ISSUE BRIEF

Technology Transfer to China to Address Climate Change Mitigation

U.S. Global Leadership: An Initiative of the Climate Policy Program at RFF

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RESOURCES FOR THE FUTURE

August 2009
Issue Brief #09-09

Resources for the Future

The Climate Policy Program at Resources for the Future (RFF) provides a framework for policymakers and stakeholders to better understand and address one of the most complex environmental issues of our time: climate change. The program has two core objectives: to develop domestic policies that are politically and economically viable and to articulate a new architecture for a global climate policy regime. Program scholars work to both support current policy efforts as well as fostering the evolution of these policies over time.

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The Climate Policy Program at RFF is funded by contributions from foundations, governments, corporations, and individuals. Current supporters include: the Doris Duke Charitable Foundation, Smith Richardson Foundation, David and Lucille Packard Foundation, Simons Foundation, Foundation for Strategic Environmental Research (MISTRA), G. Unger Vetlesen Foundation, Alcoa Foundation, U.S. Environmental Protection Agency, Center for Environmental Markets at Goldman, Sachs & Co., American Honda Motor Company, Inc., Cargill, Inc., Duke Energy, Salt River Project, ExxonMobil Corporation, Honeywell International, Inc., Novelis, Inc., and Pacificorp. For more information, contact Ray Kopp, senior fellow and director of the Climate Policy Program, at kopp@rff.org.

RESOURCES FOR THE FUTURE

Technology Transfer to China to Address Climate Change Mitigation

Takahiro Ueno[1]

Summary

This paper analyzes whether and how transfer of climate mitigation technologies to China occurs, by studying cases of seven technologies that are at the stage of deployment or diffusion. Most of these technologies were already transferred to China in terms of both technology adoption and local production. International division of labor of manufacturing and localization policies by the Chinese government facilitated local production by China, which resulted in deep cuts in production costs. Such cost reduction, coupled with technology diffusion policies by the Chinese government, then accelerated deployment and diffusion in China and other emerging economies that import Chinese products. There is a risk, however, that a sacrifice in quality as a result of Chinese localization could make those who purchase and use Chinese products hesitant and prevent further diffusion. To stimulate further adoption, developed countries can provide technical assistance for improving Chinese domestic policies, including technology diffusion policies, product quality control, and creation of sound business environments where foreign firms can safely transfer their high-quality technologies. Thus, considering the unique position of China as "the factory of the world" that eventually absorbs various technologies, effective policy will be such institutional support rather than direct aid funding for technology transfer.

1. Introduction

Addressing climate change requires global responses because of the global nature of climate. Technology transfer is expected to facilitate such global responses by bridging a gap between developed and developing countries. As is shown by technical assessment of emissions reduction potential, huge potential resides in the developing world (IPCC 2007). On the other hand, technologies for reducing greenhouse gas emissions originate mainly in developed countries. Transfer of these technologies is a key for effective reduction on a global scale.

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Currently, countries are engaged in negotiating post-2012 international climate agreements. Although technology transfer is considered one of the major pillars of future agreements, its negotiations frequently stall, as developed and developing countries tend to be in conflict, especially over treatment of intellectual property rights (IPRs) and the role of public funding. Developed countries typically argue that technology transfer occurs commercially and the role of national governments is to create business and regulatory environments that enable commercial activities. For them, IPR protection is the core of enabling environments for technology transfer. On the other hand, developing countries emphasize the role of public assistance by developed countries. Even if they agree on the critical and central role of the private sector, they continually request large-scale public funding from developed countries. In addition, they believe that protection of IPRs makes technologies less accessible and affordable and request special treatments such as compulsory licensing. Although much time already has been spent on the negotiations, discussion there still tends to be conceptual and abstract without talking about concrete examples and actual experiences.

This paper therefore aims to provide knowledge based on the reality of technology transfer by analyzing seven cases and then deriving dynamics of technology transfer from them. The cases are located in China, as this is one of the world's largest emitting countries, with massive potential for emissions reduction. Furthermore, China is frequently regarded as representative of developing countries. In the following discussion, Section 2 briefly reviews existing literature on technology transfer and summarizes major issues on technology transfer in post-2012 climate agreements; Section 3 offers a framework for the case studies; Section 4 provides overviews of the seven cases; and Section 5 examines the factors affecting technology transfer. Built on the analyses of the case studies in the previous sections, Section 6 looks at policy implications and how to engage China into post-2012 international climate agreements through technology cooperation.

2. Literature Review

The aim of this section is to identify historical roots of divergence in views on technology transfer between developed and developing countries and points of discussion at negotiations by reviewing the relevant literature briefly.

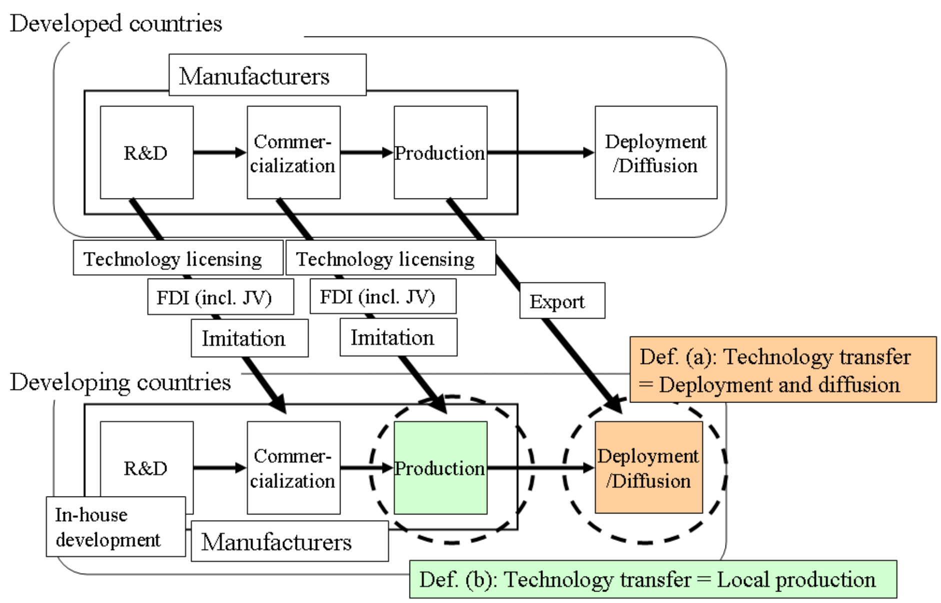
2.1 DEFINITIONS OF TECHNOLOGY TRANSFER

Before exploring the literature, technology transfer should be defined. The term may generally encompass all the activities related to flows of technical knowledge, experience, and equipment (IPCC 2000). For the purpose of analysis of climate policy, this paper defines *technology transfer* in two simple ways: (a) all the flows that end up in deployment and diffusion[2] of mitigation technologies, and (b) all the flows that lead to local production of mitigation technologies in developing countries. Figure 1 schematizes the technology development process in both developed and developing countries. Technological knowledge, experience,

[2] According to UNFCCC (2009), a technology at the deployment stage is "well understood and is available for selected commercial applications but is more costly than the established technology," and a technology at the stage of diffusion is "competitive with the established technology."

and equipment can be transferred from the upper level to the lower level through various channels between them, such as export; foreign direct investments (FDI), including joint ventures (JVs); licensing; and imitation. Whereas all the channels are relevant for the first definition, exports by developed countries are excluded for the second definition, which bypasses local production.

Figure 1. Two Definitions of Technology Transfer



From the standpoint of climate change mitigation, technology diffusion is more crucial than local production, because actual installation of mitigation technologies can reduce emissions, regardless of their origins. Nevertheless, local production should also be a focus of analysis, as it can facilitate deployment and diffusion by reducing the costs of manufacturing. This is why this paper keeps these two focuses, while putting more emphasis on the former.

