Enabling the Transfer of Environmentally Sound Technologies in the Context of Climate Change: Some Lessons from Asia[1]

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ABSTRACT

This study reviews the features and challenges of the international transfer of environmentally sound technologies (ESTs) in the context of climate change. It highlights role of an enabling environment in successful transfer of ESTs, and gives two case studies: the Japanese energy success in the 1970s and 1980s and the recent successful wind farm development in the Inner Mongolia of China. The study concludes that the creation of an effective enabling environment is key to the effective transfer of ESTs. Creating an effective involves the establishment of three appropriate partnerships: the partnership between public sector and private sector, the partnership between central government and local government; and the partnership between developing and developed countries. It also concludes that a win-win outcome could occur if the governments in both developing and developed country genuinely take practicable cooperative actions.

Keywords: Technology transfer; climate change; institutional reform

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CONTENTS

I. INTRODUCTION

In addition to strengthening emission regulations and increasing the price of fossil fuels, the transfer of environmentally sound technologies (ESTs) is often regarded as another key approach to curb the rise in greenhouse gas emission. Since the transfer of ESTs can also expand international technology trade and yield immediate and tangible economic and environmental benefits, there would seem to be substantial potential for international cooperation in this sphere based on mutual self-interests of the key stakeholders such as governments, private sector entities, financial institutions, non-governmental organizations(NGOs) and research/education institutions.

In this context, since the United Nations Framework Convention on Climate Change (UNFCCC) was signed at the 'Earth Summit' in Rio de Janeiro in 1992, increasing importance has been attached to the transfer of ESTs in international environmental initiatives. The Convention has embodied the transfer of ESTs in its several articles, such as Article 4, Article 9, Article 11, and Article 12. Furthermore, a series of special decisions were made on the transfer of ESTs by the four previous sessions of the Conference of Parties.

However, while there is broad recognition the potential benefits of technology transfer, progress to transfer ESTs has been slow. Among others, a key issue is the lack of an enabling environment that provides a platform to support the development, use, and transfer of environmentally sound technologies. What is the nature of this issue? How could this issue be solved? What are the major elements of the approach? Although these questions have been identified so far, they are mostly addressed in a general sense and most existing studies have focused on identifying general barriers to and general measures for the transfer of ESTs. Specific and well-focused studies have been lacking. This study is an effort to overcome the deficiency of existing approaches. We approach to address these questions by conducting two concrete case studies concerning the creation of the enabling environment for technology transfer.

The first case study deals with the creation of an enabling environment for energy conservation in the Japanese industry in 1970s and 1980s. The second is on the development of wind farms in Inner Mongolia of China. The case study of Japan could provide lessons for such countries under industrialization as China and Korea in their efforts to create an enabling environment for the transfer of energy efficient technologies. The case study has two orientations: one is to provide lessons for developing countries in their efforts to create a domestic enabling environment and the other is to provide lessons for both developing and developed countries in international cooperation for the transfer of renewable energy technologies. The two case studies not only provide us with lessons regarding the creation of an enabling environment, but also help us understand the nature of the issue of technology transfer.

The report is structured as follows. Section 2 reviews the features and major challenges involved in the transfer of ESTs in the context of climate change; Section 3 is a case study of Japanese energy technology innovation in 1970s and 1980s; Section 4 is a case

study of wind farm development in China's Inner Mongolia; finally, Section presents a summary and concluding comments of the report.

II. THE TRANSFER OF ESTS IN THE CONTEXT OF CLIMATE CHANGE

2.1 The elements of the transfer of ESTs

The international transfer of ESTs usually refers to a process of conveying technology from a developer in developed countries to a user in developing countries. The term "technology" has evolved from the simple technology embodied in specific capital, other inputs, and products to knowledge itself – disembodied technology (Lile and Toman, 1997). Technology transfer is a process that results in knowledge generated in one place, being utilized somewhere else (Mock, 1988). So, "technology" should include not only "hard technologies", but also "soft technologies".

However, technology is often interpreted in a narrower sense than this, to mean only the hardware of production; but hard technologies can only be successfully absorbed and developed if complementary soft technologies are in place. The past experience of technology transfer to developing countries has indicated that hard technologies cannot succeed without the local infrastructure and know-how to support them (Ross, 1991).

In the context of climate change, examples of soft technologies include capacity building, information networks, training and research, while examples of hard technologies include equipment and products to control, reduce or prevent anthropogenic emissions of GHG in energy, transportation, forestry, agriculture, industry and waste management sectors, to enhance removals by sinks, and to facilitate adaptation[2].

The fundamental elements of the process of the transfer of ESTs are the technology itself, the decision-making process of developer and user, and the information flow between developer and user. Although there are often other actors involved in the process such as governments, international organizations, NGOs, and so on, they affect the process through influencing the decision-making process of developer and user. The trajectory of the transfer of ESTs is a function of the dynamic technology transfer environment that consists of both economic and cultural variables. These variables determine the decision-making process of developer and user to a great extent.

While the economic environment is cast as the nexus of market structure and governmental interventions, the cultural environment highlights the differences in culture among firms that desire to transfer technology (Jensen and Scheraga, 1998). Market structure includes consideration of the number of competitors, the extent of the market, and the cost structure of the industry.

The transfer of ESTs brings with it both costs and benefits, and take place when the perceived benefits outweigh the perceived costs of the transfer. Both developer and user considering a transfer of technology must consider both the cost imposed by market

[2] See FCCC/SBSTA/1996/4

structure and government intervention and the cost imposed by the culture environment. An enabling environment can reduce the costs of technology transfer and provide a platform to support the development, use, and transfer of ESTs. As a consequence, the creation of an enabling environment is a key element of broad approaches to the effective transfer of ESTs.

2.2. Enabling Technology transfer under UNFCCC

Because of a general recognition of the role of technology transfer in achieving sustainable development and mitigating GHGs, substantial efforts have been taken towards creating an enabling environment for the transfer of ESTs by the UNFCCC.

The UNFCCC was signed at the 'Earth Summit' in Rio de Janeiro in 1992. Article 4.1(c) articulates that all parties shall promote and cooperate in the development, application, and diffusion, including transfer, of technologies, practices and processes that control, reduce, or prevent anthropogenic emissions of greenhouse gases not controlled by the Montreal Protocol in all relevant sectors, including the energy, transport, industry, agriculture, forestry and waste management sectors. Its Article 4.5 requires that the developed country Parties and other developed Parties included in Annex II shall take all practicable steps to promote, facilitate and finance, as appropriate, the transfer of, or access to, environmentally sound technologies and know-how to other parties, particularly developing country Parties, to enable them to implement the provision of the Convention. Its articles 4.3, 4.7, 4.8, 4.9, 9.2, 11.1, 11.5, 12.3 and 12.4 also have direct relevance to the transfer of ESTs. Since then the transfer of ESTs from industrialized to the developing countries has been central to global initiatives to reduce greenhouse gas emissions.

