Washington Internships for Students of Engineering

Climate Change Technology Transfer:
Opportunities in the Developing World

Chris Deal
Iowa State University
2007 ASME WISE Intern

August 22, 2007

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SETTING THE STANDARD

Executive Summary

During the last few years, the debate over global climate change has transformed from a discussion regarding the validity of climate change to an acceptance of global climate change as "unequivocal" and the subsequent debate of how to deal with it. Several plans have been proposed for addressing global climate change, but all of them agree on one underlying principal: this must be a global effort.

As more studies are released, it is increasingly obvious that global climate change is occurring – and at a more rapid pace than many experts initially expected. The time to act before severe consequences occur is now, but obtaining global consensus on how to mitigate greenhouse gas emissions has proven to be anything but simple. Debate has been centered on the interests of the developed versus developing countries and the countries who are willing to accept mandatory emissions cuts versus those that are not. Developed countries like China and India will soon outgrow the United States as the global leader in emissions (some sources say China already has), and the atmosphere is nearing the point where further increases in emissions could result in drastic, abrupt consequences of climate change.

In an effort to promote sustainable development within developing countries that would allow for simultaneous economic growth and emissions cuts, the United Nations Framework Convention on Climate Change included in its articles of development a section pertaining directly to international technology transfer. This was designed to promote the transfer of clean technology by industries within developed countries to developing countries.

Since its inception within the UNFCCC framework, climate change technology transfer has been incorporated in many programs with different styles of implementation and different results. The Clean Development Mechanism under the Kyoto Protocol allows for Annex I countries to transfer technology to developing countries as an alternative to some of the mandatory emissions cuts while the U.S. Government's Asia-Pacific Partnership for Clean Development and Climate attempts to create a more market-driven approach to technology transfer.

With countries like China and India looking to continue economic growth and avoid environmental degradation in the process, the potential for certain sectors and companies to reach new markets and profit from climate change technology transfer is enormous. The worldwide investment in sustainable energy jumped by over 43 percent from 2005 to 2006 and a similar growth trajectory is projected for the upcoming years.

However, a great deal must be done to encourage and allow for transfer to occur. Some problems that must be overcome include protection of intellectual property, assurance of non-corrupt host governments, international tariffs and trade barriers, and market transparency. Due to the rapid pace with which climate change is occurring, a purely market-based approach may be too slow.

The Kyoto Protocol expires in 2012, and negotiations are already underway to create a post-Kyoto agreement, ideally one that will include all countries and require efforts to be made on the part of developing countries. Climate change technology transfer will play a key role in these negotiations, especially when considering how to induce buy-in from the many different parties.

Recommendations

- Correct past mistakes when creating second generation CCTT programs. The knowledge that has been documented from the many ongoing CCTT initiatives will allow for this.
- Develop a post-Kyoto agreement that incorporates all developed countries and all major developing countries.
- This post-Kyoto agreement should be quantifiable and long-term, preferably creating a pathway for the next 50 years. This will lower uncertainty and allow for more complex, longer-term projects to be undertaken.
- Tariffs placed on clean energy technologies should be reduced or eliminated and the Harmonized Commodity Description and Coding System should be updated to combine all climate change technologies in the same category.
- Create and properly fund an oversight body that will increase communication between the several established CCTT initiatives within the United States. In addition to proper funding for an oversight body, greater funding should be allocated to a program that will serve as an information clearinghouse for CCTT programs. Two potential programs are the Clean Energy Technology Export Initiative and United States Climate Technology Cooperation Gateway, respectively.
- The United States must step up as an international leader in addressing the issue of global climate change. As a world leader in emissions and technological innovation – and due to its historical contribution to total GHG emissions – international leadership from the U.S. is crucial to addressing global climate change.

Table of Contents

About the Author

Chris Deal is an undergraduate student in Mechanical Engineering at Iowa State University. He will graduate in May 2008 with a bachelor's degree in Mechanical Engineering and minors in Entrepreneurial Studies and Spanish. During his time at Iowa State, Chris has served in many roles, including Vice President of the Student Body; Executive Co-Director of the Children's Miracle Network fundraiser, Dance Marathon; Vice President of Phi Delta Theta Fraternity; and active member of Engineers for a Sustainable World. His interests are many and varied but include sustainable development, alternative energy development, social entrepreneurship, energy policy and international affairs.

About the Program

Sponsored by several multidisciplinary engineering professional associations, Washington Internships for Students of Engineering (WISE) is a highly competitive internship program for undergraduate engineering students in their junior or senior year with an interest in public policy. The goal of the WISE program is to groom future leaders of the engineering profession who are aware of and can contribute to the intersections of technology and public policy. During the nine-week program, interns learn how government officials make decisions on complex technological issues and how engineers can contribute to legislative and regulatory policy decisions. In addition, each intern researches and presents a paper on an engineering-related public policy issue, which is then are published in the WISE Journal of Engineering and Public Policy. More information about the WISE program is available at www.wise-intern.org.

Acknowledgements

I would like to thank the following individuals for their assistance in providing information and guidance through the research and writing process for this paper:

Ron Benioff	National Renewable Energy Laboratory
Dan Bilello	National Renewable Energy Laboratory
Eldon Boes	U.S. Senate Agriculture Committee
James Bradbury	Office of U.S. Representative Jay Inslee (D-WA)
Thomas Brewer	Professor of Business Georgetown University
Melissa Carl	ASME Government Relations Staff
Adam Chambers	International Institute for Applied Systems Analysis
Joshua Craft	ASME Government Relations Staff
Derrick Freeman	Office of U.S. Senator Mark Pryor (D-AR)
Paul Gunning	Environmental Protection Agency
Matt Hinch	Office of U.S. Representative Tom Latham (R-IA)
William Jackson	Professor of Engineering George Washington University
Stephen Lehrman	Office of U.S. Senator Mark Pryor (D-AR)
Dale Medearis	Environmental Protection Agency
John Mertens	Professor of Engineering Trinity College
Anne Meyer	American Prospect
Lowell Miller	DOE Office of Sequestration, Hydrogen, and Clean Coal Fuels
Graham Pugh	DOE Climate Policy and Technology Office
Mark Radka	United Nations Environment Programme
Matthew Realff	National Science Foundation
Landon Van Dyke	Executive Office of the President – Council on Environmental Quality
Ann Vega	Environmental Protection Agency
George Weyerhaeuser	World Business Council for Sustainable Development
Kristin Zimmerman	General Motors

Abbreviations and Acronyms

AP6	Asia-Pacific Partnership on Clean Development and Climate
ASE	Alliance to Save Energy
CCTT	Climate Change Technology Transfer
CCX	Chicago Climate Exchange
CER	Certified Emission Reduction
CETE	Clean Energy Technology Exports Initiative
CDM	Clean Development Mechanism
CTI	Climate Technology Initiative
DOE	Department of Energy
EGTT	Expert Group on Technology Transfer
EIA	Energy Information Association (U.S. DOE)
EPA	Environmental Protection Agency
EU	European Union
FDI	Foreign Direct Investment
GHG	Greenhouse Gas
GtC	Gigaton of Carbon
GW	Gigawatt
HS System	Harmonized Commodity Description and Coding System
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IPR	Intellectual Property Rights
JI	Joint Implementation
NREL	National Renewable Energy Laboratory
OECD	Organisation for Economic Co-operation and Development
RE	Renewable Energy
SEFI	Sustainable Energy Finance Initiative (UNEP)
TCAPP	Technology Cooperation Agreement Pilot Project
TNA	Technology Needs Assessment
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme

UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
US-CTC	United States Climate Technology Cooperation
WEO	World Energy Outlook (IEA Report)

I. Issue Definition

On February 2, 2007, the Intergovernmental Panel on Climate Change (IPCC) released its Fourth Assessment Report stating that "warming of the climate system is unequivocal" and proclaiming with "very high confidence" that "the global average net effect of human activities since 1750 has been one of warming." This report, prepared by over 600 authors and reviewed by representatives from 113 countries, serves as the greatest consensus agreement to date of the anthropogenic influence on climate change[1].

This debate has now turned in almost all arenas – media, policy, public opinion, etc. – from whether or not climate change is occurring to what can and should be done to mitigate climate change. As mitigation is considered, more reports and studies of climate change are being completed, with many of these reports showing disconcerting results: global climate change is happening at a more rapid pace than many expected[2,3,4].

