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Breaking the Climate Impasse with China: A Global Solution

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The goal of the Harvard Project on International Climate Agreements is to help identify key design elements of a scientifically sound, economically rational, and politically pragmatic post-2012 international policy architecture for global climate change. It draws upon leading thinkers from academia, private industry, government, and non-governmental organizations from around the world to construct a small set of promising policy frameworks and then disseminate and discuss the design elements and frameworks with decision-makers. The Project is directed by Robert N. Stavins, Albert Pratt Professor of Business and Government, John F. Kennedy School of Government, Harvard University. For more information, see the Project's website: http://belfercenter.ksg.harvard.edu/climate

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Breaking the Climate Impasse with China: A Global Solution

Kelly Sims Gallagher[1]

November 10, 2009

Executive summary

Enhancing national competitiveness to sustain economic prosperity is at the heart of concerns in both the United States and China regarding climate change policy. These two countries are the largest emitters on the planet. U.S. firms and labor unions are concerned that if the United States passes domestic climate legislation and China does not, the Chinese will have a competitive advantage in pollution-intensive technologies and products. In turn, the Chinese government believes it cannot agree to reduce its emissions while continuing to industrialize and develop economically, without technology transfer and financing from industrialized countries, especially the United States.

This paper explores the question of how to reconcile both countries' need for economic advancement, which is increasingly intertwined, with the imperative need to reduce greenhouse gas emissions (GHGs). How technology transfer occurs in practice, and how low-GHG technology transfer specifically might occur, based on prior experience with China, are examined. Particular focus is devoted to the following questions: How could U.S. firms benefit economically from low-carbon technology transfer to China? And, how could China acquire the technologies it needs to continue its rapid progress of industrialization in a more climate-friendly manner? The paper is aimed at finding a partial solution that would be likely to bring both the United States and China into an international climate change mitigation regime. The ideas proposed herein certainly do not resolve many other important challenges, such as how to provide for adaptation assistance, or how to help least-developed countries attract support for improving energy access in a climate-friendly manner.

A "deal" is proposed in this paper, whereby all major-emitting countries, including the United States and China, agree to reduce emissions through implementation of significant, mutually agreeable, domestic emission-reduction

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policies. To resolve the competitiveness and equity concerns, a proposed Carbon Mitigation Fund would be created. This proposed fund is contrasted with other existing and proposed mitigation funds and finance mechanisms.

The impasse

The essence of the impasse on global climate policy is the simple fact that the two largest emitters of greenhouse gases, the United States and China, have not agreed to reduce their emissions, and both blame the other for their inaction. The U.S. Senate refused to ratify the Kyoto Protocol in 1998 mainly on the grounds that there was inadequate "developing country participation"; in other words, the concern was that if the United States ratified, it would be at a competitive disadvantage with China.[2] The Chinese government, in turn, argues that China, a far poorer country, with per-capita carbon dioxide emissions approximately one-quarter[3] those of the United States, should not be expected to act before the United States has done so. And even if the U.S. government were to pass legislation to reduce emissions, the Chinese believe China should not have the same obligation as the United States, given its different stage of development, smaller per-capita emissions, and fewer cumulative emissions.

The United States and China currently account for nearly half of annual global carbon dioxide emissions, and their combined emissions are projected to continue to account for about half of global emissions through 2050 (IEA 2007). Indeed, eighty percent of global GHG emissions come from just 20 countries. Although the two largest emitters on an aggregate basis do not currently have binding mitigation policies, European countries and Japan have already taken substantial measures to limit or reduce their emissions. The new Japanese Prime Minister, Yukio Hatoyama, has pledged to cut Japanese GHG emissions 25% below 1990 levels within 10 years. The EU-15 achieved reductions of 4 percent below 1990 levels as of the end of 2007 (European Environment Agency 2009). Also, the Australians committed in December 2008 to reduce emissions 5-15 percent below 2000 levels by 2020, and are currently creating an emissions trading regime (Commonwealth of Australia 2008).

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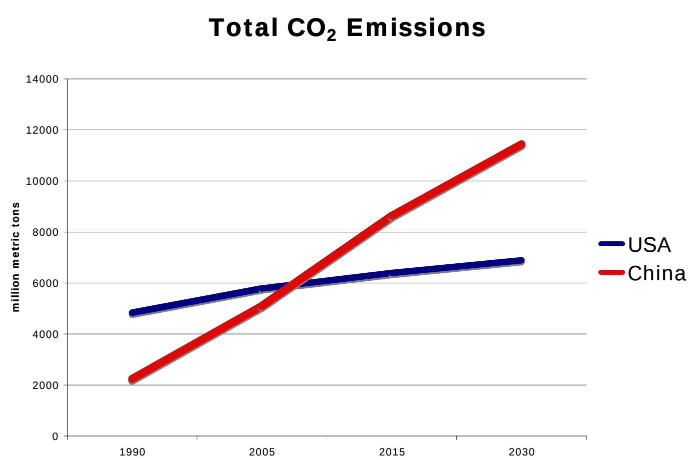
[2] Senate Resolution 98, Report No. 105-54, 105th Congress, approved July 25, 1997, states: Whereas the 'Berlin Mandate' specifically exempts all Developing Country Parties from any new commitments in such negotiation process for the post-2000 period. . . Now, therefore, be it resolved that it is the sense of the Senate that the United States should not be a signatory to any protocol to, or other agreement regarding the United Nations Framework Convention on Climate Change of 1992, at negotiations in Kyoto in December 1997, or thereafter, which would mandate new commitments to limit or reduce greenhouse gas emissions from Annex I Parties, unless the protocol or other agreement also mandates new specific scheduled commitments to limit or reduce greenhouse gas emissions for Developing Country Parties within the same compliance period. . ."

[3] According to the latest consistent data available, China's per-capita fossil-fuel CO_2 emissions in 2005 were 1.16 metric tons of carbon, and per capita emissions were 5.32 in the United States, so Chinese per-capita emissions were 22% of U.S. levels in 2005 (Marland, Boden, and Andres 2009).

The vast majority of developing countries are relatively small emitters, understandably more concerned about how to cope with the ravages of climate change than with mitigation. For the major emerging emitters, each faces unique challenges based on their national circumstances, so a portfolio of approaches will be needed. For example, India's per capita emissions are one-twentieth the size of U.S. per capita emissions, and India's projected growth in emissions is relatively small compared with China's due to the fact that a much larger fraction of India's population still relies on traditional forms of energy sources (e.g. fuelwood, crop wastes) and the relatively lighter form of manufacturing that dominates the Indian economy. Brazil's industrial, commercial, and residential emissions are very small due to Brazil's heavy use of carbon-free hydropower, and it's transition to sugarcane-based ethanol to fuel its transportation sector; Brazil's emissions largely come from deforestation.

As the two largest aggregate emitters, if the United States and China could reach agreement about how to reduce their greenhouse-gas emissions, the impasse would be broken and they could join the European Union, Japan, and other major emitters to collectively reduce emissions in earnest. Indeed, most of the other "Annex I"[4] countries would probably accept any agreement forged between the United States and China. Brazil, Indonesia, and other major emitters from deforestation and land-use change need a different solution. India will probably not agree in the near term to any international agreement on equity grounds. And least developed countries simply need more and "greener" foreign aid to help with development and adaptation. This paper explores a possible package that might convince both the United States and China to agree to join together to address climate change.

Figure 1. U.S. and Chinese CO_2 Emissions
Data source: International Energy Agency 2007, *World Energy Outlook*, Reference Case Projections



Clarifying our climate goals

An odd discordance is emerging regarding the urgency of global emissions reductions based on available science, and society's response to this knowledge. Despite the entry into force of the Kyoto Protocol in 2005, global emissions have continued to

[4] Countries listed in Annex I of the UN Framework Convention on Climate Change, which includes industrialized countries and countries undergoing the process of transition to a market economy.

steadily grow. Global carbon dioxide (CO_2) emissions from energy and cement production grew 34 percent between 1990 and 2007. Just since the turn of the century, global CO_2 emissions have grown 16 percent. U.S. GHG emissions grew 17 percent between 1990 and 2007. While the United States has long been the world's biggest GHG emitter on an annual and cumulative basis, China's annual emissions surpassed U.S. total emissions in 2007.