Adopted by the United Nations General Assembly at its nineteenth special session, the Agenda 21 is the action plan developed as a way to implement the Earth Summit agreements, and serves as an important international environment law. It has a special chapter, Chapter 34, to deal with the issue of transfer of ESTs between developed and developing countries. Chapter 34 states that access to ESTs should be promoted on favorable terms, including on concessional and preferential terms, as mutually agreed, taking into account the need to protect intellectual property right as well as the special needs of developing countries. The chapter also underlines the importance of supporting endogenous capacity building in developing countries and promoting long-term technological partnerships between holders of environmentally sound technologies and potential users.

The first Conference of Parties (COP1) of the UNFCCC, held in Berlin in 1995, made two important decisions. They are Decision 5/CP1 "Activities implemented jointly under the pilot Phase" and Decision 13/CP1 " Transfer of Technology". While Decision 13/CP1 is a special decision to address the issues involving in transfer of ESTs, Decision 5/CP1 has also a clear relevance to the transfer of ESTs. Decision 13/CP1 requests the Convention secretariat to prepare an itemized progress report on concrete measures taken by the Parties in Annex II to the Convention, with respect to their commitments related to

the transfer of ESTs and know-how. The decision reiterates supporting and promoting the development of endogenous capacities and appropriate technology in developing countries relevant to the objectives of the Convention.

The Geneva Conference of Parties (1996) also adopted a special decision on the transfer of ESTs, Decision 7/CP.2 “Development and transfer of technologies”. The decision urges Annex II Parties to expedite their efforts in the transfer of technology in fulfillment of their commitments under Article 4.5. It also urges all Parties, particularly Annex II Parties, to improve the enabling environment, including the removal of barriers and the establishment of incentives, for private sector activities that advance the transfer of technologies to address climate change and its adverse impacts. Decision 9/CP.3 “Development and transfer of technologies”, made by Kyoto Conference of Parties in 1997, urges Parties to create an enabling environment to help further stimulate private-sector investment in, and transfer of, environmentally sound technologies.

The Buenos Aires Conference of Parties (1998) reiterated the need for continued efforts by Parties to promote and cooperate in the development, application, diffusion and transfer of technologies, and formulated decision 4/CP.4. The decision (4/CP.4) also raises a list of issues and questions related to technology transfer, and requests the Chairman of the Subsidiary Body for Scientific and Technological Advice (SBSTA) to establish a consultative process to consider these issues and questions.

2.3 The Challenge

Although the crucial role of the transfer of ESTs in combating climate change has been widely recognized by all Parties, there is an apparent division about how this could and should be done between Annex II and non-Annex II Parties.

Many developing countries consider the transfer of ESTs to be essential for the attainment of sustainable development, and a prerequisite for any discussion about developing countries considering possible future reductions in GHG emissions. They believe that technology transfer should be on the most favorable conditions since industrialized countries have been major emitters of GHG in the past 200 yeas. They insist that technology transfer is a *commitment* of developed countries under the UNFCCC.

Hence, many developing countries perceive the transfer of ESTs as simply government-to-government transfer. To them, the transfer of ESTs can only be facilitated by inter-state cooperation. As a consequence, the need for increased transfer of both technical and financial resources has been at the top of their agenda in international environmental negotiations for many years (Anderson and Forsyth, 1997). They attribute the slow progress in technology transfer largely to the lack of political will of the industrialized parties to transfer ESTs on preferential and concessional terms or the inadequate implementation of Article 4.5 of the UNFCCC on technology transfer.

Developed countries, on the other hand, insist that most ESTs are owned by the private sector, and that it is the private sector and market forces that control technology development and transfer. They stress that the majority of technology is transferred from developed countries to developing countries through private trade transactions. According to OECD estimates, 77% of technology is transferred to developing countries through foreign trade (Chin, 1997).

Developed countries insist that technology transfer can not proceed successfully only on a government-to-government basis, and point to the questionable record of some previous government-to-government technology transfer programmes. To them, technology transfer needs to be seen as a complex commercial process involving the transfer of markets and management as well as environmental goods and services. As a result of this, they believe that successful transfer of ESTs lie in creating a clean-technology market in developing countries.

As a result of the above disputes, on one hand developed country Parties hitherto have not demonstrated strong will and adequate actions to implement their commitments related to the transfer of ESTs under the UNFCCC and the Agenda 21. Developing country Parties have not taken enough efforts to conduct institutional reforms needed by the effective transfer of ESTs while complaining developed country Parties lack of political will to fully implement their commitments on the other hand. Consequently, so far there does not exit a favorable environment for the transfer of ESTs, which constrains the effective transfer of ESTs.

2.4 From prisoner's dilemma to a win-win outcome

In addition to reducing the growth of greenhouse gas emissions and expanding international technology trade, the transfer and diffusion of ESTs often yield immediate and tangible economic and environmental benefits for both developing and developed countries. Thus, there would seem to be substantial potential for cooperation between developing and developed countries in this sphere based on mutual self-interests. However, as noted by the previous sessions of the Conference of Parties and the discussions above, there are not inadequate cooperative actions taken by both developed and developing countries, which results in the slow progress in the transfer of ESTs. Such a situation might be represented appropriately by the *prisoner's dilemma*.

The transfer of ESTs is in essence an economic activity. However, as we argued above, the trajectory of the transfer of ESTs is a function of the dynamic technology transfer environment. Characterized by the nexus of market structure and governmental interventions, the economic environment is comprised of preference of consumers, public policy, and international cooperation. The preference of consumers is related to the market "pull" while both public policy and international cooperation are related to the government "push". Public policy can influence the preference of consumers as well[3]. Therefore, government plays a key role in the process of the transfer of ESTs. In this

[3] For example, public information campaign might change consumers' choice in favor of environmentally friendly goods.

context, the win-win strategy or the key to overcome the current prisoner's dilemma is for governments in both developing and developed countries to show real cooperative will and take practicable cooperative actions so that an enabling environment for the transfer of EST could be created and promoted.

In support of our arguments, we will give two case studies in the next two chapters. One is on the successful creation of an energy conservation environment in Japanese industry in the 1970s and 1980s, the other is on development of wind farm in China's Inner Mongolia. While the former could provide lessons for countries under industrialization such as China in terms of creating a domestic enabling environment, the later could provide lessons for both developing and developed countries in terms of creating domestic enabling environments as well as in terms of promoting international cooperation.

