SUSTAINABLE URBAN ENERGY SYSTEMS IN CHINA

ROGER K. RAUFER*

ABSTRACT

China's urbanization level is currently below the world's average, and far below that of developed regions such as Europe or North America. Urbanization is now accelerating within the country, and since urban residents use significantly more commercial energy than rural residents, increased urbanization will likely have significant implications for the country's power generation requirements, coal use, and overall energy security. The development of new "sustainable urban energy systems" will ultimately be required to address the energy needs of this urbanization. Continued market reforms to improve resource efficiency, increased energy efficiency, and renewable energy technologies are all necessary and appropriate steps in developing these systems, but advanced technologies capable of utilizing the country's coal resources will also be necessary. In order to make advanced technologies economically viable, it will be necessary to treat such energy needs in a manner similar to industrial ecology, but at an urban scale. Chinese cities have characteristics that may be well suited to such approaches. Such sustainable urban energy systems could have important implications for meeting international environmental goals, and could lead the way to a very different sustainable energy future.

* Independent consulting engineer, specializing in environmental projects in the energy field; Ph.D., University of Pennsylvania. Dr. Raufer has worked on energy/environmental projects in China since 1990, and recently served for four years as Technical Advisor in the United Nations' headquarters, Division for Sustainable Development. He is a registered Professional Engineer in a number of U.S. states. Special thanks are due to Li Shaoyi of UNDESA and Sun Guodong of Harvard University for assistance and comments on earlier drafts; and to Amanda Garcia and the other organizers of the 2006 New York University Environmental Law Journal Colloquium, which prompted the writing of this paper.

TABLE OF CONTENTS

INTRODUCTION

China is currently 43% urbanized,[1] a figure below the world's average (48%), and far below that of developed OECD countries (76%), including the United States (80%).[2] The Chinese government now encourages urban growth as a means of encouraging economic development and minimizing economic disparities within the country. Chinese urbanization has been accelerating in recent years; the 11th Five Year Plan calls for an urbanization level of 47% by 2010,[3] although it might reach 48–

[1] Yingling Liu, *China Releases Latest Census Results*, WORLDWATCH INST., Mar. 21, 2006, http://www.worldwatch.org/node/3899. The term "urbanized" as used in this article is based upon demographics, and indicates the percentage of a country's population living in urban areas. Individual countries differ in how they report "urban" versus "rural" populations, and their definitions can be found annually in the UN's Demographic Yearbook. *See* United Nations Statistics Division, Population Density and Urbanization, http://unstats.un.org/unsd/demographic/sconcerns/densurb/default.htm (last visited Jan. 18, 2007). Typically a community or settlement of 2000 people or more is considered urban.

[2] UNITED NATIONS DEV. PROGRAMME, HUMAN DEVELOPMENT REPORT 2005, at 232–36 (2005), *available at* http://hdr.undp.org/reports/global/2005/pdf/HDR05_HDI.pdf.

[3] *Facts and Figures: China's Main Targets for 2006–2010*, PEOPLE'S DAILY, Mar. 6, 2006, *available at* http://english.peopledaily.com.cn/200603/06/eng20060306_248218.html.

50% by that time.[4] Experts project that urbanization will reach 55–60% by 2020,[5] and a U.S.-comparable 80% by 2050.[6]

There are currently about 750 million rural residents in the country, of which some 300 million will make the transition from rural areas to towns and cities over the next two decades.[7] This figure—equivalent to the entire population of the United States—will, of course, have a dramatic impact on Chinese society, with repercussions in housing, health care, education, environment, and virtually all other elements of the social milieu.

This transition holds significant implications for energy use in China. Urban residents use 3.65 times as much commercial energy as rural households, five times as much electricity, and 24.5 times as much oil and natural gas products.[8]

China is already the world's second-largest primary energy user, exceeded only by the United States.[9] It produces and consumes more coal than any other country, and growth has been exceptionally strong in recent years. It now produces 2.2 billion tons per year (compared to approximately 1 billion tons in the U.S.), and this could increase by another 18% within the next five year planning period.[10] Much of its industrial and electricity production is coal-based, and coal is expected to remain the principal fuel for the country's economic development over the coming decades.

---

[4] ACAD. OF MACROECON. RESEARCH (SDPC), MINISTRY OF COMMERCE OF THE PEOPLE'S REPUBLIC OF CHINA, STRATEGIC OPTIONS FOR THE NEW FIVE-YEAR PLAN (2006), http://english.mofcom.gov.cn/aarticle/subject/textnew/lanmua/200604/20060401826052.html.

[5] *Id.*

[6] *China to Be Moderately Developed by 2050 According to Expert*, PEOPLE'S DAILY, Aug. 7, 2006, *available at* http://english.people.com.cn/200608/07/eng20060807_290569.html.

[7] *Cities to Absorb 300m Farmers in 20 Years*, PEOPLE'S DAILY, Mar. 21, 2006, *available at* http://english.peopledaily.com.cn/200603/21/eng20060321_252246.html.

[8] Cao Guiying, Rural Population and Millennium Development Goals to 2015: Chinese Urbanization & Rural Energy Transition, Presentation at the Global Forum on Sustainable Energy (Feb. 18, 2004), http://ipx10986.ipxserver.de/index.php?id=41 (follow "IIASA / 3" hyperlink).

[9] ENERGY INFO. ADMIN., U.S. DEP'T OF ENERGY, INTERNATIONAL ENERGY ANNUAL 2004 tbl.E.1 (2006), *available at* http://www.eia.doe.gov/pub/international/iealf/tablee1.xls.

[10] *China to Boost Coal Output to Record Levels Despite Environmental Worries*, ENVTL. NEWS NETWORK, Mar. 20, 2006, http://www.enn.com/today.html?id=10092.

China's oil imports are also increasing at a dramatic rate. The country added about 5.7 million vehicles to its roads in 2005, and currently has about 30 million vehicles in use. This figure is expected to increase five-fold by 2020—to the 140–150 million range—which would still result in an ownership rate (number of vehicles per thousand population) only approaching today's current world average, and far below that of the developed economies.[11] China will be the world's largest automaker by that time,[12] suggesting that significant changes will continue in the post-2020 world.

Although China currently imports less than half of its oil requirements, this could rise to nearly 75% by 2025.[13] This strong demand has already had an important effect on oil markets.[14] A significant portion of China's oil imports (close to 46%) comes from the Middle East,[15] and the International Energy Agency suggests that much future demand will also be met from this region.[16] Thus, the energy security concerns associated with such growth will be extremely important.

Pollution is another major concern associated with such large increases in energy use in Chinese cities. Coal combustion has already had a deleterious effect, generating very high particulate and sulfur dioxide concentrations and contributing to acid rain. According to the World Bank, sixteen of the twenty most polluted

---

[11] Zheng Zheng, *Vehicle Market Growth Poses Challenges*, CHINA DAILY, May 11, 2004, at 11, *available at* http://www.chinadaily.com.cn/english/doc/2004-05/11/content_329631.htm; *Auto Sales to Climb 12% Driven by Small Car Push*, CHINA DAILY, Feb. 6, 2006, *reprinted in* APECC NEWS BRIEFING, Feb. 2006, at 14, 14–15, *available at* http://www.autoproject.org.cn/english/APECC_NEWS/APECC%20NEWS%202-2006.pdf.

[12] *China to Become No.1 Automaker by 2020*, XINHUA ONLINE, Oct. 31, 2005, http://news.xinhuanet.com/english/2005-10/31/content_3712806.htm.

[13] *See* ENERGY INFO. ADMIN., U.S. DEP'T OF ENERGY, COUNTRY ANALYSIS BRIEFS: CHINA 2 (2005), *available at* http://www.eia.doe.gov/emeu/cabs/china.pdf.

[14] Although much of the recent oil demand increase came from industrial sources (in part because of power shortages), future transportation-related demand will be significant. *See* Jeffrey Skeer & Yanjia Wang, *China on the Move: Oil Price Explosion?*, 35 ENERGY POL'Y 678, 688 (2007).

[15] ENERGY INFO. ADMIN., U.S. DEP'T OF ENERGY, COUNTRY ANALYSIS BRIEFS: CHINA 5 (2006), *available at* http://www.eia.doe.gov/emeu/cabs/China/pdf.pdf.

[16] *See* INT'L ENERGY AGENCY, WORLD ENERGY OUTLOOK 2005, at 43, 89 (2005).

cities in the world are found in China.[17] Today, those coal-based urban pollutant levels are exacerbated by a significant increase in automotive emissions of NO_x, volatile organic compounds (leading to ozone formation), and carbon monoxide. China's vehicles currently emit significantly more pollution than those in developed countries,[18] so the impacts of such growth will be significant.

In addition to such localized impacts, China's energy growth has important global implications for the environment. The country is already the world's second largest emitter of greenhouse gases, and should become the world's largest emitting country in 2009.[19]

The imminent change in China's urban infrastructure offers a unique opportunity to affect the country's energy consumption; however, changes made today to improve urban development will have impacts that will last for generations. This paper addresses the issue of energy use in China's urbanization program in three parts. Part II discusses China's urban energy situation and how it is changing. Part III discusses differences in the viewpoints of economists and engineers in addressing these changes, and how this might affect urban energy policy in China. Part IV then outlines steps toward the development of "sustainable urban energy systems" (SUES) for Chinese cities, including continued market reforms; the application of both price- and quantity-based economic mechanisms for reducing externalities and encouraging the development of new technologies; and a technology-oriented utilization of the country's coal resources, with an integrated, urbanized version of industrial ecology to help make it economically viable.

[17] *China's Environment: A Great Wall of Waste*, ECONOMIST, Aug. 21, 2004, at 55, 56.

[18] *See, e.g.*, Xiaoyan Tang, *The Characteristics of Urban Air Pollution in China*, *in* URBANIZATION, ENERGY, AND AIR POLLUTION IN CHINA: THE CHALLENGES AHEAD: PROCEEDINGS OF A SYMPOSIUM 47, 47 (2004).

[19] Keith Bradsher, *China to Pass U.S. in 2009 in Emissions*, N.Y. TIMES, Nov. 7, 2006, at C1.

I. CHINA'S URBANIZATION

A. *Municipal Governments and Energy Use*

Municipal governments typically affect energy consumption in two principal ways: 1) the municipality itself consumes energy providing municipal services (e.g., waste collection, water supply, transportation, etc.), heating municipal buildings, providing fuel for municipal vehicles and fleets, and performing comparable tasks; and 2) the municipal government, through planning functions, affects the physical nature, design, and activities within the municipality's jurisdiction (by regulating development zones, buildings, industrial activities, and parks).

Although cities around the world consume significant amounts of energy themselves, most have not historically paid much attention to the management of such energy flows. Electricity, steam, and fuels are typically treated as routine commodities, with costs delegated to municipal departments in overhead or standard budgetary procedures—much like paper clips or pencils or desks. Most do not have specialized municipal energy offices, even though major cities might face municipal energy costs in the $100 million per year range.[20]

Energy consumption by governmental institutions has been particularly fast growing in China, resulting in relatively high energy expenditures; as a result, government energy consumption has been targeted as one of ten energy efficiency areas receiving particular attention in the 11th Five Year Plan.[21] Municipal employees are likely to leave computers on continuously, set air conditioning at cooler levels, and typically have per capita energy consumption levels well above those of residents within the same city. In Beijing, for example, a recent survey found municipal employee/resident ratios of 7:1 for electricity, and 4:1 for overall energy.[22]

---

[20] SUSTAINABLE ENERGY PLANNING OFFICE, GAS TECH. INST., CITY OF PHILADELPHIA: PROPOSED SUSTAINABLE ENERGY MANAGEMENT ACTION PLAN, at i (2004).

[21] *China Outlines Ten Programs for Energy Efficiency*, PEOPLE'S DAILY, Dec. 9, 2004, *available at* http://english.peopledaily.com.cn/200412/09/eng20041209_166706.html.

