ENERGY TRANSFER IN CHINA: A PRELIMINARY STUDY

BY

XIUPING DUAN

A Thesis submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the degree of Master of Arts

Department of Geography
The University of Manitoba
Winnipeg, Manitoba
June, 1995

ISBN 0-612-13091-6

Name XIUPING DUAN

Dissertation Abstracts International is arranged by broad, general subject categories. Please select the one subject which most nearly describes the content of your dissertation. Enter the corresponding four-digit code in the spaces provided.

THE HUMANITIES AND SOCIAL SCIENCE | 0366

SUBJECT TERM | SUBJECT CODE

U·M·I

Subject Categories

THE HUMANITIES AND SOCIAL SCIENCES

COMMUNICATIONS AND THE ARTS
Architecture 0729
Art History 0377
Cinema 0900
Dance 0378
Fine Arts 0357
Information Science 0723
Journalism 0391
Library Science 0399
Mass Communications 0708
Music 0413
Speech Communication 0459
Theater 0465

EDUCATION
General 0515
Administration 0514
Adult and Continuing 0516
Agricultural 0517
Art 0273
Bilingual and Multicultural 0282
Business 0688
Community College 0275
Curriculum and Instruction 0727
Early Childhood 0518
Elementary 0524
Finance 0277
Guidance and Counseling 0519
Health 0680
Higher 0745
History of 0520
Home Economics 0278
Industrial 0521
Language and Literature 0279
Mathematics 0280
Music 0522
Philosophy of 0998
Physical 0523
Psychology 0525
Reading 0535
Religious 0527
Sciences 0714
Secondary 0533
Social Sciences 0534
Sociology of 0340
Special 0529
Teacher Training 0530
Technology 0710
Tests and Measurements 0288
Vocational 0747

LANGUAGE, LITERATURE AND LINGUISTICS
Language
General 0679
Ancient 0289
Linguistics 0290
Modern 0291
Literature
General 0401
Classical 0294
Comparative 0295
Medieval 0297
Modern 0298
African 0316
American 0591
Asian 0305
Canadian (English) 0352
Canadian (French) 0355
English 0593
Germanic 0311
Latin American 0312
Middle Eastern 0315
Romance 0313
Slavic and East European 0314

PHILOSOPHY, RELIGION AND THEOLOGY
Philosophy 0422
Religion
General 0318
Biblical Studies 0321
Clergy 0319
History of 0320
Philosophy of 0322
Theology 0469

SOCIAL SCIENCES
American Studies 0323
Anthropology
Archaeology 0324
Cultural 0326
Physical 0327
Business Administration
General 0310
Accounting 0272
Banking 0770
Management 0454
Marketing 0338
Canadian Studies 0385
Economics
General 0501
Agricultural 0503
Commerce-Business 0505
Finance 0508
History 0509
Labor 0510
Theory 0511
Folklore 0358
Geography 0366
Gerontology 0351
History
General 0578
Ancient 0579
Medieval 0581
Modern 0582
Black 0328
African 0331
Asia, Australia and Oceania 0332
Canadian 0334
European 0335
Latin American 0336
Middle Eastern 0333
United States 0337
History of Science 0585
Law 0398
Political Science
General 0615
International Law and Relations 0616
Public Administration 0617
Recreation 0814
Social Work 0452
Sociology
General 0626
Criminology and Penology 0627
Demography 0938
Ethnic and Racial Studies 0631
Individual and Family Studies 0628
Industrial and Labor Relations 0629
Public and Social Welfare 0630
Social Structure and Development 0700
Theory and Methods 0344
Transportation 0709
Urban and Regional Planning 0999
Women's Studies 0453

THE SCIENCES AND ENGINEERING

BIOLOGICAL SCIENCES
Agriculture
General 0473
Agronomy 0285
Animal Culture and Nutrition 0475
Animal Pathology 0476
Food Science and Technology 0359
Forestry and Wildlife 0478
Plant Culture 0479
Plant Pathology 0480
Plant Physiology 0817
Range Management 0777
Wood Technology 0746
Biology
General 0306
Anatomy 0287
Biostatistics 0308
Botany 0309
Cell 0379
Ecology 0329
Entomology 0353
Genetics 0369
Limnology 0793
Microbiology 0410
Molecular 0307
Neuroscience 0317
Oceanography 0416
Physiology 0433
Radiation 0821
Veterinary Science 0778
Zoology 0472
Biophysics
General 0786
Medical 0760

EARTH SCIENCES
Biogeochemistry 0425
Geochemistry 0996
Geodesy 0370
Geology 0372
Geophysics 0373
Hydrology 0388
Mineralogy 0411
Paleobotany 0345
Paleoecology 0426
Paleontology 0418
Paleozoology 0985
Palynology 0427
Physical Geography 0368
Physical Oceanography 0415

HEALTH AND ENVIRONMENTAL SCIENCES
Environmental Sciences 0768
Health Sciences
General 0566
Audiology 0300
Chemotherapy 0992
Dentistry 0567
Education 0350
Hospital Management 0769
Human Development 0758
Immunology 0982
Medicine and Surgery 0564
Mental Health 0347
Nursing 0569
Nutrition 0570
Obstetrics and Gynecology 0380
Occupational Health and Therapy 0354
Ophthalmology 0381
Pathology 0571
Pharmacology 0419
Pharmacy 0572
Physical Therapy 0382
Public Health 0573
Radiology 0574
Recreation 0575
Speech Pathology 0460
Toxicology 0383
Home Economics 0386

PHYSICAL SCIENCES

Pure Sciences
Chemistry
General 0485
Agricultural 0749
Analytical 0486
Biochemistry 0487
Inorganic 0488
Nuclear 0738
Organic 0490
Pharmaceutical 0491
Physical 0494
Polymer 0495
Radiation 0754
Mathematics 0405
Physics
General 0605
Acoustics 0986
Astronomy and Astrophysics 0606
Atmospheric Science 0608
Atomic 0748
Electronics and Electricity 0607
Elementary Particles and High Energy 0798
Fluid and Plasma 0759
Molecular 0609
Nuclear 0610
Optics 0752
Radiation 0756
Solid State 0611
Statistics 0463

Applied Sciences
Applied Mechanics 0346
Computer Science 0984

Engineering
General 0537
Aerospace 0538
Agricultural 0539
Automotive 0540
Biomedical 0541
Chemical 0542
Civil 0543
Electronics and Electrical 0544
Heat and Thermodynamics 0348
Hydraulic 0545
Industrial 0546
Marine 0547
Materials Science 0794
Mechanical 0548
Metallurgy 0743
Mining 0551
Nuclear 0552
Packaging 0549
Petroleum 0765
Sanitary and Municipal 0554
System Science 0790
Geotechnology 0428
Operations Research 0796
Plastics Technology 0795
Textile Technology 0994

PSYCHOLOGY
General 0621
Behavioral 0384
Clinical 0622
Developmental 0620
Experimental 0623
Industrial 0624
Personality 0625
Physiological 0989
Psychobiology 0349
Psychometrics 0632
Social 0451

ENERGY TRANSFER IN CHINA: A PRELIMINARY STUDY

BY

XIUPING DUAN

A Thesis submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements of the degree of

MASTER OF ARTS

ABSTRACT

Energy and transportation are two vital elements essential for economic growth. There is a symbiosis or interdependence between energy and transport, since each is beholden to the other for effective operations. The provision of transport infrastructure serves as an indispensable element in effective access to energy supplies, a truth which is highlighted in the thesis.

Examining China's experience, energy and transport have been singled out as the two most important constraints on the country's rapid economic development. Because energy producing and consuming regions are geographically distinct, expansion of energy production in the appropriate areas in the interior to meet the soaring demand for energy in the coastal regions has caused significant energy movements which rest on the adequate provision of transport infrastructure. The occurrence of bottlenecks in transport has become a major stumbling block for energy development. Therefore, large-scale infrastructure programmes have recently been initiated to remedy this situation.

The emphasis of the study is placed on coal and oil transfer on the one hand, and their attendant transport modes, railways and coastal shipping, on the other. The latter is central to the efforts to establish an integrated infrastructure system to alleviate existing bottlenecks. The alternatives to transport

programmes are explored, although much still remains to be done. The implications for regional development as well as the environment of large infrastructure undertakings are examined on a preliminary basis.

ACKNOWLEDGEMENTS

I am very grateful to Dr. Daniel Todd, my supervisor, for his invaluable help and considerable guidance throughout the preparation and writing of the thesis. Not only did he significantly improve its presentability and readability, but he also clarified many ambiguities through his critical insights. I have greatly benefited from being a student of his.