III. JAPANESE ENERGY SUCCESS IN 1970S AND 1980S

3.1 Introduction

The consumption of fossil fuels is the largest contributor to global CO_2 emission. Japan successfully reduced energy intensity and emissions of key air pollutants and CO_2 associated with energy use while maintaining a relatively high rate of economic growth. For example, from 1975 to 1989, Japan experienced an average annual economic growth rate of 5.7% while its CO_2 and SO_x emission declined by 0.005% and 4% respectively. Therefore, it set a good example for the world in terms of decoupling GDP growth from energy consumption in 1970s and 1980s. Studies showed that Japan's energy success was largely attributed to its widespread energy technology innovation[4], a process of substituting technology for fossil fuels. Furthermore, comparatively lower direct government investment characterized Japan's energy technology innovation pattern. For example, even under the much publicized national Moonlight Project[5], public funding accounted for only 3-6% of total expenditures on energy conservation R&D (Fukasaku, 1995). In this context, Japan's experience in energy technology innovation could provide some lessons for the developing economies that have not yet decoupled GDP growth from energy consumption, such as China and Korea. For example, Chinese energy efficiency is still approximately 10% below that of Japan, although recently China has experienced a significant decrease in energy intensity.

3.2 *Japanese energy policy shift after World War II*

After World War II, economic development was given the highest priority among Japanese national strategies just as most developing countries pursuit now. Accordingly, the goal of Japan's energy policy was to secure energy supply for high economic growth. From 1947 to the end of the 1950s, this energy policy promoted coal production and

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[4] See, for example, Okimoto (1987), Mowery and Rosenburg (1989), Watanabe and Yukio (199 and 1992), and Watanabe (1995).
[5] The Moonlight Project was a great initiative of the Japanese government to promote the development and commercialization of energy efficient technologies and nuclear power technologies in 1980s.

consumption due to Japan's relative rich coal resources. The government allocated a significant portion of the reconstruction loans to the coal mining industry between 1947 and 1949 (Fukasaku, 1995). In the 1950s, however, this coal-favored policy began to loose its effectiveness because of the low international petroleum price. By 1962, petroleum's share in the national energy balance firstly overtook that of coal. As a consequence, during the 1960s, the government policy was reoriented to secure supplies of low cost imported petroleum. A petroleum industry law was adopted in 1962, which enabled the Ministry of International Trade and Industry (MITI) to exercise administration guidance to coordinate the growth of the petroleum importing and refining industry.

A deficiency of Japan's post war development strategies was that the environmental dimension was ignored during the first two decades. High economic growth was coupled with the development of serious health hazards. Up to the early 1960s, pollution was so severe that it caused serious health hazards, such as the well known 'Yokkaichi air pollution' (Fukasaku, 1995). Because of increased public awareness of environmental problems, the first Air Pollution Law was passed in 1962, the Basic Law for Environmental Pollution Control in 1967 and other environment-related laws by the end of the decade. These pieces of legislation enabled the government to adopt and enforce environmental quality standards, especially emission standards for pollution that was largely attributed to energy consumption. As a result, environmental concerns became a new dimension of Japan's energy policy, the petroleum industry was guided to import low sulfur petroleum and install flue gas desulphurization equipment.

In 1973, the petroleum crisis occurred. The crisis brought Japan a serious panic because 80% of its energy consumption depended on imported petroleum. The government, which had done little to anticipate this crisis, was forced to take emergency measures to curtail petroleum consumption. Although securing energy supply and preventing environmental degradation were still the two basic goals of Japanese energy policy, the approach to achieving these goals changed significantly, considering the need to achieve energy supply security.

The new approach was characterized by emphasizing substitution of technology for petroleum, that is energy technology innovation, which was reflected in the energy policy recommendations drafted by the Advisory Committee for Energy in 1975: (i) reducing dependence on petroleum by diversifying energy sources; (ii) stabilizing petroleum supply; (iii) promoting energy conservation; and (iv) research and development of new energy sources (Fukasaku, 1995). Since energy technology innovation can simultaneously serve both the energy security and the environmental objective, it soon became one of the two cornerstones of the Japanese energy policy together with stabilizing petroleum supply. Such an energy policy shift enabled substantial institutional initiatives for energy technology innovations in the late 1970s and the entire 1980s.

3.3 Institutional initiatives for energy technology innovations

Figure 1 depicts the institutional structure for energy technology innovation in Japan. As shown in Figure 1, the institutional framework is enabled by the *Law for Rationalization of Energy Use*, which is often called the *Energy Conservation Law*. In addition to the *Energy Conservation Law*, the framework includes governmental energy technology innovation instruments and energy technology innovation related institutions. The instruments cover regulations, economic incentives, public R&D, and public information campaigns. Energy technology innovation related institutions involve universities, research institutes, financial institutions, governmental agencies, and innovators including enterprises and households.

