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Climate Change:
Technology Development and Transfer




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BACKGROUND PAPER

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TABLE OF CONTENTS

CLIMATE CHANGE: TECHNOLOGY DEVELOPMENT AND TRANFER

1. Introduction

Avoiding dangerous climate change will require major reductions in greenhouse gas (GHG) emissions, and action on this front must begin soon. In most countries, developed and developing, the call for strong GHG mitigation is still seen as a threat to their economic and social aspirations.[1] The UN Framework Convention on Climate Change (UNFCCC) gave particular emphasis to the "legitimate priority needs of developing countries for the achievement of sustained economic growth and the eradication of poverty". In fact, the interactions between the climate-change mitigation agenda and the development imperative, while sometimes portrayed as a possible conflict, could be positive and beneficial to the latter. That is to say, the need to incorporate climate-change mitigation into development activities offers the opportunity to advance sustainable development. At the same time, development itself may be set back if the world does not engage in mitigation and adaptation. Hence the climate change and sustainable development challenges are intimately intertwined.

The energy sector provides a natural arena for the convergence of climate mitigation and sustainable development strategies. This sector, as the major emitter of GHGs worldwide, plays a central role in the climate change issue. Reducing GHG emissions from energy use doubtlessly will require significant shifts in the energy system, and, as a result, its functioning and future prospects have been the focus of much examination, analysis, and debate. At the same time, it is abundantly clear that the provision of clean and adequate energy services to all of humankind, while minimizing the health and other environmental risks from energy extraction, conversion, and utilization, is a central part of the sustainable development agenda. Similarly, other areas such as forestry, agriculture and infrastructure development also sit squarely at the intersection of sustainable development and climate change.

If there is to be a reorientation of the energy and other sectors in developing countries to meet the climate change and sustainable development challenges, there is no doubt that technology will play a central role in this transformation. For this reason, the issue of technology transfer has been a constant refrain of the developing countries in the climate negotiations. This paper aims to contribute to the discussions in this area by examining the energy needs of developing countries and then taking an energy-innovation perspective to consider the kinds of technology policies and actions that might help reap a double climate and sustainable development dividend. It ultimately suggests that the technology transfer framework could usefully be broadened to one of "innovation cooperation," which is more comprehensive and recognizes the need to strengthen innovation capacities of developing countries. In order to be successful, cooperation activities will need to be tailored to local needs and conditions.

[1] The difference among these countries, of course, lies in the financial and technical resources at their disposal to take such action ("capability") and their contribution to the climate problem ("responsibility").

2. Developing countries and the climate challenge

The need for GHG mitigation

GHG emissions from the energy sector are the major contributor to the accumulation of GHGs in the atmosphere; in 2004, fossil-fuel use accounted for almost 60% of the global anthropogenic GHG emissions.[2] While there is no consensus yet on what might be the appropriate levels of CO_2-equivalent concentrations in the atmosphere to avoid "dangerous" climate change, analysts are suggesting that levels of 400 ppmv CO_2-equivalent or even lower are needed to avoid this outcome.[3] This, in turn, would require drastic reductions in global GHG emissions (possibly 80% or more, compared to 1990 levels), which means a major decoupling between the energy system and GHG emissions.

While the industrialized countries are responsible for an overwhelming majority of the past GHG emissions and still account for about half of the global GHG emissions from energy, the global GHG concentration ceiling implied by the need to avoid dangerous climate change will necessitate that developing countries also change the GHG trajectory of their energy systems even as this sector expands. In fact, the Reference Scenario of the IEA's World Energy Outlook 2008 (WEO 2008) indicates that 87% of the increase in global energy demand and 97% of the increase in energy-related CO_2 emissions between 2006 and 2030 will come from non-OECD countries, which means that there is both a need and an opportunity to reorient the energy sector of these countries.[4] It should be noted that the disparities between the per capita energy use and CO_2 emissions of the OECD and non-OECD regions are projected to remain stark – according to the WEO 2008 Reference Scenario, by 2030 per capita primary energy demand and energy-related CO_2 emissions of OECD countries will be 4.7 tons of oil equivalent (toe) and 10.1 tons of CO_2 respectively, while the corresponding numbers for non-OECD countries will be 1.5 toe and 3.8 tons. Furthermore, even these numbers mask the large differences among regions. Africa, for example, is projected to have a per capita primary energy demand of 0.5 toe and energy-related CO_2 emissions of 0.8 ton.

Notably, while the energy sector receives the most attention for mitigation, other activities (especially agriculture, deforestation, transport and industry) also are responsible for GHG emissions and therefore will need to play a role in mitigation.

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[2] IPCC 2007: Rogner, H.-H., D. Zhou, R. Bradley, P. Crabbé, O. Edenhofer, B. Hare, L. Kuijpers, M. Yamaguchi, 2007: Introduction. In Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds), Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA (2007).

[3] Hadley Center 2005: Report of the International Scientific Steering Committee, International Symposium on the Stabilisation of Greenhouse Gas Concentrations, Hadley Centre, Met Office, Exeter, UK (2005). Hansen, J., Mki Sato, P. Kharecha, D. Beerling, R. Berner, V. Masson-Delmotte, M. Pagani, M. Raymo, D.L. Royer, and J.C. Zachos, 2008: Target atmospheric CO2: Where should humanity aim? *Open Atmos. Sci. J.*, 2, 217-231 (2008).

[4] IEA 2008: *World Energy Outlook 2008*, International Energy Agency, Paris (2008).

The need for adaptation

The Fourth Assessment Report of the IPCC concluded "with high confidence that anthropogenic warming over the last three decades has had a discernible influence on many physical and biological systems".[5] Furthermore, projected changes in temperature, sea levels, and atmospheric CO_2 concentrations as well as the resulting changes in climate variables such as precipitation will lead to a range of impacts – many of these possibly severe – on ecosystems and societies. These impacts will vary across sectors and regions and will depend, of course, on the vulnerability of these systems as well as adaptation measures. In fact, the IPCC warns that climate change can impede progress towards sustainable development, either directly through adverse impacts or through erosion of the capacity to adapt.[6] Thus adaptation will play a key role in minimizing the impacts that result from a given level of climate change.

Even the most ambitious mitigation measures cannot avoid future climate impacts, yet if mitigation is not undertaken, climate impacts may become so large as to become completely unmanageable. Thus both mitigation and adaptation are needed to minimize and manage climate risks.[7]

3. Developing countries and the development challenge

Even as the concerns over climate change become more urgent, the need for development in poor countries remains pressing. There is a risk that efforts to advance development will increasingly be constrained by the superimposition of the climate challenge. Viewed differently, there is a huge opportunity, given strong political will and financial and technological support from the international community, for developing countries to move onto low-carbon, high-growth development paths. To do so, what happens in the area of energy will be crucial.

Energy needs of developing countries

Non-Annex-I countries accounted for just under 50% of the world's total primary energy supply (TPES) (with about 80% of the world's population) in 2007;[8] thus on a per capita basis, they used about one-fifth the energy compared to Annex-I countries. Figure 1 shows the TPES for non-Annex-1 countries since 1990.

[5] IPCC, 2007: Summary for Policymakers. In: *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 7-22 (2007).
[6] *ibid.*
[7] *ibid.*
[8] Based on national data from IEA 2009: *Energy Balances of OECD Countries 2009*, International Energy Agency, Paris (2009); and IEA 2009: E*nergy Balances of non-OECD Countries 2009*, International Energy Agency, Paris (2009).

