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Coal Use in the People's Republic of China, Volume 2: The Economic Effects of Constraining Coal Utilization

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NOTATION

The following is a list of the acronyms, initialisms, and abbreviations (including chemical symbols and units of measurement) used in this document.

ACRONYMS, INITIALISMS, AND ABBREVIATIONS

ADB	Asian Development Bank
AEEI	autonomous energy efficiency improvement
ANL	Argonne National Laboratory
DLP	Dynamic Linear Programming
EWC	East-West Center
GDP	gross domestic product
GHG	greenhouse gas
GNP	gross national product
I-O	input-output
LP	linear programming
MPS	material production system
PV	photovoltaic
R/P	reserves-to-production
SNA	system of national accounts

CHEMICAL SYMBOLS AND ABBREVIATIONS

CFC	chorofluorocarbon
CH_4	methane
CO_2	carbon dioxide
SO_2	sulfur dioxide

UNITS OF MEASUREMENT

bcm	billion cubic meter(s)
GW	gigawatt(s)
ha	hectare(s)
kg	kilogram(s)
kW	kilowatt(s)
m^2	square meter(s)
m^3	cubic meter(s)
mcm	million cubic meter(s)
Mtce	million tonnes standard coal equivalent
MW	megawatt(s)
tce	ton(s) coal equivalent
tty	ton(s) per thousand yuan

tcm	trillion cubic meter(s)
tonne	metric ton(s)
TWh	terawatt hour(s)
W	watt(s)
yr	year(s)

COAL USE IN THE PEOPLE'S REPUBLIC OF CHINA, VOLUME 2: THE ECONOMIC EFFECTS OF CONSTRAINING COAL UTILIZATION

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ABSTRACT

The People's Republic of China (hereafter referred to as China) is the largest producer and consumer of coal in the world. The dominance of coal in China's energy balance has come at a high price to the environment. With the recent attention given to global warming issues, China's energy consumption and production practices have become the subject of much concern. Of particular concern is China's ability to reduce CO_2 emissions by constraining coal use and the impact such policies will likely have on the Chinese economy. The study is divided into two reports. Volume 1 focuses on the full coal fuel cycle, emissions, and environmental effects. This report (Volume 2) analyzes various CO_2 mitigation strategies and determines their effect on economic growth. Contrary to what some analysts have claimed, the current work suggests that it would not be costly for the Chinese to reduce CO_2 emissions. In fact, some strategies were accompanied by increases in China's energy and economic efficiency, which actually stimulated economic growth.

SUMMARY

Global warming could prove catastrophic for most nations. Pressure is mounting among nations to reduce the causes of global warming, especially the emission of greenhouse gases (GHGs) from fossil fuel combustion. A global problem of this magnitude requires a global solution; therefore, the cooperation among energy-intensive economies — industrialized or developing nations — is crucial.

The People's Republic of China (hereafter referred to as China) is an obvious candidate to take the lead in reducing GHG emissions because it is the world's largest producer and consumer of coal. However, with a per capita income of less than $400, China is also one of the world's 25 poorest countries. Some analysts have suggested that it will be very costly to curb GHG emissions. Thus, the question arises as to the equity, if not the feasibility, of having China initiate major mitigation measures. Other analysts have suggested that efforts to cope with global warming present various opportunities to simultaneously improve energy and economic efficiency.

This report analyzes how GHG mitigation policies would affect the growth of China's economy over the next 30 years. The focus is on reducing coal use and examining the implications for reducing carbon dioxide (CO_2). Implications for other fossil fuels, renewable energy resources, and other air pollutants are also examined, specifically the partial and general equilibrium economic impacts of achieving a 20% reduction in year 2000 baseline CO_2 emissions by 2025. Given the tenor of ongoing negotiations, a phased-in compliance schedule seems appropriate for this target year. The present analysis divides the compliance period into three periods: 1990-2000, 2000-2010, and 2010-2025.

This report discusses the modifications of the official Chinese Input-Output (I-O) Table, which is the major source of sectoral and macroeconomic data used in this analysis. An I-O model is an operational, static, linear model of all purchases and sales among sectors of the economy, based on the technical relations of production. This I-O table is the most widely used tool in analyzing economic impacts and is used either alone in a mathematical programming format or as the basis of computable general equilibrium models. This report uses a 33-sector aggregation of the 1987 I-O table and updates it to the 1990 base year. The same model structure is used for baseline projections over the planning horizon; however, for policy simulations, key economic, energy, and environmental coefficients were changed.

The Dynamic Linear Programming (DLP) model is summarized equation by equation. This model format is most appropriate for a centrally planned economy. It represents an extension of I-O to an explicit optimization capability subject to various constraints that relate to labor, capital, and energy resources, plus limits on air pollution emissions. The DLP model is further extended to a consistent forecasting version that can incorporate basic assumptions that relate to growth rates in gross domestic product (GDP), population, wages, and investments.

Baseline projections for China's economy are given for the three policy periods. Basic economic parameters make a significant difference over a 35-year period. Therefore, these parameters are grouped into two major categories, and separate simulations are run for each. Category 1 — a group of "optimistic" (higher numerical value) parameters — is referred to as upper bound, and Category 2 — a group of "pessimistic" (lower numerical value) parameters — is referred to as lower bound. For example, the upper-bound economic growth assumptions lead to a GDP projection of 24,934 billion yuans in the year 2025, while the lower-bound economic growth assumptions lead to a projection of 8,591 billion yuans in that year.

Environmental pollution, energy reserves, and energy technologies are analyzed, and the emission factors for fossil fuels developed by Argonne National Laboratory (ANL) staff are adapted for the present model. The literature on reserve estimates is examined for fuel availability and electricity-generating capacity for clean alternatives (e.g., hydro, nuclear, and natural gas). This report assumes that these alternatives can reduce CO_2 emissions by more than 90% of baseline year 2025 emissions in the upper-bound (optimistic) case and by about 28% in the lower-bound (pessimistic) case. Major technological considerations such as the electricity/GDP ratio, the displacement of coal in industrial boilers, and autonomous

Five strategies to reduce CO_2 emissions are analyzed:

- Change in the sectoral mix,
- Mandated conservation,
- Interfuel substitution with current technology,
- Interfuel substitution with technological advances, and
- Combination of strategies.

The impacts on final demand (GDP), gross output, CO_2, and sulfur dioxide (SO_2) are simulated in the aggregate. Detailed impacts for different sectors are presented for each of these indicators. Investment considerations associated with various strategies are analyzed.

The major findings of the study are:

- To meet the 5% target CO_2 reduction for the year 2000, China has several options that do not adversely affect its development plans. Moreover, strategies that conserve and displace coal in industrial uses may actually boost economic growth slightly above baseline projections. It appears that actions taken to mitigate CO_2 emissions also reduce emissions of other major air pollutants, such as SO_2, by about the same amount.

- By 2010, the effective abatement requirement changes for the upper- and lower-bound cases to 57.30% and 40.50%, respectively, of that year's baseline emissions. This more stringent requirement makes most single strategies infeasible, i.e., incapable of achieving the desired emission reduction target on their own. Combining strategies can meet the target, with only a slight decrease in the baseline gross national product growth rate in the lower-bound case and no decrease in the upper-bound case.

- By 2025, fewer options are available for achieving 84.91% and 65.31% of that year's baseline CO_2 emissions. Changing the sectoral mix cannot achieve the results, and autonomous conservation can only achieve reductions of about one-half of the upper-bound target and two-thirds of the lower-bound one, and only at large penalties. However, combining interfuel substitution and technological change could attain the targeted reduction of CO_2 emissions in the upper-bound case, with little economic penalty. Still, the result highly depends on the assumption of total displacement of coal in industry and very substantial shifts to nuclear, hydro, and gas-fired electricity generation. Otherwise, China's economic growth could decrease to 1.0-3.0% below baseline. For the lower-bound case, a mix of interfuel substitution, technological change, and sectoral

hydro, and gas-fired electricity generation. Otherwise, China's economic growth could decrease to 1.0-3.0% below baseline. For the lower-bound case, a mix of interfuel substitution, technological change, and sectoral mix changes can achieve the target, but at a sizable penalty that would reduce economic growth from 3 to 0.85%.

- For 2000 and 2010, results differ only slightly between upper- and lower-bound cases, suggesting that they are robust over a broad range of assumptions relating to China's economy, energy reserves, and energy technologies.

- Although investment costs associated with these strategies may appear to be exorbitant, they are not. Projections show that China will need significantly more electricity-generating capacity under the baseline scenario. Most of these strategies do not significantly increase the demand for electricity; in fact, most call for decreases. Moreover, sufficient lead time is available to switch to cleaner fuels, while building new plants rather than retrofitting old ones. Finally, these strategies call for a decrease in exploration and extraction costs, especially for hydro and nuclear options.

- Unless the CO_2 reduction measures enacted in China are "sustainable" (i.e., become part of China's economy and energy system), it could be costly to meet the reduction requirements in 2025 and beyond, under either the upper- or the lower-bound scenario. Achieving this goal may involve restructuring the economy and implementing conservation measures that are no longer costless. In fact, without discovering major resources or developing technological innovations (in addition to those projected in this report), CO_2 reduction targets beyond 2025 may not be feasible. Moreover, these targets may not be feasible for 2025 if some of the lower-bound assumptions are too optimistic.

Figures S.1 and S.2 present results for the baseline case, Strategy 1 (change in the sectoral mix), and Strategy 5 (combination of strategies). For the upper-bound cases, Strategy 1 achieves the 5% emission reduction in 2000 without penalty, but economic growth significantly decreases by 2010. Moreover, this option is not feasible by 2025 (i.e., the target CO_2 reductions cannot be attained). However, this outcome is not a major concern because several strategies can be combined to reduce emissions in all target years.

One combination of strategies can boost economic growth (from 6.50 to 6.51%), mainly as a result of cost savings plus the right combination of general equilibrium effects. For lower-bound cases, Strategy 1 imposes a slight penalty in 2010, but this strategy would lead to a major downturn in the economy in 2025. In this case, a combination of strategies would not impose any penalty in 2010 but would significantly reduce the rate of economic growth from 3 to 0.85% in 2025.

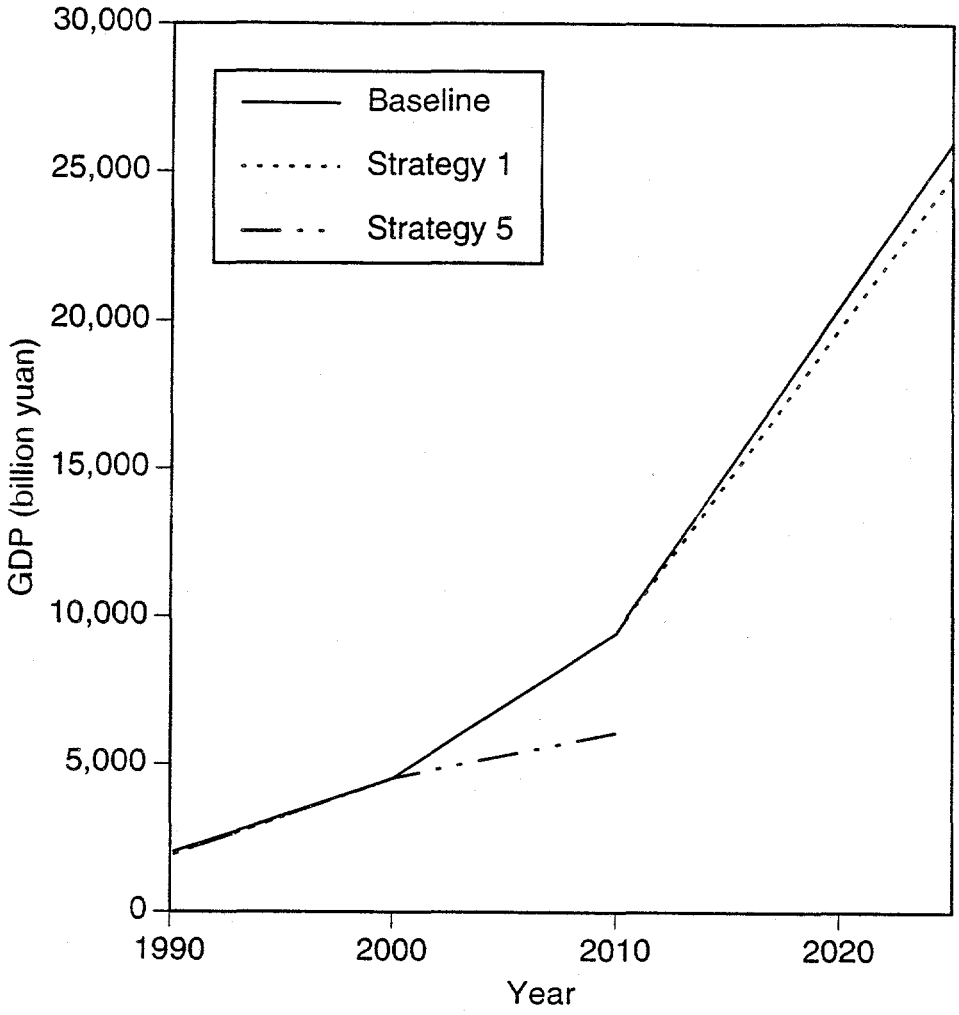

FIGURE S.1 Upper-Bound Case for China's Gross Domestic Product Projection

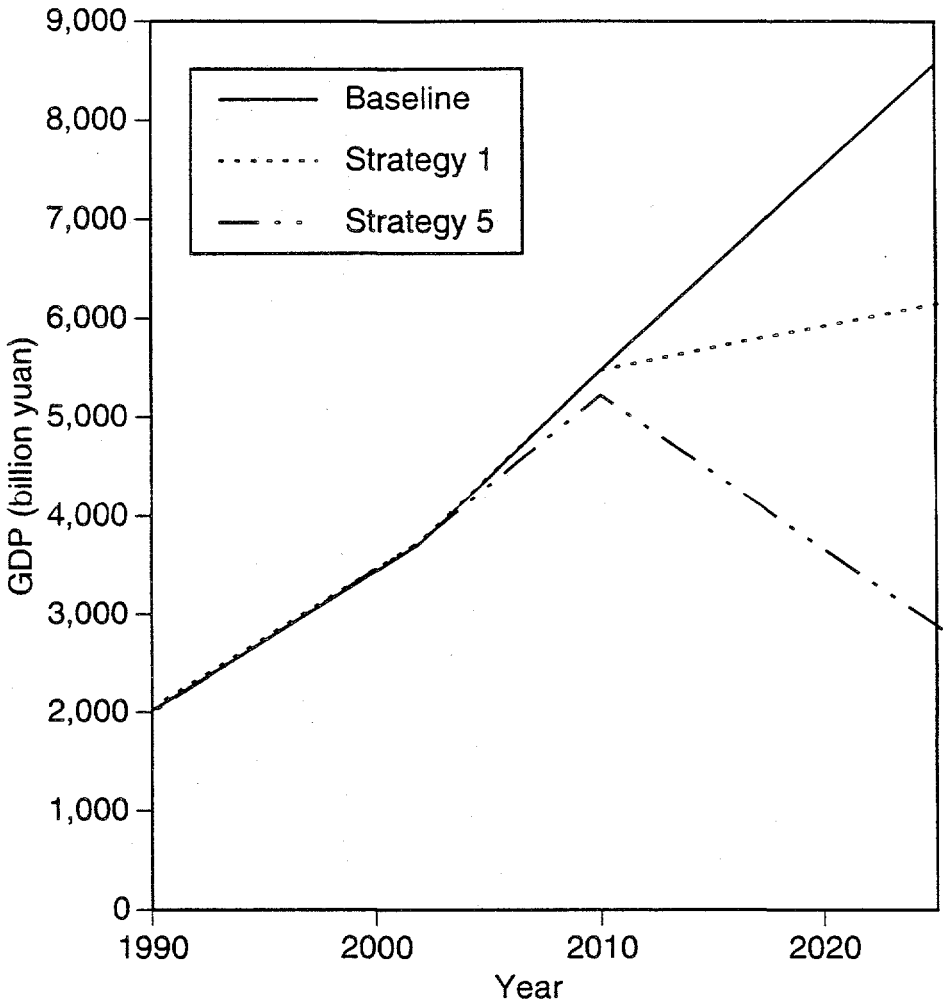

FIGURE S.2 Lower-Bound Case for China's Gross Domestic Product Projection

1 INTRODUCTION

The potential for global climate change is growing, as is the awareness of the seriousness of the problem (Intergovernmental Panel on Climate Change 1992). The emission of gases (e.g., carbon dioxide [CO_2], methane [CH_4], and chlorofluorocarbons [CFCs]) that accentuate the greenhouse effect is a major contributor. Greenhouse gases (GHGs) build up in the earth's atmosphere and trap sunlight that is usually reflected back into space from the earth's surface. The situation is global. First, every country generates GHGs. However, industrialized nations generate GHGs primarily from fossil fuel combustion, whereas developing nations emit these gases from agriculture and forest clearings. Second, these gases mix in the atmosphere, so that emissions in one location contribute to the problem worldwide.

A global problem of this magnitude requires a global solution. Natural scientists, social scientists, and policymakers have discussed the need for measures that would curtail GHG emissions (Task Force on the Comprehensive Approach to Climate Change 1991; Barrett et al. 1992). Many nations have called for an international GHG treaty, or protocol. This protocol, for example, could be patterned somewhat after the Montreal Accord, which limited the emissions of CFCs that cause holes in the ozone layer (Organization for Economic Cooperation and Development 1992).

However, scientific evidence that affirms the acceleration of greenhouse warming is not unequivocal, and mitigating GHGs is considered costly (Cline 1992; Lindzen 1992). Many nations resist making firm commitments that would lead to an accord. Moreover, no supranational institution exists that has the authority to enforce an agreement.

The result is tension among nations, especially the industrialized countries of the "North" and the developing countries of the "South." The North is alarmed at the pace at which GHG emissions are projected to rise in the South as economic development progresses. The South points out that GHGs are *stock pollutants* (i.e., they build up and are retained in the atmosphere, in many cases for decades) and notes that most of the radiative forcing caused by GHGs is the responsibility of the North's more than 100 years of industrialization (Agarwal and Narain 1991). Moreover, the developing countries state that any diversion of resources to mitigate GHGs would stifle future development. They consider it hypocrisy for the North to have been able to industrialize without such a commitment, but now call for the South to do so. Many developing countries emphasize their limitations in complying with an accord that calls for major reductions in GHGs. At the same time, many suggestions have been made to overcome this problem: (1) lower mitigation requirements for developing countries, (2) transfer technology, (3) redistribute proceeds of carbon tax, or (4) grant developing countries a large portion of emissions permits (Grubb and Sebenius 1991; Rose and Stevens 1993).

The costs of mitigating GHGs extend beyond the direct, or more obvious, expenditures for retrofitting boilers to burn cleaner fuels, constructing nuclear hydropower plants, restructuring the economy in favor of less energy-intensive goods, or installing CO_2

scrubbers. Given the interdependence of any economy, these direct expenditures stimulate important second-order, or general equilibrium, effects. These effects include ordinary price and output multipliers, input substitutions, endogenous technological changes, and investment crowding. If an economy allocates its resources optimally, any reallocation will move it away from this optimal state, thereby lowering the gross domestic product (GDP) and other major indicators of well-being.

However, several analysts state that no economy is at its optimum. In fact, strong evidence shows that many economies are wasteful of their resources, especially their energy resources (National Academy of Sciences 1991; Office of Technology Assessment 1991; Cline 1992; Ayres 1994). Numerous ways are available for implementing energy conservation measures in either a cost-saving or costless manner in both industrialized and developing countries. Also, most analysts suggest that developing countries can mitigate GHGs more readily than can industrialized nations.

This report analyzes the impacts of GHG mitigation policies on the future growth of the People's Republic of China's (hereafter referred to as China) economy over the next 30 years. The focus is primarily on reducing coal use and on examining the implications of reducing CO_2. The implications for other fossil fuels, renewable energy resources, other GHGs, and "ordinary" air pollutants are also examined.

The analysis uses a multisector Dynamic Linear Programming (DLP) model especially designed for this project. The core of the model is a 33-sector input-output (I-O) table of China's economy adapted to an optimization framework (Chenery and Clark 1959; Almon 1963; Dervis et al. 1982).

This situation is very poignant for a country like China. With a per capita GDP of about $400, China ranks among the world's 25 poorest countries. At the same time, China is a major energy user and a significant contributor to GHG emissions. The combination of its high-energy/GDP ratio for a country at its level of development and an extrapolation of its high growth rate means that China could become a leading emitter of CO_2 in 30 years. Should China decrease GHG emissions by reducing energy consumption, especially of its abundant, low-cost coal reserves? Will this strategy have a strong, negative impact on its future economic development? Highlighting the urgency of the matter is the fact that the global warming problem is a zero-sum game. Each country that does not control one ton of CO_2 shifts the burden to other countries. At the same time, the *public good* of GHG abatement means that any country can take a "free ride" on the mitigation of others.

2 ENERGY IN CHINA

The structural and institutional changes and reforms that have occurred since the 1980s are reshaping China's economy. Under the Eighth Five-Year Plan (1991-1996), China is continuing to implement reforms, to open to the outside world, and to increase production and income. Present goals include increased economic efficiency, decreased energy intensity in industry, and increased production of intermediate and final manufactured goods for trade.

China is the world's largest coal producer and consumer, the sixth largest oil producer, and the fifth largest oil consumer. China's total energy production, in terms of million tonnes standard coal equivalent (Mtce), increased 4.6% per year from 1980 to 1991. Coal and hydropower increased, but crude oil and natural gas decreased as components of energy production (Table 1). Total energy consumption, in terms of Mtce, increased 4.9% per year over the same period. In 1991, coal accounted for 76% of total energy consumption; oil, 17.0%; natural gas, 2.0%; and hydropower, 5.0% (Table 2).

From 1980 to 1991, China's GDP increased more than 10% per year, while energy consumption grew 4.9%. Energy intensity fell from 2.14 to 1.42 Mtce per $1,000 of GDP (1980 prices). The downward trend in energy intensity is attributable to (1) economic reform and growth during the last decade; (2) energy conservation policies initiated in the 1980s, which were supported by increases in energy prices; and (3) replacement of inefficient plants.

2.1 ENERGY STRUCTURE

Coal is China's most important energy source for production and consumption. China's coal consumption reached 751.1 Mtce, accounting for 76.2% of total energy consumption in 1990. However, the widespread use of coal has increased environmental pollution.

Since the mid-1980s, the composition of China's total energy consumption has been relatively stable. On the basis of 1990 data, industry accounted for the major proportion of energy consumption in China. Compared with developed countries, the level of energy use in China's households was low, especially for high-grade energy sources. Household energy consumption accounted for 16.0% of the total. In 1990, transportation and commercial consumption were about 4.6% and 4.8%, respectively. The chemical industry is the largest user of energy, followed by ferrous metals, building materials, and mining. The chemical industry accounted for 11.1% of total energy consumption in 1990 (Table 3).

China's economic structure is based heavily on its domestic supply of energy. Energy imports and exports make up a small portion of the total energy supply and demand. In 1990, China exported 58.8 Mtce, which represented about 6% of the world's energy consumption. Because China does not need to import energy on a large scale, the structure of primary energy consumption is basically the same as that of production.

TABLE 1 Total Energy Production in China, 1980-1991

		Percentage of Total Production			
Year	Total[a]	Coal	Crude Oil	Natural Gas	Hydro-power
1980	637.35	69.4	23.8	3.0	3.8
1985	855.46	72.8	20.9	2.0	4.3
1988	958.01	73.1	20.4	2.0	4.5
1989	1,016.40	74.1	19.3	2.0	4.6
1990	1,039.20	74.2	19.0	2.0	4.8
1991	1,048.40	74.1	19.2	2.0	4.7

[a] Million tonnes standard coal equivalent.

Source: *China Statistical Yearbook* (1992).

TABLE 2 Total Energy Consumption in China, 1980-1991

		Percentage of Total Production			
Year	Total[a]	Coal	Crude Oil	Natural Gas	Hydro-power
1980	602.75	72.2	20.7	3.1	4.0
1985	766.82	75.8	17.1	2.2	4.9
1988	929.97	76.2	17.0	2.1	4.7
1989	969.34	76.0	17.1	2.0	4.9
1990	987.03	76.2	16.6	2.1	5.1
1991	1,023.00	76.0	17.0	2.0	5.0

[a] Million tonnes standard coal equivalent.

Source: *China Statistical Yearbook* (1992).

TABLE 3 Total Energy Consumption in China by Sector, 1985, 1989, and 1990[a]

Sector	1985		1989		1990	
	Consumption (Mtce)	Composition (%)	Consumption (Mtce)	Composition (%)	Consumption (Mtce)	Composition (%)
Agriculture	40.45	5.3	47.42	4.9	48.52	4.9
Manufacturing	510.68	66.6	662.91	68.4	675.78	68.5
Mining	57.52	7.5	73.51	7.6	77.78	7.9
Food	23.94	3.1	32.81	3.4	32.79	3.3
Textiles	23.81	3.1	30.15	3.1	30.34	3.1
Paper	12.95	1.7	16.97	1.8	16.94	1.7
Power generation	25.12	3.3	36.57	3.8	38.67	3.9
Petroleum	10.08	1.3	16.10	1.7	17.06	1.7
Coking, gas, and coal	6.44	0.8	8.70	0.9	8.02	0.8
Chemicals	80.99	10.6	109.46	11.3	109.86	11.1
Medical	4.44	0.6	6.46	0.7	6.53	0.7
Chemical fibers	5.15	0.7	7.29	0.8	7.49	0.8
Building materials	80.20	10.5	102.06	10.5	97.22	9.8
Ferrous metal	76.40	10.0	99.80	10.3	105.55	10.7
Nonferrous metal	13.71	1.8	17.97	1.9	18.91	1.9
Machine and electricity	41.57	5.4	45.75	4.7	45.23	4.6
Other products	48.36	6.2	59.31	5.9	63.39	6.5
Construction	13.02	1.7	12.71	1.3	12.13	1.2
Transportation	37.13	4.8	44.99	4.6	45.41	4.6
Commerce	7.66	1.0	12.09	1.2	12.47	1.3
Nonmaterial products	24.70	3.2	33.39	3.4	34.73	3.5
Households	133.18	17.4	155.83	16.1	158.00	16.0
Total consumption	766.82	100.0	969.34	100.0	987.03	100.0

[a] Values may not add because of rounding.

Source: *China Statistical Yearbook* (1992).

The sectoral consumption of major fuels, including coke, is presented in Tables 4 through 8. A more detailed description of China's energy picture can be found in Bhatti et al. (1994).

2.2 ENERGY STRATEGY

Because of China's centrally planned economy, energy production is influenced significantly by economic policies and political climate. In the past, this concept resulted in inefficient use of energy. However, the Chinese government is now implementing policies that improve economic efficiency and maintain high economic growth. Now that economic reform has begun, energy development has become an important strategy.

Several measures can achieve these policy targets. Because of China's high economic growth and progress in modernization, it will need to generate substantially more electric power in the future. China plans to diversify its energy structure and, thereby, reinforce the exploration and exploitation of oil and natural gas. It also plans to develop hydropower and nuclear power.

Current levels of funds, equipment, and technology are insufficient to increase energy production. China plans to invest more in energy programs to balance energy production and consumption. In addition, the nation will encourage foreign countries to invest in energy. This plan will efficiently raise funds for energy development.

Despite diversification in energy structure, China's current official position is to continue to rely on coal as its main energy source. Inefficient transportation capacity has become the most important obstacle to the effective use of coal, and thus further development of the coal industry will highly depend on improving the transportation system. However, current plans do not include a significant commitment to reduce GHGs. This study identifies ways in which China's energy strategy may have to change, if the nation is to enter an international accord to avert global warming.

2.3 REPORT ORGANIZATION

This report is organized into four major parts. Section 3 presents the I-O table that serves as the major economic database. A discussion of the contents of the table provides the reader with important insights into the structure of China's economy.

Section 4 presents the DLP model used in this analysis. The model combines features of optimization and consistent forecasting model frameworks, which are ideally suited to analyzing one of the world's few remaining centrally planned economies. Baseline projections for target years 2000, 2010, and 2025 are presented in terms of sets of upper- and lower-bound economic and demographic parameters, which enables subsequent sensitivity analyses.

TABLE 4 Total Coal Consumption in China by Sector, 1985, 1989, and 1990[a]

Sector	1985		1989		1990	
	Consumption (Mtce)	Composition (%)	Consumption (Mtce)	Composition (%)	Consumption (Mtce)	Composition (%)
Agriculture	22.09	2.7	21.81	2.1	20.95	2.0
Manufacturing	586.13	71.8	785.65	76.0	810.91	76.8
Mining	63.16	7.7	81.29	7.9	88.22	8.4
Food	24.49	3.0	33.21	3.2	33.25	3.2
Textiles	18.68	2.3	23.70	2.3	23.59	2.2
Paper	12.51	1.5	16.44	1.6	16.40	1.6
Power generation	166.19	20.4	249.04	24.1	270.59	25.6
Petroleum	0.44	0.1	2.49	0.2	2.98	0.3
Coking, gas, and coal	32.15	3.9	45.49	4.4	45.04	4.3
Chemicals	51.90	6.4	73.93	7.1	72.41	6.9
Medical	3.70	0.5	5.52	0.5	5.48	0.5
Chemical fibers	3.15	0.4	4.38	0.4	4.48	0.4
Building materials	86.14	10.6	106.70	10.3	99.60	9.4
Ferrous metal	65.48	8.0	77.93	7.5	80.90	7.7
Nonferrous metal	6.41	0.8	7.56	0.7	8.15	0.8
Machine and electricity	27.48	3.4	30.39	2.9	29.33	2.8
Other products	24.25	2.8	27.58	2.9	30.46	2.7
Construction	5.32	0.7	4.53	0.4	4.38	0.4
Transportation	23.07	2.8	22.84	2.2	21.61	2.0
Commerce	7.38	0.9	10.24	1.0	10.58	1.0
Nonmaterial products	15.08	1.9	18.78	1.8	19.80	1.9
Households	133.18	17.4	155.83	16.1	158.00	16.0
Total consumption	814.20	100.0	1,034.27	100.0	1,055.23	100.0

[a]Values may not add because of rounding.

Source: *China Statistical Yearbook* (1992).

TABLE 5 Total Crude Oil Consumption in China by Sector, 1985, 1989, and 1990[a]

Sector	1985		1989		1990	
	Consumption (1,000 tons)	Composition (%)	Consumption (1,000 tons)	Composition (%)	Consumption (1,000 tons)	Composition (%)
Agriculture	8	0.0	8	0.0	2	0.0
Manufacturing	93,899	98.7	115,082	99.1	116,538	99.1
Mining	7,524	7.9	9,954	8.6	10,680	9.1
Food	19	0.0	25	0.0	18	0.0
Textiles	59	0.1	20	0.0	24	0.0
Paper	27	0.0	14	0.0	12	0.0
Power generation	3,408	3.6	1,858	1.6	1,440	1.2
Petroleum	70,196	73.8	87,616	75.5	86,038	73.1
Coking, gas, and coal	0	0.0	0	0.0	0	0.0
Chemicals	9,886	10.4	12,421	10.7	14,453	12.3
Medical	13	0.0	5	0.0	5	0.0
Chemical fibers	2,076	2.2	2,690	2.3	3,448	2.9
Building materials	160	0.2	231	0.2	189	0.2
Ferrous metal	202	0.2	168	0.1	165	0.1
Nonferrous metal	196	0.2	15	0.0	1	0.0
Machine and electricity	84	0.1	47	0.0	52	0.0
Other products	49	0.1	18	0.0	13	0.0
Construction	740	0.8	508	0.4	552	0.5
Transportation	443	0.5	455	0.4	521	0.4
Commerce	1	0.0	6	0.0	3	0.0
Nonmaterial products	4	0.0	12	0.0	6	0.0
Households	0	0.0	0	0.0	0	0.0
Total consumption	95,095	100.0	116,071	100.0	117,622	100.0

[a]Values may not add because of rounding.

Source: *China Statistical Yearbook* (1992).

TABLE 6 Total Natural Gas Consumption in China by Sector, 1985, 1989, and 1990[a]

Sector	1985		1989		1990	
	Consumption (million m^3)	Composition (%)	Consumption (million m^3)	Composition (%)	Consumption (million m^3)	Composition (%)
Agriculture	0	0.0	0	0.0	0	0.0
Manufacturing	10,960	84.8	11,780	78.4	12,020	78.8
Mining	3,710	28.7	3,960	26.3	3,780	24.8
Food	30	0.2	30	0.2	30	0.2
Textiles	40	0.3	20	0.1	20	0.1
Paper	30	0.2	20	0.1	20	0.1
Power generation	580	4.5	360	2.4	280	1.8
Petroleum	530	4.1	870	5.8	990	6.5
Coking, gas, and coal	0	0.0	10	0.1	10	0.1
Chemicals	4,140	32.0	4,730	31.5	4,850	31.8
Medical	40	0.3	30	0.2	30	0.2
Chemical fibers	180	1.4	330	2.2	350	2.3
Building materials	180	1.4	240	1.6	260	1.7
Ferrous metal	520	4.0	730	4.9	950	6.2
Nonferrous metal	0	0.0	40	0.3	30	0.2
Machine and electricity	590	4.6	350	2.3	370	2.4
Other products	390	3.0	60	0.4	50	0.3
Construction	1,410	10.9	1,400	9.3	1,060	7.0
Transportation	80	0.6	70	0.5	190	1.2
Commerce	0	0.0	0	0.0	0	0.0
Nonmaterial products	50	0.4	100	0.7	120	0.8
Households	430	3.3	1,680	11.2	1,860	12.2
Total consumption	12,930	100.0	15,030	100.0	15,250	100.0

[a]Values may not add because of rounding.

Source: *China Statistical Yearbook* (1992).

TABLE 7 Total Electricity Consumption in China by Sector, 1985, 1989, and 1990[a]

Sector	1985		1989		1990	
	Consumption (TWh)	Composition (%)	Consumption (TWh)	Composition (%)	Consumption (TWh)	Composition (%)
Agriculture	31.74	7.7	41.05	7.0	42.68	6.9
Manufacturing	328.34	79.7	464.65	79.2	487.33	78.2
Mining	43.29	10.5	64.47	11.0	67.51	10.8
Food	10.86	2.6	18.22	3.1	18.23	2.9
Textiles	18.57	4.5	24.34	4.1	24.66	4.0
Paper	8.09	2.0	11.44	2.0	11.98	1.9
Power generation	58.81	14.3	84.65	14.4	88.77	14.2
Petroleum	4.02	1.0	6.44	1.1	7.15	1.1
Coking, gas, and coal	0.86	0.2	1.39	0.2	1.59	0.3
Chemicals	51.35	12.5	70.71	12.1	73.51	11.8
Medical	2.32	0.6	3.88	0.7	4.23	0.7
Chemical fibers	3.34	0.8	5.50	0.9	5.92	1.0
Building materials	22.16	5.4	32.70	5.6	33.08	5.3
Ferrous metal	36.32	8.8	51.58	8.8	55.57	8.9
Nonferrous metal	17.39	4.2	25.51	4.3	26.99	4.3
Machine and electricity	32.03	7.8	36.49	6.2	36.60	5.9
Other products	18.93	4.6	27.33	4.7	31.54	5.1
Construction	7.12	1.7	6.52	1.1	6.50	1.0
Transportation	6.34	1.5	9.87	1.7	10.59	1.7
Commerce	3.80	0.9	6.87	1.2	7.62	1.2
Nonmaterial products	12.17	3.0	18.05	3.1	20.24	3.2
Households	22.25	5.4	39.52	6.7	48.08	7.7
Total consumption	411.76	100.0	586.53	100.0	623.00	100.0

[a]Values may not add because of rounding.

Source: *China Statistical Yearbook* (1992).

TABLE 8 Total Coke Consumption in China by Sector, 1985, 1989, and 1990[a]

Sector	1985		1989		1990	
	Consumption (1,000 tonnes)	Composition (%)	Consumption (1,000 tonnes)	Composition (%)	Consumption (1,000 tonnes)	Composition (%)
Agriculture	208	0.4	535	0.8	601	0.9
Manufacturing	46,227	98.6	62,571	98.3	68,088	98.5
Mining	717	1.5	1,028	1.6	1,041	1.5
Food	123	0.3	209	0.3	226	0.3
Textiles	71	0.2	116	0.2	107	0.2
Paper	9	0.0	27	0.0	25	0.0
Power generation	31	0.1	26	0.0	12	0.0
Petroleum	41	0.1	22	0.0	11	0.0
Coking, gas, and coal	141	0.3	493	0.8	766	1.1
Chemicals	7,219	15.4	8,926	14.0	9,462	13.7
Medical	3	0.0	6	0.0	31	0.0
Chemical fibers	100	0.2	176	0.3	146	0.2
Building materials	935	2.0	1,768	2.8	1,822	2.6
Ferrous metal	32,372	69.0	43,406	68.2	48,097	69.6
Nonferrous metal	731	1.6	1,156	1.8	1,120	1.6
Machine and electricity	2,601	5.5	3,691	5.8	3,754	5.4
Other products	1,133	2.4	1,521	2.4	1,468	2.1
Construction	78	0.2	91	0.1	52	0.1
Transportation	57	0.1	46	0.1	41	0.1
Commerce	27	0.1	87	0.1	77	0.1
Nonmaterial products	20	0.0	41	0.1	19	0.0
Households	230	0.5	313	0.5	269	0.4
Total consumption	46,897	100.0	63,684	100.0	69,147	100.0

[a]Values may not add because of rounding.

Source: *China Statistical Yearbook* (1992).

Section 5 presents the major technical aspects of the model. These aspects relate to energy reserves, energy technology, and GHG emissions. Again, a set of upper- and lower-bound parameters is identified for subsequent simulation and sensitivity analyses.

Section 6 uses the model presented in Section 4, together with the economic and technical data presented in Sections 3 and 5, respectively, to predict the impact of a CO_2 mitigation requirement on China's economic growth for each milestone year. The policy requirement calls for stabilizing emissions to 80% of year 2000 baseline levels, though with a phased-in compliance schedule. Appendixes A-D present supporting data.

The results are interesting and, in most cases, robust; i.e., they are not very sensitive to the choice of economic or technical parameters. The required mitigation can be obtained by a varied set of strategies that have few adverse effects on economic growth in the year 2000 and even in 2010. However, the number of options capable of attaining the mitigation target alone, or even together, is reduced dramatically by 2025, and significantly negative impacts on economic growth set in.

3 CHINESE INPUT-OUTPUT TABLE

3.1 INTRODUCTION TO INPUT-OUTPUT ANALYSIS

Every national economy has some degree of interdependence. Each production unit (e.g., private company or state-owned enterprise) relies on outside input into its production process. As a result, a single business enterprise contributes to a nation's economy far beyond its own production because it demands a succession of upstream inputs from its suppliers and downstream deliveries to its customers. The sum of these many rounds of derived demands and commodity allocations can be a large multiple of the value of the initial production. Hence, each industry generates *multiplier*, or development linkage, effects.

Input-output analysis is one of the most widely used tools in economic analysis. Developed by Nobel laureate Wassily Leontief (1986), I-O analysis has been applied in nearly every country to examine a range of topics. Such topics include the effects of economic development projects, international trade policies, technological changes, and environmental regulations. Input-output analysis has been used most frequently in the centrally planned economies of China, the former Soviet Union, and the countries of Eastern Europe, where a substitute provided the detailed information typically offered by the marketplace. In other contexts, I-O analysis has been widely used in formulating national policies and ensuring consistency between them and the decisions of individual businesses and consumers (e.g., "indicative planning" in France).

The basic I-O model is an operational, static, linear model of purchases and sales between sectors of the economy, based on the technical relations of production (e.g., Miller and Blair 1985). Many of the limitations of the basic model have been overcome by progress toward a more general model, which is generally still operational. This I-O model is a dynamic, nonlinear model of purchases and sales of commodities between sectors and institutions of an economy or economies based on the technical relationship of production and other important quantifiable variables.

To some, the general I-O definition may no longer seem to be I-O, but it does include the critical essence of the formulation. There is nothing essential about static or linear characteristics. Instead, the fundamental contributions of I-O analysis stem from such attributes as operational, model, double-entry accounting of economic interdependence; a manageable grouping of decision units; general equilibrium comprehensiveness (even across space); and the realities of technological limits. In this light, the current state of the art of I-O economics represents a formidable modeling option with a wide range of applications (Rose and Miernyk 1989).

An I-O table provides an explicit set of economic accounts for a given geographic area. This accounting system is based on a fundamental identity: that the total production of any industry, or sector, equals the amount of its products used by other businesses to produce their output plus the amount demanded for final use by consumers, investment, government, and exporters.

Figure 1 presents a schematic of the major components of an I-O table. Quadrant I corresponds to the final use of goods and services, or the net output of the economy. Quadrant II contains interindustry transactions that reflect the technological needs or purchases of each industry. It represents the processing of intermediate goods, i.e., goods produced for industry rather than for consumers (e.g., government expenditure, investment, or export)[1] needs. Quadrant III corresponds to returns to primary factors or value added (e.g., wages, salaries, profits, or taxes) that emanate from intermediate sectors. Quadrant IV represents value added associated with final demand activities (e.g., domestic help and government payrolls).

At any given time, the I-O table provides an excellent, compact snapshot of an economy. It portrays the economy's diversity, its leading producing and consuming sectors, and the role of imports and exports. It can be appended with a set of environmental accounts that link economic activity and pollution. Measures taken to mitigate this pollution can be incorporated into the table as input substitutions, energy productivity improvements, process changes, and changes in the product mix.

In mathematical terms, the basic I-O balance equation can be written compactly in matrix notation:

$$\boldsymbol{X} = \mathbf{A}\boldsymbol{X} + \boldsymbol{Y}, \tag{1}$$

where

$\boldsymbol{X}$ = total gross output of sector i;

$\mathbf{A}$ = matrix of technical coefficients (each element represents the direct inputs of good i needed to produce \$1 of good j); and

$\boldsymbol{Y}$ = autonomous final demand for the products of sector i.

The vector of annual gross output needed to deliver the exogenously given set of final demands can be solved as follows:

$$\boldsymbol{X} = (\mathbf{I} - \mathbf{A})^{-1}\,\boldsymbol{Y}. \tag{2}$$

The $(\mathbf{I} - \mathbf{A})^{-1}$ matrix is known as the Leontief Inverse. Each element represents the total direct and indirect effect on the gross output of sector i, corresponding to a one-unit change in final demand for good j. The sum of elements in a given column is known as the output multiplier for that sector. In this way, the I-O model captures the less apparent, but often sizable, multiplier effects of a change in economic conditions (e.g., major capital investment spending).

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[1] In China's I-O table, these categories are institutional consumption and fixed capital formation, respectively. Exports are shown as the net of imports.

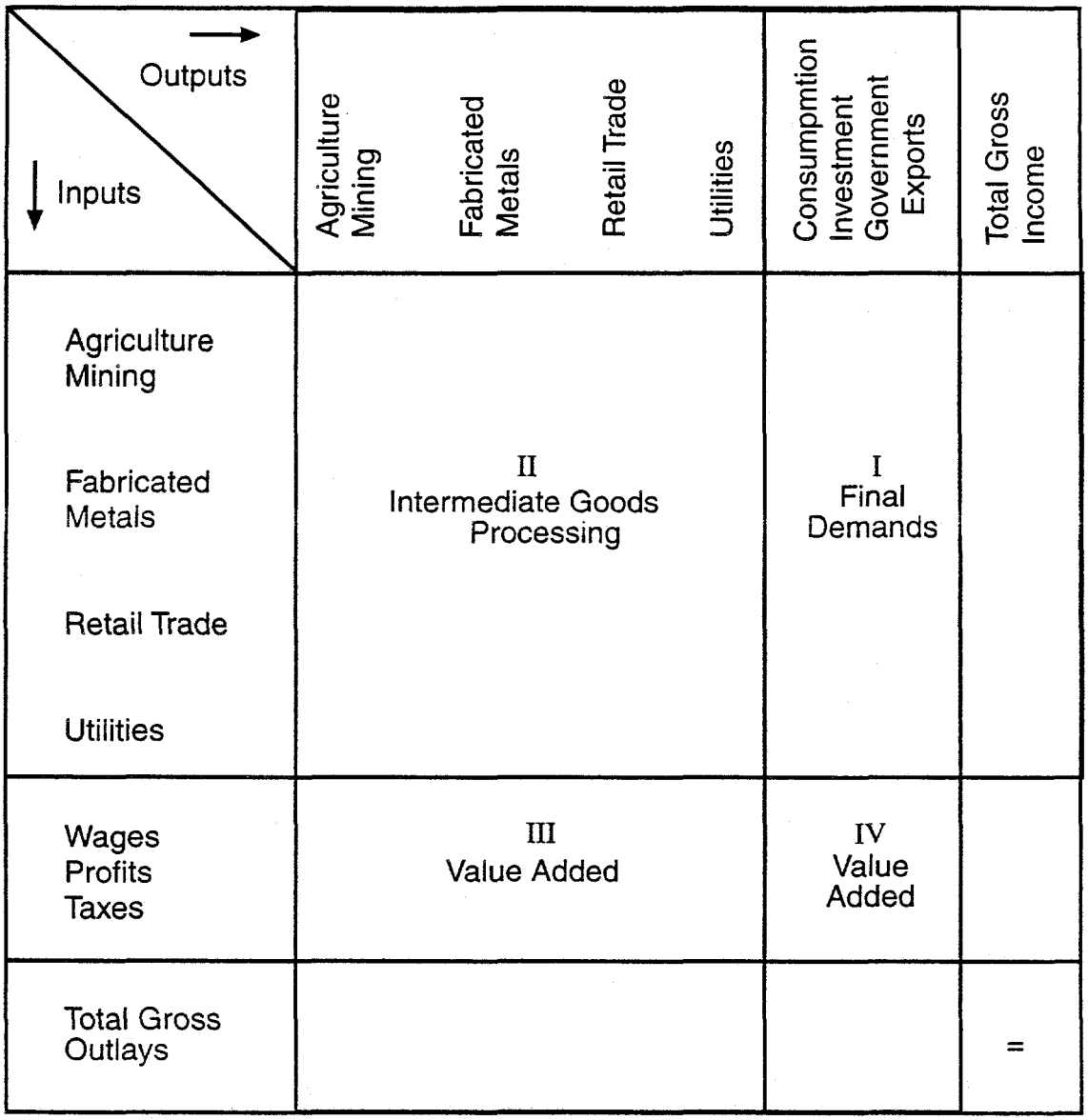

FIGURE 1 Schematic of the Major Components of an Input-Output Table

3.2 CHINESE 1987 INPUT-OUTPUT TABLE

3.2.1 Basic Features

Before the 1987 I-O table was created, China based its economic accounts only on the material production system (MPS). Tables based on this system do not include rows for the service industries in the transactions quadrant, although these purchases are included in the final consumption column. For example, in the MPS, household consumption includes both goods purchased directly by households and the imputed value of goods produced by

households for their own use. In the interindustry transactions quadrant (II), intermediate consumption includes only material products consumed by material sectors.

Because firms that produce services outside the material product sector are increasingly important in China's economy, the 1987 I-O table includes them in the interindustry transactions quadrant. The 1987 I-O table was constructed by using the System of National Accounts (SNA) definitions. Most market-oriented or mixed economies use this system (with some changes). Some changes involve dividing the sectors in the interindustry transactions quadrant into material and nonmaterial products. Others involve dividing the total accumulation sector, which is composed of fixed capital formation and changes in stock in the SNA, into both material and nonmaterial products. Therefore, the table can be considered to be a qualitative hybrid of both MPS and SNA. Essentially, the latest Chinese I-O table contains all of the information in the SNA and further distinguishes between material and nonmaterial production.

3.2.2 Summary Description of the 1987 Input-Output Table

3.2.2.1 Total Supply and Demand

In 1987, the total supply of goods and services in China was 2,745.16 billion yuan (Table 9). This total consisted of gross output of 2,566.28 billion yuan (93.5% of the total) and imports of 178.88 billion yuan (6.5%). The total demand was also 2,566.28 billion yuan: 2,558.01 billion yuan of domestic demand (94.3% of the total) and exports of 157.15 billion yuan (5.7%). The proportion of foreign trade in China's economy was relatively small compared with other developing countries. Intermediate demand was about 10 percentage points higher than domestic final demand in total domestic demand.

3.2.2.2 Interindustry Transactions and Final Demand

The manufacturing sector supplied the highest proportion of output to intermediate and final demand, including its major components: consumption (both households and institutional [government]) and capital accumulation (Table 10). In 1987, gross output in manufacturing was 1,381.2 billion yuan, which made up 57.8% of the total gross output. The sector contributed 69.2% of interindustry demand and 37.4% of total consumption. Construction supplied the highest proportion of investment in the economy (55.6% of total accumulation).

The large proportion of construction in total accumulation reflects the fact that China's economic growth in the 1980s was largely due to retrofitting existing heavy industry and developing light manufacturing industry, which induced large-scale construction work. The nonmaterial product sector output was 303 billion yuan (12.0% of the total gross output). The sector also contributed a large proportion (28.5%) of total consumption. In the

TABLE 9 Composition of Total Supply and Demand in China, 1987

Item	Amount (billions of yuan)	Composition (%)
Supply		
Total gross output	2,566.28	93.5
Total intermediate output	1,428.88	51.9
Value added	1,142.41	41.6
Labor income	568.12	20.7
Profit and tax	336.19	12.2
Depreciation	120.15	4.4
Other factors	117.94	4.3
Imports	178.88	6.5
Total	2,745.16	100.0
Demand		
Total domestic demand	2,588.01	94.3
Domestic final demand	1,164.60	42.4
Intermediate demand	1,423.41	51.9
Exports	157.15	5.7
Total	2,745.16	100.0

Source: *China Statistical Yearbook* (1988).

manufacturing sector, the food, chemical, and textile industries constituted the three largest proportions of total gross output: 7.2, 7.1, and 6.5%, respectively. The chemical industry supplied the highest proportion of interindustry demand of any manufacturing sector. Machinery supplied the second largest proportion of total accumulation, preceded by construction. The food industry supplied the highest proportion of consumption (15.6% of total consumption).

3.2.2.3 Material Consumption and Value Added

Material consumption consists of both intermediate inputs and depreciation (Table 11). The proportion of material consumption relative to total output of each of these components was obtained by partitioning the 1987 I-O table into *building blocks*. Construction supplied the highest proportion of material demand — 73.5% of total output; agriculture had the lowest — 33.7%. Agriculture showed the highest proportion of labor cost (57.6% of total output in the sector), reflecting the high labor intensity of China's agriculture.

The proportion of profits and taxes in commerce was very low (1.0% of total commercial output) because China's government significantly restricted commerce, and

TABLE 10 Percentage of Chinese Output Structure by Sector, 1987

Sector	Total Output	Interindustry Demand	Total Consumption	Total Capital Accumulation
Agriculture	18.2	15.3	30.0	4.9
Mining	3.3	5.4	0.7	0.0
Manufacturing	57.8	69.2	37.4	37.3
Food	7.2	4.2	15.6	1.1
Textiles	6.5	7.4	5.2	1.3
Chemicals	7.1	12.0	2.8	1.1
Primary metals	4.2	8.6	0.0	0.3
Machinery	5.5	5.3	1.6	16.7
Others	20.0	26.3	11.4	15.9
Construction	9.5	0.0	0.0	55.6
Transportation and communication	2.7	3.1	1.7	0.9
Commerce (trade)	4.0	6.0	2.4	2.2
Nonmaterial production	12.0	6.4	28.5	0.0
Total (%)	100.0	100.0	100.0	100.0
Total cost (billions of yuan)	2,566.3	1,423.9	727.3	437.3

Source: *China Statistical Yearbook* (1988).

privatization was not yet effective. In the manufacturing sector, most individual industries showed very low labor costs, especially among light industries such as food, textiles, and paper. This fact reflects the Chinese economy's dependence on low wages to fuel its international competitiveness. Low labor costs are also reflected in the country's increasing exports of light industrial products in the world market since the mid-1980s.

3.2.3 1990 Input-Output Transactions Table

The basis of the simulations in this report is a 1990 update of China's 1987 I-O table (Table 12). In the absence of detailed data on sectoral gross output and final demand growth, a proportional extrapolation of the 1987 table was performed, based on GDP growth.[2]

Another major modification of the 1987 I-O table improved the accuracy of the simulations to be performed below. In China's 1987 I-O table, the total direct requirements

[2] Limited data were available, but to use these data would have required rebalancing all the technical coefficients in the table. It was determined that any errors from such a procedure would be greater than holding the coefficients constant.

TABLE 11 Percentage of Material Consumption and Value Added to Total Output, 1987[a]

Sector	Material Consumption		Value Added		
	Intermediate	Depreciation	Labor Cost	Profit and Tax	Other
Manufacturing					
Agriculture	31.5	2.2	57.6	6.1	2.7
Food	73.7	1.9	4.0	16.4	4.0
Textiles	74.4	2.8	7.2	12.5	3.2
Chemicals	67.6	4.8	5.9	18.0	3.6
Machinery	64.8	4.6	10.3	16.6	3.7
Total	67.9	4.9	8.2	16.4	2.0
Construction	71.4	2.1	20.3	3.9	2.3
Transportation and communication	37.0	15.4	19.5	22.0	6.2
Commerce	46.3	5.4	38.7	1.0	8.6
Nonmaterial production	30.2	7.0	27.4	16.0	19.5
Total	100.0	100.0	100.0	100.0	100.0

[a] Values may not add because of rounding.

Source: *China Statistical Yearbook* (1988).

were composed of both goods produced in China and imports. (A separate import column is entered into final demand, but the sectoral use of imports is not as apparent. In addition, the impact computations are more complex in this format than in the modified one.) By calculating a pure *intranational* table, domestically produced goods were separated from imports. Thus, Table 12 shows a set of 33 sectors plus a distinct quadrant in the middle of the table that represents the purchases of imported goods (note that China imports such goods as metal ores, sawmills, and chemicals but is self-sufficient in goods such as agriculture and coal mining).