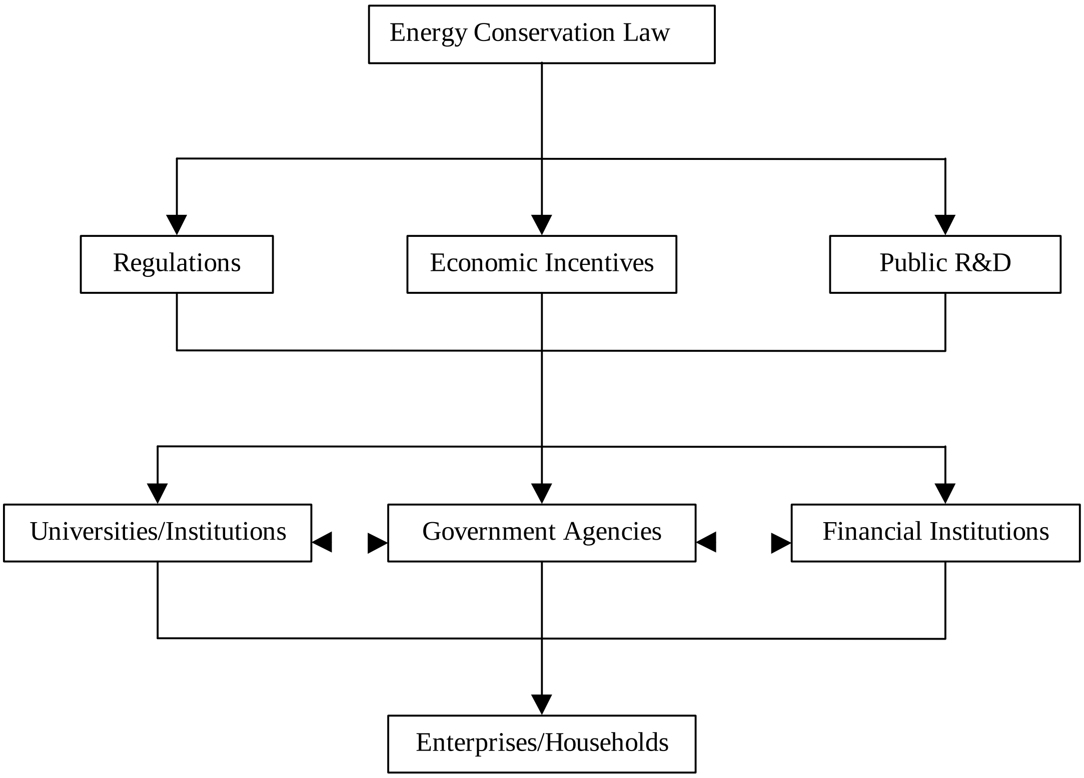

Figure 1. The institutional framework for energy technology innovation in Japan

The *Energy Conservation Law* was enacted on June 22, 1979, only one year after the second petroleum crisis, for the purpose of reducing Japan's energy vulnerability through reducing the amount of energy use. The law has four main components: (i) general provisions; (ii) guidelines for industry and for construction; (iii) regulations for industrial products, and (iv) government supported R&D. In the section on general provisions, the basic principle for government interventions is prescribed. This chapter states clearly that the MITI shall formulate and make basic public policies concerning the rational use of

energy for the purpose of promoting the comprehensive rational use of energy at factories or other places such as commercial buildings. The MITI policies created incentives for energy users to apply energy efficient technology.

Japan Development Bank (JDB) is a policy-based financial institution funded entirely by the Japanese government. The major function of JDB is to provide long-term and low interest rate loans for the projects of importance both to the people and to the national economy, but might be difficult to acquire high quality funds from private financial institutions because of high risks and/or huge investment requirement. JDB has a special low interest rate loan scheme for investments aimed at promoting rational energy use. Establishments which conduct energy technology innovations are eligible to apply. The interest rate was around 7% to 8% percent on average from 1975 to1985, which was about 1% lower than private banks'. Because of the huge size of energy efficiency investment, 1% reduction was a big stimuli for establishments to invest in energy saving. Furthermore, in most cases the payback period of JDB loan was 15 years while that of private banks was10 years.

In 1978, a special depreciation scheme was introduced to stimulate investments in energy technology innovations. Under the scheme, innovators could apply 25% of total investment for special depreciation, and receive a tax reduction by 10% for total investment cost in the first year. The projects supported by the scheme include recycling heat boiler, recycling gas boiler, energy efficient boiler for industry uses, steam accumulator, heat pump air conditioner and so on. The scheme was introduced one year before the *Energy Conservation Law* was enacted, but confirmed by the law. The program was extended to a new scheme in 1981, under which innovators could choose either a preferential taxation at 7% or special depreciation of 30% of total investment cost. This scheme is still available to innovators.

Government supported R&D is also an important element of the institutional framework. R&D can often improve the performance of equipment and reduce the cost of energy technology innovations simultaneously. Because of the free-rider problem, R&D is often funded by private enterprises at levels less than the social optimal levels(Jaffe and Stavins, 1994).

Japan's public R&D is characterized by a strong connection between the government and industry. MITI is responsible for formulating forecasts or macro targets for future technology development. The New Energy and Industrial Technology Development Organization (NEDO), a semi-governmental organization, bridges government and industry. Most of energy technology policies have been overseen by this organization. NEDO was established in October 1980, following the second petroleum crisis. Its function, as prescribed by the Energy Conservation Law and the Oil Substitution Law, is to promote the commercialization of new energy technology development and application to reduce Japan's energy vulnerabilities. New energy technology covers energy saving technologies. NEDO's function was extended to incorporate environmental technology R&D in 1990s.

NEDO is often regarded as a Japanese government agency, but it is actually a quasi-governmental organization, not a part of the government. It coordinates funds, personnel, and technology development among the government, private enterprises, universities, research institutes, local governments, and even foreign energy related institutions. Its total budget for R&D projects was 349 billion yen in fiscal year 1998, and 30.3% of its budget was allocated to energy related projects. NEDO has a stall of 1,165, of which one third is engaged in energy related projects. Approximately one third of its energy staff comes from private enterprises, less than one third are temporary governmental staffs who work with NEDO for about two or three years, and more than one third are permanent. The composition of NEDO staff further demonstrates NEDO's role of bridging the activities and interests of government and private enterprises.

NEDO has coordinated a large number of energy related R&D projects within its annual budget. It was also a main coordinator of the national Sunshine project and the Moonlight project. The Sunshine project was oriented to develop renewable energy technologies, such as solar, wind, geothermal and so forth while the Moonlight project promoted development of energy efficient technologies as well as nuclear power technologies. NEDO has played an important role in promoting the commercialization of new technologies developed under these two projects. The total budget for the two projects amounted to hundreds of billion yen. Private sector alone could not afford such a huge R&D expenditure.

Note that improving energy intensity was not a mandate in 1970s and 1980s. Rather, the government's role was limited to making guidelines and incentives for energy users. The government set the national target for lowering energy intensities, but users could decide their own strategy for energy savings. Under such a 'voluntary' institutional framework, information institutions were desperately needed to supply information about cost-effective energy technologies to users. Within the framework, the Energy Conservation Center Japan (ECCJ) has played an import role in overcoming the market failure of information under-provision.

ECCJ was established as non-profit and non-governmental organization in 1979. Its activities are very broad, but mainly oriented to providing energy technology related information. It publishes monthly magazines containing useful information on energy technologies, organizes comprehensive exhibitions and public information campaigns to raise awareness for energy conservation, provides training services for energy management, and gives recommendations for energy efficiency improvement to outstanding factories which produce machines, devices and systems, and materials.

ECCJ also maintains a 'bank of experts', boasting many experts in various fields such heat, electricity, policy and so forth. Thus, providing technical assistance to energy users is an important business of ECCJ, which can significantly reduce the learning cost of energy users. ECCJ often conducts energy surveys and collects data on energy conservation. It also offers free energy audit service for medium sized factories, small firms, and office buildings, and dispatches experts to these establishments for energy conservation. These experts are very knowledgeable not only in terms of technologies but

also in terms of governmental economic incentives for the investments to energy saving facilities. ECCJ also conducts information and consultative services by other ways, such as holding conferences for the presentations of successful energy conservation cases.

