Energy Efficiency and Renewable Energy Options for China's Economic Expansion

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In recent years, China has experienced rapid economic growth and parallel rapid increases in energy use. As a result, energy-based environmental degradation has also increased in China, especially in its urban areas. Unquestionably, China will seek to further develop its economy at a rapid rate. Is it possible for the nation to achieve its economic goals without extensive environmental problems by increasing its reliance on efficiency and renewable? What would be the benefits to the society? This paper seeks to address these questions.

Introduction

Since the late 1970s, Asian economic growth has outpaced that of any other region in the world. While the rest of the world's economy grew at an inflation-adjusted rate of 2.2% per year during 1979-1989, the 21 countries of industrializing Asia grew at a rate of 5.7% per year (Byrne 1991). China's performance was even more impressive, with the country's GNP growing at an extraordinary 9.0% during the decade (CSSB 1990:3). This pace of change-over 4 times the world average and nearly twice the rest of fast-growing Asia—is virtually unparalleled in the 20th century.

Exceptional economic growth has been accompanied by similarly rapid growth in commercial energy use. While the rest of the world increased its primary energy consumption by 2.8% per year, Asian energy use climbed more than twice as fast (6.6%) (Byrne et al. 1991). China nearly matched this growth rate, increasing its annual energy use at only the slightly less rapid rate of 6.1% (CSSB 1990:149). On a per capita basis, the difference between the rest of the world and Asia generally, and China specifically, is even more dramatic. During 1979-1989, worldwide per capita energy consumption rose at less than 0.5% per year, but Asia's per capita use grew 7 times faster, at 3.4% and China's grew at 8 times the world average—4% per year. Notably, in the same period the industrialized countries actually *decreased* their per capita rate by 0.20% (Wang et al. 1988).

Economic growth in developing countries has often been accompanied by a second, related trend. While enjoying economic growth, countries find themselves experiencing high levels of energy-induced environmental degradation. The negative environmental effects of economic growth can be especially evident in large cities where industry and populations are heavily concentrated and where large amounts of fossil fuel are consumed.

This is particularly true in China where most industrial and commercial energy use facilities are located in or near large cities (Byrne et al. 1993:325). As a result, China's large urban populations are exposed to a multitude of air pollutants, often at levels that are well above World Health Organization guidelines. Most of these pollutants are by-products of coal combustion, as coal has been the major energy source fueling development in China. Currently, coal provides three-fourths of the country's commercial energy use (CSSB 1990:149). When this fact is coupled with China's requirement for further economic expansion to meet the growing needs and desires of its population, it is clear that China faces difficulties in balancing its goals of economic growth, social health and sustainable relations between its cities and the natural environment.

Clearly, China will increase its energy consumption in order to sustain economic growth. At present, the country's industrialization process is energy-intensive and is likely to remain so for several years to come. In this respect, the key question facing China, as well as other Asian developing countries, is not whether increased energy consumption is necessary. Rather, it is whether this increase will occur within an energy efficient and environmentally sensitive development system or whether

China will reproduce the past errors of already industrialized countries and be highly energy inefficient until much later in its industrialization (Melosi 1992; Greenberg 1992), There is increasing evidence that economic competitiveness and the recovery of a healthy environment hinge upon this choice. With high- and upper middle-income countries delinking economic growth and energy consumption through the introduction of higher efficiency technologies and integrated resource planning approaches, it is a critical time for energy and environmental policy makers and planners in China.

Energy, Environment and Development Linkages

Rapid economic and energy growth in Asia has brought significant improvement in the quality of life to the region. However, Asia has simultaneously become the most energy-intensive manufacturing region in the world. China is first among Asian countries in this category, requiring nearly six times as much energy input per unit of output as industrialized countries (76 MJ/$GNP vs. 12.60 MJ/$GNP) (Levine 1992). GNP comparisons must be interpreted carefully due to non-comparability of China's GNP with that of other countries. Nevertheless, international comparisons of energy consumption per unit of GDP among selected countries give further evidence of the low level of energy efficiency in China, In 1986, for example, industrialized countries used 212 to 679 tons of coal equivalent (tee) to produce $1.0 million in national output, while Asian developing countries consumed an average of 724 tee to produce $1.0 million in national output. By contrast, China used nearly 3,200 tee to produce the same value of GDP (CSSB 1990:386,394).

In one respect, this is no surprise. China's industry is now more concentrated on processing of raw materials, and production of infrastructure and durable goods, all of which are energy-intensive activities. Historically, early stages of industrial development have brought rapid escalations in commercial energy use. The first country to industrialize in the modern era—Great Britain—saw its energy intensity of production grow by several orders of magnitude before falling even more than it had risen. This pattern is repeated in the case of Germany, France, the U.S. and Japan. It is very likely that Asia generally, and China specifically, will follow this pattern (although at a comparatively lower overall intensity . . . See Figure 1.)

But there are two aspects of the contemporary situation that should be cause for developing country concern-one economic and one environmental.