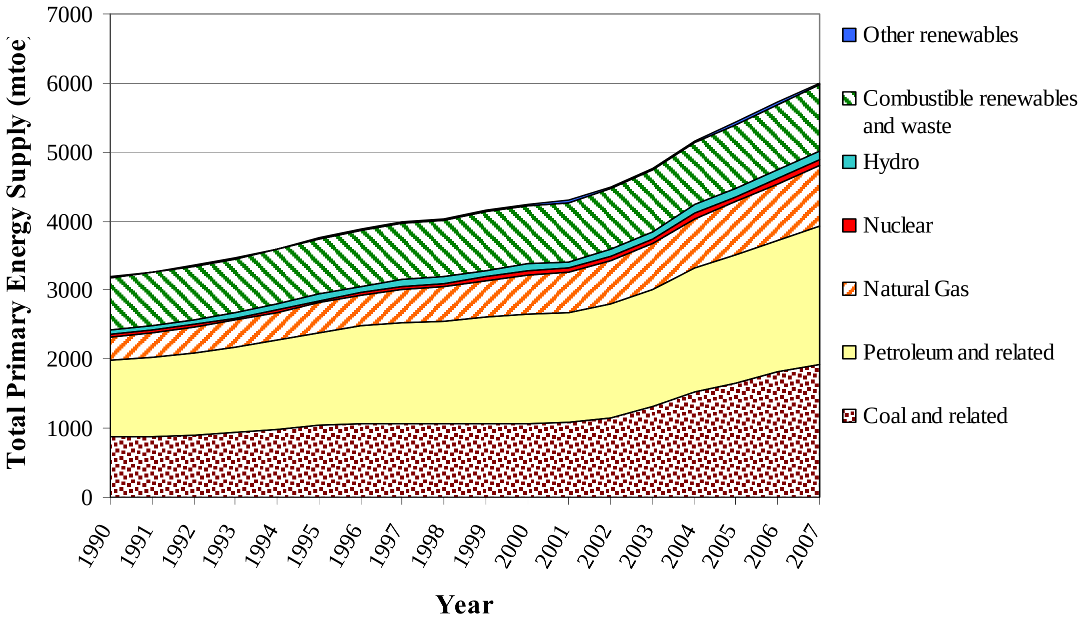

***Figure 1: Total primary energy supply for non-Annex-I countries, 1990-2007*[9]**

The following points are notable:[10]

- Non-Annex-1 countries rely heavily on fossil fuels (especially coal and petroleum) and this dependence is increasing. Almost half of the coal is used for power generation (and over half of the power generated in these countries is from coal). The transport sector in these countries accounts for about half of the petroleum use.

  While the TPES in developing countries has increased by about 3.8% per year, the supply of coal and related sources of energy has grown annually by about 4.7% per year, and that of petroleum and related products by about 6.4%. These reflect the high growth of electricity generation (and the increasing role of coal in this sector) and of the transportation sector. But it should be noted that, despite this growth, even in 2007 Annex-I countries used almost three times as much coal and over five times as much oil on a per capita basis as non-Annex-I countries. In fact, there is a clear correlation between countries' levels of income and the use of energy as well as electricity (see Figure 2). Thus, as developing countries rise up the economic ladder, their energy use is likely to increase. At the same time, it should also be seen that there is a large spread of energy use for any given level of

[9] *ibid.*
[10] *ibid.*

GDP, indicating that an increase in prosperity need not lead to a proportional increase in energy use.

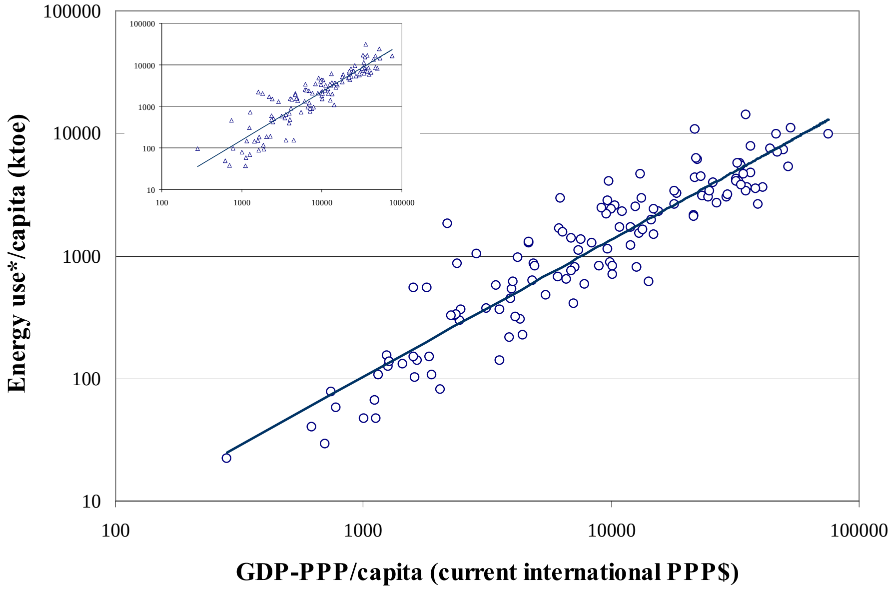

Figure 2: Energy* and electricity use as function of GDP-PPP (2006 data)[11]

Note: scales are exponential

(Insert: GDP-PPP in current international PPP$ vs. electricity consumption/capita in kWh)

* excluding combustible renewables and waste

- Non-Annex-I countries still obtain almost 16% of their energy supply from combustible renewables and traditional biomass; the corresponding number for Annex-I countries is about 3%. For many countries, these energy sources provide an even higher fraction of their primary energy: in the case of India, this number is almost 30%, for Africa as a whole, it is almost 50%, and for many poor countries, such as Nigeria and Ethiopia, it is as high as 80% and 90%, respectively. Furthermore, the use of biomass in developing countries relies primarily on inefficient combustion with attendant health and other impacts.

- Energy poverty remains widespread in developing countries. Almost one-third of the population in developing countries – almost 1.6 billion people – lacked access to electricity in 2005 (see Table 1). Africa and South Asia particularly have low electrification rates, especially in rural areas. This is a major concern since electricity is a clean and versatile energy carrier and underpins a range of activities and services that are vital to human, economic, and social development.

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[11] WB 2009: *World Development Indicators database*, World Bank, Washington, DC (2009). GDP in current international $ in terms of purchasing power parity (PPP).

Table 1: Urban and Rural Electrification Rates by Region, 2005 (%).[12]

	Urban	Rural	Total
Africa	67.9	19.0	37.8 (554)
Sub-Sahara	58.3	8.0	25.9 (547)
North Africa	98.7	91.8	95.5 (7)
Developing Asia	86.4	65.1	72.8 (930)
China and East Asia	94.9	84.0	88.5 (224)
South Asia	69.7	44.7	51.8 (706)
Latin America	98.0	65.6	90.0 (45)
Middle East	86.7	61.8	78.1 (41)
Developing countries	**85.2**	**56.4**	**68.3 (1569)**
World	**90.4**	**61.7**	**75.6 (1577)**

Note: The numbers in parentheses in the "Total" column indicate the number of people, in millions, who do not have access to electricity.

