variability. While most might acknowledge direct cause and effect in the case of sea level rise, warming's broader toll will be in intensifying the strength or frequency of otherwise ordinary weather events. "Responsibility" in these cases is harder to assess.

Fortunately, the most effective response – be it an early warning system, a stronger building code, or a new drought-resistant crop – is often the same whether the risk is natural or human-induced. At a practical level, this argues for a comprehensive approach to reducing climate risks, regardless of their source, by "mainstreaming" or integrating adaptation into development decision-making and disaster preparedness and response. This effort would extend well beyond the climate regime, as for instance, by approving multilateral development assistance only for projects that score well on climate resilience. But it is perhaps only within the climate regime that adaptation needs can gain sufficient political salience to leverage this broader response. A post-2012 agreement could advance adaptation on two fronts: proactively, by facilitating comprehensive national planning to reduce climate risk; and reactively, by helping especially vulnerable countries cope with the risks that remain.

On the proactive front, the agreement can help needy, at-risk countries develop and implement comprehensive national adaptation strategies. Such strategies could identify climate risks (from both climate change and climate variability), existing and needed adaptation capacities, and high-priority implementation needs. It would also map out policies to incorporate climate risk management into development decision-making. The agreement could designate or establish a body to provide technical assistance and to assess the adequacy of a country's national strategy. Once its strategy is approved, a country could be eligible for implementation funding through the climate regime, and the strategy could serve as a basis for targeting other multilateral or bilateral assistance.

On the reactive side, a post-2012 agreement can establish an international response fund to assist countries suffering extreme and/or long-term climate impacts. At present, post-disaster assistance is largely ad hoc, with a new round of international pledging following each event.

A fund supported by long-term funding commitments would enable a more predictable and timely response. It could narrowly target impacts directly attributable to climate change. Or a new fund could address the full range of climate-related disasters—from extreme weather events such as typhoons to long-term impacts such as sea-level rise—whatever their cause. In addition to addressing the direct impacts of climate change, this approach would help rationalize climate disaster assistance more generally by substituting regularized funding for reactive and unpredictable aid.

Key Political Challenges

Quite apart from the complexities of treaty architecture, governments face a number of critical political challenges on the road to Copenhagen and beyond, which are outlined below.

Developed Country Targets

The Bali Action Plan calls for "comparability of effort" among the developed countries. Comparability can be measured any number of ways—factors might include marginal abatement costs or willingness to support developing country efforts. But the most critical metric will be emissions, and, more specifically, the emissions target that each is willing to assume. A pivotal issue here is the base year against which emissions are measured.

In the Framework Convention, developed countries agreed on a voluntary aim (largely unmet) of reducing emissions to 1990 levels by 2000. The Kyoto Protocol also uses 1990 as a benchmark, with targets set as percentage reductions from (or, in a few cases, increases above) emission levels in that year. Continuing to rely on 1990 as the base year will make it difficult, however, to arrive at new targets that look fair. The European Union has said it will reduce emissions 20 percent below 1990 levels by 2020 (and more if other countries agree to comparable cuts). But U.S. emissions are now 15 percent above 1990 and, under most proposals before Congress, would still be above 1990 levels by 2020. Such a wide numerical gap—the U.S. at or above 1990 levels, and the EU 20 percent below—may be hard to justify. One solution is to adopt a new base year. Measured against 2005 levels, the EU's target represents a reduction of 14 percent, roughly comparable to the cuts proposed in the more ambitious bills before Congress. Europe may feel that abandoning the 1990 base year it is losing credit for efforts already undertaken. But that may a tradeoff needed to arrive at targets that appear reasonably equitable to all.

One of the most abiding features of the international climate effort has been an explicit distinction between the roles and responsibilities of developed and developing countries. Recognizing that wealthier countries bear greater historic responsibility for the buildup of greenhouse gases in the atmosphere, and that they have greater capacity to act, the Framework Convention sets out the principle of "common but differentiated responsibilities" and calls on developed countries to "take the lead" in addressing climate change.

This core principle, however, is not a static one, and a fair and effective post-2012 agreement requires a rebalancing of responsibilities to reflect new realities, most notably the soaring rise in developing country emissions. Developing countries now produce a majority of annual global emissions and, under business-as-usual scenarios, will account for 80 percent of the growth in energy-related emissions projected by 2030. A recalculation of respective responsibilities suggests it is time for the largest of the developing country emitters to assume binding international commitments.

