Facilitating Deployment of Highly Efficient Combined Heat and Power Applications in China

Analysis and Recommendations

U.S. Environmental Protection Agency
Combined Heat and Power Partnership
and
Asia Pacific Partnership
on Clean Development and Climate

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Foreword

The Asia-Pacific Partnership (APP) on Clean Development and Climate is an innovative new effort to accelerate the development and deployment of clean energy technologies. Founding partners Australia, China, India, Japan, the Republic of Korea, and the United States have agreed to work together with private sector partners to meet goals for enhancing energy security, reducing national air pollution, and confronting climate change in ways that promote sustainable economic growth and poverty reduction.

For more information on the APP, visit its Web site at <www.asiapacificpartnership.org>.

To help promote greater implementation of combined heat and power (CHP) in China, the APP has collaborated with the U.S. Environmental Protection Agency's (EPA's) Combined Heat and Power Partnership (CHPP). The goals of the APP-CHPP collaboration are to draw upon the American CHP experience to:

- Identify and help eliminate barriers to deployment of CHP systems in China.
- Educate policymakers, utilities, and energy users on the benefits of CHP.
- Develop and implement a program to facilitate the design, development, and/or operation of at least 500 megawatts (MW) of new CHP systems in China by 2010.

EPA's CHPP is a voluntary program that seeks to reduce the environmental impact of power generation by promoting the use of CHP. CHP is an efficient, clean, and reliable approach to generating power and thermal energy compared to producing electricity and heat separately. CHP can improve operational efficiency and abate energy costs, while mitigating the emissions of greenhouse gases, which contribute to climate change. CHPP works closely with energy users, the CHP industry, state and local governments, and other stakeholders to support the development of new projects and promote energy, environmental, and economic benefits through these projects.

CHPP also provides resources on CHP technologies, incentives, emissions profiles, and other information on its Web site at <www.epa.gov/chp>. For more information, contact the CHP Partnership at (703) 373-8108 or chp@epa.gov.

Report prepared by: Pacific Northwest National Laboratory, a U.S. Department of Energy government research laboratory; Energy and Environmental Analysis, Inc., an ICF International Company; Exergy Partners Corporation; and Eastern Research Group, Inc. (ERG), for the U. S. Environmental Protection Agency, Combined Heat and Power Partnership, February 2008.

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Acronyms and Abbreviations

APP	Asia Pacific Partnership
bcm	Billion Cubic Meters
Btu	British Thermal Unit
CCGC	Combined-Cycle Gas-Fired CHP
CDM	Clean Development Mechanism
CECIC	China Energy Conservation Investment Corporation
CHP	Combined Heat and Power
CHPP	U.S. EPA Combined Heat and Power Partnership
CO_2	Carbon Dioxide
DRC	Development and Reform Committee (China)
EIA	Energy Information Administration (U.S. Department of Energy)
EJ	Exa Joules
EMCA	Energy Management Company Association (China)
EMCo	Energy Management Company
EPA	U.S. Environmental Protection Agency
EPC	Energy Performance Contracts
FERC	Federal Energy Regulatory Commission

gce	Grams of Coal Equivalent
GDP	Gross Domestic Product
GW	Gigawatt
IEA	International Energy Agency
Kgce	Kilograms of Coal Equivalent
kW	Kilowatt
kWh	Kilowatt-Hour
lb	Pound
LNG	Liquefied Natural Gas
MMBtu	Million British Thermal Units
MOC	Ministry of Construction (China)
MOEP	Ministry of Electric Power (China)
MW	Megawatt
MWe	Megawatt Equivalent
MWh	Megawatt-Hour
NDRC	National Development and Reform Commission (China)
NO_X	Nitrogen Oxide
OECD	Organization for Economic Co-operation and Development
OPET	Organization for the Promotion of Energy Technologies
ppm	Part Per Million
PBFs	Public Benefits Fund
PURPA	Public Utilities Regulatory Policies Act
RMB	Renminbi
QF	Qualifying Facility
SEPA	State Environmental Protection Administration (China)
SETC	State Economic and Trade Commission (China)
SERC	State Electricity Regulatory Commission (China)
SO_2	Sulfur Dioxide
SPC	State Planning Commission (China)
T&D	Transmission and Distribution
tce	Tons of Coal Equivalent
WADE	World Alliance for Decentralized Energy

Executive Summary

In the coming decades, China faces enormous challenges as it strives to meet the energy needs of its burgeoning economy. Foremost amongst these challenges will be increasing the energy efficiency of both power and heat generation as a means to reduce environmental degradation and enhance economic development. Increased utilization of combined heat and power (CHP) represents a near-term technology solution to help meet China's energy and environmental goals. Recognizing this fact, the Chinese government has instituted a number of policies intended to increase energy efficiency and to promote CHP. As a result the amount of CHP in China has increased over the years, and now accounts for more than 13 percent of electricity capacity. A number of outstanding challenges prevent wider deployment of CHP in China, however. This paper attempts to add to the existing CHP knowledge base in China by providing a concise summary of the context, trends, and regulations affecting the Chinese CHP sector, while also providing insights based on the U.S. experience with CHP development.

To help promote greater implementation of CHP in China, the Asia Pacific Partnership (APP) on Clean Development and Climate has collaborated with the U.S. Environmental Protection Agency's (EPA's) Combined Heat and Power Partnership (CHPP). The goals of the APP-CHPP collaboration are to draw upon the American CHP experience to:

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To help accomplish these goals, the CHPP assessed the technical, economic, and strategic market opportunities for CHP in China as well as the key barriers to CHP deployment. Through its work, and based on the U.S. experience with CHP, EPA has identified five high-level recommendations that, if implemented, could build on successful Chinese efforts and greatly facilitate the deployment of highly efficient CHP in China. Specifically, CHPP recommends that China:

1. Create more consistent and predictable access to power and heat markets.
2. Move quickly to cost reflective pricing (i.e., pricing that fully reflects the true cost to generate) for separate heat and power to accelerate adoption of energy efficiency measures.
3. Ensure that market valuation of CHP outputs reflect the energy efficiency and environmental benefits of CHP.
4. Streamline rules for financial incentives and clean development mechanism (CDM) approval for CHP.
5. Ensure that smaller onsite industrial and commercial CHP projects have equal access to financing.

A natural follow-on to the content and recommendations presented in this paper will be discussions with appropriate Chinese counterparts to develop an implementation plan for the policies and programs that work for the Chinese government.

1.0 Introduction

China has seen tremendous economic growth in recent decades. The economy of the People's Republic of China is the fourth largest in the world when measured by nominal gross domestic product (GDP), and economists predict that it will surpass Germany to assume third place in early 2008. This growth has led to greater prosperity but also to dramatically increased energy consumption and environmental degradation. Chinese leaders have recognized this challenge and have instituted aggressive efforts to reduce energy consumption. China's energy consumption per 10,000 Yuan GDP decreased from 1.22 tons of coal equivalent (tce) in 2005 to 1.206 tce in 2006 (1.33 percent). In the first half of 2007, energy consumption per 10,000 Yuan GDP decreased 2.78 percent.[1] Although these results are impressive, greater increases in energy efficiency are needed, given the rate of economic growth in China. Recognizing this fact, the Chinese government has pursued policies to further increase energy efficiency nationwide, including promoting the use of combined heat and power (CHP).[2]

The latest data show that in 2005, China produced about 13.5 percent of its electricity with CHP, and this share is growing. Current CHP in China is predominantly coal-fired, serving municipal district heating systems and energy-intensive industries, and consists of mostly mid-sized or small heat plants and boilers; large power generators rarely implement CHP projects. At the same time, China has a large district heating sector that relies primarily on heat-only boilers, rather than on more efficient and less polluting CHP. Compared to other countries with large district heating sectors and many industrial consumers of heat, China has a relatively low share of CHP in both electricity and heat production. This arrangement means that some of the more obvious opportunities for CHP to access grids for greater reliability and integration are missed. It also means that there is significant potential to expand grid-based CHP with the design and implementation of the right policies. While the power and heat reforms launched in China earlier this decade should ultimately level the playing field for CHP, in the near term, the reforms appear to have made it harder to promote CHP because of the increased risk and uncertainty that comes with mid-stream reforms and, because the reforms have removed some of the price advantages that CHP systems previously enjoyed. The current challenge for Chinese policymakers is to find new ways to stimulate CHP in China using the market forces envisaged in the reforms.

Many of China's policies recognize the benefits of CHP, but a great opportunity remains to enhance the policy, economic, and institutional environments to ensure that CHP provides a greater share of power and heat generation in China. The country's policymakers, utilities, engineers, and energy users, among others, clearly possess the expertise to address the challenge of increasing energy efficiency through CHP. The purpose of this paper is to provide a concise summary of the context, trends and regulations affecting the Chinese CHP sector, while also providing insights based on the U.S. experience with CHP development. The paper is organized as follows:

- Section 2 summarizes the U.S. experience with CHP, providing insight on the challenges the United States faced with CHP deployment and the policies implemented to help overcome these challenges.

[1] Shen, 2007

[2] Combined heat and power (CHP), also known as cogeneration, is the simultaneous production of electricity and heat from a single fuel source, such as natural gas, biomass, biogas, coal, waste heat, or oil.

- Section 3 provides a summary of the U.S. Environmental Protection Agency's (EPA's) research on the context, trends, and regulations affecting the Chinese CHP sector including barriers to CHP deployment.
- Section 4 presents five high-level recommendations that, if implemented, could build on successful Chinese efforts to date and greatly facilitate the deployment of highly efficient CHP in China. More detailed recommendations are presented in Appendix A.

2.0 The United States' Experience With CHP

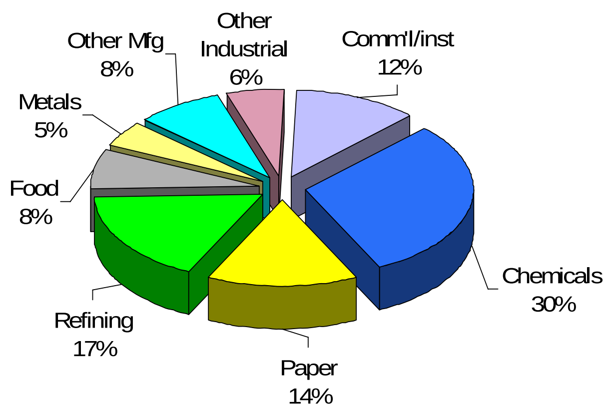
As China moves forward with new policies and incentives in the coming years, aimed to facilitate deployment of CHP, it is instructive to examine how CHP developed in the United States. By presenting information on the U.S. experience with CHP, this section can inform China's efforts to facilitate CHP development. Although power and heat sector markets are somewhat different in China and the United States, many of the barriers, and subsequent policy solutions, to further CHP development are similar in both countries. In part, the recommendations presented in Section 4 are based on what the United States has found to be particularly beneficial in promoting CHP. This section presents:

- The current status of CHP in the United States
- The history of CHP development in the United States
- Current CHP policies and incentives in the United States
- An overview of the EPA's Combined Heat and Power Partnership

2.1 Current Status of CHP in the United States

CHP is an important electric generating resource in the United States; the 85,184 megawatts (MW) of existing CHP generation capacity (at 3,364 facilities) represents more than 8 percent of total U.S. power generation capacity.[3] CHP in the United States uses a wide variety of fuels and technologies and is used in a broad range of applications. Unlike in China, district heating systems in the United States are uncommon, and most CHP systems are sited to meet the needs of an individual industrial facility or commercial building. Figure 1 shows that 88 percent of CHP capacity in the United States is found in industrial applications, primarily providing power and steam to large industries such as chemicals, paper, refining, food processing and metals. CHP in commercial and institutional applications is limited but growing (12 percent of existing capacity), providing power, heating, and, in many cases, cooling to hospitals, schools, university campuses, nursing homes, hotels, and office and apartment complexes.

Figure 1: Existing CHP Capacity in the United States – 85,184 MW (2007)

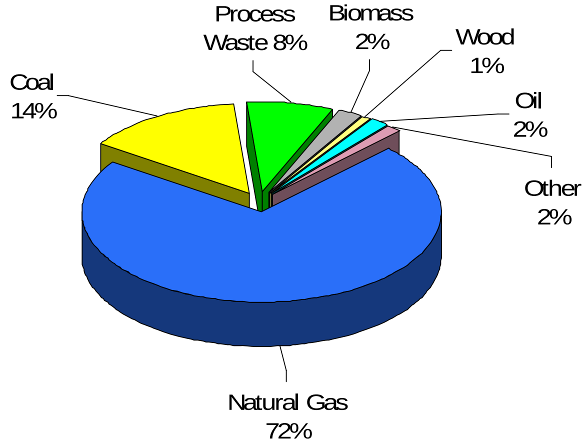


Source: Energy and Environmental Analysis, Inc., 2007

[3] Energy and Environmental Analysis, Inc., 2007

As shown in Figure 2, CHP installations in the United States use a diverse mix of fuels. Although 72 percent of CHP capacity is fueled by natural gas, coal and process wastes make up significant proportions of the current fuel mix (14 and 8 percent respectively). Biomass and wood currently fuel 3 percent of CHP capacity, but both represent growing fuels for CHP.