To understand the contents of the I-O table, it is important to understand certain conventions. The sectors listed in the left margin (row labels) represent selling sectors, and the sectors listed at the top represent purchasing sectors. (Because of space restrictions, sector numbers only appear along the top margin, but the reader should keep in mind that the sectors are in the same order in both the rows and the columns.) Hence, along any row, the table displays the sales of the sector to the left of each intermediate sector listed along the top margin, plus sales to final demand. For example, sector 2 (coal mining) sells 37 million yuan to sector 1 (agriculture). However, sector 2's largest customer is sector 11 (electricity services), to which it sells 11,450 million yuan. Most sectors use coal, often for processed steam or heat, which is the reason this report examines an electrification strategy

TABLE 12 1990 Chinese Input-Output Table (in million yuan) (pure intranational table, imports appear in bottom rows)

	Purchasers									
Sector	1	2	3	4	5	6	7	8	9	10
1 Agriculture	113,745	454	2	134	1,578	135,128	45,465	7,395	1,264	10,626
2 Coal Mining	375	383	32	85	224	498	403	39	357	577
3 Crude petroleum and natural gas productio	0	2	150	0	7	6	0	0	0	21
4 Metal ore mining	0	0	0	1,284	0	0	0	0	0	0
5 Other mining	233	573	68	71	595	381	146	46	2,150	521
6 Food Manufacturing	29,953	59	15	10	60	36,882	250	2,346	64	255
7 Manufacture of textiles	1,703	332	157	118	450	700	102,461	24,652	1,988	9,128
8 Manufacture of wearing apparel, leather and	296	293	129	93	234	162	386	6,018	426	358
9 Sawmills and manufacture of furniture	1,108	294	100	57	106	162	112	98	4,628	667
10 Manufacture of paper, cultural and educatio	595	286	86	48	195	4,844	678	642	598	24,189
11 Electricity, steam and hot water production	3,185	2,606	766	936	1,677	1,138	1,697	148	716	1,529
12 Petroleum refineries	3,571	589	494	346	908	341	347	79	558	415
13 Coking, manufacture of gas and coal produ	23	0	2	0	3	16	22	2	6	49
14 Chemical industries	49,002	1,786	724	853	1,499	3,544	19,964	3,079	2,674	7,520
15 Manufacture of building materials and other	517	736	537	169	517	2,736	149	40	280	453
16 Primary metal manufacturing	253	995	955	358	352	401	180	84	1,842	2,822
17 Manufacture of metal products	1,366	1,366	222	243	528	1,084	293	566	1,568	724
18 Manufacture of machinery	2,176	1,925	2,328	525	869	432	1,495	101	449	814
19 Manufacture of transport equipment	534	111	192	90	206	38	38	12	67	42
20 Manufacture of electric machinery and instr	202	852	392	179	258	180	284	56	203	299
21 Manufacture of electronics and communicat	7	44	47	10	18	8	17	4	10	109
22 Manufacture of instruments, meters and oth	21	75	218	18	40	26	31	2	21	39
23 Maintenance and repair of machinery and e	243	36	7	13	29	20	21	5	10	16
24 Industries not elsewhere classified	727	196	22	94	100	201	235	1,188	196	542
25 Construction	0	0	0	0	0	0	0	0	0	0
26 Freight transport and Communication	7,608	332	222	163	283	13,906	3,583	678	471	1,471
27 Commerce	6,237	1,049	489	394	840	12,896	15,080	4,511	1,544	4,848
28 Restaurants	0	0	0	0	0	0	0	0	0	0
29 Passenger transport	924	93	38	30	85	222	264	106	62	191
30 Public utilities and services to household	2,809	135	53	38	113	288	343	144	84	253
31 Cultural, education health and scientific res	4,758	407	238	118	242	2,098	680	255	181	845
32 Finance and insurance	4,929	424	178	219	241	4,127	5,166	1,500	620	1,608
33 Public administration	0	0	0	0	0	0	0	0	0	0
Total Intermediate	237,099	16,434	8,861	6,699	12,258	222,466	199,790	53,797	23,035	70,730
Imports Sector										
4 Metal ore mining	0	0	0	76	0	0	0	0	0	0
5 Other mining	3	7	1	1	7	5	2	1	27	6
9 Sawmills and manufacture of furniture	52	14	5	3	5	8	5	5	219	31
11 Electricity, steam and hot water production	27	22	6	8	14	10	14	1	6	13
14 Chemical industries	3,854	140	57	67	118	279	1,570	242	210	591
16 Primary metal manufacturing	34	134	129	48	48	54	24	11	248	380
18 Manufacture of machinery	949	839	1,015	229	379	188	652	44	196	268
19 Manufacture of transport equipment	392	81	141	66	151	28	28	9	49	30
20 Manufacture of electric machinery and instr	32	135	62	28	41	29	45	9	32	47
21 Manufacture of electronics and communicat	4	24	25	5	10	5	9	2	6	59
22 Manufacture of instruments, meters and oth	18	65	189	16	34	22	26	2	18	34
24 Industries not elsewhere classified	72	19	2	9	10	20	23	117	19	53
27 Commerce	837	141	66	53	113	1,731	2,024	606	207	851
31 Cultural, education health and scientific res	97	8	5	2	5	43	14	5	4	17
Total Imports	6,369	1,630	1,702	612	934	2,420	4,437	1,053	1,241	2,182
Primary Inputs										
Total Depreciation of Fixed Assets	16,701	8,501	5,952	1,756	3,351	6,011	7,549	1,458	1,151	3,222
Labor Income	433,209	14,823	1,036	2,242	5,360	11,012	17,950	7,326	3,923	9,704
Welfare Fund	11,729	1,136	99	191	495	1,088	1,822	704	373	910
Profits&Taxes	46,868	202	7,744	3,014	9,969	49,865	34,179	9,153	4,519	17,809
Others	20,508	2,370	18,422	609	2,927	12,280	8,866	3,461	1,375	5,161
Total Primary Input	529,015	27,032	33,253	7,812	22,102	80,257	70,367	22,101	11,340	36,807
Error	(0)	(0)	0	0	(0)	(0)	1	(0)	(0)	(0)
Total Inputs	772,483	45,096	43,817	15,122	35,294	305,143	274,594	76,950	35,615	109,719

(estimated from 1987 table with Nominal Growth)

TABLE 12 (Cont.)

	Purchasers													
Sector	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	23	4	9	20,476	1,177	198	188	382	80	417	10	9	75	400
2	11,450	13	4,150	3,680	5,274	4,656	311	692	147	223	40	20	97	51
3	2,477	27,298	361	5,585	137	538	51	100	11	9	4	0	4	1
4	0	0	0	516	0	12,857	757	306	13	0	0	0	0	0
5	442	15	58	4,060	3,087	606	348	447	91	112	38	17	65	37
6	55	6	35	8,847	188	189	120	221	56	183	34	18	14	22
7	219	26	58	10,613	2,125	655	2,548	1,938	508	525	189	75	427	1,599
8	141	28	72	933	654	682	381	1,062	244	262	112	54	136	240
9	84	13	28	445	687	277	610	2,072	380	540	129	98	140	177
10	224	21	52	4,349	7,830	517	1,736	1,888	232	2,400	631	156	133	448
11	1,175	237	430	9,659	8,031	8,295	1,657	3,406	588	978	345	104	414	219
12	3,827	740	317	4,870	4,409	2,773	672	1,986	519	848	156	47	344	124
13	33	1	241	105	447	5,176	327	572	52	69	9	2	28	14
14	513	720	250	80,619	7,917	3,437	4,151	10,573	4,633	9,954	3,887	616	1,122	1,618
15	349	156	105	2,720	9,689	4,726	1,172	2,528	795	2,573	1,288	218	424	130
16	347	84	219	2,627	4,706	42,844	20,072	26,220	5,671	15,595	1,656	823	1,558	956
17	262	53	113	2,736	2,226	1,477	4,474	5,619	906	2,640	811	287	518	306
18	666	157	208	2,852	2,844	5,287	1,531	32,631	4,997	3,627	536	457	1,634	224
19	98	16	30	193	337	456	188	1,243	8,588	90	37	17	1,665	143
20	788	47	91	1,079	1,245	1,496	752	10,687	1,725	10,826	2,500	550	875	142
21	58	8	8	90	63	126	87	874	257	512	17,121	646	71	50
22	157	62	30	429	145	339	101	857	180	558	211	663	111	61
23	18	7	12	67	72	106	52	92	20	23	13	3	55	4
24	153	5	30	498	747	776	812	796	162	473	194	77	79	2,110
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0
26	1,262	2,084	439	4,674	2,206	3,194	1,125	2,871	890	1,122	376	102	280	231
27	1,233	1,464	328	12,219	4,055	5,858	2,922	8,367	2,347	4,072	2,705	404	732	897
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0
29	96	18	10	424	254	124	146	546	118	177	111	46	53	43
30	132	23	13	578	329	182	185	709	152	237	148	62	69	55
31	245	62	42	1,730	920	465	448	1,542	347	566	293	111	166	142
32	129	91	50	4,536	2,353	2,208	1,401	4,753	1,245	2,121	1,527	335	332	345
33	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	26,658	33,461	7,788	192,208	74,154	110,518	49,323	125,981	35,954	61,729	35,112	6,018	11,620	10,788
4	0	0	0	30	0	759	45	18	1	0	0	0	0	0
5	5	0	1	50	38	8	4	6	1	1	0	0	1	0
9	4	1	1	21	32	13	29	98	18	25	6	5	7	8
11	10	2	4	81	67	69	14	29	5	8	3	1	3	2
14	40	57	20	6,341	623	270	326	832	364	783	306	48	88	127
16	47	11	29	354	634	5,774	2,705	3,534	764	2,102	223	111	210	129
18	290	69	91	1,243	1,240	2,305	667	14,224	2,178	1,581	234	199	712	98
19	72	12	22	142	247	334	138	911	6,294	66	27	13	1,220	105
20	125	7	14	171	197	237	119	1,694	273	1,716	396	87	139	22
21	31	5	3	48	34	68	47	471	138	276	9,228	348	38	27
22	137	54	26	372	126	294	87	744	156	484	183	576	96	53
24	15	1	3	49	73	76	80	78	16	47	19	8	8	208
27	166	196	44	1,640	544	786	392	1,123	315	546	363	54	98	120
31	5	1	1	35	19	9	9	31	7	12	6	2	3	3
	947	415	259	10,578	3,875	11,003	4,663	23,793	10,531	7,648	10,996	1,452	2,624	903
	7,903	2,159	675	14,451	7,194	9,844	2,293	10,582	2,840	2,691	2,100	570	1,448	640
	3,151	665	790	16,342	17,797	8,394	7,623	21,741	4,643	6,309	3,537	1,503	3,425	1,704
	337	60	75	1,558	1,672	736	724	2,081	398	614	334	147	330	150
	23,483	22,185	32	54,042	22,119	33,710	12,236	38,356	9,587	16,077	10,084	2,738	2,748	2,384
	2,667	1,250	377	10,867	5,401	5,294	3,115	8,532	2,322	3,385	2,097	598	1,076	737
	37,541	26,319	1,949	97,260	54,183	57,978	25,991	81,292	19,791	29,076	18,153	5,555	9,027	5,615
	(0)	0	(1)	(0)	(0)	(0)	(0)	0	0	(0)	(0)	0	0	0
	65,146	60,196	9,995	300,046	132,211	179,499	79,976	231,066	66,277	98,453	64,260	13,025	23,270	17,305

TABLE 12 (Cont.)

	Purchasers											
Sector	25	26	27	28	29	30	31	32	33	Total Intermediate	Final Demand	Total Output
1	1,953	12	2,892	12,063	0	1,050	2,665	1	160	360,040	412,443	772,483
2	429	696	436	76	134	617	860	11	235	37,271	7,825	45,096
3	5	77	8	4	0	15	57	0	0	36,930	6,886	43,817
4	0	0	0	0	0	0	31	0	0	15,764	(642)	15,122
5	19,125	187	427	63	40	372	878	8	169	35,478	(184)	35,294
6	352	47	1,776	15,275	125	1,463	658	3	78	99,660	205,483	305,143
7	2,138	692	5,129	201	273	1,013	1,989	54	250	174,932	99,662	274,594
8	1,807	538	1,015	66	85	327	666	28	303	18,231	58,719	76,950
9	9,614	440	1,801	117	100	809	1,174	55	151	27,274	8,341	35,615
10	1,323	872	6,455	158	153	843	16,177	327	3,323	82,410	27,310	109,719
11	1,862	1,056	1,406	310	135	1,266	2,816	19	293	59,099	6,046	65,146
12	6,264	13,339	1,487	132	2,661	1,933	1,688	39	1,488	58,309	1,888	60,196
13	84	12	56	49	1	40	129	5	32	7,610	2,386	9,996
14	10,309	3,490	2,456	156	426	2,089	21,339	44	195	261,160	38,886	300,046
15	90,592	432	2,817	289	95	2,691	3,472	70	379	133,846	(1,635)	132,211
16	43,591	525	877	16	84	602	1,031	4	57	178,406	1,093	179,499
17	24,274	538	1,899	174	104	1,521	1,744	76	370	61,084	18,893	79,976
18	12,644	659	847	70	123	754	2,212	34	1,284	87,195	143,871	231,066
19	1,715	2,982	653	8	1,262	489	529	37	515	22,623	43,653	66,277
20	10,429	511	810	137	104	667	1,667	22	112	50,166	48,287	98,453
21	280	255	302	5	57	90	1,807	17	114	23,170	41,090	64,260
22	790	99	68	0	26	49	1,472	3	7	6,907	6,118	13,025
23	144	169	266	10	33	78	207	6	88	1,944	21,327	23,270
24	2,478	610	1,810	25	19	1,089	603	11	186	17,243	62	17,305
25	0	0	0	0	0	0	0	0	0	0	401,558	401,558
26	9,718	788	968	998	227	1,146	5,103	767	2,670	71,958	40,727	112,685
27	13,359	1,985	3,245	2,857	361	1,515	5,514	77	859	125,265	45,174	170,439
28	0	0	0	0	0	0	0	0	0	0	46,755	46,755
29	299	220	931	6	53	267	3,393	212	2,213	11,775	13,444	25,219
30	384	328	1,326	7	83	336	8,265	935	2,987	21,783	73,002	94,785
31	759	5,864	2,320	56	1,671	1,230	7,575	748	2,696	39,821	152,787	192,608
32	1,243	598	32,178	85	76	737	548	975	100	76,977	1,644	78,621
33	0	0	0	0	0	0	0	0	0	0	62,583	62,583
	267,964	38,021	76,663	33,414	8,513	25,100	96,270	4,590	21,314	2,204,332	2,035,483	4,239,815
4	0	0	0	0	0	0	2	0	0	931		
5	237	2	5	1	0	5	11	0	2	440		
9	454	21	85	6	5	38	55	3	7	1,288		
11	16	9	12	3	1	11	24	0	2	495		
14	811	274	193	12	34	164	1,678	3	15	20,540		
16	5,875	71	118	2	11	81	139	1	8	24,043		
18	5,512	287	369	31	54	329	964	15	560	38,009		
19	1,257	2,185	479	6	925	359	387	27	378	16,579		
20	1,653	81	128	22	16	106	264	3	18	7,953		
21	151	137	163	3	31	49	974	9	61	12,489		
22	686	86	59	0	23	43	1,278	3	6	5,997		
24	244	60	178	3	2	107	59	1	18	1,697		
27	1,793	266	436	383	48	203	740	10	115	16,814		
31	15	120	47	1	34	25	155	15	55	813		
	18,704	3,600	2,273	472	1,185	1,519	6,731	91	1,246	148,088		
	8,443	17,271	9,275	547	3,832	27,296	5,782	2,376	2,643	198,510		
	78,111	20,962	63,215	7,414	4,140	29,424	53,729	2,713	27,571	891,488		
	3,566	947	2,733	364	187	1,271	5,968	349	3,978	47,127		
	15,617	24,913	1,679	2,813	5,865	3,083	5,386	62,970	0	555,429		
	9,152	6,971	14,601	1,731	1,497	7,091	18,742	5,532	5,831	194,844		
	114,889	71,064	91,504	12,869	15,522	68,165	89,607	73,940	40,023	1,887,397		
	0	(0)	(0)	(0)	(0)	0	0	0	0	492		
	401,558	112,685	170,439	46,755	25,219	94,785	192,608	78,621	62,583	4,240,309		

to reduce CO_2 emissions. The I-O table identifies the fossil fuel mix of the electricity services sector. Column 11 shows purchases of 11,450 million yuan of coal and 2,477 million yuan of petroleum and natural gas (the latter fuels are more finely disaggregated during the computations).

In general, the I-O table presents a snapshot of the economy at any time. It readily depicts the relative sophistication, interdependence, and self-sufficiency of the economy. These characteristics can be identified by the analysis of the size of the individual cells of the table, the relative prominence of various sectors, and the composition of domestic and imported inputs on a sector-by-sector basis.

4 THE BASIC STRUCTURE OF CHINA'S DYNAMIC LINEAR PROGRAMMING MODEL

4.1 INTRODUCTION

This section presents the multisector growth model that serves as the basis for the analysis. The emphasis is purely on economics. Section 5 discusses pollution emissions, technological changes, and related policies.

The framework is that of the DLP model. The data core of the model is the I-O transactions table for China. Unlike a simple I-O model, which requires an exogenous specification of final demand and then calculates sectoral gross outputs required to meet it based on fixed production requirements but infinite supply elasticities, the DLP formulation incorporates a range of capabilities:

- An optimizing capability in the model to pursue an objective such as maximizing economic growth. This capability also imparts choice into the model and allows for various substitutions between elements of consumption, between elements of final demand in general (consumption vs. investment), and between domestic and imported goods.
- Explicit constraints that reflect resource supply limitations.
- Policy constraints that relate to trade, environmental pollution, or population growth.
- Changing coefficients over time to represent changes in technology, consumption patterns, and factor productivity.
- The ability to project the time path of the economy (economic growth) on the basis of alternative assumptions that relate to population growth, factor productivity improvements, outside aid, and a range of policy variables.

The basic linear programming (LP) problem can be expressed as follows:

$$\max \sum_{j=1}^{n} v_j X_j \quad , \tag{3a}$$

subject to:

$$\sum_{j=1}^{n} a_{ij} X_j \leq b_i \qquad (i = 1...,m) \tag{3b}$$

and

$$X_j \geq 0 \qquad (j = 1...,n) \quad , \tag{3c}$$

where

v_j = unit value of activity (output) j;

X_j = total gross output of sector i;

a_{ij} = input of good i per unit of output of good j; and

b_i = maximum available quantity of input i.

The other variables were defined previously.

This version of an LP problem is referred to as the *primal* and has associated with it a *dual*, which is its obverse image. The optimization goal, direction of inequalities (except Equation 3c), and number of equations and unknowns are opposites in the two versions. The standard economic interpretation is to have the primal identify activity levels that maximize the value of output, while the dual assigns values (efficiency, or shadow, prices given by the dual) to the inputs to minimize production costs. For example, Section 6 calculates the shadow price of a CO_2 emission constraint.

The most basic reformulation of the problem at the macro level involves taking a basic I-O model and maximizing final demand (gross national product [GNP]) subject to supply constraints. This "choice on the demand-side" problem requires modification of Equations (3a)-(3c) as follows:

1. Change the objective function to maximize the value of final demand, $\Sigma p_j Y_j$, where p_j is the price of good j, and Y_j is the quantity of final demand for good j. Note that by the standard accounting identity:

$$\sum_{j=1}^{n} v_j X_j \equiv \sum_{j=1}^{n} p_j Y_j \quad , \tag{4a}$$

   where the former term denotes total value added.

2. Add an I-O balance constraint (recall the previous section):

$$X_i - \sum_{j=1}^{n} a_{ij} X_j = Y_i \qquad (i = 1...,n) \quad . \tag{4b}$$

3. Add explicit constraints for primary factors of production.

4. Add constraints for other key variables in the model, such as minimum consumption requirements maximum export levels, etc.

The "choice on the supply-side" problem enables analysis of the optimal mix of alternative technologies within each sector, plus the choice of imported goods or domestic substitutes.

4.2 BASIC MODEL

This model is a modification of the Dervis et al. (1982) model. Similar models are presented in Bruno et al. (1970) and Taylor (1978). The model will be run for three periods: 1990-2000, 2000-2010, and 2010-2025. Therefore, it is structured to embody long-run assumptions, such as perfect mobility of both labor and capital between sectors over the four stages of the forecast period.

An equation-by-equation presentation of the model is presented below.

a. *Objective Function:*

$$\max \sum_{t=1}^{T} \sum_{i=1}^{n} \left(\frac{1}{1+\rho}\right)^t Y_i^t \quad , \tag{5a}$$

where

Y_i = final demand for the products of sector i ($AC_i + TA_i + E_i - M_i$);

AC_i = aggregate consumption of good i (household and institutional consumption);

TA_i = total accumulation of good i (net and replacement investment);

E_i = exports of good i;

M_i = imports of good i; and

ρ = discount rate.

The program maximizes the discounted value of final demand (GNP) over the forecast period. The final demand is composed of the usual aggregate demand categories. However, in China, aggregate consumption includes both household and institutional (government) consumption. In addition, accumulation includes both investment and inventory change.

b. *Interindustry Constraint:*

$$X_i^t - \sum_{j=1}^{n} a_{ij} X_j^t = Y_i^t \qquad (i = 1...,n) \quad , \tag{5b}$$

where a_{ij} are technical coefficients.

Equation 5b is the I-O balance equation presented earlier. It embodies the technological possibilities in the economy and requires that the total supply of each good or service equals the total demand.

c. *Factor Constraints:*

$$\sum_{j=1}^{n} k_j^t X_j^t \leq \bar{K} \qquad \sum_{j=1}^{n} l_j^t X_j^t \leq \bar{L} \quad , \tag{5c}$$

where

$\bar{K}$ = total capital stock (in terms of money value);

$\bar{L}$ = total labor supply (in terms of money value);

k_j = capital-output ratio in sector j; and

l_j = labor-output ratio in sector j.

Equations 5a-5c relate to the stock and availability of primary factors of production. Because of the difficulty of obtaining capital stock estimates by type (i.e., by sector of origin), the equations depend on capital utilization (depreciation) coefficients from China's 1987 I-O table for the preliminary runs. Labor coefficients are used in an analogous manner as a proxy for sectoral employment levels.

Given the 10- to 15-year milestone dates during the projection period, perfect capital and labor mobility are assumed. For labor, this assumption means that no impediments exist to transferring this factor between sectors; i.e., the necessary training can readily be accomplished within 10 years to accommodate the relatively modest changes in the sectoral mix projected over time. In a similar manner, capital can be modified, or it can be safely assumed that the 10- to 15-year period allows for sufficient time for ordinary replacement of most equipment so that it can readily be "transferred" to new sectors.

The total labor and capital requirements can be set equal to their utilization levels in a given year if full employment and full capacity utilization are assumed. Alternatively, excess labor and capital can be incorporated into the analysis to depict more realistic situations.

One aspect of the labor supply inequality should be noted. If economic growth is 8.5% per year, but population grows at only 1.5% per year, there would appear to be an

inconsistency. (For completeness, Section 4.3 presents a method to calculate and relate different rates of economic growth and anticipate some results.) In a world in which labor remuneration is allowed to rise, but capital rates do not, capital stock should grow at the same rate as the wage bill (labor force increase plus labor remuneration) because of the constant factor shares property of the Cobb-Douglas production function. The growth in both factors is combined such that the difference between the rate of growth of gross output and the rate of growth of population is the rate of growth of labor remuneration affected by a multiplicative factor that is precisely the Cobb-Douglas coefficient for capital. The increase in the wage bill can result from a combination of economic phenomena, including increased labor force participation rates, decreased unemployment, and increased labor productivity. One advantage of this model is that it does not require any restrictive assumptions pertaining to any of these considerations.

d. *Consumption Constraint:*

$$\underline{b}\,(1+\gamma)AC_i^{t-1} \;\le\; AC_i^{t} \;\le\; \bar{b}(1+\gamma)AC_i^{t-1} \qquad (i = 1...,n)\ , \tag{5d}$$

where

$\underline{b}$ = lower bound;

γ = rate of economic growth; and

$\bar{b}$ = upper bound.

This constraint is necessary to ensure that basic human needs are met, while other adjustments are made in the final demand to maximize economic growth. (Various changes in consumption patterns can be accommodated at a later date to account for shifts in preferences as income increases [i.e., nonlinear Engel curves].) Upper bounds are included to avoid overspecialization or unreasonable shifts in tastes.

Aggregate consumption in China includes both household and institutional (government) consumption. Large amounts of government expenditures are assumed to provide basic services such as health and education and therefore require lower bounds, as do private consumption goods. Also, this constraint applied to institutional consumption would call for military expenditures being a constant proportion of the GNP.

e. *Investment, or Capital Updating, Equation:*

$$K_i^{t+1} = K_i^{t}(1 - d_i^{t}) + TA_i^{t} \qquad (i = 1...,n)\ , \tag{5e}$$

where d_i^{t} is the depreciation rate.

e′. *Alternative Investment Equation:*

$$TA_i^t = K_i^{t+1} - K_i^t. \tag{5e′}$$

The basic investment equation includes two terms that stipulate that investment in a given good (equipment type) equals the sum of replacement and gross investment. To simplify the initial runs, abstract from the replacement investment consideration; i.e., assume depreciation is zero. This step reduces the investment requirement but makes the model more tractable. These simulations are structured to follow a target growth rate, and, therefore, this simplification does not bias the model results, except that it shifts from investment goods toward export goods.

f. *Foreign Exchange Constraint:*

Foreign exchange earned by exports plus the net foreign capital inflow provide the upper bound on imports. In this model, the bound is imposed at the aggregate level. The sum of imports is thus less than the sum of both exports of all sectors and net foreign capital inflow. Net foreign capital inflows depend on the forecast of the future trade at a fixed growth rate over the period:

$$ER^t \sum_{i=1}^{n} M_i^t = ER^t \sum_{i=1}^{n} EX_i^t + FK^t \quad , \tag{5f}$$

where ER^t is the exchange rate, and FK^t is the net foreign capital inflow.

f′. *Alternative Foreign Exchange Constraint:*

In this case, net foreign capital inflow is a percentage of trade or the previous level of foreign capital inflow.

g. *Import Equation:*

$$m_i X_i^t = M_i^t \qquad i = (1...,n) \quad , \tag{5g}$$

where m_i is the import-output coefficient. Equation 5g stipulates fixed import requirements per unit of output. Unfortunately, it thus presents a rather static picture of trade. Ways are being explored to incorporate import substitution that usually accompanies industrial development. For example, China would be expected to import increasingly lower proportions of advanced machinery and equipment over time.

h. *Export Constraint:*

$$\underline{b}(1 + \gamma)E_i^{t-1} \leq E_i^t \leq \bar{b}(1 + \gamma)E_i^t - 1 \quad . \tag{5h}$$

These sets of equations place upper and lower bounds on exports. Lower bounds are needed to avoid "flip-flop" solutions, or overspecializations, typical in linear models, but that represent too great a departure from reality. Upper bounds are placed on exports for similar reasons. (This study strictly limits exports of services because of physical limitations on their role in international trade.) These bounds place China somewhere in between the "small country" case (able to export as much as it wants without affecting world prices) and the "big country" case (export levels are limited and do affect world prices).

4.3 CONSISTENT CALCULATION OF GROWTH RATES

The model presented here is a multiperiod optimizing model that requires a period-by-period specification of the constraint levels for factors (capital and labor) and an upper bound for total output (Equations 5c and 5e). Those bounds are set by expanding the corresponding baseline figures with growth factors, calculated by adapting Almon's (1963) approach of consistent forecasts, whose relevant characteristics are explained below.

Almon uses a dynamic I-O model to forecast growth in a full-employment economy. No overall optimization of the economy is attempted. He assumes that each sector minimizes the costs of capital and labor services of producing output with a Cobb-Douglas production function.

Coefficient $\underline{b}$ in Equation (5d) is set at 0.75 (a minimum consumption level of domestically produced goods at the starting year), and coefficient $\bar{b}$ in the same equation is set at 1.5 to allow for some sector specialization beyond the overall (target) growth of final demand. Once the overall growth rate in final demand is set, iterations with different wage bills are required to obtain that value. By fixing the rate of population growth, all possible increases in final demand growth are driven by increases in the wage bill, which in turn force the capital stock to rise. The consistent set of parameters that attains the target GNP growth rates is presented in Table 13. The value obtained for $\underline{K}$ is close to observed annual increases of capital in China's economy. Wages are allowed to grow over time at the same rate in each sector, but the rental value of capital is fixed and is the same for each sector. The implication is that only substitution between capital and labor is present, driven by increases in wages, and that the capital/labor combination is complementary to any other input.

Almon's basic model does not allow for factor productivity growth, but it is straightforward to obtain. The idea is to find the minimum cost of producing a given output level with a Cobb-Douglas production function whose factors are only capital and labor. The first-order conditions are a set of relations between capital and labor for a static picture of the

TABLE 13 China DLP Simulation Model Economic Parameters

Parameter/Time Period	Value	
	Lower Bound (%)	Upper Bound (%)
GNP growth[a]		
1990-2000	6	8.5
2000-2010	4	7.5
2010-2025	3	6.5
Population growth[a]		
1990-2000	[b]	1.5
2000-2010	[b]	1.2
2010-2025	[b]	0.9
Wage bill growth[a]		
1990-2000	8.23	13.22
2000-2010	5.60	12.60
2010-2025	4.20	11.20
Capital bill growth[a]		
1990-2000	9.73	14.72
2000-2010	6.80	13.80
2010-2025	5.10	12.10
Gross output growth[a]		
1990-2000	5.62	8.11
2000-2010	4.00	7.50
2010-2025	3.00	6.50
Discount rate		
All periods	4	8
Depreciation rate		
All periods	5	6.7
Exchange rate		
All periods	4.73	4.73
Trade balance		
All periods	0	0
Capital constraint		
1990	[b]	$(2.8579)10^{12}$ yuan
Labor constraint		
1990	[b]	$(1.0324)10^{12}$ yuan

[a] Annual rate, endogenous.

[b] Same as upper bound.

economy. To introduce temporal features, these first-order conditions are converted into growth rates.[3] Optimality relations in levels become optimality conditions for rates of growth. Consistency is provided to the forecast both dynamically (because growth rates of factors and output are mutually determined within a cost-minimizing scheme) and intersectorally (because each sector output is determined by I-O interconnections).

Almon's idea of factor cost minimization is adapted in this report, but for the economy as a whole, not sector by sector. All that is required is a meaningful way to shift the bounds on factors over time and to find the corresponding gross output growth, allowing for factor mobility. A less-aggregated version can be formulated if some sectors are to be studied in more detail. The optimization approach translates factor mobility into improved sector allocation and value of final demand. The consistency of Almon's model is embedded in the model presented here; however, this model optimizes (to achieve a target growth rate) rather than forecasts. Also, the model is extended to incorporate factor productivity growth.

The relationship among rates of growth of factors (again "growth" differentiating the first-order conditions) is

$$\hat{K} = \hat{N} + \hat{W} \quad , \tag{6a}$$

where

$\hat{K}$ = rate of growth of capital (capital stock minus capital productivity growth);

$\hat{N}$ = rate of growth of labor (population minus labor productivity growth); and

$\hat{W}$ = rate of growth of wages.

Also, the relationship among overall rates of growth in output is

$$\hat{X} = \hat{K} - a\hat{W} \quad , \tag{6b}$$

where $\hat{X}$ is the rate of growth of gross output, and a is the Cobb-Douglas coefficient for labor stock for the overall economy. A simultaneous specification of labor productivity growth and increased wages might lead to an unemployment outcome (unless the model is constrained).

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[3] That is, $\hat{K}^t = \dfrac{dK^t/dt}{K^t} = \dfrac{K^t}{K^t}$.

Using exogenous estimates of $\hat{N}$ and $\hat{W}$ (Table 13) allows endogenous computation of the rate of growth of capital $\hat{K}$ by means of Equation (6a). The rate of growth of the total gross output $\hat{X}$ is then calculated by using Equation (6b). These values set upper bounds on factor availability and total gross output at each time period. The rate of growth of (total) final demand is then endogenously found by the optimization procedure.

Because the model focuses only on production-side relations, it requires judgments about the long-term behavior of final demand components and iterations to make results and constraints compatible with a target in final demand growth $\hat{Y}$. Fixing $\hat{N}$ implies that iterations with different values of $\hat{W}$ might be necessary to obtain this target.

Two additional modifications are made to the previous equation set to incorporate the results of Equations (6a) and (6b).

i. *Final Demand Constraint:*

$$\underline{b}\,(1+\gamma)Y_i^{t-1} \;\le\; Y_i^t \;\le\; \bar{b}(1+\gamma)Y_i^{t-1} \qquad (i = 1...,n)\ , \tag{5i}$$

where γ is the rate of growth of overall final demand ($\gamma \equiv \hat{Y}$).

Equation 5i is a variant of constraint (3d) and allows greater flexibility in using the model. The lower bound is necessary to ensure minimum final demand levels of domestically produced commodities, and the upper bound is necessary to avoid overspecialization or unreasonable shifts in tastes.

j. *Overall Gross Output Growth Constraint:*

$$\sum_{i=1}^{n} X_i^t \le \sum_{i=1}^{n} \bar{X}_i^t \qquad (i = 1...,n)\ . \tag{5j}$$

Growth in total gross output is bounded to achieve the GNP growth targets.[4]

4.4 MODEL PARAMETERS

The parameters noted in Section 4.3, as well as those associated with economic activity, are listed in Table 13. Most cases show distinct *lower-* (low numerical value) and *upper-* (high numerical value) *bound* values. Several key parameters such as economic growth and population growth have been specified in collaboration with the contracting agency and Argonne National Laboratory (ANL) staff, and with reference to the East-West Center (EWC)/ANL (1994) report (Asian Development Bank [ADB] 1994).

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[4] In the economic-environmental simulations, the model is run to determine deviations from these targets.

agency and Argonne National Laboratory (ANL) staff, and with reference to the East-West Center (EWC)/ANL (1994) report (Asian Development Bank [ADB] 1994).

Briefly, during the past few years, China's economy has undergone phenomenal growth (i.e., in the range of 8-12%). On the basis of the experiences of other countries, the upper-bound growth rate assumes this pace can continue for a number of years, but that it must decline as the more obvious opportunities for development are exhausted. The lower-bound estimate would reflect conditions of domestic strife or difficulty in the transition of certain sectors to a greater market orientation.

The population projection is based on the upper-bound population projection offered in EWC/ANL (1994). The lower bounds from the source appear somewhat tenuous, with the specification of a population growth of only 0.1% by year 2050, so they have been ignored.

The balance of trade is assumed to be zero. It has vacillated between slightly positive and slightly negative over the past several years. The assumed value is chosen for lack of a more definitive projection on this score and does not greatly affect the analysis.

Several other key parameters are used in simulating the macroeconomic impacts of environmental policies that affect China's coal industry. These parameters include the rate of autonomous energy efficiency improvement (AEEI) (conservation), the stringency of pollution reduction requirements, fossil fuel reserve estimates, and the availability of new energy technologies.

4.5 BASELINE PROJECTION

This section tests the model and uses it to make baseline projections of the time path of China's economy and its pollution emissions. These projections are presented in Tables 14 and 15 for upper- and lower-bound parameter sets, respectively. The model is verified by comparing a simulation generated by it with China's projected 1990 I-O table. The two estimates are likely to differ because the model used here has optimizing features, while the I-O representation of the economy does not. One would expect that optimizing final demand (GNP), even under the rather tight constraints on the reallocation of consumption and exports, would exceed the actual final demand figures in the 1990 I-O table. This assumption is true because the results of the upper-bound projections are presented in columns 4 and 5 of Table 14 and can be compared with the baseline I-O numbers presented in columns 1 and 2. Baseline GNP is 18.9 billion yuan, while the optimizing model estimate is 20.8 billion yuan, a deviation of 10.2%. However, the total gross output figures are the same between the baseline and the 1990 estimate, although differences are evident at the sectoral level.

On a sector-by-sector basis, the gross output estimates in this report and the I-O projections are very close (compare individual entries in columns 2 and 5). For example, no sectors show estimates that differ by more than 20%; in most cases, they differ by less than 5.0%. The results for final demand are much more disparate. Most of the sectoral levels are at either their upper bound (1.2 times the baseline) or lower bound (0.8 times the baseline)

TABLE 14 Baseline Projections — Upper Bound

		BASE 1990			DLP 1990			DLP 2000			DLP 2010			DLP 2025			CO2
		Final Demand	Gross Output	CO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	COEFFICIENT (ton/tho Yuan)
1	Agriculture	409	772	43	491	879	49	1,387	2,171	121	2,860	4,475	249	7,354	11,509	641	0 0557
2	Coal mining	9	45	147	11	47	153	31	108	352	65	223	726	167	574	1,868	3 2568
3	Crude petroleum & natural gas prod	7	44	9	9	46	10	25	109	23	52	224	48	134	577	124	0 2141
4	Metal ore mining	(1)	15	0	0	14	0	0	28	0	0	57	0	0	146	0	0 0000
5	Other mining	0	35	0	0	31	0	0	67	0	1	138	0	2	355	0	0 0000
6	Food manufacturing	204	305	62	245	353	72	346	561	115	713	1,157	237	1,833	2,975	608	0 2045
7	Manufacture of textiles	99	275	44	79	237	38	168	502	81	346	1,035	167	890	2,663	430	0 1615
8	Manufacture of apparel	58	77	0	46	63	0	98	135	0	203	278	0	522	714	0	0 0000
9	Sawmills and manufacture of furniture	7	36	0	8	34	0	12	65	0	25	135	0	63	346	0	0 0000
10	Manufacture of paper and educ material	25	110	31	30	116	32	42	233	65	87	480	134	223	1,235	346	0 2799
11	Electricity, steam and hot water prod	6	65	509	7	64	499	19	142	1,105	39	292	2,278	101	750	5,859	7 8119
12	Petroleum refineries	2	60	39	2	61	40	7	141	92	14	290	189	37	745	486	0 6523
13	Coking, manufacture of gas & coal	3	10	84	2	9	77	5	18	154	10	38	317	25	97	816	8 4178
14	Chemical industries	21	300	166	25	287	159	38	616	342	74	1,270	704	190	3,266	1,810	0 5543
15	Manufacture of building materials	2	132	188	2	117	166	6	250	355	12	516	733	31	1,327	1,884	1 4199
16	Primary metal manufacturing	(22)	179	153	0	161	137	0	311	266	0	641	547	0	1,648	1,408	0 8542
17	Manufacture of metal products	19	80	16	23	78	15	32	148	29	66	305	59	169	784	152	0 1941
18	Manufacture of machinery	103	231	28	123	203	25	174	331	40	359	683	83	924	1,757	214	0 1218
19	Manufacture of transport equipment	27	66	8	32	54	7	46	92	11	94	190	23	242	489	60	0 1218
20	Manufacture of electric machinery	40	98	12	48	94	11	69	159	19	141	327	40	363	841	102	0 1218
21	Manufacture of electronics equip	31	64	8	37	59	7	78	125	15	161	257	31	414	662	81	0 1218
22	Manufacture of instruments	(1)	13	0	0	7	0	0	14	0	0	30	0	0	76	0	0 0000
23	Maintenance and repair of machinery	21	23	0	26	27	0	72	77	0	149	159	0	384	408	0	0 0000
24	Industries not elsewhere classified	(1)	17	0	21	40	0	29	69	0	60	143	0	156	367	0	0 0000
25	Construction	402	402	10	321	321	8	681	681	17	1,403	1,403	35	3,609	3,609	90	0 0250
26	Freight transport and communication	41	113	47	49	122	51	138	292	122	285	602	251	732	1,549	644	0 4161
27	Commerce	28	170	16	34	155	14	96	347	32	198	715	66	510	1,838	169	0 0921
28	Restaurants	46	47	4	44	44	4	79	79	7	163	163	15	418	418	39	0 0921
29	Passenger transport	14	25	3	16	29	3	46	78	9	95	160	18	245	412	47	0 1135
30	Public utilities and services to house	72	95	8	86	110	10	244	305	26	504	628	54	1,296	1,614	140	0 0864
31	Cultural, education and health services	153	193	17	183	226	20	518	620	54	1,068	1,278	110	2,746	3,286	284	0 0864
32	Finance and insurance	2	79	7	2	75	6	6	161	14	12	331	29	30	851	74	0 0864
33	Public administration	63	63	5	75	75	6	212	212	18	437	437	38	1,125	1,125	97	0 0864
	Total	1,888	4,240	1,665	2,080	4,240	1,620	4,704	9,247	3,485	9,695	19,059	7,183	24,934	49,016	18,474	

Final Demand and Gross Output in billions of 1990 Yuans

Final Demand(GDP) Growth Rate

1990-2000	8 50%
2000-2010	7.50%
2010-2025	6.50%

TABLE 15 Baseline Projections — Lower Bound

		BASE 1990			DLP 1990			DLP 2000			DLP 2010			DLP 2025			CO2
		Final Demand	Gross Output	CO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	COEFFICIEN (ton/tho Yuan)
1	Agriculture	409	772	43	491	879	49	1,099	1,720	98	1,627	2,546	142	2,534	3,966	221	0 0557
2	Coal mining	9	45	147	11	47	153	25	86	279	37	127	413	58	198	644	3 2568
3	Crude petroleum & natural gas prod	7	44	9	9	46	10	20	86	18	30	128	27	46	199	43	0 2141
4	Metal ore mining	(1)	15	0	0	14	0	0	22	0	0	32	0	0	50	0	0 0000
5	Other mining	0	35	0	0	31	0	0	53	0	0	78	0	1	122	0	0 0000
6	Food manufacturing	204	305	62	245	353	72	274	445	91	406	658	135	632	1,025	210	0 2045
7	Manufacture of textiles	99	275	44	79	237	38	133	398	64	197	589	95	307	917	148	0 1615
8	Manufacture of apparel	58	77	0	46	63	0	78	107	0	115	158	0	180	246	0	0 0000
9	Sawmills and manufacture of furniture	7	36	0	8	34	0	9	52	0	14	77	0	22	119	0	0 0000
10	Manufacture of paper and educ material	25	110	31	30	116	32	33	185	52	49	273	76	77	426	119	0 2799
11	Electricity, steam and hot water prod	6	65	509	7	84	499	15	112	875	22	166	1,296	35	258	2,019	7 8119
12	Petroleum refineries	2	60	39	2	61	40	6	111	73	8	165	108	13	257	168	0 6523
13	Coking, manufacture of gas & coal	3	10	84	2	9	77	4	14	122	6	21	180	9	33	281	8 4178
14	Chemical industries	21	300	166	25	287	159	28	488	270	42	722	400	66	1,125	624	0 5543
15	Manufacture of building materials	2	132	186	2	117	166	5	198	281	7	293	417	11	457	649	1 4199
16	Primary metal manufacturing	(22)	179	153	0	161	137	0	246	210	0	365	311	0	568	485	0 8542
17	Manufacture of metal products	19	80	16	23	78	15	25	117	23	37	173	34	58	270	52	0 1941
18	Manufacture of machinery	103	231	28	123	203	25	138	262	32	204	389	47	318	605	74	0 1218
19	Manufacture of transport equipment	27	66	8	32	54	7	36	73	9	54	108	13	83	169	21	0 1218
20	Manufacture of electric machinery	40	98	12	48	94	11	54	126	15	80	186	23	125	290	35	0 1218
21	Manufacture of electronics equip	31	64	8	37	59	7	61	98	12	91	145	18	141	226	28	0 1218
22	Manufacture of instruments	(1)	13	0	0	7	0	0	11	0	0	17	0	0	26	0	0 0000
23	Maintenance and repair of machinery	21	23	0	26	27	0	57	61	0	85	90	0	132	141	0	0 0000
24	Industries not elsewhere classified	(1)	17	0	21	40	0	23	55	0	34	81	0	54	126	0	0.0000
25	Construction	402	402	10	321	321	8	539	539	13	798	798	20	1,244	1,244	31	0.0250
26	Freight transport and communication	41	113	47	49	122	51	109	231	96	162	343	143	252	534	222	0.4161
27	Commerce	28	170	16	34	155	14	76	275	25	113	406	37	176	633	58	0.0921
28	Restaurants	46	47	4	44	44	4	62	62	6	92	92	9	144	144	13	0.0921
29	Passenger transport	14	25	3	16	29	3	37	62	7	54	91	10	85	142	16	0.1135
30	Public utilities and services to house	72	95	8	86	110	10	194	241	21	287	357	31	447	556	48	0 0864
31	Cultural, education and health services	153	193	17	183	226	20	410	491	42	607	727	63	946	1,133	98	0 0864
32	Finance and insurance	2	79	7	2	75	6	4	127	11	7	188	16	10	293	25	0 0864
33	Public administration	63	63	5	75	75	6	168	168	15	249	249	22	388	388	34	0 0864
	Total	1,888	4,240	1,665	2,080	4,240	1,620	3,725	7,323	2,760	5,514	10,840	4,086	8,591	16,888	6,365	

Final Demand and Gross Output in billions of 1990 Yuans

Final Demand Increasing Rate

1990-2000	6.00%
2000-2010	4.00%
2010-2025	3.00%

values for 1990. However, CO_2 emissions are more closely connected to gross output than to final demand levels, and the CO_2 projection for 1990 is only 2.7% below actual estimates.

An obvious implication of the GNP results is that China's economy is not optimizing at present. Given the underlying valuation system of a planned economy (the labor theory of value) and the unwieldy nature of economic planning in such a large country, this implication would not be surprising. However, some of the difference may be due to errors in the model presented here. Still, the rather minor deviation between the I-O estimate and the LP projection means that this model is likely to offer reasonable forecasts of the time-path of China's economy.

Moreover, use of this optimizing model to make projections over time is justified because China's economy will tend more toward optimization as it becomes further integrated into the world economy and makes the transition to market orientation at home. From a pragmatic standpoint, the model projections are likely to be more realistic with a multisector model based on a DLP format than with an I-O model. The former allows for reallocations and major shifts over time, while the latter simply yields linear projections.

Initial forecasts of economic output and CO_2 emissions for China's economy in the year 2000 are presented in columns 7-9. Overall, the final demand (GNP) level is projected to be 4,704 billion yuan in 2000 (a 126.1% increase over baseline); the gross output level is projected to be 9,247 million yuan (a 118.1% increase). The final demand estimates are consistent with the exogenously specified 8.5% growth rate. Significant increases in economic activity are projected in agriculture and cultural/education/health services. Some slight decreases are also projected in the machinery sectors because, at this point in the model's development, the investment equation is inadequately specified.

Estimates of CO_2 emissions are derived from the model in columns 6 and 9 (for comparison with baseline levels in column 3). Sectoral CO_2 emission coefficients are presented in the final column. They represent translations of emission factors to CO_2 coefficients of the model. These factors were obtained by ANL staff and are expressed in tons of CO_2 per million Chinese yuan in each of the 33 sectors of the economy (Section 5).

The baseline estimate of CO_2 emissions (column 3) is 1.665 billion tons in 1990. Interestingly, the optimization analysis of China's economy for this base year yields an estimate of 1.620 billion tons. Thus, while the estimate of final demand is 10.2% higher than baseline (compare columns 4 and 1 in Table 14), the associated estimate of CO_2 emissions is actually lower. This model projects that total CO_2 emissions will increase by 115.1%. The difference between total gross output growth and emissions growth is due to a change in the sectoral mix (relative proportions of sectoral outputs). It reflects the shift toward more consumer-oriented and therefore less polluting products. Also, the emission picture is likely to change dramatically once explicit constraints are inserted into the model on air pollution emissions. The results of these environmental policy simulations are presented in Section 6.

The analogous description can be offered of the lower-bound projections of Table 15. The projected growth rates are lower, as warranted by the parameters in Table 13.

5 POLLUTION EMISSIONS, ENERGY RESERVES, AND ENERGY TECHNOLOGY

This section summarizes three major technical aspects of the model:

- Emissions of CO_2 and other air pollutants such as SO_2 and CH_4,
- Availabilities of energy resources that generate relatively low levels of CO_2 or have no direct emissions of air pollutants, and
- Technological changes relating to energy intensity, energy efficiency, and energy substitution.

Raw data are presented for each case, followed by a discussion of how they are transformed into parameters and constraints for the simulations performed in Section 6. Because of the high degree of uncertainty relating to resource availability and energy technology, a set of optimistic (upper bound) and pessimistic (lower bound) estimates is included for these two aspects. Including both aspects allows the conduct of sensitivity analyses in Section 6.

5.1 POLLUTION EMISSIONS

China relies heavily on fossil fuels to supply its energy needs. Pollution results primarily due to their combustion. This report considers only air pollutants, specifically CO_2, CH_4, and SO_2.

Pollution factors express the amount of pollutant emitted per unit of fuel consumed. The pollution factors relevant to the Chinese energy sector came from two sources. First, pollution factors for coal were obtained from ANL (1994). These factors are presented in Table 16. Second, the pollution factors for natural gas and petroleum products were taken from EWC/ANL (1994). These pollution factors (tonnes of pollutants per million yuan of output) are used to calculate *emission coefficients* by combining them with fuel consumption figures in each economic sector.

Direct and total emission coefficients express the relation between economic activity and air pollution in China's economy. Direct emission coefficients account only for on-site, or partial equilibrium, effects and are calculated by finding the amount of each air pollutant emitted by each sector and then dividing the figure by the corresponding sectoral output. Total emission coefficients account for a combination of direct, indirect, and induced, or general equilibrium, effects and are found by multiplying the direct emission coefficients by the Leontief Inverse matrix (total input requirements coefficients) of China's economy (Section 3).

Direct emissions and emission coefficients for coal, petroleum, and natural gas are shown in Tables 17 through 22. Tables 23 and 24 show the combined direct emissions and

TABLE 16 Pollution Factors

Fuel	Factor	Fuel Consumption/ Production	CH_4	CO_2	CO_2 as Carbon	SO_2	Nitrous Oxide, NO_2
Coal	Coal production (million tonne)	1,087.4					
	Pollution emission (million tonne)		7.1	1939.3	528.9	15.8	8.3
	Coefficient (per tonne of coal)		0.0065137	1.7834284	0.4863896	0.0145669	0.0076329
Natural gas	Consumption (bcm[a])	13.4					
	Pollution emission (million tonne)			7.8	0		
	Coefficient (tonne per bcm of natural gas)		0	0.5821	0	0	0
Petroleum	Consumption (1,000 tons)	199,493.0					
	Pollution emission (million tonne)		0.05	72.9	0		0.34
	Coefficient (per 1,000 tons of petroleum products)		0.0000003	0.0003654	0	0	0.0000017

[a] bcm = billion cubic meters.

Sources: Coal figures are calculated from ANL (1994). Natural gas and petroleum figures are extracted from EWC/ANL (1994).

