Vinod Khosla

Whose Rules?

Terms of Discussions Around a Global Cap-and-Trade System

Global climate change is accelerating like a runaway truck. The conventional wisdom is simple: the U.S. does not want to participate in a global treaty, because India and China don't want to participate. But is that really an accurate assessment, or is it that they don't want to participate based on Western rules of engagement? What are those rules, and who makes them? The countries with the biggest bulk and heaviest sticks? And do we use moral and ethical principles? If so, whose ethics and morals? Do we consider a given country's ability to pay, its natural resources, and its rate of economic development? Many proposals have been made for carbon cap and trade, but many do not explicitly consider the above issues.

Beyond the heaviest sticks and issues of local ethics is another complex matter: the political reality in each country. What is politically acceptable, both locally and regionally, becomes even more critical in the democratic world, where the politics of today far outweigh considerations of the planet's needs in 2050. In addition, we have learned a critical lesson from recent experience: we must manage global climate risk both prudently and flexibly. We need to achieve currently defined targets, but we must also respond to changing targets quickly as new information becomes available. Considering all these issues, I suggest four criteria that any carbon emissions control system must achieve. It must meet CO_2 reduction targets, be morally acceptable, be politically acceptable in most countries, and be able to adjust to dynamic targets.

I believe that the single best way to measure progress is based not on CO_2 emissions as a whole, but rather on creating incentives for the developing world to increase its carbon productivity of GDP. That means producing more, but reducing the carbon emissions associated with each marginal dollar of GDP growth. This concept is also known as the carbon efficiency of GDP. Researchers at the McKinsey Global Institute, among many others, have created a set of global reduc-

Vinod Khosla is the Founder and CEO of KhoslaVentures, and Partner at the venture capital firm Kleiner Perkins Caufield and Byers. Previously, Khosla was the founding Chief Executive Officer of Sun Microsystems.

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tion targets and estimates of how quickly the world's GDP carbon efficiency must grow to meet those targets.[1] This approach is significantly easier for the developing world than many others that have been suggested, and should be more politically palatable. It does not ask them to slow their growth, but rather to improve the efficiency of that growth, especially in conjunction with flows of CDM (Clean Development Mechanism) funding. From a fairness standpoint, it does not unduly punish nations for their rates of growth, but rather aligns incentives so that efficiency and growth become common goals.

If we accept that increasing carbon efficiency is the key, the next question is where and how the developing nations can work toward this goal and how the CDM mechanism can be used to guide it. I believe that access to cheap capital (and thus lower financing costs) is vital; in fact, the cost of capital may be the most critical tool in developing a lower carbon GDP economy. Developing nations may be able to lower the cost of capital by leveraging relatively low-interest loans to invest in low-carbon power generation, be it electricity or biofuels. In the rest of this article, I describe these ideas and show how they might work in combination.

CONSIDERING METRICS

John Holdren, director of the White House Office of Science and Technology Policy, summarized the current situation in a recent talk:

> We have a global climatic disruption and serious harm is already occurring. Mitigation, adaptation and suffering are our only options and the more we have of the former two, the less we will have of the latter. The key question is whether we can we avoid catastrophic interference.[2]

In light of the current situation, it is clear that mitigation must happen everywhere to make a material difference. But how should the burden of mitigation be allocated? The proposals so far have been dominated by Western points of view and mostly consist of tradeoffs between the various Western constituencies, including business, labor, agricultural, and environmental groups. The proposals don't work with the priorities of many developing countries like India and China, which have mostly distanced themselves from the discussions. Is it possible to craft a set of proposals that are more likely to be acceptable to this constituency?

The first step toward responding to these questions is reviewing emissions and economic data. Figures 1 and 2 show (1) total annual CO_2 emissions by country, and (2) CO_2 emissions per capita, by country, also denoted by GDP per capita on a PPP basis.[3] Discussions in the West turn almost exclusively to one idea: reducing carbon in percentage terms from the 1990 level. While this is in line with scientific recommendations as a global target, reviewing the charts below raises further questions on how to allocate this goal among all nations. Examining Figure 1, is it reasonable to compare the cumulative emissions of two countries, one with a billion people and one with a million? Reviewing Figure 2, is it reasonable to ask a country whose per-capita income is $1,000 to meet the same percentage carbon

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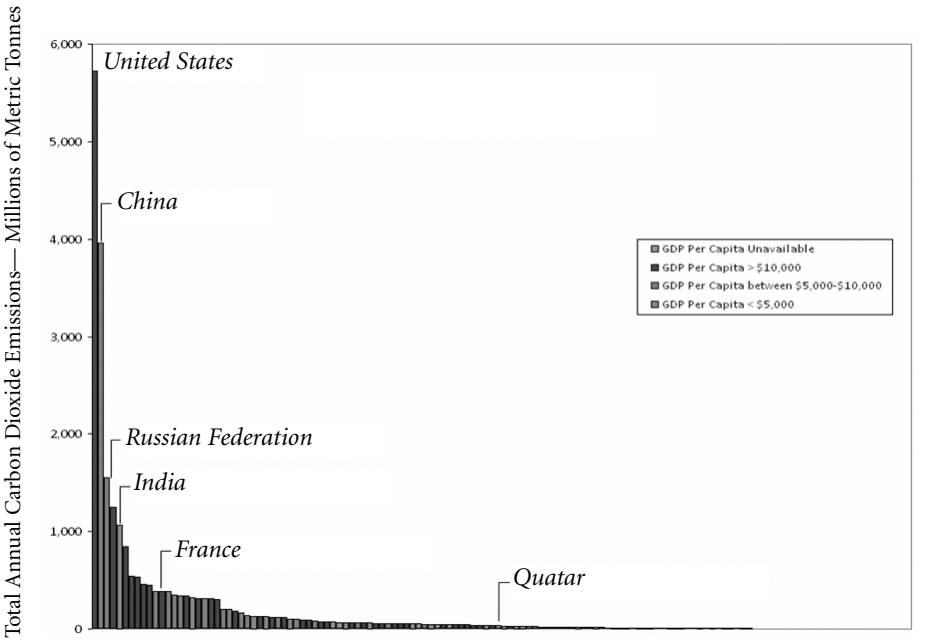

