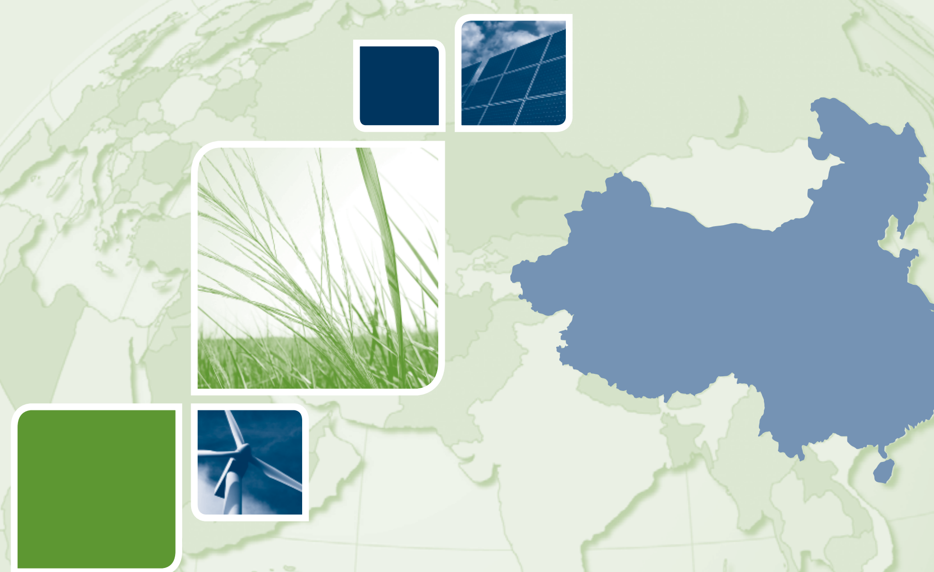
U.S. Department of Commerce
International Trade Administration

Clean Energy:
An Exporter's Guide to **China**



The International Trade Administration's mission is to create prosperity by strengthening the competitiveness of U.S. industry, promoting trade and investment, and ensuring fair trade and compliance with trade laws and agreements.

INTERNATIONAL
TRADE
ADMINISTRATION

Market Access and Compliance
1401 Constitution Ave., NW
Washington, DC 20230

T 202.482.3022
F 202.482.5444

www.trade.gov

Clean Energy:
An Exporter's Guide to **China**

by
Energy and Security Group
Reston, VA 20190

for U.S. Department of Commerce,
International Trade Administration
http://trade.gov

under contract number DG1350-07-SE-4516 ESG104 ITA

Release Date: July 2008

INTERNATIONAL
TRADE
ADMINISTRATION

Table of Contents

Abbreviations and Acronyms

Acronyms

ABS asset-backed securities
AC alternating current
ACEEE American Council for an Energy-efficient Economy
ACORE American Council on Renewable Energy
ADB Asian Development Bank
AEE Association of Energy Engineers
AESP Association of Energy Services Professionals
AFV alcohol fuel vehicle
ALM asset liability management
APM administered pricing mechanism
APP Asia–Pacific Partnership on Clean Development and Climate
AQSIQ Administration of Quality Supervision, Inspection, and Quarantine
ASE Alliance to Save Energy
ASEAN Association of Southeast Asian Nations
ASTAE Asia Alternative and Sustainable Energy
ASTM American Society for Testing and Materials
bcm billion cubic meters
BIPV building-integrated photovoltaics
BOO build, own, operate
BOOT build, own, operate, and transfer
BOV battery-operated vehicle
BPL below poverty line
BT billion tons
CATARC China Automotive Technology and Research Center
CCC China Compulsory Certification Mark
CDM Clean Development Mechanism
CE European Conformity (French acronym)
CEC China Electricity Council
CER credits for emission reductions
CET clean energy technology
CFL compact fluorescent lighting
CGC China General Certification Center
CHCP combined heat, cooling, and power
CH4 methane
CHP combined heat and power
CLASP Collaborative Labeling and Appliance Standards Program
CNCA Certification and Accreditation Administration
CNG compressed natural gas
CO2 carbon dioxide
CREIA Chinese Renewable Energy Industries Association
CSC China Standard Certification Center
CWEA Chinese Wind Energy Association
DC direct current
DFI development financial institution
DME di-methyl ether
DOC U.S. Department of Commerce
DRCs provincial Development and Reform Commissions
DSM demand-side management
EC energy conservation
ECB external commercial borrowing
ECBC Energy Conservation Building Codes
ECO Energy Efficiency Commercialization Project
EE energy efficiency
EEB Bureau of Economic, Energy and Business Affairs (United States)
EEI energy efficiency indicator
EERE Office of Energy Efficiency and Renewable Energy (United States)
EIB European Investment Bank
EJ exajoule
EMCO energy management contract
EOU export-oriented unit
EPC equipment procurement and construction
ERI Energy Research Institute
ESCO energy service company
ETC evacuated tube collectors
EV electric vehicle
EVA solid phase crystallization of evaporated silicon
Ex-Im Export–Import Bank of the United States
FAS Foreign Agricultural Service (United States)
FDI foreign direct investment
FI financial institution
FPC flat plate collector
FYP Five-Year Plan
GATT General Agreement on Tariffs and Trade
GB Guojia Biaozhun
gce gram of coal equivalent
GDP gross domestic product
GEF Global Environment Facility
Gg gigagram
GHG greenhouse gas
GNP gross national product
GPV gas-powered vehicle
GRP glass fiber–reinforced plastic
GW gigawatt
GWe gigawatt electric
GWp gigawatt peak
HFC hydrofluorocarbon
HIT heterojunction with intrinsic thin layer
HT high-tension
IBRD International Bank for Reconstruction and Development
ICB international competitive bidding
ICBC Industrial and Commercial Bank of China
IEA International Energy Agency
IEC International Electrotechnical Commission
IFC International Finance Corporation

IFI international financing institution
IGCC integrated gasification combined cycle
IIFCL India Infrastructure Finance Company Limited
INR Indian National Rupees
IP intellectual property
IPA Indian Patent Act
IPP independent power producer
IPR intellectual property rights
IREDA Indian Renewable Energy Development Agency
ITA U.S. International Trade Administration
JBIC Japan Bank for International Cooperation
JCF Japan Carbon Finance, Limited
JV joint venture
kgce kilogram of coal equivalent
kha kilohectare
KP Kyoto Protocol
kT kiloton
kV kilovolt
kW kilowatt
kWe kilowatt electric
kWh kilowatt hour
kWp kilowatt peak
LC letter of credit
LED light-emitting diode
LNG liquefied natural gas
LOLP loss of load probability
LPG liquefied petroleum gas (Propane)
M&A mergers and acquisitions
mb/d millions of barrels per day
MIGA Multilateral Investment Guarantee Agency
MJ megajoule
MMSCM million standard cubic meter
MOC Ministry of Construction
MOF Ministry of Finance
MOFCOM Ministry of Commerce
MOFTEC Ministry of Foreign Trade and Economic Cooperation
MOST Ministry of Science and Technology
MSIHC Manufacture, Storage, and Import of Hazardous Chemicals
mt million tons
MT magnetotelluric
mToe million tons of oil equivalent
MU million units
MW megawatt
MWe megawatt electric
MWeq megawatt equivalent
MWp megawatt peak
NAESCO National Association of Energy Service Companies
NB national competitive bidding
NBSC International Center of National Bureau of Statistics of China
NCCCC National Coordination Committee on Climate Change
NCE non-conventional energy
NDRC National Development and Reform Commission
N2O nitrous oxide
NOx nitrogen oxide
NPC National People's Congress
NREL National Renewable Energy Laboratory of the U.S. Department of Energy
OECD Organization for Economic Co-operation and Development
OFAC Office of Foreign Assets Control (United States)
OGL open general license
O&M operation and maintenance
OPIC Overseas Private Investment Corporation (United States)
PCF Prototype Carbon Fund
PDD Project Design Documentation
PE private equity
PECVD plasma-enhanced chemical vapor deposition
PEMF Private Energy Market Fund LP
PEMFC proton exchange membrane fuel cell
PHWR pressurized heavy water reactor
PPA power purchase agreement
PPP public–private partnership
PSU public–sector undertaking
PV photovoltaic
R&D research and development
RE renewable energy
REDP World Bank Renewable Energy Development Program
REL Renewable Energy Law
REPS renewable energy portfolio standard
RMB Chinese Yuan Renmimbi
RPS reserve energy portfolio standard
RSPM respirable suspended particulate matter
SAC Standardization Administration of China
SAFE State Administration of Foreign Exchange
SBA Small Business Administration (United States)
SDDC Song Dian Dao Cun (China's National Village Electrification Program)
SDDX Song Dian Dao Xiang (China's National Township Electrification Program)
SEFI Sustainable Energy Finance Initiative
SEK Svensk Exportkredit
SEPA State Environment Protection Administration
S/F JV Sino-Foreign Joint Venture
SHP small hydropower
SHS solar home system
SI solar ingot
SICLIP Swedish International Climate Investment Program
SME small and medium enterprise
SO2 sulphur dioxide
SOE state-owned enterprise
SPV solar PV
SWH solar water heating
TC-88 Technical Committee 88 of the IEC
tce tons of coal equivalent

T&D transmission and distribution
TEDA Tamil Nadu Energy Development Agency (India)
TERI Tata Energy Research Institute
toe tons of oil equivalent
TPES total primary energy supply
TRIPS Trade-related Aspects of Intellectual Property Rights
TüV Technische Überwachungsvereine (Germany standards/testing company)
TWh terrawatt hour
UCP Unified Customs and Practice
UL Underwriters Laboratories
UNDP United Nations Development Program
UNICITRAL United Nations Commission on International Trade
UPS uninterruptible power supply
URIF Urban Reform Incentive Fund
USAID U.S. Agency for International Development
USDA U.S. Department of Agriculture
USDOC U.S. Department of Commerce
USDOE U.S. Department of Energy
USTDA U.S. Trade and Development Agency
USTR U.S. Trade Representative
VAT value-added tax
VER Verified Emission Reduction
VSD variable-speed drive
W watt
WEEA World Energy Efficiency Association
WOFE wholly-owned foreign enterprise
Wp watt peak
WTG wind turbine generator
WTO World Trade Organization

Executive Summary

Introduction

This report is intended as a clean energy technology market overview for China, with two primary objectives: (1) to analyze the clean energy markets in China and (2) to identify opportunities for trade and investment through 2020. The report provides the following:

- analysis of the existing infrastructure of clean energy technologies and market opportunities in China through 2020 including market forecasts, market drivers, cost data, and market segment analysis.
- review of government policies for clean energy development in China.
- detailed analysis of barriers and obstacles to clean energy technologies trade and investment in China.
- definition of clean energy technologies for China.
- review of resources available to U.S. businesses that wish to enter Chinese clean energy markets.

After a short introduction, Section 1 addresses clean energy technologies for China, including information on China's overall energy status, both current and projected; a market overview; identification of clean energy policies; trade and investment opportunities for U.S. firms; and barriers to clean energy market entry, development, and commercialization. This chapter also includes annexes on Chinese policy-makers with authority over clean energy technologies and information on the renewable energy industry in China. Section 2 provides definitions of the clean energy technologies addressed in the report.

Clean Energy Technology Defined

Clean energy technologies include renewable energy, hybrid and co-generation, and energy efficiency technologies for power generation; alternative fuels; and advanced technologies for transportation. They produce power for a wide range of applications using no fuel or less fuel than fossil-fuel-based technologies, produce no or fewer pollutants than conventional technologies and can use renewable energy sources, which, unlike fossil fuels, are not depleted over time. The renewable energy technologies considered in this report are biomass and biofuels, waste-to-energy, solar power, wind power, geothermal, hydropower, and ocean power.

Biomass consists of plant and plant-derived material. Sources include agricultural residues such as rice hulls, straw, bagasse from sugarcane production, wood chips, and coconut shells and energy crops such as sugarcane or switch grass. Biomass can be used directly for energy production or processed into fuels. Waste-to-energy technology converts energy from a waste source, such as a city's municipal waste system, farms, and other agricultural operations, or waste from commercial and industrial operations. Large-scale waste-to-energy systems can supply heat or electricity in utility-based electric power plants or district heating systems. Small-scale systems can provide heating or cooking fuel and electricity to individual farms, homes, and businesses.

Solar technologies convert light and heat from the sun into useful energy. Photovoltaic (PV) systems convert sunlight into electricity, and thermal systems collect and store solar heat for air and water heating applications. *Wind* power technology converts energy in the wind into useful power; the primary market for wind power technology is for wind turbines, which convert wind energy into electricity. *Geothermal* power is generated using thermal energy from underground sources, including steam, hot water, and heat stored in rock formations; various technologies are used to generate electricity. *Hydropower* is the conversion of energy embodied in moving water into useful power. Today, hydropower supplies about 19 percent of the world's electricity. Finally, *ocean power* – sometimes referred to as tidal – technology makes use of energy in the ocean by converting it into electricity

Hybrid and co-generation power systems take advantage of the benefits of multiple technologies in a single, integrated system for power generation. Renewable-based hybrid power systems use combinations of wind turbines, PV panels, and small hydropower generators to generate electricity. Hybrid power systems typically include a diesel or other fuel-based generator (including biofuels) and may include batteries or other storage technology.

Co-generation systems, also called combined heat and power (CHP) systems, generate both electricity and useful heat. Conventional fossil-fuel-based electric power plants generate heat as a byproduct that is emitted into the environment; co-generation power plants collect this heat for use in thermal applications, thereby converting a higher percentage of the energy in the fuel into useful energy. The most efficient conventional power plants have a typical fuel-to-electricity conversion factor of about 50 percent, while co-generation plants can achieve efficiencies of over 75 percent. Examples of thermal loads that can be served by a co-generation plant are: district heating systems that provide heat for towns and neighborhoods; industrial processes that require heat, such as paper mills; institutions such as prisons and hospitals; and wastewater treatment plants.

Energy efficiency (EE) involves replacing existing technologies and processes with new ones that provide equivalent or better service using less energy. EE results in energy savings at the time that the energy service is provided. Energy service providers can also use load management to change the time that an energy service is delivered in order to reduce peak loads on an energy distribution system. Demand-side management uses both load management and EE to save the amount of primary energy required to deliver the energy service.

Almost half a billion vehicles on the world's roads contribute to half of the global oil consumption and generate about 20 percent of the world's greenhouse gases, including carbon monoxide, nitrous oxides, and particulates. *Transportation technologies* can help address these issues through the use of alternative fuels and advanced technologies. Alternative fuels for transportation include biodiesel, ethanol, natural gas, and propane. Advanced vehicle technologies include electric vehicles and hybrid electric vehicles, which offer air pollution improvements over average fossil fuel vehicles. Finally, mobile idle reduction systems and diesel engine retrofits can reduce the emissions of heavy-duty vehicles.

China: Energy Overview

Since the start of the open-door and reform policies in 1978, China has experienced consistent economic growth on the order of 9.5 percent per year. While on average energy demand grew at about 5 percent per year prior to 2001, the past seven years have seen a tremendous surge in energy-intensive heavy industries, which has dramatically accelerated energy demand. According to the National Bureau of Statistics of China, China's current energy consumption increase stands at a rate of 9.3 percent, and this rapid growth is expected to continue. In fact, China is predicted to surpass the United States as the largest energy consumer soon after 2010.

Although China's energy resources are substantial, the country's self-sufficiency is decreasing as the overall energy demand has grown much faster than its domestic output. In 2005, foreign supply accounted for 7.7 percent of the total energy consumption in China, and in 2007 the country became a net coal importer for the first time. China has become increasingly dependent on oil imports and liquid natural gas imports, the latter of which were seen for the first time in 2006. Coal is China's predominant energy source; however, with the rapid increase in energy demand and the urgency of energy and environmental security issues, the shift away from conventional energy toward clean energy has become an interesting strategic option for China.

Exploration for the use of renewable energy technologies in China began in the 1980s, but government support for these options did not officially begin until the 8th Five-Year Plan in 1991. In the late 1990s, China launched its ambitious rural electrification program, which has helped China's renewable energy consumption increase to 7.5 percent of the country's total primary energy consumption as of 2005. However, although the markets for hydropower and solar water heating technologies are mature, the use and development of most other renewable energies has lagged because of high investment costs, specific primary resource shortages, dependence on foreign technology, and small-scale production.

Renewable Resources, Capacity, and Potential

China has a large untapped potential for wind energy, perhaps as high as 750 gigawatts (GW) of potentially utilizable onshore resources (250–300 GW of which are considered commercially feasible) and over 1,000 GW of offshore resources. In recent years, Chinese wind generation technology has matured with the help of technology transfer from foreign countries and a national concession policy that stipulates 70 percent of wind turbines in developer tenders must be sourced from domestic manufacturers—which has helped the domestic industry substantially. Still, as of 2006, China's total installed wind power generation capacity was only 2.6 GW, indicating substantial growth opportunities going forward.

The resource potential for solar power in China is equally promising. China receives the equivalent energy potential of 1.7 trillion tons of coal in the form of solar radiation. By the end of 2006, the cumulative installed capacity of solar cells in China had reached 80 megawatts peaks (MWp), with rural electrification, communications, and industry accounting for the majority of the market share. Currently, China is the third-largest PV panel manufacturing country in the world behind Germany and Japan, developing 370 MWp of solar PV cell modules in 2006 – however, only 10 MWp were consumed domestically. Consequently, solar power production remains much lower than actual capacity. While policy support and government subsidy programs can be credited with 46.2 percent of China's developed capacity, high investment costs, undefined feed-in tariffs, and the lack of fiscal incentives means a significant on-grid solar PV market has yet to materialize.

Solar thermal energy for water heating is one of the most advanced renewable energy technologies in China with a mature commercial domestic market. China has a cumulative installed capacity of solar water heaters (SWHs) that surpasses 90 million square meters (m^2) of collector area—roughly 60 percent of the world's total. In fact, nearly one in ten Chinese households owns an SWH. Notably, China has over 1,000 solar water heating manufacturers, and 95 percent of the intellectual property rights for solar thermal technologies used in China are domestically owned. In 2006, the domestic production capacity stood at 6 million m^2, but the domestic market lags behind this capacity—the excess production is currently exported to Europe and Southeast Asia. China has recently developed national testing centers and a national certification center for SWH technologies based on international best practices, and this has led to improved product quality and domestic consumer confidence. Building integrated SWHs is in the early stages. Low aesthetic quality and lack of support from building developers remain challenges for the industry.

China has a vast bioenergy potential with recent average biomass resource utilization above 500 million tons of coal equivalent (tce). The majority of the resource potential comes from wood (300 million tce), followed by straw and stalk resources (150 million tce), waste water (57 million tce), and urban garbage (23 million tce). The key technologies for biomass include combined heat and power combustion (CHP), biogas, landfill, and other waste gasification. In 2006, power production from CHP amounted to 1.7 GW; biogas amounted to 500 megawatts (MW) minus rural use; and 30 MW was produced from landfill and other gasification. Biogas development is backed by the central government through strong fiscal incentives as well as investment subsidies. By the end of 2006, 17 million household biogas digesters, 140,000 municipal waste treatment facilities, and 4,000 industry sewage biogas facilities providing 1.9 million cubic meters (m^3) of biogas per year had been installed. It is estimated that the current biogas potential in China from industry could be used to generate 3.8 GW of base load electricity with 23 terawatt hours (TWh) of electricity potential by 2010. The estimate is considerably higher for 2020 projections.

Compared to biogas, liquid biofuel technology development is still in an early stage. China has important bioethanol potential based on sugarcane, cassava, corn, and broomcorn cultures. The 10th Five-Year Plan saw the beginning of a national program aimed at developing technologies for making bioethanol from broomcorn and similar cellulose waste such as corn stalk. Biodiesel development is also included in the 11th Five-Year Plan but is still at the research stage. Its commercialization will depend on production cost reductions and increased conversion rates.

The total potential for small hydropower (SHP) in China is estimated at 71.87 GW and is concentrated among more than 1,600 mountain counties in the middle and western regions. However, as of the end of 2004, only 2.1 percent of the total potential had been developed in western China, where the majority of the unelectrified poor are located. SHP is now one of the mature renewable energy technologies in China, with a significant domestic manufacturing capacity and competitive export potential in Asia. This is the result of strong fiscal support from the central government. By 2004, there were over 100 SHP manufacturers in China, with an annual production capacity of around 6.3 GW.

Energy Efficiency, Co-Generation, and Transportation

In general, production and operation energy efficiency is low in China. Recently, energy efficiency (EE) has decreased due to the growing industry sector, which has the lowest EE level. Operational efficiency for end-use equipment in China is generally 20 percent lower than the international average for advanced countries, which is mainly due to obsolete and poorly maintained production equipment. Nonetheless, the 11th Five-Year Plan includes an ambitious target to decrease energy intensity by 20 percent through 2010, which is being pursued through 10 key government programs. The challenges facing increased EE include a lack of expertise in demand-side management and energy-auditing services and a lack of capacity for innovative high-efficiency technology development.

Co-generation, or combined heat and power (CHP), remained the major heat supply source in China until recently, covering 82 percent of total heat demand and 27 percent of the total water heating demand in 2004. Mixed political signals from the provincial and central government, as well as sustained growth of coal utilization and inconsistent electricity tariff increases, have caused 90 percent of China's domestic CHP operators to take heavy losses over the last five years. The situation is similar for foreign operators. In fact, CHP installations make up almost 50 percent of the power plants closed since the beginning of 2007. Nonetheless, co-generation was identified as an important energy conservation technology for reducing coal consumption in the 11th Five-Year Plan, with ambitious targets set for its development.

China has been actively involved in the demonstration and development of large-scale clean transportation technologies since the launch of the "Clean Vehicles Action" Program in 1999. Gas-powered vehicles (GPVs) are now in operation, and those on the market are third-generation products. As of end-2006, the GPV fleet numbered 265,000 vehicles. Compressed natural gas vehicles are rapidly growing, with a fleet of 174,170 in 2006. Alcohol fuel vehicles are found in the eastern portion of the country, and the planned production level for ethanol fuel was recently set at about 1 million tons per year. There has been a considerable amount of government investment in fuel cell technology research, and a demonstration program is underway in Beijing for fuel cell bus commercialization. Finally, electric vehicle technology is under development, but applications are still limited by low power capacity as well as high production costs. Nonetheless, there is a vibrant market for electric bicycles in China, with about 10 million units produced in 2005 alone.

Market Analysis

Projections for 2010 and 2020 from government planning documents indicate that the clean technology market will increase to $186 billion (based on an exchange rate of $1 = 7.208 RMB) in 2010 and to $555 billion in 2020. Policy objectives for the five key renewable energy (RE) technologies are shown in Table A below. Market development for some renewable energy technologies has already surpassed the targets established by the government, such as wind; others like SWH, will easily reach the targets established if not overtake them. Although the domestic market for solar PV generation is not as developed as the wind and SWH markets, plans have been made for the construction of large-scale on-grid PV and concentrated solar power plants in desert areas of Inner Mongolia, Gansu, and Xinjiang provinces. Two government-led rooftop PV programs will also stimulate the PV market.

The targets for co-generation are equally ambitious. Based on the installed production capacity and the current 6.5 percent average annual growth for CHP generation in China, the total CHP generation capacity will reach 47 GW in 2010 and 87.5 GW in 2020, corresponding respectively to 37 percent and 68.5 percent of the total CHP potential.

The current cost of investment in wind energy is in the range of $1,110–1,387/kW. It is expected that with increasing domestic manufacturing capacity and technology transfer, the investment costs can be brought down to the range of $832–971/kWh by 2010. Similarly, significant future cost reductions are expected for solar PV. Other technologies, however, have less scope for cost reduction as these are already fairly mature in China and worldwide.

In China, there are currently over 80 wind turbine generator manufacturers and 200 wind developers. Domestic companies occupy over 75 percent of the market. China's solar industry has matured in recent years, with booming investments providing an important opportunity. Over 80 percent of the domestic manufacturers produce mono-ingot. Two companies—Suntech and Ningbo Solar—dominated the market prior to 2006; in that year the size of the market grew with new companies entering the scene. In total, there are over 3,500 SWH system manufacturers in China, the top ten of which are able to provide high-quality products and good after-sales services. Small hydropower technologies are mature in China, with over 100 manufacturers. Finally, as a result of energy efficiency policy and goals set forth in the 11th Five-Year Plan, the energy efficiency market is booming as numerous companies and organizations have developed operations in various fields.

Table A. Policy Objectives for Key RE Technologies.

RE	UTILIZATION	OBJECTIVES BY 2010	OBJECTIVES BY 2020
Hydropower	Large scale	140 GW	225 GW
	Small scale	50 GW	75 GW
Bioenergy	Generation	5.5 GW	30 GW
	Solid biofuel	10 bil. tons	50 bil. tons
	Biogas	19 bil. m^3	44 bil. m^3
	Bioethanol	2 mil. tons	10 mil. tons
	Biodiesel	0.2 mil. tons	2 mil. tons
Wind	Generation	5 GW	30 GW
Solar *	On-grid solar PV	150 MW	1.5 GW
	Off-grid solar PV	150 MW	0.3 GW
	Solar thermal	150 mil. m^2	300 mil. m^2
Geothermal		4 mil. tce	12 mil. tce

NDRC, 2006 Mid- and Long-term Renewable Energy Development Plan.
* Total solar PV installation includes both on-grid and off-grid generation capacity.

The largest market drivers for energy demand are urbanization and economic growth, the latter of which is a direct result of the country's booming and energy-intensive industrial exports. In 2006, according to China's National Bureau of Statistics, China's gross domestic product (GDP) increased by 10.7 percent, while the primary domestic energy consumption rose by 8.4 percent. Not surprisingly, China is dependent increasingly on energy imports to keep up with the demand.

Dependence on costly imports, and the related issue of energy security, represents another market driver. Oil imports alone reached 169 million tons in 2006, and the dependence on exports accounted for 47 percent of the oil balance. Environmental concerns are an additional market driver, specifically in response to the high polluting Chinese coal industry. The International Energy Agency (IEA) concluded that China overtook the United States as the world's biggest carbon dioxide (CO_2) emitter in 2007. The World Bank estimates the total cost of air and water pollution in China is roughly $50.22 billion, or about 2.68 percent of GDP. Acid rain is estimated to cost $4.16 billion in crop damage and $138.73 million in material damage annually. Moreover, about 54 percent of surface water resources in China have been deemed unsafe for human consumption. The Chinese Government considers these issues to be very serious, and the ambitious targets, state investment, and policy seen in recent years can be considered an important result of the country's high priority on sustainable (and sustained) development.

Energy Policy

The development of a more robust clean energy policy is accelerating in response to China's mounting energy pressures. The strategic position of renewable energy was confirmed with the passage of the Renewable Energy Law (REL), which was approved by the National People's Congress in February 2005 and took effect on January 1, 2006. The REL is a framework law that creates targets for renewable energy development and stipulates a number of broadly defined instruments to reach these targets. The targets are shown above in Table A; the overall renewable energy target as a percentage of energy consumption is 10 percent by 2010 and 15 percent by 2020. The REL mandates the establishment of priority grid access for renewable electricity generators, a feed-in tariff for renewable electricity delivered to the grid, a national and regional cost-sharing mechanism for renewable energy subsidies, a special fund for renewable energy, and favorable loan conditions and tax treatment for renewable energy.

The successful implementation of the REL depends on its implementation regulations, which further elaborate upon the policy instruments defined in the REL. Ten such regulations have been issued so far, including the Mid-and Long-term Renewable Energy Development Plan, which stipulates that renewable energy utilization should reach 300 million tce by 2010 and 600 million tce by 2020. Another is the Guidance Catalogue of the Renewable Energy Industry, which was released by the National Development and Reform Commission (NDRC) in November 2006 and aims to guide provincial decision-making on the direction for technological research and innovation and renewable energy investment. Finally, a special fund for renewable energy development supports the key fields of fossil fuel alternatives, building heating and cooling, and renewable energy electricity generation through no-interest and discount loans. An application guidebook for the funds is drafted annually and published by the NDRC and the financial department of the State Council.

China's new Energy Conservation (EC) Law was approved by the 10th State Congress on October 28, 2007, and entered into effect on April 1, 2008. The Law identifies key policy instruments, which includes setting targets, developing procedures for product standardization and efficiency labeling, and establishing incentives for EC technologies, as well as demand-side management including preferential tax policies and subsidy funds. Indeed, many preferential tax policies have been implemented to support clean energy research, development, and production. For example, since 2001 waste-to-energy projects have been value-added tax (VAT) exempt, and a 50 percent VAT discount applies for the use of energy-saving materials in buildings, for wind power projects, and for coal bed methane projects.

A draft of China's integrated Energy Law was recently published. The forthcoming law provides a framework law for overall national energy development and will include guiding principles for legislation on energy structure, energy efficiency, energy security, energy development and utilization, and energy and environmental coordination. One of the most important changes in the new Energy Law is the proposed establishment of an Energy Ministry directly under the State Council. The Energy Ministry would be responsible for overseeing energy management in China, including monitoring energy-intensive exports, approving energy and mining activities, promoting energy efficiency and inter-regional energy infrastructure, and establishing market-driven price mechanisms as well as incentive policies. The law also mandates that a 20–30 year energy strategy will be developed every five years, along with five-year energy plans. Industry Analysts anticipate that the Energy Law will be enacted in the years to come. In the meantime, the National Energy Bureau under the National Development and Reform Commission will continue to administer energy policy.

Opportunities for U.S. Clean Technology Firms in China

The opportunities for U.S firms entering the Chinese clean energy market have grown tremendously during recent years. The development of a market economy, increasing concerns about energy security, and the mounting environmental pressures have all incentivized clean technologies and facilitated their entry into the market. Yet the rapidly growing government push and resulting market pull for clean energy development presents special challenges for China due to the technological requirements necessary to reach the aggressive government goals. The commercial market for clean energy technologies in China at this time should be considered embryonic at best. As the demand for clean energy technology increases, it can be expected that there will be an increasing demand for proven, high-quality products and services—which provides an opening in the market for qualified international companies with sustainable business operations.

To fulfill the objective of a 20 percent decrease in energy intensity by 2010 (relative to 2000 levels), the Chinese Government has recognized that major developments in technology and energy management must be achieved across industrial, commercial, and residential sectors. According to China's Energy Research Institute, the investment potential for energy efficiency in China from 2007 to 2010 will be about $120–160 billion. In general, there is a lack of expertise in China in energy efficiency technologies and innovation, energy auditing, and energy management. Areas such as operation and maintenance for renewable energy (RE) generation, energy auditing and advisory services, consulting on energy management and RE integration, and standard energy services are all potentially profitable business opportunities.

Technological needs in the clean energy industry include remote monitoring and control systems for wind farms, technology for large-scale wind turbines (over 2 MW), and software for resource assessment and grid integration. In solar power, opportunities include aesthetic building integration for SWHs, improved technology in thin film, interface technology for building-integrated PV and for power plants, and high-quality converters. In bioenergy, needs include research and development (R&D) on the production of ethanol from cellulosic feedstock, high-efficient fermentation technology for higher biogas yield, demonstration of new building material and technology for digester construction and biogas storage, and biogas processing for feed-in to the natural gas grid.

Barriers for U.S. Firms

Despite the significant opportunities that the Chinese clean energy technology market presents, important barriers need to be carefully considered in developing business in China. These include lack of a transparent and consistent body of laws and regulations, lack of a supervisory mechanism for renewable energy implementation, customs regulations and a phasing out of favorable tariffs for foreign investment, and restrictions on foreign direct investment that include biofuels manufacturing. Lack of transparency in government procurement, including instances of corruption, can also present challenges as well as intellectual property rights and contract enforcement. Finally, other considerations like understanding Chinese business culture, identifying local partners, and building good government relationships are also important non-policy related barriers that must be considered.

Conclusion

In summary, China presents both unprecedented opportunities and challenges for clean energy technologies, due to the sheer scale of the market, the demand, and the projected future energy scenario. Over the last decade, China faced serious difficulties related to energy shortages and heavy pollution, both of which have been brought on by rapid economic development. In response, the government of China has actively promoted the development and deployment of renewable energy with ambitious policies and targets.

China will likely be a major net exporter of renewable energy equipment in the near term, as the country produces far more equipment than it can install domestically. However, as the demand for higher product quality and after-sales service increases, and as Chinese consumers become more conscious of efficiency and environmental concerns, this situation is likely to change. The Renewable Energy Law (REL) has already had a major impact on accelerating China's clean energy market and resulted in an increase of new renewable energy projects, particularly in the areas of wind, solar, and biomass. Ambitious targets are included in the REL for the next 10–15 years, which, when paired with the industry outlook, are likely to be even higher. Therefore, U.S. firms should anticipate a growing demand for proven, high-quality products and services in key areas such as energy service companies, energy efficiency auditing, wind farm operation and management, technological innovation of large-scale turbines, aesthetic building integration of SWHs, and improved thin-film PV technology.

Introduction

Purpose

The report's objectives are twofold: (1) to analyze the clean energy markets in China and (2) to identify opportunities for trade and investment through 2020.

Approach

The report provides the following:

- An analysis of the existing infrastructure of clean energy technologies and market opportunities in China through 2020. This includes market forecasts, market drivers, cost data, and market segment analysis.
- review of government policies for clean energy development in China.
- detailed analysis of barriers and obstacles to clean energy technologies trade and investment in China.
- definition of clean energy technologies for China.
- review of resources available to U.S. businesses that wish to engage in clean energy trade and investment in China.

Methodology

Both primary and secondary data sources were used in the preparation of this report. These included:

China Resources

- Annual reports from relevant ministries at the national level and, where available, at the provincial levels;
- List of relevant agencies, areas of operation, and contact details;
- Policy documents (e.g., China's Renewable Energy Promotion Law 2006 China's Guidance Catalogue of Renewable Energy Industry) as well as documents stating quotas, tax requirements, procurement requirements, foreign investment policy, and master plans for technology development in different sectors;
- Statistical documents containing installed capacity, energy balance, consumption, etc.;
- Five-Year Plans and ministerial long-term development plans; Annual Reports of relevant corporations;
- Data related to financial markets in China.

U.S. Government Sources

- U.S. Department of Commerce;
- U.S. Department of Energy, including the National Renewable Energy Laboratory, Energy Information Agency, and Office of Energy Efficiency and Renewable Energy;
- U.S. Trade and Development Administration;
- Export–Import Bank of the United States;
- Asia–Pacific Partnership on Clean Development and Climate.

International Institutions

- Asian Development Bank;
- World Bank;
- International Energy Agency.

Trade, Industry, and Sector Associations; Business Counsels

- Interviews conducted with key trade associations, including the Chinese Renewable Energy Industries Association (CREIA)
- Documents from the American Council on Renewable Energy (ACORE).

Transmission and Distribution Agencies, Manufacturers, Generators

- Annual Reports from various industry leaders operating in China;
- Annual Reports of major electricity generators in China.

Organization of the Report

The remainder of this report is organized as follows:

- **Section 1 provides a market overview for China**. This chapter includes information on China's overall energy status, both current and projected; a market overview; identification of clean energy policies; trade and investment opportunities for U.S. firms; and barriers to clean energy market entry, development, and commercialization. The chapter also includes annexes on Chinese policy-makers with authority over clean energy technologies and information on the renewable energy industry in China.
- **Section 2 provides a definition of clean energy technologies addressed in the report**. This chapter includes energy efficiency, distributed generation, combined heat and power, wind, solar photovoltaics, solar thermal, small hydropower, biomass, biofuels, waste-to-energy, geothermal, and ocean energy technologies.
- **Appendix A provides a compendium of trade and investment resources for U.S. clean technology firms**. Contact information for individual organizations is also included.
- Appendix B provides a directory of sustainable energy-financing sources. This directory is synthesized from the on-line resource available at *www.sef-directory.net/*, which is maintained by the Sustainable Energy Finance Initiative, a joint initiative of the United Nations Environment Program and the Basel Agency for Sustainable Energy.