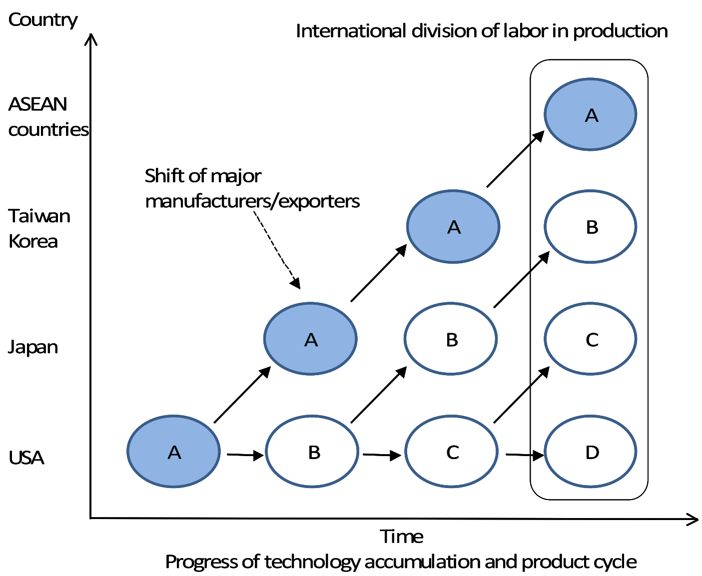
2.2 LITERATURE ON ECONOMIC DEVELOPMENT

Technology transfer often appears in the literature on economic development of developing countries, including development economics. A typical starting point of discussion on technology transfer and economic development is the classical economics theory of international trade. In this theory, goods are produced in countries where comparable advantage exists, which results in international division of labor in production. Two types of trade-driven specialization exist: horizontal and vertical. Horizontal specialization is the situation wherein a country has comparable advantages in all the stages of manufacturing of products, from upstream (component production) to downstream (assembling). In vertical specialization, a country has advantages only in part of a stream of manufacturing stages. The technological capacity necessary for manufacturing products is supposed to be transferred through various channels to the countries where comparable advantages exist.

One of the major issues of economics literature on technology transfer is whether transfer of manufacturing technologies driven by international trade has “knowledge spillover” that enhances productivity of the entire recipient economies beyond the firms receiving the technologies. Evidence on the nature and pace of such upgrading of technical capacity is mixed, as follows.[3]

According to the “flying geese model” of economic development, latecomer countries can catch up with the frontrunners after a certain time lag and enter technologically advanced sectors in which the frontrunners originally specialized. Then frontrunners move up to more advanced products (Figure 2; Suehiro 2008). Case studies in China, on which this paper focuses, have shown that the country is rapidly catching up with other industrialized nations for many manufacturing products.[4] Starting from a labor-intensive assembling stage, China gradually shifts up to more advanced stages, including production of technologically difficult components.

Figure 2. International Product Cycle and Technological Advancement[5]



Source: Suehiro (2008)

On the other hand, another study based on trade statistics argues that technological upgrading occurs only at foreign affiliates and does not extend to the entire local Chinese economy (Lemoine and Ünal-Kesenci 2004). Then, the authors of the study caution that importing foreign technologies “leads to an ever-increasing dependency” and emphasize the importance of sustained efforts to improve the dissemination of imported technologies and strengthen China’s own research and development to avoid dependence.

[3] For detailed surveys on economics literature, see Maskus (2004) and Saggi (2000). These surveys treat channels of technology transfer respectively and highlight differences among them, whereas empirical studies they surveyed do not necessarily provide decisive conclusions on what kinds of effects respective channels have.
[4] For example, see Han (2004).
[5] ASEAN stands for Association of Southeast Asian Nations.

In the 1960s and early 1970s, a more deterministic version of the latter argument prevailed as "dependency theory," which argued that developing countries were structurally dependent on developed countries and their multinational companies. The theory regarded asymmetry of technical capacity between developed and developing countries as one of the sources of structural dependence and argued that technology transfer was a requisite for economic independence and development of the south (UNCTAD 1976). Those who shared the structural views supported substantial revision of patent systems and requested prohibiting business practices of multinational companies to restrict technology transfer, for example, at the meetings of the United Nations Conference on Trade and Development (UNCTAD), the major forum on trade and development, in which developing countries are well represented. Even after the rise of newly industrialized economies (NIEs) such as Korea and Taiwan in the 1980s countered the validity of structural dependence, developing countries to some extent still hold the structural view of dependence theory.

The current divergence in the views on technology transfer seems rooted in the historical division between developed and developing countries since 1960s. Developing countries' belief in structural dependence may be part of the motivation behind their strong requests for large amounts of public funding for technology transfer and compulsory licensing of advanced technologies at the post-Kyoto negotiations. On the other hand, developed countries do not share such a view and emphasize the role of commercial activities and the importance of enabling environments in developing countries.

2.3 LITERATURE ON CLIMATE POLICY

Technology transfer has been a continuous concern since the establishment of the United Nations Framework Convention on Climate Change (UNFCCC). The Bali Action Plan, which was agreed on by the Parties to the UNFCCCC in 2007 and lays out negotiation agendas for post-2012 agreements, renewed interest in technology transfer among the international climate policy community, as the plan makes future mitigation action by developing countries contingent on support for technology transfer. Noting the difference of views between developed and developing countries, literature on climate policy treats policy questions, including treatment of intellectual property rights and roles of financial mechanisms, as follows.

One of the most contentious issues at the negotiations is treatment of intellectual property rights. As mentioned in Section 1, developing countries request compulsory licensing and other preferential treatments. The big issue is whether IPRs are barriers for technology transfer. Most of the studies this paper reviewed provide no decisive conclusion, and recent evidence tends to show that IPRs are not necessarily significant or unique barriers. Based on cases of renewable energy technologies, Barton (2007) points out that IPRs do not seem to prevent technology access by developing countries, and even stronger protection may help advanced developing countries, as foreign firms are more willing to transfer their technologies. On the other hand, based on the cases of transfer of five energy technologies in India, Ockwell et al. (2007) report limited access to the most advanced technologies by Indian firms, but they also emphasize other significant barriers, such as a lack of absorptive capacity and tacit knowledge; even if IPRs are shared with

Indian firms, they cannot manufacture advanced products without improving their technological capacity and learning tacit knowledge.[6]

Although evidence is not decisive to date, policy proposals for addressing IPR concerns have been presented recently. A paper prepared by the United Nations Department of Economic and Social Affairs (UNDESA) mentions loose application of IPRs for environmentally sound technologies, from the perspective of developing countries, especially least developed countries that are unable to license new technologies or are not benefiting from the inflows of foreign direct investments (UNDESA 2008). Tomlinson et al. (2008) also suggest flexible treatments of IPRs by governmental interventions. For example, governments can make commitments to buy out technologies that satisfy certain defined standards and put purchased technologies into the public domain. This arrangement, called “advance purchase commitments” or “innovation prizes,” can motivate private firms to invest in premature research areas by partially removing their concerns about recovery of research and development (R&D) costs. Joint R&D between developed and developing countries has also been proposed by developing countries as a means to share new technologies between developed and developing countries.

The role of financial mechanisms for technology transfer is another issue that attracts attention at negotiations. As explained by many studies, the roles of public and private finance are varied for different stages of technology development. Public finances are important for R&D activities that are risky for private firms, whereas private finances are more salient in downstream deployment and diffusion stages. Built on this understanding, a recent research report commissioned by UNFCCC reviews currently available financial resources, gaps and barriers, and potential new financial sources for various stages of technology development, based on the research literature available to date (UNFCCC 2009).