TABLE 17 Direct Emissions from Use of Coal, 1990 (million tonnes)

	Sectors	Output (Billion Yuan)	Coal (Mill. Tonne)	Methane CH4	Carbon Dioxide CO2	Sulfur Dioxide SO2	Nitrous Oxide NO2
1	Agriculture	772.5	21.9	0.143	39.069	0.319	0.167
2	Coal Mining	45.1	82.1	0.535	146.506	1.197	0.627
3	Crude petroleum and natural gas production	43.8	1.4	0.009	2.462	0.020	0.011
4	Metal ore mining	15.1	0.0	0.000	0.000	0.000	0.000
5	Other mining	35.3	0.0	0.000	0.000	0.000	0.000
6	Food Manufacturing	305.1	34.8	0.226	62.008	0.506	0.265
7	Manufacture of textiles	274.6	24.7	0.161	43.993	0.359	0.188
8	Manufacture of wearing apparel, leather and products of leather and fu	77.0	0.0	0.000	0.000	0.000	0.000
9	Sawmills and manufacture of furniture	35.6	0.0	0.000	0.000	0.000	0.000
10	Manufacture of paper, cultural and educational articles	109.7	17.1	0.112	30.584	0.250	0.131
11	Electricity, steam and hot water production and supply	65.1	282.9	1.843	504.621	4.122	2.160
12	Petroleum refineries	60.2	3.1	0.020	5.557	0.045	0.024
13	Coking, manufacture of gas and coal products	10.0	47.1	0.307	83.995	0.686	0.359
14	Chemical industries	300.0	86.1	0.561	153.611	1.255	0.657
15	Manufacture of building materials and other non-metallic mineral produ	132.2	104.2	0.679	185.799	1.518	0.795
16	Primary metal manufacturing	179.5	84.6	0.551	150.870	1.232	0.646
17	Manufacture of metal products	80.0	8.5	0.056	15.199	0.124	0.065
18	Manufacture of machinery	231.1	15.4	0.100	27.472	0.224	0.118
19	Manufacture of transport equipment	66.3	4.4	0.029	7.880	0.064	0.034
20	Manufacture of electric machinery and instruments	98.5	6.6	0.043	11.705	0.096	0.050
21	Manufacture of electronics and communications equipment	64.3	4.3	0.028	7.640	0.062	0.033
22	Manufacture of instruments, meters and other measuring equipment	13.0	0.0	0.000	0.000	0.000	0.000
23	Maintenance and repair of machinery and equipment	23.3	0.0	0.000	0.000	0.000	0.000
24	Industries not elsewhere classified	17.3	0.0	0.000	0.000	0.000	0.000
25	Construction	401.6	4.6	0.030	8.168	0.067	0.035
26	Freight transport and Communication	112.7	22.6	0.147	40.300	0.329	0.172
27	Commerce	170.4	8.7	0.057	15.483	0.126	0.066
28	Restaurants	46.8	2.4	0.016	4.247	0.035	0.018
29	Passenger transport	25.2	1.5	0.010	2.649	0.022	0.011
30	Public utilities and services to household	94.8	4.3	0.028	7.580	0.062	0.032
31	Cultural, education health and scientific research institutions	192.6	8.6	0.056	15.403	0.126	0.066
32	Finance and insurance	78.6	3.5	0.023	6.287	0.051	0.027
33	Public administration	62.6	2.8	0.018	5.005	0.041	0.021
	Total Intermediate Use	4,239.8	888.2	5.786	1,584.095	12.939	6.780
	Consumption		167.0	1.088	297.833	2.433	1.275
	Total		1,055.2	6.873	1,881.927	15.371	8.054

TABLE 18 Direct Emission Coefficients from Use of Coal, 1990 (tonnes per million yuan of output)

	Sectors	Output (Billion Yuan)	Coal (Mill. Tonne)	Methane CH4	Carbon Dioxide CO2	Sulfur Dioxide SO2	Nitrous Oxide NO2
1	Agriculture	772.5	21.9	0.185	50.576	0.413	0.216
2	Coal Mining	45.1	82.1	11.866	3,248.789	26.536	13.904
3	Crude petroleum and natural gas production	43.8	1.4	0.205	56.181	0.459	0.240
4	Metal ore mining	15.1	0.0	0.000	0.000	0.000	0.000
5	Other mining	35.3	0.0	0.000	0.000	0.000	0.000
6	Food Manufacturing	305.1	34.8	0.742	203.208	1.660	0.870
7	Manufacture of textiles	274.6	24.7	0.585	160.210	1.309	0.686
8	Manufacture of wearing apparel, leather and products of leather and fur	77.0	0.0	0.000	0.000	0.000	0.000
9	Sawmills and manufacture of furniture	35.6	0.0	0.000	0.000	0.000	0.000
10	Manufacture of paper, cultural and educational articles	109.7	17.1	1.018	278.750	2.277	1.193
11	Electricity, steam and hot water production and supply	65.1	282.9	28.291	7,746.037	63.269	33.152
12	Petroleum refineries	60.2	3.1	0.337	92.321	0.754	0.395
13	Coking, manufacture of gas and coal products	10.0	47.1	30.692	8,403.383	68.638	35.966
14	Chemical industries	300.0	86.1	1.870	511.958	4.182	2.191
15	Manufacture of building materials and other non-metallic mineral product	132.2	104.2	5.133	1,405.318	11.478	6.015
16	Primary metal manufacturing	179.5	84.6	3.070	840 503	6.865	3.597
17	Manufacture of metal products	80.0	8.5	0.694	190.042	1.552	0.813
18	Manufacture of machinery	231.1	15.4	0.434	118.893	0.971	0.509
19	Manufacture of transport equipment	66.3	4.4	0.434	118.893	0.971	0.509
20	Manufacture of electric machinery and instruments	98.5	6.6	0.434	118.893	0.971	0.509
21	Manufacture of electronics and communications equipment	64.3	4.3	0.434	118.893	0.971	0.509
22	Manufacture of instruments, meters and other measuring equipment	13.0	0.0	0.000	0.000	0.000	0.000
23	Maintenance and repair of machinery and equipment	23.3	0.0	0.000	0.000	0.000	0.000
24	Industries not elsewhere classified	17.3	0.0	0.000	0.000	0.000	0.000
25	Construction	401.6	4.6	0.074	20.341	0.166	0.087
26	Freight transport and Communication	112.7	22.6	1.306	357.637	2.921	1.531
27	Commerce	170.4	8.7	0.332	90.843	0.742	0.389
28	Restaurants	46.8	2.4	0.332	90.843	0.742	0.389
29	Passenger transport	25.2	1.5	0.384	105.058	0.858	0.450
30	Public utilities and services to household	94.8	4.3	0.292	79.971	0.653	0.342
31	Cultural, education health and scientific research institutions	192.6	8.6	0.292	79.971	0.653	0.342
32	Finance and insurance	78.6	3.5	0.292	79.971	0.653	0.342
33	Public administration	62.6	2.8	0.292	79.971	0.653	0.342

TABLE 19 Direct Emissions from Use of Natural Gas, 1990 (million tonnes)

	Sectors	Output (Billion Yuan)	Nat. Gas (10 ^9 m3)	Methane CH4	Carbon Dioxide CO2	Sulfur Dioxide SO2	Nitrous Oxide NO2
1	Agriculture	772.5	0.000	0.000	0.000	0.000	0.000
2	Coal Mining	45.1	0.071	0.000	0.041	0.000	0.000
3	Crude petroleum and natural gas production	43.8	3.636	0.000	2.117	0.000	0.000
4	Metal ore mining	15.1	0.000	0.000	0.000	0.000	0.000
5	Other mining	35.3	0.000	0.000	0.000	0.000	0.000
6	Food Manufacturing	305.1	0.030	0.000	0.018	0.000	0.000
7	Manufacture of textiles	274.6	0.020	0.000	0.012	0.000	0.000
8	Manufacture of wearing apparel, leather and products of leather and fu	77.0	0.000	0.000	0.000	0.000	0.000
9	Sawmills and manufacture of furniture	35.6	0.000	0.000	0.000	0.000	0.000
10	Manufacture of paper, cultural and educational articles	109.7	0.020	0.000	0.012	0.000	0.000
11	Electricity, steam and hot water production and supply	65.1	0.284	0.000	0.165	0.000	0.000
12	Petroleum refineries	60.2	1.003	0.000	0.584	0.000	0.000
13	Coking, manufacture of gas and coal products	10.0	0.010	0.000	0.006	0.000	0.000
14	Chemical industries	300.0	5.297	0.000	3.083	0.000	0.000
15	Manufacture of building materials and other non-metallic mineral produ	132.2	0.263	0.000	0.153	0.000	0.000
16	Primary metal manufacturing	179.5	0.962	0.000	0.560	0.000	0.000
17	Manufacture of metal products	80.0	0.030	0.000	0.018	0.000	0.000
18	Manufacture of machinery	231.1	0.188	0.000	0.110	0.000	0.000
19	Manufacture of transport equipment	66.3	0.054	0.000	0.031	0.000	0.000
20	Manufacture of electric machinery and instruments	98.5	0.080	0.000	0.047	0.000	0.000
21	Manufacture of electronics and communications equipment	64.3	0.052	0.000	0.030	0.000	0.000
22	Manufacture of instruments, meters and other measuring equipment	13.0	0.000	0.000	0.000	0.000	0.000
23	Maintenance and repair of machinery and equipment	23.3	0.000	0.000	0.000	0.000	0.000
24	Industries not elsewhere classified	17.3	0.000	0.000	0.000	0.000	0.000
25	Construction	401.6	1.074	0.000	0.625	0.000	0.000
26	Freight transport and Communication	112.7	0.192	0.000	0.112	0.000	0.000
27	Commerce	170.4	0.000	0.000	0.000	0.000	0.000
28	Restaurants	46.8	0.000	0.000	0.000	0.000	0.000
29	Passenger transport	25.2	0.009	0.000	0.005	0.000	0.000
30	Public utilities and services to household	94.8	0.025	0.000	0.015	0.000	0.000
31	Cultural, education health and scientific research institutions	192.6	0.051	0.000	0.030	0.000	0.000
32	Finance and insurance	78.6	0.021	0.000	0.012	0.000	0.000
33	Public administration	62.6	0.016	0.000	0.010	0.000	0.000
	Total Intermediate Use	4,239.8	13.390	0.000	7.794	0.000	0.000
	Consumption		1.860	0.000	1.083	0.000	0.000
	Total		15.250	0.000	8.877	0.000	0.000

TABLE 20 Direct Emission Coefficients from Use of Natural Gas, 1990 (tonnes per million yuan of output)

	Sectors	Output (Billion Yuan)	Nat. Gas (10 ^9 m3)	Methane CH4	Carbon Dioxide CO2	Sulfur Dioxide SO2	Nitrous Oxide NO2
1	Agriculture	772.5	0.000	0.000	0.000	0.000	0.000
2	Coal Mining	45.1	0.071	0.000	0.915	0.000	0.000
3	Crude petroleum and natural gas production	43.8	3.636	0.000	48.305	0.000	0.000
4	Metal ore mining	15.1	0.000	0.000	0.000	0.000	0.000
5	Other mining	35.3	0.000	0.000	0.000	0.000	0.000
6	Food Manufacturing	305.1	0.030	0.000	0.058	0.000	0.000
7	Manufacture of textiles	274.6	0.020	0.000	0.043	0.000	0.000
8	Manufacture of wearing apparel, leather and products of leather and fur	77.0	0.000	0.000	0.000	0.000	0.000
9	Sawmills and manufacture of furniture	35.6	0.000	0.000	0.000	0.000	0.000
10	Manufacture of paper, cultural and educational articles	109.7	0.020	0.000	0.107	0.000	0.000
11	Electricity, steam and hot water production and supply	65.1	0.284	0.000	2.534	0.000	0.000
12	Petroleum refineries	60.2	1.003	0.000	9.696	0.000	0.000
13	Coking, manufacture of gas and coal products	10.0	0.010	0.000	0.590	0.000	0.000
14	Chemical industries	300.0	5.297	0.000	10.277	0.000	0.000
15	Manufacture of building materials and other non-metallic mineral product	132.2	0.263	0.000	1.159	0.000	0.000
16	Primary metal manufacturing	179.5	0.962	0.000	3.120	0.000	0.000
17	Manufacture of metal products	80.0	0.030	0.000	0.221	0.000	0.000
18	Manufacture of machinery	231.1	0.188	0.000	0.474	0.000	0.000
19	Manufacture of transport equipment	66.3	0.054	0.000	0.474	0.000	0.000
20	Manufacture of electric machinery and instruments	98.5	0.080	0.000	0.474	0.000	0.000
21	Manufacture of electronics and communications equipment	64.3	0.052	0.000	0.474	0.000	0.000
22	Manufacture of instruments, meters and other measuring equipment	13.0	0.000	0.000	0.000	0.000	0.000
23	Maintenance and repair of machinery and equipment	23.3	0.000	0.000	0.000	0.000	0.000
24	Industries not elsewhere classified	17.3	0.000	0.000	0.000	0.000	0.000
25	Construction	401.6	1.074	0.000	1.556	0.000	0.000
26	Freight transport and Communication	112.7	0.192	0.000	0.994	0.000	0.000
27	Commerce	170.4	0.000	0.000	0.000	0.000	0.000
28	Restaurants	46.8	0.000	0.000	0.000	0.000	0.000
29	Passenger transport	25.2	0.009	0.000	0.201	0.000	0.000
30	Public utilities and services to household	94.8	0.025	0.000	0.153	0.000	0.000
31	Cultural, education health and scientific research institutions	192.6	0.051	0.000	0.153	0.000	0.000
32	Finance and insurance	78.6	0.021	0.000	0.153	0.000	0.000
33	Public administration	62.6	0.016	0.000	0.153	0.000	0.000

TABLE 21 Direct Emissions from Use of Petroleum Products, 1990 (million tonnes)

	Sectors	Output (Billion Yuan)	Petr.Products (1000 Tonne)	Methane CH4	Carbon Dioxide CO2	Sulfur Dioxide SO2	Nitrous Oxide NO2
1	Agriculture	772.5	10,888	0.003	3.979	0.000	0.019
2	Coal Mining	45.1	748	0.000	0.273	0.000	0.001
3	Crude petroleum and natural gas production	43.8	13,143	0.003	4.803	0.000	0.022
4	Metal ore mining	15.1	0	0.000	0.000	0.000	0.000
5	Other mining	35.3	0	0.000	0.000	0.000	0.000
6	Food Manufacturing	305.1	1,040	0.000	0.380	0.000	0.002
7	Manufacture of textiles	274.6	913	0.000	0.334	0.000	0.002
8	Manufacture of wearing apparel, leather and products of leather and fu	77.0	0	0.000	0.000	0.000	0.000
9	Sawmills and manufacture of furniture	35.6	0	0.000	0.000	0.000	0.000
10	Manufacture of paper, cultural and educational articles	109.7	326	0.000	0.119	0.000	0.001
11	Electricity, steam and hot water production and supply	65.1	11,281	0.003	4.122	0.000	0.019
12	Petroleum refineries	60.2	90,655	0.023	33.128	0.000	0.155
13	Coking, manufacture of gas and coal products	10.0	378	0.000	0.138	0.000	0.001
14	Chemical industries	300.0	26,346	0.007	9.627	0.000	0.045
15	Manufacture of building materials and other non-metallic mineral produ	132.2	4,847	0.001	1.771	0.000	0.008
16	Primary metal manufacturing	179.5	5,200	0.001	1.900	0.000	0.009
17	Manufacture of metal products	80.0	847	0.000	0.309	0.000	0.001
18	Manufacture of machinery	231.1	1,518	0.000	0.555	0.000	0.003
19	Manufacture of transport equipment	66.3	435	0.000	0.159	0.000	0.001
20	Manufacture of electric machinery and instruments	98.5	647	0.000	0.236	0.000	0.001
21	Manufacture of electronics and communications equipment	64.3	422	0.000	0.154	0.000	0.001
22	Manufacture of instruments, meters and other measuring equipment	13.0	0	0.000	0.000	0.000	0.000
23	Maintenance and repair of machinery and equipment	23.3	0	0.000	0.000	0.000	0.000
24	Industries not elsewhere classified	17.3	0	0.000	0.000	0.000	0.000
25	Construction	401.6	3,409	0.001	1.246	0.000	0.006
26	Freight transport and Communication	112.7	17,730	0.004	6.479	0.000	0.030
27	Commerce	170.4	595	0.000	0.218	0.000	0.001
28	Restaurants	46.8	163	0.000	0.060	0.000	0.000
29	Passenger transport	25.2	571	0.000	0.209	0.000	0.001
30	Public utilities and services to household	94.8	1,634	0.000	0.597	0.000	0.003
31	Cultural, education health and scientific research institutions	192.6	3,321	0.001	1.214	0.000	0.006
32	Finance and insurance	78.6	1,356	0.000	0.495	0.000	0.002
33	Public administration	62.6	1,079	0.000	0.394	0.000	0.002
	Total 33 Sectors		199,493	0.050	72.900	0.000	0.340
	Households		1,228	0.000	0.449	0.000	0.002
	Total		200,721	0.050	73.349	0.000	0.342

TABLE 22 Direct Emissions Coefficients from Use of Petroleum Products, 1990 (tonnes per million yuan of output)

	Sectors	Output (Billion Yuan)	PetrProducts (1000 Tonne)	Methane CH4	Carbon Dioxide CO2	Sulfur Dioxide SO2	Nitrous Oxide NO2
1	Agriculture	772.5	10,888	0.004	5.151	0.000	0.024
2	Coal Mining	45.1	748	0.004	6.063	0.000	0.028
3	Crude petroleum and natural gas production	43.8	13,143	0.075	109.613	0.000	0.511
4	Metal ore mining	15.1	0	0.000	0.000	0.000	0.000
5	Other mining	35.3	0	0.000	0.000	0.000	0.000
6	Food Manufacturing	305.1	1,040	0.001	1.246	0.000	0.006
7	Manufacture of textiles	274.6	913	0.001	1.215	0.000	0.006
8	Manufacture of wearing apparel, leather and products of leather and fur	77.0	0	0.000	0.000	0.000	0.000
9	Sawmills and manufacture of furniture	35.6	0	0.000	0.000	0.000	0.000
10	Manufacture of paper, cultural and educational articles	109.7	326	0.001	1.085	0.000	0.005
11	Electricity, steam and hot water production and supply	65.1	11,281	0.043	63.281	0.000	0.295
12	Petroleum refineries	60.2	90,655	0.377	550.327	0.000	2.567
13	Coking, manufacture of gas and coal products	10.0	378	0.009	13.823	0.000	0.064
14	Chemical industries	300.0	26,346	0.022	32.087	0.000	0.150
15	Manufacture of building materials and other non-metallic mineral product	132.2	4,847	0.009	13.397	0.000	0.062
16	Primary metal manufacturing	179.5	5,200	0.007	10.585	0.000	0.049
17	Manufacture of metal products	80.0	847	0.003	3.869	0.000	0.018
18	Manufacture of machinery	231.1	1,518	0.002	2.401	0.000	0.011
19	Manufacture of transport equipment	66.3	435	0.002	2.401	0.000	0.011
20	Manufacture of electric machinery and instruments	98.5	647	0.002	2.401	0.000	0.011
21	Manufacture of electronics and communications equipment	64.3	422	0.002	2.401	0.000	0.011
22	Manufacture of instruments, meters and other measuring equipment	13.0	0	0.000	0.000	0.000	0.000
23	Maintenance and repair of machinery and equipment	23.3	0	0.000	0.000	0.000	0.000
24	Industries not elsewhere classified	17.3	0	0.000	0.000	0.000	0.000
25	Construction	401.6	3,409	0.002	3.102	0.000	0.014
26	Freight transport and Communication	112.7	17,730	0.039	57.496	0.000	0.268
27	Commerce	170.4	595	0.001	1.277	0.000	0.006
28	Restaurants	46.8	163	0.001	1.277	0.000	0.006
29	Passenger transport	25.2	571	0.006	8.278	0.000	0.039
30	Public utilities and services to household	94.8	1,634	0.004	6.301	0.000	0.029
31	Cultural, education health and scientific research institutions	192.6	3,321	0.004	6.301	0.000	0.029
32	Finance and insurance	78.6	1,356	0.004	6.301	0.000	0.029
33	Public administration	62.6	1,079	0.004	6.301	0.000	0.029
		4239.8	199,493				

TABLE 23 Direct Emissions from Use of All Fossil Fuels, 1990 (million tonnes)

	Sectors	Output (Billion Yuan)	Methane CH4	Carbon Dioxide CO2	Sulfur Dioxide SO2	Nitrous Oxide NO2
1	Agriculture	772.5	0.145	43.048	0.319	0.186
2	Coal Mining	45.1	0.535	146.821	1.197	0.628
3	Crude petroleum and natural gas production	43.8	0.012	9.381	0.020	0.033
4	Metal ore mining	15.1	0.000	0.000	0.000	0.000
5	Other mining	35.3	0.000	0.000	0.000	0.000
6	Food Manufacturing	305.1	0.227	62.406	0.506	0.267
7	Manufacture of textiles	274.6	0.161	44.338	0.359	0.190
8	Manufacture of wearing apparel, leather and products of leather and fu	77.0	0.000	0.000	0.000	0.000
9	Sawmills and manufacture of furniture	35.6	0.000	0.000	0.000	0.000
10	Manufacture of paper, cultural and educational articles	109.7	0.112	30.715	0.250	0.131
11	Electricity, steam and hot water production and supply	65.1	1.846	508.908	4.122	2.179
12	Petroleum refineries	60.2	0.043	39.269	0.045	0.178
13	Coking, manufacture of gas and coal products	10.0	0.307	84.139	0.686	0.360
14	Chemical industries	300.0	0.568	166.322	1.255	0.702
15	Manufacture of building materials and other non-metallic mineral produ	132.2	0.680	187.724	1.518	0.803
16	Primary metal manufacturing	179.5	0.552	153.330	1.232	0.655
17	Manufacture of metal products	80.0	0.056	15.526	0.124	0.066
18	Manufacture of machinery	231.1	0.101	28.136	0.224	0.120
19	Manufacture of transport equipment	66.3	0.029	8.070	0.064	0.034
20	Manufacture of electric machinery and instruments	98.5	0.043	11.988	0.096	0.051
21	Manufacture of electronics and communications equipment	64.3	0.028	7.825	0.062	0.033
22	Manufacture of instruments, meters and other measuring equipment	13.0	0.000	0.000	0.000	0.000
23	Maintenance and repair of machinery and equipment	23.3	0.000	0.000	0.000	0.000
24	Industries not elsewhere classified	17.3	0.000	0.000	0.000	0.000
25	Construction	401.6	0.031	10.039	0.067	0.041
26	Freight transport and Communication	112.7	0.152	46.891	0.329	0.203
27	Commerce	170.4	0.057	15.701	0.126	0.067
28	Restaurants	46.8	0.016	4.307	0.035	0.018
29	Passenger transport	25.2	0.010	2.863	0.022	0.012
30	Public utilities and services to household	94.8	0.028	8.192	0.062	0.035
31	Cultural, education health and scientific research institutions	192.6	0.057	16.646	0.126	0.072
32	Finance and insurance	78.6	0.023	6.795	0.051	0.029
33	Public administration	62.6	0.019	5.409	0.041	0.023
	Total 33 Sectors	4239.8	5.836	1,664.789	12.939	7.120
	Households		1.088	299.364	2.433	1.277
	Total		6.924	1,964.153	15.371	8.397

TABLE 24 Direct Emissions Coefficients from Use of All Fossil Fuels, 1990 (tonnes per million yuan of output)

	Sectors	Output (Billion Yuan)	Methane CH4	Carbon Dioxide CO2	Sulfur Dioxide SO2	Nitrous Oxide NO2
1	Agriculture	772.5	0.188	55.727	0.413	0.240
2	Coal Mining	45.1	11.870	3,255.768	26.536	13.933
3	Crude petroleum and natural gas production	43.8	0.280	214.099	0.459	0.752
4	Metal ore mining	15.1	0.000	0.000	0.000	0.000
5	Other mining	35.3	0.000	0.000	0.000	0.000
6	Food Manufacturing	305.1	0.743	204.512	1.660	0.876
7	Manufacture of textiles	274.6	0.586	161.468	1.309	0.691
8	Manufacture of wearing apparel, leather and products of leather and fur	77.0	0.000	0.000	0.000	0.000
9	Sawmills and manufacture of furniture	35.6	0.000	0.000	0.000	0.000
10	Manufacture of paper, cultural and educational articles	109.7	1.019	279.942	2.277	1.198
11	Electricity, steam and hot water production and supply	65.1	28.335	7,811.852	63.269	33.447
12	Petroleum refineries	60.2	0.715	652.345	0.754	2.962
13	Coking, manufacture of gas and coal products	10.0	30.702	8,417.796	68.638	36.030
14	Chemical industries	300.0	1.892	554.322	4.182	2.341
15	Manufacture of building materials and other non-metallic mineral product	132.2	5.142	1,419.874	11.478	6.077
16	Primary metal manufacturing	179.5	3.077	854.208	6.865	3.647
17	Manufacture of metal products	80.0	0.697	194.132	1.552	0.831
18	Manufacture of machinery	231.1	0.436	121.768	0.971	0.520
19	Manufacture of transport equipment	66.3	0.436	121.768	0.971	0.520
20	Manufacture of electric machinery and instruments	98.5	0.436	121.768	0.971	0.520
21	Manufacture of electronics and communications equipment	64.3	0.436	121.768	0.971	0.520
22	Manufacture of instruments, meters and other measuring equipment	13.0	0.000	0.000	0.000	0.000
23	Maintenance and repair of machinery and equipment	23.3	0.000	0.000	0.000	0.000
24	Industries not elsewhere classified	17.3	0.000	0.000	0.000	0.000
25	Construction	401.6	0.076	25.000	0.166	0.102
26	Freight transport and Communication	112.7	1.346	416.127	2.921	1.799
27	Commerce	170.4	0.333	92.119	0.742	0.395
28	Restaurants	46.8	0.333	92.119	0.742	0.395
29	Passenger transport	25.2	0.389	113.537	0.858	0.488
30	Public utilities and services to household	94.8	0.296	86.425	0.653	0.372
31	Cultural, education health and scientific research institutions	192.6	0.296	86.425	0.653	0.372
32	Finance and insurance	78.6	0.296	86.425	0.653	0.372
33	Public administration	62.6	0.296	86.425	0.653	0.372
		4239.8				

the combined emission coefficients for all fuels. Table 25 shows the total (direct, indirect, and induced) emission coefficients.

A significant difference is apparent in the emission coefficients between Tables 24 and 25. Many sectors that generate rather low levels of CO_2 directly have a demand for inputs whose production generates significant amounts of GHGs. For example, the direct CO_2 coefficient for agriculture is about 55.7 tonnes per million yuan of output in this sector (row 1 of Table 24), but the total emission coefficient is 1,215.9 (row 1 of Table 25). Overall, the variance across sectors is substantially lower in Table 25 than they are in Table 24.

The total coefficients will be used in macroeconomic simulations presented in Section 6. Thus, some sectors that would appear to be especially attractive (e.g., agriculture, light manufacturing, and services) lose their comparative advantage when economic interaction effects are taken into account.[5]

5.2 ENERGY RESERVES

5.2.1 Energy Use

Most of the commercial energy used in China is supplied by fossil fuels. The energy balance for 1990, extracted from EWC/ANL (1994), shows that, from a total of 961.4 Mtce, only 50.7 Mtce came from hydropower. The fossil fuels (coal, natural gas, and oil), show a wide variation in terms of consumption pattern, as well as in potential reserves.

As the dominant fuel in China's economy, coal accounts for more than 75% of all energy consumption. Coal is used as an energy source for all economic sectors and as a material input for the chemical industries and coking sectors. The distribution of coal consumption is shown in the first two columns of Table 26.

Table 26 shows that the largest single sectoral consumer of coal is electricity services (sector 11), which accounts for 26.8% of the total. The next single largest consumer is the household sector (15.8%). Together, Sectors 13, 14, 15, and 16 (coke, chemicals, cement, and steel manufacturing) represent more than 30% of all coal consumption. Overall, when all of the manufacturing sectors are aggregated, their demand exceeds even electricity services.

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[5] The total coefficients have been computed by using an *open* I-O inverse, which includes only direct and indirect (interindustry) interactions. The use of a *closed* inverse (also including *induced*, consumer-related interactions) would narrow the disparities between sectors even more. The reason is because of the common nature of consumer-producer good interactions from any amount of consumer spending. The open matrix provides more conservative estimates, and it is difficult to incorporate the closed matrix into this model. However, the difference in emission coefficients and macroeconomic indicators would be very modest.

TABLE 25 Total Emission Coefficients from Use of All Fossil Fuels, 1990 (tonnes per million yuan of output)

Sectors	Methane CH4	Carbon Dioxide CO2	Sulfur Dioxide SO2	Nitrous Oxide NO2	Methane CH4
1 Agriculture	4.349	1,215.906	9.684	5.202	0.188
2 Coal Mining	32.199	8,846.306	71.956	37.861	11.870
3 Crude petroleum and natu	5.627	1,905.682	11.999	8.069	0.280
4 Metal ore mining	0.820	228.559	1.827	0.977	0.000
5 Other mining	1.352	375.073	3.016	1.604	0.000
6 Food Manufacturing	1.901	527.910	4.240	2.258	0.743
7 Manufacture of textiles	4.485	1,248.630	9.996	5.341	0.586
8 Manufacture of wearing a	0.886	246.524	1.974	1.055	0.000
9 Sawmills and manufactur	0.775	215.991	1.726	0.924	0.000
10 Manufacture of paper, cult	3.677	1,020.585	8.200	4.367	1.019
11 Electricity, steam and hot	34.110	9,415.714	76.148	40.309	28.335
12 Petroleum refineries	5.828	2,082.704	12.135	9.087	0.715
13 Coking, manufacture of g	31.833	8,729.630	71.164	37.364	30.702
14 Chemical industries	10.211	2,888.881	22.693	12.321	1.892
15 Manufacture of building m	7.660	2,124.135	17.085	9.088	5.142
16 Primary metal manufactur	9.712	2,706.876	21.645	11.567	3.077
17 Manufacture of metal pro	3.169	880.664	7.066	3.768	0.697
18 Manufacture of machinery	4.893	1,376.761	10.883	5.885	0.436
19 Manufacture of transport	1.164	327.613	2.588	1.401	0.436
20 Manufacture of electric m	2.760	769.297	6.149	3.290	0.436
21 Manufacture of electronic	0.880	246.222	1.958	1.052	0.436
22 Manufacture of instrument	0.401	113.226	0.890	0.484	0.000
23 Maintenance and repair of	0.118	32.872	0.263	0.141	0.000
24 Industries not elsewhere	0.739	205.281	1.647	0.878	0.000
25 Construction	0.076	25.000	0.166	0.102	0.076
26 Freight transport and Co	4.957	1,432.744	10.947	6.155	1.346
27 Commerce	5.442	1,525.003	12.112	6.528	0.333
28 Restaurants	0.333	92.119	0.742	0.395	0.333
29 Passenger transport	0.728	208.185	1.611	0.893	0.389
30 Public utilities and service	0.825	234.571	1.830	1.006	0.296
31 Cultural, education health	1.711	484.953	3.798	2.078	0.296
32 Finance and insurance	2.900	814.784	6.450	3.488	0.296
33 Public administration	0.296	86.425	0.653	0.372	0.296

The Total Coefficient is the product of the Leontieff inverse and the direct emission coefficient matrix.

Table 26 also presents data on the consumption of natural gas. Households consume only 12.2% of the total. Chemical industries (sector 14) are the largest consumer of natural gas, followed by crude petroleum and natural gas products (sector 3). Other significant users of natural gas are construction (sector 25), 7%; petroleum refineries (sector 12), 6.6%; and primary metal manufacturing (sector 16), 6.3%. In 1990, the electricity sector consumed only about 1.9% of the total gas available for the Chinese economy.

Table 26 also contains information on the consumption of petroleum products, such as crude oil, kerosene, and fuel oil (combined). Petroleum refineries use most of the crude oil. The most important consumers of petroleum products are chemical industries (sector 14), 13.1%; freight transportation (sector 26), 8.8%; and agriculture (sector 1), 5.4%.

The electricity sector consumed about 11 million tons of petroleum products in 1990 (5.6% of the total). Households consumed 1.2 million tons (about 0.6% of the total).

TABLE 26 Energy Consumption in China, 1990

Sectors	Coal (mill Tons)	Coal % Composition	Natural Gas (10^9 m3)	Natural Gas % Composition	All Oil Product (1,000 tons)	All Oil Products % Composition
1 Agriculture	21.9	2.1%	0.0	0.0%	10,888	5.4%
2 Coal Mining	82.1	7.8%	0.1	0.5%	748	0.4%
3 Crude petroleum and natural	1.4	0.1%	3.6	23.8%	13,143	6.5%
4 Metal ore mining	0.0	0.0%	0.0	0.0%	0	0.0%
5 Other mining	0.0	0.0%	0.0	0.0%	0	0.0%
6 Food Manufacturing	34.8	3.3%	0.0	0.2%	1,040	0.5%
7 Manufacture of textiles	24.7	2.3%	0.0	0.1%	913	0.5%
8 Manufacture of wearing appa	0.0	0.0%	0.0	0.0%	0	0.0%
9 Sawmills and manufacture of	0.0	0.0%	0.0	0.0%	0	0.0%
10 Manufacture of paper, cultura	17.1	1.6%	0.0	0.1%	326	0.2%
11 Electricity, steam and hot wat	282.9	26.8%	0.3	1.9%	11,281	5.6%
12 Petroleum refineries	3.1	0.3%	1.0	6.6%	90,655	45.2%
13 Coking, manufacture of gas a	47.1	4.5%	0.0	0.1%	378	0.2%
14 Chemical industries	86.1	8.2%	5.3	34.7%	26,346	13.1%
15 Manufacture of building mate	104.2	9.9%	0.3	1.7%	4,847	2.4%
16 Primary metal manufacturing	84.6	8.0%	1.0	6.3%	5,200	2.6%
17 Manufacture of metal product	8.5	0.8%	0.0	0.2%	847	0.4%
18 Manufacture of machinery	15.4	1.5%	0.2	1.2%	1,518	0.8%
19 Manufacture of transport equi	4.4	0.4%	0.1	0.4%	435	0.2%
20 Manufacture of electric mach	6.6	0.6%	0.1	0.5%	647	0.3%
21 Manufacture of electronics a	4.3	0.4%	0.1	0.3%	422	0.2%
22 Manufacture of instruments,	0.0	0.0%	0.0	0.0%	0	0.0%
23 Maintenance and repair of m	0.0	0.0%	0.0	0.0%	0	0.0%
24 Industries not elsewhere clas	0.0	0.0%	0.0	0.0%	0	0.0%
25 Construction	4.6	0.4%	1.1	7.0%	3,409	1.7%
26 Freight transport and Comm	22.6	2.1%	0.2	1.3%	17,730	8.8%
27 Commerce	8.7	0.8%	0.0	0.0%	595	0.3%
28 Restaurants	2.4	0.2%	0.0	0.0%	163	0.1%
29 Passenger transport	1.5	0.1%	0.0	0.1%	571	0.3%
30 Public utilities and services t	4.3	0.4%	0.0	0.2%	1,634	0.8%
31 Cultural, education health an	8.6	0.8%	0.1	0.3%	3,321	1.7%
32 Finance and insurance	3.5	0.3%	0.0	0.1%	1,356	0.7%
33 Public administration	2.8	0.3%	0.0	0.1%	1,079	0.5%
Total Intermediate Use	888.2	84.2%	13.4	87.8%	199,493.0	99.4%
Household Consumption	167.0	15.8%	1.9	12.2%	1,228.0	0.6%
Total Consumption	1,055.2	100.0%	15.3	100.0%	200,721.0	100.00%

Source: Elaborated from data in China Statistical Yearbook, 1991

5.2.2 Current Reserves

China's coal reserves are impressive on a global scale; they make up more than 11% of the world's reserves. Among these reserves, bituminous coal accounts for 75%, anthracite for 12%, and lignite for 13%. Geographically, 84% of China's coal reserves are concentrated in three areas (north, northwest, and northeast).

The total coal reserve differs substantially based on the source. British Petroleum (1993) reports coal reserves of 114,500 million metric tons (tonnes). The official document

of the Chinese government, *Energy in China 1992* (Ministry of Energy [1993]), reported a total of 290,000 million tonnes.

TABLE 27 China's Proven Reserves at the End of 1992

Fuel	Reserves
Coal	114,500 million tonnes
Oil	24 billion barrels
Natural gas	1 trillion cubic meters

Source: British Petroleum (1993).

Oil and natural gas reserves are considered to be newly emerging industries in China. The Ministry of Energy (1993) states that more than 373 sedimentary basins could yield oil. However, oil reserves are unevenly distributed, with more than 85% of the known oil reserves located in the East. Natural gas fields are more evenly distributed; some are near densely populated and developed regions. The same publication reported total (proven, probable, and possible) reserves of 78.7 billion tonnes for oil, and 33 trillion cubic meters (tcm) for natural gas.

The figures for oil and natural gas reserves provided by British Petroleum (1993) also differ (Table 27). Proven oil reserves total 24 billion barrels (approximately 3 billion tonnes), and natural gas totals 1.4 tcm. In 1992, China possessed about 2.4% of the world's total proven reserves of oil and about 1.0% of the world's proven reserves of natural gas (British Petroleum 1993).

5.3 FUTURE RESERVE POTENTIAL

5.3.1 Natural Gas

Natural gas exploitation in China has not received significant attention in the past. Exploration for natural gas has been very low, and the proven reserves are believed to be only 3% of estimated resources (43 tcm) (EWC/ANL 1994). On the other hand, the reserves classified as probable are about 8.4 tcm, and the proven reserves are estimated at 1.0 tcm (Ministry of Energy 1994).

Consumption of these reserves is low when compared with other nations. In 1990, China used 15.3 billion cubic meters (bcm), and the ratio of reserves to production is over a 68-year period. Production, though, is increasing rapidly. From 1985 to 1991, natural gas production increased 24.2%.

The electricity sector bears a higher unit price than other sectors because of discriminatory pricing. Calculations of the natural gas price for China's economy for 1990 indicate an average of 0.183 yuan/m^3. In the same year, sales to electricity services amounted to 6.43% of the total value of natural gas, even though this sector only consumed 0.28 bcm, or 1.8% of the total natural gas output.

Restrictions on the availability of natural gas are included in the DLP simulations presented in Section 6. To calculate these restrictions, two assumptions are necessary:

- *A minimum reserves-to-production (R/P) ratio for normal gas recovery.* Not all the proven natural gas reserves can be exploited at once because of physical limits. This report assumes a threshold R/P ratio equal to 2.

- *The amount of proven reserves that will be available in the future.* Any producing area passes through several stages — from initial discovery to maturity to depletion. On the basis of experience around the world for areas beginning to be explored, the amount of reserves is likely to be increased or can at least be maintained. Because China is not a mature hydrocarbon area, it is assumed that the current level of reserves can be kept constant by replacing production by reserve additions, even with sizable increases in gas use.

Both assumptions were combined to find the maximum annual extractable reserves of natural gas for China. Table 28 shows the results of these calculations. A maximum of 500,000 million cubic meters (mcm) can be used each year, which is valued at 91.634 billion yuan.

All sectors of China's economy are expected to consume more natural gas. To set an upper bound for the use of gas for power generation, this study assumed that sectors other than electricity will increase their gas demand at the same rate of growth as the GDP. The limits for consumption of natural gas by the electricity sector were calculated on the basis of this assumption and on the total gas reserve constraint explained above. The results are presented in Table 29.

5.3.2 Nuclear Power

Until recently, nuclear power has not been part of China's energy mix. Although nuclear technical energy resources and capabilities were present, the first nuclear station did not begin generating power until 1991. Construction of the 300-MW Qingshan plant began in 1985, and sharp increases in the cost of the materials used affected its commercial viability. The plant generating costs are much higher than the costs of generating electricity with coal would be in that region[6] (EWC/ANL 1994).

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[6] A proposed second stage in the Qinshan plant will consist of two additional 600-MW units; work is expected to start in this decade. Meanwhile, work on another nuclear power station, using mainly Western European equipment and consisting of two 900-MW units, was started in 1987 and was expected to start generating in 1994. The total investment of this project is more than $4.5 billion, and the average cost is estimated to be 9¢/kWh.

TABLE 28 Natural Gas Reserve Calculations for China

Category	Proven	Probable
Reserves (bcm)	1,000	8,400
Value of reserves (billion yuan)	183.268	1,539.451
Extractable reserves (billion yuan)	91.634	769.725

TABLE 29 Constraints for Natural Gas Used in the DLP Simulation (billion yuan)[a]

Assumption/Year		Total
Economywide Demand for Natural Gas (DN) Other Than in the Electricity Sector		
Year 2000	$DN2000 = (2.619) \times (1 + 0.085)^{10}$	5.922
Year 2010	$DN2010 = (2.619) \times (1 + 0.085)^{10}\ 10 \times (1 + 0.075)^{10}$	12.204
Year 2025	$DN2025 = (2.619) \times (1 + 0.085)^{10}\ 10 \times (1 + 0.075)^{10} \times (1 + 0.065)^{15}$	31.388
Electricity Sector Natural Gas Demand (DE) Potential		
Year 2000	DE2000 = 91.634 – DN2000	85.712
Year 2010	DE2010 = 91.634 – DN2010	79.430
Year 2025	DE2025 = 91.634 – DN2025	60.246

[a] These calculations were made on the basis of 91.634 billion yuan of extractable natural gas reserves.

Some coastal provinces and cities are in the early stages of conducting work for new nuclear power projects (Ministry of Energy 1993). Nuclear power is expected to play an increasingly important role in easing the pressure on the supply of fossil energy, especially in coastal areas where economic growth is very high and where there is a shortage of energy (EWC/ANL 1994). Rapidly industrializing and energy-short eastern China is a prime candidate for nuclear power expansion.

Various projections have been made over the years. By using a conservative approach, EWC/ANL (1994) projects that by the year 2000, the installed nuclear capacity will reach 3-4 GW, and by 2050, nuclear energy may supply as much as 10% of total energy and 20% of electric-generating capacity.

The same reports point to the main constraints on the expansion of nuclear power: (1) a shortage of capacity for building large nuclear plants, (2) a shortage of construction capital, and (3) an insufficient number of trained managers.

Projections of energy use correspond to a scenario of high economic growth and high technological development (EWC/ANL 1992). According to this scenario, nuclear power stations will not only be constructed to meet the energy shortfalls in the coastal areas, but also for other regions of China where large-scale development is expected. Some nuclear energy will also be used for district heating in cities in northern China.

5.3.3 Hydropower

Both the electricity sector and the hydroelectric supply have been growing rapidly (Ministry of Energy 1993). Between 1980 and 1990, the average annual growth of generated power was 7.6%. In 1991, the total installed capacity was 151.47 GW. Of that total, 113.59 GW (75%) came from thermal power plants and 37.88 (25%) from hydroelectric plants. Also in 1991, a total of 677,550 GWh was generated, and hydroelectric power plants supplied 125,090 GWh (19%).

Data on the power generation mix for 1990 were collected from *Energy in China* (Ministry of China 1993) as well as *National Response Strategy for Global Climate Change* (ADB 1994). Table 30 shows the distribution of electricity generated by each source. In 1990, hydropower accounted for about 20% of all the electricity sold — a total value of 65,146 million yuan. Assuming that the sales price of electricity is uniform across sources, the total sales of hydropower plants was on the order of 268 million yuan.[7]

The exploitable hydropower resources in China reach 380 GW, probably the largest in the world. The distribution of these resources is uneven, with about 68% of all the exploitable resources lying in southwest China, whereas the principal demand for electricity is in the East. The installed capacity is only 10% of the exploitable hydropower, so this sector has ample room for growth.

TABLE 30 Fuel Mix in Electricity Generation in China, 1990

Fuel Source	Sales (million yuan)	Share[a] (%)
Coal	47,084.1	72.27
Crude	482.4	0.74
Petroleum products	4,260.9	6.54
Natural gas	268.0	0.41
Hydropower and other	13,050.6	20.03
Total	65,146.0	100.00

[a] Values may not add because of rounding.

[7] Among the existing 22 power stations with a capacity of 1 GW and above, four stations are hydropower plants. The biggest hydropower station was built in 1988 and has a capacity of 2,715 GW.

However, investment in power plants must be coupled with investment in very long transmission lines. By the year 2000, China plans to transmit 10 GW of new hydropower generated in the Southwest to the East — a distance of 2,000 km. The magnitude of the investments for transmission is relatively large, about 1,000 yuan/kW. Transmission losses will also be significant — from 7 to 10% of total generation.

The capacity of reported hydropower facilities under construction exceeds 20 GW. Large plants are expected to be centrally funded, whereas numerous medium- and small-size hydropower stations will be constructed by using locally raised funds. By the year 2000, installed capacity of national hydropower will double that of 1991 (Ministry of Energy 1993). This estimate implies that the share of hydroelectricity in the total electricity picture would reduce slightly (from 19 to 18%) by year 2000, when an annual growth rate of 8.5% for the demand for electricity (equivalent to the upper-bound GDP growth rate) is assumed.

The projections of energy use correspond to a scenario of high economic growth and rapid technological development in the framework of policies (Ministry of Energy 1993). These policies encourage the use of sources other than coal and oil and the increasing electrification of the economy.

5.3.4 Other Renewables

Renewable sources of energy are being promoted in China. The current situation and perspectives on wind power, solar power, geothermal use, and biomass installations provide a variety of experiences and expectations. Table 31 presents some highlights of the status and future availability of renewable energy technologies in China.

The vast territory of China is suitable for solar power use in more of two-thirds of land available (Ministry of Energy 1992). Currently, the use of solar water heaters and photovoltaic (PV) cells has increased significantly. China's production capacity of PV cells exceeds 5.5 MW/yr.

Wind resources are more localized; they occur mainly in the western and northwestern parts of the country. More than 120,000 small units have a generating capacity of less than 1 kW and more than 10,000 units to raise water. Geothermal power is also used in some areas. A number of geothermal plants have a generating capacity of more than 25 MW. Biomass resources are also used and promoted in rural areas. It is likely that biomass will continue to be a major source of energy in these areas.

Although progress has been made in the area of other renewable energy sources and their diffusion in China, it is expected that they will contribute up to only 5% of the total power-generating capacity by 2050.

TABLE 31 Data Status for Renewable Fuels and Technologies in China

Fuel/Technology	Basic Information Technical Advances	Commercial Availability	Adoption Scenarios	Investment Required
Solar	China well-suited to its use; about 2 million m^2 collectors in use; 1 m^2 of collector saves 100-150 kg of coal	1.8 MW of photovoltaic (PV) cells installed (used in small loads, remote places); current production capacity is 4.5 MW/yr	--[a]	Restriction is the high initial cost
	By end of 1991, 1.8 million m^2 of solar water heater, 0.3 million m^2 of passive solar house, 0.33 million ha of greenhouse for agriculture, and 1,314 m^2 of solar dryers and 0.12 million solar cookers	Production capacity of 5.5 MW/yr Expected that by 2010 technical progress will allow into commercial use; by 2050, estimated investment per kilowatt reduced by 70% compared with 2000	By 1991, total power from PV in use is 2.55 MW Capacity 0.08 GW (2000), 16.25 GW (2020), 65 GW (2050); power generated: 0.17 TWh (2000), 35.75 TWh (2020), 140 TWh (2050)	Production cost 20 yuan/peak watts; market price is 30-40 yuan; PV power-generating system is 90 yuan/peak watts Unit investment 112 yuan/kW (10 kW); investment will decrease 10%/yr in next 20 years In 2000, investment per kilowatt of PV power to grid is 28,400 yuan and independent 39,400 yuan; by 2020, 19,800, and 29,300 yuan, respectively. In 2000, investment will be 13,200 for thermal and reduced to 10,000 yuan/kW in 2020 and 7,600 yuan/kW in 2050

TABLE 31 (Cont.)

Fuel/Technology	Basic Information Technical Advances	Commercial Availability	Adoption Scenarios	Investment Required
Wind	120,000 small units (less than 1 kW) in operation; total capacity 6.7 MW	Capacity to produce 20,000 units per year	--	--
	11 demonstration farms, total capacity 10,000 units to raise water	Twelve additional farms in five years equal 120 MW; total capacity is 1,000 MW by year 2000	--	--
	Wind power development optimistic; location complements coal and hydropower	By 1991, 10,000 units of 60-200 W	Installed capacity: 0.3 GW (2000), 0.145 GW (2020), 0.4 GW (2050); power generated: 0.09 TWh (2000), 0.45 TWh (2020), 1.28 TWh (2050); coal equivalent: 0.037, 0.152, and 0.410 Mtce	Grid — medium/large (yuan/kW): 7,160 (2000), 6,000 (2020), 5,500 (2050) Independent, mini: 10,000 (2000), 10,000 (2020), 8,000 (2050)
Biomass	80% of energy used by rural households provided by traditional biomass fuels	Biomass will continue to be a major rural energy source	Potential biogass base estimated at 82 Mtce	Cost of building an 8-m^3 biogas pit is 300 yuan
	Biogass program is spread; estimated 4.7 million CH_4 generating pits or 1 billion m^3 of CH_4 per year; contributes less than 1% to total biomass energy	5.7 million ha replanted for firewood	Energy supplied by biomass is estimated at 220 Mtce in 2010 and 110 Mtce by 2050	Cost of replacing old stove is 30-50 yuan; resulting firewood savings of 5-10%

TABLE 31 (Cont.)

Fuel/Technology	Basic Information Technical Advances	Commercial Availability	Adoption Scenarios	Investment Required
Biomass (cont.)	Total reserve 0.23 billion tons coal equivalent (tce); by 1992, capacity of biogas power stations reached 2.08 MW	Technologies to convert to high-quality commercial energy: biomass gasification, solidification, charcoal conversion, and biomass oil	The World Bank report estimates that by 2050 more than 20% of world electricity and 10% of world process will come from biomass Demand for biomass energy in 2000, 2020, 2050 (in billion tce) 0.236, 0.216, 0.13, respectively Proportion of high-quality utilization of biomass energy will increase; predicted that biogas reaches 10 million tce and 30 million tce in 2020 and 2050, respectively	Biogass power station: 5,000 yuan/kW (2000, 2020, 2050)
Geothermal	More than 3,000 fields with geothermal potential (low to medium temperature); potential to generate 1,000 MW of electricity	Eight power station demonstrations with capacities less than 300 MW; in 1992, total capacity was 28.6 MW	Direct use of geothermal power contributed to 0.3-0.5 mtce	Investment of 7,000 yuan/kW
		25.5 MW in plant in Tibet at 0.12 yuan/kWh	Installation capacity: 0.058 GW (2000), 0.1 GW (2020), 0.16 GW (2050) Power generation: 0.29, 0.5, and 0.8 TWh Coal equivalent: 0.12, 0.17, and 0.26 Mtce	Power station: 7,000 yuan/kW in 2000, 2020, 2050

Sources: Ministry of Energy (1993); EWC/ANL (1994); *People's Republic of China* (1994).

5.3.5 Conservation

Conservation is the result of taking a set of administrative, legislative, economic, and technical measures to reduce energy use in general, or, in the case of energy efficiency, reduce energy use per unit of output. Thus, it can also be thought of as an alternative source of energy supply. Energy conservation is an important goal for the Chinese government. The conservation measures achieved success in the last 10 years (Ministry of Energy 1993). Among other things, the energy consumption per unit of GDP dropped by 30%.

To pursue energy saving, management information systems have been established at different levels of the administration. Besides a number of decrees, regulations and codes of energy savings design have been published. Funding for conservation measures also have increased. In 1991, local governments and various enterprises spent 3.7 billion yuan to save 1.37 Mtce. The state also used more than 1.8 billion yuan from central funds to create an energy saving capacity of 1.15 Mtce.

The industrial sector has made a number of energy conservation achievements in both urban and rural areas. For example, in industrial and transportation activities, the energy coefficient dropped from 304 tce per million yuan in 1990 to 288 tce per million yuan — a reduction of 5.3%. Achievements in the use of electricity and the use of coal in coal-powered plants are also cited. Electricity savings are about 3% a year.

Urbanization has quickened with the opening of the Chinese economy. Some conservation measures include the use of coal briquettes, town heating, and improved efficiency of household electric appliances and lights. The rural sector has serious energy shortages. Conservation measures in this sector include the popularization of firewood/coal-saving stoves and the installation of biogas digestors. The agricultural sector has attempted efforts in ecoagriculture and restrained use of fertilizers.

5.4 UPPER-BOUND CONSTRAINTS ON ENERGY AND TECHNOLOGY

5.4.1 Constraints on Energy Use

Electricity supplied by clean fuels is projected to increase from 1990 to 2025. These fuels are supplied by hydroelectric, nuclear, and gas-fired power plants. Their share in total electricity generation will be determined by a combination of technical and economic factors. Changes in fuel composition will definitely affect reducing CO_2.

Table 32 shows the maximum amount of electricity that can be generated by each of these clean fuels for 2000, 2010, and 2025. The table shows the upper-bound baseline electricity demand (row 1) and allows comparison with the electricity generated by each fuel (rows 2a-2c). In addition, it shows the CO_2 reduction requirement for each of the target years and compares it with the maximum reduction attainable with clean fuels in electricity generation. (The reduction requirement is a combination of a CO_2 mitigation target and a compliance schedule.)

TABLE 32 Potential for Clean Fuels in Electricity Generation: Upper-Bound Parameters

No.	Parameter	1990	2000	2010	2025
1.	Upper-bound baseline electricity demand (billion 1990 yuan)	65.146	142.000	292.000	750.000
2a.	Hydropower potential (billion 1990 yuan)	13.051	24.446	45.825	117.556
2b.	Nuclear power potential (billion 1990 yuan)	0.191	1.845	17.795	532.981
2c.	Gas-fired electricity potential (billion 1990 yuan)	0.268	71.000	124.108	94.134
3.	Total of 2a-2c baseline demand (%)	20.740	68.510	64.290	99.290
4.	CO_2 reduction requirement (%)	NA[a]	5.000	57.300	83.910
5.	Maximum CO_2 reduction attainable with clean fuels in electricity generation (%)	NA	24.200	23.840	90.100

[a] NA = not applicable.

The upper-bound electricity demand was calculated by combining the forecast of economic growth with other assumptions in the DLP simulations. In valuation terms, the demand for electricity service will increase continually from 65,146 million yuan (1990) to 750,000 million yuan (2025). Several assumptions were made to calculate the maximum level, or potential, that clean fuels can attain in satisfying this electricity demand.

5.4.1.1 Hydroelectric Power

In 1990, hydropower sales from an installed capacity of 37 GW were 13.051 billion yuan. Currently, hydropower plants use only about 10% of known hydropower resources, and efforts will continue to increase hydropower capacity. By 2025, it is assumed that all currently known expansion possibilities will be exhausted, except an allowance for losses of 10% for inaccessibility, remoteness, and so on. In addition, it is assumed that the installed capacity will grow constantly at a rate of 6.3% annually for the next 35 years and

that the corresponding values of 24.446 billion and 45.825 billion yuan will be obtained for the target years 2000 and 2010. The results are shown in line 2a of Table 32.

5.4.1.2 Nuclear Power

To obtain the nuclear power potential, a scenario for 2025 is developed in which nuclear power plants satisfy 71.1% of the demand for electricity. This assumption is based on the current share of nuclear power in France as a maximum level of attainment. China is assumed to receive significant amounts of technical and financial assistance from abroad (e.g., from redistributing carbon tax revenue, selling carbon emission permits, and transferring technology). This assistance will allow for the construction of a strong nuclear industry (Section 6). In 1991, China's installed capacity was less than 300 MW; aggressive plans are in place to continue expanding (line 2b of Table 32). The considered expansion from 1990 to 2025 assumes a constant growth in installed capacity of more than 22% a year.

5.4.1.3 Natural Gas

Natural-gas-fired power plants consumed only about 1.9% of available gas in 1990. As explained earlier, the R/P ratio is very high and implies that large amounts of natural gas are available. Projections of extractable gas demand take into account that economic sectors other than electricity services will increase their natural gas consumption at the same rate as GDP growth. This report calculated the upper bound for natural-gas-fired electricity potential as a residual by subtracting the demand of these sectors for extractable gas reserves and valuing the power that could be generated from it.[8] On the basis of the discussion in Section 5.3, extractable reserves each year are constant through 2025; thus, the upper bound for natural-gas-fired electricity sharply increases in 2000 and then decreases to accommodate the growth of demand in other sectors.

5.4.2 Technological Trend Parameters

Technological changes in the energy components of the DLP model simulations come from three sources:

- Changes in electricity intensity,
- Displacement of coal, and
- Autonomous conservation.

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[8] Except from 1990 to 2000, during which the upper bound is set to be no larger than 50% of the total demand to take into account time-to-build considerations of natural gas infrastructure.

5.4.2.1 Changes in Electricity Intensity

The GDP in China will grow at twice the rate of energy consumption (EWC/ANL 1994). However, modernization in industry will lead to more intensive use of electricity. The upper-bound estimate in this report is that electricity consumption will grow at the same rate as the GDP, or electricity use will grow twice as fast as total energy consumption. This trend is typical of countries at the same state of development as China.

5.4.2.2 Displacement of Coal

It is assumed that coal purchases by all sectors, except for fabricated metals (mainly steel production) and electricity services, will be phased out as follows: 10% from 1990 to 2000, 70% from 2000 to 2010, and the remaining 20% from 2010 to 2025. This phaseout is equivalent to compounded annual average decreases of 0.96, 5.40, and 1.22% in intermediate coal consumption with respect to the baseline (Table 33). The pace of this adoption of electricity follows the path of the standard logistic, or an "S-shaped" curve.

5.4.2.3 Autonomous Conservation

The term AEEI refers to measures designed to reduce energy inputs per unit of output in production, transportation, and end use. These measures are not explicitly driven by the price mechanism but are available at zero or negative economic cost. Whereas these types of initial improvements could be relatively easy to attain, further progress is likely to

TABLE 33 Technological Change in Energy Use: Upper-Bound Parameters (percentage change)

Parameter	1990-2000	2000-2010	2010-2025
Electricity/GDP ratio			
Annual average	0	0	0
Period total	0	0	0
Displacement of coal[a]			
Annual average	0.96	5.40	1.22
Period total	10.00	70.00	20.00
Autonomous conservation[b]			
Annual average	2.50	1.50	1.00
Period total	28.01	16.05	10.46

[a] Applies to all sectors, except fabricated metals and electricity services.