Global emissions are growing much faster than previously expected (about 3 percent per year so far this century), so governments appear to be failing to act in time to address the threat of climate disruption (Gallagher 2009). New research shows that if the world wants a 75 percent chance of keeping global warming below 2°C, the world can only emit 1000 Gt CO_2 or less between 2000 and 2050 (Meinshausen et al. 2009). At current global emission rates of approximately 36 Gt CO_2 per year, the world would overspend its emissions budget for 2000-2050 in just 28 years, assuming *no growth* in emissions. If the world careens past 2°C, unsafe climatic changes are expected, including a high chance of losing the ice cover on Greenland, significant loss of the Arctic sea ice, loss of most mountain-top glaciers, major sea-level rise, loss of most threatened and endangered species, and massive bleaching of coral reefs (Schneider 2009).

In other words, while it is true that climate change is a long-term problem, there does appear to be a finite global emissions budget in the near term if we are to have a good chance of avoiding all the woes just described. Emissions from the United States and China are rapidly using up the world's budget. China's CO_2 emissions are expected to more than double (rather than decline) between 2005 and 2030 due to its rapid economic development. Absent policy measures, by 2030 China alone will account for one-third of global emissions, and the United States will account for 15 percent (IEA 2007). If the world is to live within its emissions budget, faster action to reduce emissions is required of every country than is currently occurring. Given China's currently large fraction of global emissions and its rapid projected growth, it is especially important to find a way to initially slow the growth in Chinese emissions, then reverse it within the next two decades. But China will not do so without a deal with the United States.

The core issues: technology transfer and economic competitiveness

The economic costs of reducing GHG emissions are at the heart of both countries' concerns about formally committing to an international agreement, but these anxieties manifest themselves somewhat differently in the United States and China. In the United States, the biggest concern is maintaining economic competitiveness – how to ensure that China does not gain an economic advantage if the United States must reduce emissions and China does not. Energy-intensive industries, and the labor unions associated with them, are especially worried they could lose more ground to China. For the Chinese government, access to affordable technology to reduce emissions is a fundamental challenge. The Chinese know that in many cases low-GHG-emitting technology is more expensive, so it could potentially be a big burden to shoulder these additional costs while China continues to go through its intensive period of industrialization and socio-economic development. The Chinese government also believes it is unfair for China to have to reduce emissions now because the United States went through its own stage of rapid industrialization unfettered by any carbon constraints.

An important precondition for breaking the impasse is therefore for each country to acknowledge that the other shares essentially the same concern that the costs of mitigation could be high and harmful to their domestic economies. This shared concern then can be transformed into a shared interest in reducing the costs of mitigation technologies for both countries through cooperation on clean-energy technology research and development, as well as improved mechanisms for energy-technology demonstration and deployment. It is not clear, by the way, that the costs of mitigation will inevitably be high or unmanageable (see, for example DeCanio 2003, Stern 2006, Nordhaus 2008, Ackerman 2009, CBO 2009), but these costs do depend on how rapidly and steeply emissions reductions must occur. And, the costs must be weighed against the benefits (clearly large but difficult to quantify) of avoiding catastrophic climate change. In any event, there is no doubt that the *concern* about high mitigation costs is significant and paralyzing in both countries.

The rhetoric on both sides has become quite heated. In encouraging the other to join an international climate change regime, recent policy proposals in both countries are perceived as unconstructive by the other. In the U.S. Congress, bills have been introduced that would provide free allowances for energy-intensive industries (in the form of production-related allowances in the House cap-and-trade bill) or border tax adjustments. The Chinese government has consistently called for technology transfer in the context of the UNFCCC negotiations, and in April 2009, proposed that industrialized countries donate between 0.5 to 1 percent of GDP for climate-change-related funds, one of them being for technology transfer.

The basis for the concern in the United States hinges less on empirical evidence that unilateral reductions in U.S. GHG emissions are likely to lead to widespread migration of energy-intensive industries to China (or creation of "pollution havens" in China) (see, for example, Levinson and Taylor 2008 and Copeland 2008), and more on the more general economic distress experienced by the energy-intensive industries and labor unions in recent years. Between July 2008 and July 2009, for example, steel output shrank 51 percent in the United States while rising 3 percent in China, and 2 percent in India (World Steel Association 2009).[5] Whether or not China is the cause of these industrial losses in the United States, the Chinese are routinely blamed. Many U.S. manufacturing jobs have evaporated during the past decade, and as of October

[5] Chinese steel production in 2009 was more than 10 times the amount of U.S. steel production.

2009, employment in U.S. manufacturing had contracted by 2.1 million since the onset of the recession (BLS 2009).

The five most energy-intensive industries in the United States combined account for more than half of all carbon dioxide emissions from U.S. manufacturing, but less than 6 percent of U.S. total emissions. These industries are: ferrous metals (iron and steel), non-ferrous metals (aluminum and copper), non-metal mineral products (cement and glass), pulp and paper, and basic chemicals. Together, they account for 3 percent of U.S. GDP, and less than 2 percent of nationwide employment. (Houser et al. 2008).

China's economic "miracle" of 8+ percent annual growth in GDP has been fueled largely by a tremendous reliance on its manufacturing sector. As of 2008, manufacturing and mining accounted for half of China's economic output, as compared with only 22 percent of U.S. GDP (WDI 2009). China's initial industrialization strategy was to support its manufacturing sector, and its economy is now disproportionately reliant on energy-intensive industries. In the 11^{th} 5-Year Plan, the government set forth a new economic development strategy that was intended to expand lighter industry and the service sector. If the government is successful in implementing this strategy, the GHG intensity of the Chinese economy should fall, because the heavy industries' use of coal that is a primary driver of the rapid growth in China's CO_2 emissions. But until such an industrial transformation has occurred, China's economy will remain relatively emissions-intensive. There is the further challenge that China is already locked in to relatively high-emission-future, because it has already built so many GHG-intensive factories and power plants during the last ten years. The next two decades are likely to be very similar to the last two decades with continued rapid economic growth and infrastructure development. Indeed, the Chinese government projects new demand for electricity to be 100 GW per year through 2050.

Developing countries, including China, regularly call for technology transfer in international forums. But "technology transfer" is a vague term, so it is important to clarify exactly what China wants. Technology transfer is not just the transfer of hardware from industrialized countries to developing countries. It is also transfer of knowledge, such as how to adapt and improve technologies, how to integrate technology systems, and how to commercialize and manufacture a given product. Much of this knowledge is tacit and difficult to specify. Technology transfer is not only "north-south," but it has always mainly occurred among already industrialized countries, and is increasingly occurring among developing countries. There are also cases of "south-north" technology transfer, including from China to the United States in the energy sector.

The vast majority of "technology transfer" occurs in the private sector, where technologies are mainly transferred through trade, foreign direct investment, and licensing (Popp 2008) through regular processes of technological diffusion. Technology transfer can mean licensing of technologies (at market prices), compulsory licensing of specific technologies (at reduced cost), physical transfer of equipment, transfer of knowledge about how to build, operate, and maintain production facilities, and so forth. Technology transfer occurs through the normal processes of technological diffusion. Although incorrect, the term, 'technology transfer,' is most typically understood to mean the physical transfer of explicit technologies from developed to developing countries. Because the concept and term is enshrined in the UN Framework Convention on Climate Change[6], many, if not all, developing countries believe that the industrialized countries (especially the United States) failed to live up to its commitments related to technology transfer under the UNFCCC, and so the term and concept both are highly charged and contentious.

Technology transfer is inseparable from the question of financing. Most technologies are readily available through private markets; it's just that they are often (but not always) more expensive than the conventional alternatives (see Table 1). So, one can infer that the more fundamental Chinese interest is help with the incremental costs of low-GHG technologies. There are indications that financial assistance is what the Chinese really mean when they call for technology transfer. China's proposal for a technology mechanism, submitted to the UNFCCC in late 2008[7], states, "Currently, access to financing is limited and should be enhanced to deliver technology development, deployment, adoption, diffusion, and transfer to non-Annex I parties." China sincerely believes it is justified in calling for financial assistance. Today's industrialized countries emitted most of the GHG emissions that have cumulatively built up in the atmosphere. Between 1900 and 2005, China emitted approximately 15 percent of what the United States, EU, and Japan together released into the atmosphere.

Table 1. Relative Costs of Low-Carbon Electricity Generation

Type	Levelized Cost of Electricity ($2005/MWh)
Natural gas	$50-$100
Coal	$75-$100
Carbon capture and storage (CCS)	$125-$250
Nuclear	$125-$260
Onshore wind	$100-$160
Offshore wind	$180-$290
Concentrated solar thermal	$210-$360
Solar PV distributed	$175-$400
Adapted from Al-Juaied, M. and A. Whitmore 2009 (referenced data from Hydrogen Energy).	