To date, evidence on the effectiveness of different financial channels, including Official Development Assistance (ODA) and Clean Development Mechanism (CDM), is still limited; several ex post evaluations have been presented recently. Reviewing eight energy-efficiency projects funded by the Global Environment Facility, one of the multilateral environmental ODA channels, Birner and Martinot (2005) show the effectiveness of the projects targeting institutional and regulatory changes that support adoption of energy-efficient technologies, such as energy-efficiency standards and labeling. On the other hand, another project they reviewed was less successful. The intention of the project was to buy out advanced boiler technologies from firms in developed countries and share them with firms in host countries, but it faced a series of difficulties, mainly because its design was not flexible enough to respond to rapid changes in boiler technology markets. Several studies (for example, Seres 2008) report that about half of CDM projects have brought in technologies that were not available in host countries, but it is less clear whether CDM contributes to technology diffusion in developing countries efficiently and effectively. CDM projects are sometimes criticized as receiving excessive subsidies for cheap projects, and whether they bring about additional emissions reductions has been questioned (Wara and Victor 2008).

[6] Several reports point out differences of situations among technology areas, especially between pharmaceutical and energy sectors. Whereas products and technologies are easily copied without the protection of patents in the former sector, tacit knowledge, rather than patents, is crucial for production in the latter sector, and IPRs are not considered to be a major barrier.

2.4 SUMMARY

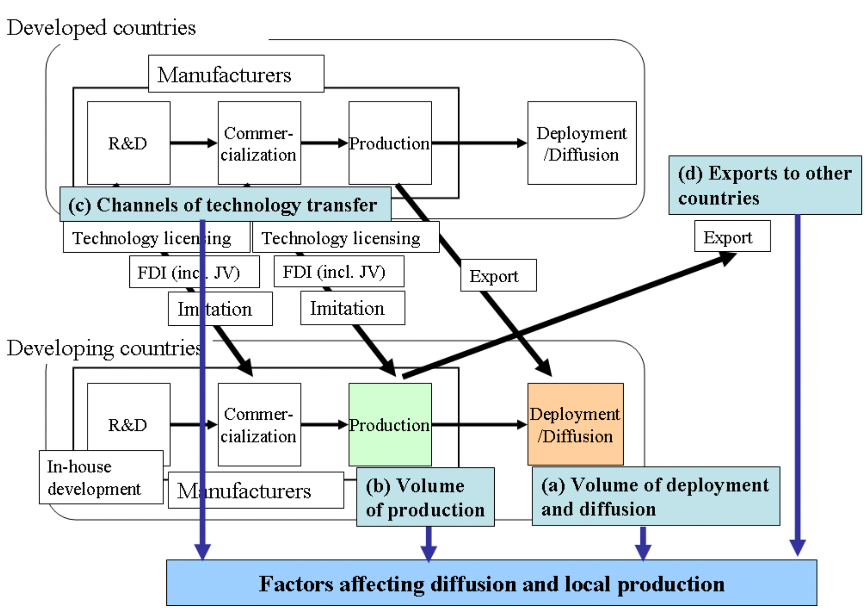
The brief review of the literature on economic development indicates that the current divergence of views on technology transfer between developed and developing countries is rooted in a historical division that can be traced back to the 1960s, even if the reality of the world economy has changed drastically since then. Noting the difference of views, climate policy literature considers possible options for post-2012 agreements, including flexible treatments of IPRs and roles of financial mechanisms, although there is little empirical evidence on whether IPRs are significant barriers for technology transfer and how efficient and effective various options of financial mechanisms are.

3. Framework for Case Studies

Under the division of views between north and south, countries are currently negotiating arrangements for technology transfer in future international climate agreements without sufficient empirical evidence, as discussed in the previous section. Thus, filling the knowledge gap with actual cases may facilitate the difficult negotiations, and the rest of this paper intends to provide analysis of cases in China.

Through case studies, this paper seeks to identify dynamics of technology transfer in China by considering what kinds of factors accelerate or prevent deployment and diffusion of mitigation technologies and why production of them is shifted to China. To address these questions, this paper takes the following two steps. First, it gathers four kinds of basic information for respective cases: (a) diffusion in China, (b) production in China, (c) channels of technology transfer, and (d) exports from China to other countries. Second, built on the gathered information, it identifies common factors among cases that drive diffusion and local production of technologies (Figure 3).

Figure 3. Framework for Case Studies



This paper looks at the following seven mitigation technologies as case studies, covering electricity, industry, and residential sectors:

1. Supercritical and ultra-supercritical coal-fired power plants (SC&USC): one of the advanced technologies for conventional coal power plants that generate electricity with high-temperature and high-pressure steams in supercritical or ultra-supercritical conditions.

2. Natural gas combined cycle power plants (NGCC): energy-efficient gas power generation combining a gas and a steam turbine, in which recovered waste heat is used for rotating a steam turbine

3. Photovoltaic power generation (PV): renewable energy technology that converts energy of sunlight into electricity by using semiconductors

4. Wind power: renewable energy technology that generates electricity by using the wind to rotate blades

5. Waste heat recovery for steel and cement plants (WHR): technology that recovers waste heat from industrial processes and recycles it for various purposes, including power generation

6. Energy-efficient room air conditioners (EE-RAC): air conditioners whose energy efficiency is improved by controlling a rotating speed of compressors with inverters or making technical improvements for compressors and heat exchangers

7. Compact fluorescent lamps (CFL): fluorescent bulbs made with sockets that fit incandescent lamps as energy-efficient alternatives

4. Overview of Case Studies

This section provides an overview of the seven case studies by comparatively describing diffusion, local production, channels, and exports to other countries.[7]

4.1 DIFFUSION IN CHINA

In all cases except PV and inverter-controlled RAC, technologies are already at the stage of deployment or diffusion, and the rate of diffusion is rapidly increasing (Table 1). An impressive example is SC and USC units: approximately 40 percent of all such units in the world operate in China, and USC plants recently have been installed at an accelerated rate. More than 100 facilities for coke dry quenching (CDQ), one of the WHR technologies for the steel sector, are currently in operation, whereas fewer than 20 facilities existed before 2000. On the other hand, the diffusion rate of PV and inverter-controlled RACs is still very low.

[7] The Appendix provides figures that summarize the information in a case-by-case manner.

Table 1. Status of Diffusion of the Case Studies

1. SC&USC	Among 713 plants planned, constructed, or operated in the world in 2008, 38 percent exist in China (Maeda 2008).
2. NGCC	In 2006, capacity in operation is about 10 gigawatts and capacity under planning or construction is 21.8 gigawatts (Ni 2007).
3. PV	In 2007, installed capacity of PV is still about 100 megawatts, and most of the units are used for off-grid capacity in rural areas (JEPIC 2008).
4. Wind	Capacity of wind power has expanded increasingly from 500 megawatts in 2002 to 12,000 megawatts in 2008.
5. WHR	Fewer than 20 CDQ facilities existed before 2000, but today more than 100 are in operation (Nakano 2008). WHR generation for cement plants was initially demonstrated just a few years ago, between 2000 and 2004, but by 2008, more than 100 plants were under planning, construction, or operation.
6. EE-RAC	Although approximately 30 million RACs are sold annually, the ratio of efficient types is still low (Mei 2006).
7. CFL	In 2003, the average number of CFLs per household was 1.5 in 6.7 lightbulbs. This figure is higher than the OECD average in 1999 (IEA 2006).

4.2 PRODUCTION IN CHINA[8]

In all the cases, technologies are manufactured in China, reflecting the Chinese position as "the factory of the world" (Table 2). The accumulated capacity of made-in-China SC and USC units already exceeds that of made-in-Japan or made-in-Europe units. Gas turbines for NGCC are manufactured jointly by Chinese manufacturers and foreign partners. With regard to renewable energy, Suntech, the leading PV manufacturer in China, is the third-largest producer of PV in the world, and Goldwind and Sinovel, Chinese domestic firms of wind turbines, are rapidly expanding their share in the domestic market by producing larger units. Domestic firms and joint ventures with Japanese manufacturers produce the facilities for WHR for the steel and cement sectors. For the residential sector, more than 70 percent of RACs and 80 percent of CFLs are produced in China.