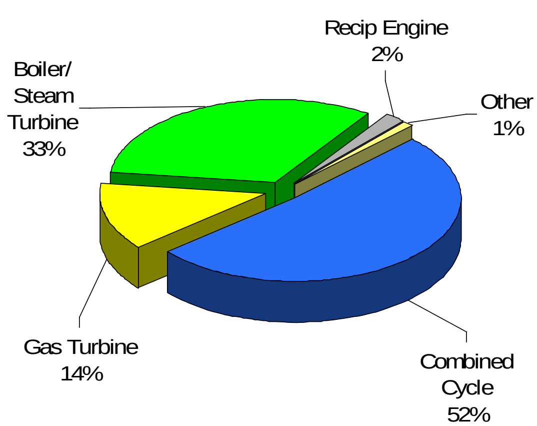
Figure 2: Existing CHP Capacity in the United States by Fuel – 85,184 MW (2007)



Source: Energy and Environmental Analysis, Inc., 2007

The prominent use of natural gas as a fuel for CHP in the United States is driven by the extensive use of gas turbine and combined cycle (gas turbine/steam turbine) systems. Figure 3 shows that combined cycles and gas turbines represent 52 and 14 percent of existing CHP capacity, respectively. Boiler/steam turbine systems represent 33 percent of total CHP capacity and are fueled by solid fuels such as coal and wood waste. Reciprocating engines, primarily fueled by natural gas, represent 2 percent of CHP capacity in the United States. Together, microturbines (small, recuperated gas turbines in the 60- to 250-kilowatt [kW] size range), fuel cells, and other technologies, such as organic Rankine cycles[4], represent less than 1 percent of installed CHP capacity.

Figure 3: Existing CHP Capacity in the United States by Technology – 85,184 MW (2007)

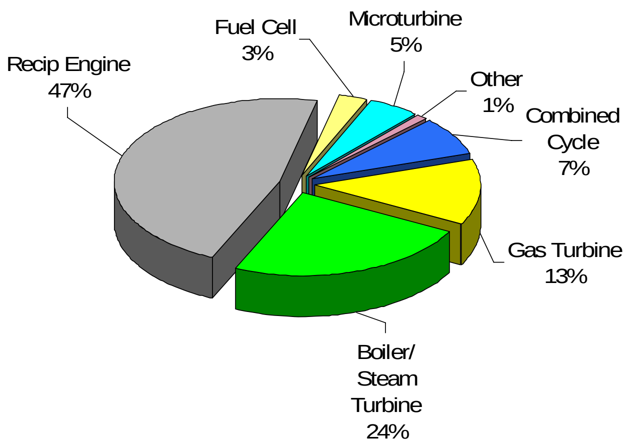


Source: Energy and Environmental Analysis, Inc., 2007

[4] The Rankine cycle is a thermodynamic cycle which converts heat into work. The heat is supplied externally to a closed loop, which usually uses water as the working fluid.

Figure 4 shows the market share of CHP technologies based on the number of installations. Reciprocating engines are the primary technology of choice, used in 47 percent of existing CHP systems in the United States. Emerging technologies such as fuel cells and microturbines are used in 8 percent of existing CHP systems in the United States.

Figure 4: Existing CHP Systems in the United States by Technology – 3,364 Sites (2007)



Source: Energy and Environmental Analysis, Inc., 2007

2.2 History of CHP Development in the United States

Decentralized CHP systems located at industrial and municipal sites were the foundation of the early electric power industry in the United States. However, as power generation technologies advanced, the power industry began to build larger and larger central station facilities to take advantage of increasing economies of scale. CHP became a limited practice utilized by a handful of industries (e.g., paper, chemicals, refining and steel) with certain characteristics—high and relatively constant steam and electric demands and access to low-cost solid fuels or waste fuels. These CHP systems were typically sized to meet the baseload thermal demand of the industrial facility and produced electricity as a “byproduct." Most of these CHP systems consisted of boiler/steam turbines that burned low-cost/low-quality fuels.

By the 1970s, a mature, regulated electric utility industry built around large, power-only central station generating plants controlled the electricity market in the United States. Utilities more often then not discouraged customer-sited CHP by imposing high back-up and standby rates and by refusing to purchase excess power from onsite generators. In addition to utility resistance, a host of regulatory barriers at the state and federal level served to further discourage broader CHP development.

In 1978, Congress passed the Public Utilities Regulatory Policies Act (PURPA), in part to encourage energy efficiency in response to the second oil crisis. PURPA encouraged energy efficient cogeneration (e.g., CHP) and small power production from renewables by requiring electric utilities to interconnect with "qualified facilities" (QFs). CHP facilities had to meet minimum fuel-specific efficiency standards (efficiency hurdles were higher for natural gas CHP) in order to become a QF. PURPA required utilities to provide QFs with reasonable standby and back-up charges and to purchase excess electricity from these facilities at the utilities' avoided cost.[5] PURPA also exempted QFs from regulatory oversight under the Public Utilities Holding Company Act and from constraints on natural gas use imposed by the Fuel Use Act. Shortly after approving PURPA, Congress also enacted a series of tax incentives for energy efficiency technologies, including CHP. The incentives included a limited-term investment tax credit of 10 percent and a shortened depreciation schedule for CHP systems.

The implementation of PURPA and the subsequent tax incentives had the expected effect on CHP development in the United States. Installed CHP capacity increased from about 12,000 MW in 1980 to more than 66,000 MW in 2000. But PURPA also had unforeseen consequences. PURPA was enacted at the same time that larger, more efficient, lower-cost combustion turbines and combined cycle systems became widely available. These technologies were capable of producing greater amounts of power in proportion to useful thermal output compared to traditional boiler/steam turbine CHP systems. The power purchase provisions of PURPA, coupled with the availability of these new technologies, resulted in the development of very large merchant plants designed for high electricity production.

For the first time, non-utility participation was being allowed in the U.S. power market, triggering the development of third-party CHP developers who had greater interest in electric markets than thermal markets, and ultimately starting the progression towards a wholesale generation market in many regions of the United States. In the 1980s and early 1990s, however, qualifying for the CHP PURPA benefits was a requirement for participation in the U.S. electric market, and third-party developers actively sought industrial facilities to serve as thermal hosts. As a result, the development of large CHP facilities (greater than 100 MW), paired with industrial facilities, increased dramatically; today almost 65 percent of existing CHP capacity—55,000 MW—is concentrated in plants greater than 100 MW in size.

The environment changed again in the mid-1990s with the advent of an unfettered wholesale market for electricity. Independent power producers could now sell directly to the market without the need for QF status, and CHP development slowed. CHP once again became disadvantaged in many ways, particularly in small applications. Access to power markets became more restricted, and utilities once again began to again impose high back-up rates and offer low buy-back rates, and users began delaying purchase decisions with an expectation of low electric prices in the future as many states began to restructure their individual power industries.

In the late 1990s, state and national policymakers rediscovered the efficiency and emissions reduction benefits of thermal-based CHP. They realized that a new generation of locally deployed CHP systems could play a critical role in meeting future U.S. energy needs and supplement the building of new central power stations and transmission lines to meet growing power demand. As a result, a number of federal agencies and states began to take actions to promote further deployment of CHP. In addition to supporting research on improved prime movers and integrated packages, the U.S. Department of Energy established eight regional CHP application centers to provide local technical assistance and educational support for CHP development. In 2001, EPA established the CHP Partnership to expand CHP development in under-utilized markets and applications. Individual states also began to develop policies and

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[5] Avoided cost is the cost an electric utility would otherwise incur to generate power if it did not purchase electricity from another source such as a qualified facility.

incentives to promote CHP. States such as California, New York, New Jersey, Pennsylvania, and Connecticut streamlined grid interconnection requirements, simplified permitting for CHP systems, and established ratepayer-financed incentive programs to promote CHP.

2.3 Current CHP Policies and Incentives in the United States

National incentives to promote CHP beyond the research and market transformation programs of the U.S. Department of Energy and EPA are currently limited in the United States. The Energy Policy Act of 2005 established limited-term tax incentives for two emerging CHP technologies (fuel cells and microturbines) and for renewable generation. Not content to wait for federal action, many state governments are developing policies and programs that address their specific energy challenges and spur greater investment in energy efficiency, renewable energy, and CHP. Key initiatives designed to promote CHP development at the state level include:

- **Enacting Output-Based Environmental Regulations**. Designing environmental regulations that account for the emissions reduction benefits of energy efficiency, renewable energy, and CHP increases the attractiveness for facilities to install clean energy technologies and increase efficiency. Output-based environmental regulations, which relate emissions to the productive output of a process (in the case of CHP this productive output includes both electricity and useful thermal output), encourage the use of fuel conversion efficiency and renewable energy as air pollution control measures. For electric generation, this unit of measure is the amount of emissions per megawatt-hour (lb/MWh). In contrast, most environmental regulations for power generators and boilers have historically established emissions limits based on heat input or exhaust concentration (lb/million British thermal units [MMBtu] or parts per million [ppm]). These traditional input-based limits do not account for the pollution prevention benefits of process efficiency and discourage the application of more efficient generation approaches.

- **Establishing Consistent and Streamlined Interconnection Standards**. Economic use of CHP for most customers requires integration with the utility grid to provide back-up power, supplement power needs, and, in selected cases, to sell excess generated power. Therefore, the key to the ultimate market success of CHP is the ability to safely, reliably, and economically interconnect with the existing utility grid system. Standard interconnection rules encourage the connection of CHP to the electric grid by establishing uniform processes and technical requirements that apply to utilities within a state. These rules reduce the uncertainty and prevent long delays and costs that CHP systems can encounter when obtaining approval for grid connection. At present, there are no uniform national standards for interconnection in the United Sates, due, in part, to the fact that jurisdiction over interconnections is split between the Federal Energy Regulatory Commission (FERC) and the states. At the federal level, FERC has adopted small generation interconnection procedures for facilities within its jurisdiction;[6] however, a growing number of states have enacted their own standards based on guidelines developed by industry organizations.

- **Removing Utility Tariff Barriers to CHP**. Customer-sited clean energy supply projects are usually interconnected to the power grid and can purchase electricity from or sell to

[6] Federal Energy Regulatory Commission, 2006

the grid. Electric utilities typically charge these customers special rates for electricity and for services associated with this interconnection. These rates include supplemental, standby, and buyback rates. The unique operating profile of clean energy supply projects (i.e., renewable energy and CHP) often requires tailored rate structures to ensure that benefits are generated for the user. If not properly designed, these rates can create unnecessary barriers to the use of CHP. Appropriate rate design is critical to allowing utility cost recovery while also providing appropriate price signals for clean energy supply. States are exploring different types of rate structures that allow utilities to maintain profitability and also encourage the deployment of customer-sited CHP.

- **Establishing Ratepayer-Funded Incentive Programs**. States are developing various incentive programs to help overcome a variety of first-cost, informational, split-incentive, and other market barriers that limit user investment in energy efficiency and CHP. Seventeen states and Washington, D.C. have adopted ratepayer financed public benefits funds (PBFs) for energy efficiency measures, and 16 states have developed PBFs for clean energy supply including CHP. Incentives include grants, rebates, state tax credits, and generation incentives. Four states (California, Connecticut, New York, and New Jersey) provide capital cost buy-down incentives ($/kW payments) that reduce user investment requirements in specific CHP projects. PBFs are typically created by levying a small charge on every customer's electricity bill, thus providing an annual revenue stream to fund energy programs. For the more comprehensive programs, funding levels range from about 1 to 3 percent of total utility revenues. PBF charges range from 0.03 to 3 mills[7] per kWh and are equivalent to about $0.27 to $2.50 on a residential customer's monthly energy bill.

- **Reviewing Utility Incentives and Planning Processes**. States are designing policies that accurately value energy efficiency, renewables, and CHP resources in a way that "levels the playing field" so public utility commissions and consumers can make fair, economically based comparisons between clean energy and other resources. More than 12 states have developed approaches that remove disincentives for utilities to invest in demand-side resources.

- **Leading by Example**. States are establishing programs that achieve energy cost savings within their own state facilities, fleets, and operations and encouraging the broader adoption of clean energy by the public and private sectors. State governments across the country are collaborating with state agencies, local governments, and schools to identify and capture energy savings within their facilities and operations, purchase or generate renewable energy, and use CHP in their facilities.

2.4 The EPA CHP Partnership

EPA's CHP Partnership (CHPP), established in 2001, represents one of the key means by which the U.S. government has promoted CHP.[8] CHPP is a voluntary program that seeks to reduce the environmental impact of power generation by promoting the use of CHP. The partnership works closely with energy users, the CHP industry, state and local governments, and other clean energy stakeholders to facilitate the development of new projects and to promote

[7] One mill is one-tenth of a cent ($0.001).
[8] The CHPP Web site can be accessed at <www.epa.gov/chp>.

their environmental and economic benefits. Industry partners include energy users in the industrial, commercial, district energy, and institutional sectors, as well as project developers and equipment suppliers. Local partners include state and local energy, environmental, natural resources, and economic development agencies. CHPP provides energy users with hands-on technical assistance in evaluating the efficiency and emissions performance of a variety of CHP project designs; permitting assistance to help guide projects through a variety of local, state, and federal requirements; and public recognition to those companies that demonstrate environmental leadership by installing clean, efficient CHP systems. By supporting potential CHP energy users and government regulators, CHPP helps expand the market for developers and equipment suppliers.