3.4 Lessons learned

Japan's energy technology innovation experience in 1970s and 1980s demonstrates or supports that:

- a domestic enabling environment for the development and adoption of energy technologies can be created by appropriate government intervention efforts;
- energy technology policy should be integrated with national economic policy and environment policy;
- such command-and-control instruments as enforcing energy-efficiency measures and environment pollution standards can effect the creation and development of an energy technology market;
- institutional reform should be oriented to promote market structure change towards alternative energy production, but also allow considerable autonomy in the ways businesses may achieve these goals;
- soft technologies, in the form of capacity building, information networks, training and know-how play an important role in the development and adoption of hard technologies, in the form of plant, machinery and equipment; and
- well-functioning markets, clear incentives, and an appropriately targeted role for direct government intervention are the three most important elements of the Japanese successful energy technology innovation story.

IV. WIND FARM DEVELOPMENT IN INNER MONGOLIA OF CHINA

4.1 Introduction

China's energy consumption experienced an annual growth rate of 5 – 6 % during the past 15 years, reaching 1,388 million tons of coal equivalent (tce) in 1996. Annual GDP growth over the same period was approximately 10%. The primary source of energy in China is coal, accounting for approximately 75% of the total commercial energy use. Oil provides about 17.6%, hydro power and nuclear power total 5.8% and natural gas provides 1.6%. China's energy consumption volume and pattern has made China the second largest energy user as well as the second largest CO_2 emitter in the world after the United States. It is expected that China's CO_2 emission will surpass that of the United States in 10 – 15 years, making China the world's largest source of GHG emission by the year 2015.

China has one of the best renewable energy endowments in the world. National wind resource potential exceeds 255 GW. Solar radiation is excellent, with 17 million Mtce (or 50,000 EJ) of solar energy absorbed at the surface annually. Hydro, biomass and geothermal resources are also abundant in some provinces. It is estimated that

approximately 300 Mtce of biomass could be used for energy purposes. The resource potential for mini-hydro is 76 GW and 6.7 GW for geothermal.

Despite this rich potential and associated environmental and social benefits, the utilization of renewable energy resources in China has been limited by a lack of reliable and economically viable technologies. So far, only small hydro power has been fully commercialized with an installed capacity of 19 GW in 1996, representing 8% of the total national generation capacity. Other renewable energy sources, in contrast, make up only a marginal share of China’s energy supply.

Inner Mongolia, however, is often regarded as a successful case of wind energy development in China, particularly in the perspective of technology transfer. It has already led China in the field of small wind generator installations, and currently ranks second behind the Xinjiang Autonomous Region in terms of wind farm development but will overtake Xinjiang in this area by the end of this century. Largely encouraged by Inner Mongolia’s successful story, the Chinese government and the World Bank recently implemented a new renewable energy project. The total investment in project is US$135 million, the ever-largest renewable energy project in China. This stand-alone renewable energy project will support the development of 190 MW of wind farms and about 10MW of solar home systems, plus related technical assistance. The project has attracted a large number of foreign and domestic companies.

Since almost all the wind farm technologies installed in Inner Mongolia are introduced from developed countries, analyzing Inner Mongolia’s wind farm development has significance at least in three perspetives: (i) could help us better understand the process of technology transfer; (ii) could provide lessons for other parts of China as well as other developing countries in terms of creating enabling environment; and (iii) could enable us to draw lessons for both developing and developed countries to overcome the current *prisoner’s dilemma* in the international transfer of ESTs.

3.4 Social, economic and environmental motivations

Inner Mongolia is one of the pioneers in terms of wind generation technology development and dissemination in China. It started its wind generation efforts in the late 1950s. Before 1988, Inner Mongolia concentrated its wind power development efforts on Household Wind Generators (HWG). In 1988, HWG installations reached 76,000 units with a total installed capacity of 7,100 kW. These installations provided more than 300,000 people in the remote rural and pastoral areas with access to electricity. Since 1989, Inner Mongolia began to construct Wind Farms (WF). By the end of 1997, the accumulated installed WF capacity reached 39, 775 kW and surpassed that of HWG (18,500 kW), marking a new era in wind energy development in Inner Mongolia. Inner Mongolia’s WF capacity ranks second in China, after the Xinjiang Autonomous Region (64,650 kW), but will exceed Xinjiang with an installed capacity of 150,000 kW by 2000 according to its development plan. Inner Mongolia’s fast WF development was largely attributed to the substantial policy and institutional initiatives of the local and state government and international cooperative efforts.

In addition to an abundant wind resource, Inner Mongolia has rich coal resources. Estimated coal reserves are 210 billion tons. Neighboring provinces and cities, such as Beijing and Tianjin, have a huge demand for energy, particularly for electricity, because of fast economic growth. Thus, Inner Mongolia can benefit from electricity production and export to other regions. Electricity generation and export are regarded as one of Inner Mongolia's basic economic development strategies. In 1997, Inner Mongolia exported 1,000MW of electricity to Beijing with a total energy equivalent about 6.5 billion kWh, which was approximately 23.3% of Beijing's total electricity consumption of that year. According to a new contract, Inner Mongolia's electricity export to Beijing will reach 2,000 MW, approximately 12 billion kWh, in 2000, which will constitute 28.26% of Beijing's total electricity demand (Chen, 1998).

Before 1989, all electricity was produced by coal in Inner Mongolia. On one hand, coal-fired electricity production and export contributed to Inner Mongolia's economic growth; on the other hand, the fast development of coal-based electricity caused serious local (particulate), regional (SO_x), and global (CO_2) environmental problems. For example, the most widely used 300 MW steam turbine generation system consumes about 4 tce of coal in generating 10,000 kWh electricity. Resultant emissions are approximately 0.5 ton of particulate, 0.08 ton of SO_x, 0.05 ton of NO_x, and 10 tons of CO_2 (Wu, 1998).

In the 1980s, the increasing global, national, and local environmental concerns resulted in the re-examination of Inner Mongolia's electrical development strategy. Power source optimization, particularly with the concern for power source diversification, became a new element of the Inner Mongolia's electricity development strategy. This new strategy aimed at reducing dependence on fossil fuel based energy systems, and addressing the increasingly serious environmental pollution problems. Therefore, wind farms provide an emission free option for the energy system development in the region. Furthermore, the areas covered by the main lines of the Western Inner Mongolia Grid have exceptional advantages for the construction of wind farms. In these contexts, wind farms development has become integrated into Inner Mongolia's electricity plan since the mid-1980s.