[8] In this section, only final products are included; component production is considered in the next section.

Table 2. Status of Local Production in the Case Studies

1. SC&USC	Harbin, Shanghai, and Dongfang produce boilers, turbines, and generators. Accumulated capacity of made-in-China units already exceeds that of units made in Japan or Europe (Epple 2004).
2. NGCC	Chinese major manufacturers of heavy machinery (Harbin, Shanghai, and Dongfang) produce turbines and generators jointly with their foreign partners (GE, Siemens, and Mitsubishi) (Yao 2008).
3. PV	In 2008, Suntech was the third-largest producer of PV in the world (PV News 2009).
4. Wind	Chinese firms, especially Goldwind and Sinovel, are expanding their production and dominate more than half of the market share in China (CWEA 2009).
5. WHR	Both Chinese firms and joint ventures produce CDQ for steel plants and WHR generation facilities for cement plants (Nakano 2008; Sorida et al. 2007).
6. EE-RAC	Although more than 70 percent of RACs in the world are produced in China, the ratio of energy-efficient products is still very low (Nikkei Business Publishing 2008).
7. CFL	China produces more than 80 percent of CFLs in the world (Du Pont and Ton 2007). More than 2,500 companies manufacture CFLs (Global Sources 2007).

4.3 CHANNELS OF TECHNOLOGY TRANSFER

Channels of transfer are varied across the cases, and for some, technologies are transferred through multiple channels, as shown in Table 3.

Technology licensing is a frequently adopted channel. For example, Chinese companies are licensed by firms in developed countries to produce SC and USC units, gas and steam turbines for NGCC, and wind turbines. Even if they have licenses to produce final products, however, Chinese firms sometimes do not have the capacity to produce key components and frequently import them from foreign firms. Chinese licensed manufacturers of SC and USC units import materials used for key components that are exposed to severe physical conditions with high-temperature and high-pressure steams. Chinese manufacturers also still import core components of gas turbines, such as blades and rotors, from their foreign partners. Semiconductor devices for inverter-controlled RAC are supplied by foreign manufacturers as well.

Joint ventures (JVs) between Chinese and foreign firms are another frequent channel of transfer. JVs manufacture components of turbines of NGCC, assembled wind turbines, WHR facilities, and compressors for RAC. Full or majority ownership by foreign firms also plays a role. For example, Chinese affiliates of Japanese manufacturers produce most inverter-controlled RACs.

With regard to PV and CFL, Chinese local manufacturers easily set up production lines by purchasing production equipment. Especially for PV, manufacturers of production equipment provide turnkey solutions that install full sets of production facilities in the factories of PV makers, allowing PV makers to start production simply by turning a key to the facility.

It is said that technologies developed by Japanese firms for WHR for both steel and cement sectors have been copied by Chinese manufacturers.

Table 3. Channels of Technology Transfer Adopted in the Case Studies

1. SC&USC	Harbin, Shanghai, and Dongfang acquired manufacturing capacity through *technology licensing* (Zhu and Zhao 2008). Foreign manufacturers sometimes *export* core components to their Chinese partners (MHI 2003).
2. NGCC	Harbin, Shanghai, and Dongfang acquired manufacturing capacity through *technology licensing*. Foreign manufacturers sometimes *export* core components to their Chinese partners (Yao 2008).
3. PV	Chinese PV manufacturers expand their production capacity by *purchasing production equipment* from European companies specializing in semiconductor production equipment (Wadagi 2008).
4. Wind	Various channels including *exports, joint ventures,* and *technology licensing* brought wind technology to China (Lewis 2006; Ni 2008).
5. WHR	Responding to *imitated* or similar products by Chinese firms, Japanese manufacturers transferred production to China through *joint ventures* (Asahi Newspaper Asia Network 2007; Nikkei Business Online 2008).
6. EE-RAC	Chinese affiliates of Japanese firms produce most inverter-controlled RACs, but one Chinese electric manufacturer developed them on its own (*in-house development*). Foreign manufacturers *export* semiconductor devices for inverters to China.
7. CFL	Medium and small enterprises set up production lines by *purchasing production equipment* on their own. Large foreign firms commission original equipment manufacturing (*OEM*) production to Chinese firms and provide *training* for them.

4.4 EXPORTS TO OTHER COUNTRIES

This section examines the status of exports of the various technologies to other countries (Table 4). The seven case studies can be classified into three groups according to their volume of exports. The first group includes those technologies whose volume of exports is already large: PV and CFL. More than 90 percent of PV modules and 70 percent of CFLs produced in China are currently exported to other countries. The second group includes those technologies whose exports have just started recently: SC and USC, NGCC, WHR for cement plants, and EE-RAC. The two major manufacturers of heavy electric machinery, Shanghai Electric and Dongfang Electric, received orders from India for large-scale SC plants, and Dongfang Turbine got an order for the main machinery for an NGCC plant in Belarus. Both a domestic firm and a joint venture export WHR power generation plants for cement plants. The third group includes those technologies that have not yet started exporting: wind turbines and CDQ. Although Goldwind's licenser originally prohibited it from exporting its products, it recently acquired another foreign company that has technologies for large-scale wind turbines. Goldwind now is looking for the opportunity to export.

Table 4. Status of Exports to Other Countries in the Case Studies

1. SC&USC	Shanghai Electric and Dongfang Electric received orders from India for large-scale SC plants (Steel Guru 2008).
2. NGCC	Dongfang Turbine got an order for the main machinery for a NGCC plant in Belarus, and its foreign partner, Mitsubishi Heavy Industry, will supply core components for gas turbines for Dongfang (MHI 2009).
3. PV	More than 90 percent of PV modules produced in China are currently exported to other countries (Wadagi 2008).
4. Wind	No export yet. Goldwind recently acquired a foreign company with technologies for large-scale wind turbines and is seeking the opportunity to export (Lewis 2007b; Schwartz and Hodum 2008).
5. WHR	No export of CDQ yet. Both a domestic firm and a joint venture export WHR power generation plants for cement plants to other countries, including Thailand.
6. EE-RAC	Although more than 40 million units are exported annually, the ratio of energy-efficient products is very low (Nikkei Business Publishing 2008).
7. CFL	More than 70 percent of CFLs produced in China are currently exported to other countries (Cheng 2007).

5. Analysis of Cases

As described in the previous section, technologies are already at the stage of deployment and diffusion in most cases, and they are produced locally in all the cases. In some cases, Chinese products are exported to other countries. Building on the information given in Section 4, this section analyzes factors that affect technology transfer in terms of both technology diffusion and local production.

5.1 COMMON FACTORS AFFECTING DEPLOYMENT AND DIFFUSION

5.1.1 Government Policies

As discussed in Section 4.1, most technologies except PV and inverter-controlled RACs are already at the stage of deployment or diffusion. One common tendency observed in these cases is that policies by the Chinese government push technology deployment and diffusion.

In China as a socialist country, *governmental plans*, including Five-Year National Development Plans, frequently play a crucial role, such as by supporting the deployment and diffusion of specific technologies. For example, the government put SC and USC technology on the list of high-techs that deserve intensive R&D support by government and also promoted the initial deployment through state-owned power generation companies, China Huaneng Group and China Power Investment Corporation. At the same time, the government requested that power generators scrap small-scale power plants (less than 1 megawatt) and replace them with large plants such as SC and USC. Likewise, during the period of the tenth and eleventh five-year plans (respectively, 2001-2005 and 2006-2010), the government developed NGCC in alignment with construction of pipelines transporting natural gas and liquefied natural gas (LNG) import terminals (Ni 2007). Concerning industrial energy efficiency, the eleventh five-year plan set a 20 percent reduction target of energy intensity per gross domestic product (GDP). To achieve the target, the government started the Top-1000 Enterprises Program, which required the top 1,000 energy-consuming companies to reduce their energy intensity by various policies and programs, including energy-efficiency diagnosis, reporting of energy consumption, voluntary agreements with the government, and energy-efficiency benchmarking efforts. The program covers many companies in the steel and cement sectors, and the government recommends installation of WHR technologies for these sectors (JMC 2007; Price et al. 2008).