In addition to providing direct support to energy users and state and local government partners, CHPP engages in market development and comprehensive outreach and education. The partnership not only works to promote CHP in a general sense by promoting the efficiency, economic, environmental, and reliability benefits of CHP, but also promotes CHP in undeveloped market sectors. To date, the CHPP has conducted market analyses of CHP opportunities in the dry mill ethanol, hotel/casino, wastewater treatment, data center, utility, and municipal sectors.[9] These analyses provide strategic market intelligence and are intended to demonstrate where CHP industry partners can focus their efforts on increasing their business's CHP market penetration.

[9] More information about the partnership's efforts in these strategic markets is available at <http://epa.gov/chp/markets/index.html>.

3.0 China and CHP

3.1 Why CHP in China?

3.1.1 China's Energy Priorities

With rapid economic development driving growth in energy demand, China faces a number of challenges as it seeks to efficiently and reliably supply energy. Key energy priorities for China based on an assessment by the World Bank[10] include:

- Ensuring energy supply reliability to meet demand growth
- Managing the environmental impact of coal
- Reducing environmental damage by increasing the use of gas and renewables
- Increasing the efficiency of energy use

3.1.1.1 Reliable Power Supply

China is the second largest producer of electricity in the world, and its power demand growth is also among the world's highest. In 2004, coal-fired power generation accounted for approximately 80 percent of the country's electricity production, with the remainder coming from hydro (16 percent), nuclear (2 percent), along with small amounts of wind, solar, and natural gas.[11] Total installed capacity in 2006 reached 622 gigawatts (GW) (compared to 900 GW in the United States) and is projected to double by 2020. In 2006 alone, China added more than 100 GW of new capacity to the grid, more than the entire installed base of Africa, and was expected to add nearly as much again in 2007.

China's growth in electric demand will continue to place strains on the country's electric grid, threatening the reliability of power supply to industrial and residential consumers. China in the past has experienced power shortages, even in areas responsible for China's export boom (Guangdong, Fujian, Zhejiang, Jiangsu, and Shanghai). The World Bank notes that in 2004, 19 out of China's 31 provinces had to ration electricity.[12] Facilitating investment in power supply and grid transmission infrastructure will remain a key concern of the Chinese government in the coming years to ensure reliable energy supply for China's growing economy.

3.1.1.2 Environmental Impact of Coal

China is the second largest energy consumer in the world. Coal accounts for approximately 70 percent of China's primary energy consumption, and China is both the largest producer and consumer of coal in the world.[13] The Development Research Center of the State Council estimates that coal's share in the country's energy balance will remain steady, accounting for 66 percent of primary energy consumption in 2010.[14]

[10] World Bank, 2007
[11] IEA, 2004a
[12] World Bank, 2007
[13] U.S. Department of Energy, 2006.
[14] World Bank, 2007

China's heavy reliance on coal causes wide-scale environmental degradation, adverse impacts on human health, and economic damage. Sulfur dioxide (SO_2) and nitrogen oxide (NO_x), the two primary causes of acid rain, are released through the combustion of coal. The World Bank notes that "in 2002, about 34 percent (or 6.6 million tons) of China's SO_2 emissions were released from power plants," and that "acid rain falls on an estimated 30 percent of China's land mass and has become a threat to agricultural output."[15] Carbon dioxide (CO_2) emissions from China's coal use are also a threat to the global environment, increasing the risk of global climate change. The Chinese government recognizes the environmental threat posed by large-scale coal use, but even ambitious targets to protect the environment are sometimes ignored by local officials who prefer economic growth over environmental protection. Stabilizing emissions will require a major effort on the part of both central government and local government. To mitigate the environmental impact of coal, China has begun to explore carbon capture and storage and other clean-coal technologies, stricter enforcement of emissions control regulation, improved sector policies (such as pricing), and greater use of CHP.

3.1.1.3 Energy Mix

China's heavy reliance on coal presents a number of environmental, health, and economic challenges. Recognizing this impact, China has sought to increase the diversity of its energy mix. In 2004, natural gas accounted for less than 3 percent of total energy consumption in China, but now gas is beginning to gain momentum.[16] Substantial growth in the gas market could be supported if reliable supplies could be secured. In the United States, natural gas constitutes the most widely used fuel for CHP applications, and although not widely available in China, the extent to which China can secure natural gas supplies for CHP use will result in increased efficiency and reduced environmental impact of energy use.

China has enormous renewable energy potential. World Bank estimates include 160 GW of wind power, more than 75 GW of commercially exploitable small hydropower, about 125 GW of biomass energy, and 6.7 GW of known geothermal energy.[17] However, in 2005, renewable sources accounted for only 16.2 percent of electricity/heat generation, with large hydropower plants accounting for 99 percent of this total.[18] To increase renewable energy demand, China adopted the China Renewable Energy Law in 2004 that mandates that electricity suppliers meet a portion of their needs from renewable resources.

3.1.1.4 Energy Efficiency

China's economy is much more energy intensive compared to that of many other industrialized nations, partly due to heavy industry, fuel structure, the use of less advanced technologies, and resource management. Since 1980, however, China has significantly improved its energy efficiency. Energy intensity[19] in China has declined from 2.49 in 1980 to 0.85 in 2004, and in 2005, the Chinese government released an ambitious goal of reducing energy intensity by 20 percent from 2005 levels by 2010.

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[15] World Bank, 2007
[16] U.S. Department of Energy, 2006
[17] World Bank, 2007
[18] IEA, 2005
[19] Energy intensity is measured as tons of oil equivalent of energy consumed per thousand real dollars of GDP.

Future energy efficiency gains represent a challenge as an increasingly market-based economy makes government-mandated programs less likely to succeed and will require price signals as well as stronger regulatory oversight. The World Bank notes that "energy intensity reductions will be heavily influenced by the speed at which China's major energy-consuming industries move closer to international efficiency standards."[20] Moreover, growth in living standards in China will lead to significant construction and infrastructure investments, and the inherent efficiency of this infrastructure, once built, will dominate Chinese energy demand trends for many years to come.

3.1.2 Potential Role of CHP

China has significant opportunities to improve its energy efficiency and reduce CO_2 emissions from its use of coal in the industrial, building, and energy transformation sectors. These sectors are also particularly important for CHP development in China.

Chinese industry consumes a much larger share of final energy demand than in developed countries. Expanding the use of CHP at the industrial level can help reduce this energy consumption, especially since typical heat-only boilers in China tend to be quite inefficient by international comparison.

Roughly half of China's population lives in northern regions where temperatures fall below 40 degrees Fahrenheit for more than 90 days every year. China's urban residential stock is expected to more than double over the next 20 years, which will ensure an increasing demand for space heating and other home energy uses. Increasing the use of CHP in large buildings, and of CHP in district heating, could significantly help manage energy demand and mitigate the associated environmental impact.

But perhaps CHP can play the largest role in improving the efficiency of energy transformation, particularly the efficiency of China's power and heat plants. CHP is significantly more efficient than separate production. Moreover, China's existing district heating plants and industrial boilers tend to be quite inefficient, meaning the potential gains are even greater. The same is also true regarding China's power production.

Extensive deployment of CHP can be a critical part of the solution to China's energy challenges. CHP can allow China to more efficiently use its energy resources, easing some of the stress on these resources and enhancing the reliability of both power and thermal energy supplies. CHP can also facilitate energy diversification, utilizing China's vast renewable resources and exploiting waste heat and waste gas opportunities from heavy industries. Finally, CHP can be an important approach to improve energy efficiency in China's inefficient district heating infrastructure by providing energy efficient heat supply.

The Chinese government has established a goal for CHP capacity. According to the *2010 CHP Development Planning and 2020 Development Goal*, released by the Energy Bureau of China's National Development and Reform Commission (NDRC), the total installed capacity of CHP will reach 200 GW by 2020, accounting for 22 percent of total installed capacity of power generation that year. This goal is expected to increase China's annual energy saving potential in

[20] World Bank, 2007

2020 by 30 million tce. In addition, 13 million tons of CO_2, and 0.6 million tons of SO_2 will be reduced annually, compared to the separate production of heat and power.[21]

3.2 Baseline Inventory of Current CHP Capacity

Estimates of current CHP capacity vary between information sources, and there is clearly a need for better information and tracking of CHP trends. The following summarizes CHP inventory data from Chinese as well as international data sources. Uncertainty in these numbers exists, indicating a need for a more robust tracking and inventory system.

3.2.1 Chinese Data

China has two major sources of statistics on CHP: the primary one is the Ministry of Electric Power, which collects data on CHP above 6 MW connected to the grid.[22] The data do not include end-use CHP. The other data source is the Ministry of Construction (MOC), which only collects information on CHP for residential heat supply (such as district heating for residential buildings; see Section 3.3.2). Neither of these data sources includes industrial CHP that is not connected to the grid, creating the possibility that Chinese CHP statistics underestimate the total amount of CHP in China. The available data also seem to focus more on capacity than on actual supply, which makes it difficult to determine if CHP primarily supplies heat or power. This situation is a particular problem with large central station power plants that supply steam or hot water to adjacent facilities or near-by district heating systems and seems to have been a growing practice encouraged by recent policies. However, reports from Chinese sources indicate that the thermal output is often minimal, yet the full power capacity of the power plant is usually reported as CHP capacity, further distorting the data.

According to the China Electricity Council of the Ministry of Electric Power, the total installed CHP capacity in China was 69.8 GW by the end of 2005, representing a 44.7 percent increase from 2004. These data indicate that CHP accounted for 13.5 percent of total electricity supply in 2005. The top three provinces with the highest installed CHP capacity include Shandong (11.0 GW), Jiangsu (10.4 GW), and Liaoning (5.2 GW). Provinces experiencing the fastest growth in CHP capacity between 2004 and 2005 include Jiangsu (277.8 percent), Zhejiang (158.7 percent), and Hunan (149 percent).

With respect to heat generation, CHP supplied 1.9 exajoules (EJ) in 2005, representing a 16.2 percent increase compared to 2004. The heat generated by CHP within the provinces of Jiangsu, Shandong, and Zhejiang accounts for 41.4 percent of the national total heat generated by CHP.

China Electricity Council data suggest that there were 1,990 CHP installations with a capacity above 6 MW in 2005.[23] CHP units are primarily distributed within cold regions and regions with high demand for industrial heat and hot water.[24] The Taiyuan Number One CHP Plant, with an installed capacity of 1.4 GW, is often cited as the largest CHP facility in China. This situation is an example, however, of the data uncertainties identified earlier. The Taiyuan

[21] Zhou, 2007
[22] The 6-MW value appears to be MW thermal, most likely a reporting limit developed for district heating systems.
[23] The 6-MW floor appears to be a MW thermal capacity.
[24] Wang, 2007

facility is a six-unit central station coal power plant most likely optimized for power production. Data are not readily available on how much useful thermal output is supplied by this plant, but it is likely that including the entire plant power capacity in CHP statistics overestimates actual CHP impact.

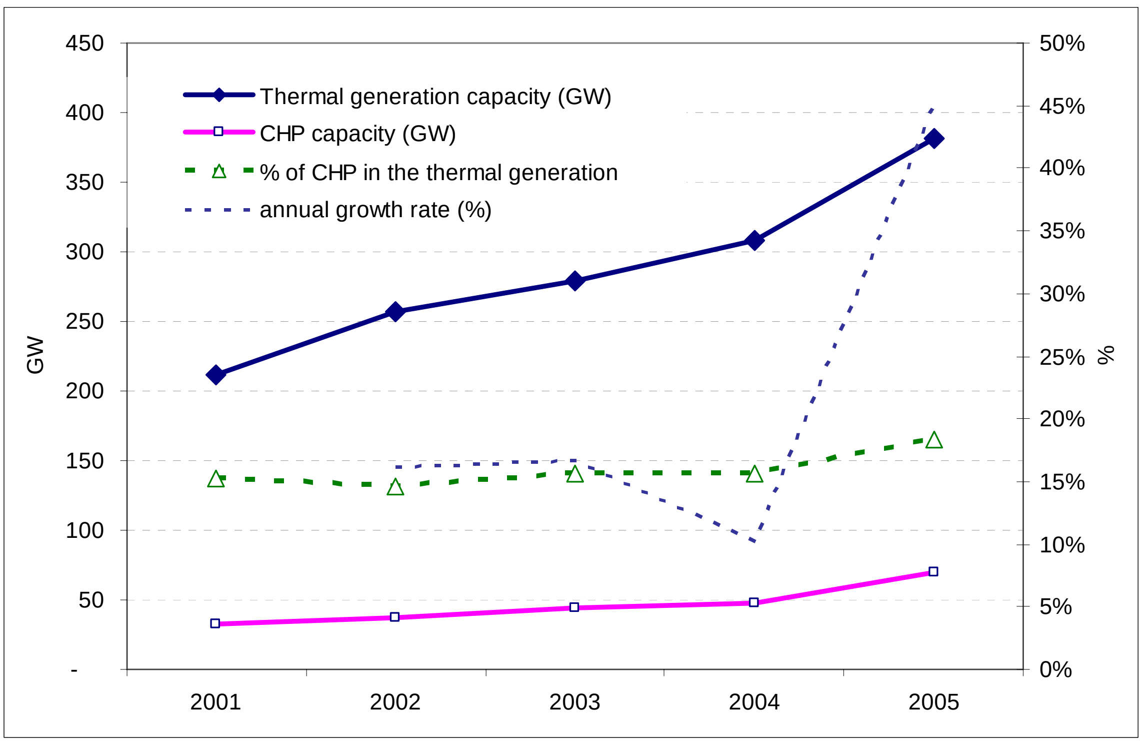
Historical data of CHP from 2001 to 2005, only including CHP units greater than 6 MW, are shown in both Table 1 and Figure 5. The annual growth rates of CHP are 16 percent during 2002 and 2003, dropping to 10 percent in 2004, and increasing again to 45 percent in 2005. In addition, the ratio of CHP capacity to total thermal generation has increased from 15.3 percent (2001) to 18.3 percent (2005).