Figure 1. Total Annual Carbon Dioxide Emissions, in Millions of Metric Tonnes, 2003

Source: World Resource Institute, citing IEA data.

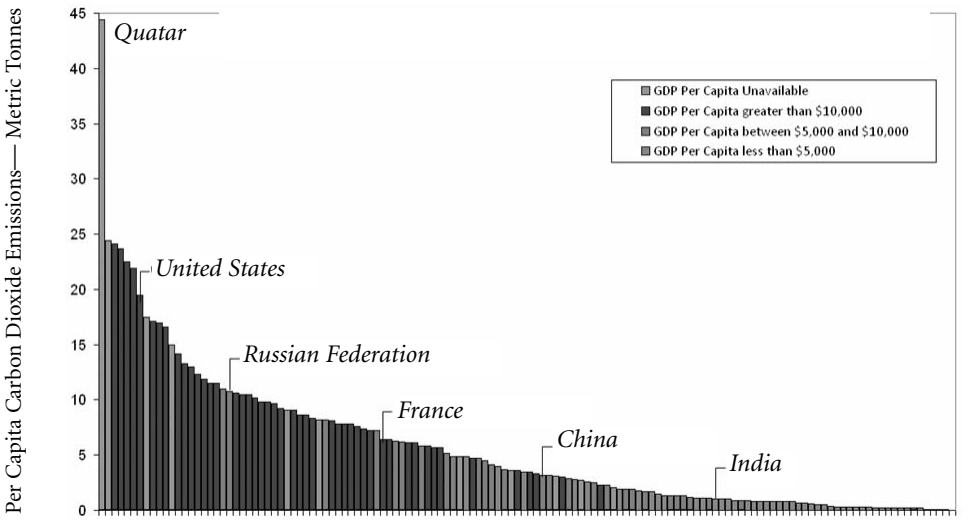

Figure 2. Per-capita Carbon Dioxide Emissions in Metric Tonnes, 2003

Source: World Resource Institute, citing IEA data.

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reduction as one whose per-capita income is $40,000? Should a country with a per-capita income of $1,000 and an economic growth rate of 2 percent achieve the same reduction as another with the same per-capita income and a 10 percent growth rate? Who decides where to draw the lines? What protocols are used to assess fairness and what standards apply?

Even if a definition of fairness can be established, what is fair and what is pragmatic often do not correspond, especially in democracies. Perhaps the only morally defensible—fair—thing to do is to give every human being an equal right to pollute the air. That means an equal per-capita emissions quota. Being strictly fair, using the closest thing to a universal moral code, would suggest that the per-capita allocation should be based on the total cumulative stock of carbon emissions throughout history rather than an equal current annual flow of carbon emissions per capita. In computing the stock of carbon emissions they have emitted per capita over time, developed nations would include their historical emissions, potentially starting at the dawn of the Industrial Revolution in 1750 or so.

But the answer this leads to is impractical from the scientists' perspective of total atmospheric carbon. Though carbon calculations can get convoluted, it is important to realize that emissions during the last 50 years are the dominant culprits by virtue of their magnitude. As of 2006, the population of the OECD, approximately 1 billion persons, was emitting roughly as much carbon dioxide equivalent as the remaining 5.5 billion people.[4] Hence, developing nations argue, quite reasonably, that it is only fair that the OECD and the developed world bear the principal burden for reductions, especially since they have the highest incomes and greatest capability to invest in reducing their carbon footprint.

Unfortunately, this fair formula does not work well for the planet or for much of its politics, given the heavyweight clout and self-interest of the Western world, which would have to radically change its carbon emissions and hence its energy-use profile, draining investment funds and causing significant business dislocations. Moreover, the common refrain, even within some environmental circles, is that India and China don't want to do their part to reduce global carbon emissions, and that no coordinated action can possibly succeed without them. Of course, every country wants to continue its development priorities while offsetting the burden of carbon abatement to the "commons"—this is the classic "free rider" problem. However, I believe that most countries will participate in a scheme that they can still sell to their people.

In that vein, India's Prime Minister, Manmohan Singh, has stated categorically that India would sign on to a cap-and-trade system that allocates equal carbon emissions to every human being. India has also stated that its per-capita carbon emissions will never exceed those of the developed world. But even with that promise, the Western world will not sign on to a system that allocates every human being an equal right to pollute. Meanwhile, what India and China are refusing to sign up for is something different: a system devised by the environmental groups in the developed world that makes it harder for them to get to the same level of

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per-capita GDP as the developed world and its concomitant energy consumption, even assuming they could get to similar levels of energy efficiency per dollar of GDP. India and China are not currently at the same level of efficiency that the developed world has achieved, and would have to work harder and invest more than they do currently to get to similar efficiency levels. But, as we will see, in this situation lies one potential fair and universal solution.

