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WILL WE FIND THE SOLUTION? THE LIMITED ROLE OF TECHNOLOGY TRANSFER IN REDUCING THE GROWTH OF GREENHOUSE GAS EMISSIONS FROM DEVELOPING COUNTRIES

Technocratic opinion suggests that existing, advanced technologies can help to decouple economic growth and greenhouse gas emissions in developing countries. Researches suggest that if these technologies are transferred to developing countries, they may *"jump over"* the most polluting phase of development. This paper explores the role of technology transfer in the reduction of developing countries' greenhouse gas emissions. Examples are taken from the electricity and transport sectors. It is argued that however transferred energy efficiency and renewable energy technologies can significantly contribute to emission reduction, more radical technological changes needed, otherwise progressive carbon lock-in occurs. It is also argued that comprehensive policies and some conditions are crucial for successful technology transfer, but domestic innovation and consumption related measures are also needed in order to avoid scaling-out of efficiency gains.

In this essay energy related examples are taken with special focus on electricity generation and transport sectors. Reason for this specification is twofold. Firstly, CO_2 is the biggest single contributor to greenhouse gas emission (GHG) and fossil fuels are responsible for 2/3 of global CO_2 emission (MARLAND 2006[1]). Estimates say that total CO_2 emissions will rise by at least 30% by 2030 (IEA 2006). Secondly, access to energy is a crucial factor of poverty mitigation, development and competitiveness in the developing world, thus energy related carbon emission will most likely increase with development if decarbonisation does not come about, and will represent the biggest challenge in GHG mitigation. The forms of cited carbon mitigation measures are energy efficiency (EE) and renewable energies (RES).

Eco-efficient, greener technologies are available for developing countries (developing country) that were not in place for developed countries (DdC) in their earlier stage of development. Free trade, globalization and foreign direct investments (FDI) claim to enhance a theoretical possibility for developing countries to use of this latecomer advantage to *"jump over"* the dirty phase of development (UNRUH 2000), while they build up their production and consumption capacities to avoid the environmental *"mistakes"* of the western world (GOLDEMBERG 1998, Perkins 2003).

Due to lower levels of pre-established routines and system lock-in in developing countries (GOLDEMBERG 1998), this leapfrogging process can be faster and cheaper, however the scope and speed is highly questionable (PERKINS et al. 2005). There is strong technocratic belief in business circles (e.g. GWEC 2006) and in academia

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[1] 2003 data.

(e.g. PACALA et al. 2004, GOLDEMBERG 2006), that commercially available, less carbon intensive technologies will be enough to decouple developing countries' growing carbon emission.

In this process, transfer of technologies can play a significant role (e.g. IPCC 2000, WORRELL 2001). According to WORRELL (2001:29) technology transfer is a *"process involving assessment, agreement, implementation, evaluation and adaptation and repetition"*. In line with others, he identifies *"institutional barriers and policies that influence the transaction process...* (it's) *efficiency in particular in the adaptation and repetition stages."*

The conditions and limits of technology transfer, as a GHG mitigation factor are discussed hereafter.

Cleaner energy technology transfer may work more as *"catching up"* with developed countries rather then radical *"leapfrogging ahead"*.

It is often seen that with technology transfer better technologies are employed then the local average, but they are not necessarily the best options available. Early studies emphasise that technology transfer doesn't work if it does not meet the needs and capabilities of the receiver (BERQUIN, R. 1981, SAMLI, 1985, RAMANATHAN 2002), that is part of the explanation this *"compromise"*.

So the first question is: why would developing country governments take action for the reason of GHG mitigating technology transfer?

Developing countries' primary priorities are poverty mitigation, development and competitiveness. This is especially valid for energy supply and fuel investments that are hardly driven by climate change concerns (IPCC 2000). For this reasons, successful transfer of energy related carbon mitigation technologies and strategies is more likely if they help in meeting other socio-economic goals (PERKINS 2003).

Securing energy supply, diversification of resources is especially important for fast growing developing economies.