I would also like to extend my deep appreciation to Dr. Romanowsiki, a professor in the Department of Geography, and Professor T. Henley, the assistant director of the Natural Resources Institute, for their useful comments and suggestions.

I am also indebted to Dr. Berierly, a professor and the graduate chairman of the Department of Geography, for his kind encouragement and help during my graduate study in the University of Manitoba.

Special thanks are due to Dr. B. Kaya and Dr. Zhang Lei who provided constant help and expressed concern for my research work in many ways. Sincere appreciation is also extended to my colleagues in China for their helpful information. Finally, I must express my personal debt to my parents in China for their spiritual support in this endeavour.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

PREFACE

THE ROLE OF ENERGY IN THE NATIONAL ECONOMY

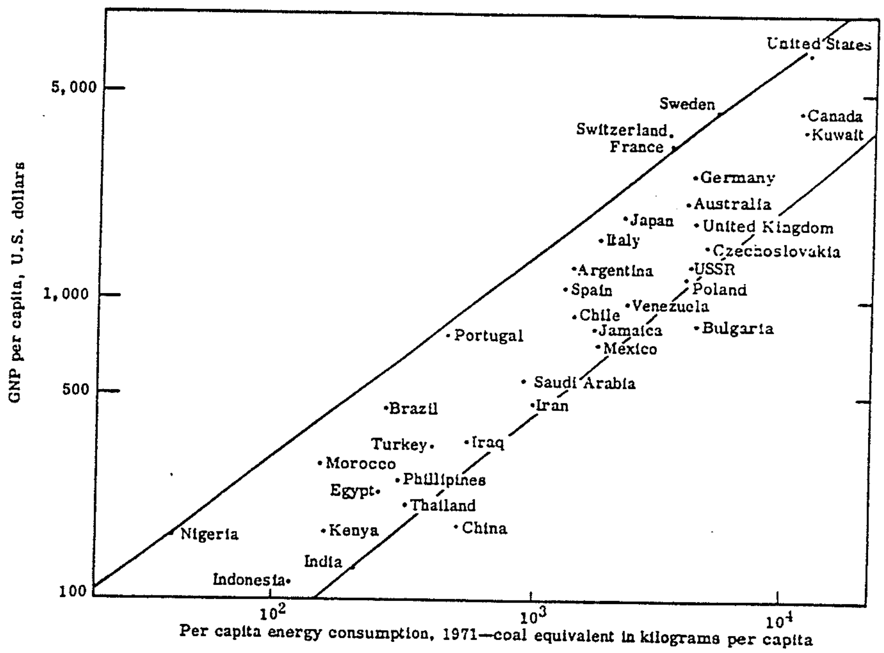
There is little doubt that energy represents one of the most important resource bases which any society can wish for; indeed, human existence and development vitally depend upon its accessibility. Energy deserves its claim to take priority over many other resources essential for economic growth simply because it intimately involves every segment of the nation's economy.

The primary and best-known application of energy resources derives from their capacity for work, a capacity manifested either by fuel combustion or through conversion to electric power. This work is fundamental to both residential (domestic) activities and economic activities. The main uses of energy in the residential sector are to be found in cooking, lighting, transportation, and heating or cooling. In some developing countries, such as India, nearly half of the total energy consumed is earmarked for such basic requirements as household cooking and lighting (Pachauri, 1977). In the commercial, agricultural and industrial sectors, meanwhile, energy is used in the production of goods and services. Energy-using equipment is installed to reduce the time required to perform any activity by assisting human energy through mechanical or chemical means and heating or lighting methods. It is an important input in the production process, along with labour, capital and raw materials. Industrial energy-use represents a large portion of total energy consumption in both industrialized and industrializing countries. Transport activity occurs in the residential, commercial, government, agricultural and industrial sectors. Transportation not only straddles the spectrum of economic activities, serving as an indispensable element in their operations, but it is vital to the effective use of energy, without it, residential and business customers alike would be deprived of energy supplies. Ironically, the transport sector itself is dependent on energy supply; for the sector would be prevented from functioning if the supply of fuels were to falter. Thus, there is a symbiosis or interdependence between energy and transport, since each is beholden to the other for effective operations. There is also a growing and important use of energy resources as raw materials for noncombustion or nonpower purposes. The typical applications, for example, may be found in their use as petrochemical feedstocks derived from crude oil, and as feedstocks in fertilizer production, manufactured from natural gas. In the United States, 80 percent of these nonenergy applications are derived from oil and 20 percent from coal and natural gas.

The historical relationship between energy use and economic development has been explored in detail by a host of individuals of varying background. From wood to coal to oil and gas to electric power, a clear trend is discernible: each energy substitute is more efficient and more readily produced and transported than its predecessor; each energy transition represents a breakthrough of humankind harnessing energy resources and a spur to rapid industrialization and modernization. For example, the replacement of wood by coal "changed the economic history of Britain, then of the rest of Europe and finally of the world. It led to the industrial revolution, to new methods of manufacture, to the expansion of existing industries and to the exploration of untapped natural resources" (Nef, 1977, p.140). Similarly, for more recent times, "The impact of electrification in industrial processes is the clearest case in point. A significant but not well-recognized aspect of electrification was its effect on the overall productive efficiency of the economy, particularly in the manufacturing sector" (Schurr and Darmstadter, 1976, p.6).

The history of economic development thus shows a parallel development whereby energy consumption has occurred in more and more convenient forms. As the modern economy evolves, its energy requirements correspondingly increase. Shortages of energy can have severe repercussions on national income, development of human and physical resources and the overall pace of economic growth. The relationship between economic growth and energy consumption is brought out in Figure P.1, in which gross national product (GNP) per capita for selected countries is plotted against their respective per capita energy consumption levels. The pattern observed clearly establishes a strong correlation between economic development and energy consumption. This relationship can also be

Figure P.1 Relationship between Per Capita Energy Consumption and Per Capita GNP



Source: Prasad and Reddy, 1976

examined by energy intensity, the ratio of the energy consumed to the gross domestic product (GDP) produced, which reflects the intensity of energy usage for the aggregate economy. For countries in the earlier stages of modernization, it is generally expected that energy-use----particularly in its commercial forms in the modern sector----will intensify, notwithstanding higher relative costs. Historical studies of the industrial countries also show a phase of increasing energy intensity, especially during the periods of rapid growth in heavy industry; a trend which is later overshadowed by one displaying reductions in the energy/GDP ratios as economies mature and their structure shifts towards services and the more complex manufactured products compatible with high value-added transformation (Siddayao, 1986).

The review of the relationships between energy and development suggests that the linkage to economic growth is stronger in the developing countries than in the industrial countries. Low levels of per capita income drive the developing countries towards rapid industrialization in their endeavours to catch up with the developed countries. Their development aspirations clearly necessitate the expansion of industrial and agricultural output rapidly, the development of modern skill-intensive work-forces and services, the building of transportation and communication networks, and the associated improvements in economic productivity: all of which involve large quantities of energy input. Also under the current fuel-using technology, it is unlikely for developing countries to reduce their energy intensities in anything like the same large proportions as the industrial countries in the short or medium term, thus leading to an even greater use of energy. As shown in Table P.1, the increase in commercial energy consumption for the developing world outstripped the increase in economic growth, reflecting a continued rise in energy intensity. These increases contrast with the industrial countries, where energy intensities were declining both immediately before and after 1973 when oil prices experienced an abrupt rise.

Table P.1 World Economic Growth and Commercial Energy Consumption 1970-78 (percent per year)

	Economic growth rates		Growth in commercial energy consumption		Change in energy intensity	
	1970-73	1973-78	1970-73	1973-78	1970-73	1973-78
World	5.6	3.4	4.8	2.5	-0.8	-0.9
All industrial countries[a]	5.4	2.9	4.1	1.5	-1.3	-1.4
All developing countries[b]	6.7	5.3	8.0	7.3	1.3	2.0

Note: [a] Western and Eastern Europe (including USSR), United States, Canada, Japan, Australia, and New Zealand.
[b] All others, including OPEC members, China, and other Asian centrally planned economies.
Source: Derived from data in World Bank, *World Economic and Social Indicators* (Washington, D.C., 1979); United Nations, *World Energy Supplies 1973-1978*, Series J, No.22 (New York, 1979)
In: Dunkerley, Ramsay, Gordon and Cecelski, 1981.