China
National Capital
Xi'an City
International Boundary
Provincial Boundary
Hunan Province Name
Disputed Boundary
500 km
0 500 Miles
RUSSIA
KAZAKHSTAN
MONGOLIA
KYRGYZSTAN
AFG.
PAK.
INDIA
NEPAL
BHUTAN
BANGLADESH
MYANMAR
LAOS
VIETNAM
THAILAND
CAMBODIA
NORTH KOREA
SOUTH KOREA
PHILIPPINES
Lake Baikal
Lake Balkhash
Yellow Sea
East China Sea
South China Sea
Bay of Bengal
Taiwan
Hong Kong
Beijing
Tianjin
Shanghai
Chongqing
Harbin
Hailar
Qiqihar
Changchun
Shenyang
Dalian
Hohhot
Shijiazhuang
Taiyuan
Jinan
Qingdao
Yantai
Zhengzhou
Nanjing
Hefei
Hangzhou
Wuhan
Nanchang
Changsha
Fuzhou
Xiamen
Guangzhou
Nanning
Haikou
Guiyang
Kunming
Chengdu
Xi'an
Lanzhou
Xining
Yinchuan
Yumen
Golmud
Lhasa
Shiqunhe
Kashgar
Kulja
Karamay
Urumqi
Heilongjiang
Jilin
Liaoning
Nei Mongol
Hebei
Shanxi
Shandong
Jiangsu
Anhui
Henan
Shaanxi
Ningxia
Gansu
Qinghai
Xinjiang
Xizang
Sichuan
Hubei
Zhejiang
Jiangxi
Hunan
Fujian
Guizhou
Yunnan
Guangxi
Guangdong
Hainan

Section 1: China

Chapter 1: China's Energy Status

Since the start of China's open-door and reform policies in 1978, China has experienced consistent economic growth on the order of 9.5 percent per year.[1] During that time, energy demand grew roughly 5 percent per year, but has grown significantly more than that in the last seven years.[2] Historically, China's industrial development was labor-intensive and heavily dependent on manufacturing with relatively low energy intensity, but since 2001, China has seen a surge in energy-intensive heavy industry.

Energy Supply and Demand

At the beginning of the new millennium, both the Chinese Government and the International Energy Agency (IEA) predicted a 3–4 percent growth in energy demand for China between 2000 and 2010. These scenarios were based on expectations of a structural shift away from heavy industry and toward light industry, as well as a projected economic growth rate of 7–8 percent.[3] These forecasts reflected trends in energy consumption from around the year 2000 and were established following the scaling back of the centrally orchestrated conglomerate-building ambitions in China that followed the Asian financial crisis.[4] They also reflected a continuous increase in energy intensity efficiency since 1978.

However, the shift away from heavy industry failed to materialize and the trend toward greater energy efficiency reversed around 2002. As a result, according to China's National Bureau of Statistics, the rate of increase for energy consumption in China currently stands at 9.3 percent.[5] The most recent IEA forecast predicts that China's average increase in energy consumption will be up to 3.2 percent per year from 2005 to 2030 with a 5.1 percent annual growth rate from 2005 to 2015 (see Figure 1.1 below). In comparison, the Chinese Government's new forecast for the average annual growth in energy consumption is 4 percent.[6] These new scenarios are based on the expectation that China's heavy-industry sector will continue to expand and depend on the stability of the national energy policy environment.

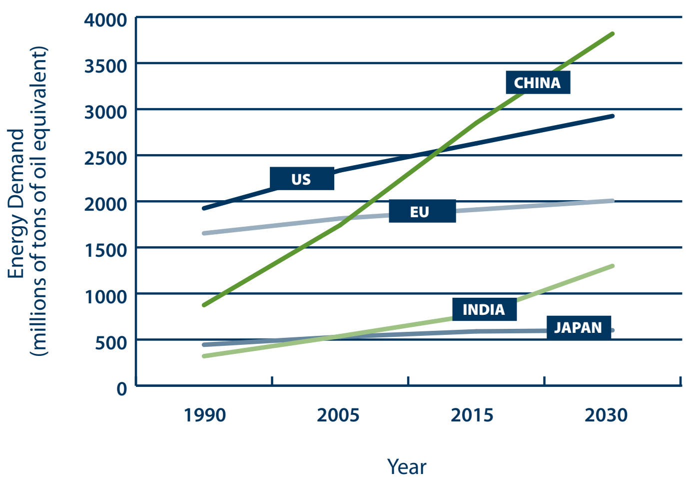
Currently, China is the world's second-largest energy consumer after the United States. According to recent scenarios from the IEA, China will surpass the United States as the largest energy consumer soon after 2010. China's energy demand will rise from 1,742 million tons of oil equivalent (mToe) in 2005 to 2,851 mToe in 2015 and 3,819 mToe in 2030.[7] Such an increase will significantly affect international energy consumption patterns, as shown in Figure 1.2.

Although China's energy resources are substantial, the country's self-sufficiency is decreasing. Since 2004, China's overall energy demand has grown much faster than the domestic output. In 2005, foreign supply accounted for 7.7 percent of the total energy consumption in China, as shown in Figure 1.3.

Coal is China's predominant energy source. In 2005, coal accounted for 69 percent of China's total energy consumption, but domestic coal production is no longer sufficient to meet China's increasing demand. China became a net coal *importer* for the first time in 2007. In 2030, net imports are expected to reach 3 percent of China's coal demand and 7 percent of global coal trade.[8]

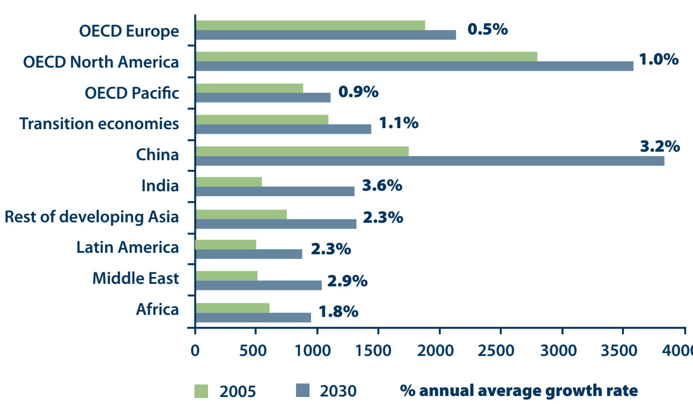
China's oil balance deficit has been increasing rapidly for more than a decade. The country became a net importer of petroleum in 1993. In 2006, China imported 3.7 million barrels of oil per day (mb/d); nearly half its domestic petroleum consumption (see Figure 1.4 below). Such a trend is likely

Figure 1.1: China Energy Consumption in the Future (mToe)



Source: World Energy Outlook 2007, IEA

Figure 1.2: Primary Energy Demand by Region



Source: International Energy Agency, World Energy Outlook 2007: China and India Insights (Paris, France: OCED/IEA, 2007).

to continue in the future as China will become increasingly dependent on oil to power its growing automotive fleet and emerging industrial capacity. The IEA predicts China's oil consumption will reach 13.1 mb/d in 2030, while the share of imports will rise from 50 to 80 percent.

In addition, liquefied natural gas (LNG) imports are also increasing rapidly. China imported LNG for the first time in 2006. The imports amounted to 0.9 billion cubic meters (bcm) and originated mainly in Australia. China's LNG imports are expected to increase sharply to 12 bcm in 2010 to 28 bcm in 2015 and to 128 bcm in 2030.[9]

Current Status of Chinese Clean Energy Technology

Chinese research on the develoment of Clean Energy technologies started in the 1980s, but the dissemination of related technologies to domestic suppliers has remained relatively slow. However, with the rapid increase in energy demand and the recent rise of energy and environmental security issues, the shift away from conventional energy has become an important strategic option for China and an area of potential market penetration from American companies.

Renewable Energy

Government policy recognized the importance of sustainable, renewable energy, and energy efficiency only after the 1991 application of the 8th Five-Year Plan. Renewable energies emerged as a promising alternative to coal and other fossil fuels due to accelerated economic growth and the serious environmental degradation caused by the rapid increase in energy demand.

Figure 1.3: China's Overall Energy Demand and Output

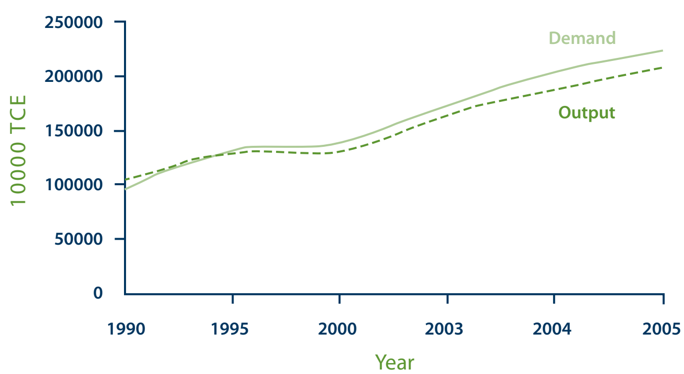
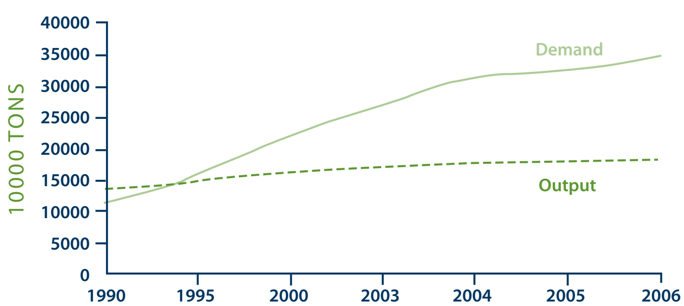


Figure 1.4: China's Petroleum Output and Demand



As a major plank in China's energy strategy, renewable energies now play a significant role in meeting the country's energy demand, structuring the energy industry's development patterns, reducing environmental pollution, and promoting economic development.

In 2005, China's renewable energy consumption rose to 116 mToe and amounted to 7.5 percent of the country's total primary energy consumption.[10] However, while the market for hydropower and solar water heating technologies is mature, the use and development of most other renewable energies have lagged behind thanks to high investment costs, specific primary resource shortages, dependence on foreign technology, and small-scale production.

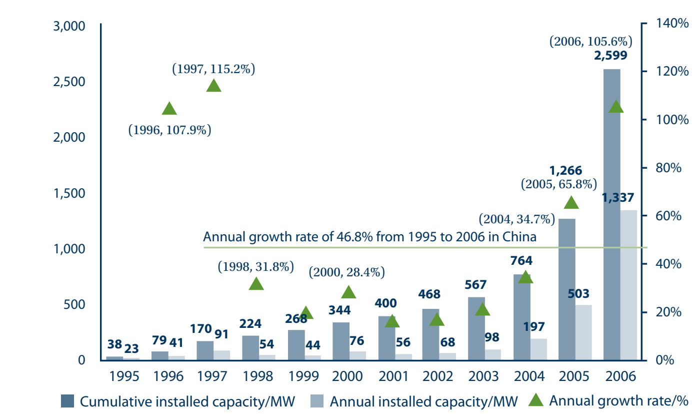
Wind

Several studies indicate China has 750 gigawatts (GW) of potentially utilizable onshore wind resources (250 to 300 GW of which is commercially feasible) and over 1,000 GW of offshore resources. The development of wind energy in China began in the 1980s with rural electrification in coastal region, but since 2005 Renewable Energy Law (REL), the wind energy sector has been rapidly expanding. Under the new policy set forth in the REL, 15 provinces and municipalities have installed 1,226 megawatts (MW) of wind energy capacity, a 65.6 percent increase installed wind power in that year alone.[11] As of 2006, the total wind power generation capacity installed in 16 provinces had reached 2,599 MW, doubling the amount for 2005.[12] Figure 1.5 below shows the historical development of installed wind power capacity in China.[13]

In addition to the adoption of the REL, other factors have contributed to the current boom in wind energy development, including:

- In recent years, Chinese wind generation technology has matured with the help of technology transfer from foreign countries;
- China's wind turbine manufacturers are locally developing technology adapted to Chinese weather conditions,

Figure 1.5: Cumulative Capacity of Wind Power Installed in China, 1995–2006



Source: Li Junfeng and Gao Hu, China Wind Power Report 2007 Z(China Environmental Science Press). www.gwec.net/uploads/media/wind-power-report.pdf with the goal of reducing the purchase price for wind turbines as well as investment costs for wind farms;

- National policy for national and provincial concessions stipulates that 70 percent of wind turbines in developer tenders must be sourced from domestic wind turbine manufacturers;
- Most of the wind developers engage in wind farm development with no profit margin or at a loss, possibly to obtain additional wind development projects from the authorities and avoid being barred from future developments.

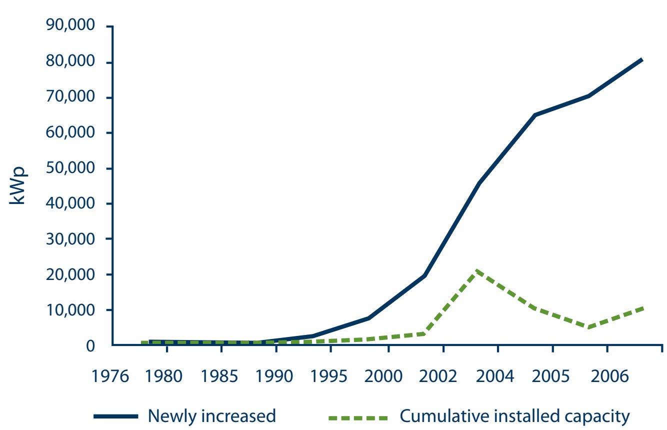
To establish a viable commercial market in wind energy production, experts have suggested additional tax reductions and feed-in tariffs.

Solar PV and Hybrid Systems

The potential for solar power in China is equally promising. Compared with other countries at the same latitude, China has significant solar resources, amounting to 1.7 trillion tons of coal received in the form of solar radiation. In the period 1971–2000, total radiation ranged from 1050–2450 kWh/m^2; areas with over 1050 kWh/m^2 accounted for more than 96 percent of the country, and areas with over 1400 kWh/m^2 accounted for more than 60 percent. The areas with the strongest resources are found in the western and central portions of the country.[14]

By the end of 2006, the cumulative installed capacity of solar cells in China had reached 80 megawatt peaks (MWp) (see Figure 1.6 below). The largest share of this capacity was found in rural electrification (43.1 percent), followed by communication and industrial uses. The market for photovoltaic (PV) power generation in China is mainly composed of communications, industrial applications, rural off-grid supply, grid-connected systems, and small solar products. Among these applications, rural electrification and grid-connected generation require support from the government.

Figure 1.6: Cumulative Installed PV Capacity in China



Source: Li Junfeng *et al., China Solar PV Report 2007* (China Environmental Science Press).

China has developed an important PV panel production capacity. Currently, China is the third-largest PV panel manufacturing country in the world behind Germany and Japan. China's production capacity increased over two distinct periods. First, solar panel production capacity increased from 200 kilowatt peaks (kWp) before 1984 to 4.5 MWp in 1988 as a result of technology transfer from the United States and Canada, which enabled China to start operating seven solar panel production lines.[15]

The second hike in Chinese PV production capacity stems from the expansion of the international demand around 2002. In 2004, PV production in China reached 50 MW, quadrupling the 2003 production. In 2005 and 2006, PV production continued to increase from 130 to 369.5 MWp. The actual production capacity is much higher than the current production level, which is restrained by silicon shortages. By the end of 2006, the total PV production capacity distributed among 39 manufacturers amounted to 1.6 gigawatt peaks (GWp).[16]

Ninety percent of China's PV panel production is exported to foreign countries.[17] The export of solar panels reached $1.2 billion in 2006.[18] Domestic solar PV applications are mainly used in solar/wind or solar/diesel hybrid systems as well as solar home system (SHS) packages for rural electrification and off-grid generation in northwestern China. Good marketing has made SHS especially popular in plateau regions under the name of "sun on horseback." Due to various factors such as high investment costs, undefined feed-in tariffs, and lack of fiscal incentives, a significant on-grid solar PV market has yet to materialize.

Policy support and government subsidy programs have had an important impact on the development of domestic solar PV production capacity. In fact, 46.2 percent of the current production capacity results from such programs.[19] From 1998 to 2001, the Brightness Program, backed by the World Bank and the Global Environment Facility (GEF) through the Renewable Energy Development Program (REDP), promoted the installation of SHS in seven remote rural northwestern provinces of China—Xinjiang, Qinghai, Gansu, Inner Mongolia, Shaanxi, Sichuan, and Tibet. In 2001, the Chinese Government launched *Song Dian Dao Xiang* (the National Township Electrification Program [SDDX]), a continuation of the Brightness Program and an ambitious large-scale rural electrification program targeting the same provinces. SDDX resulted in the development of 721 solar or solar/wind hybrid off-grid power generation systems for a total capacity of 19 MW.[20] The program, which ended in June 2003, has provided 1.3 million people in 1,000 townships with access to electricity. Under SDDX, total capital investment reached $600 million.[21] SDDX will be followed by a further phase, *Song Dian Dao Cun*, or the National Village Electrification Program (SDDC), which was in the final design stages as of near end-2007.

The Chinese Government is promoting domestic PV development from the following aspects:[22]

- Following the Brightness Program and SDDX, SDDC will electrify another 1 million households in 20,000 villages by installing 100 MW of off-grid solar systems in remote rural and pastoral areas of Tibet, Qinghai, Inner Mongolia, Xinjiang, Ningxia, Gansu, and Yunnan, where grid extension is not feasible. The strategic scheme and the programs are being designed by China's government and a related program of the World Bank.
- The government is constructing large-scale on-grid PV power plants and solar thermal power plants in less developed areas in Inner Mongolia, Gansu, and Xinjiang, which will start from Dunhuang in Gansu and Lasha or Ali in Tibet during the period of the 11th Five-Year Plan. In fact, China planned to start up the biggest solar PV power station in the desert in 2003. A pre-feasibility study had been conducted, and the results were reported to the industry in Dunhuang, Gansu, in September 2003.
- The Start-up Roof PV Program involves constructing on-grid rooftop solar PV power generation in economically booming areas, such as Beijing, Shanghai, Jiangsu, Guangdong, and Shandong. At present, there are more than 10 pilot rooftop PV power stations in Shanghai with a total capacity around 2,000 kW and an annual yield of 2 million kWh. The feasibility study on the 100,000 Roof PV Program is being conducted by Shanghai Jiaotong University. The program aims to install 10,000 rooftop PV on-grid systems by the end of 2010 and another 90,000 systems by 2015.[23] This attempt indicates a direction for China's on-grid PV development.

Solar Water Heating

Solar thermal energy for water heating is one of the most advanced renewable energy technologies in China with a mature commercial market. Notably, China has over 1,000 solar water heating manufacturers, and 95 percent of the intellectual property rights (IPR) for solar thermal technologies used in China are domestically owned.[24] In the past 10 years, the growth rate for solar water heating has reached 15 percent per year, as shown in Figure 1.7. is currently China's solar water heating production surface around 90 million m^2, or 60 percent of the world's total.[25] In fact, nearly one in 10 Chinese households owns an SWH. In 2006 alone, China installed 20 million m^2 of solar thermal production. However, the increase in installed solar thermal surface lags behind the equipment production capacity, which has an annual increase rate of 28 percent.[26] In 2006, the domestic production capacity stood at 6 million m^2. The excess production is currently exported to Europe and Southeast Asia.

Manufacturing standards and product quality for SWH systems are increasingly rigorous with newly developed national testing centers and a national certification center for SWH technologies. Although solar thermal use has increased in developing cities, such as Kunming and Qingdao, market expansion is constrained by the following factors: deficient techniques to integrate SWH technology into buildings; lack of installation support by commercial residence developers in major cities such as Shanghai and Guangdong; and low aesthetic quality, which reduces the appeal of SWH systems for some customers.

Bioenergy

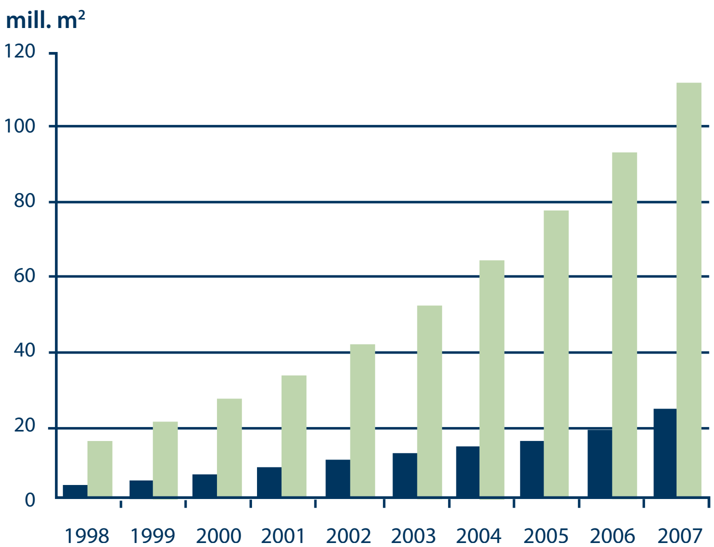
China has a vast bioenergy potential with recent average biomass resource utilization above 500 million tce.[27] Table 1.1 displays the country's bioenergy potential per biomass and provides the key production technologies.

As of 2006, 39 biomass combustion facilities, with a total generation capacity of 1284 MW, have been approved by the National Development and Reform Commission (NDRC) and local provincial Development and Reform Commissions (DRCs). These new projects have a combined investment of about $1.39 billion. In 2006, the planned investments resulted in the installation of 54 MW of power generation capacity with no clear deadline for the installation of the total approved capacity. Table 1.2 displays the key technologies in biomass production in China and their current status of deployment.

Biogas utilization began in rural China during the 1970s and has made considerable progress since then. Biogas is now widely used in small-scale household production (8–10 m^3 tanks). Biogas development is backed by the central government through strong fiscal incentives as well as investment subsidies to rural households amounting to about $763.04 million between 2003 and 2006.[28] Under the government subsidies program, households in northwestern and northeastern China receive $166.5 toward the purchase of a system; households in southwestern China receive $138.7: and households in other areas receive $111.[29] As a result, by end-2006, 17 million household biogas digesters,[30] 140,000 municipal waste treatment facilities, and 4,000 industry sewage biogas facilities providing 1.9 million m^3 of biogas per year[31] had been installed.

Biogas production amounted to 500 MW in 2006, but the potential exists for substantially more. The estimated resource potential, according to a 2002 estimate of feedstock, includes 2.5 billion tons of wastewater from industry and 49 million tons of solid excrement from feed lots. There is an estimated potential of 14.5 billion m^3 per year of industrial-scale biogas, of which 10.6 billion m^3 come from industry, 2.7 billion m^3 come from large feedlots, and 1.2 billion m^3 come from small livestock farms. It is estimated that the above could be used to generate 3.8 GW of base load electricity with 23 TWh of electricity potential or could be used like natural gas for supporting peak load periods. The estimated potential in 2020 is vastly higher, including 41.5 billion m^3 of industrial-scale biogas, comprising 21.5 billion m^3 from industry and 20 billion m^3 from livestock farms. This would amount to an installed capacity potential of 13.8 GW, assuming an efficiency-of-conversion increase. Only 1.2 billion m^3 out of the current 14 billion m^3 industrial-scale biogas potential is currently being used; most of the gas produced is vented, since the industry is focus on waste treatment and not energy production. Therefore, the potential for the industrial biogas industry is huge and, with only about 10 percent being exploited, largely untapped.

Figure 1.7: Total Installed Capacity of SWH in China
Accumulate solar thermal installed areas



Data: Signifficient effect of solar thermal in energy conservation and emission reduction.

Source: Luo Zhentao and Huo Zhenchen, *Outstanding Effect of SWH in Energy Conservation*. (Solar Thermal Utilization Association of China Rural Energy Industry Association, November 2007); Solar Energy, November 2007. www.tynzz.com

Table 1.1: Biomass Potential in China by Source

RESOURCES	ANNUAL POTENTIAL (TCE)	REMARKS
Straw & stalk	150 million	
Waste water	57 million	80 billion m3 biogas
Wood	300 million	
Urban garbage	13 million	120 billion tons

Source: NDRC, Mid- and Long-term Renewable Energy Development Plan, August 2006.

The government aims to increase biogas utilization by improving rural liming conditions and by promoting the livestock and poultry industries, industry waste biogas, and city sewage treatment.

Liquid biofuel technology is also in an early stage of development. China does however have important bioethanol potential based on sugarcane, cassava, corn, and broomcorn cultures. In accordance with the 10th Five-Year Plan, national Program 863 targeted developing technologies for making bioethanol from broomcorn and similar cellulose waste such as corn stalk. Biodiesel development is also included in Program 863 as of the 11th Five-Year Plan, but is still at the research stage. Its commercialization will depend on production cost reductions and increased conversion rates. Several demonstrations of biofuel have begun in Guangxi, Chongqing, and Sichuan, with cassava as the resource; demonstration stations in the Northeast and Shandong are being constructed with broomcorn.

Small Hydro

According to Chinese domestic regulations, small hydropower (SHP) refers to a power generation capacity lower than 50 MW. The total potential for SHP stations in China is estimated at 71.87 GW and is distributed among more than 1,600 mountain counties in middle and western China (see Figure 1.8 below). The potential for SHP is especially important in western China, where 70 percent of the unelectrified rural population is located.

China began utilizing small hydro for rural electrification in the early 1960s. So far, around 800 counties have been electrified with SHP stations connected to local transmission grids. By the end of 2004, however, only 2.1 percent of the total SHP potential had been developed in western China.[32] By the end of 2006, there were more than 40,000 SHP stations installed in rural China with a total power generation capacity of 50 GW and an annual yield of over 150 terrawatt hours (TWh).[33] Figure 1.9 below shows the developed and remaining potentials for SHP power generation per region.

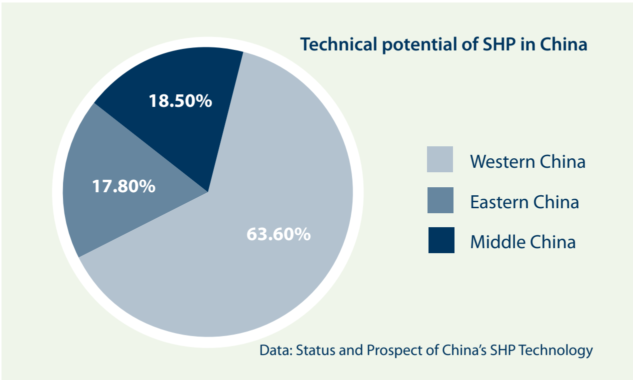
SHP is one of the mature renewable energy technologies in China, with a significant domestic manufacturing capacity and competitive export potential in Asia. This is the result of strong fiscal support from the central government. SHP manufacturers benefit from significantly

Table 1.2: Key Technologies in Biomass Production and Current Status

UTILIZATION	TECHNOLOGIES	STATUS IN 2006	REMARKS
Power generation	Combustion (CHP)	1700 MW	
	Biogas	500 MW	
	Landfill & gasification	30 MW	
Clean fuel	Biogas	9 billion m3	For rural life
Clean biofuel	Biodiesel Bioethanol	Research	Key project in Program 863 from 11th FYP

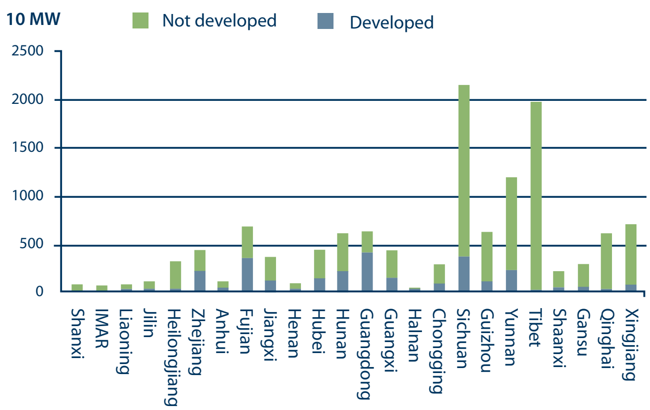
Source: NDRC, Mid- and Long-term Renewable Energy Development Plan, August 2006.

Figure 1.8: Total Potential for SHP in China



Source: "Current Status and Prospect of China's SHP," presentation of International Workshop on China Renewable Energy Strategy Development, August 16, 2006. http://newenergy.com.cn/html/2006-8/2006816_11456_1.html

Figure 1.9: Development Potential for SHP in China



Source: "Current Status and Prospect of China's SHP," presentation of International Workshop on China Renewable Energy Strategy Development, August 16, 2006. http://newenergy.com.cn/html/2006-8/2006816_11456_1.html

lower value-added taxes–currently at 6 percent, compared to 17 percent for other sectors. By 2004, there were over 100 SHP manufacturers in China, with an annual production capacity of around 6.3 GW.

Development of hydropower is focused on the areas of the Jinshajiang River, the Yanpanjiang River, the Daduhe River, upstream of the Huanghe River, and the Nujiang River basin. To accelerate the development of SHP, the Chinese Government is combining rural electrification with the SHP Generation Fuel Program, as well as exporting electricity from Tibet.

Energy Efficiency

In general, production and operation energy efficiency is low in China. Recently, energy efficiency (EE) has decreased due to the growing industry sector, which has the lowest energy efficiency level. Seventy-five percent of the total energy consumption increase comes from the industrial sector.[34] In the past six years, energy efficiency has further decreased as a result of the shift away from light industry toward heavy industry, which has a comparatively lower end-product value for higher energy consumption. Figure 1.10 shows China's energy consumption by sector over the past six years.

Table 1.3 compares China's energy efficiency to the international average for major industrial products.

The level of energy efficiency for all industrial products is included in Table 1.3 and is much lower than the overall international average. This is especially obvious for crude oil refining, as well as ethane and paper and cardboard production. Operation efficiency for end-use equipment in China is generally 20 percent lower than the international average for advanced countries, as shown in Table 1.4 below.

The discrepancy in EE between China and the international average is mainly due to obsolete production equipment installed several decades ago, which has received little or no maintenance and has been poorly managed for the last 20 year

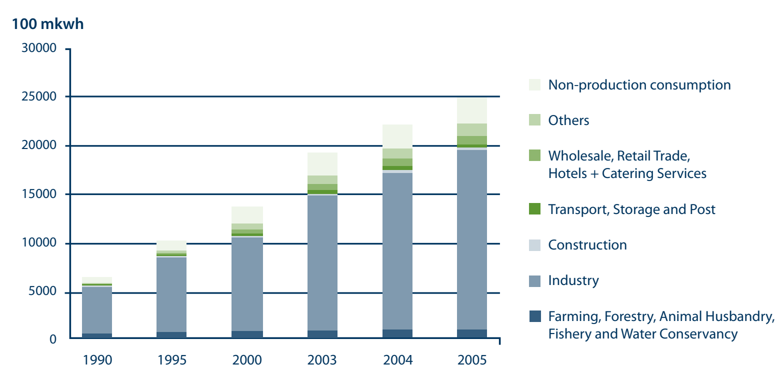
To improve energy performance, the Chinese Government set an ambitious target to decrease energy intensity by 20 percent in the 11th Five-Year Plan period, which spans from 2006 to 2010. Ten key programs in eight intensive industries are planned by the NDRC and provincial governments to achieve the target (details are provided in the EE market forecast section), including the annual publication of each province's energy intensity.

Co-Generation

In China, the use of combined heat and power (CHP) generation for heat supply began in the 1950s. At its maximum development in the 1980s and 1990s, CHP generation made an important contribution to national energy savings. Despite a relative decline, CHP remains a major heat supply source in China.

Political constraints often hamper the development of CHP generation. Heat generation from CHP falls within provincial or local jurisdiction, whereas electricity generation is subject to central government feed-in policies. Because of its clean power generation process and high efficiency, CHP receives support from local and provincial

Figure 1.10: China's Energy Consumption by Sector from 1990 to 2005



Data: NBSC, Statistic Yearbook 2006

authorities. However, because of its low electricity yield, CHP has not received central government support through feed-in tariffs. In addition, up until 2005, CHP was categorized as small-scale thermal power generation with no grid connection possibility.

As a result of the mixed political signals from local/provincial and central governmental levels, as well as sustained growth of coal utilization and inconsistent electricity tariff increases, CHP has faced extra difficulties. Since 2002, 90 percent of China's domestic CHP operators have faced losses.[35] The situation is similar for foreign operators as French and American investors have retreated from China's CHP market since 2004. According to recent data from NDRC, CHP installations make up almost 50 percent of the power plants closed since the beginning of 2007.[36] Figure 1.11 displays the status of CHP generation in China as of 1998.

Clean Transportation Technology

Before 1993, China's national energy output in liquid fuel was higher than domestic consumption. Incentives for the development of clean fuel transportation technology were small, and research was not significant. Research on clean fuel transportation technology really began in the second half of the 1990s, with governmental support to universities but without private-sector involvement. The turning point occurred in 1999, when China's Ministry of Science and Technology (MOST) launched the Clean Vehicles Action Program, a demonstration and development program for large-scale clean transport technology that is currently in operation. Figure 1.12 below displays the program's operational organization chart.

Table 1.3: Comparison of Energy Efficiencies for Major Products between Chinese Domestic and International Averages

PRODUCT TYPE	ENERGY EFFICIENCY					
	CHINA			INTERNATIONAL AVERAGE *	DISCREPANCY IN 2004	
	1990	2000	2004		ABSOLUTE	%
Power plant electric supply coal consumption (gce/kwh)	392	363	349	299.4	49.6	16.57
Thermal power generation coal consumption (gce/kwh)	427	392	376	312	64	20.51
Alternating current consumption for electrolytic aluminum (kwh/t)	16233	15480	15080	14100	980	7.00
Steel (large plants) (kgce/ton)	997	784	705	610	95	15.57
Cement (kgce/ton)	201.1	181	157	127.3	29.7	23.33
Crude oil refining (kgce/ton)	102.5	118.4	112	73	39	53.42
Ethene (kgce/ton)	1580	1125	1004	629	375	59.62
Synthetic ammonia (large-scale production) (kgce/ton)	1343	1327	1314	970	344	35.46
Paper and cardboard (kgce/ton)	1550	1540	1500	640	860	134.38

Source: Qinyi Wang, International Petroleum Economics, 2006, No.2.
* Data are for the advanced counties in 2003.

Table 1.4: Discrepancy in Operational Efficiency of End-Use Equipment between China and the International Average

END-USE EQUIPMENT	OPERATIONAL EFFICIENCY %	DISCREPANCY WITH INTERNATIONAL AVERAGE, %
Boilers in industry	65	15–20
Middle and small-size motors	87 (design)	20 (operation)
Fans and pumps	75 (design)	20 (operation)
Vehicles	9.5 L/100 km	25 (European)
Trucks	7.6 L/100 ton km	100
Fluvial navigation	—	10–20

Source: Yu Cong, China's Successful Case of Energy Efficiency in Industry (Energy Research Institute, NDRC, April 3, 2007).

Gas-Powered Vehicles

Gas-powered vehicles (GPVs) have come into operation since related technologies (e.g., gas storage systems) have matured – the GPVs presently on the market are third-generation products. GPV technologies have now been introduced in 17 large cities and two provinces (Sichuan and Hainan—see Figure 1.13), and total a 265,000 unit vehicle fleet. GPV technology is expected to go into large-scale production in the near future.

Fleet growth is faster for CNG vehicles than LPG vehicles. Recently, the CNG fleet grew at an average of 30,000 cars per year, from 22,300 in 2001 to 174,170 in 2006; reaching 66 percent of the GPV fleet (see Figure 1.14).

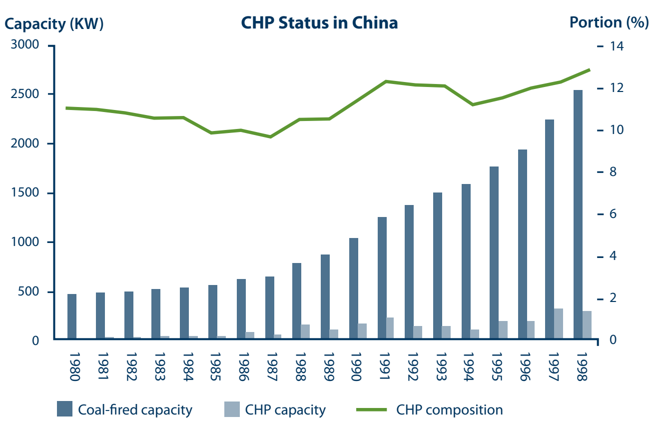
China began its alcohol fuel vehicles (AFVs) development about 30 years ago. Initially, ethanol fuel vehicle pilots were formally launched in five cities (Nanyang, Zhengzhou, and Lyoyang Nanyang in the province of Henan; Ha'erbin and Zhaodong in the province of Heilongjiang) to be later extended to five provinces (Jilin, Liaoning, Heilongjiang, Henan, and Anhui) and parts of other provinces (Jiangsu, Hebei, Shandong, and Hubei—see Figure 1.15). Recently, the planned production level for ethanol fuel was set at about 1 million tons per year. Methanol gasoline fuel was primarily applied in Shanxi Province. Research on di-methyl ether (DME) fuel produced through clean coal technology is only beginning.