Many plans have been proposed for climate change mitigation, from the mandatory greenhouse gas (GHG) cuts included in the Kyoto protocol to the voluntary international development programs in the Asia-Pacific Partnership on Clean Development and Climate (AP6). Climate change is different from past environmental dangers because unlike previous crises like acid rain, climate change occurs on a global scale. GHG reductions must then occur on a global scale also, with all countries participating in the effort. Developed countries, the part of the world with the highest GHG intensities (total GHG emissions divided by country population), must promote clean energy technology to significantly lower their emissions while developing countries like China and India cannot follow the same industrialization process taken by the United States and European Union in the past. Developing countries must be allowed to continue their economic growth but must do so in a sustainable fashion. International trade of clean technology, hereafter

[1] IPCC, 2007, Summary for Policymakers, In: "Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change," [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M.Tignor and H.L. Miller (eds.)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[2] Levin, K., and Pershing, J., 2007, "Climate Science 2006: Major New Discoveries," World Resources Institute, Washington, DC, USA.

[3] Collins, W., Colman, R., Haywood, J., Manning, M., and Mote, P., 2007, "The Physical Science behind Climate Change," *Scientific American*, August 2007, pp. 64-73.

[4] Bohannon, J., 2007, "Climate Change: IPCC Report Lays Out Options for Taming Greenhouse Gases," *Science*, 316(5826).

referred to as climate change technology transfer (CCTT), provides means for developing countries to leapfrog the pollution that accompanies rapid development. CCTT will allow developed countries to export their advanced, clean technologies to developing countries in order to promote sustainable development and climate change mitigation. This paper will explore climate change technology transfer, explaining its operation, history, successes and failures, future potential, and opportunities for use in the developing world.

II. Terminology and Scope

This paper will use the definition given for 'technology transfer' from the IPCC as the working definition for CCTT:

"*a broad set of processes covering the flows of know-how, experience and equipment for mitigating and adapting to climate change amongst different stakeholders such as governments, private sector entities, financial institutions, non-governmental organizations and research/education institutions*[5]."

The focus of this paper will be specific to energy-related technologies.

For the purposes of this paper, a successful CCTT program will be treated as a program in which both parties – the country/organization transferring technology and the host country for transfer – have a net positive gain from the interaction. This definition, although seemingly common sense, is important because there have been situations in which perverse incentives have allowed for one party to benefit at the cost of the second party. The inherent complexity in dealing with many layers of regulations and property protection creates the potential for unintended consequences. Proper administration of CCTT programs will promote the primary goals of mitigating global climate change and appropriately rewarding both parties according to the respective effort and risk assumed by each.

III. Author Bias

The underlying goal of the author in writing this paper is to promote the mitigation of global climate change. A secondary goal is to produce programs that will fairly reward the efforts of

[5] IPCC, 2002, "IPCC Special Report: Methodological and Technological Issues in Technology Transfer," A Special Report of WG III, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

participating parties. All facts will be presented in a neutral manner, but any bias that does exist will be oriented towards these two primary goals.

IV. Purpose

CCTT is intended to promote sustainable development among the world's developing countries so that the environmental degradation that accompanies industrialization can be avoided. CCTT promotes dissemination of knowledge gained by the world's industrialized nations during their development and the technology efficiency gains that have since occurred.

In return, developed countries that participate in CCTT are able to enter foreign markets where they can export greater quantities of products and services, positively benefiting their trade ratio with the rest of the world. Through private companies, the source of the vast majority of technology transfer, technology transfer programs can be used to bring sustainable economic growth to developing nations while helping developed nations to increase their exports.

V. History

CCTT received global attention during the United Nations Framework Convention on Climate Change (UNFCCC) proceedings held in Rio de Janeiro in 1992, more commonly known as the Earth Summit. The articles produced from this convention are still the basis of international collaboration to deal with climate change. Technology transfer is specifically mentioned in Article 4.5 of the convention text:

The developed country Parties and other developed Parties included in Annex II shall take all practicable steps to promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound technologies and know-how to other Parties, particularly developing country Parties, to enable them to implement the provisions of the Convention...[6]

The next major international CCTT initiative occurred when the Kyoto Protocol was adopted under the UNFCCC in Kyoto, Japan in 1997 with the goal of reducing global greenhouse gas emissions of industrialized countries by 5.2 percent compared to the year 1990 (which represents

[6] UNFCCC, 1992, "United Nations Framework Convention on Climate Change," Retrieved July 23, 2007, from http://unfccc.int/resource/docs/convkp/conveng.pdf.

a 29 percent reduction in emissions when compared to expected emissions for the year 2010[7]). Incorporated into the Kyoto Protocol were two programs promoting international technology transfer: the Clean Development Mechanism (CDM) and the Joint Implementation (JI) programs. The CDM program allows industrialized countries with mandatory emissions reductions to invest in an emissions reduction program in a developing country as an alternative to making all required reductions domestically. In exchange for successfully implemented programs, a CDM oversight body awards certified emissions reductions (CERs) to the Annex I country (a developed country required to make emissions cuts under the Kyoto Protocol) that can be traded through international carbon markets and used to comply with emissions limits. JI programs are similar but involve two industrialized countries rather than one industrialized and one developing country.

The Clinton Administration was actively involved in the drafting of the Protocol and was a signatory to the agreement. However, the protocol was never presented to Congress for ratification due to passage of U.S. Senate Resolution 98, also known as the Byrd-Hagel Resolution. This resolution stated that the United States should not be a signatory to any protocol that did not include binding targets and timetables for developing as well as industrialized nations or “would result in serious harm to the economy of the United States” and was passed by the Senate with a unanimous vote (95-0)[8]. Vice President Al Gore symbolically signed the Kyoto Protocol in November 1998, but it was never presented to Congress. The Kyoto Protocol was rejected again by the United States in early 2001 when the Bush Administration stated that it would not sign on to any agreement that could potentially harm the country’s economic progress and did not require developing countries like India and China to also agree to set reductions. The protocol became international law on February 16, 2005, following ratification by Russia which satisfied the clause that 55 percent of Annex I countries from 1990 be represented. As of June 6, 2007, a total of 174 countries and government entities, representing 61.6 percent of Annex I emissions and over 68 percent of the world’s population, have ratified the protocol[9].

[7] UNFCCC, 1998, “Climate Talks to Explore How to Put Kyoto Protocol into Action,” Press Release, Retrieved July 23, 2007, from http://stone.undp.org/maindiv/gef/newslet/June98.pdf.

[8] S. Res. 98, “A resolution expressing the sense of the Senate regarding the conditions for the United...” 105th US Congress, Retrieved July 23, 2007, from http://www.thomas.gov/cgi-bin/query/D?c105:1:./temp/~c105g8qYBV::.

[9] UNFCCC, “Status of Ratification – Latest Count,” Retrieved July 23, 2007, from http://unfccc.int/kyoto_protocol/background/status_of_ratification/items/2613.php.

The CDM and JI programs are both currently in progress and will remain so during the extent of the Kyoto Protocol, which is binding until 2012. Because the United States did not ratify the protocol, it is not a participant in the CDM or JI programs. The United States is, however, a participant in several CCTT programs. Appendix III lists over 50 domestic and international CCTT efforts, obtained through the U.S. Climate Technology Cooperation (US-CTC) Gateway website[10]."

VI. The Process

Kline, Vimmerstedt, and Benioff provide information on the background, rationale, and successful methods of technology transfer[11]. Generic technology transfer focuses on moving 'high' technology within a developed country setting. Much time has been spent studying how to bridge the "valley of death" that separates public to private sector financing of new technologies[12].

Rene Kemp notes that the most successful technology transfer efforts usually encompass a technology "regime change," such as the change from internal-combustion aircraft with drive propellers to jet engine aircraft. These regime changes take a considerable amount of time – up to several decades – due to the mismatch between new technology and differences in economic, financial, organizational, and sociological factors. This mismatch is even greater in cross-societal (in this case, from a developed country to a developing country) technology transfer. Kemp summarizes the key factors influencing technology transfer as follows[13]:

- Available knowledge and expertise (in both countries)
- The presence of early niche markets
- Potential for extension, overcoming initial limitations, and achieving cost reductions

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[10] US-CTC, "US Government Supported Programs," U.S. Climate Technology Cooperation Gateway, Retrieved July 24, 2007 from http://www.usctcgateway.net./usctc/programs/.
[11] Kline, D., Vimmerstedt, L., and Benioff, R., 2002, "Clean Energy Technology Transfer: A Review of Programs under the UNFCCC," National Renewable Energy Laboratory, Golden, CO, USA.
[12] Murphy, L., Edwards P., 2003, "Bridging the Valley of Death: Transitioning from Public to Private Sector Financing," National Renewable Energy Laboratory, Golden, CO, USA.
[13] Kemp, R., 1997, "Environmental Policy and Technical Change: A Comparison of the Technological Impact of Policy Instruments," Edward Elgar Publishing Inc., Northampton, MA, USA.