4.3 Policy and institutional initiatives

The policies for wind farm development in Inner Mongolia consist of central government and local government policies, including, wind farm grid-connection regulation, wind electricity pricing, taxation, and government credit, etc.

The former Ministry of Power Industry issued the *Regulation on Grid-Connection Management of Wind Farms* in 1994. According to the regulation, all utilities have an obligation to purchase electricity produced by wind farms. The regulation stipulates that wind farms can sell electricity to power grids at a price based on electricity production cost plus reasonable profit, and the difference between the wind electricity price and the grid's average electricity price should be shared by the whole grid. In 1995, the Inner Mongolia Price Administration approved that the wind farms could sell electricity to

power grids at 0.71 yuan/kWh while the coal-fired power plants at 0.35 yuan/kWh. The Inner Mongolia Price Administration also approved that the Inner Mongolia Utility could increase its electricity price by 0.2 yuan/kWh to all its consumers in order to recover the added cost of wind electricity purchase.

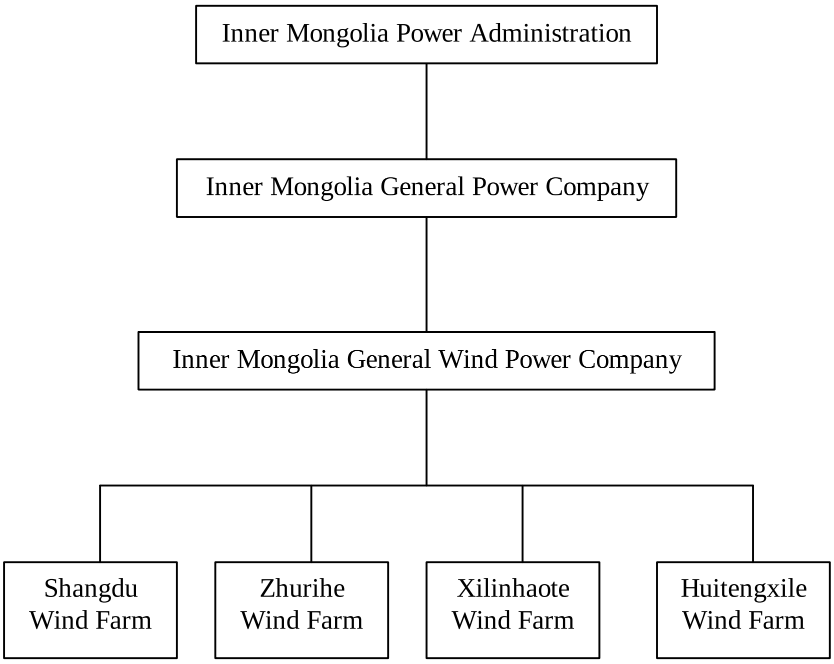

Figure 2. The institutional infrastructure of wind farm development in Inner Mongolia

Since 1995 the Inner Mongolia government has reduced the Surtax of the Value Added Tax (VAT) of wind farms from 8% to 3%. The local government also provided wind farms with preferential land use policy. According to the policy, land royalties are calculated according to the land actually used or the land occupied by the wind farm buildings, facilities, and roads. Foreign investors can enjoy two years of complete income tax exemption and another two years of half income tax exemption from the year of profit making. If their investment ranges from 3.01 million US dollars to 5 million US dollars, foreign investors can also enjoy 5 years of land royalty exemption if the land occupied is cultivated land or 10 years of land royalty exemption if the land has not been used.

In 1995, the Energy Conservation Investment Company, a financial policy institution affiliated with the State Planning Commission, provided 16 million yuan of energy conservation loans for the purchase of the four 250 kW wind turbines installed in Inner Mongolia's Xilinhaote wind farm. In 1996 the State Economic and Trade Commission (SETC) chose the construction of the Huitengxile wind farm as the demonstration project of its *Shuangjia* Program, and financed a 200 million yuan loan for the project. The interest rate of the loan is 13% and the payback period is 7 years[6].

[6] In 1996, the long-term commercial interest rate was about 15%.

In line with the policy initiatives, an institutional infrastructure has also been established for the development of wind farms in Inner Mongolia. As shown in Figure 2, the Inner Mongolia Wind Power General Company (IMWPGC) is the core of the infrastructure. As an affiliation of the Inner Mongolia General Power Company, IMWPGC was set up in 1995. IMWPGC is an independent legal entity, and currently operates four wind farms, viz., Shuangdu Wind Farm, Zhurihe Wind Farm, Xilinhaote Wind Farm, and Tenghuixile Wind Farm, with more than 100 employees.

4.4 The role of international investment and technology transfer

Most of the wind turbines installed in Inner Mongolia are imported from abroad since neither Inner Mongolia nor China as a whole has the capability to manufacture the wind turbines with capacity over 600 kW. Table 1 summarizes the wind turbine installations in the four wind farms in Inner Mongolia. As shown in Table 1, completely domestically made wind turbines only account for only 0.7% of the total installed capacity of the four wind farms. Wind turbines made by joint venture companies account for 5.5%, and the remainder are completely foreign made. Denmark is the largest wind turbine supplier to Inner Mongolia, and its wind turbines account for 74.4% of the total installed capacity of the four wind farms. Wind turbines made in US and Germany account for 16.6% and 2.5%, respectively.

Table 2 lists the international investment in the four wind farms since 1993. The total investment for the accumulated 39,775 kW of installed capacity is approximately 377.9 million yuan (45.9 million US dollar). The accumulated international investments have already reached 114.4 million yuan (13.9 million US dollars), or 30% of the total investment. International investments from bilateral and multilateral sources are usually provided with favorable conditions. They are either government grants or low interest rate soft loans. For example, of the 4 million US dollars loans from the Danish government, 85% is interest free loan and the rest is commercial loan. The interest rate for the 3.7 million US dollars of US government soft loan is only 0.75% with a payback period of 9 years. So, we can see that international assistance and technology transfer have played a very important role in Inner Mongolia's wind farm development and dissemination.

4.5 Barriers

- High costs for imported wind turbines

Manufacture of wind turbines requires high technology inputs. Due to the limitation of technical and human resources, China is not yet able to produce large wind turbines. As shown in Table 1, almost all the installed wind turbines in the wind farms of Inner Mongolia are imported from abroad. The cost for imported wind turbines is as high as 8,000-9,000 yuan/kW. Since the cost of wind turbines normally constitutes about 75% of the total wind farm investment, this becomes a major contributor to the high wind electricity production cost, which makes wind farms not competitive compared with

conventional coal-fired power plants. The sale price for wind electricity is 0.71 yuan/kWh, while the electricity from coal-fired plants is sold at 0.35 yuan/kWh. It is estimated that the cost of wind turbines could be reduced by 30% if they are produced domestically (Zhao et al., 1998).

