Annu. Rev. Energy Environ. 1997. 22:357–401

INTERNATIONAL TECHNOLOGY TRANSFER FOR CLIMATE CHANGE MITIGATION AND THE CASES OF RUSSIA AND CHINA

Eric Martinot, Jonathan E. Sinton, and Brent M. Haddad[1]
University of California at Berkeley, Energy and Resources Group, 310 Barrows, Berkeley, California 94720

KEY WORDS: technology diffusion, energy efficiency, renewable energy, capacity building, foreign direct investment

ABSTRACT

The environmental agenda for mitigating climate change through international transfers of technology is linked with a diverse literature, reviewed here within a framework that combines technological, agent/agenda, and market/transaction perspectives. Literature that bears on international technology transfer for climate change mitigation is similar in many ways for Russia and China: opportunities for energy efficiency and renewable energy, economic reform and restructuring, the difficulties enterprises face in responding to market conditions, international assistance policies, international joint ventures, market intermediation, and capacity building for market development. In both countries, capacity building means enhancing market-oriented capabilities in addition to technological capabilities. For Russia, institutional development is critical, such as new commercial legal codes and housing-sector changes beyond privatization. For China, technology policies and modernization programs significantly influence technology transfers.

[1]Eric Martinot is also with the Stockholm Environment Institute–Boston, 11 Arlington St., Boston, Massachusetts 02116. Jonathan Sinton is also with the Lawrence Berkeley National Laboratory, International Energy Studies Group, Berkeley, California 94720.

1056-3466/97/1022-0357$08.00

CONTENTS

INTRODUCTION

Global climate change has been a much-debated subject, but little question remains that the global climate is changing, with possibly grave consequences for human societies. In its 1996 second assessment report, the Intergovernmental Panel on Climate Change (IPCC) concluded that human-induced climate change represents an important new stress on ecosystems and socioeconomic systems (1, 2). Globally, energy use is responsible for 85% of anthropogenic carbon-dioxide (CO_2) emissions and for one fourth of anthropogenic methane emissions. Technologies for increasing the efficiency of energy supply and consumption, for switching to low-carbon fuels like natural gas, and for developing renewable energy sources and nuclear power have become recognized as important means for reducing CO_2 emissions associated with energy use and thus for mitigating global climate change. China and Russia are respectively the second-largest and third-largest contributors to global CO_2 emissions, after the United States; together these three countries accounted for 43% of industrial CO_2 emissions in 1992 (3).

In recent years, attention has focused on international technology transfer as an instrument to mitigate global environmental problems. Transfer and diffusion of technologies for reducing greenhouse gas emissions have been featured prominently in much of the international dialogue on climate change. The Framework Convention on Climate Change (FCCC), signed by 155 nations at the United Nations Conference on Environment and Development (UNCED) in 1992 and ratified into force in 1994, requires parties to "promote and cooperate in the development, application, diffusion, including transfer, of technologies, practices, and processes that control, reduce, or prevent anthropogenic emissions of greenhouse gases" (4, p. 7). In Agenda 21, a blueprint for sustainable development agreed upon by 178 countries at UNCED, technology transfer is seen as a significant potential instrument of sustainable development (5). Chapter 34 of Agenda 21, entitled "transfer of environmentally sound technology, cooperation and capacity-building," calls for access to scientific and technical information; promotion of technology transfer projects; promotion of indigenous technologies; capacity building; and long-term technological partnerships between suppliers and recipients of technology. The IPCC stated that climate change mitigation "depends on reducing barriers to the diffusion and transfer of technology" (1, p. 18).

These repeated calls for greater "access to" and "transfer of" environmentally sound technologies from "those who have the technologies" to "those who don't" represent a clear international environmental agenda. While governments are the parties to the FCCC, this agenda is also implicitly or explicitly being carried out through a wide variety of activities and decisions by private-sector firms (particularly multinational corporations), multilateral and bilateral development assistance agencies, United Nations agencies, non-governmental organizations, and individual consumers. The agendas of these agents may explicitly target environmental goals, may conflict with environmental goals, or may coincide with but not target environmental goals, but clearly many different agents and agendas are involved (6–8).

A tremendous volume of literature that scales across many disciplines is potentially relevant to this environmental agenda and to understanding the intersection of international technology transfer with climate change mitigation. This diverse literature tends to be organized or categorized by topic (see Table 1). Because this literature is so diverse, no comprehensive framework can encompass all of it—one must choose particular views. Our "road map" through this literature highlights features and perspectives that are salient to international technology transfer for climate change mitigation. We employ a framework with three sets of perspectives. Technological perspectives highlight technology needs, choices, and development. Agent/agenda perspectives highlight the different types of agents that can influence international technology transfer and the confluences or conflicts of their agendas (motivations) with the international environmental agenda. Market/transaction perspectives highlight the evolution of markets and the types of institutions and transactions that underlie them. These perspectives follow each other logically: Technological development

Table 1 Categories of literature related to technology transfer for climate change mitigation

General
Technology innovation, development, and diffusion
International technology transfer
International trade
Foreign direct investment, joint ventures, and international production
Political economy of international technology flows
Energy efficiency, renewable energy, and nuclear power technologies
Coal-combustion and gas-combustion technologies
Energy development policies and energy-related sectoral policies
Electric-utility sector restructuring and privatization
Multilateral development assistance
Energy and rural development
Technology choice and appropriate technology
UN literature on trade, development, and environment
International technology transfer for environmental goals
Market institutions underlying capitalist economies
Market failures, barriers, and transformation
Joint implementation
Country-specific
International technology transfer (specific country cases)
Energy supply and consumption (geography and infrastructure)
Technological capabilities and technology development policies
Sociocultural contexts for energy consumption
Macroeconomic, business, and market environments
Energy- and environment-related policies and regulation
Economic transitions and restructuring

and opportunities evoke a variety of agent motivations, and markets offer rules and structure for agents to act on those interests (of course feedback exists, e.g. markets also influence technological development).

Our framework is drawn from similar ones in the literature. For example, Reddy & Zhao (9) provide an organizing framework for international technology transfer literature that includes supplier perspectives, recipient perspectives, and transaction perspectives. Another example is Segafi-nejad's (10) technology transfer framework, which includes four clusters of interacting variables: technology characteristics, transfer modes, organizational characteristics, and environmental characteristics. Market/transaction perspectives also have roots in transaction cost and institutional economics (11, 12).

After looking at the general literature related to international technology transfer, we review literature specific to Russia and China, also organized through these three perspectives. In doing so, we address the question of

Table 2 Macroeconomic and structural indicators for Russia and China[a]

Indicator	Russia	China
Population (millions)	148	1211
Average monthly wage, 1995 (US $)[b]	120	55
GNP/capita, 1995 (US $)	2250	570
GDP growth in 1995 (%)	−4	10.5
Foreign direct investment, 1995 (billion US $)	2	38
Electricity consumption/capita, 1995 (kWh)	5600	830
Primary energy consumption/capita, 1995 (toe)	4.4	0.7

[a]Sources: (13–16).
[b]Based on exchange-rate equivalents.

what parts of the general literature and the country-specific literature are most relevant to the environmental agenda of technology transfer for climate change mitigation in these countries. Despite stark differences in macroeconomic and structural indicators (Table 2), we find that the answers for Russia and China have much in common. Both countries are emerging from centrally planned economic systems and are engaged in a transition towards market-oriented economies, while many institutional conditions still reflect the planned economic systems. The approach to market-oriented economic reforms, the behavior of newly private enterprises, the viability of joint ventures, government policies, multilateral and bilateral assistance, market intermediation, and capacity building are important topics for both countries. We also find that there are important differences related to motivations for technology transfer.

INTERNATIONAL TECHNOLOGY TRANSFER

In this section we first explore the meaning of international technology transfer. We then review the general categories of literature that are relevant to international technology transfer for climate change mitigation, employing the technological, agent/agenda, and market/transaction perspectives described above. We conclude this section with a review of the literature that directly addresses the environmental agenda for climate change mitigation.

The Meaning of International Technology Transfer

International technology transfer is certainly an interdisciplinary subject, and as such it has been written about by scholars and practitioners of economics, political science, history, management, engineering, industrial relations, international business and finance, marketing, law, sociology, and anthropology. Not surprisingly, while technology transfer frameworks and models are numerous in the literature, there are no coherent, overarching theories of technology transfer. Reddy & Zhao, in reviewing this literature, conclude that "given the inherent complexity of the subject, findings, conclusions, and contentions of what we know about international technology transfer are fragmented along various specialties" (9, p. 285).

Different perspectives of technology transfer stem from different views of technology: as a commodity, as knowledge, and as a socioeconomic process (17). The classical economic view of technology is essentially that it is an information-based commodity that can be reproduced without cost and transmitted from one agent to another. In this view, technology transfer is as simple as making a photocopy of design documents or obtaining a working artifact. In historical development-assistance contexts, technology was often a euphemism for capital, also reflecting this view of technology-as-commodity. But many in the field of technology transfer share the view of technology as knowledge (18). This knowledge is brought about through a learning process, and thus technology transfer is fundamentally a process of learning. In this view, transfer of inanimate objects—such as machines and blueprints—by itself does not constitute technology transfer, a view echoed by Rosenberg & Frischtak (19, p. vii):

> . . .instead of being regarded as public information, technology might be more usefully conceptualized as a quantum of knowledge retained by individual teams of specialized personnel. This knowledge, resulting from their accumulated experience in design, production, and investment activities, is mostly tacit, that is, not made explicit in any collection of blueprints and manuals. . . .each individual firm is a locus where the progressive accumulation of technical knowledge takes place. . .

Robinson (20, p. 1) sees technology transfer as a two-way learning process and therefore calls it *technology communication*, which he defines as "the development by people in one country of the capacity on the part of nationals of another country to use, adopt, replicate, modify, or further expand the knowledge and skills associated either with a different manner of consumption or product use, or a different method of manufacture or performance of either a product or service."

Similarly, Heaton et al (6, p. vii) advocate a new mindset and terminology, *technology cooperation*, to replace what they call "the bankrupt notion that technology can be 'transferred' full-blown from one economic and cultural context to another." In the "technology-transfer mindset," technologies are viewed as objects and technology transfers are onetime transactions that maintain the dependency of the recipient. In contrast, technology cooperation means a partnership and an "active, enduring collaboration between parties" that develops the skills and resources to adapt and adopt technologies to the specific contextual conditions and goals in which technologies will be employed and fosters long-term technology management and incremental improvement. The concept of technology cooperation was suggested even earlier by Schmidheiny (21), who sees commercially beneficial cooperation between firms as being at the core of successful technology transfer for sustainable development.

For us, technology encompasses a combination of hardware, services, and knowledge. We also prefer the concept of technology cooperation and find the term *technology transfer* unsatisfactory. But we use *technology transfer* here because it commonly appears in the literature. Many other terms in the literature are used in place of or in parallel with the term *transfer* that have slightly different connotations, including *diffusion, dissemination, deployment, development*, *adoption*, *application*, *communication*, *cooperation*, and *market penetration*. Fundamentally all of these terms describe socioeconomic processes of technological change and learning. Diffusion commonly connotes an "invisible hand" process of technological change through dispersed and uncoordinated decisions over time, although diffusion is used to mean many different things (and is sometimes used as a synonym for transfer). Dissemination connotes an active donor-recipient process through which those who have objects or knowledge attempt to provide it to those who do not. Deployment similarly connotes an active process by one agent as a source of technology. Adoption calls attention to the agent that chooses or utilizes a technology and the factors that influence that choice.

Technological Perspectives

The above array of terminology illustrates the difficulties in isolating technology transfer from the broader process of technological change. Technological perspectives consider the links between technology transfer and domestic technology development, diffusion, choice, and adaptation for local conditions (22–24). For example, McIntyre & Papp (25) consider the rate of domestic diffusion to be a key aspect of international technology transfer, and they believe that the choice of technology and transfer mechanism (mode) critically affects domestic diffusion. They also conclude, along with others such as Goulet (26), that the choice of technology is not merely a "value-free" technical or economic choice but rather a choice with political implications for the distribution of externalities, costs, and benefits of the transfer. Others have begun to acknowledge that a linear model of technology development, which starts with research and then moves through innovation, transfer, and diffusion phases, fails to capture the complexity of an integrated social and economic process of technological change in which all of these processes take place in parallel in space and time (27).

Technological perspectives include the large literature that identifies technical options for reducing greenhouse-gas emissions, which include increasing energy efficiency of existing end uses and of new equipment and processes, increasing energy efficiency of energy production and conversion, expanding the use of renewable energy, switching to less carbon-intensive fuels, and relying more on nuclear power (1, 2, 28, 29). Technologies for improved energy efficiency fall into three major categories: (*a*) major industrial-process replacements (usually associated with large industrial restructuring activities), (*b*) incremental technical improvements or renovations to existing processes and infrastructure, and (*c*) expanded market supply and demand of higher-efficiency versions of equipment such as industrial boilers, refrigerators, lighting, windows, and motors. Much of the energy efficiency literature analyzes the technical potential for energy efficiency in different applications and sectors, the technologies needed to achieve that potential, and the costs and economic returns of these technologies (30–35). Similarly, technical-economic potential is analyzed in literature on renewable energy technologies and economics, which shows that a wide range of renewable energy technologies are at or near commercially viable stages of development (36–39).

But the notion of distinguishing pure technical potential from the complex process of technological change has come under attack. For example, Shove (40) has challenged the conventional notion that "technical potential" for energy efficiency and greenhouse gas–emissions reductions can be separated from the barriers and constraining social and economic factors to technology transfer, and she argues for a more integrated view of "socio-technical potential." Achieving socio-technical potentials does not mean closing an imaginary gap between technical potential and technical reality but rather implies a complex social process of technological change.