- The building of an actor network (suppliers, customers, regulators) whose semi-coordinated actions can bring about substantial shifts in interconnected technologies and practices
- The overcoming and accommodation of social opposition and consumer resistance

Successful CCTT programs represent a concerted effort, usually from both public and private sector representatives. Before an actual technology transfer program can be implemented, the public sector must first adequately prepare an area. This preparation includes general infrastructure buildup, host country technology needs assessments (TNAs), information technology improvements, and the availability of risk-financing options. Before private industry will be interested in investing to begin an international project, the project risks must be assessed and there must be potential for success.

A. Differing viewpoints: Regulated vs. Market-based

The Kyoto Protocol mandates emissions cuts from all developed countries that have ratified the agreement. This top-down approach requires governments to implement policies that communicate and produce the necessary reductions among domestic industries. Communication of policies is not an issue for developed nations but problems could be encountered if emissions reductions were required of developing countries, where the communication structure often does not allow top-down initiatives to pass from national to local government. Rather than the top-down approach followed by the Kyoto Protocol, the Bush Administration prefers to follow a market-based, bottom-up approach where companies work directly with local officials to conduct projects. The AP6 is the primary CCTT initiative being undertaken by the Administration. This partnership, explained in greater depth in the following section of this paper, relies on a combination of government assistance for market preparation and traditional market mechanisms for technology transfer to occur. Supporters of the program point to success from the numerous programs started in 18 months since the AP6 was established while opponents point out that most of these programs are preparatory (i.e. creating metrics on non-fiscal costs such as environmental degradation, health care, etc.) and claim that the voluntary participation will not occur quick enough to effectively deal with global climate change.

B. Oversight bodies

To facilitate the CCTT process, several oversight bodies have been created. The jurisdiction of these oversight bodies ranges from an international to a domestic scale. Four examples are included below, beginning with an international viewpoint and transitioning to a domestic viewpoint.

Expert Group on Technology Transfer: On an international scale, the Expert Group on Technology Transfer (EGTT) was established under the UNFCCC in 2001 "with the aim to enhance the implementation of the [UNFCCC] framework and to advance the technology activities under the Convention." The work of the EGTT has focused on five main themes of the technology transfer framework: (1) technology needs and needs assessments, (2) technology information, (3) enabling environments, (4) capacity-building, and (5) mechanisms for technology transfer[14].

Climate Technology Initiative: The Climate Technology Initiative (CTI) is a multilateral initiative that works closely with the UNFCCC process and the EGTT. The mission of CTI is to bring countries together to foster international cooperation in the accelerated development and diffusion of climate-friendly and environmentally sound technologies and practices. It was established in 1995 by 23 International Energy Agency (IEA) and Organisation for Economic Co-operation and Development (OECD) countries and gained status as an IEA Implementing Agreement in 2003. CTI activities include conducting TNAs, sponsoring seminars/symposia, conducting implementation activities, and carrying out training courses[15].

Asia-Pacific Partnership on Clean Development and Climate: The AP6 is a multilateral organization focusing on technology transfer between the United States, Australia, Japan, South Korea, China, and India. It was established in 2006 and is operated by a Policy and Implementation Committee responsible for the implementation of activities of the Partnership and engaging representatives of the private sector, development banks, research institutions, and

[14] UNFCCC, 2007, "Expert Group on Technology Transfer: Five Years of Work," Druck Center Meckenhim, Bonn, Germany.
[15] CTI, 2005, "Climate Technology Initiative: Celebrating 10 Years," Retrieved July 23, 2007, from http://www.climatetech.net.

other relevant organizations[16]. Roughly based on Title XVI of the Energy Policy Act of 2005, the AP6 is a voluntary program established to advance the partners' efforts under the UNFCCC framework to open developing markets to private investment and development. After starting in January 2006, the AP6 had over 110 projects underway as of July 2007[17].

Clean Energy Technology Exports Initiative: As one of the many efforts currently underway in the United States, the Clean Energy Technology Exports (CETE) Initiative is a program created by the U.S. Senate. It is designed to increase U.S. clean energy technology exports to international markets through increased coordination among federal agency programs and between these programs and the private sector. Within existing resources, CETE is designed to help to catalyze, facilitate, and support an expansion of clean energy technology use in developing countries and countries in transition while increasing the value of U.S. clean energy technology exports to these markets[18].

VII. Potential Benefits

A. Capability of Current Technology

Pacala and Socolow have outlined a route using current technology during the next 50 years to stabilize atmospheric carbon dioxide levels at less than a doubling of pre-industrial levels. This is the level generally considered to be the separation point between inconvenient consequences and truly dangerous consequences – such as the melting of the Greenland ice cap – of global climate change. Their system focuses on holding emissions constant near the present level of approximately 7 billion tons of carbon per year (7 GtC/year), which would require halving the predicted 14 GtC/year of emissions in 2055. Pacala and Socolow split the 7 GtC/year of carbon that must be eliminated into seven "wedges" with each GtC/year represented by one wedge. Pacala and Socolow then described 15 current technologies that could account for their elimination as shown in Table 1. It should be noted that after 50 years, technological advances

[16] AP6, 2006, "Charter for the Asia-Pacific Partnership on Clean Development and Climate," Retrieved July 23, 2007, from http://www.asiapacificpartnership.org.
[17] Aritake, T., 2007, "Meeting of Asia-Pacific Climate Partnership Considers Pilot Projects; Canada Eyes Joining," The Bureau of National Affairs, (140).
[18] CETE, 2001, "Five-Year Strategic Plan of the Clean Energy Technology Exports Initiative," Retrieved July 23, 2007, from http://www.pi.energy.gov/documents/CETE_StratPlan.pdf.

will be required for further reductions in global emissions, but this paper's focus does not extend that far into the future[19].

Table 1. Summary List of Technologies for Climate Change Mitigation

Developed by Pacala and Socolow*

End-user efficiency and conservation

- (1) Increase fuel economy of automobiles
- (2) Reduce automobile use by telecommuting, mass transit, and urban design
- (3) Reduce electricity use in homes, offices and stores

Power generation

- (4) Increase efficiency of coal-fired power plants
- (5) Increase gas base load power (reduce coal base load power)

Carbon capture and storage (CCS)

- (6) Install CCS at large, base load coal-fired power plants
- (7) Install CCS at coal-fired plants to produce hydrogen for vehicles
- (8) Install CCS at coal-to-synfuels power plant

Alternative energy sources

- (9) Increase nuclear power (reduce coal)
- (10) Increase wind power (reduce coal)
- (11) Increase photovoltaic power (reduce coal)
- (12) Use wind to produce hydrogen for fuel cell cars
- (13) Substitute biofuels for fossil fuel

Agriculture and Forestry

- (14) Reduce deforestation, increase reforestation & afforestation, add plantations
- (15) Increase tillage conservation in cropland

* The estimated quantities of each technology required for a "wedge" have been omitted in this summary in order to focus attention in the context of this paper on the *types of technologies* rather the amounts of them needed to meet a specific goal.

Source: Pacala and Socolow

Compiled by: Thomas L. Brewer[20]

B. Principals for Successful CCTT

Knowing that the technology is available to make the necessary short-term emissions cuts, the focus then turns to what factors are necessary for changes to be implemented. According to the IEA,[21] successful projects:

- *Address an environmental problem*
- *Build the market for environmentally-sound technologies*
- *Are cost-effective*

[19] Pacala, S., and Socolow, R., 2004, "Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies," *Science*, 305(5686), pp. 968-972.

[20] Brewer, T., 2007, "Climate Change Technology Transfer: International Trade and Investment Policy Issues in the G8+5 Countries, Retrieved 31 July, 2007, from http://www.usclimatechange.com.

[21] Smith, A., 2001, "Technology Without Borders: Examples of Successful Technology Transfer," IEA, Paris, France.