Table 1. Wind turbine installations in wind farms in Inner Mongolia

Wind turbine type	Capacity per set (kW)	Installation number	Date of export electricity to the grid	Manufacture country	Installed capacity (kW)
Windpower	100	5	Dec., 1989	United States	500
Windpower	100	6	April, 1992	United States	600
Huafeng	55	5	June, 1993	China	275
HSM	250	4	Sept., 1993	Germany	1,000
NTK300	300	12	Nov., 1994	Denmark	3,600
Hangfa	120	10	Dec., 1994	China-Demark joint venture	1,200
HSM-luotuo	250	4	Nov., 1995	China-Germany joint venture	1,000
M1500-600	600	9	Oct., 1996	Denmark	5,400
M1500-600	600	33	Oct., 1997	Demark	19,800
Zond-40	550	10	Dec., 1997	United States	5,500
Total installed capacity					39,775

Table 2. International investment in wind farms in Inner Mongolia

Year	Amount (10^3USD)	Investment type	Country
1993	1,765	government grant	Germany
1996	4,000	mixture of soft and commercial loan	Demark
1996	3,650	soft loan	The United States
1997		mixture of soft and commercial loan	The Netherlands
Total	13,915		

- Lack of clear and authoritative wind electricity price guidelines

The former Ministry of Power Industry issued an important regulation regarding wind electricity price in 1994. According to this regulation, wind electricity price should be based on full production cost plus *reasonable* profit, and the price difference between wind electricity price and the average electricity price of the power grid should be shared by the whole grid. Although the Regulation has played crucial roles in China's wind farm development, it has important deficiencies in implementation. First, the wind electricity pricing principle is rather ambiguous, on which wind farms and utilities have difficulties to achieve a price that could be accepted by both sides, because they are now two different economic bodies and both seek profit-maximization. Second, since the power grid is operated by different regional utilities, there are difficulties in sharing the price difference among different regional utilities. Third, any pricing principles and price changes have to be approved by the local price administration authorities. Now the price difference is shared with the Inner Mongolia Power Grid, thus bore by the consumers in Inner Mongolia. This means that under the current price mechanism, the more wind electricity Inner Mongolia produces, the more of its higher cost its consumers have to bear. Since a large proportion of the electricity produced in Inner Mongolia enters the North China Power Grid, and is consumed by Beijing, Tianjin, and other cities/regions, the fairness issue has generated concerns with power producers, policymakers, and consumers.

- Inadequate economic incentives

As China is now incapable of producing large wind turbines, these wind turbines have to be imported from abroad. Wind farms, therefore, have to pay duty, import VAT, and surtax. The duty rate for wind turbines is 6%, the import VAT is 17%, and the VAT surtax rate 8%-11%, respectively. Wind farms also need to pay income tax of 33%, and production VAT of 17%. The Inner Mongolia government has given wind farms some special treatment in terms of income tax and import VAT surtax. But only the central government has the authority to adjust the VAT rate and the import duty rate. So far the central government has not given wind farms special VAT treatment. Furthermore, as wind electricity production does not need such intermediate input as coal as in coal electricity production, wind farms often pay more VAT than coal-fired power plants for an unit of electricity sale. For example, in 1995 wind farms paid 0.71 yuan of VAT per kWh of electricity sale in Inner Mongolia, while coal-fired power plants paid 0.35 yuan (Zhao el al., 1998). As a result, heavy taxation increases the production costs of wind electricity, and makes wind farm less competitive in the energy market.

- Lack of standard wind electricity purchase contract

The regulation issued by the former Ministry of Power Industry in 1994 requires utilities to purchase the electricity produced by wind farms, but it does not provide a standard wind electricity purchase contract for wind farms and utilities. Since there are often conflict of interests between wind farms and utilities, they have difficulties reach a self-enforced agreement without clear rules. Lack of regulations that guarantee wind farms'

right to access the power grid is an important barrier to attract more investment in wind farms, and thus impedes large-scale development of wind farms in the future.

- Inadequate participation of private sector companies

Of the accumulated investment in Inner Mongolia's wind farms, approximately 57% or 216 million yuan came from the central government, 30% or 114 million yuan from foreign aid, and only 13% or 44 million yuan was locally financed. The investment from the central government and that from foreign aid were mainly for setting up demonstration projects. In a long-term perspective, it would be unrealistic to expect that huge needs of investment for wind farm construction should still depend on the central government support and international aid. In this context, inadequate participation of private sector companies would become a major barrier to sustainable development of wind farms.

4.6 Lessons learned

Inner Mongolia's wind farm development experience demonstrates or supports that:

- to create an enabling environment is the key to effective international transfer of ESTs;
- the creation of an enabling environment lies largely in the establishment of three appropriate partnerships: the partnership between developing countries and developed countries, the partnership between central government and local government, and the partnership between public sector and private sector;
- market structure, low technical capacity, and inadequate finance in developing countries are the three primary barriers to effective international transfer of ESTs;
- it is unlikely that only the market demand for clean-energy technologies will be enough by itself in developing countries in the short term, thus, construction and administration of favorable and fair public policy are also a necessity for effective technology transfer;
- while it is true that climate change is not an immediate priority for developing countries, these countries have pursued measures to address climate change in their development strategies;
- government in developed countries could play an import role in the international transfer by providing developing countries with technical and financial assistance to establish the appropriate enabling environment; and
- both developing and developed countries could benefit from the international transfer of ESTs and at least it is true in a long perspective.

V. SUMMARY AND CONCLUDING COMMENTS

No matter how one evaluates the risk of climate change, there is widespread agreement that international cooperation is an important element of any plan to curb the rise in greenhouse gas emissions. Among the broad approaches advanced for international cooperation are various efforts that improve the international transfer and diffusion of ESTs for reducing baseline emissions in developed and developing countries alike. In addition to reducing the growth of greenhouse gas emissions and expanding international technology trade, the transfer and diffusion of ESTs often yield immediate and tangible economic and environmental benefits.

Thus, there would seem to be substantial potential for international cooperation in this sphere based on mutual self-interests. In this context, increasing importance has been attached to the transfer of environmentally sound technologies under UNFCCC, particularly for the implementation of the Kyoto Protocol. However, while there is broad recognition in principle of the potential benefits, there is substantial controversy in practice about how this could and should be done between developed and developing countries. These differences in opinions posed significant constraints on the effective transfer of environmentally sound technologies.