The United States and China

The United States has the ignominious designation of being the only industrialized country to not ratify the Kyoto Protocol, while for years being the world's largest emitter of greenhouse gasses (China recently surpassed the U.S., but remains far below in emissions per capita). Thus, the United States bears great responsibility, and high expectations, in the international negotiations now underway in preparation for COP15 in Copenhagen.

One of eight industrialized nations collectively known as the Group of Eight, the United States is the only G8 country without a comprehensive national policy on climate change. The presumption has been that this would change under the Obama administration.

The United States has two options for implementing a national climate policy:

1. **A comprehensive climate and clean energy bill** that sets limits on total greenhouse gas emissions and new standards for clean energy generation
2. **Regulations** promulgated by the Environmental Protection Agency through a rule-making process set forth in the Clean Air Act (CAA).

Climate Legislation

The U.S. House of Representatives recently passed a historic piece of legislation known as the American Clean Energy and Security Act, or ACES. This comprehensive national climate and energy legislation would establish an economy-wide, greenhouse gas (GHG) cap-and-trade system and critical complementary measures to help address climate change and build a clean energy economy. ACES would reduce greenhouse gas emissions 17% below 2005 levels by 2020 and 83% below 2005 levels by 2050.

Now that the House has passed the ACES Act, the fate of climate and clean energy legislation falls to the U.S. Senate. The Senate Energy and Natural Resources Committee, chaired by Sen. Jeff Bingaman (D-New Mexico) passed on June 17 an American Clean Energy Leadership Act (S.1462). This bill addresses several energy issues, including many addressed under ACES, but *does not* include a cap on global warming emissions.

Several Senate Committees will be addressing additional aspects of a clean energy and climate bill beginning in September and October. These measures will likely be combined to create the Senate counterpart to the ACES Act. If the Senate passes this combined bill, differences between the Senate and House bills would have to be reconciled, with the final bill passed by both houses of Congress, before the bill could be sent to President Obama and signed into law.

However, with health care legislation up for debate, the full U.S. Senate may not have sufficient time to debate its version of a comprehensive climate and clean energy bill before the COP15 meeting in December. While this would weaken President Obama's hand going into Copenhagen, it should not be interpreted as the U.S. abdicating on the Administration's stated intention of re-engaging with the international community to forge a common response to the threat of global warming. Moreover, the U.S. has already taken significant steps to reduce emissions, most importantly with the passage of the American Recovery and Reinvestment Act of 2009.

EPA Regulations

While the immediate future of climate and clean energy legislation in Congress looks uncertain, the possibility of the regulation of greenhouse gas emissions by the Environmental Protection Agency appears to be moving forward.

In April 2007 the U.S. Supreme Court ruled in *Massachusetts vs EPA* that the EPA has the authority to regulate greenhouse gas emissions under the auspices of the Clean Air Act if the Agency found that such emissions posed a threat to human health and welfare. Shortly after the Obama Administration took office, the EPA announced it would undertake an assessment of whether CO2 should indeed be regulated under the CAA. In March of 2009, the Agency issued an "endangerment finding" that concluded that such emissions are pollutants that threaten the public's health and welfare, thus beginning what could be a lengthy rulemaking process before any actual regulations go into effect.

EPA Administrator Lisa Jackson signed the Final Mandatory Reporting of Greenhouse Gases Rule on September 23, 2009. This Rule will require fossil fuel suppliers, vehicle and engine manufacturers, and facilities that emit over 25,000 metric tons of GHGs annually to report their emissions to the EPA. Starting in January 2010, some 10,000 facilities across the country will begin their emissions reporting for the first time, accounting for roughly 85% of American greenhouse gas emissions.

While the EPA process is far from ideal, it allows for an alternative course of action to reduce global warming pollution if Congress doesn't pass legislation in a timely manner. However, it's unclear if the EPA regulatory process without federal legislation will send the signal to the international community that the U.S. is sufficiently committed to a new, strong international agreement on climate.

China

Chinese decision-makers have set aggressive domestic energy targets in a suite of domestic policies even as China continues to seek rapid growth to raise living standards in the country (China's GDP per capita is less than one tenth of the U.S. GDP per capita). Unveiled in June 2007, "China's National Climate Change Program" linked its energy policies as key elements of China's climate change mitigation efforts. This policy has been strengthened and complemented with additional initiatives, including a set of industry, transportation and construction energy conservation policies announced by Premier Wen Jiabao in January 2009.