Coal is the most widely available traditional energy source in China and India. Using the example of coal, the main problems of technology transfer will be illustrated. Rapidly extending coal fired power-plans cause significant local environmental and health problems (GARG 2001), and is the biggest CO2 source. Due to coal's strategic importance in security of supply, diversification and price stability, in the forthcoming decades China and India will heavily count on coal (MCMULLAN 2001, VUURAN 2003, YANG 2006). Mainly economic concerns over relatively low levels of power plant efficiency induce demand for coal-technology transfer from developed countries (MARTINOUT 2001, RAGHUVANSHI 2006). These end-of-pipe (EOP) efficiency technologies, in line with other cleaner coal technologies like gasification and emission control (HE 2002, WEIDOU 2004), represent important opportunities to –as GOLDEMBERG (1998) puts it *"leapfrog over"* current dirty phases of development or even *"leapfrog ahead"* of current Western technology standards. The problem is that these technology transfers are not radical carbon-free technologies, and without any kind of extra credit given to clean coal technologies and advanced energy efficiency technologies, they are unlikely to diffuse (WATSON et al. 2000, MCMULLEN 2001).

Uncertainty of energy supply endangers development goals, while price increases and fluctuations can easily melt the derived GDP gains (AWERBUCH et al. 2006). Security concerns lead to strict policies on energy efficiency and utilization of domestic RES resources with the possible positive side effect of GHG reduction (LU et al. 2006). Such policies can be justified by the avoided costs and risks of imported energy (MOREIRA et al. 1999, AWERBUCH et al. 2006).

Local environmental concerns are usually much higher on the agenda in developing countries than global GHG mitigation, thus carbon emission reduction technologies that have other, additional positive environmental effects are more likely to spread (GARG 2001). Despite some slight doubts (e.g. KRAM 1998) about the strength of synergies between GHG abatement[1] and other local environmental benefits[2], comparative case studies (e.g. WANG 1999, BURAN et al. 2003, Aunan 2004) and large scale examples, for example the public transport fuel switch project to natural gas in Delhi (BELL 2004) and the ethanol programme in Brazil (MOREIRA et al. 1999), seem to underline the claim of this synergy.

Available technologies have to find a market to spread. The first step to upscale transferred EE and RES technologies is to find a niche market (KEMP et al. 1998). A typical niche market for renewables is rural electrification (LORENZO 1997, WILKINS 2002). The plethora of small scale wind and photovoltaic (PV) projects in developing countries (e.g. RADY 1992, Acker et al. 1996, DRENNEN et al. 1996, LEW 2000, AL-SOUD 2004, NARVARTE et al. 2005) have shown that where electricity grid expansion is costly, whilst intermittent electricity supply is generally accepted. RES projects can be successful even with small subsidies (BISWAS 2004). Thus the transfer of the latest and cheapest technologies to these rural areas can help to avoid future carbon emissions by preventing fossil fuel dependency. The problem with rural and small scale renewable electrification projects is their marginal overall share in terms of electricity access and GHG reduction effect[3] (SEBITOSI 2005). Despite this problem these niche markets are important to upscale transferred RES and EE technologies.

Governmental action is needed to enable the diffusion of transferred technology.

Larger scale renewable energy projects need defined government intervention (HUACUZ 1995, LU et al. 2006). technology transfer of state-of-the-art wind turbines, modern biomass, large scale PV, etc *"don't buy themselves"*. Incentives and support policies are needed to spread these less polluting energy technologies speedily (MCKIBBIN 2006).

An additional obstacle to environmentally friendly energy technologies is that in most developing countries (conventional) *"electricity and fossil fuels are often subsidised"* for socio-political reasons (BHATTACHARYYA 1995, OECD 1996, BEERS 2001), and risk-avoiding firms tend not to invest into the newest technologies, preferring mature, even end-of-pipe-technologies. Hence without government intervention[4], locally innovated or transferred EE and RES technologies find themselves in a relatively worse competitive position (WILKINS 2002: 15).