Electric Vehicles

Government support for electric vehicle (EV) research and development started early in the 1990s. The many research projects conducted since that time have not gone past the experimental stage with manufacturing trials, as EV technology applications are still limited by low power capacity and autonomy as well as high production costs.

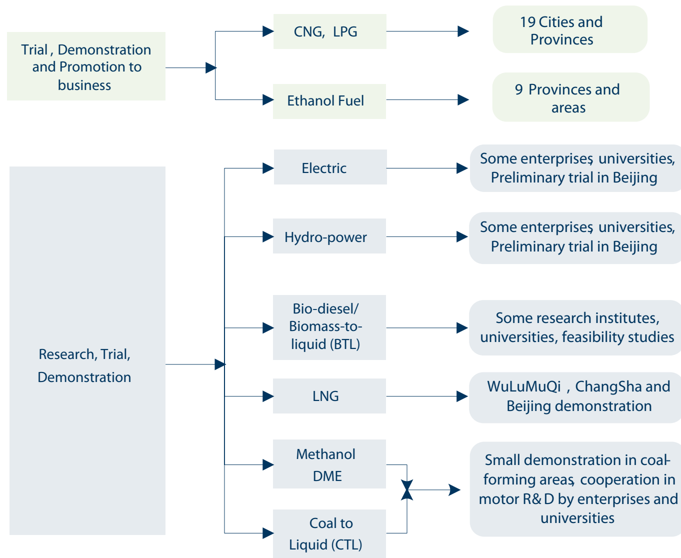
Nonetheless, market growth for electric bicycles has been impressive. There were over 1,200 electric bicycle manufacturers and 3,000 parts suppliers in 2005, for a total production of about 10 million units. This dramatic growth is largely due to legislation banning gasoline-fueled scooters in several major Chinese cities, including Beijing and Shanghai.

Figure 1.11: Status of CHP in China



Data: Wang Zhenming, Potential Analysis on CHP China

Figure 1.12. Organizational Chart for Clean Vehicles Action Program



Source: China Automotive Technology and Research Center, CATRC

Fuel Cell Electric Vehicles

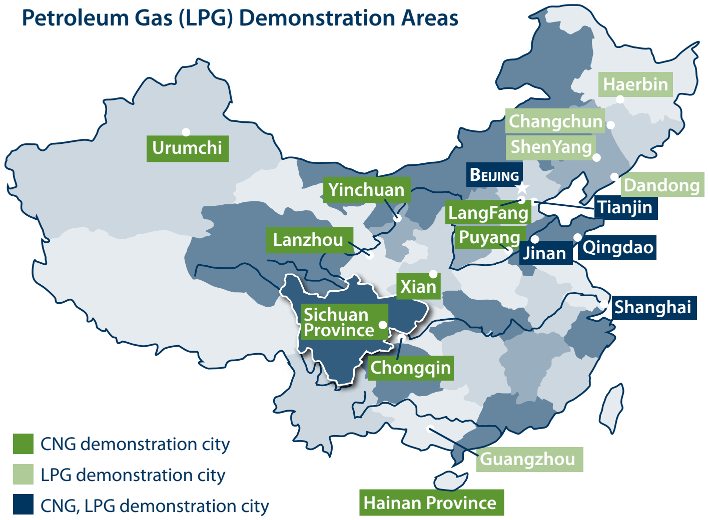
Many of China's research institutions have invested in proton exchange membrane fuel cell (PEMFC) research and development since the 1990s, with the main research projects conducted in:

- Dalian Institute of Chemical Physics;
- Beijing FuYuan Pioneer New Energy Material Co., Ltd.;
- Shanghai Sun Li High Technology Co., Ltd;
- Beijing Lu Neng Power Sources Co., Ltd.

From 2001 to 2005, MOST approved a RMB 880 million ($122 million) research and development program to develop advanced hybrid electric fuel cell vehicles. Private sector investment is expected to bring in another $200–300 million from 2005 to 2010.

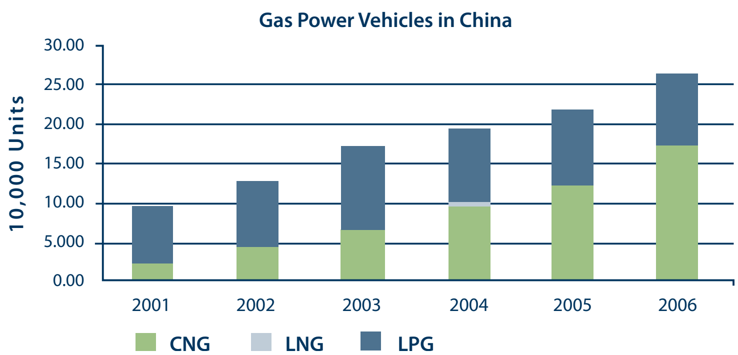
In March 2003, the Chinese Government launched a demonstration program in Beijing for fuel cell bus commercialization. This program is backed by the United Nations Development Program (UNDP) and the Global Environment Facility (GEF) as part of a demonstration project for 46 Daimler Chrysler–manufactured Citaro buses involving five countries and six cities over 2003–2008. The MOST and the municipal authorities signed the supply contract for three fuel cell buses with Daimler Chrysler in May 2004.

Figure 1.13. Compressed Natural Gas (CNG) and Liquefied Petroleum Gas (LPG) Demonstration Areas



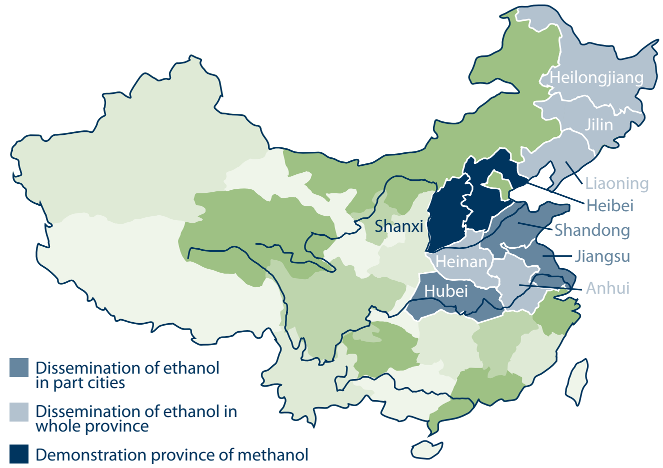
Source: database of China Automotive Technology and Research Center, CATRC

Figure 1.14. Breakdown of GPVs in China



Source: database of China Automotive Technology and Research Center, CATRC

Figure 1.15. Distribution of AFV Development



Source: database of China Automotive Technology and Research Center, CATRC

Chapter 2: Market Analysis

China's clean energy technology market is booming, with significant domestic production capacity. There are currently over 80 wind turbine manufacturers and 200 wind developers in China; domestic companies occupy over 75 percent of the domestic market. China's solar industry is growing rapidly, with a current capacity of 2,500 tons per year in solar ingot production. Significantly, there are over 3,500 solar water heating (SWH) system manufacturers in China, representative of the fact that China has the largest SWH market in the world. Finally, China's energy efficiency market is booming as a result of the goals set forth in the 11th Five-Year Plan. The major Chinese market players in wind, solar PV, SWH, hydropower, and energy efficiency are given in Annex 1.

Renewable Energy

Presently, total renewable energy utilization reaches only 7.5 percent of China's energy consumption. However, the potential renewable energy market is vast. As a component of China's energy strategy, the development of renewable energy receives support from the central government through a Mid- and Long-term Renewable Energy Development Plan, which has been released to implement the REL.

The Mid- and Long-term Renewable Energy Development Plan draws an ambitious blueprint for China's renewable energy development. The plan emphasizes renewable energy development for hydropower, biogas, solar thermal, and geothermal technologies as mature technologies with high potential for economic benefits. Wind, biomass, and solar PV power generation are also earmarked for accelerated development. According to the plan, renewable energy utilization should reach 300 million tce by 2010 and 600 million tce by 2020, as shown in Tables 1.5 and 1.6 below. The mid- and long-term projections from the plan indicate that the clean technology market will increase to $185.9 million in 2010 and approximately to $554.94 million in 2020 (see Table 1.7 below).

Market development for some of the renewable energy technologies has surpassed the targets established by the Mid- and Long-term Renewable Energy Development Plan. China's wind power generation capacity has experienced a steady increase since 2000. Between 2002 and 2007, the average annual growth rate was 97 percent. As a result, the total installed capacity for wind power generation reached 5 GW in 2007, three years ahead of the goal set forth in the plan.[37]

The solar water heating market is also rapidly expanding. Based on the recent annual surface installation increase of 15 percent, the objective for 2010 of 150 million

Table 1.5: Goals for RE Utilization in RE Development Plan

TIMELINE	UTILIZATION	PROPORTION OF ENERGY CONSUMPTION
2010	300 million tce	10%
2020	600 million tce	15%

Data: NDRC, Mid- and Long-term Renewable Energy Development Plan, August 2006.

Table 1.6: Objectives for Key RE technologies.

RE	UTILIZATION	OBJECTIVES BY	OBJECTIVES BY 2020
Hydropower	Large scale	140 GW	225 GW
	Small scale	50 GW	75 GW
Bioenergy	Generation	5.5 GW	30 GW
	Solid biofuel	10 bil. tons	50 bil. tons
	Biogas	19 bil. m^3	44 bil. m^3
	Bioethanol	2 mil. tons	10 mil. tons
	Biodiesel	0.2 mil. tons	2 mil. tons
Wind	Generation	5 GW	30 GW
Solar *	On-grid solar PV	150 MW	1.5 GW
	Off-grid solar PV	150 MW	0.3 GW
	Solar thermal	150 mil. m2	300 mil. m2
Geothermal		4 mil. tce	12 mil. tce

Data: NDRC, Mid- and Long-term Renewable Energy Development Plan, August 2006.
* Total solar PV installation includes both on-grid and off-grid generation capacity.

Table 1.7: Government Objectives for Renewable Energy Market Potential

RESOURCES	MARKET POTENTIAL UNTIL 2010*	MARKET POTENTIAL UNTIL 2020*	ESTIMATED INVESTMENT COSTS
Hydropower	$76.3 billion	$180.36 billion	$971.14/kW
Biomass generation	$3.47 billion	$27.75 billion	$971.14/kW
Wind	$1.09 billion	$23.86 billion	$901.78/kW
Biogas	$11.38 billion	$26.36 billion	$416.2/hh
Solar	$240 million	$18.04 billion	$10,405/kW
Others	$92.95 million	$277.47 million	

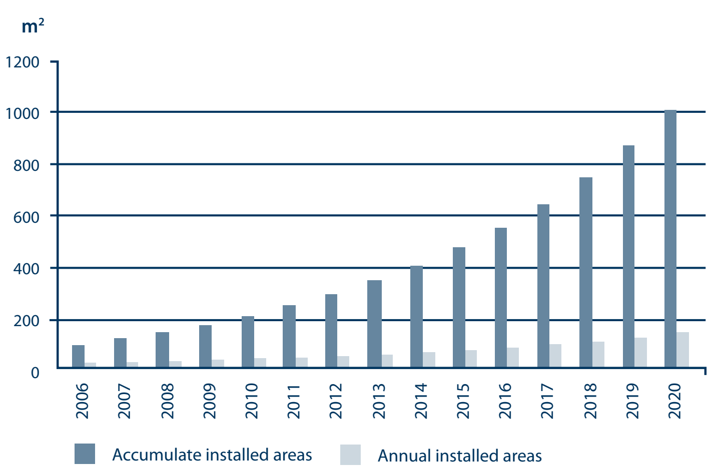
Data are from Mid- and Long-term Renewable Energy Development Plan.
* Data for 2020 are from NDRC, Mid- and Long-term Renewable Energy Development Plan, August 2006. Data for 2010 are calculated on the basis of estimated investment cost and estimated generation capacity from 2006 to 2010.

m² production surface (as established in the Mid- and Long-term Renewable Energy Development Plan) should be attained easily, as shown in Figure 1.16 below.

The domestic market for solar PV generation is relatively undeveloped compared to the markets for wind and solar water heating. China's government however is making efforts to promote a domestic solar PV generation market including the following programs:

- Government subsidy programs: Although the Brightness Program and SDDX have significantly improved rural electrification through solar PV generation, 3 million households in target areas remain without electricity. It is expected that 1.5 million households will be electrified through grid extensions as well as small and mini-hydro installations, but the remaining 1.5 million households will need to be electrified through solar PV and solar/wind hybrid systems.38 The Village Electrification Program (SDDC) was to originally electrify 1 million households in 20,000 villages by installing off-grid solar systems with a 100-MW total generation capacity in remote rural areas of Tibet, Qinghai, Inner Mongolia, Xinjiang, Ningxia, Gansu, and Yunnan;39 however, the final plan and design for this program has yet to be confirmed.
- Construction of PV power stations: Plans have been made for the construction of large-scale on-grid PV power plants and solar thermal power plants in desert areas of Inner Mongolia, Gansu, and Xinjiang Provinces. The first plants will be constructed before the end of the 11th Five-Year Plan period in Dunhuang in the province of Gansu and in Lasha in the province of Tibet. The construction of the world's biggest solar PV power station has been actively planned since 2003.
- Start-up Roof PV Program and 100,000 Roof PV Program: the Start-up Roof PV Program promotes the construction of on-grid roof solar PV power generation in areas with dynamic economies such as Beijing, Shanghai, Jiangsu, Guangdong and Shandong. At present, there are more than 10 pilot roof PV power stations in Shanghai with a total generation capacity of 2,000 kW and an annual yield of 2 million kWh. Feasibility studies for the 100,000 Roof PV Program are currently being conducted by Shanghai Jiaotong University. The objective of this program is to install 10,000 rooftop PV on-grid systems by the end of 2010 and another 90,000 systems by 2015.[40] According to industry experts, one of the bottlenecks for large-scale on-grid application of solar PV generation is related difficulties in establishing the appropriate feed-in tariffs to stimulate the market. The Shanghai Roof PV Program provides the opportunity to fine-tune feed-in tariff policies for solar PV on-grid generation.

Figure 1.16: Solar Water Heating Forecast Through 2020 Based on an Estimated Annual Growth Rate of 15 percent



Data: Based on scheme on promoting solar thermal in China, International Energy Net

According to Tsing Capital in Beijing,[41] when combined with the environmental protection field, the market value of the clean tech industry totals over $200 billion. In the renewable energy sector, $2.8 billion has been invested in wind, $8.1 billion in solar thermal energy, $1.7 billion in solar PV, $3.1 billion in ethanol, and $1.3 billion in biodiesel. An additional $172 billion has been spent on environmental protection. Tsing Capital predicts energy generation will become the most popular segment of clean tech venture capital in the 2007–2008 period, followed by water and energy efficiency.

Energy Efficiency

In October 2005, Premier Wen Jiabao announced that China's energy intensity over the national GDP must decline by 20 percent between 2005 and 2010. The key policy initiatives toward reaching this goal were an emphasis on domestic technological innovations with planned leaps in key areas, close monitoring of current global technological developments, and leadership initiatives in emerging strategic sectors.

The new energy efficiency targets were included in the 11th Five-Year Plan. Planned reductions in energy intensity for the industrial sector account for 80 percent of total reduction targets. Reductions in industrial energy intensity will depend on the GDP growth level, with the planned reduction in energy intensity at 24 percent for a 7.5 percent GDP annual growth and a 26 percent reduction for a 9 percent GDP annual growth. The energy efficiency reduction targets are ambitious, and the challenge is to define appropriate measures and policies to reach the objectives. At present, China's central government has taken or will take the following operational measures:

- Put forward a series of structural adjustment policies in various industrial sectors and sub-sectors;
- Lower or cancel tax rebates on high-energy-intensity production exports;
- Implement the Top-1,000 Enterprises Energy Efficiency Program, which plans for the 1,000 highest energy-consuming enterprises in China to reduce their energy consumption by 100 million tce from 2005 to 2010;

- Promote the application of mature high-energy-efficiency technologies;
- Eliminate inefficient processes and appliances.

According to the energy efficiency targets, the environmental impact of key energy-consuming sectors and unit energy consumption indicators for China's main products should reach the international average in the first quarter of this century. According to the plan, the energy efficiency of mass-market products with high-energy consumption should reach the mid-1990s' international average for developed countries. Targets are more ambitious for some products such as automobiles and specific electric appliances for household use, whose energy efficiency should now be almost on par with the current international average for advanced countries.

Table 1.10 shows the 10 energy consumption programs put forward by the NDRC to reach the energy efficiency targets. These programs have been identified by the central government as the most effective means by which to reduce energy consumption as technology becomes mature within these areas.

The 20 percent energy savings targets established for the next five years seem difficult to achieve, but there is substantial potential to conserve energy throughout China's well developed supply chain, including energy extraction, conversion, transport, storage, distribution, and end use. On the other hand, it is an ambitious target that will require much capital, suitable market mechanisms, subsidies, and the cooperation of energy-intensive industries to curb demand. Currently the national energy reduction rate stands at only 1.23 percent, and only Beijing met the projected energy consumption reduction in 2006 out of all 34 provinces and municipalities.

Since then, China's central government has placed greater attention on energy saving and places it as an equal priority with economic development when assessing the leadership of the governors of provinces and municipalities. Since 2006 more and more measures have been successively issued by NDRC to guarantee the planned savings target, and more capital was invested in the energy efficiency field in 2007. At the end of 2007, China had achieved a 3 percent

Table 1.8: Unit Energy Consumption Indicator for Main Products

PRODUCTS	UNIT	2000	2005	2010 (PLANNED)
Coal consumption for thermal power supply	tce/kwh	3.92×10-4	3.70×*10-4	3.55×*10-4
Energy consumption per ton of steel	tce/t	0.906	0.760	0.730
Comparable energy consumption per ton of steel	tce/t	0.784	0.700	0.685
Specific energy consumption of 10 kinds of nonferrous metal	tce/t	4.809	4.665	4.595
Specific energy consumption for aluminum	tce/t	9.923	9.595	9.471
Specific energy consumption for copper	tce/t	4.707	4.388	4.256
Oil refining unit energy factor	tce/t.factor	0.014	0.013	0.012
Specific energy consumption of ethylene plant	tce/t	1.296	1.070	0.993
Specific energy consumption by synthetic ammonia	tce/t	1.372	1.210	1.140
Specific energy consumption by soda	tce/t	1.553	1.503	1.400
Specific energy consumption by cement	tce/t	0.181	0.159	0.148
Specific energy consumption by construction ceramics	tce/m2	0.01004	0.0099	0.0092
Specific energy consumption by railway transportation	tce/mt km	0.01041	0.00965	0.0094

Data from NDRC, 11th Five-Year Energy Plan.

Table 1.9: Energy Efficiency Indicators for Main Energy Consumption Equipment

PRODUCTS	UNIT	2000	2010 (PLANNED)
Coal-fired industrial boilers (operational)	%	65	70–80
Small and medium-size generators (design)	%	87	90-–92
Wind turbines (design)	%	70–80	80-–85
Pumps (design)	%	75–80	83-–87
Air compressors (design)	%	75	80-–84
Room air conditioners (energy efficiency rate)		2.4	3.2-–4
Refrigerator energy efficiency indicator (EEI)	%	80	62-–50
Cookstove for household use (heat efficiency)	%	55	60-–65
Gas water heater for household use (heat efficiency)	%	80	90-–95
Economic status of average automobile (fuel burning)	L/100 km	9.5	8.2-–6.7

Data from NDRC, 11th Five-Year Energy Plan.

Table 1.10: The 10 Key EE Programs Put Forward by NDRC

PROJECTS	FOCUS
Coal-fired industrial boiler alteration	Low-efficiency industrial boilers: alteration or replacement
Regional CHP projects	Heating CHP, industrial CHP, distributed CHP, CHCP, integrated utilization thermal power plants
Surplus heat and pressure utilization projects	Equipment alterations for surplus heat, pressure, and energy utilization in building materials as well as in steel and chemical sectors
Petroleum conservation and alteration projects	Electricity, petroleum, petrochemical, building material, chemical, and transportation; promoting biodiesel and bioethanol
Energy conservation (EC) on motor systems	Alteration of low-efficiency motors, EC alteration on drag equipment of motor systems, timing alteration on large and mid-sized variable motor systems
Energy system optimization	Systematic EC alteration in oil refining, ethylene, synthesis ammonia, and steel factories
EC in buildings	Improving the EE of buildings by 50%, EC restructuring for the existing buildings, integrating RE in buildings construction, promoting EC in wall materials, and industrializing the EC building material
Green lighting	Improving product quality, reducing costs, promoting innovations on EC lamp
EC for govt. organizations	EC restructuring of existing buildings, EE alterations on electrification, supervision for new building
EC monitoring and technology service systems	Alteration of EC monitoring equipment; energy audits for energy-intensive enterprises

Data from NDRC, 11th Five-Year Energy Plan.

reduction in energy consumption. 2008 will most likely be an important year for the energy-saving target, since the benefits of many big energy efficiency projects will begin to be seen. It is also the middle of the 11th Five-Year Plan.

Co-Generation

With the development of the 10 key energy conservation programs put forward by the NDRC (under the 11th Five-Year Plan as shown in Table 1.10 above), co-generation has been identified as an important energy conservation technology for reducing coal consumption. One expert estimates that CHP can save 48 million tce per year in China.[42]

According to China's CHP development plan, the installed CHP generation capacity should reach 120 GW by 2010, 15 percent of the total electricity generation capacity, and 200 GW in 2020, 22 percent of the total electricity generation capacity. To achieve these objectives, the average capacity installed annually must be around 9 GW through 2020.[43]

Based on the currently installed production capacity and the current 6.5 percent average annual growth for CHP generation in China, the total CHP generation capacity will reach 47 GW in 2010 and 87.5 GW in 2020, corresponding, respectively, to 37 percent and 68.5 percent of the total CHP potential.

Clean Transportation Technology

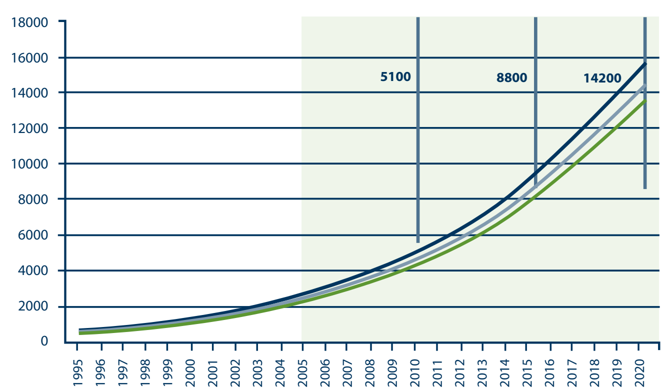
In 2006, China's vehicle fleet totaled roughly 40 million units — it is expected to reach 140 million in 2020 (see Figure 1.17). This increase is caused by a reduction in car prices, due to lower tariffs since China joined the World Trade Organization (WTO). Car price reductions are expected to continue as China develops a significant domestic production capacity, with the government identifying the car industry as a "pillar industry." Another important driver for the expansion of the domestic vehicle fleet will be the increase in consumer purchasing power.

The rapid expansion of the vehicle fleet will undoubtedly increase demand for oil. Based on reference scenarios, oil consumption for transportation is expected to exceed 50 percent of the total domestic oil demand by 2020. The Chinese Government has set targets to limit the oil demand to 125 million tons in 2020, with plans to reduce the oil demand by 20 percent through use of clean transportation technology, as shown in Figure 1.18.

Market Drivers

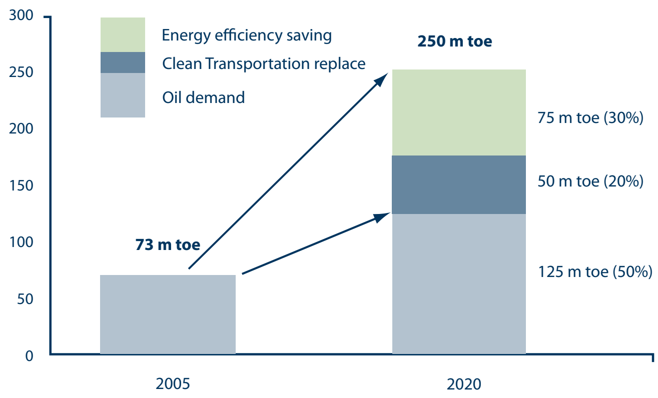
According to the most recent "BP-Statistical Review of World Energy," China is now the world's second largest energy consumer behind only the United States. Their energy consumption accounts for an astounding 15.6 percent of world's entire energy total. Since 2001, China's elasticity ratio for energy consumption averaged around 1, meaning any rise in GDP depends on a rise in energy consumption. As a result, China's 2006 GDP increase of 10.7 percent caused energy consumption to rise by 8.4 percent,

Figure 1.17: Projections for the Number of Vehicles in China (in tens of thousands)



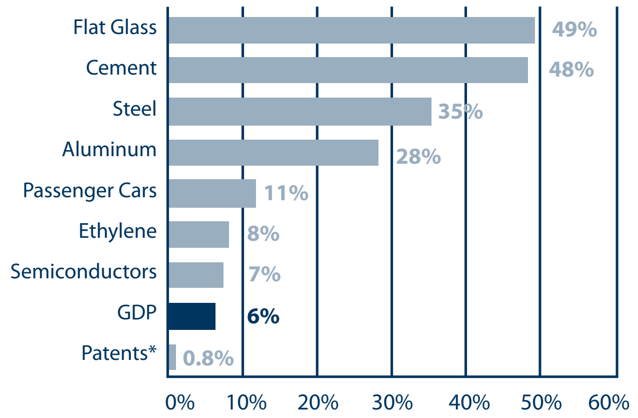
Source: China Automotive Technology and Research Center (CATARC).

Figure 1.18: Vehicle Fuel in 2020



Data from CATARC, 2006.

Figure 1.19: China's Share of Global Production (2006)



Source: Daniel H. Rosen and Trevor Houser, China Energy: A Guide for the Perplexed (Peterson Institute for International Economics, May 2007).

while the global increase was only 2.4 percent.[44] This is in large part due to the increasing demand China's energy consumption due to urbanization and economic growth.

Figure 1.19 demonstrates, steel, aluminum, cement, and chemicals manufacturers have been the beneficiaries of the growing demand for heavy industries and energy intensive products.[45]

The industrial production capacity however far exceeds domestic demand as the Chinese Government has turned to exports to sustain economic growth and maintain profit margins. This "workshop of the world" mentality has led industrial energy demand to grow to 70 percent of total domestic energy consumption.

These drivers will continue to impact China's energy demand going forward. The huge urban market demand and booming investment in energy-intensive heavy industries together ensure a sustained energy consumption increase over the long term, as shown in Table 1.11.

Table 1.11: Trends in Industrial Energy Demand (mToe)

	1990	2005	2015	2030	2005–2015*	2005–2030*
Total energy	242	478	833	1046	5.7%	3.2%
Iron and steel	42	132	260	273	7.0%	2.9%
Non-metallic minerals	56	109	157	142	3.7%	1.1%
Chemicals and petrochemicals	38	74	119	127	4.9%	2.2%
Other	106	163	298	504	6.2%	4.6%
CO_2 emissions (Mt)	800	1430	2186	2373	4.3%	2.0%

Source: IEA, World Energy Outlook 2007.

Shortage of Liquid Fuel and High Dependency on Imports

In 2006, China consumed 350 million tons of crude oil, up 6.7 percent from 2005, while its oil output rose 1.6 percent to 183.7 million tons. Oil imports for 2006 reached 169 million tons, indicating a dependence on imports of 47 percent.[46]

According to the IEA, the share of oil imports will account for 70 percent of the total oil consumption in China by 2020, with the trend continuing until 2030. In 2020, China's crude oil production will reach its peak at approximately 200 million tons. As Figure 1.20 shows, after 2020, production will decrease, and the gap between the domestic oil demand and production will expand rapidly.

Environmental Concerns

Coal dominates China's energy supply, creating severe pollution. Sulphur dioxide (SO_2) discharge exceeded 25 million tons in 2005. In 2007, SO_2 and dust discharge exceeded 80 percent of the gross discharge total resulting mainly from energy consumption and domestic energy production.[47] According to the World Bank, SO_2 and nitrogen oxide (NO_x) emissions could reach 40 mt and 35 mt, respectively, in 2020 if no additional control measures are taken. Figures 1.21 and 1.22 display the areas affected by SO_2 discharge in China and the expected coal consumption to 2020, respectively.

The World Bank estimates the total cost of air and water pollution in China in 2003 was $50.22 billion, or about 2.68 percent of the GDP. According to conservative estimates, the economic burden of premature mortality and morbidity associated with air pollution was $21.82 billion in 2003, or 1.16 percent of the national GDP. Another evaluation of the health losses due to ambient air pollution using willingness-to-pay measures estimates the cost at 3.8 percent of the GDP.[48]

Acid rain areas occupy over one-third of the country's soil surface. Acid rain is estimated to cost $4.16 billion in crop damage and $971.14 million in material damage annually.[49] More than 90 percent of the coal-burning plants are not equipped with desulphurization units. Coal exploitation has caused land collapse of over 988,421 acres. Annual sewage discharge from coal exploitation amounts to 3 billion m^3. Mine exhaust emissions amount to 9–12 billion m^3.[50]

Water pollution is also a cause for serious concern. Between 2001 and 2005, 54 percent of surface water resources were deemed unsafe for human consumption.[51] Estimates suggest the cost of groundwater depletion is around $6.94 billion per year. Cost estimates for polluted water usage by industry are comparable in magnitude, bringing the overall cost of water scarcity associated with water pollution to $20.4 billion, or about 1 percent of GDP.

Important Greenhouse Gas (GHG) Emissions

According to the IEA, China overtook the United States as the world's largest carbon dioxide (CO_2) emitter in 2007 (Figure 1.23), though its per capita emissions will reach only 60 percent of those of the OECD countries in 2030. Since the Kyoto Protocol came into force in 2005, China has become one of the largest Clean Development Mechanism (CDM) markets in the world. Currently, 2,701 CDM projects are in the pipeline.

The Clean Development Mechanism (CDM) is one of China's most important avenues for clean energy and advanced technology transfer. It provides not only additional venture capital, but also incentivizes other nations to invest in Chinese power generation and increase Chinese efficiency. In October 2005, the National Coordination Committee on Climate Change (NCCCC) released their "Measures for Operation and Management of Clean Development Mechanism Projects in China" program, which highlights the special rules for regulation of CDM developments in China, as follows:

a. Priority areas for CDM development in China are:

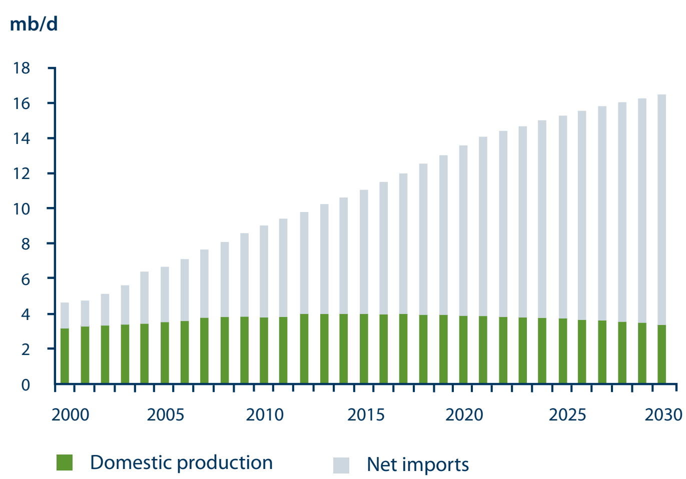
- Energy efficiency improvement projects;
- Development and utilization of new and renewable energy;
- Methane recovery and utilization.

b. If no foreign buyer has been determined when a project is submitted to NDRC for approval, which implies that the price of credits for emission reductions (CERs) is not fixed, the Project Design Documentation (PDD) must indicate the emissions reductions for the project will be transferred into China's national account in the CDM registry and can be transferred back out only with the authorization of China's National Designated Authority.

c. Only Chinese-funded projects or Chinese-holding enterprises are qualified to become the owner of CDM projects. To ensure the technology transfers to China, the joint ventures seeking approval from NDRC must conform to the "51/49" ownership rule.

d. Because CERs are owned by the Chinese Government and the emissions reductions generated by specific CDM

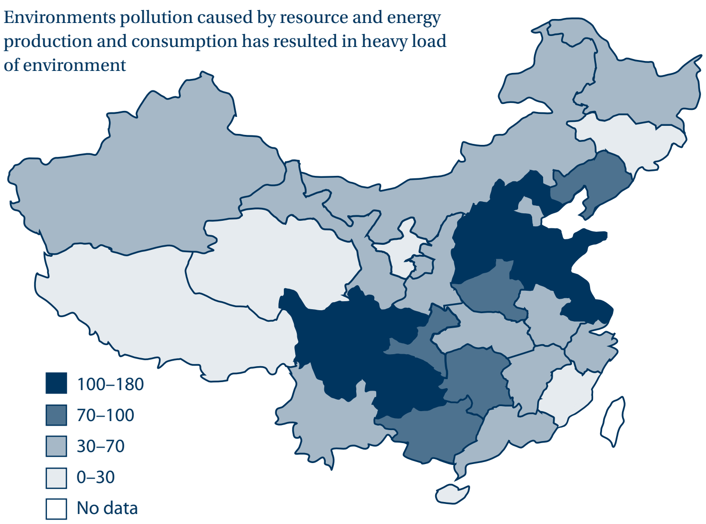
Figure 1.20: China's Oil Balance



Source: IEA, *World Energy Outlook 2007*.

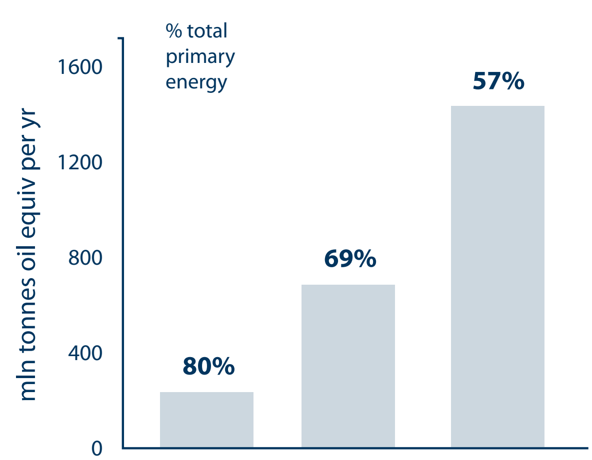
Figure 1.21: SO2 Discharge in China

Environments pollution caused by resource and energy production and consumption has resulted in heavy load of environment



Source: Yande Dai, *China Energy Supply and Demand Situation and Energy Conservation Policy* (ERI, NDRC, March 2007).

Figure 1.22: Continued Reliance on Coal



Source: IEA, *World Energy Outlook 2005*.

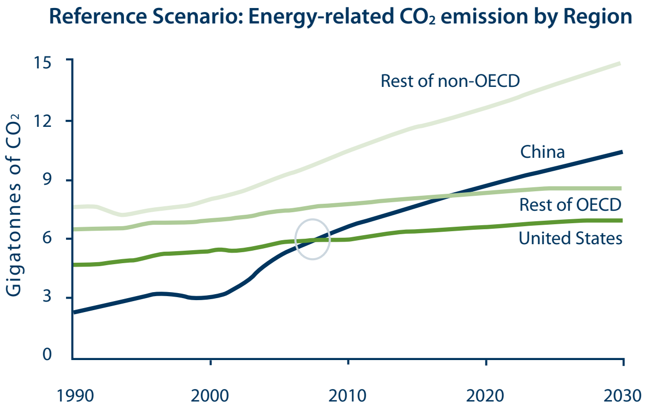
projects belong to the project owners, revenues from the transfer of CERs shall be owned jointly by the Government of China and the project owners.

Cost Analysis

Current Investment Cost and Cost Forecast through 2020

The current cost of investment in wind energy is in the range of $1,109.88–1,387.35/kW. It is expected that with increasing domestic manufacturing capacity and technology transfer, the investment costs can be lowered to the range of $832.41–971.14/kWh by 2010. Similarly, significant future cost reductions are expected for solar PV. Other more mature technologies, however, have less scope for cost reduction both in China and worldwide. The scenario for investment costs in renewable technologies is shown in Table 1.12.