[22] *Beijing Municipal Government Departments to Cut Energy Consumption by 8 pct this Year*, PEOPLE'S DAILY, June 25, 2005, *available at*

China's leaders are well aware of the importance of energy in their economy, and one of the key priorities of the 11th Five Year Plan, covering the period through 2010, is to reduce energy consumption per unit of GDP by 20% over that five year period.[23] This is likely to prove rather difficult, however, since the trend in recent years has actually been in the opposite direction; energy use has grown faster than GDP for the past several years.[24]

Recent price increases in the international oil market and electric power shortages within China have raised the profile of energy within the country, and a new State Council Energy Leading Group was formed in 2005, headed by Premier Wen Jiabao.[25] This group is supposed to address the "macro" issues associated with the energy situation, including conservation, environmental protection, and energy security. It is currently drafting a new "umbrella" energy law to deal with the "complicated contradictions and problems"[26] associated with China's rapid economic development and the changing international energy market.

China has been attempting to improve energy efficiency throughout its economy, not just in municipal governments. In the two decades between 1980 and 2000, China's government added twenty-two administrative measures, seven standards, eight plans, and fourteen policies designed to promote energy-saving technology.[27] Efforts continue today, with international support (e.g., the Global Environmental Facility's (GEF) China End Use Energy Efficiency Project[28] and World Bank/GEF efforts to

---

http://english.peopledaily.com.cn/200506/25/eng20050625_192295.html.

[23] Fu Jing, *Energy Law Aims at Power Conservation*, CHINA DAILY, Feb. 7, 2006, at 2, *available at* http://www.chinadaily.com.cn/english/doc/2006-02/07/content_517704.htm.

[24] JONATHAN E. SINTON ET AL., CHINA SUSTAINABLE ENERGY PROGRAM, EVALUATION OF CHINA'S ENERGY STRATEGY OPTIONS 1 (2005).

[25] *See* Press Release, Embassy of the P.R.C. in the U.S., Premier Wen Heads New Energy Group (May 27, 2005) (*available at* http://www.china-embassy.org/eng/gyzg/t197477.htm).

[26] News Release, Nat'l Dev. & Reform Comm'n P.R.C., Drafting of Energy Law Initiated (Apr. 4, 2006) (*available at* http://en.ndrc.gov.cn/newsrelease/t20060404_65175.htm).

[27] SINTON ET AL., *supra* note 24, at 10.

[28] *See* Global Envtl. Facility, Project Database, China: End Use Energy Efficiency Project, http://www.gefonline.org/projectDetails.cfm?projID=966 (last visited Feb. 2, 2007) (noting that "[t]he project fosters a strategic approach to developing, implementing and enforcing a comprehensive and effective

support energy management companies in China).[29]

The country already has an energy conservation law, but it is rather vague, laying out broad principles for action rather than specific mandates. Its implementation has been called "uneven."[30] While energy conservation constituted 10–13% of investment in supply in the early 1980s, this figure dropped to about 7% in the 1990s, and in recent years was even lower.[31] Sinton et al. conclude that "energy efficiency is seriously underfunded" in the country.[32] China's urban infrastructure offers truly significant opportunities—in terms of efficiency, district heating, and waste management—for sizable municipal energy improvements.

B. *Urban Planning and Energy Use*

Energy concerns have played an even smaller role in urban planning. In China, two forms of planning affect urban energy use. The first is the economic and social development planning historically associated with socialist governance, such as developing Five-Year Plans. This form of planning exists at all levels of government (national, provincial, and municipal), and the governmental entities that perform it are typically referred to as planning commissions. The second form of planning is urban planning related to actual physical development, usually associated with the Construction Ministry in some manner. These entities also exist at the national, provincial, and municipal levels, typically in the form of city planning departments or bureaus. Such groups are responsible for many of the local decisions about land use, building permits, and comparable development practices.

The Communist Party evolved as a rural/peasant-based revolutionary alternative to the political class of the "consumptive cities," and so urban development in the People's Republic of China (P.R.C.) was ideologically driven. Urban development occurred in three stages after the founding of the P.R.C. in 1949:

energy conservation policy and regulatory system consistent with the objectives of the Energy Conservation Law of 1998" and that GEF's contribution is seventeen million dollars (U.S.)).

29 *See* Global Envtl. Facility, Project Database, China: Energy Conservation Project, Phase II, http://www.gefonline.org/projectDetails.cfm?projID=1237 (last visited Feb. 2, 2007).

30 SINTON ET AL., *supra* note 24, at 11.

31 *Id.* at 10.

32 *Id.*

1) an early growth stage, from the early 1950s to mid-1960s, associated with industrial development, especially in many inland cities; 2) a static (and even slightly declining) period from the mid-1960s to late 1970s, associated with a period of economic and political disruption; and 3) a rapid expansion since 1978, associated with political and market-oriented reforms.[33]

Urban planning in the 1950s evolved out of industrial site planning. Cities were viewed as parasitic, and—after reconstructing basic utility and sanitation functions—the idea was to turn them into "productive centres" based on industrialized manufacturing processes.[34] During this period, "the main task of urban planning was to support the 156 key industrial projects aided by the Soviet Union,"[35] and urban planning itself tended toward the Soviet model. For strategic defense reasons, new cities were located in the central and western interior, rather than in coastal areas. The growth of the urban population increased faster than that of the national population, and the country experienced a steady rate of urbanization.[36]

During the political and economic upheaval of the Cultural Revolution, however, millions of urban residents were sent to the countryside, primarily for reasons of political control. Population movement was closely monitored, and urban planners—typically viewed as bourgeoisie intellectuals who might have something to learn from rural peasants—were often sent to the countryside.[37] China's urban population remained static or declined,[38] and a significant number of the country's urban planning institutions and activities were eliminated during this period.

This changed significantly in 1978, however, when economic and political reforms were instituted, and the government decided

---

[33] Shunfeng Song & Kevin Honglin Zhang, *Urbanisation and City Size Distribution in China*, 39 URB. STUD. 2317, 2319–20 (2002).

[34] Roger C.K. Chan & Yao Shimou, *Urbanization and Sustainable Metropolitan Development in China: Patterns, Problems and Prospects*, 49 GEOJOURNAL 269, 269 (1999).

[35] Anthony Gar-on Yeh & Fulong Wu, *The Transformation of the Urban Planning System in China from a Centrally-Planned to Transitional Economy*, 51 PROGRESS IN PLAN. 167, 177 (1999).

[36] *See generally id.* (providing a broad overview of urban planning and development since the founding of the P.R.C.).

[37] *See* Tingwei Zhang, *Challenges Facing Chinese Planners in Transitional China*, 22 J. PLAN. EDUC. & RES. 64, 69–70 (2002).

[38] Song & Zhang, *supra* note 33, at 2319.

to encourage urbanization as a means of facilitating economic development. As economic restructuring took hold, China experienced strong economic growth, booming urban development, and large-scale infrastructure improvements. The urban population grew accordingly, and approximately 150 million people migrated into Chinese cities during the first two decades of reform. The urbanization rate increased from approximately 18% in 1978 to 43% today, and the number of cities has increased from 191 to 667.[39] Urbanization today is increasing at 1.4–1.5% per year, and has been accelerating.[40]

In 1989, the country adopted the City Planning Act of China—the first urban planning act in China's history—which established the legal framework for land use determinations, development rights, real estate markets, and related planning tasks. The Act declared that "[t]he state shall guide itself by the principle of strictly controlling the size of large cities and developing medium-sized and small cities to an appropriate extent in the interest of a rational distribution of productive forces and of the population."[41] This reinforced a 1979 national urban policy, which sought to control the growth of the big cities, moderately develop the medium-sized ones, and actively promote growth in small-sized ones.[42]

---

[39] *Id.* at 2320.

[40] *Cities to Absorb 300m Farmers in 20 Years*, *supra* note 7; Lei Shen et al., *Urbanization, Sustainability and the Utilization of Energy and Mineral Resources in China*, 22 CITIES 287, 293–94 (2005).

[41] City Planning Law (P.R.C.), art. 4, *translated at* http://www.china.org.cn/english/environment/34354.htm.

[42] *See* Simon X.B. Zhao et al., *Globalization and the Dominance of Large Cities in Contemporary China*, 20 CITIES 265, 265 (2003); Chan & Shimou, *supra* note 34, at 269 (finding that China's largest cities continued to grow in the 1980s and 1990s in spite of contrary aspirations); Qinxue Wang & Kuninori Otsubo, *Urban Expansion in China During the Last Two Decades*, *in* STUDY ON THE PROCESSES AND IMPACT OF LAND-USE CHANGE IN CHINA 107, 108 (Kuninori Otsubo ed., 2002), *available at* http://www-cger.nies.go.jp/lugec/ReportIIX_E/011_Urban%20China.pdf (analyzing digital land use maps from 1984 and 1997 and finding growth rates of more than 50% in China's megacities—Beijing, Shanghai, and Guangzhou—over that period); *but cf.* Song & Zhang, *supra* note 33, at 2326 (citing studies showing that the development of very large cities might be more consistent with efficient globalization, providing the opportunity for consumption scale, population size, and specialized labor markets necessary for promoting service-oriented industries, as well as providing environmental and social amenities); Xiaobin Zhao & Li Zhang, *Urban Performance and the Control of Urban Size in China*, 32 URB. STUD. 813, 824, 835 (1995) (finding that large cities are more efficient than smaller cities economically, socially, and

As part of the reform program, the government initially established four "special economic zones" (SEZs) in Shenzhen, Zhuhai, Shantou, and Xiamen—and the spectacular success of the open door policy reforms[43] has affected Chinese urban development since that time. This has significantly increased the importance of the second form of planning, the local construction/planning bureaus.

There have been two subsequent major boom/bust waves of "development zone" creation in China after the success of the SEZs, driven primarily by local governments. In the early 1990s, a one year explosive "zone fever" increased the number of such development zones from 117 to 2700. By the mid-1990s, however, the central government had stepped in and cancelled 1200 of these zones, returning much of the land to agricultural use.[44] In the early 2000s, a similar boom created approximately 6866 development zones, of which more than 4800 were subsequently cancelled by the central government.[45]

While the primary focus of these local development zones is supposed to be economic development, the ability of local governments to expropriate land on the urban fringe from farmers[46]—sometimes at the behest of special interests and/or real

environmentally, and concluding that in transitioning to a global economy China should encourage the development of large cities).

[43] The Shenzhen SEZ had a population of approximately 300,000 persons in 1979, but today its population is approaching 11 million, although 9 million do not possess *hokou* (the permanent residence registration required to obtain many social services). *See* Chen Hong, *Feeling the Pinch of a Growing Population*, CHINA DAILY, July 23, 2005, at 3, *available at* http://www2.chinadaily.com.cn/english/doc/2005-07/23/content_462662.htm; Mee Kam Ng, *City Profile: Shenzhen*, 20 CITIES 429, 429 (2003) (describing Shenzhen's transition from "a sleepy border town" in 1978 to a city of approximately seven million population in 2000, of which three million were "unregistered 'floating' population").

[44] F. Frederic Deng & Youqin Huang, *Uneven Land Reform and Urban Sprawl in China: The Case of Beijing*, 61 PROGRESS IN PLAN. 211, 217 (2004).

[45] Cao Desheng, *4,800 Development Zones Cancelled*, CHINA DAILY, Aug. 24, 2004, at 1, *available at* http://www.chinadaily.com.cn/english/doc/2004-08/24/content_368120.htm (as *China Cancels 4,800 Development Zones*).