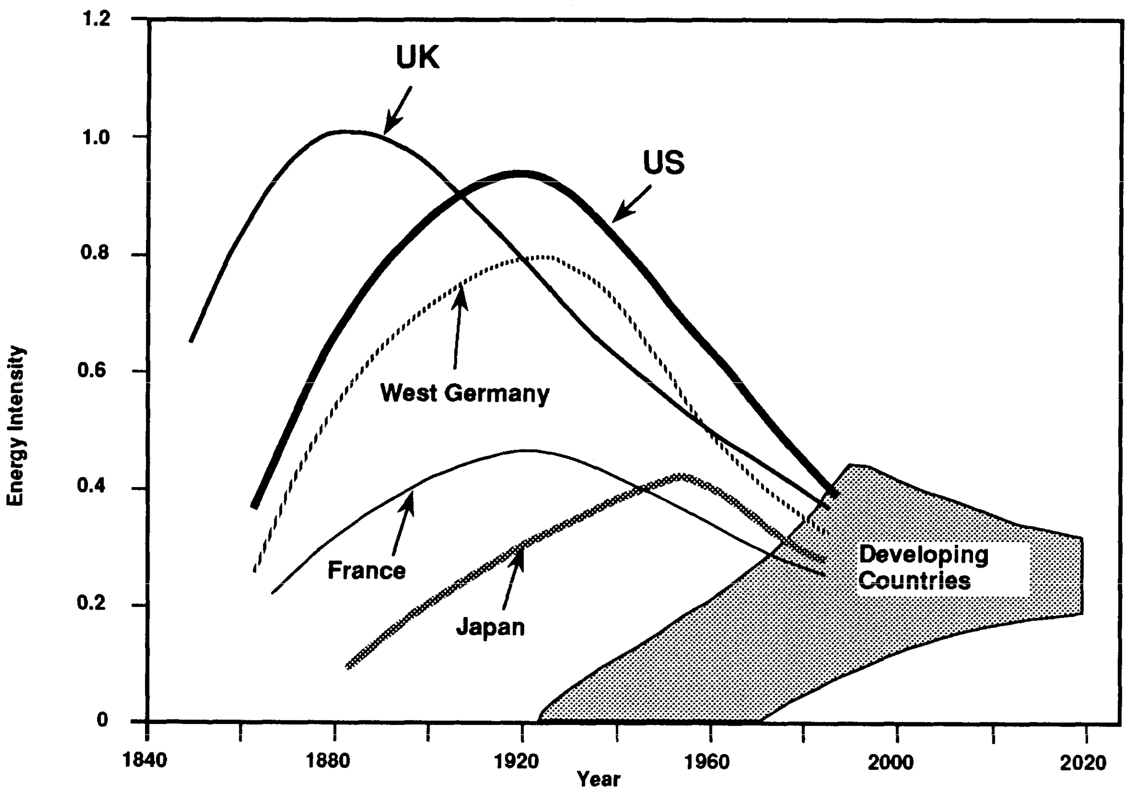
Energy-Economy Linkages

First, the world economy is far more significant in affecting national development than was previously the case. While China's domestic economy is the tenth largest in the world (and growing) (World Bank 1993) and, therefore, may not need to depend as much as other countries (like South Korea) on trade, it is very important to recognize that the country's high energy intensity of production places China at a competitive disadvantage in world markets for most products except textiles and heavy industry. Indeed, the industrialized countries have actively moved heavy industrial production (such as steel and petrochemicals) to the Pacific basin. If China is to be competitive over the long term, it is essential that its energy intensities decline soon, before developed countries are able to exploit their energy efficiency advantage to dominate emerging markets and technologies.

High energy intensities have significant implications for energy supply as well. While China has large coal reserves, it is important to recognize that they are not large on a per capita basis. Indeed, China's coal wealth *on a per capita basis is* only slightly above the world average—2.6 ktce for China compared to 2.3 ktce for the world as a whole (Levine 1992:405-435). Thus, if China is to meet its aims of economic growth for all of its people, the country needs to reduce its energy intensity in the near future.

Relatedly, industrializing countries need to recognize that wealthier countries are in the process of delinking their economic growth from energy consumption. An international comparison of GDP and energy consumption growth rates shows a trend toward economic growth based on decreasing energy consumption growth rates. (See Figure 2.)

In both economic and energy terms, the high-income group (as defined by the World Bank [World Bank 1993]) controls and absorbs a disproportionate share of the world's resources. In fact, GDP per capita in the high-income group is roughly twice that of the sum of the other three groups' averages for 1985, while high-income per capita energy use is approximately three times that of the summed averages of the other three groups (Wang et al. 1988). Energy intensity among high-income countries and to a lesser degree, upper-middle-income countries, has slowed in the post-energy crisis period (after 1980), raising the possibility that economic growth in these groups will be accompanied by smaller (or even negative) energy consumption growth. But the reverse has been the case for low- and lower-middle-income countries. These



Note: **Energy intensity is expressed as the amount of energy (in equivalent metric tons of petroleum) consumed to yield $1,000 of Gross Domestic Product.**

Source: **A. Reddy and J. Goldemberg. 1991. "Energy for the Developing World." In Scientific American. (ed.) *Energy for Planet Earth.* (New York: W. H. Freeman): 64.**