Owing to low levels of per capita consumption, the trend of increased energy usage in developing countries is expected to continue. The average annual consumption growth rate in developing countries during the period 1973-80 was 6.63 percent as compared with 0.50 percent in developed countries (including the former Soviet Union and Eastern Europe) with a growth rate differential of over 6.0 percent between the two groups. In 10 years the share of developing countries (including China) increased by about 6.51 points, from 19.79 percent in 1980 to 26.30 percent in 1990. Should this growth rate continue, the share of developing countries in global energy demand may reach 50 percent or more by 2010 (Park and Labys, 1994).

It is worth recalling that when developed countries were going through the energy-intensive phase of industrialization with the building of basic infrastructure and heavy industries, their industrial energy consumption grew faster than their industrial output. Developing countries are now going through similar stages of energy-intensive industrialization. Security of energy supply is therefore enormously important and becomes a cardinal aim of national policy. Nowhere is this more evident than in China.

THE GENERAL SITUATION OF CHINA'S ENERGY

With a land area of about 9.6 million km^2 and a population of over 1.1 billion, China requires vast supplies of energy for its modernization plans. Energy access has always been held vital to China's industrial development, since its economic structure is based primarily on the domestic supply of fuel resources.

In the forty years and more elapsing since the founding of the People's Republic of China, there has been dramatic progress in the country's aggregate production and in the energy projects needed to augment that production. In 1949 China's total output of primary energy was only 23 million tonnes of coal equivalent (mtce)[1] and its total output of electricity was only 4.3 billion kWh; by 1989, however, the total output of primary energy had reached one billion tonnes of coal equivalent, a 43.5-fold increase as compared with 1949, making an average annual growth rate of 13 percent. Its 1949 petroleum output was infinitesimal, but by 1992 it was producing 202.7 mtce or 141.8 million tonnes from domestic sources. In 1992, China ranked first in world production of raw coal and sixth in petroleum output.

Despite the successes in developing energy supply, the gap between energy supply and demand remains a weakness in the national economy, hampering economic development. Long-term economic strategy emphasizing heavy industrial development carries with it a large demand for energy. With the onset of economic reform in 1978, industry has been characterized by especially strong growth, averaging more than 10 percent per year. This growth, in turn, imposes huge burdens on the energy-supply sector. Table P.2 provides one measure of these burdens, showing how China's average annual energy consumption growth rate in the 1980s far outstripped other major economies. During the span of the Seventh Five-Year

[1] Generally this unit is chosen as a means of depicting energy use on a national or international scale. In China it refers to million tonnes of standard coal with thermal equivalent of 7,000 kilocalories per kilogram. All fuels are converted into standard coal.

Plan (1986-90), for instance, gross industrial and agricultural output value increased by more than 100 percent, whereas primary energy (standard coal equivalent) rose by only 18 percent and generated power increased by 39 percent (Anonymous, 1993). All the signs suggest that energy growth continues to lag far behind economic growth during the Eighth Five-Year Plan (1991-95) period. This reflects the urgency of the energy problem in China and its potential inhibiting effects on industrial development.

Table P.2 Energy Consumption Growth in China and the World, 1981-1991, average annual growth rate (%)

Commodity	China	Japan	Australia	USA	World
Crude Oil	3.4	1.0	0.6	0.4	0.8
Coal	5.9	2.2	2.8	1.8	1.8
Natural gas	2.6	7.4	4.5	0.2	3.0
Total Primary Energy	5.3	2.6	2.2	1.1	2.0

Source: British Petroleum Company, 1984-92 (June 1992).

China is already the third largest energy consumer in the world behind the United States and the former Soviet Union. The rapid climb in energy consumption is projected to continue, driven by the goal of quadrupling economic output between 1980 and 2000. Despite these trends, per capita energy use is still low (Table P.3). The shortage of energy, particularly electric power and petroleum products, pervades contemporary China. According to a 1990 *China Daily* report, in 1989 the nation produced 575 billion kilowatt-hours, 70 billion less than needed. As a result, about one-third of China's industrial enterprises were unable to operate at full capacity. In rural regions, biomass energy constitutes the primary fuel for daily needs, while commercial energy accounts for only one-fifth of the total. With an estimated 40 percent of China's peasants living without electricity, a large-scale increase in the supply of commercial energy will be required if the government wishes to press ahead with its plan to install electric power in rural areas (Xin, 1988).

Table P.3 Per Capita Energy Use in China and Other Countries, 1989

	Per capita GNP ($)	Per capita energy use (million BTUs)	Global rank in per capita energy use
China	374	24	78
India	314	12	109
Canada	20,224	400	5
United States	21,039	309	7
Former Soviet Union	9,288	194	13
United Kingdom	14,669	150	22
Germany	19,633	179	18
Japan	23,072	128	29

Source: The World Bank, 1991.

Inefficiency plays a part in China's energy shortages. By any measure, the country's energy efficiency is not very high by comparison with other countries (Table P.4). Although, in truth, there has been an improvement in recent years. On average, China's major industries consume some 30 to 90 percent more energy than similar industries in developed countries. For example, the steel industry is 60 percent more energy-intensive than is its counterpart in the industrialized world, and paper production requires about 40 percent more energy in China than elsewhere (The World Resources Institute, 1994-1995).

Table P.4 International Comparisons of Primary Commercial Energy Consumption Relative to GDP, 1980-1988 (kg of oil equivalent[a]/1980 US$)

	1980	1988
Developing Countries		
China	1.44	1.03
India (1980, 1987)	0.74	0.76
Korea, Republic of	0.74	0.59
Brazil	0.43	0.41
Developed Countries		
Canada	0.97	0.76
France	0.32	0.28
Germany	0.32	0.29
Japan	0.35	0.28
United Kingdom	0.40	0.32
United States	0.73	0.57

Note: [a] normally taken as equal to 10,000 kilocalories; 1kg of oil equivalent = 0.7kg of coal equivalent, or 1mtce = 0.7mtoe (million tonnes of oil equivalent).
Source: The World Bank, 1991.

Table P.5 Projected Energy Balance of China, 2000

Demand/supply scenarios	Total primary energy demand (btce)	Total primary energy supply (btce)	Deficit (mtce)
SCENARIO ONE[a]	1.56	1.48[c]	80
	1.56	1.30[d]	260
SCENARIO TWO[b]	1.70	1.48[c]	220
	1.70	1.30[d]	400

Note: btce--billion tonnes of coal equivalent
mtce--million tonnes of coal equivalent

[a] Satisfies the requirement of quadrupling China's GVAIO (Gross Value of Agricultural Output) between 1980 and 2000. Based on sectoral analysis, this scenario considers a change in economic structure, technical improvements, and energy conservation.

[b] Postulates that the energy elasticity coefficient in China is 1, meaning that energy demand will quadruple with GVAIO by 2000 to 2.4 btce. Subtracting 300 mtce saved from increased technical efficiency and 400 mtce saved from structural changes, final demand is estimated to be 1.7 btce.

[c] High case production of primary energy.

[d] Low case production of primary energy.

Source: Fridley[2], 1991.

China's energy problems have been a major concern for the nation's economic planners for years. Nonetheless, industrial development will continue to be constrained by energy shortages, as no improvement in China's primary energy balance is expected by the turn of the century (Table P.5). By 2000, the supply-demand imbalance could range between 80 mtce and 400 mtce depending upon the effectiveness of energy conservation measures and the adoption of newer technologies.

To enable the country to proceed with reform and industrialization, major emphasis was given to expanding the energy industry in the Seventh Five-Year Plan as well as increasing efficiencies in utilization. The Eighth Five-Year Plan similarly promotes active development of China's energy sector. At the same time, equal priority was given to the construction of transport infrastructure as expansion of energy industry will intensify the transportation bottlenecks.

ENERGY TRANSFER: A CRITICAL ISSUE IN CHINA

With its complex geology and about 7 percent of the world's total land area, China is well endowed with energy resources (Table P.6).

Table P.6 Estimated Energy Mineral Reserves of China

Energy Minerals	Reserves	Unit	Share of World (%)	Potential
Coal	114.5[a]	billion tonnes	11.0	Sizeable
Natural Gas	1.0	trillion cubic metres	0.8	Moderate
Petroleum	3.2[b]	billion tonnes	2.4	Sizeable

Note: [a] Proved recoverable reserves of coal.
[b] Speculative reserve estimates due to lack of detailed exploration and estimation of western onshore basins.
Source: British Petroleum Company, 1984-92 (June 1992).