[b] Applies to all sectors, except electricity services.

emerge at a slower pace. On the basis of work by Chandler (1990) and Cline (1992), these considerations are modeled according to the following time path for the annual rate of growth in AEEI: 2.50% from 1990 to 2000, 1.50% from 2000 to 2010, and 1.00% from 2010 to 2025 (equivalent to cumulative period total rates of 28.01, 16.05, and 10.46%, respectively). These reductions affect purchases by all energy users, except for energy inputs in electricity production.

5.5 LOWER-BOUND CONSTRAINTS IN ENERGY AND TECHNOLOGY

The implications for the parameter values, *ceteris paribus*, are assessed under the following assumptions:

- Clean fuels penetrate electricity generation at a slower pace.
- Electricity consumption grows at a rate that is higher than the GDP; coal is displaced by electricity as an intermediate commodity less quickly; and autonomous gains in energy efficiency are modest.

5.5.1 Constraints on Energy Use

A set of lower-bound constraints for clean fuels reflects the following possible conditions:

- Domestic or international prices of petroleum and more modest natural gas availability so that fuel prices and unitized capital prices for power generation still favor coal as a prominent fuel for base and intermediate load generation;
- Financial constraints that perpetuate the use of coal to generate intermediate electricity, even in the presence of hydroelectric projects with smaller net present cost (because of the large capital investment that hydropower plants require at the beginning of the project's life); and
- Constrained use of nuclear power because of health/safety and national security considerations.

The parameters in the previous section are based on optimistic assumptions regarding energy reserves and technology. As a counterpoint, another set of parameters

based on somewhat pessimistic assumptions is used in conjunction with the lower-bound economic parameters in a second set of DLP simulations.[9]

5.5.1.1 Hydropower

It is assumed that only 63% of the total hydropower potential is used at the end of the period from 2010 to 2025.[10] This assumption means that approximately 10.97% of the upper baseline electricity demand in 2025 would be hydro-based, a figure not far from France's 1990 total generation with the same technology (13.60%) (EUROSTAT 1991).

5.5.1.2 Nuclear Power

The upper-bound case assumed that by 2025, China would reach France's current percentage of nuclear power generation (71.1%, the highest in the world). The lower-bound case assumed that by 2025 China will be able to generate a maximum of 30% nuclear, a share similar to the current figure for some European countries (e.g., in 1990, Germany's share was 31.13%).

5.5.1.3 Gas-Fired Electricity

Without more complete information, the lower-bound gas-fired electricity potential is assumed to be 25% (period by period) of the upper-bound potential. The effects of interfuel competition are assumed to be spread in a similar way across generation techniques (except for nuclear, which is modeled as a regulated commodity). The ramifications of these conditions for key parameters are presented in Table 34.

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[9] Pessimistic energy parameter assumptions applied to pessimistic economic parameter assumptions obtain contradictory results. The reason is that lower-bound economic forecasts yield the following electricity sector outputs: year 2000 — 112 billion yuan; year 2010 — 166 billion yuan; and year 2025 — 258 billion yuan. Use of these figures would mean that all the coal-fired electricity generation could be met by clean fuel alternatives by 2025, a more optimistic condition than for the upper-bound combination of economic and energy parameters. Therefore, for the lower-bound energy coefficient adjustments representing interfuel substitution, the lower-bound energy availability parameters were applied to an upper-bound baseline electricity projection (that is why row 1 of Table 34 reads "Upper Baseline Electricity Demand"). This yields coefficient changes that reflect truly pessimistic projections of clean fuel utilization. In the lower-bound simulations in Section 6, both lower-bound economic and energy parameters were used, except for this one modification.

[10] This amount is equivalent to 70% of potential net of transmission and distribution losses.

TABLE 34 Potential for Clean Fuels in Electricity Generation: Lower-Bound Parameters

No.	Parameter	1990	2000	2010	2025
1.	Upper baseline electricity demand (billion 1990 yuan)	65.146	142.000	292.000	750.000
2a.	Hydropower potential (billion 1990 yuan)	13.051	22.067	37.341	82.289
2b.	Nuclear power potential (billion 1990 yuan)	0.191	1.440	10.863	225.000
2c.	Gas-fired electricity potential (billion 1990 yuan)	0.268	66.963	62.075	47.067
3.	Total of 2a-2c baseline demand (%)	20.740	63.710	33.770	47.320
4.	CO_2 reduction requirement (%)	NA[a]	5.000	40.500	65.310
5.	Maximum CO_2 reduction attainable with clean fuels in electricity generation (%)	NA	20.130	5.480	28.340

[a] NA = not applicable.

5.5.2 Technological Trend Parameters

A set of lower-bound technological change parameters was also calculated and reflects rates of growth in electricity consumption corresponding to an extremely accelerated modernization of production. Included are two distinct, but simultaneous, movements:

- One movement totally phases out the dual structure of production derived from enduring chronic brownouts (in certain regions, electricity is available one-third of the time every day of the year), while keeping current production techniques.

- The other movement replaces some current technologies with electricity-intensive ones (for example, steel production from metal scrap).

This enhanced penetration of electricity is still not assumed to displace all of the use of coal in steam boilers and direct heating processes. Finally, it is possible that substantial gains in autonomous energy efficiency had been attained during the past decade, and the rhythm

of non-price conservation decreases in an environment dominated by new technologies and market-allocated prices. The ramifications are presented in Table 35.

5.5.2.1 Change in Electricity Intensity

In China, the electricity/GDP ratio tends to rise as income increases, with an average growth rate of 7.3% per capita from 1950 to 1980. But as China's economy matured while using old technologies, that figure decreased to a rate of 3.6% per capita from 1974 to 1980 (Huang 1994). In the upper-bound case, it is assumed that the ratio reached steady state (0% growth) in 1990 and maintained this value over the entire time horizon. Given the extraordinary ambitions to increase the electrification of the economy, an electricity elasticity of 1.20 is now assumed (similar to that of Singapore and Thailand [between 1990 and 2000]) for the three simulation periods, which implies a rate of growth of the electricity/GDP ratio equal to only 20% of the increase in the GDP.

5.5.2.2 Displacement of Coal

A logistic adoption path, as in the upper-bound case, is again assumed, although now it calls for less than complete saturation of electricity by 2025. By 2025, only 70% of the total intermediate consumption is phased out as follows: 10% from 1990 to 2000, 40% from 2000 to 2010, and 20% from 2010 to 2025.

TABLE 35 Technological Change in Energy Use: Lower-Bound Parameters (percentage change)

Parameter	1990-2000	2000-2010	2010-2025
Electricity/GDP ratio			
Annual average	1.70	1.50	1.30
Period total	18.36	16.05	21.38
Displacement of coal[a]			
Annual average	0.96	3.420	1.22
Period total	10.00	40.00	20.00
Autonomous conservation[b]			
Annual average	1.50	1.00	0.50
Period total	16.05	10.46	7.77

[a] Applies to all sectors, except fabricated metals and electricity services.

[b] Applies to all sectors, except electricity services.

5.5.2.3 Autonomous Conservation

On the basis of major discussions of the range of AEEI (Manne and Richels 1992), the figures of the upper-bound case were reduced downward, assuming that AEEI is 1.5% from 1990 to 2000, 1.0% from 2000 to 2010, and 0.5% from 2010 to 2025. The corresponding figures for the lower-bound case are presented in Table 35.

6 SIMULATION RESULTS

6.1 INTRODUCTION

This section presents the results of the economic-environmental policy simulations for target years 2000, 2010, and 2025. These results are compared with the baseline projections presented in Section 4. Generally, environmental policy in China can significantly affect economic growth. Moreover, major factors that influence this outcome have been identified. The results should be useful to analysts interested in projections of the future of China's economy, as well as those in a position to minimize potential negative impacts.

Five sets of policy simulations were run; each represented a different abatement strategy and variant of the model presented in this report (Table 36):

- Strategy 1: Change in Sectoral Mix,
- Strategy 2: Mandated Conservation,
- Strategy 3: Interfuel Substitution with Current Technology,
- Strategy 4: Interfuel Substitution with Technological Advances, and
- Strategy 5: Combination of Strategies.

The last strategy represents an approximation of the optimal combination of the first four strategies to minimize economic cost (in this study defined in terms of the penalty on economic growth).

Two sets of simulations were conducted on the basis of upper- and lower-bound assumptions. The economic parameters formulated in Section 4 and the technical parameters formulated in Section 5 (for energy reserves and energy technologies) were used. Major economic parameters for each of the various simulations are summarized in Table 37. The technical parameters are repeated in the simulations presented in the following sections.

The CO_2 emission reduction target used in this analysis is a stabilization of emissions at 20% of the year 2000 baseline. Because of the projected growth in China's economy, a progressively higher overall mitigation level will cap emissions at 80% of their year 2000 levels over the policy horizon. Moreover, most nations have not agreed to immediate attainment of reduction targets, but to phasing them in according to a compliance schedule (International Energy Agency 1992). Accordingly, 25, 60, and 100% are phased in for 2000, 2010, and 2025, respectively. Table 38 summarizes these considerations; the compliance schedule was chosen in conjunction with the sponsor's and ANL's staff. The mitigation time path is compared with baseline CO_2 emission projections in Figure 2.

All of these analyses, except for strategies 1 and 5, have run two simulations: (1) with a compliance CO_2 emission reduction target level constraint and (2) without an

TABLE 36 Carbon Emission Reduction Strategy Simulations

Strategy	Simulation Method	Special Considerations
Change in sectoral mix	DLP with CO_2 constraint	Favors sectors with low emissions (less energy-intensive sectors)
Mandated conservation (across the board)	DLP with reduced energy and emission coefficients, as well as CO_2 emission constraint	Targets energy-intensive sectors (now less intensive)
Interfuel substitution	DLP with multiple activities per sector,[a] CO_2 constraints, and fuel constraints	Favors natural gas, nuclear, and hydro
Technological change (nonfossil fuel technologies)	DLP with reduced coal use and reduced energy coefficients in general per sector,[b] and CO_2 constraints	Favors nonfossil alternatives
Combination of 1, 3, and 4	DLP with multiple activities per sector, CO_2 constraints, fuel constraints, and higher fuel costs	Favors natural gas, nuclear, and hydro; also targets less energy-intensive sectors

[a] Each of the activities in the electricity services sector represents the production of output with a single fuel — coal, oil, natural gas, hydro, or nuclear.

[b] The strategy represents a combination of coal displacement and AEEI in all sectors, as well as improved fuel combustion efficiency in the electricity services sector.

TABLE 37 China's DLP Simulation Model Economic Parameters

Parameter/ Time Period	Lower Bound (%)	Upper Bound (%)
GNP growth[a]		
1990-2000	6	8.50
2000-2010	4	7.50
2010-2025	3	6.50
Population growth		
1990-2000	b	1.50
2000-2010	b	1.20
2010-2025	b	0.90
Wage bill		
1990-2000	8.23	13.22
2000-2010	5.60	12.60
2010-2025	4.20	11.20
Capital bill		
1990-2000	9.73	14.72
2000-2010	6.80	13.80
2010-2025	5.10	12.10
Gross output		
1990-2000	5.62	8.11
2000-2010	4.00	7.50
2010-2025	3.00	6.50
Discount rate		
All periods	4	8
Depreciation rate		
All periods	5	6.70
Exchange rate		
All periods	4.73	4.73
Trade balance		
All periods	0	0
Capital constraint, 1990	b	$(2.8579)10^{12}$ yuan
Labor constraint, 1990	b	$(1.0324)10^{12}$ yuan

[a] Annual rate, endogenous.

[b] Same as upper bound.

TABLE 38 CO_2 Reduction Requirements and Compliance Schedule

Parameter/ Year	(1) Baseline Emissions (million tonne)	(2) = 0.8(1) Target Emissions (million tonne)	(3) Goal Compliance (%)	(4) = (3) × 697 Goal Compliance (million tonne)	(5) = 3,485 – (4) Achieved Emissions (million tonne)	(6) = [(1 – 5) + 1] Achieved Reduction (%)
Upper Bound[a]						
2000	3,485	2,788	25.00	174	3,311	5.00
2010	7,183	2,788	60.00	418	3,067	57.30
2025	18,473	2,788	100.00	697	2,788	84.91
	(1)	(2) = 0.8(1)	(3)	(4) = (3) × 552	(5) = 2760 – (4)	(6) = [(1 – 5) + (1)]
Lower Bound[b]						
2000	2,760	2,208	25.00	138	2,622	5.00
2010	4,085	2,208	60.00	331	2,429	40.50
2025	6,365	2,208	100.00	552	2,208	65.31

[a] For the upper-bound case, the goal is to reach an emissions cap (target) of 2,788 million tonne of CO_2, which represents a 20% reduction of year 2000 baseline emissions. In the year 2000, this goal requires the reduction of 697 million tonne. However, the attainment of this target is phased in at compliance levels of 25, 60, and 100% in 2000, 2010, and 2025, respectively.

[b] For the lower-bound case, the goal is to reach an emission cap (target) of 2,208 million tonne of CO_2. This target is also phased in at compliance levels of 25, 60, and 100%.

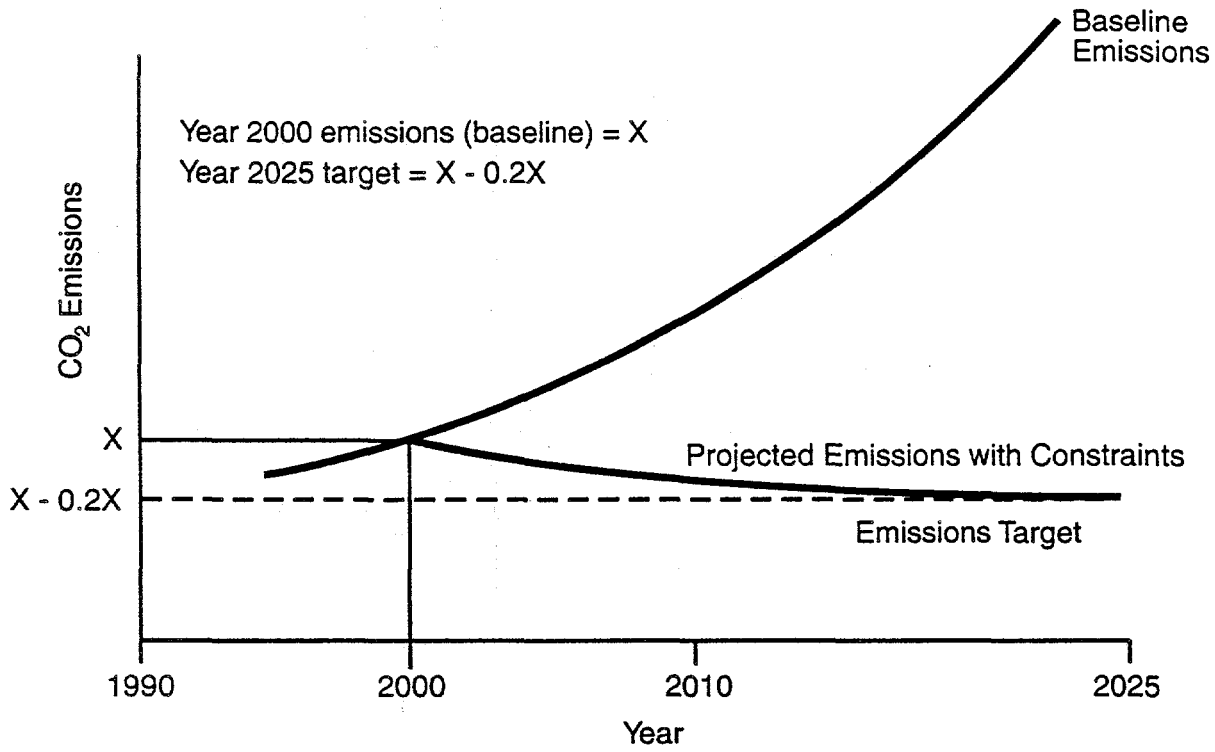

FIGURE 2 Projected CO_2 Emissions for China (upper-bound case)

explicit constraint, thereby identifying the maximum attainable emission reduction with that strategy. For Strategy 1, the two cases are (1) with a CO_2 emission reduction constraint plus sectoral constraints on final demand that limit major rearrangements of the economy (Section 4), and (2) with a CO_2 emission reduction constraint, but a relaxation of the final demand constraints. Finally, only one simulation is manageable and relevant to Strategy 5.

6.2 SIMULATIONS FOR THE YEAR 2000: UPPER-BOUND CASE

6.2.1 Strategy 1: Change in Sectoral Mix

This simulation examines what changes in relative proportions of sectoral gross output can meet the CO_2 emission reduction policy target at the lowest macroeconomic cost to China's economy. The rationale for this strategy is that some sectors have lower CO_2 emissions per unit of output than others. Moreover, given the general equilibrium nature of this model, elements of both direct and indirect emissions per unit of GNP are incorporated (Section 5). Heavy industry is characterized by much larger direct emissions coefficients than are the service sectors. For example, compare the direct coefficient for electricity services (7.8119 ton/thousand yuan [tty]) and coking (84,178 tty) with that of the service sector

(0.0864 tty) and agriculture (0.0557 tty).[11] However, with respect to total coefficients, the relative superiority of the cultural/educational/social service sector over the electricity services decreases from a factor of 100 to a factor of 50; the relative superiority of the agricultural sector over electricity services decreases from a factor of 125 to a factor of 12.

The results of simulating Strategy 1 are presented in Table 39. Total CO_2 emissions are reduced to 3,311 million tons in the year 2000, thus reducing emissions by 5%, without loosening any of the sectoral constraints to avoid dramatic changes in final demand, as is necessary for other target years. Moreover, SO_x emissions are reduced by even more (5.09%). This reduction comes at a relatively small cost of lowering the GDP (total final demand) growth from 8.50 to 8.46%. Overall, the GDP is less than 1% lower in the year 2000 than the baseline estimate (4,686 billion yuan vs. 4,704 billion yuan), while the gross output of the simulation is equal to the baseline level.

Gross output in most sectors declines. The most significant declines are found in coal mining, paper, electricity, petroleum refining, and cultural/educational/social services. Gross output in agriculture, food manufacturing, and freight transportation increases.

Strategy 1 is not likely to be a prime strategy to meet all of the required reductions in later target years because it calls for a significant rearrangement of the economy. However, it can provide useful insights in two related ways. The first insight is as a general guide to a greener economy. Relative price changes lead to a shift toward less energy-intensive goods. The second insight is that the secular time path associated with economic development calls for increased industrialization first and then increased service orientation. Coupled with this fact is China's fast-rising real wage rate and subsequent increase in consumer spending.

A "w/o constraint" (without constraint) simulation was not run because the 5% compliance target was so readily obtained by keeping more reasonable upper and lower bounds on final demand (80 and 120% of baseline, respectively).

6.2.2 Strategy 2: Mandated Conservation

One of the primary strategies for pollution mitigation is conservation. Conservation is often characterized as an improvement in energy efficiency or productivity and can be interpreted in one of two ways: (1) technology and energy prices are fixed, but energy use can be reduced by eliminating wasteful practices, or (2) energy use can be reduced by implementing energy-saving technological advances. These practices are often referred to as AEEIs to distinguish them from alterations in energy use in response to changes in relative prices. Other conservation measures are those mandated, or regulated, by the government.

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[11] Some sectors do not use significant amounts of coal, and therefore have no direct coefficients. Because these sectors use inputs directly and indirectly from other sectors in the economy, all total CO_2 coefficients are positive (columns 2 and 4 of Table 37).

TABLE 39 Simulation Results: China DLP Model 1-U (1990-2000)

		Baseline 2000				DLP 1990				DLP 2000				CO2 COEFFICIENT	SO2 COEFFICIENT
		Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	(ton/tho Yuan)	(ton/tho Yuan)
1	Agriculture	1,387	2,171	121	1	491	879	49	0	1,387	2,249	125	1	0.0557	0.0004
2	Coal mining	31	108	352	3	11	47	153	1	16	89	290	2	3.2568	0.0265
3	Crude petroleum & natural gas prod	25	109	23	0	9	46	10	0	25	105	23	0	0.2141	0.0005
4	Metal ore mining	0	28	0	0	0	14	0	0	0	27	0	0	0.0000	0.0000
5	Other mining	0	67	0	0	0	31	0	0	0	68	0	0	0.0000	0.0000
6	Food manufacturing	346	561	115	1	245	353	72	1	482	719	147	1	0.2045	0.0017
7	Manufacture of textiles	168	502	81	1	79	237	38	0	168	498	80	1	0.1615	0.0013
8	Manufacture of apparel	98	135	0	0	46	63	0	0	98	134	0	0	0.0000	0.0000
9	Sawmills and manufacture of furniture	12	65	0	0	8	34	0	0	12	64	0	0	0.0000	0.0000
10	Manufacture of paper and educ material	42	233	65	1	30	116	32	0	42	228	64	1	0.2799	0.0023
11	Electricity, steam and hot water prod	19	142	1,105	9	7	64	499	4	10	128	1,000	8	7.8119	0.0633
12	Petroleum refineries	7	141	92	0	2	61	40	0	3	135	88	0	0.6523	0.0008
13	Coking, manufacture of gas & coal	5	18	154	1	2	9	77	1	5	18	150	1	8.4178	0.0686
14	Chemical industries	36	616	342	3	25	287	159	1	36	606	336	3	0.5543	0.0042
15	Manufacture of building materials	8	250	355	3	2	117	166	1	3	245	347	3	1.4199	0.0115
16	Primary metal manufacturing	0	311	266	2	0	161	137	1	0	302	258	2	0.8542	0.0069
17	Manufacture of metal products	32	148	29	0	23	78	15	0	32	145	28	0	0.1941	0.0016
18	Manufacture of machinery	174	331	40	0	123	203	25	0	174	325	40	0	0.1218	0.0010
19	Manufacture of transport equipment	46	92	11	0	32	54	7	0	46	89	11	0	0.1218	0.0010
20	Manufacture of electric machinery	69	159	19	0	48	94	11	0	69	154	19	0	0.1218	0.0010
21	Manufacture of electronics equip	78	125	15	0	37	59	7	0	52	89	11	0	0.1218	0.0010
22	Manufacture of instruments	0	14	0	0	0	7	0	0	0	13	0	0	0.0000	0.0000
23	Maintenance and repair of machinery	72	77	0	0	26	27	0	0	36	41	0	0	0.0000	0.0000
24	Industries not elsewhere classified	29	69	0	0	21	40	0	0	29	69	0	0	0.0000	0.0000
25	Construction	681	681	17	0	321	321	8	0	681	681	17	0	0.0250	0.0002
26	Freight transport and communication	138	292	122	1	49	122	51	0	138	296	123	1	0.4161	0.0029
27	Commerce	96	347	32	0	34	155	14	0	96	346	32	0	0.0921	0.0007
28	Restaurants	79	79	7	0	44	44	4	0	79	79	7	0	0.0921	0.0007
29	Passenger transport	46	78	9	0	16	29	3	0	46	77	9	0	0.1135	0.0009
30	Public utilities and services to house	244	305	26	0	86	110	10	0	244	302	26	0	0.0864	0.0007
31	Cultural, education and health services	518	620	54	0	183	226	20	0	457	558	48	0	0.0864	0.0007
32	Finance and insurance	6	161	14	0	2	75	6	0	6	160	14	0	0.0864	0.0007
33	Public administration	212	212	18	0	75	75	6	0	212.25	212	18	0	0.0864	0.0007
	Total	4,704	9,247	3,485	27	2,080	4,240	1,620	13	4,686	9,247	3,311	26		

Final Demand and Gross Output in billions of 1990 Yuans

Final Demand(GDP) Growth Rate
1990-2000 8.46%

CO2 Emission Reduction
1990-2000 5.00%

These measures are not in response to relative price changes. However, they differ from AEEI, which is at least always economically viable. Mandated levels of conservation cannot always be achieved on this basis and may involve uneconomic options.

Before performing this analysis, some important implications of the pure conservation strategy should be noted. Any reduction in energy use lowers total production costs in most sectors. What are the implications of this cost reduction? One possibility is price decreases. However, in most economies, prices are "sticky" downward. Moreover, this model would have difficulty simulating such price decreases and the responses to them. Other possibilities are available, including energy cost decreases being offset by the costs of operating and depreciating energy-saving equipment. This possibility is simulated by increasing the machinery coefficient in each sector by an amount equal to the sum of the cost savings of the various fuels.[12,13]

The results of this simulation of Strategy 2 with a 5% CO_2 emission reduction constraint are presented in Table 40. The overall decline in the GDP is only 0.01% (from 8.5 to 8.49%), and the gross output is essentially the same as the baseline. The gross outputs of the metal ore mining, coking, and primary metal sectors increase because these support the machinery industry. However, significant decreases in the gross outputs of energy extraction, petroleum refining, and electricity are projected.

In addition to the phased-in compliance schedule (Table 38), this study simulated the full 20% mitigation level for Strategy 2 for the year 2000. Such a reduction level is considered achievable by costless conservation measures (Chandler 1990; Cline 1992).[13] In addition, across-the-board 20% reductions are assumed in both primary and secondary energy use in each sector.

Not every sector can meet a 20% autonomous conservation target, but any sectoral deviations from this economywide attainable level would not significantly affect the results. The optimal level of conservation would also call for differentiation across sectors. Recalling the discussion of CO_2 emission coefficients, the prime sectoral targets for conservation would be those with larger coefficients. Therefore, the estimates of negative impacts on GDP should be considered as upper bounds.

The results of simulations w/o constraint are presented in Table 41. First, CO_2 emissions are projected to be 2,587 million tons, or a 25.78% decrease from baseline. The

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[12] New machinery is not purchased on a current account in an I-O table, but as the capital accumulation element final demand. This aspect is modeled to create no significant bias. In fact, it may be superior to the inclusion of these costs in the depreciation row because placing it in intermediate sectors also incorporates the indirect effects of simulating the production of this machinery.

[13] Simulations were also run in which the cost savings were transferred to labor. The results for these two offset cases were essentially the same, and only the machinery offset case is presented.

TABLE 40 Simulation Results: China DLP Model 2-U (1990-2000), with Constraint

		Baseline 2000				DLP 1990				DLP 2000				CO2	SO2
		Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	COEFFICIENT (ton/tho Yuan)	COEFFICIENT (ton/tho Yuan)
1	Agriculture	1,387	2,171	121	1	491	879	49	0	1,392	2,780	124	1	0.0446	0.0003
2	Coal mining	31	108	352	3	11	47	153	1	32	115	300	2	2.6054	0.0212
3	Crude petroleum & natural gas prod	25	109	23	0	9	46	10	0	25	104	18	0	0.1713	0.0004
4	Metal ore mining	0	28	0	0	0	14	0	0	0	37	0	0	0.0000	0.0000
5	Other mining	0	67	0	0	0	31	0	0	0	85	0	0	0.0000	0.0000
6	Food manufacturing	346	561	115	1	245	353	72	1	347	719	118	1	0.1636	0.0013
7	Manufacture of textiles	168	502	81	1	79	237	38	0	168	645	83	1	0.1292	0.0010
8	Manufacture of apparel	98	135	0	0	46	63	0	0	99	173	0	0	0.0000	0.0000
9	Sawmills and manufacture of furniture	12	65	0	0	8	34	0	0	12	85	0	0	0.0000	0.0000
10	Manufacture of paper and educ material	42	233	65	1	30	116	32	0	42	299	67	1	0.2240	0.0018
11	Electricity, steam and hot water prod	19	142	1105	9	7	64	499	4	19	150	936	8	6.2495	0.0508
12	Petroleum refineries	7	141	92	0	2	61	40	0	7	144	75	0	0.5219	0.0006
13	Coking, manufacture of gas & coal	5	18	154	1	2	9	77	1	5	24	163	1	6.7342	0.0549
14	Chemical industries	36	616	342	3	25	287	159	1	36	792	351	3	0.4435	0.0033
15	Manufacture of building materials	6	250	355	3	2	117	166	1	3	317	360	3	1.1359	0.0092
16	Primary metal manufacturing	0	311	266	2	0	161	137	1	0	414	283	2	0.6834	0.0055
17	Manufacture of metal products	32	148	29	0	23	78	15	0	32	191	30	0	0.1553	0.0012
18	Manufacture of machinery	174	331	40	0	123	203	25	0	175	540	53	0	0.0974	0.0008
19	Manufacture of transport equipment	46	92	11	0	32	54	7	0	46	119	12	0	0.0974	0.0008
20	Manufacture of electric machinery	69	159	19	0	48	94	11	0	69	207	20	0	0.0974	0.0008
21	Manufacture of electronics equip	78	125	15	0	37	59	7	0	64	136	13	0	0.0974	0.0008
22	Manufacture of instruments	0	14	0	0	0	7	0	0	0	19	0	0	0.0000	0.0000
23	Maintenance and repair of machinery	72	77	0	0	26	27	0	0	73	99	0	0	0.0000	0.0000
24	Industries not elsewhere classified	29	69	0	0	21	40	0	0	29	89	0	0	0.0000	0.0000
25	Construction	681	681	17	0	321	321	8	0	683	872	17	0	0.0200	0.0001
26	Freight transport and communication	138	292	122	1	49	122	51	0	139	374	124	1	0.3329	0.0023
27	Commerce	96	347	32	0	34	155	14	0	96	446	33	0	0.0737	0.0006
28	Restaurants	79	79	7	0	44	44	4	0	79	101	7	0	0.0737	0.0006
29	Passenger transport	46	78	9	0	16	29	3	0	46	100	9	0	0.0908	0.0007
30	Public utilities and services to house	244	305	26	0	86	110	10	0	245	390	27	0	0.0691	0.0005
31	Cultural, education and health services	518	620	54	0	183	226	20	0	520	794	55	0	0.0691	0.0005
32	Finance and insurance	6	161	14	0	2	75	6	0	6	208	14	0	0.0691	0.0005
33	Public administration	212	212	18	0	75	75	6	0	213	272	19	0	0.0691	0.0005
	Total	4,704	9,247	3,485	27	2,080	4,240	1,620	13	4,701	11,836	3,311	28		

Final Demand and Gross Output in billions of 1990 Yuans

Final Demand(GDP) Growth Rate
1990-2000 8.49%

CO2 Emission Reduction
1990-2000 5.00%

TABLE 41 Simulation Results: China DLP Model 2-U (1990-2000), without Constraint

		Baseline 2000				DLP 1990				DLP 2000				CO2	SO2
		Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	COEFFICIENT (ton/tho Yuan)	COEFFICIENT (ton/tho Yuan)
1	Agriculture	1,387	2,171	121	1	491	879	49	0	1,387	2,172	97	1	0.0446	0.0003
2	Coal mining	31	108	352	3	11	47	153	1	31	90	234	2	2.6054	0.0212
3	Crude petroleum & natural gas prod	25	109	23	0	9	46	10	0	25	81	14	0	0.1713	0.0004
4	Metal ore mining	0	28	0	0	0	14	0	0	0	29	0	0	0.0000	0.0000
5	Other mining	0	67	0	0	0	31	0	0	0	67	0	0	0.0000	0.0000
6	Food manufacturing	346	561	115	1	245	353	72	1	346	561	92	1	0.1636	0.0013
7	Manufacture of textiles	168	502	81	1	79	237	38	0	168	504	65	1	0.1292	0.0010
8	Manufacture of apparel	98	135	0	0	46	63	0	0	98	135	0	0	0.0000	0.0000
9	Sawmills and manufacture of furniture	12	65	0	0	8	34	0	0	12	66	0	0	0.0000	0.0000
10	Manufacture of paper and educ material	42	233	65	1	30	116	32	0	42	234	52	0	0.2240	0.0018
11	Electricity, steam and hot water prod	19	142	1105	9	7	64	499	4	19	117	731	6	6.2495	0.0506
12	Petroleum refineries	7	141	92	0	2	61	40	0	7	113	59	0	0.5219	0.0006
13	Coking, manufacture of gas & coal	5	18	154	1	2	9	77	1	5	19	127	1	6.7342	0.0549
14	Chemical industries	36	616	342	3	25	287	159	1	36	619	275	2	0.4435	0.0033
15	Manufacture of building materials	6	250	355	3	2	117	166	1	3	247	281	2	1.1359	0.0092
16	Primary metal manufacturing	0	311	266	2	0	161	137	1	0	323	221	2	0.6834	0.0055
17	Manufacture of metal products	32	148	29	0	23	78	15	0	32	149	23	0	0.1553	0.0012
18	Manufacture of machinery	174	331	40	0	123	203	25	0	174	422	41	0	0.0974	0.0008
19	Manufacture of transport equipment	46	92	11	0	32	54	7	0	46	93	9	0	0.0974	0.0008
20	Manufacture of electric machinery	69	159	19	0	48	94	11	0	69	162	16	0	0.0974	0.0008
21	Manufacture of electronics equip	78	125	15	0	37	59	7	0	64	106	10	0	0.0974	0.0008
22	Manufacture of instruments	0	14	0	0	0	7	0	0	0	14	0	0	0.0000	0.0000
23	Maintenance and repair of machinery	72	77	0	0	26	27	0	0	72	77	0	0	0.0000	0.0000
24	Industries not elsewhere classified	29	69	0	0	21	40	0	0	29	69	0	0	0.0000	0.0000
25	Construction	681	681	17	0	321	321	8	0	681	681	14	0	0.0200	0.0001
26	Freight transport and communication	138	292	122	1	49	122	51	0	138	292	97	1	0.3329	0.0023
27	Commerce	96	347	32	0	34	155	14	0	96	348	26	0	0.0737	0.0006
28	Restaurants	79	79	7	0	44	44	4	0	79	79	6	0	0.0737	0.0006
29	Passenger transport	46	78	9	0	16	29	3	0	46	78	7	0	0.0908	0.0007
30	Public utilities and services to house	244	305	26	0	86	110	10	0	244	305	21	0	0.0691	0.0005
31	Cultural, education and health services	518	620	54	0	183	226	20	0	518	620	43	0	0.0691	0.0005
32	Finance and insurance	6	161	14	0	2	75	6	0	6	162	11	0	0.0691	0.0005
33	Public administration	212	212	18	0	75	75	6	0	212	212	15	0	0.0691	0.0005
	Total	4,704	9,247	3,485	27	2,080	4,240	1,620	13	4,687	9,247	2,587	20		

Final Demand and Gross Output in billions of 1990 Yuans

Final Demand(GDP) Growth Rate
1990-2000 8.46%

CO2 Emission Reduction
1990-2000 25.78%

growth in GDP is also slightly decreased from 8.50 to 8.46%, and gross output is essentially the same as the baseline. The sectors whose gross output increases or decreases the most are the same as those found for the with constraint case (Table 40), although the absolute value of the changes is lower.

An interesting aspect of these results is that all energy-use coefficients were decreased by 20%, which should yield the target 20% reduction in CO_2 emissions, as well as emissions of all other pollutants. However, these results indicate a 25.78% decrease in CO_2, which is attributable to negative multiplier effects associated with the reduction in energy production. Offsetting this fact is that improvements in energy efficiency essentially reduce the effective price of energy, thus making it more attractive. Therefore, the implicit penalty against energy-intensive goods is eased, and there is some substitution toward them (somewhat the reverse of Strategy 1). This phenomenon is well acknowledged in the literature (Khazzoom 1993; Rose and Lin 1994). However, in the simulation, this incentive effect is relatively weak. This fact also pertains to the (5%) with constraint case.

6.2.3 Strategy 3: Interfuel Substitution with Current Technology

Simulating the impacts of interfuel substitution uses the baseline technology and focuses on the response to changes in the relative attractiveness of various fuels due to either direct or social costs (e.g., environmental externalities), subject to fuel availability constraints. As such, both interfossil fuel substitution and the substitution of other forms of energy (predominantly hydro and nuclear) are considered for fossil fuels. The technological and fuel use availability parameters are those developed in the previous section and are reproduced in Table 42.

Interfuel substitution possibilities exist in several sectors besides electricity services, but only to a limited degree. The use of coal in many sectors of China's economy is a prime candidate for displacement by electricity, but this consideration is grouped in the category of technological change simulated in Strategy 4. Otherwise, substitution possibilities are quite limited. Increased use of oil is not a viable option. Small amounts of gas or electricity could be substituted for oil (most oil outside of electricity services is used for lubricants and transportation fuels). Therefore, this section focuses on interfuel substitution in electricity services, which is the largest consumer of primary energy. The result can be generalized to interfuel substitution in other sectors, and the model presented in this report can be modified to explicitly analyze interfuel substitution in several sectors simultaneously.

Various possibilities for interfuel substitution are present. For example, projections for the year 2000 show sufficient gas reserves to generate all electricity needs in China. Also, the combination of hydro and nuclear resources is adequate to fill most of the needed capacity (Section 5). Of course, considerations of investment requirements and fuel mix diversity need to be taken into account. Accordingly, some limits were placed on the extent of substitution away from coal and oil toward natural gas and hydro/nuclear in the electricity services sector. The new mix is presented in column 2 of Table 43 and can be compared with the baseline

TABLE 42 Potential for Clean Fuels in Electricity Generation: Upper-Bound Parameters

No.	Parameter	1990	2000	2010	2025
1.	Upper-bound baseline electricity demand (billion 1990 yuan)	65.146	142.000	292.000	750.000
2a.	Hydropower potential (billion 1990 yuan)	13.051	24.446	45.825	117.556
2b.	Nuclear power potential (billion 1990 yuan)	0.191	1.845	17.795	532.981
2c.	Gas-fired electricity potential (billion 1990 yuan)	0.268	71.000	124.108	94.134
3.	Total of 2a-2c baseline demand (%)	20.740	68.510	64.290	99.290
4.	Effective CO_2 reduction requirement (%)	NA[a]	5.000	57.300	83.910
5.	Maximum CO_2 reduction attainable with clean fuels in electricity generation (%)	NA	24.200	23.840	90.100

[a] NA = not applicable.

TABLE 43 Percentage of Electricity Sector Fuel Mix: Upper-Bound Values

Fuel	1990	2000	2010	2025
Coal	70.27	28.20	34.10	0.00
Oil	7.30	3.30	1.60	0.70
Natural gas	0.41	50.00	42.50	12.86
Other (hydro and nuclear)	20.03	18.50	21.80	86.70

requirements in column 1 of that table.[14] Rather than choose a fuel mix that simply meets the 5% CO_2 reduction criterion in the electricity services sector, this study chose the one that achieves the maximum reduction possible in that sector — 24.20% in the year 2000.[15]

The results of a simulation of interfuel substitution to meet the 5% CO_2 emission reduction target in the year 2000 are presented in Table 44. Under this strategy, the GDP grows by only 8.51% rather than by the 8.50% baseline estimate. An interesting feature of this simulation is that the overall CO_2 emission reduction is 216 million tons, but the electricity services sector achieves a reduction of 269 million tons. As a result, this sector's actions enable some more polluting sectors to expand their output under the with constraint scenario. (This scenario is not the case when the constraint is dropped.) The gross output of all sectors, except coal mining, increases over baseline levels. In fact, the sum of sectoral gross output levels is 4.5% higher than baseline. However, the GDP (total final demand) is essentially the same.

The maximum attainable mitigation under Strategy 3 leads to a 9.07% CO_2 emission reduction (Table 45). Overall, 269 million of the 316 million tons of CO_2 mitigation stem from the electricity services sector and the rest from a change in the economywide sectoral mix. Most of the latter comes from a reduction in coal mining. Petroleum and other mining gross output increases, which reflects the interfuel substitution modeled. The gross output of all other sectors is virtually unchanged.

Strategy 3 yields an improvement of more than 0.05 percentage points in the economic growth rate over Strategy 1, in which the CO_2 emission reduction had to be met entirely by changes in the sectoral mix. Strategy 3 would also yield the additional benefit of a 9.43% decrease in SO_x.

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[14] Even the electricity sector simulations did not require the use of the formal fuel choice (LP) submodel. The attainment of a least-cost mix of fuel subject to a single constraint is simply a cost-effectiveness exercise — the lowest cost fuel is used up to its constraint level; the next least costly fuel is used up to its constraint level, etc. Under the assumption of equal annual fuel costs (combined capital and operating), all choices are arbitrary, *ceteris paribus*. However, various considerations need to be taken into account such as the relative ease of converting power plants from coal to gas compared with building new nuclear or hydro facilities, but keeping in mind limitations on how quickly the conversion process can take place (recall the discussion in Section 5). Thus, for the year 2000, coal use is displaced by natural gas up to 50%, which is less than its potential of 60.4%. Nuclear and hydro are substituted for coal up to their availability limits. Similar procedures are used for subsequent years. The constraints for additional GHGs would require the use of a formal LP model. Also, for example, a CH_4 emission constraint would tip the balance from natural gas toward nuclear and hydro.

[15] Strategies such as mandated conservation, interfuel substitution, and technological change manifest themselves in changes in CO_2 (and SO_x) emission coefficients in the right columns of the various tables. For the case of interfuel substitution, only the electricity services sector emission coefficients change.

TABLE 44 Simulation Results: China DLP Model 3-U (1990-2000)

		BASELINE 2000				DLP 1990				DLP 2000				CO2 COEFFICIENT	SO2 COEFFICIENT
		Final Demand	Gross Output	CO2 (MIL TON)	SO2 (MIL TON)	Final Demand	Gross Output	CO2 (MIL TON)	SO2 (MIL TON)	Final Demand	Gross Output	CO2 (MIL TON)	SO2 (MIL TON)	(TON/THO YUAN	(TON/THO YUAN)
1	Agriculture	1,387	2,171	121	1	491	879	49	0	1,387	2,171	121	1	0.0557	0.0004
2	Coal mining	31	108	352	3	11	47	153	1	31	94	307	3	3.2568	0.0265
3	Crude petroleum & natural gas prod	25	109	23	0	9	46	10	0	25	120	26	0	0.2141	0.0005
4	Metal ore mining	0	28	0	0	0	14	0	0	0	28	0	0	0.0000	0.0000
5	Other mining	0	67	0	0	0	31	0	0	0	73	0	0	0.0000	0.0000
6	Food manufacturing	346	561	115	1	245	353	72	1	346	561	115	1	0.2045	0.0017
7	Manufacture of textiles	168	502	81	1	79	237	38	0	168	502	81	1	0.1615	0.0013
8	Manufacture of apparel	98	135	0	0	46	63	0	0	98	135	0	0	0.0000	0.0000
9	Sawmills and manufacture of furniture	12	65	0	0	8	34	0	0	12	65	0	0	0.0000	0.0000
10	Manufacture of paper and educ material	42	233	65	1	30	116	32	0	42	233	65	1	0.2799	0.0023
11	Electricity, steam and hot water prod	19	142	1,105	9	7	64	499	4	19	141	836	7	5.9237	0.0480
12	Petroleum refineries	7	141	92	0	2	61	40	0	7	134	87	0	0.6523	0.0008
13	Coking, manufacture of gas & coal	5	18	154	1	2	9	77	1	5	18	154	1	8.4178	0.0686
14	Chemical industries	36	616	342	3	25	287	159	1	36	616	342	3	0.5543	0.0042
15	Manufacture of building materials	6	250	355	3	2	117	166	1	6	250	356	3	1.4199	0.0115
16	Primary metal manufacturing	0	311	266	2	0	161	137	1	0	311	266	2	0.8542	0.0069
17	Manufacture of metal products	32	148	29	0	23	78	15	0	32	148	29	0	0.1941	0.0016
18	Manufacture of machinery	174	331	40	0	123	203	25	0	174	332	40	0	0.1218	0.0010
19	Manufacture of transport equipment	46	92	11	0	32	54	7	0	46	92	11	0	0.1218	0.0010
20	Manufacture of electric machinery	69	159	19	0	48	94	11	0	69	159	19	0	0.1218	0.0010
21	Manufacture of electronics equip	78	125	15	0	37	59	7	0	81	128	16	0	0.1218	0.0010
22	Manufacture of instruments	0	14	0	0	0	7	0	0	0	14	0	0	0.0000	0.0000
23	Maintenance and repair of machinery	72	77	0	0	26	27	0	0	72	77	0	0	0.0000	0.0000
24	Industries not elsewhere classified	29	69	0	0	21	40	0	0	29	69	0	0	0.0000	0.0000
25	Construction	681	681	17	0	321	321	8	0	681	681	17	0	0.0250	0.0002
26	Freight transport and communication	138	292	122	1	49	122	51	0	138	292	121	1	0.4161	0.0029
27	Commerce	96	347	32	0	34	155	14	0	96	347	32	0	0.0921	0.0007
28	Restaurants	79	79	7	0	44	44	4	0	79	79	7	0	0.0921	0.0007
29	Passenger transport	46	78	9	0	16	29	3	0	46	78	9	0	0.1135	0.0009
30	Public utilities and services to house	244	305	26	0	86	110	10	0	244	305	26	0	0.0864	0.0007
31	Cultural, education and health services	518	620	54	0	183	226	20	0	518	620	54	0	0.0864	0.0007
32	Finance and insurance	6	161	14	0	2	75	6	0	6	161	14	0	0.0864	0.0007
33	Public administration	212	212	18	0	75	75	6	0	212	212	18	0	0.0864	0.0007
	Total	4,704	9,247	3,485	27	2,080	4,240	1,820	13	4,707	9,247	3,169	24		

Final Demand and Gross Output in billions of 1990 Yuans

Final Demand(GDP) Growth Rate
1990-2000 8.51%

CO2 Emission Reduction
1990-2000 9.07%

TABLE 45 Simulation Results: China DLP Model 3-U (1990-2000), with Constraint

		BASELINE 2000				DLP 1990				DLP 2000				CO2 COEFFICIENT	SO2 COEFFICIENT
		Final Demand	Gross Output	CO2 (MIL TON)	SO2 (MIL TON)	Final Demand	Gross Output	CO2 (MIL TON)	SO2 (MIL TON)	Final Demand	Gross Output	CO2 (MIL TON)	SO2 (MIL TON)	(TON/THO YUAN)	(TON/THO YUAN)
1	Agriculture	1,387	2,171	121	1	491	879	49	0	1,387	2,269	128	1	0.0557	0.0004
2	Coal mining	31	108	352	3	11	47	153	1	31	99	321	3	3.2568	0.0265
3	Crude petroleum & natural gas prod	25	109	23	0	9	46	10	0	25	125	27	0	0.2141	0.0005
4	Metal ore mining	0	28	0	0	0	14	0	0	0	29	0	0	0.0000	0.0000
5	Other mining	0	67	0	0	0	31	0	0	0	78	0	0	0.0000	0.0000
6	Food manufacturing	346	561	115	1	245	353	72	1	346	586	120	1	0.2045	0.0017
7	Manufacture of textiles	168	502	81	1	79	237	38	0	168	525	85	1	0.1615	0.0013
8	Manufacture of apparel	98	135	0	0	46	63	0	0	98	141	0	0	0.0000	0.0000
9	Sawmills and manufacture of furniture	12	65	0	0	6	34	0	0	12	68	0	0	0.0000	0.0000
10	Manufacture of paper and educ material	42	233	65	1	30	116	32	0	42	244	68	1	0.2799	0.0023
11	Electricity, steam and hot water prod	19	142	1,105	9	7	64	499	4	19	148	874	7	5.9237	0.0480
12	Petroleum refineries	7	141	92	0	2	61	40	0	7	140	91	0	0.6523	0.0008
13	Coking, manufacture of gas & coal	5	18	154	1	2	9	77	1	5	19	161	1	8.4178	0.0686
14	Chemical industries	36	616	342	3	25	287	159	1	36	644	357	3	0.5543	0.0042
15	Manufacture of building materials	6	250	355	3	2	117	166	1	6	262	371	3	1.4199	0.0115
16	Primary metal manufacturing	0	311	266	2	0	161	137	1	0	325	278	2	0.8542	0.0069
17	Manufacture of metal products	32	148	29	0	23	78	15	0	32	154	30	0	0.1941	0.0016
18	Manufacture of machinery	174	331	40	0	123	203	25	0	174	346	42	0	0.1218	0.0010
19	Manufacture of transport equipment	46	92	11	0	32	54	7	0	46	97	12	0	0.1218	0.0010
20	Manufacture of electric machinery	69	159	19	0	48	94	11	0	68	166	20	0	0.1218	0.0010
21	Manufacture of electronics equip	78	125	15	0	37	59	7	0	81	134	16	0	0.1218	0.0010
22	Manufacture of instruments	0	14	0	0	0	7	0	0	0	15	0	0	0.0000	0.0000
23	Maintenance and repair of machinery	72	77	0	0	26	27	0	0	72	81	0	0	0.0000	0.0000
24	Industries not elsewhere classified	29	69	0	0	21	40	0	0	29	72	0	0	0.0000	0.0000
25	Construction	681	681	17	0	321	321	8	0	681	711	18	0	0.0250	0.0002
26	Freight transport and communication	138	292	122	1	49	122	51	0	138	305	127	1	0.4161	0.0029
27	Commerce	96	347	32	0	34	155	14	0	96	362	33	0	0.0921	0.0007
28	Restaurants	79	79	7	0	44	44	4	0	79	82	8	0	0.0921	0.0007
29	Passenger transport	46	78	9	0	16	29	3	0	46	81	9	0	0.1135	0.0009
30	Public utilities and services to house	244	305	26	0	86	110	10	0	244	318	27	0	0.0864	0.0007
31	Cultural, education and health services	518	620	54	0	183	226	20	0	518	648	56	0	0.0864	0.0007
32	Finance and insurance	6	161	14	0	2	75	6	0	6	168	15	0	0.0864	0.0007
33	Public administration	212	212	18	0	75	75	6	0	212	222	19	0	0.0864	0.0007
	Total	4,704	9,247	3,485	27	2,080	4,240	1,620	13	4,706	9,661	3,311	26		

Final Demand and Gross Output in billions of 1990 Yuans

Final Demand(GDP) Growth Rate
1990-2000 8.51%

CO2 Emission Reduction
1990-2000 5.00%

6.2.4 Strategy 4: Interfuel Substitution with Technological Advances

The technological advances (change) strategy combines three phenomena: (1) changes in the overall energy/GDP ratio; (2) electrification or, more specifically in the case of China, displacement of coal by electricity for a range of uses in industry; and (3) AEEI.[16] The parameters associated with each of these considerations are those developed in Section 5 and are reproduced in Table 46.

It is assumed that no change in the energy/GDP ratio in China will occur over the next 30 years because of offsetting forces, quite apart from autonomous conservation. This study also assumes no cost penalty for the various technological changes because of factors noted in conjunction with Strategy 3. In electrification, large central power stations can generate electricity (for power, heat, etc.) at much less cost than numerous small-scale operations in industry.

Table 47 presents the results of simulating Strategy 3 without limiting CO_2 emission reductions to 5% in the year 2000. The average rate of growth and GNP is projected to be 8.59% as a result of this strategy. This fact highlights that electrification and autonomous conservation have substitution and multiplier effects that actually stimulate the economy. Moreover, the technological change strategy reduces CO_2 by 30.59% from the year 2000 baseline projections.

TABLE 46 Percentage of Technological Change in Energy Use: Upper-Bound Parameters

Parameter	1990-2000	2000-2010	2010-2025
Electricity/GDP ratio			
Annual average	0	0	0
Period total	0	0	0
Displacement of coal[a]			
Annual average	0.96	5.40	1.22
Period total	10.00	70.00	20.00
Autonomous conservation[b]			
Annual average	2.50	1.50	1.00
Period total	28.01	16.05	10.46

[a] Applies to all sectors, except fabricated metals and electricity services.

[b] Applies to all sectors, except electricity services.

[16] A similar concept was considered in mandated, or autonomous, conservation in Strategy 2.

TABLE 47 Simulation Results: China DLP Model 4-U (1990-2000), with Constraint

		Baseline 2000				DLP 1990				DLP 2000				CO2	SO2
		Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	COEFFICIENT (ton/tho Yuan)	COEFFICIENT (ton/tho Yuan)
1	Agriculture	1,387	2,171	121	1	491	879	49	0	1,378	2,981	109	1	0.0366	0.0003
2	Coal mining	31	108	352	3	11	47	153	1	31	112	241	2	2.1546	0.0176
3	Crude petroleum & natural gas prod	25	109	23	0	9	48	10	0	25	108	16	0	0.1515	0.0003
4	Metal ore mining	0	28	0	0	0	14	0	0	0	41	0	0	0.0000	0.0000
5	Other mining	0	67	0	0	0	31	0	0	0	93	0	0	0.0000	0.0000
6	Food manufacturing	346	561	115	1	245	353	72	1	343	771	102	1	0.1328	0.0011
7	Manufacture of textiles	168	502	81	1	79	237	38	0	166	695	73	1	0.1049	0.0008
8	Manufacture of apparel	98	135	0	0	46	63	0	0	98	185	0	0	0.0000	0.0000
9	Sawmills and manufacture of furniture	12	65	0	0	8	34	0	0	12	91	0	0	0.0000	0.0000
10	Manufacture of paper and educ material	42	233	65	1	30	116	32	0	42	323	59	0	0.1825	0.0015
11	Electricity, steam and hot water prod	19	142	1,105	9	7	64	499	4	19	165	1,199	10	7.2834	0.0589
12	Petroleum refineries	7	141	92	0	2	61	40	0	7	144	77	0	0.5331	0.0006
13	Coking, manufacture of gas & coal	5	18	154	1	2	9	77	1	5	21	122	1	5.8870	0.0480
14	Chemical industries	36	616	342	3	25	287	159	1	38	863	319	2	0.3696	0.0028
15	Manufacture of building materials	6	250	355	3	2	117	166	1	6	347	330	3	0.9506	0.0077
16	Primary metal manufacturing	0	311	266	2	0	161	137	1	0	442	281	2	0.6363	0.0051
17	Manufacture of metal products	32	148	29	0	23	78	15	0	32	204	26	0	0.1273	0.0010
18	Manufacture of machinery	174	331	40	0	123	203	25	0	173	460	37	0	0.0797	0.0006
19	Manufacture of transport equipment	46	92	11	0	32	54	7	0	91	199	16	0	0.0795	0.0006
20	Manufacture of electric machinery	69	159	19	0	48	94	11	0	68	219	17	0	0.0796	0.0006
21	Manufacture of electronics equip	78	125	15	0	37	59	7	0	71	159	13	0	0.0793	0.0006
22	Manufacture of instruments	0	14	0	0	0	7	0	0	0	20	0	0	0.0000	0.0000
23	Maintenance and repair of machinery	72	77	0	0	28	27	0	0	72	106	0	0	0.0000	0.0000
24	Industries not elsewhere classified	29	69	0	0	21	40	0	0	29	96	0	0	0.0000	0.0000
25	Construction	681	681	17	0	321	321	8	0	675	932	15	0	0.0166	0.0001
26	Freight transport and communication	138	292	122	1	49	122	51	0	137	402	114	1	0.2842	0.0020
27	Commerce	96	347	32	0	34	155	14	0	95	481	29	0	0.0601	0.0005
28	Restaurants	79	79	7	0	44	44	4	0	78	108	6	0	0.0600	0.0005
29	Passenger transport	46	78	9	0	16	29	3	0	46	107	8	0	0.0766	0.0006
30	Public utilities and services to house	244	305	26	0	86	110	10	0	242	418	24	0	0.0570	0.0004
31	Cultural, education and health services	518	620	54	0	183	226	20	0	514	851	48	0	0.0569	0.0004
32	Finance and Insurance	6	161	14	0	2	75	6	0	6	224	13	0	0.0564	0.0004
33	Public administration	212	212	18	0	75	75	6	0	211	291	17	0	0.0569	0.0004
	Total	4,704	9,247	3,485	27	2,080	4,240	1,620	13	4,710	12,656	3,311	26		

Final Demand and Gross Output in billions of 1990 Yuans

Final Demand(GDP) Growth Rate
1990-2000 8.52%

CO2 Emission Reduction
1990-2000 5.00%

Table 48 presents the results of the strategy simulation with constraint. As in Strategy 3, the minimal CO_2 emission reduction target is easily attained and allows the economy to adjust its output mix accordingly to maximize the GDP. In fact, the gross output of every sector is higher than the baseline.