Local industry development is an important motivation for government action to spread transferred EE or RES technologies. The most well known example is the Brazilian ethanol policy that was driven by the need to subsidize the agricultural sector and the sugar cane industry. Intensive government intervention successfully reduced the production costs of alcohol (MOREIRA et al. 1999) and helped to upscale the technology to a competitive level[5]. The interesting result is the enormous pull effect that was created for ethanol engines that reacted in the automobile industry

[1] E.g. fuel switching, energy conservation, combustion technologies.
[2] E.g NOx, SOx emission, particular matters.
[3] Relatively successful PV project in Kenya could reach a 4% penetration in rural areas.
[4] Elimination of perverse subsidies or support for EE and RES.
[5] Price of ethanol in Brazil can be 80% of gas.

and *"re-enforced"* the technology transfer. Case studies (e.g. FORSYTH 1998, LEW 2000, LEWIS 2007) for example highlighting the failure of local PV manufactures in Brazil due to a lack of local manufacturing and distributing capacities, or the success of UK windpump manufacturers in Africa due to stable connections, underline the importance of local partnership in successful renewable energy technology transfer (FORSYTH 1998).

The general lesson drawn here is in line with STERN'S suggestion (2006): successful technology transfer is the outcome of market pull, technology push, governmental actions and market forces.

Despite *"comprehensive policy documents"* in developing countries, additional governmental actions in terms of *"direction and regulation"* are needed for the adoption of these technologies and to yield economic and environmental gains (D'SA et al. 2006:278).

The flip-side is the case of *"pervasive diffusion"* of these technology transfers, and two long term implications are noted.

Firstly, these technology transfers further enforce carbon lock-in (AUNAN 2004), because they multiply vested interests into the carbon economy, enforcing traditional carbon based *"techno-institutional complexes"* (UNRUH 2000). This is extremely important in the electricity generation sector, where asset lifetimes are over 20 years and return times are long (GELLER 2003). This means that even a radical technology shift can take several decades. Trends of dependency on fossil fuels, intense centralized power grid enhancement in Asian countries (KENNEDY 1997) and the rapid increase of energy related CO2 may indicate that these have already affected developed countries' trajectories (LUUKKANEN et al. 2002).

Secondly, if these efficiency technology transfers decrease prices, in the long run they will increase consumption (PEDOBNIK 2006:155), and therefore GHG emissions as well. At this *"accelerated phase"*, carbon abatement will be much more expensive (HUESMANN 2003). In this sense, long term logic justifies claims that developing countries should commit themselves to environmental targets and should put stringent regulation in place BEFORE this lock-in occurs; they can prevent some environmental problems and uncontrolled GHG emission at an earlier stage and at lower costs then developed countries, and development does not necessarily have to be sacrificed (ANDERSON 2001:302). Without such policies, technology transfer is unlikely to deliver desired GHG reduction.

The implication of the above is that governmental intervention and the systematic removal of barriers is unlikely to occur if advantages gained by the transferred technology don't meet with the needs of the receiver.

Several studies have dealt with obstacles of the transfer of less carbon intensive technologies (e.g. FORSYTH 1999, WILKINS 2002, GALLAGHER 2006). It is now a general consensus that even the best technologies can fail if necessary socio-economic conditions are not in place, if the hosts' capabilities are limited (BERKHOUT 2003, KATHURIA 2002). These barriers are national context dependent (IPCC 2000). Given the space limit of this paper, only capital constraints and FDI, and the role of software and human capital are discussed here.

CAPITAL NEEDS AND COSTS OF TECHNOLOGY TRANSFER

Technology transfer under financial constraints and unsuitable policies might result in the *"lock-out"* of the most efficient technologies. An example is the spreading of mid-sized (up to 750 MW) wind turbines[1] in India instead of bigger, more efficient, state-of-the-art ones (1,8-2,5 MW), which are much more cost-effective but their capital intensity is also much higher (BAKSHI 2002, JAGADEESH 2000). The main reason for smaller turbine instalments is that they are simply exported from Europe, where they are replaced by bigger ones. Given the fact that the lifetime of these turbines is over 20 years, this shows how RES technology transfer can result in less efficient position fixation.

In other cases these financial constraints can lead to radical energy technology change, with intense technology transfer involvement. The example of small island states underlines the importance of resources in technology trajectories and economical rationality. These states, due to the lack of local fossil fuels and financial constraints, have extensively employed advanced, cleaner technologies for the utilization of renewable resources (DUI 2004, WEISSER 2004a, WEISSER 2004b).