There is limited evidence that China has experienced trouble acquiring certain advanced technologies from foreign firms even when China has been prepared to pay for them. Sometimes the foreign technologies do not initially work well in China (e.g.

[6] According to the UNFCCC (1992), "They [developed countries in Annex I] shall also provide such financial resources, including for the transfer of technology, needed by the developing country Parties to meet the agreed full incremental costs of implementing measures that are covered by paragraph 1 of this Article and that are agreed between a developing country Party and the international entity or entities referred to in Article 11, in accordance with that Article."

[7] Submitted together with the G-77.

coal gasifiers); other times the Chinese firms don't know how to manufacture or operate the technologies once the equipment has been licensed or physically transferred (Gallagher 2006). And, sometimes the costs of the foreign technologies have been prohibitively expensive (e.g. equipment for the proposed but never built IGCC plant in Yantai)[8]. If the Chinese government concern is really about overcoming the higher costs of low-GHG technologies, then the physical transfer of technologies may not be the main barrier; rather, the incremental costs must be overcome.

Many low-GHG technologies are estimated to be relatively cheap or even "negative" in cost if the savings from energy efficiency technologies outweigh the costs over time (for an optimistic view, see McKinsey 2009). Some low-GHG technologies are much more expensive than the high-carbon alternative – plug-in hybrid cars, power plants coupled with carbon capture and storage (CCS), and solar PV, to name a few. In one recent study comparing the costs of different power plant configurations in the Chinese context, the capital costs of integrated gasification combined cycle (IGCC) technologies were almost twice as expensive as conventional coal-fired power plants, not including the costs of capturing CO_2 (Zhao et al. 2008). China has already brought numerous high-efficiency ultra-supercritical (USC) coal plants on line, and is building more.[9] But, so far, the technology for capturing the CO_2 from super-critical or USC plants ("post-combustion" capture) appears to be expensive. Coal gasification, which is the core technology for IGCC, and polygeneration may offer a relatively economical pathway for CO_2 capture, but it is still considerably more expensive than coal-fired power without CO_2 capture.[10] In a recent study based on 2008 U.S. data (which are probably not a good proxy for Chinese conditions), it was estimated that building a new IGCC plant with 90% capture of CO_2 would be 70 percent more expensive than building a new IGCC plant without capture (Al-Juaied and Whitmore 2009). These extremely high costs are likely to come down as more plants are built because technologies like IGCC with carbon capture are "first-of-a-kind" demonstration plants, but as experience is gained through the construction and operation of numerous plants, the costs will likely fall.

[8] In addition, the Yantai IGCC project was developed by the former State Electricity Company, which was divided into 5 power groups and 2 grid groups due to the reform in 2003. After that, no one was clearly put in charge of the project.

[9] USC plants are highly efficient – more efficient than most of the existing coal plants in the United States, and so they are inherently better from a climate change point of view than a run-of-the-mill power plant in China. "Super-critical" and "USC" refer primarily to the pressure at which steam is circulated in the plant.

[10] The costs of capture are inherently uncertain because CO_2 is not captured at commercial scale in very many places. Some studies have estimated that the costs of post-combustion capture will be more or less on par with pre-combustion capture and oxy-fuel combustion (e.g. IPCC 2005, MIT 2007, McKinsey 2008), and others suggest that pre-combustion capture technologies are currently much less expensive than post-combustion capture, and likely to be come even more economically attractive in the future (Rubin, Chen, and Rao 2007, and Chen and Rubin 2009).

Aside from higher incremental costs, other often-cited barriers to technology transfer include concerns about insufficient protections for intellectual property (on the part of the owner of the technology), trade barriers including tariffs, investment risk, high interest rates, insufficient human and institutional capabilities, inadequate understanding of local needs and demands, lack of confidence about "unproven" technologies, and high transaction costs (IPCC 2000, 19). Any or all of these barriers to technology transfer may be important in specific circumstances, but this paper asserts that the two most important barriers are the higher incremental costs and lack of aligned incentives.

Table 2. Annual estimates of market for carbon mitigation technologies to 2050

Source	Global	Developing Countries	China
UNDP 2007	$25-$50 billion annually	-	-
IEA 2008	$400 billion (ACT) - $1.1 trillion (BLUE) annually through 2050	$240 billion (ACT) - $645 billion (BLUE) annually through 2030	-
Expert Group on Technology Transfer 2009	$260-830 billion annually through 2030	$82-264 billion annually through 2030	$154 billion annually (all energy)
China Greentech Initiative 2009	-	-	$500 billion - $1 trillion annually (all "green")

Notes: IEA's ACT scenario brings global emissions back to 2005 levels by 2050, and the BLUE scenario would bring global emissions to 50% below 2005 levels by 2050. The IEA scenarios include R&D investments. The baseline cumulative investments between 2005-2050 are estimated at $254 trillion (6% of cumulative GDP).

Less commonly understood is that international technology transfer does not occur without strong, aligned incentives to motivate it. If a developing country or foreign firm sees an exploitable market for a certain technology or product, then it has a natural market-based incentive to commercialize that technology. But, in the absence of climate policies such as a carbon tax, cap-and-trade regime, or performance standards within that country, there is no local incentive to deploy low-GHG emitting technologies. In other words, domestic, enforceable policy must exist in order to elicit clean technology transfer from foreign firms as well as to motivate the development and deployment of clean energy technologies in both developing and industrialized countries (IPCC 2000, Oshita and Ortolano 2002, Gallagher 2006a, Lewis 2007). As noted by the IPCC in its special report on technology transfer, "The need for governments' commitment in the transfer and development of technology. . . is vital for the transfer process." Indeed, the report states that an important role for government is, "Setting and enforcing standards for improved efficiency and GHG emission controls"

(IPCC 2000, 216). Technology transfer, and especially leapfrogging to cleaner technologies, is not automatic even though it is desirable (Gallagher 2006b).

The U.S. national interest and policy proposals towards China

The United States has two primary interests with respect to China and other major emitters: (1) protect *and* enhance U.S. economic competitiveness, and (2) encourage and induce China to reduce its own emissions in order to avoid catastrophic climate change because only with the full participation of all major emitters does the United States (and the rest of the world) have a chance of meeting its climate goals.

For both economic and political reasons, the U.S. government will try to protect and support currently carbon-intensive U.S. firms through the transition to a low-carbon economy. The government must also devise a low-GHG industrial strategy that incubates, sustains, and enables U.S. firms with low-GHG technology to flourish in the global marketplace. U.S. government support of a world-class American industry in low-carbon mitigation and adaptation technologies creates an opportunity for U.S. firms to enjoy first-mover advantage in a low carbon-economy. A gigantic market is projected to grow for climate-friendly technologies during this century, and the majority of the estimated global market will flourish in China.

Estimates of the size of the world market for climate mitigation technologies vary, of course, but by all accounts the market is large. These estimates are presented in Table 2. One recent report indicates that the global market for "diffusion" of carbon mitigation technologies will range from $260-$830 billion annually through 2030. The market for diffusion of carbon mitigation technologies in developing countries is estimated at $82-$264 billion annually, with $154 billion being located in China (UNFCCC 2009, 24). The International Energy Agency estimates there will be a 50 percent increase in world primary energy demand between 2005-2030, and that China and India alone account for 45% of the increase. Cumulative world investment in energy-supply infrastructure between 2006-2030 could be as large as $22 trillion, with China alone accounting for $3.7 trillion of this total (IEA 2007).

But, if the major developing countries enact, implement, and enforce GHG-reduction policies, they will be *forming a new market*. If U.S. firms are well positioned to sell cleaner energy technologies, when any other country establishes domestic climate policies, a market for these technologies is created for the U.S. firms. U.S. companies like GE (turbines), Honeywell (energy services), Ford Motor Co. (hybrids), American Superconductor (wind, smart-grid), Chevron (advanced fuels), A123 Systems (batteries), PPG Industries (fiberglass and protective coatings for wind turbines), and Zoltek (carbon fiber) are all examples of firms that could benefit from creation of such markets.[11]

[11] See Bradsher 2009 for a discussion of U.S. firms' experience penetrating the renewables market.