[46] *See* DAVID ZWEIG, INTERNATIONALIZING CHINA: DOMESTIC INTERESTS AND GLOBAL LINKAGES 268 (2002) (observing that "weak property rights over land and unclear lines of financial responsibility for zones that were not completed or successful made expropriating land an acceptable strategy for gaining lower tax rates or ill-begotten wealth"); *see also* Deng & Huang, *supra* note 44, at 231 (citing a comment by a Chinese expert that "the local government would be a fool if it does not create development zones given the huge profit from land expropriation"); Pankaj Mishra, *China's New Leftist*, N.Y. TIMES, Oct.

estate speculators—has become a major source of developmental tensions in China in recent years. The zones are often located on the urban fringe, away from the city's built area, on prime agricultural land. Municipal governments often make substantial investments in the area, building municipal government offices, providing grading, and putting into place a new urban grid (i.e., roads, electricity, sewers, etc.)—giving rise to what has been considered a Chinese-style form of urban sprawl.

While such areas might have been developed in response to perceived market demand, in many cases the planned economic development does not occur, and the newly developed areas remain vacant, even after investment. At other times, residential and commercial interests intercede, significantly changing the physical results of the planning. The end result is often longer commuting requirements for municipal employees, inadequate transportation to the new zones, land speculation, resource wastage, and inefficient urban spatial forms.

C. *Recent Urban Development*

As noted above, the reform program has always envisioned that urban development would be channeled toward small and medium-sized cities. Most of China's educated urban planners (about 60%) are concentrated in its major cities and provincial capitals, however, and not in its small and medium-sized cities.[47] These small/medium cities have much less planning expertise, yet they are the ones that are expected to bear much of the brunt of future urban expansion.

An ongoing project with United Nations Development Programme (UNDP) is currently trying to address this situation. The UNDP's 21st Century City Planning, Management and Development (City PMD) project is working with five pilot cities to address capacity development issues in physical planning, environmental planning, urban management and economic restructuring. Based on the experience of these pilot city efforts, it originally sought to prepare a set of national guidelines for small and medium-sized cities throughout the country; however, in view of the complexity of this task, it subsequently developed an

---

15, 2006, § 6 (Magazine), at 48 ("According to Chinese officials, 60% of land acquisitions are illegal.").

[47] *See* Zhang, *supra* note 37, at 66.

"observational" report outlining the problems associated with urbanization in these cities.[48] Although the report addressed natural resources, energy has not played a particularly important role in any urban development analyses in Chinese cities.

Yet cities have faced important energy decisions associated with China's torrid growth. Over the five year period 2000–2005, China experienced annual production growth rates of 24.7% for rolled steel, 12.1% for cement, 35.7% for cars, 16% for color TVs, 29.9% for air conditioners, and 64.4% for personal computers.[49] This growth demanded energy, and when faced with power shortages,[50] officials responded as one might expect—more coal-based power generation. In 2005, an official 63,260 Megawatts (MW) of capacity were added—roughly equivalent to adding the entire electric generating capacity of Austria, Belgium, Denmark, and the Netherlands—and 84% of this was coal-based generation.[51] It is a coal-based legacy that will be very long-lived.

In late 2004, the National Development and Reform Commission (NDRC) issued a decree to stop local authorities from building unauthorized power plants, noting that there were at that time approximately 120,000 MW of unapproved plants under construction—about twice the level of approved facilities.[52] While new facilities are expected to have emissions control technology for sulfur dioxide emissions, it is not clear exactly how "unauthorized" facilities would comply with such requirements—or whether such technology would be operated even if it were installed.[53] The cumulative environmental effects of existing

[48] The five cities are Guiyang, Liuzhou, Meishan, Sanmenxia, and Taiyuan; the city of Jinan was originally included, but subsequently dropped out of the project. *See* UNDP, 21 Century City Planning, Management and Development in China, http://www.cicete.org/21century/Home.htm (last visited Feb. 2, 2007); UNDP, CICETE & CHINA ACAD. OF URBAN PLANNING & DESIGN, SOME OBSERVATIONS CONCERNING CHINA'S URBAN DEVELOPMENT (2006) (unpublished, on file with author).

[49] Zhou Dadi, Sustainable Energy Development in China, Presentation at UN CSD-14 (May 2006) (on file with author).

[50] And in many cases, the opportunities inherent in providing land for new project development.

[51] E-mail from Li Shaoyi, UN Dep't of Econ. & Social Affairs, to author (May 10, 2006, 16:25:21 EST) (on file with author) (citing statistics from Zhou Dadi, Energy Research Inst., Nat'l Dev. & Reform Comm'n).

[52] Matt Pottinger, *China Cracks Down on Overinvestment in Power*, WALL ST. J., Dec. 16, 2004, at A15.

[53] Matt Pottinger et al., *A Hidden Cost of China's Growth: Mercury*

facilities and such spectacular growth is thus extremely worrisome—both within the country and internationally.

Planning in Chinese cities may actually have exacerbated the problem. The planning commissions (the first form of planning) are actively involved in economic development, and each of the cities in the City PMD project had designated "pillar" industries. Somewhat surprising for the project's technical advisors, it was determined that every one of the five small and medium-sized cities within the project had selected energy-intensive aluminum production as a pillar industry. City officials had already developed and were actively trying to develop such facilities—despite a lack of raw materials, a lack of electricity, long distances to markets, and a host of other concerns. As one advisor noted: "Local planners were attracted by the big boost that such projects would provide to the size of GDP of their economies."[54] Clearly energy concerns played a minimal role in their considerations. To make matters worse, Chinese aluminum facilities tend to be much smaller than those in the rest of the world, and since many employ coal-fired units for electricity production, there can also be considerable pollution.

The national government subsequently decided to step in as local governments throughout the country sought to develop in this manner, and energy demands, pollution, and ultimately excess production capacity became significant.[55]

Migration, WALL ST. J., Dec. 17, 2004, at A1 (quoting an official who suggests that only 5% of coal-fired units have such emissions control technology). Recently, however, there has been significant investment in the flue gas desulfurization (FGD) technology within the country, and figures suggest that 13% of thermal units now have such equipment. More than 200 GW of FGD are currently under construction, which should bring totals into the 66% range. *See* De'an Zhuang et al., *Shiwu qijian woguo huodianchang tuoliu sheshi jianshe yu yunxing qingkuang zongshu* [Summary of Thermal Power Plant FGD Installation and Operation During the Tenth Five Year Plan in China], Presentation at Environment Proceedings of the 7th Sino-American Tech. & Eng'g Conference (Oct. 2006). But it has also been reported that, even after installation, 60% of FGD units are not operated because of financial costs and lack of governmental oversight. Xiaohua Sun, *Authorities Work on SO2 Trade System*, CHINA DAILY, Sept. 14, 2006, *available at* http://www.chinadaily.com.cn/china/2006-09/14/content_688449.htm.

[54] Le-Yin Zhang, Globalisation and the Quality of Growth—New Challenges for Asia-Pacific Cities, Presentation at the Asia-Pacific Leadership Forum: Sustainable Development for Cities, at 13 (Feb. 25–26, 2004), http://www.susdev.gov.hk/html/en/leadership_forum/zhang_le_yin_paper.pdf.

[55] *China's Aluminum Sector Reined in*, ASIA TIMES ONLINE, Apr. 29, 2006,

China's urbanization program thus faces myriad concerns. It is clear that the quest for economic development is paramount. The national government has stepped in to curtail municipal development zones, unauthorized power plants, or aluminum facilities as necessary, but the urban growth continues—and, as suggested by the figures above, the energy infrastructure supporting that growth relies on coal.[56]

The transition to SUES in China will obviously have to address both short-term energy management and longer-term planning issues. Comparably polluted, coal-based industrial cities in both the U.S. and Europe made notable improvements with a transition to cleaner fuels—primarily oil and natural gas. This was a decades-long transition, however, occurring over time as technological advancements, economic considerations, and increasing environmental awareness provided the basis for a shift to clean fuels.[57] Officials in Chinese cities are faced with the seemingly intractable problem of trying to accomplish an even cleaner fuels transition—in a compressed time period, without oil and natural gas resources—during a period of radical economic growth.

http://www.atimes.com/atimes/China_Business/HD29Cb01.html (reporting that "since 2004, the nation has suspended or stopped new aluminum manufacturing projects worth a total of 17.3 billion yuan (US$2.16 billion)").

[56] *See* Shen et al., *supra* note 40, at 293. The authors suggest that energy and resource consumption could ultimately serve as a constraint on China's urbanization strategy, with potentially severe resource supply shortages. *Id.* at 292. Their modeling analysis is based upon historical trends, however, and does not fully address technological progress or resource substitution. *Id.* at 291–92. While oil and natural gas are identified as potential concerns in that modeling, there is plenty of coal. *Id.* at 293.

[57] *See* AIR MGMT. SERVS., DEP'T OF PUB. HEALTH, ANALYSIS OF PHILADELPHIA'S EMISSIONS/AIR QUALITY TRENDS 5 (1989) (reporting that in Philadelphia, 40% of emissions reductions between the mid-1960s and the mid-1980s were attributed to fuel changes, with another 10% coming from industrial cutbacks and energy conservation, over and above those obtained through pollution control technologies); *see also* Nebojša Nakićenović, *Decarbonization: Doing More with Less*, 51 TECH. FORECASTING & SOC. CHANGE 1, 1 (1996) (suggesting that a global decarbonization has been occurring for an even longer period, and calculating a long-term reduction in carbon intensity per unit value added of 1.3% per year on a global basis since the mid-1800s; "technological and organizational innovations" and "an enormous accumulation of knowledge" are cited as the bases for productivity increases).

II. ENGINEERS VS. ECONOMISTS

A. *Competing Regulatory Approaches to Energy and Environmental Regulation*

Historically, "sanitary engineers," today's environmental engineers, played a key role in the development of the city planning profession, advocating systematic large-scale reshaping of cities to accomplish water-carriage sewerage, waste disposal, and related health and environmental urban goals.[58] The importance of economists in urban development has been readily apparent from the discussion above, and both engineers and economists will play a key role in achieving sustainable urban energy systems. But engineers and economists tend to think about energy and environmental systems in very different ways.

The engineering worldview considers any process in terms of inputs, outputs, and the "box" of the process itself. The process might be a car engine, a power plant, a refinery, or a city. Inputs might consist of fuels, material resources, food, and water, while outputs could include finished goods, heat, light, and pollution. The original regulatory framework that evolved to deal with environmental pollution utilized such a worldview.[59] Governments typically set environmental goals in the form of environmental quality standards, and then employed technology-oriented requirements (such as emission, design, and performance standards), that would achieve and maintain these goals. China, the U.S., and many other countries employed such a regulatory approach in their cities.

In recent decades, however, economists offered an alternative regulatory approach. In their (theoretical) view, governments would set environmental goals at the point where the marginal

[58] *See, e.g.*, Jon A. Peterson, *The Impact of Sanitary Reform upon American Urban Planning, 1840–1890*, *in* INTRODUCTION TO PLANNING HISTORY IN THE UNITED STATES 13, 17–19 (Donald A. Krueckeberg ed., 1983); ROGER K. RAUFER, POLLUTION MARKETS IN A GREEN COUNTRY TOWN: URBAN ENVIRONMENTAL MANAGEMENT IN TRANSITION 5 (1998).