Figure 1.23: World CO_2 Emissions



Source: IEA, World Energy Outlook 2006

Table 1.12: Investment Cost and per kWh Cost for Existing Technologies in China

	WIND ENERGY	SOLAR PV	SOLAR THERMAL	WASTE CHP	GEOTHERMAL	BIOGAS
Investment	$1,109.88–1,387.35	$8,324.1–11,098.78 per kWp	$277.47 per m2	$6,936.74 per kWe	$32.68–52.72 per m^2	$166.48–277.47 /hh
Operation and maintenance	$0.012 per kWh	$0.006 per kWh	$2.77 per m2	$0.003 per kWe	$2.5–4.16 per m^2	$8.32–13.87/a
Electricity production costs	$0.06–0.1 per kWh	$0.5–0.7 per kWh	N/A	N/A	N/A	N/A
Expected cost reduction	Small	Prices of $5 per Wp (2010) to $20 per Wp (2020)	Small	None	The price is decreasing.	Small

Source: Azure International, proprietary research.

Chapter 3: Clean Energy Policies

The policy environment in China is a determining factor for the development of clean energy technology. Moreover, clean energy policy development is currently accelerating in response to China's mounting energy pressures. This section provides an overview of the key existing and planned policies.

Renewable Energy Law

The strategic position of renewable energy in China's energy policy was first affirmed through the Renewable Energy Law (REL) approved by the National People's Congress in February 2005. The REL is a framework law, which went into effect January 1, 2006. It set targets for renewable energy development and stipulates a number of broadly defined instruments to reach these targets.

The REL mandates the establishment of priority grid access for renewable electricity generators, a feed-in tariff for renewable electricity delivered to the grid, a national and regional cost-sharing mechanism for renewable energy subsidies, a special fund for renewable energy, and favorable loan conditions and tax treatment for renewable energy. See Table 1.13: Instruments in REL.

However, the general policy directions set out within this framework law are often vague and need to be further elaborated in implementing regulations in order to give clear signals for renewable energy development to

Table 1.13: Instruments in REL.

INSTRUMENTS OF REL	SPECIFICATION
National renewable energy target	▸ Establishes the strategic position of renewable energy. ▸ Identifies the scale of market development and plans for each step of renewable energy development. ▸ Identifies the types of technologies. ▸ Identifies the priority key locations for development.
Grid connection priorities	▸ Assurance that renewable energy power generation is a priority for grid connection. ▸ Grid companies must accept all the power generated by renewable energy with the price fixed by the government. ▸ Grid companies are required to invest in and construct transmission systems and the connection components for renewable energy integration to the grid.
Classifying tariffs for RE power	▸ The government determines the price based on the average cost or cost with advanced technologies or bidding price. ▸ The price, application period, adjustment measures and appeal procedures are not yet clearly determined in REL.
Sharing costs at national level	▸ Costs for on-grid renewable energy electricity and off-grid generators in rural areas are shared by grid consumers in the whole country. ▸ Costs for biofuel are to be shared regionally. It is not mentioned in which region in REL.
Renewable energy special fund	**Special fund covers:** ▸ Technology research, standards development, and pilot projects; ▸ Household renewable energy utilization projects in rural and pastoral areas; ▸ Off-grid electrification projects in remote areas; ▸ Renewable energy resource assessments and evaluation, as well as establishment of information systems; ▸ Establishment of the localized renewable energy manufacturing industry; ▸ Special fund comes from central and local finance as well as the balance of cost sharing.
Policies on favorable credit treatment	▸ Financial institutions may offer preferential loans with national financial interest subsidies to eligible renewable energy development and utilization projects that are listed in the national guidance catalogue for renewable energy industry development. ▸ National policy banks, national banks, bilateral aid funds, and international multilateral aid banks or financial organizations are able to supply favorable loans.
Policies on favorable tax treatment	▸ A preferential tax will be given to renewable energy projects listed in the guidance catalogue for renewable energy industry development. ▸ Detailed implementation measures should be issued by the taxing authority.

Source: Renewable Energy Law

the market. Development of such implementing regulations is underway.

Implementing Regulations of the Renewable Energy Law

The successful implementation of the REL depends on the implementation of regulations, which remain general and leave substantial room for interpretation. By the end of 2007, 10 implementing regulations had been issued regarding the development of renewable energy.

Mid- and Long-term Renewable Energy Development Plan

The Mid- and Long-term Renewable Energy Development Plan was published in August 2006. It sets goals for the development of each renewable energy technology for both 2010 (10 percent) and 2020 (15 percent).

Management Regulations for Electricity Generation from Renewable Energy

The National Development and Reform Commission released the Management Regulations for Electricity Generation from Renewable Energy in February 2006. The regulations establish the authority for approval of renewable energy projects, the eligibility rules for renewable electricity for policy and fiscal support, and a system for managing grid access.

Hydro projects on major rivers over 250 MW and wind projects over 50 MW are to be approved by the NDRC. Other projects are approved by the provincial-level DRCs with notification provided to NDRC. Biomass, geothermal, wave, and solar PV are declared eligible for policy and fiscal support.

Grid companies are required to grant priority access to renewable energy generators, both from the large national power groups and from independent power producers. Furthermore, grid companies are responsible for the construction, expansion, and adaptation of the grid to facilitate access for medium- and large-scale renewable energy projects.

The China Electricity Council (CEC) is to supervise the operation of renewable electricity generators, the settlement of feed-in tariffs, and the relationship between renewable electricity generators and the grid companies.

Tentative Management Measures for Price and Sharing of Expenses for Electricity Generation from Renewable Energy

The Tentative Management Measures for Price and Sharing of Expenses for Electricity Generation from Renewable Energy were published in January 2006. The measures stipulate two mechanisms for determining the feed-in price for renewable electricity:

- The State Council sets the price;
- The price is determined by a competitive bidding round for a project development concession. The concession and bidding process exists at both the national and the provincial levels.

In addition to the above two pricing mechanisms, the management measures determine the feed-in tariff for biomass generation, which consists of the benchmarking price of desulferized coal-fired units plus a 0.03 $/kWh premium. For new projects, this premium will be decreased by 2 percent each year.

To finance the cost of the feed-in tariffs, the Notice on Adjusting the Local Grid Feed-in Tariff, was released in June 2006 and instituted a national surcharge of 0.0001 $/kWh[52] on electricity sales.

Guidance Catalogue of the Renewable Energy Industry

The "Guidance Catalogue of the Renewable Energy Industry" was released by the NDRC in November 2006. This guidance catalogue specifies the key renewable energy technologies supported by the government, the utilization of these technologies, and their development status (see Annex 3 for details). The aim of the catalogue is to guide decision-making on the direction of technological research and innovation, as well as the direction of renewable energy investment. Based on the catalogue, each province and municipality is to develop plans for supporting renewable energy technological development, pilot projects, and renewable energy investment that fit the local context.

Interim Measures on a Special Fund for Renewable Energy Development

The REL mandated the establishment of a special fund for renewable energy development. To ensure efficient use of the special fund, the Interim Measures on a Special Fund for Renewable Energy Development were released by the Ministry of Finance (MOF) in May 2006.

The special fund, through no-interest and discount loans, supports the key fields of fossil fuel alternatives, building heating and cooling, and renewable energy electricity generation (see Table 1.14). The amount of special funds for each year is published by the MOF and NDRC at the end of each previous year. According to the *China Reform Newspaper* of the NDRC, the special funds increased to $2.96 billion for energy conservation and emissions reduction in 2007, of which $1.25 billion was to be used to support the 10 key projects in energy conservation and capacity building. This amount is 13 times greater than in 2006.[53]

An application guidebook for the funds is drafted annually and published by the NDRC and the financial department of the State Council, in which the conditions for application are stipulated, as well as the fields and technologies supported by the special funds. Corresponding training is held by the Application Steering Committee of the National Energy Foundation Project and China Project Application Net to explain the details of the application. To date, two application guidebooks have been published, including:

- Special Funds Application Guidebook for RE Integrated in Buildings,[54] published by the MOF and Ministry of Construction (MOC). It stipulates the technologies for RE building integration, especially for:
  - Building-integrated solar water heating, solar thermal air conditioners, and solar PV;
  - Heat pumps with sources of ground, aquifer, fresh water, sea water, and sewage.
- 2007 Technology Innovation Fund Guidelines for a Number of Key Projects,55 published by the Ministry of Science and Technology (MOST). It stipulates that private small and medium enterprises (SMEs) and joint ventures obeying "51/49" rules that have RE-related technological innovation are eligible to apply for innovation funds up to $140,000 as interest-free or discount loans. In addition, the innovation funds support technology transfer through fiscal support in the form of $100,000–$280,000 interest-free loans.[56]

Based on this application guidebook, companies can apply for the special funds support through the Energy Bureau of provincial DRCs and the provincial Department of Finance under the Ministry of Finance.

Other Implementing Regulations

The effectiveness of the REL depends on carrying out its implementing regulations, many of which must still be developed. One regulation is of special importance: preferential financing and taxation, which would significantly reduce the gap between the market competitiveness of renewable technologies and existing power generators. Industry experts have been appealing for several years to make progress on this regulation, but thus far have remained unsuccessful.

Table 1.14: Key Fields Supported by Special Funds

KEY FIELDS	TECHNOLOGIES	REMARKS
Fossil fuel alternatives	Biodiesel	Made from sugarcane, cassava, and broomcorn.
	Bioethanol	Made from oil crops, oil fruit, and oil aquatic plants.
Building heating and	Solar	Integration in building.
cooling systems	Geothermal	
Electricity generation	Wind	
	Solar PV	
	Ocean energy	

Source: NDRC, Interim Measures on Special Fund for Renewable Energy Development.

Energy Conservation Policies

The Chinese Government is increasingly focused on energy efficiency and conservation. In this section the key energy conservation policies are outlined.

Energy Conservation Law

The new Energy Conservation Law was approved by the 10th State Congress on October 28, 2007, and will enter into effect April 1, 2008.[57] The law revises the existing Energy Conservation Law (EC Law) of 1998 and identifies five key policy instruments, which are shown in Table 1.15. Like the REL, the EC Law sets broad targets, but lacks the regulatory muscle to implement many of the changes it hopes to make.

Incentive Policy for Energy Conservation

Enterprises can apply for a subsidy for energy efficiency improvements to the NDRC and provincial DRCs at the beginning of each year. The subsidies are disbursed to the enterprises in batches. Applications that fall under the Top-1,000 Enterprises Energy Efficiency Program and the NDRC's key 10 energy efficiency programs in the 11th Five-Year Plan get priority in subsidy allocation. The local provincial governments annually gather the proposals from industry and submit them to NDRC for final approval. MOF then transfers the subsidies to the provincial Departments of Finance, which in turn transfer the subsidies to the enterprises.

In addition to this incentive scheme, a new fiscal incentive for energy efficiency projects was recently established under the Tentative Management Measures for Fiscal Subsidy Funds on Energy Conservation Technological Innovation (August 2007). The implementation period for this new incentive spans from August 2007 through December 2010. The policy awards an investment subsidy of $27.75 per tce saved for investments in energy conservation measures. The subsidy is disbursed on the basis of the actual amount of energy saved. The energy savings are audited by a third party and verified by a qualified certification organization such as the China General Certification Center (CGC). The government budget for this incentive is open-ended and separate from the existing incentive policy budget.

Tax Incentives

Many special preferential tax policies have been implemented to support clean energy research, development, and production. For example, since 2001 waste-to-energy projects have been value-added tax (VAT) exempt. A 50 percent VAT discount applies for the use of energy-saving materials in buildings, for wind power projects, and for coal bed methane projects. Furthermore, since 2005 small-scale hydro has had a reduced VAT rate of 6 percent, and both large-scale hydro production and ethanol production have been VAT exempt -- ethanol is also exempt from the consumption tax.

Moreover, there are income tax deductions for various energy-saving and environmental technologies for both domestic and foreign firms.

Government Procurement Policies

There are a number of Chinese government procurement laws, including the Government Procurement Law, Contract Law, Public Bidding Law, and Law against Unfair Competition, all of which are important to American firms looking to enter the Chinese market. There are also a number of regulations regarding the financing of government procurement, supervision of government procurement agents, and registration of suppliers. Most procurements are conducted in one of the following ways:

- Public invitation;
- Invited bidding;
- Competitive negotiation;
- Single-source procurement;
- Request for quotation;
- Other methods confirmed by the department of government procurement under the State Council.

"The Government Procurement Law was enacted for the purpose of regulating government procurement activities, including improving efficiency in the use of government funds, safeguarding the interests of the state and the public, and promoting transparency in governance. The law establishes the principles for government procurement, including openness and transparency, fair competition, impartiality, honesty, and good faith."[58] Government procurement information not involving commercial secrets is published in the *China Financial and Economic News, China Government Procurement Net, and China Government Procurement Journal.*

If government procurement occurs through public bidding, relevant information is to be published by media selected by related government agencies. Experts who evaluate the bids are to be randomly selected, and must make evaluations in accordance with pre-set procedures.[59]

With the rapid growth of procurement and increasing concern over energy efficiency, Chinese policy-makers are beginning to realize their actions can lead the rest of the market, both through the direct buying and the setting of examples. It should be noted however that although the government procurement process is becoming more transparent, there are still significant biases toward domestic products.

In December 2004, China's Ministry of Finance (MOF), in tandem with the NDRC, announced a new policy for government energy efficiency procurement. The program started in 2005 and was rolled out to all levels of government, including central, provincial, and local governments; schools; and hospitals. In 2006, the total amount of government purchasing for energy and water conservation products increased to about $1.297 billion.[60]

The Chinese Government's "List of Energy Efficient Products for Government Procurement" specifies the products all provincial governments should seek to procure. The MOF and NDRC have the responsibility to develop and update this energy efficiency list. The efficiency specifications for each product are those underlying China's current energy efficiency labeling program run by the China Standard Certification Center (CSC, formerly the China Certification Center for Energy Conservation Products). Qualified procurement models must receive CSC certification, which can present a problem for U.S. firms and their products.

Standards and Quality System

China requires strict conformity with assessment licenses, quality and safety licenses, testing, and labeling verifications for many products. The Administration of Quality Supervision, Inspection, and Quarantine (AQSIQ) is responsible for China's standards development and conformity assessment policies. Two independent agencies under AQSIQ, the Standardization Administration of China (SAC) and the Certification and Accreditation Administration (CNCA), play the dominant role in standards development and conformity assessment policies, respectively.

In general, exporters to China should be aware of three broad regulatory requirements in the standards and testing area. First, AQSIQ maintains approximately 20,000 national standards, of which about 2,800 are mandatory. The mandatory standards are known as *Guojia Biaozhun* or GB standards. Compliance with these standards, generally related to safety or quality, is mandatory for both domestic and imported products.

Second, numerous government agencies in China mandate industry-specific standards or testing requirements for products under their jurisdiction, in addition to the GB standards and the China Compulsory Certification (CCC) Mark. The CCC Mark is a compulsory safety Certification and combines China's previous two inspection systems—one to check the contents of products for import and export and the other for quality control. Although China already has some standards related to clean energy technology, most notably for solar water heating systems, these standards still need to be harmonized with international standards, such as the standards of the International Electrotechnical Commission (IEC).

Furthermore, an appropriate Chinese certification scheme based on international standards must be developed for type certification and project certification (post-installation). For example, development of international standards for wind turbines takes place in the Technical Committee 88 (TC-88) of the IEC. Often national standards are based on these IEC recommendations, as was the case with China's standards for wind turbines. Recent scientific and technical developments however may lead

Table 1.15: Instruments in the EC Law

INSTRUMENTS OF EC LAW	SPECIFICATIONS
National energyconservation target	▸ Energy conservation is a key strategic policy objective. ▸ Technologies are identified for energy conservation. ▸ The reporting process is identified, as well as the mechanism for assigning responsibility, approvals, and appraising.
Management of energy conservation	▸ Develops a procedure for product standardization, industrial process standardization, and energy-saving labels for appliances. ▸ Identifies an energy-saving assessment and appraisal system for fixed asset investment projects. ▸ Phases out energy-intensive equipment and production processes. ▸ Calls for improved public awareness on energy conservation through industry associations.
Key industries targeted for energy conservation	▸ Energy-intensive industry. ▸ Building energy savings. ▸ Public facilities energy savings. ▸ Enterprises with annual energy consumption over 10,000 tce.
Technological advances	▸ Identify energy conservation technologies. ▸ Draft guidance catalogues of energy conservation technologies.
Incentive measures	▸ Special funds for technology innovation, pilot projects, and the 10 key energy efficiency programs of the NDRC. ▸ Preferential tax for EC technologies and products. ▸ Preferential loans for research on EC technologies, EC products, and technology innovation. ▸ Preferential tax for demand-side management (DSM), energy management contracts (EMCOs), and voluntary agreements.

Source: Energy Conservation Law

to additional standards that can meet the special requirements of the Chinese market.

With respect to PV, the existing Chinese standards for PV are being assessed. Two Chinese standards became Reference Standards for IEC. In addition, China changed its Module Standard to correspond with IEC 61215.

Forthcoming Energy Law

To date, several laws regarding coal, electric power, energy conservation, and renewable energy development have been released, but often these lack the strong integrated approach a complex energy portfolio requires. China's increasing dependence on imports, its rapid demand increase, and severe environmental damage has caused traditional energy sources to become outdated from an investment perspective.

A draft of China's integrated Energy Law was recently published. The Energy Law is an integrated framework law for overall national energy development and will include guiding principles for legislation on energy structure, energy efficiency, energy security, energy development and utilization, and energy and environmental coordination. Table 1.16 provides an outline of the main instruments included in the new Energy Law. One of the most important changes is the proposed establishment of an Energy Ministry directly under the State Council.

The draft of the Energy Law has been posted on the Web site of the Office of the National Energy Leading Group,[61] only available in Chinese. It is anticipated that passage of the bill will be achieved in 2009 after being approved by the National People's Congress.

Table 1.16: Instruments of China's Forthcoming Energy Law

INSTRUMENTS	SPECIFICATIONS
Energy management	▸ Establishes an Energy Ministry under the State Council, to oversee energy management in China. ▸ Clarifies the role of industry associations in providing information on industry statistics, standardization, technologies, market development, and consultancy for policy decision-making and to enterprises. ▸ Enhances the management of exports of energy-intensive products. ▸ Establishes an energy statistics and forecasting system.
Energy strategy and plan	▸ A 20–30-year energy strategy will be published and revised by the State Council once every five years. ▸ A five-year energy plan will be published one year after the publication of the economic plan and social development plan. ▸ The provinces are to develop provincial energy plans according to their specific needs and report to the State Council energy department.
Energy development and conversion	▸ Property of energy resources belongs to the state. ▸ Development of mining, renewable energy, and energy production and conversion should be approved by the State Council energy department. ▸ Establishment of environmental compensation mechanism for energy production and conversion.
Energy supply and service	▸ Business on energy supply should be approved by the State Council energy department. ▸ Construction of an inter-regional energy infrastructure is encouraged. ▸ Establishment of energy universal service compensation mechanism.
Energy conservation	▸ Allows the government to encourage energy conservation for optimizing industry and consumption structures and to support energy conservation technology as well as energy management and conservation in key industries. ▸ Establishes energy conservation market mechanisms and perfect consultancy and service system. ▸ Promotes energy efficiency labeling, EMCOs, voluntary agreement, and DSM.
Energy reserve	▸ Increases strategic reserves of petroleum, natural gas, uranium, and high-quality coal.
Energy emergency	▸ Emergency back-up capacity is to be constructed. ▸ Basic supply of energy for emergency conditions is determined by order of importance from essential national institutions, national defense facilities, emergency command agencies, the communication and transportation hub, and emergency medical treatment.
Rural energy	▸ Develops a preferential tax, financial, and price policy encouraging investment in rural energy. ▸ Promotes utilization of new and renewable energy such as CHP, biomass, wind, and solar energy. ▸ Increases the proportion of rural grid coverage. ▸ Promotes rural energy conservation system and services.
Energy tariff and tax	▸ Establishes market-driven energy price mechanism. ▸ Allows the government to determine or guide tariffs for the use of pipelines and grids of strategic public importance. ▸ Implements incentive tariff policy for new and renewable energy development. ▸ Allows the government to guide the energy price for energy-intensive and polluting industries. ▸ Establishes a national and provincial expenditure budget system. ▸ Establishes government investment for environmental protection in mine areas, rural energy development, energy technology research and development, energy conservation, and development and utilization of renewable energy.

Table 1.16: Instruments of China's Forthcoming Energy Law (continued)

INSTRUMENTS	SPECIFICATIONS
Energy technology	▸ Promotes energy technology development for innovation and research on energy resource exploration; energy conversion and transportation technology; comprehensive utilization of clean energy technologies; energy conservation and emission reduction technologies; and energy security production technologies. ▸ Increases budget for energy technology development at national and provincial government levels. ▸ Promotes enhancing public awareness.
Energy international cooperation	▸ Establishes a mechanism for international energy cooperation, management, and coordination. ▸ Establishes publication of "Industry Guidance Catalogue for Foreign Investment on Energy Sector" and relevant policy. ▸ Promotes international cooperation in energy trade, energy transportation, capacity building, and energy security.
Supervision and inspection	▸ Proposes three supervision methods: State Congress, administration, and society. ▸ Promotes energy performance site checking. ▸ Calls for publication of energy performance of high-intensity enterprises.
Liability	▸ Assigns liability to different government officials, energy enterprises, and energy end-users as well as to the public at large.

Chapter 4: Opportunities for U.S. Firms in China

Since China's entry into the WTO in 2001, the opportunities for U.S. firms to enter the Chinese market are accelerating. This potential is often extremely attractive to foreign manufacturers, investors, and other firms. The opportunities for U.S firms entering the Chinese clean energy market have likewise grown tremendously over the last few years thanks to increasing energy security concerns and mounting environmental pressures. In this section, two key enablers are considered:

- New and emerging Chinese Government energy policies;
- Lag in the current Chinese CET market relative to those in the European Union and North America.

Ambitious objectives for China's renewable energy development are evident from government policies. According to China's Energy Research Institute, the investment potential for energy efficiency in China from 2007 to 2010 is $120–160 billion.[62] For renewable energy, the main technologies promoted are hydro, wind, solar PV, solar thermal, biomass electric power generation, and biofuels. The areas of geothermal and ocean energy are also mentioned in these policies.

To fulfill the objective of a 20 percent decrease in energy intensity by 2010 (relative to 2000 levels), the Chinese Government has recognized that major developments in technology and energy management must be achieved across industrial, commercial, and residential sectors. Furthermore, evolution of the energy infrastructure provides avenues for broader adoption of renewable energy technologies.

Personal and materials transportation is likewise a core factor in China's energy demand policy. Given the rapid urbanization of China, the demand for intra-city and inter-city transportation is growing rapidly. It can be expected that more fuel-efficient and lower-emission vehicles will be increasingly popular in China. The booming personal transport sector is especially driving a need for alternative liquid fuels and more efficient personal and mass transit solutions.

The rapidly growing government push, and resulting market pull, for clean energy development presents special challenges for China due to the technological requirements necessary to reach the aggressive government goals. These challenges are elaborated upon below.

Need for High-quality Equipment, Products, and Services

The commercial market for clean energy technologies in China is developing. As CET demand picks up, increasing demand for proven, high-quality products and services can be expected, providing an opening in the market for qualified international companies with sustainable business operations.

Expanding Market for High- quality Equipment

To succeed in the competition, more and more RE manufacturers are eager to increase their product quality by introducing process line or purchasing production licenses from international top manufacturers as well as cooperating with them through technology transfer.

To successfully achieve China's energy efficiency target (a 20 percent decrease in energy intensity by 2010), along with targeted improvements in public awareness and new building improvements, more and more small and medium enterprises (SMEs) are looking to improve their energy performance by introducing effective energy management and importing high-quality and efficient proven equipment.

Professional Clean Energy Technology Services

The development of CET service companies has not been well established in China. In fact, the entire concept of energy service companies (ESCOs) is generally unknown to many Chinese companies. Some key areas of opportunity for professional ESCOs include: operation and maintenance for renewable energy generation, energy auditing and advisory services, consultancy on energy management and RE integration, and ongoing energy efficiency services within a large business. There will be a growing market for all of these services for international and domestic businesses operating in China.

Proven Energy Conservation Technology

Increasing energy efficiency performance is one of China's key energy strategies. Except for the 10 EC programs and Top-1000 Enterprises Program being used by the government to achieve the objective, there is a need to improve public awareness, as well as technology and advisory services to help SMEs improve their energy performance. However, there is a lack of expertise in China regarding energy efficiency technologies and innovation, energy auditing, and energy management. As a result, there is a need for qualified consultancy companies in these areas.

At present, SMEs have to find energy-savings solutions themselves, but information on which technologies are suitable for particular kinds of energy efficiency improvement is not readily available. There is also a lack of proven energy efficiency technologies, providing an important opportunity for U.S. firms to provide expert consultancy and technology services.

Energy Technology Development Opportunities

China can benefit greatly from firms that offer key technology solutions. Table 1.17 below provides an overview of the areas of technology development where foreign companies provide unique solutions that China currently does not have.

Given the ambitious near-term targets set by the Chinese Government for deployment of renewable energy technologies and energy efficiency improvements, as well as the increased investment in industry, there is currently substantial opportunity for U.S. firms in China.

Table 1.17: Key Areas of Opportunity for U.S. Clean Tech Firms

TECHNOLOGY	OPPORTUNITY
Wind energy	▸ Dedicated O&M service companies. ▸ Remote monitoring systems and control systems. ▸ Wind turbine design and testing. ▸ Technologies for large-scale wind turbines (capacity over 2 MW). ▸ Software for wind resource assessment, grid integration, and wind power prediction.
Solar thermal	▸ Aesthetic building integration. ▸ High-quality installation. ▸ After-sales service.
Solar PV	▸ Improved technology in thin-film solar panels. ▸ Cooperation for technology transfer to increase the quality of solar PV products and decrease the cost. ▸ Technology on high-quality converters to increase the conversion efficiency. ▸ Interface technology for building-integrated PV (BIPV) and for power plants. ▸ High-quality crystalline silicon technology. ▸ Technology/software for optimizing PV systems. ▸ Ultra-thin stainless steel bands for soft solar PV panels used in BIPV.
Biofuels	▸ R&D cooperation on the production of ethanol from cellulosic feedstock.
Biogas	▸ Training on technology, equipment, and service;, development of high-efficient fermentation technology for higher biogas yield. ▸ Demonstration of new building material and technology for digester construction and biogas storage; high-pressure biogas storage. ▸ Reliable (more than 7,000 hours/year) biogas heat and power co-generation. ▸ Efficient post-treatment technology for water and solids after fermentation. ▸ Biogas fuel cell development cooperation. ▸ Biogas purification with air intake (biological sulfur removal). ▸ Biogas processing for feed-in natural gas grid and as transport biofuel.
Geothermal	▸ Technology and equipment for geological exploration and project development.

Source: Guidance Catalogue of the Renewable Energy Industry and interviews

Chapter 5: Investment and Financing of Renewable Energy and Energy Efficiency

By the year 2020, China plans to develop 120,000 MW of renewable energy. This would account for 12 percent of China's total installed energy-producing capacity. China's growth target for renewable energy production will require an investment of approximately $100 billion by 2020. The challenges involved in attracting this investment are significant and will depend on the enabling policy and regulatory frameworks being developed to entice energy investors. Financing needs include:

Project Equity. Equity capital in China is typically sourced from the government, strategic investors and joint ventures, private equity funds, utilities, or capital markets (i.e., public equities or bonds). Joint ventures in particular are one of the main sources of project equity in China. Of late, the number of new renewable energy private equity funds and investors has increased to include both pure equity and quasi-equity funding.

Project Debt. The bulk of the financing provided to a project is usually in the form of senior debt. A significant amount of innovation in debt-financing instruments is currently in progress in China by organizations such as the World Bank, export credit agencies, and other development finance institutions to reduce risks and improve access to long-term financing.

End-User Finance. As renewable energy markets continue to grow in China, end-user finance will become important.

Small and Medium Enterprise Finance. SMEs will play an increasingly important role in providing technologies and services in China; however, these markets are rarely served by bank financing. Niche organizations such as E&Co, which is active in China, provide business planning and advisory services as well as critical seed capital, but additional funding sources are needed in this area.

Financing Sources for Clean Energy

Clean energy financing sources in China include:

Government agencies. Government agencies, at the national and local levels, will continue to be a key source of funding for clean energy investments in China. China's renewable energy program has made significant achievements in small hydropower, biogas plants, solar hot water systems, and recently PV and wind systems due in large part to government support. For instance, the Ministry of Science and Technology and the National Development and Reform Commission jointly launched the International Science and Technology Cooperation on New and Renewable Energy on November 12, 2007. Special funds will be earmarked for the launch of the program.

Multilateral and Bilateral Organizations. Both the World Bank and the Asian Development Bank have made significant lending commitments to renewable energy and energy efficiency in the Asia region, with particular emphasis on China. For example, the World Bank has committed $86 million of a total $132 million project for follow-up to the China Renewable Energy Scale-up Project. This project hopes to demonstrate early success in large-scale renewable energy investments with participating local developers. The project comprises two components: a 100-MW wind farm at Huitengxile in Inner Mongolia and a bundle of small hydro construction and rehabilitation projects in Zhejiang Province. The World Bank also has a dedicated program for promoting clean energy in Asia—the Asia Alternative and Sustainable Energy (ASTAE) Program, which seeks to mainstream investment in renewable energy and energy efficiency in the region.

The Asian Development Bank (ADB) recently approved $35 million in funding for the Gansu Clean Energy Development Project and $600,000 in support for establishing a Clean Development Mechanism Fund and has a number of energy efficiency projects being considered for approval. GEF has supported over 28 projects under the climate change focal area in China, valued at over $376 million. Bilateral organizations providing financing and technical assistance include GTZ and KfW of Germany, Triodos Bank of the Netherlands, and export credit agencies from a number of countries including the United States, Japan, and Europe.

International and Local Finance Institutions. International and local financial institutions have been active in supporting clean energy in China. International investors include entities such as Citigroup, Actis, and Credit Suisse, while local financial institutions include China Merchants Bank, China Development Bank, and the Industrial and Commercial Bank of China (ICBC).

Besides long-term loans, short-term bonds are an important way to expand financing channels and reduce costs. In May 2005, the People's Bank of China sold the first short-term bond; since then, 364 short-term bonds have been issued with a total of approximately $67.8 billion.[63]

Trust funds are another financing channel to reduce costs. The bank commission trust company operates as the client's capital, the enterprises act as the main body of the loan, and the capital received from the trust company is used to meet medium and long-term requirements.

The All-China Federation of Industry & Commerce, together with the New Energy Chamber and some membership enterprises, has recently proposed to the NDRC to set up so-called Industry Investment Funds for New Energy, which will benefit new energy enterprises.

Grants/soft loans. Such loans refer to financing or credit support from a government institution or multilateral institution. Government financing sources have special criteria or non-commercial objectives.

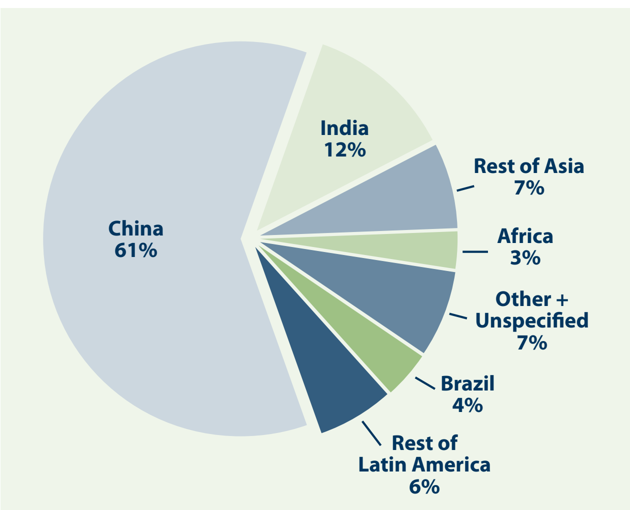
Public Offering. Renewable energy enterprises can access capital through public offerings. China GoldWind, for instance, a wind turbine manufacturer in Xinjiang Province, received approximately $260.4 million by public offering in December 2007. [64]

Carbon Finance. Both the CDM and the emerging voluntary carbon markets are providing a revenue stream to increase the financial viability of clean energy projects in China. In 2006, the global carbon market amounted to $30 billion, up from $11 billion in 2005. CDM accounted 88 percent of this market. As noted in Figure 1.24 below, China received 61 percent of the market's volume.

According to national policy, joint CDM ventures must abide by the"51/49" rule , in which case the profit from the carbon market is logically allocated in accordance with the share.

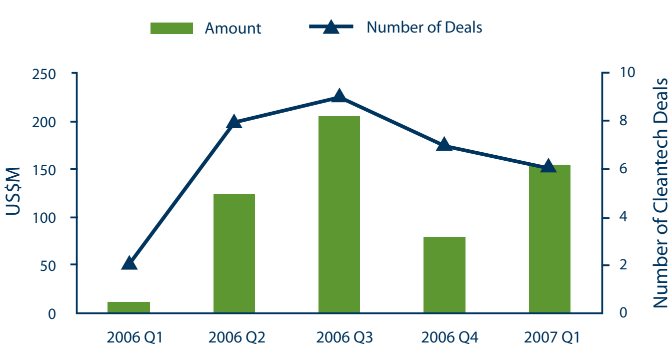
The easiest way to enter China's carbon market is to purchase Verified Emission Reductions (VERs) on the voluntary market. Compared to CDM trade, VER is a flexible mechanism for joint ventures with foreign shares over 50 percent. According to ICF International predictions,[65] global VER requirements will reach 0.4 billion tonnes of CO_2 by 2010, of which three-quarters come from group buys and the remainder from private buyers. Based on the current VER price of $5.5/ton, the potential of the VER market is $2.2 billion, 40 percent of which is in China.[66] VERs are applicable to wind projects, small hydropower projects, biogas utilization, landfill projects, and hydrofluorocarbon (HFC) and N_2O decomposition projects, the latter of which is favored by the Chinese government.

Figure 1.24: Carbon Sellers in 2006



Source: Viakatta Putti, "CDM Market Outlook," a presentation at the Africa Lighting Carbon Finance Workshop, October 2007.

Figure 1.25: Clean Tech Venture Investments by Quarter



Source: Cleantech Group LLC, "China Cleantech Venture Capital Investment Report," .2006–2007.

Venture Capital and Private Equity Investment

U.S. investment in clean technology companies worldwide has increased steadily from around $590 million in 2000 to $2.6 billion in 2007.[67] The implementation of China's Renewable Energy Law and the 11th Five-Year Plan are the main policy drivers in China's clean tech industry and will continue to stimulate the market going forward. In the first quarter of 2007, $154 million was invested in six deals – almost 14 times the amount invested in the first quarter of 2006. This investment expected to expand the Chinese clean tech markets to around $700 million in 2008.[68] Figure 1.25 displays the number of deals by quarter.

Private equity funds will also continue to seek opportunities in the Chinese market. Note that China will likely be more selective in bringing in overseas investors as the total amount of foreign investment continues to grow. Therefore, the major problems faced by private equity investors in China are no-exit mechanisms and political risks.

Table 1.18 shows the main private equity and venture capital firms in the Chinese clean technology market.[69]

Table 1.18: Selected Private Equity and Venture Capital Investment Firms in China

NAME OF FIRM	COMPANY INVESTED
Sino-Belgium Direct Equity Investment Company	Goldwind
HSBC Infrastructure Fund Management	Canadian Solar
London Asia Capital	China New Energy
DragonTech Venture Management	Suntech Power
Actis Capital LLP	Suntech Power
Natexis Private Equity	Suntech Power
Prax Capital	Suntech Power

Source: Azure-international

Chapter 6: Barriers to Clean Energy Trade and Investment for U.S. Firms

Despite the significant opportunities the Chinese clean energy market presents, important barriers remain that must be considered before developing a successful Chinese business strategy. These barriers are addressed below:

Intellectual Property Rights Enforcement

Although China's leadership has recognized the importance of improving the protection of intellectual property (IP), IP theft remains a major challenge to U.S. companies. The latest U.S. trade losses due to counterfeiting and piracy in China remain unacceptably high. Copyright industry losses were estimated at over $2.9 billion in 2007. In FY2007, 80 percent of the fake products seized at the U.S. border, valued at $158 million, came from China. This $158 million figure represents a 25 percent increase compared to the value of FY2006 seizures. Taking steps to protect your U.S. intellectual property in China is a critical part of doing business with China.