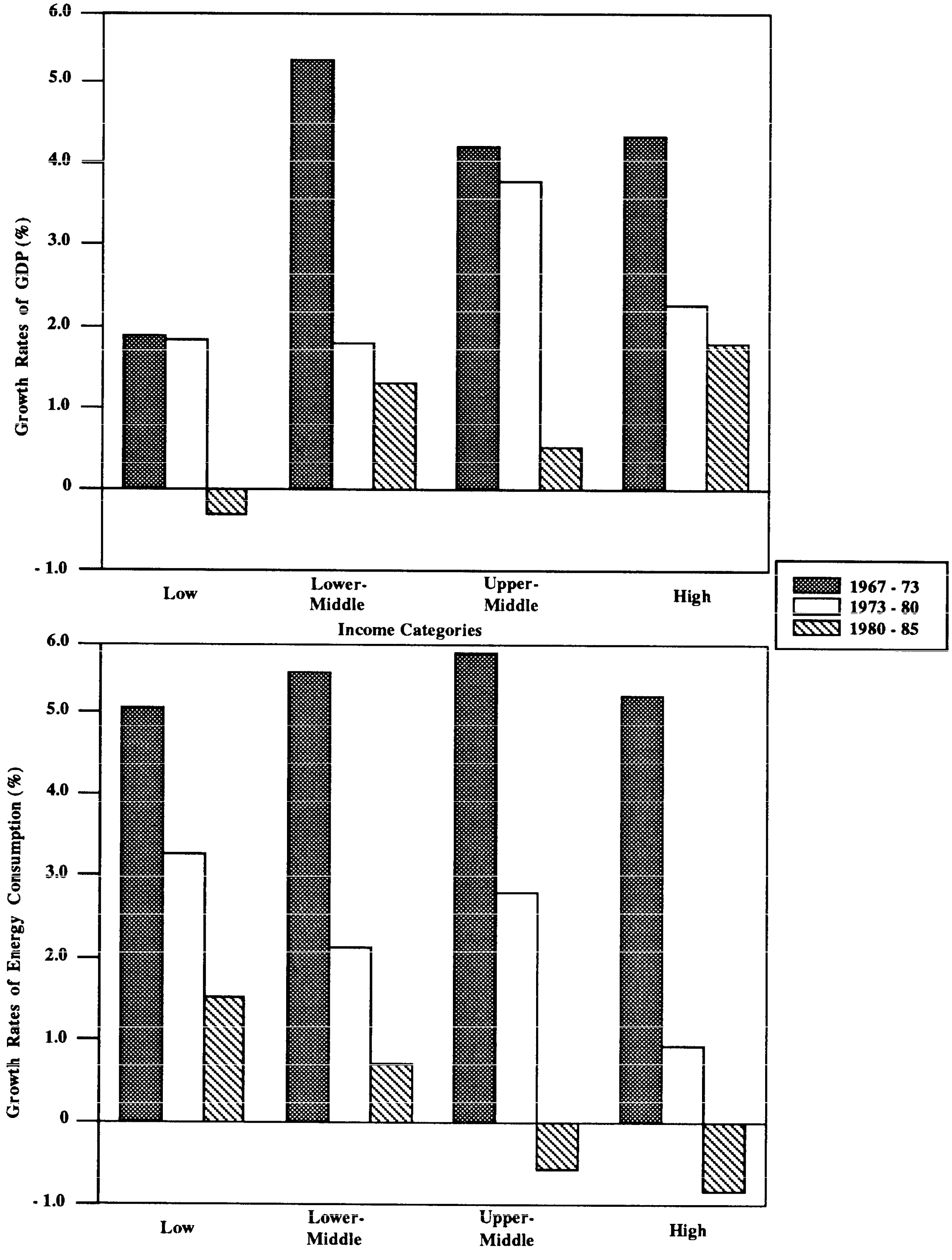
Figure 1. Evolution of Energy Intensities in Industrial Countries

countries have required continuous growth in energy consumption to sustain even modest levels of economic growth.

A statistical regression analysis of energy conservation and economic growth during 1967-1985 demonstrates these points. Regression estimates of the relationship between energy consumption growth and GDP growth by income group are shown in Table 1.

This regression indicates an inverse relation between country income and energy requirements for development during the 1967-1985 period. Thus, low-income and lower-middle-income countries in every time period require higher energy consumption growth per capita than the higher income countries to achieve the same rate of GDP growth. This energy requirement was highest during the pre-shortage period of 1967-1973 when low-income countries needed roughly six times the growth in energy consumption of high-income countries (12.84 vs. 1.67) in order to secure the same GDP growth rate. Since the oil crises of the 1970s, all income categories have learned how to produce goods and services with comparatively less energy. Even so, the lower income countries have been much less successful in reducing their energy requirements of production. In the post-shortage period, the consequences of this become very clear. The upper-middle and high-income countries have *negative* energy requirements for GDP growth, while low and lower-middle income countries continue to have *positive* energy requirements.

Recently available data on China tend to support this conclusion. During the initial stage of industrial development (before 1978), with few appropriate efficiency measures being taken, the growth rate in energy consumption was equal to or greater than that of the economy. After 1978, a series of energy policies were formulated to promote energy efficiency. As a result, energy consumption growth slowed while economic growth rates continued to climb. But despite the impressive success of China's efficiency-oriented policies, it ended the decade of the 1980's with the highest ratio of energy input per unit of output (Byrne et al., 1993).



Source: Center for Energy and Environmental Policy, University of Delaware.

Figure 2. Comparison of GDP and Energy Consumption Growth Rates

While there has. . . . . the country has a long way to go before it will be possible to convince its planners that economic growth does not hinge necessarily on increasing consumption growth.

Energy-Environment Linkages

A second challenge for China concerns the environmental impacts of rapid, energy-intensive, economic growth. A basic measure of the problem is the level of-urban air

Table 1. Regression Estimates of Annual Growth Rates in Energy Consumption and GDP Per Capita, Using Two-Stage Least Squares Procedures

	Pre-shortage (1963-73)		Energy-shortage (1973-80)		Post-shortage (1980-85)	
	ENG	**GDP**	**ENG**	**GDP**	**ENG**	**GDP**
Variables						
ENG	---	-0.13	---	-0.22	---	-0.08
GDP	0.97	---	4.73*	---	1.04*	---
OTP	0.06	---	0.07	---	0.02	---
EXP	---	0.25*	---	0.25*	---	0.32
INV	---	0.06	---	0.10	---	0.14*
Income Category						
Low Income	12.84		-1.25		0.12	
Lower-Middle Income	11.00		-3.36		0.12	
Upper-Middle Income	11.49		-14.57		-0.05	
High Income	1.67		-10.10		-2.32	
R-square	0.33	0.60	0.62	0.27	0.59	0.61
Standard Error	7.38	1.95	4.69	2.26	2.54	2.21