Another reason why it is in the U.S. interest to get these major emitters to commit to clear, enforceable emission reduction policies is that if these countries implement concrete policies to reduce GHG emissions, the problem of "leakage" goes away. Leakage can be defined as the displacement of emissions from one country to another as a result of the imposition of policy in the first and lack of a policy in another. This problem is otherwise known as the "pollution haven" effect. There is a large body of studies about the extent to which pollution havens occur and why (Copeland and Taylor 2005, K.P. Gallagher 2009). There are two primary concerns – that firms will relocate to the place where weaker environmental regulations exist, or that due to the competitive advantage created by the imposition of regulations in the first country, firms in the country without regulation will have a competitive advantage, and will therefore produce (and pollute) more. In general, there is weak evidence internationally for the first kind of pollution haven because costs of environmental regulation are relatively small (i.e. that firms actually move to take advantage of weaker environmental policy), but the competitive disadvantage problem could be real until such time as the country without regulation imposes it.

In the United States, two main types of proposals for how to enhance competitiveness and induce developing countries to join an international agreement are commonly advocated. Enhancing competitiveness often manifests itself as protecting incumbent industries, but it can also be done through industrial policy that supports new industries, or through investments in energy-technology innovation. To induce the participation of developing countries, some have suggested border tax measures[12] against imports from countries that do not have climate policies. Such border taxes would be assessed based on the GHG emissions associated with each product, and so would be tremendously difficult to enforce administratively. In a recent study on the economic and environmental effects of border tax adjustments, the authors concluded that the "benefits produced by border adjustments would be too small to justify their administrative complexity or their deleterious effects on international trade" (McKibben and Wilcoxen 2008). In addition, imposition of such border taxes risks retaliatory measures on the part of other countries, which could harm U.S. exports. There is the further problem that the border tax measures could be counterproductive in encouraging countries to come to the table. Indeed, U.S. imposition of border tax measures is unlikely to have much of an effect on the Chinese because they don't export energy-intensive products to the United States. Less than 3 percent of Chinese

[12] In an op-ed published in the *New York Times* on October 10, 2009, Senators Kerry and Graham wrote, "We cannot sacrifice another job to competitors overseas. China and India are among the many countries investing heavily in clean-energy technologies that will produce millions of jobs. There is no reason we should surrender our marketplace to countries that do not accept environmental standards. For this reason, we should consider a border tax on items produced in countries that avoid these standards. This is consistent with our obligations under the World Trade Organization and creates strong incentives for other countries to adopt tough environmental protections."

aluminum production, 2 percent of paper production, and 1 percent of chemicals and cement are exported to the United States (Houser et al. 2008).

H.R. 2454, The American Clean Energy and Security Act of 2009[13] has several provisions designed to address the competitiveness and developing country participation issues. First, from 2012-2025, a large number (15%) of emission allowances are given annually for free to “energy-intensive, trade-exposed” industries. Oil refiners similarly receive 2 percent of the allowances. More allowances are given away for free to electricity producers, natural gas producers, and heating oil distributors, with stipulations that the fixed components of relevant prices should not increase. Revenue from sales of 0.5 percent of the allowances is allocated to worker assistance and job training through 2021, rising to 1 percent in 2022. The bill also contains provisions for adaptation and clean technology transfer – starting with 2 percent of the allowances through 2021, scaling to 8 percent in 2027. Half of these are to be used for adaptation and half for clean technology transfer (Waxman and Markey 2009, Committee on Energy & Commerce 2009). The bill creates a Clean Technology Account, to be administered by the State Department, to provide U.S. resources to encourage widespread deployment of clean technologies to developing countries that have either “ratified an international treaty or have undertaken nationally appropriate mitigation activities achieving substantial greenhouse gas reductions.”

Finally, offset provisions are included with the goal of reducing the costs of emissions permits, and also providing a mechanism for encouraging developing countries to join the regime.[14] Up to 2 billion tons of offsets are permitted, half of which must be domestically derived, and half of which must come from international sources. If the EPA Administrator determines that there are insufficient domestic offsets available, greater use of international offsets are permitted, although they are slightly discounted (less valuable). Again, international offsets can only be purchased from countries that have become parties to an international agreement (Democratic Staff of Committee on Energy and Commerce 2009). Although the exact provisions for how such an international offset program would work are not provided in the bill, one can infer that these offsets would be generated much like CDM projects generate certified emission reduction (CER) credits, in that the seller of the credit must certify that the emission reductions verifiably exist before the buyer can purchase them.

In 2008, Senators Biden, Hagel, Lugar, Menendez, and Snowe introduced a bill to create an International Clean Technology Deployment Fund. This fund would be used to add the consideration of climate change to the U.S. foreign assistance strategy, encourage the export of U.S. clean energy technology. It imposes a condition that only developing countries that have taken on their own climate change commitments would

[13] Otherwise known as the Waxman-Markey bill.

[14] “Offsets” are to be defined by the U.S. EPA, but are understood to include forestry, agricultural, or other projects that reduce emissions relatively cheaply.

be eligible for the CTDF. In the bill, $2 billion is authorized for FY09-FY11. This bill is broadly consistent with the recommendations in this paper.

China's national interest and policy proposals towards the United States

China recognizes that it shares a common interest with the United States in avoiding dangerous climate change. To provide just two examples, as the Chinese government noted in a report released in 2008, that with a coastline over 18,000 km long, China is vulnerable to the adverse effects of sea level rise. Also, China's water resources are at great risk, especially due to the accelerated melting of glaciers in western China, which could reinforce the drought in northern China (State Council 2008).

The challenge of reducing GHG emissions in China is great due to China's heavy reliance on coal (70 percent of primary energy supply), and China's current period of industrialization. Per-capita GDP is low – approximately $2,500 – though there are big disparities in per-capita income, with the coastal regions generally being much more prosperous than the western provinces. China's GHG emissions are currently dominated by industry (residential energy consumption is very low), so China's GHG emissions are intimately connected with the economic growth. China is concerned about maintaining economic competitiveness in an economy that is much more dominated by heavy industry and manufacturing than is the U.S. economy. Acquisition of affordable low-GHG technologies is therefore of primary concern, and unlike the United States, the Chinese do not have all the technologies they would need. They will either have to invest in innovation to develop indigenous technologies, or they will have to purchase them from abroad. This is why the official Chinese policy has been so heavily tilted towards calls for "technology transfer."

Like all other developing countries, China is also motivated by concerns about fairness. Although to many in the United States, China appears to be a veritable economic behemoth, China is very much a developing country with low per capita income, more than 700 million living in rural areas, and tens of millions of people migrating from the countryside to cities each year in search of work (Xinhua 2007). The Chinese are acutely aware that their per-capita emissions are about one-quarter U.S. per capita emissions, and also aware that their cumulative historical emissions are a fraction of U.S. emissions. These perceived inequities are why the Chinese proposed in May 2009 that between 0.5 and 1.0 percent of industrialized countries' GDP be put into a set of funds to help finance technology transfer, adaptation, and so forth. This large number is obviously a negotiating position, but it makes clear how serious the Chinese are about financial assistance.

Breaking the impasse: a new climate package

All of the above challenges and constraints must be addressed if the United States and China are to come to agreement. A package containing the following elements might break the Sino-U.S. impasse[15]:

- Specific and enforceable domestic policies to reduce GHG emissions in industrialized countries, including in the United States[16]
- Specific and enforceable domestic policies to reduce GHG emissions in other major emitting countries[17], including in China
- A new Carbon Mitigation Fund (CMF) to support low-carbon technology deployment in major-emitter developing countries
- International cooperation on low-GHG research, development, and demonstration
- Reform of energy subsidies to remove supports for carbon-intensive fuels

Domestic emission-reduction policies from all major emitters are needed in order to act in time to avoid a 2°C global temperature rise (Gallagher 2009). Such policies should embrace a "slow-stop-reverse" pathway for emissions reductions (NCEP 2004), so that at first, emissions are reduced below business-as-usual growth, then emissions growth is halted, and finally reversed.

Concrete, enforceable, domestic GHG reduction policies from all major emitters eliminate concerns about competitiveness, thereby dismissing the "leakage" problem. Such domestic, enforceable policies also create the incentive for the Carbon Mitigation Fund (CMF) to be used. If domestic policies are enacted and incremental financing is available, then developing countries should be able to leapfrog to low-GHG technologies. If demand for low GHG technologies rises in China and elsewhere, then U.S. firms as well as those firms from other industrialized countries can expand their sales of technologies and services to these major developing countries. These domestic policies could be packaged into "portfolios" of domestic commitments where countries would agree to, "conform to the requirements specified by their respective domestic laws, regulations, and official planning documents." (Stavins 2009). The idea of coordinated domestic mitigation policies was also proposed in the Bali Action Plan, which suggested that "nationally appropriate mitigation actions" (NAMAs) be considered as a potential mitigation mechanism (Wold, Hunter, and Powers 2009).