- Nuclear and non-hydro, non-biomass renewables (geothermal, solar, wind, etc.) remain responsible for a very small portion of the overall energy supply in most of these countries.
- Poorer countries generally have less efficient energy economies and systems. The energy intensity (i.e., energy use per unit GDP) of Africa as a whole, for example, was 0.28 tons of oil equivalent (toe)/thousand US$[13] while that of the OECD countries was 0.18 toe/thousand US$.[14, 15] As another example, the efficiency of electricity generation from coal in non-OECD countries was about 31% in 2006, while that of OECD countries was 37%.[16] Such inefficiency leads to citizens in poorer countries paying more for the same amount of energy services even as they have fewer financial resources.[17]

[12] IEA 2006: *World Energy Outlook 2006*, International Energy Agency, Paris (2006).
[13] Constant 2000 US$ in terms of purchasing power parity (PPP).
[14] *Ibid.*
[15] *Op. cit. 8.*
[16] *Op. cit. 4.*
[17] The poor spend a higher fraction of their income for energy services (IEA 2002: *World Energy Outlook 2002*, International Energy Agency, Paris (2002)) because of both their lower income and the lower efficiency of their energy conversion devices.

Energy and sustainable development

Energy services are central to economic, human and social development.[18] Figure 3 shows that human development and energy supply are intimately inter-linked: up to a point, improvement in human development is associated with greater per capita energy use. At the same time, beyond that point, at higher levels of human development, there is a large variation in energy use among countries. That is to say, very high levels of energy use are not necessary for reaching high human development. Therefore, the development pathway not only determines the energy use in the country but also the "efficiency" with which energy advances human development.

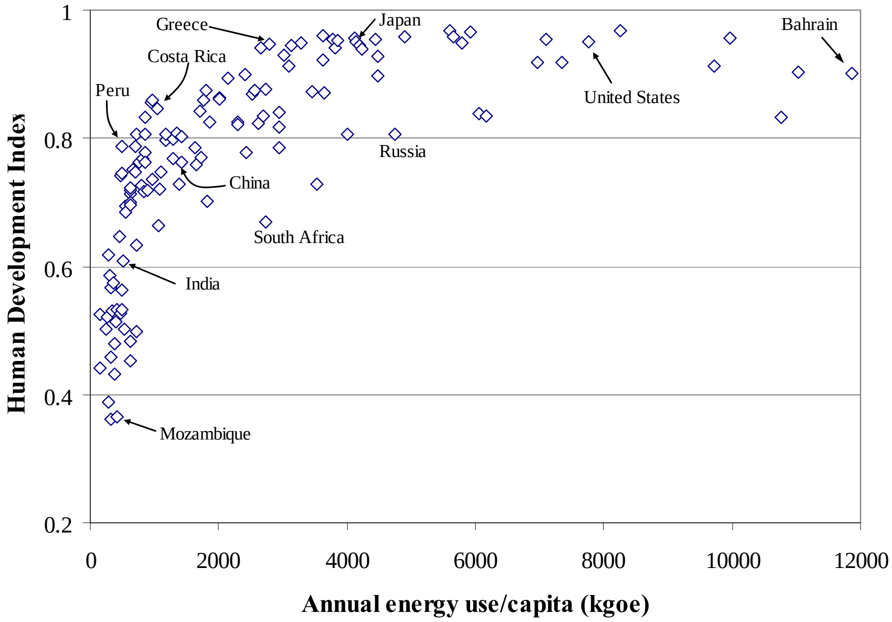

Figure 3: Annual energy use per capita vs. the Human Development Index

It is also recognized that the achievement of Millennium Development Goals (MDGs) is intimately linked to the availability of adequate clean energy services (see Appendix I for a detailed perspective on the linkages between energy services and MDGs).[19]

Thus, the energy challenges facing developing countries can broadly be categorized into the following inter-related areas: expanding of affordable energy supply and services ("adequacy" and "affordability"); improving the efficiency of conversion of energy

[18] UNDP 2000: *World Energy Assessment: Energy and the Challenge of Sustainability*, J. Goldemberg (ed.), UNDP / UN-DESA / World Energy Council (2000). UNDP 1997: *Energy After Rio: Prospects and Challenges,* A. K. N. Reddy, R, H. Williams and T. B. Johansson (eds.), UNDP, New York (1997).

[19] Modi, V., S. McDade, D. Lallement, and J. Saghir. *Energy and the Millennium Development Goals*. New York: Energy Sector Management Assistance Programme, United Nations Development Programme, UN Millennium Project, and World Bank (2006).

supply into energy services ("efficiency"); and replacing traditional energy technologies by modern, clean energy technologies ("modernity").

4. The role of technology in meeting climate/development challenges

Technological change plays a key role in the development of economies and societies. Technologies play a central role in helping meet human needs, providing energy, communication, transportation, and other services as key to human development, and underpinning the evolution of agricultural, industrial, energy and health sectors.

In relation to climate change, mitigation will require interventions across the economy, but particularly in the energy, agricultural, forestry, and industrial sectors. Adaptation will involve paying attention to habitation and human settlements, agricultural and health systems, water management, as well as disaster and other risk management approaches.[20]

Technology and a clean energy transition

Technologies play a central role in the energy sector, all the way from exploration for, and exploitation of, existing and new sources of energy, conversion into useful forms of energy that satisfy human needs and underpin modern economies, and end-use by various actors. New and improved technologies have allowed cheaper, more efficient, and cleaner ways of converting energy into desirable end-use forms and services. In fact, the reduction in global energy intensity over the past decades – an annual decline of 1.4% between 1980 and 2006[21] – could not have been achieved without the development of more efficient energy-conversion and end-use technologies.

Energy technology innovation – which involves research and development of new technologies, efforts to improve existing technologies, and the widespread deployment of these new and improved technologies – is and will remain a cornerstone of the modern energy system. As in the past, energy innovation will continue to play a key role in helping the energy system respond to societal imperatives and challenges.

Meeting the climate and developmental challenges simultaneously will require a significant shift in the technological trajectory of developing countries. The problem is complicated by the enormous scale of the energy system and the long lifetimes of much of the capital stock associated with energy extraction and conversion. Yet the relatively small size of the energy sectors in developing countries at present can also serve as an opportunity. These countries are likely to expand their energy systems substantially in

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[20] Adaptive and mitigative responses need not be only technological but could also involve behavioral change (e.g., altered settlement or transportation choices), managerial approaches (e.g., altered farm practices or demand-side management), and policy (e.g., risk insurance policies or incentives for renewables). *(Op. cit. 5)* In most cases, though, even though technology may not be the driver of the response, it can be an enabler.

[21] IEA 2008: E*nergy Balances of non-OECD Countries 2008*, International Energy Agency, Paris (2008).

the coming decades. The energy demand in non-OECD countries is projected to increase by as much as 75% between 2006 and 2030, according to a recent IEA reference scenario; in absolute terms, this increase is projected to be seven times the increase in OECD countries. This offers the opportunity to develop this energy infrastructure so that it simultaneously addresses climate and sustainable development imperatives. Realizing this opportunity will depend on not just developing countries but also industrialized countries, since it is the latter that are the loci of much energy innovation.

5. Technologies for developing countries

The energy and other development challenges facing developing countries are daunting enough; meeting them in a way that advances the climate change and sustainable development agenda adds on another layer of complexity. Improved technologies and practices for the energy system could certainly play an important role in this regard, but in order to be successful, technology strategies will need to be based on a better understanding of what impedes the realization of the potential gains that improved technologies have to offer.

"Transferable" technologies and products

In many cases, technologies/products do not need to be significantly modified or redesigned and therefore their transfer to developing countries is relatively simple in technical terms at least. In some cases, the "transfer" of technologies across national borders may involve transport of assembled goods or local assembly of imported parts. More often than not, especially in countries with relatively large markets, firms may engage in local sourcing of parts (made to original design specifications) as a way to reduce costs. This, of course, requires the availability of local capabilities to establish such manufacturing facilities. This may happen, for example, when an automobile manufacturer establishes operations in a large developing country. Other examples of "transferable" technologies include high-efficiency turbines and motors as well as household electronics.