- *Have a legitimate chance for success in the real world*
- *Do not make other problems worse*

Additionally, many barriers must be overcome for successful technology transfer to occur. These include:

- *Building local skills*
- *Engaging the private sector*
- *Using development assistance effectively*
- *Developing innovative financing*

One of the most important factors in successful CCTT is the host country's policy towards sustainable energy development. In a recent study commissioned by the United Nations Environment Programme (UNEP) under its Sustainable Energy Finance Initiative it is explained that markets with strong, consistent political support of sustainable energy development have thrived while markets with start-stop mechanisms (i.e. fluctuating incentives or tax breaks with changes in government leadership) and/or a bias towards domestic players (i.e. high tariffs to protect domestic manufacturers) have developed unevenly. In broad terms, policies that reduce the time to market for sustainable energy products and show reasonable certainty about future support will promote greater investment and a greater likelihood of success of CCTT programs[22].

C. Recent Increases in Investment and Growth

In their study of *Global Trends in Sustainable Energy Investment*, Greenwood et al. explain that worldwide investment in sustainable energy jumped by more than 43 percent between 2005 and 2006, from $49.6 billion to $70.9 billion. A similar growth trajectory has been projected for 2007, and the upward trend has continued so far through the first quarter of the year[23]. Figures 1 through 4 show how different sectors of renewable energy have grown over the past years.

An overview of renewables (not including hydroelectricity) shows that they currently only account for 0.5 and 2.0 percent, respectively, of energy and power globally.[24] These figures,

[22] Greenwood, C., Hohler, A., Liebreich, M., Sonntag-O'Brien, V., Usher, E., 2007, "Global Trends in Sustainable Energy Investment 2007," UNEP-SEFI.
[23] Greenwood et al.
[24] IEA, 2006, "World Energy Outlook 2006," OECD/IEA, Paris.

however, can be misleading. With lifetimes of 40 – 60 years, capital turnover in power plants is very slow. The current power plant technology gives a picture of technology options that were available in the 1950s – 1970s.

Current investments paint a different picture. Out of the $110 billion - $125 billion that was invested in approximately 120 Gigawatts (GW) of new power generation globally in 2006, $30.8 billion was in new renewables (excluding hydro), which was approximately 25 percent of all investments. In an industry that has seen stagnant or declining R&D spending from public and private sources[25], renewable energy (RE) received $25.2 billion in new technology and manufacturing capacity investment, on top of $21.5 billion invested in new generating capacity. This large investment indicates that investors are expecting to see strong growth in the RE sector in the near future. The argument that renewable energy will remain more expensive than current electricity generation sources is often made; according to the IEA, renewables cost approximately 28 percent more per installed GW. However, this figure does not include several variables such as account operating expenditures, fuel costs, and carbon markets/taxes. In developing countries, fuel costs alone are equivalent to investments in generating

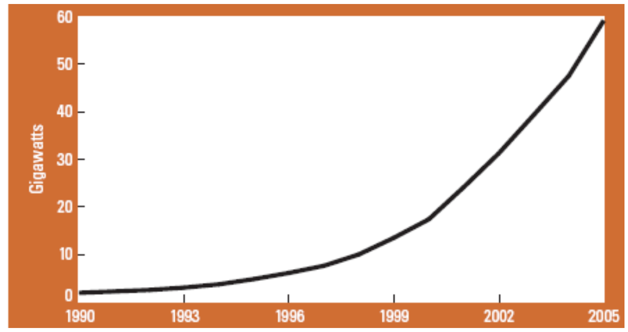

Figure 1. Wind Power, Existing World Capacity (1990-2005). Source: Martinot, E. et al.

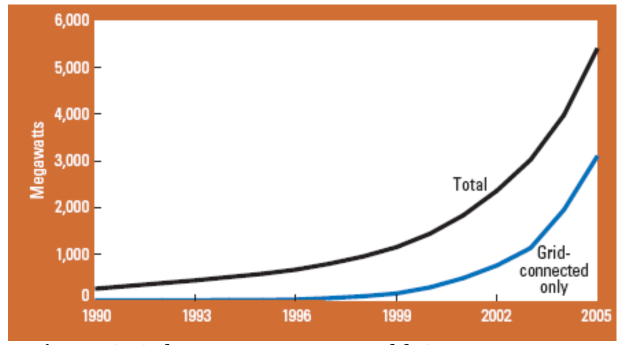

Figure 2. Solar PV, Existing World Capacity (1990-2005). Source: Martinot, E. et al.

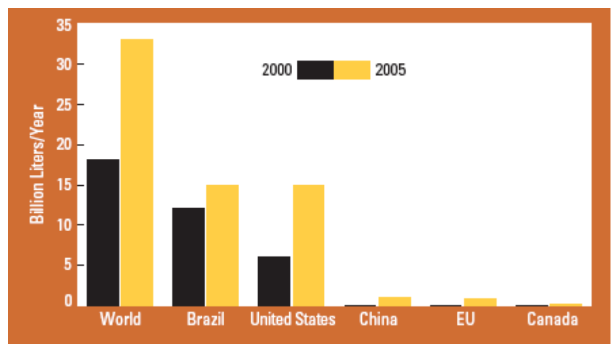

Figure 3. World Fuel Ethanol Production (2000 and 2005). Source: Martinot, E. et al.

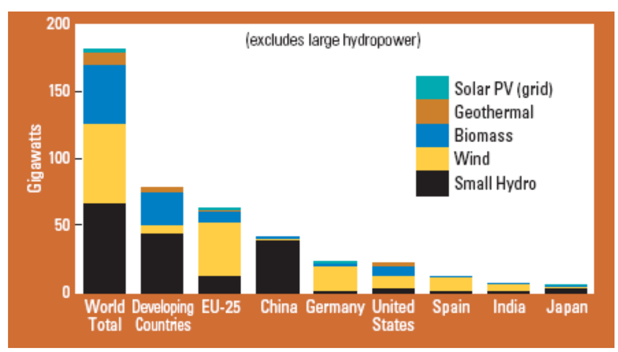

Figure 4. Renewable Power Capacities for Developing Countries, EU, and Top 6 Individual Countries (2005). Source: Martinot, E. et al.

[25] Runci, P., 2005, "Energy R&D Investment Patterns in IEA Countries: An Update," Technical Paper PNWD-3581, Pacific Northwest National Laboratory/Joint Global Change Research Institute.

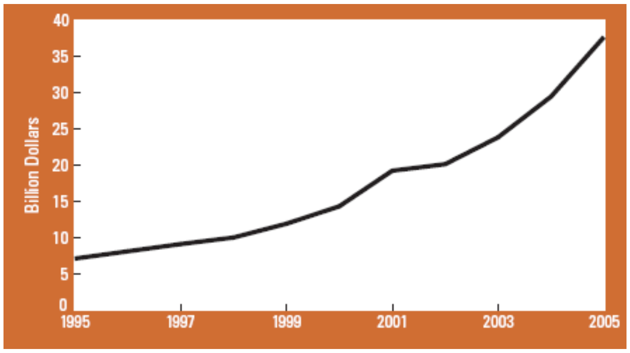

Figure 5. Annual Investment in Renewable Energy (1995-2005). Source: REN21

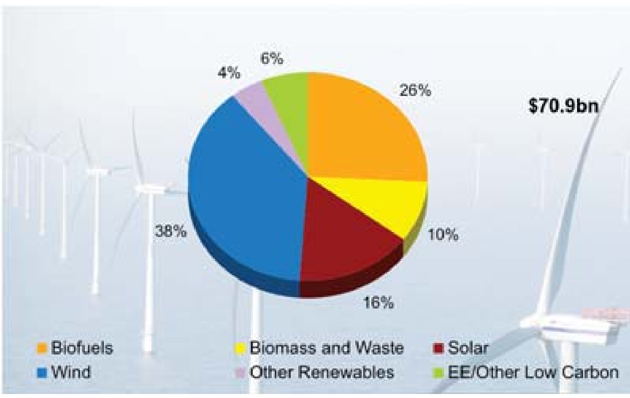

Figure 6. Global Investment in Sustainable Energy by Technology, 2006. Source: Greenwood et al.

capacity annually[26]. Figure 6 shows the respective areas of sustainable energy investment from 2006.