Regulations and incentives also play a role in technology diffusion. With tax breaks, subsidies, and mandatory purchase of electricity by power companies, the government has boosted installation of wind turbines (Lewis 2007b; Ni 2008). In the residential sector, energy-efficiency standards and labeling (S&L) for electric appliances contributes to excluding energy-wasting products from the market and making energy-efficient products visually discernible from less efficient ones. S&L functions well for the noninverter type of efficient RACs (Mei 2006). Subsidies by both the central and local governments boost diffusion of CFLs.

5.1.2 Price Reduction by Local Production

By switching from imports to local production, the prices of products and facilities embodying advanced technologies go down sharply. For construction of thermal power plants, the purchasing cost of the main machinery is reduced dramatically by switching to local products: compared with Japan, construction unit cost (cost per kilowatt) of SC and NGCC plants is more than 70 percent lower in China.[9] Local production also results in similar price cuts for the rest of the technologies this report studies (Table 5).

Low labor cost is the biggest factor for price reduction, especially the cost of labor-intensive assembling, which is dramatically lowered by local production. This is not the sole factor, however. For example, Chinese manufacturers and joint ventures standardize specifications of equipment for SC plants and WHR facilities for cement plants and produce the standardized products with lower total costs by saving the additional cost of customization. Another factor is intensified competition among component suppliers. Chinese manufacturers of electric appliances make their products fit with components from different suppliers and intensify competition among them. Such competition lowers purchasing costs for manufacturers of final products (Marukawa 2007).

[9] The unit cost includes not only the purchasing cost of the machinery, but also the labor cost of construction. The very low labor cost in China may largely explain the difference in construction cost per kilowatt hour, but it alone is not sufficient to account for such a great difference. Cost reduction by local production should also significantly contribute to the difference.

Table 5. Reduction of Manufacturing Costs and Prices by Local Production[10]

1. SC&USC	Construction costs per kilowatt hour of SC plants are about 20 percent of those in Japan.
2. NGCC	Construction costs of NGCC plants are about 25 percent of those in Japan.
3. PV	Manufacturing cost of labor-intensive module process is significantly reduced (Marigo 2007).
4. Wind	Prices of local products are about 30 percent of those of imported products (JEPIC 2006).
5. WHR	Initial costs of WHR generation plants for cement plants are reduced by half; initial costs of CDQ are about 75 percent of those in Japan (NDRC 2008; NEDO 2008).
6. EE-RAC	Manufacturing costs of labor-intensive assembling process are significantly reduced; competition among components suppliers also reduces purchasing costs of manufacturers of final products (Marukawa 2007).
7. CFL	Even before 2000, the price of local CFL products was about $4, whereas the price of imported products was about $10 (Lin 1999).

5.2 COMMON FACTORS ACCELERATING LOCAL PRODUCTION

From the standpoint of foreign firms, the biggest decision is whether to export their products to China or produce them locally. Considering the motivations underlying their choice of channels, this subsection discusses factors accelerating local production.

In the cases where foreign firms shift their production or license their technologies to China, two types of motivations behind their decision are observed. First, economic rationality drives international division of labor of manufacturing, as the classical theory of international trade predicts. Labor-intensive processes such as assembling tend to be transferred to China because foreign firms seek the lower labor costs. Among the cases this paper examines, the assembling processes of turbines for thermal power generation and RACs have already been shifted to China. Production of mature technologies such as CFLs has also moved to China, as the technological advantage of developed countries is already marginal. The so-called big three lighting companies—GE, Philips, and Osram—outsource manufacturing of their products to Chinese companies by an original equipment manufacturing (OEM) model. On the other hand, foreign firms export to China technologically advanced components such as metal materials for SC and USC boilers, blades and rotors for gas turbines, and semiconductor devices for inverter-controlled RACs. Because it is still difficult for Chinese manufacturers to produce these items on their own, they have to rely on imports from foreign companies.

Second, localization policies of the Chinese government motivate foreign firms to license their technologies to Chinese manufacturers. Localization policies typically require technology transfer from foreign firms in exchange for market entry. In the case of SC and USC, because only Chinese firms can bid for the main

[10] Information on construction costs of SC&USC and NGCC plants is derived from FEPC (2003) and SERC (2007). In this table, construction costs in Japan are compared with those in China, but this simple comparison does not adequately reflect the differences in specifications for environmental equipment between Japan and China; if Chinese power plants were required to satisfy as stringent environmental standards as Japanese plants do, construction costs in China would be much greater.

machinery (boiler, turbine, and generator) for new power plants, foreign manufacturers have to find a Chinese partner in order to supply their products to China (Imai et al. 2007). Licensing is a familiar way to collaborate with Chinese partners. Under licensing arrangements, foreign manufacturers often supply key components to Chinese partners, and Chinese manufacturers produce other components and assemble them all into final products. As for NGCC, in exchange for market entry, the Chinese government requested foreign manufacturers to transfer their technology to Chinese firms to enable them to produce on their own (Nikkei Net 2006). As a result of the arrangement, the proportion of local contents has increased, while foreign manufacturers continue to export core components to China (Yao 2008). Similar policies are also pursued for wind turbines (Ni 2008; Schwartz and Hodum 2008). The government set a target for local content at 70 percent and makes it a requisite for bidding for large-scale wind power projects.

Competition with imitated or similar Chinese products drives local production in the case of WHR technologies for steel and cement sectors. Japanese manufacturers originally exported the facilities to China, but Chinese manufacturers started producing imitated or similar products with very small labor and material costs. To compete with low-priced Chinese products, the Japanese firms needed to reduce manufacturing costs by establishing JVs with their Chinese partners and relying on local production in China (Asahi Newspaper Asia Network 2007; Nikkei Business Online 2008).

In summary, international division of labor driven by economic rationality occurs between China and developed countries: labor-intensive processes and mature technologies are shifted to China, while technologically advanced products are still imported from developed countries. In addition to the economic dynamics, the localization policy of the Chinese government motivates foreign firms to license their technologies in exchange for market entry. Sometimes competition with imitated products also drives local production in China.

5.3 POSSIBLE CONTRIBUTION OF EXPORT FROM CHINA TO GLOBAL DIFFUSION

In addition to domestic diffusion, production in China may contribute to global diffusion of mitigation technologies. In general, China is “the factory of the world”: it exports a variety of products, taking advantage of lower labor cost. As described in Section 4.4, several mitigation technologies have been already exported to other countries. Assuming that the current trend continues in the future, made-in-China mitigation technologies could prevail in the world.

