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Mitigating Climate Change Through Technology Transfer: Addressing the needs of Developing Countries

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Provisions for the transfer of technology will be at the heart of any significant international agreement to decrease the production of greenhouse gases (GHG) by developing nations.[1] The Bali 'Road Map' agreed in December 2007 by the parties to the United Nations Framework Convention on Climate Change, makes technology one of its pillars, and calls for 'enhanced action on technology development and transfer,' to be provided 'in a measurable, reportable, and verifiable manner.' This reflects a political reality: developing nations are unlikely to accept any form of commitment to control GHG emissions without a reciprocal commitment by developed nations to assist in providing the technologies needed to help reduce these emissions and to facilitate economic development in a climate-conserving manner.

The need for technology transfer also reflects a practical economic reality. Achieving significant GHG emission reductions will require new technologies everywhere, especially in developing nations, which will need both to slow their GHG emission growth rate and to improve their economic futures. And it will also require enormous investment in new facilities and equipment, using both existing and newer technologies. These technologies and investments are beneficial even if there is no follow-on climate change agreement along the Kyoto model and there is instead only an effort to reduce GHG emissions in the leading economies.

It is essential to envision how technology transfer can actually work and to think out some of the issues that might arise in different sectors. In general, some technological processes, e.g. Brazilian production of biofuel from sugarcane, are already cheaper than other existing energy sources such as petroleum, so that the necessary capital investment should be forthcoming from the private sector, both for research and for installation. Other technological processes, however, require a subsidy or regulatory encouragement. This may be because the technology requires research and development before it can become economically attractive; this is the case, for example, with photovoltaic production of electricity, the cost of which has been steeply declining over the years. A subsidy or regulation may also be required because the technological process is not economical enough to

[1] I want to thank the International Centre for Trade and Sustainable Development and particularly Moustapha Kamal Gueye, the Chatham House Energy, Environment and Development Programme and particularly Bernice Lee, and the sponsors of the June 2008 Copenhagen seminar on Trade and Climate Change (the Government of Denmark, the German Marshall Fund of the United States, and the International Institute for Sustainable Development) for the opportunity to explore and develop these issues.

compete in the market unless the prices are adjusted to reflect the environmental externalities of GHG emissions. Some advanced GHG-emission-reducing technologies such as carbon capture and storage (CCS) are simply not economical at current prices. Hence, they will be applied only if required by law, subsidized by governments, or made competitive by a substantial carbon tax.

There are several possible rationales for international technological transfer and subsidy. First, in all cases, including the case of the technology that is economically attractive, one may want to subsidize developing nations for actual technology costs (whether implicit in prices or explicit in the form of licence fees), on the theory that the costs of research should be paid by the developed world. Second, for the same reason, one may want to provide substantial developed-world support for the research needed to bring new technologies to economic viability. Third, for those technologies that increase costs beyond the economic level, it can be argued that developed nations should pay the incremental costs of adopting GHG-saving technologies in comparison with other technologies. Finally, but least strongly, there is a broad argument for paying even a share of costs that could be borne privately as a way of sharing overall costs between the developed and the developing world, presumably on the grounds that the developed world has contributed most to the current level of GHG gases in the atmosphere.

There are many different technologies involved and they differ from sector to sector. For the sake of encouraging thinking, a selection is chosen in this paper; the examples considered are summarized in Table 1, with the 2030 mitigation potential in the developing world shown, based on the IPCC Mitigation analysis.[2] Each sector is unique in the way the technology fits into the economy and is regulated or subsidized to encourage the reduction of emissions. Each sector therefore brings significantly different technology development, technology transfer, and investment concerns.

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[2] Terry Barker et al., *Technical Summary: Mitigation, Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (2007).

Table 1: A selection of climate change mitigation technologies

Technology sector	Developing world mitigation potential (2030, per annum)	Responsive technology examples	Methods of encouragement	International technology transfer and investment: special issues
Renewable electricity sources	0.63GtCO_2eq[3]	Wind Photovoltaic	Private market Subsidy Regulation	Transfer of product or of industry?
Carbon-based energy production	0.39 GtCO_2eq[4]	Carbon capture and storage	Regulation Research support	Public R&D
Biofuels	0.46GtCO_2eq[5]	Ethanol	Private market Regulation Subsidy	Market competition
Industrial efficiency	0.16GtCO_2eq[6] (steel alone)	Steel and cement production	Regulation	Market competition
Consumer conservation	1.50GtCO_2eq[7]	More efficient appliances	Regulation Subsidy	Willingness to subsidize consumer?
Nuclear	0.72GtCO_2eq[8]	Nuclear facilities	Subsidy Research support	International security, Commercial competition