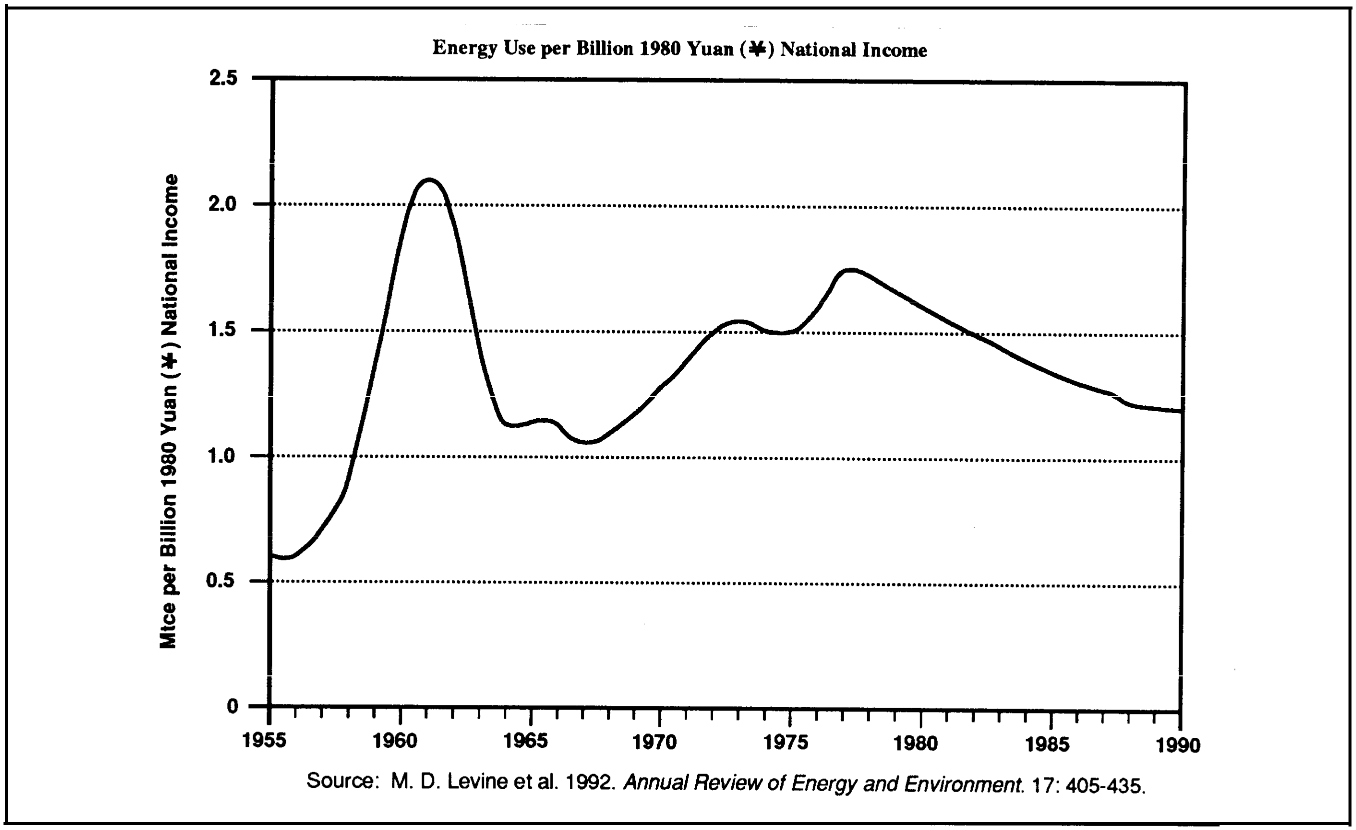
Note: ENG: Annual growth rate of energy consumption
GDP: Annual growth rate of GDP
OTP: Annual growth rate of oil exports to GDP
EXP: Annual growth rate of exports
INV: Annual growth rate of investment
Income category: Dummy variables for each group of countries

*Statistically significant at 0.05 level.
Source: Center for Energy and Environmental Policy, University of Delaware.

pollution. Data from China indicates that suspended particulate matter (SPM) from combustion amounted to 14 million tons and SO_2 emissions amounted to 15.6 million tons, respectively, in 1989 (Xu and Hao 1993). Urban air pollution associated with these emission levels is most serious in winter and spring due to coal-burning for heat. According to data from China's air quality monitoring network, the annual average of SPM emissions in 1989 reached 432 ug/m^3 for all its cities combined; and was 526 ug/m^3 in the northern cities, and 318 ug/m^3 in the southern cities. The SO_2 annual average in 1989 reached 105 ug/m^3 for all cities, 93 ug/m^3 and 119 ug/m^3 in the northern and southern cities, respectively (Xu and Hao 1993).