6.2.5 Strategy 5: Combination of Strategies

The modest CO_2 reduction target of 5.0% in the year 2000 can be attained by any of the first four strategies. A combination of strategies 1-4 is not required, although this option is available. However, it would also appear that the vastly superior option is Strategy 4, which can attain higher CO_2 (and SO_x) emission reductions than the other strategies and still increase the rate of economic growth.

6.2.6 Summary

Table 49 summarizes the results of this section. On the basis of relatively optimistic economic and technical assumptions, the modest CO_2 reduction requirement of 5% for the year 2000 is readily attainable by each of the four major strategies. Moreover, only the sectoral mix in mandated conservation strategies imposes any penalties, and these are relatively modest. Moreover, the CO_2 reduction efforts also yield approximately equivalent reductions in SO_2.[17]

6.3 SIMULATIONS FOR 2010 AND 2025: UPPER-BOUND CASE

6.3.1 Year 2010

Table 50 summarizes the results of simulating the five strategies. First, the effective emission reduction requirement increases significantly in 2010 (i.e., 57.30%). This result is a combination of the fact that (1) baseline CO_2 emissions increase by 7.5% per year (the same growth rate as the GDP) between 2000 and 2010 and (2) the compliance rate jumps from 25 to 60% of the target cap of 2.788 billion tons of CO_2 (Table 38).

These results differ from those for the year 2000 in several ways. First, none of the singular strategies (1-4) can meet the 57.30% CO_2 mitigation target, except Strategy 1 (when fewer constraints on the final demand are imposed). Because these strategies cannot meet the CO_2 constraint, they are labeled as "infeasible." Table 50 indicates that the *maximum* achievable CO_2 reductions are 35.23, 8.62, and 53.19% for strategies 2, 3, and 4, respectively. The interfuel substitution strategy (Strategy 3) is especially limited for the year 2000 because

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[17] This result is true of all major air pollutants discussed in Section 5, although CH_4 emissions increase, given the sizable gas utilization associated with Strategy 3.

TABLE 48 Simulation Results: China DLP Model 3-U (1990-2000), with Constraint

		Baseline 2000				DLP 1990				DLP 2000				CO2 COEFFICIENT	SO2 COEFFICIENT
		Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	(ton/tho Yuan)	(ton/tho Yuan)
1	Agriculture	1,387	2,171	121	1	491	879	49	0	1,387	2,178	80	1	0.0366	0.0003
2	Coal mining	31	108	352	3	11	47	153	1	31	82	176	1	2.1546	0.0176
3	Crude petroleum & natural gas prod	25	109	23	0	9	46	10	0	25	79	12	0	0.1515	0.0003
4	Metal ore mining	0	28	0	0	0	14	0	0	0	30	0	0	0.0000	0.0000
5	Other mining	0	67	0	0	0	31	0	0	0	68	0	0	0.0000	0.0000
6	Food manufacturing	346	561	115	1	245	353	72	1	346	563	75	1	0.1328	0.0011
7	Manufacture of textiles	168	502	81	1	79	237	38	0	168	507	53	0	0.1049	0.0008
8	Manufacture of apparel	98	135	0	0	46	63	0	0	98	135	0	0	0.0000	0.0000
9	Sawmills and manufacture of furniture	12	65	0	0	8	34	0	0	12	66	0	0	0.0000	0.0000
10	Manufacture of paper and educ material	42	233	65	1	30	116	32	0	42	236	43	0	0.1825	0.0015
11	Electricity, steam and hot water prod	19	142	1,105	9	7	64	499	4	19	120	876	7	7.2834	0.0589
12	Petroleum refineries	7	141	92	0	2	61	40	0	7	105	56	0	0.5331	0.0006
13	Coking, manufacture of gas & coal	5	18	154	1	2	9	77	1	5	15	89	1	5.8870	0.0480
14	Chemical industries	36	816	342	3	25	287	159	1	36	630	233	2	0.3696	0.0028
15	Manufacture of building materials	6	250	355	3	2	117	166	1	6	253	241	2	0.9506	0.0077
16	Primary metal manufacturing	0	311	266	2	0	161	137	1	0	323	206	2	0.6363	0.0051
17	Manufacture of metal products	32	148	29	0	23	78	15	0	32	149	19	0	0.1273	0.0010
18	Manufacture of machinery	174	331	40	0	123	203	25	0	174	336	27	0	0.0797	0.0006
19	Manufacture of transport equipment	46	92	11	0	32	54	7	0	91	146	12	0	0.0795	0.0006
20	Manufacture of electric machinery	69	159	19	0	48	94	11	0	69	160	13	0	0.0796	0.0006
21	Manufacture of electronics equip	78	125	15	0	37	59	7	0	71	116	9	0	0.0793	0.0006
22	Manufacture of instruments	0	14	0	0	0	7	0	0	0	15	0	0	0.0000	0.0000
23	Maintenance and repair of machinery	72	77	0	0	26	27	0	0	72	77	0	0	0.0000	0.0000
24	Industries not elsewhere classified	29	69	0	0	21	40	0	0	29	70	0	0	0.0000	0.0000
25	Construction	681	681	17	0	321	321	8	0	681	681	11	0	0.0166	0.0001
26	Freight transport and communication	138	292	122	1	49	122	51	0	138	294	84	1	0.2842	0.0020
27	Commerce	96	347	32	0	34	155	14	0	96	351	21	0	0.0601	0.0005
28	Restaurants	79	79	7	0	44	44	4	0	79	79	5	0	0.0600	0.0005
29	Passenger transport	46	78	9	0	16	29	3	0	46	78	6	0	0.0766	0.0006
30	Public utilities and services to house	244	305	26	0	86	110	10	0	244	305	17	0	0.0570	0.0004
31	Cultural, education and health services	518	620	54	0	183	226	20	0	518	622	35	0	0.0569	0.0004
32	Finance and insurance	6	161	14	0	2	75	6	0	6	164	9	0	0.0564	0.0004
33	Public administration	212	212	18	0	75	75	6	0	212	212	12	0	0.0569	0.0004
	Total	4,704	9,247	3,485	27	2,080	4,240	1,620	13	4,743	9,247	2,419	19		

Final Demand and Gross Output in billions of 1990 Yuans

Final Demand(GDP) Growth Rate
1990-2000 8.59%

CO2 Emission Reduction
1990-2000 30.59%

TABLE 49 Summary of Simulation Results, Year 2000: Upper-Bound Case[a]

Simulation	GNP Growth (%)	CO_2 Emission Reduction (%)	SO_2 Emission Reduction (%)
Baseline	8.50	NA[b]	NA
Change in sectoral mix			
With constraint[c,d]	8.46	5.00	5.09
Without constraint[e]	NA	NA	NA
Mandated conservation			
With constraint[d]	8.49	5.00	4.82
Without constraint[d]	8.46	25.78[f]	24.83
Interfuel substitution			
With constraint[d]	8.51	5.00	5.20
Without constraint[d]	8.51	9.07[f]	9.43
Technological change			
With constraint[d]	8.52	5.00	4.98
Without constraint[d]	8.59	30.59[f]	30.47
Combination[g]	NA	NA	NA

[a] CO_2 reduction target: 20% of year 2000 baseline emissions, but only 25% compliance, which translates into 5% of year 2000 emissions.

[b] NA = not applicable.

[c] Constraint that sets limits on changes in sectoral output levels.

[d] Constraint that requires CO_2 emissions be reduced by 5% of year 2000 baseline.

[e] Loosens constraint on sectoral output levels (see text).

[f] Represents maximum achievable reduction.

[g] Abatement target can be achieved by every other strategy; hence, examination of a combination of strategies is redundant.

TABLE 50 Summary of Simulation Results, Year 2010: Upper-Bound Case[a]

Simulation	GNP Growth (%)	CO_2 Emission Reduction (%)	SO_2 Emission Reduction (%)
Baseline	7.50	NA[b]	NA
Change in sectoral mix			
With constraint[c,d]	Infeasible	NA	NA
Without constraint[d,e]	2.89	57.30	58.33
Mandated conservation			
With constraint[d]	Infeasible	NA	NA
Without constraint[d]	7.49	35.23[f]	35.02
Interfuel substitution			
With constraint[d]	Infeasible	NA	NA
Without constraint[d]	7.50	8.62[f]	9.09
Technological change			
With constraint[d]	Infeasible	NA	NA
Without constraint[d]	7.50	53.19[f]	53.74
Combination[d]	7.50	57.30	57.89

[a] CO_2 reduction target: 20% of year 2000 baseline emissions, but only 60% compliance, which translates into 57.30% of year 2010 emissions.

[b] NA = not applicable.

[c] Constraint that sets limits on changes in sectoral output levels.

[d] Constraint that requires CO_2 emissions be reduced by 57.30% of year 2010 baseline.

[e] Loosens constraint on sectoral output levels.

[f] Represents maximum achievable reduction.

of the upper bounds included for the available nuclear power (Table 42). In general, strategies are infeasible because of limits in technology and reserves of energy alternatives to coal.

A combination of strategies can attain the 57.30% level because all are mutually exclusive.[18] What might a combination of strategies entail? Economic principles suggest that, for a single constraint, decision-makers will exhaust each option in sequence, beginning with the least-cost one and progressing to others also in the least-cost sequence. This principle is illustrated in Figures 3 and 4, which are stylized depictions of the other strategies in terms of constant costs and positioning. Figure 3 represents the direct response in terms of costs at the sectoral level. Conservation is often considered costless or cost-saving, even though if mandated levels are high enough, this would not be the case. Interfuel substitution involves some costs, and technological change often is viewed as costly because it requires new equipment. Strategy 2 (change in the product mix) is not included in Figure 3 because it is not an individual sectoral response.

Interestingly, the positioning of these strategies changes when one considers macro impacts, as indicated by the relative increases or decreases in GDP growth rates (Table 50; these are more dramatically differentiated in Table 51). In this case, technological change is growth enhancing, interfuel substitution growth neutral, and mandated conservation growth dampening. The change in the sectoral mix strategy can be included in the macro-level case and is also growth dampening.

Figures 3 and 4 can also represent the reaction to both externally imposed reduction requirements ("command-and-control" or standards) or the adjustment to a carbon tax.[19] The carbon tax would be displayed in Figure 3 as a horizontal line positioned on the vertical axis at a given tax level. The adjustment to the tax is usually analyzed at the micro level, but this report performed a macro analysis, which is more comprehensive. The analysis reveals a positioning of individual strategies that may differ (Rose and Lin 1994). These factors have been taken into account.

Strategy 5 (the combination strategy) for 2010 uses Strategy 4 to its limit and then uses a portion of Strategy 3 to make up the difference between 53.19% CO_2 mitigation and 57.30%. The results indicate that the combination of strategies can reduce CO_2 emissions without decreasing economic growth (see the last row in Table 50). Strategy 1 could have attained the 57.30% emission reduction target, but only at a substantial decrease in economic growth to a level of 2.89%.

Individual sectoral responses in terms of gross output, final demand, CO_2 emissions, and SO_x emissions are displayed in Table 38.

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[18] The one exception is mandated conservation (Strategy 2) and AEEIs (Strategy 4) that overlap so much; therefore, Strategy 2 is eliminated from consideration in the combined case.

[19] Pezzey (1990) and Rose et al. (1994) have indicated how response to an international system of marketable permits would be equivalent to that of a carbon tax.

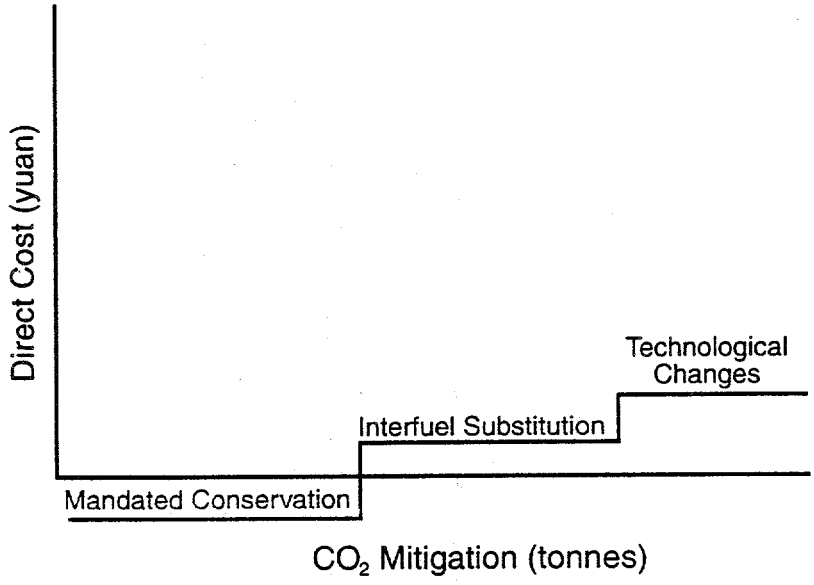

FIGURE 3 Micro Marginal Cost of Strategies

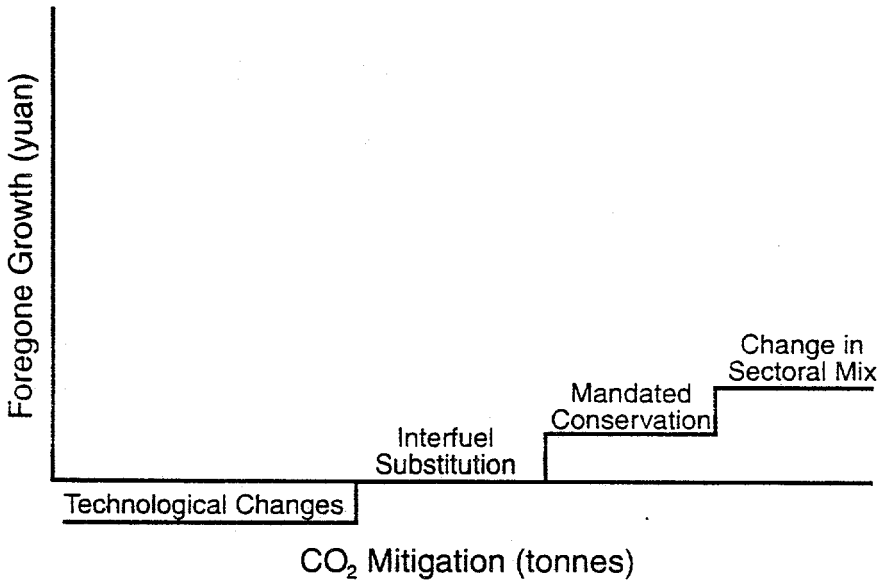

FIGURE 4 Macro Marginal Cost of Strategies

TABLE 51 Summary of Simulation Results, Year 2025: Upper-Bound Case[a]

Simulation	GNP Growth (%)	CO_2 Emission Reduction (%)	SO_2 Emission Reduction (%)
Baseline	6.50	NA[b]	NA
Change in sectoral mix			
With constraint[c,d]	Infeasible	NA	NA
Without constraint[d,e]	Infeasible	NA	NA
Mandated conservation			
With constraint[d]	Infeasible	NA	NA
Without constraint[d]	6.49	43.31[f]	43.47
Interfuel substitution			
With constraint[d]	Infeasible	NA	NA
Without constraint[d]	6.50	31.07[f]	32.91
Technological change			
With constraint[d]	Infeasible	NA	NA
Without constraint[d]	6.51	62.86[f]	63.93
Combination[d,g]	6.51	84.91	86.36

[a] CO_2 reduction target: 20% of year 2000 baseline emissions and with 100% compliance; translates into 84.91% of year 2025 emissions.

[b] NA = not applicable.

[c] Constraint that sets limits on changes in sectoral output levels.

[d] Constraint that requires CO_2 emissions be reduced by 84.91% of year 2025 baseline.

[e] Loosens constraint on sectoral output levels.

[f] Represents maximum achievable reduction.

[g] Loosens constraint on sectoral output slightly (see text).

6.3.2 Year 2025

Table 51 presents the results of the upper-bound simulations for 2025. An 84.91% reduction of the gross flow of year 2025 CO_2 emissions is required, which is a Herculean task. In fact, none of the strategies is solely capable of meeting the reduction requirement. However, the technological change strategy, together with either the interfuel substitution or mandated conservation strategy, could attain it with little economic penalty. A simulation of a combination of the first two strategies showed that the results are slightly growth enhancing (see the last row in Table 51).

Although the technological change strategy is somewhat more speculative than the others, it becomes less so over time. That is, 30 years should be sufficient for it to be likely to discover major new natural gas deposits, improve combustion efficiency, and reduce the cost and improve the safety features of nuclear power plants.

6.4 SIMULATIONS FOR 2000, 2010, AND 2025: LOWER-BOUND CASE

Simulations for the five strategies were performed with the pessimistic, or lower-bound, parameters described in Sections 4 and 5. The major economic parameters are given in Table 37, while the technical parameters are repeated in Tables 52, 53, and 54. The major difference in the economic parameters for the lower-bound cases was a GDP growth rate 1-2% lower than the optimistic or upper-bound cases. The lower-bound technical parameters call for a natural gas and nuclear potential about 50% of the upper-bound values, a displacement of coal by electricity to have a saturation level of 70% rather than 100%, a greater than 1% increase in the electricity/GDP ratio, and an AEEI 0.5-1.0% lower than the upper-bound values.

6.4.1 Year 2000

Qualitatively, the lower-bound results for the year 2000 are the same as the upper-bound cases (compare Tables 55 and 49). The 5% CO_2 reduction target can be met with only a very slight reduction in the GDP growth, if any. In fact, Strategy 4 increases the rate of economic growth. The results for mandated conservation are essentially the same (reduction) between upper- and lower-bound cases because they both simulate a direct 20% reduction in energy use. Strategy 4 (technological change) yields only slightly more than half of the reduction in CO_2 than its upper-bound counterpart. Also, reductions in SO_2 are very close to the CO_2 reduction levels attained.

6.4.2 Year 2010

Qualitatively, the results for 2010 are essentially the same as the upper-bound cases (compare Tables 56 and 50). It is worth noting that, in this case, interfuel substitution

TABLE 52 Potential for Clean Fuels in Electricity Generation: Lower-Bound Parameters

No.	Parameter	1990	2000	2010	2025
1.	Lower-bound baseline electricity demand (billion 1990 yuan)	65.146	142.000	292.000	750.000
2a.	Hydropower potential (billion 1990 yuan)	13.051	22.067	37.341	82.289
2b.	Nuclear power potential (billion 1990 yuan)	0.191	1.440	10.863	225.000
2c.	Gas-fired electricity potential (billion 1990 yuan)	0.268	66.963	62.075	47.067
3.	Total 2a-2c baseline demand (%)	20.740	63.710	33.770	47.320
4.	CO_2 reduction requirement (%)	NA[a]	5.000	40.500	65.210
5.	Maximum CO_2 reduction attainable with clean fuels in electricity generation (%)	NA	20.130	5.480	28.340

[a] NA = not applicable.

TABLE 53 Percentage of Electricity Sector Fuel Mix: Lower-Bound Values

Fuel	1990	2000	2010	2025
Coal	70.27	32.99	60.63	52.05
Oil	7.30	3.30	1.60	0.70
Natural gas	0.91	47.16	21.26	6.28
Other (hydro and nuclear)	20.03	16.55	16.51	40.97

TABLE 54 Percentage of Technological Change in Energy Use: Lower-Bound Parameters

Parameter	1990-2000	2000-2010	2010-2025
Electricity/GDP ratio			
Annual average	1.70	1.50	1.30
Period total	18.36	16.05	21.38
Displacement of coal[a]			
Annual average	0.96	3.42	1.22
Period total	10.00	40.00	20.00
Autonomous conservation[b]			
Annual average	1.50	1.00	0.50
Period total	16.05	10.46	7.77

[a] Applies to all sectors, except fabricated metals and electricity services.

[b] Applies to all sectors, except electricity services.

possibilities are much more limited and yield less than a 2% maximum reduction in CO_2. Also, Strategy 5 cannot be attained by strategies 3 and 4 alone, as in the upper-bound case. Strategy 1 must be used to attain the last 8.60% (40.5% - 30.01% + 1.89%). This decreases economic growth to 3.91%.

6.4.3 Year 2025

Qualitatively, the results for 2025 are similar to the corresponding upper-bound cases (compare Tables 57 and 51). However, the growth penalty for Strategy 1 is enormous, and it calls for a 3.92% reduction in GDP growth between 2010 and 2025.

Again, a combination of strategies 3 and 4 cannot achieve the CO_2 reduction target of 65.21%. Thus, there is reason to simulate Strategy 5. Strategy 2 (mandated conservation), is excluded from consideration in the mixed strategy because it would be extremely costly (if not impossible) to implement this strategy. The strategy calls for 10% conservation from 2010 to 2025 in addition to 30% between 1990 and 2010, along with an AEEI of 7.77% for the period in addition to a cumulative AEEI of 26.51% between 1990 and 2010 (Table 54). The 7.39% reduction in CO_2 attainable by Strategy 3 plus the 34.92% reduction attainable by Strategy 4 still leaves the country 23% short of the 65.31% emission reduction target. Accessing the change in sectoral mix strategy is extremely costly, which reduces economic growth for Strategy 5 to 0.85%.

TABLE 55 Summary of Simulation Results, Year 2000: Lower-Bound Case[a]

Simulation	GNP Growth (%)	CO_2 Emission Reduction (%)	SO_2 Emission Reduction (%)
Baseline	6.00	NA[b]	NA
Change in sectoral mix			
With constraint[c,d]	5.96	5.00	5.15
Without constraint[e]	NA	NA	NA
Mandated conservation			
With constraint[d]	5.99	5.00	4.96
Without constraint[d]	5.96	25.78[f]	25.58
Interfuel substitution			
With constraint[d]	6.00	5.00	5.23
Without constraint[d]	6.00	7.62[f]	7.97
Technological change			
With constraint[d]	6.01	5.00	4.97
Without constraint[d]	6.03	15.54[f]	15.46
Combination[g]	NA	NA	NA

[a] CO_2 reduction target: 20% of year 2000 baseline emissions, but only 25% compliance; translates into 5% of year 2000 emissions.

[b] NA = not applicable.

[c] Constraint that sets limits on changes in sectoral output levels.

[d] Constraint that requires CO_2 emissions be reduced by 5% of year 2000 baseline.

[e] Loosens constraint on sectoral output levels.

[f] Represents maximum achievable reduction.

[g] Abatement target can be achieved by every other strategy; hence, examination of a combination of strategies is redundant.

TABLE 56 Summary of Simulation Results, Year 2010: Lower-Bound Case[a]

Simulation	GNP Growth (%)	CO_2 Emission Reduction (%)	SO_2 Emission Reduction (%)
Baseline	4.00	NA[b]	NA
Change in sectoral mix			
With constraint[c,d]	Infeasible	NA	NA
Without constraint[d,e]	3.52	40.50	41.72
Mandated conservation			
With constraint[d]	Infeasible	NA	NA
Without constraint[d]	3.99	35.23[f]	35.02
Interfuel substitution			
With constraint[d]	Infeasible	NA	NA
Without constraint[d]	4.00	1.89[f]	1.87
Technological change			
With constraint[d]	Infeasible	NA	NA
Without constraint[d]	3.99	30.01[f]	30.36
Combination[d]	3.91	40.50	40.97

[a] CO_2 reduction target: 20% of year 2000 baseline emissions, but only 60% compliance; translates into 40.50% of year 2010 baseline emissions.

[b] NA = not applicable.

[c] Constraint that sets limits on changes in sectoral output levels.

[d] Constraint that requires CO_2 emissions be reduced by 40.50% of year 2010 baseline.

[e] Loosens constraint on sectoral output levels.

[f] Represents maximum achievable reduction.

TABLE 57 Summary of Simulation Results, Year 2025: Lower-Bound Case[a]

Simulation	GNP Growth (%)	CO_2 Emission Reduction (%)	SO_2 Emission Reduction (%)
Baseline	3.00	NA[b]	NA
Change in sectoral mix			
With constraint[c,d]	Infeasible	NA	NA
Without constraint[d,e]	-3.92	65.31	67.27
Mandated conservation			
With constraint[d]	Infeasible	NA	NA
Without constraint[d]	3.00	43.15[f]	43.07
Interfuel substitution			
With constraint[d]	Infeasible	NA	NA
Without constraint[d]	2.99	34.92[f]	35.37
Technological change			
With constraint[d]	0.85	65.31	65.82
Without constraint[d]	6.51	62.86[f]	63.93
Combination[d]	6.51	84.91	86.36

[a] CO_2 reduction target: 20% of year 2000 baseline emissions and with 100% compliance; translates into 65.31% of year 2025 emissions.

[b] NA = not applicable.

[c] Constraint that sets limits on changes in sectoral output levels.

[d] Constraint that requires CO_2 emissions be reduced by 65.31% of year 2025 baseline.

[e] Loosens constraint on sectoral output levels.

[f] Represents maximum achievable reduction.

6.5 INVESTMENT ANALYSIS

Section 4 shows that this model lacks a sophisticated investment equation. This limitation is potentially important and could significantly reduce the accuracy of the results. However, this limitation is not a major factor. It is estimated that investment requirements for the CO_2 mitigation strategies simulated in this section are very small.

Moreover, several studies foresee, and many policymakers pronounce, that industrialized countries will assist China in mitigating CO_2. Examples include redistribution of international carbon tax revenues, revenues from selling marketable permits, or technology transfers associated with joint implementation.

The computations used in the investment analysis are provided on separate spreadsheets found in Appendix B. This investment analysis uses three major constructs. First is a capital cost factor for electricity generation and transmission for power plants of various types (Table B.1 in Appendix B), as well as an investment factor for exploring and producing the associated fuels (Table B.2 in Appendix B). Second are baseline projections of electricity demand (Tables 14 and 15). Third are projections of electricity demand associated with two major strategies (Tables 47, 48, 53, and 54). Only an investment analysis is conducted for the upper-bound cases, as defined in Sections 4-6. However, these cases are likely to be upper-bound cases in terms of investment requirements.

This investment cost analysis begins with multiplying the cost factors by two types of electricity demand projections — baseline and mitigation strategy. The investment ascribed to a given strategy is the difference between these projections, i.e., the *incremental* investment.[20] One of the reasons that the investment estimates are so low is that China's economy is projected to undergo continual high growth over the forecast period. This growth signals the need for significant investment in electricity generation, even in the absence of any efforts to curb CO_2 emissions. Some key summary data are presented in Table 58 and in Appendix B.

The results for Strategy 3 (interfuel substitution) are presented in Table 58. The switch toward natural gas and nuclear power requires more investment for power plants that use these fuels and a reduction in investment for the other three kinds of power plants in each of the three simulation periods, though to varying degrees. Negative investment implies that, as the amount of a particular fuel used decreases, less money is needed for replacing and expanding investment than is needed in the baseline case. The same is true for the fuel cost, though to varying degrees. Thus, large investments per unit of capacity for nuclear power plants also go hand in hand with relatively small increases in investment on the fuel side. These two aspects for all fuels taken together lead to an estimate of negative gross investment associated with Strategy 3 for all three time periods.

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[20] The baseline electricity projections use fixed fuel proportions, fixed electricity-generating technology, and fixed combustion efficiency between 2000 and 2025.

TABLE 58 Gross Investment for CO_2 Mitigation: Interfuel Substitution and Technological Change Strategies (billions of 1990 dollars)

Strategy/Investment	Per Year 1990-2000	Per Year 2000-2010	Per Year 2010-2025
Interfuel Substitution			
Generation transmission	-8.3[a]	-7.4	38.8
Exploration production	5.4	0.1	-72.2
Total	-2.9	-7.3	-33.4
Technological Change			
Generation transmission	-6.1	-19.5	22.0
Exploration production	08.1	-27.7	-75.2
Total	-14.2	-8.2	-53.2

[a] Negative numbers indicate savings with respect to baseline case (see text).

For Strategy 4 (technological change), investment reflects the cost of added electricity capacity to support the displacement of coal (Table 22). However, strongly offsetting this investment are conservation and improvements in combustion efficiency. Although the investment requirements in power generation/transmission are positive for the last two time periods (2000-2010 and 2010-2025), the fuel cost savings are substantially greater, especially for oil.[21]

Even without fuel cost savings, if plant construction estimates are analyzed, a maximum of $38.8 billion is needed during any given year. This figure amounts to less than 2% of the GDP in 2010 and 1.5% of the GDP in 2025.[22]

The investment burden is also eased because China is a growing economy. The strategy presented in this report calls for a slow phase-in of nuclear power before 2010 and a moderate phase-in of natural gas between 1990 and 2000. In most cases, power plants do not have to be scrapped or retrofitted; rather, the "substitution" comes through expansion investment in electricity capacity that would have been required anyway. Overall, the investment burden for mitigating CO_2 is less costly in growing economies.

Also, China is likely to receive assistance in meeting CO_2 mitigation commitments associated with an international agreement on global warming. Currently, policymakers are exploring opportunities for joint implementation, with its emphasis on technology transfer

[21] This fact overlooks some of the other benefits of using less oil, such as managing foreign exchange.

[22] Cost savings associated with relieving China of constructing industrial boilers and other sector-specific coal-burning equipment displaced by electricity have been omitted in the technological change strategy.

from industrialized to developing countries. Joint implementation generalizes to an international market in CO_2 permits, or entitlements. Estimates by Barrett et al. (1992), Rose and Stevens (1993), and others range in the billions, if not tens of billions, of dollars per year for revenues that China is likely to receive for selling some of its permit stock. Similar size transfers are envisioned if carbon tax revenues are redistributed (Manne and Richels 1992).

However, there is still a potentially important opportunity cost associated with some of the strategies simulated — the fact that China's vast coal resources will not be used (unless some inexpensive way is found to scrub the CO_2 out of coal gases). On the lower-bound side, some penalty might be calculated for the cost differential between coal and other fuels (although this penalty is likely to be very small when capital and fuel costs are combined). On the upper-bound side, a loss in the asset value of coal not burned might be considered. This analysis indicates that the former estimate would be close to zero, while the latter might appear to be large. Still, the asset value should be analyzed in terms of discounted present values of differential losses between burning coal now and some time in the future.

Finally, an investment burden of 1% of the GDP is still meaningful if it displaces investment in ordinary plants and equipment and if the ensuing general equilibrium effects are dampening. Even here, the economic impacts are not likely to translate more than proportionately. That is, investment requirements to mitigate CO_2 that are 1% of the GDP are likely to reduce the GDP by at most 1%. Given all of the other factors noted above, the impact will probably be much less.

6.6 SUMMARY OF THE RESULTS

The results of six sets of simulations are presented in Tables 49-53. These results include upper-bound simulations for 2000, 2010, and 2025, as well as lower-bound simulations for the same target years. The major findings are discussed in the following:

- To meet the 5% target CO_2 reduction for the year 2000, China has several options that do not adversely affect its development plans. In fact, strategies that involve conservation and displacement of coal in industrial uses may actually boost economic growth very slightly above baseline projections. Moreover, it appears that actions taken to mitigate CO_2 emissions also reduce emissions of other major air pollutants, such as SO_x, by approximately as much.

- By 2010, the effective abatement requirement becomes 57.30% and 40.50% for the upper- and lower-bound cases, respectively, of that year's emissions. This stiffening of the requirement renders most single strategies infeasible, i.e., incapable of achieving the desired emission reduction target on their own. A combination of strategies can attain

the target with only a slight decrease in the baseline GNP growth rate in the lower-bound case and no decrease in the upper-bound one.

- By 2025, fewer options are open for achieving the target of 84.91% and 65.31% of that year's baseline CO_2 emissions. A change in sectoral mix cannot achieve the results, and autonomous conservation can only achieve reductions of about one-half of the upper-bound target and two-thirds of the lower-bound one, and only at a very great penalty in both cases. However, interfuel substitution and technological change could be combined to attain the targeted reduction of CO_2 emissions in the upper-bound case, and with little economic penalty. Still, the result highly depends on the assumption of total displacement of coal in industry and very substantial shifts to nuclear, hydro, and gas-fired electric power generation. Otherwise, China's economy could suffer reductions of economic growth 1.0-3.0% below baseline. For the lower-bound case, a mix of interfuel substitution, technological change, and sectoral mix changes can achieve the target, but at a sizable penalty that would reduce economic growth from 3 to 0.85%.

- For 2000 and 2010, the results presented in this report do not differ significantly between upper- and lower-bound cases, suggesting they are robust over a broad range of assumptions relating to China's economy, its energy reserves, and energy technologies for those years.

- Unless the CO_2 reduction measures enacted in China are sustainable (i.e., work their way into the very fabric of the Chinese economy and energy system), it could become costly to achieve the reduction requirements in 2025 and beyond under either the upper- or lower-bound scenario. Doing so may have to involve restructuring the economy and implementing conservation measures that are no longer costless. In fact, unless major resource discoveries or technological innovations occur, over and above those projected in this report, CO_2 reduction targets beyond 2025 may not even be feasible. This possibility may even be the case for 2025 if some of the lower-bound assumptions have been too optimistic.

7 BIBLIOGRAPHY

Agarwal, A., and S. Narain, 1991, *Global Warming in an Unequal World: A Case of Environmental Colonialism*, Centre for Science and Environment, New Delhi, India.

Albouy, Y., 1991, *Coal Pricing in China: Issues and Reform Strategy*, The World Bank, Washington, D.C.

Allen, F.H., and R.D. Seba, 1993, *Economics of Worldwide Petroleum Production*, Oil & Gas Consultants International, Inc., Tulsa, Okla.

Almon, C., 1963, "Consistent Forecasting in a Dynamic Multi-Sector Model," *Review of Economics and Statistics* 65:148-161.

ANL, 1994, "Analysis of Coal Fuel Cycle in China," prepared for Argonne National Laboratory, Argonne, Ill., by SFA Pacific, Inc., Mountain View, Calif.

Asian Development Bank, 1994, *National Response Strategy for Global Climate Change: People's Republic of China*, TA 1690-PRC, Technical Assistance Project, Manila, Philippines.

Ayres, R., and U. Simonis (eds.), 1994, *Industrial Metabolism: Restructuring for Sustainable Development*, United Nations University Press, Tokyo, Japan.

Barrett, S., et al., 1992, *Combating Global Warming: A Global System of Tradeable Carbon Emission Entitlements*, United Nations Conference on Trade and Development, Geneva, Switzerland.

Bhatti, N., et al., 1994, *Coal Use in the People's Republic of China, Volume 1: Environmental Impacts,* ANL/DIS/TM-18, Argonne National Laboratory, Argonne, Ill., Nov.

British Petroleum, 1993, *BP Statistical Review of World Energy*, Employee Communications and Services, London, United Kingdom.

Bruno, M., et al., 1970, "Dynamic Input-Output, Trade and Development," in A. Carter and A. Brody (eds.), *Applications of Input-Output Analysis*, North-Holland, Amsterdam, the Netherlands.

Chandler, W. (ed.), 1990, *Carbon Emissions Control Strategies,* World Wildlife Fund and the Conservation Foundation, Washington, D.C.

Chenery, H., and P. Clark, 1959, *Interindustry Economics*, Wiley, New York, N.Y.

Cheng, C., 1984, *The Demand and Supply of Primary Energy in Mainland China*, Chung-Hua Institution for Economic Research, Taipei, Taiwan.

China Coal Industry Yearbook, 1986, Ministry of Coal Industry, Beijing, People's Republic of China, Economic Information and Agency Press, Hong Kong.

China Statistical Yearbook, 1988, State Statistical Bureau of China, China Statistical Press, Beijing, People's Republic of China.

China Statistical Yearbook, 1991, 1992, State Statistical Bureau of China, Beijing, People's Republic of China, Hong Kong Center for the Advancement of Science and Technology, Ltd.

China Statistical Yearbook, 1992, State Statistical Bureau of China, China Statistical Publishing House, Beijing, People's Republic of China.

"China: Treating the New Frontier with Caution," 1994, *Petroleum Economist* 61:8-12, June.

"Chinese Number Games," 1993, *Energy Economist* 140:11-13.

"Chinese Number Games," 1994, *Energy Economist* 140:10-14.

Cline, W., 1992, *The Economics of Global Warming*, Institute for International Economics, Washington, D.C.

"Coal in China," 1994, *Mining Journal* 80, July 8.

Dervis, K., J. de Melo, and S. Robinson, 1982, *General Equilibrium Models for Development Policy*, Cambridge University Press, Cambridge, Mass.

Dorian, J.P., and D.G. Fridley, 1985, *China's Energy and Mineral Industries: Current Perspectives*, Westview Press, Boulder, Colo.

Dowlatabad, H., and M.A. Toman, 1991, *Technology Options for Electricity Generation*, Johns Hopkins University Press, Baltimore, Md.

"Electricity in China: Power Surge," 1994, *The Economist* 330(7855):81-82.

Gibbons, R.J., 1993, "Power Funding," *The China Business Review* 20(6):28-32.

Goldstein, C., 1992, "China's Generation Gap," *Far Eastern Economic Review* 155(23):45-47.

Goldstein, C., 1992, "The Nuclear Option: China's Programme Dogged by Delays," *Far Eastern Economic Review* 155(23):50-51.

Grubb, M., and J. Sebenius, 1991, "Participation, Allocation, and Adaptability in International Tradeable Emission Permit Systems for Greenhouse Gas Control," Paper prepared for Organization for Economic Cooperation and Development Workshop on Tradeable Greenhouse Gas Permits, Paris, France.

Hamburger, J., 1993, "Lighting the Way for Energy Savings," *The China Business Review* 20(6):42-44.

Huang, J.P., 1993, "Electricity Consumption and Economic Growth. A Case Study of China," *Energy Policy* 21(6):717-720.

Input-Output Table of China 1987, 1990, Department of Balances of National Economy of the State Statistical Bureau and Office of the National Input-Output Survey, China Statistical Publishing House, Beijing, People's Republic of China.

Intergovernmental Panel on Climate Change, 1992, *Climate Change: The IPCC Scientific Assessment* (revised), Cambridge University Press, New York, N.Y.

International Energy Agency, 1988, *Mineral Industry in China*, United Nations, New York, N.Y.

International Energy Agency, 1990, *Mineral Industry in China*, United Nations, New York, N.Y.

International Energy Agency, 1992, *Climate Change Policy Initiatives*, prepared by the Organization for Economic Cooperation and Development, Paris, France.

Khazzoom, D., 1980, "Economic Implications of Mandated Efficiency Standards for Household Appliances," *Energy Journal* 1:21-39.

Kim, Y.C., 1993, "Multicriteria Generation — Expansion Planning with Global Environmental Considerations," *IEEE Transactions on Engineering Management* 40:158-163.

"Late Welcome for Foreign Funds," 1994, *Petroleum Economist* 61:8-12, June.

Leontief, W., 1986, *Input-Output Economics* (2nd Ed.), Oxford University Press, Oxford, United Kingdom.

Lin, X., and K.R. Polenske, 1993, "Input-Output Anatomy of China's Energy-Demand Change, 1981-1987," Multiregional Planning Research, Massachusetts Institute of Technology, Cambridge, Mass.

Lindzen, R., 1992, *Global Warming: The Origin and Nature of the Alleged Scientific Consensus Regulation*, Vol. 13, pp. 87-98.

Manne, A., and R. Richels, 1991, "Global CO_2 Emission Reductions: The Impacts of Rising Energy Costs," *Energy Journal* 12:87-107.

Miller, R.E., and P.D. Blair, 1985, *Input-Output Analysis: Foundations and Extensions*, Prentice-Hall, Englewood Cliffs, N.J.

Ministry of Energy, 1993, *Energy in China 1992*, Beijing, People's Republic of China.

National Academy of Sciences, 1991, *Policy Implications of Greenhouse Warming*, National Academy Press, Washington, D.C.

Nordhaus, W, 1993, "Rolling the DICE: The Optimal Transition Path for Controlling Greenhouse Gases," *Resource and Energy Economics* 15:27-50.

Office of Technology Assessment, 1991, *Changing by Degrees: Steps to Reduce Greenhouse Gases*, Washington, D.C.

Pezzey, J., 1992, "The Symmetry between Controlling Pollution by Price and by Quantity," *Canadian Journal of Economics* 25:983-91.

Polenske, K.R., and X. Chen, 1991, *Chinese Economic Planning and Input-Output Analysis*, Oxford University Press, New York, N.Y.

Rose, A., and W. Miernyk, 1989, "Input-Output Analysis: The First Fifty Years," *Economic Systems Research* 1:229-271.

Rose, A., and S. Lin, 1994, "Regrets or No Regrets — That Is the Question: Economic Impacts of a Conservation Strategy for CO_2 Mitigation," Paper presented at the International Meeting of the International Association for Energy Economics, Stavanger, Norway, May.

Rose, A., and B. Stevens, 1993, "The Efficiency and Equity of Marketable Permits for CO_2 Emissions," *Resource and Energy Economics* 15:117-46.

Rose, A., B. Stevens, and P. Li, 1994, "A Global Marketable Permits Approach to CO_2 Mitigation: Implications of U.S. Energy Demand," in E.C. van Ierland (ed.) *International Environmental Economics*, North-Holland, Amsterdam, the Netherlands

Schneider, D., et al., 1993, "Power Plays," *The China Business Review* 20(6):20-27.

Smil, V., 1988, *Energy in China's Modernization, Advances and Limitations*, M.E. Sharpe, Inc., Armonk, N.Y.

State Statistical Bureau, 1988, *China Statistical Yearbook, 1988*, International Centre for the Advancement of Science and Technology, Ltd., Beijing, People's Republic of China.

Statistical Office of the European Community (EUROSTAT), 1991, *Energy Monthly Statistics* 10:35.

Tang, C., and S.J. La Croix, 1993, "Energy Consumption and Economic Activity in China," *The Energy Journal* 14:21-36.

Task Force on the Comprehensive Approach to Climate Change, 1991, *A Comprehensive Approach to Addressing Potential Climate Change,* U.S. Department of Justice, Environment and Natural Resources Division, Washington, D.C.

Taylor, L., 1979, *Macro Model for Developing Countries*, McGraw-Hill Book Company, Inc., New York, N.Y.

APPENDIX A1:

UPPER-BOUND SIMULATIONS

SIMULATION BASELINE: CHINA DLP MODEL 0-U 6/17/94

		BASE 1990			DLP 1990			DLP 2000			DLP 2010			DLP 2025			CO2
		Final Demand	Gross Output	CO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	COEFFICIENT (ton/tho Yuan)
1	Agriculture	409	772	43	491	879	49	1,387	2,171	121	2,860	4,475	249	7,354	11,509	641	0 0557
2	Coal mining	9	45	147	11	47	153	31	108	352	65	223	726	167	574	1,868	3 2568
3	Crude petroleum & natural gas prod	7	44	9	9	46	10	25	109	23	52	224	48	134	577	124	0 2141
4	Metal ore mining	(1)	15	0	0	14	0	0	28	0	0	57	0	0	146	0	0 0000
5	Other mining	0	35	0	0	31	0	0	67	0	1	138	0	2	355	0	0 0000
6	Food manufacturing	204	305	62	245	353	72	346	561	115	713	1,157	237	1,833	2,975	608	0 2045
7	Manufacture of textiles	99	275	44	79	237	38	168	502	81	346	1,035	167	890	2,663	430	0.1615
8	Manufacture of apparel	58	77	0	46	63	0	98	135	0	203	278	0	522	714	0	0 0000
9	Sawmills and manufacture of furniture	7	36	0	8	34	0	12	65	0	25	135	0	63	346	0	0 0000
10	Manufacture of paper and educ material	25	110	31	30	116	32	42	233	65	87	480	134	223	1,235	346	0 2799
11	Electricity, steam and hot water prod	6	65	509	7	64	499	19	142	1,105	39	292	2,278	101	750	5,859	7 8119
12	Petroleum refineries	2	60	39	2	61	40	7	141	92	14	290	189	37	745	486	0.6523
13	Coking, manufacture of gas & coal	3	10	84	2	9	77	5	18	154	10	38	317	25	97	816	8.4178
14	Chemical industries	21	300	166	25	287	159	36	616	342	74	1,270	704	190	3,266	1,810	0.5543
15	Manufacture of building materials	2	132	188	2	117	166	6	250	355	12	516	733	31	1,327	1,884	1.4199
16	Primary metal manufacturing	(22)	179	153	0	161	137	0	311	266	0	641	547	0	1,648	1,408	0.8542
17	Manufacture of metal products	19	80	16	23	78	15	32	148	29	66	305	59	169	784	152	0.1941
18	Manufacture of machinery	103	231	28	123	203	25	174	331	40	359	683	83	924	1,757	214	0.1218
19	Manufacture of transport equipment	27	66	8	32	54	7	46	92	11	94	190	23	242	489	60	0.1218
20	Manufacture of electric machinery	40	98	12	48	94	11	69	159	19	141	327	40	363	841	102	0.1218
21	Manufacture of electronics equip	31	64	8	37	59	7	78	125	15	161	257	31	414	662	81	0.1218
22	Manufacture of instruments	(1)	13	0	0	7	0	0	14	0	0	30	0	0	76	0	0.0000
23	Maintenance and repair of machinery	21	23	0	26	27	0	72	77	0	149	159	0	384	408	0	0.0000
24	Industries not elsewhere classified	(1)	17	0	21	40	0	29	69	0	60	143	0	156	367	0	0.0000
25	Construction	402	402	10	321	321	8	681	681	17	1,403	1,403	35	3,609	3,609	90	0.0250
26	Freight transport and communication	41	113	47	49	122	51	138	292	122	285	602	251	732	1,549	644	0.4161
27	Commerce	28	170	16	34	155	14	96	347	32	198	715	66	510	1,838	169	0.0921
28	Restaurants	46	47	4	44	44	4	79	79	7	163	163	15	418	418	39	0.0921
29	Passenger transport	14	25	3	16	29	3	46	78	9	95	160	18	245	412	47	0.1135
30	Public utilities and services to house	72	95	8	86	110	10	244	305	26	504	628	54	1,296	1,614	140	0.0864
31	Cultural, education and health services	153	193	17	183	226	20	518	620	54	1,068	1,278	110	2,746	3,286	284	0.0864
32	Finance and insurance	2	79	7	2	75	6	6	161	14	12	331	29	30	851	74	0 0864
33	Public administration	63	63	5	75	75	6	212	212	18	437	437	38	1,125	1,125	97	0.0864
	Total	1,888	4,240	1,665	2,080	4,240	1,620	4,704	9,247	3,485	9,695	19,059	7,183	24,934	49,016	18,474	

Final Demand and Gross Output in billions of 1990 Yuans

Final Demand(GDP) Growth Rate

1990-2000	8.50%
2000-2010	7.50%
2010-2025	6.50%

SIMULATION RESULT: CHINA DLP MODEL 2-U (1990-2000)

6/27/94

		Baseline 2000				DLP 1990				DLP 2000				CO2 COEFFICIENT	SO2 COEFFICIENT
		Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	(ton/tho Yuan)	(ton/tho Yuan)
1	Agriculture	1,387	2,171	121	1	491	879	49	0	1,387	2,172	97	1	0.0446	0.0003
2	Coal mining	31	108	352	3	11	47	153	1	31	90	234	2	2.6054	0.0212
3	Crude petroleum & natural gas prod	25	109	23	0	9	46	10	0	25	81	14	0	0.1713	0.0004
4	Metal ore mining	0	28	0	0	0	14	0	0	0	29	0	0	0.0000	0.0000
5	Other mining	0	67	0	0	0	31	0	0	0	67	0	0	0.0000	0.0000
6	Food manufacturing	346	561	115	1	245	353	72	1	346	561	92	1	0.1636	0.0013
7	Manufacture of textiles	168	502	81	1	79	237	38	0	168	504	65	1	0.1292	0.0010
8	Manufacture of apparel	98	135	0	0	46	63	0	0	98	135	0	0	0.0000	0.0000
9	Sawmills and manufacture of furniture	12	65	0	0	8	34	0	0	12	66	0	0	0.0000	0.0000
10	Manufacture of paper and educ material	42	233	65	1	30	116	32	0	42	234	52	0	0.2240	0.0018
11	Electricity, steam and hot water prod	19	142	1105	9	7	64	499	4	19	117	731	6	6.2495	0.0506
12	Petroleum refineries	7	141	92	0	2	61	40	0	7	113	59	0	0.5219	0.0006
13	Coking, manufacture of gas & coal	5	18	154	1	2	9	77	1	5	19	127	1	6.7342	0.0549
14	Chemical industries	36	616	342	3	25	287	159	1	36	619	275	2	0.4435	0.0033
15	Manufacture of building materials	6	250	355	3	2	117	166	1	3	247	281	2	1.1359	0.0092
16	Primary metal manufacturing	0	311	266	2	0	161	137	1	0	323	221	2	0.6834	0.0055
17	Manufacture of metal products	32	148	29	0	23	78	15	0	32	149	23	0	0.1553	0.0012
18	Manufacture of machinery	174	331	40	0	123	203	25	0	174	422	41	0	0.0974	0.0008
19	Manufacture of transport equipment	46	92	11	0	32	54	7	0	46	93	9	0	0.0974	0.0008
20	Manufacture of electric machinery	69	159	19	0	48	94	11	0	69	162	16	0	0.0974	0.0008
21	Manufacture of electronics equip	78	125	15	0	37	59	7	0	64	106	10	0	0.0974	0.0008
22	Manufacture of instruments	0	14	0	0	0	7	0	0	0	14	0	0	0.0000	0.0000
23	Maintenance and repair of machinery	72	77	0	0	26	27	0	0	72	77	0	0	0.0000	0.0000
24	Industries not elsewhere classified	29	69	0	0	21	40	0	0	29	69	0	0	0.0000	0.0000
25	Construction	681	681	17	0	321	321	8	0	681	681	14	0	0.0200	0.0001
26	Freight transport and communication	138	292	122	1	49	122	51	0	138	292	97	1	0.3329	0.0023
27	Commerce	96	347	32	0	34	155	14	0	96	348	26	0	0.0737	0.0006
28	Restaurants	79	79	7	0	44	44	4	0	79	79	6	0	0.0737	0.0006
29	Passenger transport	46	78	9	0	16	29	3	0	46	78	7	0	0.0908	0.0007
30	Public utilities and services to house	244	305	26	0	86	110	10	0	244	305	21	0	0.0691	0.0005
31	Cultural, education and health services	518	620	54	0	183	226	20	0	518	620	43	0	0.0691	0.0005
32	Finance and insurance	6	161	14	0	2	75	6	0	6	162	11	0	0.0691	0.0005
33	Public administration	212	212	18	0	75	75	6	0	212	212	15	0	0.0691	0.0005
	Total	4,704	9,247	3,485	27	2,080	4,240	1,620	13	4,687	9,247	2,587	20		

Final Demand and Gross Output in billions of 1990 Yuans

Final Demand(GDP) Growth Rate
1990-2000 8.46%

CO2 Emission Reduction
1990-2000 25.78%

SIMULATION RESULT: CHINA DLP MODEL 2-U (1990-2000), W/ CONSTRAINT

8/3/94

		Baseline 2000				DLP 1990				DLP 2000				CO2	SO2
		Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	COEFFICIENT (ton/tho Yuan)	COEFFICIENT (ton/tho Yuan)
1	Agriculture	1,387	2,171	121	1	491	879	49	0	1,392	2,780	124	1	0.0446	0.0003
2	Coal mining	31	108	352	3	11	47	153	1	32	115	300	2	2.6054	0.0212
3	Crude petroleum & natural gas prod	25	109	23	0	9	46	10	0	25	104	18	0	0.1713	0.0004
4	Metal ore mining	0	28	0	0	0	14	0	0	0	37	0	0	0.0000	0.0000
5	Other mining	0	67	0	0	0	31	0	0	0	85	0	0	0.0000	0.0000
6	Food manufacturing	346	581	115	1	245	353	72	1	347	719	118	1	0.1636	0.0013
7	Manufacture of textiles	168	502	81	1	79	237	38	0	168	645	83	1	0.1292	0.0010
8	Manufacture of apparel	98	135	0	0	46	63	0	0	99	173	0	0	0.0000	0.0000
9	Sawmills and manufacture of furniture	12	65	0	0	8	34	0	0	12	85	0	0	0.0000	0.0000
10	Manufacture of paper and educ material	42	233	65	1	30	116	32	0	42	299	67	1	0.2240	0.0018
11	Electricity, steam and hot water prod	19	142	1105	9	7	64	499	4	19	150	936	8	6.2495	0.0506
12	Petroleum refineries	7	141	92	0	2	61	40	0	7	144	75	0	0.5219	0.0006
13	Coking, manufacture of gas & coal	5	18	154	1	2	9	77	1	5	24	163	1	6.7342	0.0549
14	Chemical industries	36	616	342	3	25	287	159	1	36	792	351	3	0.4435	0.0033
15	Manufacture of building materials	6	250	355	3	2	117	166	1	3	317	360	3	1.1359	0.0092
16	Primary metal manufacturing	0	311	266	2	0	161	137	1	0	414	283	2	0.6834	0.0055
17	Manufacture of metal products	32	148	29	0	23	78	15	0	32	191	30	0	0.1553	0.0012
18	Manufacture of machinery	174	331	40	0	123	203	25	0	175	540	53	0	0.0974	0.0008
19	Manufacture of transport equipment	46	92	11	0	32	54	7	0	46	119	12	0	0.0974	0.0008
20	Manufacture of electric machinery	69	159	19	0	48	94	11	0	69	207	20	0	0.0974	0.0008
21	Manufacture of electronics equip	78	125	15	0	37	59	7	0	64	136	13	0	0.0974	0.0008
22	Manufacture of instruments	0	14	0	0	0	7	0	0	0	19	0	0	0.0000	0.0000
23	Maintenance and repair of machinery	72	77	0	0	26	27	0	0	73	99	0	0	0.0000	0.0000
24	Industries not elsewhere classified	29	69	0	0	21	40	0	0	29	89	0	0	0.0000	0.0000
25	Construction	681	681	17	0	321	321	8	0	683	872	17	0	0.0200	0.0001
26	Freight transport and communication	138	292	122	1	49	122	51	0	139	374	124	1	0.3329	0.0023
27	Commerce	96	347	32	0	34	155	14	0	96	446	33	0	0.0737	0.0006
28	Restaurants	79	79	7	0	44	44	4	0	79	101	7	0	0.0737	0.0006
29	Passenger transport	46	78	9	0	16	29	3	0	46	100	9	0	0.0908	0.0007
30	Public utilities and services to house	244	305	26	0	86	110	10	0	245	390	27	0	0.0691	0.0005
31	Cultural, education and health services	518	620	54	0	183	226	20	0	520	794	55	0	0.0691	0.0005
32	Finance and insurance	6	161	14	0	2	75	6	0	6	208	14	0	0.0691	0.0005
33	Public administration	212	212	18	0	75	75	6	0	213	272	19	0	0.0691	0.0005
	Total	4,704	9,247	3,485	27	2,080	4,240	1,620	13	4,701	11,836	3,311	26		