Figure 7 shows how sustainable energy investment differs throughout the world, categorized by investment type. The EU, driven by a commitment to Kyoto and a higher awareness of climate change, has seen the greatest public market investment in sustainable energy while the United States, although not bound by Kyoto, was the global leader in venture capital and private equity investment in sustainable energy. This is due to its enabling market for innovation and motivation from sub-federal level incentives from state and local governments and private sector businesses and investors. Although the majority of sustainable energy investment is still located in the developed world, capital has started shifting to developing countries due to stronger Foreign Direct Investment (FDI) and greater availability of private capital within emerging markets. China,

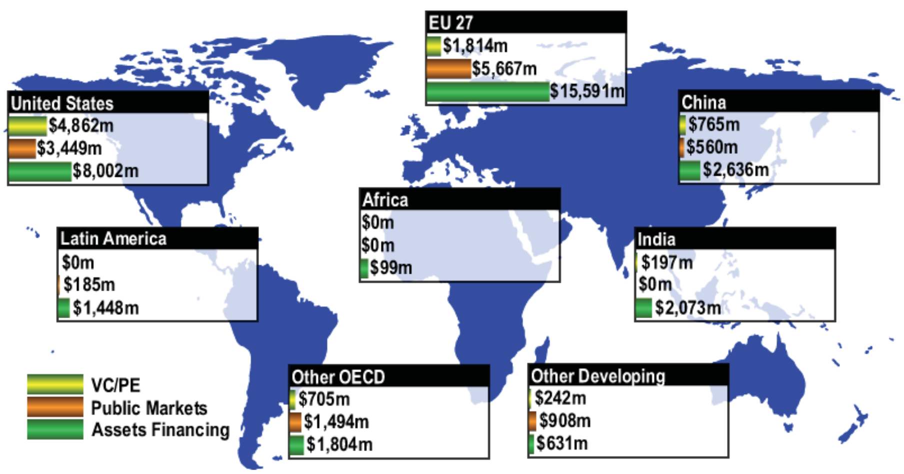

Figure 7. Global Investment in Sustainable Energy by Region and Investment Type, 2006
Source: Greenwood et al.

[26] IEA, 2003, "World Energy Outlook 2003," OECD/IEA, Paris.

India, and Brazil are all key players in global sustainable energy markets, with China leading in solar, India in wind, and Brazil in biofuels. Developing countries accounted for 21 percent of global sustainable energy investment in 2006, compared to 15 percent in 2005[27].

D. Mitigation Effects of Renewable Energy Growth

The IEA predicted in its 2006 World Energy Outlook (WEO) report that new renewables (excluding hydro) would provide 11 percent of new energy capacity additions from 2004 to 2015. However, since 2006, this forecast has been outpaced. Wind energy alone accounted for nearly 10 percent of the new capacity growth, showing a growth rate over nine times faster than that of the power sector as a whole. Greenwood et al. present a comparison of how different RE growth trajectories will influence future RE capacity and overall carbon mitigation in terms of Pacala and Socolow's wedge structure. Table 2 shows the effect on carbon mitigation in the year 2030 from different investment strategies in renewable energy, ranging from the IEA WEO report that forecast 9 percent of installed power capacity being from renewables to a 23 percent forecast by the Global Wind Energy Council. Based on the assumptions listed, these growth rates would offset anywhere from 16 to 47 percent of the carbon emissions called for by Pacala and Socolow (note: Pacala and Socolow call for 7 wedges by 2054, which is approximated as 3.5 wedges by 2030).

Table 2. Comparative Effects of Different Renewable Energy Growth Rates[28]

RE Growth Rate (2007 - 2030)	RE Growth Scenario	RE Capacity in 2030 (GW)	RE Share & Rank of New Energy Additions (2004 – 2030)	RE Share & Rank of 2030 Installed Capacity	Carbon Mitigation in 2030 (GtC)	Percentage of Total Necessary Mitigation to Stabilize Emissions
7%	Rate needed to reach 9% installed RE capacity by 2030	674	15%; 3rd after gas and coal	**9%**; 4th after coal, gas, and hydro	0.6	16%
10%	**-**	1300	32%; 1st ahead of gas and coal	**17%**; 3rd after coal and gas	1.2	34%
19% until 2010, 10% thereafter	Growth rate forecast by GWEC	1781	44%; 1st ahead of gas and coal	**23%**; 3rd and coal and gas	1.7	47%

E. Increases in Preparatory Work

Success in technology transfer depends on the level of preparation in the host country and its ability to receive the technology. There is no generic solution that can be implemented; each

[27] Greenwood et al.
[28] Greenwood et al.

country must be treated on an individual basis. According to CTI, the following are elements of successful TNAs and implementing activities[29]:

1. *Establishment of collaborative partnerships between key stakeholders with the common purpose of enhancing technology transfer.*
2. *Implementation of technology transfer needs assessments (including evaluations of both alternative technologies and the definition of technology transfer priorities).*
3. *Design and implementation of technology transfer plans and specific actions.*
4. *Evaluation and refinement of the actions and plans (an ongoing process).*
5. *Dissemination of technology information.*

Table 3 lists countries that have conducted TNAs through UNFCCC programs. It should be noted that this is not an exhaustive list and is limited to what could be found through documents of the CTI, EGTT, and UNFCCC.

Table 3. Countries and Regions that have Completed Technology Needs Assessments

Albania	Lesotho
Armenia	Macedonia
Azerbaijan	Malawi
Bolivia	Mauritius
Botswana	Mexico
Brazil	Moldova
Burundi	Nigeria
Chile	Niue
China	Paraguay
Comoros	Peru
Cote D'Ivoire	Philippines
Croatia	Samoa
Democratic Republic of Congo	Senegal
Dominican Republic	South Korea
Ecuador	Southern African Development Community
Egypt	Tajikistan
Georgia	Tanzania
Ghana	Thailand
Guyana	Tunisia
Haiti	Turkmenistan
Indonesia	Uzbekistan
Kazakhstan	Vietnam
Kenya	Zimbabwe
Lebanon	

[29] CTI, 2001, "Methods for Climate Change Technology Transfer Needs Assessments and Implementing Activities: Experiences of Developing and Transition Countries," International Center for Environmental Technology Transfer, Japan.

Conducting TNAs often falls under the duties of CCTT oversight bodies. Two primary reasons account for this: (1) TNAs are an expense that few private companies will assume, and (2) TNAs are considered to be catalytic programs in that they will encourage much greater investment after completion.

F. Subsidiary Benefits of CCTT Investment

Private companies take part in technology transfer projects because of the potential to enter profitable new markets. This is why market preparation techniques like TNAs and policy changes are imperative for successful CCTT programs. However, the benefits of transfer programs do not cease with profit margins. The basis of institutional support from organizations like UNFCCC and AP6 is the environmental benefits that accompany CCTT. Successful transfer and proper administration of these programs will allow developing countries to continue economic development while avoiding the environmental degradation that would occur with cheap development as the underlying driver.

Participation in technology transfer programs allows countries to take steps that will help prepare for the potential of mandatory emissions reductions in the future. These future mandatory reductions programs (i.e. second generation of Kyoto or AP6) will most likely incorporate CCTT mechanisms, so current efforts like the implementation of TNAs and other market-preparation initiatives will pave the way for immediate influx of CCTT programs.

In some cases, current participation in technology transfer programs may allow countries and/or companies to participate in voluntary carbon exchange programs like the Chicago Climate Exchange (CCX). If this is possible, companies have the potential of receiving even greater and more immediate benefits if they can cut emissions below targets.

Other benefits of technology transfer include the positive publicity that comes with any company or country focusing on positive environmental practices. A company that puts forth effort to assist in the sustainable development of the third world, even if a profit is likely to result from the investment, will be able to gain recognition as a green company, something that many consumers are starting to take into consideration[30].

Finally, CCTT based on developing new sources of renewable energy or on making more efficient use of current energy sources can allow developing countries to make better use of domestic resources, and in the process, increase energy security by lowering dependence on foreign energy.

IX. Problems that Must be Overcome

Nearly all CCTT initiatives currently in operation could be considered as first generation. Accordingly, these initiatives have experienced the growing pains that often accompany new programs. The following problems have occurred consistently in CCTT programs and will need to be further addressed:

Concept of Additionality

As the CDM is a route for Annex I countries under the Kyoto Protocol to avoid costly domestic emissions reductions, guidelines exist to prevent the overuse and misuse of the system. One of these guidelines, "environmental additionality," is the concept that any project implemented under CDM must be a project that would not occur in the absence of CDM status. This idealistic approach to technology transfer inherently goes against traditional business sense by requiring companies to operate projects that seem unprofitable (if it would be profitable the project would not qualify for CDM status). Understandably, there is also controversy in determining what would and would not have occurred without CDM and which projects meet the requirement of additionality.

Perverse Incentives

Also called the law of unintended consequences, perverse incentives can come into play any time a rule or regulation is established. For example, an unintended consequence of the rule of additionality is that host countries will be cautious of implementing more stringent domestic

[30] "Going Green," 2007, Fortune Magazine online, Retrieved July 24, 2007, from http://money.cnn.com/magazines/fortune/goinggreen/2007/index.html.

environmental regulations, like efficiency improvements and renewable energy incentives, because while these will enable domestic development projects, they would result in the loss of additionality status. In effect, the perverse incentive of additionality is for countries to slow or cease their own development.