The question is not whether India and China would participate, but rather the terms on which they—and others—would do so. The United States will have its own ideas of what system works best, though even it is deeply divided on the issue politically. Europe, which has lower per-capita emissions than the U.S., may be the most flexible and committed to carbon reductions (and have significantly greater political support for reductions). Russia and the Arab world may have other geopolitical interests, including the use of their strategic energy assets. Brazil may be most focused on its land assets, and its recent discovery of large oil fields off the coast could change its priorities. Africa may give the issue lower priority given the various other challenges it faces. Clearly, any formula will have to include some country-specific considerations. As many critics have pointed out, the U.S. has a larger land mass and a lower population density than most countries, and thus longer average distances to travel. Thus, by its very nature, the U.S. will use more fossil fuels for travel than its higher-density European counterparts.

The basic terms of the discussion around carbon cap-and-trade must change and new formulas must be devised to share the pain of carbon emissions reductions between the world's citizens, with allowances to deal with factors like density and climate (a colder country will use more fossil fuel for heating)... What allocation of responsibility for carbon reduction might be acceptable to most countries, whether they are developed or developing?

Given all these facts, it is not hard to conclude that the basic terms of the discussion around carbon cap and trade must change and new formulas must be devised to share the pain of carbon emissions reductions between the world's citizens, with allowances to deal with factors like density and climate (a colder coun-

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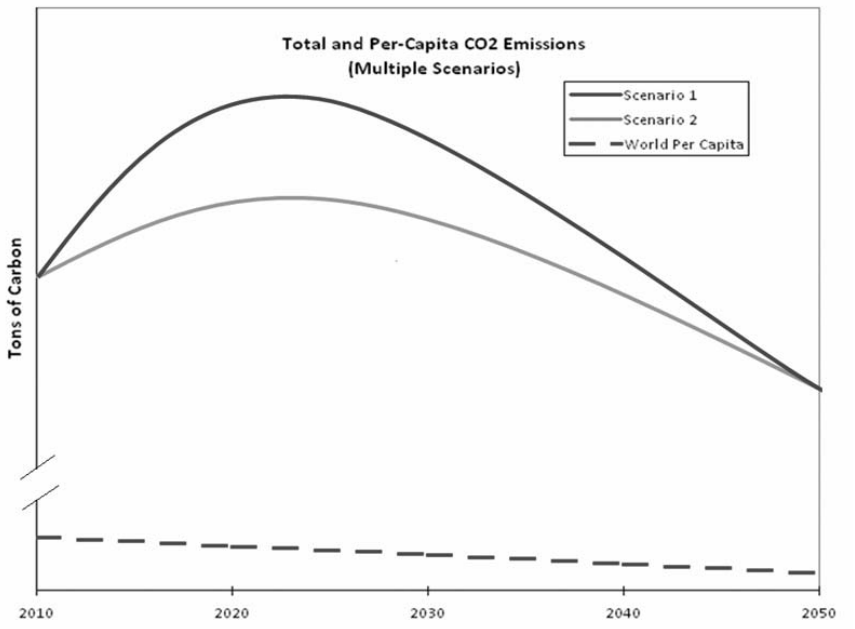

Figure 3. Annual Total and Per-Capita Global Carbon Emissions Scenarios.

try will use more fossil fuel for heating). There is a general consensus that emissions reductions are needed and that our responsibility is to avoid the tragedy of the commons. What allocation of responsibility for carbon reduction might be acceptable to most countries, whether they are developed or developing?

CONSIDERING SCENARIOS

Figure 3 shows two hypothetical scenarios as approximate trend lines. These are two potential pathways for achieving the most widely—if not universally—accepted per-capita emissions target. The target is to return to two tons of carbon per year (2tc/yr) per person by 2050. Those pathways would reduce carbon emissions on different trajectories and achieve different levels of carbon in the atmosphere. The long-term goal, though still subject to considerable debate, is often set at stabilizing atmospheric carbon at approximately 450 parts per million (ppm) of carbon dioxide equivalent by 2050. The Intergovernmental Panel on Climate Change (IPCC) says that doing so would give us a 50 percent probability of limiting temperature increases to about two degrees Celsius,[5] though experts such as James Hansen (at NASA) and others have suggested ranges between 350 ppm and 550 ppm.[6]

The simplest way to look at these trajectories is to understand that each level of carbon in the atmosphere results in a different level of risk of catastrophic or runaway climate change: the higher that atmospheric carbon content, the greater

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the risk we face. The science on the magnitude of the change at each level of carbon in the atmosphere is uncertain, but recent indications point to the "safe" levels being lower than was generally accepted even a few years ago.

Thus we understand the need to combine both prudence and flexibility. Not only must we achieve the above targets; we must also be willing and able to respond to changing targets quickly as new information comes becomes available. What we know about the impact of climate change is important, but what we don't know—and will learn over the next few years and decades—is even more crucial. Thus, the principles behind a global cap-and-trade deal should allow for dynamic adjustment, as opposed to a new multi-year Kyoto-style negotiation among almost 200 countries. The need to respond flexibly to changing information on climate change and carbon emissions is evidenced by the significant changes in the history and near-term forecasts of global emissions.