However baseline efficiency can be very different in different developed economies. As with mitigation costs, these are not necessarily dependent on available opportunities (KRAM 1998.[2]). Large scale, capital intensive investments might look good at the micro level, but could be less appealing at macro level in economies where capital is scare (WEYANT 1998:9). Derived from this, the question might be: which mitigation actions have net costs, and which are no-regret-solutions. Estimates show that carbon emissions projections for no-regret solutions can be 10-30% lower than without these options (WEYANT 1998).

Calculations on the Chinese electricity sector suggest that even if *"significant carbon emission limits are put in place"* it would not cost more than BAU (LARSON et al. 2003).

Nevertheless, developing countries are usually less well-off in terms of capital and the main target of FDI, thus the role FDI is important.

FDI is often regarded as a main vehicle of technology transfer. Its direction used to be exclusively considered from developed to developing countries. Least developed countries with low technical level, and developing countries in the 1950-60s generally, often received not only specific knowledge, but *"package technologies"* with technical assistance (KAYNAK 1985). Often failure of this kind of technology transfer caused disappointment in the developing world, and revealed the complexity of technology transfer and the role of host country circumstances that were not ideal for integrating the new technology into the economy and society (POZNANSKI 1984), or where technology donors did not understand the special, local conditions (GUERIN 2001).

This sheds light on the complexity of technology transfer. Due to space constraints only the software element of technology transfer is highlighted here. Research found that the positive spill over effect of technology transfer on productivity and efficiency is not automatic, but requires a minimum level of accumulated human capital and R&D in the host country (XU 2000, POTTERIE 2001).

Wind energy examples can be cited here. In South-India, some 40% of wind turbines are situated in sub-optimal locations, due to insufficient design knowledge (BAKSHI 2004), while the lack of wind technology certification capacities hinders domestic turbine production in India and China (KLINE 2004). This finding underlines the importance of scientific capacity development in host countries (HARRIS

[1] In recent 2-3 years this trend has changed, but the already installed capacities will unlikely be replaced by newer technologies.
[2] E.g. natural gas supply, large existing investments in carbon-free alternatives and low energy use/GDP as conditions.

2004). For the spread of transferred technologies as a precondition, firms must get involved in adaptation and the creation of technologies (PACK 1997:87). This underlines the importance of domestic innovation capacities for the effectiveness of technology transfer adaptation. Heavy dependence on FDI and FDI transferred technologies can result *"atrophy"* of domestic innovation, thus the chance to develop *"tailor-made"* solutions.

Possible advantages of recently experienced south-south (S-S) FDI flow (UNCTAD 2006) and S-S technology transfer are worth mentioning here. One is that more equally developed countries with similar opportunities and problems can more easily find solutions (ESWA 2004), and developing country multinationals (developing country MNCs) are more likely to have more roots in the local economy, and thus have a more positive effect (GELB 2005: 201). Another issue is the possibility created to share complementary assets for technological improvement and technology transfer.

Regarding energy sector related technology transfer one should be cautious about exaggerating possibilities created by S-S FDI for three reasons. Firstly, because significant portions of these investments are mainly mergers and acquisitions[1], without EE or RES investments (UNCTAD 2006). Secondly, because lower environmental performance of these developing country MNCs might reinforce the lock-out effect and result in lower efficiency level fixation. Thirdly, because most host countries (e.g. mainly in Africa) might lack the above mentioned minimum human capital.

Based on the above, one can conclude that technology transfer does definitely have a role in developing countries' GHG mitigation, but success depends on several circumstances, and is based on a complex approach. Adequate policies and tools have to be developed to fully utilize opportunities.

The most important limit of technology transfer is the scale of emissions growth.

Under current trends, developing countries energy-use patterns will soon converge with those of developed countries' (MIELNIK et al. 2000). Future population levels and growth will be main elements of carbon emissions (WEYANT 1998). Key developing countries show very high economic growth, with the implication that: even if significant efficiency increase is achieved (compared to the relatively low current standards) this can be easily offset by rapid economic growth-induced emissions increases (KRAM 1998[2]). Different calculations exist, but even twofold eco-efficiency and EE gains in a relatively short term (2-3 decades) can be out-scaled by consumption and development in a decade, and in 25 years the environmental impact can be the same as it was initially (HUESEMANN 2003).