Renewable technologies for electricity production have typically been developed by the private sector, save for basic government R & D exemplified by airfoil design for wind production and basic research in photovoltaic technology. There are major industries producing both wind and photovoltaic electricity, with developing world firms among the leaders.[9] In the developed

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[3] Combined wind and solar/PV entries for non-OECD nations in table TS.3 of Barker et al.
[4] Combined CCS + coal and CCS + gas entries in Id.
[5] Based on 46 % non-OECD share of 600–1500 MtCO_2eq cited on pp. 49–50 of Barker et al., *Technical Summary*.
[6] Based on estimated global steel emissions of 1500–1600 MtCO_2eq given for steel industry, adjusted by China 26% market share and 40% mitigation potential, all taken from pp. 460–61 of Lenny Bernstein, 'Industry', Chapter 7 of *Mitigation, Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (2007).
[7] Calculated from Table TS.6 of Barker et al. *Technical Summary*. The number represents negative cost possibilities.
[8] Table TS.3 in Barker et al., *Technical Summary*.
[9] See J. Barton, *Intellectual Property and Access to Clean Energy Technologies in Developing Countries, An Analysis of Solar Photovoltaic, Biofuel and Wind Technologies*, International Centre for Trade and Sustainable Development, Issue Paper No. 2 (December 2007).

world, some of these technologies are becoming economically competitive in some circumstances; otherwise deployment of these technologies is encouraged by national requirements that utilities buy particular portions of renewably-produced electricity or by requirements that they pay particular prices (‘feed-in tariffs’) for such electricity. Presumably, developing nations will be expected to enact similar regulations; until the new technologies are competitive, such regulations will increase the developing-world cost of electricity or require a national subsidy. A share of this increased cost might be appropriately covered as part of technology transfer. There will, of course, be value in subsidy for global technology development – but the fact of competition between developed and developing world firms in supplying the equipment will raise political issues as to how the funding of such research should be allocated.

CCS offers the potential of low-emission electricity production from coal and other sources, but raises new technology development and transfer issues. The key components of the technology already exist, including amine solvents for stripping carbon dioxide from a gas stream and the ability to discharge carbon dioxide into depleted petroleum fields. Nevertheless, there is as yet no prototype for large-scale integration of these various technologies; prototypes are being considered under publicly-funded programs (although the US programme, FutureGen, was just closed down). The funding of such prototype programs is expensive, with the cost typically shared with industry; national governments may be unwilling to commit the funds unless national firms gain a significant benefit, for instance, through manufacturing key components. These technologies will generally bring a substantial economic cost; stripping the carbon dioxide imposes an energy penalty as well as an economic penalty. This technology will thus not be deployed without further support of prototyping as well as subsidy or regulation; for developing-world deployment, the subsidies will almost certainly have to come from the developed world. There will be the same issue as with wind and turbines with respect to competition among developed- and developing-nation manufacturers.

Biofuels raise very different issues. There are many available technologies based, for example, on sugar, corn and vegetable oil, as well as significant research, much funded by the public sector, on new approaches, particularly those that would convert cellulose into fuel. Many of the technologies are economically competitive or can be competitive with a limited subsidy or with a regulation that marketed fuels must include certain proportions of biofuels. Technology transfer to the developing world will generally involve establishment of local production facilities based on local agricultural energy sources. The industry will spread on its own in search of new sources of biomass, and many facilities will need no subsidy. There will certainly be international subsidies for the development of biofuel technologies for particular developing world crops, such as jatropha. Where the technologies are not competitive without a regulatory requirement, there is an argument that the cost should be subsidized so that the developing-nation fuel buyer does not have to bear the incremental cost – and a counter-argument that the cost should be borne by that fuel buyer as a way to encourage conservation. The shaping of any actual new agreements in this area will be heavily affected by the US political commitment to a relatively inefficient corn-based domestic ethanol industry, by the competition for resources links between biomass-based fuel production and food-oriented agriculture, and by the politics of agricultural subsidy programmes.

The industrial sector is one of the most important and also one of the most problematic; it is already concentrated heavily in the developing world. Taking steel as an example, it is clear that increased energy efficiency will require research into the relevant technologies, extensive investment in upgrading or replacing the current industrial capacity, and increased capital cost in the new facilities. This will involve, for example, new mechanisms to achieve energy efficiency, recovery of certain of the gases, and ultimately alternative ways to reduce iron ore.[10] Some of the capital costs will be cost- effective and decrease operating costs.[11] The necessary new research will almost certainly be subsidized by the developed world in a new international technology transfer arrangement, and presumably the technology that has been developed within the developing world will be shared. The incremental cost of building the facilities to comply with the new emissions reduction goals is likely to be substantial. Developed-world funding will raise enormous controversy because the developing-world producers are in direct competition with politically powerful developed-world steel industries.