Forecasting is an inexact science—as multiple examples over the years have shown. In particular, much economic forecasting is essentially a regression of old data; it cannot account for technological evolution, shifts, and shocks because these cannot be predicted.

For example, in 2002, in its GLOBE report, the IEA forecast that emissions in 2008 would be 42 gigatons (GT) per year and that they would double from 2008 to 2050 under scenarios of business as usual.[7] Only five years later, an updated IPCC report, relying on 2004 data, predicted that 2008 emissions would be 55 GT, or more than 30 percent higher.[8] Why did these numbers grow so much in the short span of five years? The answer is uncertainty. In addition to growth, there are large uncertainties around measurement, and the projected growth rates for India and China have increased dramatically, thus changing their forecasts for energy consumption and carbon emissions.

Thus, econometric models are only as good as the research and assumptions upon which they are based—and in my view, the assumptions made so far are extremely tenuous. Projecting the growth rate of India or Russia in 2050 is like projecting the world's 2008 growth rate in the early 1900s. With the accelerating rate of change in society and heightened global dynamics, it is nearly impossible to make accurate predictions. Of course, it is also unrealistic and unwise to abandon modeling entirely, but given its inherent limits, we must recognize these limits and treat the output accordingly. The key point is not that forecasts are inaccurate but that the global response must be dynamic and flexible. Thus the system must adapt

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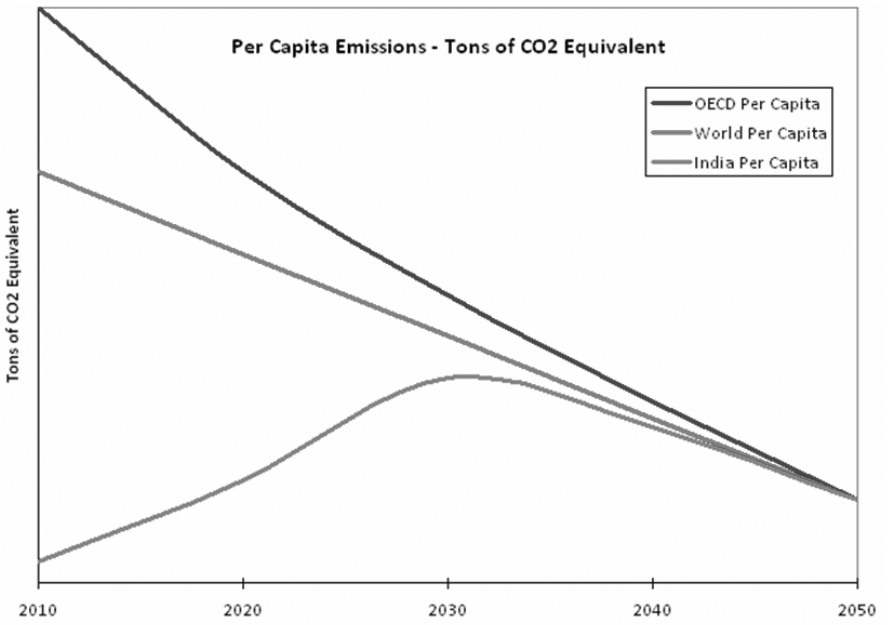

Figure 4. Hypothetical Scenario of Required Per-Capita Carbon Emissions Trends.

as the results come in without requiring political negotiations at each stage. Developing technology to allow for rapid response is critical, but we must also allow for a rapid, maybe even automatic, policy response.

FORECASTING, AND BLACK SWANS

Forecasting is an inexact science—as multiple examples over the years have shown. In particular, much economic forecasting is essentially a regression of old data; it cannot account for technological evolution, shifts, and shocks because these cannot be predicted. One of the more famous examples is McKinsey's 1980 estimation of the mobile phone market in 2000 for AT&T: it forecast a market size of approximately one million phones. The actual market in 2000 exceeded 100 million—an error by a factor of 100. Similarly, the Energy Outlook Retrospective from the Energy Information Administration (EIA) noted that, on average, its forecast of average oil prices had been off by 52 percent; natural gas prices were off by 64 percent, and coal prices were off by 47 percent.[9] The fundamental problems here are those of forecasting: gaining false precision at the expense of accuracy, obscuring underlying assumptions, and inputting what is measurable while ignoring what is not. Furthermore, most forecasts fail to recognize that extreme events with high unpredictability are responsible for most of society's evolution—what author

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Nicholas Nassim Taleb calls a "Black Swan." Three features characterize a Black Swan event:

1. It is an outlier before it happens, as traditional expectations from the past do not predict it.
2. It carries a significant impact.
3. Despite being previously unpredictable, after the fact observers derive explanations to justify it.

To summarize: "rarity, extreme impact, and retrospective (though not prospective) predictability."[10]

Technology shocks are one of the best examples of this maxim in action: ranging from the Internet, to the agricultural revolution, to the rise (and demise) of the traditional telecommunications infrastructure. Forecasting is an inexact science; its errors are further compounded by dramatic changes in inputs and assumptions, often rendering history a poor base from which to extrapolate.

To summarize all I have said so far, I see four key criteria that any carbon emissions control system must achieve:

It must meet global CO_2 reduction targets. Any scheme must converge upon this target value, be it 350, 450, or 550 ppm worldwide.