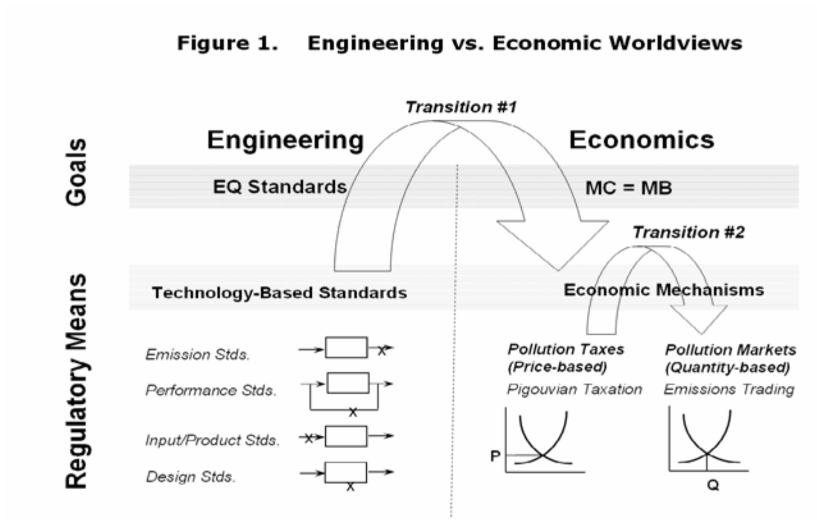
[59] A good example would be the Clean Air Act of 1970 in the U.S. (the first truly effective air pollution control legislation in the country). 42 U.S.C. §§ 7401–7671 (2000). One might also trace the same regulatory framework back much earlier—for example, the requirements for "best practicable means" to address pollution concerns in the Alkali Act of 1863 in Britain. *See* Alkali, Etc., Works Regulation Act, 1906, 6 Edw. 7, c. 14. (Eng.).

costs (MC) of installing pollution control equipment would equal the marginal benefits (MB) of doing so. All environmental concerns about public health, ecosystem damage, and similar issues could theoretically be incorporated into these curves. There is no "invisible hand" that would guide society to that singular point, however, so economists have also developed two regulatory means to achieve it: one based on prices (i.e., Pigouvian taxes),[60] and the other based on quantities (i.e., emissions trading). These price and quantity mechanisms are really different sides of the same coin, but there are important differences in their application, particularly within the political arena.

Figure 1 outlines these two worldviews, as well as two transitions currently occurring throughout the world. Transition No. 1 is a transition from the engineering to the economics worldview when dealing with pollution problems. Note that this transition concerns the regulatory means for accomplishing pollution reductions, not the goal setting agenda.[61] The regulatory means that the economists offer have some extremely useful properties: 1) they allow the government to focus on setting environmental targets, rather than dictating stack-by-stack means; 2) they are economically efficient; 3) this efficiency can in turn influence "real world" goal-setting, allowing us to purchase more environmental protection; and 4) pollution always bears a cost, leading polluters to continuously seek for means of reducing it. Hence, countries around the world (including China) now routinely use economic regulatory means to achieve engineering- and science-based environmental goals.

[60] Pigouvian taxes are named after Prof. Arthur Pigou, who proposed them in his classic text, *The Economics of Welfare*, in 1920. In such a scheme, the government sets a tax on pollution. Those with marginal costs lower than the tax will employ pollution control, while those with higher marginal costs will pay the tax. If the government sets the tax properly, it can thus achieve the point where MC=MB. ARTHUR PIGOU, THE ECONOMICS OF WELFARE (1920).

[61] *See* ROBERT N. STAVINS, RES. FOR THE FUTURE, ENVIRONMENTAL ECONOMICS 14 (2004), *available at* http://www.rff.org/documents/RFF-DP-04-54.pdf (observing that "dramatic" changes with regards to the means of environmental policy—that is, acceptance of market-based instruments over the past twenty years—may provide a model for making progress on economic goal-setting).



Transition No. 2 is occurring within the economic regulatory means, as countries shift from price- to quantity-based instruments.[62] Governments everywhere have a long history (and administrative success) in collecting taxes, and economists have also tended to promote price-based mechanisms,[63] so this has been viewed as the traditional economic instrument. The mechanisms that have evolved in the U.S., however, follow the quantity-based approach, which is more closely aligned with private property rights, markets, and minimal wealth transfers to the public sector. The U.S. encouraged a quantity-based economic foundation for the Kyoto Protocol, even though it subsequently withdrew from that agreement. Other countries have embraced quantity-based regulatory approaches as well; in 2004, it was projected that the

[62] Note, however, that this is still a nascent transition, and most experience outside the U.S. has been for CO_2 control, although related programs exist in fishing quotas and transferable development rights, among others. *See, e.g.*, Paul Wallis, *Transferable Fishing Quotas: Experience in OECD Countries*, *in* IMPLEMENTING DOMESTIC TRADABLE PERMITS FOR ENVIRONMENTAL PROTECTION 109, 109–21 (1999); Vincent Renard, *Application of Tradable Permits to Land-Use Management*, *in* IMPLEMENTING DOMESTIC TRADABLE PERMITS FOR ENVIRONMENTAL PROTECTION, supra, at 53, 53–73; JOHN M. REILLY & SERGEY PALTSEV, MIT JOINT PROGRAM ON THE SCIENCE & POLICY OF GLOBAL CHANGE, AN ANALYSIS OF THE EUROPEAN EMISSION TRADING SCHEME (2005), *available at* http://mit.edu/globalchange/www/MITJPSPGC_Rpt127.pdf.

[63] *See generally* T.H. TIETENBERG, RES. FOR THE FUTURE, EMISSIONS TRADING: PRINCIPLES AND PRACTICE (2d ed. 2006) (discussing historical price versus quantity debates for pollution control).

European Union's (EU) Emissions Trading System for CO_2 would be about ten times larger than the U.S. acid rain program.[64] Even countries like China have begun exploring such quantity-based pollution control programs.[65]

These transitions have also occurred in the area of renewable energy. As with pollution control, Europe initially used a price-based system for encouraging renewable energy system (RES) development. Three countries—Germany, Denmark, and Spain—offered powerful price supports designed to encourage wind power projects.[66] With these high price-level supports, the market responded with dramatic increases in wind power capacity, and all three countries were able to develop strong wind turbine manufacturing capabilities as well. Wind developers and the environmental community obviously hailed such development, but these price supports can be extremely costly. They are also contrary to the EU's idea of a liberalized, market-oriented approach to energy systems.

The U.S., on the other hand, tended to rely on a quantity-based "obligation" for RES, usually in the form of a Renewable Portfolio Standard (RPS).[67] The trading of "green certificates" or renewable energy credits associated with RES can help achieve that RPS in an economically efficient manner, and states like Texas were very successful in implementing such programs.[68] These markets are similar to the emissions trading markets; both are artificial, in that demand has been created by governmental fiat, and both typically require a sophisticated institutional

[64] JOSEPH KRUGER & WILLIAM A. PIZER, RES. FOR THE FUTURE, THE EU EMISSIONS TRADING DIRECTIVE: OPPORTUNITIES AND POTENTIAL PITFALLS 42 (2004), *available at* http://www.rff.org/documents/RFF-DP-04-24.pdf.

[65] *See infra* notes 93–97.

[66] *See* Am. Wind Energy Ass'n, Global Wind Energy Market Report, http://www.awea.org/pubs/documents/globalmarket1999.html (last visited Feb. 2, 2007).

[67] Note, however, that the production tax credit also played a very significant role. *See, e.g.*, Everett Britt, *Renewable Electric Generation 2004: Incentives, Obligations, and Concerns*, 19 NAT. RESOURCES & ENV'T 34, 34–35 (2005) (noting that successful nationwide development of wind energy in the United States is attributable, in part, "to the benefits and availability of the [Production Tax Credit]").

[68] *See* RYAN WISER & OLE LANGNISS, LAWRENCE BERKELEY NAT'L LAB., THE RENEWABLES PORTFOLIO STANDARD IN TEXAS: AN EARLY ASSESSMENT 7, 15–17 (2001), *available at* http://eetd.lbl.gov/ea/EMS/reports/49107.pdf.

infrastructure.[69]

As with pollution control, European countries began to make a transition from price-based support to quantity-based market programs for RES support. This transition has not been as smooth. Individual country RES markets in Europe tend to be small and, relative to government price supports, quite volatile. Further, since RES technology is relatively new and not competitive in economic terms, the surety of government price support has been extremely important for project development. Industry groups recognize that a trading scheme might ultimately be a viable policy, but suggest that this would require a harmonized EU system, rather than country-by-country development.[70]

This recent engineering/economics policy experience might be summarized as follows:

1. Economics can be a powerful tool in addressing externality issues, but as a regulatory means, not necessarily for setting goals.
2. The U.S. has tended towards quantity-based approaches, while Europe, China and others have tended towards price-based approaches—but this is now beginning to change.
3. Quantity-based externality markets are artificial, with demand coming from the government; institutional factors play a key role.
4. The price- to quantity-based transition has been easier for pollution control than renewable energy.
5. Quantity-based markets can be volatile, and very difficult for new (non-competitive) technology.

B. *How Does this Policy Debate Affect Chinese Cities?*

Unlike Western economies that superimposed environmental regulatory measures—both engineering and economic—onto a market economy already accomplishing at least some measure of resource efficiency, China is still making the overall transition to a full market economy, and resource efficiency is still very low. Basically, Western economies moved from market economies to

[69] *See generally id.* (discussing the obligations imposed on electricity retailers to incorporate renewable energy into their portfolios in the Texas RPS).

[70] *See, e.g.*, Danish Wind Indus. Ass'n, Europe Policy, http://www.windpower.org/composite-167.htm (last visited Feb. 2, 2007).

market economies with engineering-oriented environmental regulation, and then to market economies with economic-oriented environmental regulation. China is still trying to establish a fully-functioning market economy. Not surprisingly, then, there is still tremendous resource waste and inefficiency within China's energy economy. It has been estimated that China's energy consumption per unit of GDP is still 2.4 times the world's average, and 8.7 times that of Japan.[71]

China also has a "dual" economy, and the two parts can operate in very different ways. China has an international economy—the one that scares so many Western nations—with a strong import/export base. It is dependent upon trade: in 2006, 70% of the country's "official exchange rate" GDP was made up of imports and exports (compared with approximately 22% in the US).[72] It also has a domestic economy, which has historically been hampered by problems associated with centralized planning (e.g., the difficulty of enforcing commercial contracts, the lack of property rights, the lack of infrastructure for shipping products, etc.). Western companies often complain about the difficulty of doing business in this domestic economy, but Chinese companies face these very same problems as well.

These two elements of China's economy are obviously linked and interrelated—the massive influx of imported commodities in recent years is being used to develop China's domestic infrastructure, and energy imports have been increasing for many of China's domestic companies—but it is also clear that the energy transition in China's cities is affected by this economic dichotomy. Studwell has categorized the "parallel" economies slightly differently: a) "an export economy . . . backed up by a modest, but rapidly growing, domestic private sector"; and b) the "traditional state sector."[73] He stated that "it is reasonable to guess that at the start of the twenty-first century, China's parallel public and private economies were roughly equal in size," but that the urban areas

[71] Jing, *supra* note 23.

[72] When calculated on the more inclusive, domestic-oriented "purchasing power parity" basis, the import/export percentage (at 18%) is below the comparable percentage in the U.S. *See* U.S. CIA, The World Factbook, China Economy, https://www.cia.gov/cia/publications/factbook/geos/ch.html#Econ (last visited Feb. 3, 2007).

[73] JOE STUDWELL, THE CHINA DREAM: THE QUEST FOR THE LAST GREAT UNTAPPED MARKET ON EARTH 219 (2002).

remained only one-third private.[74]

Faced with continued resource inefficiency, a domestic economy still wrestling with the transition to markets, and urban economies still heavily reliant on public sector institutions and economic planning (as the City PMD aluminum case makes evident), it seems somewhat unrealistic to expect China to follow recent Western experience immediately and directly. By applying the engineering/economics policy findings noted above to China's urban situation, however, a number of steps become evident.

III. SUSTAINABLE URBAN ENERGY SYSTEMS IN CHINA

The first three steps toward SUES in China are the following:

Step 1. Markets and Energy Efficiency: Recognize that economics plays a fundamental role; China must continue its transition to resource (and energy) efficiency under a market economy;

Step 2. Quantity-Based International Approaches: Use established Kyoto Protocol-type quantity-based systems for externalities in the international component of its economy (as discussed below), but be a bit more cautious about these on the domestic side;

Step 3. Price-Based Domestic Approaches: Continue to build on price-based domestic experience, extending this to RES and pollution control.