The economics and politics are again different for conservation by consumers. Here, many technologies are efficient and ready to be adopted

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[10] Barker et al., *Technical Summary*, p. 60, and Bernstein, 'Industry'.
[11] McKinsey & Company, *The Case for Investing in Energy Productivity* (February 2008).

without subsidy, as for insulation and illumination in residences; the number presented in Table 1 – which represents the largest savings of any sector – reflects benefits that are all actually cost saving. There is certainly an issue for the poor that such technologies sometimes impose a higher capital cost (while paying back the investment over the long run). Might the poorer consumer be given access to subsidized credit in such cases? Or might there be incentive payments like those sometimes made by utilities in California to encourage the use of more efficient home appliances? Other technologies may require regulation, such as those designed to encourage greater automotive energy efficiency. Compliance with such regulation is almost certain to make the automobile more expensive. But it seems unlikely, in political terms, that developed nations would be willing to subsidize the costs of such compliance.

Nuclear power raises a world of its own, with concerns about nuclear safety, about the fuel cycle and fuel disposal, and about weapons proliferation. Much of the research will be undertaken by the public sector; much of the technology transfer will involve elaborate mixes of public and private responsibility under the supervision of the International Atomic Energy Agency. This complexity and political matrix is exemplified in the US–Indian nuclear negotiation that has just been concluded but began with a joint statement by President Bush and Prime Minister Singh in 2005. Technology transfer in this sector will almost certainly involve further arrangements of this kind; it may also appropriately involve new efforts to internationalize those nuclear material production facilities that may be used for both civilian and military purposes; and it will be affected by commercial competition among reactor manufacturers.

Three important conclusions derive from this review. First, the financial heart of what will be needed is actual physical investment in new facilities, e.g. biomass production facilities, windfarms, CCS add-ons to coal-based utility plants, efficiency improvements to steel production facilities, and adoption of more energy- efficient transport and housing technologies in the developing world. This will often require subsidies or regulatory incentives, (and sometimes the removal of subsidies or regulatory incentives that operate against a low-carbon economy). The immediate tasks are structuring the incentives appropriately and raising the capital needed for facilities using the emissions-reducing technologies. The task will be enormous, as exemplified by the enormous rate of growth of the Chinese economy.

Moreover, many of the investments are already economical for the public sector at current energy prices – in other words, public financial intervention may not be needed, once markets are structured correctly. Where international financial assistance is needed, some sectors will be relatively easy. For example, donor nations will probably be quite comfortable contributing to developing-world biofuel production at a time of high energy prices. In contrast, where there is competition with politically sensitive industries, as in the case of steel, technology transfer and international funding will be politically very difficult. There will need to be consideration of subsidizing consumers as well as subsidizing industry. And it may be difficult to build support for subsidizing technology transfer to nations such as China and India which hold substantial capital reserves and whose sovereign wealth funds and firms are buying US and EU firms. The differences among sectors suggest that there can be much greater progress in some sectors than others; sectoral agreements might also combine subsidies with international alignment of regulatory requirements or standards.

Second, the review suggests the important role of public-sector support for research and development of new technologies. There will need to be such support, for example, for new forms of biomass, for prototypes of CCS coal-based electricity production, and perhaps for new generations of nuclear power. Technologies for photovoltaics for electricity production or advanced batteries for automotive use will need to be coaxed down a learning curve so that they become economically competitive with existing lower-cost but higher-emissions technologies. It is crucial that the choice of such technologies be made with a view to helping developing nations.

There will be tensions even in this area, because nations often support technological research precisely for the neo-mercantilist goal of favouring their own firms, and this motivation contributes to domestic political support. Nations should certainly include plans for disseminating the technology as part of their research support planning. Sometimes dissemination may be best achieved by creating commercial incentives for firms, for example through patents, and sometimes simply by publishing details of a new technology. Nations might be able to overcome mercantilist incentives on a basis of reciprocity, for example by reciprocally allowing foreign firms as well as their own to benefit from their research support.[12] Or they might find it best to create a global fund to invest in the development of GHG-emission reduction technologies. The world energy system is globalized and everyone benefits from reductions.