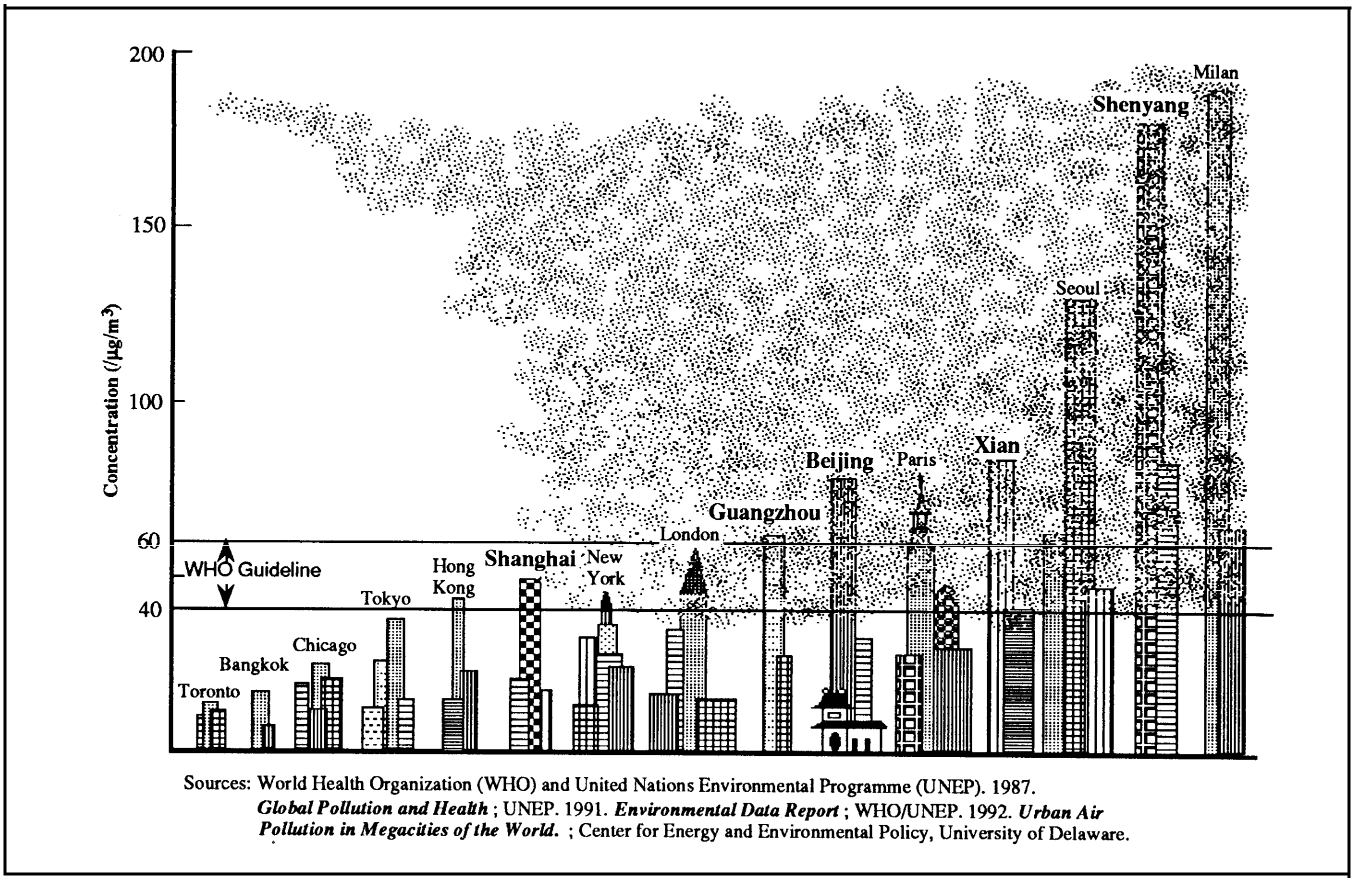
International studies have also revealed striking evidence of declining environmental quality in urban China. According to a report issued by the World Health Organization (WHO) and the U. N. Environment Program, for example, five of the 10 cities with the world's highest SPM were in China—Shenyang, Xian, Beijing, Shanghai and Guangzhou. With regard to SO_2, three of the five Asian cities with the highest monitored concentrations were in China—Shenyang, Guangzhou and Beijing. The concentrations of SPM and SO_2 in China's major cities are well above those set by WHO for healthy urban air. (See Figures 4 and 5.)

With large $S0_2$ emissions comes another environmental threat—acid rain. With rapid development, regions in China threatened by acid rain have expanded greatly. Based on measurements by China's Meteorological Department, rainfall acidity has increased not only in urban areas, but also in most rural parts of China. In the east, acid rain has extended beyond the Yangtze River, with PH values less than 5.0 found in the Jiaodong



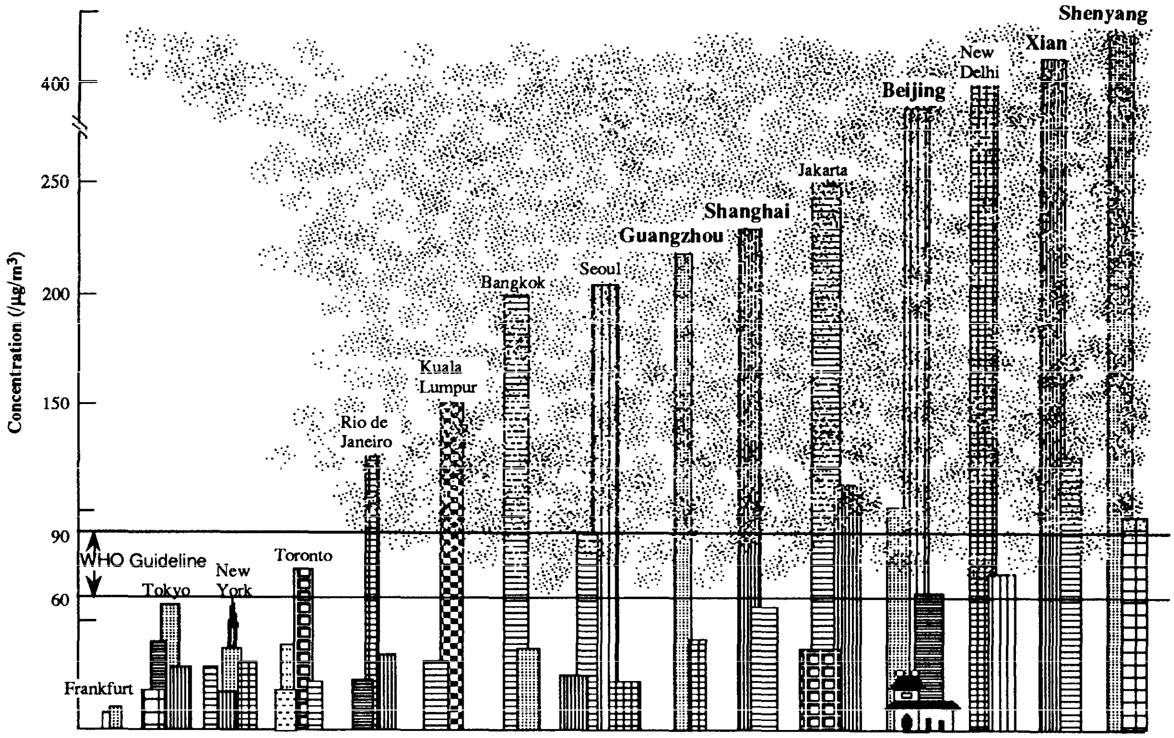
Source: M. D. Levine et al. 1992. *Annual Review of Energy and Environment.* 17: 405-435.