Agent/Agenda Perspectives

Agent/agenda perspectives consider the questions of which agents are involved in technology transfers and why transfers take place. While governments, United Nations agencies, the World Bank, non-governmental organizations, and educational and research institutions are all technology transfer agents, the role of private firms (particularly multinational corporations) is dominant. We begin with multinational corporations because "there is little debate in the literature that the primary 'agent' of technology transfer from the home country is the multinational corporation," say Reddy & Zhao (9, p. 286). McIntyre & Papp (25, p. 5) agree:

> . . .the preponderance of international technology flows tends to be commercially motivated, with the multinational corporation occupying the commanding heights. The multinational, usually a private sector entity freed from many national constraints, is often the critical transmission belt of capital, ideas, and technology across national boundaries. . .

MULTINATIONAL CORPORATIONS Multinational corporations seek international sales, market share, and cheaper production costs through equipment transfers and foreign direct investment (19, 41). Corporations are concerned about acceptable risks and ensuring protection of intellectual property. Here relevant literature includes theories of international trade, multinational investment, international production, and international regimes to protect intellectual property. While international theories of trade have remained rooted in neoclassical macroeconomic views of comparative advantage of labor and capital, new theories of foreign investment, production, and the multinational firm have emerged. For example, interactions of firms within an industry are described (at a "mesoeconomic" level) by theories of industrial economics, games, and innovation (42). Theories of the firm apply at the microeconomic level (43); for example, Hennart (44) demonstrates that a wide variety of the types of foreign direct investment decisions undertaken by multinational corporations can be explained with transaction-cost theory. Trade barriers can also explain patterns of foreign investment, as corporations have learned that they must establish foreign subsidiaries in a growing number of countries or enter into joint ventures to reach otherwise protected markets (45). Corporate decision-making that takes into account environmental goals, including decisions about technology transfer, is the subject of a growing literature on corporate environmentalism (21, 46, 47).

RECIPIENT-COUNTRY FIRMS As with multinational corporations, cost minimization using foreign technologies is a strong motivation for many recipient-country firms to transfer technologies. But other motivations may be quite different from those of supplier firms (especially if recipient firms are state-owned), such as (*a*) technical capabilities, quality, or cost reductions that they cannot achieve on their own; (*b*) the higher perceived status of "international level" technologies; (*c*) access to managerial and marketing expertise, (*d*) access to export markets; and (*e*) access to distribution networks or other organizational assets (48). Recipient-country firms may also seek energy-efficiency and renewable-energy technologies to comply with domestic environmental regulations.

NATIONAL GOVERNMENTS Recipient governments may seek to increase capabilities for domestic technology development and to increase foreign investment in their country. Donor governments may fund transfers of research and expertise to support political goals, but more often they are interested in policies that expand foreign markets for national firms and increase exports. Governments can affect international technology transfer through trade policies, protection of intellectual property rights, or policies affecting the attractiveness and character of foreign investment (49, 50). Literature themes include (*a*) donor and recipient governments as facilitators or gatekeepers of technology transfer, (*b*) national dependencies on technology imports, (*c*) the implications of free trade versus protectionism for patterns of international technology transfer, and (*d*) regulatory regimes and mechanisms for controlling transfer. From an international political-economy perspective, relevant questions include how technology transfer contributes to changes in strategic and political relationships between countries (including technological "balance of power"), economic competitiveness, and military superiority (25, 45).

MULTILATERAL AGENCIES WITH DEVELOPMENT GOALS Because development assistance by the World Bank and other multilateral and bilateral agencies has a large influence on energy-technology development and on international technology transfer, the literature on development assistance and energy-sector lending by these agencies is relevant to this discussion (35, 51, 52). In traditional development assistance, the critical factors for economic growth were seen as capital investment and technology (53). In this development paradigm, technology transfer was very much a transfer of objects, such as power plants and communications infrastructures, selected and specified by donors, that were thought necessary for economic development. More recently, development assistance has emphasized structural-adjustment policies as preconditions for development lending, and technology transfer has evolved into an instrument by multilateral agencies for achieving desired economic and policy reforms. For example, much development-related technology transfer for higher efficiency of electricity production and use has occurred in the context of electric power–sector reform and restructuring. The World Bank's policies on energy efficiency put technology transfer in the context of encouraging proper economic incentives (35, pp. 76–77):

> . . .there is the need to put in place policies, legislation, mechanisms, systems, institutions, and incentives that facilitate technology transfer and encourage the use of the most efficient competitive technologies. . . .long term potential for major improvements in the conversion of energy into environmentally-benign economic output lies in incentive structures or processes that channel new investment into the most up-to-date and efficient competitive technologies.

MULTILATERAL AGENCIES WITH ENVIRONMENTAL GOALS Some multilateral agencies, such as the Global Environment Facility (GEF), have climate change mitigation as an explicit objective and seek the most cost-effective means to accomplish this objective (54, 55). The GEF has adopted a strategy for mitigating climate change that calls for removing market barriers to otherwise-profitable investments in energy-efficiency and renewable-energy technologies in developing countries and countries in transition. Various United Nations (UN) agencies have contributed conference reports and recommendations to the general literature. The UN Commission for Sustainable Development (UNCSD) was formed in 1992 and given the responsibility to monitor progress in implementation of Agenda 21, including the transfer of environmentally sound technologies (56–59). The UN Conference on Trade and Development (UNCTAD) has traditionally dealt with trade, technology transfer, and development issues and has also attempted to develop an international code of conduct for technology transfer (60–62). The International Energy Agency offers technical support to many developing countries for environmental and climate change mitigation goals (63).

NON-GOVERNMENTAL ORGANIZATIONS Non-governmental organizations (NGOs) can play a crucial role in technology transfer policies and activities. Traditionally, the environmental impacts of technology transfers have been high on the agendas of many NGOs in both supplier and recipient countries (64). NGOs have also been at the forefront of concerns about technology choice and the "appropriateness" of technologies transferred through development assistance and commercial channels, the social and cultural impacts of such transfers, and the needs for technology adaptation to suit local conditions and minimize unwanted impacts (26, 65). More recently, environment- and development-oriented NGOs have successfully pressed governments toward new climate-change policies that can affect international technology transfer and are participating in ongoing climate policy formulation. As mentioned in the next section, recipient-country NGOs have also provided market intermediation functions for technology transfer and have themselves been initiators of renewable energy–technology transfers (66, 67).

Market/Transaction Perspectives

Market/transaction perspectives consider how to achieve sustainable markets for technologies to mitigate climate change and thus harness the power of market-based incentives to accomplish environmental goals. Experience with development assistance for renewable-energy projects in developing countries over the past two decades illustrates the importance of market/transaction perspectives. In the 1970s and 1980s, development assistance agencies attempted to transfer many small-scale renewable-energy technologies such as biogas, cooking stoves, wind turbines, and solar heaters. Many projects were considered failures because of poor technical performance, lack of attention to user needs and local conditions, and lack of replication of the original projects. Projects emphasized onetime technology demonstrations that failed to understand or provide incentive structures, failed to demonstrate institutional and commercial viability, failed to account for continuing maintenance requirements, and failed to generate sustainable markets for the technologies demonstrated (67–71).

Many authors now view the development process in a market-oriented context, in which technology transfer is intertwined with development assistance aimed at promoting functioning domestic commercial markets, including domestic production capability, access to financing, stakeholder partnerships, information channels, institutional capacities, and the removal of other market barriers. The need to support markets, market institutions, and entrepreneurs as the primary agents of development and technology transfer can be seen in alternative views of the development process that have come from schools of institutional economics (72).

A market/transaction perspective is reflected in models of technology transfer that address the questions of when and how technology transfer transactions occur. For example, a model by Robinson (73) includes three dependent variables for both the supplier and recipient sides of a technology transfer transaction: the choice of technology, the modes of transfer employed, and the propensity to conduct technology transfer transactions. These variables are dependent on five main groups of independent variables: perceived costs, perceived risks, anticipated benefits, the cost of modifying the technology, and supplier-government and recipient-government policies and regulations.

Below we review four market/transaction perspectives that are especially relevant to technology transfer for climate change mitigation: market barriers, market intermediation, capacity building for market development, and technology transfer modes.

MARKET BARRIERS Market barriers may prevent seemingly cost-effective energy technologies from diffusing to the extent that their potential and cost-effectiveness suggest they will. Market barriers to energy efficiency are well characterized in the literature and reflect the existence of (*a*) energy prices that do not reflect true costs, (*b*) incomplete information, (*c*) externalities, (*d*) short time horizons of consumers (coupled with high front-end capital costs), (*e*) limited or "bounded" rationality of consumers, (*f*) transaction costs, (*g*) imperfect capital markets, (*h*) public goods, and (*i*) institutionally mismatched costs and benefits (74–77). Barriers to renewable energy are similar to those for energy efficiency and also include more technology-specific barriers such as issues of utility planning and acceptance, limits to utility grid operation with intermittent sources, siting and building restrictions, permit risks, the difficulty of incorporating fuel price–risk assessment for fossil fuels into planning models, and the problems of adapting existing market institutions that are structured for conventional energy infrastructure (38, 68, 70, 78). The World Bank and the UN argue that technology transfers face these same market barriers (35, 57). Many studies describe barriers to private-sector technology transfers in terms of the following factors: (*a*) poor macroeconomic and regulatory conditions;

(*b*) weak or distorted demand for environmentally superior technology; (*c*) low technical capability to access, adapt, and develop technology; (*d*) too little information about technological alternatives; (*e*) missing connections between potential partners and the problems of scaling cultural gaps and fostering long-term relationships; and (*f*) lack of intellectual property protection (6, 79).

MARKET INTERMEDIATION The World Bank and many others have recognized that market intermediation is needed to reduce market barriers associated with information, management, technology, and financing (35). Intermediation services may include some of the following: (*a*) information dissemination; (*b*) referrals; (*c*) training and consulting; (*d*) establishment of energy-service companies; (*e*) energy audits; (*f*) drafting of codes and standards; (*g*) identification of macroeconomic and sectoral barriers and the means to overcome them; (*h*) technology intermediation between potential supplier and recipient firms; and (*i*) feasibility, evaluation, and packaging of projects for public or private financing. NGOs, government agencies, and private firms are all important purveyors of market intermediation. There are many cases where market intermediation by NGOs played a key role in the success of particular technology transfer efforts (67).

CAPACITY BUILDING FOR MARKET DEVELOPMENT The UN has used the term "capacity building" to denote the enhancement of skills and capabilities among both individuals and institutions. In its broader meaning, capacity building refers to both skills enhancement and the creation of new institutions and conditions that support functioning markets. For example, functioning markets require availability of information, acceptable levels of risk, appropriate skills, a system of property definitions, oversight and intermediation bodies, decision-making autonomy for buyers and sellers, and stable political and legal regimes (80–82). Much of the focus on capacity building has been on enhancing scientific and technical skills, capabilities, and institutions in developing countries as a precondition for assessing, adapting, managing, and developing technologies (83). The need for enhanced skills and capabilities can also occur in the areas of financing, marketing, maintenance, service, information dissemination, utility regulation, policy development, technology transfer, market intermediation, tax policies, macroeconomic policies, and property rights. Many studies acknowledge that capacity-building needs vary greatly from country to country, and they stress that case studies and other types of analyses should assess the needs of particular countries.

TECHNOLOGY TRANSFER MODES Market/transaction perspectives also include analyses of the modes of technology transfer (the types of transactions that occur). Common modes are direct sales of equipment and services, technical assistance contracts, turnkey projects, wholly owned subsidiaries, joint ventures, licensing agreements, coproduction research and development (R&D) agreements, personnel exchanges, and information transfers from documents and conferences. While wholly owned subsidiaries have traditionally been the dominant mode of foreign direct investment, international joint ventures have been growing in number throughout the 1980s, and various theories of international joint ventures have been advanced to explain this phenomenon (84–88). Three reasons for the trend, advanced by Datta (84), are as follows. (*a*) Host governments are increasingly requiring foreign investment in the form of joint ventures. (*b*) Multinational corporations began to realize that the knowledge of complex and volatile local business environments by local partners can be a significant asset. (*c*) There is a growing trend to internationalize business to reduce costs. Contractor (89) sees transaction costs as determinants of a firm's choice of the mode of transfer. Kogut (85) explains joint ventures in terms of transaction costs, strategic behavior, and transfer of organizational knowledge and learning. Kogut further suggests that some forms of tacit knowledge can only be transferred through a joint venture because the knowledge is organizationally embedded and not conducive to licensing or other forms of transfer. Joint ventures as an effective mechanism for environmental technology transfer have been discussed extensively by the United Nations and other public agencies (57–59).

Strategies at the Intersection of Technology Transfer and Climate Change

There is a growing body of literature specifically devoted to the intersection of international technology transfer with sustainable development and global climate change mitigation (6, 7, 27, 47, 50, 79, 90–99). A common theme of this literature concerns what policy options or strategies by governments and other agents can accelerate the transfer and diffusion of less greenhouse gas–intensive technologies, a process that Nakićenović & Victor (95) call "overt technology transfer." The international environmental agenda for climate change commonly presumes some "baseline" scenario and then asks, relative to this baseline, how technological change within a country can be significantly affected by actors outside the country through active, incremental interventions. Answers to this question are often rooted in different paradigms of economic development. As the role of the private sector has increased within the prevailing economic development paradigm, so too does literature at the intersection of technology transfer and climate change search for ways to harness private-sector activities for sustainable development and technology transfer. For example, one policy option relies on voluntary activities by multinational corporations to promote sustainable development, and Baram (47) outlines several strategies for encouraging private voluntary codes of environmental conduct by multinational corporations.

Prominent among this literature is Agenda 21 (5), which outlines several strategies for promoting technology transfer that reflect not only the need for hardware but also for building associated local capacities and for providing the following market intermediation services: (*a*) information networks and clearinghouses that disseminate information and provide advice and training; (*b*) government policies creating favorable conditions for both public-sector and private-sector transfers; (*c*) institutional support and training for assessing, developing, and managing new technologies; (*d*) collaborative networks of technology research and demonstration centers; (*e*) international programs for cooperation and assistance in R&D and capacity building; (*f*) technology-assessment capabilities among international organizations; and (*g*) long-term collaborative arrangements between private businesses for foreign direct investment and joint ventures.