Coal, of which China has 11 percent of world reserves, forms the backbone of its energy system, supplying over 74 percent of all commercial energy. Oil is of rising importance not only as a source of transport fuel and chemical feedstock but also as an export commodity. At the end of 1991, China's proven oil reserves were estimated at 3.2 billion tonnes, which represented 2.4 percent of the world's total. Oil currently makes up just 19 percent of China's energy mix. Natural gas proven reserves were estimated at 920.4 million tonnes of oil equivalent, or 0.8 percent of the world amount (British Petroleum Company, 1984-92 (June 1992)). Although natural gas supplies are thought to be large, investment in exploration and infrastructure has been minimal, and natural gas currently plays a minor role, accounting for only about 2 percent of primary energy. In addition to the fuel resources, China has a large hydroelectric potential, although this is more latent than real with currently only 10 percent of the potential being exploited. In fact, hydroelectric power is responsible for a mere 20 percent of China's electricity, since most of the electricity is generated from coal-fired thermal plants.

While blessed with relatively abundant energy resources, China is cursed by their uneven distribution. Although the country has 18 major sedimentary basins containing oil and gas, 85 percent of proven crude oil reserves are in the eastern part of China and north of the Yangtze River. Similarly, proven coal reserves are also unevenly distributed, with an estimated 76 percent located in north and north-west China. Of the total coal reserves, Shanxi province and Inner Mongolia together contain near 50 percent, the south-west is responsible for 9.6 percent, and east China holds only 6 percent (Xin, 1988). Nearly 80 percent of the hydro capacity is located in the south-west and the north-west.

In marked contradistinction, the principal energy-consuming regions are generally found in the east, north-east and south-central parts of the country, particularly where these parts debouch into the coastal provinces. These areas are, for the most part, heavily populated and economically developed. Their distance from energy-rich reserves and producing centres translates into pressing problems for the transportation network.

While effective energy supply is impossible without ample investment in resource extraction and processing, growth and expansion of these activities will require an efficient transport system. In fact, the transportation of energy supplies places a heavy burden on an already overtaxed transport system and results in bottlenecks and further energy shortage. Coal, as the longstanding dominant fuel supply in China, has long borne the brunt of transfer difficulties. Coal backlogs and deterioration in stockpiles became regular problems during the late 1970s (Ledic, 1989). The lack of railway facilities has periodically halted increases in output at coal mines. Many mines in China determine their output targets not on the basis of their productive capacity but on the basis of the transport facilities at their disposal. Oil transfer is not as severely constrained as coal transfer, since oil is not the principal energy source (accounting for just 19 percent of total energy supply) in the first place, and, in any event, some of the oil pipeline network is currently underutilized. However, because most new refineries were placed either far from oilfields or from readily-accessible transport links, oil-rich regions often have excess refining capacity over local demand while oil-poor but economically influential regions enjoy large modern refining complexes, leading to long-distance transportation. This anomalous situation has forced some refineries and petrochemical complexes in the coastal areas to resort to oil imports from overseas.

Since the Open-Door reforms adopted in 1978, China's regional gaps in economic development have widened. Differences in regional economic levels have resulted in wide gaps in energy consumption. Southeastern China, in the throes of rampant economic expansion, is desperate for energy. Increased specialization in production to achieve economies of scale will exacerbate regional differences between suppliers of energy and customers for it. Serious regional imbalances pose a daunting challenge to the existing transportation network. Since 1979 transport, along with energy supply, have been treated as the two most important constraints on China's economic development. Large investment in transport infrastructure----railways and ports----is receiving high priority. The rationale for this investment constitutes the subject-matter of what is to follow in this thesis.

THE FOCUS OF THIS THESIS

Bottlenecks in energy supply and transport provision have long been considered the two main obstacles to Chinese economic development. Their combination--energy transfer--is confronted with a compounded bottlenecks problem. This thesis defines the characteristics of China's energy production and consumption pattern in the first place, and traces regional supply-demand mismatch as the underlying reason for energy transfer in the second. Chapter 1, the first substantive chapter in this thesis, addresses the context of energy supply and the attendant problems of meeting regional demands for energy. Given the importance of coal and oil, the interregional flows of coal and oil transfer are reviewed in considerable detail in Chapter 2. The thesis then examines, in the succeeding chapter, the roles of the various elements of transport infrastructure----ports and railways----in alleviating the problem of energy transfer, and describes the major on-going projects in China. Chapter 4, for its part, analyses the implications for regional development of large infrastructure undertakings, besides contemplating their relevance to the question of national energy self-sufficiency[1]. Environmental implications are stressed at this

[1] I am assuming that the policy of energy self-sufficiency is maintained over the medium term. It may, however, be dispensed with as part and parcel of the adjustments which China would be required

juncture. Finally, the major issues unearthed in the preceding chapters are concluded in the summary form. To begin with, however, it is necessary to dwell on the context of China and its energy supply and transfer situation. For that purpose, we turn next to Chapter 1.

---

to make as a member in good faith of the World Trade Organisation.

CHAPTER 1 ENERGY MISMATCH IN REGIONAL CONTEXT

THE GENERAL PATTERN OF ENERGY CONSUMPTION

Surging economic growth in China has relied largely on high consumption of energy resources, a process which has resulted in excessive demand for even more resources. China's primary energy needs are largely satisfied by coal, and coal accounted for 76 percent of the total energy consumption in 1990. Although high, this share of the total energy mix has dropped from the early 1950s, when coal supplied around 95 percent of energy consumption. Nevertheless it is up markedly from a low of 70 percent experienced in 1976 (Table 1.1). Crude oil, which represented 17 percent of total primary energy consumption in 1990, has grown in importance as an additional source of energy in China since the late 1950s and early 1960s. It was during these years that several oil discoveries were made in China, and crude was found to be a relatively inexpensive fuel needed to supplement coal. However, the stagnation of oil production in the early 1980s blemished the rosy outlook that China would definitely become an oil giant in the 1980s. The government ordered all oil-fired plants to switch to coal-fired boilers by 1985 and any new oil-fired boilers were ruled out. Coal, accordingly, increased its share in total energy consumption. The abundance of coal in China and the relatively slow development of offshore and additional onshore oil deposits suggest that coal will remain as the critical energy source in China for the foreseeable future, although the government is making increasing efforts to develop both hydropower and nuclear energy. In 1991 consumption of coal in China accounted for more than 25 percent of the world's demand for this mineral, a proportion, it is worth noting, higher than the 21.9 percent commandeered by the U.S.A.(Table 1.2).

Table 1.1 China's Primary Energy Consumption and Its Composition

Year	Total[a,b] (mtce)	Percentage of Total (%) Coal	Oil	Natural Gas	Hydroelectricity
1952	46.95	95.00	3.37	0.02	1.61
1957	96.44	92.32	4.59	0.08	3.01
1958	175.99	94.62	3.92	0.06	1.40
1960	301.88	93.90	4.11	0.45	1.54
1963	155.67	88.93	7.20	0.81	3.06
1965	189.01	86.45	10.27	0.63	2.65
1970	292.91	80.89	14.67	0.92	3.52
1975	454.25	71.85	21.07	2.51	4.57
1976	478.31	69.91	23.00	2.81	4.28
1979	585.88	71.31	21.79	3.30	3.60
1980	602.75	72.15	20.76	3.10	3.99
1982	620.67	73.67	18.91	2.56	4.86
1985	766.82	75.81	17.10	2.24	4.85
1986	808.50	75.83	17.20	2.26	4.71
1987	866.32	76.21	17.02	2.13	4.64
1988	929.97	76.17	17.05	2.06	4.72
1989	969.34	75.97	17.08	2.06	4.89
1990	987.03	76.19	16.63	2.05	5.13

Note: [a] Excluding bio-energy, solar, geothermal and nuclear energy.
[b] Mtce refers to million tonnes of standard coal with thermal equivalent of 7,000 kilocalories per kilogram. The conversion is as follows (Figures in brackets refer to thermal equivalent):
1kg coal (5,000kcal) = 0.714kg standard coal
1kg crude oil (10,000kcal) = 1.43kg standard coal
1cubic metre natural gas (9,310kcal) = 1.33 kg standard coal
The conversion of hydropower into standard coal is calculated on the basis of the consumption quota of standard coal for thermal power generation of the year.