Because U.S. registered patents and trademarks provide no protection outside the United States, securing your IP rights in China and other countries is essential. If, for example, you enter the Chinese market without having registered your trademark in China (in English, and ideally, in Chinese as well), one of your competitors, distributors or partners could register before you and bar you from selling or manufacturing products bearing your trademark in China. This practice, commonly known as "trademark squatting," is among one of the most frequent problems faced by U.S. industry. Additionally, mandatory technology transfer requirements and "patent squatting" have become problems for U.S. industry in China.

China has three tracks for seeking enforcement of IP rights – civil, criminal and administrative. However, the lack of effective and deterrent enforcement of IP rights remains a serious problem. Enforcement efforts, particularly at the local level, are restricted by poor coordination among Chinese Government ministries and agencies, local protectionism and corruption, high thresholds for initiating investigations and prosecuting criminal cases, lack of training, and inadequate and non-transparent processes. If a company does not register its IP rights in China, China's three enforcement tracks not only are not available to you but also may be used against you. Sophisticated counterfeiters manipulate the loopholes in the Chinese system to prevent market access for foreign technology.

The United States has consistently made the protection and enforcement of IP a top priority and recently launched the Strategy Targeting Organized Piracy (STOP!), a U.S. Government initiative to fight global counterfeiting and piracy. The Department of Commerce plays a critical role in this effort by providing U.S. businesses, including SMEs, specific IP resources to educate and assisting them with protecting and enforcing their IPR. See Appendix A for a list of resources.

Legal and Regulatory Environment

Chinese laws and regulations for clean technology tend to be broadly defined and lack specific implementing rules and measures. This can make it difficult for U.S firms to determine precisely whether their activities match or contradict a particular regulation.

While the Energy Conservation Law has played an important role in improving energy efficiency, it is widely recognized that the law's incentives and enforcement regulations are too weak. It is expected that more incentives will be provided and a more restrictive management system adopted in the amended Energy Conservation Law currently under review by the National People's Congress.

Several much needed regulations are also not yet in place under the Renewable Energy Law. A governmental guiding price has not been implemented for wind power generation. And while competitive tendering is effective for large wind power projects, no mechanism exists to price small wind projects and improvements of existing wind farms. Feed-in tariffs are also not fixed nationwide, increasing the risk for project developers and capital investors.

The overlapping responsibilities and areas of authority among government organizations often cause additional confusion to foreign companies. China lacks an open system that disseminates planning information, project approval, and pricing to the public. As a result, foreign companies often face ad hoc decision-making and an often cryptic response from the government to their questions. It is therefore advised that U.S firms carry out due diligence and seek professional advice before entering the Chinese market.

Clean Energy Technology–Related Customs Regulations and Trade Tariffs

Foreign companies operating in China are required to pay an income tax, which is calculated differently according to the percentage of ownership a foreign firm has in a joint venture. China intends to eventually phase out its two-tier income tax system for domestic and foreign enterprises, because domestic enterprises have long resented rebates and other tax benefits enjoyed by foreign-invested firms. The move toward national treatment will mean the gradual elimination of special tax breaks enjoyed by foreign investors. According to the framework of corporate income tax reform, the corporate income tax will be unified to domestic and foreign direct investment (FDI) companies, meaning FDI companies will no longer have advantages in terms of favorable tariffs.

A comprehensive guide to China's customs regulations is available in the *Customs Clearance Handbook* compiled by China's General Administration of Customs. It contains the tariff schedule, national customs rules, and appropriate regulations. This guide can be purchased at bookshops in China.

Restrictions on Foreign Direct Investment

Although the Chinese Government encourages foreign investment in the clean energy industry, the "Catalogue for the Guidance of Foreign Investment Industries (2007 revised),"[70] does limit foreign firms to some degree. In the catalogue, which came into force December 1, 2007, foreign industries are divided into "encouraged," "restricted," and "prohibited." The items related to clean energy technologies are summarized below:

Encouraged Sectors: Development and utilization of clean-coal technologies; construction and operation of hydropower stations with the main purpose of generating power; construction and management of nuclear power plants (Chinese partner shall hold the majority of shares); and construction and management of new energy power plants (solar, wind, magnetic, geothermal, tide, and biomass energy). New energy power equipment is however limited to equity joint ventures and cooperative joint ventures.

Restricted Sectors: Manufacturing of biofuels; construction and management of conventional coal-fired condensing steam power plants whose unit installed capacity is less than 300,000 kW within the small grids of Tibet, Xinjiang, and Hainan Provinces; and coal-fired condensing-extraction steam power plants with dual use unit co-generation.

Prohibited Sectors: Construction and management of conventional coal-fired condensing steam power plants whose unit installed capacity is less than 300,000 kW outside the small grids of Tibet, Xinjiang, and Hainan Provinces.

The National Development and Reform Commission and Ministry of Commerce jointly issued a new "Industrial Catalog for Foreign Investment." It is recommended that U.S. firms look through the related special laws and regulations carefully before investing or pursuing business in China.

Lack of Government Relations

In China, *Guangxi* (relationship) is a complicated matter. Building quality government relationships should be a primary business development focus for many U.S firms, especially for those firms entering the Chinese market for the first time. There will be unpredictable challenges and it is important for U.S. firms to coordinate with the Chinese Government when dealing with issues of foreign trade and economic cooperation. Lack of a government relationship will create unnecessary difficulties and delays in acquiring government approvals. A good relationship can pave the way. In addition, the Chinese Government tends to protect local firms, especially state-owned firms, from imports, while encouraging exports. Although WTO accession is certainly helping in this area, progress is being made only gradually.

There are resources available to help U.S. firms develop relationships with the Chinese Government. The U.S. Commercial Service in Beijing also offers a wide range of services to assist U.S. companies in finding Chinese partners. See Appendix A for a list of additional resources.

Low Awareness of Intercultural Issues

There is a large culture gap between the United States and China, which is too often ignored. Intercultural sensitivity is critical, and should be considered a core focus for any company working in China. Between the two countries the ideas of law, profit, decision-making, market orientation, business relationships, and technical standards are quite different. Low awareness of how to navigate these differences will cause misunderstandings and miscommunication and can cause conflicts of interest as time goes on.

A good way to prevent cultural conflict is to visit China in order to gain a better perspective and understanding, which can provide a company great insight into the country, the culture, the business climate, and its people. Chinese companies prefer and respect face-to-face meetings, which demonstrate a U.S. company's commitment to working in China. Note that China has many different regions and that each province is unique both economically and socially.

Relative Higher Product Prices

Generally U.S. production costs and product prices are higher than Chinese production costs and prices. Most Chinese consumers are very sensitive to price and will usually choose the less expensive product unless better after-sales service or clearly better product quality is available.

Government Procurement

The transparency of government procurement is a concern for foreign companies. Local relationships and networking of domestic companies play a very important role in procurement, which may lead to unfair competition and may put U.S firms in a weak position.

Corruption in government departments remains widespread, though the government continues to call for improved self-discipline and anti-corruption efforts at all levels. For competitive procurement contracts, there is little direct evidence that corrupt practices have influenced awards or resulted in a failure to enforce competitive measures. However, competitive procedures are not followed for the bulk of procurement in China.

Contract Enforcement

The Contract Law came into force on October 1, 1999, and contains both general and specific provisions. Technology Contract Regulations were published in 2002. There are some other laws and regulations regarding contract enforcement, such as:

- Administration of Technology Import and Export;
- Administrative Measures on Prohibited and Restricted Technology Exports;
- Administrative Measures on Prohibited and Restricted Technology Imports;
- "Catalogue of Technologies Prohibited and Restricted for Import";
- Circular (Ministry of Foreign Trade and Economic Cooperation & State Administration of Foreign Exchange) Administration of Foreign Exchange Sale and Payment Related to Technology Import Contracts (February 20, 2002).

Technology contract regulation is divided between domestic technology contracts ruled by the Contract Law of 1999, and technology contracts with at least one foreign party, ruled by the Technology Regulations of 1985 and a long string of closely related legislation. The greatest problem for technology contracts remains dual regulations and unfair restrictions. The technology transfer sub-section has many parallel articles to the regulations and leaves additional room for maneuvering to the contract parties themselves.

One of the problems in contract enforcement is that China does not enforce foreign judgments, in particular U.S. judgments. Problems caused by improper interpretation of contract documents may therefore lead to ineffective enforcement. It is unclear who will interpret the Contract Law since the National People's Congress (NPC) Standing Committee has jurisdiction but has not yet fulfilled its role. Instead the Supreme Court has created a series of suggested interpretations. There is also the possibility that other ministries of the State Council will claim the right to implement the new law in the absence of NPC interpretation.

Payment Security

Letters of credit and documentary collection are common methods for payment, under which foreign exchange is allocated by the central government for an approved import. Although the Bank of China dominates China's trade-finance business, most Chinese commercial banks, such as the China Construction Bank, Industrial and Commercial Bank of China, and the Agricultural Bank of China, have the authority to issue letters of credit for imports. Foreign banks with branches or representative offices in China can also issue letters of credit.

China has been a member of the International Chamber of Commerce since 1995 and is subject to the Unified Customs and Practice (UCP) 500 Code regarding international trade payments. Nevertheless, terms and conditions are generally negotiable in practice and determined on a transaction-by-transaction basis in the form of a "silent" confirmation.

Documentary collection is less formal and more flexible. The exporter submits a full set of trade documents for payment collection to the bank designated in the contract. The Chinese bank sends the documents to the home office for examination and in some cases passes them on to the buyer for further examination. Payment is made after the documents have met the approval of all parties. This method of payment provides less coverage against default and should be used with caution. It is the responsibility of the exporter to determine the specific instructions to be used in the collection letter.

E-commerce in China has great potential. However, Internet security needs to be taken into account. In April 2005, the Law on Electronic Signatures took effect and enhanced the safety of on-line transactions.

Conclusion

China presents both unprecedented opportunities and challenges for clean energy technologies, due to the sheer scale of the market, the demand, and the projected future energy scenario. Over the last decade, the country has faced serious challenges related to energy shortages and heavy pollution, both of which have been brought on by rapid economic development. In response, the government of China has actively promoted the development and deployment of renewable energy with progressive and ambitious policies and targets. This combination of factors represents a host of opportunities for U.S. firms. While some technologies, such as solar water heating and hydropower, are mature and their markets relatively stable, others—such as large-scale wind power, building-integrated PV, and energy efficiency—lag behind in global competitiveness due to resource shortages, lack of expertise, and/or dependence on foreign technology.

Though China's clean energy market is clearly growing, it lags behind the more rapid development of heavy industry. China will therefore likely be a major net exporter of renewable energy equipment in the near term, as the country produces far more equipment than it can install domestically. However, as the demand for higher product quality and after-sales service increases, and as Chinese consumers become more conscious of efficiency and environmental responsibility, this situation will change. The Renewable Energy Law has already had a demonstrable effect on China's clean energy market and resulted in an increase of new renewable energy projects, particularly in the areas of wind, solar, and biomass. Ambitious targets were included in the REL for the next 10–15 years, which when paired with the industry outlook are likely to be even higher. Therefore, U.S. firms should anticipate a growing demand for proven, high-quality products and services in key areas such as energy service companies, energy efficiency auditing, wind farm operation and management, technological innovation of large-scale turbines, aesthetic building integration of SWH, and improved thin-film PV technology.

Annex 1. Major Market Players in China

Wind Power

In China, there are currently over 80 wind turbine generator (WTG) manufacturers and 200 wind developers. Domestic companies occupy over 75 percent of the domestic market. The top seven WTG manufacturers and top 10 developers share 80 percent of the market (see Table 1.19).

To date, Chinese WTG technology lags behind, and key technology and licenses still belong to European and U.S. companies. Narrowing the technological gap will require important investments in WTG technical development from Chinese companies. The leading Chinese WTG companies are shown in Table 1.20.

China has developed a mature solar industry market in recent years, with booming investments at the international level providing an important opportunity. The capacity of the solar industry feedstock production lines increased sharply in 2007 and now surpasses 2,500 tons per year, as shown in Table 1.21.

In 2005, the total production capacity for solar industrial ingot reached 5,842 tons while the actual production stood at 2,386 tons. Over 80 percent of the domestic manufacturers produce mono-ingot, as shown in Table 1.22.

In 2005, the market for solar cells was dominated by two companies, Suntech and Ningbo Solar. In 2006, the size of the solar cell market multiplied by 11, and new companies rushed into this sector. Table 1.23 below identifies the current players.

In 2005, the production capacity for solar modules was 858 MWp, with an actual production of 284 MWp, as shown in Table 1.24.

Solar Water Heating

In total there are over 3,500 solar water heating (SWH) system manufacturers in China, the top 10 of which are able to provide high-quality products and good after-sales services. These top 10, listed in Table 1.25, share less than 20 percent of the market.[71]

Small Hydropower

Small hydropower technologies are mature in China. Of over 100 manufacturers, 10 qualified manufacturers were published in the 2007 China Renewable Energy Industry Blue List, and they are listed in Table 1.26. The Web sites of these manufacturers are also provided.

Energy Efficiency

The energy efficiency market is booming as a result of the policy and goals set forth in the 11th Five-Year Plan. Numerous companies and organizations have developed energy efficiency operations in various fields. Many of the top 500 companies, such as GE, ABB, Siemens, Schneider, and Panasonic, have expanded their energy efficiency businesses all over China. Some of them sell energy efficiency products such as energy-saving lamps and high-efficiency motors directly to the consumer or provide technical solutions and services for plants and buildings. Table 1.27 shows the top

Table 1.19: Wind Market Shares by Developers and WTG Companies in the First Half of 2007

1H07 INSTALLATIONS SHARE BY DEVELOPER (TOTAL: 1,094MW, EST. EQUITY WEIGHTED CAP.)		
COMPANY	MARKET SHARE FOR THE YEAR	% OF MARKET
Longyuan	292,390	27
Ningxia Power	131,775	12
CPI	123,525	11.3
Shenhua	138,763	12.7
Keshiketeng County Huifeng New Energy Co. Ltd.	48,510	4.4
Datang	47,750	4.4
IMAR Wind Power	45,000	4.1
Beijing Energy Investment	47,250	4.3
Huaneng	34,538	3.1
CECIC	31,500	3.0
Huadian	28,900	2.6
CWIC	23,250	2.1
Shandong Luneng	21,650	2.0
13 cos (<1% each)	79,550	0.1

1H07 WTG MARKET SHARES BY COMPANY (TOTAL: 1,094MW)		
MANUFACTURER NAME (YW)	MARKET SHARE FOR THE YEAR	% OF MARKET
Goldwind	392,250	36
Sinovel	156,000	14
Dongfang Electric Machinery	121,500	11
Vestas	101,350	9
GE Wind	115,500	11
Gamesa	110,500	10
Nordex	19,500	2
Suzlon Energy Ltd.	62,500	6
Windey	8,250	0.75
ENGGA	1,500	0.14
China Creative	3,000	0.27
Shanghai Electric	2,500	0.23

Source: Azure International

10 energy efficiency consulting companies in China. Table 1.28 displays the main products produced by the top energy efficiency players in China.

Table 1.21: Solar Ingot Feedstock Production Lines

COMPANY	CAPACITY (TONS/YEAR)	BEGINNING OF EXPLOITATION
Sichuan E'Mei Sli feedstock pilot line	100	1999
Sichuan E'Mei Si Feed Stock Production	200	2006
Luo Yang Zhong Gui (First Phase)	300	2005
Luo Yang Zhong Gui (First Phase)	700	2007
Luo Yang Zhong Gui (Third Phase)	2000	2008
Sichuan Leshan Xingguang Si	1260	2007

Source: Kong Li, *The Development of PV Technology in China* (Institute of Electrical Engineering, Chinese Academy of Sciences, November 2006).

Table 1.20: Leading Companies in WTG Technology in China

COMPANY	TYPE OF COMPANY	TECH/LICENSE	UNITS CAP.
Gamesa	Wholly owned foreign enterprise (WOFE)	Gamesa	0.85 MW
GE	WOFE	GE	1.5 MW
NCWA-Acciona	Sino–foreign joint venture (S/F JV)	Acciona	1.5 MW
NCWA-Acciona-Wandian (Beijing) Ltd.	S/F JV	Own/Wandian	0.6 MW
Nordex-Xian Weide	S/F JV	Nordex	0.6 MW
Nordex-Ningxia	S/F JV	Repower	1.3 MW
Suzlon Energy Ltd.	WOFE	Suzlon	1.25 MW, 2.1 MW
Vestas (850)	WOFE	Vestas	0.85 MW
Vestas (2 MW)	WOFE	Vestas	2 MW
Sinovel-Dalian Heavy Industry	State-owned enterprise (SOE)	Fuhrlaender	1.5 MW
Dongfang Electric Machinery	SOE	Repower	1.5 MW
Goldwind Science & Technology Co., Ltd. (750 kW)	SOE	Repower	0.75 MW
Huayi (Zhejiang) Wind Power Co., Ltd.	Domestic private	Own	0.78 MW
Windey (Zhejiang) Wind Generating Engineering Co., Ltd.	SOE	Own/Windey/ Garrad Hassan	0.75 MW

Source: Azure International

Table 1.22: Manufacturers of Solar Ingot (2005)

MANUFACTURER	TYPE	CAPACITY (TONS)	PRODUCTION (TONS)
Ling Long	Mono-ingot	2250	1126
Jinzhou Huari	Mono-ingot	800	400
Trina Solar	Mono-ingot	180	60
New Energy Research Institute of Qinghai	Mono-ingot	270	0
Tianwei Yingli	Cast	770	260
Ningbo Jingyuan	Cast	90	40
Jingsu Sunda	Mono-ingot	350	100
Jinggong	Cast	132	0
Others	Mono-Ingot	1000	400
	Total	**5,842: 4,850 Mono Si; 992 Poly Si**	**2,386: 2,086 Mono Si; 300 Poly Si**

Source: Kong Li, *The Development of PV Technology in China* (Institute of Electrical Engineering, Chinese Academy of Sciences, November 2006).

Table 1.23: Solar Cell Manufacturers

COMPANY	PRODUCTION IN 2005 (MWP/YEAR)	CAPACITY BY 2006 (MWP/YEAR)
Suntech	82	300
Ningbo Solar Power	20	100
Nanjing PV-Tech	5	200
Tianwei Yingli	3	60
Yunnan Tianda PV	3	50
Jiangsu Linyang Solarfun	1	100
Shenzhen Topry	9.6 (monosilicon: 3, amorphous silicon: 6.6)	68 (monosilicon: 38, amorphous silicon: 30)
Shenzhen Riyuehuan	2 (amorphous silicon)	2 (amorphous silicon)
Shanghaijiaoda	7	25
Jinneng	2.1 (amorphous silicon)	7.5 (amorphous silicon)
Shenzhen Trony	2 (amorphous silicon)	5 (amorphous silicon)
Total	145.7 (crystalline: 133, amorphous silicon: 12.7)	1673.5 (crystalline: 1629, amorphous silicon: 44.5)

Source: Kong Li, *The Development of PV Technology in China* (Institute of Electrical Engineering, Chinese Academy of Sciences, November 2006).

Table 1.24: Manufacturers of Solar Modules

COMPANY	CERTIFICATION	CAPACITY (MWP)	2005 PRODUCTION (MWP)
SunTech (Wuxi)	TüV	120	78
Solar Energy-Tech (Shanghai)	TüV	100	45
Tianwei Yingli (Baoding)	TüV	50	13
BP Jiayang	TüV	50	8
Solar Energy (Ningbo)	TüV/CE/UL	50	15
Jiangsu Linyang	TüV	50	6
Trinar Solar (Changzhou)	TüV	50	10
Others		388	109
	Total	**858**	**284**

Source: Kong Li, *The Development of PV Technology in China* (Institute of Electrical Engineering, Chinese Academy of Sciences, November 2006)

Table 1.25: The Top 10 SWH Manufacturers in China

MANUFACTURER	COLLECTOR TYPE
Himin	Evacuated tube
Tsinghua Sunshine	All-glass evacuated tube
Huayang	All-glass evacuated tube and evacuated tube
Aucma	Evacuated tube
Sijimicoe	All-glass evacuated tube
Guangpu	All-glass evacuated tube
Gomang	Matel superconducting heat pipe
Szlinuo	Evacuated tube
Sangle	U-type evacuated tube
Sunpu	All-glass evacuated tube and evacuated tube

Source: 2007 China Renewable Energy Industry Blue List, http://www.in-en.com/data/html/energy_1556155694129395.html

Table 1.26: China's Top 10 Small Hydropower Manufacturers

MANUFACTURERS	WEB SITES
Zhejiang Jinlun Electromechanical Co. Ltd.	*www.zjjl.com/*
Hangzhou Electric Equipment Works	*www.chinaheew.com/index_c.php*
Kunming Electric Machinery Co., Ltd.	*/http://cn.5095.cnele.com/*
Sichuan Dongfeng Electric Machinery Co., Ltd.	*www.dongfengem.com/disp.asp?xh=493*
Zhejiang Linhai Electric Machinery Co. Ltd.	*www.lhemc.com/about.htm*
Zhejiang Yueqing Electric Machinery Works	*www.yueqing.org/zjyq/content/scqy/gdqy/corporation/yqjijei.htm*
Nanning Generating Equipment General Works	*www.ngegw.com/*
Henan Xixia Hydropower Equipment Co. Ltd.	*www.xxsd.net/*
Sichuan Hongya Hydro Turbine Works	*www.hyslj.com/about.asp*
Hangzhou Nanwang Automatic Technologies Co. Ltd.	*www.hznwauto.com/*

Source: Beijing Development and Reform Commission, http://www.bjpc.gov.cn/tztg/200704/t155937.htm (Chinese version)

Table 1.27: Top 10 Consulting Companies in the EE Field in China

COMPANY	EXPERTISE	WEB SITE
China IPPR Engineering Corporation	Construction, industry, infrastructure	*www.ippr.com.cn/*
Wuzhou Engineering Design Research Institute	Construction, industry	*www.wuzhou.com.cn/*
China Electronic Engineering Design Institute	Construction, industry, consulting	*www.ceedi.com.cn/*
Institute of Architecture Design & Research Institute of Chinese Academy of Sciences	Construction, infrastructure	*www.adcas.cn/ (Chinese Web site)*
China Architecture Design & Research Group	Construction	*www.cadreg.com.cn/*
China Enfi Engineering Technology Co. Ltd.	Construction	*www.enfi.com.cn*
Sinothru Construction Consultants Co. Ltd.	Construction, infrastructure	*http://ztcec.cn*
CECIC Blue-Sky Consulting Management Co. Ltd.	Industry	*www.cecic-consulting.com.cn/english/*
China Coal Research Institute	Industry	*www.ccri.com.cn/*
China Machinery International Engineering Design & Research Institute	Industry	*www.cmiei.com*
Fifth Survey & Design Institute of Railway	Infrastructure	*www.t5y.cn/*

Source: Azure-international

Table 1.28: Main EE Products and Players

COMPANY	PRODUCT	WEB SITE
GE	Green electric products, high-efficiency motors, energy conservation switches, electricity control systems, etc.	*www.ge.com.cn*
ABB	High-efficiency motors, energy conservation switches, electricity control systems, etc.	*www.abb.com.cn/*
Schneider Electric	Energy conservation switches, electricity control systems, etc.	*www.schneider-electric.com.cn*
Siemens	High-efficiency motors, energy conservation switches, electricity control systems, etc.	*www.siemens.com.cn*
Fuji Electric	Electric meters, clean energy, UPS, monitoring systems, etc.	*www.fujielectric.com.cn*
Mitsubishi Electric in China	Industry control systems, high-efficiency motors, energy conservation switches, electricity control systems, etc.	*www.mitsubishielectric.com.cn*
Delta Electronics, Inc.	VSD motors, energy conservation power source, etc.	*www.delta.com.tw/*
Panasonic China	Industry control systems, high-efficiency motors, energy conservation switches, electricity control systems, etc.	*www.panasonic.com.cn*
Moeller	Low-voltage electric appliances	*www.moeller.cn*

Source: Azure-international

Annex 2. Chinese Policy-makers with Authority over Clean Energy Technologies

National-level Decision-making Authorities and Procedure

The Constitution accords the National People's Congress (NPC) the highest position in China. Its main functions are:

- To enact and revise basic laws in China;
- To examine and approve the plan for national economic and social development.

The State Council of the People's Republic of China, namely, the Central People's Government, is the highest executive entity of state power, as well as the highest body of state administration. It is responsible for:

- Carrying out the principles and policies of the Communist Party as well as the regulations and laws adopted by the NPC;
- Dealing with such affairs as China's internal politics, diplomacy, national defense, finance, economy, culture, and education.

The State Council is composed of the General Affairs Office, 28 ministries and commissions, 17 directly affiliated entities, and seven working offices, in addition to a number of directly administered institutions.

Main Responsibilities and Functions of Individual Institutions

National Development and Reform Commission: After merging with the State Council Office for Restructuring the Economic System and part of the State Economic and Trade Commission in 2003, the State Planning Commission was restructured into the NDRC, which is a macroeconomic management agency under the State Council. The NDRC studies and formulates policies for economic and social development, maintains a balance of economic aggregates, and oversees the overall economic system.

One of NDRC's roles is to coordinate China's forward strategy and policy implementation in the energy and environmental fields. NDRC's missions in these fields are as follows:

- Advancement of China's sustainable development strategy;
- Research and preparation of drafts on the comprehensive utilization and conservation of resources;
- The establishment and coordination China's ecology rebuilding plan;
- Policy creation for the comprehensive utilization and conservation of resources;
- Coordination of the environmental protection industry.

The Energy Bureau of the NDRC is responsible for studying energy development and utilization both at home and abroad and putting forward energy development strategies and major policies; formulating development plans and making recommendations on energy sector reform; administering oil, natural gas, coal, power, and other parts of the energy sector and national oil reserves; and formulating policy measures for energy conservation and renewable energy development.

The NDRC coordinates its activities with other governmental agencies as follows:

Ministry of Commerce (MOFCOM):

- Is in charge of domestic and international trade and economic cooperation;
- Formulates policies and regulations for standardizing market operation and circulation order;
- Promotes the establishment and improvement of the market system; deepens the reform of the circulation system;
- Monitors and analyzes market operation, commodity supply and demand, and conducts international economic operation;
- Coordinates state support matters; investigates the harm that subsidies and other government interventions can bring to industries.

Ministry of Environmental Protection (MEP):

- Is in charge of natural ecological conservation and environmental pollution prevention;
- Strengthens supervision on nuclear safety; enforces environmental regulations;
- Improves supervision and administration;
- Safeguards the environmental rights and interests of the public; promotes the sustainable development of the society, economy, and environment.

Ministry of Science and Technology (MOST):

- Proposes macro-strategy for scientific and technological development, including policies, guidelines, and regulations for promoting economic and social development in line with science and technology;
- Studies major issues of promoting economic and social development with science and technology;
- Formulates plans and priority areas for scientific and technological development;
- Promotes national science and technology development, including capacity building and compiling annual plans for the development of civil-use science and technology;
- Proposes policies, guidelines, and measures to adapt science and technology system to the socialist market economy.

Ministry of Land and Resources

- Investigates and plans management, protection, and rational utilization of such natural resources as land, mineral reserves, and marine resources;
- Drafts related laws, policies, and regulations on the management, protection, and utilization of such natural resources;
- Formulates technical standards, specifications, and methods for the management of such resources;
- Compiles and implements national plans for land use;
- Supervises land resource administrative departments in enforcing laws and plans on land, mineral, and marine resources; oversees protection of land owner rights as well as settling disputes;
- Manages the State Oceanic Administration and State Bureau of Mapping and Surveying.

Ministry of Construction

- Formulates policies, guidelines, regulations, and related development strategies, as well as long- and medium-term plans, for urban planning, village and town planning, engineering construction, urban construction, village and town construction, the construction and building industry, and the housing and real estate industry;
- Consults with industry on survey and design; oversees the undertakings of urban utilities; and conducts industrial administration;
- Provides guidance for the planning of cities, villages, and towns; urban surveying; and municipal engineering surveying;
- Standardizes the building market; supervises engineering bidding; and oversees engineering quality and safety.

Ministry of Transportation

- Formulates development strategies, policies, guidelines, regulations, and long- and medium-term development plans for highway and waterway industries; supervises their implementation;
- Oversees data analysis and information synthesis of the transport industry; controls the transportation of the country's key materials, cargo, and passengers; and organizes construction of key national highways and waterway transportation;
- Guides the reform of the transportation system; maintains fair competition in the highway and waterway transportation industry;
- Formulates scientific and technological policies, technical standards, and specifications for the transport industry; promotes the technical progress of the transport industry.

Ministry of Water Resources

- Formulates water-related policies, legislation, development strategies, and medium- and long-term development plans, including water conservation and demand management policies;
- Ensures integrated management of water resources, including atmospheric water, surface water, and groundwater;
- Formulates water resource protection plans in accordance with related national laws, regulations, and standards concerning resource and environment protection;
- Formulates economic regulatory measures for the water sector; conducts macro-economic regulation of the utilization of funds within the water industry; and provides recommendations on water pricing, taxation, credit, and financial affairs;
- Reviews proposals and feasibility study reports on large- and medium-sized capital construction projects in the water sector;
- Drafts and maintains technical standards for the water sector as well as specifications and codes for water works;
- Organizes the protection of hydraulic facilities, water areas, dykes, and coast lines and the regulation, reclamation, and development of major water bodies;
- Guides activities related to rural water resources;
- Organizes water and soil conservation nationwide.

Ministry of Finance

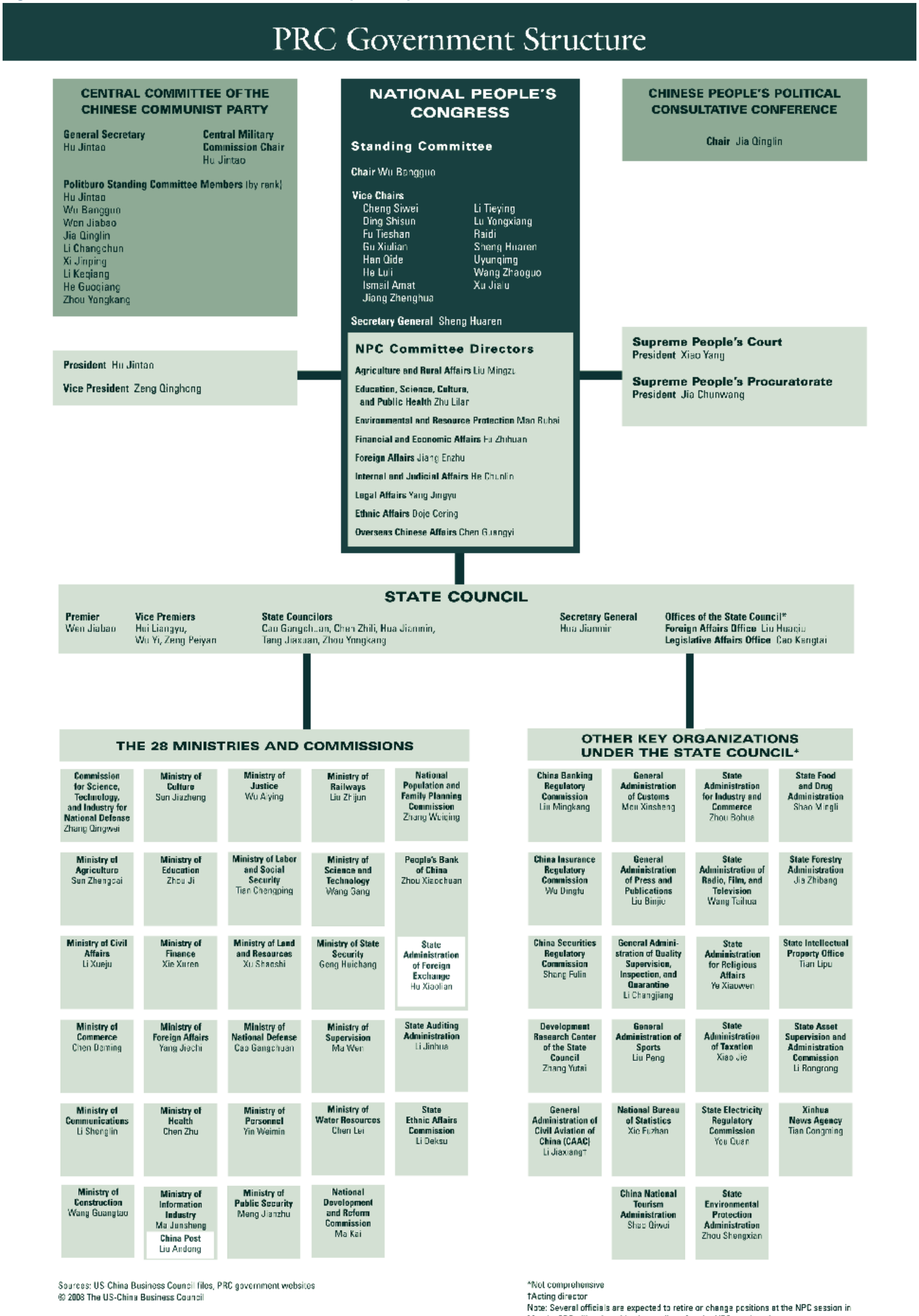
- Formulates strategies, policies, guidelines, medium- and long-term development plans, and reform programs for public finance and taxation; participates in macroeconomic policy making;
- Drafts laws and regulations on public finance and financial and accounting management; organizes negotiations concerning external finance and debts; and signs related agreements/accords;
- Prepares the draft annual budget of the central government and its final accounts; organizes budget implementation;
- Proposes tax legislation plans; reviews proposals on tax legislation and tax collection regulations with the State Tax Administration before reporting to the State Council;
- Administers the central expenditures; formulates government procurement policies; and manages the budgetary non-trade-related foreign exchange of government agencies;
- Supervises central government expenditures for economic development, the appropriation of funds for central government financed projects, and funds for technological innovation and new product testing;
- Monitors the implementation of fiscal and tax policies, laws, and regulations.

Figure 1.28 below displays the organizational structure of the Chinese Government.

Contact Information of Main National-Level Decision-making Authorities in Clean Energy Technology

Table 1.29 below provides the contact information for key personnel in the clean energy technology sector in China.

Figure 1.28: Government Structure of the People's Republic of China[72]



Local-level Decision-making Authorities and Procedure

In accordance with the existing administrative divisions of the country, there are People's Congresses in the provinces (autonomous regions and municipalities directly under the Central Government), counties (cities), and townships (towns), and those at or above the county level have standing committees. There is government representation at all levels.

Local People's Congresses are the local organs of state power. They have the power to decide on important local affairs in their respective administrative areas. The People's Congresses of provinces, autonomous regions, and municipalities directly under the Central Government have the power to formulate local laws and regulations.

Local people's governments are local administrative organs of the state. Working under the unified leadership of the State Council, they report on their work to the People's Congresses at the corresponding levels and their standing committees and to the organs of state administration at the next highest level. They have overall responsibility for the administrative work within their respective administrative areas.[73]

There are altogether 23 provinces, five autonomous regions, and four municipalities (the last group includes Beijing, Shanghai, Tianjin, and Chongqing) under direct central government control, as well as two special Administrative Regions (Hong Kong and Macau).