Premier Wen has also announced that China will be adding greenhouse gas goals in its 12th Five Year Plan, to begin in 2011, although no details are available yet. To date, China has: adopted a 20% reduction in national energy intensity by 2010, and has reduced national energy intensity (energy use per unit GDP) in each of the past three years); passed a national renewable energy standard of 15 percent by 2020; implemented a range of energy efficiency programs; raised taxes on petroleum; adopted new rural vehicle fuel economy standards; put China's energy conservation law into effect; required green government procurement; and announced a new program in May 2009 to provide subsides to promote efficient home appliances. Notably, China also dedicated approximately 1/3 of its stimulus package towards infrastructure projects that will promote energy efficiency.

China is now a larger emitter than the United States yet will not sign on to any sort of hard limits to its emissions without a clear commitment by the United States to do so. To create some negotiating room for itself, Beijing has publicly called for much more aggressive cuts from the developed world—a 40-percent reduction by 2020 from 1990 levels. The U.S. State Department negotiating team has already indicated that this is an untenable goal for the United States, regardless of what some may consider the possibility of such cuts. This is disappointing especially now that China is taking these issues more seriously than ever before and is showing signs that they may be prepared to commit to some sort of mandate under a new treaty.

Are international negotiations then at an impasse? Not neccesarily. If we look beyond the stated target caps in the U.S. ACES legislation to consider the potential reductions in greenhouse gases from its complementary requirements for energy efficiency and renewable energy, as well as the additional reductions that could potentially be captured by other parts of the legislation in verifiable offsets, then the picture improves. An increasing number of stakeholders in the international climate negotiations are calling for a different accounting measure which will show the full potential of the legislation to make reductions in emissions below business-as-usual, or BAU scenarios by the energy provisions of the bill plus a flexible architecture in the legislation which can get more cuts down the road. The Center for American Progress, a U.S.-based think tank, calls for measuring such progress using "carbon cap equivalents" as a way of profiling a country's commitment to meeting emissions reductions.

With this carbon cap equivalents approach the better measure of what each country is doing is derived by adding up the full range of supplemental and complementary proposals to each country's carbon cap and converting this into one comparable figure of what these emissions reductions would effectively amount to if they had been the result of a carbon cap alone. The modeling will be complex, but should open up the language of the hoped-for Copenhagen treaty so that signatory nations can demonstrate their acceptance of the treaty goals through such equivalents—representing the full range of their policy profile to reduce greenhouse gas emissions—above and beyond their formal cap.

A recent proposal by the Australian delegation to the U.N. Framework Convention on Climate Change Ad-Hoc Working Group on Long-Term Cooperative Action calls for something similar to this "carbon-cap-equivalents" approach. Namely, the Australians propose that in Copenhagen countries are allowe to meet their nationally appropriate mitigation targets through measures over and above a carbon cap. This is not an attempt to side-step the goals of the UNFCCC process, but rather to provide a more honest comparison of what we are all doing in ways that are not only appropriate for our particular economic histories but also are compatible with the restrictions and opportunities provided by our individual policy frameworks.

Taking this broader view, and considering the full breadth of complementary actions contemplated by the proposed ACES legislation, a different picture emerges. According to a recent study by the World Resources Institute, if one considers the full range of complementary provisions in the ACES legislation—in addition to the "cap-and-trade" portions—such as international forestry projects, industrial performance standards, residential energy-efficiency measures, and international offsets, then emissions reductions of up to 23 percent below 1990 levels by 2020 are realizable—an outcome that would actually meet the European Union's standards.[xvii] WRI further projects that such a full range of actions under the bill would lead to emissions reductions of 77 percent below 1990 levels by 2050, a result consistent with what is needed by the international community as a whole to contain the increase of average global temperatures to the catastrophe-averting limit of 2°C.

This frame can also help track progress of the major emitters in the developing world. China appears to be making steady progress toward its goal of achieving a 20-percent reduction in energy intensity by 2010, as well as implementing a host of additional clean energy and energy efficiency policies. But because thus far the solutions to global warming have been framed only in terms of the formal carbon caps that have been agreed to by a given country, the international media and policymakers don't generally count other improvements in a country's carbon profile in their assessment of the country's commitment to the process or of their real improvements. This needs to be changed in order to get a fair comparison of what everyone is doing.