Source: China Energy Statistical Yearbook, 1991

Table 1.2 Energy Consumption in China and in World, 1991 (million tonnes of oil equivalent)

	China	Japan	Australia	USA	World
Crude oil	117.9 (3.8)	247.3 (7.9)	31.1 (1.0)	774.4 (24.7)	3,141.4
Coal	543.8(24.9)	78.7 (3.6)	39.9 (1.8)	477.9 (21.9)	2,186.2
Natural gas	13.4 (0.8)	49.5 (2.8)	16.5 (0.9)	507.7 (28.7)	1,769.7
Total Primary Energy	685.7 (8.7)	438.2 (5.6)	88.8 (1.1)	1,952.0 (25.0)	7,807.6

Source: British Petroleum Company (1984-92).

Of all the sectors, industry demands the largest share when it comes to energy consumption of all the fuels. This fact is evident from Table 1.3, a table which takes into account energy conversion (processing to produce petroleum and coal derivatives, and power generated at thermoelectric plants), subtracts energy losses, and is stock-adjusted. The table yields the following shares of total final energy consumption throughout China in 1990: industry[1], 67.4 percent; construction, 1.3 percent; agriculture, 5.2 percent; transport, 4.8 percent; commerce, 5 percent and households, 16.2 percent. The breakdown of final energy consumption by fuels is as follows: coal, 54.9 percent; petroleum, 14.9 percent; natural gas, 2 percent; electric power, 25.9 percent and miscellaneous (heated water)[2], 2.3 percent (Kambara, 1992).

[1] it includes: (1) extraction of natural resources, including mining and lumbering; (2) processing of agriculture products; (3) manufacture of industrial products; (4) repair of capital goods; (5) electricity generation and supply, water purification and gas production.

[2] The "heated water" category refers to heated water mainly used in food, paper and textile industries.

Table 1.3 Final Energy Consumption in China, 1990
(million tonnes coal equivalent)

	Raw coal & coal products	Crude oil & petroleum products	Natural gas	Electricity	Heated water	Total
Industry	328.32	75.02	14.43	180.97	17.48	616.22 (67.4%)
Construction	3.11	4.77	1.41	2.65	0.03	11.97 (1.3%)
Agriculture	15.47	15.08	0.00	17.40	0.00	47.95 (5.2%)
Transport	15.11	23.98	0.07	4.32	0.02	43.5 (4.8%)
Commerce etc.	21.30	12.27	0.16	11.36	0.47	45.56 (5.0%)
Residential	118.69	4.57	2.47	19.60	3.05	148.38 (16.2%)
Total	502.05 (54.9%)	135.68 (14.9%)	18.54 (2.0%)	236.30 (25.9%)	21.05 (2.3%)	913.61 (100.0%)

Sectoral Shares (%)

	Raw coal & coal products	Crude oil & petroleum products	Natural gas	Electricity	Heated water
Industry	65.4	55.3	77.8	76.6	83.1
Construction	0.6	3.5	7.6	1.1	0.1
Agriculture	3.1	11.1	0.0	7.4	0.0
Transport	3.0	17.7	0.4	1.8	0.1
Commerce etc.	4.2	9.0	0.9	4.8	2.2
Residential	23.6	3.4	13.3	8.3	14.5
Total	100.0	100.0	100.0	100.0	100.0

Source: China Energy Statistical Yearbook, 1991

Table 1.4 Final Energy Consumption in China, various shares in the 1980s (%)

		Raw coal & coal products	Crude oil & petroleum products	Natural gas	Electricity	Heated water
Industry and Construction	1980	54.4	14.5	4.7	24.2	2.2
	1985	55.7	13.1	3.3	25.7	2.2
	1990	52.8	12.7	2.5	29.2	2.9
Agriculture	1980	32.8	34.9	0.0	32.3	0.0
	1985	40.0	27.7	0.0	32.3	0.0
	1990	32.3	31.4	0.0	36.3	0.0
Transport	1980	49.7	46.4	--	3.9	--
	1985	46.0	46.8	--	7.2	--
	1990	34.8	55.2	--	9.9	--
Commerce etc.	1980	48.7	32.9	0.3	15.3	2.8
	1985	53.3	24.9	0.2	20.7	0.8
	1990	46.7	26.9	0.3	24.9	1.0
Residential	1980	91.0	2.3	0.3	4.7	1.7
	1985	88.2	2.8	0.4	7.1	1.5
	1990	79.9	3.1	1.7	13.2	2.1
Total	1980	58.6	16.1	3.3	20.1	1.9
	1985	60.0	14.3	2.3	21.6	1.8
	1990	54.9	14.9	2.0	25.9	2.3

Source: China Energy Statistical Yearbook, 1989 and 1991.

Table 1.4 illustrates the percentage changes of final energy consumption during the critical decade of the 1980s through a comparison of the years 1980, 1985 and 1990. Consumption of coal, which is clearly the dominant source of energy for all sectors, contracted quite sharply in the transport and household sectors, where electricity and oil expanded. Electricity will probably continue to take up coal's share in the future. The rising electricity supply of the last few years has not kept pace with the rise in demand so that the existing industrial capacity is not infrequently underutilised because of an inadequate power supply. Continuing rapid electrification in China will keep power demand growing at between 8 and 10 percent annually during the 1990s, resulting in a near doubling of electricity demand by the year 2000. This suggests increased usage of coal, as coal-fired power stations are the predominant source of electricity. In 1990, the total coal consumed amounted to 1.055 billion tonnes, with the power industry accounting for 25.6 percent, the metallurgical industry for 8.5 percent and domestic consumption for 15.8 percent. Endowed with a combination of large coal reserves and low-cost production, the Chinese economy will continue to rely on coal as its principal energy source to the end of the century and beyond.

Oil demand growth in China averaged 6.7 percent per year between 1985 and 1990 (Fridley[1], 1991), although this aggregate figure does not accurately reflect high growth rates for petrochemical feedstocks, gasoline, and diesel fuel (11.5, 10, and

8.5 percent respectively); a decline in the consumption of kerosene; and slow growth in fuel oil demand (4.5 percent). In the 1990s, oil demand growth is expected to vary between 5 and 7 percent, reaching 2.7-2.8 million barrels per day (b/d)[1] in 1995 and 3.4-4.0 million b/d in 2000 (Fridley[1], 1991). The total crude oil consumption in 1990 reached 118 million tonnes, with oil refining raking the largest share (73.1 percent), and the chemical industry (12.3 percent) and oil and gas extraction sectors (9.1 percent) acquiring substantial amounts as well.

With output of crude oil from China's major onshore oil fields still remaining at near peak or peak levels, demand for oil in China is expected soon to outstrip domestic supplies. This would make China slide into oil-import dependence. As a matter of fact, the import surge saddled China with a net oil-import bill of US$2.3 billion in 1993, the first deficit since the Daqing oil fields in the northeast began full production in the early 1970s (Goldstein, 1994). Refined products were the chief culprit accounting for the deficit, since crude oil managed to register a marginal export surplus. This is quite a changeover for a nation that had long taken pride in its status as Asia's largest oil exporter outside the Middle East. Worse still, the bill can only rise further in the next few years. As of 1990 and subsequent years, the balance of supply and demand of gasoline, diesel and fuel oil all fell into the negative group; that is to say, China was compelled to resort

[1] 1 million b/d = 50 million tonnes/year (average)

to importing to cover shortfalls. Most refineries, located inland and not easily accessible because of poor transportation, have been unable to get enough crude to produce the badly-needed products. It was reported by SINOPEC, the state refinery operator, that many inland refineries were running at levels well below capacity as they could not get hold of enough domestic crude, and bigger plants along the coast were running around or below 80 percent of capacity. Explosive demand spurred by the economic boom in conjunction with the inability of local refineries to meet demand pushed the government to relax restrictions hitherto imposed on product imports to the needy south of China. Security of energy supply is becoming a pressing problem and, accordingly, expansion of the energy sectors is receiving much attention from the government. The above discussion has set the scene; the discussion following will embellish it.

THE DEVELOPMENT OF ENERGY INDUSTRY AND ENERGY SUPPLY

The ambitious official plans will be worthless if there are no fundamental improvements in energy supply so as to permit it to meet energy needs. Since 1949, the energy industry has undergone substantial growth in China, the outcome of a serious commitment by the government to expand the industry in the light of a huge resource inventory, a need to supply raw material inputs to a large industrial base, and a desire to maintain a high level of self-sufficiency in resources. Forty years ago, China was regarded as an oil-poor country, the coal industry was just beginning to expand but accounted for only 2 percent of world output, and the country was trying to rehabilitate itself after the war-torn years of the 1930s and 1940s. Today, the energy industry has evolved to become one of the largest on Earth, helping to fuel the growth of what is arguably the fastest-growing economy not only in Asia but in the world.