Avoidance of Responsibility

A common criticism of CCTT, especially under programs like Kyoto where emissions cuts are mandatory, is that it allows industrialized countries to continue using fossil fuels while paying developed countries to not do so. Under Kyoto, some believe that this will actually increase emissions because the credits received through CCTT programs will allow industrialized countries to emit more while developing countries are not tied to emissions cuts. Additionally, CDM allows industrialized countries to use land in developing nations at the expense of local people. Some of these programs, including nuclear power plants, clean coal plants, and industrial agriculture, could have serious environmental ramifications if not operated correctly.

Market Transparency and Enabling Environment for Transfer

In order for successful CCTT to occur, the host country market must offer an enabling environment. Companies must be sure that they are entering a market where all requirements are presented up front and openly with no types of bribes or other forms of corruption necessary to operate. The projects themselves must also be transparent. Claims have been made of hired consulting firms working in secrecy to create projects and deals in order to avoid public accountability and verification. Transparency is necessary to avoid a commodity market for CERs. Without full disclosure, CERS have been purchased at subsistence levels in developing countries and then sold at global trading levels to earn huge profits for companies in the developed world.

In most developing countries investment in sustainable energy is still driven by policy. Developing countries often are faced with the challenge of promoting a fast-growing economy with less-mature capital markets. This often results in investments favoring conventional, fossil-fueled energy generation. Policies that encourage sustainable energy investment, such as incentives, tax breaks, innovative financing, and risk management, are key to promoting sustainable development but are difficult to implement in developing countries.

Intellectual Property Protection

A major obstacle for many companies in CCTT is the lack of intellectual property rights (IPR) protection outside of developed countries. Developing countries tend to focus on industrial development and wish to disseminate knowledge to allow for greater production whereas industrialized nations place a greater value on services and intellectual property as a commodity. Private companies are unwilling to incorporate high technology in CCTT without guarantee of IPR. Instead, companies will freely transfer technology that they feel will not offer them loss of competitive advantage.

The ethanol industry can be used as an illustration. China is looking to develop its ethanol industry but has a poor IPR record. The United States ethanol industry was willing to transfer technology related to pre-treatment techniques for cellulosic ethanol since there were no concerns about competition from China. However, the U.S. ethanol industry would not share its latest biological enzyme technology advancements because it has a clear competitive advantage in this area. In order for high-tech intellectual property to be shared in markets with little IPR, companies will require either significant investment from partner companies in the host country or reassurance from the host country government that IPR will be respected[31].

Tariffs and Trade Barriers

International trade naturally involves issues with tariffs. This is no different with CCTT. Any products that are transported internationally, from solar photovoltaic panels to wind turbine components, will be taxed with tariffs. The tariff rate depends on the country and the technology being transferred. This results in higher costs, a detriment for companies to participate in technology transfer.

[31] Mani, M., 2007, "Warming up to Trade? Harnessing International Trade to Support Climate Change Objectives," World Bank Group.

Global trading is typically tracked using a Harmonized Commodity Description and Coding System (HS system). This HS system contains over 5,000 product codes, employing a six-digit code for each product. At this six-digit HS code level, clean energy technologies often are lumped together with other products that would traditionally not be classified as clean or sustainable technology. Also due to this confusing classification, clean technologies are frequently difficult to track, resulting in international trade data that could be overestimated or underestimated[32].

Lack of International Agreement

Since not all countries have ratified the Kyoto Protocol and no emissions reductions are required of developing countries that have ratified Kyoto, some individuals in the EU have proposed a "Kyoto Tariff" on countries like the United States to compensate for the loss in competitiveness that has resulted from the EU having to adhere to emissions reductions. A World Bank study simulation shows that this type of tariff could result in a loss of approximately 7 percent of U.S. exports to the EU with energy-intensive industries like cement and steel suffering losses of up to 30 percent. This study notes that these estimates are actually conservative due to not incorporating trade diversion effects that could result in the EU shifting to trading partners without the Kyoto Tariff[33].

Speed of Implementation

The Asia-Pacific Partnership attempts to avoid many problems encountered under the Kyoto Protocol and Clean Development Mechanism by promoting an approach that is market-based and voluntary. The oversight body funds catalyst programs – programs that will pave the way for investment from the private sector. For example, the AP6 funded a $500,000 feasibility study for multi-million dollar power plant. The study indicated that the power plant would be profitable and private industry subsequently built the plant. Private companies rarely are willing to fund feasibility studies and conduct other market preparation activities, the basis of the AP6. However, without mandatory reduction levels, a pure reliance on private industry provides for no

[32] Mani, M., 2007, "Warming up to Trade? Harnessing International Trade to Support Climate Change Objectives," World Bank Group

[33] Ibid

definite emissions reductions. With the increasing effects of global climate change, a purely market-based approach may be too slow.

X. Conclusions

Climate change technology transfer has played an increasingly significant role in recent history and will undoubtedly continue growing in its importance. Multiple factors point towards this conclusion. The renewable energy and energy efficiency market is growing at a rate of over 40 percent annually and does not show any signs of slowing. Couple this financial incentive with the post-Kyoto negotiations and policy incentives that could accompany these discussions and the future looks very bright for technology transfer.

Current CCTT efforts have been far from perfect. The Clean Development Mechanism under the Kyoto Protocol and the Asia-Pacific Partnership on Clean Development and Climate have each shown significant problems. It must be remembered, however, that these are both first generation programs and this should be expected. The underlying basis for CCTT, sustainable development of developing countries and increased exports for developed countries, provides enough potential benefit to continue to improve and grow current and future CCTT programs.

Many barriers to CCTT are still present. These exist in several forms including tariffs and trade barriers, unprepared markets, lack of market transparency and corruption, and lack of intellectual property protection. Steps are being taken to address these barriers, such as the numerous TNAs that have been completed in different countries, but much still remains to be done.

The United States, by not signing Kyoto Protocol, finds itself in a position where there are both challenges and opportunities. This position does allow the United States to attempt new initiatives such as the AP6, but the United States has received international criticism due to its lack of commitment on the issue of global climate change. Although one of its primary reasons for not joining the Kyoto Protocol was to protect the national economy, the United States' refusal to sign the protocol could result in a loss of competitive advantage in the clean energy sector due to lack of incentives for private development in the field and the potential for serious economic challenges if "Kyoto Tariffs" were ever passed.

Climate change technology transfer programs in the United States, although each having a slightly different approach to technology transfer, replicate many functions and could benefit greatly from greater communication and sharing of best practices. Since the United States is not party to the Kyoto Protocol, it does not have an overarching CCTT program like the CDM to which it must adhere. This has resulted in several different programs being implemented with slightly different means of conducting technology transfer.

Most importantly, however, is the conclusion that above all else, *something must be done soon to address global climate change*. Climate change indicators such as melting glaciers and ice caps, summer heat waves, and frequency of natural disasters are occurring with greater regularity than many have expected. The technology to address global climate change exists, but policy makers and the public must decide to act on the facts that are available before drastic climate change occurs.

XI. Recommendations

Learn from the past when creating second generation CCTT programs. The Clean Development Mechanism and Asia-Pacific Partnership are not perfect, but have shown positive advances in the realm of international technology transfer. The problems should not be allowed to overshadow the future potential of CCTT. Review measures should be further refined to promote best practices and avoid the perverse incentives that have been present in past CCTT programs.

A post-Kyoto agreement that incorporates all developed countries and all major developing countries must be found. The United States is currently the world's largest producer of greenhouse gases but will soon be surpassed by China (according to some sources, China already surpassed the United States in 2006[34]). Global climate change is an international problem and must be solved with a global effort, but the agreement of these two nations that make up over 40 percent of global emissions will be paramount to producing a plausible post-Kyoto solution to

[34] Netherlands Environment Assessment Agency, 2007, "Chinese CO2 Emissions in Perspective," 22 June 2007. Retrieved July 23, 2007, from http://www.mnp.nl/en/service/pressreleases/2007/20070622ChineseCO2emissionsinperspective.html.

global climate change. Climate change technology transfer – under proper administration – should be used as an incentive to attract developing countries and developed countries alike.

In addition to buy-in from all countries, this post-Kyoto agreement should be quantifiable and long-term, preferably creating a pathway for the next 50 years[35]. This would reduce current levels of uncertainty and allow for more long-term projects to be undertaken. A quantifiable, long-term pathway would serve as a point of reference for development programs and encourage greater technological development and deployment in the renewable energy and energy efficiency sector.