These steps alone will not be enough to deal with the energy and environmental impacts of China's urbanization program, however, particularly in light of the coal-based future of its cities. There was plenty of pollution when the U.S. and Europe decided to pursue environmental protection strategies in the 1960s and 1970s, even though they had fully functioning markets. The U.S. has pursued energy efficiency, and has managed to cut its energy per GDP figure in half since 1950. Even with such efficiency gains, however, it consumes three times as much energy now as it did then.[75] And RES in urban applications, while valuable, is

---

[74] *Id.* at 220–21.

[75] PETER W. HUBER & MARK P. MILLS, THE BOTTOMLESS WELL: THE TWILIGHT OF FUEL, THE VIRTUE OF WASTE, AND WHY WE WILL NEVER RUN OUT

limited by the dispersed nature of the resource, its collection/capture material requirements, its intermittent nature, and the lack of dispatching capabilities.

SUES in Chinese cities are not simply a market or an energy efficiency economic problem—they are also characterized by important technological and political components as well. Indeed, these may be paramount, because economic solutions fail if the technology required to achieve the desired goal doesn't yet exist. "Induced technological change" has thus become the latest mantra of climate change economists. A recent paper in the journal *Energy Policy*, for example, suggests that stabilizing climate represents "a difficult energy technology as well as economic problem."[76] The authors suggest that the use of quantity- or price-based approaches described above to meet emissions constraints is unlikely to be politically palatable (i.e., costs will be too high), and there is also serious doubt about their ability to induce the technological change required. Instead, technology itself is the better target: "instead of using market mechanisms as means of meeting national emission targets, the mechanisms would be better used to induce the least cost adoption of newly developed technologies."[77] The bigger challenge is "the research and development and eventual deployment of new, scaleable carbon emission-free energies."[78] Larry Goulder, an economist at Stanford, suggests that it is not a matter of one or the other—both emissions and technology instruments will be necessary.[79]

So it seems that a fourth step is needed for SUES, particularly with respect to China's domestic urban situation:

Step 4. Back to the Engineering Side: Remember the engineering side of the policy debate—and develop an advanced, integrated, urbanized form of energy-oriented industrial ecology in Chinese cities.

OF ENERGY 113 (2005).

[76] Chris Green et al., *Challenges to a Climate Stabilizing Energy Future*, 35 ENERGY POL'Y 616, 624 (2007).

[77] *Id.* at 625.

[78] *Id.* at 624.

[79] LAWRENCE H. GOULDER, PEW CTR. ON GLOBAL CLIMATE CHANGE, INDUCED TECHNOLOGICAL CHANGE AND CLIMATE POLICY 18–22, 31 (2004), *available at* http://www.pewclimate.org/docUploads/ITC%5FReport%5FF2%2Epdf (concluding that induced technological change reduces the cost of emissions reductions and alters the optimal timing of emissions abatement).

A. *The Four Steps of SUES in China*

Step 1. Markets and Energy Efficiency

The resource inefficiency of China's economy was noted earlier, and it has received considerable attention over recent decades. It was deeply ingrained in the planned economy. As an example, employers usually paid for their employees' home heating, often at little or no cost to the employee, and normally without any monitoring of consumption. This brought about tremendous waste. Energy consumption for heating in China has been about three times that of developed countries under the same meteorological conditions.[80]

Economists have articulated idealized visions of the transition from a planned to a "socialist market" economy, such as the following analysis of energy efficiency in China:

> Any rational energy policy must be based on market mechanisms, with limited intervention to regulate monopolies and overcome market failures. The basic mechanisms of a market-based strategy should include: a) market pricing of energy supplies; b) energy supply sector restructuring; c) privatization and re-regulation of transmission and distribution networks for electricity, gas, and heat supply enterprises; and d) privatization of energy suppliers.[81]

Such an idealized market-driven system has not yet occurred in China (or anywhere else, for that matter), but the country has nonetheless instituted significant economic reforms, across the whole energy front. This has included radically changing the structure and regulation of the power sector, liberalizing fuel prices, addressing trade barriers under its World Trade Organization (WTO) accession agreements, and restructuring its major domestic oil companies.

But much remains to be done. Numerous national considerations—environmental protection, energy security, social inequities, and a host of other concerns—all make a claim to be

---

[80] Orgs. for the Promotion of Energy Techs., Building Energy-saving: Problem Analysis and Suggestions, http://www.zeri.org.cn/Energy%20Documents/Documents.htm (follow "Building Energy-saving: Problem Analysis and Suggestions" hyperlink) (last visited Sept. 14, 2006).

[81] William U. Chandler et al., *Energy Efficiency: New Approaches to Technology Transfer*, *in* ENVIRONMENT, ENERGY, AND ECONOMY: STRATEGIES FOR SUSTAINABILITY 267 (Yoichi Kaya & Keiichi Yokobori eds., 1997), *available at* http://www.unu.edu/unupress/unupbooks/uu17ee/uu17ee0g.htm.

part of the "limited intervention" in the quote above. Interestingly, even such a pro-market analysis suggests that "where markets leave large, cost-effective energy efficiency resources untapped," it would be appropriate to adopt "policies and programmes to improve energy efficiency to maximum cost-effective levels."[82]

Given the continued state-sector involvement in the urban economy, continued attention to market reforms to improve resource efficiency is an obvious need. Since urban residents use more energy, and since the development of new urban infrastructure will affect energy use for generations, increased attention to energy efficiency—even beyond the levels achieved under market reforms—appears to be the most fundamental step toward SUES in China. Most of the prescribed efforts in energy efficiency (such as the internationally-supported GEF and World Bank projects noted earlier) target industry, buildings, and transport. While these targets are critically important, and require further support, Chinese municipal governments need to attend to energy efficiency opportunities in the following areas as well:

- *District heating and cooling.* Less than half of the cities in China currently have a district heating supply infrastructure; those systems that do exist tend to be relatively small, with inefficient boiler and delivery technology. Electrical demand is also being driven by air conditioning use in urban areas; this increases as per capita incomes rise, but much of the growth comes from small-scale, relatively inefficient window units. Integrating combined heat and power (CHP) and district heating/cooling systems into new urban design—even if the actual systems are not yet available—offers a longer-term means of addressing energy demand requirements in fast-growing urban areas.[83]

---

[82] *Id.* at 268.

[83] *See* JACK S. SIEGEL, ENERGY RES. INT'L, FOREIGN INVOLVEMENT IN COMBINED HEAT AND POWER IN CHINA: POLICIES AND SUCCESSES 10–11 (2004); Naiyi Hu et al., *Energy and Environmental Conservation Through District Heating*, 102 ENERGY ENG'G 10, 18 (2005). One group supporting the use of CHP in Chinese cities recently warned developers about "over-excitement" concerning the market there, noting considerable regulatory uncertainty within the electricity sector, and little governmental policy commitment to CHP. WORLD ALLIANCE FOR DECENTRALIZED ENERGY, WORLD SURVEY OF DECENTRALIZED ENERGY 2005, at 7 (2005), *available at* http://www.localpower.org/documents_pub/report_worldsurvey05.pdf. Although

- *Waste management.* Numerous waste-to-energy facilities have been built in China in recent years, primarily in large and middle-sized cities. These facilities can provide both thermal and electrical energy services, and in some cities around the world, they are also tied in to district heating systems. Methane capture and use in urban landfills, digester gas cogeneration at municipal wastewater treatment facilities, and similar municipal efforts can also be attractive under the Clean Development Mechanism (CDM) because of the high global warming potential of this gas.[84]
- *Urban design.* Various urban design measures (e.g., increased green space, reduced sprawl, infill and "brownfield" reutilization rather than new "greenfield" development, non-automobile transportation systems, etc.) can often have significant impacts on municipal energy use. Such measures are sometimes captured under the label "smart growth" in the West.[85] Urban design considerations can play a particularly important role in reducing transportation fuel use. Newman and Kenworthy have analyzed a wide range of urban factors (including transportation energy) in forty-six cities around the world, and found that "[r]apidly developing Asian cities have considerably less efficient and sustainable transportation systems than would be expected from their levels of wealth." They determined that "[t]hese cities are pouring their productive financial and human capital into auto-related activity but are not showing much benefit from it."[86]

---

liberalization of fuel prices has raised coal and natural gas prices, new costs could not be passed through to urban customers in their electricity and heating prices. *See id.* at 16.

[84] The World Bank estimates that urban residents generate from two to three times as much solid waste as rural residents, making future urbanization an even greater concern. WORLD BANK, WHAT A WASTE: SOLID WASTE MANAGEMENT IN ASIA 1 (1999).

[85] *See, e.g.*, John S. Miller & Lester A. Hoel, *The "Smart Growth" Debate: Best Practices for Urban Transportation Planning*, 36 SOCIO-ECON. PLAN. SCI. 1, 4–8 (2002) (discussing various definitions of "smart growth").

[86] PETER NEWMAN & JEFFREY KENWORTHY, SUSTAINABILITY AND CITIES: OVERCOMING AUTOMOBILE DEPENDENCE 124–25 (1999).

Step 2: Quantity-based International Approaches

When the U.S. first introduced emissions trading in the mid-1970s, it was not because of economic ideals. Instead, it grafted an economic mechanism onto the technologically-oriented command/control requirements evident on the engineering side of the Figure 1. This allowed "emissions reduction credits" (ERCs) for improvements made to the baseline conditions defined by the 'black box' technical requirements.[87] Later, in 1990, the full economic ideas evident in quantity-based economic thinking were introduced for total pollutant loading to address acid rain impacts, in the form of "emission allowances."[88]

The resulting emissions control for sulfur dioxide thus had two economic instruments: localized ERCs traded off the technical (i.e., engineering-oriented) baseline, and broader, quantity-based (i.e., economics-oriented) emission allowances for total pollutant loading. This dual-trading approach was a template for the Kyoto Protocol, which follows the same basic framework. There is credit trading of project- (and technology-) oriented baseline changes under the CDM and Joint Implementation, as well as quantity-based trading of assigned amount units (AAUs) between Annex I countries.[89]

As a developing country, China can participate in the Kyoto Protocol under the CDM.[90] It has no emissions reduction requirement and its participation under CDM is purely voluntary,

---

[87] For illustrative figures and discussion of this engineering/economics transition, see RAUFER, *supra* note 58, at 137–45.

[88] *See* U.S. EPA, Acid Rain Program SO_2 Allowances Fact Sheet, http://www.epa.gov/airmarkets/arp/allfact.html (last visited Feb. 2, 2007).

[89] For more information about the Kyoto Protocol trading mechanisms, see United Nations Framework Convention on Climate Change, The Mechanisms Under the Kyoto Protocol: The Clean Development Mechanism, Joint Implementation and Emissions Trading, http://unfccc.int/kyoto_mechanisms/items/1673.php (last visited Feb. 2, 2007).

[90] For more information about the Clean Development Mechanism, see United Nations Framework Convention on Climate Change, Clean Development Mechanism Homepage, http://cdm.unfccc.int/index.html (last visited Feb. 2, 2007). CDM is the only Kyoto Protocol "flexibility mechanism" that has two goals: a) greenhouse gas reductions; and b) sustainable development. *See, e.g.*, Ronald B. Mitchell & Edward A. Parson, *Implementing the Climate Change Regime's Clean Development Mechanism*, 10 J. ENV'T & DEV. 125, 126 (2001) ("The CDM is designed to help industrialized, Annex 1 countries meet their targets at lower cost than otherwise possible while engaging developing, Non-Annex-1 countries in processes that mitigate climate change and foster sustainable development.").

on a project-by-project basis. The national government, through its designated national authority (DNA), gets to decide which projects are appropriate, and how the project must meet sustainable development criteria.