In 1994, the Ad Hoc Working Group on Technology Transfer and Cooperation of Environmentally Sound Technologies, formed within the UN Commission for Sustainable Development, saw the technology transfer problem as one of inadequate financial resources and limited human and institutional capacities (57). The Working Group recommended that governments and international organizations provide more financing and "improve access" to environmentally sound technologies, including clearinghouses and information systems to disseminate information. Although the Working Group recommended facilitating access to technologies in the public domain, it recognized that private-sector activity was key to technology transfer and advocated linkages between research and industry. In more recent sessions of the Commission for Sustainable Development (58, 59), these themes were further explored and activities by governments were proposed that would provide access to and dissemination of information, institutional development and capacity building, and financing and partnership arrangements.

Similar policies and strategies are prescribed in non-UN literature as well. Seven generic policy solutions are typical: public-source financing (grants or loans), cooperative R&D programs that encourage domestic technological development and diffusion, institution building and new institutions, information exchange, better "access" to technologies than free markets and multinational corporations would normally provide, training and skills development, and encouragement of international joint ventures and private investment. Other authors emphasize the importance of creating the proper macroeconomic and policy conditions for transfers and then letting markets dictate technology choice and transfer modes (50, 97). Policies for strong international intellectual-property protection are also advocated (100).

Heaton et al (27) analyze the types of policy changes necessary to achieve a technological "transformation" towards more environmentally sustainable technologies. In their view, successful technology transfer policies must make available financial resources, must reduce or eliminate barriers to technology transfer, must promote capacity building within developing countries, and must promote new forms of intermediation or "technology brokering." Capacity building should target technology acquisition, skills development, and local policies and institutions. Market intermediation should include matching technologies with applications, brokering partnerships, and facilitating negotiations and financing packages. In a later work, Heaton et al (6) reject the government-policy-as-primary paradigm and propose partnerships and consensus among industry, academia, international organizations, NGOs, and governments. They recommend diffusing environmental technology through transnational commercial networks, developing business charters for environmental technology cooperation, and creating environmental-technology investment corporations financed sustainably through private sources. They also favor sector-specific environmental technology intermediaries.

Although there is general agreement that capacity building is important, the record of capacity building in practice so far is poor. Capacity building is neither easy nor quick, as Barnett (7, pp. 15–16) concludes: "there is a great deal of uncertainty about precisely what capacities are needed and how they are developed. . . .Unfortunately, experience suggests that the necessary competencies can, at best, only be improved slowly, and that many of the requirements are cumulative, and involve tacit and uncodified knowledge that is difficult to purchase on the international market."

Finally, government policies for "joint implementation" (JI) or "activities implemented jointly" (AIJ) are an evolving bilateral strategy linked to technology transfer for climate change mitigation. Joint implementation is defined broadly in the Framework Convention on Climate Change as activities to address climate change carried out cooperatively by interested parties, although various governments have adopted a variety of interpretations and programs (101, 102). Through joint implementation, governments can create policies that facilitate climate change mitigation in other countries and receive credit for such interventions under their climate change–treaty obligations.

THE CASE OF RUSSIA

In understanding the application of the environmental agenda for climate change mitigation to the case of Russia, we find several important perspectives within both the general literature and the Russia-specific literature. Historical technology transfer with the Soviet Union is still relevant to Russia because many remnants of Soviet-era institutions and mentalities remain. Relevant technologies for climate change mitigation and related issues of technological development in Russia are strongly influenced by large energy inefficiencies in existing infrastructure, the dominance of natural gas in Russia's energy mix, and Russia's advanced technological capabilities. Domestic government agencies and bilateral and multilateral donors have addressed the problems of energy efficiency, making these agent/agenda perspectives relevant. Literature on joint ventures and foreign direct investment is extremely relevant to Russia because of the predicament facing newly privatized enterprises and the realities of the post-Soviet economy. Finally, transaction perspectives highlight barriers to transfer and diffusion of technologies for climate change mitigation, and the need for market intermediation and capacity building to overcome these barriers.

Historical Perspectives: The Soviet Union

Historical literature on technology transfer with the Soviet Union was frequently most concerned with the impact of Western technology on Soviet economic performance and military strength, the need for foreign technology in a centrally planned economy, and the political and military implications of Soviet technology transfers to other countries. Within the Soviet Union there was always some ambivalence toward imports of foreign technologies. On the one hand, the Soviet Union needed Western technology, and this drove much of the transfer and cooperation that did occur. On the other hand, there was a desire to remain economically self-sufficient and isolated from the influence of capitalist countries, corporations, and market fluctuations. The Soviet Union maintained an official policy of autarky for much of the Soviet period. In general, the need for Western technology arose for two main reasons: the fundamental inability of the Soviet administrative/planned economy to produce the innovations required for continued progress and the need to fill short-term gaps in production when plan targets were not met or when special requirements arose. During the early years of the Soviet Union in the 1920s, the Soviets saw foreign technology as key to economic development and signed many technical cooperation agreements with Western countries. In the period following World War II, trade with the West came to a standstill, but by the 1960s trade again had resumed and persisted through the end of the Soviet era. The availability of Western credit, foreign-exchange earnings, and/or counter-trade possibilities was often the limiting factor in technology transfers and cooperation agreements. Throughout these periods, Soviet leaders generally acknowledged the critical role of Western technology in improving Soviet technological performance (103–106).

Direct foreign investment was not permitted in the Soviet Union until 1987, and the Soviets traditionally engaged in more passive forms of technology transfer, such as equipment purchases and licensing. After 1965, Soviet policy acknowledged the importance of longer-term "embodied" technology transfer, including licenses with technical assistance, longer-term industrial cooperation agreements, and turnkey plants. License agreements were seen as especially effective as quick and cheap ways to narrow the "technology gap" between East and West. Turnkey plants were also regarded as an effective channel of technology transfer; within the Soviet system it was much easier and faster to put in an entirely new plant with Western technical and managerial expertise than to force radical innovations on existing plants where management and workers were resistant to changes. Beyond immediate recipients, the impact of new foreign technologies and their domestic diffusion was considered low by Western analysts (103, 105). But the technological capabilities and skills of Russians were not significant impediments to diffusion; rather, the characteristics of the centrally planned economy were to blame: shortages of construction labor, transportation, and complementary inputs; managerial incentives that discouraged innovation; a lack of specific manufacturing expertise; and quality problems.

Since 1992, post-Soviet Russia has undergone radical changes, including elimination of price controls, massive privatization, fundamental economic reforms, violent political battles, and tax and currency reforms. These changes have had profound impacts on technology transfer and CO_2 emissions. For example, industrial output declined by 50% from 1990 to 1995 by officially reported statistics,[2] and energy consumption fell by 20–25% (107). Since 1992, real energy prices have increased at different rates for different fuels, but by 1996 prices for all forms of energy paralleled levels seen in Western Europe and other developed countries, and few energy subsidies remained except for residential space heat and hot water.[3] Higher energy prices and the overall process of economic restructuring and new investments in selected industries mean that enterprises are becoming more energy efficient and are actively seeking new technologies.

Technological Perspectives: Energy Efficiency, Gas, and Domestic Capabilities

Relevant technologies for climate change mitigation are strongly influenced by the characteristics of energy use in Russia. Russia's energy system is comparable in size and sophistication to energy systems in most developed countries, and per capita energy consumption is also comparable to many developed countries. Russia produces the most oil and gas of any country in the world, and

[2]The unreported economy was said to account for 20–40% of GDP by 1995, so official figures can be misleading.

[3]In addition to heat and hot water subsidies, residential electricity was cross-subsidized through higher industrial electricity rates.

natural gas accounts for over 40% of primary energy consumption. Massive centralized district-heating networks supply heat to over 75% of the population, and district-heat consumption accounted for more than 30% of total primary energy consumption in 1990 (107, 108). Yet tremendous inefficiencies in this energy system are a legacy of the Soviet era, and large improvements in energy efficiency are possible. Important technological developments include (*a*) reducing natural gas–pipeline leakages; (*b*) power-plant fuel switching from oil and coal to gas; (*c*) energy-efficiency improvements in industry, heat supply, and buildings; (*d*) new, higher-efficiency equipment such as motors and motor vehicles; and (*e*) renewable-energy sources. Because over half of electricity production is fueled by natural gas, combined-cycle gas-turbine technology also has a high potential to make electricity production more efficient (109–115).

A large body of evidence suggests that many energy-efficiency improvements are possible that can provide high economic rates of return. Specific technologies with high technical-economic potential for energy efficiency include (*a*) meters, valves, and automated controls for district-heating supply, distribution, and consumption, especially in the residential sector; (*b*) reduction of heat leakages and better insulation of buildings and heat distribution pipes in the residential and industrial sectors; (*c*) secondary process-heat recovery in industry; (*d*) variable-speed motor drives in industry and energy production; (*e*) low-cost measures in industry such as boiler tuning, energy monitoring and control systems, and minor industrial-process changes; (*f*) industrial cogeneration with combined-cycle gas turbines; and (*g*) municipal lighting. Negative or flat growth rates of energy consumption in the 1990s have had two important implications for energy efficiency: (*a*) The decline in electricity demand from 1990 to 1995 has left widespread surplus electric-power capacity and thus reduced the short-term economic benefits of electricity efficiency in many regions (in contrast to developing countries where immediately avoided capacity costs can justify large investments in efficiency). (*b*) Renovation and improvement of existing infrastructure play a larger role in greenhouse-gas reductions than do new equipment and construction (116–126).

Russia receives practically none of its energy supply from non-hydropower-renewable energy, but many economically favorable opportunities exist for renewable energy in Russia, particularly for wind, biomass, solar thermal, and geothermal. Among the renewable-energy technologies closest to commercial potential are grid-connected wind farms, autonomous wind-diesel hybrid systems, residential solar hot-water heating, and biomass-fueled boilers using forest products and agricultural wastes (116, 127–131).

In many ways, Russia's technological capabilities already parallel those in many developed countries. Skilled engineers and scientists are plentiful. Virtually all types of industrial and consumer equipment are produced domestically—a legacy of the Soviet policy of self-sufficiency—and most equipment designs can be a target for improved energy efficiency. Many technologies for energy efficiency, renewable energy, nuclear power, and advanced gas combustion have already been developed in Russia, although they may not be commercialized. Some advanced technologies, such as wind turbines, variable-speed motor drives, and gas turbines, are produced in Russia, but the quality and performance of foreign technologies are considered superior, and domestic manufacturers must improve quality to become competitive. Other technologies, such as high-efficiency refrigerators, automobiles, and industrial motors, could be produced in Russia, but only low-efficiency models are available so far (111, 114–116, 127, 132–134).

Agent/Agenda Perspectives: Government, Bilateral, and Multilateral Agencies

Russian government energy policies and programs are relevant to technology transfer for climate change mitigation. Before 1992, Soviet energy policies focused on increasing the supply of energy rather than improving the efficiency of existing energy use or reducing materials intensities in the economy, and government motives for increased energy efficiency were token at best (135). Although Russian energy policies have still favored the supply side (15), recent policy developments have emphasized energy efficiency. After several years of legislative consideration, a national law on energy efficiency was adopted in 1996 (136). The law provides incentives and mandates for equipment production and investments for energy efficiency and allows independent power producers in electric-power markets (which should also have an effect on the transfer of renewable-energy technologies). Various regional energy-efficiency funds also have been established that are essentially energy-supply taxes used to fund government-administered energy-efficiency programs. While these policies and programs will have an impact on greenhouse-gas emissions, the government's motivations are primarily political (centralized administration of large energy-efficiency funds) and economic: Federal and regional government agencies view energy efficiency as a means to improve enterprise economic efficiency and viability, and they see the potential for production of energy-efficiency technologies as a means to reutilize idle industrial capacity and labor in the face of severely declining industrial production and harsh economic conditions.

Bilateral and multilateral technical assistance to Russia for energy efficiency in the early 1990s was motivated in large measure by the desire of Western governments to see market-oriented reforms and privatization take root. Some bilateral and European Union assistance emphasized technical training of personnel, technical audits of industrial and energy facilities, policy advice, and foreign equipment transfers for technology demonstrations. Much of the early assistance was ineffective, but the assistance evolved with the recognition that Russians were technically sophisticated but needed market-related assistance in many forms. International assistance soon began to focus on helping enterprises to develop business plans for energy-efficiency projects and on understanding the economic and financial analyses involved, on creating market institutions, and on financing arrangements to make credit available to enterprises for energy-efficiency investments (125, 137–140). Bilateral assistance has also focused on electric power–system reform and restructuring and transfer of "soft" technologies such as demand-side management approaches to energy efficiency.

By 1996, the World Bank and Global Environment Facility (GEF) were both starting to provide assistance to Russia for energy efficiency, each for different reasons, highlighting the importance of these agency perspectives. The GEF approved a capacity-building grant to remove market barriers to energy efficiency, consistent with GEF program objectives for climate change mitigation (54). The World Bank approved two loans to Russia related to energy efficiency that will result in significant international energy technology transfers (141, 142). The larger of these two, a $300 million loan for energy-efficiency improvements to existing multifamily residential buildings, illustrates how energy efficiency can be used as an instrument within policy-based structural adjustment lending by the World Bank. As with other structural adjustment–based lending, this loan's primary objective is a policy one—in this case to allow enterprises to divest themselves of social assets like residential buildings so that the enterprises can become more efficient. In achieving this policy objective, energy efficiency is a means to lower housing operating costs and make the divestiture process viable for the municipal governments that will take over responsibility for the buildings.