Table 1: Capacity of Thermal Power Generation and CHP (GW)

Capacity	**2001**	**2002**	**2003**	**2004**	**2005**
Thermal Generation Capacity	211	257	279	308	381
CHP Capacity	32	37	44	48	70

Source: Wang, 2007

Figure 5: Capacity, Annual Growth Rate of Thermal Power Generation and CHP, 2001-2005



Source: Wang, 2007

3.2.2 International Data

According to International Energy Agency (IEA) data, CHP accounted for 12.7 percent of total Chinese electricity supply in 2004, with 56 MW of capacity (see Table 2), whereas Chinese data suggest that CHP accounted for 13.5 in 2005. IEA estimates that CHP will grow to

220 GW by 2020, assuming greater use amongst district heating systems and industry. Data from IEA, the Organization for the Promotion of Energy Technologies (OPET), the World Alliance for Decentralized Energy (WADE), and China's Initial National Communication on Climate Change indicate that CHP has experienced growth in recent years with installed capacity increasing from 17 GW in 1995 to 56 GW in 2004. In 2001, CHP capacity in China equaled 32 GW, though this number excludes CHP units with capacities of less than 6 MW.[25] According to WADE, this number had risen to 48 GW by 2003 and 50 GW by 2004.[26] IEA provides a different number for 2004 (56 GW) (see Table 3).

Table 2: Power Supply in China, 2003-2004

Power	2003 GW	2003 % of total	2004 GW	2004 % of total	2003/2004 Increase %
Total	393		440		12.0
Fossil	292	74.4	325	73.9	11.3
Of which CHP	*48*	*12.2*	56	12.7	16
Hydro	94	23.9	108	24.5	14.9
Other	6.8	1.8	7	1.6	12.9

Sources: IEA, 2006; IEA, 2007b; WADE, 2006

Table 3: Growth of CHP in China, 1995-2004

Year	GW	Annual Growth (%)
1995	17	n.a.
1996	18	12%
1997	21	12%
1998	23	12%
1999	26	12%
2000	29	12%
2001	32	11%
2002	40	25%
2003	48	20%
2004	56	17%

Note: Data for 1996-1999 and 2002 are estimated.
Sources: PRC, 2004; OPET, 2003; WADE, 2006; IEA, 2007b.

WADE also provides rough information on the sectoral breakdown of CHP in 2000, presented in Table 4.

[25] OPET, 2003
[26] WADE, 2006

Table 4: CHP by Sector, 2000

Sector	MW Installed
Petroleum	6,400
Chemicals	1,885
Pulp and Paper	1,500
Metals	520
District heating	1,000

Source: WADE, 2006.

3.3 Overview of Power and District Heating Sectors in China

Over the past decade, China has embarked on several policy reforms that could have a profound affect on the viability of CHP. In addition to the policies outlined in Section 3.4, there have been significant reforms in the power and district heating sectors in China. Policies that favor centralized installations away from load centers or those that do not provide a competitive advantage to more efficient plants will typically put CHP at a disadvantage. Likewise, tariffs for CHP products are strongly influenced, if not determined by, national policy on power and heat tariffs. The same holds true with collections and payment mechanisms, as well as many other issues important to the financial viability of CHP.

3.3.1 Power Sector Reforms

China's power sector is in the midst of a transition from a vertically integrated, government-owned monopoly to an unbundled, market-oriented industry with many of the characteristics of reformed power sectors in other parts of the world. The objectives of this reform, similar to those that have been implemented elsewhere in China, are to increase the overall efficiency of the sector; achieve a more rational allocation of risk and return among private investors, consumers, and the government; spur technological innovation; and improve the industry's environmental profile. To these ends, the government envisions a restructured electric sector in which generation will be fully competitive in large regional markets, transmission and distribution will be regulated monopoly services, and retail service will be competitive—that is, that consumers will be able to choose among providers and products.

The rapid growth in China's power sector has led to significant supply imbalances, with periods of power shortages punctuated by power oversupply. Currently, China is emerging out of a period of severe shortages. Supplies are stabilizing, but some regions still experience blackouts and forced disruptions because of supply imbalances.

China began power sector reforms in the 1980s as part of larger economic reforms, though change was relatively slow initially. By late 2002, China had moved from a single integrated utility to an unbundled power sector. China now has two grid companies (a large one covering most of the country, and a small one in the south). In addition, it has five large generation companies and a series of smaller generation companies.[27] It also has a series of local

[27] Five state-owned generating companies were established in 2002: China Huaneng Corporation, China Huadian Corporation, China Power Investment Corporation, China Guodian Corporation, and China Datang Corporation. The total generating capacity controlled by each generating company is about 30 GW. Each generation company's

distribution companies and a regulator (the State Electricity Regulatory Commission). Power prices are still regulated, though prices of coal (the main fuel) are in principle set by the market. The regulator does not set the power prices, but rather this is the role of NDRC. As a result, prices are based on social factors in addition to economic ones.

IEA provides data on the regional breakdown of power production by fuel source (but not by equipment type) (see Table 5). Where the share of fossil-fired capacity is low, the balance is primarily supplied by hydropower (though the southern China and east China grid had 5.3 and 3 percent, respectively, of nuclear power). As hydropower tends to be very inexpensive, CHP might be less competitive long-term in regions with large shares of hydropower, such as central China (43 percent hydro), southern China (36.4 percent) and northwest China (30.4 percent). In the short term, regional differences in power tariffs do not seem to be primarily driven by differences in production costs. Hence, Beijing has some of the lowest power tariffs, but not the lowest costs.

Table 5: Geographic Distribution of Fossil-Fired Power Generation, 2003

Grid	Installed Capacity (GW)	Fossil's Share of Capacity (%)
North China grid	81.8	96.3
Northeast China grid	35.3	85.5
Northwest China grid	20.7	69.2
East China grid	65.2	80.2
Central China grid	47.4	56.8
Southern China grid	41.6	58.2
Total	292.1	74.4

Source: IEA, 2006

China has made substantial improvements in reforming its power prices, and more reforms are planned. China does not use a systematic, comprehensive, or transparent cost-based pricing system. Instead of starting with a detailed "bottom-up" review of costs, China's price-setting authority takes existing prices as the starting point. With each electric company, NDRC enters into a negotiation process that generally focuses on factors that tend to change unit prices, such as the addition of expensive new sources of power. As coal prices have risen in recent years, power prices have not fully kept pace. A new NDRC formula links power prices to coal prices, but it only passes on approximately 70 percent of the increase in coal prices to the price of electricity. This system has put a tremendous squeeze on generators. Small generators (such as those that often own CHP facilities) typically find it more difficult to weather such financial pressure; thus, this spread in power and coal prices has created disincentives for CHP. This situation also creates other challenges for CHP. CHP producers often are not directly connected to the grid, so their power prices are not regulated. This situation means that they can, in principle, pass on higher costs to their customers if there were fuel price clauses in the contract. In reality, though, the courts have often aligned with consumers instead of independent power producers when power prices exceed regulated tariffs, even when contracts clearly state that prices can float based on a formula related to fuel prices. Also, the fact that independent power prices can rise above those of grid power means that consumers have an incentive to buy regulated grid power. The main incentives to buy cogenerated power are onsite reliability in the

share of installed capacity in each regional power system is about the same. The total generating capacity controlled by these five generating companies is 46 percent of the total generating capacity in China.

face of frequent grid-based power shortages, and cost-effectiveness (when considering the combined value of power and heat supply). Appendix B contains information about system dispatch practices in China.

With the power reforms, grid access should become more transparent over time, but this transparency has not yet been achieved. For example, the two main grid companies also own generation assets. The larger of these companies, State Grid Corporation of China, actually owns more than 30 GW of generation assets (mostly hydro and coal-fired stations). This creates a built-in disincentive against independent, cogenerated power. CHP producers are viewed as competitors to the five large generation companies, and so, institutionally, getting equal access to a grid can be difficult. China's power sector has only been unbundled for five years, so institutional and personal ties from the integrated system have not entirely disappeared. The State Grid Company of China owns five of the six regional grids, as well as the interregional transmission lines and about 75 percent of the distribution assets in its service territory.

In China, the grid is not entirely integrated throughout the country, though significant progress has been made in recent years in adding interregional connections. From the perspective of CHP, however, this change can actually increase the degree of competition with remote power generation sources, as a more integrated grid allows more distributed generators to supply power to the grid. Moreover, the power tariff builds the price of transmission into the generation price. There is therefore no advantage for local power generation, even though transmission and distribution costs may be significantly lower; this is one reason that most CHP projects are not integrated into the grid, but rather, they supply power and heat directly to nearby customers.

China has begun to experiment with competition between power generators and has a plan to roll out this approach on a region-by-region basis. In 2004, the government launched pilot power markets in the Northeast and East; a pilot market followed in southern China in 2005. In Northeast China, 20 generators were originally selected to participate with 15 percent of their normally allocated power to be bid into the market. The first phase in the Northeast is already underway and involves establishing systems for trading and market supervision, as well as opening part of the generation market for competitive bidding. Pricing is divided into a regulated capacity charge and a market-based energy price. The second phase will extend competition coverage and launch trial bilateral transactions between generators and independent distributors or large consumers. The third phase will include introducing retail competition and establishing a generation capacity market. The exact timing of each phase has not been clearly defined, and the exact elements of each phase vary regionally, but the Chinese government has embraced the idea of a phased introduction. In addition to broadening the competition within the regions with pilot programs, the government plans to roll competition out to the three regions that do not yet have competition.

One challenge facing the Chinese power sector is the complex nature of the reform process; periods of reform are full of uncertainty, particularly when the full spectrum of reform is not defined but rather slowly evolves over time. This scenario can inhibit investment, particularly by smaller companies or in new technologies. The goals behind this competition policy include establishing an open, competitive, and orderly power market; breaking down provincial protectionism; and stimulating investment. Efficiency was not a major goal of the reforms launched in 2002.

The power industry is now overseen by three main institutions: the NDRC, the State Electricity Regulatory Commission, and the state-owned Assets Supervision and Administration Commission. The NDRC itself has three relevant bureaus: the Energy Bureau (responsible for power sector policy and strategy and project approval), the Pricing Department (sets power prices), and the Environment and Resources Comprehensive Utilization Department (deals with energy efficiency). The State Electricity Regulatory Commission regulates the sector, apart from setting prices and approving projects. It also develops reform plans. The State-Owned Assets Supervision and Administration Commission controls ownership of state-owned companies in the power sector, overseeing their management and performance.

A large share of the power sector is still in state hands, which includes the five main generators, the grid companies, and most distribution assets. In the 1980s, the government began encouraging foreign investment in the sector, with a goal of 50 percent foreign direct investment. Initially, much of this investment came from development banks such as the World Bank, but over time, foreign companies increased their investments as well. Foreign investment accelerated when the government adopted a policy it called “new price for new power,” which meant that new power generators could charge higher prices to recover costs and provide a fixed return on investment. With the power reforms, though, this policy was eventually cancelled, and now all plants are reimbursed on an output basis. A capital cost component is included in their compensation, based on an estimated number of hours of operation annually. Beginning in 2004, all new generators were paid a standard offer price based on the technology and the province, but plants built before 2004 receive payment on a differentiated basis.

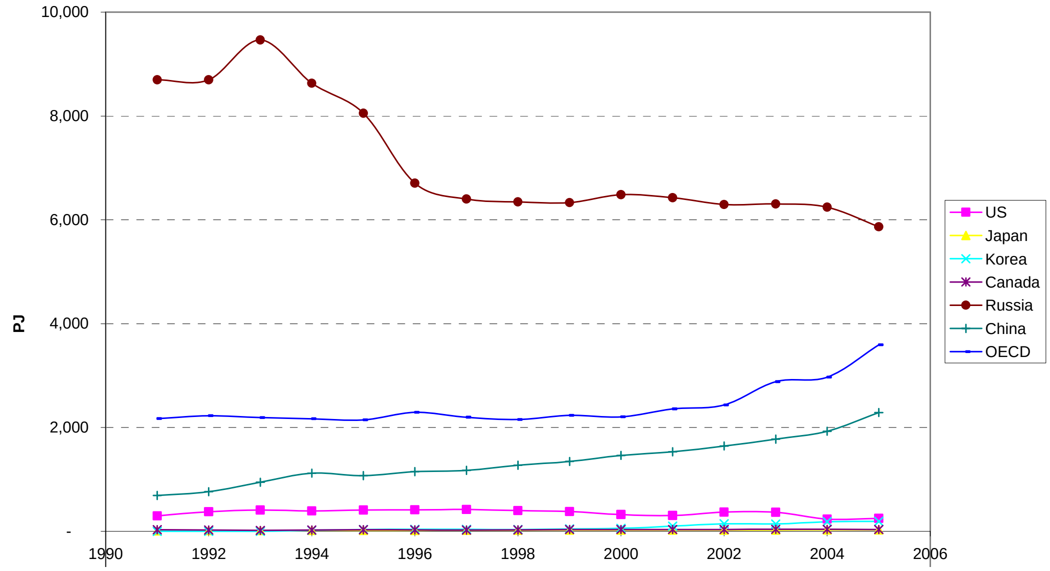
Each generator operates roughly the same number of hours annually, regardless of operating costs or efficiency. In practice, independent CHP producers have found that they get relatively low compensation for their power output sold to the grid, and they can have high connection charges. The low compensation might be based on an economically unfavorable formula for splitting costs between power and heat production, since heat prices are regulated separately and heat sold directly to industrial consumers is not regulated. In other words, the price paid for CHP power might reflect a relatively low share of the costs of CHP production, and as such, it may be difficult to recover the remaining costs from the heat sales.