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[15] As mentioned in the introduction, this paper does not endeavor to resolve all the important international policy challenges. But, clearly, there also needs to be assistance for least-developed countries, especially African countries, including adaptation funds, the Clean Development Mechanism, and capacity building through the GEF.

[16] Otherwise known as the Annex I countries of the Kyoto Protocol

[17] These should include the developing countries ranked by total GHG emissions (e.g. China, India, South Korea, Iran, Mexico, Indonesia, South Africa, Saudi Arabia, Ukraine, Brazil).

In order to eliminate leakage, the domestic policies of all major emitters should result in comparable emissions reductions. If the reductions are not comparable, they must at least be acceptable to other countries agreeing to the regime. The form of these policies should be left to the individual countries because they will know which policies are most suitable to their unique national circumstance, but one could imagine harmonized carbon taxes, cap-and-trade regimes with comparable caps and other design elements (e.g., safety valve), or harmonized regulatory policies.[18]

But, enforceable domestic emission-reduction commitments from developing countries would come at a price to the industrialized world. If the industrialized world wants earlier action from developing countries (which is necessary to meet climate goals), it must be prepared to help finance the adoption of more expensive GHG-reduction technologies as a matter of fairness. The United States and other industrialized countries emitted most of the greenhouse gases already in the atmosphere without having to pay for the environmental consequences. Given that the industrialized countries had a “free ride” for so long, it is only fair that they help pay for the transition in countries that are still industrializing. Funding for the Carbon Mitigation Fund should come from the largest cumulative emitters, proportional to their cumulative per-capita emissions adjusted for economy size, dating back to a certain year, as discussed below.

The carbon mitigation fund

The proposed Carbon Mitigation Fund (CMF) would reduce the costs to developing countries of acquiring and deploying advanced, low-GHG-emitting technologies in the near term. In essence, it addresses one of the main barriers to the diffusion of low-carbon technologies in developing countries by financing the upfront incremental costs.

The fund would be technology neutral -- that is, it could be used for all low-GHG technologies, including coal with CCS, nuclear energy, renewable energy, and energy efficiency, subject to the laws of domestic countries (e.g. carbon storage regulations, nuclear prohibitions). To start the fund, the top cumulative per-capita emitters would make a contribution for a 10-year period.[19] In other words, there would be no determination by the CMF about technologies that are permissible. This decision is left to the recipient country, and is therefore governed by domestic rules and regulations.

Charitable donations from wealthy individuals, philanthropic organizations, the private sector, NGOs, and the public should also be encouraged. The fund should not be

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[18] Harmonized regulatory policies were called “policies and measures” during the negotiations leading up to the Kyoto Protocol, and were favored largely by the Europeans.

[19] This paper is neutral on where the cutoff should be in terms of contributions to the fund. The formula could be that the top 10, top 20, or all emitters contribute based on their cumulative emissions.

permanent because over time, developing countries should take on the costs of carbon mitigation themselves, but it must exist long enough to provide investment certainty. Two consecutive 10-year fund periods seem to be appropriate to begin with. At the end of the first 10 years, contributions would be re-calculated proportional to each country's cumulative per-capita emissions dating back to the base year, including the subsequent ten years.

The fund would leverage the private sector, and act like a commercial bank. Most transactions would take place in the domestic market on a commercial basis. Each new facility being built (e.g. power plant, building, factory) would do an international competitive solicitation for the technology to be provided. Then, once the technology provider was selected through the competitive procurement process, the firm would arrange for financing from private banks for the cost of the facility, not including the incremental cost of the low-carbon technology. Once the firm has received provisional approval from the commercial bank for the project, it would submit an application to the CMF for a grant to cover the incremental cost of the project. So long as the project met all the criteria set forth by the CMF, it would receive the grant.

The CMF could also provide low-interest loans for developing and industrialized countries alike, even if the loan applicants did not meet CMF criteria (e.g. did not originate from a country with domestic emission-reduction policies, or did not conduct a competitive procurement).

Competitive procurement processes would have to be specified. In the case of the Global Environment Facility, specific procurement guidelines, procedures, and methodologies are in place, and procurement performance in projects is periodically monitored. Procurement records are publicly available (GEF 2007). The World Bank also provides clear procurement policies for its borrowers (World Bank 2006). These and other institutional examples provide a starting point.

Criteria for grant acceptance would be that the new technology reduced GHG emissions at least a certain percentage below the baseline calculated for that year, that an international competitive solicitation was conducted for the technology, that the project had been provisionally approved by a private-sector bank (which would do the due diligence on the cost-effectiveness of the project), and that the project originates from a country that has implemented binding mitigation policies domestically. If all four conditions were met, the CMF would automatically grant the funds.

In negotiating the deal, the industrialized countries contributing to the fund should press for reasonable reductions in trade and/or non-tariff barriers to trade and investment in low-GHG technologies. Such tariffs exist, and, for example, they are imposed on compact-fluorescent light bulbs, multiple walled insulating units of glass, and thermostats. These tariffs are imposed by both developing and industrialized countries, and create barriers to technology transfer by raising the cost of these energy-efficient and renewable energy products (Brewer 2008). Other non-tariff barriers to trade and investment would need to be addressed as well. One recent example is China's prohibition of any wind turbines with a capacity of less than 1 GW, which excludes 850 kW designs, which are common for European manufacturers (Bradsher 2009).

GHG-emission baselines will differ among countries, and these baselines will change over time as cleaner technologies are introduced into the market. The incremental costs of low-GHG technologies will also change as costs come down through R&D, economies of scale, and learning. The CMF would employ a professional technical staff, which would be responsible for establishing GHG emission and technology cost baselines for each country annually. These standardized baselines would be used to calculate the incremental cost associated with new technologies in order to determine the level of disbursement from the CMF. The baselines would be updated annually so as to continuously create an incentive for the deployment of cleaner technologies.

Institutionally, the CMF should be a new entity. It could, however, be housed in the World Bank or any other existing institution. It is beyond the scope of this paper to provide detailed recommendations about exactly how this institution should be created, and where it should be located, but essential characteristics include having a professional staff that is highly competent in both engineering and finance. Staff experience in philanthropy would be desirable given that this will be a grant-making institution. It should not have a cumbersome review process similar to that of the CDM and its Executive Board. To the contrary, the CMF should operate just like a bank with project approval being relatively automatic once the conditions specified above are met. The main difference, of course, is that the CMF would mainly provide grants.

Size of the CMF

It is not clear how big of a fund would be needed. Estimates in the literature range widely, as reviewed in Table 2. The 2007-2008 UN Human Development Report provided an estimate of $25-50 billion in annual incremental costs (UNDP 2007). The IEA estimated in 2008 that additional investment costs for carbon mitigation (incremental costs over their baseline scenario) to bring global CO_2 emissions back to current levels by 2050 would be approximately $18-$49.5 trillion between 2005-2050, which is $400 billion to $1.1 trillion per year globally. For developing countries, IEA estimates that the total incremental costs between 2005-2050 are $10.8- 29 trillion, or $240-$645 billon per year.[20] The Expert Group on Technology Transfer of the UNFCCC released its

[20] The ranges represent the difference between IEA's ACT and BLUE scenarios. The ACT scenario brings global emissions back to 2005 levels by 2050, and the BLUE scenario would bring global emissions to 50% below 2005 levels by 2050. The IEA scenarios include R&D investments. The baseline cumulative investments between 2005-2050 are estimated at $254 trillion or $5.4 trillion/year. The $254 trillion is equal to 6% of estimated cumulative GDP during that time period.

recommendations in May 2009, which called for incremental financing of $262-670 to $332-835 billion globally per year through 2030. The Expert Group's estimate of the amount of incremental financing needed to enable the "diffusion" of carbon mitigation technologies in developing countries was approximately $82-$264 billion per year (UNFCCC 2009, 24). In October 2009, the European Council committed the EU and Member States to contribute a "fair share" of the additional public finance that developing countries are expected to need, and the EU estimated that €22-50 billion ($33-75 billion) would be needed annually by 2020. The EU stated that all countries, except the least developed, should contribute to this total through an agreed global contribution formula based on countries' emission levels and ability to pay, though the EU asserted that emission levels should be weighted more heavily than ability to pay, and the weight on emissions should increase over time (Council of the EU 2009).