Although some have decried the fact that taking emissions trading into countries lacking the rule of law and firm property rights is "inviting chaos,"[91] most of the institutional compliance mechanisms for project-based CDM actually lie outside the country. The CDM Executive Board decides whether the baseline determination is adequate or not and designated operational entities (DOEs) act as auditors and conduct validation and verification analyses of the emission credits.

Indeed, CDM has the very real advantage of introducing market-based thinking, transparency, and environmental accountability into project development in countries such as China, and as such represents a very positive step. It does so, unfortunately, with extremely high transaction costs, since that outside assurance of legitimacy comes at a rather high price. But high transaction costs can be dealt with in projects having either high global warming potentials, or operating on a large scale. Landfill gas and waste projects which address methane meet the former criterion, and some of the urban projects noted below might well fit the latter.

When CDM was first developed, some mordantly referred to it as the "China Development Mechanism." One early market analysis, for example, suggested that China would capture fully 60% of the CDM marketplace.[92] Since then, estimates have dropped, but China is still expected to play a major role—perhaps 35 or 45%. This could represent hundreds of millions of dollars in clean energy investment in the country. China has endorsed CDM, and after a slow start, it is now actively encouraging project development.[93]

---

[91] Ruth Greenspan Bell, *Market Failure*, ENVTL. FORUM, Mar.–Apr. 2006, at 28. Bell notes that China's "historical experience with written laws for managing complex relationships is very shallow." *Id.* at 31.

[92] ZhongXiang Zhang, Estimating the Size of the Potential Market for the Kyoto Flexibility Mechanisms, Presentation at the Institute for Global Environmental Strategies CDM International Workshop (Jan. 26–27, 2000), http://www.iges.or.jp/en/cp/output_all/workshops/International/pdf/6_Zhang%201.pdf.

[93] *See* Office of Nat'l Coordination Comm. on Climate Change, Clean Development Mechanism in China, http://cdm.ccchina.gov.cn/english (last

China is interested in introducing such mechanisms domestically,[94] given their very attractive economic efficiency properties, and has taken a number of steps in this direction with international assistance from organizations such as the Asian Development Bank,[95] the U.S. Environmental Protection Agency,[96] and international NGOs.[97] While utilizing an internationalized environmental trading mechanism like CDM offers some very positive opportunities for China, introducing quantity-based mechanisms into the domestic marketplace—lacking rule of law, property rights, and environmental transparency—is more problematic.

The need for a sophisticated institutional infrastructure to support such quantity-based systems remains a daunting obstacle for China. The U.S. gained experience over more than a dozen years with its engineering-oriented command/control ERC trading approach before adopting the quantity-based acid rain program in 1990. Furthermore, those early efforts were labeled as "controlled trading," to emphasize to polluters the continual governmental oversight required in the emissions market.

CDM and the trading approaches under the Kyoto Protocol are immediately beneficial for China, but given the country's domestic institutional and political structure, the development of quantity-based systems should proceed along a cautious, incremental and compliance-driven path.

visited Feb. 2, 2007).

[94] Andrew Batson, *Beijing Considers Market-Based System to Battle Pollution*, WALL ST. J., Mar. 29, 2006, at A8; *see also* Jolene Lin Shuwen, *Assessing the Dragon's Choice: The Use of Market-Based Instruments in Chinese Environmental Policy*, 16 GEO. INT'L ENVTL. L. REV. 617, 619 (2004); Jinnan Wang et al., *Controlling Sulfur Dioxide in China: Will Emission Trading Work?*, ENV'T, June 2004, at 28, 28.

[95] *See* P.N. FERNANDO ET AL., ASIAN DEV. BANK, ENERGY DIV. (EAST), EMISSIONS TRADING IN THE ENERGY SECTOR: OPPORTUNITIES FOR THE PEOPLE'S REPUBLIC OF CHINA (1999); RICHARD D. MORGENSTERN ET AL., RES. FOR THE FUTURE, EMISSIONS TRADING TO IMPROVE AIR QUALITY IN AN INDUSTRIAL CITY IN THE PEOPLE'S REPUBLIC OF CHINA 1 (2004), *available at* http://www.rff.org/Documents/RFF-DP-04-16.pdf.

[96] Jintian Yang & Stephanie Benkovic, *The Feasibility of Using Cap and Trade to Achieve Sulfur Dioxide Reductions in China*, SINOSPHERE J., July 2002, at 10, 10.

[97] David Biello, *Emissions Trading with Chinese Characteristics*, ENVTL. FIN., Sept. 2002, http://www.environmental-finance.com/2002/0209sep/acidrain.htm.

Step 3. Price-based Domestic Approaches

In the late 1970s, China modified its pollution control regulatory program, and, like the U.S., introduced an economic mechanism.[98] It adopted a pollution levy system designed to target those emission sources not in compliance, and collected a fee based on each kilogram of pollution above the level targeted by the command/control (i.e., technology) requirements. As such, this was not a full-fledged Pigouvian tax (since it applied only to excess emissions), but rather an incremental attempt to improve compliance utilizing economic techniques. The levy was later modified to address certain compliance problems,[99] and again to bring it a bit closer to the economic ideal of Pigouvian taxation.[100] Problems remain, however. The levies are still too low and they are not always collected; polluters routinely engage in fee negotiations with governmental officials without any public transparency.[101]

The U.S. and Europe have moved from market economies with engineering-oriented environmental regulation to market economies with economic-oriented environmental regulation. They began with a technological, engineering approach to building a domestic regulatory pollution control infrastructure, and then added more sophisticated economic mechanisms onto that base. China, however, has not successfully established a market economy; as such, it is trying to adopt economic mechanisms without all of the necessary market efficiencies or the requisite technology-oriented regulatory infrastructure.[102]

---

[98] *See* Robert A. Bohm et al., *Environmental Taxes: China's Bold Initiative*, ENV'T, Sept. 1998, at 10, 11.

[99] The revision of "four small pieces" addressed: a) long term violators; b) new sources not meeting standards, or old ones that were not operating installed pollution control equipment; c) delays in making fee payments; and d) false data or interference with the local environmental protection bureau's actions. *See* H. Keith Florig et al., *China Strives to Make the Polluter Pay*, 29 ENVTL. SCI. & TECH. A268 (1995).

[100] These revisions include collecting fees on all emissions (albeit higher rates on "excess" ones), increasing the levy rates, and adjusting the emissions to account for pollution equivalency and geographical considerations. *See* Bohm et al., *supra* note 98, at 33.

[101] U.N. DEV. PROGRAMME & CHINA INT'L CTR. FOR ECON. AND TECH. EXCH., URBAN AIR POLLUTION CONTROL IN CHINA: A SECTOR REVIEW REPORT (Roger Raufer et al. eds., 2000), *available at* http://www.cicete.org/newindex/page/urban.

[102] *See generally* ELIZABETH C. ECONOMY, THE RIVER RUNS BLACK: THE

The national environmental program remains relatively small in China—the State Environmental Protection Administration has about 300 employees, versus 6000 in the U.S. EPA headquarters[103]—and local environmental protection bureau officials must therefore carry a major part of the burden in accomplishing environmental compliance. In the 1990s, local township and village enterprises (TVEs) generated much of the new wealth in China—and unfortunately, much of the new pollution as well. As noted earlier, local officials have usually been much more interested in economic development than in environmental protection.

While it is difficult to envision a completely successful implementation of economic mechanisms (price- or quantity-based) without institutional reform[104] (e.g., the realization of an established rule of law), the price-based pollution tax levy is already well aligned with the government's traditional role as tax collector. This suggests that, on the domestic front, China would be well served by retaining (and upgrading) its price-based pollution levy system. It also suggests that attention to local environmental compliance and to the impacts of urban energy systems is particularly important for environmental progress in the country.

A similar situation exists for renewable energy. China recently adopted a renewable energy law (which went into effect in 2006),[105] encouraging and supporting renewable energy, but leaving important regulatory policy decisions to the NDRC. The NDRC has mapped out both mid- and long-term strategies for RES,[106] and intends to raise $180 billion over the next fifteen years for such systems.[107]

ENVIRONMENTAL CHALLENGE TO CHINA'S FUTURE (2004) (discussing recent environmental efforts in China).

[103] *Id.* at 107 n.45.

[104] For a set of proposed regulatory initiatives, see Eric W. Orts, *Environmental Law with Chinese Characteristics*, 11 WM. & MARY BILL RTS. J. 545, 558–66 (2003).

[105] *See* Zhu Li, *China's Renewables Law: Renewables Challenge for the People's Republic*, RENEWABLE ENERGY WORLD, July 2, 2005, http://www.earthscan.co.uk/news/article/mps/UAN/432/v/3/sp/.

[106] *China Maps out Mid- and Long-Term Plan for Renewable Energy Development*, PEOPLE'S DAILY, Nov. 8, 2005, *available at* http://english.peopledaily.com.cn/200511/08/eng20051108_219862.html.

[107] *China to Raise $180 bln for Renewable Energy Projects*, PEOPLE'S DAILY, Nov. 8, 2005, *available at* http://english.peopledaily.com.cn/200511/08/

The policy situation for wind power is indicative of the difficulty China faces in supporting renewable energy systems. China has explored a range of policy approaches in the past, with the World Bank and others suggesting a quantity-based "mandatory market share" approach similar to an RPS.[108] China has implemented a wind resource concession approach, which has essentially evolved into a tendering arrangement—a situation which has some market-oriented characteristics (such as competitive bidding), but nonetheless tends to protect existing major players.[109] It will probably do little to develop China's wind power manufacturing industry, which is critical if renewables are to play a sizable role in the country's future.[110]

The success of Europe's price-based strategy in this area has been noted, and it initially appeared that China might follow such an approach. Early drafts of the wind pricing regulation, which followed the passing of the renewables law utilized a price-based feed-in tariff approach, and "stated clearly that the grid price for wind power would reflect the 'nominal tariff of local desulfurized coal-fired power plants,' plus a subsidy of ¥0.23 ($0.028 US) per kilowatt-hour (kWh)."[111] Yet this price-based approach had disappeared by early 2006, and the final regulations returned to competitive bidding—much to the dismay of China's wind industry, which decried the market's volatility and uncertainty,

eng20051108_219762.html.

[108] Roger Raufer & Shujuan Wang, *Navigating the Policy Path for Support of Wind Power in China*, 6 CHINA ENV'T SERIES 37, 40 (2003), *available at* http://wilsoncenter.org/topics/pubs/4-feature_3.pdf.

[109] RYAN WISER ET AL., CTR. FOR RES. SOLUTIONS, RENEWABLE ENERGY POLICY OPTIONS FOR CHINA: A COMPARISON OF RENEWABLE PORTFOLIO STANDARDS, FEED-IN TARIFFS, AND TENDERING POLICIES 14 (2002), *available at* http://www.resource-solutions.org/lib/librarypdfs/IntPolicy-Feed-in_LawsandRPS.pdf.

[110] A more sanguine view and discussion of this issue can be found in JOANNA LEWIS & RYAN WISER, A REVIEW OF INTERNATIONAL EXPERIENCE WITH POLICIES TO PROMOTE WIND POWER INDUSTRY DEVELOPMENT 7–8 (2005) (discussing the impact of various support policies on local wind power manufacturing). Lewis and Wiser agree that "[a] long-term, stable feed-in tariff has proven to be the most successful mechanism for promoting wind energy utilization to date," but suggest that quantity-based (i.e., RPS) systems or concessions could be successful "if implemented carefully." *Id.*

[111] Yingling Liu, *Behind the Chilly Air: Impacts of China's New Wind Pricing Regulation*, WORLDWATCH INST., Mar. 30, 2006, http://www.worldwatch.org/node/3904. The November 2005 draft "also stipulated that the return on investment for renewable energy power projects should be higher than the average return on investment of traditional power projects." *Id.*

noting that it was exactly the opposite of the conditions necessary to foster development of a new technology.