It must be politically acceptable in most countries. No scheme is likely to be acceptable to every country, but we must strive for an approach that is politically viable for most sovereign entities and thus minimizes the number who opt out or become "freeriders."

It must be morally acceptable. While the concept of fairness is open to debate, any system must be fair in assigning the responsibility for the problem in rough proportion to the primary pollution caused historically and prospectively by each country, especially considering their current per-capita income. Pragmatically, fairness will have to be defined in a way that is maximally but not universally acceptable.

It must be dynamic. From a policy perspective, any emissions control system must have the flexibility to revise safe targets and goals as better information and research becomes available, without requiring a new set of negotiations. From a technology perspective, working toward carbon reductions now is important, but the primary goal is to work toward significant carbon reduction capability in the future (even at some cost in terms of emissions today). Thus, investing in technology that can reduce carbon emissions in the future offers greater benefits than simply reducing emissions today.

CONSIDERING APPROACHES

How might the carbon emissions reduction proceed? Figure 4 shows one hypothetical pathway, with the OECD working to reduce its per-capita emissions of CO_2, while countries like India experience a temporary increase in those per-capita emissions, but level off around an acceptable per-capita emissions level, which

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is likely to be about two tons of CO_2 equivalent (CO_2e) per year. In this scenario, countries like India and China could offer to go beyond their responsibility to have their per-capita emissions equal the world's average. They could accept an additional constraint by agreeing not to exceed the per-capita emissions of the OECD countries. India's prime minister has made such an offer, but that will not be sufficient to achieve global carbon reduction targets. One current thought among developed country planners, as highlighted in the recent Stern report,[11] is that by 2050 the developed world would be required to reduce its carbon emissions by an agreed-upon percentage relative to 1990 levels, with some interim goals set for 2020. Within this thinking, some suggest giving the developing world until 2020 to start making reductions in absolute carbon emissions.

Is this basic approach, as outlined above, fair? It may or may not be, depending upon the country involved. Should the same date for capping carbon emissions be used for all countries, even if they are in very different stages of development, just because the developed world needs them to cap emissions? If we concede that different countries are on different developmental trajectories, who decides what the date should be for each country to start capping its total emissions? We need objective criteria that are smooth and continuous in their demands on countries to invest in carbon reductions. Those criteria must apply to every country as uniformly as possible as they become capable of investing in the carbon commons. This approach may be fair for China but not for India; or, it may be fair to require India to reduce emissions but not Bangladesh.

One thing is clear: we need concrete measures from countries like India and China because they will very soon constitute a majority of the carbon emissions flow—if they have not already. According to some reports, China may already be the world's largest CO_2 emitter,[12] another point of contention for many in the West who see no pragmatic value in any scheme that does not require Chinese reductions. Even if the Chinese have substantially lower per-capita emissions and a lesser ability to respond to the need for carbon mitigation because of their lower per-capita incomes, should we still require them to reduce carbon emissions? Despite these issues, and the potential for forecasting and measuring discrepancies, it is still clear that by 2050, almost every country must approach the global per-capita target of 2tc/yr/person. If India and China are outside of a cap-and-trade treaty, fairness will not matter. Higher total worldwide carbon emissions could potentially condemn the world to Professor Holdren's "suffering" option outlined earlier. Is there an option that better fulfills most of our criteria, while still offering enough incentives for the heavyweights, both developing and developed, to participate?

I believe such an approach does exist. Pragmatically, the developed world has been the primary cause of greenhouse gas (GHG) emissions, and will continue to release higher per-capita emissions than the per-capita quota. If it wants to continue to do so, it can afford to pay the developing world for this privilege. One instrument to facilitate this is the clean development mechanism (CDM). The CDM sets up a trading contract in which the developed world pays the developing countries

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to execute carbon reduction projects. Developing nations get credits for reducing emissions beyond the business-as-usual scenarios, but they are not penalized if they fail to achieve specific targets. This approach is a win-win. The developed world can reduce its carbon footprint by reducing emissions in the developing world where it might be cheaper to do so, essentially by outsourcing its carbon mitigation responsibilities. Meanwhile, the developing world gets more carbon-efficient investment opportunities, accelerating its development and generally reducing its energy needs. Many will agree on the equity of this arrangement, but it isn't likely to be enough. We still need additional approaches.

In addition to CDMs, what could the developed world offer to developing countries to give them greater incentives to reduce carbon emissions? What could it offer that would not be too costly to the developing world's development goals? Before discussing additional options, it is important to look back at previous efforts such as the Kyoto protocol. The Kyoto protocol divides the world's nations into two groups. Annex 1 countries include members of the OECD, and countries with economies in transition, including members of the former Soviet Union and several other Central and Eastern European states. All others are non-Annex 1 countries. The criteria for being a "developed" (Annex 1) country or a "developing" one are somewhat arbitrary.

Given these criteria, where should the cutoff be in per-capita GDP? Absolute carbon caps based on 1990 carbon emissions penalize fast-growing countries, and are especially unfair for those countries with low per-capita emissions. They are even worse for the slow-growth, very poor economies in some of the African nations. Eritrea's per-capita emissions are 1 percent of those in the U.S. (0.2 tons of CO_2 per capita) percent and its per-capita income is $900.[13] Should it be responding in any way to the need for carbon mitigation?