If the low-end estimate of the UNFCCC's Expert Group is used ($82 billion per year), and this number is divided by 20 contributors, each would pay an average $4 billion per year (of course, some countries would be paying more, and some less, depending on formula for contributions). For the new funds that have been proposed and operationalized (see Table 2), some industrialized countries have already demonstrated that they are willing to put up $85 million - $2 billion per year absent developing country commitments, so an average of $4 billion does not seem impossible, assuming that all major emitters have agreed to enforce domestic policies. The United States would certainly be responsible for more than the average. Just for the sake of comparison, if the U.S. allocation resulted in a $6.5 billion responsibility, this figure would be equivalent to 8 percent of projected annual revenue in the Waxman-Markey cap-and-trade bill if there were a 100 percent auction. To put this figure in perspective, $6.5 billion is 5 tenths of 1 percent of U.S. GDP ($14 trillion in 2008), 4 percent of the 2008-2009 AIG bailout ($150 billion), and 26 percent of the U.S. Department of Energy budget ($24.1 billion in 2008).

The funds should be disbursed on a first-come-first-serve basis to encourage early action in case this amount is insufficient, and a mid-term review at five years should be conducted to determine if the funds contributed are sufficient.

Contributions to the CMF

Various formulas for contributions to the CMF can be used, and the major emitters will undoubtedly carefully negotiate this formula. Individual countries and the research community have suggested many different burden-sharing proposals.[21] Many

[21] For a review of approaches and proposals, please see Berk and van Elzen (2001). Some of the most prominent for emissions allocations are the Global Commons Institute's "contraction and convergence" approach (Meyer 2001), the more recent proposal to differentiate mainly based on individual per-capita income (Chakravarty et. al 2009), a proposal modifying the GDR approach (Cao 2008), and a new proposal for introducing graduated commitments where developing countries gradually increase their level of effort to reduce GHG emissions (Bosetti and Frankel 2009).

of these proposals have been for how to allocate responsibilities for *emissions reductions*. Here, different proposals for how to allocate responsibility for *financing* are reviewed.

Any discussion of burden-sharing arrangements inevitably begins with the principle of "common but differentiated responsibilities" enshrined in the UNFCCC and in Article 3.1 of the Kyoto Protocol. The notion that wealthier, industrialized countries have a greater responsibility to deal with the climate change problem is unassailable, and deeply entrenched in the history of the international negotiations on climate change. Indeed, currently industrialized countries developed without any constraints on their emissions of greenhouse gases. But, the principle of common but differentiated responsibilities is vague. Different proposals seek to operationalize the idea, and two of these proposals are reviewed here.

The Greenhouse Development Rights (GDR) approach proposes a formula that takes into account both responsibility and capacity. Capacity is defined as a function of per-capita PPP-adjusted GDP (where all emissions deriving from consumption below a per-capita income of $9,000/year (PPP) are excluded), and responsibility is defined as a function of cumulative per-capita emissions since 1990, with an adjustment to exclude emissions associated with consumption below the basic development threshold specified above. The authors then develop a single metric, the Responsibility and Capacity Indicator (RCI), which combines both, weighing capacity somewhat heavier than responsibility. The RCI result places 34% of the burden on the United States, 27% on Europe, and 7% on China for the period 1990-2005. The GDR authors interpret this burden-sharing arrangement as formula for both emissions reductions and financing. The authors assume that 1 percent of gross world product will be needed for mitigation and adaptation, which would then translate into $212 billion/year for the United States, $164 billion/year for Europe, and $43 billion/year for China (Baer, Athanasiou and Kartha 2007).

An alternative approach offered by researchers at the Development Research Center of the Chinese State Council is to develop National Emission Accounts (NEAs), where countries would be assigned emission entitlements based on a formula that combines historical cumulative per-capita emissions, and current per-capita emissions. If the real per-capita emissions of a country are greater than its per-capita emission entitlement, then the country must compensate others for its extra emissions by buying permits through an international emissions trading mechanism. If a country's emissions are lower than its allocation, then it can sell its extra emissions. The global allocation of emissions entitlements of each country is established according to a principle that no country has the right to impose external harm on any other country without providing compensation. The compensation is provided through the purchase of permits (DRC 2009).

No precise formula is offered here; rather, this paper proposes simply that the major emitters should contribute an amount that is proportional to the sum of their cumulative per-capita emissions dating back to a certain date, with an adjustment for the size of the economy. It may be desirable to choose a certain fixed year for population to avoid creating an incentive to increase population in order to reduce responsibility for financial contributions, but it's hard to imagine countries deliberately increasing their population in order to reduce their climate obligations. For the base emissions year, 1992 seems reasonable because it is the year of the first formal recognition of the climate change problem as embodied in the UNFCCC. Of course, the base year and the formula itself would be subject to negotiation.

With this approach, per-capita emissions would be calculated annually, with an adjustment for the size of each country's economy in that year, and then the cumulative per-capita emissions for major emitters would be determined. Using this approach, each major emitter would then contribute to the fund in proportion to their share of responsibility for historical cumulative emissions. These proportions should be re-calculated periodically to update the data and re-allocate responsibility.

The CMF is not official development assistance (ODA). Contributions to the CMF could be sourced from a portion of revenues from domestic or international cap-and-trade regimes or carbon tax programs, though countries would have complete freedom to determine how to raise the funds.

A bilateral fund instead?

A bilateral agreement between the United States and China is an interesting theoretical alternative to a multilateral one, but a practical impossibility. A bilateral agreement would have nearly all of the same elements as described above, including clear, significant, and enforceable domestic GHG-reduction policies in both the United States and China. Both countries would be free to choose the policy approach that best suits their national circumstance, but the policies would have to be deemed acceptable by the other. Together, the two countries would cooperate on research, development, and demonstration of low or zero-GHG-emitting technologies. The United States would create a Carbon Mitigation Fund to support the deployment of low-carbon technologies in China, and China alone. As in the multilateral option, U.S. firms would be given the opportunity to bid on equal footing alongside Chinese firms on all commercial projects in an open and transparent manner in exchange for providing the financing. The United States could also require that the Chinese sign the WTO's agreement on government procurement.

The principal advantage to the bilateral option is that the United States could restrict the use of the fund to U.S. and Chinese firms. Thus, the market for low-carbon technologies created by the new Chinese policies would be for Chinese and U.S. firms alone to exploit, and they would have a major competitive advantage against other foreign firms in the Chinese market.

Whether or not European, Japanese, Korean, and other countries would accept such market restrictions is an open question. But, it is likely such an agreement would run afoul of international agreements including the OECD Arrangement on Guidelines for Officially Supported Export Credits or the World Trade Organization is not clear. The OECD Arrangement was initially designed to prohibit individual countries from offering subsidized interest rates. When countries began tying their aid to promote exports, the "Helsinki package" was negotiated in 1991 to counter such practices. Tied aid is technically permitted for commercially non-viable projects if they have some public goods benefit – e.g. environmental protection, hence the ambiguity in this case (Evans and Oye 2001).

Of course, the biggest downside to the bilateral approach is that the United States would have to shoulder the entire cost of the CMF itself. The benefit of unfettered Chinese market access may be worth it, but it would be expensive. These costs and benefits should be quantified in future research. There would also be diplomatic costs. To all the countries that have participated in the painstaking UNFCCC process, it would almost certainly be viewed as a slap in the face for the United States and China to turn their backs on the longest-standing forum for international climate policy negotiations. Moreover, the European Union, Japan, and other industrialized countries are likely to counter either by fighting the fund in the WTO, or by establishing their own funds with China, creating a "funds" race with China where each country tries to outdo the other in providing the most preferential terms for the Chinese and their own firms. No doubt the Chinese would happily fuel the competition for its market.

Instead of creating a new fund-supporting institution, the United States could try to use existing export promotion institutions for the transfer of funds. The Ex-Im Bank, Agency for International Development, and Overseas Private Investment Corporation (OPIC) are three such entities. OPIC's mission is to provide financing, political risk insurance, and investment funds, but it currently does no work in China. USAID was prohibited from providing aid to China for decades because it is a communist country, and its current programs are small. Although it was prohibited for a number of years from working in China after the Tiananmen Square incident in 1989, the Trade and Development Agency (TDA) is again funding various forms of technical assistance, early investment analysis, training, orientation visits and business workshops for U.S. firms in developing and middle-income countries, but in 2008 it only obligated $46 million across 54 counties around the world (TDA 2009). That leaves the Ex-Im Bank as the sole existing bilateral institution available to serve as the fund manager. The Ex-Im Bank's mission is to support U.S. exports by providing export financing through its loan, guarantee, and insurance programs in cases where the private sector is unable or unwilling to provide financing or when such support is necessary to level the playing field due to financing provided by foreign governments to their exporters that are in competition for export sales with U.S. exporters.