3.3.2 District Heating Reforms

3.3.2.1 District Heating Market

The district heating market is developing rapidly in China. While individual systems in China do not rank among the largest in the world yet, there are so many smaller systems that China today is the second largest district heating producer in the world, after Russia. Figure 6 shows the development of the district heating market in China and in other countries. District heating in China grew steadily from 1991 to 2005. Table 6 shows that growth has occurred in most major sectors but has been strongest in the residential sector and the commercial sector (though commercial demand, such as to heat offices, stores and schools, is still quite small relative to total demand).

Figure 6: District Heating Market in China, Asia, and the OECD, 1991-2005



Source: IEA, 2007a

Table 6: Growth in District Heating Demand, 1994-2004

Country	Growth rate (%)
People's Republic of China:	72
- Industrial sector	44
- Residential sector	190
- Commercial sector	881
Korea	352
Japan	70
OECD Total	26

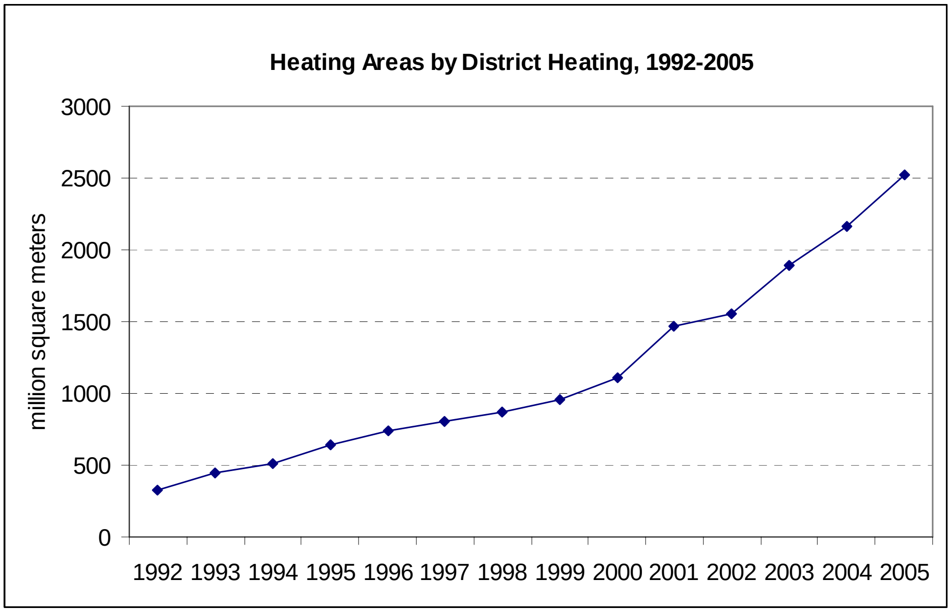
Source: IEA, 2007a

By the end of 2003, 321 of China's 660 cities had district heating. In 2005, the total heating area of district heating reached 2.52 billion square meters, representing an increase of 17 percent compared to the previous year (see Figure 7). In 2005, CHP also provided 82 percent of the steam and 30 percent of the hot water used for district heating.[28] The district heating sector has grown rapidly, increasing by 72 percent between 1994 and 2004. Major efforts are underway to consolidate small, coal-fired boilers into large coal or gas-fired boilers, but coal is still the dominant fuel. CHP exists in the district heating sector, but there is little official published data on the extent of it. Chinese experts estimate that 15.6 to 28.8 percent of Chinese district heating is generated at CHP plants.[29] A handful of Chinese cities also have district cooling, including

[28] Wang, 2007
[29] Wang, 2007

Beijing, Guangzhou, and Shanghai, though these systems tend to be limited to certain districts within the cities.

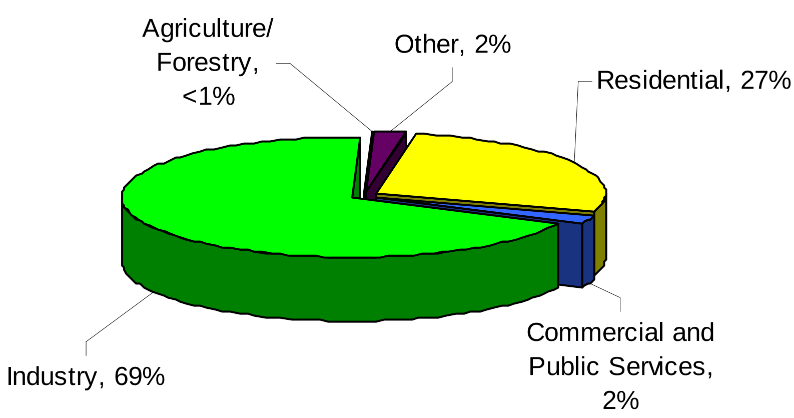
Figure 7: Heating Areas by CHP, 1992- 2005



Source: Wang, 2007

The industrial sector receives approximately two-thirds of the district heating supply in China, and the residential sector consumes most of the rest. Within industry, the chemical and petrochemical sectors are the largest consumers of district heating (see Figure 8).

Figure 8: 2004 Heat Demand in China by Sector



Source: IEA, 2007a

3.3.2.2 District Heating Policies

China's heating policy has undergone a transformation from a symbol of welfare (i.e., government subsidized) to a commodity with a huge market over the past few years. In 2003, the Ministry of Construction (MOC) announced heat-sector reforms. The reforms stated that residential consumers must now pay for heat. In response, prices have increased and cities are gradually installing meters and switching to consumption based billing. In addition, all new buildings in areas with district heating must have metering and controls. Before China announced heat-sector reforms in 2003, providing sufficient and low-priced heating to residents who live in areas with cold winters had long been regarded as a part of a social welfare system in China. Heating costs were often measured by heated square meters, not by actual heating consumption. For some residents, heating costs are still covered by their employers. *Strengthening the Measures of Urban Central-Heating Supply*, a law issued by the State Council in 1986, grants heating industries a reduction in or exemption from the regulatory tax, which should facilitate adoption of reasonable tariffs for heat supply.

At the end of 2002, the MOC and seven other ministries released guidelines titled *Opinions in Promoting the Commercialization of Public Municipal Industries*, which signaled the start of market transformation of community services, such as heating supply. The guidelines cover issues such as opening the public utility market for investment, improving management practices in the heat industry, and reforming tariff regulation. They focus on pilot cities to test the concept. Hence, in 2003, the MOC launched pilot heating reform in the heating zones. The reforms were further reinforced in late 2005, with publication of additional goals, and an expansion of the pilot program. The 2005 document focuses on transferring payment responsibility to individuals, metering heat use and establishing consumption-based billing, modernizing heat supply systems, and reforming pricing and regulation.

Progress to date on many heat reform issues has been city-specific. Some cities (such as Beijing and Liaoning) are quite advanced in their reforms, while most have not yet undertaken reforms to make pricing consumption based. The World Bank has collaborated with some cities on their reforms, such as Tianjin.

3.4 Review of Chinese Policies to Promote CHP (1989-2007)

Since 1989, China has promulgated many polices and recommendations to help increase the efficiency of energy use. Several specifically target the role of CHP, while others address the issue indirectly. These policies and regulations show an understanding of the value of CHP and have served to expand the use of CHP, yet opportunities remain to further facilitate deployment of CHP.

3.4.1 CHP-Specific Policies/Regulations

By 2007, China had issued four major national policies and regulations focused specifically on CHP. (Note: the term "cogeneration" has been explicitly written in the title of the adopted policies and regulations. Hereafter, we use CHP and cogeneration interchangeably) These four polices/regulations are described in the following subsections:

3.4.1.1 Regulations for Encouraging Development of Small-Cogeneration Plants and Restricting Construction of Small Condensing Plants (1989)

Regulations for Encouraging Development of Small-Cogeneration Plants and Restricting Construction of Small Condensing Power Plants was issued in 1989 by the State Planning Commission (SPC), now the NDRC. This regulation states that industrial or residential heating boilers should, but are not required to, convert to CHP when conditions are met (although there is no specific information to define the conditions). The regulation also states that the local planning commission and economic commission should be in charge of project planning and approval, and that the electricity generation from CHP plants should be driven by the heat load. The regulation also states that CHP units are not required to engage in peak-load adjustment, and that the fuel supply for CHP should be guaranteed. Materials and equipment for CHP development should also be integrated into mandatory planning based on financing channels. The regulation suggests several financing mechanisms for developing CHP, such as establishing a special fund, self-financing by cogenerators and offering low-interest loans. Foreign investment is not mentioned as a financing channel.

3.4.1.2 Regulations for Cogeneration Development (1998)

Regulations for Cogeneration Development was published nine years later, in 1998, by SPC, the State Economic and Trade Commission (SETC), the MOC, and the Ministry of Electric Power (MOEP). It includes the first legal explanation of the term “cogeneration” in Chinese national policy by defining the total heating efficiency and the ratio between heat and electricity by CHP unit capacity. This regulation also suggested removing the grid connection fee for electricity generated by newly built CHP plants and newly installed capacity at expanded CHP plants.

3.4.1.3 Regulations for Cogeneration Development (2000)

On the basis of the experiences and comments obtained from the implementation of the previous two regulations, NDRC, SETC, MOC, and the State Environmental Protection Administration (SEPA) issued the *Regulations for Cogeneration Development* in 2000, the first comprehensive national CHP policy. In contrast to the previous two regulations, it explicitly states that if there is any difference between this document and other documents in explaining CHP policies issued by the NDRC, SETC, MOC or SEPA, the content in the 2000 regulation takes precedence (Article 22).

For the first time, these regulations clarified the procedures for approving CHP projects (Article 6). For example, NDRC is in charge of project approval if CHP unit capacity is above 25 MW and for combined-cycle gas-fired power plants with electricity generation capacity over 25 MW. The Development and Reform Committee (DRC) is in charge of project approval at the autonomous, provincial, and municipal city levels for CHP projects under 25 MW, but reports to NDRC for documentation. If the foreign capital involved in a CHP project is over $30 million, NDRC is the administrative agency for project approval.

The 2000 regulation re-addresses some CHP definitions listed in the 1998 regulation (Article 7). For example, the total heat efficiency should be greater than 45 percent. The annual average ratio between heat and electricity should be greater than 100 percent for a CHP unit with a capacity below 50 MW (meaning it provides more heat than electricity), and higher than 50 percent for a CHP unit with a capacity between 50 MW and 200 MW. The annual average ratio between heat and electricity during the heating season should be more than 50 percent for an extraction/condensing steam duel-use heating unit with a capacity of more than 200 MW. Heat efficiency and the ratio between heat and electricity are defined as:

> Heat Efficiency = (provided heat + provided electricity * 3600 kilojoule (kJ)/kWh) / (the total consumption of fuel * fuel unit in low heat value) * 100%
>
> Ratio between Heat and Electricity = provided heat / (provided electricity * 3600 kJ/kWh) * 100%

In addition, the regulation adds a description of combined-cycle gas-fired CHP (CCGC) systems, and suggests that its annual average efficiency should be more than 55 percent, and the annual average ratio between heat and electricity should be higher than 30 percent for all capacity units (Article 7).

Moreover, the regulation gives special attention to CCGC by explaining the reasons for promoting this technology (Article 14). It states that:

- CCGC has several advantages: it is energy efficient, less polluting, and close to the heat and electricity load. The Chinese government encourages using natural gas, coalbed gas, and other gases as fuel for CCGC.
- Promoting CCGC should be scaled appropriately, taking into consideration the size of the local heat and power market, and providing heat as the main purpose. In order to improve integrated utilization of resources and the capability of seasonal adjustment, it encourages the implementation of residual-heat boiler(s) for burning compensation.
- The natural gas price should be determined based on the fact that CCGC creates a large and stable gas demand and provides support for peak-adjustment for the natural gas pipe grid.
- A small-scale CHP system, which consists of small-scale gas-fired generating unit(s), residual-heat boiler(s), and other equipment, can be installed in plants, enterprises, office buildings, commercial buildings, hotels, hospitals, banks, and schools. The regulation states that small-scale CHP systems are beneficial because they are efficient, consume less land, protect the environment, and improve reliability.

The regulation further states that heating bills should be calculated according to the heat consumed by consumer unit. It suggests that new residential buildings should be charged for heat according to actual consumption. All heating tariffs will adopt this principle by 2010 (Article 18).