Table 1.29: Contact Information for Key Personnel in China's CET Sector

National Development and Reform Commission	38 South Yuetan Street, Beijing, 100824	+86 10 6850 2872	Minister: Ma Kai	*www.sdpc.gov.cn*	*ndrc@ndrc.gov.cn*
Ministry of Commerce	2 Dong Chang An Street, Beijing 100731	+86 10 6512 1919	Minister: Chen Deming	*www.mofcom.gov.cn/*	*http://gzly.mofcom.gov.cn/website/pubmail/send_mail_en.jsp*
State Environmental Protection Administration	115 Nan Xiao Street, Xi Zhi Men Nei, Beijing, 100035	+86 10 6711 6801	Minister: Zhou Shengxian	*http://english.sepa.gov.cn/*	*mailbox@sepa.gov.cn*
Ministry of Science and Technology	15 B Fuxing Road, Beijing	+86 10 5888 1521, 5888 1527	Minister: Wan Gang	*www.most.gov.cn/eng/index.htm*	*http://appweblogic.most.gov.cn/eng/guestbook/guestbook.htm*
Ministry of Land and Resources	No. 64 Funei Street,100812 Beijng,China	+86 10 6655 8407/08/20	Minister: Xu Shaoshi	*www.mlr.gov.cn*	*www.mlr.gov.cn/hdpt/zxpt/*
Ministry of Construction	No. 9 Sanlihe Lu, Xicheng District, Beijing, 100835	+86 10 6839 4114	Minister: Wang Guangtao	*www.cin.gov.cn/*	*cin@mail.cin.gov.cn*
Ministry of Communication	11 Jianguomennei Dajie, Dongcheng District, Beijing 100736	+86 10 6529 2114	Minister: Li Shenglin	*www.moc.gov.cn*	*jtbweb@moc.gov.cn*
Ministry of Water Resources	No. 2 Tiao Baiguang Road, Beijing, 100053	+86 10 6320 2114	Minister: Chen Lei	*www.mwr.gov.cn*	*webmaster@mwr.gov.cn*
Ministry of Finance	3 Nansanxiang Sanlihe, Beijing 100820	+86 10 6855 1114	Minister: Xie Xu	*/www.mof.gov.cn/*	*webmaster@mof.gov.cn*

Annex 3. Guidance Catalogue of the Renewable Energy Industry [74]

SERIAL NUMBER	PROJECT	INSTRUCTION AND TECHNICAL INDICATOR	STATUS QUO OF DEVELOPMENT
I. Wind energy			
Wind energy power generation			
1	Off-grid wind power generation	It is used for rural electrification where the grid fails to cover, including two kinds of electricity generation/ supply, individual household plant and concentrated village plant.	Basic commercialization
2	On-grid wind power generation	It is used for grid-connected electrification, including land and offshore network-forming wind power electricity generation, which can generate electricity through single machine networking and multi-machines networking electricity generation.	Land networking wind power electricity generation: offshore networking electricity generation; technological research and development
Equipment/fitting manufacture			
3	Wind resources evaluation and analysis software	It is used for undertaking technological and economic evaluation upon regional wind energy resources so as to select the correct wind field. Its main functions include: measurement of treatment and statistical analysis of wind, formation of wind map, wind resource evaluation, wind generating set and annual electricity yield by wind field and etc.	Technology research, development or introduction
4	Wind field design and optimization software	It is used for optimized design of electricity field (i.e. micro-location selection and arrangement plan design and optimization of wind generating set). Its main functions include: confirming the influence of wake flow of wind generating set and adjusting the distributing distance between wind generating sets, undertaking analysis and prediction upon noise of wind generating set and wind field, eliminating the section failing to meet the requirement of technology, land quality and environment; optimizing the location-selection of wind generating set automatically, providing visualized interface of the design process, undertaking technical and economic analysis and etc.	Technology research and development
5	Wind concentrated and remote monitoring system	It is used for concentrated and remote monitoring of wind generating set and wind field operation. Its main functions include: timely collecting, analyzing and reporting the wind situation and set and supervision data of wind field operation by means of modern information and communication technology, undertaking efficiency optimization and safety guarantee system automatically or via the feedback of instruction.	Technology research and development
6	Construction of wind field and maintenance of exclusive equipment	It is used for transport of land and offshore wind generating set, on-the-spot lift and maintenance.	Technology research and development
7	Off-grid wind turbines generating system	It is used for independent system and concentrated village electricity generation, including wind power independent electricity generation and wind-solar photovoltaic hybrid generate electricity system to ensure its system safety, economic and continuous and reliable electricity supply.	Basically commercialized

SERIAL NUMBER	PROJECT	INSTRUCTION AND TECHNICAL INDICATOR	STATUS QUO OF DEVELOPMENT
8	Wind power generating set of network-forming	It is used for networking wind power generation, including land and offshore generating set. Offshore wind generating set shall be adapted to oceanic geology, hydrologic condition and climate.	Land wind generating set: above-sea wind generating set of the primary stage of commercialization; technology research and development
9	Total design software of wind generating set	It is used for the total design of structural dynamics modeling and analysis, limit load and fatigue load calculation, and win generating set dynamic emulation.	Technology research, development or introduction
10	Wind mill blade	It is used for supporting large scale wind mill set with its capacity no less than 1,000 kw.	Technology research and development
11	Wind mill blade design software	It is used for designing large scale Wind mill blade pneumatic shape and its construction technique	Technology research and development
12	Wind mill blade material	It is used for manufacturing of high strength, low-mass, large-volume blade, including GRP and carbon fiber reinforced plastics	Technology research and development
13	Wind mill wheel hub	It is used for supporting wind generating set with its capacity no less than 1,000 kw.	Technology research and development
14	Wind mill driving system	It is used for supporting wind generating set with its capacity no less than 1,000 kw.	Technology research and development
15	Wind mill deviation system	It is used for supporting wind generating set with its capacity no less than 1,000 kw.	Technology research and development
16	Wind mill braking system / mechanic braking	It is used for supporting wind generating set with its capacity no less than 1,000 kw.	Technology research and development
17	Wind mill generator	It is used for supporting wind generating set with its capacity no less than 1,000 kw, including double- fed generator and permanent magnet generator.	At the beginning of commercialization, technology research and development (permanent magnet generator)
18	Wind generating operation control system and converter	It is used for supporting wind generating set with its capacity no less than 1,000 kw, including: off-grid wind generating controller; speed-loss wind generating controller; variable-speed constant-frequency wind-power generating controller and converter.	Technology research and development
19	Wind mill generating set safety guarantee system	It is used for ensuring the safety of wind generating set on occasion of extreme weather, system failure and grid failure	Technology research and development
20	Testing equipment for compatibility between electricity and magnet in wind mill generating set, lighting impulse	It is used for testing the compatibility between electricity and magnet in wind mill generating set and lighting impulse in order to make the set adaptable to natural environment.	Technology research and development
21	Design of Integration between Wind Power and Power Grid and grid stability analysis software	It is used for evaluating the large-scale wind field integration system and stability of the grid	Technology research and development
22	Wind field electricity generating capacity prediction and grid scheduling and matching software	It is used for monitoring and collecting information about the performance and generating capacity upon the wind generating capacity, analyzing and estimating the variation of the wind field in the second day and its generating output, making scheduling plan for grid enterprise and promoting large-scale wind field development and operation.	Technology research and development

SERIAL NUMBER	PROJECT	INSTRUCTION AND TECHNICAL INDICATOR	STATUS QUO OF DEVELOPMENT
23	Wind field smooth transition and controlling system	It is used for providing support for the smooth transition of large-scale wind field in case of grid integration failure.	Technology research and development
II. Solar energy			
Utilization of solar energy and heat utilization			
24	Off-grid solar energy photovoltaic electricity generation	It is used for supplying electricity to the resident area where the grid fails to cover, including independent household system and concentrated village.	Basic commercialization
25	Networking solar energy photovoltaic electricity generation	It is used for supplying grid with electricity, including building integrated solar energy photovoltaic electricity generation	Technology research and development and project model
26	Solar energy for electricity generation	It is used for supplying electricity to the resident area where the grid fails to cover, including tower solar energy electricity generator, trough-shaped solar energy electricity generator, disk-shaped solar energy electricity generator and instant focal solar energy electricity generator	Technology development
27	Industrial photovoltaic electricity resources	It is used for supplying electricity to scattered meteorological station, seismic station, highway station, broadcast and television, satellite ground station, hydrometry, solar energy navigation mark, highway and railway signal and solar energy cathodic protection system.	Commercialization
28	Solar energy lighting system	Including solar energy street lamp, yard lamp, lawn lamp, billboard, solar energy LED cityscape lamp and etc.	Commercialization
29	Solar energy vehicle	Including: solar energy-driven automobile, solar energy motor-assisted bicycle and etc.	Technology research and development, project model
30	Solar energy photovoltaic sea water desalination system	It is used for providing fresh water to remote island resident area where fresh water is in scarcity.	Technology research and development, project model
31	Photovoltaic Pump	It is used for providing fresh water to the western drought-hit area, and remote and population-scattered area, to the construction and amelioration of grassland and reforestation in the desert.	Commercialization
32	Solar energy water heater for household	It is used for providing life heat water to the residents, including flat-type solar energy water heater, vacuum solar energy water heater and etc.	Commercialization
33	Solar energy concentrated heating system	It is used for providing heat water or heating to the residents or industry and commerce, including solar energy concentrated	Technology research and development, extension and application
34	Solar energy air-conditioner system	It is used for realizing heat and cold convertibility and providing cooling and air-conditioner service (via solar energy collector and absorption refrigerating machine.	Technology research and development and model project
35	Zero solar energy building complex	It is used for meeting the demand of energy in building via integrating solar energy collector(realizing solar energy collecting system and air-conditioner system) in the building(roof and external wall) and solar energy photovoltaic Cell.	Technology research and development
Equipment/ outfit manufacture			
36	Off-grid solar energy photovoltaic electricity generating system	It is used in independent household system and concentrated village plant	Commercialization
37	Networking solar energy photovoltaic electricity generating system	It is used for supplying energy to grid, including building integrated solar energy photovoltaic electricity generating system.	Technology research and development, project model

SERIAL NUMBER	PROJECT	INSTRUCTION AND TECHNICAL INDICATOR	STATUS QUO OF DEVELOPMENT
38	Solar energy electricity generating system	Including: tower solar energy light and heat electricity generating system, trough-shaped solar energy light and heat electricity generating system, disk-shaped solar energy light and heat electricity generating system and instant focal solar energy generating system.	Technology development
39	Crystal silicon solar energy cell	Including: Single crystal silicon solar energy cell and multi-crystal silicon solar energy cell	Commercialization and technology amelioration
40	Membrane solar energy cell	Including: multi-junction amorphous thin-film solar cell, polycrystalline thin-film solar energy cell, compound thin-film solar energy cell	Technology research and development
41	Other new type solar energy cell	Including: flexible underlay solar energy cell, spot light solar energy cell, HIT heterojunction solar energy cell, organic solar energy cell, nanometer noncrystal solar energy cell, mechanic stacking solar energy cell, thin-film noncrystal silicon/minicrystal stacking solar energy cell and etc.	Technology research and development
42	Architectural solar energy arrays	It is used in architectural integrated solar energy photovoltaic electricity generating system, including semi-translucidus photovoltaic electricity generating system, photovoltaic that can be interchanged with building units, photovoltaic glass curtain wall, photovoltaic sun-shield and etc.	Technology research and development
43	Solar energy cell and its component parts manufacture equipment	It is used for manufacturing solar energy cell and its component parts, including: solar energy silicon furnace charge outfit manufacture, multicrystal ingot casting, wire cutting machine, saw squarer, silicon slice polishing equipment, silicon slice cleaner, diffusion equipment, PECVD, hard coat equipment, screen printing, drying and sinter equipment, wafer scriber, automatic welding, component part layer press and etc.	Technology research and development or introduction
44	Solar energy cell test equipment	Including: solar energy cell separation equipment, solar analog meter, high voltage insulation test equipment and etc.	Technology research and development
45	Solar cell auxiliary material for production use	Including: low low-iron toughened glass, EVA, solar cell back packaging composite membrane, silver plasm and aluminum plasm, weld and etc.	Technology research and development
46	Photovoltaic electricity generating system, controller of electricity use and discharging	It is used for controlling intellectually the process of electricity charging and discharging	Technology research and development
47	Ac/dc inverter for photovoltaic electricity generating system,	It is used for off-grid and networking ac/dc inverter, the latter needs the function of networking invert, maximum power tracking, protection for the prevention of island effect and etc.	Technology research and development
48	Household photovoltaic and wind/light complementary control/inverter	It is used for photovoltaic and wind/light complementary electricity generating system with its volume less than 1 kw.	Technology research and development
49	(exclusive)storage cell	It is used for independent photovoltaic and wind electricity generating system, with the endurance capacity for excessive charging and discharging performance and long service life.	Technology research and development

50	Redox liquid storage cell	It is used in independent photovoltaic electricity generation and wind power electricity generation system; its storage capacity shall reach one hundred megawatts when its power is ranged from dozes to several hundred kw.	Technology research and development and project model
SERIAL NUMBER	**PROJECT**	**INSTRUCTION AND TECHNICAL INDICATOR**	**STATUS QUO OF DEVELOPMENT**
51	Photovoltaic silicon material	It is used for the production of solar cell crystal silicon.	Technology research and development or introduction
52	Concentrated and remote control system for the use of photovoltaic electricity generating system	It is used in the operation data in collecting, transmitting solar radiation, environmental parameters and photovoltaic electricity generation and realizing concentrated or remote control monitoring.	Technology research and development
53	Reflector for the use of solar energy heat and light electricity generation	It is used for supporting various solar energy light and heat electricity generating system.	Technology research and development
54	Automatic tracking equipment for light and heat generating reflector	It is used for supporting various solar energy light and heat electricity generating system so as to automatically track solar radiation, adjust the angle of the reflector and absorb the maximum solar energy.	Technology research and development
55	Light and heat collector	It is used for supporting various solar energy light and heat electricity generating system to absorb solar radiation from the reflector, i.e. "solar boiler" within small volume and high conversion efficiency.	Technology research and development
56	Light and heat electricity generating and heat storage equipment	It is used for supporting various solar energy light and heat electricity generating system, ensuring the relative stability of light and heat electricity generation via the heat energy absorbed by the storage collector.	Technology research and development
57	Instant light and heat electricity generating equipment	It is used for supporting instant solar energy light and heat electricity generating system, including alkali metal thermoelectric converter, Semiconductor electricity generator, thermion electricity generator and photovoltaic electricity generator.	Technology research and development
58	Solar energy light and heat system, architectural application design, optimization, measurement and evaluation software.	It is used for the design and emulation of optimized architectural heating equipment geared to the applied solar energy light and heat system in different regions, different lighting conditions in China; for measurement and evaluation upon the solar energy light and heat system used in the processing of building.	Technology research and development and extension and application
III. Biomass energy			
Biomass energy and biological fuel production			
59	Gas supply and electricity generation by large and medium-sized methane project	Including large scale livestock and poultry farm, Breeding area, urban sewage project	Commercialization, extension and application
60	Instant Electricity by Biomass fuel	Electricity generation by utilizing crop straw, and wood	Technology update and project model
61	Biomass liquefied gas supply and electricity generation	Liquefied gas supply and electricity generation by utilizing crop straw, and wood	Technology research and development, extension and application
62	Electricity generation by utilizing urban solid refuse	Electricity generation by utilizing urban solid refuse, including fuel and methane.	Basic commercialization

63	Biological liquefied fuel	Production of liquefied fuel by utilizing non-grain crop and wood biomass.	Technology research and development
64	Biomass solid fuel	Transforming crop straw and wood to solid fuel as the alternative of coal.	Project model
SERIAL NUMBER	**PROJECT**	**INSTRUCTION AND TECHNICAL INDICATOR**	**STATUS QUO OF DEVELOPMENT**
Equipment/ component parts manufacture and raw material production			
65	Biomass direct-fired boiler	It is used for supporting biomass direct-fired boiler system, for which technological performance and specification shall be used.	Technology update
66	Biomass fuel gas combustion engine	It is used for supporting electricity generation via liquefied biomass. Its performance and specification shall be used in liquefied biomass electricity generation system.	Technology research and development
67	Liquefied biomass tar catalyzing and cracking equipment	It is used for cracking tar arisen in the process of gasification to available and disposable gas.	Technology research and development
68	Liquefied biomass fuel production outfit	It is used for producing the aforesaid various liquefied biomass fuel.	Technology research and development and project model
69	Plantation of energy plant	It is used for providing various biological fuel production with non-crop biomass material such as sweet sorghum, cassava, purging-nut tree, sugar cane.	Project model, extension and application
70	Breeding of energy plant	It is used for breeding and cultivating energy crop which boasts stable and high yield and, innocuity to ecological environment and adaptability to barren mountains and waste, sandlot and alkali land.	Technology research and development and project model
71	High-efficiency, wide-range methane strain improvement	It is used for improving the yield of methane project and its usage in relatively low temperature.	Technology research and development
V. Geothermal energy			
Electricity generation by utilizing geothermal energy and heat utilization			
72	Electricity generation by utilizing geothermal energy	Including electricity generation by utilizing geothermal steam, double-circulation geothermal electricity generating system and flash geothermal electricity generating system (the latter two is adaptable to middle and low geothermal resources.	Technology research and development
73	Heat supply by utilizing geothermal energy	Including single circulation direct heating and double-circulation indirect heating.	Project model, extension and application
74	Geothermal source heat pump heating and/or air conditioner	Including underground water source, river and lake water source, sea water source, sewage sources (including urban sewage, industrial sewage, hospital sewage)and soil geothermal source heat pump.	Project model
75	Underground thermo energy storage system	The storage types include such energies as solar energy, and the cool and heat set off by air conditioners in the buildings.	Technology research and development
Equipment/outfit manufacture			
76	Drilling equipment exclusively for geothermal well use	It is used for drilling geothermal well, which shall be adapted to its geological structure, high temperature and corrosion hydraulic conditions and the requirement for making the well.	Technology research and development
77	Geothermal well pump	It is used for supporting geothermal heating and geothermal source heat pump system, which shall be adapted to its high temperature and corrosion.	Technology research and development
78	Water source thermal pump assembly	It shall be adapted to the temperature of underground water or sea water as well as their temperature.	Technology research and development and project model

79	Geothermal Energy design, optimization and evaluation system	It is used for undertaking measurement and evaluation upon the building adaptable to the geothermal energy in different regions and with different types.	Technology research and development, extension and application
SERIAL NUMBER	**PROJECT**	**INSTRUCTION AND TECHNICAL INDICATOR**	**STATUS QUO OF DEVELOPMENT**
80	Utilization of water heat source	The temperature difference of water is utilized to cool and heat the building, including utilizing such water sources as underground water, sewage in urban treatment sewage treatment factory.	Project model, extension and application
V. Ocean energy			
Ocean power generation			
81	Ocean power generation	Including: tidal power generation, wave power generation, marine thermoelectric power generation and ocean current power generation.	Technology research and development and project model
Equipment/ outfit manufacture			
82	Ocean power generation outfit	Including: the outfit of wave power generation, marine thermoelectric power generation and ocean current power generation.	Technology research and development
VI. Hydropower			
Waterpower			
83	Networking Waterpower	Various waterpower in line with the requirement of watershed development, and environmental protection	Commercialization
84	Small-scale off-grid waterpower	It is used for electricity and energy usage in in-place development, neighborhood electricity supply and solving the problems in remote area for electricity and energy use.	Commercialization
Equipment/outfit manufacture			
85	Water turbine-typed spectrum	It is used for manufacture and type selection of water turbine, improvement of the efficiency and quality of water turbine, reduction of construction cost and standardization of the equipment market.	Technology research and development
86	Automatic hydroelectric technology	It is used for the automatic management of hydroelectric operation, the improvement of its performance and the reduction of its operational cost.	Technology update
87	Large-scale and high-efficiency water turbine generating set	It is used for improving the capacity, performance and efficiency of water turbine generating set.	Technology research and development
88	Integration technology of small plant	It is used in small waterpower with its capacity less than 1,000 kw for realizing the control and integration of such auxiliary equipments as petroleum, water and gas and such supervision integration as speed regulation, excitation, protection and measurement, improving its credibility and reducing its equipment construction cost.	Technology update

Section 2: Clean Energy Technologies Defined

This report covers clean energy technologies (CETs) including renewable energy technologies, energy efficiency, hybrids and cogeneration, and clean transportation technologies. CETs are more environmentally friendly than traditional, fossil fuel-based technologies. CETs can either use natural resources such as sunlight, wind, rain, tides, geothermal heat, and plants, which are naturally replenished, and/or use processes to use energy more efficiently.

CETs include renewable energy, hybrid and cogeneration, and energy efficiency technologies for power generation and alternative fuels and advanced technologies for transportation. This chapter presents an overview of these technologies.

Renewable Energy Technologies

Renewable energy technologies considered in this report include biomass and biofuels, waste-to-energy, solar power, wind power, geothermal, hydropower, and ocean power.

Biomass

Biomass consists of plant and plant-derived material. Sources of biomass include agricultural residues such as rice hulls, straw, bagasse from sugarcane production, wood chips, and coconut shells and energy crops such as sugarcane or switch grass. Biomass can be used directly for energy production or processed into fuels. Examples of biomass fuels are liquid and gel fuels including oil and alcohol and pelletized biomass for gasification and combustion. Liquid biomass–derived fuels can be used as substitutes for or additives to fossil fuels.

Although the conversion of biomass into energy results in the release of carbon into the atmosphere, biomass-based energy is considered to be carbon neutral because of the carbon sequestered by plants during the growth of the biomass material. For biomass resources to be renewable, their cultivation must be managed carefully to ensure sustainable harvesting and land use. The use of biomass for energy production can result in competition with food crops, either directly, when food crops themselves are used for energy production, or indirectly, when land and water that would be used to grow crops is used instead for energy crops.

Biomass technologies include equipment for industrial processes that produce heat and steam; electrical power generation through combustion, liquefaction, or gasification; and transportation fuels such as ethanol and biodiesel. Biomass is converted into energy through one of two pathways: thermochemical and biochemical. Thermochemical conversion occurs by combustion, gasification, or pyrolysis. Biochemical conversion results from anaerobic digestion or fermentation. The energy products produced from these biomass conversion processes are electricity, heat, and biofuels.

TEXTBOX 2.1: BIOMASS ENERGY RESOURCES.

Solid biomass: Wood, vegetal waste (including wood waste and crops), conventional crops (oil and starch crops), charcoal, animal wastes, and other wastes (including the biodegradable fraction of municipal solid wastes) used for energy production.

Liquid biofuels: Biodiesel and bioethanol (also includes biomethanol, bio-oil, and biodimethylether).

A) Biodiesel: Biodiesel can be used in pure form or may be blended with petroleum diesel at any concentration for use in most modern diesel engines. Biodiesel can be produced from a variety of feedstocks, such as oil feedstock (rapeseed, soybean oils, jatropha, palm oil, hemp, algae, canola, flax, and mustard), animal fats, or waste vegetable oil.

B) Bioethanol: The largest single use of ethanol is as a fuel for transportation or as a fuel additive. It can be produced from a variety of feedstocks such as sugarcane, corn, and sugar beet. It can also be produced from cassava, sweet sorghum, sunflower, potatoes, and hemp or cotton seeds or derived from cellulose waste.

Biogas: Methane and carbon dioxide produced by anaerobic digestion or fermentation of biomass, such as landfill gas and digester gas.

Combustion

Direct combustion is a widely used process where biomass is converted into useful power through exposure to high temperatures. Heat from the process can be used to produce steam, which in turn can drive a turbine to generate electricity. Depending on the combustion process, various pre-treatment steps such as sizing (shredding, crushing, and chipping) and drying are required. The heating value and moisture content of the biomass determine the efficiency of the combustion process. Drying prior to the combustion process (e.g., with waste heat) helps to lower the moisture content and raise the heating value to acceptable levels.

Gasification

In the gasification process, biomass is thermochemically converted into gaseous fuel by means of partial oxidation of the biomass at high temperatures. This process requires less oxygen than combustion. In addition to the gaseous fuel, gasifiers produce heat and ash. To maximize the efficiency of gasification-based systems, beneficial uses should be developed for all three products.

The main processes of a gasification plant are fuel feeding, gasification, and gas clean-up. Fuel feeding prepares and introduces the feedstock into the gasifier. The gasifier converts the feedstock into a fuel gas containing carbon monoxide, hydrogen, and methane. In the gas clean-up process, harmful impurities are removed from the fuel gas to allow for safe usage in gas-burning engines or turbines.

Pyrolysis

Pyrolysis is also a thermochemical conversion process that converts biomass into liquid, solid, and gaseous substances by heating the biomass to about 500 degrees Celsius in the absence of air. The pyrolysis process includes feedstock preparation and the application of liquid and char for heat production. Alternative technologies include rapid thermal processing and the vacuum pyrolysis process. The latter involves the thermal decomposition of matter under reduced pressure for conversion into fuels and chemicals. Fast pyrolysis refers to the rapid heating of biomass in the absence of oxygen. Feedstocks for the pyrolysis process include forestry residue (sawdust, chips, and bark) and by-products from the agricultural industry (bagasse, wheat straw, and rice hulls).

Fermentation

Anaerobic digestion is a type of fermentation that biochemically converts organic material, especially animal waste, into biogas that consists mainly of methane and carbon dioxide and is comparable to landfill gas. The biomass is converted by bacteria under anaerobic conditions—without oxygen present. Biogas plants consist of two components: a digester (or fermentation tank) and a gas holder. The digester is a cube- or cylinder-shaped waterproof container with an inlet into which the fermentable mixture is introduced in the form of liquid slurry.

Fermentation of sugars is a biochemical process that entails the production of ethanol (alcohols) from sugar crops (sugarcane, beet) or starch crops (maize, wheat). The biomass is ground and the starch is converted by enzymes and bacteria into sugars. Yeast then converts the sugars into ethanol. Pure ethanol can be obtained by distillation; the remaining solids can be used as cattle feed. In the case of sugarcane, the remaining bagasse can also be used as fuel for boilers or electricity generation processes. These multiple applications allow ethanol plants to be self-sufficient and even to sell surplus electricity to utilities.

Bioethanol is primarily produced by fermentation of sugarcane or sugar beet. A more complex and expensive process involves producing bioethanol from wood or straw using acid hydrolysis and enzyme fermentation. Production of bioethanol from corn is a fermentation process, but the initial processing of the corn requires either wet or dry milling. Residues from corn milling can be used or sold as animal feed. Bioethanol from wheat requires an initial milling and malting (hydrolysis) process.

Biofuels

As defined by the United Nation's, "there are various pathways to convert feedstock and raw materials into biofuels. First-generation biofuel technologies, such as the fermentation of plant sugars or the transesterification of plant oils, are well established. Second-generation biofuel technologies include, among others, acid hydrolysis of wood chips or straw for bioethanol. The technology for extracting oil from oilseeds has essentially remained the same for the last 10 to 15 years."[75] Biodiesel production is a relatively simple process. However, economic small-scale production of biodiesel still requires sufficient feedstock, some equipment, capital, and skills.

While many of the above conversion processes are accomplished on a large scale, new and emerging technologies make it possible to produce electricity, heat, and fuels on a smaller scale and with modular systems. These technologies are being developed for off-grid applications and at an economic scale suitable for developing countries. An example of a modular biopower system [50 kilowatts electric (kWe)] is pictured above.[76]

Where biomass is produced in conjunction with agriculture for food production, it represents an additional value stream. Biofuels are produced in many countries, albeit in varying quantities and at different costs. Liquid biofuels have the potential to provide communities in developing countries with multiple energy services such as electricity for lighting, small appliances, and battery charging; income generation and educational activities; and pumping water, cooking, and transportation.

Waste-to-Energy

Waste-to-energy technology produces energy from waste, such as waste from a city's municipal waste system, farms and other agricultural operations, or commercial and industrial operations. Large-scale waste-to-energy systems can supply heat or electricity in utility-scale electric power plants or district heating systems. Small-scale systems can provide heating or cooking fuel and electricity to individual farms, homes, and businesses.

In incineration systems, waste is converted into useful energy through combustion. Modern incineration plants include materials separation processes to remove hazardous or recyclable materials from the waste stream before it is incinerated. Improvement in combustion processes and emissions controls minimizes the emission of particulate matter, heavy metals, dioxins, sulfur dioxide, and hydrochloric acid associated with waste combustion. Incineration plants emit fewer air pollutants than coal-fired plants but more than gas-fired plants. While Denmark and Sweden are leaders in the use of incineration technologies for energy generation, other European countries and Japan use the technology as a primary waste-handling system.

Landfill gas systems collect landfill gas for use in boilers, process heaters, turbines, and internal combustion engines, thereby reducing direct emissions of methane and other gases into the atmosphere or displacing the use of fossil fuels for power generation. Landfill gas contains varying amounts of methane and other gases, depending on the type of deposited waste and the characteristics of the landfill. Landfill gas can be piped directly to nearby buildings and used in boilers for heat or industrial processes or used in on-site electric generation plants that can supply electricity to the landfill itself, nearby industries, or to the electric power grid. The amount and type of waste in a landfill, its size, extent of landfill operating activity, and proximity to energy users are all factors that affect a landfill gas project's viability. Environmental precautions to minimize the emission of air pollutants are necessary to meet environmental regulations.

Anaerobic digester systems convert animal and human waste into methane and carbon dioxide, which can be used in turbines and internal combustion engines in electric power plants. Municipal waste treatment plants and confined animal feeding operations can be sources of waste for the digesters. Converting the waste into electricity reduces air and water pollution and the costs associated with processing the waste.

Other new and emerging waste-to-energy technologies use thermal and chemical conversion processes to convert solid waste into fuels.

Solar Power

Solar power is energy from the sun. Solar technologies convert light and heat from the sun into useful energy. Photovoltaic (PV) systems convert sunlight into electricity. Thermal systems collect and store solar heat for air and water heating applications. Concentrating solar power systems concentrate solar energy to drive large-scale electric power plants. Solar power systems produce little or no emissions and have a minimal impact on the environment.

Photovoltaics

PV power systems convert light from the sun into electricity. PV cells are devices made of semiconducting materials similar to those used in computer chips. When these devices are connected to an electrical circuit and exposed to light, they release electrons that flow through the circuit, creating an electric current. PV panels, shown above,[77] are devices that contain a varying number of PV cells and convert sunlight into direct current (DC) electricity. PV panels are typically incorporated into systems that combine batteries and electronic control equipment to provide full-time DC and/or alternating current (AC) power. Typical applications include lighting, electronics, telecommunications, and small-scale water pumping.

Solar Thermal

Solar thermal technology uses flat and concentrating absorbers that collect heat energy from the sun for such processes as crop drying, food processing, water and space heating, industrial process heat, and electricity generation.

Solar water heating systems, such as the ones pictured in China's Yunnan Province,[78] consist of a solar collector and a storage tank. The collector is typically a rectangular box with a transparent cover, through which pipes run, carrying water that is heated by the sun. The pipes are attached to an absorber plate, which is painted black to absorb the heat. As the sun's heat warms the collector, the water is heated and passed to the storage tank, which stores the hot water heated for domestic use. As explained by the National Renewable Energy Laboratories, "Solar water heating systems can be either active or passive. Active systems rely on pumps to move the liquid between the collector and the storage tank, while passive systems rely on gravity and the tendency for water to naturally circulate as it is heated. Simpler versions of this system are used to heat swimming pools."[79]

Solar heating systems to dry food and other crops can improve the quality of the product while reducing waste. Solar driers outclass traditional open-air drying and have lower operating costs than mechanized fuel-based driers. The three types of solar driers are natural convection, forced convection, and tent driers. In natural convection driers, air is drawn through the dryer and heated as it passes through the collector, then partially cooled as it picks up moisture from the product drying. The flow of air is caused by the lighter warm air inside the dryer moving toward the cooler outside air. In forced convection, a fan is used to create the airflow, reducing drying time by a factor of 3 and the area of collector required by up to 50 percent. A photovoltaic panel can be used to generate electricity for the fan. Tent driers combine the drying chamber and collector and allow for a lower initial cost. Drying times are not much lower than for open-air drying, but the main purpose is to provide protection from dust, dirt, rain, wind, and predators; tent driers are usually used for fruit, fish, coffee, or other products for which wastage is otherwise high.

Passive Solar

Passive solar systems integrate solar air heating technologies into a building's design. Buildings are designed with materials that absorb or reflect solar energy to maintain comfortable indoor air temperatures and provide natural daylight. Floors and walls can be designed to absorb and retain heat during warm days and release it during cool evenings. Sunspaces operate like greenhouses and capture solar heat that can be circulated throughout a building. Trombe walls are thick walls that are painted black and made of a material that absorbs heat, which is stored during the day and released at night. Passive solar designs can also cool buildings, using vents, towers, window overhangs, and other approaches to keep buildings cool in warm climates.

Other Solar Technologies

Solar technologies can be used for residential, commercial, and industrial applications. Commercial and industrial applications can include air preheating for commercial ventilation systems, solar process heating, and solar cooling. A solar ventilation system can preheat the air before it enters a conventional furnace, reducing fuel consumption. Solar process heat systems provide large quantities of hot water or space heating for industrial applications. A typical system includes solar collectors that work with a pump, a heat exchanger, and one or more large storage tanks. Heat from a solar collector can also be used for commercial and industrial cooling of buildings, much like an air conditioner but with more complex technology.

Concentrated solar power systems focus sunlight on collectors that serve as a heat source to produce steam that drives a turbine and electricity generator. Concentrating solar power systems include parabolic-trough, dish-engine, and power tower technologies. Parabolic-trough systems concentrate the sun's energy through long rectangular, u-shaped mirrors, which are tilted toward the sun and focus sunlight on a pipe, heating the oil in the pipe and then using it in a conventional steam generator to produce electricity. Dish-engine systems use a mirrored dish similar to a satellite dish, which collects and concentrates the sun's heat onto a receiver, which in turn absorbs the heat and transfers it to fluid within the engine. The heat causes the fluid to expand against a piston or turbine to produce mechanical power, which is then used to run a generator to produce electricity. Power tower systems use a large field of mirrors to concentrate sunlight onto the top of a tower, where molten salt is heated and flows through a receiver. The salt's heat is used to generate electricity through a conventional steam generator. Because molten salt efficiently retains heat, it can be stored for days before being converted into electricity and ensures power production on cloudy days and after the sun has set.

Wind Power

Wind power technology converts energy in the wind into useful power. Historically, wind power technology was used for mechanical applications such as grain milling and water pumping and is still used for such purposes. Today, the primary market for wind power technology is for wind turbines, which convert wind energy into electricity.

Wind power for electricity generation is the fastest growing segment of the power sector, driven by the low cost of electricity generation, short project development and construction times, and government policies favoring clean and renewable energy technologies. The world's approximately 74,000 megawatts (MW) of installed wind capacity meet about 1 percent of the total global electricity demand. In the United States, as of December 2007, total installed wind capacity was approximately 14,000 MW, with an additional 5.7 MW under construction. Wind power accounts for about 20 percent of Denmark's electricity production, 9 percent of Spain's, and 7 percent of Germany's.

According to a recent study,[80] India and China alone are expected to add 36,000 MW of wind power capacity by 2015, representing over 80 percent of the Asian wind market during that period. Market growth in those countries is being driven by the growth of independent power producers (IPP) in India and by electric utilities in China. Major wind turbine manufacturers, including Vestas, GE, Suzlon, Gamesa, and Nordex, are establishing manufacturing facilities in India and China on the basis of strong market growth for their products in those countries. Suzlon, an Indian wind manufacturing company, is also active in the global wind market, including Europe and North America, as both an equipment supplier and project developer.

Large wind power generating plants, often called wind farms, can be integrated into agricultural and other land uses; a wind farm in Hawaii is shown at right.[81] Wind farms typically use tens to hundreds of wind turbines rated between 600 kilowatts (kW) and 5 MW and produce between 50 and hundreds of megawatts of electric power. In some countries, especially Denmark, Germany, and the United Kingdom, interest in offshore projects is increasing. In these projects, turbines are installed in the shallow waters of coastal areas, where they are exposed to the strong prevailing coastal winds and can be located close to large load centers.

Medium-sized turbines, between 10 and 600 kW, are used in distributed energy applications, supplementing or replacing grid power on farms and other commercial or industrial sites. Small wind turbines, in the 100 watt (W) to 10 kW range, are suitable for household, water pumping, or village power applications.

Conventional horizontal-axis wind turbines for electricity generation consist of a rotor, nacelle, tower, and foundation. The rotor consists of wind-spun blades that drive a gearbox and electric generator in the nacelle, which is located at the top of the tower. (Some turbine designs do not include a gearbox.) The tower and foundation support the nacelle and rotor at a height above the ground where winds are strong. Other wind turbine designs include vertical-axis turbines and small turbines designed for urban use.

Geothermal

Geothermal power is generated using thermal energy from underground sources. Different technologies are used to generate electricity using geothermal resources, which include steam, hot water, and heat stored in rock formations. Dry steam power plants use geothermal steam directly to drive a turbine and electric generator. Water condensed from the process is pumped underground and turned back into steam. Flash steam plants generate power by releasing hot water from underground pressurized reservoirs to drive turbines in an electric power plant. Both types of steam power plants release small amounts of gases and steam into the atmosphere.

Binary-cycle plants have no gas emissions and operate by passing hot water from a geothermal source through a heat exchanger, where heat from the water is transferred into a fluid that drives a turbine for electricity generation. Binary-cycle plants are more efficient than dry steam or flash steam systems and are the preferred technology for projects currently in the planning phase.