Final Demand and Gross Output in billions of 1990 Yuans

Final Demand(GDP) Growth Rate
1990-2000 8.49%

CO2 Emission Reduction
1990-2000 5.00%

SIMULATION RESULT: CHINA DLP MODEL 2-U (2000-2010)

8/1/94

		Baseline 2010				DLP 2000				DLP 2010				CO2	SO2
		Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	COEFFICIENT (ton/tho Yuan)	COEFFICIENT (ton/tho Yuan)
1	Agriculture	2,860	4,475	249	2	1,387	2,172	97	1	2,860	4,477	180	1	0.0401	0.0003
2	Coal mining	65	223	726	6	31	90	234	2	65	171	401	3	2.3449	0.0191
3	Crude petroleum & natural gas prod	52	224	48	0	25	81	14	0	52	148	23	0	0.1542	0.0003
4	Metal ore mining	0	57	0	0	0	29	0	0	0	60	0	0	0.0000	0.0000
5	Other mining	1	138	0	0	0	67	0	0	1	137	0	0	0.0000	0.0000
6	Food manufacturing	713	1,157	237	2	346	561	92	1	713	1,157	170	1	0.1472	0.0012
7	Manufacture of textiles	346	1,035	167	1	168	504	65	1	346	1,039	121	1	0.1163	0.0009
8	Manufacture of apparel	203	278	0	0	98	135	0	0	203	278	0	0	0.0000	0.0000
9	Sawmills and manufacture of furniture	25	135	0	0	12	66	0	0	25	137	0	0	0.0000	0.0000
10	Manufacture of paper and educ material	87	480	134	1	42	234	52	0	87	482	97	1	0.2016	0.0016
11	Electricity, steam and hot water prod	39	292	2278	18	19	117	731	6	39	221	1,243	10	5.6245	0.0456
12	Petroleum refineries	14	290	189	0	7	113	59	0	14	210	99	0	0.4697	0.0005
13	Coking, manufacture of gas & coal	10	38	317	3	5	19	127	1	10	39	239	2	6.0608	0.0494
14	Chemical industries	74	1,270	704	5	36	619	275	2	74	1,278	510	4	0.3991	0.0030
15	Manufacture of building materials	12	516	733	6	3	247	281	2	6	510	522	4	1.0223	0.0083
16	Primary metal manufacturing	0	641	547	4	0	323	221	2	0	676	416	3	0.6150	0.0049
17	Manufacture of metal products	66	305	59	0	32	149	23	0	66	309	43	0	0.1398	0.0011
18	Manufacture of machinery	359	683	83	1	174	422	41	0	359	939	82	1	0.0877	0.0007
19	Manufacture of transport equipment	94	190	23	0	46	93	9	0	94	191	17	0	0.0877	0.0007
20	Manufacture of electric machinery	141	327	40	0	69	162	16	0	141	336	29	0	0.0877	0.0007
21	Manufacture of electronics equip	161	257	31	0	64	106	10	0	120	203	18	0	0.0877	0.0007
22	Manufacture of instruments	0	30	0	0	0	14	0	0	0	30	0	0	0.0000	0.0000
23	Maintenance and repair of machinery	149	159	0	0	72	77	0	0	149	159	0	0	0.0000	0.0000
24	Industries not elsewhere classified	60	143	0	0	29	69	0	0	60	143	0	0	0.0000	0.0000
25	Construction	1,403	1,403	35	0	681	681	14	0	1,403	1,403	25	0	0.0180	0.0001
26	Freight transport and communication	285	602	251	2	138	292	97	1	285	601	180	1	0.2996	0.0021
27	Commerce	198	715	66	1	96	348	26	0	198	719	48	0	0.0663	0.0005
28	Restaurants	163	163	15	0	79	79	6	0	163	163	11	0	0.0663	0.0005
29	Passenger transport	95	160	18	0	46	78	7	0	95	161	13	0	0.0817	0.0006
30	Public utilities and services to house	504	628	54	0	244	305	21	0	504	628	39	0	0.0622	0.0005
31	Cultural, education and health services	1,068	1,278	110	1	518	620	43	0	1,068	1,278	80	1	0.0622	0.0005
32	Finance and insurance	12	331	29	0	6	162	11	0	12	336	21	0	0.0622	0.0005
33	Public administration	437	437	38	0	212	212	15	0	437	437	27	0	0.0622	0.0005
	Total	9,695	19,059	7,183	56	4,687	9,247	2,587	20	9,848	19,058	4,652	36		

Final Demand and Gross Output in billions of 1990 Yuans

Final Demand(GDP) Growth Rate
2000-2010 7.46%

CO2 Emission Reduction
2000-2010 35.23%

SIMULATION RESULT: CHINA DLP MODEL 2-U (2010-2025)

8/1/94

		Baseline 2025				DLP 2010				DLP 2025				CO2	SO2
		Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	COEFFICIENT (ton/tho Yuan)	COEFFICIENT (ton/tho Yuan)
1	Agriculture	7,354	11,509	641	5	2,860	4,477	180	1	7,354	11,516	416	3	0.0361	0.0003
2	Coal mining	167	574	1868	15	65	171	401	3	167	408	861	7	2.1104	0.0172
3	Crude petroleum & natural gas prod	134	577	124	0	52	148	23	0	134	340	47	0	0.1387	0.0003
4	Metal ore mining	0	146	0	0	0	60	0	0	0	157	0	0	0.0000	0.0000
5	Other mining	2	355	0	0	1	137	0	0	2	353	0	0	0.0000	0.0000
6	Food manufacturing	1,833	2,975	608	5	713	1,157	170	1	1,833	2,977	395	3	0.1325	0.0011
7	Manufacture of textiles	890	2,663	430	3	346	1,039	121	1	890	2,674	280	2	0.1046	0.0008
8	Manufacture of apparel	522	714	0	0	203	278	0	0	522	717	0	0	0.0000	0.0000
9	Sawmills and manufacture of furniture	63	346	0	0	25	137	0	0	63	353	0	0	0.0000	0.0000
10	Manufacture of paper and educ material	223	1,235	346	3	87	482	97	1	223	1,241	225	2	0.1814	0.0015
11	Electricity, steam and hot water prod	101	750	5859	47	39	221	1,243	10	101	522	2,643	21	5.0621	0.0410
12	Petroleum refineries	37	745	486	1	14	210	99	0	37	488	206	0	0.4227	0.0005
13	Coking, manufacture of gas & coal	25	97	816	7	10	39	239	2	25	102	558	5	5.4547	0.0445
14	Chemical industries	190	3,266	1810	14	74	1,278	510	4	190	3,293	1,183	9	0.3592	0.0027
15	Manufacture of building materials	31	1,327	1884	15	6	510	522	4	16	1,313	1,208	10	0.9201	0.0074
16	Primary metal manufacturing	0	1,648	1408	11	0	676	416	3	0	1,762	975	8	0.5535	0.0044
17	Manufacture of metal products	169	784	152	1	66	309	43	0	169	797	100	1	0.1258	0.0010
18	Manufacture of machinery	924	1,757	214	2	359	939	82	1	924	2,570	203	2	0.0789	0.0006
19	Manufacture of transport equipment	242	489	60	0	94	191	17	0	242	493	39	0	0.0789	0.0006
20	Manufacture of electric machinery	363	841	102	1	141	336	29	0	363	868	69	1	0.0789	0.0006
21	Manufacture of electronics equip	414	662	81	1	120	203	18	0	281	484	38	0	0.0789	0.0006
22	Manufacture of instruments	0	76	0	0	0	30	0	0	0	77	0	0	0.0000	0.0000
23	Maintenance and repair of machinery	384	408	0	0	149	159	0	0	384	409	0	0	0.0000	0.0000
24	Industries not elsewhere classified	156	367	0	0	60	143	0	0	156	369	0	0	0.0000	0.0000
25	Construction	3,609	3,609	90	1	1,403	1,403	25	0	3,609	3,609	58	0	0.0162	0.0001
26	Freight transport and communication	732	1,549	644	5	285	601	180	1	732	1,546	417	3	0.2697	0.0019
27	Commerce	510	1,838	169	1	198	719	48	0	510	1,851	110	1	0.0597	0.0005
28	Restaurants	418	418	39	0	163	163	11	0	418	418	25	0	0.0597	0.0005
29	Passenger transport	245	412	47	0	95	161	13	0	245	413	30	0	0.0736	0.0006
30	Public utilities and services to house	1,296	1,614	140	1	504	628	39	0	1,296	1,616	90	1	0.0560	0.0004
31	Cultural, education and health services	2,746	3,286	284	2	1,068	1,278	80	1	2,746	3,288	184	1	0.0560	0.0004
32	Finance and insurance	30	851	74	1	12	336	21	0	30	866	49	0	0.0560	0.0004
33	Public administration	1,125	1,125	97	1	437	437	27	0	1,125	1,125	63	0	0.0560	0.0004
	Total	24,934	49,016	18,474	143	9,648	19,058	4,652	36	24,786	49,016	10,472	81		

Final Demand and Gross Output in billions of 1990 Yuans

Final Demand(GDP) Growth Rate
2010-2025 6.49%

CO2 Emission Reduction
2010-2025 43.31%

SIMULATION: CHINA DLP MODEL 3-U (1990/2000)

7/14/94

		BASELINE 2000				DLP 1990				DLP 2000				CO2 COEFFICIENT	SO2 COEFFICIENT
		Final Demand	Gross Output	CO2 (MIL TON)	SO2 (MIL TON)	Final Demand	Gross Output	CO2 (MIL TON)	SO2 (MIL TON)	Final Demand	Gross Output	CO2 (MIL TON)	SO2 (MIL TON)	(TON/THO YUAN	(TON/THO YUAN)
1	Agriculture	1,387	2,171	121	1	491	879	49	0	1,387	2,171	121	1	0.0557	0.0004
2	Coal mining	31	108	352	3	11	47	153	1	31	94	307	3	3.2568	0.0265
3	Crude petroleum & natural gas prod	25	109	23	0	9	46	10	0	25	120	26	0	0.2141	0.0005
4	Metal ore mining	0	28	0	0	0	14	0	0	0	28	0	0	0.0000	0.0000
5	Other mining	0	67	0	0	0	31	0	0	0	73	0	0	0.0000	0.0000
6	Food manufacturing	346	561	115	1	245	353	72	1	346	561	115	1	0.2045	0.0017
7	Manufacture of textiles	168	502	81	1	79	237	38	0	168	502	81	1	0.1615	0.0013
8	Manufacture of apparel	98	135	0	0	46	63	0	0	98	135	0	0	0.0000	0.0000
9	Sawmills and manufacture of furniture	12	65	0	0	8	34	0	0	12	65	0	0	0.0000	0.0000
10	Manufacture of paper and educ material	42	233	65	1	30	116	32	0	42	233	65	1	0.2799	0.0023
11	Electricity, steam and hot water prod	19	142	1,105	9	7	64	499	4	19	141	836	7	5.9237	0.0480
12	Petroleum refineries	7	141	92	0	2	61	40	0	7	134	87	0	0.6523	0.0008
13	Coking, manufacture of gas & coal	5	18	154	1	2	9	77	1	5	18	154	1	8.4178	0.0686
14	Chemical industries	36	616	342	3	25	287	159	1	36	616	342	3	0.5543	0.0042
15	Manufacture of building materials	6	250	355	3	2	117	166	1	6	250	356	3	1.4199	0.0115
16	Primary metal manufacturing	0	311	266	2	0	161	137	1	0	311	266	2	0.8542	0.0069
17	Manufacture of metal products	32	148	29	0	23	78	15	0	32	148	29	0	0.1941	0.0016
18	Manufacture of machinery	174	331	40	0	123	203	25	0	174	332	40	0	0.1218	0.0010
19	Manufacture of transport equipment	46	92	11	0	32	54	7	0	46	92	11	0	0.1218	0.0010
20	Manufacture of electric machinery	69	159	19	0	48	94	11	0	69	159	19	0	0.1218	0.0010
21	Manufacture of electronics equip	78	125	15	0	37	59	7	0	81	128	16	0	0.1218	0.0010
22	Manufacture of instruments	0	14	0	0	0	7	0	0	0	14	0	0	0.0000	0.0000
23	Maintenance and repair of machinery	72	77	0	0	26	27	0	0	72	77	0	0	0.0000	0.0000
24	Industries not elsewhere classified	29	69	0	0	21	40	0	0	29	69	0	0	0.0000	0.0000
25	Construction	681	681	17	0	321	321	8	0	681	681	17	0	0.0250	0.0002
26	Freight transport and communication	138	292	122	1	49	122	51	0	138	292	121	1	0.4161	0.0029
27	Commerce	96	347	32	0	34	155	14	0	96	347	32	0	0.0921	0.0007
28	Restaurants	79	79	7	0	44	44	4	0	79	79	7	0	0.0921	0.0007
29	Passenger transport	46	78	9	0	16	29	3	0	46	78	9	0	0.1135	0.0009
30	Public utilities and services to house	244	305	26	0	86	110	10	0	244	305	26	0	0.0864	0.0007
31	Cultural, education and health services	518	620	54	0	183	226	20	0	518	620	54	0	0.0864	0.0007
32	Finance and insurance	6	161	14	0	2	75	6	0	6	161	14	0	0.0864	0.0007
33	Public administration	212	212	18	0	75	75	6	0	212	212	18	0	0.0864	0.0007
	Total	4,704	9,247	3,485	27	2,080	4,240	1,620	13	4,707	9,247	3,169	24		

Final Demand and Gross Output in billions of 1990 Yuans

Final Demand(GDP) Growth Rate
1990-2000 8.51%

CO2 Emission Reduction
1990-2000 9.07%

SIMULATION: CHINA DLP MODEL 3-U (1990/2000), W/ CONSTRAINT

8/8/94

		BASELINE 2000				DLP 1990				DLP 2000				CO2	SO2
		Final Demand	Gross Output	CO2 (MIL TON)	SO2 (MIL TON)	Final Demand	Gross Output	CO2 (MIL TON)	SO2 (MIL TON)	Final Demand	Gross Output	CO2 (MIL TON)	SO2 (MIL TON)	COEFFICIENT (TON/THO YUAN	COEFFICIENT (TON/THO YUAN
1	Agriculture	1,387	2,171	121	1	491	879	49	0	1,387	2,269	126	1	0.0557	0.0004
2	Coal mining	31	108	352	3	11	47	153	1	31	99	321	3	3.2568	0.0265
3	Crude petroleum & natural gas prod	25	109	23	0	9	46	10	0	25	125	27	0	0.2141	0.0005
4	Metal ore mining	0	28	0	0	0	14	0	0	0	29	0	0	0.0000	0.0000
5	Other mining	0	67	0	0	0	31	0	0	0	76	0	0	0.0000	0.0000
6	Food manufacturing	346	561	115	1	245	353	72	1	346	586	120	1	0.2045	0.0017
7	Manufacture of textiles	168	502	81	1	79	237	38	0	168	525	85	1	0.1615	0.0013
8	Manufacture of apparel	98	135	0	0	46	63	0	0	98	141	0	0	0.0000	0.0000
9	Sawmills and manufacture of furniture	12	65	0	0	8	34	0	0	12	68	0	0	0.0000	0.0000
10	Manufacture of paper and educ material	42	233	65	1	30	116	32	0	42	244	68	1	0.2799	0.0023
11	Electricity, steam and hot water prod	19	142	1,105	9	7	64	499	4	19	148	874	7	5.9237	0.0480
12	Petroleum refineries	7	141	92	0	2	61	40	0	7	140	91	0	0.6523	0.0008
13	Coking, manufacture of gas & coal	5	18	154	1	2	9	77	1	5	19	161	1	8.4178	0.0686
14	Chemical industries	36	616	342	3	25	287	159	1	36	644	357	3	0.5543	0.0042
15	Manufacture of building materials	6	250	355	3	2	117	166	1	6	262	371	3	1.4199	0.0115
16	Primary metal manufacturing	0	311	266	2	0	161	137	1	0	325	278	2	0.8542	0.0069
17	Manufacture of metal products	32	148	29	0	23	78	15	0	32	154	30	0	0.1941	0.0016
18	Manufacture of machinery	174	331	40	0	123	203	25	0	174	346	42	0	0.1218	0.0010
19	Manufacture of transport equipment	46	92	11	0	32	54	7	0	46	97	12	0	0.1218	0.0010
20	Manufacture of electric machinery	69	159	19	0	48	94	11	0	68	166	20	0	0.1218	0.0010
21	Manufacture of electronics equip	78	125	15	0	37	59	7	0	81	134	16	0	0.1218	0.0010
22	Manufacture of instruments	0	14	0	0	0	7	0	0	0	15	0	0	0.0000	0.0000
23	Maintenance and repair of machinery	72	77	0	0	26	27	0	0	72	81	0	0	0.0000	0.0000
24	Industries not elsewhere classified	29	69	0	0	21	40	0	0	29	72	0	0	0.0000	0.0000
25	Construction	681	681	17	0	321	321	8	0	681	711	18	0	0.0250	0.0002
26	Freight transport and communication	138	292	122	1	49	122	51	0	138	305	127	1	0.4161	0.0029
27	Commerce	96	347	32	0	34	155	14	0	96	362	33	0	0.0921	0.0007
28	Restaurants	79	79	7	0	44	44	4	0	79	82	8	0	0.0921	0.0007
29	Passenger transport	46	78	9	0	16	29	3	0	46	81	9	0	0.1135	0.0009
30	Public utilities and services to house	244	305	26	0	86	110	10	0	244	318	27	0	0.0864	0.0007
31	Cultural, education and health services	518	620	54	0	183	226	20	0	518	648	56	0	0.0864	0.0007
32	Finance and insurance	6	161	14	0	2	75	6	0	6	168	15	0	0.0864	0.0007
33	Public administration	212	212	18	0	75	75	6	0	212	222	19	0	0.0864	0.0007
	Total	4,704	9,247	3,485	27	2,080	4,240	1,620	13	4,706	9,661	3,311	26		

Final Demand and Gross Output In billions of 1990 Yuans

Final Demand(GDP) Growth Rate
1990-2000 8.51%

CO2 Emission Reduction
1990-2000 5.00%

SIMULATION: CHINA DLP MODEL 3-U (2000/2010)

8/1/94

		BASELINE 2010				DLP 2000				DLP 2010				CO2 COEFFICIENT	SO2 COEFFICIENT
		Final Demand	Gross Output	CO2 (MIL TON)	SO2 (MIL TON)	Final Demand	Gross Output	CO2 (MIL TON)	SO2 (MIL TON)	Final Demand	Gross Output	CO2 (MIL TON)	SO2 (MIL TON)	(TON/THO YUAN	(TON/THO YUAN)
1	Agriculture	2,860	4,475	249	2	1,387	2,171	121	1	2,860	4,476	249	2	0.0557	0.0004
2	Coal mining	65	223	726	6	31	94	307	3	65	199	650	5	3.2568	0.0265
3	Crude petroleum & natural gas prod	52	224	48	0	25	120	26	0	52	241	52	0	0.2141	0.0005
4	Metal ore mining	0	57	0	0	0	28	0	0	0	57	0	0	0.0000	0.0000
5	Other mining	1	138	0	0	0	73	0	0	1	154	0	0	0.0000	0.0000
6	Food manufacturing	713	1,157	237	2	346	561	115	1	713	1,157	237	2	0.2045	0.0017
7	Manufacture of textiles	346	1,035	167	1	168	502	81	1	346	1,035	167	1	0.1615	0.0013
8	Manufacture of apparel	203	278	0	0	98	135	0	0	203	278	0	0	0.0000	0.0000
9	Sawmills and manufacture of furniture	25	135	0	0	12	65	0	0	25	135	0	0	0.0000	0.0000
10	Manufacture of paper and educ material	87	480	134	1	42	233	65	1	87	480	134	1	0.2799	0.0023
11	Electricity, steam and hot water prod	39	292	2,278	18	19	141	836	7	39	291	1,741	14	5.9776	0.0482
12	Petroleum refineries	14	290	189	0	7	134	87	0	14	274	179	0	0.6523	0.0008
13	Coking, manufacture of gas & coal	10	38	317	3	5	18	154	1	10	38	317	3	8.4178	0.0686
14	Chemical industries	74	1,270	704	5	36	616	342	3	74	1,270	704	5	0.5543	0.0042
15	Manufacture of building materials	12	516	733	6	6	250	356	3	12	516	733	6	1.4199	0.0115
16	Primary metal manufacturing	0	641	547	4	0	311	266	2	0	641	548	4	0.8542	0.0069
17	Manufacture of metal products	66	305	59	0	32	148	29	0	66	304	59	0	0.1941	0.0016
18	Manufacture of machinery	359	683	83	1	174	332	40	0	359	683	83	1	0.1218	0.0010
19	Manufacture of transport equipment	94	190	23	0	46	92	11	0	94	190	23	0	0.1218	0.0010
20	Manufacture of electric machinery	141	327	40	0	69	159	19	0	141	327	40	0	0.1218	0.0010
21	Manufacture of electronics equip	161	257	31	0	81	128	16	0	166	264	32	0	0.1218	0.0010
22	Manufacture of instruments	0	30	0	0	0	14	0	0	0	30	0	0	0.0000	0.0000
23	Maintenance and repair of machinery	149	159	0	0	72	77	0	0	149	159	0	0	0.0000	0.0000
24	Industries not elsewhere classified	60	143	0	0	29	69	0	0	60	143	0	0	0.0000	0.0000
25	Construction	1,403	1,403	35	0	681	681	17	0	1,403	1,403	35	0	0.0250	0.0002
26	Freight transport and communication	285	602	251	2	138	292	121	1	285	602	250	2	0.4161	0.0029
27	Commerce	198	715	66	1	96	347	32	0	198	715	66	1	0.0921	0.0007
28	Restaurants	163	163	15	0	79	79	7	0	163	163	15	0	0.0921	0.0007
29	Passenger transport	95	160	18	0	46	78	9	0	95	160	18	0	0.1135	0.0009
30	Public utilities and services to house	504	628	54	0	244	305	26	0	504	628	54	0	0.0864	0.0007
31	Cultural, education and health services	1,068	1,278	110	1	518	620	54	0	1,068	1,278	110	1	0.0864	0.0007
32	Finance and insurance	12	331	29	0	6	161	14	0	12	331	29	0	0.0864	0.0007
33	Public administration	437	437	38	0	212	212	18	0	437	437	38	0	0.0864	0.0007
	Total	9,695	19,059	7,183	56	4,707	9,247	3,169	24	9,700	19,059	6,564	51		

Final Demand and Gross Output in billions of 1990 Yuans

Final Demand(GDP) Growth Rate
2000-2010 7.50%

CO2 Emission Reduction
2000-2010 8.62%

SIMULATION: CHINA DLP MODEL 3-U (2010/2025)

8/1/94

		BASELINE 2025				DLP 2010				DLP 2025				CO2 COEFFICIENT	SO2 COEFFICIENT
		Final Demand	Gross Output	CO2 (MIL TON)	SO2 (MIL TON)	Final Demand	Gross Output	CO2 (MIL TON)	SO2 (MIL TON)	Final Demand	Gross Output	CO2 (MIL TON)	SO2 (MIL TON)	(TON/THO YUAN	(TON/THO YUAN)
1	Agriculture	7,354	11,509	641	5	2,860	4,476	249	2	7,354	11,518	642	5	0.0557	0.0004
2	Coal mining	167	574	1,868	15	65	199	650	5	167	442	1,439	12	3.2568	0.0265
3	Crude petroleum & natural gas prod	134	577	124	0	52	241	52	0	134	557	119	0	0.2141	0.0005
4	Metal ore mining	0	146	0	0	0	57	0	0	0	146	0	0	0.0000	0.0000
5	Other mining	2	355	0	0	1	154	0	0	2	532	0	0	0.0000	0.0000
6	Food manufacturing	1,833	2,975	608	5	713	1,157	237	2	1,833	2,976	609	5	0.2045	0.0017
7	Manufacture of textiles	890	2,663	430	3	346	1,035	167	1	890	2,665	430	3	0.1615	0.0013
8	Manufacture of apparel	522	714	0	0	203	278	0	0	522	715	0	0	0.0000	0.0000
9	Sawmills and manufacture of furniture	63	346	0	0	25	135	0	0	63	346	0	0	0.0000	0.0000
10	Manufacture of paper and educ material	223	1,235	346	3	87	480	134	1	223	1,236	346	3	0.2799	0.0023
11	Electricity, steam and hot water prod	101	750	5,859	47	39	291	214	2	101	750	580	5	0.7732	0.0063
12	Petroleum refineries	37	745	486	1	14	274	179	0	37	705	460	1	0.6523	0.0008
13	Coking, manufacture of gas & coal	25	97	816	7	10	38	317	3	25	97	815	7	8.4178	0.0686
14	Chemical industries	190	3,266	1,810	14	74	1,270	704	5	190	3,269	1,812	14	0.5543	0.0042
15	Manufacture of building materials	31	1,327	1,884	15	12	516	733	6	31	1,327	1,884	15	1.4199	0.0115
16	Primary metal manufacturing	0	1,648	1,408	11	0	641	548	4	0	1,645	1,405	11	0.8542	0.0069
17	Manufacture of metal products	169	784	152	1	66	304	59	0	169	782	152	1	0.1941	0.0016
18	Manufacture of machinery	924	1,757	214	2	359	683	83	1	924	1,754	214	2	0.1218	0.0010
19	Manufacture of transport equipment	242	489	60	0	94	190	23	0	242	490	60	0	0.1218	0.0010
20	Manufacture of electric machinery	363	841	102	1	141	327	40	0	363	840	102	1	0.1218	0.0010
21	Manufacture of electronics equip	414	662	81	1	166	264	32	0	420	671	82	1	0.1218	0.0010
22	Manufacture of instruments	0	76	0	0	0	30	0	0	0	76	0	0	0.0000	0.0000
23	Maintenance and repair of machinery	384	408	0	0	149	159	0	0	384	408	0	0	0.0000	0.0000
24	Industries not elsewhere classified	156	367	0	0	60	143	0	0	156	367	0	0	0.0000	0.0000
25	Construction	3,609	3,609	90	1	1,403	1,403	35	0	3,609	3,609	90	1	0.0250	0.0002
26	Freight transport and communication	732	1,549	644	5	285	602	250	2	732	1,548	644	5	0.4161	0.0029
27	Commerce	510	1,838	169	1	198	715	66	1	510	1,838	169	1	0.0921	0.0007
28	Restaurants	418	418	39	0	163	163	15	0	418	418	39	0	0.0921	0.0007
29	Passenger transport	245	412	47	0	95	160	18	0	245	412	47	0	0.1135	0.0009
30	Public utilities and services to house	1,296	1,614	140	1	504	628	54	0	1,296	1,615	140	1	0.0864	0.0007
31	Cultural, education and health services	2,746	3,286	284	2	1,068	1,278	110	1	2,746	3,286	284	2	0.0864	0.0007
32	Finance and insurance	30	851	74	1	12	331	29	0	30	851	74	1	0.0864	0.0007
33	Public administration	1,125	1,125	97	1	437	437	38	0	1,125	1,125	97	1	0.0864	0.0007
	Total	24,934	49,016	18,474	143	9,700	19,059	5,036	38	24,941	49,016	12,734	97		

Final Demand and Gross Output in billions of 1990 Yuans

Final Demand(GDP) Growth Rate
2010-2025 6.50%

CO2 Emission Reduction
2010-2025 31.07%

SIMULATION: CHINA DLP MODEL 4-U (1990-2000)

7/14/94

		Baseline 2000				DLP 1990				DLP 2000				CO2 COEFFICIENT	SO2 COEFFICIENT
		Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	(ton/tho Yuan)	(ton/tho Yuan)
1	Agriculture	1,387	2,171	121	1	491	879	49	0	1,387	2,178	80	1	0.0366	0.0003
2	Coal mining	31	108	352	3	11	47	153	1	31	82	176	1	2.1546	0.0176
3	Crude petroleum & natural gas prod	25	109	23	0	9	46	10	0	25	79	12	0	0.1515	0.0003
4	Metal ore mining	0	28	0	0	0	14	0	0	0	30	0	0	0.0000	0.0000
5	Other mining	0	67	0	0	0	31	0	0	0	68	0	0	0.0000	0.0000
6	Food manufacturing	346	561	115	1	245	353	72	1	346	563	75	1	0.1328	0.0011
7	Manufacture of textiles	168	502	81	1	79	237	38	0	168	507	53	0	0.1049	0.0008
8	Manufacture of apparel	98	135	0	0	46	63	0	0	98	135	0	0	0.0000	0.0000
9	Sawmills and manufacture of furniture	12	65	0	0	8	34	0	0	12	66	0	0	0.0000	0.0000
10	Manufacture of paper and educ material	42	233	65	1	30	116	32	0	42	236	43	0	0.1825	0.0015
11	Electricity, steam and hot water prod	19	142	1,105	9	7	64	499	4	19	120	876	7	7.2834	0.0589
12	Petroleum refineries	7	141	92	0	2	61	40	0	7	105	56	0	0.5331	0.0006
13	Coking, manufacture of gas & coal	5	18	154	1	2	9	77	1	5	15	89	1	5.8870	0.0480
14	Chemical industries	36	616	342	3	25	287	159	1	36	630	233	2	0.3696	0.0028
15	Manufacture of building materials	6	250	355	3	2	117	166	1	6	253	241	2	0.9506	0.0077
16	Primary metal manufacturing	0	311	268	2	0	161	137	1	0	323	206	2	0.6363	0.0051
17	Manufacture of metal products	32	148	29	0	23	78	15	0	32	149	19	0	0.1273	0.0010
18	Manufacture of machinery	174	331	40	0	123	203	25	0	174	336	27	0	0.0797	0.0006
19	Manufacture of transport equipment	46	92	11	0	32	54	7	0	91	146	12	0	0.0795	0.0006
20	Manufacture of electric machinery	69	159	19	0	48	94	11	0	69	160	13	0	0.0796	0.0006
21	Manufacture of electronics equip	78	125	15	0	37	59	7	0	71	116	9	0	0.0793	0.0006
22	Manufacture of instruments	0	14	0	0	0	7	0	0	0	15	0	0	0.0000	0.0000
23	Maintenance and repair of machinery	72	77	0	0	26	27	0	0	72	77	0	0	0.0000	0.0000
24	Industries not elsewhere classified	29	69	0	0	21	40	0	0	29	70	0	0	0.0000	0.0000
25	Construction	681	681	17	0	321	321	8	0	681	681	11	0	0.0166	0.0001
26	Freight transport and communication	138	292	122	1	49	122	51	0	138	294	84	1	0.2842	0.0020
27	Commerce	96	347	32	0	34	155	14	0	96	351	21	0	0.0601	0.0005
28	Restaurants	79	79	7	0	44	44	4	0	79	79	5	0	0.0600	0.0005
29	Passenger transport	46	78	9	0	16	29	3	0	46	78	6	0	0.0766	0.0006
30	Public utilities and services to house	244	305	26	0	86	110	10	0	244	305	17	0	0.0570	0.0004
31	Cultural, education and health services	518	620	54	0	183	226	20	0	518	622	35	0	0.0569	0.0004
32	Finance and insurance	6	161	14	0	2	75	6	0	6	164	9	0	0.0564	0.0004
33	Public administration	212	212	18	0	75	75	6	0	212	212	12	0	0.0569	0.0004
	Total	4,704	9,247	3,485	27	2,080	4,240	1,620	13	4,743	9,247	2,419	19		

Final Demand and Gross Output in billions of 1990 Yuans

Final Demand(GDP) Growth Rate
1990-2000 8.59%

CO2 Emission Reduction
1990-2000 30.59%

SIMULATION: CHINA DLP MODEL 4-U (1990-2000), W/ CONSTRAINT

8/8/94

		Baseline 2000				DLP 1990				DLP 2000				CO2 COEFFICIENT	SO2 COEFFICIENT
		Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	(ton/tho Yuan)	(ton/tho Yuan)
1	Agriculture	1,387	2,171	121	1	491	879	49	0	1,376	2,981	109	1	0.0366	0.0003
2	Coal mining	31	108	352	3	11	47	153	1	31	112	241	2	2.1546	0.0176
3	Crude petroleum & natural gas prod	25	109	23	0	9	46	10	0	25	108	16	0	0.1515	0.0003
4	Metal ore mining	0	28	0	0	0	14	0	0	0	41	0	0	0.0000	0.0000
5	Other mining	0	67	0	0	0	31	0	0	0	93	0	0	0.0000	0.0000
6	Food manufacturing	346	561	115	1	245	353	72	1	343	771	102	1	0.1328	0.0011
7	Manufacture of textiles	168	502	81	1	79	237	38	0	166	695	73	1	0.1049	0.0008
8	Manufacture of apparel	98	135	0	0	46	63	0	0	98	185	0	0	0.0000	0.0000
9	Sawmills and manufacture of furniture	12	65	0	0	8	34	0	0	12	91	0	0	0.0000	0.0000
10	Manufacture of paper and educ material	42	233	65	1	30	116	32	0	42	323	59	0	0.1825	0.0015
11	Electricity, steam and hot water prod	19	142	1,105	9	7	64	499	4	19	165	1,199	10	7.2834	0.0589
12	Petroleum refineries	7	141	92	0	2	61	40	0	7	144	77	0	0.5331	0.0006
13	Coking, manufacture of gas & coal	5	18	154	1	2	9	77	1	5	21	122	1	5.8870	0.0480
14	Chemical industries	36	616	342	3	25	287	159	1	36	863	319	2	0.3696	0.0028
15	Manufacture of building materials	6	250	355	3	2	117	166	1	6	347	330	3	0.9506	0.0077
16	Primary metal manufacturing	0	311	266	2	0	161	137	1	0	442	281	2	0.6363	0.0051
17	Manufacture of metal products	32	148	29	0	23	78	15	0	32	204	26	0	0.1273	0.0010
18	Manufacture of machinery	174	331	40	0	123	203	25	0	173	460	37	0	0.0797	0.0006
19	Manufacture of transport equipment	46	92	11	0	32	54	7	0	91	199	16	0	0.0795	0.0006
20	Manufacture of electric machinery	69	159	19	0	48	94	11	0	68	219	17	0	0.0796	0.0006
21	Manufacture of electronics equip	78	125	15	0	37	59	7	0	71	159	13	0	0.0793	0.0006
22	Manufacture of instruments	0	14	0	0	0	7	0	0	0	20	0	0	0.0000	0.0000
23	Maintenance and repair of machinery	72	77	0	0	26	27	0	0	72	106	0	0	0.0000	0.0000
24	Industries not elsewhere classified	29	69	0	0	21	40	0	0	29	96	0	0	0.0000	0.0000
25	Construction	681	681	17	0	321	321	8	0	675	932	15	0	0.0166	0.0001
26	Freight transport and communication	138	292	122	1	49	122	51	0	137	402	114	1	0.2842	0.0020
27	Commerce	96	347	32	0	34	155	14	0	95	481	29	0	0.0601	0.0005
28	Restaurants	79	79	7	0	44	44	4	0	78	108	6	0	0.0600	0.0005
29	Passenger transport	46	78	9	0	16	29	3	0	46	107	8	0	0.0766	0.0006
30	Public utilities and services to house	244	305	26	0	86	110	10	0	242	418	24	0	0.0570	0.0004
31	Cultural, education and health services	518	620	54	0	183	226	20	0	514	851	48	0	0.0569	0.0004
32	Finance and insurance	6	161	14	0	2	75	6	0	6	224	13	0	0.0564	0.0004
33	Public administration	212	212	18	0	75	75	6	0	211	291	17	0	0.0569	0.0004
	Total	4,704	9,247	3,485	27	2,080	4,240	1,620	13	4,710	12,656	3,311	26		

Final Demand and Gross Output in billions of 1990 Yuans

Final Demand(GDP) Growth Rate
1990-2000 8.52%

CO2 Emission Reduction
1990-2000 5.00%

SIMULATION: CHINA DLP MODEL 4-U (2000-2010)

8/2/94

		Baseline 2010				DLP 2000				DLP 2010				CO2 COEFFICIENT	SO2 COEFFICIENT
		Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	(ton/tho Yuan)	(ton/tho Yuan)
1	Agriculture	2,860	4,475	249	2	1,387	2,178	80	1	2,860	4,487	42	0	0.0093	0.0001
2	Coal mining	65	223	726	6	31	82	176	1	65	142	57	0	0.4053	0.0033
3	Crude petroleum & natural gas prod	52	224	48	0	25	79	12	0	52	142	15	0	0.1091	0.0001
4	Metal ore mining	0	57	0	0	0	30	0	0	0	62	0	0	0.0000	0.0000
5	Other mining	1	138	0	0	0	68	0	0	1	139	0	0	0.0000	0.0000
6	Food manufacturing	713	1,157	237	2	346	563	75	1	713	1,160	29	0	0.0254	0.0002
7	Manufacture of textiles	346	1,035	167	1	168	507	53	0	346	1,044	21	0	0.0201	0.0002
8	Manufacture of apparel	203	278	0	0	98	135	0	0	203	279	0	0	0.0000	0.0000
9	Sawmills and manufacture of furniture	25	135	0	0	12	66	0	0	25	136	0	0	0.0000	0.0000
10	Manufacture of paper and educ material	87	480	134	1	42	236	43	0	87	485	17	0	0.0345	0.0003
11	Electricity, steam and hot water prod	39	292	2278	18	19	120	876	7	39	347	2,367	19	6.8225	0.0552
12	Petroleum refineries	14	290	189	0	7	105	56	0	14	187	81	0	0.4307	0.0001
13	Coking, manufacture of gas & coal	10	38	317	3	5	15	89	1	10	28	21	0	0.7732	0.0063
14	Chemical industries	74	1,270	704	5	36	630	233	2	74	1,292	116	1	0.0901	0.0005
15	Manufacture of building materials	12	516	733	6	6	253	241	2	12	520	93	1	0.1793	0.0014
16	Primary metal manufacturing	0	641	547	4	0	323	206	2	0	673	365	3	0.5423	0.0044
17	Manufacture of metal products	66	305	59	0	32	149	19	0	66	307	8	0	0.0257	0.0002
18	Manufacture of machinery	359	683	83	1	174	336	27	0	400	737	12	0	0.0163	0.0001
19	Manufacture of transport equipment	94	190	23	0	91	146	12	0	188	301	5	0	0.0162	0.0001
20	Manufacture of electric machinery	141	327	40	0	69	160	13	0	141	331	5	0	0.0163	0.0001
21	Manufacture of electronics equip	161	257	31	0	71	118	9	0	108	186	3	0	0.0162	0.0001
22	Manufacture of instruments	0	30	0	0	0	15	0	0	0	30	0	0	0.0000	0.0000
23	Maintenance and repair of machinery	149	159	0	0	72	77	0	0	149	159	0	0	0.0000	0.0000
24	Industries not elsewhere classified	60	143	0	0	29	70	0	0	60	144	0	0	0.0000	0.0000
25	Construction	1,403	1,403	35	0	681	681	11	0	1,403	1,403	8	0	0.0055	0.0000
26	Freight transport and communication	285	602	251	2	138	294	84	1	285	606	50	0	0.0824	0.0004
27	Commerce	198	715	66	1	96	351	21	0	198	723	9	0	0.0118	0.0001
28	Restaurants	163	163	15	0	79	79	5	0	163	163	2	0	0.0118	0.0001
29	Passenger transport	95	160	18	0	46	78	6	0	95	161	3	0	0.0186	0.0001
30	Public utilities and services to house	504	628	54	0	244	305	17	0	504	629	9	0	0.0137	0.0001
31	Cultural, education and health services	1,068	1,278	110	1	518	622	35	0	1,068	1,282	18	0	0.0137	0.0001
32	Finance and insurance	12	331	29	0	6	164	9	0	12	337	5	0	0.0135	0.0001
33	Public administration	437	437	38	0	212	212	12	0	437	437	6	0	0.0137	0.0001
	Total	9,695	19,059	7,183	56	4,743	9,247	2,419	19	9,777	19,059	3,362	26		

Final Demand and Gross Output in billions of 1990 Yuans

Final Demand(GDP) Growth Rate
2000-2010 7.50%

CO2 Emission Reduction
2000-2010 53.19%

SIMULATION: CHINA DLP MODEL 4-U (2010-2025)

8/2/94

		Baseline 2025				DLP 2010				DLP 2025				CO2	SO2
		Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	COEFFICIENT (ton/tho Yuan)	COEFFICIENT (ton/tho Yuan)
1	Agriculture	7,354	11,509	641	5	2,860	4,487	42	0	7,354	11,544	32	0	0.0028	0.0000
2	Coal mining	167	574	1868	15	65	142	57	0	167	318	1	0	0.0039	0.0000
3	Crude petroleum & natural gas prod	134	577	124	0	52	142	15	0	134	356	31	0	0.0867	0.0000
4	Metal ore mining	0	146	0	0	0	62	0	0	0	163	0	0	0.0000	0.0000
5	Other mining	2	355	0	0	1	139	0	0	2	359	0	0	0.0000	0.0000
6	Food manufacturing	1,833	2,975	608	5	713	1,160	29	0	1,833	2,984	2	0	0.0007	0.0000
7	Manufacture of textiles	890	2,663	430	3	346	1,044	21	0	890	2,689	2	0	0.0007	0.0000
8	Manufacture of apparel	522	714	0	0	203	279	0	0	522	717	0	0	0.0000	0.0000
9	Sawmills and manufacture of furniture	63	346	0	0	25	136	0	0	63	351	0	0	0.0000	0.0000
10	Manufacture of paper and educ material	223	1,235	346	3	87	485	17	0	223	1,249	1	0	0.0006	0.0000
11	Electricity, steam and hot water prod	101	750	5859	47	39	347	2,367	19	101	895	5,577	45	6.2321	0.0503
12	Petroleum refineries	37	745	486	1	14	187	81	0	37	461	178	0	0.3862	0.0000
13	Coking, manufacture of gas & coal	25	97	816	7	10	28	21	0	25	67	0	0	0.0058	0.0000
14	Chemical industries	190	3,266	1810	14	74	1,292	116	1	190	3,333	78	0	0.0234	0.0000
15	Manufacture of building materials	31	1,327	1884	15	12	520	93	1	31	1,341	11	0	0.0079	0.0000
16	Primary metal manufacturing	0	1,648	1408	11	0	673	365	3	0	1,741	851	7	0.4891	0.0039
17	Manufacture of metal products	169	784	152	1	66	307	8	0	169	791	2	0	0.0022	0.0000
18	Manufacture of machinery	924	1,757	214	2	400	737	12	0	1,054	1,925	3	0	0.0016	0.0000
19	Manufacture of transport equipment	242	489	60	0	188	301	5	0	484	775	1	0	0.0016	0.0000
20	Manufacture of electric machinery	363	841	102	1	141	331	5	0	363	853	1	0	0.0016	0.0000
21	Manufacture of electronics equip	414	662	81	1	108	186	3	0	277	479	1	0	0.0016	0.0000
22	Manufacture of instruments	0	76	0	0	0	30	0	0	0	77	0	0	0.0000	0.0000
23	Maintenance and repair of machinery	384	408	0	0	149	159	0	0	384	409	0	0	0.0000	0.0000
24	Industries not elsewhere classified	156	367	0	0	60	144	0	0	156	371	0	0	0.0000	0.0000
25	Construction	3,609	3,609	90	1	1,403	1,403	8	0	3,609	3,609	9	0	0.0025	0.0000
26	Freight transport and communication	732	1,549	644	5	285	606	50	0	732	1,560	52	0	0.0334	0.0000
27	Commerce	510	1,838	169	1	198	723	9	0	510	1,861	1	0	0.0007	0.0000
28	Restaurants	418	418	39	0	163	163	2	0	418	418	0	0	0.0007	0.0000
29	Passenger transport	245	412	47	0	95	161	3	0	245	415	2	0	0.0048	0.0000
30	Public utilities and services to house	1,296	1,614	140	1	504	629	9	0	1,296	1,619	6	0	0.0035	0.0000
31	Cultural, education and health services	2,746	3,286	284	2	1,068	1,282	18	0	2,746	3,297	12	0	0.0035	0.0000
32	Finance and insurance	30	851	74	1	12	337	5	0	30	868	3	0	0.0034	0.0000
33	Public administration	1,125	1,125	97	1	437	437	6	0	1,125	1,125	4	0	0.0035	0.0000
	Total	24,934	49,016	18,474	143	9,777	19,059	3,362	26	25,170	49,016	6,861	52		

Final Demand and Gross Output in billions of 1990 Yuans

Final Demand(GDP) Growth Rate
2010-2025 6.51%

CO2 Emission Reduction
2010-2025 62.86%

SIMULATION: CHINA DLP MODEL 5-U (2000-2010), W/ CONSTRAINT

8/10/94

		Baseline 2010				DLP 2000				DLP 2010				CO2	SO2
		Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	COEFFICIENT (ton/tho Yuan)	COEFFICIENT (ton/tho Yuan)
1	Agriculture	2,860	4,475	249	2	1,387	2,178	80	1	2,859	4,487	42	0	0.0093	0.0001
2	Coal mining	65	223	726	6	31	82	176	1	65	142	57	0	0.4053	0.0033
3	Crude petroleum & natural gas prod	52	224	48	0	25	79	12	0	52	142	15	0	0.1091	0.0001
4	Metal ore mining	0	57	0	0	0	30	0	0	0	62	0	0	0.0000	0.0000
5	Other mining	1	138	0	0	0	68	0	0	1	139	0	0	0.0000	0.0000
6	Food manufacturing	713	1,157	237	2	346	563	75	1	713	1,160	29	0	0.0254	0.0002
7	Manufacture of textiles	346	1,035	167	1	168	507	53	0	348	1,044	21	0	0.0201	0.0002
8	Manufacture of apparel	203	278	0	0	98	135	0	0	203	279	0	0	0.0000	0.0000
9	Sawmills and manufacture of furniture	25	135	0	0	12	66	0	0	25	136	0	0	0.0000	0.0000
10	Manufacture of paper and educ material	87	480	134	1	42	236	43	0	87	485	17	0	0.0345	0.0003
11	Electricity, steam and hot water prod	39	292	2278	18	19	120	876	7	39	347	2,068	17	5.9598	0.0482
12	Petroleum refineries	14	290	189	0	7	105	56	0	14	187	81	0	0.4307	0.0001
13	Coking, manufacture of gas & coal	10	38	317	3	5	15	89	1	10	28	21	0	0.7732	0.0063
14	Chemical industries	74	1,270	704	5	36	630	233	2	74	1,292	116	1	0.0901	0.0005
15	Manufacture of building materials	12	516	733	6	6	253	241	2	12	520	93	1	0.1793	0.0014
16	Primary metal manufacturing	0	641	547	4	0	323	206	2	0	673	365	3	0.5423	0.0044
17	Manufacture of metal products	66	305	59	0	32	149	19	0	66	307	8	0	0.0257	0.0002
18	Manufacture of machinery	359	683	83	1	174	336	27	0	400	737	12	0	0.0163	0.0001
19	Manufacture of transport equipment	94	190	23	0	91	146	12	0	188	301	5	0	0.0162	0.0001
20	Manufacture of electric machinery	141	327	40	0	69	160	13	0	141	331	5	0	0.0163	0.0001
21	Manufacture of electronics equip	161	257	31	0	71	116	9	0	108	186	3	0	0.0162	0.0001
22	Manufacture of instruments	0	30	0	0	0	15	0	0	0	30	0	0	0.0000	0.0000
23	Maintenance and repair of machinery	149	159	0	0	72	77	0	0	149	159	0	0	0.0000	0.0000
24	Industries not elsewhere classified	60	143	0	0	29	70	0	0	60	144	0	0	0.0000	0.0000
25	Construction	1,403	1,403	35	0	681	681	11	0	1,403	1,403	8	0	0.0055	0.0000
26	Freight transport and communication	285	602	251	2	138	294	84	1	285	606	50	0	0.0824	0.0004
27	Commerce	198	715	66	1	96	351	21	0	198	723	9	0	0.0118	0.0001
28	Restaurants	163	163	15	0	79	79	5	0	163	163	2	0	0.0118	0.0001
29	Passenger transport	95	160	18	0	46	78	6	0	95	161	3	0	0.0186	0.0001
30	Public utilities and services to house	504	628	54	0	244	305	17	0	504	629	9	0	0.0137	0.0001
31	Cultural, education and health services	1,068	1,278	110	1	518	622	35	0	1,068	1,282	18	0	0.0137	0.0001
32	Finance and insurance	12	331	29	0	6	164	9	0	12	337	5	0	0.0135	0.0001
33	Public administration	437	437	38	0	212	212	12	0	437	437	6	0	0.0137	0.0001
	Total	9,695	19,059	7,183	56	4,743	9,247	2,419	19	9,776	19,059	3,067	23		

Final Demand and Gross Output in billions of 1990 Yuans

Final Demand(GDP) Growth Rate
2000-2010 7.50%

CO2 Emission Reduction
2000-2010 57.30%

SIMULATION: CHINA DLP MODEL 5-U (2010-2025), W/ CONSTRAINT

8/10/94

		Baseline 2025				DLP 2010				DLP 2025				CO2	SO2
		Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	COEFFICIENT (ton/tho Yuan)	COEFFICIENT (ton/tho Yuan)
1	Agriculture	7,354	11,509	641	5	2,859	4,487	42	0	7,354	11,544	32	0	0.0028	0.0000
2	Coal mining	167	574	1868	15	65	142	57	0	167	318	1	0	0.0039	0.0000
3	Crude petroleum & natural gas prod	134	577	124	0	52	142	15	0	134	356	31	0	0.0867	0.0000
4	Metal ore mining	0	146	0	0	0	62	0	0	0	163	0	0	0.0000	0.0000
5	Other mining	2	355	0	0	1	139	0	0	2	359	0	0	0.0000	0.0000
6	Food manufacturing	1,833	2,975	608	5	713	1,160	29	0	1,833	2,984	2	0	0.0007	0.0000
7	Manufacture of textiles	890	2,663	430	3	346	1,044	21	0	890	2,689	2	0	0.0007	0.0000
8	Manufacture of apparel	522	714	0	0	203	279	0	0	522	717	0	0	0.0000	0.0000
9	Sawmills and manufacture of furniture	63	346	0	0	25	136	0	0	63	351	0	0	0.0000	0.0000
10	Manufacture of paper and educ material	223	1,235	346	3	87	485	17	0	223	1,249	1	0	0.0006	0.0000
11	Electricity, steam and hot water prod	101	750	5859	47	39	347	2,068	17	101	895	1,504	12	1.6805	0.0133
12	Petroleum refineries	37	745	486	1	14	187	81	0	37	461	178	0	0.3862	0.0000
13	Coking, manufacture of gas & coal	25	97	816	7	10	28	21	0	25	67	0	0	0.0058	0.0000
14	Chemical industries	190	3,266	1810	14	74	1,292	116	1	190	3,333	78	0	0.0234	0.0000
15	Manufacture of building materials	31	1,327	1684	15	12	520	93	1	31	1,341	11	0	0.0079	0.0000
16	Primary metal manufacturing	0	1,648	1408	11	0	673	365	3	0	1,741	851	7	0.4891	0.0039
17	Manufacture of metal products	169	784	152	1	66	307	8	0	169	791	2	0	0.0022	0.0000
18	Manufacture of machinery	924	1,757	214	2	400	737	12	0	1,054	1,925	3	0	0.0016	0.0000
19	Manufacture of transport equipment	242	489	60	0	188	301	5	0	484	775	1	0	0.0016	0.0000
20	Manufacture of electric machinery	363	841	102	1	141	331	5	0	363	853	1	0	0.0016	0.0000
21	Manufacture of electronics equip	414	662	81	1	108	186	3	0	277	479	1	0	0.0016	0.0000
22	Manufacture of instruments	0	76	0	0	0	30	0	0	0	77	0	0	0.0000	0.0000
23	Maintenance and repair of machinery	384	408	0	0	149	159	0	0	384	409	0	0	0.0000	0.0000
24	Industries not elsewhere classified	156	367	0	0	60	144	0	0	156	371	0	0	0.0000	0.0000
25	Construction	3,609	3,609	90	1	1,403	1,403	8	0	3,609	3,609	9	0	0.0025	0.0000
26	Freight transport and communication	732	1,549	644	5	285	606	50	0	732	1,560	52	0	0.0334	0.0000
27	Commerce	510	1,838	169	1	198	723	9	0	510	1,861	1	0	0.0007	0.0000
28	Restaurants	418	418	39	0	163	163	2	0	418	418	0	0	0.0007	0.0000
29	Passenger transport	245	412	47	0	95	161	3	0	245	415	2	0	0.0048	0.0000
30	Public utilities and services to house	1,296	1,614	140	1	504	629	9	0	1,296	1,619	6	0	0.0035	0.0000
31	Cultural, education and health services	2,746	3,286	284	2	1,068	1,282	18	0	2,746	3,297	12	0	0.0035	0.0000
32	Finance and insurance	30	851	74	1	12	337	5	0	30	868	3	0	0.0034	0.0000
33	Public administration	1,125	1,125	97	1	437	437	6	0	1,125	1,125	4	0	0.0035	0.0000
	Total	24,934	49,016	18,474	143	9,776	19,059	3,067	23	25,170	49,016	2,788	19		