3.4.1.4 Temporary Regulation for Project Development Management of Cogeneration and Power Generation of Integrated Utilization of Coal Tailing (2007)

The most recent CHP policy, titled *Temporary Regulation for Cogeneration and Power Generation of Integrated Utilization of Coal Tailings*, was issued by NDRC and MOC on January 17, 2007. This policy is written based on the State Council's Decision on Investment Institution Reform and is in line with the 11th Five-Year Plan published in 2005 (Article 1), which identifies CHP as one of the 10 energy efficiency priority programs. Although CHP and power generation using coal tailings are contained in one policy document, this regulation has separate explanations for each, and joint paragraphs for both when applicable.

In contrast to the 2000 regulation, which provides a detailed technical explanation and definition of CHP technology, this newly released policy focuses on the issues related to CHP project administration.

The first section, "General Rules," states that the Development and Reform Commissions (including Economic Commissions and Economic and Trade Commissions) should be in charge of power generation planning, project application and approval, ratification, and related monitoring (Article 3).

In the "Planning" section, the regulation reiterates that the planning of CHP development should be based on the national development plan for power generation, national industrial policies, the general development planning of a local city where a CHP plant will be built, taking into account city size, local industrial development, and natural resources. The planning should be considered prior to the retrofit of existing power plants and the shut down of small heat plants and boilers (Article 4). The regulation also states that the planning of CHP should be integrated into provincial (including municipal and autonomous region) power generation planning. Regional CHP power capacity should be integrated into national planning of power generation (Article 4), and that supplying heat should be set as a precondition for CHP development. Areas without concentrated heat loads are not encouraged to develop CHP (Article 9).

For the first time, the geographic priorities for developing CHP are clearly identified. Regions with severe winters and concentrated heat loads (such as north of the Qin Mountain and the Huai River, the Xinjiang Autonomous Region, Qinghuai, and the Tibet Autonomous Region) should actively develop CHP to replace small heat-only boilers. In regions with hot summers and cold winters (such as the southern areas of the Long River), CHP should be developed where there are concentrated heat loads. Trigeneration (the simultaneous generation of power, heat, and cooling) is also encouraged in these hot-summer-and-cold-winter regions. For regions with hot summers and warm winters, there is little need for CHP development except for some industrial areas that have concentrated heat loads (Article 10). Additionally, industrial parks with large heat loads should pursue CHP development if possible (Article 11). In areas with existing CHP plants, the regulation discourages the development of additional end-use sited CHP plants. Except for large-scale enterprises such as petroleum, chemical, steel, and paper industries, the regulation does not encourage the use of CHP to serve single enterprises (Article 12).

The regulation states that back-pressure turbine CHP units represent the preferred prime mover among CHP projects. If a back-pressure unit cannot meet the heat load, the regulation encourages the use of large-scale high-efficiency generating units with a capacity of 200 MW and higher (Article 13).

Moreover, the regulation states that the service territory of CHP projects that use hot water as the heating medium should be set within 20 kilometers of the load, and that no similar projects should exist within 10 kilometers. For CHP projects that use steam as the heating medium, the service territory should be 8 kilometers or less, and there should be no similar projects built within that 8-kilometer range (Article 15).

The section of "Ratification" states that environmental concerns must be considered as prerequisites for project approval. Except for back-pressure units, the annual energy consumption and local environmental pollutants of the CHP projects should be lower than the levels of separate heat and power generation, or the project will not be approved (Article 16).

In the "Support and Guaranty" section, the regulation states that the central government will encourage the use of a variety of approaches to solve heating problems in medium and small cities, such as the use of biomass, solar, geothermal and other renewable energy, as well as the use of natural gas, coal gas, and other resources to implement CHP (Article 20). This is the prologue for NDRC's Preliminary Dispatch Rule for Power Generation of Energy Conservation, which was issued on August 2, 2007. Price setting for electricity (Article 22) and heat (Article 23) generated by CHP are also better defined, as are issues related to dispatch (Article 24) in this section. The regulation states that the grid electricity price should be based on NDRC's Temporary Regulation for Grid Tariff Management. In the regions with a price bidding mechanism, the grid price should be determined by market competition. For regions without a price bidding mechanism, the grid price of newly built CHP projects should be based on the public grid electricity price of newly built coal-fired units (Article 22). The plant gate price of heat produced by CHP projects should be determined by provincial pricing administrative agencies and authorized city and county governmental agencies, which will make decisions based on relevant national regulations, heat cost and profit ratios. The goal is to gradually implement the same price for heat whether the heat is produced by CHP or by other means.

In the "Monitoring and Inspection" section, the regulation states that annual inspection of CHP projects will be implemented by the provincial Development and Reform Commissions and other related agencies (Article 27). It also states that CHP should be given an advantage for connecting to the grid (Article 24), though it does not provide details on how that advantage will be implemented.

3.4.2 CHP Relevant Policies

CHP is regarded as a key energy efficiency technology in cutting China's soaring energy use. China is undergoing an aggressive national campaign to reduce energy consumption, improve energy efficiency and mitigate environmental pollution. The following policies related to energy efficiency, and renewable energy development in China are related to CHP development.

3.4.2.1 Air Pollution Prevention Law (2000)

To improve deteriorating air quality, China issued the *Air Pollution Prevention Law* in 2000. The law explicitly mentions CHP twice. Article 28 of Chapter 3 states that CHP should be promoted in coal-burning-for-heating-regions, and that new coal-burning boilers for heating purposes are not allowed to be built in regions where CHP systems already provide coverage. The law states that if Article 28 is violated, the county-level administrative agencies in charge of environmental protection will order generators to terminate violations and/or issue fines of 50,000 RMB.

3.4.2.2 Cleaner Production Law (2002)

The *Cleaner Production Law*, issued in 2002, does not explicitly mention CHP, but Article 26 of Chapter 3 states that to the extent technically and economically feasible, enterprises shall recover and utilize their own wastes or wasted heat generated from production processes, or transfer these wastes to other enterprises or individuals that have the ability to do so. In addition, both Articles 7 and 35 mention tax advantages for cleaner production, which can include CHP. With respect to products produced from wastes and materials reclaimed from wastes, the law states that the taxation authorities shall reduce or exempt such products from value added tax in accordance with relevant national regulations.

3.4.2.3 China Eleventh Five-Year Plan (2005)

Facing daunting challenges from soaring energy demand and a deteriorating environment, the Chinese government called for building a resource-conserving and environmentally friendly society in its *Eleventh Five-Year Plan*, released in 2005. This plan is widely regarded as the most important road map for China's social and economic development for the period from 2006 to 2010.

In this newest national plan, 10 priority programs related to energy conservation have been identified for meeting a goal to reduce energy intensity and mitigate primary pollutants by 20 percent and 10 percent, respectively, by 2010, compared to the same levels in 2005. The 10 programs include:

1) Energy efficiency improvement of industrial boilers
2) District heating and power generation
3) Recovery of residual heat and pressure
4) Oil saving and substitution
5) Energy conservation of motor system
6) Optimization of energy systems
7) Energy conservation in buildings
8) Energy-efficient lighting
9) Energy conservation in governmental buildings and vehicles
10) Building the energy conservation monitoring and technological support system

CHP ranks second in this list. In addition, other target programs seem related to this area as well, such as the projects (3), (6) and (7).

The Chinese government clearly seems committed to fulfilling its ambitions of energy conservation. In the first half of 2007, China closed small thermal power plants with capacities totaling 6.95 million kW, 70 percent of the annual goal. By the end of July 2007, the central government allocated 21.3 billion RMB to support energy conservation and mitigation projects, up 13 percent compared to the previous year. On September 1, 2007, NDRC, along with the other 16 national governmental agencies and departments, kicked off a public campaign to call for every Chinese citizen and the whole society to actively participate in energy conservation and greenhouse gas mitigation.

3.4.2.4 The China Renewable Energy Law (2005)

Increased use of renewable energy resources is seen as a key strategic element in maintaining the balance between energy supply and demand in China, as well as mitigating carbon emissions resulting from burning fossil fuels. At present, traditional, noncommercial renewables (e.g., fuel wood) provide China with energy of more than 300 million tce annually. In 2005, hydropower installations provided 397 billion kilowatt hours (kWh) of power, accounting for approximately 16 percent of China's total electricity output.[30] China's total annual use of renewables surpassed 159 million tce, accounting for 7 percent of the nation's total energy use in 2005.[31]

The *China Renewable Energy Law* was issued on February 28, 2005, and became effective on January 1, 2006. In January 2006, three key regulations were issued: 1) Regulation on Management of Renewable Power, 2) Regulation on Renewable Power Pricing and Cost Sharing, and 3) Guideline Catalogue for Renewable Energy Industry Development.

This *China Renewable Energy Law* has resulted in electricity feed-in incentives for power produced from biomass/biofuel based CHP and should help accelerate the deployment of biomass CHP in China. At present, biomass energy resources in China are utilized mainly through conventional combustion technologies. Biomass gasification, liquefaction, and power generation technologies are, however, gradually being developed. For gasification, the main method promoted and used is anaerobic fermentation, though technology for the direct gasification of biomass resources is also being developed. China currently has a total of more than 17 million household biogas digesters and more than 1,600 industrial-scale biogas plants, which together produce more than 8 billion cubic meters of biogas annually. In terms of biomass liquefaction technology, China is in an investigative and experimental phase. Currently the main technologies developed and in use are ethanol fuel technology and bio-oil technology. China has already established two large ethanol fuel production bases, one in the North and one in the South, with a total annual production capacity of greater than 1 million tons. Biomass power generation in China, with an installed capacity of almost 2,000 MW, consists mainly of CHP in sugar mills and power generation using rice husks and municipal solid waste. Other types of biomass power generation, such as that achieved through biomass gasification or hybrid fuel technologies, have not yet reached significant scale in China.[32]

3.4.2.5 Energy Development in the Eleventh Five-Year Guidance (2007)

In line with China's *Eleventh Five-Year Guidance* issued in 2005, NDRC released its energy development blueprint for the same period in April 2007, titled *Energy Development in the Eleventh Five-Year Guidance*. In this public policy, NDRC details its goal for national and industrial energy conservation. Energy intensity will be decreased from 1.22 tce/10k yuan (in 2005 constant RMB) in 2005 to 0.98 tce in 2010, which will reduce carbon emissions by 360 million metric tons and SO_2 emissions by 8.4 million metric tons in 2010. Table 7 presents the unit energy consumption of key industrial products. For example, for the Chinese plan to reduce the fuel intensity of thermal power plants by 4 percent from 2005 to 2010, the energy intensity for cement and steel will drop 5.7 percent and 4 percent, respectively, during the same period.

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[30] National Bureau of Statistics of China, 2007
[31] National Bureau of Statistics of China, 2007
[32] Chinese Renewable Industries Association, 2006

Table 7: Unit Energy Consumption of Key Industrial Products

Name	Unit	2000	2005	2010
Electricity generation of thermal power plants	gram coal equivalent (gce)/kWh	392	370	355
Cement	Kilograms coal equivalent (Kgce)/ton	181	159	148
Steel	Kgce/ton	906	760	730

Note: Units are in grams of coal equivalent and kilograms of coal equivalent.

In developing the power generation industry, the government will promote CHP, trigeneration, and combined-cycle coal gasification power plants. Back-pressure units should be considered as a favorite technology in regions that have large industrial heat loads. Building 300 MW high-efficiency CHP units will be preferred in regions that have a concentrated residential heating load. The rate of urban district heating will rise from 30 percent to 40 percent, with newly built CHP units providing more than 40 GW of power capacity.

The highest priority technologies related to distributed energy systems are identified as micro-scale steam engines, energy storage, and trigeneration technologies.

3.4.2.6 Urban Heat Tariff Interim Measures (2007)

Heat tariff reform has long been recognized as an important step to promote CHP and energy savings in residential space heating. In order to develop and standardize the formation mechanism of the urban heat tariff, NDRC and MOC issued the *Urban Heat Tariff Interim Measures* in June 2007. Article 4 of Chapter 1 explicitly states that the government encourages the development of CHP and district heating and allows non-public capital (including foreign capital) to invest, construct, and manage heating supply facilities to promote the gradual commercialization of heating industries.

Article 5 of Chapter 1 states that the heat tariff, in principle, is determined by the government (tariff administrative agencies at the regional and local levels), but that in some regions (where conditions are suitable), the heat tariff is determined by heat suppliers and their customers. The measures state that the heat tariff varies according to type of customer, and that it is based on costs to generate heat (accounting for a reasonable heat loss in transmission), taxes, and profits. For CHP projects, the costs to generate heat should be distributed between heat and electricity generation, but the criteria for doing so are not specifically outlined.

If a heat supplier suffers financial losses due to a low heat tariff and/or because the fuel price increases by more than 10 percent, the supplier can submit a written request to the tariff administrative agencies to adjust the heat tariff. In addition, consumers can also provide suggestions to the tariff administrative agencies regarding the tariff level. Although the interim measures suggest that heat tariffs be based on the actual costs incurred by the heat supplier, the fact that the tariff can be affected by supplier and consumer requests can result in unfavorable conditions for CHP.