Technologies and products needing adaptation

In most cases, some (or significant) product modification or redesign is needed for the technology/product to be useable in the local context or markets. Such modifications may be carried out locally or with the help of the original equipment manufacturer. Once again, local technological capabilities can play an important role in this adaptation process. Examples of this include boilers that may need to be tailored to local coal characteristics and/or ambient conditions; "green" or "climate-proof" building designs that need to take into account local climatic conditions as well as use patterns by occupants; electrical equipment such as air-conditioners or refrigerators, where the compressor and other components may need some changes in order to perform suitably in local conditions; or crops which need to be modified for local soil and rainfall patterns.

Technologies for local unmet needs

In many developing countries, there is a range of technologies and products that are "local," i.e., they meet needs that are particular to these countries and/or are locally developed. Often, global technology markets do not develop products for the poorer citizens of the developing countries since these markets are not seen as attractive enough, even though cumulatively this group's needs may present a significant opportunity.[22] Thus, these technologies are generally outside the mainstream global energy innovation system and, in many cases, even outside the established commercial markets in developing countries.

Examples include cookstoves and other biomass-burning devices (such as ovens), small-scale biomass conversion technologies (such as biomass gasifiers for power and thermal applications and biogas digesters), and kerosene and solar lanterns. Technology development and deployment activities in this area remain small and fragmented (although there are some notable successes, such as the Chinese improved cookstove program).

This group of technologies is particularly important because it is relevant to a large fraction of the world's population who are living in energy poverty and is key to meeting the "modernity" challenge. The development of suitable clean and high-efficiency energy technologies for the energy poor can have a significant positive impact not only on advancing the sustainable development goals in developing countries but also on the climate front. Examples include traditional household cookstoves where the provision of a replacement technology which provides more efficient and clean energy services can lead to climate as well as development gains (see Box 1). Similarly, energy technologies to deliver power to villages could have a transformative effect on rural populations by opening up avenues for economic and social development.

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[22] This is what C.K. Prahlad referred to as the "fortune at the bottom of the pyramid." (C.K. Prahalad, *The Fortune at the Bottom of the Pyramid: Eradicating Poverty Through Profits,* Wharton School Publishing: Philadelphia, PA (2004)).

Box 1: Cooking with biomass burning and (un)sustainable development

About 2.5 billion people worldwide rely on biomass as their primary cooking fuel, often burning it in open fires or simple three-stone or mud stoves. The human, social, and environmental costs of this dependence on biomass are now understood to be enormous:

- The burden of fuel collection falls mainly upon women and children, who can spend up to 3-4 hours gathering fuel resources every day.[23]
- The use of biomass for cooking and other energy services such as space heating is a major contributor to indoor air pollution. It has been estimated that indoor air pollution leads to annual excess mortality of 400-550,000 in India,[24] ~ 420,000 in China,[25] ~390,000 in Africa,[26] and about 1.6 million worldwide.[27] The WHO estimates that indoor air pollution from these fuels is the sixth largest health risk factor in developing countries, responsible for the loss of about 38 million disability-adjusted life years (DALYs) in developing countries with significant social and economic costs.[28]
- The products of incomplete combustion (PICs) that result from the way biomass is burnt in traditional stoves (and even some "improved" stoves) have been shown to have significant global warming implications.[29] It is estimated, for example, that the greenhouse impact (on a 20-year timeframe) of PICs from biofuels in 1990 was almost a quarter of that from energy use in Asia, even if the biomass was harvested sustainably.[30]

Long-term technology development

Given that the technological transformation needed for meeting the climate and the sustainable development challenges will need to be a continuous process and not a

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[23] UNDP 1997: *Energy After Rio: Prospects and Challenges,* A. K. N. Reddy, R, H. Williams and T. B. Johansson (eds.), UNDP, New York (1997).

[24] Smith KR. National burden of disease in India from indoor air pollution. Proc. Natl. Acad. Sci. USA 97:13286-93 (2000).

[25] Zhang J, Smith KR. Indoor air pollution from household fuel combustion in China: A review. Presented at 10th Int. Conf. Indoor Air Qual. Climate, Beijing, China (2005).

[26] Ezzati M, Lopez AD, Rodgers A, Vander Hoorn S, Murray CJL. Selected major risk factors and global and regional burden of disease. Lancet 360:1347—60 (2002)

[27] WHO 2002: World Health Report 2002. World Health Organization, Geneva (2002).

[28] *Ibid.*

[29] Smith KR, Uma R, Kishore VVN, Zhang J, Joshi V, Khalil MAK. Greenhouse implications of household stoves: an analysis for India. Annu. Rev. Energy Environ. 25:741—63 (2000); Venkataraman C, Habib G, Eiguren-Fernandez A, Miguel AH, and Friedlander SK. Residential biofuels in South Asia: Carbonaceous aerosol emissions and climate impacts, Science, 307(5714), 1424-1426 (2005).

[30] Streets DG, Waldhoff ST. Greenhouse-gas emissions from biofuel combustion in Asia. Energy 24:841-55 (1999).

one-time step change, adequate attention will also need to be paid to technologies for the long-term. Examples include solar-photovoltaic-based power generation and hybrid vehicles, where the advanced technological options are in the early deployment state or in niche markets because of economic reasons, although there is little technical risk to deploying these technologies. Other technologies that are still in the pre-commercial or early deployment state, such as integrated gasification combined cycle (IGCC), present both technical as well as market risk. Technology development efforts can help reduce both these categories of risk. This will also require enhancing the global technology development budgets and efforts to ensure a pipeline of innovation for the future.

Deployment issues, barriers and approaches

Even when a technology offers improved performance in terms of efficiency (as compared to currently-deployed technologies), reduced (local and GHG) emissions, or quality of service delivered, its deployment may remain limited because of a number of factors, which include:

- Economics, i.e., such products may cost more compared to the existing product: This perhaps is the single largest barrier to deployment of new technologies. Competing with incumbent technologies, where existing market penetration has allowed for refinements and cost reductions, often becomes difficult, especially when coupled with consumer uncertainty about the new products.
- Information and trust, i.e., there may be a lack of publicly available or trustworthy information about the improved performance attributes of the product: To deploy new technologies, consumers must have information and confidence about this option in relation to the *status quo*. This is particularly true for cases in which the purchasers are individuals or small firms that do not have the technical and financial wherewithal to make performance assessments and relate them to investment decisions (where larger firms may be able to carry out their own evaluation of technologies). This could be true for technologies in the energy, agriculture, or even health area.
- Market organization, i.e., the technology or product may not have access to appropriate marketing/distribution/servicing channels: Accessing the market may turn out to be a showstopper for a new technology in many cases, especially if the technology requires widespread distribution channels and/or service/maintenance support (as in the case of household appliances or automobiles or improved cookstoves). In many cases this becomes a “chicken-and-egg” problem because a firm may not have resources to build up a distribution or service network until its sales have risen. In other cases, especially building technologies, there is a lack of alignment between the incentives of the builders (to keep down building costs) and of the user of the building (to keep down operating expenses), which can impede the adoption of improved building design and energy-saving technologies.