As technology transfer focused solutions don't contest the growth model, eco-efficiency improvements further promote consumption-growth. Thus it is a real threat that growth and consumption will out-scale efficiency gains.

CONCLUSIONS

The role of energy related technology transfer in greenhouse gas emissions from developing countries was discussed in this paper.

It has been shown in GHG emission reduction technology transfer does have a role, but only if certain circumstances stand, and if they contribute to multiple

[1] That raise significant security concerns.
[2] P. 174.

goals. It has been pointed out that technology transfer can easily result in progressive carbon lock-in when GHG reduction becomes more difficult.

Transferred technologies need nisch markets to upscale and government actions to yield economic and environmental gains. developing countries motivations, needs and capabilities with a special attention on domestic innovative capacities were emphasised, as an important factor of technology transfer adoption and further GHG reduction technologies' development.

The main conclusion is that technology transfer and domestic innovation could easily be insufficient, if development and energy consumption growth induced carbon emission out-scales carbon emission reduction results, thus the importance of complex, early policy formulation is stressed that can lead to radical technology change and addresses population and consumption problems.

REFERENCES

ACKER, R. and KAMMEN, D. (1996): The quiet (energy) revolution: Analysing the dissemination of photovoltaic power systems in Kenya. *Energy Policy*, Volume 24, Issue 1, January 1996, pp. 81-111.

AL-SOUD, HRYSAT, E. S. (2004): Rural photovoltaic electrification program in Jordan. *Renewable and Sustainable Energy Reviews*. Volume 8, Issue 6, December 2004, pp. 593-598.

ARENTSEN M., R. KEMP, and E. LUITEN (2002): "Technological change and innovation for climate protection: The governance challenge". In *Global warming and social innovation: The challenge of a carbon-neutral society*, edited by M. KOK, W. VERMEULEN, A. FAAIJ and D. DE JAGER. London: Earthscan.

AUNAN, K. et al. (2004): Co-benefits of climate policy – lessons learned from a study in Shanxi, China. *Energy Policy* Volume 32, Issue 4 , March 2004, pp. 567-581.

AWERBUCH, S., RAPHAEL, S. (2005): Exploiting the oil-GDP effect to support renewables deployment. *Energy Policy* Volume 34, Issue 17 , November 2006, pp. 2805-2819.

BAKSHI, R. (2002): Wind energy in India. *Power Engineering Review*, Vol. 22, Issue 9. pp. 16-18.

BARQUIN, R. (1981): Some introductory notes on the transfer of technologies. In *Industrial development and technology transfer*. Edited by SOEN, D. London: George Godwin.

BEERS, C., MOOR, A. (2001): *Public Subsidies and Policy Failures*. MPG Books Ltd; Cornwall.

BELL, R. G. et al. (2003): Clearing the air: how Delhi Broke the logjam on air quilaty reform. *Environment* Vol. 46, No. 3 pp. 22-39.

BERKHOUT, F., SMITH, A., STIRLING, A. (2003): Socio-technological regimes and transition contexts. *SPRU Electronic Working Papers*, No. 106. Sussex, UK. Accessed on 5 March 2007 at http://www.sussex.ac.uk/spru/1-6-1-2-1.html

BISWAS, W., DIESENDORF, M. and BRYCE, P. (2004): Can photovoltaic technologies help attain sustainable rural development in Bangladesh? *Energy Policy*, Volume 32, Issue 10, July 2004.

BHATTACHARYYA, C. S. (1995): Estimation of coal subsidies in India. *National Resource Forum*. Volume 19, Issue 2, 1995, pp. 135-142.

BURAN, B. et al. (2003): Environmental benefits of implementing alternative energy technologies in developing countries. *Applied Energy* 76 (2003) 89-10.

CASSEN, R. et al. (1982): *Rich Country Interests and Third World Development*. London: Croon Helm.