Politics and economics confuse the issue too. As a result of politics in western countries, internal negotiations with environmental groups, and a western failure to understand local politics and values in the developing world, impractical solutions are often proposed that are more suited to fast-developing countries. Economics is a principal driver for the adoption of technology and business practices: because of risk adjustments, the cost of capital in the developing world is generally higher than in the developed world, so many solutions that work in the latter are not viable in the former. If we keep the Kyoto definition of Annex 1, there is still the issue of the cost of capital which may contain solutions that meet the separate and common goals of both the developed and developing worlds. The most often cited questions of fairness are the need for shared pain and wanting countries like India and China to do more than just commit to good intentions. What could fairly and flexibly quantify this effort to reduce emissions and make the process measurable?

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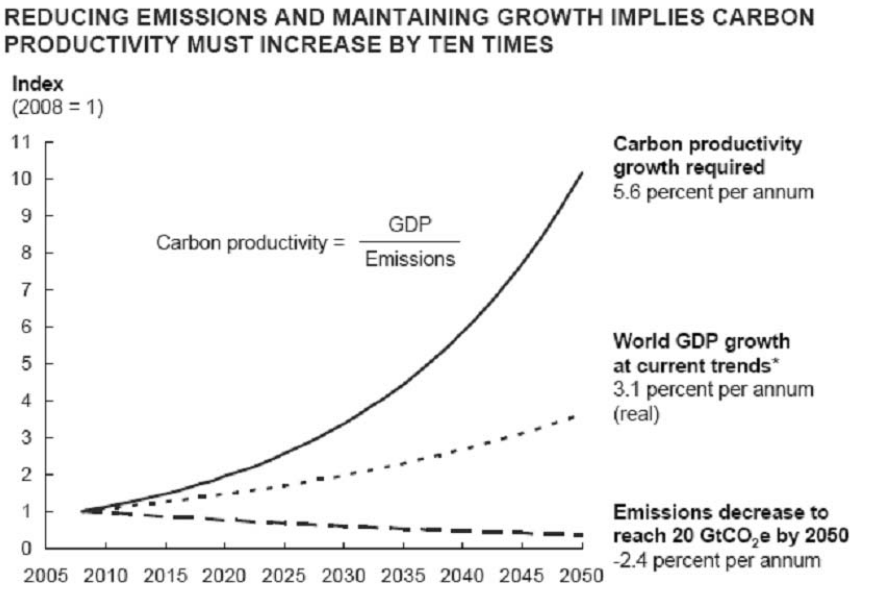

Figure 5. Scale of Emissions Productivity Required.
Source: McKinsey Global Institute, p. 17.

MY PROPOSAL: A CARROT AND A STICK

This leads us into my primary proposal: offering a carrot and a stick for the developed world, beyond just CDMs. For the developed world, an approach based on CDMs carries significant advantages, primarily in the degree of control it has over the funds allocated through it. This leverage can be directed toward requiring the recipient nations to make a hard, measurable commitment on carbon emissions. Any approach must meet the developing world's need to not limit its growth, while at the same time providing actual incentives for reducing carbon emissions. What measurable objective makes sense? The most advantageous way to measure progress is not based on CO_2 emissions as a whole, but rather on creating incentives for the developing world to increase its carbon productivity of GDP: producing more, but reducing the carbon emissions associated with each marginal dollar of GDP growth. This is the concept of carbon efficiency.

Given a 3.1 percent world GDP growth rate, researchers at McKinsey and Co. have estimated that the carbon efficiency of the world's GDP needs to grow at about 5.6 percent per annum to meet the set of global reduction targets they recommend.[14] This increase in carbon efficiency can become the measurable objective that the developed world can ask developing nations to meet in return for CDMs and any other incentives. As Figure 5 shows, a moderate increase in efficiency, sustained over time, provides exponential benefits. This approach is significantly easier and more politically palatable for the developing world than a hard carbon emissions cap might be: it asks nations not to slow their growth, but rather to

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improve the efficiency of that growth, especially in conjunction with flows of CDM funding. The exact percentage for improvement in carbon efficiency should be subject to negotiation. From a fairness standpoint, it does not unduly punish nations (as in the Eritrea example cited above) that are not achieving stratospheric levels of growth, but, rather, aligns incentives, so that efficiency and growth become common goals. With the developed nations working toward this goal themselves, and the developing nations having incentives to do the same through the suggested mechanisms, we would have a pathway toward meeting GHG reduction targets worldwide.

The most advantageous way to measure progress is not based on CO_2 emissions as a whole, but rather on creating incentives for the developing world to increase its carbon productivity of GDP: producing more, but reducing the carbon emissions associated with each marginal dollar of GDP growth. This is the concept of carbon efficiency.

If we accept that increasing carbon efficiency is the key, the next question is where and how the developing nations can work towards this goal and how the CDM mechanism can be used to guide it. Earlier I noted that access to cheap capital, along with lower financing costs, is vital. In fact, the cost of capital may be the most critical tool in developing an economy with a lower carbon GDP, since the amortized cost of energy or energy consumption (like cost per mile driven for transportation) often depends materially on it. Paying an additional fee up front (e.g., for solar power capital costs or an electric car) can lead to significant savings in fossil fuel over time; the resultant cost of a KWh or a mile driven depends a great deal on the cost of capital. For developing nations, one approach to lowering the cost of this capital may be leveraging the relatively low-interest sovereign loans that they are granted and applying them toward the capital costs of low-carbon power generation (be it electricity or biofuels). Essentially, developing nations would be utilizing the cheaper access to capital of a developed nation (which is lending its balance sheet) to develop lower-cost energy.