- Finance, i.e., consumers may not have access to capital: In many cases, a new technology may be beneficial economically or otherwise and the potential consumers may even be aware of these benefits, but they may not have the financial ability to pay its higher up-front costs. The consumer in this case could be an individual or a small firm that does not have access to credit, or even a larger firm (if the capital costs are very large, as in the case of power plants).
- Human or institutional capabilities: The successful deployment of new technologies may require labor with appropriate training or skills. It may be difficult, for example, to implement construction technologies and techniques for energy-efficient or climate-proof buildings if skilled labor is not available. Similarly, in the case of agriculture, providing training and information to farmers is crucial so that they use the new technologies (such as high-yielding varieties or herbicide-tolerant crops) appropriately.
- Infrastructure needs, i.e., appropriate supporting infrastructure may not exist or may not be available in appropriate geographical areas. This is particularly true of technologies that involve a system-wide transformation. A movement to electric vehicles, for example, may depend on a network of charging stations (the same way the diffusion of the internal-combustion-engine is contingent on a network of refueling stations).

Programs and activities to enhance deployment of new technologies, therefore, need to take into consideration the nature of barriers specific to each technology and set in place policies and mechanisms that eliminate or overcome these barriers. In the case of economic hurdles to deployment, underwriting the incremental costs of the improved technology (as the Global Environment Facility has done in some cases) can remove the barrier. Other examples include: labeling programs to provide information to consumers (such as energy-efficiency ratings); standards to promote minimum performance levels to help transform markets (such as building standards or automobile fuel-economy or pollution standards); and programs that provide financing for individuals or small and medium enterprises. Policies can help create markets for new technologies as in the case of feed-in tariffs that support the deployment of renewable energy technologies. The development of infrastructure and of human and institutional capabilities almost necessarily requires appropriate governmental support and policies.

Developing technology solutions to “local” unmet needs may be advanced by directing global innovation capabilities toward this challenge. This could involve refining existing technologies or developing new ones that provide clean and adequate energy services to the world’s energy poor, as well as designing and funding deployment programs. The main benefit would be on the sustainable development front, although with some concomitant gains in climate mitigation. Along with the development of suitable technologies, it is important to note that the adaptation of these technologies to local needs and constraints is critical, since these may vary significantly from country to country. Thus, the requisite technology solutions might be highly heterogeneous, rather than a simple universally-useable technology. Beyond technology solutions, innovative delivery mechanisms are also needed for scaling up deployment. These might include financing models targeted towards poor people or small-scale businesses. It will also require development of product supply and service chains – this is a particular issue for rural areas where the density of customers may be too low to support the natural development of such networks.

Most of the energy technologies discussed here present some synergy between GHG mitigation and other sustainable development objectives. This may not always be the case. For instance, concerns have been raised about the effect of biofuels produced from agricultural biomass on food prices, as well as deforestation. This points to the need for careful analyses that anticipate local or system-wide risks that might result from the deployment of new technologies.

6. An innovation-based agenda for a technological transition

Given that the technology needs of developing countries in relation to climate challenges are diverse and that deployment requires a range of activities (not only technical, but many others as well), the term "technology transfer" provides too narrow a perspective and framework for successfully leveraging technologies for meeting climate challenges.

Success requires paying attention to all elements of the innovation chain (see Figure 4) and the agenda for moving ahead must be viewed in these terms, with the understanding that the necessary elements must be appropriately tailored both to the specifics of the technology as well as national circumstances.[31] At the same time, the importance of controlling GHGs "through the application of new technologies on terms which make such an application economically and socially beneficial" must also be recognized, as highlighted in the UNFCCC.

This is a very different view from a traditional "technology transfer" model that implicitly suggests that (a) needs of different countries are similar, (b) all technologies can simply be "transferred" to meet these needs, and (c) "transferring" these technologies will be sufficient. As illustrated earlier, the needs of different countries may be very different, as is the (socio-economic, institutional, behavioral, and even environmental) context of technology use. Thus factors such as consumer preferences and purchasing power, regulatory and market conditions, and available energy resources may play a major role in determining the kinds of energy goods and services that will be successfully deployed in a country. Developing a small-scale power generating unit for rural areas may require basic research (for example, understanding the combustion characteristics of

[31] The UNFCCC also noted, "[p]olicies and measures to protect the climate system against human-induced change should be appropriate for the specific conditions of each Party and should be integrated with national development programmes..."

local biomass), technology development (e.g., developing a biomass gasifier), product development (e.g., developing a biomass-gasifier-based power generating unit), large-scale manufacturing, and market development (which may involve setting up product supply and maintenance networks, making financing available, as well as strategy (such as targeting particular consumer groups and niche markets to begin with)). Each of these activities needs knowledge of different kinds and, given the level of locally-available expertise, different kinds of cooperation. Developing a clean-coal power plant or an energy-efficient building or a solar-lighting solution for villages will each require different kinds of activities along the innovation chain and, again, different kinds of cooperation.

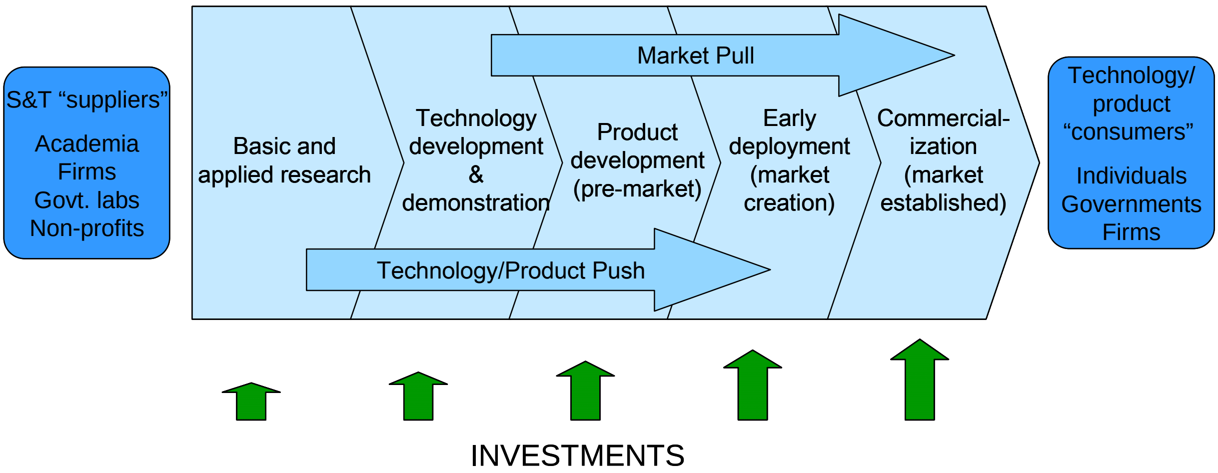

Figure 4: Main steps in the innovation chain[32]

Accordingly, the agenda for leveraging technology for meeting the climate challenge could have five elements: finance assistance, technology development in Annex-I countries, joint technology and product development, knowledge sharing for enhancing deployment, and capacity building in non-Annex-I countries.

Financial assistance

For cases in which high cost is the barrier to the deployment of improved energy technologies that advance climate mitigation as well as the development agenda, industrialized countries will need to fund the incremental costs of these technologies. Such an approach has already been implemented by the Global Environment Facility although on a very limited scale.

The kind of financial assistance and mechanism that may be appropriate depends on the kind of technology under consideration. In the case of more efficient power plants,

[32] Adapted from Grubb, M. Technology Innovation and Climate Change Policy: an overview of issues and options. Keio Economic Studies, 41(2): 103-132 (2004), and IEA 2008: *Energy Technology Perspectives 2008*, International Energy Agency, Paris, (2008).

covering the incremental capital cost of the plant may overcome the main barrier to deployment; in the case of renewable energy technologies such as solar and wind power, covering some part of feed-in tariffs may be a more efficient way to encourage an increasing contribution by these clean energy sources to meet developing country energy and climate challenges.