ACES has as its midterm carbon cap targets a reduction of 17 percent below 2005 levels by 2020. These targets apparently give the Obama administration precious little to meet global expectations about U.S. action on climate change. For starters these caps fall below the European Union's agreed-upon 20 percent reductions below 1990 levels by 2020. If the U.S. were to meet its allies at these goals, then the European Union would increase their midterm reductions to 30 percent. At its current levels ACES does not trigger this critical shift.

So, where do negotiations stand now? ACES is most likely as good as U.S. politics can possibly deliver at this given moment. And when a full accounting is given of what can be achieved in terms of its carbon cap equivalent, it becomes a more attractive piece of legislation than it at first may appear. This legislation is not too ambitious for the U.S. Congress to eventually pass. It could be sufficient as a positive incentive to move along the Copenhagen negotiations, so long as other countries are allowed to count the full measure of their improvements in energy efficiency, intensity, and other complementary polices as part of the demonstration of how they are reducing their global warming emissions.

V. Conclusion

While there has been progress made moving climate legislation through the U.S. Congress in 2009, final enactment is not likely, which would make it difficult for the new Administration to commit to a specific emissions target in Copenhagen. In that case, Copenhagen is unlikely to produce a full and final agreement that could be submitted to governments for ratification. A more realistic outcome may be an agreement on the basic architecture of the post-2012 climate framework -- for instance, binding economy-wide targets for developed countries, policy commitments for the major emerging economies, and support mechanisms for technology, finance, and adaptation in developing countries. This intermediary agreement could then serve as the basis for further negotiations in 2010 on specific commitments in a full and final agreement.

Realistically, the most governments may be able to achieve in Copenhagen is consensus on the basic framework of a post-2012 agreement, with the details to be filled in later. To be credible, such an interim agreement would have to spell out at a minimum have which countries would be assuming commitments, and of what type. But unless Congress had already passed mandatory climate legislation (an unlikely prospect) the United States would not be ready to commit to a specific emissions target. Thus it is unlikely that other countries would be prepared to specify the content of their commitments either. Given the need for swift, strong action, such a limited outcome might readily be dismissed as a failure. But if it were to prove possible, a firm agreement that all the major economies are finally prepared to negotiate measurable and verifiable commitments would in fact be a major step forward. It would qualify Copenhagen as a success, and would for the first time lay a foundation upon which could be erected an equitable and effective post-2012 agreement.

In his epic work *The Great Transformation*, Karl Polanyi described how in the century or more leading to World War II, governments provided the structures and policies to support and shape a modern market economy. At the same time, those governments needed to mitigate the harsh social effects of unregulated and uncontrolled economic practices. It is a good history lesson for the challenges we are confronting now.

The clean energy transformation will actually be greater still in the sense that it will need to be much faster, more global, and altogether more equitable than anything yet seen in human history. Humanity needs to completely reconstruct its energy infrastructure, while protecting the world's most vulnerable from whatever amount of irreversible global warming is already primed into the system.

The transformation has already begun. The United Nations Environment Program estimates that 2.3 million people are presently employed in the global renewable energy sector.[xviii] In recent years, venture capital (VC) investment in the clean-tech sector has boomed—jumping 78 percent in North America in 2006, so that clean tech now accounts for 11 percent of all VC investments, trailing only the software and biotech sectors. In China, clean tech VC investments soared 147 percent just between 2005 and 2006, representing 19 percent of all VC investment in that country.

Meanwhile, the renewable energy sector is growing at an incredible pace. From 2002—2007, solar energy grew by 41 percent, wind energy by 24 percent, and biofuels by 20 percent.[xix]

Compare these rates to the 5.9 percent growth rate for coal and 1.8 percent growth rate for oil, and the trend is clear: renewable energy is now the dominant source of new energy generation, by far.

Tipping points are easier to decipher in retrospect than in advance. No one can say for sure whether the substantial shifts in energy markets and energy policies over the past few years are the precursors to a clean energy revolution. Just as the events of the past few years have surprised us, so will those ahead. And the financial crisis which engulfed the global economy will likely have impacts on energy markets for some time to come.

Even with those substantial caveats, the evidence presented in this report suggests that when historians look back on 2008, they will conclude that a 21st-century energy revolution was well under way. Whether they will also be able to say that the world was able to avert catastrophic climate change will be determined by the decisions we make in Copenhagen and in the decade ahead. Urgency and vision are the twin pillars on which humanity's hope now hangs.

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