Quality issues may make other countries hesitant to purchase Chinese products, however, as illustrated by the following example. Recently, subcritical coal power plants in India experienced serious troubles with core components and stopped operation.[11] Chinese manufacturers had supplied the main machinery for these plants. Responding to the questions it received about the performance of the Chinese equipment, the Indian government’s Central Electricity Authority set up a technical committee for quality inspection of the equipment supplied by Chinese manufacturers (Senguputa 2008, Das 2008). Although low-priced Chinese products tend to be popular among emerging economies such as India, they may hesitate to adopt Chinese products, especially when they are concerned about the quality of core components where problems would

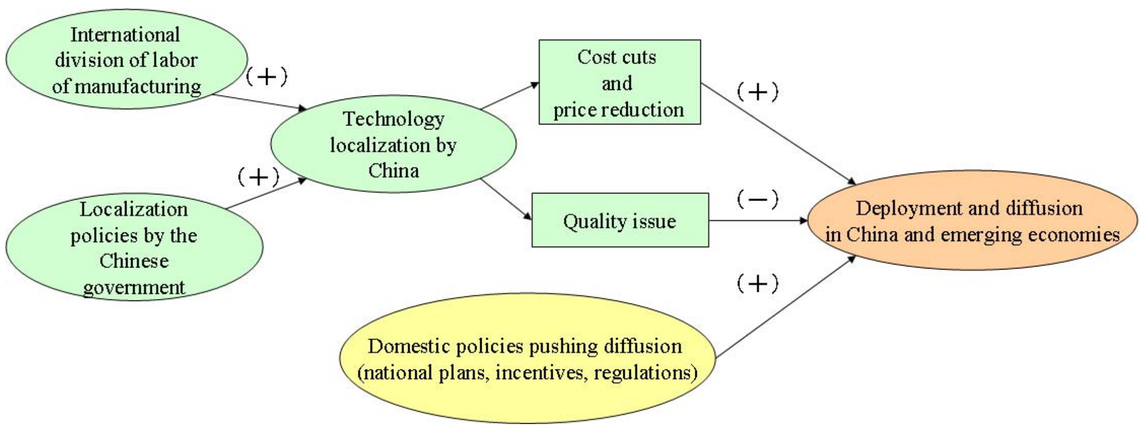
[11] Subcritical plants are technologically less advanced than SC and USC.

cause serious accidents. Likewise, while the CFLs exported to other countries are cheap, the quality is reported to be very low (USAID/ASIA 2007).

5.4 OVERALL PICTURE EMERGING FROM ANALYSIS

By connecting factors affecting diffusion and local production, an overall picture of technology transfer to China emerges, as shown in Figure 4. Both government policies pushing technology diffusion and price reduction by local production are major factors for technology diffusion in China. Price reduction also expands export to other countries, especially emerging economies, and may contribute to global diffusion of mitigation technologies. Local production in China is boosted by both international division of labor of manufacturing and localization policies by the Chinese government. Although local production reduces production costs and thus prices, quality may be sacrificed in some cases. The quality issue may discourage other countries from purchasing Chinese products.

Figure 4. Dynamics of Technology Transfer to China



6. Policy Implications

This section treats policy issues based on the cases examined in the previous sections. First it discusses desirable policy options derived directly from the findings of the case studies. Then it examines two central issues in the literature on climate policy: treatment of intellectual property rights and public funding by developed countries. Finally, it suggests how developed countries should engage China in the post-2012 international climate regime through technology and technical cooperation.

6.1 POLICY OPTIONS DERIVED FROM THE FINDINGS OF THE CASE STUDIES

As discussed in Section 2, from the perspective of climate change, technology diffusion is a more important aspect of technology transfer than local production. As shown in Figure 4, illustrating the dynamics of technology transfer to China, domestic policies for technology diffusion, international division of labor of manufacturing, and localization policies by the Chinese government are positive factors for diffusion, whereas the quality issue is a negative one. Taking these dynamics into account, to boost diffusion in China, policies are necessary that strengthen the positive factors and remedy the negative one. The following subsections examine options for policies and international cooperation regarding the various factors.

6.1.1 Domestic Policies for Technology Diffusion

As shown in the case studies, the Chinese government has already adopted a suite of policies that facilitate technology diffusion, including the five-year plans, incentives, and regulations. Furthermore, it may reinforce policies and programs supporting diffusion of climate mitigation technologies, as China has a strong intention to accelerate the diffusion of energy-efficient technologies and renewable technologies in order to enhance its own interests such as energy security and sustainable society.

To support these Chinese efforts, developed countries can provide technical assistance that facilitates formulation and implementation of such polices and programs. Among the case studies in this paper, technical assistance for formulating and implementing standards and labeling for RACs has been continuously provided through public and charitable funding from developed countries. Such policy development assistance (PDA) can be coordinated among donor countries to make it more efficient, for example, by establishing an international fund dedicated to matching mitigation efforts by developing countries with technical assistance and providing necessary funding for them (Sugiyama and Ohshita 2006).

6.1.2 International Division of Labor of Manufacturing

International division of labor is a result of trade-driven transfer of production. As argued by developed countries, enabling environments for commercial activities are crucial for enlarging local production by attracting foreign firms' direct investments or licensing agreements with Chinese companies. Without such environments, private firms in developed countries may hesitate to bring their technologies to China, for fear of unintentional leaks of their technologies and unstable business practices that may negatively affect their business activities. In all the cases studied in this paper, the assembling processes and matured technologies were eventually moved to China, but with sounder business environments, the pace of transfer would be accelerated.

Although it is up to the Chinese government whether it reforms domestic business and regulatory environments, developed countries can provide capacity-building support once China determines to reform.

6.1.3 Localization Policies by the Chinese Government

Even if localization policies function effectively in China in terms of increasing local production and then diffusing technologies, governments of developed countries are likely not to have motivations to support these policies, because their industrial competitiveness could be drained along with the outflow of production in the long run. From the standpoint of developed countries, means to enhance local production should be the creation of enabling environments, instead of localization policies, so as to make it possible for firms in developed countries to retain a choice between direct investment and licensing. On the other hand, the Chinese government has a strong interest in industrial development through obtaining and localizing foreign technologies. These conflicting interests leave little room for cooperation in localization policies between China and developed countries. Furthermore, compatibility of these policies with the rules of the World Trade Organization (WTO) could be challenged by other WTO members, as Lewis (2007a) discusses for the case of wind power.

6.1.4 Quality Issue

Importing countries of Chinese products can take actions to induce the manufacturers to improve the quality of their products by appealing to the export interests of China. Strong negative reaction to the low quality of Chinese products frequently occurs in their export markets. As China sees these export markets as more and more important, it will be sensitive to reactions by foreign users and consumers. Once Chinese manufacturers are requested to improve the quality of their products by their consumers or to satisfy higher quality standards set by other governments, they would make efforts to meet the demand in order to maintain their export markets. Meeting more stringent standards in export markets may possibly strengthen Chinese standards. From the standpoint of manufacturers, it is sometimes impractical to maintain two production lines for both high- and low-quality products. It is then reasonable for the government to set product standards at the same level as those of export markets. This trade-driven upgrading of standards is called “trading up” (Vogel 1995).

Cooperation with firms in developed countries may be helpful for improving product quality. Business environments where foreign firms can do their business with safety are crucial for inducing such cooperation.

6.2 TREATMENT OF INTELLECTUAL PROPERTY RIGHTS AND PUBLIC FUNDING BY DEVELOPED COUNTRIES

This subsection treats the two central issues in the literature on climate policy.

6.2.1 Treatment of Intellectual Property Rights

In the cases this paper reviewed, protection of intellectual property rights (IPRs) is not a barrier for technology transfer, in terms of both technology diffusion and local production.

From the perspective of technology diffusion, license fees could cause price increases and thereby prevent diffusion. In the cases studied, however, price reduction by local production has been so steep that it seems the price increment by licensing is almost canceled out. With regard to energy technologies, R&D cost is just 5 percent of manufacturers’ total cost. Even if original manufacturers put the full R&D cost into license fees, price reduction by local production still would far exceed the cost increment by licensing. Although loosening protection of IPRs could further reduce the price by lessening license fees and lead to more diffusion, foreign firms would cut down their R&D investment, feeling anxiety over the failure to recover R&D cost; innovative technologies necessary for long-term reduction would be deterred because of insufficient private R&D funding.

From the perspective of local production, firms in developed countries could block technology transfer by refusing to license their technologies or making many restrictions for licensees. If so, Chinese companies could be severely restricted in the use of advanced technologies. In the cases studied, however, foreign firms have provided their technologies under licensing or technology transfer agreements.

Thus, protection of IPRs is not a barrier for technology transfer, at least, not for China. Flexible treatment of IPRs such as compulsory licensing is likely to be irrelevant for further enhancement of technology diffusion and local production.

6.2.2 Public Funding by Developed Countries

Installation of advanced technologies typically requires additional costs. Addressing the cost issue is a key for accelerating technology diffusion. There are two strategies to deal with it: reducing the additional costs and compensating them. As shown in the case studies, cost reduction by local production is one of the main factors accelerating diffusion in China, and in some cases, installation cost is cut by more than half.