3.4.2.7 Temporary Measures for Dispatching Electricity Generated by Energy Conservation Projects (2007)

One of the key challenges to China's CHP development has been the lack of policies to facilitate grid connection. In addition, the grid companies often dispatch more generation hours to centralized power generation due to perceptions about its relatively stable supply and demand. On August 2, 2007, NDRC, SEPA, SERC and the Bureau of Energy jointly issued *Temporary Measures for Dispatching Electricity Generated by Energy Conservation Projects*. The temporary measures include the first-ever ranking list (shown below) in which dispatch priority is set based on the type of fuel and/or technology used to generate electricity:

1) Power generating units using renewable energy resources that do not have adjustable capability, such as wind energy, solar energy, ocean energy, and hydro power
2) Power generating units using renewable energy resources that have adjustable capability, such as hydropower, biomass, and geothermal energy
3) Nuclear energy-generating units
4) Coal-fired CHP units where electricity is determined by heat load, as well as generation units that use waste heat, waste pressure, waste gas, coal tailing, and coal gas
5) Power generating units fired with natural gas, coalbed methane, and coal gasification technology
6) Other coal-fired generating units, including CHP generating units without heat load
7) Oil-fueled generating units

The temporary measures are expected to increase the dispatch hours of energy-efficient generating units and limit small coal-fired and oil-fired generating units. According to a preliminary estimate from NDRC, the new dispatch policy (along with the mandatory shutdown of small-scale thermal generating units, totaling 50 GW) will help China save 90 million metric tons of raw coal and reduce 216 million metric tons of carbon emissions and 2.2 million metric tons of SO_2 in 2010.

3.4.2.8 Natural Gas Utilization Policy (2007)

The NDRC published its policy on utilizing natural gas on September 3, 2007. The document's purpose is to relieve the tension between natural gas supply and demand, optimize natural gas consumption structure, improve energy efficiency, and reduce emissions. All activities using natural gas in China must adhere to this policy. The NDRC policy categorizes natural gas usage into four purposes: 1) urban fuel, 2) industrial fuel, 3) electricity generation, and 4) fuel for the chemical industry. In addition, due to the comprehensive social, environmental and economic benefits achieved through the utilization of natural gas, the NDRC created four categories concerning its use: 1) preferred, 2) permitted, 3) restricted, and 4) forbidden. CHP for urban fuel gas use falls in the preferred category, and methanol made from natural gas, base-loaded natural gas electricity power stations, and liquefied natural gas (LNG) projects fueled by large and medium gas fields are forbidden. Supplies of natural gas to projects that already utilize natural gas remain at the current level. State-approved fertilizer projects are also guaranteed a long-term and stable supply. In areas severely short of natural gas supply, the policy recommends coal as a substitute for natural gas, if feasible. For projects under construction or projects already licensed where a contract between a buyer and supplier of natural gas has been established, the policy calls for the contract to be executed according to its existing conditions; otherwise, there are no exceptions to the policy for new natural gas projects or natural gas fields.

3.4.2.9 Others

In addition to the policies outlined already, the *Initial Communication on Climate Change From the People's Republic of China* lists CHP as part of its climate change mitigation policy and strategy. Moreover, all generators must now compete, and the special CHP feed-in tariffs have been eliminated. A two-year tax holiday still exists for CHP, but applying it to a project depends on the willingness of the locality, which loses tax revenue when it applies this national policy.

3.5 CHP Industry Trends and Opportunities in China

From 2006 to 2010, and from 2010 to 2020, China's estimated economic growth rate will be approximately 7.5 to 8 percent and 6 to 7 percent, respectively.[33] As a result, strong development of the power industry will be sustainable throughout the next 15 years. By 2020, China's power generation installed capacity should reach 1,350 GW. Annual average added capacity will be 30 to 40 GW. Coal will continue as the primary energy source for power generation through 2020, and thermal power plants could comprise 60 percent of total installed capacity. By 2020, CHP capacity is expected to reach 200 GW, accounting for 30 percent of thermal power.[34]

The best applications for CHP are those that can meet high coincidental thermal and electric loads that persist most of the year. The high thermal loads of district heating plants makes these plants in China an excellent fit for expanded CHP deployment if the electricity can be sold to the grid or used by industry. Facilities that can take advantage of opportunity fuels such as biomass, can be particularly good opportunities for CHP. Among the large-scale, commercialized energy conversion technologies, CHP has the highest efficiency rate, between 60 percent and 80 percent. If trigeneration is used to produce heat, electricity, and cooling, the efficiency rate can reach 90 percent. EPA's preliminary research on where the best opportunities for future CHP development exist indicates that there are substantial opportunities in residential district heating applications and in individual industrial and institutional facilities. In addition, fuel supply considerations will impact how CHP develops.

3.5.1 Opportunities for Residential District Heating CHP

With rapid urbanization, 206 million people in northern China will require centralized heating in 2010, increasing to 269 million in 2020. In 2001, urban centralized heating met approximately 27 percent of the country's thermal load, and approximately 25 to 30 percent of centralized heating systems employed CHP. If, by 2020, centralized heating systems meet 40 percent of China's thermal load, and CHP accounts for 40 percent of this supply, CHP for residential heating will total 40 GW. This scenario would save 35 million tons of standard coal per year.[35] IEA data also indicate that district heating for residential use represents an important growth area for CHP.

[33] Mei, 2007
[34] Mei, 2007
[35] Mei, 2007

3.5.2 Opportunities for Industrial CHP

IEA estimates that current penetration of industrial CHP in China is only about 20 percent of its estimated potential, representing the lowest level of any of the countries surveyed (other countries surveyed tapped 30 to 100 percent of their potential. The other countries included Organization for Economic Co-operation and Development (OECD) countries plus Russia and Brazil). IEA data do not show a breakdown by sector for China, but do highlight results showing that the petrochemical/chemical sectors are particularly important growth sectors. It also publishes a Chinese estimate that the cement sector could generate substantial amounts of electricity from waste heat (approximately 30 to 40 kWh per ton of clinker). Additional industrial sectors where the opportunity for CHP development exists include: coke, steel, pulp/paper, and textiles. If 80 percent of current industrial heating were to switch to CHP, 60 GW of CHP capacity would exist. By 2020, if 80 percent of newly added industrial heating was supplied through CHP, another 60 GW of CHP could result.[36] Opportunities exist to increase industrial CHP in China by increasing the use CHP in industrial district heating systems and by promoting integrated onsite CHP within specific facilities. Facilities that can take advantage of opportunity fuels such as biomass or process wastes can be particularly good opportunities for onsite CHP, an area of increased focus by China's emerging energy services industry. Onsite CHP is also applicable to large commercial/institutional facilities.

3.5.3 Fuel Supply Considerations

Natural gas is a clean fuel that is very commonly used in CHP applications around the world. Today, China is highly reliant on coal, but it has plans to increase natural gas supply. The extent to which China can substitute natural gas for coal will have a dramatic effect on the environmental effects of power and heat generation in China, especially if it can employ natural gas-fired CHP systems. Natural gas made up 2.8 percent of total primary energy supply in 2005, a far lower rate than the world average of 24 percent and the average level in Asia, which is 8.8 percent.[37] Natural gas demand will grow at a greater rate than that of coal and oil in the decade to come, due to the gradual improvement of natural gas infrastructure and market developments in China. Some 5,000 MW (or 1.7 percent) of thermal-fired power was generated with natural gas in China in 2003. The district heating sector consumes slightly more natural gas than the power sector, so in relative terms, a slightly larger share of district heating is gas fired (4 percent).[38] It is estimated that natural gas demand will be 100 billion cubic meters (bcm) in 2010, 150 bcm in 2015, and 200 bcm in 2020. The share of natural gas in primary energy consumption will reach 6 percent in 2010 and approximately 9 percent in 2020.[39] Currently, China gets natural gas from three main sources[40]:

- LNG, through a limited but growing number of LNG terminals
- Domestic offshore gas production
- The West-East gas pipeline, which is the largest of the sources

[36] Mei, 2007
[37] Bloomberg News, 2007
[38] IEA, 2007a
[39] U.S. Department of Energy, Energy Information Administration, 2007
[40] U.S. Department of Energy, Energy Information Administration, 2006

With respect to opportunity fuels, China currently has more than 1,500 biogas digester construction projects that generate approximately 1,500 million cubic meters of biogas each year. The installed capacity of biomass generation is currently about 2 GW, among which sugar cane-fired power capacity accounts for 1.7 GW, and landfill methane-powered accounts for 0.2 GW.[41] Coke oven gas, blast furnace gas, pulp and paper woody biomass, and black liquor are also emerging as possible recyclable fuel sources in China. Using biogas and other opportunity fuels to generate both heat and power in CHP applications presents China with a great opportunity. Utilizing these fuels is not only cost-effective in CHP applications but might have additional benefits, including displacing purchased fossil fuel, freeing up landfill space, and reducing tipping fees associated with waste disposal.

3.6 CHP Business Models and Structures in China

Rather than adhering to a single approach/model, China has used a range of approaches to CHP development. Many different financial models and applications for CHP exist, including large-scale CHP owned by generation companies, CHP for district heating, third-party CHP for industrial parks, third-party CHP for one customer, and end-use based CHP. The business structure for each of these models is different, and only in the large-scale CHP owned by generation companies is most of the power sold to the grid. The business models can also be classified into the following two major categories: 1) grid-connected and 2) stand alone. The following is a summary of the various categories of CHP in China based on EPA research[42]:

3.6.1 CHP Systems Designed to Provide Energy to the Grid

CHP systems designed to provide energy to the grid (power and or thermal) are typically owned by government, utilities, and district heating enterprises.

- **CHP Owned by Large, State-Owned Power Generators**. This type of CHP is typically large, greater than 300 MW or more per plant. New plants being designed by the China Energy Conservation Investment Corporation (CECIC) in this category are typically 300 MW or larger, coal-fired, and not particularly efficient. These systems sell CHP power to the grid and heat to either local industry or district heating companies. Geographically, this type of CHP is concentrated in northern China.
- **CHP Owned by Provincial or Municipal Companies**. CHP plants in this category are connected to the grid but do not sell power to the grid. Typically, such plants are owned by special CHP production companies. The plants sell the power to local industry or other large consumers (although they might also "illegally" sell power to the local power distribution company as well). Heat is sold to local industry or the local district heating company. This type of CHP is much smaller, typically between 6 and 12 MW, and is coal fired. Geographically, this type of CHP is concentrated south of the Yangtze River where district heating is used for a relatively short period in the winter, if at all.
- **CHP in Industrial Parks**. This type of CHP is typically privately owned, often by holding companies. Like the previous category, this CHP is connected to the grid but does not sell power to the grid. It serves both industry and residential consumers. Some of these CHP systems sell heat directly to industrial plants while others sell it to these

[41] China's National Climate Change Program, 2007
[42] Wang Zhenming, China Cogeneration Study Group; Jiang Guo and other staff, CECIC Blue Sky Investment; Zhou Fuqui, BECon; and Feng Jainghua, Beijing Energy-Net (personal communication, September 2007 in Beijing)

plants via district heating companies. Some observers noted that the central government has closed many of these types of CHP facilities in recent years, but other data indicate that this category of CHP is growing. It is possible that both trends are true, as the government pursues a policy of closing smaller boilers and production facilities in favor of larger, consolidated ones. Industrial park CHP is typically located in the middle part of China (in the cold winter-hot summer zone), and particularly common around Shanghai.

The difference between CHP owned by provincial or municipal companies and CHP in industrial parks may be more related to geography than ownership structure and business model. Many holding companies that own local CHP have some investment from local government. At the same time, "locally owned CHP" might be owned by companies with some private investment.

3.6.2 CHP Systems Designed to Serve the Internal Loads of a Single Facility

CHP systems designed to serve the internal loads of a single facility are end-user owned (commercial or industrial enterprise) or owned by energy management companies (EMCos)[43] where services are provided through an energy performance contract (EPC).

- **CHP Owned by Industrial Plants**. Under current Chinese policy, only large manufacturers can own their own CHP plants. This policy might be because coal constitutes the predominant fuel, and coal tends to lend itself to large power installations. However, many, if not most, large manufacturers—such as steel mills, refineries, and large chemical plants—have onsite CHP. Such industrial CHP consumes all power and most of its heat production on site. Such CHP might not be connected to the grid officially. This type of CHP is often the build-own-operate-transfer type in which the developer sells both the heat and steam to industry based on contracts signed before the facilities are built. CHP owned by industrial plants has the greatest opportunity to take advantage of multiple fuels, including opportunity fuels, and technologies. As such, this type of CHP has the greatest potential for CO_2 reductions.
- **CHP Owned by Large Commercial Buildings and Facilities**. This category appears to be very small and does not appear to be growing as quickly as the other CHP sectors. It is the only CHP category where natural gas appears to be the predominant fuel. These small CHP facilities have struggled to obtain permission to connect to the grid even for safety reasons.

Developers of small-scale CHP for end-use applications appear to have much more difficulty than companies that develop large-scale, grid-based CHP.