Figure 3. Energy Use for China's Gross National Product, 1955-1990



Sources: World Health Organization (WHO) and United Nations Environmental Programme (UNEP). 1987. ***Global Pollution and Health*** ; UNEP. 1991. ***Environmental Data Report*** ; WHO/UNEP. 1992. ***Urban Air Pollution in Megacities of the World.*** ; Center for Energy and Environmental Policy, University of Delaware.

Figure 4. Annual SO_2 Average Concentration in Selected Cities: 1980-1984



Sources: World Health Organization (WHO) and United Nations Environmental Programme (UNEP). 1987. *Global Pollution and Health* ; UNEP. 1991. *Environmental Data Report* ; WHO/UNEP. 1992. *Urban Air Pollution in Megacities of the World.* ; Center for Energy and Environmental Policy, University of Delaware.

Figure 5. Annual Suspended Particulate Matter Averages in Selected Cities: 1980-1984

peninsula. This is particularly true in Guangzhou, whose annual average rainfall PH value decreased from 5.36 in 1986 to 4.34 in 1989, indicating that rainfall acidity increased nine-fold during that period (Xu and Hao 1993).

These high pollutant concentrations in China's air and rainfall are a direct outgrowth of the country's reliance on high-sulfur coals and on inefficient energy systems to fuel development. The environmental implications of energy-intensive development bring into even sharper focus the need for China to rethink its energy orientation. In a wide variety of energy applications (discussed below), avoiding or reducing SO_2 and other pollutant emissions by improving energy efficiency may be the most economical and healthy choice for China.

Energy Efficiency and Renewable as Economic Alternatives

Over the last decade, China has made important progress in reducing the energy intensity of its industrial production. Since 1980, energy consumption in China has grown by about 50%. But GDP has increased by about 120%. Typically, industrializing countries have ratios of energy to economic growth greater than 1.0. Prior to 1978, China's ratio of its economic growth rate to its energy consumption growth rate averaged about 1.3. Since that time, however, China has managed to reduce its ratio to 0.42 (Levine and Liu 1990).

Key to this progress were ambitious energy conservation programs included in the sixth and seventh Five-Year Plans (1981-85 and 1986-90). By 1990, an estimated 600 million tons of coal equivalent had been saved as a result of the country's conservation programs. It is estimated that the cumulative economic value of energy savings from the Government's conservation programs begun in 1984 had reached 320 billion yuan by 1990. Since China continues to experience energy supply shortages (reported in the *People's Daily [People's Daily]* to be over 50 billion kWh), these savings have been realized in the form of *avoided* economic losses that would have occurred without improvements in energy efficiency. That is, if China had not successfully launched its energy conservation programs, energy shortages would have been greater, leading to idled industrial capacity and the loss of economic output .

Using the experience of energy-efficiency programs launched during the sixth Five-Year Plan (1981 -1985), economic benefits can be shown to accrue to China's investment in this option. According to Levine and Liu (Levine and Liu 1990), for example, it cost approximately 400 yuan to add the energy equivalent of one ton of coal to the capacity of China's energy system for the 1981-1985 period. However, estimates of the cost of saving the equivalent of one ton of coal range from 50 to 340 yuan for the country's technology modernization projects. For example, improvements of domestic coal burning efficiency cost 100 yuan for saving the equivalent of one ton of coal; the renovation of industrial furnaces and boilers cost 140 yuan and 250 yuan, respectively. Overall, China's 8.2 billion-yuan-investment in energy-efficiency in the Sixth Five-Year Plan (1981-1985) is calculated to have saved energy at the rate of 290 Yuan per ton of coal equivalent; or 73% of what it would have cost the country to supply the energy through its current system (Levine and Liu 1990).

While China's success in improving energy efficiency deserves praise, there are still many opportunities for cost-effective investment in energy efficiency. In fact, China's existing energy system is highly inefficient as a recent study by Mark Levine and Liu has shown (Levine and Liu 1990). For example, they indicate that raw coal (which accounted for nearly 76 percent of China's total energy consumption in 1990) supplied nearly 60 percent of China's commercial sector end-use energy consumption, compared to less than 23 percent for electricity for that sector (Levine and Liu 1990). Coal intensity is particularly high in urban areas where industrial activity and commercial energy facilities are concentrated. Because of abundant and cheap coal supplies, many Chinese cities power their factories and households by directly burning coal. In Shanghai, for example, there were over 10,000 industrial boilers and 800,000 residential stoves powered by coal in the mid-1980s (Huang 1986).