Even after cutting the incremental costs by local production, financing the remaining cost difference between ordinary and advanced technologies is crucial for diffusion. In the cases studied in this paper, they sometimes have been compensated by saved costs from energy efficiency and conservation. In other cases, subsidies and tax incentives by the government assist diffusion.

Funding sources provided by developed countries also play a role. Among them is the Clean Development Mechanism (CDM), which awards emissions reduction credits called certified emissions reductions (CERs) to mitigation projects implemented in developing countries.[12] In the case studies, projects of USC, NGCC, wind power, and WHR for both the steel and cement sectors claim CDM credits. This may imply that CDM boosts technology diffusion in China.

It is difficult, however, to prove to what extent CDM contributes to diffusion. Wara and Victor (2008) question whether these projects are really induced by CDM credits. They find that almost all projects of hydro, wind, and natural gas power in China are applying to claim CDM credits. Considering that the Chinese government makes efforts to deploy and diffuse these technologies on its own, it seems that at least some of these projects would be implemented even without CDM, enabled by Chinese domestic policies.

The form of money delivery is another issue in financing technology diffusion. The scale of money provision through CDM credits depends on the carbon market price. It tends to be much larger than actual incremental costs, as the price of credits, which is correlated to some extent with the price of European allowances, usually exceeds incremental costs. On the other hand, direct funding for incremental costs can limit the scale of financial flows to developing countries, while still achieving the same amount of emissions reduction. In other words, compared with carbon credits, direct funding can result in greater emissions reduction with the same amount of financial flows. It remains unclear, however, that governments of

[12] One of the core principles of CDM is “additionality”: only projects that would not be implemented without credits may be approved as CDM projects. Because CDM credits offset emissions in developed countries, credibility of emissions reduction by projects is critical. If credits are awarded for nonadditional projects, this will add more emissions from developed countries.

developed countries or international institutions can provide direct funding for incremental costs in an efficient and effective manner, considering the difficulty of exact assessment of incremental costs and cumbersome bureaucratic procedures accompanying international public funding.[13]

In summary, while financing the incremental costs is crucial for technology diffusion, the appropriate means remains unclear. Especially, the forms of money delivery—credits, direct funding, or a combination thereof—need to be further considered. In addition to compensation of cost additions, reducing them by local production is also important for saving installation costs and then limiting the scale of necessary public funding.

6.3 HOW TO ENGAGE CHINA IN POST-2012 CLIMATE AGREEMENTS THROUGH TECHNOLOGY COOPERATION

Engagement of China in post-2012 climate agreement is one of the central concerns at negotiations. Recently, there has been a growing expectation for technology cooperation to derive significant mitigation actions and commitments from major developing countries such as China and India. Furthermore, technology cooperation on clean energy and climate between the United States and China has been attracting attention, as it has provided an incentive for building trust and partnership between them (Lieberthal and Sandalow 2009; Pew Center and Asia Society 2009).

As the case studies of this paper show, technologies at the stages of deployment and diffusion tend to be transferred to China eventually through the mechanism described in Figure 4. This is a special feature of the country as "the factory of the world." If we assume that this tendency will continue in the future, China can be a provider of climate mitigation technologies to the world in 2020. At least for China, acceleration of current dynamics should be pursued, rather than creation of new channels of transfer, for example, by massive public funding. As discussed in Sections 6.1 and 6.2, further acceleration of technology transfer, in terms of both technology diffusion and local production, can be achieved by development and implementation of policies for pushing technology deployment and diffusion (such as regulations and incentives) and creating sound business environments for foreign firms. It is up to the Chinese government whether it pursues such domestic policies, but once it determines to make improvements and reinforce these policies, China is likely to welcome assistance for policy development and implementation. Therefore, technology cooperation at downstream stages of development should be bolstered by institutional support.

On the other hand, China and other developing countries often request access to precommercial technologies that are still at the stage of R&D or demonstration. Such measures typically include joint R&D activities and public funding for technology demonstration. Because technologies at upstream stages are beyond the scope of the case studies of this paper, it is difficult to say how cooperation in precommercial technologies works, but such cooperation could nourish trust between developed and developing countries, which is a prerequisite for global climate cooperation. In Europe, cooperation in megascale facilities for basic science since the early 1950s strengthened unity among the nations and produced the

[13] For further discussion on forms of delivery, see Hall et al. (2008).

initial momentum for integration.[14] Learning from this history, cooperation in precommercial technologies may function as a stepping-stone to global cooperation.

Technology cooperation alone, however, cannot be sufficient for deriving significant mitigation action. As Hall et al. (2008) discuss, policies for developing-country engagement include various measures, and a practical strategy is to pursue a portfolio of options in parallel to find a way to effectively engage China and other major developing countries. Among various measures, the role of technology cooperation will be supplemental, aiding in the acceleration of technology transfer and trust building.

[14] See Ueno (2006).

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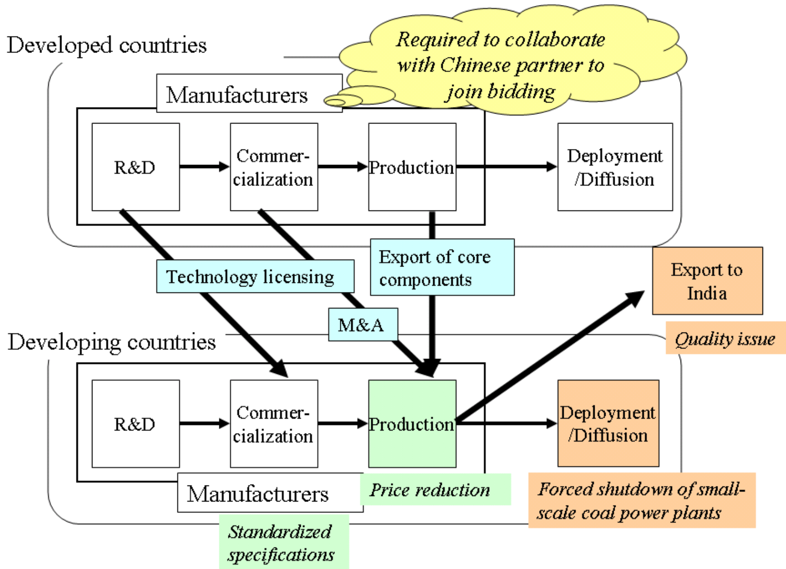
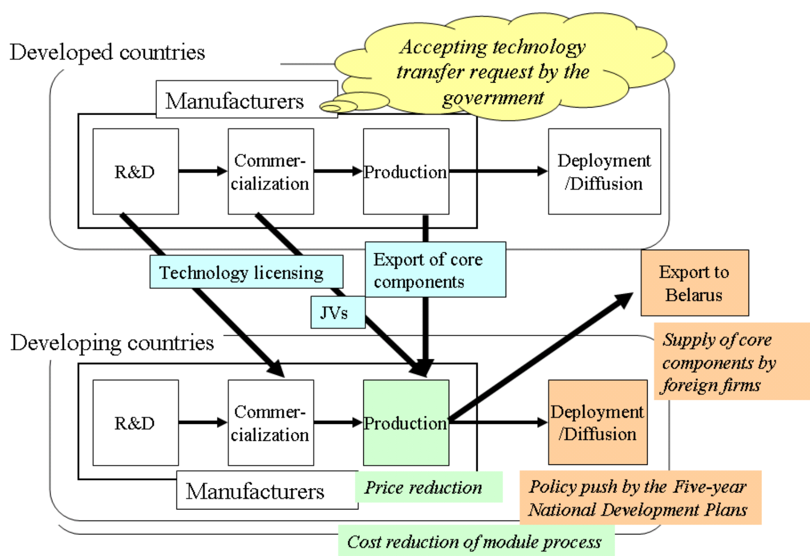
Appendix: Summary Figures of the Seven Case Studies

The following summary figures for each of the seven case studies detail case by case the information given in the diagram in Figure 3.