Throughout the past four decades the Chinese government was determined to develop and expand the coal and petroleum industries. Investment levels varied through time, depending on the different emphases of the five-year economic plans. One way of characterizing a government's commitment to the development of its national energy industry is by assessing the growth (or decline) of capital investment levels over time. During the 39-year period between 1953 and 1991, approximately 43.3 percent of China's state investment in capital construction went to the coal, petroleum, power and coke industry. Table 1.5 lists historical values and percentages of investment in capital construction undertaken by the Chinese government with respect to the various branches of the energy industry. Capital construction refers to construction, expansion, transformation, and restoration projects of all sectors of the national economy, including the construction of mines and factories. Investment can be construed as the amount of work done in capital construction in money terms, or the scale and progress of capital construction during a certain period of time. Investment in capital construction is one component of total investment in fixed assets, with the other component being investment in technical renovation and transformation. Cumulative government funds invested for each five-year planning period are shown in Table 1.5, along with annual investment values for 1986 through 1991.

Table 1.5 Investment in Capital Construction by Branch of Industry[a] (bn,yuan/%)

Years (Period)	Total state industrial investment[b,c]	Energy Industry: Total	Coal	Petroleum	Power	thermal-electricity	Coking
1953-7	25.3	7.3	3.0	1.2	3.0	2.0	0.2
(1 FYP)	(100)	(28.9)	(11.7)	(4.7)	(11.7)	(7.9)	(0.8)
1958-62	72.8	20.6	8.7	2.5	8.9	4.9	0.5
(2 FYP)	(100)	(28.3)	(12.0)	(3.4)	(12.2)	(6.7)	(0.7)
1963-5	21.0	6.4	2.5	1.6	2.2	1.1	0.5
(Adjustment)	(100)	(30.5)	(12.0)	(7.8)	(10.5)	(5.3)	(2.2)
1966-70	54.2	15.5	4.7	3.9	6.9	3.3	0.1
(3 FYP)	(100)	(28.6)	(8.7)	(7.2)	(12.6)	(6.1)	(0.1)
1971-5	97.8	31.1	9.1	8.9	12.9	6.1	0.2
(4 FYP)	(100)	(31.8)	(9.3)	(9.1)	(13.2)	(6.2)	(0.2)
1976-80	123.2	49.0	13.6	13.1	21.9	9.9	0.3
(5 FYP)	(100)	(39.8)	(11.0)	(10.7)	(17.8)	(8.1)	(0.3)
1981-5	154.7	69.6	20.3	14.6	33.0	14.6	1.6
(6 FYP)	(100)	(45.0)	(13.1)	(9.5)	(21.4)	(9.5)	(1.0)
1986-90	378.6	202.3	35.2	37.9	122.5	68.6	7.1
(7 FYP)	(100)	(53.5)	(9.3)	(10.0)	(32.3)	(18.1)	(1.9)
of which:							
1986	53.2	26.7	5.8	3.9	16.2	8.5	0.9
	(100)	(50.2)	(10.9)	(7.3)	(30.5)	(16.0)	(1.7)
1987	68.3	34.0	6.0	5.9	21.1	10.7	1.1
	(100)	(49.8)	(8.8)	(8.6)	(30.9)	(15.7)	(1.6)
1988	79.6	41.2	6.4	8.6	25.0	14.6	1.2
	(100)	(51.8)	(8.0)	(10.8)	(31.4)	(18.3)	(1.5)
1989	82.2	44.6	7.1	9.4	26.8	15.3	1.4
	(100)	(54.3)	(8.6)	(11.4)	(32.6)	(18.6)	(1.7)
1990	95.3	55.8	9.9	10.1	33.5	19.5	2.4
	(100)	(58.6)	(10.4)	(10.6)	(35.1)	(20.5)	(2.5)
Total (1953-90)	927.6 (100)	401.8 (43.3)	97.1 (10.5)	83.7 (9.0)	211.3 (22.8)	110.5 (11.9)	10.5 (1.1)

Note: Figures are rounded.
[a] Refers to state-owned industrial enterprises.
[b] Includes the following heavy and light industries----metallurgical, power, coal, petroleum, chemical, machine-building, forest, building materials, textile, food, and paper-making.
[c] Beginning in 1985, the Chinese government amended its statistical reporting procedures to bring the nation's economic data into accordance with United Nations and World Bank reporting styles. Coal industry now records as coal-mining and dressing; and petroleum industry as petroleum and natural gas extraction and petroleum processing.

Source: China Energy Statistical Yearbook, 1991

It can be elicited from the table that, since the 1970s, the investment devoted to the energy industries has risen considerably, especially in the power industry. Between 1953 and 1990, capital investment in the power industry accounted for nearly one-fourth of that invested in all state industries, and for almost one-half of that invested in the energy industries. The investment earmarked for the petroleum industry jumped from 3.4 percent in the Second Five-Year Plan (FYP) to 7.2 percent in the third FYP as a result of the determination to bring about self-reliance in the wake of the withdrawal of Soviet aid. It was the motivation behind exploring and developing China's own oil fields (Daqing and Shengli). During the Seventh FYP period, the share of investment devoted to the petroleum industry rebounded from the low level of the Sixth FYP period to assume a level larger than that going into the nation's coal industry. This course was pursued in an attempt to stem the decline in output at virtually all the country's oil fields. The coal industry, vital for industrial growth, has always been top priority for investment, receiving the highest level of investment in the mid-1980s. This reflected efforts undertaken at that time by the Chinese government to step up construction of large- and medium-sized coal-mines to improve the geographical distribution of China's coal industry and to alleviate the shortages of coal then being experienced in East, North-East, and South-Central China. The increased production emanating from North China intensified the regional supply-demand mismatch.

The investment directed into a particular industry in China has generally been done to boost the size, output, and efficiency of the industry. Historical output trends of coal, crude oil, natural gas, therefore, mirror the investment in the coal and petroleum industries (Figure 1.1).

China is very dependent on its coal output for meeting the lion's share of energy consumption, so the development of coal production provides a reliable guarantee for sustaining the nation's economic development. In 1990, over 74 percent of the primary energy production was supplied by coal. While the coal industry has been the victim of erratic political behaviour, it has generally succeeded in increasing since 1949. For the pursuit of ambitious industrialization plans, it was apparent that coal production would have to increase dramatically, since this was the major resource from which China's vast expansion in energy requirements was to be derived. Coal output growth was positive and rapid after rehabilitation and reconstruction of the economy had been mostly completed in 1952. However this trend only lasted until about 1960, when coal output began to drop sharply (Figure 1.1). Throughout the 1960s, the coal industry was particularly disturbed by political upheavals. By the late 1960s and early 1970s China's coal industry had at last recovered from the depredations of the Cultural Revolution and the Great Leap Forward. In 1971 output of coal had reached 1960 levels after ten years of political and social disturbances. Thereafter, the coal industry advanced at a