Market/Transaction Perspectives: Joint Ventures and the Predicament of Privatized Enterprises

With the breakup of the Soviet Union in 1991, the centrally planned administrative economic system vanished. But Russia is still far from operating as a market economy even though most enterprises have been privatized and most prices are market-based. The literature on economic reform and restructuring in the former Soviet Union has pointed more often to the failures of Western economic prescriptions than to the successes (143–145). Of particular relevance to technology transfer with Russia are discussions about the predicament of newly privatized enterprises (146–149). In the Soviet economy, central planners told enterprises how much to produce, where to send outputs and get inputs, and what prices to pay (150, 151). Enterprises produced extremely narrow and specialized product lines. Specialized design institutes separate from enterprises were often responsible for developing new products and processes. Enterprise-manager incentives discouraged innovation. Quality of goods was unimportant. Now enterprise managers must learn to make decisions for themselves, think creatively, identify and select suppliers for inputs, market their products and broaden their product lines, build innovation capacity, control quality, and manage their financial balances and resources. In the words of Yavlinsky and Braguinsky (148, pp. 92–93),

> Most enterprises in the present-day Russian economy are still very far from becoming privately owned corporations to which standard incentive schemes can be applied. Instead they constitute a new and previously unknown class of enterprises that we call post-state-owned enterprises. . . .managers who recognized new opportunities nevertheless failed to change over to normal market behavior because of a tremendously high switching cost. . . .To enter the market economy, [these enterprises] would have to pay for market research, create an after-service network, develop new marketable products, establish a system of quality control, shape a new network for distributors, and retrain the labor force.

The predicament of privatized enterprises bears on climate change mitigation in two significant ways. First, enterprises as consumers of energy and potential investors in more energy-efficient technologies must learn to think in cost-minimizing ways, understand financial and economic analysis of energy efficiency investments, and have access to credit. Second, enterprises as producers of technologies need to develop innovative capabilities to make new and more energy-efficient products (including renewable-energy technologies) and need to develop the business, marketing, and distribution capabilities to sell those products.

Modes of international technology transfer that assist Russian enterprises in these processes are important to the environmental agenda for climate change mitigation. One such mode is the joint venture. Julian Cooper saw the potential for joint ventures to address energy efficiency in 1991, and his message is still relevant (152, p. 42):

> Energy saving and conservation technologies. . . .could well offer scope for joint ventures. . . .Whereas Western economies have more than fifteen years of experience in adapting to the shock of higher energy prices and have developed appropriate new technologies for enhanced energy efficiency, the pricing practices of the Soviet economy have served to isolate the country's technical specialists and managers from this experience. The joint venture could offer an effective means of reducing this gap within a relatively brief period of time.

The factors cited in the general literature on international joint ventures as to why firms choose to transfer technologies through joint ventures are relevant to Russia. "Joint ventures offer a unique opportunity of combining the distinctive competencies and the complementary resources of participating firms," says Datta (84, p. 86). In a Russian joint venture, a foreign partner can contribute the most essential ingredients, which the Russian partner often lacks—managerial, marketing, and financial expertise and commercial experience with a specific technology. At the same time, joint ventures allow Western partners to benefit from the existing contacts and experience of their Russian partners related to government regulations, licenses, and supplier networks and relationships. This last point is especially important in Russia, where business contacts tend to be highly personalized rather than anonymous and where navigating government corruption and bureaucracy require great skill and experience (153).

With the coming of Perestroika and Gorbachev's attempts to modernize, reform, and open the economy, joint ventures were allowed in the Soviet Union for the first time in 1987 (154, 155). A 1990 survey of US-Soviet joint ventures showed that Soviets favored joint ventures because joint ventures provided acquisition of foreign currency, access to modern technology, improvement in the quality of goods produced, technological and managerial know-how, and increased worker pay and status (156). These preferences remain, and now Russians also look to joint ventures for access to business and commercialization expertise. The risks of foreign investments and joint ventures in Russia have been perceived as high by potential foreign investors, with often-conflicting views about the viability of joint ventures (157–160). In the early 1990s, many investors shied away from Russia, and the scale of foreign investments was tiny compared with the potential.

Market/Transaction Perspectives: Barriers, Intermediation, and Capacity Building

Many transaction barriers limit international technology transfers with Russia. These same barriers also limit domestic purchases and investments in more energy-efficient technologies and other technologies for greenhouse gas–emissions reductions. Thus the literature on market failures and transaction barriers in both developed- and developing-country contexts is relevant to the environmental agenda for climate change mitigation. Transaction barriers in Russia that are similar to those in both developed and developing countries include those related to lack of information and uncertainties, institutionally mismatched costs and benefits, market acceptance of technologies, bilateral trade restrictions, and high front-end capital costs. Other barriers in Russia are more reflective of developing countries, such as macroeconomic instability (especially inflation and fluctuating exchange rates), political instability, bureaucracy and corruption, weak market and legal institutions and lack of enforcement mechanisms, the lack of an adequate commercial legal code, the lack of Western-style accounting systems, an undeveloped commercial banking sector, monopoly production, and state-owned enterprises. Many barriers are unique to Russia, including those related to technical and organizational characteristics of district-heating infrastructure; highly personalized economic relationships and networks; continually changing tax and customs laws; housing privatization and responsibility; separation of innovation from production; and the lack of historical experience with cost-minimization, innovation, marketing, financing, negotiating, and competition (111, 116, 161–163).

One example of significant infrastructural and institutional barriers is the problem of energy efficiency in residential buildings. Residential heat and hot-water meters are nonexistent in Russia, so consumers pay fixed heating costs independent of consumption and thus have no incentive to purchase and install energy-efficient technologies. Even with heat meters, renovations to multi-family buildings require owner-tenants to organize into owner associations, collectively assume responsibility for the building from a city government or enterprise, and collectively manage and implement improvements to buildings (164). Another example of a unique barrier is the "distance" separating Russian and foreign firms. During the Soviet era, all technology transfers were conducted through the Ministry of Foreign Trade and controlled by central planning authorities (151). Thus enterprise managers were far removed from foreign markets and had little experience in evaluating, understanding, and selecting foreign technologies. This lack of experience remains. The "distance" separating Russian and foreign firms also reflects the difficulties foreign firms have in learning about potential Russian partners or customers and ascertaining their financial condition (because financial audit and disclosure norms and regulations are undeveloped).

Because of these pervasive market barriers, explicit strategies to promote technology transfer for climate change mitigation through development of strong market intermediaries for energy efficiency and renewable energy are especially relevant to the case of Russia. Market intermediation can provide the information, skills, analysis, partner matching, financial evaluation, market services, project evaluation and specification, and financing necessary to overcome transaction barriers. Several examples of emerging market-intermediaries exist in Russia, including energy-service companies. Many forms of market intermediation represent important institutional innovations for Russia (116, 162).

Market barriers and the predicament of newly privatized enterprises also illustrate the importance of capacity-building strategies. Russia still lacks the associated managerial, financial, legal, policy, and market-transaction skills and institutions needed to take full advantage of its domestic technological capabilities and the opportunities for international technology transfer and profitable investments in energy efficiency and renewable energy. Further technology development and technology transfer in Russia in support of greenhouse-gas reductions will require new capacities, and the literature associated with capacity building for greenhouse-gas mitigation is relevant. But in contrast to much of the literature on technology transfers with developing countries, which emphasizes indigenous technological capacities as preconditions for successful transfer and diffusion, the literature most relevant to Russia focuses on market-oriented capacities. Capacity building in Russia means that managers and officials in all sectors of the economy need to learn how to reduce costs; make economic and financial decisions about capital investments; prepare business plans and financing proposals; solicit and evaluate bids from suppliers, consultants, and contractors; write and enforce contracts; and commercialize and market new technologies. Especially notable is the lack of commercial know-how and innovation experience in turning designs into reliable high-quality commercial products and services.

The market/transaction perspectives discussed above are summarized in Table 3 in our concluding section, along with the technological and agent/agenda perspectives discussed earlier in this section. In particular, we have seen that joint ventures are an important mode of technology transfer for developing business, marketing, and quality-control capabilities among Russian enterprises that face many hurdles in adapting to a market economy. And overcoming market barriers means providing information and credit, building new institutions, and building capabilities in economic and financial analysis and other market-oriented skills. International technology transfers for climate change mitigation have been motivated by the large potential economic gains from energy efficiency improvements and the prospect of industrial conversion to new technologies. Economic reforms have been aided by the cost reductions made possible by energy efficiency and other energy technologies, and these reforms motivate multilateral and bilateral technology transfers. We now turn to China, to which many of the perspectives on Russia apply.

THE CASE OF CHINA

As with Russia, we find several perspectives within both the general literature and the China-specific literature to be important to understanding the application of the environmental agenda for climate change mitigation to China. A review of historical technology transfer with China provides the background to more recent economic transformation and rapid growth, fueled in part by foreign investment. Relevant technologies for climate change mitigation are closely tied to energy-efficiency improvements and more efficient equipment of all types, to the dominance of coal in China's energy mix, and to major campaigns for industrial modernization. A range of agent motivations stem from development, trade, and environmental concerns. The literature on joint ventures and foreign direct investment is relevant to China for the same reasons that it is relevant to Russia. Finally, as with Russia, a market/transaction perspective highlights the barriers to transfer and diffusion of technologies for climate change mitigation and the need for market intermediation and capacity building to overcome these barriers.

Historical Perspectives: Economic Transformation

Technological exchanges between China and other parts of the world have played major historical roles since antiquity. The spread of gunpowder is an early example. Since the 1600s, when Jesuit missionaries introduced new European mathematics and astronomy, most of the transfers have been from other countries into China (165). In the nineteenth and early twentieth centuries, missionaries, foundations, and businesses helped to spread Western innovations such as modern pharmaceuticals, surgery, railroads, chemical fertilizers and pesticides, and the telegraph and telephone (166). During its long occupation of Northeast China, Japan built a large industrial base that formed the core of Chinese heavy industry for many years after the establishment of the People's Republic in 1949, despite the loss of a great deal of Japanese equipment to the Soviet Union, which helped to "liberate" the region (167). On the other hand, the Soviet Union was the primary source of technical assistance to the new People's Republic until escalating animosity between the two countries led to the Soviet Union's withdrawal of all support in the late 1950s (168). China followed a policy of strict self-reliance in most spheres of activity until the mid-1970s, when the country gradually began to acquire and copy turnkey plants. Control over such exchanges was highly centralized and politicized, and there tended to be little diffusion or capacity building associated with such projects. After Mao Tse-tung's death in 1976 and the initiation of economic-system reforms under the leadership of Deng Xiaoping, China began to open up rapidly to the outside world and began to accelerate scientific and technological exchange through multiple channels.

Like the Soviet Union, China went through a phase of buying turnkey plants (169). Many companies sold technology to China through licenses and direct equipment sales. Chinese policy on acquisition of foreign technologies emphasized absorption of equipment without risking any more contact than necessary with the "polluting" influence of Western (and capitalist) systems of technology development and management. This policy began to change in the late 1970s, and technology transfers increasingly involved foreign partners in management of joint ventures, and training of Chinese partners. The government has eagerly sought technology transfers through joint ventures (and in some sectors has even required it), although it has often resisted a high degree of control by foreign partners.

Since the end of the 1970s, China has undergone a remarkable series of changes in the economic, political, and social spheres. Wide-ranging economic system reforms have changed agricultural markets and land ownership; fostered the growth of a rural, nonstate industrial sector that rivals the state-owned sector in size; allowed enterprise forms to multiply; created functioning markets for most commodities (and to a limited extent for labor and capital as well); and revised the rules governing management of state-owned enterprises. The reforms have fostered local autonomy, and, while falling short of severing ties between the state and enterprise management, have rendered China's central planning system nearly vestigial. The state still plays a crucial role in selecting technologies and funding their acquisition and development, but increasingly, market-oriented local governments, enterprises, and research and engineering organizations have become very important. These changes have had far-reaching implications for the motivations and means to acquire, adapt, and develop new technologies.

Technological Perspectives: Energy Efficiency, Coal, and Industrial Modernization

A large literature describes the technologies needed for mitigating greenhouse-gas emissions in China and for addressing local environmental problems (170–180). Because China's energy supply is dominated by coal (three quarters of primary energy supply in 1993), important technologies to reduce greenhouse-gas emissions include improved coal mining and processing; more efficient coal combustion in power generation; and increased shares of natural gas, renewable energy sources, and nuclear power. On the demand side, industrial consumption accounts for two thirds of total final energy consumption, while industrial energy use is much less efficient than in developed countries. Thus energy efficiency in industry represents the largest single opportunity to reduce CO_2 emissions. Seven sectors are responsible for almost 80% of CO_2 emissions from industry: electric power, building materials, iron and steel, chemicals, coal mining and processing, and oil and gas extraction. Across all sectors, coal-fired industrial boilers by themselves accounted for over one third of China's coal consumption (in 1993). Therefore, more efficient boiler models represent a large potential for greater energy efficiency. Because steel and cement dominate industrial production, technologies and techniques that reduce the use of these energy-intensive materials in a variety of applications also offer significant potential. Residential energy use provides another significant opportunity to increase energy efficiency, especially through more efficient appliances and cooking stoves. Across all sectors, many energy-efficiency opportunities present attractive economic rates of return. Renewable-energy technologies, particularly wind farms, solar hot-water heating, and biomass technologies, also show great potential for economic viability. Indeed, extensive diffusion of rural biomass technologies has already occurred.

China already has a certain capacity for domestic technology development for technologies related to greenhouse gas–emissions reductions, because the government has supported organizations dedicated to research, development, technical assistance, and funding of equipment in these areas. But transfers of technology from other, mainly developed countries have been an important element in China's various strategies for development of domestic capabilities. China has targeted a variety of technologies for imports, like flue-gas desulfurization equipment, efficient electric motors and lights, wind turbines, and large-scale industrial process equipment for the metals, building materials, chemicals, and other energy-intensive industries. Rather than try to reinvent the wheel, China seeks to "leapfrog" through transfers to the level of technologically advanced countries (181–184).

As with Russia, reforms that have forced increasing numbers of enterprises to face market forces have also had far-reaching implications for technology decisions. Domestic technology development and diffusion have been especially closely linked with reforms in the industrial sector and with the changing environment in which technology development and transfers have been occurring (185–187). Technology policy, including the "Four Modernizations" campaign of the 1970s, energy-sector technology policy, and an extensive system of energy quotas and norms have all had a large impact on the energy intensity of the economy (188–191). Technology development has also been affected by an extensive set of environmental policies and regulations and a system of environmental protection bureaus and, more recently, by new, market-based mechanisms for environmental protection (192–194). Yet technology development has left some industries behind, notably rural so-called town and village enterprises (TVEs), which now account for over one third of total industrial production in China and commonly use older, inefficient equipment and processes.