Final Demand and Gross Output in billions of 1990 Yuans

Final Demand(GDP) Growth Rate
2010-2025 6.51%

CO2 Emission Reduction
2010-2025 84.91%

APPENDIX A2:

LOWER-BOUND SIMULATIONS

SIMULATION BASELINE: CHINA DLP MODEL 0-L

6/17/94

		BASE 1990			DLP 1990			DLP 2000			DLP 2010			DLP 2025			CO2
		Final Demand	Gross Output	CO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	COEFFICIEN (ton/tho Yuan)
1	Agriculture	409	772	43	491	879	49	1,099	1,720	96	1,627	2,546	142	2,534	3,966	221	0.0557
2	Coal mining	9	45	147	11	47	153	25	86	279	37	127	413	58	198	644	3.2568
3	Crude petroleum & natural gas prod	7	44	9	9	46	10	20	86	18	30	128	27	46	199	43	0.2141
4	Metal ore mining	(1)	15	0	0	14	0	0	22	0	0	32	0	0	50	0	0.0000
5	Other mining	0	35	0	0	31	0	0	53	0	0	78	0	1	122	0	0.0000
6	Food manufacturing	204	305	62	245	353	72	274	445	91	406	658	135	632	1,025	210	0.2045
7	Manufacture of textiles	99	275	44	79	237	38	133	398	64	197	589	95	307	917	148	0.1615
8	Manufacture of apparel	58	77	0	46	63	0	78	107	0	115	158	0	180	246	0	0.0000
9	Sawmills and manufacture of furniture	7	36	0	8	34	0	9	52	0	14	77	0	22	119	0	0.0000
10	Manufacture of paper and educ material	25	110	31	30	116	32	33	185	52	49	273	76	77	426	119	0.2799
11	Electricity, steam and hot water prod	6	65	509	7	64	499	15	112	875	22	166	1,296	35	258	2,019	7.8119
12	Petroleum refineries	2	60	39	2	61	40	6	111	73	8	165	108	13	257	168	0.6523
13	Coking, manufacture of gas & coal	3	10	84	2	9	77	4	14	122	6	21	180	9	33	281	8.4178
14	Chemical industries	21	300	166	25	287	159	28	488	270	42	722	400	66	1,125	624	0.5543
15	Manufacture of building materials	2	132	188	2	117	166	5	198	281	7	293	417	11	457	649	1.4199
16	Primary metal manufacturing	(22)	179	153	0	161	137	0	246	210	0	365	311	0	568	485	0.8542
17	Manufacture of metal products	19	80	16	23	78	15	25	117	23	37	173	34	58	270	52	0.1941
18	Manufacture of machinery	103	231	28	123	203	25	138	262	32	204	389	47	318	605	74	0.1218
19	Manufacture of transport equipment	27	66	8	32	54	7	36	73	9	54	108	13	83	169	21	0.1218
20	Manufacture of electric machinery	40	98	12	48	94	11	54	126	15	80	186	23	125	290	35	0.1218
21	Manufacture of electronics equip	31	64	8	37	59	7	61	98	12	91	145	18	141	226	28	0.1218
22	Manufacture of instruments	(1)	13	0	0	7	0	0	11	0	0	17	0	0	26	0	0.0000
23	Maintenance and repair of machinery	21	23	0	26	27	0	57	61	0	85	90	0	132	141	0	0.0000
24	Industries not elsewhere classified	(1)	17	0	21	40	0	23	55	0	34	81	0	54	126	0	0.0000
25	Construction	402	402	10	321	321	8	539	539	13	798	798	20	1,244	1,244	31	0.0250
26	Freight transport and communication	41	113	47	49	122	51	109	231	96	162	343	143	252	534	222	0.4161
27	Commerce	28	170	16	34	155	14	76	275	25	113	406	37	176	633	58	0.0921
28	Restaurants	46	47	4	44	44	4	62	62	6	92	92	9	144	144	13	0.0921
29	Passenger transport	14	25	3	16	29	3	37	62	7	54	91	10	85	142	16	0.1135
30	Public utilities and services to house	72	95	8	86	110	10	194	241	21	287	357	31	447	556	48	0.0864
31	Cultural, education and health services	153	193	17	183	226	20	410	491	42	607	727	63	946	1,133	98	0.0864
32	Finance and insurance	2	79	7	2	75	6	4	127	11	7	188	16	10	293	25	0.0864
33	Public administration	63	63	5	75	75	6	168	168	15	249	249	22	388	388	34	0.0864
	Total	1,888	4,240	1,665	2,080	4,240	1,620	3,725	7,323	2,760	5,514	10,840	4,086	8,591	16,888	6,365	

Final Demand and Gross Output in billions of 1990 Yuans

Final Demand Increasing Rate

1990-2000	6.00%
2000-2010	4.00%
2010-2025	3.00%

SIMULATION: CHINA DLP MODEL 1-L (1990-2000)

8/1/94

		Baseline 2000				DLP 1990				DLP 2000				CO2 COEFFICIENT	SO2 COEFFICIENT
		Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	(ton/tho Yuan)	(ton/tho Yuan)
1	Agriculture	1,099	1,720	96	1	491	879	49	0	1,099	1,781	99	1	0.0557	0.0004
2	Coal mining	25	86	279	2	11	47	153	1	12	70	229	2	3.2568	0.0265
3	Crude petroleum & natural gas prod	20	86	18	0	9	46	10	0	20	84	18	0	0.2141	0.0005
4	Metal ore mining	0	22	0	0	0	14	0	0	0	21	0	0	0.0000	0.0000
5	Other mining	0	53	0	0	0	31	0	0	0	52	0	0	0.0000	0.0000
6	Food manufacturing	274	445	91	1	245	353	72	1	382	569	118	1	0.2045	0.0017
7	Manufacture of textiles	133	398	64	1	79	237	38	0	133	394	64	1	0.1615	0.0013
8	Manufacture of apparel	78	107	0	0	46	63	0	0	78	106	0	0	0.0000	0.0000
9	Sawmills and manufacture of furniture	9	52	0	0	8	34	0	0	9	51	0	0	0.0000	0.0000
10	Manufacture of paper and educ material	33	185	52	0	30	116	32	0	33	180	50	0	0.2799	0.0023
11	Electricity, steam and hot water prod	15	112	875	7	7	64	499	4	8	101	792	6	7.8119	0.0633
12	Petroleum refineries	6	111	73	0	2	61	40	0	3	107	70	0	0.6523	0.0008
13	Coking, manufacture of gas & coal	4	14	122	1	2	9	77	1	4	14	119	1	8.4178	0.0686
14	Chemical industries	28	488	270	2	25	287	159	1	28	480	266	2	0.5543	0.0042
15	Manufacture of building materials	5	198	281	2	2	117	166	1	2	194	275	2	1.4199	0.0115
16	Primary metal manufacturing	0	246	210	2	0	161	137	1	0	239	204	2	0.8542	0.0069
17	Manufacture of metal products	25	117	23	0	23	78	15	0	25	115	22	0	0.1941	0.0016
18	Manufacture of machinery	138	262	32	0	123	203	25	0	138	257	31	0	0.1218	0.0010
19	Manufacture of transport equipment	36	73	9	0	32	54	7	0	36	71	9	0	0.1218	0.0010
20	Manufacture of electric machinery	54	126	15	0	48	94	11	0	54	122	15	0	0.1218	0.0010
21	Manufacture of electronics equip	61	98	12	0	37	59	7	0	41	70	9	0	0.1218	0.0010
22	Manufacture of instruments	0	11	0	0	0	7	0	0	0	11	0	0	0.0000	0.0000
23	Maintenance and repair of machinery	57	61	0	0	26	27	0	0	29	32	0	0	0.0000	0.0000
24	Industries not elsewhere classified	23	55	0	0	21	40	0	0	23	54	0	0	0.0000	0.0000
25	Construction	539	539	13	0	321	321	8	0	539	539	13	0	0.0250	0.0002
26	Freight transport and communication	109	231	96	1	49	122	51	0	109	235	98	1	0.4161	0.0029
27	Commerce	76	275	25	0	34	155	14	0	76	274	25	0	0.0921	0.0007
28	Restaurants	62	62	6	0	44	44	4	0	62	62	6	0	0.0921	0.0007
29	Passenger transport	37	62	7	0	16	29	3	0	37	61	7	0	0.1135	0.0009
30	Public utilities and services to house	194	241	21	0	86	110	10	0	194	239	21	0	0.0864	0.0007
31	Cultural, education and health services	410	491	42	0	183	226	20	0	362	441	38	0	0.0864	0.0007
32	Finance and insurance	4	127	11	0	2	75	6	0	4	127	11	0	0.0864	0.0007
33	Public administration	168	168	15	0	75	75	6	0	168	168	15	0	0.0864	0.0007
	Total	3,725	7,323	2,760	21	2,080	4,240	1,620	13	3,711	7,323	2,622	20		

Final Demand and Gross Output in billions of 1990 Yuans

Final Demand(GDP) Growth Rate
1990-2000 5.96%

CO2 Emission Reduction
1990-2000 5.00%

SIMULATION RESULT: CHINA DLP MODEL 2-L (1990-2000)

8/1/94

		Baseline 2000				DLP 1990				DLP 2000				CO2 COEFFICIENT	SO2 COEFFICIENT
		Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	(ton/tho Yuan)	(ton/tho Yuan)
1	Agriculture	1,099	1,720	96	1	491	879	49	0	1,099	1,720	77	1	0.0446	0.0003
2	Coal mining	25	86	279	2	11	47	153	1	25	71	185	2	2.6054	0.0212
3	Crude petroleum & natural gas prod	20	86	18	0	9	46	10	0	20	64	11	0	0.1713	0.0004
4	Metal ore mining	0	22	0	0	0	14	0	0	0	23	0	0	0.0000	0.0000
5	Other mining	0	53	0	0	0	31	0	0	0	53	0	0	0.0000	0.0000
6	Food manufacturing	274	445	91	1	245	353	72	1	274	445	73	1	0.1636	0.0013
7	Manufacture of textiles	133	398	64	1	79	237	38	0	133	399	52	0	0.1292	0.0010
8	Manufacture of apparel	78	107	0	0	46	63	0	0	78	107	0	0	0.0000	0.0000
9	Sawmills and manufacture of furniture	9	52	0	0	8	34	0	0	9	52	0	0	0.0000	0.0000
10	Manufacture of paper and educ material	33	185	52	0	30	116	32	0	33	185	41	0	0.2240	0.0018
11	Electricity, steam and hot water prod	15	112	875	7	7	64	499	4	15	93	579	5	6.2495	0.0506
12	Petroleum refineries	6	111	73	0	2	61	40	0	6	89	47	0	0.5219	0.0006
13	Coking, manufacture of gas & coal	4	14	122	1	2	9	77	1	4	15	101	1	6.7342	0.0549
14	Chemical industries	28	488	270	2	25	287	159	1	28	490	217	2	0.4435	0.0033
15	Manufacture of building materials	5	198	281	2	2	117	166	1	2	196	223	2	1.1359	0.0092
16	Primary metal manufacturing	0	246	210	2	0	161	137	1	0	256	175	1	0.6834	0.0055
17	Manufacture of metal products	25	117	23	0	23	78	15	0	25	118	18	0	0.1553	0.0012
18	Manufacture of machinery	138	262	32	0	123	203	25	0	138	334	33	0	0.0974	0.0008
19	Manufacture of transport equipment	36	73	9	0	32	54	7	0	36	73	7	0	0.0974	0.0008
20	Manufacture of electric machinery	54	126	15	0	48	94	11	0	54	128	12	0	0.0974	0.0008
21	Manufacture of electronics equip	61	98	12	0	37	59	7	0	50	83	8	0	0.0974	0.0008
22	Manufacture of instruments	0	11	0	0	0	7	0	0	0	11	0	0	0.0000	0.0000
23	Maintenance and repair of machinery	57	61	0	0	26	27	0	0	57	61	0	0	0.0000	0.0000
24	Industries not elsewhere classified	23	55	0	0	21	40	0	0	23	55	0	0	0.0000	0.0000
25	Construction	539	539	13	0	321	321	8	0	539	539	11	0	0.0200	0.0001
26	Freight transport and communication	109	231	96	1	49	122	51	0	109	231	77	1	0.3329	0.0023
27	Commerce	76	275	25	0	34	155	14	0	76	276	20	0	0.0737	0.0006
28	Restaurants	62	62	6	0	44	44	4	0	62	62	5	0	0.0737	0.0006
29	Passenger transport	37	62	7	0	16	29	3	0	37	62	6	0	0.0908	0.0007
30	Public utilities and services to house	194	241	21	0	86	110	10	0	194	241	17	0	0.0691	0.0005
31	Cultural, education and health services	410	491	42	0	183	228	20	0	410	491	34	0	0.0691	0.0005
32	Finance and insurance	4	127	11	0	2	75	6	0	4	128	9	0	0.0691	0.0005
33	Public administration	168	168	15	0	75	75	6	0	168	168	12	0	0.0691	0.0005
	Total	3,725	7,323	2,760	21	2,080	4,240	1,620	13	3,712	7,323	2,048	16		

Final Demand and Gross Output in billions of 1990 Yuans

Final Demand(GDP) Growth Rate
1990-2000 5.96%

CO2 Emission Reduction
1990-2000 25.78%

SIMULATION RESULT: CHINA DLP MODEL 2-L (1990-2000), W/ CONSTRAINT

8/3/94

		Baseline 2000				DLP 1990				DLP 2000				CO2 COEFFICIENT	SO2 COEFFICIENT
		Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	(ton/tho Yuan)	(ton/tho Yuan)
1	Agriculture	1,099	1,720	96	1	491	879	49	0	1,102	2,202	98	1	0.0446	0.0003
2	Coal mining	25	86	279	2	11	47	153	1	25	91	237	2	2.6054	0.0212
3	Crude petroleum & natural gas prod	20	86	18	0	9	46	10	0	20	82	14	0	0.1713	0.0004
4	Metal ore mining	0	22	0	0	0	14	0	0	0	29	0	0	0.0000	0.0000
5	Other mining	0	53	0	0	0	31	0	0	0	68	0	0	0.0000	0.0000
6	Food manufacturing	274	445	91	1	245	353	72	1	275	569	93	1	0.1636	0.0013
7	Manufacture of textiles	133	398	64	1	79	237	38	0	133	510	66	1	0.1292	0.0010
8	Manufacture of apparel	78	107	0	0	46	63	0	0	78	137	0	0	0.0000	0.0000
9	Sawmills and manufacture of furniture	9	52	0	0	8	34	0	0	9	67	0	0	0.0000	0.0000
10	Manufacture of paper and educ material	33	185	52	0	30	116	32	0	33	237	53	0	0.2240	0.0018
11	Electricity, steam and hot water prod	15	112	875	7	7	64	499	4	15	119	741	6	6.2495	0.0506
12	Petroleum refineries	6	111	73	0	2	61	40	0	6	114	60	0	0.5219	0.0006
13	Coking, manufacture of gas & coal	4	14	122	1	2	9	77	1	4	19	129	1	6.7342	0.0549
14	Chemical industries	28	488	270	2	25	287	159	1	29	627	278	2	0.4435	0.0033
15	Manufacture of building materials	5	198	281	2	2	117	166	1	2	251	285	2	1.1359	0.0092
16	Primary metal manufacturing	0	246	210	2	0	161	137	1	0	328	224	2	0.6834	0.0055
17	Manufacture of metal products	25	117	23	0	23	78	15	0	25	151	24	0	0.1553	0.0012
18	Manufacture of machinery	138	262	32	0	123	203	25	0	138	428	42	0	0.0974	0.0008
19	Manufacture of transport equipment	36	73	9	0	32	54	7	0	36	94	9	0	0.0974	0.0008
20	Manufacture of electric machinery	54	126	15	0	48	94	11	0	54	164	16	0	0.0974	0.0008
21	Manufacture of electronics equip	61	98	12	0	37	59	7	0	50	107	10	0	0.0974	0.0008
22	Manufacture of instruments	0	11	0	0	0	7	0	0	0	15	0	0	0.0000	0.0000
23	Maintenance and repair of machinery	57	61	0	0	26	27	0	0	58	78	0	0	0.0000	0.0000
24	Industries not elsewhere classified	23	55	0	0	21	40	0	0	23	70	0	0	0.0000	0.0000
25	Construction	539	539	13	0	321	321	8	0	541	690	14	0	0.0200	0.0001
26	Freight transport and communication	109	231	96	1	49	122	51	0	110	296	99	1	0.3329	0.0023
27	Commerce	76	275	25	0	34	155	14	0	76	353	26	0	0.0737	0.0006
28	Restaurants	62	62	6	0	44	44	4	0	63	80	6	0	0.0737	0.0006
29	Passenger transport	37	62	7	0	16	29	3	0	37	79	7	0	0.0908	0.0007
30	Public utilities and services to house	194	241	21	0	86	110	10	0	194	309	21	0	0.0691	0.0005
31	Cultural, education and health services	410	491	42	0	183	226	20	0	412	629	43	0	0.0691	0.0005
32	Finance and insurance	4	127	11	0	2	75	6	0	5	164	11	0	0.0691	0.0005
33	Public administration	168	168	15	0	75	75	6	0	169	215	15	0	0.0691	0.0005
	Total	3,725	7,323	2,760	21	2,080	4,240	1,620	13	3,723	9,373	2,622	20		

Final Demand and Gross Output in billions of 1990 Yuans

Final Demand(GDP) Growth Rate
1990-2000 5.99%

CO2 Emission Reduction
1990-2000 5.00%

SIMULATION RESULT: CHINA DLP MODEL 2-L (2000-2010)

8/1/94

		Baseline 2010				DLP 2000				DLP 2010				CO2	SO2
		Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	COEFFICIENT (ton/tho Yuan)	COEFFICIENT (ton/tho Yuan)
1	Agriculture	1,627	2,546	142	1	1,099	1,720	77	1	1,627	2,547	102	1	0.0401	0.0003
2	Coal mining	37	127	413	3	25	71	185	2	37	97	228	2	2.3449	0.0191
3	Crude petroleum & natural gas prod	30	128	27	0	20	64	11	0	30	84	13	0	0.1542	0.0003
4	Metal ore mining	0	32	0	0	0	23	0	0	0	34	0	0	0.0000	0.0000
5	Other mining	0	78	0	0	0	53	0	0	0	78	0	0	0.0000	0.0000
6	Food manufacturing	406	658	135	1	274	445	73	1	406	658	97	1	0.1472	0.0012
7	Manufacture of textiles	197	589	95	1	133	399	52	0	197	591	69	1	0.1163	0.0009
8	Manufacture of apparel	115	158	0	0	78	107	0	0	115	158	0	0	0.0000	0.0000
9	Sawmills and manufacture of furniture	14	77	0	0	9	52	0	0	14	78	0	0	0.0000	0.0000
10	Manufacture of paper and educ material	49	273	76	1	33	185	41	0	49	274	55	0	0.2016	0.0016
11	Electricity, steam and hot water prod	22	166	1296	10	15	93	579	5	22	126	707	6	5.6245	0.0456
12	Petroleum refineries	8	165	108	0	6	89	47	0	8	119	56	0	0.4697	0.0005
13	Coking, manufacture of gas & coal	6	21	180	1	4	15	101	1	6	22	136	1	6.0608	0.0494
14	Chemical industries	42	722	400	3	28	490	217	2	42	727	290	2	0.3991	0.0030
15	Manufacture of building materials	7	293	417	3	2	196	223	2	3	290	297	2	1.0223	0.0083
16	Primary metal manufacturing	0	365	311	3	0	256	175	1	0	385	237	2	0.6150	0.0049
17	Manufacture of metal products	37	173	34	0	25	118	18	0	37	176	25	0	0.1398	0.0011
18	Manufacture of machinery	204	389	47	0	138	334	33	0	204	534	47	0	0.0877	0.0007
19	Manufacture of transport equipment	54	108	13	0	36	73	7	0	54	109	10	0	0.0877	0.0007
20	Manufacture of electric machinery	80	186	23	0	54	128	12	0	80	191	17	0	0.0877	0.0007
21	Manufacture of electronics equip	91	145	18	0	50	83	8	0	68	114	10	0	0.0877	0.0007
22	Manufacture of instruments	0	17	0	0	0	11	0	0	0	17	0	0	0.0000	0.0000
23	Maintenance and repair of machinery	85	90	0	0	57	61	0	0	85	90	0	0	0.0000	0.0000
24	Industries not elsewhere classified	34	81	0	0	23	55	0	0	34	82	0	0	0.0000	0.0000
25	Construction	798	798	20	0	539	539	11	0	798	798	14	0	0.0180	0.0001
26	Freight transport and communication	162	343	143	1	109	231	77	1	162	342	102	1	0.2996	0.0021
27	Commerce	113	406	37	0	76	276	20	0	113	409	27	0	0.0663	0.0005
28	Restaurants	92	92	9	0	62	62	5	0	92	92	6	0	0.0663	0.0005
29	Passenger transport	54	91	10	0	37	62	6	0	54	91	7	0	0.0817	0.0006
30	Public utilities and services to house	287	357	31	0	194	241	17	0	287	357	22	0	0.0622	0.0005
31	Cultural, education and health services	607	727	63	0	410	491	34	0	607	727	45	0	0.0622	0.0005
32	Finance and insurance	7	188	16	0	4	128	9	0	7	191	12	0	0.0622	0.0005
33	Public administration	249	249	22	0	168	168	12	0	249	249	15	0	0.0622	0.0005
	Total	5,514	10,840	4,086	32	3,712	7,323	2,048	16	5,488	10,840	2,646	21		

Final Demand and Gross Output in billions of 1990 Yuans

Final Demand(GDP) Growth Rate
2000-2010 3.99%

CO2 Emission Reduction
2000-2010 35.23%

SIMULATION RESULT: CHINA DLP MODEL 2-L (2010-2025)

8/1/94

		Baseline 2025				DLP 2010				DLP 2025				CO2 COEFFICIENT	SO2 COEFFICIENT
		Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	(ton/tho Yuan)	(ton/tho Yuan)
1	Agriculture	2,534	3,966	221	2	1,627	2,547	102	1	2,534	3,968	143	1	0.0361	0.0003
2	Coal mining	58	198	644	5	37	97	228	2	58	141	297	2	2.1104	0.0172
3	Crude petroleum & natural gas prod	46	199	43	0	30	84	13	0	46	117	16	0	0.1387	0.0003
4	Metal ore mining	0	50	0	0	0	34	0	0	0	54	0	0	0.0000	0.0000
5	Other mining	1	122	0	0	0	78	0	0	1	122	0	0	0.0000	0.0000
6	Food manufacturing	632	1,025	210	2	406	658	97	1	632	1,026	136	1	0.1325	0.0011
7	Manufacture of textiles	307	917	148	1	197	591	69	1	307	922	96	1	0.1046	0.0008
8	Manufacture of apparel	180	246	0	0	115	158	0	0	180	247	0	0	0.0000	0.0000
9	Sawmills and manufacture of furniture	22	119	0	0	14	78	0	0	22	122	0	0	0.0000	0.0000
10	Manufacture of paper and educ material	77	426	119	1	49	274	55	0	77	428	78	1	0.1814	0.0015
11	Electricity, steam and hot water prod	35	258	2019	16	22	126	707	6	35	180	911	7	5.0621	0.0410
12	Petroleum refineries	13	257	168	0	8	119	56	0	13	168	71	0	0.4227	0.0005
13	Coking, manufacture of gas & coal	9	33	281	2	6	22	136	1	9	35	192	2	5.4547	0.0445
14	Chemical industries	66	1,125	624	5	42	727	290	2	66	1,135	408	3	0.3592	0.0027
15	Manufacture of building materials	11	457	649	5	3	290	297	2	5	452	416	3	0.9201	0.0074
16	Primary metal manufacturing	0	568	485	4	0	385	237	2	0	607	336	3	0.5535	0.0044
17	Manufacture of metal products	58	270	52	0	37	176	25	0	58	275	35	0	0.1258	0.0010
18	Manufacture of machinery	318	605	74	1	204	534	47	0	318	886	70	1	0.0789	0.0006
19	Manufacture of transport equipment	83	169	21	0	54	109	10	0	83	170	13	0	0.0789	0.0006
20	Manufacture of electric machinery	125	290	35	0	80	191	17	0	125	299	24	0	0.0789	0.0006
21	Manufacture of electronics equip	141	226	28	0	68	114	10	0	96	165	13	0	0.0789	0.0006
22	Manufacture of instruments	0	26	0	0	0	17	0	0	0	27	0	0	0.0000	0.0000
23	Maintenance and repair of machinery	132	141	0	0	85	90	0	0	132	141	0	0	0.0000	0.0000
24	Industries not elsewhere classified	54	126	0	0	34	82	0	0	54	127	0	0	0.0000	0.0000
25	Construction	1,244	1,244	31	0	798	798	14	0	1,244	1,244	20	0	0.0162	0.0001
26	Freight transport and communication	252	534	222	2	162	342	102	1	252	533	144	1	0.2697	0.0019
27	Commerce	176	633	58	0	113	409	27	0	176	638	38	0	0.0597	0.0005
28	Restaurants	144	144	13	0	92	92	6	0	144	144	9	0	0.0597	0.0005
29	Passenger transport	85	142	16	0	54	91	7	0	85	142	10	0	0.0736	0.0006
30	Public utilities and services to house	447	556	48	0	287	357	22	0	447	557	31	0	0.0560	0.0004
31	Cultural, education and health services	946	1,133	98	1	607	727	45	0	946	1,133	63	0	0.0560	0.0004
32	Finance and insurance	10	293	25	0	7	191	12	0	10	298	17	0	0.0560	0.0004
33	Public administration	388	388	34	0	249	249	15	0	388	388	22	0	0.0560	0.0004
	Total	8,591	16,888	6,365	49	5,488	10,840	2,646	21	8,540	16,888	3,608	28		

Final Demand and Gross Output in billions of 1990 Yuans

Final Demand(GDP) Growth Rate
2010-2025 2.99%

CO2 Emission Reduction
2010-2025 43.15%

SIMULATION: CHINA DLP MODEL 3-L (1990/2000)

8/2/94

		BASELINE 2000				DLP 1990				DLP 2000				CO2 COEFFICIENT	SO2 COEFFICIENT
		Final Demand	Gross Output	CO2 (MIL TON)	SO2 (MIL TON)	Final Demand	Gross Output	CO2 (MIL TON)	SO2 (MIL TON)	Final Demand	Gross Output	CO2 (MIL TON)	SO2 (MIL TON)	(TON/THO YUAN	(TON/THO YUAN)
1	Agriculture	1,099	1,720	96	1	491	879	49	0	1,099	1,720	96	1	0.0557	0.0004
2	Coal mining	25	86	279	2	11	47	153	1	25	76	248	2	3.2568	0.0265
3	Crude petroleum & natural gas prod	20	86	18	0	9	46	10	0	20	94	20	0	0.2141	0.0005
4	Metal ore mining	0	22	0	0	0	14	0	0	0	22	0	0	0.0000	0.0000
5	Other mining	0	53	0	0	0	31	0	0	0	57	0	0	0.0000	0.0000
6	Food manufacturing	274	445	91	1	245	353	72	1	274	445	91	1	0.2045	0.0017
7	Manufacture of textiles	133	398	64	1	79	237	38	0	133	398	64	1	0.1615	0.0013
8	Manufacture of apparel	78	107	0	0	46	63	0	0	78	107	0	0	0.0000	0.0000
9	Sawmills and manufacture of furniture	9	52	0	0	8	34	0	0	9	52	0	0	0.0000	0.0000
10	Manufacture of paper and educ material	33	185	52	0	30	116	32	0	33	185	52	0	0.2799	0.0023
11	Electricity, steam and hot water prod	15	112	875	7	7	64	499	4	15	112	697	6	6.2331	0.0505
12	Petroleum refineries	6	111	73	0	2	61	40	0	6	106	69	0	0.6523	0.0008
13	Coking, manufacture of gas & coal	4	14	122	1	2	9	77	1	4	14	122	1	8.4178	0.0686
14	Chemical industries	28	488	270	2	25	287	159	1	28	488	270	2	0.5543	0.0042
15	Manufacture of building materials	5	198	281	2	2	117	166	1	5	198	282	2	1.4199	0.0115
16	Primary metal manufacturing	0	246	210	2	0	161	137	1	0	246	210	2	0.8542	0.0069
17	Manufacture of metal products	25	117	23	0	23	78	15	0	25	117	23	0	0.1941	0.0016
18	Manufacture of machinery	138	262	32	0	123	203	25	0	138	263	32	0	0.1218	0.0010
19	Manufacture of transport equipment	36	73	9	0	32	54	7	0	36	73	9	0	0.1218	0.0010
20	Manufacture of electric machinery	54	126	15	0	48	94	11	0	54	126	15	0	0.1218	0.0010
21	Manufacture of electronics equip	61	98	12	0	37	59	7	0	63	101	12	0	0.1218	0.0010
22	Manufacture of instruments	0	11	0	0	0	7	0	0	0	11	0	0	0.0000	0.0000
23	Maintenance and repair of machinery	57	61	0	0	26	27	0	0	57	61	0	0	0.0000	0.0000
24	Industries not elsewhere classified	23	55	0	0	21	40	0	0	23	55	0	0	0.0000	0.0000
25	Construction	539	539	13	0	321	321	8	0	539	539	13	0	0.0250	0.0002
26	Freight transport and communication	109	231	96	1	49	122	51	0	109	231	96	1	0.4161	0.0029
27	Commerce	76	275	25	0	34	155	14	0	76	275	25	0	0.0921	0.0007
28	Restaurants	62	62	6	0	44	44	4	0	62	62	6	0	0.0921	0.0007
29	Passenger transport	37	62	7	0	16	29	3	0	37	62	7	0	0.1135	0.0009
30	Public utilities and services to house	194	241	21	0	86	110	10	0	194	241	21	0	0.0864	0.0007
31	Cultural, education and health services	410	491	42	0	183	226	20	0	410	491	42	0	0.0864	0.0007
32	Finance and insurance	4	127	11	0	2	75	6	0	4	127	11	0	0.0864	0.0007
33	Public administration	168	168	15	0	75	75	6	0	168	168	15	0	0.0864	0.0007
	Total	3,725	7,323	2,760	21	2,080	4,240	1,620	13	3,727	7,323	2,550	20		

Final Demand and Gross Output in billions of 1990 Yuans

Final Demand(GDP) Growth Rate
1990-2000 6.00%

CO2 Emission Reduction
1990-2000 7.62%

SIMULATION: CHINA DLP MODEL 3-L (1990/2000), W/ CONSTRAINT

8/3/94

		BASELINE 2000				DLP 1990				DLP 2000				CO2 COEFFICIENT	SO2 COEFFICIENT
		Final Demand	Gross Output	CO2 (MIL TON)	SO2 (MIL TON)	Final Demand	Gross Output	CO2 (MIL TON)	SO2 (MIL TON)	Final Demand	Gross Output	CO2 (MIL TON)	SO2 (MIL TON)	(TON/THO YUAN	(TON/THO YUAN
1	Agriculture	1,099	1,720	96	1	491	879	49	0	1,099	1,769	99	1	0.0557	0.0004
2	Coal mining	25	86	279	2	11	47	153	1	25	78	255	2	3.2568	0.0265
3	Crude petroleum & natural gas prod	20	86	18	0	9	46	10	0	20	97	21	0	0.2141	0.0005
4	Metal ore mining	0	22	0	0	0	14	0	0	0	23	0	0	0.0000	0.0000
5	Other mining	0	53	0	0	0	31	0	0	0	59	0	0	0.0000	0.0000
6	Food manufacturing	274	445	91	1	245	353	72	1	274	457	93	1	0.2045	0.0017
7	Manufacture of textiles	133	398	64	1	79	237	38	0	133	409	66	1	0.1615	0.0013
8	Manufacture of apparel	78	107	0	0	46	63	0	0	78	110	0	0	0.0000	0.0000
9	Sawmills and manufacture of furniture	9	52	0	0	8	34	0	0	9	53	0	0	0.0000	0.0000
10	Manufacture of paper and educ material	33	185	52	0	30	116	32	0	33	190	53	0	0.2799	0.0023
11	Electricity, steam and hot water prod	15	112	875	7	7	64	499	4	15	115	717	6	6.2331	0.0505
12	Petroleum refineries	6	111	73	0	2	61	40	0	6	109	71	0	0.6523	0.0008
13	Coking, manufacture of gas & coal	4	14	122	1	2	9	77	1	4	15	125	1	8.4178	0.0686
14	Chemical industries	28	488	270	2	25	287	159	1	28	502	278	2	0.5543	0.0042
15	Manufacture of building materials	5	198	281	2	2	117	166	1	5	204	290	2	1.4199	0.0115
16	Primary metal manufacturing	0	246	210	2	0	161	137	1	0	253	216	2	0.8542	0.0069
17	Manufacture of metal products	25	117	23	0	23	78	15	0	25	120	23	0	0.1941	0.0016
18	Manufacture of machinery	138	262	32	0	123	203	25	0	138	270	33	0	0.1218	0.0010
19	Manufacture of transport equipment	36	73	9	0	32	54	7	0	36	75	9	0	0.1218	0.0010
20	Manufacture of electric machinery	54	126	15	0	48	94	11	0	54	129	16	0	0.1218	0.0010
21	Manufacture of electronics equip	61	98	12	0	37	59	7	0	63	104	13	0	0.1218	0.0010
22	Manufacture of instruments	0	11	0	0	0	7	0	0	0	12	0	0	0.0000	0.0000
23	Maintenance and repair of machinery	57	61	0	0	26	27	0	0	57	63	0	0	0.0000	0.0000
24	Industries not elsewhere classified	23	55	0	0	21	40	0	0	23	56	0	0	0.0000	0.0000
25	Construction	539	539	13	0	321	321	8	0	539	555	14	0	0.0250	0.0002
26	Freight transport and communication	109	231	96	1	49	122	51	0	109	238	99	1	0.4161	0.0029
27	Commerce	76	275	25	0	34	155	14	0	76	282	26	0	0.0921	0.0007
28	Restaurants	62	62	6	0	44	44	4	0	62	64	6	0	0.0921	0.0007
29	Passenger transport	37	62	7	0	16	29	3	0	37	63	7	0	0.1135	0.0009
30	Public utilities and services to house	194	241	21	0	86	110	10	0	194	248	21	0	0.0864	0.0007
31	Cultural, education and health services	410	491	42	0	183	226	20	0	410	505	44	0	0.0864	0.0007
32	Finance and insurance	4	127	11	0	2	75	6	0	4	131	11	0	0.0864	0.0007
33	Public administration	168	168	15	0	75	75	6	0	168	173	15	0	0.0864	0.0007
	Total	3,725	7,323	2,760	21	2,080	4,240	1,620	13	3,727	7,531	2,622	20		

Final Demand and Gross Output in billions of 1990 Yuans

Final Demand(GDP) Growth Rate
1990-2000 6.00%

CO2 Emission Reduction
1990-2000 5.00%

SIMULATION: CHINA DLP MODEL 3-L (2000/2010)

8/2/94

		BASELINE 2010				DLP 2000				DLP 2010				CO2	SO2
		Final Demand	Gross Output	CO2 (MIL TON)	SO2 (MIL TON)	Final Demand	Gross Output	CO2 (MIL TON)	SO2 (MIL TON)	Final Demand	Gross Output	CO2 (MIL TON)	SO2 (MIL TON)	COEFFICIENT (TON/THO YUAN	COEFFICIENT (TON/THO YUAN)
1	Agriculture	1,627	2,546	142	1	1,099	1,720	96	1	1,627	2,546	142	1	0.0557	0.0004
2	Coal mining	37	127	413	3	25	76	248	2	37	126	410	3	3.2568	0.0265
3	Crude petroleum & natural gas prod	30	128	27	0	20	94	20	0	30	127	27	0	0.2141	0.0005
4	Metal ore mining	0	32	0	0	0	22	0	0	0	32	0	0	0.0000	0.0000
5	Other mining	0	78	0	0	0	57	0	0	0	85	0	0	0.0000	0.0000
6	Food manufacturing	406	658	135	1	274	445	91	1	406	658	135	1	0.2045	0.0017
7	Manufacture of textiles	197	589	95	1	133	398	64	1	197	589	95	1	0.1615	0.0013
8	Manufacture of apparel	115	158	0	0	78	107	0	0	115	158	0	0	0.0000	0.0000
9	Sawmills and manufacture of furniture	14	77	0	0	9	52	0	0	14	77	0	0	0.0000	0.0000
10	Manufacture of paper and educ material	49	273	76	1	33	185	52	0	49	273	77	1	0.2799	0.0023
11	Electricity, steam and hot water prod	22	166	1,296	10	15	112	697	6	22	166	1,227	10	7.3838	0.0598
12	Petroleum refineries	8	165	108	0	6	106	69	0	8	156	102	0	0.6523	0.0008
13	Coking, manufacture of gas & coal	6	21	180	1	4	14	122	1	6	21	181	1	8.4178	0.0686
14	Chemical industries	42	722	400	3	28	488	270	2	42	723	401	3	0.5543	0.0042
15	Manufacture of building materials	7	293	417	3	5	198	282	2	7	294	417	3	1.4199	0.0115
16	Primary metal manufacturing	0	365	311	3	0	246	210	2	0	365	312	3	0.8542	0.0069
17	Manufacture of metal products	37	173	34	0	25	117	23	0	37	173	34	0	0.1941	0.0016
18	Manufacture of machinery	204	389	47	0	138	263	32	0	204	389	47	0	0.1218	0.0010
19	Manufacture of transport equipment	54	108	13	0	36	73	9	0	54	108	13	0	0.1218	0.0010
20	Manufacture of electric machinery	80	186	23	0	54	126	15	0	80	186	23	0	0.1218	0.0010
21	Manufacture of electronics equip	91	145	18	0	63	101	12	0	92	147	18	0	0.1218	0.0010
22	Manufacture of instruments	0	17	0	0	0	11	0	0	0	17	0	0	0.0000	0.0000
23	Maintenance and repair of machinery	85	90	0	0	57	61	0	0	85	90	0	0	0.0000	0.0000
24	Industries not elsewhere classified	34	81	0	0	23	55	0	0	34	81	0	0	0.0000	0.0000
25	Construction	798	798	20	0	539	539	13	0	798	798	20	0	0.0250	0.0002
26	Freight transport and communication	162	343	143	1	109	231	96	1	162	342	142	1	0.4161	0.0029
27	Commerce	113	406	37	0	76	275	25	0	113	406	37	0	0.0921	0.0007
28	Restaurants	92	92	9	0	62	62	6	0	92	92	9	0	0.0921	0.0007
29	Passenger transport	54	91	10	0	37	62	7	0	54	91	10	0	0.1135	0.0009
30	Public utilities and services to house	287	357	31	0	194	241	21	0	287	357	31	0	0.0864	0.0007
31	Cultural, education and health services	607	727	63	0	410	491	42	0	607	727	63	0	0.0864	0.0007
32	Finance and insurance	7	188	16	0	4	127	11	0	7	188	16	0	0.0864	0.0007
33	Public administration	249	249	22	0	168	168	15	0	249	249	22	0	0.0864	0.0007
	Total	5,514	10,840	4,086	32	3,727	7,323	2,550	20	5,515	10,840	4,008	31		

Final Demand and Gross Output in billions of 1990 Yuans

Final Demand(GDP) Growth Rate
2000-2010 4.00%

CO2 Emission Reduction
2000-2010 1.89%

SIMULATION: CHINA DLP MODEL 3-L (2010/2025)

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		BASELINE 2025				DLP 2010				DLP 2025				CO2 COEFFICIENT	SO2 COEFFICIENT
		Final Demand	Gross Output	CO2 (MIL TON)	SO2 (MIL TON)	Final Demand	Gross Output	CO2 (MIL TON)	SO2 (MIL TON)	Final Demand	Gross Output	CO2 (MIL TON)	SO2 (MIL TON)	(TON/THO YUAN	(TON/THO YUAN)
1	Agriculture	2,534	3,966	221	2	1,627	2,546	142	1	2,534	3,968	221	2	0.0557	0.0004
2	Coal mining	58	198	644	5	37	126	410	3	58	193	630	5	3.2568	0.0265
3	Crude petroleum & natural gas prod	46	199	43	0	30	127	27	0	46	187	40	0	0.2141	0.0005
4	Metal ore mining	0	50	0	0	0	32	0	0	0	50	0	0	0.0000	0.0000
5	Other mining	1	122	0	0	0	85	0	0	1	147	0	0	0.0000	0.0000
6	Food manufacturing	632	1,025	210	2	406	658	135	1	632	1,025	210	2	0.2045	0.0017
7	Manufacture of textiles	307	917	148	1	197	589	95	1	307	918	148	1	0.1615	0.0013
8	Manufacture of apparel	180	246	0	0	115	158	0	0	180	246	0	0	0.0000	0.0000
9	Sawmills and manufacture of furniture	22	119	0	0	14	77	0	0	22	119	0	0	0.0000	0.0000
10	Manufacture of paper and educ material	77	426	119	1	49	273	77	1	77	426	119	1	0.2799	0.0023
11	Electricity, steam and hot water prod	35	258	2,019	16	22	166	1,227	10	35	259	1,573	13	6.0685	0.0492
12	Petroleum refineries	13	257	168	0	8	156	102	0	13	242	158	0	0.6523	0.0008
13	Coking, manufacture of gas & coal	9	33	281	2	6	21	181	1	9	33	281	2	8.4178	0.0686
14	Chemical industries	66	1,125	624	5	42	723	401	3	66	1,126	624	5	0.5543	0.0042
15	Manufacture of building materials	11	457	649	5	7	294	417	3	11	457	649	5	1.4199	0.0115
16	Primary metal manufacturing	0	568	485	4	0	365	312	3	0	568	485	4	0.8542	0.0069
17	Manufacture of metal products	58	270	52	0	37	173	34	0	58	270	52	0	0.1941	0.0016
18	Manufacture of machinery	318	605	74	1	204	389	47	0	318	605	74	1	0.1218	0.0010
19	Manufacture of transport equipment	83	169	21	0	54	108	13	0	83	169	21	0	0.1218	0.0010
20	Manufacture of electric machinery	125	290	35	0	80	186	23	0	125	290	35	0	0.1218	0.0010
21	Manufacture of electronics equip	141	226	28	0	92	147	18	0	142	227	28	0	0.1218	0.0010
22	Manufacture of instruments	0	26	0	0	0	17	0	0	0	26	0	0	0.0000	0.0000
23	Maintenance and repair of machinery	132	141	0	0	85	90	0	0	132	141	0	0	0.0000	0.0000
24	Industries not elsewhere classified	54	126	0	0	34	81	0	0	54	126	0	0	0.0000	0.0000
25	Construction	1,244	1,244	31	0	798	798	20	0	1,244	1,244	31	0	0.0250	0.0002
26	Freight transport and communication	252	534	222	2	162	342	142	1	252	533	222	2	0.4161	0.0029
27	Commerce	176	633	58	0	113	406	37	0	176	633	58	0	0.0921	0.0007
28	Restaurants	144	144	13	0	92	92	9	0	144	144	13	0	0.0921	0.0007
29	Passenger transport	85	142	16	0	54	91	10	0	85	142	16	0	0.1135	0.0009
30	Public utilities and services to house	447	556	48	0	287	357	31	0	447	556	48	0	0.0864	0.0007
31	Cultural, education and health services	946	1,133	98	1	607	727	63	0	946	1,133	98	1	0.0864	0.0007
32	Finance and insurance	10	293	25	0	7	188	16	0	10	293	25	0	0.0864	0.0007
33	Public administration	388	388	34	0	249	249	22	0	388	388	34	0	0.0864	0.0007
	Total	8,591	16,888	6,365	49	5,515	10,840	4,008	31	8,592	16,888	5,894	45		

Final Demand and Gross Output in billions of 1990 Yuans

Final Demand(GDP) Growth Rate
2010-2025 3.00%

CO2 Emission Reduction
2010-2025 7.39%

SIMULATION: CHINA DLP MODEL 4-L (1990-2000)

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		Baseline 2000				DLP 1990				DLP 2000				CO2 COEFFICIENT	SO2 COEFFICIENT
		Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	(ton/tho Yuan)	(ton/tho Yuan)
1	Agriculture	1,099	1,720	96	1	491	879	49	0	1,099	1,721	73	1	0.0426	0.0003
2	Coal mining	25	86	279	2	11	47	153	1	25	77	189	2	2.4641	0.0201
3	Crude petroleum & natural gas prod	20	86	18	0	9	46	10	0	20	74	13	0	0.1754	0.0003
4	Metal ore mining	0	22	0	0	0	14	0	0	0	23	0	0	0.0000	0.0000
5	Other mining	0	53	0	0	0	31	0	0	0	53	0	0	0.0000	0.0000
6	Food manufacturing	274	445	91	1	245	353	72	1	274	445	69	1	0.1546	0.0013
7	Manufacture of textiles	133	398	64	1	79	237	38	0	133	399	49	0	0.1221	0.0010
8	Manufacture of apparel	78	107	0	0	46	63	0	0	78	107	0	0	0.0000	0.0000
9	Sawmills and manufacture of furniture	9	52	0	0	8	34	0	0	9	52	0	0	0.0000	0.0000
10	Manufacture of paper and educ material	33	185	52	0	30	116	32	0	33	185	39	0	0.2116	0.0017
11	Electricity, steam and hot water prod	15	112	875	7	7	64	499	4	15	125	907	7	7.2834	0.0589
12	Petroleum refineries	6	111	73	0	2	61	40	0	6	97	57	0	0.5835	0.0006
13	Coking, manufacture of gas & coal	4	14	122	1	2	9	77	1	4	13	80	1	6.1388	0.0500
14	Chemical industries	28	488	270	2	25	287	159	1	28	491	208	2	0.4242	0.0032
15	Manufacture of building materials	5	198	281	2	2	117	166	1	5	199	214	2	1.0757	0.0087
16	Primary metal manufacturing	0	246	210	2	0	161	137	1	0	251	182	1	0.7259	0.0058
17	Manufacture of metal products	25	117	23	0	23	78	15	0	25	117	17	0	0.1473	0.0012
18	Manufacture of machinery	138	262	32	0	123	203	25	0	138	265	24	0	0.0924	0.0007
19	Manufacture of transport equipment	36	73	9	0	32	54	7	0	66	107	10	0	0.0923	0.0007
20	Manufacture of electric machinery	54	126	15	0	48	94	11	0	54	126	12	0	0.0924	0.0007
21	Manufacture of electronics equip	61	98	12	0	37	59	7	0	41	71	7	0	0.0923	0.0007
22	Manufacture of instruments	0	11	0	0	0	7	0	0	0	11	0	0	0.0000	0.0000
23	Maintenance and repair of machinery	57	61	0	0	26	27	0	0	57	61	0	0	0.0000	0.0000
24	Industries not elsewhere classified	23	55	0	0	21	40	0	0	23	55	0	0	0.0000	0.0000
25	Construction	539	539	13	0	321	321	8	0	539	539	10	0	0.0193	0.0001
26	Freight transport and communication	109	231	96	1	49	122	51	0	109	232	76	1	0.3253	0.0022
27	Commerce	76	275	25	0	34	155	14	0	76	275	19	0	0.0698	0.0006
28	Restaurants	62	62	6	0	44	44	4	0	62	62	4	0	0.0697	0.0006
29	Passenger transport	37	62	7	0	16	29	3	0	37	62	5	0	0.0879	0.0007
30	Public utilities and services to house	194	241	21	0	86	110	10	0	194	241	16	0	0.0660	0.0005
31	Cultural, education and health services	410	491	42	0	183	226	20	0	410	492	32	0	0.0659	0.0005
32	Finance and insurance	4	127	11	0	2	75	6	0	4	128	8	0	0.0657	0.0005
33	Public administration	168	168	15	0	75	75	6	0	168	168	11	0	0.0661	0.0005
	Total	3,725	7,323	2,760	21	2,080	4,240	1,620	13	3,735	7,323	2,331	18		

Final Demand and Gross Output in billions of 1990 Yuans

Final Demand(GDP) Growth Rate
1990-2000 6.03%

CO2 Emission Reduction
1990-2000 15.54%

SIMULATION: CHINA DLP MODEL 4-L (1990-2000), W/ CONSTRAINT

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		Baseline 2000				DLP 1990				DLP 2000				CO2 COEFFICIENT	SO2 COEFFICIENT
		Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	(ton/tho Yuan)	(ton/tho Yuan)
1	Agriculture	1,099	1,720	96	1	491	879	49	0	1,097	1,936	82	1	0.0426	0.0003
2	Coal mining	25	86	279	2	11	47	153	1	25	86	212	2	2.4641	0.0201
3	Crude petroleum & natural gas prod	20	86	18	0	9	46	10	0	20	84	15	0	0.1754	0.0003
4	Metal ore mining	0	22	0	0	0	14	0	0	0	25	0	0	0.0000	0.0000
5	Other mining	0	53	0	0	0	31	0	0	0	60	0	0	0.0000	0.0000
6	Food manufacturing	274	445	91	1	245	353	72	1	273	500	77	1	0.1546	0.0013
7	Manufacture of textiles	133	398	64	1	79	237	38	0	133	449	55	0	0.1221	0.0010
8	Manufacture of apparel	78	107	0	0	46	63	0	0	78	120	0	0	0.0000	0.0000
9	Sawmills and manufacture of furniture	9	52	0	0	8	34	0	0	9	59	0	0	0.0000	0.0000
10	Manufacture of paper and educ material	33	185	52	0	30	116	32	0	33	208	44	0	0.2116	0.0017
11	Electricity, steam and hot water prod	15	112	875	7	7	64	499	4	15	140	1,020	8	7.2834	0.0589
12	Petroleum refineries	6	111	73	0	2	61	40	0	6	109	64	0	0.5835	0.0006
13	Coking, manufacture of gas & coal	4	14	122	1	2	9	77	1	4	15	90	1	6.1388	0.0500
14	Chemical industries	28	488	270	2	25	287	159	1	28	552	234	2	0.4242	0.0032
15	Manufacture of building materials	5	198	281	2	2	117	166	1	5	223	240	2	1.0757	0.0087
16	Primary metal manufacturing	0	246	210	2	0	161	137	1	0	282	205	2	0.7259	0.0058
17	Manufacture of metal products	25	117	23	0	23	78	15	0	25	132	19	0	0.1473	0.0012
18	Manufacture of machinery	138	262	32	0	123	203	25	0	138	298	28	0	0.0924	0.0007
19	Manufacture of transport equipment	36	73	9	0	32	54	7	0	65	121	11	0	0.0923	0.0007
20	Manufacture of electric machinery	54	126	15	0	48	94	11	0	54	141	13	0	0.0924	0.0007
21	Manufacture of electronics equip	61	98	12	0	37	59	7	0	41	80	7	0	0.0923	0.0007
22	Manufacture of instruments	0	11	0	0	0	7	0	0	0	13	0	0	0.0000	0.0000
23	Maintenance and repair of machinery	57	61	0	0	26	27	0	0	57	69	0	0	0.0000	0.0000
24	Industries not elsewhere classified	23	55	0	0	21	40	0	0	23	62	0	0	0.0000	0.0000
25	Construction	539	539	13	0	321	321	8	0	538	607	12	0	0.0193	0.0001
26	Freight transport and communication	109	231	96	1	49	122	51	0	109	261	85	1	0.3253	0.0022
27	Commerce	76	275	25	0	34	155	14	0	76	310	22	0	0.0698	0.0006
28	Restaurants	62	62	6	0	44	44	4	0	62	70	5	0	0.0697	0.0006
29	Passenger transport	37	62	7	0	16	29	3	0	37	69	6	0	0.0879	0.0007
30	Public utilities and services to house	194	241	21	0	86	110	10	0	193	272	18	0	0.0660	0.0005
31	Cultural, education and health services	410	491	42	0	183	226	20	0	410	553	36	0	0.0659	0.0005
32	Finance and insurance	4	127	11	0	2	75	6	0	4	144	9	0	0.0657	0.0005
33	Public administration	168	168	15	0	75	75	6	0	168	189	12	0	0.0661	0.0005
	Total	3,725	7,323	2,760	21	2,080	4,240	1,620	13	3,728	8,237	2,622	20		

Final Demand and Gross Output in billions of 1990 Yuans

Final Demand(GDP) Growth Rate
1990-2000 6.01%

CO2 Emission Reduction
1990-2000 5.00%

SIMULATION: CHINA DLP MODEL 4-L (2000-2010)