Third, the examples imply that the costs specifically assignable to technology are likely to be very small compared with the overall capital and investment costs. Each technology is in competition with a number of others, and there are relatively competitive markets for the production of electricity and fuel as well as for such products as automobiles and housing materials. In contrast to the pharmaceutical sector, where there can be enormous price differentiation, manufacturing costs in most of the sectors relevant to climate change form a large portion of the overall product cost, with research and development only a small portion. Hence there is little room for differential pricing between the developed- and developing-world markets. To take an example, the pharmaceutical firm Merck has, on average, a possibility of marking up its products 2.9 times manufacturing costs;[13] the corresponding number for Vestas, a wind turbine firm, is 0.20.[14] The result is low royalties in the GHG sectors; for example, they are in the order of 1% of the sales price for wind turbines and 0.1 cent per litre of fuel for the enzymes used in producing fuel from maize.[15]

Therefore, there is little if any need for an intellectual property agreement specific to the climate change technology sector analogous to the 2001 Doha Declaration allowing public health concerns to override certain of the provisions of the international agreement on Trade Related Intellectual Property Rights (TRIPS). The European Parliament has suggested considering such a provision.[16] There certainly will be patents, but the effective royalties on patents in the climate change sectors are likely to be small as a result of the competitive structures in those sector. There is one troubling historical example, a patent granted to UNOCAL that would have covered all gasoline reformulated to satisfy certain California emissions goals

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[12] See, e.g., John Barton, Preserving the Global Scientific and Technological Commons (April 2003), available at stdev.unctad.org/capacity/Barton.doc. The link to this earlier paper was suggested by Bernice Lee.

[13] Based on 2007 10-K Statements filed with the US Securities and Exchange Commission, showing that cost of product is 25.4% of sales. Mark-up is calculated as Sales-Manuf Cost/Sales.

[14] Based on 2007 Annual Report showing that cost of product is 83% of sales.

[15] Barton, *Intellectual Property and Access*.

[16] European Parliament resolution of 29 November 2007 on trade and climate change (2007/2003(INI)).

– it was ultimately struck down on antitrust grounds.[17] Nor does experience under the Montreal Protocol provide strong support for a special intellectual property provision – there were few intellectual property issues, with the exception of several disputes over the international licensing of certain manufacturing processes to potential competitors (a context which is always going to be difficult).[18] Should there be future intellectual property issues, they are almost certainly best dealt with on an ad hoc basis. Indeed, to the extent that the key market for many of the new technologies, e.g. coal/CCS electricity production, is in fact a (middle-income) developing-world market, weakening of intellectual property to favour this market might impose a disincentive to private-sector research.

It follows that the two new World Bank funds, the Clean Technology Fund and the Strategic Climate Fund,[19] will have to undertake very sophisticated approaches to the different sectors in which they will operate. The most important ways in which they can contribute are likely to be technology development and assistance in creating the national regulatory structures needed to strengthen incentives to invest in GHG-emissions reduction. Creating the kind of global energy research fund suggested above might be very valuable, as would be the encouragement of economic and regulatory research for nations such as China and India. It is not clear, however, that the World Bank funds are organized for such mission. There is, for example, no indication that there will be a scientific advisory board for the funds. To do such tasks well, the funds will need sophisticated scientific, engineering, and regulatory advice and might end up looking more like venture capital firms than like banks.

In their financial activity, these funds can be expected to focus their attention on the incremental costs of complying with environmental requirements, for example in operating electrical grids – but they will to face the issues that, in some sectors the most efficient ways of reducing GHG emissions are actually cost-saving and therefore can be served by private capital. They might even want to consider consumer subsidies in some sectors. And they will have to consider their relationship to the incentives created by any extension of the Clean Development Mechanism or of a cap-and-trade system, such as that

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[17] US Federal Trade Commission, In the Matter of Union Oil Company of California, Docket 9305; Press Release, 10 June 2005.
[18] S. O. Andersen, K. M. Sarma and K. M. Taddonio, *Technology Transfer for the Ozone Layer; Lessons for Climate Change* (Earthscan, London, 2007).

recently suggested by Nicholas Stern.[20] Moreover, they will have to face the difficult task of allocating their resources between the really poor nations which most need funding but will contribute relatively little to GHG emission in the near future, and the nations with rapidly growing economies which have substantial capital of their own but contribute most significantly to GHG emission. Further, they will constantly have to balance the good against the better in deciding how to deal with technologies that reduce but do not eliminate GHG emission. The task of these funds will be very much more difficult and complex than that of the prototype technology transfer fund for the ozone layer, which dealt with significantly less fraught political issues.

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[19] World Bank Press Release No. 2009/001/SDN, 1 July 2008.
[20] Nicholas Stern, *Key Elements of a Global Deal on Climate Change* (London School of Economics 2008).