Agent/Agenda Perspectives: Development, Trade, and Environment Motivations

Technology transfer for climate change mitigation with China is strongly linked to several interrelated agendas, all of which point to diverse categories of literature. These categories include local and regional environmental issues, China's high profile in international development and security issues, and China's enormous and rapidly growing market potential.

The breadth and depth of China's intractable energy and environmental problems are sobering (195–197). Industrialization and greater use of fossil fuels associated with economic growth have worsened already bad environmental conditions. Acid rain (both in China and in nearby countries like Japan) and urban air pollution from coal combustion are serious problems. Since the early

1980s, the international community has paid increasing attention to China's environmental problems and to China's role in regional and global environmental issues. Many multilateral and bilateral (especially from Japan) assistance programs have been aimed at fostering the capability within China to deploy energy-efficient, renewable-energy, and emissions-control technologies. China is now the largest single recipient of World Bank funding, much of which has been used for environmental protection (198). The Asian Development Bank has also given China a great deal of financial and technical support for energy efficiency and environmental protection (199). Japan has a well-funded effort to help China adopt more environmentally friendly technologies through its Green Aid program (200). The United States has offered various kinds of assistance, including support for an energy-efficiency center in Beijing (140, 201). In 1996, the Global Environment Facility was developing grants to China for reducing market barriers to production of more energy-efficient equipment like industrial boilers and refrigerators, for energy efficiency investments in rural town-and-village enterprises, and for creating energy-management companies to provide private-sector market intermediation.

The Chinese government has had long-standing policies and programs to promote greater efficiency in energy supply and end use and the development of renewable and nuclear energy. Imports of technology from developed countries have been a key element in these efforts. These policies and programs have been motivated in part by the concerns about domestic environmental issues noted above and in part by concerns about economic development. Under the central planning system, China's energy system was highly centralized and oriented towards the supply side. This orientation began to change in the late 1970s, when leaders began to realize that energy supplies and state-controlled investment capital would be insufficient to reach economic development goals. Thus began a series of policy innovations in the 1980s, including support for energy efficiency on a scale unprecedented in any developing nation, policies to speed the introduction of renewable energy technologies (particularly in rural areas with biomass fuel shortages and with no access to electricity), and fostering of collective and private coal mines in rural areas—as well as open markets for their output (202–209). A key element of reforms has been the gradual introduction of markets for energy products. In the 1980s a "dual track" price system was established, whereby a portion of most commodities were sold at low, in-plan prices, and a portion at higher market prices. By the mid-1990s, nearly all coal was sold at market-set, unsubsidized prices. Some progress has been made in reforming electricity rate structures, while oil prices have remained under tight control, and delivered heat and residential fuels continue to be heavily subsidized. There is a great deal of speculation, though not a great deal of evidence, that rising energy prices have spurred adoption of more energy-efficient technologies (170, 210).

Motivations for technology transfers with China by Western governments, such as the United States and Japan, also encompass trade, security, and other foreign policy objectives. Japan in particular is strongly interested in developing a relationship of mutual economic prosperity, military security, and environmental well-being with China. Japanese transfers of manufacturing, energy, and environmental technologies—not to mention generous financing—have become some of Japan's primary means to preserve its interests in Northeast Asia. Policies of Western governments to promote technology transfer include targeting sectors for export credits and loan guarantees, providing grants and loans, and supporting technical assistance and market research programs (211–214).

The prospect of reaching China's vast and rapidly growing domestic markets has spurred a multitude of firms in other countries to seek opportunities to establish manufacturing bases in China, requiring transfer and adaptation of equipment and know-how. As economic activity has expanded (at an average rate of 8–9% per year from 1980 to 1995), China has become a much wealthier country than it was two decades ago, and one that is increasingly integrated into the world trading system. The consequences for technology transfer have been manifold. Opportunities for commercial exchanges with other countries have multiplied, and as exports have grown, China has had greater ability to import the commodities and technologies it desires.

Market/Transaction Perspectives: Joint Ventures and the Nature of Chinese Enterprises

The reasons that make general literature and country-specific literature on joint ventures relevant to technology transfer for climate change mitigation in the case of Russia also apply to China. In China's case, government domestic-production requirements serve to increase foreign direct investment as a mode of technology transfer compared to sales or licensing. Firms from other countries that have actively sought to market environmental products and technologies for commercial reasons in China (a recent example being wind turbines) are finding increasingly that they must establish joint ventures. Wholly owned subsidiaries are much less common in China than joint ventures because of the need for local partners who know the regulatory and bureaucratic "system" and because of highly personalized networks of business contacts, much as in the Russia case. Motives for joint ventures can be quite different on the foreign and Chinese sides. A foreign partner will likely be interested in Chinese domestic market share, short-term returns, low production costs, and favorable tax treatment. The Chinese pursue joint ventures because they are seeking capital, management expertise and organizational knowledge, technical expertise, and new markets (215). Uncertain of domestic markets and joint venture risks, foreign firms are often cautious of committing to such investment. As China's economic-system reforms deepen, the literature on technology transfer through joint ventures from developed to developing nations is becoming more relevant, especially since China shares many institutional weaknesses (e.g. lack of well-developed credit markets, weak intellectual-property protection, and an inadequate legal system) with other developing countries.

The patterns of joint ventures and technology transfer in China are quite different for the different forms of enterprises—state-owned, rural town-and-village enterprises (TVEs), and private-sector firms. As stated above, the spectacular rise of TVEs has had a major impact on energy consumption because these enterprises now account for over one third of total industrial production. These enterprises must compete on the open market and therefore face real incentives for innovation and efficiency. Yet these enterprises often lack the human and capital resources to improve the efficiency of either their processes or their products and could benefit greatly from technology transfer and joint venture partnerships. To date, there have been relatively few instances of technology transfer with TVEs; foreign joint ventures—particularly in energy supply and energy-intensive manufacturing sectors—more typically involve a partnership with a state-owned enterprise. In particular, commercial technology transfers with large impacts on greenhouse-gas emissions have tended to be large industrial projects in state-owned enterprises in the steel, manufacturing, and energy-production sectors (169, 216–218). This situation highlights the relevance of the literature on economic reforms and the differentiated behavior of different enterprise forms in China's mixed economy.

The experience since the late 1970s in operating joint ventures in China has suggested improvements in the business environment for foreign investment, and this literature is important to the environmental agenda for climate change mitigation (219, 220). This experience includes sectoral case studies of transfers to China that draw lessons about the policies and conditions affecting decisions to transfer technologies, the modes and management of transfers, and the success of transfers (221, 222); these studies often recommend that the Chinese government select priority sectors and technologies, provide financial incentives, and build the capacity for technological absorption and innovation. Some accounts of foreign ventures in China are highly personal but provide insights into those issues important to performance of technology transfers (215, 223, 224). Guides to foreign businesspeople on how to run a successful venture in China often touch directly on transfers of manufacturing technologies, generally through case studies (225–227). China's ever-changing landscape of policies governing foreign investments has given rise to numerous guides that deal with technology transfer regulations, including intellectual-property rights (228, 229). Another large body of literature deals more retrospectively with investment in China, often analyzing the reasons for success or failure through case-study analysis (230, 231). Sections on technology transfer typically focus on the mode of transfer and the importance of developing the technical capacity of the Chinese partner. Some authors also focus on the transfer of managerial techniques needed to take full advantage of new hardware (232).

Market/Transaction Perspectives: Barriers, Intermediation, and Capacity Building

As with Russia, the literature on market failures and transaction barriers in both developed and developing country contexts is relevant to the environmental agenda for climate change mitigation in China. Many of the barriers to transfer and diffusion of renewable-energy and energy-efficiency technologies in China are similar to those in other developing nations, despite often great differences in technical capability and political economy. Lack of capital and flexible financing mechanisms, lack of information about potential markets and partners, lack of technical and market-oriented managerial expertise, and mismatched incentives are common to China. Although China has strong environmental regulations and policies that indirectly promote energy efficiency, the lack of effective enforcement is another institutional barrier. While many energy prices are now set by markets, subsidies remain in many important sectors. Currency conversion restrictions hinder foreign transactions, as do regulations that deny most enterprises the right to make import and export decisions.

Studies of joint ventures and other forms of technology transfer often discuss transaction barriers. One notable example is Behrman et al (233), who analyze barriers to technology transfer for China. They conclude that while Chinese enterprises are eager to accept foreign technology, foreign firms are hesitant. Barriers cited that affect the propensity of foreign firms to transfer technology include lack of information about China in general, closed domestic markets, lack of strong government protection of intellectual-property rights, and disagreements with Chinese partners over exports versus domestic sales. Barriers affecting the propensity of Chinese firms to seek transfers include lack of information about foreign suppliers and products and poor information exchange and connection between enterprises and government agencies and research institutes in China. Factors that affect the effectiveness of transfers include the willingness or ability of suppliers to transfer know-how along with hardware; the capacity of recipient firms to absorb that know-how; the ability of recipient firms to understand the associated requirements of transferred technology; cultural differences; a lack of supporting technological infrastructure, skills, and materials; and the willingness of recipient firms to make necessary changes in the enterprise's organization, production layouts, employee skills, and levels of employment.

Because of these transaction barriers, market intermediation is important in China. In the past, very significant market intermediation for energy efficiency has been provided by government-sponsored local energy-efficiency centers throughout China. These centers have provided technical and management advice, feasibility studies and research, training, enterprise energy audits, partner matching, and public education (234). Thus private-sector market intermediation has not been as critical an issue for technology transfer as in the case of Russia. But government support for these centers is diminishing, and the centers will need to evolve into more market-oriented entities to survive.

Many forms of capacity building can help overcome transaction barriers. The same types of capacity building outlined for Russia hold for China, although technical capacities are equally or more important than institutional and managerial capacities in the case of China. In addition, strengthening intellectual-property rights and China's legal system in general will greatly ease the process of transferring and protecting foreign technologies. The lack of fully functioning markets for credit and the difficulty of obtaining and using foreign credit are serious obstacles to carrying out even those projects with excellent financial returns. The effective barring of the most efficient segment of China's economy—rural town-and-village enterprises—from access to large amounts of credit means that those enterprises with the strongest incentives to use energy efficiently are thwarted. Furthermore, strong protection of local industries on the part of local governments prevents many high-performing enterprises from growing and thereby capturing economies of scale, including improvements in energy efficiency.

Ironically, many of the barriers to adoption of technologies for climate change mitigation arise from the decentralization of decision-making authority that has accompanied these reforms. This illustrates again how the literature on economic-system reforms is important to the environmental agenda for climate change mitigation. Weakening of central political and economic authority means that the state has lost much of its ability to impose a unified set of market and administrative rules, particularly in the absence of a well-developed system of legal authority. The weakening of central authority makes it more difficult to overcome barriers to adoption of energy-efficient and renewable technologies through policies that have been adopted in other countries, such as energy performance standards, uniform emissions standards, permitting, and fee-collection systems. Fragmentation of authority at the regional and local levels also prevents adoption of techniques that have been effective at those levels in other countries, such as utility regulation that promotes demand-side management. On the other hand, strong local leadership on environmental issues can lead to local policy environments that favor adoption of more environmental technologies. Thus, many of these types of policies await a stronger state capacity to implement uniform and binding regulations on a national scale.

The market/transaction perspectives discussed above are summarized in Table 3, along with the technological and agent/agenda perspectives discussed previously in this section. We have seen that technology transfers involving common forms of Chinese enterprises can be quite different. Overcoming market barriers means meeting the need for technical know-how, information, and credit and strengthening intellectual-property protection. There is also a growing need for private-sector market intermediation, particularly in energy efficiency, as the state role diminishes. Development, trade, and environment goals are all strong motivations for technology transfers. Technology imports have historically been emphasized in domestic policies, and China receives high levels of foreign direct investment. Joint ventures in particular are an important technology transfer mode for developing China's domestic technological capabilities. Technology policies have been influential in shaping technological development and realizing the gains possible from energy efficiency and long-term industrial modernization.

CONCLUSION

The environmental agenda for technology transfer as an instrument to mitigate climate change, which we discussed at the beginning of the paper, is based upon the notion that some "baseline" future can be altered through proactive "incremental" interventions. As we have seen, strategies to carry out this agenda essentially address the "increment" question: How can the process of technological change within a country be significantly affected by agents outside the country through incremental interventions? This question is linked to a vast array of potentially relevant literature at the intersection of technology transfer, international investment and trade, bilateral and multilateral development and environmental assistance, policies for capacity building, technologies for greenhouse-gas reduction, technological change and development, domestic energy policies, energy geography and infrastructure, economic transitions, and market transformation.

In the cases of Russia and China, we have addressed the "increment" question by noting several features of this vast landscape of literature that are worth understanding and investigating in greater depth for these countries. Table 3 summarizes the features that we have emphasized for Russia and China, posited against the international technology transfer perspectives examined early in the paper.