In addition to the country's many cost-effective opportunities to improve energy efficiency, China also has a number of economical renewable energy alternatives. Renewable are sometimes mistakenly regarded in China to be only a rural, and usually, modest contributor to energy supply. This stereotype is not uncommon. Thus, an assessment made just a decade ago estimated that U.S. wind resources were capable of providing only 10% of U.S. energy needs. Now, based on more precise resource surveys completed in the past two years, U.S. experts have concluded that wind from just a few states in the midwestem part of the country is sufficient to provide the electricity needs of the entire United States. Total U.S. wind resources, assuming moderate restrictions on land use, could provide 10,800 TWh per year, or 384% of current U.S. generation (Grubb and Meyer 1993), typically at a cost of less than 6.0 cents per kWh (Cavallo et al. 1993).

Given China's abundant renewable resources, the development of an energy system fueled by renewable energy is hardly far-fetched. China's geothermal resources are the world's largest and can be used for electricity supplies far beyond local needs (Smil 1984). One calculation for China, based on data from the Chinese Academy of Meteorological Science, estimates total wind electric potential at 7,000 TWh per year (Grubb and Meyer 1993). This is over 10 times current Chinese electric consumption. If this resource can be harnessed, at least in some regions, at 6.0 cents per kWh, this would provide users relatively low cost power without adverse environmental impacts. Similarly, the prospect for photovoltaic (PV) technology in China is strong. Most parts of China receive reasonably good levels of solar insolation, in the range of 2000 kWh/m^2/year. This technology can more quickly bring electricity service to China's agriculturally-based communities at lower cost than conventional grid power. In addition, PV can be deployed to meet rapidly growing village and small-town electricity demand, especially from building loads such as lighting and ventilation. China has built its first 100kW PV power station recently in Qinghai Province *(People's Daily* 1993) and the nation currently has the ability to annually produce about 5 MW of solar cells (Yan and Ju). These provide a good beginning but more can be done to develop this energy option.

Strategic use of renewable sources can improve the overall efficiency of China's energy system in two ways. First, renewable reduce fuel risks because, unlike fossil fuels, there is no variability in the fuel cost of these energy sources. Thus, renewable energy can contribute diversity in fuel supply while offering some protection from sudden changes in domestic or international fuel prices. Second, renewable sources typically are not dependent on economies of scale for their development. Instead, renewable can be scaled to the size needed and, subsequently, expanded to meet new growth in demand. This feature, commonly termed modularity, means that renewable can be given increased priority when use of fossil technology would be too expensive due to the relatively small scale of demand, or when fuel costs (including transportation) are prohibitive.

Energy Efficiency and Renewable as Environmental Alternatives

In addition to their economic value, energy efficiency and renewable offer important health and environmental benefits that justify investing China's engineering talent and creativity, as well as scarce capital, in their rapid development. One clear area to focus attention is on China's coal-burning practices. The widespread use of coal as heating fuel for urban buildings and an industrial feedstock are inherently problematic from an environmental point of view.

In the "best" of circumstances, this fuel's use can lead to major air pollution and solid waste disposal problems. It is reported by Chinese authorities that 90 percent of SO_2 and 73 percent of industrial dust in Chinese cities come from direct coal-burning. Inefficient use of coal only exacerbates an already significant tendency toward environmental degradation. In China, the problem is becoming acute because more than 83 percent of the coal burned in China is not sorted or washed (Smil 1984).

Just as energy efficiency may be a more economical way of meeting energy needs for economic growth, many times it can also provide environmental benefits more effectively than postponing action and trying later to backfit technology to remove pollution. In some cases, it may even be more effective than investing in new combustion technology. Recent analyses conducted in the U. S. have indicated that investment in end-use efficiency in lighting and refrigeration can be more competitive than investment in new combustion technology as a means of reducing SO_2 emissions. Waiting until later to address the problem and relying on retrofit technologies is the most costly route to a solution. (See Table 2.)

Thus, on environmental and economic grounds, there can be strong justification for China's investment in energy efficiency. Such investment could help China to reduce emissions of SO_2 at roughly 855 yuan per ton of SO_2 avoided (using an average of the lighting and refrigeration examples above). Retrofitting combustion technology requires an investment of 2,850 yuan to remove a ton of SO_2 (Temple, Barker & Sloane 1990). This difference can have considerable long-term economic importance for China, as can be shown by a practical example of reducing SO_2 emissions in large cities to levels that are consistent with WHO guidelines. For example, if one were to set a five-year planning goal of achieving a 60 *micrograms/m*^{3} target (that is, the WHO guideline) in the cities of Beijing, Guangzhou and Xian and allowing for continued energy consumption growth, we estimated that the three cities would need to reduce SO_2 emissions by an average of 15-25% per year.

Table 2. Costs of Reducing SO_2 Emissions (based on U.S. Data)

	¥/Ton SO_2 Removed (Avoided)
New Combustion Technology	
Wet FGD Technologies	1,710 - 2,935
Dry Injection Technologies	1,680 - 2,680
Retrofit Technology	
Wet FGD Technologies	2,310 - 3,935
Dry Injection Technologies	2,165 - 3,475
End-Use Efficiency	
High Efficiency Refrigeration	1,310 - 2,165
High Efficiency Lighting (CFL)	425 - 640

Note: 1990 US$ converted to Chinese Yuan at a rate of US$1.00 = 4.00 Yuan (China).

Source: Temple, Barker and Sloan. 1990. *Clean Air Response: A Guidebook to Strategies*. (Palo Alto, CA: Electric Power Research Institute): Table III-7 and III-8.

This is a significant challenge. Such a reduction would translate into a 1.5 billion yuan investment in desulfirization technology if a "grow now, backfit later" strategy were adopted. But investing in energy efficiency could achieve the same environmental result at a cost to China of only about 0.5 billion yuan. The savings of 1.0 billion yuan would be in the form of freed-up capital that would not have to be used either for health care or environmental control technology, but instead could be used to improve the energy supply and distribution infrastructure, which in turn would have substantial economic benefits to the country. Thus, it is possible to meet energy, environmental *and* economic goals through an energy efficiency strategy.