Geothermal energy was first used for electric power in Italy in the early 18th century. Geothermal resources are found worldwide in areas where geothermal energy is accessible at shallow levels. Areas with usable geothermal resources include the western United States, the southwestern coast of South America, a few areas in Europe and East Africa, and a significant portion of the Asia–Pacific region. New developments in geothermal power technology will use heat from hot, dry rock formations in and beneath the earth's crust.

Hydropower

Hydropower is the conversion of energy embodied in moving water into useful power. People have been harnessing the power of water for thousands of years for irrigation and operation of mechanical equipment and more recently for electricity generation. In fact, hydroelectric power now supplies about 19 percent of the world's electricity. In the United States, hydropower accounts for only 7 percent of the total electricity production, but over 70 percent of the total installed renewable energy capacity. Most industrialized nations have developed their hydropower potential, but undeveloped resources remain in countries such as China, India, Brazil, and regions of Africa and Latin America. In some countries with access to large untapped hydro resources, the resources are located far from electric load centers, posing a problem for transmission of electricity over long distances. Solving this technological problem and providing efficient transmission of electric power from off-grid hydropower plants is a major opportunity for investment and leadership in many countries around the world.

Hydropower plants are a clean, emission-free source of electricity. The natural hydrological cycle replenishes the resource, but also making it vulnerable to droughts. Competition for scarce water resources for agriculture, recreation, and fishing can affect the availability of water for power production. However, the potential for small hydro project development for rural electrification remains high in countries with concentrations of rural populations living near rivers and streams.

Large hydropower plants with capacities in the tens of megawatts are typically impoundment systems and require a dam that stops or reduces a river's flow to store water in a reservoir. Penstocks carry water from the reservoir to water turbines, which in turn drive electric generators. Impoundment systems offer the advantage of controlled power output and other benefits such as water recreation associated with reservoirs, irrigation, and flood control. However, dams negatively impact fish populations by interfering with migration patterns. Water quality both in the reservoir and downstream of the dam can be affected by changes in water flow and dissolved oxygen levels. Large new hydropower projects often require planning to remove communities from areas that will be flooded after a dam is built and other measures to manage environmental impact. Recent research has also raised concern about the possible effect of large reservoirs on atmospheric concentrations of greenhouse.

Small hydropower plants, such as the one shown at right,[82] with capacities ranging from a few kilowatts to several megawatts, are typically diversion systems, which divert some water from a river through a canal or penstock to a turbine. Small hydropower plants can provide electricity for isolated rural populations. These systems range in size from household-sized systems to ones that can supply power to entire villages and commercial or industrial loads. Diversion systems, also called run-of-river systems, do not require dams or reservoirs, are suitable for small hydropower projects, and have less impact on the environment. Small hydropower projects are being aggressively developed as part of rural electrification programs; in some cases innovative financing approaches are used in countries such as India, Sri Lanka, and Nepal.

Pumped storage systems require two reservoirs at different heights. They pump water during periods of low electric demand between the two heights and release water from the upper reservoir during periods of high demand.

Ocean Power Technology

Ocean power technology makes use of energy embodied in the ocean by converting it into electricity. Some systems convert the energy in moving ocean water into electricity, using either the vertical motion of waves or the horizontal motion of ocean currents. Other systems use temperature differences at different levels of the ocean to generate electricity. Ocean power technology is in the research and development stage, with several commercial prototypes being tested.

Tidal power technology converts the energy in tidal motion caused by the gravitational forces of the sun and moon on ocean water into electricity. Tidal stream systems operate similarly to wind turbines, using tidal turbines to convert energy in ocean currents into a rotational motion to drive turbines and power generators. Like wind turbines, tidal turbines can use horizontal-axis or vertical-axis machines. These systems rely on currents caused by ocean tides moving through and around obstructions such as entrances to bays and other geographical features. Tidal barrage systems are similar to hydropower dams, using differences in height of water on either side of a dam to generate electricity. Barrage systems use a dam-like structure and gates to store and release water as tides cause water levels to rise and fall.

Wave power technology extracts energy from the vertical motion of ocean water caused by waves. Wave power systems can be built offshore, in deep water typically far from coastlines or onshore in shallower water along the coast. Onshore systems show more promise because of their potential proximity to large load centers. Oscillating water column systems use rising and falling water caused by waves to compress and expand an air column in a vertical steel or concrete structure. The oscillating air pressure levels cause a turbine to spin, which drives an electric generator. Tapered channel systems use wave power to fill a raised reservoir with water, which is then allowed to flow through turbines. Pendulor wave systems consist of a rectangular structure with a hinged door that swings with the motion of waves. The swinging door operates a hydraulic pump that drives a turbine.

Ocean thermal energy conversion systems use temperature differences between warm surface water and cool deep water to convert a liquid into gas. The expanding gas drives a steam turbine and electric power generator. Closed-cycle systems circulate warm surface water through a heat exchanger where a fluid with a low boiling point is vaporized. A second heat exchanger condenses the vapor using cool deep water. Open-cycle systems use ocean water itself as the heat transfer fluid, boiling warm surface water in a low-pressure chamber. Water vapor drives a turbine and is condensed back into liquid using cool deep water. Hybrid systems use a combination of open- and closed-cycle arrangements. A by-product of ocean thermal energy systems is cold water, which can be used in building cooling systems, agriculture, and fisheries applications. Open- and hybrid-cycle systems desalinate ocean water in the vaporization process and could also be a source of fresh water. Ocean thermal energy conversion systems work in areas where the difference between the surface of the ocean and deeper water is about 20 degrees Celsius, which is often the case in tropical coastal areas.

As with other renewable energy technologies, ocean power technology projects are capital intensive, but typically have lower operating costs than fuel-based power technologies.

It should be noted that ocean power systems can impact migration patterns in ocean species and cause other environmentally troubling consequences. Systems employing barrages can cause silt buildup that affects tidewater and coastal ecosystems. These consequences can however be mitigated by careful selection of project sites.

Energy Efficiency

The efficiency of an energy conversion process is the ratio of the useful energy produced by the process to the amount of energy that goes into it. Primary energy is fossil fuel, nuclear, hydroelectric, or renewable energy extracted for use in an energy conversion process. Secondary energy is a high-quality form of energy such as electricity or refined fuel that can be used to provide energy services. An energy service is an end use provided by a process or device that requires secondary energy. Useful energy is the energy that goes toward providing an intended energy service. For example, the light produced by a lighting application is useful energy, whereas the heat produced by the application is not. Energy efficiency can be measured at different points in the process of converting a fuel or other energy resource into an end-use energy service. Efficiency points include the following:

- Extraction efficiency is a measure of the amount of primary energy delivered to a power plant or refinery per unit of energy contained by the energy resource in the ground or atmosphere and required by the extraction process.
- Power plant or refinery conversion efficiency is the ratio of the quantity of secondary energy produced by a power plant, refinery, or other conversion facility to the quantity of primary energy required by the process.
- Transmission and distribution efficiency is the ratio of secondary energy delivered to an end-use facility to the quantity of that energy produced by the power plant or refinery.
- End-use efficiency is a measure of the quantity of useful energy provided by a device or process per unit of energy delivered to the device or process.

Some analyses of energy efficiency also include a measure of the actual need for the energy service. For example, an office building that provides lighting for an unoccupied room or a factory that runs electric machines after the needed process is complete would be less efficient than a building equipped with motion sensors that provide lights only when people are in a room or a factory that shuts down equipment not being used.

Energy efficiency measures involve replacing existing technologies and processes with new ones that provide equivalent or better energy service using less energy. The value of the saved energy typically covers the cost of deploying the new technologies and processes, especially when the increase efficiency occurs downstream in the conversion process. For example, improving the efficiency of a pumping system in an industrial facility by redesigning the circulation system to minimize friction in pipes will result in the need for a smaller motor to drive pumps, which in turn consumes less energy. The reduced electricity demand will result in reduced losses in the entire chain, from the generation plant through the distribution system.

Energy efficiency results in savings at the time the energy service is provided. Energy service providers can also use load management to change the time that an energy service is delivered in order to reduce peak loads on an energy distribution system. Demand-side management (DSM) uses both load management and energy efficiency to save the amount of primary energy required to deliver the energy service.

Energy savings provide several benefits. For energy consumers, benefits include reduced costs and reduced emissions; for energy service providers, efficiency reduces the need for (and cost of) fuel; and for governments and communities alike, efficiency reduces CO2 emissions and can help meet targets for global warming pollutants. Energy efficiency programs can reduce future investment requirements, enhance competitiveness by lowering input and operating costs, free up capital for other social and economic development priorities, and contribute to environmental stewardship objectives. It can also contribute to long-term resource planning and management, hedge fuel risks, and reduce operation and maintenance (O&M) costs. Energy efficiency programs promote improvement and investment in energy generation, delivery, end-use equipment, facilities, buildings, and infrastructure that increase useful energy output or services.

Combining energy efficiency and renewable energy policies maximizes the impact of energy policy on emission reductions. Reducing growth of energy demand allows low- or no-emission renewables to keep up with electric demand. Without coordination, new renewable capacity would be outstripped by increased demand, requiring increased fossil fuel capacity to meet the growth. A combined policy also takes advantage of the temporal synergy of the two approaches: Energy efficiency programs can meet shorter-term goals because efficiency measures can be implemented quickly and at relatively low cost. Renewable energy programs can meet longer-term goals, with new capacity coming on line as the efficiency programs achieve their goals.

Demand Side Management (DSM) is the practice of changing energy consumption patterns to reduce the need for new energy generation capacity. DSM can include energy efficiency programs, peak load reduction programs, real-time and time-of-use energy pricing, interruptible load tariffs, direct load control, and shifting demand from peak to off-peak periods.

Building codes provide guidelines for the construction industry to achieve energy-saving goals through improvements in lighting, heating, and cooling. Special programs promote the development of zero-energy buildings, which combine energy efficiency with energy production technologies to maximize the amount of a building's energy that it generates on site.

In the transportation sector, vehicle efficiency standards, public transportation programs, and urban planning minimize the consumption of transportation fuels while maintaining adequate levels of transportation services.

Industrial efficiency measures the decrease in energy use and pollution in the industrial sector. Investment in efficient motor and pumping systems, combined heat and power, and distributed on-site energy generation results in long-term energy savings and can help industries compete while meeting environmental regulations.

Energy efficiency measures require capacity-building efforts to empower institutions and individuals to implement energy-saving programs and make energy-saving decisions. Examples of capacity building include establishing energy audit procedures and auditor training programs, developing systems to track energy consumption patterns and establish benchmarks, establishing energy management systems, creating certification systems for energy practitioners, developing energy management guidelines, and facilitating technology transfer.

Hybrids and Co-generation

Hybrid and co-generation power systems take advantage of the benefits of multiple technologies in a single, integrated system. Hybrid power systems use combinations of power generating technologies to generate electricity. Co-generation systems, also called combined heat and power (CHP) systems, generate both electricity and useful heat.

Hybrid Power System Technology

Renewable-based hybrid power systems use combinations of wind turbines, photovoltaic panels, and small hydropower generators to generate electricity. Hybrid power systems typically include a diesel or other fuel-based generator and may include batteries or other storage technology. A completely renewable hybrid power system might use a biofuel-based generator in place of a diesel or other fossil fuel generator. Hybrid power system applications are typically small to medium in scale (producing between 100 watt-hours and tens of megawatt-hours per day) and generate electricity for distributed power generation applications, in remote areas for village power, and for communications and military installations around the world.

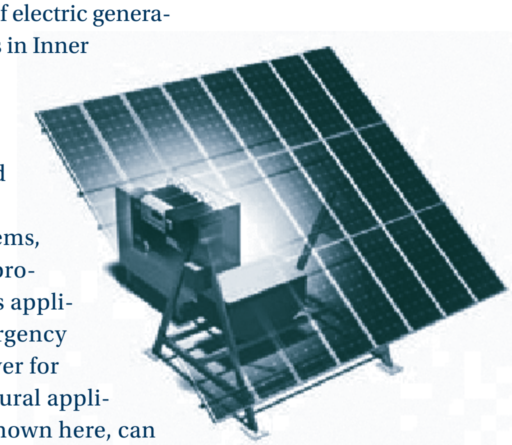
Hybrid power system designers select technologies on the basis of the renewable resource available at a particular location to take advantage of resource complementarity. For example, a wind–solar hybrid system can make use of both solar and wind power in areas that experience windy periods at night after the sun has set. A solar–hydropower hybrid system would be appropriate at a location that is near a stream or river and has sunny weather during dry periods of the year when stream flow is low. In some cases, the renewable resource may complement varying availability of fossil fuel resources, such as in areas in the Arctic that experience high winds, when transportation of fuels to remote locations is difficult or impossible due to winter conditions.

Renewable penetration is a measure of the relative contribution of renewable and non-renewable resources in a hybrid power system that includes fossil-fuel-based generation. The simplest and therefore lowest-cost designs are low-penetration systems in which the renewable power components produce sufficient power to save up to 20 percent on fossil fuel consumption. Medium- and high-penetration systems can save up to 40 and 70 percent on fuel consumption, respectively, but are more costly to design and complex to operate because they require additional control equipment to ensure the system's stability.

Advanced hybrid power systems use new technologies for power generation, storage, and system control. New technologies for research and experimental hybrid power systems include natural gas turbines, fuel cells, advanced batteries, flywheels, and other technologies.

Examples of Hybrid Power Systems

Over 400 simple wind–solar–battery hybrid systems provide between 500 and 600 W of electric generation capacity for rural households in Inner Mongolia, China. Each system consists of a 300-W wind turbine and 100- to 200-W photovoltaic array that charges deep-cycle lead acid batteries.



Packaged hybrid power systems, such as the one shown at left,[83] produce power for communications applications, disaster relief, and emergency power and can also provide power for rural electrification and agricultural applications. The SunWize product shown here, can meet continuous loads of 100 to 350 W, equivalent to 2.4 to 8.4 kWh/day.

A final example is a wind–hydro–diesel hybrid system in Coyhaique, Chile, which was designed to provide over 15 percent of the regional capital's electricity needs and to displace about 600,000 liters of diesel fuel annually.

Co-generation System Technology

Conventional fossil-fuel-based electric power plants generate heat as a by-product that is emitted into the environment through gas flues, cooling towers, and by other methods. Co-generation power plants collect this heat for use in thermal applications, thereby converting a higher percentage of the energy in the fuel into useful energy. The most efficient conventional power plants have a typical fuel-to-electricity conversion factor of about 50 percent, while co-generation plants can achieve efficiencies of over 75 percent. Co-generation plants generate more useful power than conventional plants using the same amount of fuel and also produce less pollution per unit of useful energy.

Co-generation plants are most effective when located near a thermal load center. Examples of thermal loads that can be served by a co-generation plant are district heating systems that provide heat for towns and neighborhoods, industrial processes that require heat such as paper mills, institutions such as prisons and hospitals, and wastewater treatment plants.

Co-generation plants either primarily produce electricity and collect exhaust heat from the electricity generation process (topping cycle plant) or primarily generate heat and use excess thermal energy to drive an electricity generating process (bottoming cycle plant). Co-generation plants can be large (greater than about 25 MW) and based on conventional natural gas turbines, combined-cycle natural gas turbines, or steam turbines. Smaller co-generation plants (25 kW to 25 MW) use reciprocating or Stirling engines to run an electric generator and collect the waste heat from the engine's exhaust system for thermal applications. These smaller plants can be fired by biomass or industrial and municipal waste. Very small co-generation plants (1–25 kW) for distributed energy applications use some of the heat from water or space heating systems to generate electricity for a single household or small business.

Clean Transportation Technologies

Alternative fuels for transportation include biodiesel, ethanol, natural gas, and propane. Biofuels produced from agricultural products are considered renewable fuels because they can be grown annually. Biofuels also produce fewer air pollutants when burned in vehicle engines. Advanced transportation technologies include electric vehicles, hybrid electric vehicles, mobile idle reduction systems, and diesel retrofits.

Biodiesel is a fuel derived from biomass that can be burned in diesel engines, including those in light- and heavy-duty diesel vehicles. Biodiesel can be used in all diesel vehicles and produces fewer emissions than fossil fuel diesel. Because biodiesel is produced from biomass, it can be considered a carbon-neutral fuel from a global warming perspective, although carbon emissions from the production and transportation of biodiesel contribute to its carbon footprint. Biodiesel fuel can easily be distributed through the existing fueling infrastructure.

Ethanol can be mixed with gasoline and used in vehicle engines designed to burn gasoline–ethanol mixtures. E85 fuel consisting of 85 percent ethanol and 15 percent gasoline can reduce air pollutant emissions and be used in vehicles with modified engines or with engines designed for use with ethanol fuel mixtures. Existing fueling stations can be modified to distribute ethanol-based fuels.

Compressed and liquefied natural gas (CNG and LNG) can be used in engines designed or modified for use with the fuels. Natural gas engines produce lower emissions than gasoline engines. Wide-scale use of natural gas as a transportation fuel requires adoption of the specialized vehicles by consumers and transportation companies and development of new fueling infrastructure. Propane (LPG) can be used in passenger and light-duty delivery vehicles and in forklifts and mowers. Propane costs vary from 5 to 40 percent less than gasoline and can result in reductions in air pollutants.

Electric vehicles are appropriate for neighborhood use. Using electricity in electric vehicles represents about a 30 percent reduction in fuel costs over conventional fuels. Using electricity from the conventional grid results in a 50 percent reduction in emissions compared to conventional fossil fuel vehicles.

Hybrid electric vehicle technology can be used in passenger and light-duty vehicles and in buses and trucks. Hybrid electric vehicles are more efficient than fossil-fuel-only vehicles and offer slight air pollution improvements over average fossil fuel vehicles. Plug-in hybrids offer an improvement over hybrid electric vehicles by allowing for some of the vehicle's energy to be supplied by the electric power grid and potentially by renewable energy sources. Because electric power tends to be cleaner than power from internal combustion engines, this approach can result in overall reductions in transportation-related pollution.

Fuel efficiency and air emissions for heavy-duty diesel vehicles can be improved with new technologies. Mobile idle reduction systems provide alternative power sources for use when trucks are idle but still require power for heating and cooling. Diesel engine retrofits including exhaust catalysts and filters reduce the emission of air pollutants.

Summary

This section has presented only a brief summary of the clean energy technologies included in this assessment report. There is a considerable wealth of information on these technologies and on the ongoing research and development of other alternative energy technologies from national laboratories such as the National Renewable Energy Laboratory (NREL) of the U.S. Department of Energy, as well as various renewable energy industry associations. Other resources for U.S. firms are included in Appendix A of this document.

Appendix A. Resources for U.S. Firms

The following table provides a compendium of trade and investment resources for U.S. clean technology firms, with a brief description of each resource. Contact information for individual organizations can be found by at each listed Web site. The provision of this list of resources does not constitute endorsement of any organization.

ORGANIZATION	WEB SITE	DESCRIPTION
A. U.S. GOVERNMENT		
U.S. Department of Commerce (DOC), International Trade Administration (ITA)	*www.trade.gov*	DOC/ITA participates in the development of U.S. trade policy, identifies and resolves market access and compliance issues, administers U.S. trade laws, and undertakes a range of trade promotion and trade advocacy efforts. ITA has more than 2,000 dedicated individuals posted at U.S. embassies and commercial offices around the world, including in China and India. ITA's lead business unit for trade promotion is the U.S. Commercial Service, which supports U.S. businesses through its global network of offices. The Commercial Service promotes the export of American goods and services worldwide and includes special programs for India and China. A resource guide for U.S. exporters to China, including a listing of legal services for China, is available at *www.buyusa.gov/china/en/contactchina.html*. The India site is available at *www.buyusa.gov/india/en/*. The U.S. Commercial Service offers four ways to grow international sales: world-class market research, trade events that promote products and services to qualified buyers, introductions to qualified buyers and distributors, and counseling through every step of the export process. For more information about how our worldwide network can help your company, call 1-800-USA-TRADE or contact our Export Assistance Centers. ITA's other business units include: Market Access and Compliance, which resolves market access issues, identifies and reduces trade barriers, and ensures that foreign countries are in compliance with trade agreements; Manufacturing and Services, which advocates policies to help U.S. companies be competitive at home and around the world and ensures industry's voice is reflected in policy development; and Import Administration, which administers various trade laws and monitors subsidies. ITA also has various resources to help in this fight including: one-on-one consultations with IPR trade specialists; IP attaches in China, Brazil, India, Russia, Thailand and Egypt to assist American businesses and actively engage with local IP agencies; the China IPR Advisory Program that provides U.S. companies a one-hour free legal consultation with a volunteer attorney experienced in IPR matters; IPR toolkits available online at *www.stopfakes.gov* containing detailed information on local IP laws and resources, as well as helpful local contact information in key foreign markets; free monthly China IPR Webinar series for U.S. industry; a hotline (1-866-999-HALT) answered by IPR experts to help businesses secure and enforce their IP rights; a Trade Fair IPR Initiative to promote protection of IP at domestic and international trade fairs; domestic outreach programs including a U.S. PTO China Roadshow; as well as a free, web-based IPR Module available at *www.stopfakes.gov* to help SMEs evaluate, protect, and enforce their IP both in the United States and overseas.

Export–Import Bank of the United States (Ex-Im Bank)	*www.exim.gov*	Ex-Im Bank is the official export credit agency of the United States. Ex-Im Bank's mission is to assist in financing the export of U.S. goods and services to international markets. Ex-Im Bank enables U.S. companies—large and small—to turn export opportunities into real sales helping to maintain and create U.S. jobs and contribute to a stronger national economy. Ex-Im Bank does not compete with private-sector lenders but provides export financing products that fill gaps in trade financing. Ex-Im Bank assumes credit and country risks that the private sector is unable or unwilling to accept and helps to level the playing field for U.S. exporters by matching the financing that other governments provide to their exporters. Clean energy is a priority for Ex-Im Bank, and the agency offers its most favorable terms for these technologies.
Overseas Private Investment Corporation (OPIC)	*www.opic.gov*	OPIC helps U.S. businesses invest overseas, fosters economic development in new and emerging markets, complements the private sector in managing risks associated with foreign direct investment, and supports U.S. foreign policy. Because OPIC charges market-based fees for its products, it operates on a self-sustaining basis at no net cost to taxpayers. OPIC has made clean energy investment a priority and offers favorable terms for these technologies.
U.S. Agency for International Development (USAID)	*www.usaid.gov*	USAID is an independent agency that provides economic, development, and humanitarian assistance around the world in support of the foreign policy goals of the United States. Currently, USAID is operational in India (but not China). In India, USAID works with local partners to increase viability in the power sector, conserve resources, and promote clean technologies and renewable energy. USAID facilitates sharing of energy and environment best practices between the United States and India and among South Asian countries.
US Department of Agriculture (USDA)	*www.usda.gov*	The Foreign Agricultural Service (FAS) of USDA works to improve foreign market access for U.S. products, build new markets, improve the competitive position of U.S. agriculture in the global marketplace, and provide food aid and technical assistance to foreign countries. FAS has the primary responsibility for USDA's international activities—market development, trade agreements and negotiations, and the collection and analysis of statistics and market information. It also administers USDA's export credit guarantee programs. USDA helps increase income and food availability in developing nations by mobilizing expertise for agriculturally led economic growth. USDA is also active in bioenergy development, domestically and overseas.

U.S. Department of Energy (USDOE)	*www.energy.gov*	USDOE is committed to reducing America's dependence on foreign oil and developing energy efficient technologies for buildings, homes, transportation, power systems, and industry. The Office of Energy Efficiency and Renewable Energy (EERE) seeks to strengthen America's energy security, environmental quality, and economic vitality in public–private partnerships that enhance energy efficiency and productivity; bring clean, reliable, and affordable energy technologies to the marketplace; and make a difference in the everyday lives of Americans by enhancing their energy choices and their quality of life. EERE leads the federal government's research, development, and deployment efforts in energy efficiency. EERE's role is to invest in high-risk, high-value research and development (R&D) that is critical to the nation's energy future and would not be sufficiently conducted by the private sector acting on its own. Program activities are conducted in partnership with the private sector, state and local governments, USDOE national laboratories, and universities. EERE offers financial assistance for renewable energy and energy efficiency R&D. EERE also works with stakeholders to develop programs and policies to facilitate the deployment of advanced clean energy technologies and practices. EERE has bilateral agreements in clean energy with India and China and participates in the Asia–Pacific Partnership on Clean Development and Climate (APP) (see below).
U.S. Department of State (State)	*www.state.gov*	State is the lead U.S. foreign affairs agency, and the Secretary of State is the president's principal foreign policy adviser. The department advances U.S. objectives and interests in shaping a freer, more secure, and more prosperous world through its primary role in developing and implementing the president's foreign policy. The Bureau of Economic, Energy and Business Affairs (EEB) formulates and carries out U.S. foreign economic policy, integrating U.S. economic interests with our foreign policy goals so that U.S. firms and investors can compete on an equal basis with their counterparts overseas. It implements U.S. economic policy in cooperation with U.S. companies, U.S. Government agencies, and other organizations. State also manages U.S. embassies overseas and coordinates U.S. activities under the APP (see below).
U.S. Embassy in China	*http://beijing.usembassy-china.org.cn*	The embassy provides information on travel, doing business in China, an IPR toolkit (*http://beijing.usembassy-china.org.cn/ipr.html*), and other useful information for U.S. visitors to China. The U.S. Commercial Service has offices throughout China as well.
U.S. Department of Treasury (Treasury)	*www.treasury.gov*	The Office of Foreign Assets Control (OFAC) of Treasury administers and enforces economic and trade sanctions based on U.S. foreign policy and national security goals against targeted foreign countries, terrorists, international narcotics traffickers, and those engaged in activities related to the proliferation of weapons of mass destruction. OFAC acts under presidential wartime and national emergency powers, as well as authority granted by specific legislation, to impose controls on transactions and freeze foreign assets under U.S. jurisdiction.
U.S. Small Business Administration (SBA)	*www.sba.gov*	SBA's mission is to aid, counsel, assist, and protect the interests of small-business concerns; to preserve free competitive enterprise; and to maintain and strengthen the overall economy of our nation. SBA also helps small businesses to compete in the global marketplace.

U.S. Trade and Development Agency (USTDA)	*www.tda.gov*	USTDA's mission is to advance economic development and U.S. commercial interests in developing and middle-income countries. To this end, the agency funds various forms of technical assistance, investment analysis, training, orientation visits, and business workshops that support the development of a modern infrastructure and a fair and open trading environment. In carrying out its mission, USTDA gives emphasis to economic sectors that may benefit from U.S. exports of goods and services.
U.S. Trade Representative (USTR)	*www.ustr.gov*	USTR is an agency of over 200 people with specialized experience in trade issues and regions of the world. They negotiate directly with foreign governments to create trade agreements, resolve disputes, and participate in global trade policy organizations. They also meet with governments, business groups, legislators, and public interest groups to gather input on trade issues and explain the president's trade policy positions.
StopFakes	*www.stopfakes.gov*	International Trade Administration of the Department of Commerce manages StopFakes, which provides access to information on promoting trade and investment, strengthening the competitiveness of U.S. industry, and ensuring fair trade and compliance with trade laws and agreements.
B. Non–U.S. Government Organizations		
Alliance to Save Energy (ASE)	*www.ase.org/*	Programs in the United States and abroad (including China and India) conduct research, advise policy-makers, and educate decision-makers on energy efficiency issues. The China program educates manufacturers and government officials on efficient windows and other technologies. In India, ASE is working on municipal water delivery.
Amerex Brokers, LLC	*www.amerexenergy.com/*	A division of the GFI Group that operates markets in electrical power, natural gas, emission allowances, and renewable energy credits. Also provides energy procurement services to large commercial and industrial customers.
American Council for an Energy-Efficient Economy (ACEEE)	*www.aceee.org/*	Non-profit organization provides technical and policy assessments, policy support, business, and public interest collaborations. Organizes conferences and provides information dissemination through publications and education.
American Council on Renewable Energy (ACORE)	*www.acore.org/*	ACORE establishes collaborative research and communication among leaders of financial institutions, government, professional service providers, and others in the wind, solar, geothermal, biomass and biofuels, hydropower tidal and current energy, and waste energy industries. Organizes an annual international ministerial-level workshop on renewable energy in Washington, D.C.
Asia-Pacific Partnership on Clean Development and Climate (APP)	*www.asiapacificpartnership.org*	The APP is a Presidential initiative to accelerate the development and deployment of clean energy security, reduce harmful air pollution, and greenhouse gas (GHG) emissions intensity in the context of sustained economic growth. The United States, Australia, China, India, Japan, the Republic of Korea, and Canada (accounting for over half of the world's GHG emissions, energy consumption, GDP, and population) agreed to work together and the private sector to expand investment and trade in cleaner energy technologies. Led by the State Department, the APP is an industry-focused, technology-driven, results-oriented partnership. Through Activities like the Clean Energy Technologies Trade Mission to China and India, the Department of Commerce seeks to position U.S. companies to make commercial sales while removing obstacles that restrict the ability of U.S. companies to do business in partner countries.

Association of Energy Engineers (AEE)	*www.aeecenter.org/*	Non-profit society of energy professionals in 77 countries promotes interest in sustainable development. Publishes industry newsletters for facility managers, renewable energy developers, environmental managers, and energy service providers.
China Embassy in United States	*www.china-embassy.org/eng*	Provides information on China and its economy and trade, ministry information, and some policy documents.
Cultural Savvy	*www.culturalsavvy.com/*	Provides training and consulting services for international business travelers. Includes some on-line information.
E Source	*www.esource.com/*	For-profit company originally operated as a Rocky Mountain Institute project. E Source provides analysis of retail energy markets, services, and technologies to its members, which include electric and gas utilities, large corporate and institutional energy users, government agencies, energy service companies, manufacturers, consultants, and others in over 20 countries.
Evolution Markets	*new.evomarkets.com/*	Provides financial and brokerage services for the global green market and clean energy sector.
Intergovernmental Panel on Climate Change	*www.grida.no/climate/ipcc/tectran/index.htm*	This site provides an overview of methodological and technological issues in technology transfer, including financing and partnerships, and sectoral analyses.
International Cultural Enterprises, Inc.	*www.businessculture.com*	Publishes best-practice reports, audio guides, and Web-based reports on country-specific business practices, customs, negotiating tactics, communication, and other issues. Also provides cross-cultural training and consulting services.
National Association of Energy Service Companies (NAESCO)	*www.naesco.org/*	The energy service industry trade organization advocates for the delivery of cost-effective energy services, provides industry information and data, and helps establish industry standards.
Organization for Economic Co-operation and Development (OECD) Directorate for Financial and Enterprise Affairs	*www.oecd.org/*	The OECD Investment Committee provides guidelines for multinational enterprises covering business ethics and sustainable development. Also provides investment statistics and analysis and investment codes.
Organization for International Investment	*www.ofii.org/*	Represents interests of U.S. subsidiaries of companies headquartered abroad. Educates public and policy-makers about positive role U.S. subsidiaries play in U.S. economy and ensures that U.S. subsidiaries are not discriminated against in state or federal law. Provides peer-to-peer forums for U.S. subsidiaries.
Renewable Energy Access	*www.renewableenergyaccess.com*	Company directory is a searchable list of companies by function. Searching for financial services companies generates a list of clean energy finance companies worldwide.
RenewableEnergyStocks.com	*www.renewablenergystocks.com*	Provides information on renewable energy investing and links to renewable energy industry information.
The Association of Energy Services Professionals (AESP)	*www.aesp.org/*	Membership organization of electric and natural gas utilities, public benefits associations, regulatory and non-profit entities, vendors, manufacturers, and consulting firms provides professional development programs and networking opportunities and promotes knowledge transfer.
The Lett Group	*www.lettgroup.com/*	Trains executives and professionals in business etiquette, manners, and other skills using international protocol.

UNEP Sustainable Energy Finance Initiative	*www.sefi.unep.org/*	Provides financiers with tools and access to networks to foster investment in sustainable energy projects.
World Energy Efficiency Association (WEEA)	*www.weea.org/*	Assists developing and reindustrializing countries in assessing information on energy efficiency. Publications include best practices and case studies on energy efficiency projects, financing, and ESCOs. Also publishes directories of international energy organizations and companies.
World Trade Organization	*www.wto.org/*	The WTO site provides information on trade goods, rules, and regulations; intellectual property rights, including trade-related aspects of Intellectual Property Rights (TRIPS); accessions, government procurement, and other commerce and trade topics. Information on China and the WTO is available at *www.wto.org/english/thewto_e/countries_e/china_e.html*; information on India and the WTO is available at *www.wto.org/english/thewto_e/countries_e/india_e.htm*.

Appendix B. Sustainable Energy Finance Directory

This directory is synthesized from the on-line resources available at *www.sef-directory.net/*, which is maintained by the Sustainable Energy Finance Initiative (SEFI), a joint initiative of the United Nations Environment Program and the Basel Agency for Sustainable Energy. It has been updated as of late 2007.

Note that financing for clean energy technologies has increased significantly in the last few years. This directory provides information on a number of these sources based on information from SEFI but is not exhaustive.