DRENNEN, T., ERICKSON, J. and CHAPMAN, D. (1996): Solar power and climate change policy in developing countries. *Energy Policy*, Volume 24, Issue 1, January 1996.

D'SA, A., MURTHY, K. (2006): Environmental Reform in the Electricity Sector: China and India. The *Journal of Environment & Development* Vol. 15. No. 2. pp. 158-183.

DUI, N., CARVALHO, M. (2004): Increasing renewable energy sources in island energy supply: case study Porto Santo. *Renewable and Sustainable Energy Reviews*, Volume 8, Issue 4, August 2004, pp. 383-399.

ESWA Report to the Forum on "Multilateralism and Regionalism: The New Interface", pre event of the 11th session of the UNCTAD XI (2004) Exploring potential of South-South agreements including global systems of trade preferences. http://www.escwa.org.lb/divisions/lib/Uploads/south-south.pdf

FORSYTH, T. (1998): Renewable Energy Investment and Technology Transfer in Asia. Report to Royal Institute of International Affairs, 7 May 1998.

GALLAGHER K. S. (2006): "Limits to leapfrogging in energy technologies? Evidence from the Chinese automobile industry". *Energy Policy*, 34 (4) pp. 383-394.

GARG, A. et al. (2001): Sub-region (district) and sector level SO2 and NOx emissions for India: assessment of inventories and mitigation flexibility. *Atmospheric Environment* 35 (2001) pp. 703-713.

GELB, S. (2005): South-South investment: the case of Africa. In *Africa in the World Economy* – The National, Regional and International Challenges Fondad, The Hague, December 2005 www.fondad.org. Accessed on 10 February 2007 at http://www.fondad.org/publications/africaworld/Fondad-AfricaWorld-Chapter16.pdf.

GELLER, H. (2003): *Energy revolution*. Island Press: Washington developing country.

GWEC (2006): Global wind energy outlook 2006. www.gwec.org accessed on 1st March 2007.

GOLDBERG, J. (1998): Leapfrog energy technologies. *Energy Policy* Vol. 26. No 10.

GUERIN, T. (2001): Transferring environmental technologies to China: recent developments and constraints. *Technological Forecasting and Social Change* Vol. 67, pp. 55-75.

HARRIS, E. (2004): Building scientific capacity in developing countries. *Science and Society* EMBO reports Vol. 5, No 1.

HE, B., CHEN, C. (2002): Energy ecological efficiency of coal fired plant in China. *Energy Conversation and Management* Vol. 43. Issue 18.

HUACUZ, J. M., MARTINEZ, A. M. (1995): Renewable energy rural electrification: sustainability aspects of the Mexican programme in practice (1995) Natural Resources Forum, 19 (3), pp. 223-231.

HUACUZ, J. M. (2005): The road to green power in Mexico – reflections on the prospects for the large-scale and sustainable implementation of renewable energy. *Energy Policy*, 33(16), pp. 2087-2099.

HUESMANN, M. H. (2003): The limits of technological solutions to sustainable development. *Clean Technology and Environmental Policy* Vol. 5, pp. 21-34.

IPCC (2000): *Methodological and technological issues in Technology Transfer*. http://www.grida.no/climate/ipcc/tectran/196.htm.

JAGADEESH, A. (2000): Wind energy development in Tamil Nadu and Andhra Pradesh, India: Institutional dynamics and barriers – A case study. *Energy Policy* Vol. 28. Issue 3.

KATHURIA, V. (2002): Technology transfer for GHG reduction, A framework with application to India. *Technological Forecasting and Social Change*, Vol. 69 (4) pp. 405-430.

KAYNAK, E. (1985): Transfer of Technology from Developed to Developing Countries: Some Insights from Turkey. In *Technology Transfer* edited by SAMLI, A., C. London: Quorum Books.

KENNEDY, H. T. (1997): China, India, SE Asia to spend billions constructing, upgrading transmission systems. *Power Engeneering International* 1997 January/February.

KLINE, D. et al. (2004): Clean energy technology transfer: a review of programs under the UNFCCC. Mitigation and Adaptation Strategies for Global Change Vol. 9, pp. 1-35.