From a technological perspective, Russia and China face both similar and divergent situations with respect to technology transfer for climate change

Table 3 Framework for literature review and relevant country-specific perspectives

International technology transfer	The case of Russia	The case of China
Technological perspectives		
Links between technology transfer and domestic technology development, diffusion, and adaptation Energy efficiency, fuel switching, and renewable energy technologies	Energy efficiency in industry, district-heating systems, and buildings Fuel switching from oil and coal to natural gas Electricity from wind and geothermal Widespread technological expertise and capabilities	Energy efficiency in industry and industrial modernization More-efficient coal combustion Electricity and heat from wind, biomass, and solar Influential technology policies
Agent/agenda perspectives		
Multinational corporations Recipient-country firms National governments Multilateral agencies with development goals Multilateral agencies with environmental goals Non-governmental organizations	Strong cost-reduction and regional-development motivations for energy efficiency International assistance aimed at market-oriented reforms Low levels of foreign direct investment Multilateral bank loans	Development, trade, security, and environment motivations Technological development an important motivation Technology imports emphasized in policies High levels of foreign direct investment Multilateral bank loans
Market/transaction perspectives		
Market barriers Market intermediation Capacity building for market development Technology transfer modes	Joint ventures as vehicles for developing business, marketing, quality-control capabilities Predicament of newly privatized enterprises facing market economy Need for information, credit, economic and financial analysis skills, private-sector intermediation Need for institutional changes (e.g. in housing and district-heating sectors)	Joint ventures as vehicles for developing technological capabilities Influence of enterprise form (state-owned, TVE, private-sector) on technology transfers Need for technical know-how, information, credit, intellectual-property protection Growing need for private-sector intermediation as state role diminishes

mitigation. For example, while Russia is currently experiencing electric-power surpluses, China is struggling to expand electric-power supplies fast enough to keep pace with rapid economic growth. Coal dominates China's domestic energy resources and consumption, while the majority of Russia's energy supplies come from natural gas. China's problem is more-efficient coal combustion, whereas Russia suffers from large losses from natural-gas pipelines. Nevertheless, opportunities for improved energy efficiency are similar in both countries, especially for industry and district heating, and renewable-energy technologies like wind and biomass offer commercial potential in both countries.

From an agent/agenda perspective, motivations for technology transfer are different for the two countries. In the case of China, both public and private motivations for technology transfer are influenced by pressing local and regional environmental issues in the face of a rapidly growing economy. In the case of Russia, motivations have been strongly influenced by the need for economic development and the transformation of idle industrial capacity and labor in the face of a collapsing industrial sector, particularly in defense-related industries. China has received bilateral and multilateral assistance that is overwhelmingly directed at environmental problems, whereas Russia has received assistance directed primarily at the transition to a privatized, market economy. In both countries, the motivations of foreign multinational firms to access new markets, profit from investments, and reduce production costs will dominate greenhouse-gas reductions linked to international technology transfer.

From a market/transaction perspective, joint ventures are an important form of technology transfer in both countries. Both countries are experiencing transitions away from centrally planned economies that affect the capabilities of enterprises to engage in technology transfer, and in both countries the remnants of central-planning management mentalities and institutions are slow to change. Barriers to technology transfer are significant and also are very similar in the two countries, as are the critical needs for market-oriented capacity building and market intermediation. In both countries, the conventional development prescription for improved energy efficiency—elimination of energy subsidies, privatization, and greater institutional efficiency—is entirely inadequate because of transaction barriers and the difficulties that privatized enterprises face in a market-oriented economy. Capacity building in a variety of forms must accompany such prescriptions. Needs and strategies for capacity building deserve special note because, in our view, capacity building represents a critical intervention well suited to be the "increment" of the environmental agenda.

The vast literature related to technology transfer for climate change mitigation is not in the most accessible and usable form for researchers and practitioners investigating a particular country. As Table 1 shows, the literature spans numerous disciplines, definitions and topics overlap, and separate intellectual dialogues run in parallel or in divergent directions. Although technology transfer is obviously an important and well-tread category of investigation, understanding it presents a challenge. We see an important need for further research into international technology transfer by those with country-specific expertise, but individual country cases need to be in a form accessible to researchers and practitioners in the field of climate change mitigation. In this paper, we have organized our views into the literature through three perspectives—technological, agent/agenda, and market/transaction. This framework for reviewing the literature and for emphasizing important country-specific perspectives, as illustrated in tabular form in Table 3, has allowed us to sort through a wide and diverse literature and apply it to two specific countries. Future research can continue to build upon and refine this framework and incorporate additional country perspectives.

Literature Cited

1. Watson RT, Zinyowera MC, Moss RH, eds. 1996. *Climate Change 1995: Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses*. Contrib. Work. Group II, 2nd Assess. Rep. Intergov. Panel Clim. Change. New York: Cambridge Univ. Press
2. Bruce JP, Lee H, Haites EF, eds. 1996. *Climate Change 1995: Economic and Social Dimensions of Climate Change.* Contrib. Work. Group III, 2nd Assess. Rep. Intergov. Panel Clim. Change. New York: Cambridge Univ. Press
3. World Resourc. Inst., UN Environ. Program, UN Dev. Program, World Bank. 1996. *World Resources 1996-97.* Washington, DC: World Resourc. Inst.
4. UN. 1992. *Framework Convention on Climate Change.* Geneva: UNEP/WMO Info. Unit Clim. Change
5. UN. 1993. *Agenda 21: Programme of Action for Sustainable Development.* New York: UN
6. Heaton GR Jr, Banks RD, Ditz DW. 1994. *Missing Links: Technology and Environmental Improvement in the Industrializing World.* Washington, DC: World Resourc. Inst.
7. Barnett A. 1995. *Do Environmental Imperatives Present Novel Problems and Opportunities for the International Transfer of Technology?* New York: UN
8. Mintzer IM, ed. 1992. *Confronting Climate Change: Risks, Implications and Responses.* Cambridge, UK: Cambridge Univ. Press
9. Reddy MN, Zhao LM. 1990. International technology transfer: a review. *Res. Policy* 19:285–307
10. Sagafi-nejad T. 1991. International technology transfer literature: Advances in theory, empirical research, and policy. See Ref. 20, pp. 199–224
11. Williamson OE. 1985. *The Economic Institutions of Capitalism.* New York: Free Press
12. North DC. 1990. *Institutions, Institutional Change, and Economic Performance.* Cambridge, UK: Cambridge Univ. Press
13. Sinton JE, Fridley DG, Levine MD, Yang FQ, Zhenping J, et al. 1996. *China Energy Databook.* LBL-32822. Berkeley, CA: Lawrence Berkeley Natl. Lab.
14. State Statistical Bureau of China. 1996. *China Statistical Yearbook 1996.* Beijing: China Stat. Publ. House
15. Int. Energy Agency. 1995. *Energy Policies of the Russian Federation: 1995 Survey.* Paris: IEA
16. Commonwealth of Independent States Statistical Commission. 1996. *The Statistical Handbook of Social and Economic Indicators for the Former Soviet Union.* New York: Norman Ross

17. Rosenberg N. 1982. *Inside the Black Box: Technology and Economics.* New York: Cambridge Univ. Press
18. Kranzberg M. 1986. The technical elements in international technology transfer: Historical perspectives. See Ref. 25, pp. 31–46
19. Rosenberg N, Frischtak C, eds. 1985. *International Technology Transfer: Concepts, Measures and Comparisons.* New York: Praeger
20. Robinson RD, ed. 1991. *The International Communication of Technology: A Book of Readings.* New York: Taylor & Francis
21. Schmidheiny S, with Bus. Counc. Sustain. Dev. 1992. *Changing Course: A Global Business Perspective on Development and the Environment.* Cambridge, MA: MIT Press
22. Segal A. 1986. From technology transfer to science and technology institutionalization. See Ref. 25, pp. 95–116
23. Silverberg G. 1994. *The Economics of Growth and Technical Change: Technologies, Nations, Agents.* Aldershot, UK: Elgar
24. Grubb M, Chapuis T, Duong MH. 1995. The economics of changing course: Implications of adaptability and inertia for optimal climate policy. *Energy Policy* 23(4/5):417–32
25. McIntyre JR, Papp DS, eds. 1986. *The Political Economy of International Technology Transfer.* New York: Quorum Books
26. Goulet D. 1977. *The Uncertain Promise: Value Conflicts in Technology Transfer.* New York: IDOC/North Am.
27. Heaton G, Repetto R, Sobin R. 1991. *Transforming Technology: An Agenda for Environmentally Sustainable Growth in the 21st Century.* Washington, DC: World Resourc. Inst.
28. Panel on Policy Implications of Greenhouse Warming; Comm. Sci., Eng. Public Policy; Natl. Acad. Sci.; Natl. Acad. Eng.; Inst. Med. 1992. *Policy Implications of Greenhouse Warming: Mitigation, Adaptation, and the Science Base.* Washington, DC: Natl. Acad. Press
29. Watson RT, Zinyowera MC, Moss RH, eds. 1996. *Technologies, Policies and Measures for Mitigating Climate Change.* Intergov. Panel Clim. Change Tech. Pap. I
30. Fickett AP, Gellings CW, Lovins AB. 1990. Efficient use of electricity. *Sci. Am.* 263(3):64–74
31. Philips M. 1991. *The Least-Cost Energy Path for Developing Countries: Energy-Efficiency Investments for the Multilateral Development Banks.* Washington, DC: Int. Inst. Energy Conserv.
32. Levine MD, Gadgil A, Meyers S, Sathaye J, Stafurik J, Wilbanks T. 1991. *Energy Efficiency, Developing Nations, and Eastern Europe.* Berkeley, CA: Lawrence Berkeley Natl. Lab.
33. Levine MD, Geller H, Koomey J, Nadel S, Price L. 1992. *Electricity End-Use Efficiency: Experience with Technologies, Markets, and Policies Throughout the World.* Berkeley, CA: Lawrence Berkeley Natl. Lab.
34. Schipper L, Meyers S, Howarth R, Steiner R. 1993. *Energy Efficiency and Human Activity: Past Trends, Future Prospects.* Cambridge, UK: Cambridge Univ. Press
35. World Bank. 1993. *Energy Efficiency and Conservation in the Developing World: The World Bank's Role.* Washington, DC: World Bank
36. Ahmed K. 1994. *Renewable Energy Technologies: A Review of the Status and Costs of Selected Technologies.* Tech. Pap. 240, Energy Ser. Washington, DC: World Bank
37. Johansson TB, Kelly H, Reddy AKN, Williams RH, eds. 1993. *Renewable Energy: Sources for Fuels and Electricity.* Washington, DC: Island
38. World Energy Council. 1994. *New Renewable Energy Resources: A Guide to the Future.* London: Kogan Page
39. Jackson T, ed. 1993. *Renewable Energy: Prospects for Implementation.* Stockholm: Stockholm Environ. Inst.
40. Shove E. 1995. Gaps, barriers and conceptual chasms: Theories of technology transfer and energy in buildings. *Proc. Eur. Counc. Energy Effic. Econ. Summer Study–Sustainability and the Reinvention of Gov.: A Challenge for Energy Effic.,* Vol. 1. Latitudes, Mandelieu, France
41. Safarian AE, Bertin GY, eds. 1987. *Multinationals, Governments and International Technology Transfer.* New York: St. Martin's
42. Cantwell J. 1989. *Technological Innovation and Multinational Corporations.* Cambridge, MA: B Blackwell
43. Pitelis CN, Sugden R, eds. 1991. *The Nature of the Transnational Firm.* New York: Routledge
44. Hennart JF. 1991. The transaction costs theory of joint ventures—An empirical study of Japanese subsidiaries in the United States. *Manage. Sci.* 37(4):483–97
45. Gilpin R. 1987. *The Political Economy of International Relations.* Princeton, NJ: Princeton Univ. Press
46. Schwartz P, Collyns N, Hamik K, Henri J. 1992. Modifying the mandate of existing

institutions: Corporations. See Ref. 8, pp. 281–91
47. Baram MS. 1994. Multinational corporations, private codes, and technology transfer for sustainable development. *Environ. Law* 24(1):33–65
48. Samli AC, ed. 1985. *Technology Transfer: Geographic, Economic, Cultural, and Technical Dimensions.* Westport, CT: Quorum Books
49. Porter ME. 1990. *The Competitive Advantage of Nations.* New York: Free Press
50. von Moltke K. 1992. International trade, technology transfer and climate change. See Ref. 8, pp. 295–304
51. Saunders R. 1993. *The World Bank's Role in the Electric Power Sector: Policies for Effective Institutional, Regulatory, and Financial Reform.* Washington, DC: World Bank
52. Baum WC, Tolbert SM. 1985. *Investing in Development: Lessons of World Bank Experience.* New York: Oxford Univ. Press
53. Riddel RC. 1987. *Foreign Aid Reconsidered.* Baltimore: Johns Hopkins Univ. Press
54. Global Environmental Facility. 1996. *Operational Strategy.* Washington, DC: Glob. Environ. Facil.
55. UN Dev. Prog., UN Environ. Prog., World Bank. 1994. *Global Environment Facility: Independent Evaluation of the Pilot Phase.* Washington, DC: World Bank
56. UN Econ. Soc. Counc., Comm. Sustainable Dev. 1993. *Progress Achieved in Facilitating and Promoting the Transfer of Environmentally Sound Technology, Cooperation and Capacity-Building: Report of the Secretary-General.* E/CN.17/1993/10. 1st Sess. New York: UN Econ. Soc. Counc.
57. UN Econ. Soc. Counc., Comm. Sustainable Dev. 1994. *Education, Science, Transfer of Environmentally Sound Technologies, Cooperation and Capacity Building: Report of the Inter-Sessional Ad Hoc Open-Ended Working Group on Technology Transfer and Cooperation.* E/CN.17/1994/11. 2nd Sess. New York: UN Econ. Soc. Counc.
58. UN Econ. Soc. Counc., Comm. Sustainable Dev. 1995. *Transfer of Environmentally Sound Technologies, Cooperation, and Capacity-Building: Report of the Secretary-General.* E/CN.17/1995/17. 3rd Sess. New York: UN Econ. Soc. Counc.
59. UN Econ. Soc. Counc., Comm. Sustainable Dev. 1996. *Transfer of Environmentally Sound Technologies, Cooperation, and Capacity-Building: Report of the Secretary-General.* E/CN.17/1996/13. 4th Sess. New York: UN Econ. Soc. Counc.
60. UN Conf. Trade Dev. 1990. *Transfer and Development of Technology in the Least Developed Countries: An Assessment of Major Policy Issues.* UNCTAD/ITP/TEC/12. New York: UN Conf. Trade Dev.
61. UN Conf. Trade Dev. 1995. *Negotiations on an International Code of Conduct on the Transfer of Technology: Report by the Secretary-General of UNCTAD.* TD/CODE TOT/60. New York: UN Conf. Trade Dev.
62. UN Conf. Trade Dev., Gov. Norway. 1993. *Report of the Workshop on the Transfer and Development of Environmentally Sound Technologies,* Oslo, Oct. 13–15. Geneva: UN Conf. Trade Dev.
63. Int. Energy Agency. 1996. *International Energy Technology Collaboration: Benefits and Achievements.* Paris: IEA
64. Environ. Defense Fund, Nat. Resourc. Defense Counc. 1994. *Power Failure: A Review of the World Bank's Implementation of Its New Energy Policy.* New York: Environ. Def. Fund
65. Willoughby KW. 1990. *Technology Choice: A Critique of the Appropriate Technology Movement.* Boulder, CO: Westview
66. Dubash NK, Oppenheimer M. 1992. Modifying the mandate of existing institutions: NGOs. See Ref. 8, pp. 265–80
67. Kozloff K, Shobowale O. 1994. *Rethinking Development Assistance for Renewable Electricity.* Washington, DC: World Resourc. Inst.
68. Barnett A. 1990. The diffusion of energy technology in the rural areas of developing countries: A synthesis of recent experience. *World Dev.* 18(4):539–53
69. Hurst C. 1990. Establishing new markets for mature energy equipment in developing countries: Experience with windmills, hydro-powered mills and solar water heaters. *World Dev.* 18(4):605–15
70. Foley G. 1993. Renewable energy in Third World development assistance—learning from experience. See Ref. 39, pp. 193–202
71. Goldemberg J, Johansson TB, eds. 1995. *Energy as an Instrument for Socio-Economic Development.* New York: UN Dev. Prog.
72. Hodgson GM, Samuels WJ, Tool MR, eds. 1994. *The Elgar Companion to Institutional and Evolutionary Economics,* 2 Vols. Brookfield, VT: Elgar