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		Baseline 2010				DLP 2000				DLP 2010				CO2	SO2
		Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	COEFFICIENT (ton/tho Yuan)	COEFFICIENT (ton/tho Yuan)
1	Agriculture	1,627	2,546	142	1	1,099	1,721	73	1	1,627	2,544	58	0	0.0229	0.0002
2	Coal mining	37	127	413	3	25	77	189	2	37	100	122	1	1.2173	0.0099
3	Crude petroleum & natural gas prod	30	128	27	0	20	74	13	0	30	103	15	0	0.1444	0.0002
4	Metal ore mining	0	32	0	0	0	23	0	0	0	33	0	0	0.0000	0.0000
5	Other mining	0	78	0	0	0	53	0	0	0	78	0	0	0.0000	0.0000
6	Food manufacturing	406	658	135	1	274	445	69	1	406	658	51	0	0.0772	0.0006
7	Manufacture of textiles	197	589	95	1	133	399	49	0	197	588	36	0	0.0610	0.0005
8	Manufacture of apparel	115	158	0	0	78	107	0	0	115	158	0	0	0.0000	0.0000
9	Sawmills and manufacture of furniture	14	77	0	0	9	52	0	0	14	77	0	0	0.0000	0.0000
10	Manufacture of paper and educ material	49	273	76	1	33	185	39	0	49	271	29	0	0.1052	0.0009
11	Electricity, steam and hot water prod	22	166	1296	10	15	125	907	7	22	248	1,689	14	6.8225	0.0552
12	Petroleum refineries	8	165	108	0	6	97	57	0	8	134	69	0	0.5160	0.0003
13	Coking, manufacture of gas & coal	6	21	180	1	4	13	80	1	6	18	40	0	2.2402	0.0182
14	Chemical industries	42	722	400	3	28	491	208	2	42	720	161	1	0.2240	0.0016
15	Manufacture of building materials	7	293	417	3	5	199	214	2	3	289	151	1	0.5213	0.0042
16	Primary metal manufacturing	0	365	311	3	0	251	182	1	0	369	241	2	0.6533	0.0052
17	Manufacture of metal products	37	173	34	0	25	117	17	0	37	173	13	0	0.0744	0.0006
18	Manufacture of machinery	204	389	47	0	138	265	24	0	204	391	18	0	0.0469	0.0004
19	Manufacture of transport equipment	54	108	13	0	66	107	10	0	97	159	7	0	0.0469	0.0004
20	Manufacture of electric machinery	80	186	23	0	54	126	12	0	80	186	9	0	0.0469	0.0004
21	Manufacture of electronics equip	91	145	18	0	41	71	7	0	61	105	5	0	0.0469	0.0004
22	Manufacture of instruments	0	17	0	0	0	11	0	0	0	17	0	0	0.0000	0.0000
23	Maintenance and repair of machinery	85	90	0	0	57	61	0	0	85	90	0	0	0.0000	0.0000
24	Industries not elsewhere classified	34	81	0	0	23	55	0	0	34	81	0	0	0.0000	0.0000
25	Construction	798	798	20	0	539	539	10	0	798	798	9	0	0.0113	0.0001
26	Freight transport and communication	162	343	143	1	109	232	76	1	162	344	63	0	0.1826	0.0011
27	Commerce	113	406	37	0	76	275	19	0	113	406	14	0	0.0351	0.0003
28	Restaurants	92	92	9	0	62	62	4	0	92	92	3	0	0.0351	0.0003
29	Passenger transport	54	91	10	0	37	62	5	0	54	91	4	0	0.0468	0.0003
30	Public utilities and services to house	287	357	31	0	194	241	16	0	287	357	12	0	0.0348	0.0002
31	Cultural, education and health services	607	727	63	0	410	492	32	0	607	727	25	0	0.0348	0.0002
32	Finance and insurance	7	188	16	0	4	128	8	0	7	188	7	0	0.0348	0.0002
33	Public administration	249	249	22	0	168	168	11	0	249	249	9	0	0.0350	0.0002
	Total	5,514	10,840	4,086	32	3,735	7,323	2,331	18	5,525	10,840	2,859	22		

Final Demand and Gross Output in billions of 1990 Yuans

Final Demand(GDP) Growth Rate
2000-2010 3.99%

CO2 Emission Reduction
2000-2010 30.01%

SIMULATION: CHINA DLP MODEL 4-L (2010-2025)

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		Baseline 2025				DLP 2010				DLP 2025				CO2 COEFFICIENT	SO2 COEFFICIENT
		Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	(ton/tho Yuan)	(ton/tho Yuan)
1	Agriculture	2,534	3,966	221	2	1,627	2,544	58	0	2,534	3,954	53	0	0.0134	0.0001
2	Coal mining	58	198	644	5	37	100	122	1	58	148	91	1	0.6165	0.0050
3	Crude petroleum & natural gas prod	46	199	43	0	30	103	15	0	46	159	20	0	0.1234	0.0001
4	Metal ore mining	0	50	0	0	0	33	0	0	0	50	0	0	0.0000	0.0000
5	Other mining	1	122	0	0	0	78	0	0	1	121	0	0	0.0000	0.0000
6	Food manufacturing	632	1,025	210	2	406	658	51	0	632	1,022	41	0	0.0399	0.0003
7	Manufacture of textiles	307	917	148	1	197	588	36	0	307	909	29	0	0.0316	0.0003
8	Manufacture of apparel	180	246	0	0	115	158	0	0	180	245	0	0	0.0000	0.0000
9	Sawmills and manufacture of furniture	22	119	0	0	14	77	0	0	22	118	0	0	0.0000	0.0000
10	Manufacture of paper and educ material	77	426	119	1	49	271	29	0	77	419	23	0	0.0539	0.0004
11	Electricity, steam and hot water prod	35	258	2019	16	22	248	1,689	14	35	479	2,983	24	6.2321	0.0503
12	Petroleum refineries	13	257	168	0	8	134	69	0	13	203	98	0	0.4809	0.0002
13	Coking, manufacture of gas & coal	9	33	281	2	6	18	40	0	9	26	24	0	0.9288	0.0075
14	Chemical industries	66	1,125	624	5	42	720	161	1	66	1,107	140	1	0.1264	0.0008
15	Manufacture of building materials	11	457	649	5	3	289	151	1	5	448	117	1	0.2615	0.0021
16	Primary metal manufacturing	0	568	485	4	0	369	241	2	0	563	347	3	0.6168	0.0050
17	Manufacture of metal products	58	270	52	0	37	173	13	0	58	267	10	0	0.0392	0.0003
18	Manufacture of machinery	318	605	74	1	204	391	18	0	318	600	15	0	0.0248	0.0002
19	Manufacture of transport equipment	83	169	21	0	97	159	7	0	83	169	4	0	0.0249	0.0002
20	Manufacture of electric machinery	125	290	35	0	80	186	9	0	125	290	7	0	0.0249	0.0002
21	Manufacture of electronics equip	141	226	28	0	61	105	5	0	149	236	6	0	0.0249	0.0002
22	Manufacture of instruments	0	26	0	0	0	17	0	0	0	26	0	0	0.0000	0.0000
23	Maintenance and repair of machinery	132	141	0	0	85	90	0	0	132	141	0	0	0.0000	0.0000
24	Industries not elsewhere classified	54	126	0	0	34	81	0	0	54	126	0	0	0.0000	0.0000
25	Construction	1,244	1,244	31	0	798	798	9	0	1,244	1,244	9	0	0.0073	0.0000
26	Freight transport and communication	252	534	222	2	162	344	63	0	252	534	60	0	0.1129	0.0006
27	Commerce	176	633	58	0	113	406	14	0	176	630	12	0	0.0183	0.0001
28	Restaurants	144	144	13	0	92	92	3	0	144	144	3	0	0.0183	0.0001
29	Passenger transport	85	142	16	0	54	91	4	0	85	142	4	0	0.0268	0.0002
30	Public utilities and services to house	447	556	48	0	287	357	12	0	447	556	11	0	0.0198	0.0001
31	Cultural, education and health services	946	1,133	98	1	607	727	25	0	946	1,132	22	0	0.0198	0.0001
32	Finance and insurance	10	293	25	0	7	188	7	0	10	290	6	0	0.0199	0.0001
33	Public administration	388	388	34	0	249	249	9	0	388	388	8	0	0.0200	0.0001
	Total	8,591	16,888	6,365	49	5,525	10,840	2,859	22	8,593	16,888	4,142	32		

Final Demand and Gross Output in billions of 1990 Yuans

Final Demand(GDP) Growth Rate
2010-2025 2.99%

CO2 Emission Reduction
2010-2025 34.92%

SIMULATION: CHINA DLP MODEL 5-L (2000-2010), W/ CONSTRAINT

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		Baseline 2010				DLP 2000				DLP 2010				CO2 COEFFICIENT	SO2 COEFFICIENT
		Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	(ton/tho Yuan)	(ton/tho Yuan)
1	Agriculture	1,627	2,546	142	1	1,099	1,721	73	1	1,627	2,753	63	0	0.0229	0.0002
2	Coal mining	37	127	413	3	25	77	189	2	18	77	94	1	1.2173	0.0099
3	Crude petroleum & natural gas prod	30	128	27	0	20	74	13	0	30	97	14	0	0.1444	0.0002
4	Metal ore mining	0	32	0	0	0	23	0	0	0	31	0	0	0.0000	0.0000
5	Other mining	0	78	0	0	0	53	0	0	0	84	0	0	0.0000	0.0000
6	Food manufacturing	406	658	135	1	274	445	69	1	780	1,090	84	1	0.0772	0.0008
7	Manufacture of textiles	197	589	95	1	133	399	49	0	197	574	35	0	0.0610	0.0005
8	Manufacture of apparel	115	158	0	0	78	107	0	0	115	156	0	0	0.0000	0.0000
9	Sawmills and manufacture of furniture	14	77	0	0	9	52	0	0	14	73	0	0	0.0000	0.0000
10	Manufacture of paper and educ material	49	273	76	1	33	185	39	0	49	244	26	0	0.1052	0.0009
11	Electricity, steam and hot water prod	22	166	1296	10	15	125	907	7	11	223	1,308	11	5.8611	0.0474
12	Petroleum refineries	8	165	108	0	6	97	57	0	4	112	58	0	0.5160	0.0003
13	Coking, manufacture of gas & coal	6	21	180	1	4	13	80	1	6	17	38	0	2.2402	0.0182
14	Chemical industries	42	722	400	3	28	491	208	2	42	679	152	1	0.2240	0.0016
15	Manufacture of building materials	7	293	417	3	5	199	214	2	3	283	147	1	0.5213	0.0042
16	Primary metal manufacturing	0	365	311	3	0	251	182	1	0	348	227	2	0.6533	0.0052
17	Manufacture of metal products	37	173	34	0	25	117	17	0	37	167	12	0	0.0744	0.0006
18	Manufacture of machinery	204	389	47	0	138	265	24	0	204	375	18	0	0.0469	0.0004
19	Manufacture of transport equipment	54	108	13	0	68	107	10	0	54	104	5	0	0.0469	0.0004
20	Manufacture of electric machinery	80	186	23	0	54	126	12	0	80	177	8	0	0.0469	0.0004
21	Manufacture of electronics equip	91	145	18	0	41	71	7	0	61	100	5	0	0.0469	0.0004
22	Manufacture of instruments	0	17	0	0	0	11	0	0	0	14	0	0	0.0000	0.0000
23	Maintenance and repair of machinery	85	90	0	0	57	61	0	0	42	47	0	0	0.0000	0.0000
24	Industries not elsewhere classified	34	81	0	0	23	55	0	0	34	79	0	0	0.0000	0.0000
25	Construction	798	798	20	0	539	539	10	0	798	798	9	0	0.0113	0.0001
26	Freight transport and communication	162	343	143	1	109	232	76	1	162	352	64	0	0.1826	0.0011
27	Commerce	113	406	37	0	76	275	19	0	113	406	14	0	0.0351	0.0003
28	Restaurants	92	92	9	0	62	62	4	0	92	92	3	0	0.0351	0.0003
29	Passenger transport	54	91	10	0	37	62	5	0	54	86	4	0	0.0468	0.0003
30	Public utilities and services to house	287	357	31	0	194	241	16	0	287	344	12	0	0.0348	0.0002
31	Cultural, education and health services	607	727	63	0	410	492	32	0	307	418	15	0	0.0348	0.0002
32	Finance and insurance	7	188	16	0	4	128	8	0	7	189	7	0	0.0348	0.0002
33	Public administration	249	249	22	0	168	168	11	0	249	249	9	0	0.0350	0.0002
	Total	5,514	10,840	4,086	32	3,735	7,323	2,331	18	5,480	10,840	2,431	19		

Final Demand and Gross Output in billions of 1990 Yuans

Final Demand(GDP) Growth Rate
2000-2010 3.91%

CO2 Emission Reduction
2000-2010 40.50%

SIMULATION: CHINA DLP MODEL 5-L (2010-2025), W/ CONSTRAINT

8/10/94

		Baseline 2025				DLP 2010				DLP 2025				CO2 COEFFICIENT	SO2 COEFFICIENT
		Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	Final Demand	Gross Output	CO2 (mil ton)	SO2 (mil ton)	(ton/tho Yuan)	(ton/tho Yuan)
1	Agriculture	2,534	3,966	221	2	1,627	2,753	63	0	2,128	3,290	44	0	0.0134	0.0001
2	Coal mining	58	198	644	5	18	77	94	1	25	86	53	0	0.6165	0.0050
3	Crude petroleum & natural gas prod	46	199	43	0	30	97	14	0	20	80	10	0	0.1234	0.0001
4	Metal ore mining	0	50	0	0	0	31	0	0	0	40	0	0	0.0000	0.0000
5	Other mining	1	122	0	0	0	84	0	0	0	127	0	0	0.0000	0.0000
6	Food manufacturing	632	1,025	210	2	780	1,090	84	1	548	867	35	0	0.0399	0.0003
7	Manufacture of textiles	307	917	148	1	197	574	35	0	268	735	23	0	0.0316	0.0003
8	Manufacture of apparel	180	246	0	0	115	156	0	0	156	204	0	0	0.0000	0.0000
9	Sawmills and manufacture of furniture	22	119	0	0	14	73	0	0	19	91	0	0	0.0000	0.0000
10	Manufacture of paper and educ material	77	426	119	1	49	244	26	0	67	282	15	0	0.0539	0.0004
11	Electricity, steam and hot water prod	35	258	2019	16	11	223	1,308	11	15	335	1,373	11	4.1015	0.0331
12	Petroleum refineries	13	257	168	0	4	112	58	0	6	113	54	0	0.4809	0.0002
13	Coking, manufacture of gas & coal	9	33	281	2	6	17	38	0	7	21	19	0	0.9288	0.0075
14	Chemical industries	68	1,125	624	5	42	879	152	1	57	819	104	1	0.1264	0.0008
15	Manufacture of building materials	11	457	649	5	3	283	147	1	5	359	94	1	0.2615	0.0021
16	Primary metal manufacturing	0	568	485	4	0	348	227	2	0	443	273	2	0.6168	0.0050
17	Manufacture of metal products	58	270	52	0	37	167	12	0	50	210	8	0	0.0392	0.0003
18	Manufacture of machinery	318	605	74	1	204	375	18	0	276	485	12	0	0.0248	0.0002
19	Manufacture of transport equipment	83	169	21	0	54	104	5	0	72	127	3	0	0.0249	0.0002
20	Manufacture of electric machinery	125	290	35	0	80	177	8	0	108	231	6	0	0.0249	0.0002
21	Manufacture of electronics equip	141	226	28	0	61	100	5	0	83	133	3	0	0.0249	0.0002
22	Manufacture of instruments	0	26	0	0	0	14	0	0	0	17	0	0	0.0000	0.0000
23	Maintenance and repair of machinery	132	141	0	0	42	47	0	0	57	63	0	0	0.0000	0.0000
24	Industries not elsewhere classified	54	126	0	0	34	79	0	0	46	99	0	0	0.0000	0.0000
25	Construction	1,244	1,244	31	0	798	798	9	0	1,078	1,078	8	0	0.0073	0.0000
26	Freight transport and communication	252	534	222	2	162	352	64	0	109	314	35	0	0.1129	0.0006
27	Commerce	176	633	58	0	113	406	14	0	76	414	8	0	0.0183	0.0001
28	Restaurants	144	144	13	0	92	92	3	0	125	125	2	0	0.0183	0.0001
29	Passenger transport	85	142	16	0	54	88	4	0	37	69	2	0	0.0268	0.0002
30	Public utilities and services to house	447	556	48	0	287	344	12	0	194	256	5	0	0.0198	0.0001
31	Cultural, education and health services	946	1,133	98	1	307	418	15	0	410	524	10	0	0.0198	0.0001
32	Finance and insurance	10	293	25	0	7	189	7	0	12	212	4	0	0.0199	0.0001
33	Public administration	388	388	34	0	249	249	9	0	168	168	3	0	0.0200	0.0001
	Total	8,591	16,888	6,365	49	5,480	10,840	2,431	19	6,219	12,414	2,208	17		

Final Demand and Gross Output in billions of 1990 Yuans

Final Demand(GDP) Growth Rate
2010-2025 0.85%

CO2 Emission Reduction
2010-2025 65.31%

APPENDIX B:

INVESTMENT ANALYSIS SUMMARY TABLES

TABLE B1. CAPITAL COSTS FOR ELECTRICITY GENERATION AND TRANSMISSION
(million dollars per MW installed capacity)

	Generation	Transmission	Total
Coal	$1.106	$0.221	$1.327
Oil	0.790	0.221	1.011
Natural Gas	0.527	0.221	0.748
Hydro	1.216	0.221	1.437
Nuclear	1.520	0.221	1.741

Sources: Dowlatabad, and Torman (1991); Kim (1993); and East-West Center (1994).

TABLE B2. CAPITAL COSTS FOR EXPLORATION AND PRODUCTION
(dollars of investment per dollar of electricity sales)

	Exploration	Production	Total
Coal	$0.000	$0.092	$0.092
Oil	0.198	0.422	0.620
Natural Gas	0.297	0.410	0.707
Nuclear	0.116	0.233	0.349

Sources: Fraser and Seba (1993); *Petroleum Economist; Energy Economist;* and *Mining Journal* (various issues).

TABLE B3. INCREMENTAL GROSS INVESTMENT IN ELECTRICITY GENERATION/TRANSMISSION--INTERFUEL SUBSTITUTION STRATEGY, UPPER BOUND CASE[a]
(in billions of 1990 dollars)

Generation Type	1990-2000	2000-2010	2010-2025
Coal	-$175.8	-$195.8	-$1,226.2
Oil	-12.2	-27.5	-88.1
Natural Gas	111.5	120.3	50.0
Hydro	-12.0	-30.0	-79.2
Nuclear	5.8	59.6	1,925.2
Total	-$82.8	-$73.6	$582.2

[a]A negative figure implies savings with respect to the baseline.

TABLE B4. INCREMENTAL GROSS INVESTMENT IN ELECTRICITY GENERATION/TRANSMISSION--INTERFUEL SUBSTITUTION STRATEGY, UPPER BOUND CASE[a]
(in billions of 1990 dollars)

Generation Type	Per Year 1990-2000	Per Year 2000-2010	Per Year 2010-2025
Coal	-$17.6	-$19.6	-$81.7
Oil	-1.2	-2.8	-5.9
Natural Gas	11.2	12.0	3.3
Hydro	-1.2	-3.0	-5.3
Nuclear	.6	6.0	128.3
Total	-$8.3	-$7.4	$38.8

[a]A negative figure implies savings with respect to the baseline.

TABLE B5. INCREMENTAL GROSS INVESTMENT IN ELECTRICITY GENERATION/TRANSMISSION--TECHNOLOGICAL CHANGE STRATEGY, UPPER BOUND CASE[a]
(in billions of 1990 dollars)

Generation Type	1990-2000	2000-2010	2010-2025
Coal	-$44.0	$140.9	$238.3
Oil	-3.4	10.8	18.3
Natural Gas	-.1	.5	.8
Hydro	-13.0	42.2	71.5
Nuclear	-.2	.5	.9
Total	-$60.9	$194.9	$329.8

[a]A negative figure implies savings with respect to the baseline.

TABLE B6. INCREMENTAL GROSS INVESTMENT IN ELECTRICITY GENERATION/TRANSMISSION--TECHNOLOGICAL CHANGE STRATEGY, UPPER BOUND CASE[a]
(in billions of 1990 dollars)

Generation Type	Per Year 1990-2000	Per Year 2000-2010	Per Year 2010-2025
Coal	-$4.4	$14.1	$15.9
Oil	-.3	1.1	1.2
Natural Gas	-.01	.05	.05
Hydro	-1.3	4.2	4.8
Nuclear	-.02	.05	.06
Total	-$6.1	$19.5	$22.0

[a]A negative figure implies savings with respect to the baseline.

TABLE B7. INCREMENTAL GROSS INVESTMENT IN FUEL EXPLORATION/PRODUCTION–INTERFUEL SUBSTITUTION STRATEGY, UPPER BOUND CASE[a]
(in billions of 1990 dollars)

Fuel Type	1990-2000	2000-2010	2010-2025
Coal			
For Electricity	-$6.0	-$16.7	-$93.9
For Other Sectors	-16.2	-52.3	-298.7
Oil			
For Electricity	-3.6	-14.3	-64.6
For Other Sectors	-63.7	-253.3	-1,142.2
Natural Gas			
For Electricity	51.7	141.9	233.5
For Other Sectors	91.4	174.1	204.1
Nuclear			
For Electricity	0.4	3.7	78.5
Total	$54.0	$1.1	-$1,083.2

[a]A negative figure implies savings with respect to the baseline.

TABLE B8. INCREMENTAL GROSS INVESTMENT IN FUEL EXPLORATION/PRODUCTION–INTERFUEL SUBSTITUTION STRATEGY, UPPER BOUND CASE[a]
(in billions of 1990 dollars)

Fuel Type	Per Year 1990-2000	Per Year 2000-2010	Per Year 2010-2025
Coal			
For Electricity	-$0.6	-$1.7	-$6.3
For Other Sectors	-1.6	-5.2	-19.9
Oil			
For Electricity	-0.4	-1.4	-4.3
For Other Sectors	-6.4	-25.5	-76.1
Natural Gas			
For Electricity	5.2	14.2	15.6
For Other Sectors	9.1	17.4	13.6
Nuclear			
For Electricity	0.0[b]	0.4	5.2
Total	$5.4	$0.1	-$72.2

[a]A negative figure implies savings with respect to the baseline.
[b]Less than 0.05 billion dollars

TABLE B9. INCREMENTAL GROSS INVESTMENT IN FUEL EXPLORATION/ PRODUCTION–TECHNOLOGICAL CHANGE STRATEGY, UPPER BOUND CASE[a]
(in billions of 1990 dollars)

Fuel Type	1990-2000	2000-2010	2010-2025
Coal			
For Electricity	-$2.3	-$2.2	-$6.1
For Other Sectors	-8.9	-45.7	-209.0
Oil			
For Electricity	-2.5	-3.7	-6.0
For Other Sectors	-63.1	-211.6	-846.3
Natural Gas			
For Electricity	-0.3	-0.4	-0.7
For Other Sectors	-4.0	-14.1	-60.5
Nuclear			
For Electricity	0.1	0.3	0.9
Total	-$80.9	-$277.5	-$1,127.9

[a]A negative figure implies savings with respect to the baseline.

TABLE B10. INCREMENTAL GROSS INVESTMENT IN FUEL EXPLORATION/ PRODUCTION–TECHNOLOGICAL CHANGE STRATEGY, UPPER BOUND CASE[a]
(in billions of 1990 dollars)

Fuel Type	Per Year 1990-2000	Per Year 2000-2010	Per Year 2010-2025
Coal			
For Electricity	-$0.2	-$0.2	-$0.4
For Other Sectors	-0.9	-4.6	-13.9
Oil			
For Electricity	-0.2	-0.4	-0.4
For Other Sectors	-6.3	-21.2	-56.4
Natural Gas			
For Electricity	-0.0[b]	-0.0[b]	-0.0[b]
For Other Sectors	-0.4	-1.4	-4.0
Nuclear			
For Electricity	0.0[b]	0.0[b]	0.1
Total	-$8.1	-$27.7	-$75.2

[a]A negative figure implies savings with respect to the baseline.
[b]Less than 0.05 billion dollars.

APPENDIX C1:

EXPLORATION/PRODUCTION INVESTMENT SPREADSHEETS

Fixed Asset Investment
(from Energy in China)

	(in million Yuan)		Output		
	Coal Mining and Preparation	Petroleum and NatGas Extraction	Coal (Mt)	Oil (Mt)	Gas (10^8 m3)
1987	9,865	16,621	928.1	134.14	138.7
1990	16,446	23,113	1079.9	138.31	135.1
Ratio 1990/1987	1.667	1.391			

Investment Requirements to Increase Oil Reserves
(from National Response ..]

PriceIndex '90-80 1.92
PriceIndex '90-85 1.62

	81-85	86-90	Increase
Investment Per Ton of Oil Added	49.1	83.1	1.692
Average Production Cost per ton	43.6	177.6	4.073

Other data

Nat Gas - From '85 to 90 an investment of 1.78 million Yuan to add 100 million m3. (with great variation from basin to basin) [Nat. Response..]
or 56.1798 m3 per Yuan invested or 1,780,000 Yuan per 10^8 m3

Nat Gas - They are developing a 1bn dollar project for 100 new wells and 200 refurbish ones. It will add 68 bn m3 of gas during 1995-2015.
[Petroleum Economist], or 68 m3 per dollar invested or 1,470,588 Dollars per 10^8 m3

Summary Table

	Coal (Yuan per tonne)	Oil (Yuan per tonne)	Gas (Yuan per m3)
Investment/Output for 1990	15.229		
Investment to Increase a Unit in Reserves		83.1	0.0178

* Expressed in 1990 Yuan

BASELINE CALCULATIONS

BASELINE IN 1990

	Coal	Oil Prod	Gas
Electric Generated in 1990(mill Yuans)	47,084	4,742	268
Fuel Used	283.00	11.28	10.00
(units)	mill Tons	mill Tons	10 ^ 8m3
Coefficient	166.37	420.39	26.80
(Yuan of Electricity per Volume of Fuel)			

Electricity Generation 1990	(mill Yuan)	Fuel Used for Ele	Units	Coefficient (Yuan of electricity per unit of fuel)
Coal	47,084	283.00	mill Tons	166.37 (Y/Ton)
Oil Prod	4,742	11.28	mill Tons	420.39 (Y/Ton)
Gas	268	10.00	10 ^ 8m3	26.80 (Y/10^8 m3)

BASELINE PROJECTIONS	2000	2010	2025	Fuel Mix Share
Total Electric Demand(millYuan)	142,000	292,000	750,000	
Electricity Generated by Fuel (mill Yuan)				
Coal	102,623	211,028	542,025	72.27%
Oil	10,338	21,258	54,600	7.28%
Nat Gas	582	1,197	3,075	0.41%
Fuel Requirements for Electricity in Volume Units (using Coeff above)				
Coal (mill Ton)	617	1,268	3,258	
Oil (mill Ton)	25	51	130	
Nat Gas (* 10^8 m3)	22	45	115	
Fuel Requirements for all Intermediate Sectors in Volume (from Electric Req and Share				Fuel Share of Intermediate Use
Coal (mill Ton)	1,935	3,980	10,223	31.87%
Oil (mill Ton)	435	894	2,297	5.65%
Nat Gas (* 10^8 m3)	291	599	1,538	7.46%
Fuel Requirements for all Intermediate Sectors in bill Yuan (from Electric Req and Share of Interm)				
Coal	80.8	166.2	426.9	31.87%
Oil	317.4	652.6	1676.3	5.65%
Nat Gas	6.6	13.6	34.9	7.46%

TABLE 2. PROJECTED FOSSIL FUELS CAPACIY REQUIREMENTS (BASELINE SCENARIO)

		1990	2000	2010	2025
Coal Total Produced	(mill Tons per Year)	888	1,935	3,980	10,223
Coal for Electricity	(mill Tons per Year)	283	617	1,268	3,258
Oil Total Produced	(mill Tons per Year)	199	435	894	2297
Oil for Electricity	(mill Tons per Year)	11	25	51	130
Natural Gas	(10^8 M3 per Year)	134	410	808	2,326
Nat Gas for Electricty	(10^8 M3 per Year)	10	40	82	209
	New Oil/Gas - Total	1.4881	1.0618	1.1061	0.9875
	New Oil/Gas - Elec	1.1385	0.6204	0.6204	0.6204
	Oil/Gas Total	1.3118	1.0618	1.1061	0.9875
	Oil/Gas Electr	1.1316	0.6204	0.6204	0.6204

TABLE 3 . GROSS INVESTMENT IN FOSSIL FUELS
(BASELINE SCENARIO)

		Total Reserves to be Replaced			Investment Required to Find Additional Reserves (in million Yuans)			Investment Required to Increase Production Capacity (in million Yuans)			Total Required Investment (in million Yuans)		
	UNITS	1990-2000	2000-2010	2010-2025	1990-2000	2000-2010	2010-2025	1990-2000	2000-2010	2010-2025	1990-2000	2000-2010	2010-2025
Coal Total Produced	mill Tons	14,117	29,577	106,519	0	0	0	214,993	450,431	1,622,173	214,993	450,431	1,622,173
Coal for Electricity	mill Tons	4,499	9,426	33,947	0	0	0	68,509	143,549	516,976	68,509	143,549	516,976
Oil Total Produced	mill Tons	3,171	6,645	23,933	263,535	552,232	1,988,799	563,223	1,180,222	4,250,429	826,758	1,732,454	6,239,228
Oil for Electricity	mill Tons	180	376	1,353	14,948	31,228	112,463	31,946	66,740	240,355	46,894	97,967	352,818
Natural Gas	*10^8 m3	2,718	6,090	23,507	21,606	48,414	186,879	29,895	66,988	258,575	51,501	115,402	445,453
Nat Gas for Electricty	*10^8 m3	248	606	2,182	1,973	4,816	17,343	2,730	6,663	23,997	4,703	11,479	41,340

TABLE 3A. GROSS INVESTMENT IN FOSSIL FUELS, DOLLARS
(BASELINE SCENARIO)

1 US$ =	4.78 Yuan	Total Reserves to be Replaced			Investment Required to Find Additional Reserves (in million US Dollars)			Investment Required to Increase Production Capacity (in million US Dollars)			Total Required Investment (in million US Dollars)		
	UNITS	1990-2000	2000-2010	2010-2025	1990-2000	2000-2010	2010-2025	1990-2000	2000-2010	2010-2025	1990-2000	2000-2010	2010-2025
Coal Total Produced	mill Tons	14,117	29,577	106,519	0	0	0	44,978	94,232	339,367	44,978	94,232	339,367
Coal for Electricity	mill Tons	4,499	9,426	33,947	0	0	0	14,332	30,031	108,154	14,332	30,031	108,154
Oil Total Produced	mill Tons	3,171	6,645	23,933	55,133	115,530	416,067	117,829	246,908	889,211	172,962	362,438	1,305,278
Oil for Electricity	mill Tons	180	376	1,353	3,127	6,533	23,528	6,683	13,962	50,283	9,811	20,495	73,811
Natural Gas Total	10^8 m3	2,718	6,090	23,507	4,520	10,128	39,096	6,254	14,014	54,095	10,774	24,143	93,191
Nat Gas for Electricty	10^8 m3	248	606	2,182	413	1,007	3,628	571	1,394	5,020	984	2,401	8,649

STRATEGY 3 CALCULATIONS

COAL

In 1990:		
Coal Based Electric Output	47,084 mill Yuan	
Coal Used	283 mill Tons	
Coefficient	166.375 Yuan of electricity per Ton of Coal	

	2000	2010	2025
Total Electricity Dem.(mill Yuan)	142,000	292,000	750,000
Electricity from Coal	28.1%	34.1%	0.0%
Electricity from Coal(Yuan)	39,902	99,572	0
Coal for Electricity(mill Tons)	240	598	0
% of Coal Interm. Demand used for Elect.	31.9%	31.9%	31.9%
Total Coal	753	1,878	200

OIL

In 1990:		
Oil Based Electric Output	4,742 mill Yuan	
Oil Used	11.281 mill Tons	
Coefficient	420.388 Yuan of electricity per Ton of Oil	

	2000	2010	2025
Total Electricity Demand (mill Yuan)	142,000	292,000	750,000
Electricity from Oil	3.4%	1.6%	0.6%
Electricity from Oil(Yuan)	4,757	4,760	4,725
Oil for Electricity(mill Tons)	11.316	11.322	11.240
% of Oil Interm. Demand used for Elect.	5.7%	5.7%	5.7%
Total Oil	200	200	199

TABLE 1. CAPITAL COSTS FOR EXPLORATION AND DEVELOPMENT OF FOSSIL FUELS

		Exploration	Production	Total
Coal	(Yuan per tonne)	0	15.2	15.229
Oil	(Yuan per tonne)	83.1	177.6	260.7
Natural Gas	(Yuan per m3)	0.080	0.110	0.190

TABLE 2. PROJECTED FOSSIL FUELS CAPACIY REQUIREMENTS
[STRATEGY 3]

		1990	2000	2010	2025
Coal Total Produced	(mill Tons per Year)	1,055	753	1,878	200
Coal for Electricity	(mill Tons per Year)	283	240	598	0
Oil Total Produced	(mill Tons per Year)	201	200	200	199
Oil for Electricity	(mill Tons per Year)	11	11	11	11
Natural Gas	(10^8 M3 per Year)	153	5,000	5,000	5,000
Nat Gas for Electricty	(10^8 M3 per Year)	10	2,649	4,631	3,512

TABLE 3. GROSS INVESTMENT IN FOSSIL FUELS
[STRATEGY 3]

		Total Reserves to be Replaced			Investment Required to Find Additional Reserves (in million Yuans)			Investment Required to Increase Production Capacity (in million Yuans)			Total Required Investment (in million Yuans)		
	UNITS	1990-2000	2000-2010	2010-2025	1990-2000	2000-2010	2010-2025	1990-2000	2000-2010	2010-2025	1990-2000	2000-2010	2010-2025
Coal Total Produced	mill Tons	9,038	13,152	15,584	0	0	0	137,636	200,296	237,334	137,636	200,296	237,334
Coal for Electricity	mill Tons	2,614	4,192	4,489	0	0	0	39,803	63,833	68,357	39,803	63,833	68,357
Oil Total Produced	mill Tons	2,004	2,001	2,991	166,497	166,257	248,547	355,834	355,322	531,190	522,331	521,579	779,737
Oil for Electricity	mill Tons	113	113	169	9,403	9,406	14,061	20,097	20,102	30,052	29,500	29,508	44,113
Natural Gas	10^8 m3	25,765	50,000	75,000	204,832	397,500	596,250	283,415	550,000	825,000	488,247	947,500	1,421,250
Nat Gas for Electricty	10^8 m3	13,296	36,401	61,075	105,705	289,386	485,548	146,259	400,408	671,827	251,964	689,794	1,157,375

TABLE 3A. GROSS INVESTMENT IN FOSSIL FUELS, DOLLARS
[STRATEGY 3]

1 US DOLLAR = 4.78 YUAN

	UNITS	Total Reserves to be Replace 1990-2000	2000-2010	2010-2025	Investment Required to Find Additional Reserves (in million US Dollars) 1990-2000	2000-2010	2010-2025	Investment Required to Increase Production Capacity (in million US Dollars) 1990-2000	2000-2010	2010-2025	Total Required Investment (in million US Dollars) 1990-2000	2000-2010	2010-2025
Coal Total Produced	mill Tons	9,030	13,152	15,584	0	0	0	28,794	41,903	49,652	28,794	41,903	49,652
Coal for Electricity	mill Tons	2,614	4,192	4,489	0	0	0	8,327	13,354	14,301	8,327	13,354	14,301
Oil Total Produced	mill Tons	2,004	2,001	2,991	34,832	34,782	51,997	74,442	74,335	111,128	109,274	109,117	163,125
Oil for Electricity	mill Tons	113	113	169	1,967	1,968	2,942	4,204	4,205	6,287	6,172	6,173	9,229
Natural Gas Total	*10^8 m3	25,765	50,000	75,000	42,852	83,159	124,738	59,292	115,063	172,594	102,144	198,222	297,333
Nat Gas for Electricty	10^8 m3	13,296	36,401	61,075	22,114	60,541	101,579	30,598	83,767	140,550	52,712	144,308	242,129

TABLE 4. INCREMENTAL GROSS INVESTMENT IN FOSSIL FUELS. DOLLARS
[STRATEGY 3]

1 US$ = 4.78 Yuan

	UNITS	Net Reserves to be Replaced 1990-2000	2000-2010	2010-2025	Incremental Investment Required to Find Additional Reserves (in million US Dollars) 1990-2000	2000-2010	2010-2025	Incremental Investment Required to Increase Production Capacity (in million US Dollars) 1990-2000	2000-2010	2010-2025	Total Incremental Required Investment (in million US Dollars) 1990-2000	2000-2010	2010-2025
Coal Total Produced	mill Tons	(5,080)	(18,425)	(90,934)	0	0	0	(16,183)	(52,329)	(289,715)	(16,183)	(52,329)	(289,715)
Coal for Electricity	mill Tons	(1,885)	(5,234)	(29,458)	0	0	0	(6,005)	(16,677)	(93,853)	(6,005)	(16,677)	(93,853)
Oil Total Produced	mill Tons	(1,168)	(4,645)	(20,942)	(20,301)	(80,748)	(364,069)	(43,387)	(172,573)	(778,083)	(63,688)	(253,321)	(1,142,153)
Oil for Electricity	mill Tons	(67)	(263)	(1,184)	(1,160)	(4,565)	(20,586)	(2,479)	(9,757)	(43,996)	(3,639)	(14,322)	(64,583)
Natural Gas Total	*10^8 m3	23,047	43,910	51,493	38,332	73,031	85,642	53,038	101,048	118,499	91,369	174,079	204,142
Nat Gas for Electricty	10^8 m3	13,048	35,795	58,894	21,701	59,534	97,951	30,027	82,373	135,529	51,728	141,907	233,480

STRATEGY 4 CALCULATIONS

Technical Coefficients for Strategy 4 - Electricity

Data From IO Table	UPPER 2000	2010	2025
Gross Output Sector 11	64,210	63,415	62,426
Coal	10,514	9,720	8,730
Crude + Gas	2,477	2,477	2,477
Oil	3,827	3,827	3,827
Modification to add Petroleum Products			
Coal	10,514	9,720	8,730
Petr Products	6,106	6,106	6,106
Gas	306	306	306
Technical Matrix A			
Coal	0.164	0.153	0.140
Petr Products	0.095	0.096	0.098
Gas	0.005	0.005	0.005
Strategy 4 Electric Projection			
Total Electric Demand (mill Yuan)	120,310	346,930	894,860
Fuel Requirements For Electricity (A* TotElecDemand) (mill Yuan)			
Coal	19,700	53,176	125,142
Petroleum Products	11,440	33,404	87,526
Gas	574	1,675	4,389
Fuel Requirements for Electricity in Volume			
Coal (mill ton)	472	1,273	2,997
Petroleum Products (mill ton)	16	46	120
Gas(*10^8 m3)	25	74	193
Fuel for All Intermediate Uses (in Billion Yuan)			
Coal	50.6	76.7	151.1
Petr Products	147.7	256.0	562.9
Gas	4.3	7.2	17.7
Fuel for Intermediate in the Economy in Volume			
Coal (mill ton)	1,211	1,836	3,618
Petr Prod (mill ton)	202	351	771
Gas(*10^8 m3)	191	317	781
Shares of Total Intermediate Demand			
Coal	39.0%	69.3%	82.8%
Petr Products	7.7%	13.0%	15.5%
Gas	13.3%	23.3%	24.8%
Total Output In Billion Yuan			
Coal	81.6	141.7	318.1
Petr Products	105.0	187.2	461.0
Gas	79.1	141.7	355.6

Total Fuel Output for Intermediate Sectors - Strategy 4

	In Billion Yuan 2000	2010	2025
Coal	50.6	76.7	151.1
Petr Products	147.7	256.0	562.9
Nat Gas	4.3	7.2	17.7
Fraction			
Coal	38.97%	69.34%	82.84%
Petr Products	7.75%	13.05%	15.55%
Gas	13.26%	23.26%	24.75%

Prices

	Coal	Petr Prod	Natural Gas
Output 90 (mill Yuan	45,096	100,946	3,067
Price 90 (Yuan)	41.7590 Yuan/ton	729.8512 Yuan/ton	0.2270 Yuan/m3
	1079.9	138.31	13510
	1079.9	138.31	135.1
Price 90			
Coal	41.759		
Oil	729.851		
Gas	0.227		

TABLE 2. PROJECTED FOSSIL FUELS CAPACITY REQUIREMENTS
[STRATEGY 4]

		1990	2000	2010	2025
Coal Total Produced	(mill Tons per Year)	1,055	1,211	1,836	3,618
Coal for Electricity	(mill Tons per Year)	283	472	1,273	2,997
Oil Total Produced	(mill Tons per Year)	201	202	351	771
Oil for Electricity	(mill Tons per Year)	11	18	46	120
Natural Gas	(10^8 M3 per Year)	153	191	317	781
Nat Gas for Electricty	(10^8 M3 per Year)	10	25	74	193
	Oil/Gas Total	1.3118	1.0618	1.1061	0.9875
	Oil/Gas Electr	1.1316	0.6204	0.6204	0.6204

TABLE 3. GROSS INVESTMENT IN FOSSIL FUELS
[STRATEGY 4]

		Total Reserves to be Replaced			Investment Required to Find Additional Reserves (in million Yuans)			Investment Required to Increase Production Capacity (in million Yuans)			Total Required Investment (in million Yuans)		
	UNITS	1990-2000	2000-2010	2010-2025	1990-2000	2000-2010	2010-2025	1990-2000	2000-2010	2010-2025	1990-2000	2000-2010	2010-2025
Coal Total Produced	mill Tons	11,328	15,236	40,906	0	0	0	172,515	232,022	622,960	172,515	232,022	622,960
Coal for Electricity	mill Tons	3,773	8,726	32,026	0	0	0	57,463	132,885	487,729	57,463	132,885	487,729
Oil Total Produced	mill Tons	2,015	2,766	8,415	167,464	229,830	699,301	357,902	491,188	1,494,535	525,368	721,018	2,193,836
Oil for Electricity	mill Tons	135	307	1,243	11,215	25,530	103,267	23,968	54,561	220,700	35,183	80,091	323,966
Natural Gas	*10^8 m3	1,718	2,539	8,236	13,657	20,181	65,475	18,896	27,924	90,594	32,553	48,105	156,069
Nat Gas for Electricty	*10^8 m3	178	495	2,003	1,402	3,937	15,925	1,940	5,447	22,035	3,342	9,384	37,960

TABLE 3A. GROSS INVESTMENT IN FOSSIL FUELS, DOLLARS
[STRATEGY 4]

		Total Reserves to be Replace			Investment Required to Find Additional Reserves (in million US Dollars)			Investment Required to Increase Production Capacity (in million US Dollars)			Total Required Investment (in million US Dollars)		
	UNITS	1990-2000	2000-2010	2010-2025	1990-2000	2000-2010	2010-2025	1990-2000	2000-2010	2010-2025	1990-2000	2000-2010	2010-2025
Coal Total Produced	mill Tons	11,328	15,236	40,906	0	0	0	36,091	48,540	130,326	36,091	48,540	130,326
Coal for Electricity	mill Tons	3,773	8,726	32,026	0	0	0	12,022	27,800	102,035	12,022	27,800	102,035
Oil Total Produced	mill Tons	2,015	2,766	8,415	35,034	48,082	146,297	74,875	102,759	312,664	109,909	150,841	458,961
Oil for Electricity	mill Tons	135	307	1,243	2,346	5,341	21,604	5,014	11,415	46,171	7,360	16,755	67,775
Natural Gas	*10^8 m3	1,718	2,539	8,236	2,857	4,222	13,698	3,953	5,842	18,953	6,810	10,064	32,650
Nat Gas for Electricty	*10^8 m3	176	495	2,003	293	824	3,332	406	1,140	4,610	699	1,963	7,941

TABLE 4. INCREMENTAL INVESTMENT IN FOSSIL FUELS, DOLLARS
[STRATEGY 4]

		Net Reserves to be Replaced			Incremental Investment Required to Find Additional Reserves (in million US Dollars)			Incremental Investment Required to Increase Production Capacity (in million US Dollars)			Total Incremental Required Investment (in million US Dollars)		
	UNITS	1990-2000	2000-2010	2010-2025	1990-2000	2000-2010	2010-2025	1990-2000	2000-2010	2010-2025	1990-2000	2000-2010	2010-2025
Coal Total Produced	mill Tons	(2,789)	(14,342)	(65,612)	0	0	0	(8,886)	(45,692)	(209,040)	(8,886)	(45,692)	(209,040)
Coal for Electricity	mill Tons	(725)	(700)	(1,920)	0	0	0	(2,311)	(2,231)	(6,119)	(2,311)	(2,231)	(6,119)
Oil Total Produced	mill Tons	(1,156)	(3,880)	(15,517)	(20,098)	(67,448)	(269,769)	(42,954)	(144,149)	(576,547)	(63,053)	(211,597)	(846,316)
Oil for Electricity	mill Tons	(45)	(69)	(111)	(781)	(1,192)	(1,924)	(1,669)	(2,548)	(4,112)	(2,450)	(3,740)	(6,036)
Natural Gas	10^8 m3	(1,000)	(3,551)	(15,271)	(1,663)	(5,906)	(25,398)	(2,301)	(8,172)	(35,142)	(3,964)	(14,079)	(60,541)
Nat Gas for Electricty	10^8 m3	(72)	(111)	(178)	(120)	(184)	(297)	(165)	(254)	(411)	(285)	(438)	(707)

CALCULATIONS FOR NUCLEAR GROWTH

Investment of Coal, 1990	16,446 Yuan
Sales of Coal from Electricity, 1990	47,084 million Yuan
Coefficient	0.349 Yuan Invested per Yuan of Electric Output
Nuclear Share in 1990	0.29%

TABLE 5. ELECTRICTY GENERATED BY NUCLEAR POWER, BILLION DOLLARS

	1990	2000	2010	2025	1990-2000	2000-2010	2010-2025
Baseline	0.19	0.19	0.19	0.19	100.0%	100.0%	100.0%
Strategy 3	0.19	1.44	10.86	225.00	753.9%	754.4%	2071.3%
Strategy 4	0.19	0.35	1.02	2.62	184.7%	288.4%	257.9%

TABLE 6. INVESTMENT FOR NUCLEAR FUEL, BILLION DOLLARS (investment coefficient from above times the amount of elect nuclear sales)

	1990	2000	2010	2025
Baseline	0.1	0.1	0.1	0.1
Strategy 3	0.1	0.5	3.8	78.6
Strategy 4	0.1	0.1	0.4	0.9

TABLE 7. INCREMENTAL INVESTMENT FOR NUCLEAR FUEL, BILLION DOLLARS

	1990	2000	2010.	2025
Strategy 3	0.000	0.436	3.728	78.524
Strategy 4	0.000	0.056	0.289	0.850

APPENDIX C2:

GENERATION/TRANSMISSION INVESTMENT SPREADSHEETS

Strategy 3. U. BOUND	HIGH GROWTH OF RATE				BUSINESS AS USUAL						
	MIX (%MTCE)				MIX (% MCTE)						
YEAR	1990	2000	2010	2025	1990	2000	2010	2025	(B$/GW),G	(+T+D)	(B$/MW),GTD
COAL	72.27	28.2	34.1	0	72.27	72.27	72.27	72.27	1.106	0.2212	1.3272
OIL	7.3	3.3	1.6	0.7	7.3	7.3	7.3	7.3	0.79	0.2212	1.0112
NATURAL GAS	0.41	50	42.5	12.86	0.41	0.41	0.41	0.41	0.527	0.2212	0.7482
HYDRO	20.01	17.2	15.7	15.7	20.01	20.01	20.01	20.01	1.216	0.2212	1.4372
NUCLEAR	0.2	1.3	6.1	71	0.2	0.2	0.2	0.2	1.52	0.2212	1.7412
DEMAND (TIMES BASELINE)	1.00	2.18	4.48	11.51	1.00	2.18	4.48	11.51			
TOTAL CAPACITY (GW)	137.89	300.56	618.06	1587.47	137.89	300.56	618.06	1587.47			
	CAPACITY BY FUEL (GW)										
COAL	99.65	84.76	210.76	0.00	99.65	217.22	446.67	1147.27			
OIL	10.07	9.92	9.89	11.11	10.07	21.94	45.12	115.89			
NATURAL GAS	0.57	150.28	262.67	204.15	0.57	1.23	2.53	6.51			
HYDRO	27.59	51.70	97.03	249.23	27.59	60.14	123.67	317.65			
NUCLEAR	0.28	3.91	37.70	1127.11	0.28	0.60	1.24	3.17			
	NET INVT. BY FUEL (GW)										
		1990-2000	2000-2010	2010-2025		1990-2000	2000-2010	2010-2015			
COAL		0.00	126.00	0.00		117.56	229.45	700.60			
OIL		0.00	0.00	1.22		11.88	23.18	70.77			
NATURAL GAS		149.72	112.39	0.00		0.67	1.30	3.97			
HYDRO		24.10	45.34	152.20		32.55	63.53	193.98			
NUCLEAR		3.63	33.79	1089.40		0.33	0.63	1.94			
	TOTAL NET MW	177.45	317.52	1242.83		162.98	318.10	971.26			
	NET INVT. BY FUEL (BD)								INV(3-U) - INV(BASUSUAL)		
COAL		0.00	167.23	0.00		156.03	304.53	929.83	-156.03	-137.30	-929.83
OIL		0.00	0.00	1.24		12.01	23.44	71.56	-12.01	-23.44	-70.32
NATURAL GAS		112.02	84.09	0.00		0.50	0.97	2.97	111.52	83.12	-2.97
HYDRO		34.64	65.16	218.74		46.78	91.31	278.79	-12.14	-26.15	-60.05
NUCLEAR		6.32	58.84	1896.87		0.57	1.11	3.38	5.76	57.74	1893.49
	TOTAL NET INV. (BD)	152.98	375.32	2116.85		215.88	421.35	1286.53	-62.90	-46.03	830.32
	GROSS INVT. BY FUEL (GW)										
COAL		18.29	154.22	0.00		150.75	301.79	923.93			
OIL		3.20	3.27	6.17		15.23	30.48	93.33			
NATURAL GAS		149.90	162.44	72.81		0.86	1.71	5.24			
HYDRO		33.29	62.55	200.72		41.74	83.56	255.82			
NUCLEAR		3.72	35.10	1108.25		0.42	0.84	2.56			
	TOTAL GROSS GW	208.41	417.58	1387.95		208.99	418.37	1280.87			
	GROSS INV. BY FUEL (BD)								INV(3-U) - INV(BASUSUAL)		
COAL		24.27	204.69	0.00		200.07	400.53	1226.24	-175.80	-195.85	-1226.24
OIL		3.24	3.31	6.24		15.40	30.82	94.37	-12.16	-27.51	-88.13
NATURAL GAS		112.16	121.54	54.48		0.64	1.28	3.92	111.52	120.25	50.56
HYDRO		47.85	89.90	288.47		59.99	120.09	367.66	-12.14	-30.19	-79.19
NUCLEAR		6.48	61.11	1929.69		0.73	1.45	4.45	5.76	59.65	1925.24
	TOTAL GR INV. (BD)	194.00	480.54	2278.88		276.82	554.18	1696.65	-82.82	-73.64	582.23

Strategy 4. U. BOUND	HIGH GROWTH OF RATE				BUSINESS AS USUAL						
	MIX (%MTCE)				MIX (%MCTE)						
YEAR	1990	2000	2010	2025	1990	2000	2010	2025	(B$/GW),G	(+T+D)	(B$/GW),GTD
COAL	72.27	72.27	72.27	72.27	72.27	72.27	72.27	72.27	1.106	0.2212	1.3272
OIL	7.3	7.3	7.3	7.3	7.3	7.3	7.3	7.3	0.79	0.2212	1.0112
NATURAL GAS	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.527	0.2212	0.7482
HYDRO	20.01	20.01	20.01	20.01	20.01	20.01	20.01	20.01	1.216	0.2212	1.4372
NUCLEAR	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	1.52	0.2212	1.7412
DEMAND (TIMES BASELINE)	1.00	1.85	5.33	13.74	1.00	2.18	4.48	11.51			
TOTAL CAPACITY (GW)	137.89	254.65	734.32	1894.09	137.89	300.56	618.06	1587.47			
	CAPACITY BY FUEL (GW)										
COAL	99.65	184.04	530.69	1368.86	99.65	217.22	446.67	1147.27			
OIL	10.07	18.59	53.61	138.27	10.07	21.94	45.12	115.89			
NATURAL GAS	0.57	1.04	3.01	7.77	0.57	1.23	2.53	6.51			
HYDRO	27.59	50.96	146.94	379.01	27.59	60.14	123.67	317.65			
NUCLEAR	0.28	0.51	1.47	3.79	0.28	0.60	1.24	3.17			
	NET INVT. BY FUEL (GW)	1990-2000	2000-2010	2010-2015							
COAL		84.38	346.66	838.16		117.56	229.45	700.60			
OIL		8.52	35.02	84.66		11.88	23.18	70.77			
NATURAL GAS		0.48	1.97	4.76		0.67	1.30	3.97			
HYDRO		23.36	95.98	232.07		32.55	63.53	193.98			
NUCLEAR		0.23	0.96	2.32		0.33	0.63	1.94			
	TOTAL NET MW	116.98	480.58	1161.97		162.98	318.10	971.26			
	NET INVT. BY FUEL (BD)								INV(4-U) - INV(BASUSUAL)		
COAL		111.99	460.08	1112.41		156.03	304.53	929.83	-44.04	155.55	182.58
OIL		8.62	35.41	85.61		12.01	23.44	71.56	-3.39	11.97	14.05
NATURAL GAS		0.36	1.47	3.56		0.50	0.97	2.97	-0.14	0.50	0.58
HYDRO		33.58	137.95	333.53		46.78	91.31	278.79	-13.20	46.64	54.74
NUCLEAR		0.41	1.67	4.04		0.57	1.11	3.38	-0.16	0.56	0.66
	TOTAL NET INV. (BD)	154.96	636.58	1539.15		215.88	421.35	1286.53	-60.93	215.23	252.62
	GROSS INVT. BY FUEL (GW)										
COAL		117.57	407.94	1103.51		150.75	301.79	923.93			
OIL		11.88	41.21	111.47		15.23	30.48	93.33			
NATURAL GAS		0.67	2.31	6.26		0.86	1.71	5.24			
HYDRO		32.55	112.95	305.54		41.74	83.56	255.82			
NUCLEAR		0.33	1.13	3.05		0.42	0.84	2.56			
	TOTAL GROSS MW	162.99	565.54	1529.83		208.99	418.37	1280.87			
	GROSS INVT. BY FUEL (BD)								INV(4-U) - INV(BASUSUAL)		
COAL		156.04	541.42	1464.58		200.07	400.53	1226.24	-44.04	140.89	238.34
OIL		12.01	41.67	112.71		15.40	30.82	94.37	-3.39	10.84	18.34
NATURAL GAS		0.50	1.73	4.68		0.64	1.28	3.92	-0.14	0.45	0.76
HYDRO		46.78	162.33	439.12		59.99	120.09	367.66	-13.20	42.24	71.46
NUCLEAR		0.57	1.97	5.32		0.73	1.45	4.45	-0.16	0.51	0.87
	TOTAL GR INV. (BD)	215.89	749.12	2026.41		276.82	554.18	1696.65	-60.93	194.94	329.76