Quantity-based systems are indeed probably closer to the economist's ideal of a liberalized energy market, and may well work for broader, regional-scale environmental concerns. However, Chinese cities would be better served by the surety of a price-based approach for RES as well as pollution control over the next several years, as the country develops the institutional capabilities required to implement trading systems.

Step 4. Back to the Engineering Side

Chinese cities have a wide range of energy needs—fuels for transport, heating, cooking, electrical power, space heating, etc.—but they face daunting energy supply challenges. The country has little petroleum or natural gas, and must rely on imports to provide such premium fuels. But China has one fuel source in abundance: coal.

While the inefficient combustion of coal has led to severe air pollution and other environmental concerns, a radically different vision of coal use in Chinese cities is possible—one which is closely attuned to the engineering side of the policy debate noted above.[112] In this vision, advanced technologies such as integrated gasification combined cycle (IGCC) units gasify the coal, generating both efficient thermal energy services (steam for district heating, chillers, etc.) and electrical power for the growing city. "Polygeneration" (polygen) applications utilizing liquefaction technological approaches can provide a range of chemicals (including methanol, dimethyl ether, Fischer-Tropsch [F-T] liquids, and town gas) that can serve as additives to transportation fuels, supplies for nascent chemical industries, and clean fuels for domestic cooking and other assorted energy needs.[113] Over the

[112] This does not mean ignoring the economics, of course. As noted earlier, one of the major issues in climate change policy is the question of how best to induce technological change. *See generally* Ian Sue Wing, *Representing Induced Technological Change in Models for Climate Policy Analysis*, 28 ENERGY ECON. 539 (2006), *available at* http://people.bu.edu/isw/papers/snowmass.pdf (discussing different models for inducing technological change); GOULDER, *supra* note 79 (discussing induced technological change).

[113] Robert H. Williams & Eric D. Larson, *A Comparison of Direct and Indirect Liquefaction Technologies for Making Fluid Fuels from Coal*, ENERGY FOR SUSTAINABLE DEV., Dec. 2003, at 103.

longer term, these same processes might be used to generate hydrogen for fuel cells, or serve as a starting point for further advanced chemical processes in so-called "carbon refining"[114] applications. Another key element is their potential suitability for capturing CO_2 for storage.

A further step might integrate nuclear power into the mix. China is currently developing a different kind of nuclear energy technology than the light water reactors routinely employed in the West. Small scale "pebble bed" reactors are gas cooled, "inherently safe" reactors that can be built in much smaller modular units (200 MW in size) that could be integrated into urban energy supply programs.[115] Research in the 1970s suggested that nuclear facilities might be able to provide the process heat for coal gasification and liquefaction processes, and increase the output by 40–50%.[116] Current designs typically use energy in the coal to drive the processes, but it may be possible to increase output significantly by treating the coal more like a chemical feedstock. Nuclear facilities have already served in district heating applications in other countries around the world, so their integration into an urban energy system is feasible.[117]

Such technological systems have the potential to significantly reduce air pollution and greenhouse gas emissions in Chinese cities—even though they are unlikely to occur as a response to

[114] Robert Williams uses the term "carbon refineries" in referring to technologies in which "heavy oil, coal, natural gas, MSW [municipal solid waste], biomass inputs→H_2 and/or carbon neutral energy carrier outputs." *See* Robert H. Williams, Energy Supply: Technological Opportunities & Priorities for State R&D in Addressing 21st Century Challenges, Presentation at the Fall Meeting of the Assoc. of State Energy Research & Tech. Transfer Insts. (Nov. 13, 2002), http://www.asertti.org/events/fall/2002/williams.pdf.

[115] Yuanhui Xu, *HTGR Advances in China*, NUCLEAR ENG'G INT'L, Mar. 2005, at 22; Yuliang Sun et al., *The HTR-10 Test Reactor Project and Potential Use of HTGR for Non-Electric Application in China*, *in* NON-ELECTRIC APPLICATIONS OF NUCLEAR ENERGY 211, 211–12 (1995), *available at* http://www.iaea.org/inis/aws/htgr/fulltext/28031224.pdf. For a popular press article about this program, see Spencer Reiss, *Let a Thousand Reactors Bloom*, WIRED, Sept. 2004, at 158, 160.

[116] *See, e.g.*, R.N. Quade, *Design and Application for a High-Temperature Nuclear Heat Source*, *in* SPECIALISTS' MEETING ON PROCESS HEAT APPLICATIONS TECHNOLOGY 31, 31 (1979), *available at* http://www.iaea.org/inis/aws/htgr/fulltext/iwghtr6_3.pdf.

[117] In a review of a draft version of this paper, Sun Guodong (a clean coal technology expert at Harvard University) expressed considerable reservations about this viability, based upon system integration concerns.

energy needs in the marketplace (or at least not within the time period required to meet both domestic and international environmental goals).

B. *Implementation of SUES*

The implementation of Steps 1 through 3 for a SUES program in Chinese cities is already underway, and implementation concerns have already been noted. These include the need for further market reforms, the difficulty of enforcing emissions trading provisions, the low fees and lack of transparency within the pollution levy system, and similar regulatory issues.

Implementation of Step 4 has also begun. China has already signed a number of agreements concerning advanced coal technologies, and is currently exploring their feasibility at a number of sites around the country.[118] As noted earlier, it is also conducting pilot-scale research efforts in the nuclear field. Given the advanced technical nature of the processes and their current high cost when compared with readily available alternatives, it is apparent that there will not be an immediate near-term shift toward using them in Chinese cities. While such technologies are possible, they tend to be very expensive—and their cost effectiveness will depend upon a much more sophisticated view of the city's energy needs.

That view is likely to be found in an integrated urban energy approach, operating in a manner much like the symbiotic relationships that form the basis of "industrial ecology"[119]—but focusing on energy, and operating at an urban scale (rather than at

[118] *See* Yuzhuo Zhang, Shenhua Group Corp., Shenhua Coal Conversion Technology and Industry Development, Presentation at the GCEP International Workshop on Exploring Opportunities for Research to Integrate Advanced Coal Technologies with CO_2 Capture & Storage in China (Aug. 22–23, 2005), http://gcep.stanford.edu/pdfs/wR5MezrJ2SJ6NfFl5sb5Jg/16_china_zhangyuzhuo.pdf; *see also* Nicol D. Innocenti, *Sasol Taps into China's Demand for Oil*, FIN. TIMES, June 29, 2004, at 24; GUODONG SUN, HARVARD U. BELFER CTR. FOR SCI. & INT'L AFFAIRS, ADVANCED COAL TECHNOLOGIES IN A SUSTAINABLE ENERGY SYSTEM: PREPARING AND PRESERVING THE APPROPRIATE TECHNOLOGICAL OPTIONS IN CHINA 1 (2005), *available at* http://bcsia.ksg.harvard.edu/BCSIA_content/documents/Harvardmostactworkshop.pdf.

[119] For an introduction and discussion of definitions, see ANDY GARNER & GREGORY A KEOLEIAN, NAT'L POLLUTION PREVENTION CTR. FOR HIGHER EDUC., INDUSTRIAL ECOLOGY: AN INTRODUCTION 3–5 (1995), *available at* http://www.umich.edu/~nppcpub/resources/compendia/INDEpdfs/INDEintro.pdf.

the manufacturing site or eco-industrial park). Cities themselves have historically been viewed as a rich site of such industrial symbiosis.[120]

The potential savings of this integrated urban energy approach for cities has attracted academic attention. In November 2005, Imperial College London established a £4.5 million (BP-funded) project to research the use of energy in cities.[121] A presentation on its website asks the question: "Can cities become as efficient as chemical complexes?"[122] The presentation suggests that urban integration through "network superstructures" and optimization procedures such as those found in petrochemical complexes results in 20–50% energy savings.[123]

China has also recognized the broader potential value of such integrated thinking (known as the "circular economy"),[124] and is currently drafting legislation that is expected to be introduced in 2007.[125] It is also undertaking a research project exploring the "internal flows" associated with high efficiency clean coal and polygen energy applications.[126] Sun has pointed out that widespread application of coal-based polygen systems in China requires a higher degree of integration of traditionally separated energy infrastructures, and identifies "improving system integration" as one of the key technical problems which must be addressed in its adoption.[127]

---

[120] Pierre Desrochers, *Cities and Industrial Symbiosis: Some Historical Perspectives and Policy Implications*, J. INDUS. ECOLOGY, Fall 2001, at 29, 30. The late urban theorist Jane Jacobs went so far as to call them "waste-yielding mines" that had the fortunate characteristic of not depleting over time, but rather growing richer over time as their waste niches were developed. *Id.* at 34.

[121] *See* Imperial College London, Energy Futures Lab, Urban Energy Systems, http://www3.imperial.ac.uk/energyfutureslab/research/projects/urban_energy_systems (last visited Feb. 2, 2007).

[122] Nilay Shah, Urban Energy Systems—Modelling and Analysis, *available at* http://www3.imperial.ac.uk/portal/pls/portallive/docs/1/1117904.PDF.

[123] *Id.*

[124] *See* Zengwei Yuan et al., *The Circular Economy: A New Development Strategy in China*, J. INDUS. ECOLOGY, Winter/Spring 2006, at 4, 4–5.

[125] *China to Draft Law for Circular Economy*, CHINA DAILY, July 31, 2005, *available at* http://www.chinadaily.com.cn/english/doc/2005-07/31/content_464904.htm.

[126] YI WANG ET AL., CHINA CLEAN ENERGY PROGRAM, STRATEGIC DIRECTION IN CLEAN UTILIZATION OF COAL 36 (2004), *available at* http://www.chinacleanenergy.org/docs/cleanpower/CoalGasificationRptEN17jun06.pdf.

[127] SUN, *supra* note 118, at 3. Other technical problems identified include

DeLaquil et al. have modeled the costs of advanced, high technology polygen applications within the country, and concluded that:

> China can support its social and economic development objectives for the next 50 years and beyond with clean and renewable energy that is derived mostly from its indigenous resources. This conclusion is notable enough by itself, but what is most remarkable is that it appears there would be essentially no added cost over the long term to pursue this sustainable energy path relative to an unsustainable "business-as-usual" energy development strategy.[128]

Their modeling makes numerous assumptions, develops a range of scenarios, and introduces both emissions and energy security constraints. The results indicate that the up-front investment costs of the advanced technology systems will certainly be higher, and that efficiency and renewable energy must continue to play a key role. But, as another team member writes: "When the objective is to shift to a clean energy system over a long time period, these [clean coal] costs do not present an overwhelming barrier."[129]

The potential development of that longer-term, phased evolution has already received some consideration. Princeton and Tsinghua Universities have conducted a joint "Syncity" research program, and have suggested that polygen technologies might be developed utilizing a four-phase approach.[130] The first phase

"reducing excessive downtime from key components of the gasifier, developing new gasification technologies for low-rank coals and smaller-scale applications, developing deep-cleaning technologies to meet more stringent environmental regulations at competitive costs, and developing high-efficiency but low-cost air-separation technologies." *Id.*

[128] Pat DeLaquil et al., *Modeling China's Energy Future*, ENERGY FOR SUSTAINABLE DEV., Dec. 2003, at 55. This work was part of a broader effort by the Task Force on Energy Strategies and Technologies to the China Council for International Cooperation on Environment and Development (CCICED). *See generally* TASK FORCE ON ENERGY STRATEGIES & TECHS., CCICED, TRANSFORMING COAL FOR SUSTAINABILITY: A STRATEGY FOR CHINA (2003).

[129] MARC JACCARD, SUSTAINABLE FOSSIL FUELS: THE UNUSUAL SUSPECT IN THE QUEST FOR CLEAN AND ENDURING ENERGY 204 (2005). Jaccard was also a CCICED task force member. *See* TASK FORCE ON ENERGY STRATEGIES & TECHS., *supra* note 128.