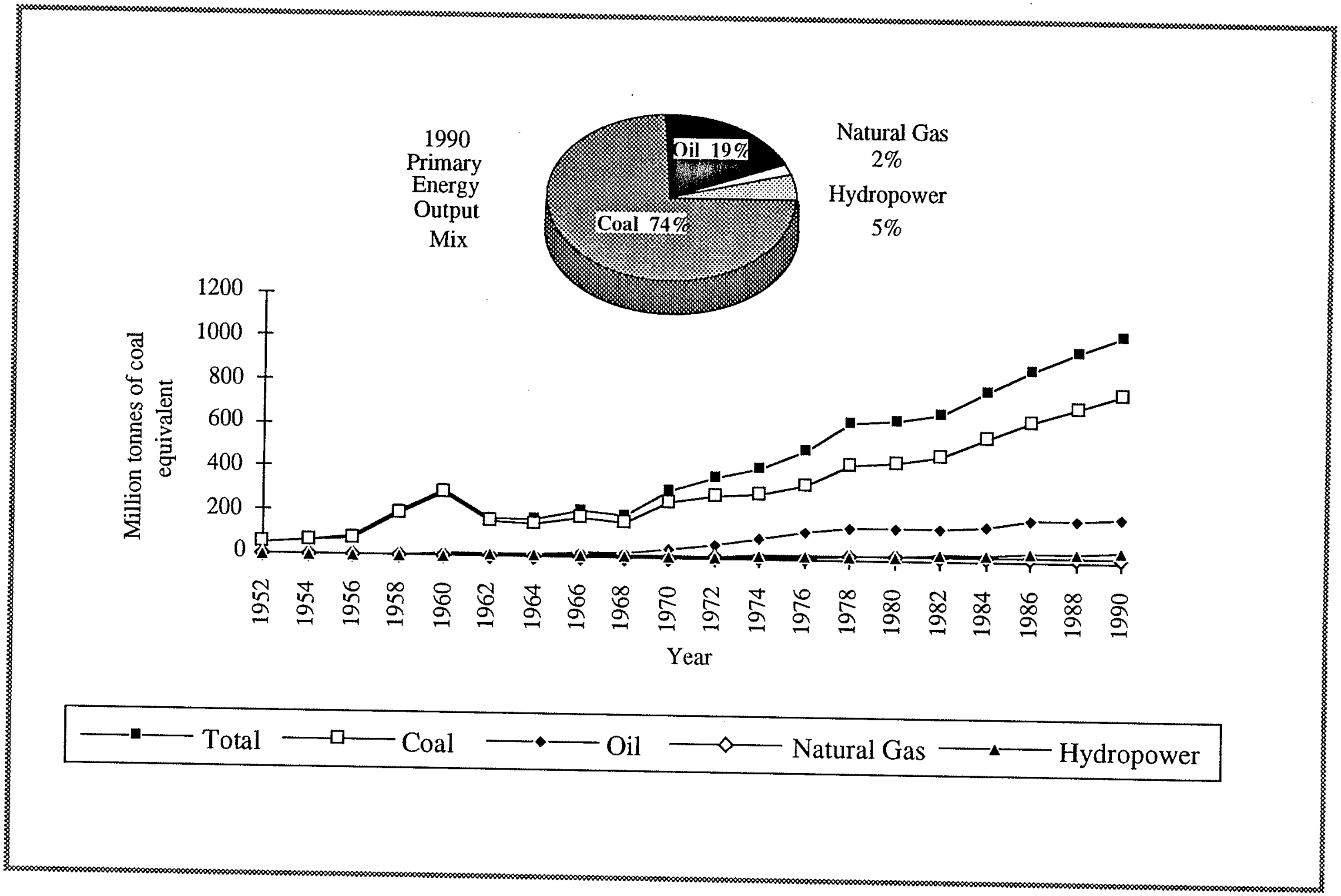


Figure 1.1 Primary Energy Production Trend

relatively smooth and steady pace. The Sixth Five-Year Plan (1981-85), was particularly noteworthy, since it accorded high priority to the expansion and development of China's energy industries, including coal, whose production rose 40.2 percent during the five years. The 1980s as a whole witnessed rapid development of the coal industry, and were characterized by investment in large-scale centrally-controlled mines, the promotion of local mines, and the expansion of collective and individually-operated mines.

Today, China represents the third largest producer of energy in the world. In 1991, the nation's raw coal production reached 1.007 billion tonnes (BT), which was 63.3 percent greater than output in 1981. Its present-day production of coal constitutes the world's largest, accounting for just under one-quarter of global production in 1991 (Table 1.6).

Table 1.6 Energy Production of China, 1981-1991 (million tonnes, unless otherwise noted)

	1981	1989	1990	1991	%change:1991 over 1981	1991 world rank	% of total
Crude oil	101.0	137.6	138.3	139.6	+38.2	5	4.5
Coal[a]	616.5	993.8	1004.0	1007.0	+63.3	1	22.9
Natural gas[b]	11.6	12.9	13.4	13.4	+15.5	22	0.7
Refined petroleum[c]	74.8	106.6	116.6	116.1	+55.4	5	NA

Note: [a]excludes coke.
[b]million tonnes oil equivalent.
[c]throughput.
Source: British Petroleum Company (1984-92)

Coal exports in China are still on a small scale and make up a negligible fraction of total coal production. But they have expanded significantly in recent years, owing to improved infrastructure, additional coal production at the Pingshuo coalfield (Shanxi Province)[1], and expanded selling efforts by the China National Coal Import and Export Corporation. In the meantime, coal imports rose to a peak of $132 million worth in 1985 before subsequently dropping off (Table 1.7). China's largest market for coal exports is Japan. This country annually imports about 4 million tonnes (MT) of coal from China. The European Union and HongKong are other major importers of Chinese coal. The potential for China to increase coal exports to neighbouring Asia-Pacific countries is relatively large, as it is one of the lowest-cost producers of coal in the Pacific Rim and it contains some relatively good-quality coal fields. Overall, if China's coal exports are to grow substantially in the near future, constraints imposed by growing domestic demand and persistent transport problems will have to be eased.

Table 1.7 Energy Exports and Imports in China, 1970-1991 ($US'000,000)

	Coal, coke and briquettes		Petroleum and petroleum products	
	Exports	Imports	Exports	Imports
1970	50	29	8	11
1975	159	86	862	41
1980	242	124	4,120	140
1985	579	132	6,630	308
1989	680	91	3,582	1,465
1990	755	74	4,460	1,054
1991	829	46	3,975	1,847

Note: Figures are rounded.
Source: General Administration of Customs, PRC (1983-92)

[1] The Antaibao mine, jointly developed by Occidental Petroleum Corporation and China, opened in September 1987, and was one of the largest coal surface mines in the world. With a good reserve and favourable location regarding railway access, it will provide major export earnings for China--80 percent of its 12MT capacity will be shipped to the port of Qinhuangdao and exported mainly to the Asia-Pacific region.

Unlike coal, crude oil production in China was not severely hit by the Great Leap Forward in the late 1950s, the withdrawal of Soviet technicians in the early 1960s, and the detrimental Cultural Revolution in the late 1960s, in large part owing to its importance to the nation's overall economy and the overriding desire to achieve self-sufficiency. At the foundation of the People's Republic in 1949, China's oil industry was virtually nonexistent. Since then it has developed to a stage where China is now the world's fifth largest crude oil producer. The discovery of the Shengli oil field in 1962, the initiation of large-scale production at Daqing in 1963, and the opening up of the Dagang oil and gas field in 1967 were all promising developments in China's oil industry in the 1960s. During the period extending from 1971 to 1978, oil production grew very rapidly, achieving an average annual growth rate of 16.50 percent (Chow, 1991). However, oil production suddenly stagnated in 1979, rising by only 2.0% compared with 1978; and in both 1980 and 1981 production actually declined. Production at Daqing, the biggest oil field in China, peaked in 1976 at around 50 million tonnes/year.

Daqing contrived to produce more water than oil, partly for reasons of its peculiar geology, and partly because water injection has been used there since the beginning of production in 1960. Indeed, water content increased to the point where it made up 52.3 percent of total flow in 1980, before rising to 71 percent by late 1983. Shengli and Huabei are also handicapped by complex geological conditions. The almost universal use of water injection as the production method stemmed in large part from the desire to maximize short-term output to meet higher production quotas. The strength of the method rested on its ability to sustain output for extended periods, although this was accomplished at the cost of a severe reduction in the ultimate recovery rate. Clearly, the short-sighted policy of forcing oil production at the expense of exploration and development work in the 1970s brought about output stagnation, to say nothing of jeopardizing long-term production prospects. It was only following an infusion of Western technology and technical assistance that enhanced recovery was achieved. The natural decline rate of the oilfields fell from 9.5 percent in 1980, through 7.9 percent in 1981 to 4.4 percent in 1983 and 2.9 percent in 1984; and, accordingly, production levels picked up again (Chow, 1991). However, the "technological window" is expected to close rapidly, meaning that such production gains are likely to be short-lived. Thus, since the 1980s increased efforts have been devoted to exploration so as to raise oil reserves instead of simply emphasizing increases in short-term production.

The exploration activities focused on the areas close to currently-producing wells, mainly in the eastern fields represented by Daqing, Shengli and Dagang. At the same time, prospecting and tapping offshore oil resources in such areas as the Bohai Sea and the Beibu Gulf in the South China Sea were also actively pursued in co-operation with foreign enterprises. Nevertheless, the growth rate of oil output came to a virtual standstill after 1986. Total crude production rose only 0.45 percent in 1989, matched by a 0.46 percent increase in 1990. In 1991, crude production rebounded only slightly, rising 0.91 percent over 1990 to reach 139.57 million tonnes. Uncertainty surrounds prospects in the oil and gas sector, where increases in output will depend on whether the Daqing field starts declining and whether new fields are discovered and developed.