Technology deployment in Annex-I countries

There is an urgent need to begin deploying improved energy technologies in industrialized countries. In the case of technologies in the pre-commercial or early deployment stage, enhancing deployment in industrialized countries generally will be the fastest route to cost reduction, as the benefits of "learning-by-doing" accumulate. In fact, a recent report by the International Energy Studies group at Lawrence Berkeley National Laboratory indicated that the deployment of new technologies can cost more in developing countries than in industrialized countries.[33] Enhanced deployment will also help reduce technical risk as these technologies are likely to be refined through operational experience with a diversity of customers.

While large-scale deployment is unlikely to take place in the absence of national climate mitigation policies, targeted policies aimed at key technologies need to be implemented sooner rather than later. There already are examples of these kinds of policies, such as renewable energy portfolio standards and feed-in tariffs that promote the deployment of renewable energy technologies and tax benefits for hybrid vehicles, but there needs to be systematic assessment of technologies that would be of particular interest to developing countries so as to target them.

Joint technology and product development

This involves a cooperative technical program *that is driven by energy and technology needs of developing countries* rather than the technology agenda of industrialized countries. Such a program would have elements that cover all aspects of technological development, going from basic research to demonstration and early deployment, with the combination of activities for any specific technology being shaped by a nuanced understanding of the innovation gaps for that technology.

1. In the case of a mature, well-developed commercial technology such as supercritical power plants, this program would involve refinement and adaptation of the technologies to meet local conditions. More efficient, lower emissions

[33] "Capital, fuel and other costs are all higher for combined cycle units in India than in the US, while they are comparable for the technologically mature coal plants in the two countries. As the combined cycle technology matures, the cost differential may narrow in the future to as low as $6/t C. A key conclusion of this study is that to the extent project-based activities, e.g., under CDM, rely on new technologies to reduce carbon emissions from similar sources, the cost of carbon reduction may be higher in developing countries, since new technology costs in a nascent market are often higher in these countries." (Sathaye J. and Phadke, A. "Cost and carbon emissions of coal and combined cycle power plants in India: international implications" Lawrence Berkeley National Laboratory Formal Report 2005-01-01)

coal-based power generation technologies are a priority for developing countries which still depend heavily on coal in their electricity sector.

2. In the case of emerging technologies such as fuel cells, the program would involve some joint applied R&D, significant adaptation to local conditions, and even joint demonstration activities. In many cases, it might also be possible to leverage the S&T capabilities of developing countries to promote basic research in areas that have broad ramifications for energy technologies (such as materials).
3. Lastly, the program would have a major component aimed at the development of technologies and products that aim to advance the provision of energy services for the energy poor and for rural areas. This last element, although offering modest climate benefits, would offer enormous sustainable development gains. As affordable, clean energy access is critical to poverty eradication, industrialized countries' cooperation on this is important to achieving the MDGs. This would be an immense confidence-building measure for cooperation on climate change.

*Knowledge sharing for enhancing deploym*ent

This is particularly important in cases where non-economic barriers hinder the deployment of technologies that otherwise make sense from the economic, climate and/or sustainable development point of view. Sharing of experiences in industrialized or other developing countries and policy approaches to overcome these barriers should be very helpful. At the same time, exploration of new and innovative approaches, such as social, marketing and entrepreneurial delivery mechanisms, should also yield valuable results. Furthermore, analysis and development of appropriate policies and programmatic approaches, tailored to the needs of specific technologies and national circumstances, would be helpful. It also would be useful to explore alternative ways of enhancing and accelerating innovation such as innovation challenges/prizes (e.g., the US Department of Energy's prize for efficient LED light bulbs), the creation of guaranteed markets, and intellectual property (IP)-sharing approaches (see Box 2).

Capacity building in non-Annex-I countries

Since climate change is a long-term (i.e., multi-decadal) challenge, a case can be made that building local innovation capacity in non-Annex-I countries will be critical for helping with technology adaptation, development of appropriate technologies, and effective deployment. This will not come about just from staffing a few high-tech labs, but also from training the next generation of technically competent people. Therefore it is critical to strengthen local education and research institutions and ensure that they link up to international innovation activities. Skills sharing and transfer can be facilitated through international cooperation, perhaps organized by sector or trade – e.g., green building and construction skills.

Box 2: Intellectual Property Rights [34]

Intellectual property rights (IPRs) have emerged as a major issue in the technology-related discussions under the UNFCCC. Many developing countries have expressed the concern that IPRs will stand in the way of technology transfer by adding to the costs of mitigation or adaptation technologies or by reducing access to technologies. This is leading to proposals such as placing climate-relevant intellectual property (IP) in the public domain, compulsory licensing, or covering licensing costs.

But IPRs play very different roles in different technologies – in some cases, it may be a simple application of IP but, in most cases, what is referred to as "technologies" really are engineered systems that incorporate a range of technologies. For example, an integrated gasification combined cycle plant consists of a gasifier (which itself has a number of components), a gas-cooling and cleaning unit, a combustion turbine, and a steam turbine (in very simple terms). Each of these sub-systems would involve a range of IPRs, mostly patents. Putting all the sub-systems together, i.e., systems integration, is a very complex task, which requires a range of technical skills as well as tacit knowledge. Thus, development of engineered products and systems (which is what is ultimately needed) requires significant technological (and managerial) capabilities. Since different developing countries have different levels of technological capabilities, access to IP may not provide a full solution for all. Countries with a technical base may be able to develop products if they have access to IP, but countries with limited capabilities may not be able to do so. Therefore, access to IP is only part of the process for enabling technological change in developing countries to meet climate challenges.

It would be more fruitful if the discussion on climate technology issues would not be posed as a technology transfer issue that hinges on the availability of IP but rather as an issue of both access to technologies and products, with the coverage of incremental costs, and successful deployment of these technologies, which in turn requires a focus on technological and broader innovation capability building.

Appendix II presents, in a simple taxonomical form, the technological needs for developing countries and the kinds of activities that likely would be needed for successful implementation.

7. Key areas of innovation cooperation

While the specific areas of cooperation at the national or regional level will need to emerge from a local energy and technology needs assessment, there are certain technology areas that have commonality across multiple regions and countries. These

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[34] Based on Sagar, A.D. and Anadon, L.D., *Climate Change: IPR and Technology Transfer*, Background paper prepared for the UNFCCC Secretariat (2009).

technology areas include: renewable energy technologies, energy efficiency and cleaner coal power generation.

Renewable energy technologies

Renewable energy technologies, in principle, have the potential to enhance energy access and energy security as well as climate mitigation. Recent years have seen enormous growth in the investment in renewables (up six-fold since end-2004 to reach $120 billion at end-2008) and their deployment (a six-fold increase in global PV capacity and a 2.5-fold increase in wind power between end-2004 and end-2008).[35] While the bulk of investment occurred in Europe and the U.S., China, India and some other developing countries are also seeing significant investment in renewable energy. China has emerged as the largest solar photovoltaic manufacturer. Significant technical work is still needed to overcome the large barriers of costs as well as broader applicability (through improved power storage, for example). At the same time, deployment of renewable energy technologies will also help drive down costs and provide incentives for further private R&D. Therefore a global deployment effort using mechanisms such as feed-in tariffs (with international support for the costs associated with these tariffs in developing countries) will yield global gains (see Box 3).