To promote international trade and ease the process of transferring products, *tariffs placed on clean energy technologies should be reduced or eliminated*. Along with this, *the Harmonized Commodity Description and Coding System should be updated to combine all climate change technologies in the same category*. Removal of trade barriers will promote greater participation from private companies in international technology transfer. Updating the HS System will reduce the confusion that is currently present in the system and make tariff reductions for clean energy technologies much simpler.

To allow for dissemination of best practices, *an oversight body should be established and properly funded within the United States that will increase communication between the several established CCTT initiatives*. To avoid adding another layer of bureaucracy, it would be more efficient to take an established oversight body and increase its funding and mission to include oversight of all domestic CCTT programs. One potential oversight body would be the Clean Energy Technology Exports (CETE) Initiative. This program, created in 2001, has seen limited success due to lack of funding. However, the legislation that authorizes this initiative is currently in committee and would allow for a ten-fold funding increase of the organization. *In addition to greater funding for an oversight body, more funding should be given to programs that allow for exchange of information between the many CCTT initiatives.* The U.S. Climate Technology

[35] Lauvergeon, A., Reiten, E., 2007, "Policy Directions to 2050: A business contribution to the dialogues on cooperative action," World Business Council on Sustainable Development.

Cooperation has an excellent website (http://www.usctcgateway.net/) that should be utilized as a basis for this.

As an international leader, *the United States must step up to address the issue of global climate change*. Signs of climate change are becoming increasingly frequent and show no signs of slowing. The United States must step up by agreeing to emissions limitations and then combine forces with the rest of the industrialized world in convincing developing nations on emissions controls; it cannot wait for developing countries like China and India to accept emissions cuts before it will do the same.

Appendix I. Case Study #1 – Korea

This case study was taken from *Methods for Climate Change Technology Transfer Needs Assessments and Implementing Activities: Experiences of Developing and Transition Countries* and reprinted with permission from the Climate Technology Initiative. The following excerpt documents a project of the Technology Cooperation Agreements Pilot Project (TCAPP), a CCTT initiative that was a precursor to CTI but has since been discontinued. This case study illustrates the importance of proper needs assessments.

Example of Technology Transfer Implementation: Korea's Energy Management Program[36]

The Republic of Korea initiated a cooperative program with the U.S. Technology Cooperation Agreements Pilot Project in 1999 to prioritize climate change technology needs and implement follow-on to promote the transfer of the selected technologies. The Ministry of Commerce, Industry and Energy (MOCIE) of the Republic of Korea chairs a TCAPP steering committee and has designated Korea Energy Management Corporation (KEMCO) to lead the implementation of technical TCAPP activities for Korea.

Technology Priorities

The Korean team held scoping meetings among relevant stakeholders in March 1999 to select priority technologies for climate change technology cooperation. In addition to greenhouse gas mitigation potential and energy development benefits, four additional criteria were used in selecting priority technologies:

1) The technology must hold near-term market potential.
2) Successful widespread implementation of the technology requires intervention by public institutions to overcome market barriers.
3) There is a need for demonstrating new technologies or energy management systems to open up new markets for advanced technologies.
4) Soft technologies (e.g., new management systems and other tools for use of advanced technologies) should be given consideration along with hardware.

[36] CTI (2001)

Based on these criteria, three priority technologies were selected. The three priority technologies are:

- Energy management (Know-how in energy management, advanced energy auditing and energy service companies (ESCOs), etc.)
- Methane recovery from organic waste
- Waste energy recovery using heat pumps

Implementing Actions

For the Energy Management project, KEMCO, working with its U.S. counterpart, facilitated meetings between U.S. and Korean companies interested in partnering on future energy efficiency projects. One Korean company (EPS Korea) and one U.S. company (Sempra Energy Services) were selected to work with KEMCO and Hyundai to perform an energy audit of the Hyundai company facility in Ulsan. The team developed a proposal prioritizing the plant's greatest potential priorities for energy savings. EPS Korea, Sempra and Hyundai coordinated the technical support, while KEMCO's role, in addition to providing technical assistance, includes review of the proposal, barrier reduction and financing assistance. Based on this proposal, Hyundai is now implementing a pilot heat wheel project with Honeywell Corporation for approximately US$30 million. This project, if successful, should open the door for other energy service projects at this plant and others. Other projects have been agreed to or are being pursued in the Energy Management and Methane Recovery areas. To build capacity to implement additional projects, Korea TCAPP is supplementing these pilot projects with training and certification programs to improve energy auditing techniques in Korea.

According to Korea's implementers, the TCAPP project has been effective because the host country has played a pivotal role in the identifying and prioritizing of technologies. In the process of identifying and addressing barriers to technology dissemination, the participation of a wide range of stakeholders has been particularly important. It is also notable that Korea has chosen not just hard technologies, but energy services.

The Korea experience is an example of how a successful technology transfer program can bring together government and other stakeholders, including research institutions and both domestic and international private companies to promote technology transfer. Korea has designed the prioritization of technology needs within an overall strategic approach that incorporates follow-on actions, including training, certification, and coordinated steps to develop pilot projects. Through the design and implementation of such projects, the experience and capacity of the host country institutions will be enhanced, so as to attract additional projects. Indeed, Korea does not consider the pilot projects to be the objective of the program, but rather tools for developing technology transfer models which can be replicated elsewhere.

Appendix II. Case Study #2 – India

The following case study was taken from *Technology Without Borders: Case Studies of Successful Technology Transfer* and reprinted with permission from the International Energy Agency. This excerpt documents the role that private financing can play in technology transfer projects. It should be noted that facts and figures may be out-dated.

Government Policies and Private Finance Work Together:

India Renewable Resources Development Project[37]

Technology Without Borders: Case Studies of Successful Technology Transfer © 2001, pp. 49-52

During the 1990s, new tax policies and changes in power regulations improved the investment climate for renewable-energy technologies in India. At the same time, the Indian government, the World Bank and the Global Environmental Facility (GEF) supported a renewable-energy development project to improve the functioning of commercial markets for wind, mini-hydro and solar PV technologies. The project, along with assistance from Denmark and other sources helped the India Renewable Energy Development Agency (IREDA) to promote and finance private investment in renewable energy. IREDA now conducts marketing campaigns, offers business training, provides various types of credit and subsidies and offers other financial incentives.

360 MW of commercially-operated wind capacity and 65 MW of mini-hydro capacity were commissioned through public and private financing. Results for solar PV technology have been less than were hoped for. Even so, more than 2,200 solar home systems and solar lanterns have been financed with IREDA support. In West Bengal, the project demonstrated five solar power systems of 25 kW each, supplying electricity to about 500 families connected into village-scale grids. They are managed and maintained by co-operatives.

Helping the Private Sector Create a Market for Renewables

A project limited to direct financing of renewable energy would have had limited impact. This project in India went considerably further, raising awareness of the viability of wind power and

[37] Smith, A., 2001, "Technology Without Borders: Examples of Successful Technology Transfer," IEA, Paris, France.

other renewable-energy technologies. As a result, many financial institutions began to invest in renewable-energy technologies. IREDA sponsored business meetings and training programs that attracted more than 2,000 participants from state agencies, companies and banks. These meetings were supplemented by publications and advertisements aimed at helping small- and medium-sized companies market their renewable-energy products. IREDA also published several "best-practice" manuals on wind-energy projects and investments, offered financial consulting services and appraised projects for developers.

Because there was skepticism about the quality of some wind-turbines, IREDA worked with the Ministry of Non-conventional Energy Sources (MNES) to develop a wind-turbine certification program. One cause of poor performance in the turbines, it was found, was improper location. So, IREDA and MNES prepared guidelines on site planning and selection. World Bank/GEF assistance increased IREDA's ability to develop a sales and service infrastructure for solar PV systems. Several years into the project, it became clear that the lack of after-sales service and difficulties in getting credit were hindering development of the rural market. In 1998, the project began to test different models for providing services. In one model, a rural energy-service company leased PV systems to households for a monthly fee that included service and maintenance. The companies using this model were local, with strong ties to the community. Most already provided some type of related service. With training, this service has been extended to cover maintenance of PV systems.