Similarly, China can capture significant environmental benefits by modest-scale substitutions of renewable energy for coal. For example, if China converted three percent of its wind energy potential to electric generation (Yan and Ju argue that about 10 percent of the country's wind potential is utilizable), this would represent approximately 10 percent of the country's current electricity consumption and would avoid 80 million tons of CO_2, and 1.5 million tons of SO_2 emissions annually[1] (EPA 1994). These avoided emissions equal three percent of the country's annual CO_2 releases and over 9 percent of its yearly SO_2 releases (Lawrence Berkeley Laboratory 1993). Similar or better results could be attainable from the exploitation of the country's geothermal, biomass and solar energy (Yan and Ju). Thus, greater use of renewable in the energy system is feasible and will offer sizable environmental benefits to China.

Policies for Realizing the Potential of Energy Efficiency and Renewable

How can energy efficiency and renewable be systematically evaluated in relation to conventional energy supply options so that their benefits are maximized? Based on U.S. experience, integrated resource planning (IRP) would seem to be a valuable approach for realizing China's energy efficiency and renewable potential.

IRP has proven a quite successful tool for American electric utilities to identify efficiency investment options. In fact by 1990, U.S. utilities were annually investing $1.2 billion (nearly 7 billion yuan) in energy efficiency and annually saving the equivalent of the energy generated by 40 large electric power plants (Hirst 1992). The figures are even higher today. Recent projection of electric utility use of renewable suggests impressive growth in reliance on this option in the near future (Kelly, Henry, and Weinberg 1993:1011).

In recognition of the success of IRP, the U.S. Energy Policy Act of 1992 (EPACT) encourages all American electric utilities to adopt this method of assessing energy investment options. Defined by EPACT, IRP is:

> *a planning and selection process for new energy resources that evaluates the full range of alternatives, including new generating capacity, power purchases, energy conservation and efficiency, cogeneration and district heating/cooling applications, and renewable energy resources, in order to provide adequate and reliable service to a utility's customers at the lowest system cost (Energy Policy Act 1992).*

It is intended to be a comprehensive tool that provides an integrated and consistent treatment of demand and supply resources while accounting for diversity, reliability, dispatchability, risk and other factors.

Since China is in the process of assembling its industrial infrastructure for the 21st century, this is a critical time for developing efficiency and renewable in the end-use sectors—buildings, transportation, industrial processes and agriculture. To apply IRP into its energy planning, China needs to reform its existing institutional and economic structures. First, China should give energy conservation and energy efficiency higher priority in energy planning. Also, China's energy planning should begin to set goals and timetables for switching to the use of renewable energy resources in areas where grid extension is too costly and where off-grid opportunities for the use of renewable is economically warranted.

Equally important, China's centralist approach to the management of its energy system needs to be changed. Although recent reform policies have begun to use market mechanisms to encourage decentralization, in many areas such reforms have yet to reach the energy system. First, state control over energy prices must be phased out, and energy resources must be priced in terms of their economic and environmental value. Second, governmental subsidies for energy production and consumption should be gradually ended so that energy producers and consumers bear the actual costs of energy and can adjust their practices accordingly. Third, local initiatives and participation should be encouraged in managing the energy system and its development. The current cornmand-and-control approach to implementation should be replaced over time with market-oriented incentives and local regulation.

Also, China needs to adopt specific regulatory and economic measures to promote energy efficiency and renewable for both the supply and demand side. On the supply side, technology assessments in which all technology options for supplying energy are evaluated in terms of cost, energy output and environmental impacts is required; resource strategies that include a mix of energy supply efficiency investment and renewable development are needed. On the demand side, energy users should be encouraged to reduce their energy requirements by adopting energy efficiency and renewable options that reduce utility peak load and assist energy users in better controlling their patterns of energy usage. For example, energy taxes to discourage waste and investment incentives to promote conservation and renewable opportunities should be incorporated into the country's energy development planning so that demand-side resource options are fully exploited.

In addition, China needs to seek international support on energy efficiency and environmental improvements. Such support can come in the form of financial and technical assistance, international monitoring and technology transfer.

- The Global Environment Facility endorsed by the developed countries at the 1992 UN Conference on Environment and Development should be implemented with specific plans to help China make the transition from its current problematic energy and environmental bases of development to sustainable ones.

- China should join the international community in monitoring global environmental quality to ensure that global environmental quality targets are met.

- Because we share a "common future," as the World Commission on Environment and Development observed in its 1987 report, developed countries should be prepared to transfer their less energy-intensive and environmentally-sound "green" technologies and products to their developing partners. Also, worldwide information exchanges on new "green" technologies would be of great assistance to developing countries, including China.

Conclusion

Economic growth is now and will remain a dominant goal for China. However, it is possible to achieve economic growth in an energy-efficient and environmentally balanced manner. Pursuing an alternative energy path emphasizing efficiency and renewable can be in China's long term economic and environmental interest. These energy sources provide important tools for improving the productivity of China's economy and fossil energy system. At the same time, they offer the country a way to reduce health-threatening pollution in the wake of rapid development. Several Western countries are actively pursuing energy efficiency and renewable energy options. China can move quickly in this direction because it can invest in efficiency and renewability from the outset, rather than having to rebuild its energy system as industrialized countries must do. Because energy efficiency and renewable energy provide for economic growth without further depleting China's fuel reserves or harming the natural environment, they need to be examined in detail as complementary means of meeting the country's development aspirations.

Endnote

1. This calculation is based on U.S. EPA estimates for U.S. power plants of 0.77 lbs CO_2/kWh and 0.0128 lbs SO_2/kWh. See EPA (1994), *Energy Star Program.* Environmental benefits can be expected to be greater in China, considering the relatively inefficient technologies on which the country's energy system is currently based.

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