For example, it has been estimated that the cost of solar thermal power in 2013 would drop from $0.169/KWh to $0.136/KWh if the cost of capital dropped from 8 percent to 3 percent, a rate not uncommon in sovereign lending.[15] Alternatively, institutions like the World Bank or the IMF could become facilitators of the move

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to low-carbon GDP growth in the developing world. One could even demand that under the CDM, the developing world utilizes the best available low-carbon technology that can be economically justified for projects that depend on these lower-cost loans for low-carbon development.

This becomes an even more attractive proposition if we recognize that, as Arthur C. Clarke put it, technology is rapidly expanding the art of the possible and that the technologies we are likely to use in 2030 have probably not been invented or even thought of today. The developing countries could accept these low-carbon loans voluntarily, based on conditions set by the loan-providing institution (like the IMF, World Bank, or Asian Development Bank). This formulation also solves the related issue of technology transfer. Since most low-carbon technology resides in private hands and is not subject to transfer at the whim of the western governments, lower-cost funding would create the incentive for these innovative technology providers to undertake projects in the developing world.

How might efficiency improve? Figure 6 shows the gains in efficiency over time from the perspective of the U.S., the OECD, and India—with more rapid improvement to come from countries (like India and China) where relatively easy marginal gains can be had. As the technology improves, the use of this "best available technology" condition would drive its adoption. The benefits from substantial energy security and lower energy prices would accrue to all economies because of the slower growth in demand.

If the world's economic growth increased beyond 3 percent, the world's need for carbon efficiency improvements would also increase, but that increase would apply equally to all countries without major new negotiations—assuming that the system is capable of a dynamic response. Ideally, we would still keep the other constraints like caps on total carbon emissions in the developed world. Then, all Annex 1 countries would accept additional constraints: an agreed-upon reduction (many scientists recommend at least 75 percent) from 1990 levels by 2050, and hopefully with additional targets for 2020 to ensure that we are on course to meet our 2050 targets. It would also behoove us to require that the non-Annex 1 countries do not exceed the average per-capita carbon emissions of the Annex 1 or OECD countries and that they remain below the hopefully declining per-capita emissions of the developed countries.

Clearly, what is fair is in the eye of the beholder, but this approach comes as close as possible to using a definition of fairness that is likely to appeal to a majority of the world's population. Though it is imperfect, a focus on carbon-efficient GDP improvements largely uncouples the requirement for carbon reductions from GDP per capita and GDP growth rates. This is critical to the politics of the developing world, and an important first step, but it may not be enough by itself. For selected global industries, additional constraints such as sector-specific caps may be needed to make the system politically acceptable in the developed world; the Stern report notes that steel and cement are possibilities.[16] Political realities in the west will forestall the adoption of policies that cause widespread losses of

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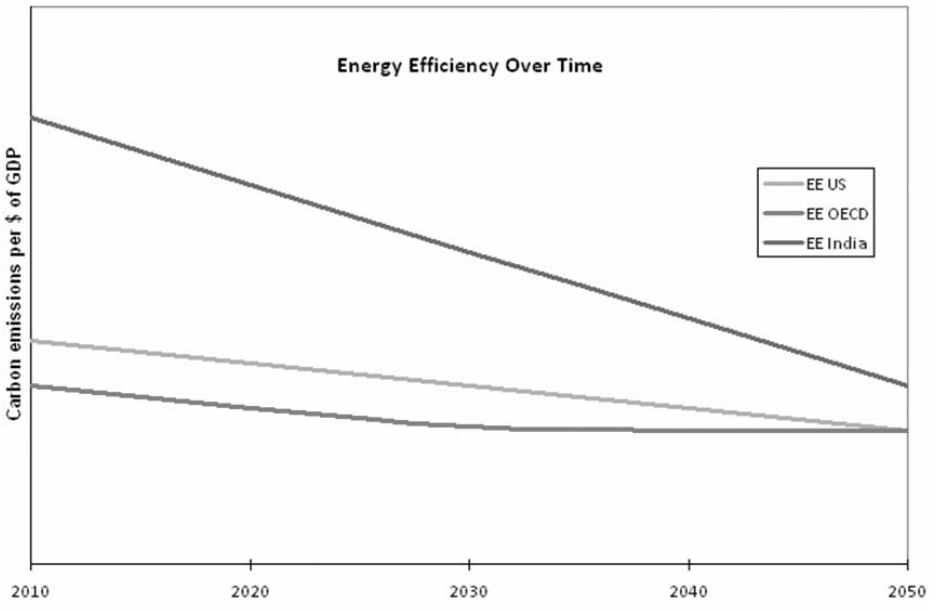

Figure 6. Hypothetical Scenario of Energy Efficiency Improvements Required.

employment, especially if the jobs in question are outsourced to the developing world. The sector-based approach offers an alternative by encouraging innovation across the spectrum, instead of encouraging industry to find the country that is most willing to turn a blind eye to pollution.