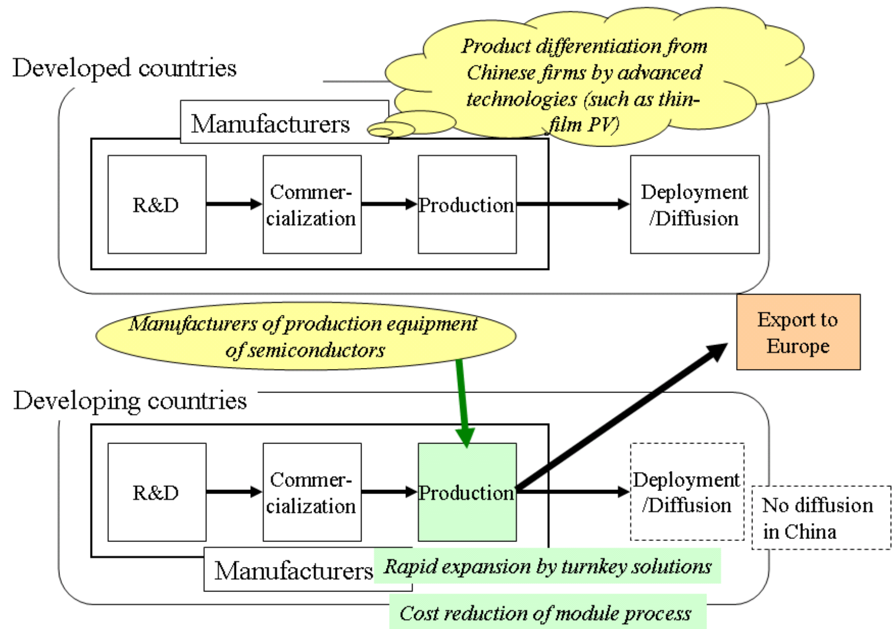
1. Supercritical and Ultra-supercritical Coal-Fired Power Plants (SC&USC)



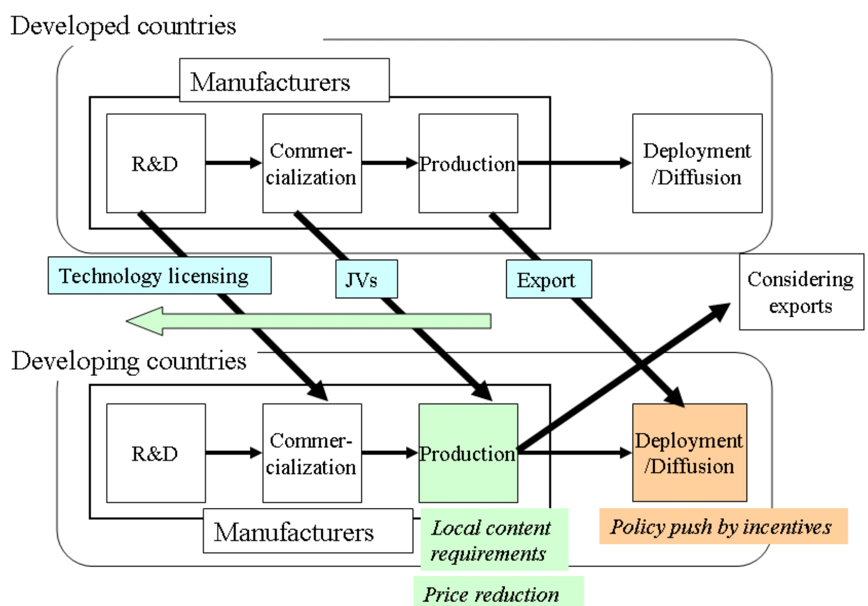
2. Natural Gas Combined Cycle Power pplants (NGCC)



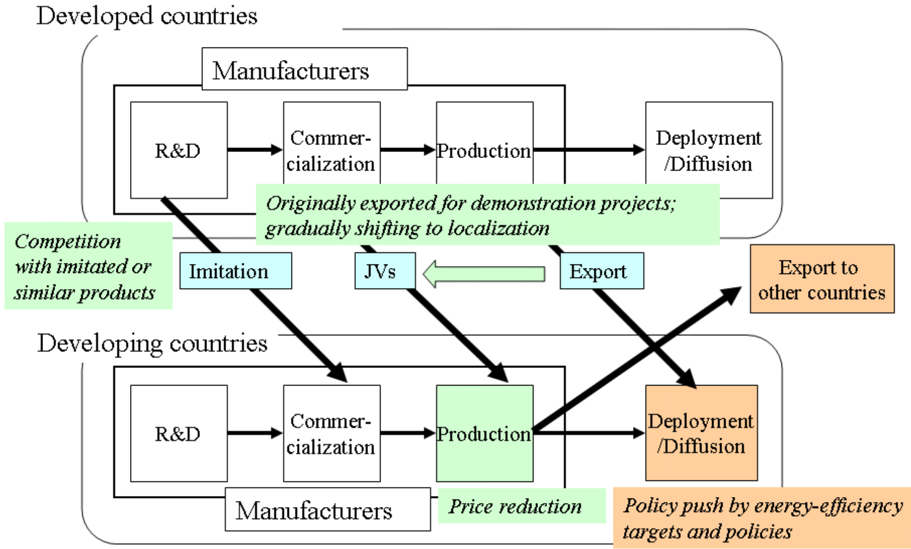
3. Photovoltaic Power Generation (PV)



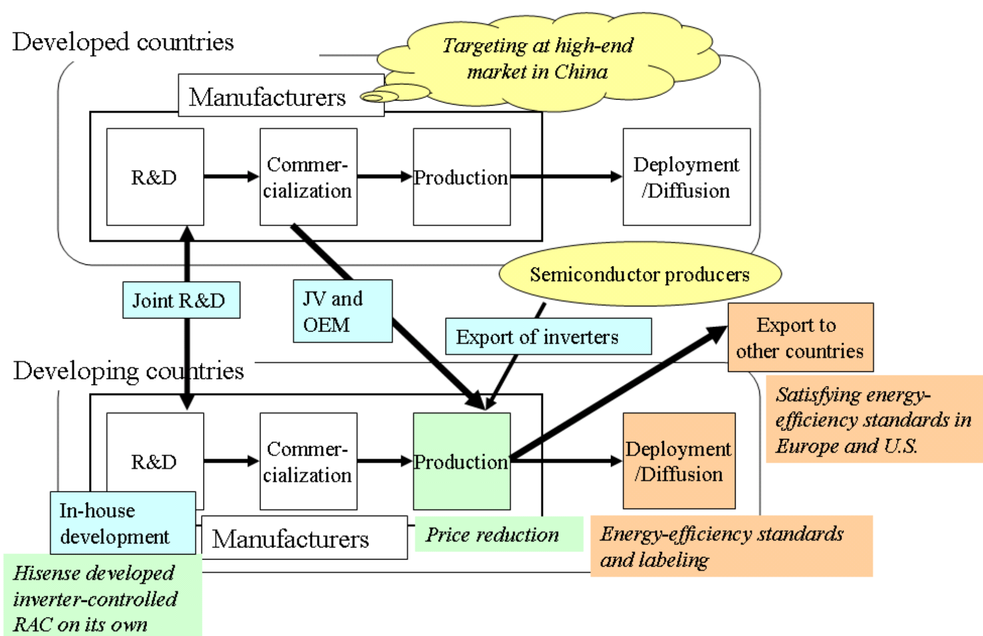
4. Wind Power



5. Waste Heat Recovery for Steel and Cement Plants (WHR)



6. Energy-Efficient Room Air Conditioners (EE-RAC)



7. Compact Fluorescent Lamps (CFL)