How is the CMF different from other funds and financing mechanisms?

Several international funds or finance mechanisms for carbon mitigation already exist, including the Global Environment Facility, the Clean Development Mechanism, the Clean Technology Fund operated by the World Bank, and numerous bilateral funds such as Japan's Cool Earth Initiative. Many other types of funds have been proposed by different countries and researchers, and for an excellent review of all the funds and financing mechanisms, existing and proposed, see Lazarus and Polycarp (2009). Table 3 provides an abbreviated summary of a selection of the existing and proposed funds and mechanisms, and how they compare to the CMF. In addition, some countries have already pledged international financing for low-carbon technologies without specifying the mechanism. A variant to the deal proposed here is the proposal to pursue a series of "climate accession deals" where industrialized countries would provide financial resources, technology, or other kinds of support in exchange for specific country-level commitments (Victor 2008). Examples of such country-level commitments provided by Victor (2008) for China include increasing the energy efficiency of power plants, and using more natural gas and nuclear energy to generate electricity.

The proposed CMF is different from the other funds and financing mechanisms listed in Table 3, in several respects. First, the fund imposes the critical condition that developing countries must implement domestic GHG mitigation policies to qualify for financing from the CMF. The CMF is different from the CDM and the World Bank Clean Energy Technology Fund in that it would support all technologies that reduce GHG emissions, subject only to the domestic laws in each country, with no quotas on countries or technologies.

The CMF versus the CDM

To begin, it is worth clarifying that the CDM is not a fund, but rather a mechanism that can facilitate technology transfer and finance for low-GHG projects in developing countries. When utilizing the CDM, industrialized countries or firms make investments in projects in developing countries with the expected returns of certified emission reductions (CERs). Or, they can simply purchase the CERs through an exchange. The four most important contrasts between this paper's proposed package, including the CMF, and the CDM relate to developing country commitments, financing obligations for industrialized countries, certification, and scale.

First is the requirement that developing countries must make binding domestic mitigation commitments in order to access the CMF. This CMF requirement greatly diminishes (and ideally eliminates) the competitiveness concern on the part of industrialized countries because the incentive for firms in countries like China to take advantage of weaker or no carbon mitigation policies disappears (assuming the domestic policies are more or less equivalent). Second, industrialized countries would be obliged to provide funds to the CMF in exchange for these developing country commitments, whereas with the CDM, industrialized countries have no obligation to utilize the CDM. Third, the CDM explicitly provides a mechanism for industrialized countries to receive credits for emissions reductions achieved in developing countries. The CMF, as envisioned in this paper, does not provide a crediting mechanism. With respect to scale, the CMF is designed to overcome the constraints that currently exist in the CDM which have hindered scale-up in terms of total financing, technology transfer, and emissions reductions thus far.

The CMF would support all technologies allowable by domestic law in the recipient country so no country would be constrained in its mitigation strategy by CMF technology restrictions. The CDM does not currently permit all technologies to qualify. The CMF would also have no quotas on the amount of funding that could go to any one country. So long as applicants met the criteria, funds would be disbursed on a first-come-first-serve basis until funds ran out. There would also be no cumbersome national and international review process, as currently exists for the CDM. Commercial banks would do due diligence on the projects, and the CMF staff would review the project application to ensure that the project met all the stated criteria. Of course, there would need to be occasional spot checks on projects to verify that they were implementing the project as stated in the application. If any projects were found to be deviating from their certified project, they should lose the financing and be held liable.

Both the CDM and CMF require that baselines be calculated for projects. Under the CMF, however, these baselines would be calculated on a country-by-country basis for *types* of projects each year by CMF professional staff. These baselines would be updated annually. While less precise than a project-by-project baseline, the aggregated baseline streamlines the process considerably. If a particular baseline proved to be too weak or too strong, it could be corrected in the following year. The baselines will naturally become less GHG-intensive over time, and this provides a continual incentive for the introduction of cleaner technology.

Related to the baseline issue is the persistent critique of the CDM about whether projects undertaken through the CDM are "additional" to what would have been done otherwise. This "additionality" concern is eliminated by the requirement that all recipient countries must have implemented binding domestic mitigation policies.

In theory, by the way, the CMF could coexist with international emissions trading. Since all participating countries would have domestic mitigation policies, an overall "cap" could be derived, and an international emissions trading regime created. The CMF would be unaffected by the prevailing carbon price of an international emissions trading regime, which would fluctuate (unless there was a "price collar" or "floor and ceiling" constraining the price). Individual countries could, of course, choose to implement any domestic carbon mitigation policies to reduce their emissions, including by instituting a domestic cap-and-trade program.

A final advantage of the CMF as compared with some other options is that it could be created quickly, enabling more rapid emission reductions in developing countries and thereby minimizing carbon "lock-in" (Unruh 2000).

How might U.S. firms and labor benefit economically from low-carbon technology transfer to developing countries, including China?

China is likely to be by far the largest market in the world for low-carbon technologies once it implements a domestic climate policy. It is already by far the largest source of CDM projects, having captured about 50 percent of the anticipated CDM projects expected to deliver emission reductions by 2012 (Hepburn 2009).

To the extent that U.S. firms are competitive in low-carbon technologies, the establishment of new GHG policies in places like China together with the financing provided by the CMF creates new markets for them to sell their products. This would create U.S. jobs, boost exports, reduce trade deficits, and help green the industrial sector in the United States. No intellectual property is "given" to China; rather, U.S. firms with low-GHG technologies and products can sell them to China through any and all commercial means including licensing, formation of joint ventures, and trade.

Although the United States is still a world leader in clean energy technologies, the world marketplace for low-GHG technologies has become much more competitive. For the CMF to benefit U.S. firms, they will certainly need to boost innovative efforts. Some U.S. firms are at the cutting edge, and some are not. Only one of the top ten wind turbine producers is a U.S. firm (GE Wind). Six are European, two are Chinese, and one is Indian. None of the top four global producers of photovoltaics (PV) were based in the United States as of 2008. Although the United States ranks fifth in PV production overall, it ranked first in thin film sales in 2008 (REN21 2009). Currently, two Japanese producers (Panasonic EV Energy and Sanyo) share over 85 percent of the world's market of batteries for hybrid-electric vehicles. These rankings show that the United States faces competition, but is still in the race. The CMF would be market-creating and thus creates a strong market incentive for firms to develop and sell low-carbon technologies.

With effort and determination, the United States could plausibly dominate the world market once again. A major effort was started with the American Reinvestment and Recovery Act of 2008, which provided unprecedented sums of funding for investments in U.S. energy research, development, and demonstration (RD&D), graduate student fellowships in energy, worker re-training, and factory re-tooling. The United States currently ranks first in new renewables capacity investment, and second to China, ironically, in renewables capacity overall (REN21 2009). If these big pushes could be sustained, the United States could be highly competitive once again.

How could China and other developing countries acquire the technologies they need to continue their rapid process of industrialization in a climate-friendly manner?

The energy sector is rapidly growing in China. In 2006, China installed 101 GW of new coal-fired power, 90 GW of which was coal-fired power. In 2007, China installed an additional 91 GW for a total of 713 GW (China Electricity Council 2008). The International Energy Agency in its reference scenario projects that China's electricity capacity will grow from approximately 700 GW in 2007 to 1,775 GW by 2030 (IEA 2007). There is no question that China will continue to build new power plants, expand its electrical grid, and develop its transportation system to sustain its economic development. But, there is a real question about whether China will implement low-GHG technologies during this timeframe or not.

There are many instances in China where the higher costs of advanced and cleaner technologies prevented them from being adopted. One infamous case was the proposed integrated gasification combined cycle (IGCC) plant in Yantai, Shandong province. This was to be China's first IGCC plant, which would have been valuable since carbon dioxide can be captured from IGCC plants with retrofits. When the Chinese government went out to bid for the gasifiers, the cost was prohibitively expensive. Several U.S. firms bid on the plant, including GE and Shell, but the Chinese government cancelled the plant due to its higher cost. An interesting wrinkle in this story is that U.S. DOE proposed "showcasing" U.S. technology in the Chinese IGCC plant as early as 1994, but Congress rejected the proposal in 1995, reinforcing the Chinese government's impression that U.S. rhetoric to help China with energy and environment was hollow (Evans and Oye 2000). This is a case in point of how the existence of financing for incremental costs could have led to the purchase of U.S. technology on the part of the Chinese, and subsequent technology transfer to China.