[130] Eric D. Larson, The Princeton-Tsinghua Collaboration on Low Emission Energy Technologies and Strategies for China, Presentation to the First Annual Meeting of the Carbon Mitigation Initiative (Jan. 16, 2002), http://www.princeton.edu/~energy/presentations/pdfs/Larson.pdf.

would establish the technologies, utilizing petroleum residuals as feedstock and/or making higher value products from coal. A second phase would shift toward a fully coal-based system, emphasizing the production of high-value chemicals and process heat, as well as fuels and electricity. The third phase would focus new construction on dedicated fuels streams and electricity production, and would also begin to sequester CO_2. The final stage would be a fully advanced technological system, with full polygeneration, producing hydrogen and electricity, and sequestering all CO_2.[131]

While higher oil prices should make the development of polygen schemes more attractive, China will have to overcome considerable institutional barriers to such development. The potential benefits of this approach require an integrated urban energy system, but the current organizational "chimney" structure of energy services in municipalities is not well suited to such integration.[132] There is little awareness at the municipal level about polygen technologies; about their potential cost and development; about the environmental, energy security, national interest, flexibility and efficiency advantages they offer; or about the role that they might play in transforming Chinese cities in the future, in a technologically advanced manner.

The adoption of a policy of integrated energy development requires steady commitment, which will be tested through the likely booms and busts of China's future energy development. In times of power shortages, threatened oil market disruptions, and record natural gas prices, such policies might look attractive, but they will appear much less so during anticipated power surpluses, when oil and natural gas prices drop, or when economic growth levels drop.

In spite of these barriers, Chinese cities offer some important favorable conditions for the development and implementation of SUES:

---

[131] *Id.*

[132] Brian Anderson, *Barriers to the Implementation of Coal Syngas/Polygeneration (CSP) in China*, ENERGY FOR SUSTAINABLE DEV., Dec. 2003, at 25.

- Chinese cities tend toward energy self-sufficiency. Much of the wealth in China in recent decades has come from "township and village enterprises," and local governmental officials have placed significant emphasis on local economic development. Local governments have taken actions to ensure that their own energy needs were met during periods of power shortages,[133] building local power plants and facilities—even if this sometimes had the effect of ignoring or contradicting national policies.
- The Chinese political culture tends toward large-scale projects. Technological systems are developed within a socio-political context, and most of China's "Third and Fourth Generation" political leaders were/are engineers. The Three Gorges Dam is indicative of a political culture in which technocratic, large-scale energy projects are viewed in a positive light.[134]
- The energy security threat aligns both local and national interests. Continued local economic development and the country's role in international affairs are both affected by China's dependence upon outside energy sources. To the extent that SUES addresses this problem, it could bring local and national resources to bear.
- The SUES approach is consistent with the high technology goals and knowledge-based economy that the country hopes to develop. China is already beginning to worry about its role as a low-value-added manufacturing economy, in a world where future wealth will be determined by knowledge, information, and services. SUES offers a means of developing and utilizing a local energy resource in a manner consistent with loftier economic development goals.

The high technology SUES approach will only develop over time, but there is no reason why other more immediate urban energy measures could not be implemented at the municipal level

[133] Robert M. Wirtshafter & Ed Shih, *Decentralization of China's Electricity Sector: Is Small Beautiful?*, 18 WORLD DEV. 505, 505–06 (1990).

[134] As one example, a proposal we made for Chinese wind power development that suggested a small scale, entrepreneurial, trial-and-error approach for market growth, see Raufer & Wang, *supra* note 108, was viewed as inconsistent with the country's energy planning, which sought more dramatic, larger scale project development.

by urban planners, environmental regulators, and other city officials. The following three examples are indicative of the opportunity for immediate action.

First, the "community energy management" (CEM) approach suggested by Sadownik and Jaccard employs specific strategies for urban planners in Chinese cities:[135] encouraging land-use development that would make district heating most economical; facilitating the continued use of bicycle transportation; encouraging greater mixed land use and density in suburban developments; replacing decentralized and uncontrolled coal combustion for individual apartment blocks with "community" facilities employing environmental controls; and similar measures.[136] Small and medium-sized cities such as those currently included under the City PMD project would be well served to utilize such measures. It is obviously much more desirable to direct urban planning and transportation system design toward sustainable energy use at the outset than to undo years of infrastructure problems at a later date.

Second, while it might be somewhat surprising to outsiders, few environmental agencies (anywhere in the world) employ energy efficiency as an air quality management tool. Vine has suggested that there are several reasons for this, including cultural, technical, and programmatic barriers.[137] These include the different organizational cultures of energy and air quality program personnel; the difficulty of quantifying energy savings; the difficulty of linking those savings to emissions reductions; and the reliability of the emissions reductions. Given China's coal-based energy system and current air pollutant levels, Chinese cities are especially likely to see sizable air quality benefits from energy efficiency, probably much more so than cities within the developed world. As such, Chinese cities should incorporate energy efficiency measures as a form of air quality management in their local environmental protection bureaus.

[135] Bryn Sadownik & Mark Jaccard, *Sustainable Energy and Urban Form in China: The Relevance of Community Energy Management*, 29 ENERGY POL'Y 55, 56 (2001).

[136] The authors suggest that "China can achieve urban residential and transportation emissions reductions of approximately 14% for CO_2, 10% for SO_2, 40% for NO_x and 14% for particulate emissions in 2015 by adopting certain aspects of CEM." *Id.* at 55.

[137] Edward Vine, *Opportunities for Promoting Energy Efficiency in Buildings as an Air Quality Compliance Approach*, 28 ENERGY 319, 333 (2003).

And third, the International Council for Local Environmental Initiatives (ICLEI) has a Cities for Climate Protection™ (CCP) Campaign, which is designed to encourage cities to adopt policies and measures that will achieve quantifiable reductions in local greenhouse gas emissions, while also improving local air quality and enhancing urban sustainability. The CCP has enlisted more than 674 local governments in thirty countries worldwide, although no Chinese cities are listed.[138] CCP cities agree to conduct an emissions inventory, and ICLEI has developed software tools that assist cities in this task, based primarily upon fuel use in various categories (e.g., residential, commercial, industry, transport, etc.). The software then evaluates the emissions reductions associated with energy efficiency actions in municipal programs. The use of such software programs could help form an initial understanding of energy flows within Chinese cities.

Ultimately, however, this understanding must be translated into integrated, energy-focused urbanized industrial ecology, with "network superstructures" and optimized procedures operating in the real world of Chinese cities, not merely within the halls of academia. Such an integrated urban energy program, incorporating a technology-oriented gasification/polygen/nuclear energy infrastructure, as well as energy efficiency, renewable energy, and industrial-ecology-like measures, would appear to be the most feasible path forward for the development of SUES in China. Such a program would offer a means of utilizing the abundant (and necessary) domestic energy resources in the country in an environmentally appropriate manner, enabling China to meet both its urbanization energy needs and sustainable development goals.

C. *International Support for Chinese SUES*

As noted earlier, climate change is more than just an economic problem—it requires a transformation of the energy infrastructure of cities and nations around the world. The development of SUES in China would certainly have positive repercussions with respect to international control of greenhouse gas emissions. But there are other externalities besides CO_2—

[138] Int'l Council for Local Envtl. Initiatives, CCP Participants, http://www.iclei.org/index.php?id=809 (last visited Feb. 2, 2007).

including the reduction of localized pollutants, energy security, system resiliency, and poverty alleviation—which would be enhanced if such SUES approaches became readily available in countries around the world. The international community thus has an important stake in ensuring their successful development in China.

This would appear to be exactly the appropriate role for the Asia Pacific Partnership for Clean Development and Climate (AP6)[139]—complementing the economics/emissions-oriented Kyoto Protocol on the technology side, with a series of measures designed to foster SUES development. The six countries of the AP6 are currently responsible for about half of the world's greenhouse gas emissions, and with both China and India included in the Partnership, this fraction will increase in future years.[140] As noted earlier, induced technological change clearly impacts the cost and timing of emission abatement options under climate change policies, and China's coal-based SUES needs seem to offer the most challenging (and appropriate) target available for AP6.[141]

The fourth SUES step might also lay the groundwork for what Ausubel terms "big green energy machines."[142] Urbanization increases the spatial density of end use energy consumption, and a "hard green" energy path relying on large, very clean, high-technology options for power plants may ultimately offer an urban

[139] Asia-Pacific P'ship on Clean Dev. & Climate, Homepage, http://www.asiapacificpartnership.org (last visited Feb. 2, 2007).

[140] BRIAN S. FISHER ET AL., AUSTRALIAN BUREAU OF AGRIC. & RES. ECON., TECHNOLOGICAL DEVELOPMENT AND ECONOMIC GROWTH 1 (2006), *available at* http://www.abare.gov.au/publications_html/climate/climate_06/06_climate.pdf.

[141] Unfortunately, the U.S. has seen public sector R&D funding for energy decline significantly since the early 1980s. *See id.* at 19–20. There is a decided concern in the country about using "industrial policies," and having the government (instead of the market) trying to "pick the winners;" but as noted earlier, there is also an important role for governmental support for such new technologies in their nascent stages. *See generally* Gregory F. Nemet & Daniel M. Kammen, *U.S. Energy Research and Development: Declining Investment, Increasing Need, and the Feasibility of Expansion*, 35 ENERGY POL'Y 746 (2007).

[142] These might include zero emission power plants (ZEPPs)—with superfast (30,000 rpm), super-powerful (5 or 10 Gigawatt) combustion turbines utilizing CO_2 sequestration—and "SuperGrids" with superconducting cables wrapped around pipes carrying liquid hydrogen. Jesse H. Ausubel, *Big Green Energy Machines*, INDUST. PHYSICIST, Oct.–Nov. 2004, at 20, 21; Jesse H. Ausubel, *Some Ways to Lessen Worries About Climate Change*, ELECTRICITY J., Jan.–Feb. 2001, at 24, 30.

energy version very different from the distributed, land-intensive "soft green" paths currently associated with environmentalism. As Huber writes, on an energy basis, "the Softs prescribe the environmental equivalent of suburban sprawl; Hards prescribe the equivalent of living in the city."[143] He notes that the one real and growing scarcity is the scarcity of wilderness,[144] and an urbanized future that protects and conserves such irreplaceable natural assets may very well need to rely on concentrated forms of energy.

CONCLUSION

Chinese urbanization is accelerating in conjunction with its economic development, and this offers a unique opportunity to affect the energy infrastructure for generations to come. Energy use has not played a significant role in urban planning, however, and the country is hampered by its current and future dependence on coal.

The development of SUES in China requires continued efforts to accomplish market-oriented economic reforms, introducing resource efficiency into the economy; further efforts to introduce energy efficiency and conservation measures; and additional use of renewable energy technologies. But such measures alone are not likely to be sufficient.

The fact that China must depend upon coal to meet its myriad urban energy needs suggests that environmentally acceptable development will require a range of advanced technological processes, including coal gasification and liquefaction, carbon capture and storage, and potentially small scale modular nuclear facilities. The key to making these processes economically viable is integration; energy needs must be addressed through an integrated design approach based upon an industrial ecology model, but operating at an urban scale.

Chinese cities may be well suited to this approach: they tend toward self sufficiency in economic matters; they exist within a political culture that could foster large-scale technological development; the energy security threat aligns both local and national interests; and the approach is compatible with the high technology, knowledge-based economy, and environmental

[143] PETER HUBER, HARD GREEN: SAVING THE ENVIRONMENT FROM THE ENVIRONMENTALISTS 107 (1999).

[144] *Id.* at 196.

protection goals of the country.

While today's environmentally benign vision is a decentralized energy system utilizing small scale wind, solar, and other renewable energy technologies, tomorrow's urbanized future might well possess a very different vision: concentrated, powerful, large-scale, super-clean, advanced energy technologies. If the need for such systems does evolve, it is likely to become evident first in Asian megacities. Development of coal-based SUES in Chinese cities is thus a first step in helping to keep options open for an alternative sustainable energy future.