Many developing countries regard the transfer of environmentally sound technologies as simply government-to-government transfer. To them, the transfer of ESTs can only be facilitated by inter-state cooperation. They believe that successful transfer of ESTs lie in the full complementation of the Article 4.5 of the UNFCCC on technology transfer. Developed countries, on the other hand, insisted that most ESTs are owned by the private sector, and that it is the private sector and market forces that control technology development and transfer. They believe that successful transfer of ESTs lie in creating a clean-technology market in developing countries.

We argue that the international transfer of ESTs is a process of transaction between the companies in developed and developing countries. The trajectory of technology transfer is a function of the dynamic technology transfer environment. The dynamic technology transfer environment is comprised of preference of consumers, public policy, and international cooperation. The preference of consumers is related to the market "pull", public policy to the government "push", and international cooperation to the reduction of transaction cost. The dynamic technology transfer environment can significantly affect the decision-making processes of companies and/or consumers involved in technology transfer. Whether a win-win outcome could arise lies largely in the dynamics of technology transfer environment. In this context, both developed and developing countries need to continually renew their efforts to create an environment that will enable sustainable transfer of environmentally sound technologies.

It is clear that significant GHG emission over the next 50 years will come from countries now undergoing rapid industrialization, and that low energy efficiency will still be a major contributor to GHG emission. Thus, transfer of energy efficient technologies has substantial potential for GHG emission mitigation. However, successful transfer of

energy efficient technologies can only take place if an enabling environment is in place in these recipient countries. In this regard, useful lessons can be drawn for these countries from Japan's experience in the 1970s and 1980s. During the period, while enjoying a rapid economic growth Japan maintained a negative growth of energy consumption and CO_2 and SO_x emissions. The Japanese energy success lies in its successful institutional reforms that resulted in change in market structure.

The case study of wind farm development in Inner Mongolia of China has demonstrated the importance of the creation of an enabling environment, and the role of the central and local government and the international cooperation. This case study argues strongly for reconsidering the role of governments in both developing and developed countries in technology transfer. To be true, most technology transfer is conducted through private sector, and any government involvement has to be in conjunction with this. However, ultimately, governments have a paramount role in ensuring that the right sort of technology is transferred. Only governments can establish the right sort of institutions to enable this to happen.

From the study, following points could be derived as a summary:

1) The trajectory of the international transfer of ESTs is governed by the dynamic technology transfer environment, thus, the creation of an effective enabling environment is key to the effective transfer of ESTs at present;
2) The key to creating an effective enabling environment is to establish three appropriate partnerships, viz., the partnership between public sector and private sector, the partnership between central government and local government; and the partnership between developing and developed countries;
3) Market structure, low technical capacity, and scarce finance are three primary contributors to the lack of an effective enabling environment in developing countries;
4) Institutional reforms should be oriented toward promoting structural market changes that promote and encourage clean production, but also allow considerable autonomy in the ways individual businesses may achieve these ends;
5) It is unlikely that at least in short term only the market demand for clean technologies will sufficient in developing countries to achieve significant levels of technology transfer;
6) Governments in developed countries can play an important role in the international transfer of ESTs by providing developing countries with technical and financial assistance to establish an effective enabling environment;
7) A win-win could occur if the governments in both developing and developed country genuinely take practicable cooperative actions; and
8) The following questions merit special investigation efforts in the future: a) what are the most needed technologies in the near, medium, and long perspective in terms of economics and GHG mitigation effects? b) what are the mechanisms that could lead to self-enforced agreements in transfer of ESTs between developing and developed countries? and c) what are the efficient instruments facilitating the transfer of ESTs in developing and developed countries?

REFERENCES

Anderson, D. and Forsyth, T. (1997). Rapporteurs' report for workshop presentations and discussions. In: Forsyth, T. (ed.) *Positive Measures for Technology Transfer Under the Climate Change Convention.* London: The Royal Institute of International Affairs.

Chen, T. M. (1998). The discussion on the wind power transition to Beijing. *Wind Power* No.1: 44 – 44.

Chin, J. (1997). The framework convention on climate change: a general overview of innovative approaches to technology transfer. In: Forsyth, T. (ed.) *Positive Measures for Technology Transfer Under the Climate Change Convention.* London: The Royal Institute of International Affairs.

Forsyth, T. (1997). Foreign investment and technology transfer for climate change mitigation: a background, In: Forsyth, T. (ed.) *Positive Measures for Technology Transfer Under the Climate Change Convention.* London: The Royal Institute of International Affairs.

Jaffer, A.B. and Stavins, R.N. (1994). The energy paradox and the diffusion of conservation technology. *Resource and Energy Economics* 16(2):91-122.

Jensen, O.W. and Scheraga, C.A. (1998). Transferring technology: cost and benefits. *Technology in Society* 20: 99-112.

Lile, R. and Toman, M. (1997). Promoting international transfer of "clean" technology. Paper prepared for Mutually Beneficial Opportunities for Technology Transfer to Promote International Greenhouse Gas Reductions Workshop, Beijing, November 14-17, 1997.

Fukasaku, Y. (1995). Energy and environment policy integration: the case energy conservation policies and technologies in Japan. Energy Policy 23(12): 1063 – 1076.

Mock, J.E. (1988). Technology transfer – an overview. *A Synthesis of Technology Transfer Methodologies*, Proceedings of U. S. Department of Energy Technology Transfer Workshop, Washington, D.C..

Mowery and Roenberg (1989). *Technology and the pursuit of economic growth*. Cambridge: Cambridge University Press.

Okimota, D. T. (1987). Regime characteristics of Japanese industrial policy. In: Patric, H. (ed.) *Japan's high-technology industries*. Seattle: University of Washington Press.

Ross, T. (1991). Global climate change: the role of technology transfer. A report for the United Nations Conference on Environment and Development.

Watanabe C. and Yukio H. (1991). Introducing power of Japanese technological innovation – mechanisms of Japan's industrial science and technology policy. *Japan and the World Economy* 3: 361 – 390.

Watanabe C. and Yukio H. (1992). Japan's science and technology policy in 1990s: MITI's role at a turning point. *Japan and the World Economy* 4: 47 – 67.

Watanabe C. (1995). Mitigation global warming by substitution technology for energy: MITI's efforts and new approach. *Energy Policy* 23(4/5): 447 – 461.

Wu, Y. D. (1998). Wind farm influence to environment. *Wind Power* No.3: 1-3.