KULKARNI, J. (2003): A Southern Critique of the Globalist Assumptions about Technology Transfer in Climate Change Treaty Negotiations. *Bulletin of Science, Technology & Society*, Vol. 23, No. 4, pp. 256-264 (2003).

KRAM, T. (1998): The cost of greenhouse-gas abatement. In *Economics and policy issues in climate change*. Edited by Nordhaus, W.: Resources for the future: Washington developing country.

LARSON, E. et al. (2003): Future implications of China's energy – technology choices. *Energy Policy* 31 (2003) pp. 1189-1204.

LEWIS, J., WISER, R. (2007): Fostering a renewable energy technology industry: An international comparison of wind industry policy support mechanisms. *Energy Policy*, Volume 35, Issue 3, March 2007, pp. 1844-1857.

LEW, D. (2000): Alternatives to coal and candles: wind power in China. *Energy Policy*, Volume 28, Issue 4, April 2000, pp. 271-286.

LORENZO, E. (1997): Photovoltaic rural electrification. Progress in Photovoltaics: Research and Applications, 5 (1), pp. 3-27.

LU, X., PAN, L., CHEN, Y. (2006): Sustaining Economic Growth in China under Energy and Climate Security Constraints. *China & World Economy* 14 (6), pp. 85–97.

LUUKKANEN, J., KAIVO-OJA, J. (2002): ASEAN tigers and sustainability of energy use - decomposition analysis of energy and CO_2 efficiency dynamics. *Energy Policy* Volume 30, Issue 4.

MARLAND, G., BODEN, T. A. and ANDRES R. J. (2006): Global, Regional, and National CO_2 Emissions. In *Trends: A Compendium of Data on Global Change*. Carbon Dioxide Information Analysis Center. Accessed 15 February 2007 at http://cdiac.ornl.gov/trends/emis/tre_glob.htm.

MARTINOT, E. (2001): World Bank energy projects in China: influances on environmental protection. *Energy Policy* Vol. 29, Issue 8.

MCKIBBIN, W. (2006): Environmental Consequences of Rising Energy Use in China. *Asian Economic Policy Review* 1 (1), pp. 157–174.

MCMULLAN, J. T., WILLIAMS, B. C. and MCCAHEY, S. (2001): Strategic consideration for clean coal R&D. Volume 29, Issue 6 , May 2001, pp. 441-452.

MIELNIK, O., GOLDEMBERG, J. (2000): Converging to a common pattern of energy use in developing and industrialized countries. *Energy Policy* Vol. 28 pp. 503-508.

MOREIRA, J., R., GOLDBEMBERG, J. (1999): The alcohol program. *Energy Policy* Vol. 27. pp. 229-245.

NAKICENOVIC, N., GRUBLER, A., MCDONALD, A. (1998): *Global Energy Perspectives*. Cambridge University Press: Cambridge.

NARVARTE, L., LORENZO, E., AANDAM, M. (2005): Lessons from a PV pumping programme in South Morocco. *Progress in Photovoltaics: Research and Applications*. Volume 13, Issue 3, May 2005, pp. 261-270.

OECD (1996): Improving the Environmental Through Reducing Subsidies. OECD: Paris.

PACALA, S. et al. (2004): Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies. *Science* 305, p. 968.

PACK, H., SAGGI, K. (1997): Inflows of Foreign Technology and Indigenous Technological Development. *Review of Development Economics* 1 (1), pp. 81–98.

PEDOBNIK, B. (2006): *Global Energy Shifts*. Temple University Press: Philadelphia.

PERKINS, R. (2003): Environmental leapfrogging in developing countries: A critical assessment and reconstruction. *National Resources Forum* Vol. 27. pp. 177-188.

PERKINS R., and NEUMAYER E. (2005): "The international diffusion of new technologies: A multitechnology analysis of latecomer advantage and global economic integration". *Annals of the Association of American Geographers*, 95 (4): pp. 789-808.

POTTERIE, B., LICHTENBERG, F. (2001): Does foreign direct investment transfer technology across borders? *The Review of Economics and Statistics*, August 2001, Vol. 83, Issue 3: pp. 490-497.