India is Now a Major Player in the Renewable-Energy Business

Some 1,200 MW of wind-power capacity is now on-line in India, more than two-thirds of the total wind-power capacity in all developing countries. Most is privately owned. Part of the government's success in encouraging private investment in wind farms can be attributed to IREDA's efforts. By the late 1990s, dozens of domestic wind-turbine manufacturers had emerged, many of them joint ventures with foreign partners. Many of these manufacturers produced the latest high-technology turbine designs. Although most wind-turbine blades are still imported, domestic production of blades has now begun. Blades and synchronous generators are being exported to Europe. Installed wind-generation costs declined from around $1,200/kW in 1991, to between $815 and $1,050/kW in 1998. Equipment certification has reduced risks for project developers. The number of Indian consultants qualified to develop wind-power projects has increased considerably.

It remains to be seen whether the market for renewable energy can survive in the absence of tax incentives that prevailed in the 1990s. Some concessions by state utilities will be important for continued private-sector investment. The recent decline in wind-farm development in Tamil Nadu has been attributed to inadequate substations and weak distribution connections. Wind-power projects in India have been plagued by poor maintenance and repair, rotor blade failures due to manufacturing defects and control-system failures due to disregard of grounding regulations.

The solar PV market in India has grown considerably. The project helped increase solar PV capacity from 0.6 MW from 6,200 systems in the early 1990s to 50 MW from 675,000 systems in 2000. India now exports PV modules.

Lessons Learned

- Partnerships that link government policies with private financing can work. A combination of tax incentives, favorable clean-electricity generation policies and acceptance of the technologies by commercial investors created the right environment for private investment in renewables.
- Funds and expertise provided by international organizations can help increase the capacity and effectiveness of a developing-country agency like IREDA.
- Government policies play an important role in technology transfer. Tax incentives helped stimulate the market. Import tariffs on equipment continue to inhibit clean-technology deployment.
- Different business models for the delivery of solar PV in rural areas need to be explored.

Appendix III. Listing of Domestic and International Initiatives in CCTT

Initiative	Sponsoring Organization	Sponsoring Countries	Website
AgSTAR	Department of Agriculture, Department of Energy (DOE), Environmental Protection Agency (EPA)	United States	http://www.epa.gov/agstar/index.html
Asia-Pacific Partnership for Clean Development and Climate (AP6)		Australia, China, India, Japan, South Korea, United States	http://www.asiapacificpartnership.org/
Brazilian Network of Civil Organizations for Renewable Energy (RENOVE)	United Nations Environment Programme (UNEP), US Agency for International Development (USAID)	Brazil	http://www.renove.org.br/
Carbon Sequestration in Agriculture and Forestry Program	EPA	United States	http://www.epa.gov/sequestration/international.html
Carbon Sequestration Leadership Forum (CSLF)	DOE	19 Countries	http://www.fe.doe.gov/programs/sequestration/cslf/
Central African Regional Program for the Environment (CARPE)	USAID	United States	http://www.usaid.gov/our_work/environment /climate/country_nar/carpe_profile.html
Clean Cities International	DOE	Bangladesh, Brazil, Central America and Caribbean, Chile, India, Mexico, Peru, Philippines, and the United States	http://www.eere.energy.gov/cleancities/ international.html
Clean Development Mechanism (CDM)	Kyoto/United Nations Framework Convention on Climate Change (UNFCCC)	Signatories to Kyoto Protocol	http://cdm.unfccc.int/
Clean Energy Technology Exports Initiative (CETE)		United States	
Climate Change Technology Program (CCTP)	Interagency, led by DOE	United States	
Climate Technology Cooperation Gateway	EPA, USAID	United States	
Climate Technology Initiative (CTI)	UNFCCC	Austria, Canada, Finland, Germany, Japan, Norway, Republic of Korea, United Kingdom, United States	http://www.climatetech.net/
Climate Technology Partnership (CTP)	DOE, EPA, USAID	United States	http://www.usaid.gov/our_work/environment/climate/ pub_outreach/story_egypt.html
Coal-bed Methane Outreach Program	EPA	United States	http://www.epa.gov/cmop/international.html
Collaborative Labeling and Appliance Standards Program (CLASP)	DOE, EPA, USAID	United States	http://www.clasponline.org/
E+Co	-	United States	http://www.eandco.net/index.php
EcoLinks	EPA	United States	http://www.ecolinks.org/resources/
eeBuildings	EPA	United States	http://www.epa.gov/eebuildings/index.html
EMBARQ	World Resources Institute	United States	http://www.embarq.wri.org/
Energy Efficiency Industry Partnership (EEIP)	Alliance to Save Energy (ASE), DOE	United States, China, Dominican Republic, Indonesia, Mexico, Thailand	http://www.ase.org/section/program/eeip
Expert Group on Technology Transfer (EGTT)	UNFCCC	Signatories to UNFCCC	http://ttclear.unfccc.int/ttclear/jsp/
FRAME	USAID	United States	http://www.frameweb.org/

Global Gas Flaring Reduction (GGFR)	World Bank Group	Norway	http://tinyurl.com/89kq9
Global Nuclear Energy Partnership (GNEP)	DOE	United States	http://www.gnep.energy.gov/
Global Village Energy Partnership (GVEP)	Assorted Companies		http://www.gvep.org
Integrated Environmental Strategies Program (IES)	EPA	United States	http://www.epa.gov/ies/index.htm
International Center for Environmental Finance (ICEF)	EPA, Global Environment & Technology Foundation		http://www.environmentalfinance.net
International Cleaner Production Cooperative	EPA		http://es.epa.gov/cooperative/international/
International Energy Agency Demand-Side Management Program (IEADSM)	International Energy Agency (IEA)	18 IEA Member Countries	http://dsm.iea.org/
International Partnership for the Hydrogen Economy (IPHE)	several international organizations	16 Countries	http://www.iphe.net/
Joint Implementation (JI)	Kyoto/UNFCCC	Signatories to Kyoto Protocol	http://ji.unfccc.int/
Landfill Methane Outreach Program (LMOP)	EPA	United States	http://www.epa.gov/lmop/international.htm
Methane-to-Markets	EPA	20 Partner Countries	http://www.methanetomarkets.org/
Municipal Network for Energy Efficiency (MUNEE)	USAID	United States	http://www.munee.org/
National Greenhouse Gas Inventories Program (NGGIP)	Organisation for Economic Co-operation and Development (OECD), IEA	Signatories to UNFCCC	http://www.ipcc-nggip.iges.or.jp/org/ aboutNGGIP.htm
Natural Gas STAR Program	EPA	United States	http://www.epa.gov/gasstar/international.htm
NREL International Programs	DOE – National Renewable Energy Laboratory (NREL)	United States	http://www.nrel.gov/international/ country_activities.html
Partnership for Clean Fuels and Vehicles (PCFV)	UNEP		http://www.unep.org/pcfv/
Partnership for Clean Indoor Air (PCIA)			http://www.pciaonline.org
Promoting an Energy Efficient Public Sector (PePS)	Several US Governmental Agencies & Non-profits		http://www.pepsonline.org/programs.html
Renewable Energy Network (RENET) of Eurasia	-	Azerbaijan, Kazakhstan, Kyrgyzstan, Tajikistan, and Uzbekistan	http://www.eurasiare.net/
Solar Light for Africa (SLA)	USAID	United States	www.solarlightforafrica.org
South Asia Regional Initiative for Energy Cooperation and Development (SARI/Energy)	DOE, NREL, US Chamber of Commerce	United States, Countries of South Asia	http://sari-energy.org/
Sustainable Energy Development Program (SEDP)	USAID, DOE	United States	http://www.sedp.ph/
Technology Cooperation Agreement Pilot Project (TCAPP)*		United States	
Transition to New Technologies (TNT)	International Institute for Applied Systems Analysis		http://www.iiasa.ac.at/Research/TNT/WEB /index.htm
USAID's Global Climate Change Program	USAID	United States	http://www.usaid.gov/our_work/environment /climate/index.html

US-Asia Environmental Partnership (US-AEP)	USAID	United States, India, Sri Lanka, Thailand, Vietnam, Philippines, and Indonesia.	http://www.usaep.org/transition.html
USEA Energy Partnership Programs	US Energy Association	United States	http://www.usea.org/programs.htm
US-India Partnership on Climate Change	USAID	India, United States	http://www.usaid.gov/in/our_work/program_areas/energy_environment.htm
Voluntary Aluminum Industrial Partnership (VAIP)	EPA	United States	http://www.epa.gov/highgwp/aluminum-pfc/international.html
Watergy	Alliance to Save Energy	-	http://www.watergy.org/
West African Regional Program (WARP)	USAID	17 Countries	http://www.usaid.gov/locations/sub-saharan_africa/countries/warp/

*Denotes an organization that is no longer operational

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