Three pilot EMCos were created in 1998 with the assistance of the Chinese government, the World Bank, and the Global Environmental Fund (GEF) for the purpose of accelerating industrial and commercial based energy efficiency including onsite CHP. These companies (Beijing Yuanshen Energy Technology Company, Ltd.; Liaoning EMCo; and Shandong EC Engineering Company, Ltd.) have developed 475 energy efficiency projects, saving 1.29 million tce.[44] The success of these companies has led to the development of the Energy Management Company Association (EMCA), created in April 2004, to accelerate the use of EPCs in China. It

[43] An energy management company is the Chinese equivalent of an energy service company in the United States.
[44] Shen, 2007

is clear from the World Bank and other experts promoting energy services in Asia that the primary problem for increasing energy efficiency (which directly applies to industrial CHP) is the lack of commercially viable financing. Rather than a lack of available funds, gaining access to available funds at local commercial banks appears to constitute the problem. This issue is due to a disconnect between current lending practices and the needs of EPCs. Currently commercial bank loans in China are secured on capital assets rather than the EPC economics that flow from energy savings.

3.7 Barriers to CHP Deployment in China

As highlighted in Section 3.4, the Chinese government has promulgated multiple policies aimed at increasing energy efficiency and the use of CHP, indicating a strong commitment to reducing the environmental impacts of power and heat production while improving the reliability of its critical energy infrastructure. Despite these positive developments, however, a number of barriers to CHP deployment still exist in China. In addition to barriers seen in other countries, including lack of capital, lack of information, and electricity prices that do not reflect the full direct and indirect costs of power, China has its own unique barriers, as presented in the following sections.

3.7.1 Overarching Barriers

Overarching barriers to CHP deployment include:

- **Uncertainty During Reforms**. Much of China's industrial base is in transition and is attempting to cope with enormous economic change and restructuring. This situation creates added uncertainty, which can discourage innovation, making it harder to commit needed funds for CHP and/or energy efficiency investments.
- **Shortage of Domestic Equipment Suppliers and CHP Professionals**. China has a shortage of specialized professionals and companies trained and/or providing high-end CHP equipment and services.
- **Lack of Experience of EMCos.** Chinese EMCos and third-party energy service companies that deliver energy efficiency measures through EPCs are in the early stages of development. EMCos constitute an ideal means of supporting CHP in industry and commercial buildings, but they lack information and experience on certain technologies, application practices, and measurement and verification techniques.

3.7.2 Electric Sector Barriers

A number of barriers within the electric sector make it difficult for CHP to gain greater market share.

- **Interconnection**. Perhaps one of the greatest barriers to CHP deployment is the lack of consistent and predictable access to electric and thermal grids, except in a few locations (Shanghai and some rural interconnections have been made). There is a need for a defined and predictable process and schedule as much as technical standards. In addition, the permitting process to construct new CHP is somewhat unclear.
- **Pricing**. Where interconnections are allowed, CHP generators often receive a price for power that is lower than conventional generators. Power prices also do not cover the full

cost of coal and other production costs, leading to irrational retail pricing, which does not give electricity consumers adequate signals to invest in CHP and energy efficiency. China's approach to generation pricing also increases grid companies' disincentives for energy efficiency, load management, and improved pricing for retail consumers. In addition, transmission and distribution (T&D) costs are included in the price of power, which could be an advantage for customer-sited CHP systems (as they do not have to pay for T&D), but constitutes a disadvantage for district systems.

- **Institutional**. Centralized generators often do not understand and might try to inhibit end-use CHP, which is viewed as competition. Electric companies' revenues are determined by power sales, so any reduction in sales will result in reduced profits for the company. In general, end-user CHP and energy efficiency programs reduce power consumption, or at least reduce the growth of energy demand, which reduces utility profits. In addition, the grid companies, which control dispatch, also own some generation assets, creating a conflict of interest against CHP.

3.7.3 Financial, Legal, and Regulatory Barriers

Financial and regulatory policies, including lending controls, foreign investment laws, company formation regulations, and even the Clean Development Regulation, impede CHP deployment by increasing financial risk to project developers.

- **Lack of Access to Financing for Small and Medium-sized CHP Projects**. Small and medium-sized companies constitute primary CHP developers. By definition, they lack large assets and might have low credibility with domestic banks, which can prevent the formation of needed CHP capital.
- **Lending Controls**. China's capital markets—equity and commercial paper—rank among the smallest financial markets in the world. China's financial system channels only about one-quarter of new investment into private companies, despite private companies accounting for more than half of the GDP. In addition, in an effort to reign in unbridled expansion of heavy industry, the Chinese government has barred lending to steel and cement companies, blocking a vital pathway to for CHP finance. A cap on interest rates also exists that unintentionally discourages "risk-based" lending, and, given the perceived risk of CHP due to its unfamiliarity, financing for CHP projects suffers.[45]
- **Foreign Equity Investment Restrictions**. Structuring a foreign equity investment in China remains a difficult task due to constraints to how foreign investors can bring money to China and the conditions under which profits can be repatriated. Typically, the advantages of investing in clean energy accrue more to Chinese than foreigners, restricting the flow of foreign clean energy capital into China.
- **Clean Development Mechanism (CDM)**. As implemented in China, the CDM can increase the risk to developers in organizing investment in clean energy because it significantly increases up-front costs and can cause major regulatory delays.

[45] Chandler, 2007

4.0 Recommendations to Facilitate Highly Efficient CHP in China

The expanded use of CHP is a national priority in China. The government recognizes that increased deployment of CHP can be a critical part of meeting its energy challenges and has promulgated policies designed to promote further development of CHP. Based on the U.S. experience with CHP and the analysis of trends in China presented in this paper, EPA has identified five high-level recommendations that, if implemented, could build on successful Chinese efforts to date and greatly facilitate the deployment of highly efficient CHP in China in all promising market sectors. The recommendations that follow highlight areas that represent major barriers to CHP, based on discussions with Chinese experts and experience in other countries. In crafting these recommendations, EPA has sought to find both well-tested approaches to enhancing the market for CHP and approaches that can build on successful Chinese policies to date. These recommendations are meant to highlight approaches and policy tools, rather than provide detailed prescriptive solutions. Additional specific recommendations, expanding on these five basic points, are presented in Appendix A.

1. **Create more consistent and predictable access to power and heat markets**. Consistent and predictable access to markets is key to encourage a steady flow of investment. It allows investors to more easily assess risks and costs, and then structure projects to deal with them. Establishing consistent and predictable access to electric and thermal grids by creating and clarifying standardized technical, permitting and contractual requirements for interconnection is a very important step toward such predictable access. Standards could be developed at the national level and applied at the regional/provincial level. A focus on establishing a defined, predictable interconnection process should be pursued in conjunction with developing specific technical requirements. In addition, allowing CHP projects to sell power and heat to both the grid and directly to individual consumers would create flexibility in CHP electricity sales, and hence, make CHP a more profitable and less risky venture for investors. As such, it could result in more CHP installations and access to CHP for a wider range of potential customers.

2. **Move quickly to cost reflective pricing for separate heat and power to accelerate adoption of energy efficiency measures**. For CHP to compete on a level playing field with conventional heat and power generation, pricing for separate heat and power should reflect the true costs of production and delivery. Under the current system, grid prices might be artificially low, for example, by not passing through increases in coal costs. Also, large generators might have advantages in terms of their access to state-sponsored financing. These advantages can inadvertently put clean energy, like smaller-scale CHP, at a disadvantage. Ensuring that all costs of power generation include the tariffs of traditional power will help level the playing field and make CHP more competitive. In addition, until recently, CHP power was reimbursed based on a formula that subtracted the value of the heat from the power price. The new approach of benchmarking the value of CHP to coal-fired power is an excellent step in ensuring that CHP prices capture the value of CHP. Implementing the new CHP pricing policy is important in moving toward cost-reflective pricing.

3. **Market valuation of CHP outputs should reflect the energy efficiency and environmental benefits of CHP**. The Chinese government recognizes the multiple

benefits of CHP which include cost savings, reduced emissions, and enhanced reliability. Regulations and policies should be developed to reflect these benefits by including CHP as a recognized energy efficiency option appropriately benefiting from policies targeted specifically for CHP.

4. **Streamline rules for financial incentives and CDM approval for CHP**. China has established several financial incentives for CHP, ranging from tax incentives to access to power grids. The incentives are not always consistently implemented in each province, however. Clear, simple rules to access such financial incentives can maximize their effectiveness. Likewise, ensuring that the rules are durable is important; frequently changing rules for financial incentives can actually raise investor risk and thus encourage investors to delay or reduce investment. The CDM approval process could also be clarified for CHP projects, so that transaction costs in developing projects do not become a major barrier to project implementation.

5. **Ensure that smaller industrial and commercial CHP projects have equal access to financing**. A general lack of familiarity with CHP technology in many parts of the world has constituted a significant barrier to increased CHP deployment. One way in which this lack of familiarity manifests itself is through the reluctance of capital markets to finance CHP projects. Emerging Chinese EMCos represent an ideal means to support CHP in industry and commercial buildings. However, EMCos in China face significant difficulties in securing financing from local financial institutions due to a disconnect between current lending practices of those institutions and the needs of energy efficiency-based projects. The lack of availability of loans from local banks is mainly caused by the banks' inability to understand and properly evaluate the risks and benefits of such projects whose core assets lie in new technologies that would lead to energy savings. Furthermore, according to current government policy, loans to high energy-consuming industries are limited. Such restrictions should not include energy-efficient projects operating within those industries. Wider adoption of CHP will require the implementation of smaller-scale CHP projects, and the Chinese government should work to ensure that such projects can receive required financing.

In addition to these five recommendations, the Chinese government would enhance its ability to track progress on CHP if it had more robust and publicly available data on CHP. Estimates of current CHP capacity vary between information sources, creating uncertainty on the market. Likewise, there does not appear to be data on CHP heat and power production, nor on the trends with efficiency of CHP plants in China. Credible statistics would aid the government in better understanding CHP, setting goals, and tracking progress. Robust tracking of CHP data is also important to track progress towards meeting environmental and efficiency goals. While a robust baseline will help with policymaking and with encouraging investment, China can also learn about its progress on CHP by ensuring that its data are internationally compatible and comparable, for example, by ensuring that the IEA has the most accurate China data in its international statistical database.

Appendix A: Specific Recommendations to Facilitate Deployment of Highly Efficient CHP in China

Section 4 of this report presents five high-level recommendations to facilitate the deployment of highly efficient CHP. In addition to these high-level recommendations, EPA has developed more specific recommendations that the Chinese government can pursue to increase CHP deployment, as follows:

General

- Identify multiple CHP champions within China at the national and provincial levels and within non-government entities that can help progress CHP deployment in China.
- Make alliances with international financial institutions to help secure financing for CHP projects. (China's CHP goals are often in line with environmental/development goals of these institutions.)
- Develop regional regulatory guides for American, Chinese, and other international investors since permitting varies substantially from region to region, and it can be difficult for foreign investors and small domestic companies to know the regulations in each region.
- Codify the construction permitting process as the current process is not well-documented and lacks transparency.
- Increase financial support for CHP research and development and facilitate knowledge transfer with countries with greater CHP experience.
- Evaluate CHP goals in other countries to inform Chinese goals.
- Develop a CHP feasibility study, design, installation, and operation "best practices" guide. Performance of CHP systems is greatly dependent on optimal design, integrated installation and operation and maintenance, as well as service.
- Accelerate the development of the EMCo industry within the framework of the Chinese/World Bank/Global Environmental Fund collaboration. Financing is critical to success of a project. EMCos are essential for CHP systems designed to serve the internal loads of a single facility.

Potential Policy/Incentive Actions

- Government agencies at all levels should take the lead in purchasing energy-efficient CHP electrical and thermal energy.
- Institute a special surcharge to help fund CHP. Such surcharges are common; for example, such a surcharge exists for the Three Gorges Dam. The money could be used regionally to fund guarantees for CHP projects.
- Foster EMCos by providing EMCos and banks with training on CHP and its benefits along with instruction on investment payback analysis.
- Establish attractive feed-in tariffs for electricity from municipal and industrial CHP facilities (or develop effective mechanisms to apply the new rule that CHP power will get the same price as coal-fired power).
- Initiate specific demand side management (DSM) activities targeting energy intensive market sectors as a source of funding, a practice that has been extremely successful in

North America in slowing down demand growth. Also allow local governments considerable latitude to raise DSM funds.

- Create energy performance targets for energy-intensive industries as a tool to spur innovation and to increase enterprise competitiveness.
- Require regular reporting of energy use, energy efficiency measures, and CHP utilization from industrial and district heating facilities.
- Specifically include a requirement for buildings to consider CHP within building energy codes.
- Increase the level of resources at the local level for enforcement of building energy code violations as a means to spur interest in energy efficiency and CHP.

Appendix B: System Dispatch in China

The following excerpt is from the International Energy Agency, "China's Power Sector Reforms. Where to Next?" p.45 (IEA, 2006).

System dispatch is managed at three levels: inter-regional, regional and provincial. The dispatching center within State Grid Company of China (SG) is in charge of all the interregional transmission lines and facilities. Regional dispatching centers manage transmission-dispatching within each region. Provincial dispatching centers oversee scheduling to implement yearly contracts and to conduct real-time balancing to control provincial power systems.

Generator dispatch in areas of the country that do not have competitive power markets (i.e., most of China) is done on the basis of an average tariff level for each plant, which is approved annually by NDRC. Generators are paid a single energy-based price (i.e., per kWh) for their output, which is intended to cover the annual capital and operating expenses. Dispatching of plants depends on a combination of this price and a preset allocation of operating hours, which varies according to the plant. Specifically, the grid company schedules a month-long load curve, according to historic patterns of usage and load forecasts. Each plant is dispatched according to its type, assumed operating hours, and a forecast load curve.

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