Debt Capital				
TITLE	FINANCE TYPE	SOURCE OF CAPITAL	TECHNOLOGY TYPES	
Asian Development Bank (ADB)	Debt, equity, fund development, risk mitigation	Member countries	Energy efficiency, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind Other activities: capacity building, institutional development, policy and regulatory activities, project development, and CDM support. ADB has committed $1 billion per year for renewable energy and energy efficiency over the next few years. Of special note are its efforts to catalyze local financing institutions and the private sector to participate in the delivery of clean energy services and to include modern energy access.	
DEG German Investment and Development Company	Debt capital	Public	Energy efficiency, bioenergy, Small hydropower	
E+Co	Debt capital	Multilateral, Bilateral, foundations, private sector	Energy efficiency, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind Also provides business planning support and seed capital	
European Investment Bank (EIB)	Debt capital	Capital markets	Energy efficiency, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind	

	GEOGRAPHIC FOCUS	CONTACT
	West Asia, South Asia, Southeast Asia, East Asia	6 ADB Avenue, Mandaluyong City 0401 Metro Manila Philippines Tel: +632 632 4444 Fax: +632 636 2444 *information@adb.org* *www.adb.org*
	West Asia, East Asia, Southeast Asia, North Africa, Central and Eastern Europe, Central and South America, South Asia, Sub-Saharan Africa	CONTACT—China: DEG Representative Office Beijing Beijing Sunflower Tower, Suite 1110 No. 37 Maizidian Street Chaoyang District 100026 Beijing People's Republic of China Tel: +86 10 8527 5168 Fax: +86 10 8527 5170 *degbj@public3.bta.net.cn, stb@degchina.com* *www.deginvest.de/EN_Home/index.jsp* CONTACT—India: DEG Representative Office New Delhi 21, Jor Bagh New Delhi–110 003 India Tel: +91 11 2465 5138, 3012 Fax: +91 11 2465 3108 *deg@degindia.com www.deginvest.de/EN_Home/index.jsp*
	West Asia, North Africa, Central and South America, South Asia, Southeast Asia, East Asia, Sub-Saharan Africa	Hongcheng Plaza Building, Suite 1302 Qingnian Road Kunming 650021 Yunnan, China Tel: +86 871 312 0934 Fax: +86 871 310 0897 *EandCo.China@EandCo.net* *www.energyhouse.com*
	Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe, South Asia, Sub-Saharan Africa	100 Boulevard Konrad Adenauer L-2950 LuxembourgLuxembourg Tel: +35 2 43791 Fax: +35 2 437704 *info@eib.org* *www.eib.org*

International Finance Corporation	Debt, equity, fund development, risk mitigation	IFC funds, GEF, other	Energy efficiency, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind, among others	
Triodos Renewable Energy for Development Fund	Debt capital	Bilaterals, multilaterals, foundations, private sector	Bioenergy, geothermal, small hydropower, solar (PV and thermal), wind	

	Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe, South Asia, Sub-Saharan Africa	CONTACT—China Michael Ipson, Country Manager 15th Floor, China World Tower 2 China World Trade Center No. 1 Jian Guo Men Wai Avenue Beijing, China 100004 Tel: +86 10 5860 3000 Fax: +86 10 5860 3100 *mipson@ifc.org* *www.ifc.org/ifcext/eastasia.nsf/Content/China* Mario Fischel, General Manager Private Enterprise Partnership for China R. 2716, 27th Floor CCB Sichuan Building No. 88, Tidu Street Chengdu, Sichuan Province P. R. China, 610016 Tel: + 86 28 8676 6622 Fax: N/A *mfischel@ifc.org* *www.ifc.org/ifcext/eastasia.nsf/Content/China* Guwahati–781 005, Assam Tel: +91 361 2463 133 36 Fax: +91 361 2463 152 *SouthAsia@ifc.org* *www.ifc.org/India*	CONTACT—India New Delhi Paolo Martelli, Director, South Asia or Anil Sinha, General Manager, SEDF 50-M, Shanti Path, Gate No. 3 Niti Marg, Chanakyapuri New Delhi–110 021 Tel: +91 11 4111 1000 Fax: +91 11 4111 1001/02*SouthAsia@ifc.org* *www.ifc.org/ifcext/southasia.nsf/Content/India_overview* Mumbai Sujay Bose, Senior Manager Godrej Bhavan, 3rd Floor Murzban Road, Fort Mumbai–400 001, Maharashtra Tel: +(91 22 6665 2000 Fax: +91 22 6665 2001 *SouthAsia@ifc.org* *www.ifc.org/ifcext/southasia.nsf/Content/India_overview* Chennai Prasad Gopalan, Principal Investment Officer Giriguja Enclave, No. 56 2nd Floor, 1st Avenue Shanti Nagar, Adyar Chennai–600 020, Tamil Nadu Tel: +91 44 2446 2570 Fax: +91 44 2446 2571 *SouthAsia@ifc.org* *www.ifc.org/ifcext/India* Guwahati Sushanta Kumar Pal, Business Development Officer First Floor, Orion Place Next to Mizoram House Christian Basti, G S Road
	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Sub-Saharan Africa	Utrechtseweg 60, P.O. Box 55 3700 AB Zeist The Netherlands Tel: +31 30 693 6500 Fax: +31 30 693 6566 *tredf@triodos.nl* *www.triodos.com* Team members Bob Assenberg Tel: +31 30 693 65 60 *bob.assenberg@triodos.nl*	Gerrit-Jan Brunink Tel: +31 30 693 65 78 *gerrit-jan.brunink@triodos.nl* Helena Korhonen Tel: +31 30 693 65 41 *helena.korhonen@triodos.nl* Martijn Woudstra Tel: +31 30 694 26 91 *martijn.woudstra@triodos.nl*

Verde Ventures, Conservation International	Debt capital		Energy efficiency	
World Bank	Loans, guarantees, analytic, and advisory services to developing countries	Member countries	Energy efficiency, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind	
Private Equities				
TITLE	FINANCE TYPE	SOURCE OF CAPITAL	TECHNOLOGY TYPES	
Actis Energy Fund	Private equities		Energy efficiency, cleaner fuels, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind, fuel cells	
Al Tayyar Energy	Private equities		Bioenergy, small hydropower, solar (PV and thermal), wind	
Battery Ventures	Private equities	Limited partners	Energy efficiency, cleaner fuels, solar (PV and thermal), wind, fuel cells	

	Southeast Asia, Central and South America, Oceania, Sub-Saharan Africa	2011 Crystal Drive, Suite 500 Arlington, Virginia 22201 USA Tel: +1 703 341 2400, +1 800 406 2306 Fax: +1 703 553 0721 *verdeventures@conservation.org* *www.conservation.org/xp/verdeventures/*
	West Asia, South Asia, Southeast Asia, East Asia	CONTACT—India Hema Balasubramanian *hbalasubramanian@worldbank.org* Sunita Malhotra *smalhotra@worldbank.org* Tel: +91 11 24617241 CONTACT—Washington, D.C. Junhui Wu 1818 H Street, N.W. Washington, D.C. 20433 USA Tel: +1 202 458 1405 Fax: +1 202 522 1648 *Jwu@worldbank.org*

	GEOGRAPHIC FOCUS	CONTACT
	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and South America, Sub-Saharan Africa	CONTACT—China Benjamin Cheng, Investment Principle 712 China World Tower 2 No. 1 Jianguomenwai Street Chaoyang District Beijing 100004 People's Republic of China Tel: +86 10 6505 6655 Fax: N/A *bcheng@act.is* *www.act.is* Delhi Steven Enderby, Partner NBCC Place, 1st Floor, East Tower Bhisham Pitamah Marg Pragati Vihar New Delhi–110003 India Tel: +91 11 4366 7000 Fax: +91 11 4366 7070 *senderby@act.is* *www.act.is* CONTACT—India Bangalore Subba Rao Telidevara, Partner 15 Rest House Crescent Bangalore–560001 India Tel: +91 80 2555 0651 Fax: +91 80 2555 0592 *stelidevara@act.is* *www.act.is* Mumbai JM Trivedi, Partner 704, 7 Floor Dalamal House Jamnala Bajaj Road Nariman Point Mumbai–400021 India Tel: +91 22 2281 6430 Fax: +91 22 2282 0737 *jtrivedi@act.is* *www.act.is*
	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Sub-Saharan Africa	Granville (Pete) Smith P.O. Box 757 Abu Dhabi United Arab Emirates Tel: +971-2-681-4004 Fax: +971 2 681 4005 *pete@altayyarenergy.com* *www.altayyarenergy.com*
	South Asia, Southeast Asia, West Asia, North America, Western Europe	Ramneek Gupta *rgupta@battery.com* Mark Sherman mark@battery.com

CDC Group PLC	Private equities	Private	Energy efficiency, bioenergy, geothermal, small hydropower, solar (PV and thermal), Wind	
E+Co	Debt capital	Multilateral, bilateral, foundations, private sector	Energy efficiency, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind	
EnviroTech Financial, Inc.	Private equities		Energy efficiency, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind, fuel cells	
Global Environment Fund	Private equities		Bioenergy, geothermal, small hydropower, solar (PV and thermal), wind	
Good Energies Inc.	Private equities	Private	Solar (PV and thermal), wind	
Jane Capital Partners LLC	Private equities		Energy efficiency, cleaner fuels, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind, fuel cells	
New Energies Invest AG (Bank Sarasin + Cie)	Private equities	Rights offering	Energy efficiency, bioenergy, small hydropower, solar (PV and thermal), wind, fuel cells	

	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and South America, Sub-Saharan Africa	6 Duke Street, St. James's London SW1Y 6BN United Kingdom Tel: +44 0 20 7484 7700 Fax: +44 0 20 7484 7750 *enquiries@cdcgroup.com* *www.cdcgroup.com*	930 Winter Street, Suite 2500 Waltham, Massachusetts 02541 USA Tel: +1 781 478 6600 Fax: +1 781 478 6601 *www.battery.com*
	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and South America, Sub-Saharan Africa	CONTACT—China Wu Jing, Investment Officer Laura Colbert, Communications Officer Zhu Xiaonan, Office Manager Hongcheng Plaza Building, Suite 1302 Qingnian Road Kunming 650021 Yunnan, China Tel: +86 871 312 0934 Fax: +86 871 310 0897 *EandCo.China@EandCo.net* *www.energyhouse.com*	CONTACT—Main Office Christine Eibs Singer 383 Franklin Street Bloomfield, New Jersey USA Tel: +1 973 680 9100 Fax: +1 973 680 8066 *chris@energyhouse.com* *www.energyhouse.com*
	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe, Sub-Saharan Africa	Gene Beck, President EnviroTech Financial, Inc. 333 City Boulevard West, 17th Floor Orange, California 92868-5905 USA Tel: +1 714 532 2731 Fax: +1 714 459 7492 *gbeck@etfinancial.com* *www.etfinancial.com*	
	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Sub-Saharan Africa	1225 Eye Street N.W., Suite 900 Washington, D.C. 20005 USA Tel: +1 (02 789 4500 Fax: +1 202 789 4508 *info@globalenvironmentfund.com* *www.globalenvironmentfund.com*	
	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe, Sub-Saharan Africa	Michael Ware 1250 24th Street, N.W., Suite 300 Washington, D.C. 20037, USA Tel: +1 202 466 0582 Fax: +1 202 466 0564 *www.goodenergies.com*	
	South Asia, Southeast Asia, East Asia, North America, Oceania	Neal Dikeman 505 Montgomery, 2nd Floor San Francisco, California 94111 USA Tel: +1 415 277 0180 Fax: +1 415 277 0173 *dikeman@janecapital.com* *www.janecapital.com*	
	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe, Sub-Saharan Africa	Andreas Knörzer Elisabethenstrasse 62 CH-4002 Basel Switzerland Tel: +41 0 61 277 7477 *andreas.knoerzer@sarasin.ch* *www.newenergies.ch/index_ei.html*	

OCM/GFI Power Opportunities Fund	Private equities	Corporate pension funds, insurance companies, foundation endowments, etc.	Energy efficiency	
Private Energy Market Fund LP (PEMF)	Private equities	Private	Bioenergy, wind	
Robeco Milieu Technologies	Private equities	Private	Energy efficiency, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind	
Sigma Capital	Private equities		Energy efficiency, bioenergy, small hydropower, solar (PV and thermal), wind	
Triodos International Fund Management BV	Private equities	Institutional and private investors	Bioenergy, geothermal, small hydropower, solar (PV and thermal), wind, fuel cells	

	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe, Sub-Saharan Africa	11611 San Vicente Boulevard, Suite 710 Los Angeles, California 90049 USA Tel: +1 310 442 0542 Fax: +1 310 442 0540 *info@gfienergy.com* *www.gfienergy.com*
	South Asia, Southeast Asia, East Asia, West Asia, Central and Eastern Europe, Western Europe,	Gustaf Godenhielm (Tekniikantie 4 D) P.O. Box 92 02151 Espoo Finland Tel: +358 9 469 1208 Fax: +358 9 469 1207 *gustaf.godenhielm@pemfund.com* *www.pemfund.com*
	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe, Sub-Saharan Africa	Postbus 973 3000 AZ Rotterdam The Netherlands Tel: +31 10 224 12 24 Fax: +31 10 411 52 88 *info@robeco.nl* *www.robeco.nl*
	Southeast Asia, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe	Bruce Woodry, Chairman and CEO P.O. Box 1002 Harbor Springs, Michigan 49740 USA Tel: +1 231 526 9585 Fax: N/A *woodry@sigmacapital.net* *www.sigmacapital.net/*
	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and South America, Western Europe, Sub-Saharan Africa	Utrechtseweg 60, P.O. Box 55 3700 AB Zeist The Netherlands Tel: +31 30 693 6500 Fax: +31 30 693 6566 *tredf@triodos.nl* *.www.triodos.com* Team members Bob Assenberg Tel: +31 30 693 65 60 *bob.assenberg@triodos.nl* Gerrit-Jan Brunink Tel: +31 30 693 65 78 *gerrit-jan.brunink@triodos.nl* Helena Korhonen Tel: +31 30 693 65 41 *helena.korhonen@triodos.nl* Martijn Woudstra Tel: +31 30 694 26 91 *martijn.woudstra@triodos.nl*

UBS (Lux) Equity Fund Future Energy	Private equities		Energy efficiency, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind	
Warburg Pincus Investment Consulting Company Ltd.	Private equities	Private	Energy efficiency, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind	

Public Equities

TITLE	FINANCE TYPE	SOURCE OF CAPITAL	TECHNOLOGY TYPES	
New Alternatives Fund	Public equities	This is an open and mutual fund that seeks shareholders.	Energy efficiency, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind	

	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe, Sub-Saharan Africa	CONTACT—Beijing 1609 China World Tower 1 Jian Guo Men Wai Avenue Beijing 100004 People's Republic of China Tel: +86 10-6505 22 13,+86 10-6505 22 14, +86 10-6505 22 15 Fax: +86 10-6505 11 79 CONTACT—Shanghai Room 3407 Citic Square No. 1168 Nanjing Xi Lu Shanghai 200041 People's Republic of China Tel: +86 21 5292 55 55 Fax: +86 21 5292 55 52	CONTACT—India 2/F, Hoechst House Nariman Point Mumbai–400 021 India Tel: +91 22 281 4649, +91 22 281 4676 Fax: +91 22 230 9000, +91-22-281 4673 CONTACT—Main Office Gerhard Wagner, Socially Responsible Investments Analyst Gessnerallee 3 8098 Zurich Switzerland Tel: +41 1 235 55 52 Fax: +41 1 235 55 30 *gerhard.wagner@ubs.com* *www.ubs.com/swedenfunds.com*
	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe, Sub-Saharan Africa	CONTACT—Beijing Beijing Representative Office 9th Floor, China World Tower 1 1 Jianguomenwai Avenue Beijing 100004 China Tel: +86 10 5923 2533 Fax: +86 10 6505 6683 *www.warburgpincus.com* CONTACT—Shanghai Shanghai Representative Office Unit 2201, Bund Center Office Tower No. 222 Yanan Road (East) Shanghai, 200002 China Tel: +86 21 6335 0308 Fax: +86 21 6335 0802 *www.warburgpincus.com*	CONTACT—India Mumbai Office 7th Floor, Express Towers Nariman Point Mumbai–400 021 India Tel: +91 22 6650 0000 Fax: +91 22 6650 0001 *www.warburgpincus.com* CONTACT—Main Office Almack House 28 King Street, St. James's London SW1Y 6QW United Kingdom Tel: +44 207 360 0306 Fax: +44 207 321 0881 *www.warburgpincus.com*

	GEOGRAPHIC FOCUS	CONTACT
	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe, Sub-Saharan Africa	150 Broadhollow Road, Suite 360 Melville, New York 11747 USA Tel: +1 800 423 8383 Fax: N/A *info@newalternativesfund.com* *www.newalternativesfund.com*

New Energy Fund LP	Public equities	High-net-worth individuals, family offices, foundations, and institutions	Energy efficiency, cleaner fuels, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind, fuel cells	
Carbon Finance				
TITLE	**FINANCE TYPE**	**SOURCE OF CAPITAL**	**TECHNOLOGY TYPES**	
Carboncredits.nl	Carbon finance		Energy efficiency, cleaner fuels, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind, fuel cells	
Climate Change Capital	Carbon finance, equity, venture capital	Public, private	Energy efficiency, renewable energy	
CO2e	Other	Finance through sale of emissions credits	Energy efficiency, cleaner fuels, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind	

South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe, Sub-Saharan Africa (This is a global fund, since it is a global phenomenon.)	527 Madison Avenue, 6th Floor New York, New York 10022 USA Tel: +1 212 419 3918 Fax: +1 212 419 3971 *www.newenergyfundlp.com*

GEOGRAPHIC FOCUS	CONTACT	
South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, Oceania, Western Europe, Sub-Saharan Africa	Carboncredits.nl Juliana van Stolberglaan 3 The Hague The Netherlands Tel: +31 70 3735 495 Fax: +31 70 3735 000 *carboncredits@senternovem.nl* *www.carboncredits.nl*	
Global, active in China and India	CONTACT —London 3 More London Riverside London SE1 2AQ, London United Kingdom Tel: +44 0 20 7939 5000 Fax: +44 0 20 7939 5030	CONTACT—China Climate Change Capital 9/F China Life Tower 16 Chao Wai Da Jie Beijing 100020 Tel: +86 10 85253797 Fax:+86 10 85253197
West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe, South Asia, Southeast Asia, East Asia, Sub-Saharan Africa	CONTACT—India CantorCO2e India Private Limited 10th Floor, Raheja Chambers Free Press Journal Marg Nariman Point Mumbai–400 021 India Tel: +91 986 753 1203 Fax: N/A *mumbai@cantorco2e.com* *www.co2e.com*	CONTACT—International Office 181 University Avenue, Suite 1500 Toronto, Ontario Canada M5H 3M7 Tel: +1 416 350 2177 Fax: +1 416 350 2985 *cdm@cantorco2e.com* *www.co2e.com*

EcoSecurities	Carbon finance	Public, private	Renewable energy, waste management, industrial efficiency.	
European Carbon Fund	Carbon finance		Energy efficiency, cleaner fuels, geothermal, solar (PV and thermal), wind	
IFC-Netherlands Carbon (CDM) Facility (INCaF)	Carbon finance		Energy efficiency, cleaner fuels, bioenergy, geothermal, small hydropower, wind	
Japan Carbon Finance, Ltd. (JCF)	Carbon finance	Major Japanese private enterprises and policy-lending institutions	Energy efficiency, cleaner fuels, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind, fuel cells	
KfW Carbon Fund	Carbon finance		Energy efficiency, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind, fuel cells	
Natsource	Carbon finance	Public, private	Energy efficiency, renewable energy	
Prototype Carbon Fund (PCF)	Carbon finance	Trust Fund administered by the World Bank	Energy efficiency, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind	

	Global, including China and India	CONTACT—China Unit 708, China Resources Building 8 Jianguomen Bei Avenue Beijing, 100005 Tel: +86 10 6518 1081 Fax: +86 10 6518 1085 *china@ecosecurities.com* CONTACT—International Office 181 University Avenue, Suite 1500 Toronto, Ontario Canada M5H 3M7 Tel: +1 416 350 2177 Fax: +1 416 350 2985 *cdm@cantorco2e.com* *www.co2e.com*
	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe, Sub-Saharan Africa	CONTACT—China Li Chao Beijing Tel: +86 106 655 5735 CONTACT—Asia (w/o China) Anne Dargelos Tel: +33 01 58 55 66 28 CONTACT—Main Office Laurent Segalen Tel: +44 0 207 648 0118 Fax: +33 015 855 2965 *www.europeancarbonfund.com/*
	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and South America, Oceania, Sub-Saharan Africa	2121 Pennsylvania Avenue, N.W. Washington, D.C. 20433 USA. Tel: +1 202 473 4194 Fax: +1 202 974 4348 *carbonfinance@ifc.org* *www.ifc.org/carbonfinance*
	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, Oceania, Western Europe, Sub-Saharan Africa	1-3, Kudankita 4-chome Chiyoda-ku Tokyo 102-0073 Japan Tel: +81 3 5212 8870 Fax: +81 3 5212 8886 *jcf@jcarbon.co.jp* *www.jcarbon.co.jp/*
	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe, Sub-Saharan Africa	Palmengartenstrasse 5-9 60325 Frankfurt Germany Tel: +49 69 7431 4218 Fax: +49 69 7431 4775 *carbonfund@kfw.de* *www.kfw-foerderbank.de*
	Global, including China and India	Natsource LLC 100 William Street, Suite 2005 New York, New York 10038 Tel: +1 212 232 5305 Fax: +1 212 232 5353
	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, Oceania, Western Europe, Sub-Saharan Africa	1818 H Street, N.W. Washington, D.C. 20433 USA *helpdesk@carbonfinance.org* *prototypecarbonfund.org*

Swedish International Climate Investment Program (SICLIP)	Carbon finance		Energy efficiency, bioenergy, wind	
Svensk Exportkredit (SEK)–Sweden	Export credits		Bioenergy, geothermal, small hydropower, solar (PV and thermal), wind	
World Bank Carbon Finance	Carbon finance	Public, private	Energy efficiency, renewable energy	
Insurance				
TITLE	**FINANCE TYPE**	**SOURCE OF CAPITAL**	**TECHNOLOGY TYPES**	
Aon Global Risk Consultants Ltd.	Insurance		Bioenergy, geothermal, small hydropower, solar (PV and thermal), wind	
Miller Insurance Group	Insurance		Wind	

South Asia, Southeast Asia, East Asia, West Asia, Central and Eastern Europe, Central and South America, Sub-Saharan Africa	Kungsgatan 43 Box 310, SE-631 04 Eskilstuna Sweden Tel: +46 16 544 2241, +46 16 544 2043 Fax: +46 16 544 2099 *angela.kallhauge@stem.se, gudrun.knutsson@ energimyndigheten.se* *www.energimyndigheten.se*
West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe, South Asia, Southeast Asia, East Asia, Sub-Saharan Africa	P.O. Box 16368, SE-103 27 Västra Trädgårdsgatan 11 B Stockholm Sweden Tel: +46 8 61 38 300 Fax: +46 8 20 38 94 *nfo@sek.se* *www.sek.se/*
Global, including China, India	The World Bank Carbon Finance Unit 1818 H Street, N.W. Washington, D.C. Tel: +1 202 473 1000 *www.carbonfinance.org*

GEOGRAPHIC FOCUS	CONTACT	
South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe, Sub-Saharan Africa	CONTACT—China Richard Dong Aon Corporation Beijing Representative Office Room 1206 Capital Tower Beijing 6 Jia Jian Guo Men Wai Avenue Chaoyang District Beijing 100022 The People's Republic of China Tel: +86 10 6563 0671 Fax: +86 10 6563 0672 *richard_dong@aon-cofco.com.cn* *www.aon.com/as/en/china*	CONTACT—India Prabodh Thakker, Chairman 302 Dalamal House Jamnalal Bajaj Marg Nariman Point Mumbai–400 021 India Tel: +91 22 6656 0505 Fax: +91 22 6656 0506 *prabodh_thakker@aon-asia.com* *www.aon.com/as/en/india* CONTACT—Main Office Aon Limited, 8 Devonshire Square London EC2M 4PL United Kingdom Tel: +44 0 20 7623 5500 Fax: +44 0 20 7621 1511 *www.aon.co.uk*
South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe, Sub-Saharan Africa	Susanna Lam, Director Miller Insurance Services (Hong Kong) Ltd. Tel: +852 2525 6982 *susanna.lam@miller-insurance.com* *www.miller-insurance.com/China-Energy* David Horne, Director Energy Tel: +44 0 20 7031 2582 *david.horne@miller-insurance.com* *www.miller-insurance.com/China-Energy*	CONTACT—Main Office Dawson House 5 Jewry Street London EC3N 2PJ United Kingdom Tel: +44 0 20 7488 2345 Fax: N/A *info@miller-insurance.com* *www.aon.co.uk*

Multilateral Investment Guarantee Agency (MIGA)	Insurance		Energy efficiency, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind	
Swiss Re	Insurance		Energy efficiency, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind	

Other

TITLE	FINANCE TYPE	SOURCE OF CAPITAL	TECHNOLOGY TYPES	
Capital Equity Partners	Financial engineering and investment banking	Debt capital, private equities, public equities, funds of funds, carbon finance, export credits, insurance, private placements	Energy efficiency, cleaner fuels, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind, fuel cells	

	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe, Sub-Saharan Africa	1818 H Street N.W. Washington, D.C. 20433 USA Tel: +1 202 473 1000 Fax: +1 202 522 0316 *migainquiry@worldbank.org* *www.miga.org*	
	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe, Sub-Saharan Africa	CONTACT—China Eric Gao, Branch Manager Beijing Branch 23rd Floor, East Tower, Twin Towers No. B12, Jian Guo Men Wai Avenue Chao Yang District Beijing 100022 China Tel: +86 10 6563 8888 Fax: +86 10 6563 8800 *Eric_gao@swissre.com* *www.swissre.com* CONTACT—India Dhananjay Date, Managing Director 9th Floor, Essar House 11 K Khadye Marg Mahalaxmi Mumbai–400 034 India Tel: +91 22 6661 2121 Fax: +91 22 6661 2122 *Dhananjay_date@swissre.com* *www.swissre.com*	CONTACT—Asia–Pacific Headquarters Darryl Pidcock Hong Kong Branch 61/F Central Plaza 18 Harbour Road G.P.O. Box 2221 Wanchai, HK Hong Kong Tel: +852 2827 4345 Fax: +852 2827 6033 *Darryl_Pidcock@swissre.com* *www.swissre.com*

	GEOGRAPHIC FOCUS	**CONTACT**	
	West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe, South Asia, Southeast Asia, East Asia, Sub-Saharan Africa	410 Park Avenue New York, New York 10022 USA Tel: +1 928 436 4212 Fax: +1 270 447 3738 *contact@capitalequitypartners.com* *www.capitalequitypartners.com*	Aiken Capital Partners +1 212 751 5007 Same address

The Global Environment Facility (GEF)	Grants to developing countries	Member governments	Energy efficiency, bioenergy, geothermal, small hydropower, solar (PV and thermal), wind	
Japan Bank for International Cooperation (JBIC)	Other	Japanese government		
Kreditanstalt fur Wiederaufbau (KfW Bankengruppe)	Small and medium enterprise (SME), project, and export finance	German government	SMEs, clean energy	

	Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe, South Asia, Sub-Saharan Africa	CONTACT—China Guangyao Zhu, Director General (Political Focal Point) International Department Ministry of Finance Beijing 100820 People's Republic of China Tel: +86 10 6855 3101 Fax: +86 10 6855 1125 *www.gefweb.org* Jinkang Wu, Director (Operational Focal Point) Ministry of Finance International Financial Institution Division IV Department of International Affairs Beijing 100820 People's Republic of China Tel: +86 10 6855 3101 Fax: +86 10 6855 1125 *jk.wu@mof.gov.cn* *www.gefweb.org* Sudhir Mital, Joint Secretary (Operational Focal Point) Ministry of Environment and Forests Room 414, Paryavaran Bhawan CGO Complex, Lodhi Road New Delhi–110 003 India Tel: +91 11 243 6 3956 Fax: +91 11 24 6 9192 *Mital_sudhir@nic.in* *www.gefweb.org* CONTACT—Main Office 1818 H Street, N.W., MSN G6-602 Washington, D.C. 20433 USA Tel: +1 202 473.0508 Fax: +1 202 522.3240, 3245 *secretariat@thegef.org* *www.gefweb.org*
	South Asia, Southeast Asia, East Asia	CONTACT—China 3131 31st Floor China World Trade Center, No. 1 Jian Guo Men Wai Avenue Beijing 100004 People's Republic of China Tel: +86 10 6505 8989, 3825, 3826, 3827, 1196, 1197 Fax: +86 10 6505 3829, 1198 *www.jbic.go.jp/english/* CONTACT—India Rajeev Singh, Deputy Secretary (Political Focal Point) Department of Economic Affairs Ministry of Finance Room N. 66-C, North Block New Delhi–110001 India Tel: +91 11 230 93881 Fax: +91 11 230 92477 *r_p_singh@nic.in* *www.gefweb.org* CONTACT—India 3rd Floor, DLF Centre Sansad Marg New Delhi–110001 India Tel: +91 11 2371 4362, 4363, 7090, 6200 Fax: +91 11 2371 5066, + 91 11 2373 8389 *www.jbic.go.jp/english/* CONTACT—Main Office 4-1, Ohtemachi 1-chome, Chiyoda-ku Tokyo 100-8144 Japan Tel: +03 5218 3101 Fax: +03 5218 3955 *www.jbic.go.jp/english/*
	South Asia, Southeast Asia, East Asia, West Asia, North Africa, Central and Eastern Europe, Central and South America, North America, Oceania, Western Europe, Sub-Saharan Africa	Charlottenstrasse 33/33a 10117 Berlin Tel: +49 30 20264 0 Fax: +49 30 20264 5188 *www.kfw.de/EN*

Chapter Notes

[1] Yang Jingyin, Zhen Zexiang, and Guo Yimin, I*nternational Status Comparative Study on China's Economy and Social Development in 2006* (International Center of National Bureau of Statistics of China, November 30, 2006). www.stats.gov.cn/tjfx/fxbg/t20061128_402368780.htm

[2] Dai Yande, *China Energy Supply and Demand Situation and Energy Conservation Policy* (ERI of NDRC, March 2007). HYPERLINK "/http://neec.no/uploads/File/Whatsup/whatsupforneec/EM-" /http://neec.no/uploads/File/Whatsup/whatsupforneec/EM-workshop/BJPDF/27-0900-Dai%20Yan%20De.pdf

[3] Daniel H. Rosen and Trevor Houser, *China Energy: A Guide for the Perplexed* (Peterson Institute for International Economics May 2007). HYPERLINK "www.iie.com/publications/papers/rosen0507.pdf" www.iie.com/publications/papers/rosen0507.pdf

[4] *Ibid.*

[5] National Bureau of Statistics of China. www.stats.gov.cn/english/

[6] China National Development and Reform Commission., "11th Five-Year Energy Plan."

[7] International Energy Agency, World Energy Outlook 2007: China and India Insights (Paris, France: OCED/IEA, 2007)

[8] *Ibid.*

[9] *Ibid.*

[10] NDRC, Mid- and Long-term Renewable Energy Development Plan, August 2006. Note: this figure does not include traditional biomass combustion for cooking and heating in rural households. According to the IEA's 2007 *World Energy* Outlook estimates, which include traditional biomass consumption, China's renewable energy consumption accounted for about 15 percent of China's total primary energy consumption in 2005.

[11] Shi Pengfei, Statistics on *Wind Farms in China*, 2005 (Chinese Wind Energy Association , March 23, 2006). www.cwea.org.cn/download/display_info.asp?cid=2&sid=&id=2

[12] Shi Pengfei, *Statistics on Wind Farms in China*, 2006 (Chinese Wind Energy Association, March 18, 2007). www.cwea.org.cn/download/display_info.asp?cid=2&sid=&id=19

[13] Data on installed wind capacity by province compiled by Azure International Technology Development Ltd. (Beijing) based on proprietary research. Data are not available from the Chinese Government on renewable energy capacities per province

.[14] Li Junfeng et al., *China Solar PV Report 2007* (China Environmental Science Press).

[15] Chen Yingjie and Fu Zhongwen, "Development Tendency and Outlook of Solar PV Industry," July 18, 2006. http://market.ccidnet.com/market/article/content/420/200607/135747.html

[16] "2007–2008 China's Solar PV Industry Development Analysis Report," November 8, 2007.

[17] "2007 Chinese Renewable Energy Weekly Monitoring Report (07/10/13 – 07/10/19),"October 21, 2007. www.ccei.org.cn/shownews.asp?ID=25482

[18] Liu Yanlong, *Analysis of China's Battery Exports* (China Chemical and Physical Power Supply Industry Association, June 19, 2007).www.cibf.org.cn/iec_newsdetail.php?id=78

[19] "2007–2008 China's Solar PV Industry Development Analysis Report," November 8, 2007.

[20] NDRC, Mid- and Long-term Renewable Energy Development Plan, August 2006.

[21] *Wind Energy Country Study* (GTZ, September 2007). (A portion of the $600M capital investment was used for the installation of 268 mini-hydropower facilities with a total generation capacity around 293 MW.)

[22] NDRC, Mid- and Long-term Renewable Energy Development Plan, August 2006.

[23] "Prospect of Roof PV development of China," *International New Energy Net* (April 14, 2006). /www.in-en.com/newenergy/html/newenergy-2006200604145255.html

[24] NDRC, Mid- and Long-term Renewable Energy Development Plan, August 2006.

[25] Han Weiping, *The Concept of Green Building Integrated with Design*, vol 23, no. 6, p. 117. www.gotoread.com/vo/5274/page553552.html

[26] GTZ, "Wind Energy Country Study," September 2007.

[27] NDRC, Mid- and Long-term Renewable Energy Development Plan, August 2006.

[28] Gansu Lintao rural energy office.

[29] Gansu Lintao rural energy office.

[30] "Interesting Times—Focus on Clean Energy Investment Opportunities in China" *New Energy Finance* (September 22, 2006).

[31] Heinz-Peter Mang, *Biogas Investments as a Profitable Business in China* (Chinese Academy of Agricultural Engineering, June 14, 2007).

[32] "Current Status and Prospect of China's SHP," presentation of International Workshop on China Renewable Energy Strategy Development, August 16, 2006. http://newenergy.com.cn/html/2006-8/2006816_11456_1.html

[33] Li Qidao, "Situation, Data, Analysis and Suggestions to Small Hydro," thesis of China Energy Net, September 7, 2007.

[34] NBSC, Statistic Yearbook 2006

[35] Han Xiaoping, "CIO of China Energy Network," presentation in Briefing Workshop on Current Situation and Prospects of CHP Industry, September 2005.

[36] NDRC, List of small thermal power plants that have been closed from January to September 2007. www.sdpc.gov.cn/zcfb/zcfbgg/2007gonggao/W020071221580581956235.xls

[37] Calculated by the Azure International Research Team, as of December 2007.

[38] Wu Guihui, *Development of Decentralized Energy in China* (July 2007). www.chinainfo.gov.cn/data/200708/1_20070822_159913.html

[39] NDRC, Mid- and Long-term Renewable Energy Development Plan, August 2006.

[40] Shanghai local government Web site material, August 22, 2006. www.shtong.gov.cn/node2/node4429/node4437/node70463/userobject1ai85052.html

[41] Information presented at the United States–China Clean Energy Forum in January 2008.

[42] Wu Guihui, *Development of Decentralized Energy in China* (July 2007). www.chinainfo.gov.cn/data/200708/1_20070822_159913.html

[43] Ibid.

[44] Data from "BP Statistical Review of World Energy," June 2007.

[45] In 2005 there were 113 cities of more than 1 million people, which means a large domestic market for basic materials and intense pressure on supply—which has grown at breakneck speed since 2001. Data from NBSC, *Statistic Yearbook 2006*.

[46] "BP Statistical Review of World Energy," June 2007.

47 Yande Dai, *China Energy Supply and Demand Situation and Energy Conservation Policy* (ERI, NDRC, March 2007).

48 The World Bank and State Environmental Protection Administration of China, *Cost of Pollution in China* (February 2007).

49 *Ibid*.

50 Yande Dai, *China Energy Supply and Demand Situation and Energy Conservation Policy* (ERI, NDRC, March 2007).

51 The World Bank and State Environmental Protection Administration of China, *Cost of Pollution in China* (February 2007).

52 NDRC, Notice on Adjusting the Local Grid Feed-in Tariff, June 2006.

53 "21.3 Billion RMB Special Funds on Energy Conservation," *Financial Observer of the China Reform Newspaper*, July 31, 2007./www.crd.net.cn/ShowNews.asp?NewsID=7906

54 *Special Funds Application Guidebook for RE in Building Integration*. www.cin.gov.cn/zcfg/jswj/jskj/200706/P020070606463375283662.doc

55 *2007 SME Technology Innovation Fund Guidelines for a Number of Key Projects* (Chinese version). www.innofund.gov.cn/innofile/se_02_t02.asp

56 "Support Notice for *2007 SME Technology Innovation Fund guidelines for a Number of Key Projects*" (Chinese version). www.innofund.gov.cn/innofile/se_02_t03.asp

57 Energy Conservation Law, 2007 version.

58 http://www.gov.cn/english/laws/2005-10/08/content_75023.htm

59 "Anti-corruption Policies in Asia and the Pacific: Thematic review of provisions and practices to curb corruption in public procurement." www.oecd.org/dataoecd/62/49/35593529.pdf

60 "China Focus: China Begins Compulsory Procurement of Energy-saving Items," December 2007. http://en.ec.com.cn/article/enindustry/enenergy/eneereport/200712/528299_1.html

61 The Office of the National Energy Leading Group is a department of the NDRC. http://en.ndrc.gov.cn/

62 Bai Quan, *Energy Efficiency in China: Strategies and Financing Options* (ERI of NDRC).

63 Second China New Energy International Forum. www.cnecc.org.cn/luntan2/kms.htm

64 Sina Finance News; Haitong Stock Company. finance.sina.com.cn/stock/s/20080129/20541971337.shtml

65 www.icfi.com/

66 *VER and Carbon Neutral in Volunteer Emission Reduction Market* (Azure CDM team material, May 16, 2007).

67 Thomson Financial/NVCA. www.cvca.com.cn/template/newstemplate.asp?ArticleID=1052

68 Cleantech Network™ LLC. www.cleantechventure.com69 Thomson Financial/NVCA. www.cvca.com.cn/template/newstemplate.asp?ArticleID=1052

69 *New Energy Finance*.

70 The full catalogue is available in English at www.fdi.gov.cn/pub/FDI_EN/Laws/law_en_infor.jsp?docid=87372.

71 China Investment Consulting Web, *2007–2008 Market Analysis and Investment Consulting Report on China SWH*, November 2007. www.ocn.com.cn/reports/2006112tynrsq.htm

72 Source: United States–China Business Council. www.chinabusinessreview.com/public/0611/prc-government-structure.pdf; PRC Government Web sites.

73 Source: www.china.org.cn/e-china/politicalsystem/index.htm

74 NDRC, "Guidance Catalogue of Renewable Energy Industry," November 29, 2005.

75 http://www.un.org/esa/sustdev/csd/csd15/documents/csd15_bp2.pdf

76 Photo courtesy of U.S. Department of Energy/National Renewable Energy Laboratory (USDOE/NREL) (www.nrel.gov).

77 Photo courtesy of USDOE/NREL.

78 Photo courtesy of USDOE/NREL.

79 http://www.nrel.gov/learning/re_solar_hot_water.html

80 Emerging Energy Research, *Asia Pacific Wind Power Markets & Strategies, 2006–2015* (December 2006). Available from www.emerging-energy.com.

81 Photo courtesy of USDOE/NREL. (USDOE used to denote United States Department of Energy since DOE has been used already to refer to the Department of Environment)

82 Photo courtesy of USDOE/NREL.

83 See www.sunwize.com/.