Energy efficiency

Improved efficiency in end-use (lighting, space heating/cooling, household appliances, industrial processes, transport) offers some of the lowest-cost mitigation opportunities across many countries.[36] Some components are supposed to have zero or even negative costs. Developing countries, often with relatively inefficient processes and technologies, are argued to have a large potential for low-cost efficiency gains. Every single national climate strategy includes a strong plank on energy efficiency. But various barriers (e.g. lack of information and knowledge, inadequate incentives and lack of appropriate regulation) mean that energy efficiency underperforms as a mitigation option. A concerted effort on realizing these potential benefits will require not just adapting technological options for local use but also overcoming various non-economic barriers. In some cases, global coordination for a technology transition – such as from incandescent bulbs to energy-efficient lighting, a policy already pursued in Australia and the European Union – may be desirable.

Cleaner-coal power generation

At least in the medium-term, coal will stay a linchpin of a globally-expanding power sector. The WEO 2008 Reference Scenario, for example, indicates that almost half of the global power generation in 2030 will be coal-based and coal use in the power sector will account for one-fifth of the global primary energy demand.[37] Given that the global

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[35] REN212009: *Renewables Global Status Report: 2009 Update,* REN21, Paris (2009).
[36] See, for example, *Pathways to a Low-Carbon Economy: Version 2 of the Global Greenhouse Gas Abatement Cost Curve,* McKinsey & Company (2009).
[37] *Op. cit. 4.*

generation capacity is projected to increase by over 70% between 2006 and 2030, the deployment of clean-coal power plants is urgently needed. This in turn requires technical activities to make commercially available advanced options such integrated gasification combined cycle (IGCC), the adaptation of these options to local conditions, and the incentives to promote deployment (including covering incremental costs in developing countries). Development and demonstration of carbon capture and storage (CCS) technologies in different environments is also urgently needed, and international cooperation has a key role to play in this effort.

Box 3: Feed-in tariffs

A feed-in-tariff system provides a guarantee to any investor that, if s/he produces electricity from a renewable resource, a designated agency (such as the power authority or a utility company) will "feed" the electricity into the grid and pay a pre-defined price or "tariff". The "tariff" is set in such a way that the average investor will get a reasonable return on her/his investment. The policy also specifies a declining scale, meaning that the designated tariff will fall every year (mainly because the generation costs are expected to decline every year). The buying agency (the state power authority or utility company) will sell electricity to users at either regulated or market prices, depending on local practice. In the case of regulated prices, the difference between the feed-in tariff and the retail price of electricity is compensated by subsidies or tax rebates. In most feed-in tariff schemes, such as those in operation in Germany and Spain, the tariff is generally differentiated with reference to the electricity generation costs of different types of technologies. In Germany, the scheme initially adopted a set price as a percentage of the retail price of electricity, but in 2000 the tariff rate was differentiated according to the type of renewable energy source, e.g. solar, wind, geothermal, hydro, and landfill gas.

Feed-in tariffs could, without great difficulty, be adapted and applied in developing countries. In fact, countries such as China and South Africa are already adopting variants of such policies. But scaling up and replicating these initiatives in other countries requires financial support.

8. Technology Transfer Proposals

There have been a range of proposals relating to technology transfer in the international negotiations. These include new funding mechanisms such as the Multilateral Clean Technology Fund, the Multilateral Technology Acquisition Fund, and the World Climate Change Fund, a venture capital fund for emerging climate technologies; activities such as technology needs assessment; cooperative efforts such as joint R&D or technology-oriented agreements; enhanced access to IPRs; and a range of governance mechanisms and bodies. All of these are oriented at overcoming specific barriers to (or enhancing) the deployment of technologies in developing countries. There are also proposals that take a more comprehensive view of innovation such as Centers of

Excellence. Probably the most detailed of these is the concept of "Climate Innovation Centers" (CICs) that aim to support innovation activities for mitigation and adaptation technologies. In fact, many of the activities of the innovation chain (such as joint technology and product development, knowledge sharing, and capacity building) could be greatly facilitated and advanced by CICs in different parts of the world that could work on problems and technological solutions specific to a region.[38] These CICs could be funded partly by the Annex-I countries and partly by the host country (for example, Brazil, China, India, and South Africa could be suitable candidate countries by virtue of their significant technical manpower). They would involve researchers from industrialized and developing countries and would link up to academic and government research organizations as well as private firms in the region. They would be geared toward not only generating technological advances, but also building local technology innovation capacity (see Box 4).

Box 4: Climate Innovation Centers[39]

The concept of Climate Innovation Centers, formally proposed in the UNFCCC negotiations by the Indian government as an evolution of its earlier CleanNet proposal, has received increasing attention at various venues, such as the High-Level Meeting on Climate Change and Technology Transfer at Beijing in November 2008; COP-14 in Poznan; and more recently, various climate change negotiations in the run-up to Copenhagen. This concept has also been mooted by various analysts.[40]

The proposal of Climate Innovation Centers (CICs) is motivated by the understanding that technology could help meet the specific climate and energy needs of developing countries but these countries often have limited innovation capabilities to realize the potential of these technologies. Furthermore, it is well-understood that successful technological innovation is underpinned by "systems of innovation" that comprise a range of actors and institutions that support various activities along the innovation

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[38] This is somewhat similar to the idea of the Consultative Group on International Agricultural Research (CGIAR) centers, although the analogy may be limited and the design of the CICs may need to be very different.

[39] Based on *CleanNet: A Network of Climate Innovation Centres,* Government of India (2009) and Sagar, AD, Bremner, C, and Grubb, M., "Public-private roles and partnerships for innovation and technology transfer" in UN-DESA 2008: *Climate Change: Technology Development and Technology Transfer* (Background paper for the Beijing High-level Conference on Climate Change: Technology Development and Technology Transfer Beijing, China, 7-8 November 2008)

[40] Grubb, M., Bremner, C., and Omassoli, S. *Low Carbon Technology Innovation and Diffusion Centres*. The Carbon Trust: London (2008); Sagar, AD "Technology Cooperation in the Greenhouse," presented at Key Elements in Breaking the Global Climate Change Deadlock meeting, Center for Global Studies/OECD/Center for International Governance Innovation, Paris, March 2008; and Vera, I. *Climate Change and Technology Transfer: The Need for a Regional Perspective*. UN-DESA Policy Brief no. 18, UN: New York (2009).

chain.[41] Thus these CICs would help enhance technology innovation in developing countries to accelerate and scale-up deployment of technologies that can help these countries meet pressing energy and climate (mitigation and adaptation) challenges while advancing sustainable development.

These CICs would be a collaborative effort between Annex-I and non-Annex-I countries to bring to bear global innovation capabilities to meet local needs of developing countries. The developing-country location of CICs will help shape their activities in accordance with the local context and also allow for linkages to local firms, universities and other institutions (and ideally one would also like linkages to industrialized-country institutions), which will enhance the potential for successful innovation as well as capacity building within developing countries. Each CIC would serve the needs of a region and the network of CICs would build synergies across developing countries.

The CICs would engage in all aspects of innovation, going all the way from helping develop technologies and products to product demonstration, market creation activities, design of delivery models, incubation of enterprise, and development of appropriate policy regimes. Thus, CIC activities may involve:

- Technical research to find technology solutions for specific needs.
- Product development to embody those technology solutions.
- Supporting the development and piloting of appropriate business models to enhance deployment.
- Incubating enterprises through training and provision of finance and other support to entrepreneurs.
- Identifying and helping overcome the diverse range of regulatory and policy barriers to the development and diffusion of such products.
- Providing a platform for sharing of best practices and advanced experience including through "learning by doing".
- Promoting capacity building in technical areas, policy analysis, business and entrepreneurship.