POZNANSKI, K. (1984): Technology Transfer: West-South Perspective. *World Politics*, Vol. 37, No. 1 (Oct., 1984), pp. 134-152.

RADY, H. (1992): Renewable energy in rural areas of developing countries: Some recommendations for a sustainable strategy. *Energy Policy*, Volume 20, Issue 6, June 1992, pp. 581-588.

RAGHUVANSHI, S. et al. (2006): Carbon dioxide emissions from coal based power generation in India. *Energy Conversation and Management* Vol 47, Issue 4.

RAMANATHAN, R. (2002): Successful transfer of environmentally sound technologies for greenhouse gas mitigation: a framework for matching the needs of developing countries. *Ecological Economics* 42 (2002) pp. 117-129.

RÜBBELKE, T. (2006): Climate policy in developing countries and conditional transfers. *Energy Policy*, Volume 34, Issue 13, September 2006, pp. 1600-1610.

SAMLI, A., C. (1985): Technology Transfer: The General Model. In: *Technology Transfer*. Edited by SAMLI, A., C. London: Quorum Books.

SAMLI, A., C. (1985): Technology Transfer to Third World Countries: The General Model. In: *Technology Transfer*. Edited by SAMLI, A., C. London: Quorum Books.

STERN, N. (2006): *Stern review on the economics of climate change*. Great Britain: The Stationery Office.

UNRUH, G., C. (2000): Understanding carbon lock-in. *Energy Policy* Vol 28., pp. 817-830.

UNCTAD (2006) World investment report FDI from Developing and Transition Economies: Implications for Development. www.unctad.org accessed on 10 February 2007 at http://www.unctad.org/Templates/WebFlyer.asp?intItemID=3968&lang=1.

VUUREN, D. et al. (2003): Energy and emission scenarios for China in the 21st century – exploration of baseline development and mitigation options. *Energy Policy* Volume 31, Issue 4 , March 2003, pp. 369-387.

SEBITOSI, A. B., PILLAY, P. (2005): Energy services in sub-Sahara Africa: how conducive is the environment? *Energy Policy* Volume 33, Issue 16 , November 2005, pp. 2044-2051.

WANG, X. and SMITH, K. R. (1999): Secondary Benefits of Greenhouse Gas Control: Health Impacts in China. *Environ. Sci. Technol.*, 33, 18, pp. 3056 – 3061.
WATSON, J., XUE, L., OLDHAM, G., MACKERRON, G. and THOMAS, S. (2000): "International Perspectives On Clean Coal Technology Transfer to China". *Final Report to the Working Group on Trade and Environment*, CCICED. Access on 10 March 2007 http://www.iisd.org/pdf/cctt_final_report_aug00.pdf.
WEIDOU, N., JOHANSSON, T. (2004): Energy for sustainable development in China. *Energy Policy* Vol. 32. Issue 10.
WEISSER, D. (2004a): On the economics of electricity consumption in small island developing states: a role for renewable energy technologies? *Energy Policy*, Volume 32, Issue 1, January 2004, pp. 127-140.
WEISSER, D. (2004b): Power sector reform in small island developing states: what role for renewable energy technologies? *Renewable and Sustainable Energy Reviews*, Volume 8, Issue 2, April 2004, pp. 101-127.
WEYANT, J. (1998): The Costs of Carbon Emissions Reduction. In: *Economics and policy issues in climate change*. Nordhaus, W., Resources for the future: Washington developing country.
WILKINS, G. (2002): *Technology Transfer for Renewable Energy*. Earthscan: London.
WORRELL, E. et al. (2001): Technology transfer of energy efficient technologies in industry: a review of trends and policy issues. *Energy Policy* 29 (2001) pp. 29-43.
XU, B. (2000): Multinational enterprises, technology diffusion, and host country productivity growth. *Journal of Development Economics* Vol. 62 (2000) pp. 477-493.
YANG, H. (2006): Overview of the Chinese electricity industry and its current uses. www.electricitypolicy.org.uk Access on 9 March 2007 at http://www.electricity policy.org.uk/pubs/wp/eprg0517.pdf
IEA (2006): *World Energy Outlook 2006*. IEA: Paris.