This package should enable China and other developing countries to acquire the technologies they need in order to achieve low-carbon development. The package provides incremental funding for the costs of low-GHG technologies, and thus addresses a major barrier to "technology transfer" as well as the equity and fairness concerns raised by many developing countries. It has been argued by some that some of the large developing countries do not "need" such financing because they are becoming large economies, but this argument fails to address the equity dimension.

International low-GHG research, development, and demonstration cooperation

All countries have a strong incentive to invest in clean-energy technology innovation, but none have as big an incentive as the two largest energy consumers in the world – the United States and China. Thus, there could be benefits to energy-technology cooperation between the two countries. Energy-technology innovation can reduce the cost of existing technologies, and improve the menu of options for the future. Cooperation on technologies like carbon capture and storage (CCS) with China is in the U.S. interest because CCS is a technology that could permit both countries to continue using their vast coal reserves while drastically reducing emissions. Cooperation could enable both countries to share costs, share risk, increase the speed of unit cost reductions, and accelerate learning about and acceptance of these technologies. There have been other proposals for international cooperation on energy-technology innovation. One proposal is to create regional centers of innovation (Sagar 2008). The Clean Energy Research Center (CERC) agreed to in July 2009 between the United States and China is a promising start.

Reform of energy subsidies

Historically, neither the United States nor China has displayed an appetite for increasing the price of retail fuels in their economies. China directly subsidies energy retail prices and also controls electricity prices. The United States also subsidizes fossil fuel producers through a variety of mechanisms at the level of approximately $10 billion per year for traditional fossil fuels according to a recent report (Adeyeye et al. 2009). Ideally, both countries would increase the price of fossil fuels to account for their environmental and public health externalities. Failing that, they should at least eliminate subsidies to fossil fuel producers.

Summary and Conclusion

In summary, enhancing national competitiveness to sustain economic prosperity is at the heart of concerns in both the United States and China regarding climate change policy. In order for these two major emitters to join an international regime to reduce their GHG emissions, they must be satisfied that the other is acting responsibly and fairly, and that their ambitions for economic development can be realized. For China and other major developing countries, this package would greatly reduce or eliminate the incremental costs of low-GHG technologies, facilitate "technology transfer," and help achieve more sustainable development. For the United States and other industrialized countries, the package greatly diminishes competitiveness concerns and opens new markets to their firms.

In essence, a "deal" to break the U.S.-China impasse is proposed in this paper, where all major-emitting countries, including the United States and China, agree to reduce emissions through implementation of significant, mutually agreeable, domestic emission-reduction policies. To resolve the competitiveness and equity concerns, a proposed Carbon Mitigation Fund would be created. This fund would provide financing for the incremental costs of low-GHG technologies in developing countries so long as those countries had implemented domestic climate mitigation policies, conducted internationally competitive procurement processes, and did not have significant trade and non-tariff barriers to trade and investment in low-GHG technologies. There would be no direct relationships between the policies adopted and the projects funded by the CMF.

The principal advantage to this deal is that it may offer a way for both the United States and China to step forward together in some kind of climate change commitment sooner rather than later. Global early action increases the probability that dangerous climate change can be avoided. For the United States, this deal would reduce competitiveness and leakage concerns because China and other major developing country emitters would have comparable emission-reduction policies. The CMF acts to create a larger market for U.S. clean-technology goods and services, and so should cause U.S. industries to grow, adding jobs to their workforce. For China, the unfairness is reduced because the countries that have contributed the most pollution to the atmosphere historically come together to finance the incremental costs of the low-GHG technology to major developing countries including China. The combination of the developing country policies and the CMF creates the incentive for low-GHG technologies and related knowledge to be transferred to developing countries, if necessary, using private markets, banking services, and transparent commercial practices.

Several topics have been raised in this paper that are deserving of additional research, even though they were not in the scope of this paper. The precise form and function of the CMF institution needs more consideration, as does the literal formula for determining which countries are responsible for contributing to the CMF, in which proportions. More research on procurement practices, calculation of emission baselines, and other barriers to transfer is warranted. Also, research on exactly how to compare the impact of disparate mitigation policies would be useful because it may not always be straightforward to quantify and compare emissions reductions. Quantification of the possible costs and benefits to the United States and other major industrialized country emitters would be helpful to better determine the extent to which private firms from industrialized country markets could benefit from the larger market created by the CMF.

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Table 3. A Selection of Existing and Proposed Multilateral Mitigation Funds and Financing Mechanisms

	Carbon Mitigation Fund	World Bank Clean Technology Fund	Multilateral Climate Technology Fund	GEF Trust Fund	Clean Development Mechanism	World Climate Change Fund
Proposed By	Gallagher	UK, Japan, U.S. Governments	China and the G-77	Originally part of the World Bank, then proposed at Earth Summit to make independent	Brazil (originally) and other G-77 countries	Mexico
Objective	To accelerate the deployment of low-GHG technologies in developing countries	To promote transition to low-carbon economies through financing the deployment of low-carbon technologies and sector-specific strategies	Address all aspects of cooperation on technology research, development, diffusion, and transfer of environmentally-sound technologies	To help developing countries and economies in transition to contribute to the overall objective of the UNFCCC. The projects support measures that minimize climate change damage by reducing the risk, or the adverse effects, of climate change.	To assist developing country parties to the UNFCCC to "achieve sustainable development and contribute to the ultimate objective of the convention"	To widen the scale of global mitigation and adaptation activities
Total Amount	USD$10-$20 billion per year, TBD	$4 billion pledged	Not specified. China's Premier, Wen Jiabao, later called for 0.5-1% of industrialized country GDP	$2.9 billion total as of 2008	Unlimited. As of 12/08, more than 1200 projects have been submitted for approval.	$10 billion per year
Nominal Annual Amount	USD$10-$20 billion per year, TBD	Undetermined	Not specified	varies	varies	$10 billion per year
Type of Funding	Grants and low interest loans for incremental costs of low-carbon technologies if developing country has met conditions for access to fund	Grants, concessional financing, MDB financing, loans	Not specified	Primarily grants, but also concessional financing	Investment	Not specified
Period	Depends on negotiated deal, not permanent (10-20 years, then revisit)	2008-2012 initially	Not specified	Ongoing	Through 2012	Not specified
Source of Funds	Major cumulative emitters on per capita basis, plus charitable donors	UK and Japan (U.S. withdrew pledge), as well as Australia, France, Germany, Norway, Spain, Sweden	Annex II parties to the UN Framework Convention on Climate Change (industrialized countries)	Industrialized donor countries, replenish every four years	Industrialized country governments or firms who wish to acquire emission reduction credits	In accordance with "common but differentiated responsibilities" based on GDP, population, and emissions
Status	Proposed	Not yet operational	Proposed	Operational since 1994	Operational	Proposed

Conditions	To access fund, developing country must have enacted enforceable domestic carbon mitigation policies. Competitive procurement. Trade and investment barriers must be minimal.	ODA-eligibility (according to OECD/DAC guidelines) and an active multilateral development bank (MDB) country program	An Executive Body on Technology (established through UNFCCC) will authorize activities eligible for funding, including "research, development, transfer, and diffusion" as well as define policies on patents, public domain techs, and establishment of tech excellence centers. Funds must be new and additional to ODA.	A country is an eligible recipient of GEF grants if it is eligible to borrow from the World Bank or if it is an eligible recipient of UNDP technical assistance through its country Indicative Planning Figure (IPF).	Supervised by an Executive Board of the UNFCCC that must approve all certified CDM projects. Designated National Authorities (DNAs) must pre-screen and pre-approve all projects in country before going to EB.	Contributions to the fund subject to levy for adaptation fund. Countries choosing not to contribute cannot withdraw. Also, a cap on withdrawals to a single country of no more than 15%.
Mechanism	Grants and loans		See conditions		See conditions	
Institutional operator and function	Operator to be determined through negotiation; operator annually sets country baselines and determines incremental costs, reviews solicitations, and conducts spot verification	Trustee of World Bank	UNFCCC governments	Independent operation, but is trustee of the World Bank	UNFCCC governments	UNFCCC governments
Data sources: various, see also http://www.climatefundsupdate.org/listing/international-climate-initiative						