CLOSING THOUGHTS

No overarching global cap-and-trade scheme will be easy to create and administer, from either a political or an economic perspective. In Tom Friedman's words, "We're having a Green Party, not a Green Revolution."[17] Revolutions produce dislocations, and winners and losers; people and institutions get hurt. The situation is complicated further by the basic drive of the capitalistic system to economic efficiency. But this very drive can be turned on its head and the capitalist system can be used to more efficiently achieve the goals of a carbon-constrained world. Some aspects of this process will not appeal to individuals in the environmental community. They have been key in identifying and alerting the world to this potentially catastrophic problem, but they have also promoted impractical solutions, often by disregarding the importance of economic gravity, which dictates that the cheapest solutions win in developing countries. Economics, not environmental whims, must drive global solutions. Given the scale of capital needed, public funding will not be sufficient; the key is to attract private capital, motivated by profit rather than social goodwill.

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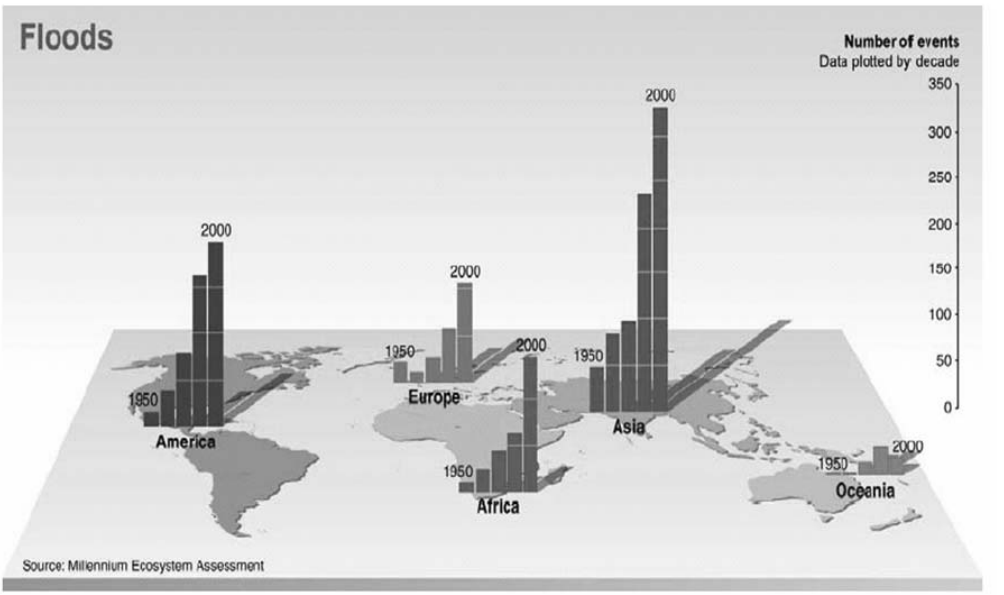

Figure 7. Number of Flood Events by Continent and Decade Since 1950. *Source:* Millennium Ecosystem Assessment.

We must be pragmatic. For example, from a grid perspective, every nuclear plant the environmental community stopped was likely replaced by an even dirtier coal plant. The environmentalists may be more responsible than the power industry for causing more coal plants to be built, thus increasing carbon emissions: nuclear energy releases almost zero carbon! Today, we must again be wary of uneconomic solutions to significant problems, such as the idea that hybrid cars constitute a large-scale solution: a recent McKinsey and Co. report noted that hybrids have a carbon abatement cost of approximately $90 per ton, making them the most expensive large-scale solution.[18] Are hybrids or some other low-carbon transportation technology likely to be adopted in 80 percent of the next billion cars we ship on this planet? In a world with limited investment dollars, the case for green technology has to make economic and environmental sense, and we must lower the risk of adopting new technologies. Consumer preferences are only part of this risk.

Also, any fair compromise must include another source of carbon emissions: deforestation. Here we need a carrot-and-stick approach, rewarding a reduction in deforestation with carbon credits that have at least equal economic value to the landholders, and penalizing countries that don't achieve deforestation targets. For example, WTO accords could be appended to make it possible to prohibit agricultural exports, or at least biofuel exports, from countries that don't meet deforestation reduction targets, in addition to the carbon incentives to preserve forests.

But, as Tom Friedman said, it will not be easy. Today, approximately 2.5 percent of the Gross World Product (GWP) is spent on defense; the U.S. spends clos-

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er to 5 percent of its GDP. Estimates indicate that avoiding the catastrophic consequences of climate change and (re)creating a low-carbon world will not be free.[19] For example, the Stern report estimated that doing so will cost approximately 1 percent to 2 percent of GWP; mid-range IPCC estimates are about 0.5 percent to 1 percent of GWP. But these estimates suggest it will be cheaper than our "impact-weighted" defense costs if we consider the relatively high probability of catastrophic change and the rapidly rising cost of events related to extreme weather. For example, the U.S. General Accounting Office noted that "claims paid on weather-related losses totaled more than $320 billion between 1980 and 2005" and that "climate change may increase losses by altering the frequency or severity of weather-related events."[20] Weighing the costs of these consequences, it may well feel like a bargain to avoid them if we act in a timely manner. Figure 7 shows the effect of one specific weather-related event over time.

In my opinion, climate change is a far more critical and potentially more catastrophic problem than national defense, terrorism or nuclear proliferation, even though all those problems are urgent and potentially catastrophic. Some of the costs of insurance (much like the costs for defense and anti-terrorism efforts) are warranted to mitigate the risk of the calamitous damage we face. But it may be cheaper to implement a global mechanism to work towards reducing carbon emissions. In any case it is vital, and a working cap-and-trade system offers one tool for aligning the interests of a disparate group of countries, industries, and people.

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