73. Robinson RD. 1991. Toward creating an international technology transfer paradigm. See Ref. 20, pp. 9–24
74. Reddy AKN. 1991. Barriers to improvements in energy efficiency. *Energy Policy* 19:953–61
75. Levine MD, Hirst E, Koomey JG, McMahon JE, Sanstad AH. 1994. *Energy Efficiency, Market Failures, and Government Policy.* Berkeley, CA: Lawrence Berkeley Natl. Lab.
76. Golove WH, Eto JH. 1996. *Market Barriers to Energy Efficiency: A Critical Reappraisal of the Rationale for Public Policies to Promote Energy Efficiency.* LBL-38059. Berkeley, CA: Lawrence Berkeley Natl. Lab.
77. Jaffe AB, Stavins RN. 1994. The energy paradox and the diffusion of conservation technology. *Resour. Energy Econ.* 16:91–122
78. US Congr., Off. Technol. Assess. 1992. *Fueling Development: Energy Technologies for Developing Countries.* OTA-E-516. Washington, DC: US Gov. Print. Off.
79. Rath A, Herbert-Copley B. 1993. *Green Technologies for Development: Transfer, Trade, and Cooperation.* Ottawa: Int. Dev. Res. Cent.
80. Haddad B. 1996. *Putting Markets to Work: The Design and Use of Marketable Permits and Obligations.* Paris: OECD. In press
81. Haddad B. 1996. *Evaluating the market niche.* PhD thesis. Univ. Calif., Berkeley
82. Geller H, Nadel S. 1994. Market transformation strategies to promote end-use efficiency. *Annu. Rev. Energy Environ.* 19:301–46
83. UN Conf. Trade Dev. 1995. *Technological Capacity-Building and Technology Partnership: Field Findings, Country Experiences and Programmes.* New York/Geneva: UN Conf. Trade Dev.
84. Datta DK. 1988. International joint ventures: A framework for analysis. *J. Gen. Manage.* 14(2):78–91
85. Kogut B. 1988. Joint ventures: Theoretical and empirical perspectives. *Strategic Manage. J.* 9:319–32
86. Chowdhury J. 1992. Performance of international joint ventures and wholly owned foreign subsidiaries: A comparative perspective. *Manage. Int. Rev.* 32(2):115–33
87. Shane SA. 1993. The effect of cultural differences in perceptions of transaction costs on national differences in the preference for international joint ventures. *Asia Pac. J. Manage.* 10(1):57–69
88. Parkhe A. 1993. “Messy” research, methodological predispositions, and theory development in international joint ventures. *Acad. Manage. Rev.* 18(2):227–68
89. Contractor FJ. 1991. Interfirm technology transfers and the theory of multinational enterprise. See Ref. 20, pp. 57–78
90. Costanza M. 1990. *Developing Countries and the Significance of Environmental Technology Transfer to an Agreement on Climate Change.* ENV/EC/EN/90.5. Paris: OECD
91. Touche Ross Management Consultants. 1991. *Global Climate Change: The Role of Technology Transfer.* Prepared for UK Dep. Trade Ind. Overseas Dev. Admin. London: Touche Ross
92. MacDonald GJF. 1992. *Climate Change: A Challenge to the Means of Technology Transfer.* Inst. Glob. Cooperation and Conflict., Univ. Calif., San Diego
93. Bowser R, Conbere S, Maranion B, Miller A. 1992. *Southern Exposure: Global Climate Change and Developing Countries.* College Park, MD: Cent. Glob. Change
94. Goldemberg J, Monaco LC. 1991. Transfer and adaptation of environmentally sound energy technologies. *Int. Symp. Environmentally Sound Energy Technol. Their Transfer Developing Countries Eur. Econ. Transition, Milan, Italy*
95. Nakićenović N, with Victor D. 1993. Technology transfer to developing countries. *Energy* 18(5):523–38
96. Grubb M. 1990. *Energy Policies and the Greenhouse Effect, Vol. 1: Policy Appraisal.* Brookfield, VT: Dartmouth
97. Guertin DL, Gray JE, Bailly HC, eds. 1993. *Energy Technology Cooperation for Sustainable Economic Development.* Lanham, MD: Univ. Press Am.
98. Pachauri RK, Bhandari P, eds. 1994. *Climate Change in Asia and Brazil: The Role of Technology Transfer.* New Delhi: Tata Energy Res. Inst.
99. Organ. Econ. Coop. Dev. (OECD). 1994. *Effective Technology Transfer, Cooperation, and Capacity Building for Sustainable Development: Common Reference Paper.* OECD Work. Pap. No. 75. Paris: OECD
100. Gollin M. 1991. Using intellectual property to improve environmental protection. *Harvard J. Law Technol.* 4(Spring):193–235
101. Dixon RK, Sathaye JA, Meyers SP, Masera OR, Makarov AA, et al. 1996. Greenhouse gas mitigation strategies: Preliminary results from the U.S. country studies program. *Ambio* 25(1):26–32
102. Watt E, Sathaye J, de Buen O, Masera O, Gelil IA, et al. 1995. *The Institutional*

Needs of Joint Implementation Projects. LBL-36453. Berkeley, CA: Lawrence Berkeley Natl. Lab.
103. Bornstein M. 1985. *The Transfer of Western Technology to the USSR.* Paris: OECD
104. Zaleski E, Wienert H. 1980. *Technology Transfer Between East and West.* Paris: OECD
105. Hanson P. 1985. Soviet assimilation of Western technology. In *Trade, Technology, and Soviet-American Relations,* ed. B Parrott, pp. 63–81. Bloomington, IN: Indiana Univ. Press
106. Stockholm Environ. Inst. 1991. *Environmental Technology Transfer to Eastern Europe: A Selected Bibliography.* Stockholm: Stockholm Environ. Inst.
107. Center for Energy Efficiency. 1995. *Russian Energy Picture.* Moscow: Cent. Energy Effic.
108. Nekrasov AS, Borisova IN, Kretinina YuS, Polyanskaya TM, Suzdal'tseva LF, Voronina SA. 1993. Russia's energy system: Development alternatives. *Stud. Russ. Econ. Dev.* 4(6):477–513
109. Sinyak Y. 1991. Soviet energy dilemma and prospects. *Annu. Rev. Energy Environ.* 16:123–44
110. Chandler WU, Makarov AA, Zhou D. 1990. Energy for the Soviet Union, Eastern Europe and China. *Sci. Am.* 263:120–27
111. Cooper RC, Martinsen KD, Moe A, Schipper L. 1992. *Reduction of Greenhouse Gas Emissions in the Post Soviet Economies: A Role for Western Business?* Lysaker, Nor: Fridtjof Nansens Inst.
112. Dienes L, Dobozi I, Radetzki M. 1994. *Energy and Economic Reform in the Former Soviet Union.* London: St. Martin's
113. Sagers MJ. 1995. The Russian natural gas industry in the mid-1990s. *Post-Sov. Geogr.* 36(9):521–64
114. Campbell RW. 1980. *Soviet Energy Technologies: Planning, Policy, Research and Development.* Bloomington, IN: Indiana Univ. Press
115. Auer MR. 1993. Transferring gas-turbine technologies to the former Soviet Union. *J. Technol. Transf.* 18(1/2):55–61
116. Martinot E. 1995. *Energy efficiency and renewable energy in Russia: Perspectives and problems of international technology transfer and investment.* PhD thesis. Univ. Calif., Berkeley
117. Schipper L, Cooper RC. 1991. *Energy Use and Conservation in the USSR: Patterns, Prospects, and Problems.* LBL-29830. Berkeley, CA: Lawrence Berkeley Natl. Lab.
118. Bashmakov IA, Chupyatov VP. 1991. *Energy Conservation: The Main Factor for Reducing Greenhouse Gas Emissions in the Former Soviet Union.* Richland, WA: Pac. Northwest Lab.
119. US Congr. Off. Technol. Assess. 1993. *Energy Efficiency Technologies for Central and Eastern Europe.* OTA-E-562. Washington, DC: US Gov. Print. Off.
120. US Congr. Off. Technol. Assess. 1994. *Fueling Reform: Energy Technologies for the Former East Bloc.* OTA-ETI-599. Washington, DC: US Gov. Print. Off.
121. Schipper L, Martinot E. 1994. Energy efficiency in former Soviet republics: Opportunities for the West. *Int. J. Glob. Energy Issues* 6(3/4/5):216–27
122. Opitz MW. 1994. *Potential space-heating energy efficiency improvements in district-heated Russian apartment buildings.* MS thesis. Mass. Inst. Technol.
123. Matrosov YuA, Butovsky IN, Watson RK. 1994. Case studies of energy consumption in residential buildings in Russia's middle belt area. *Energy Build.* 20:231–41
124. Fromme JW. 1996. Energy conservation in the Russian manufacturing industry: Potentials and obstacles. *Energy Policy* 24(3):245–52
125. Evans M. 1996. *Russian Business Opportunities in Energy Efficiency and Renewable Energy.* PNNL-11154. Washington, DC: Pac. Northwest Natl. Lab.
126. Cooper RC, Schipper L. 1992. The efficiency of energy use in the USSR—an international perspective. *Energy Int. J.* 17:1–24
127. Batenin V. 1990. Alternative power sources in use in the USSR. *Ambio* 19(4): 220–24
128. Martinot E. 1992. Wind-generated electric power in the former Soviet republics: Geographical prospects. *Post-Sov. Geogr.* 334: 219–36
129. Martinot E, Perminov E. 1995. Wind power in Russia today: Development, resources, and technology transfer. *Proc. Windpower '95, Washington, DC,* pp. 215–24. Washington, DC: Am. Wind Energy Assoc.
130. Kozlov V. 1994. Alternative power in the former USSR and scope for international cooperation. *Int. J. Glob. Energy Issues* 6(3/4/5):170–82
131. Popel OS, Shpilrain EE. 1995. *Utilization of solar energy in Russia.* Presented at Finnish-Russian Symp. New Renewable Energy Sources, Helsinki Tech. Univ. Moscow: Inst. High Temperatures
132. Kelly WJ, Shaffer HL, Thompson JK. 1986. *Energy Research and Development*

in the USSR: Preparations for the Twenty-First Century. Durham, NC: Duke Univ. Press