[41] See, for example, Nelson, R. (ed.) *National Innovation Systems: A Comparative Analysis*, Oxford University Press: Oxford, UK (1993); Edquist, C. "Systems of Innovation: Perspectives and Challenges," in *The Oxford Handbook of Innovation*, J. Fagerberg, D.C. Mowery, and R.R. Nelson (Eds.), Oxford University Press: Oxford, UK (2004)

9. Concluding Remarks

- Technology development and transfer plays a central role in achieving climate goals and sustainable development and in realizing synergies between these intertwined challenges.
- Major international cooperation arrangements are indispensable to mobilize the political will and the vision needed to reach an ambitious science-based agreement that will secure technological and financial support for mitigation and adaptation.
- Energy poverty remains widespread in developing countries, limiting a range of activities that are vital to human, economic and social development. Therefore accessibility and affordability of environmentally-sound technologies remain crucial to achieving sustainable development and climate goals.
- Meeting the climate and developmental challenges simultaneously will require a significant shift in the technological trajectory of developing countries. The problem is complicated by the enormous scale of the energy system and the long lifetimes of much of the required capital stock. Yet the relatively small size of the energy sectors in many developing countries represents an opportunity to leapfrog to low-carbon and more efficient technologies.
- Successful technology development and transfer requires attention to all the elements of the technology innovation chain, with the understanding that the necessary elements must be appropriately tailored both to the specifics of the technology as well as to the national or regional circumstances.
- Although the upfront capital costs of renewable energy technologies remain higher than for alternative conventional fuel technologies, their costs are coming down and will continue to decline. A global programme of investment in renewable energy technologies needs to be considered so that these technologies become affordable by populations in many developing countries.
- Energy efficiency represents in many cases the lowest cost mitigation opportunity. Transfer of technology and sharing of knowledge represent the core of a proposed global programme in energy efficiency.
- While technology will continue playing an important role in addressing the challenges of climate change and sustainable development, improved practices and management approaches as well as human behavioral changes can also play an important role in energy consumption as well as in areas as diverse as agriculture, forestry, transport, and industry.

Appendix I: Important linkages between energy services and the Millennium Development Goals

Goal 1: Eradicate extreme poverty and hunger

Importance of energy to achieving the Goal

- Access to affordable energy services from gaseous and liquid fuels and electricity enables enterprise development.
- Lighting permits income generation beyond daylight hours.
- Machinery increases productivity.
- Local energy supplies can often be provided by small-scale, locally owned businesses creating employment in local energy service provision and maintenance, fuel crops, etc.
- Privatization of energy services can help free up government funds for social welfare investment.
- Clean, efficient fuels reduce the large share of household income spent on cooking, lighting, and heating (equity issue—poor people pay proportionately more for basic services).
- Most (95 percent) staple foods need cooking before they can be eaten and need water for cooking.
- Post-harvest losses are reduced through better preservation (for example, drying and smoking) and chilling/freezing.
- Energy for irrigation helps increase food production and access to nutrition.

Goal 2: Achieve universal primary education

Importance of energy to achieving the Goal

- Energy can help create a more child-friendly environment (access to clean water, sanitation, lighting, and space heating/cooling), thus improving attendance at school and reducing drop-out rates.
- Lighting in schools helps retain teachers, especially if their accommodations have electricity.
- Electricity enables access to educational media and communications in schools and at home that increase education opportunities and allow distance learning.
- Access to energy provides the opportunity to use equipment for teaching (overhead projector, computer, printer, photocopier, science equipment).
- Modern energy systems and efficient building design reduce heating/cooling costs.

Goal 3: Promote gender equality and empower women

Importance of energy to achieving the Goal

- Availability of modern energy services frees girls' and young women's time from survival activities (gathering firewood, fetching water, cooking inefficiently, crop processing by hand, manual farming work).
- Clean cooking fuels and equipment reduce exposure to indoor air pollution and improve health.
- Good quality lighting permits home study and allows evening classes.
- Street lighting improves women's safety.
- Affordable and reliable energy services offer scope for women's enterprises.

Goal 4: Reduce child mortality

Importance of energy to achieving the Goal

- Indoor air pollution contributes to respiratory infections that account for up to 20 percent of the 11 million child deaths each year (WHO 2002, based on 1999 data).
- Gathering and preparing traditional fuels expose young children to health risks and reduce time spent on child care.
- Provision of nutritious cooked food, space heating, and boiled water contributes towards better health.
- Electricity enables pumped clean water and purification.

Goal 5: Improve maternal health

Importance of energy to achieving the Goal

- Energy services are needed to provide access to better medical facilities for maternal care, including medicine refrigeration, equipment sterilization, and operating theatres.
- Excessive workload and heavy manual labor (carrying heavy loads of fuelwood and water) may affect a pregnant woman's general health and well being.

Goal 6: Combat HIV/AIDS, malaria, and other major diseases

Importance of energy to achieving the Goal

- Electricity in health centers enables night availability, helps retain qualified staff, and allows equipment use (for example, sterilization, medicine refrigeration).
- Energy for refrigeration allows vaccination and medicine storage for the prevention and treatment of diseases and infections.
- Safe disposal of used hypodermic syringes by incineration prevents re-use and the potential further spread of HIV/AIDS.
- Energy is needed to develop, manufacture, and distribute drugs, medicines, and vaccinations.
- Electricity enables access to health education media through information and communications technologies (ICTs).

Goal 7: Ensure environmental sustainability

Importance of energy to achieving the Goal

- Increased agricultural productivity is enabled through the use of machinery and irrigation, which in turn reduces the need to expand quantity of land under cultivation, reducing pressure on ecosystem conversion.
- Traditional fuel use contributes to erosion, reduced soil fertility, and desertification. Fuel substitution, improved efficiency, and energy crops can make exploitation of natural resources more sustainable.
- Using cleaner, more efficient fuels will reduce GHG emissions, which are a major contributor to climate change.
- Clean energy production can encourage better natural resource management, including improved water quality.
- Energy can be used to purify water or pump clean ground water locally, reducing time spent collecting it and reducing drudgery.

Source: DFID (Department for International Development, UK), 2004. *Energy for the Poor: Underpinning the Millennium Development Goals*. (2004).
http://www.dfid.gov.uk/Documents/publications/energyforthepoor.pdf

Appendix II: A taxonomy of energy technology needs in developing countries and activities to enhance innovation

	Key issue for developing countries	Examples	AREA OF ACTIVITY								
			Basic Science	Applied R&D	Product Devt/Tech Adaptation	Demo/Early Deployment	Large-scale deployment	Financial subsidy	Enterprise incubation	Policy/ business analysis	Knowledge sharing
Commercial technology	Cost; adaptation	Ultra-supercritical power plants; hybrid cars; solar-PV systems			√	√	√	√		√	
Commercial technology	Market organization; information; finance	Advanced space conditioning; CFLs			√	√	√			√	√
Emerging/ pre-commercial technology[1]	Technology risk; cost; adaptation	IGCC; fuel cells; LEDs; 2^{nd}/3^{rd} generation biofuels		√	√	√		√	√	√	
Enabling technologies	Leveraging local capabilities for participating in value-chains	Materials	√	√					√		√
"Local" technology/ Product[2]	Limited technology/ product development	Cookstoves; biomass gasifiers; solar lanterns		√	√	√	√	√	√	√	√

Notes: 1. Indicates need for large-scale deployment in industrialized countries, which will assist in driving down costs of the technologies

2. Indicates need for large-scale deployment in developing countries (since these are the main/sole markets for these technologies).

- Shaded area indicates activities that may be undertaken in "climate innovation centers."

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