133. Campbell RW. 1985. Technology transfer in the Soviet energy sector. In *Trade, Technology, and Soviet-American Relations*, ed. B Parrott, pp. 141–68. Bloomington, IN: Indiana Univ. Press
134. Minist. Sci. Technol. Policy Russ. Fed. 1995. *Equipment and Installations for Renewable Energy Sources Utilization*. Moscow: Minist. Sci. Technol. Policy Russ. Fed.
135. Gustafson T. 1989. *Crisis Amid Plenty: The Politics of Soviet Energy Under Brezhnev and Gorbachev*. Princeton, NJ: Princeton Univ. Press
136. Cent. Energy Effic. 1996. Energy efficiency. *Q. Bull. No. 10*. Moscow: Cent. Energy Effic./Washington, DC: Pac. Northwest Lab.
137. Int. Energy Agency. 1994. *Proc. West-West Evaluation Seminar on Energy Efficiency Assistance to the FSU, May 19–20*. Paris: IEA
138. Int. Energy Agency. 1996. *Energy Efficiency Assistance in CEEC and FSU, Past Performance and Future Financing*. Summary notes of a workshop held June 20–21. Paris: IEA
139. UN Econ. Comm. Eur. 1992. *East-West Energy Efficiency: Policies, Programmes, Technologies and Who's Who*. ECE Energy Ser. 10. Geneva: UN Econ. Comm. Eur.
140. Chandler WU, Parker JW, Bashmakov I, Marousek J, Pasierb S, Dadi Z. 1996. *Energy Efficiency Centers: Experiences in the Transition Economies*. PNNL-10965. Washington, DC: Pac. Northwest Natl. Lab.
141. World Bank. 1995. *Staff Appraisal Report: Russian Federation Gas Distribution Rehabilitation and Energy Efficiency Project*. Washington, DC: World Bank
142. World Bank. 1996. *Staff Appraisal Report: Russian Federation Enterprise Housing Divestiture Project*. Washington, DC: World Bank
143. Aslund A. 1994. Lessons of the 1st 4 years of systemic change in Eastern Europe. *J. Comp. Econ.* 19(1):22–38
144. Ellman M. 1994. Transformation, depression, and economics—some lessons. *J. Comp. Econ.* 19(1):1–21
145. Bachurin A. 1996. Russia's economy will grow through labor and the skill of management. *Probl. Econ. Transit.* 39(5):63–78
146. Aleksashenko S, Goland Yu, Grigoryev O, Deliagin M, Kashin V, et al. 1996. Russia toward the year 2000. *Probl. Econ. Transit.* 39(5):6–62
147. Campbell RW. 1991. *The Socialist Economies in Transition: A Primer on Semi-Reformed Systems*. Bloomington, IN: Indiana Univ. Press
148. Yavlinsky G, Braguinsky S. 1994. The inefficiency of laissez-faire in Russia: Hysteresis effects and the need for policy-led transformation. *J. Comp. Econ.* 19(1):88–116
149. Krueger G. 1995. Transition strategies of former state-owned enterprises in Russia. *Comp. Econ. Stud.* 37(4):89–109
150. Gregory PR. 1990. *Restructuring the Soviet Economic Bureaucracy*. Cambridge: Cambridge Univ. Press
151. Nove A. 1986. *The Soviet Economic System*. Boston: Allen & Unwin
152. Cooper J. 1991. Soviet technology and the potential of joint ventures. See Ref. 156, pp. 37–56
153. Handelman S. 1994. The Russian 'Mafiya.' *Foreign Aff.* 73(2):83–96
154. UN Econ. Comm. Eur. 1988. *East-West Joint Ventures*. Geneva: UN Econ. Comm. Eur.
155. UN Conf. Trade Dev. 1990. *Joint Ventures as a Channel for the Transfer of Technology*. Workshop USSR Minist. Extern. Econ. Relat. UNCTAD/ITP/TEC/9. New York: UN Conf. Trade Dev.
156. Sherr AB, Korolev IS, Faminsky IP, Artemova TM, Yakovleva EL, eds. 1991. *International Joint Ventures: Soviet and Western Perspectives*. New York: Quorum Books
157. Feller G, Mikheyev V. 1994. Braving myriad rigors to invest in Russia. *Mergers Acquis.* 28(5):23–26
158. Kvint V. 1994. Don't give up on Russia. *Harvard Bus. Rev.* Mar/Apr:62–74
159. Mukhetdinova NM. 1995. Foreign investment in Russia. *Russ. East Eur. Finance Trade* 31(3):87–96
160. Astapovich A, Grigoryev L. 1994. Foreign investment in Russia: Problems and solutions. *Probl. Econ. Transit.* 36(10):82–100
161. Brendow K. 1995. Energy reforms and foreign direct investments in energy projects in the Commonwealth of Independent States. *Int. J. Glob. Energy Issues* 7(5/6):237–45
162. Martinot E. 1997. Energy efficiency and renewable energy in Russia: Transaction barriers, market intermediation, and capacity building. *Energy Policy*. In press
163. Evans M. 1995. *Joint Implementation in Countries in Transition: An Analysis of the Potential and the Barriers. PNL-*

10480. Washington, DC: Pac. Northwest Natl. Lab.

164. Martinot E. 1997. *Investments to Improve the Energy Efficiency of Existing Residential Buildings in Countries of the Former Soviet Union*. Washington, DC: World Bank. In press
165. Spence JD. 1969. *To Change China; Western Advisers in China, 1620–1960*. Boston: Little Brown
166. May ER, Fairbank JK, eds. 1986. *America's China Trade in Historical Perspective: The Chinese and American Performance*. Cambridge, MA: Harvard Univ. Press
167. Kinney AR. 1982. *Japanese Investment in Manchurian Manufacturing, Mining, Transportation and Communications, 1931–1945*. New York: Garland
168. Nelsen HW. 1989. *Power and Insecurity: Beijing, Moscow and Washington*. Boulder, CO: Lynne Rienner
169. Robinson RD, ed. 1987. *Foreign Capital and Technology in China*. New York: Praeger
170. Sinton JE. 1996. *Energy efficiency in Chinese industry: Positive and negative influences of economic system reforms*. PhD thesis. Univ. Calif., Berkeley
171. China State Plan. Comm. State Sci. Technol. Comm. 1994. *Priority Program for China's Agenda 21*. Beijing: China State Plan. Comm. State Sci. Technol. Comm.
172. Chen HZ, Veziroglu TN, Reay DA, eds. 1996. *Proc. Int. Conf. Energy Environ., Shanghai*. New York: Begell House
173. Johnson TM. 1995. Development of China's energy sector: Reform, efficiency, and environmental impacts. *Oxford Rev. Econ. Policy* 11(4):118–32
174. Liu F. 1993. *Energy Use and Conservation in China's Residential and Commercial Sectors: Patterns, Problems, and Prospects*. LBL-33867. Berkeley, CA: Lawrence Berkeley Natl. Lab.
175. Liu ZP, Sinton JE, Yang FQ, Levine MD, Ting M. 1994. *Industrial Sector Energy Conservation Programs in the People's Republic of China During the Seventh Five-Year Plan (1986–1990)*. LBL-36395. Berkeley, CA: Lawrence Berkeley Natl. Lab.
176. Natl. Environ. Prot. Agency of China, State Plan. Comm. China, UN Dev. Prog., World Bank. 1994. *China: Issues and Options in Greenhouse Gas Control*, 12 Vols. Washington, DC: World Bank, China and Mongolia Reg.
177. Wu ZX, He JK, Zhang AL, Xu Q, Zhang SY, Sathaye J. 1994. A macro-assessment of technology options for CO_2 mitigation in China's energy system. *Energy Policy* 22(11):907–13
178. World Bank. 1993. *China Energy Conservation Study*. 10813-CHA. Washington, DC: World Bank
179. Qiu DX, Gu SH, Catnia P, Huang K. 1996. Diffusion of improved biomass stoves in China. *Energy Policy* 24(5):463–69
180. World Bank. 1996. *China: Renewable Energy for Electric Power*. 15592-CHA. Washington, DC: World Bank
181. Asian Pac. Cent. Transfer Technol. 1986. *Technology Policies and Planning, Vol. 1: People's Republic of China*. Bangalore: Asian Pac. Cent. Transfer Technol.
182. Chang RY. 1984. *Technology Issues in the Capital Goods Sector: The Experience of the People's Republic of China*. Geneva: UN
183. Conroy R. 1992. *Technological Change in China*. Paris: OECD
184. McDonald TD. 1990. *The Technological Transformation of China*. Washington, DC: Natl. Def. Univ. Press
185. Byrd WA. 1991. *The Market Mechanism and Economic Reforms in China*. Armonk, NY: Sharpe
186. Lieberthal KG, Lampton DM, eds. 1992. *Bureaucracy, Politics, and Decision Making in Post-Mao China*. Berkeley: Univ. Calif. Press
187. Naughton B. 1995. *Growing Out of the Plan: Chinese Economic Reform, 1978–1993*. New York: Cambridge Univ. Press
188. Baark E. 1986. *The Technology Policy Reforms in China 1980–85: Concepts, Incentives, and Actors*. Roskilde, Denmark: Inst. Econ. Plan., Roskilde Univ. Cent.
189. Baum R, ed. 1982. *China's Four Modernizations: The New Technological Revolution*. Boulder, CO: Westview
190. Lieberthal K, Oksenberg M. 1988. *Policy Making in China: Leaders, Structures, and Processes*. Princeton, NJ: Princeton Univ. Press
191. Wang YF. 1993. *China's Science and Technology Policy, 1949–1989*. Aldershot, Hants, England: Avebury
192. Ross L. 1988. *Environmental Policy in China*. Bloomington, IN: Indiana Univ. Press
193. Sinkule BJ, Ortolano L. 1995. *Implementing Environmental Policy in China*. Westport, CT: Praeger
194. Ross L. 1994. The next wave of environmental policy in the People's Republic of China. *China Bus. Rev.* Jul/Aug:30–33
195. He BC. 1991. *China on the Edge: The Crisis of Ecology and Development*. San Francisco: China Books Period.

196. Smil V. 1988. *Energy in China's Modernization: Advances and Limitations.* Armonk, NY: Sharpe
197. Smil V. 1993. *China's Environmental Crisis: An Inquiry into the Limits of National Development.* Armonk, NY: Sharpe
198. Young WR. 1991. *China, the World Bank, and the global technological revolution: Learning new strategies of science and technology for development.* PhD thesis. Univ. Calif., Berkeley
199. Asian Dev. Bank. 1995. *Technical Assistance to the People's Republic of China for Establishing a Center for the Transfer of Environmentally Sound Technology.* Manila: Asian Dev. Bank
200. Dixon RK, Sathaye JA, Meyers SP, Masera OR, Makarov AA, et al. 1996. Greenhouse gas mitigation strategies: Preliminary results from the U.S. Country Studies Program. *Ambio* 25(1):26–32
201. Chandler WU, Zhou DD, Hamburger J. 1993. *U.S.-China Cooperation for Global Environmental Protection.* Washington, DC: Pac. Northwest Natl. Lab.
202. Albouy Y. 1991. *Coal Pricing in China: Issues and Reform Strategy.* World Bank Discuss. Pap. 138, China Mongolia Dep., Washington, DC: World Bank
203. Byrne J, Shen B, Li XG. 1996. The challenge of sustainability: Balancing China's energy, economic and environmental goals. *Energy Policy* 24(5):455–62
204. Levine MD, Liu F, Sinton JE. 1992. China's energy system: Historical evolution, current issues, and prospects. *Annu. Rev. Energy Environ.* 17:405–35
205. Lu YZ. 1993. *Fueling One Billion: An Insider's Story of Chinese Energy Policy Development.* Washington, DC: Washington Inst.
206. Qu GP. 1992. China's dual-thrust energy strategy: Economic development and environmental protection. *Energy Policy* 20(6):500–6
207. Wu K, Li BS. 1995. Energy development in China: National policies and regional strategies. *Energy Policy* 23(2):167–78
208. Yang FQ, Duan N, Huan ZJ, Levine MD, Martin NC, et al. 1994. *A Review of China's Energy Policy.* LBL-35336. Berkeley, CA: Lawrence Berkeley Natl. Lab.
209. Hamburger J. 1995. *China's Energy and Environment in the Roaring Nineties: A Policy Primer.* PNL-10631. Washington, DC: Pac. Northwest Lab.
210. Johnson TM. 1992. China's power industry, 1980–1990: Price reform and its effect on energy efficiency. *Energy* 17(11):1085–92
211. Taylor RP. 1996. *Greater China and Japan: Prospects for an Economic Partnership in East Asia.* London: Routledge
212. Holton RH, Xi W, eds. 1989. *U.S.-China Economic Relations: Present and Future.* Berkeley, CA: Inst. East Asian Stud., Univ. Calif.
213. US Congr. Off. Technol. Assess. 1987. *Technology Transfer to China.* OTA-ISC-340. Washington, DC: US Gov. Print. Off.
214. Yuan JD. 1996. United States technology transfer policy toward China: Post-cold war objectives and strategies. *Int. J.* 51(2):314–38
215. De Bruijn EJ, Jia XF. 1993. Transferring technology to China by means of joint ventures. *Res. Technol. Manage.* 36(1):17–22
216. Lawson EK, ed. 1988. *U.S.-China Trade: Problems and Prospects.* New York: Praeger
217. Etienne G, with Astier J, Bhushan H, Zhong D. 1992. *Asian Crucible: The Steel Industry in China and India.* Newbury Park, CA: Sage
218. Lin XN. 1996. *China's Energy Strategy: Economic Structure, Technological Choices, and Energy Consumption.* Westport, CT: Praeger
219. Ho AK. 1990. *Joint Ventures in the People's Republic of China: Can Capitalism and Communism Coexist?* New York: Praeger
220. UN Cent. Transnatl. Corp. 1988. *Foreign Direct Investment in the People's Republic of China.* New York: UN Cent. Transnatl. Corp.
221. Keidel A. 1986. *The Role of Technology Transfer for China's Economic Future.* US Congr. Off. Technol. Assess. Washington, DC: US Gov. Print. Off.
222. UN. 1992. *Technology Transfer and Development in a Changing International Environment: Policy Challenges and Options for Cooperation: Materials and Recommendations of a Seminar for Developing Countries of Asia.* New York: UN
223. Bauer EE. 1986. *China Takes Off: Technology Transfer and Modernization.* Seattle: Univ. Wash. Press
224. Mann J. 1989. *Beijing Jeep: The Short, Unhappy Romance of American Business in China.* New York: Simon & Schuster
225. Child J, Lu Y, eds. 1996. *Management Issues in China, Vol. II: International Enterprises.* London: Routledge
226. Engholm C. 1989. *The China Venture: America's Corporate Encounter with the*

People's Republic of China. Glenview, IL: Scott, Foresman
227. Steidlmeier P. 1995. *Strategic Management of the China Venture.* Westport, CT: Quorum Books
228. Dong SZ, Zhang DN, Larson MR. 1992. *Trade and Investment Opportunities in China: The Current Commercial and Legal Framework.* Westport, CT: Quorum Books
229. Leuenberger T, ed. 1990. *From Technology Transfer to Technology Management in China.* New York: Springer-Verlag
230. Pomfret R. 1991. *Investing in China: Ten Years of the Open Door Policy.* Ames, IA: Iowa State Univ. Press
231. Schnepp O, Von Glinow MA, Bhambri A. 1990. *United States–China Technology Transfer.* Englewood Cliffs, NJ: Prentice Hall
232. Fischer WA. 1986. *The Transfer of Western Managerial Knowledge to China.* US Congr. Off. Technol. Assess. Washington, DC: US Gov. Print. Off.
233. Behrman JN, Fisher WA, Simon DF. 1991. Transferring technology to China. See Ref. 20, pp. 79–92
234. Sinton JE, Levine MD. 1997. Energy efficiency in China: Accomplishments and challenges. *Energy Policy.* In press

Annual Review of Energy and the Environment
Volume 22, 1997

CONTENTS