Since petroleum is a major foreign-exchange earner, oil supply for domestic use is affected by the oil trade. China imported oil before the discovery and development of its own fields, but annual imports never exceeded 3 percent of total domestic energy consumption during the 1950s. China began to export crude oil and coal for commercial purposes in the mid-1970s. Oil exports peaked at about 30 percent of domestic production in 1985, rewarding China with some $6.63 billion which accounting for over 20 percent of total foreign-exchange earnings (Table 1.8). Such earnings are used to purchase much-needed foreign equipment and technology. The value of crude oil and refined petroleum exports in 1991 accounted for nearly 79 percent of that year's total energy export value (Table 1.9). Japan is also China's biggest petroleum export customer, and likely will remain so in the years ahead. Singapore is the second largest customer, having refineries which process the crude on behalf of China. In 1991 Japan accounted for 48.4 percent of China's total petroleum and petroleum-product export revenues. In the light of growing domestic demand for oil and a slow-down in production growth, by the mid-1990s the volume and direction of petroleum trade will change significantly. The shift in China's position from an export competitor to a competitor for supplies is likely to be felt first in the petroleum industry. Table 1.8 also clearly illustrates China's growing reliance on imported crude oil and products. In 1993 China imported 15.68 million tonnes of crude, an increase of 48 percent over the situation applying in 1991. Problems may arise as the need to export oil to earn foreign exchange will conflict with the country's domestic oil requirements to satisfy economic growth.

Table 1.8 China's Oil Trade Balance, 1982-1991 (million tonnes)

	Crude production	Exports			Ratio exports/ production	Imports		
		Crude	Products	Total		Crude	Products	Total
1982	102.10	14.68	4.91	19.59	0.19	0.64	0.93	1.57
1983	106.10	14.83	4.91	19.74	0.19	0.37	0.98	1.35
1984	114.50	22.01	5.70	27.71	0.24	0.25	0.88	1.13
1985	124.90	30.03	6.21	36.24	0.29	0.72	0.90	1.62
1986	130.69	28.50	5.46	33.96	0.26	1.72	3.23	4.95
1987	134.14	27.23	4.94	32.17	0.24	1.72	3.23	4.95
1988	137.05	26.05	4.79	30.84	0.23	1.96	4.22	6.18
1989	137.64	24.39	4.74	29.13	0.21	3.26	5.34	8.60
1990	138.30	23.99	5.26	29.25	0.21	2.83	2.7	5.53
1991	139.60	22.60	4.81	27.41	0.20	5.97	4.61	10.58

Source: General Administration of Customs, PRC (1987-92); British Petroleum (1984-92).

Table 1.9 China's Energy Trade by Commodity, 1991

Exports	Value ($USm.)	Ranking in value	% of total	Imports	Value ($USm.)	Ranking in value	% of total
Crude oil	2,956.8	1	61.5	Crude oil	926.4	1	47.7
Petroleum products	822.9	2	17.1	Petroleum products	901.9	2	46.4
Coal	748.5	3	15.6	Coal	47.2	3	2.4
Coke, semi-coke	80.4	4	1.7	Others	66.9	---	3.4
Others	199.8	---	4.2				

Source: General Administraiton of Customs, PRC (1983-92); Mineral Policy Program (1993)

In confronting this dilemma, the Chinese government realizes that it must take every means possible to continue to exploit oil resources and at least maintain current levels of production while stepping up exploration efforts. Foreign bids were welcomed for major offshore exploration areas, and most recently, for onshore oil acreages also. The objective for development of China's oil industry in the Eighth Five-Year Plan period will be to stabilize production in traditional East China fields while developing new ones in West China. The output of crude oil in 1995 will top 145 MT (including 5 MT from offshore fields), up 7 MT from the 1990 production. Onshore production will increase just 2 MT per year between 1991 and 1995. Exploration and development activities are to be expanded at the long-established Daqing, Shengli, and Liaohe major oil fields to help ensure stability increases in crude petroleum output in East China. Increasing efforts are to be made just to maintain current levels of production at Daqing----about 55 MT a year----or nearly 40 percent of the country's total output.

China's Eighth Five-year Plan (1991-5) calls for an average annual growth rate in GNP of 6 percent, with the value of industrial output in 1995 exceeding the 1990 level by more than 37 percent (Anonymous, 1991). China's ambitious economic and industrial targets imply continued heavy reliance on the energy sector. Several options can be exercised to increase energy availability. China can: (1) expand domestic mines, oil fields and refineries using capital investment; (2) search for and discover new energy reserves; (3) import energy from abroad; or (4) invest in mines, oil fields and /or processing facilities abroad. In view of China's Eighth Five-Year Plan, the government is at this time emphasizing options 1 and 2 as the most viable means to boost domestic energy production. In so doing, the dependence on option 3 will be reduced in line with the circumstance of a general shortage of foreign exchange. The next section will elaborate further on energy supply and demand, but expressly from the regional perspective.

REGIONAL MISMATCH IN ENERGY SUPPLY AND DEMAND

More than four decades of energy production undoubtedly facilitated energy supply; however, the uneven distribution of energy supply over China's enormous territory is presenting the country with huge problems. The North and North-East are rich in coal and oil respectively, and the South-West is endowed with hydro-power.

Conversely, the coastal regions where most major cities and industrial areas are located, are compelled to rely on outside- and frequently distant-sources of energy supplies. Shanghai, for example, has to import all its coal, oil and electricity from elsewhere (Kambara, 1992). As Table 1.10 and Figure 1.2 attest, the larger eastern region accounted for 63 percent of total industrial output value and 44.4 percent of energy consumption, the largest share among the three big regions on both counts; whereas its energy production only constituted 25.6 percent of the country's total. By contrast, the central and western big regions, with industrial output values only registering 25 percent and 12 percent respectively, have a combined share of 74.4 percent (in 1990) of China's total energy production. In terms of a six-division regional breakdown, the leading consumer of primary energy was the East, with 240.4 mtce, followed by the Central-South (185.2 mtce), and the North (180.4 mtce). The North-East was also a relatively large consumer, using 166.6 mtce. The South-West and North-West were much less significant. Table 1.11 summarizes regional supplies and demand for primary energy. It emerges that the North-East, South-West and North-West have been able to achieve balance in energy supply and consumption; indeed, they have even managed a small surplus. As of 1990, the North showed a large supply surplus, whereas the East and the Central-South, regions of great economic importance, suffered deficits (Figure 1.3). These latter two regions have had to secure their energy resources through inputs from other regions or from overseas so as to satisfy their high economic growth levels. The following analysis will focus on two vital energy resources: coal and oil.

Table 1.10 Shares of Energy Production and Consumption Among Three Big Regions[a,b], 1990 (%)

	The Eastern	The Central	The Western
Total energy production	25.56	53.74	18.90
raw coal	21.93	58.19	19.87
crude oil	42.72	49.79	7.49
Total energy consumption	44.38	33.90	18.37
coal	42.61	39.08	18.31
oil	58.71	24.79	10.33
Gross value of industrial output (GVIO)	63.04	24.99	11.98
National income	53.01	30.04	16.33

Note: [a] Energy production and consumption figures are calculated on the basis of different thermal equivalent of each region, so their sum disagrees with the country's total.
[b] Three regions are divided as follows (see Figure 1.2):
The eastern region includes: Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Guangxi and Hainan;
The central region includes: Shanxi, Inner Mongolia, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei and Hunan;
The western region includes: Sichuan, Guizhou, Yunnan, Xizang, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang.

Source: China Energy Statistical Yearbook, 1991

Table 1.11 Regional Primary Energy Supply and Consumption, Economic Growth in China[a], 1990

	North	North-East	East	Central-South	South-West	North-West	Total
Primary energy production (mtce)	303.1	216.8	160.0	144.3	109.2	87.2	1020.6
Share in total (%)	29.7	21.2	15.7	14.1	10.7	8.5	100
Primary energy consumption (mtce)	180.4	166.6	240.4	185.2	104.4	76.9	953.9
Share in total (%)	18.9	17.5	25.2	19.4	10.9	8.1	100
Naitonal income (billion yuan)	185.4	169.6	488.8	354.5	154.4	81.2	1433.9
Share in total (%)	12.9	11.8	34.1	24.7	10.8	5.7	100

Note: [a] The division of six regions can be seen from Figure 1.3.
Source: China Statistical Yearbook, 1991 and China Energy Statistical Yearbook, 1991

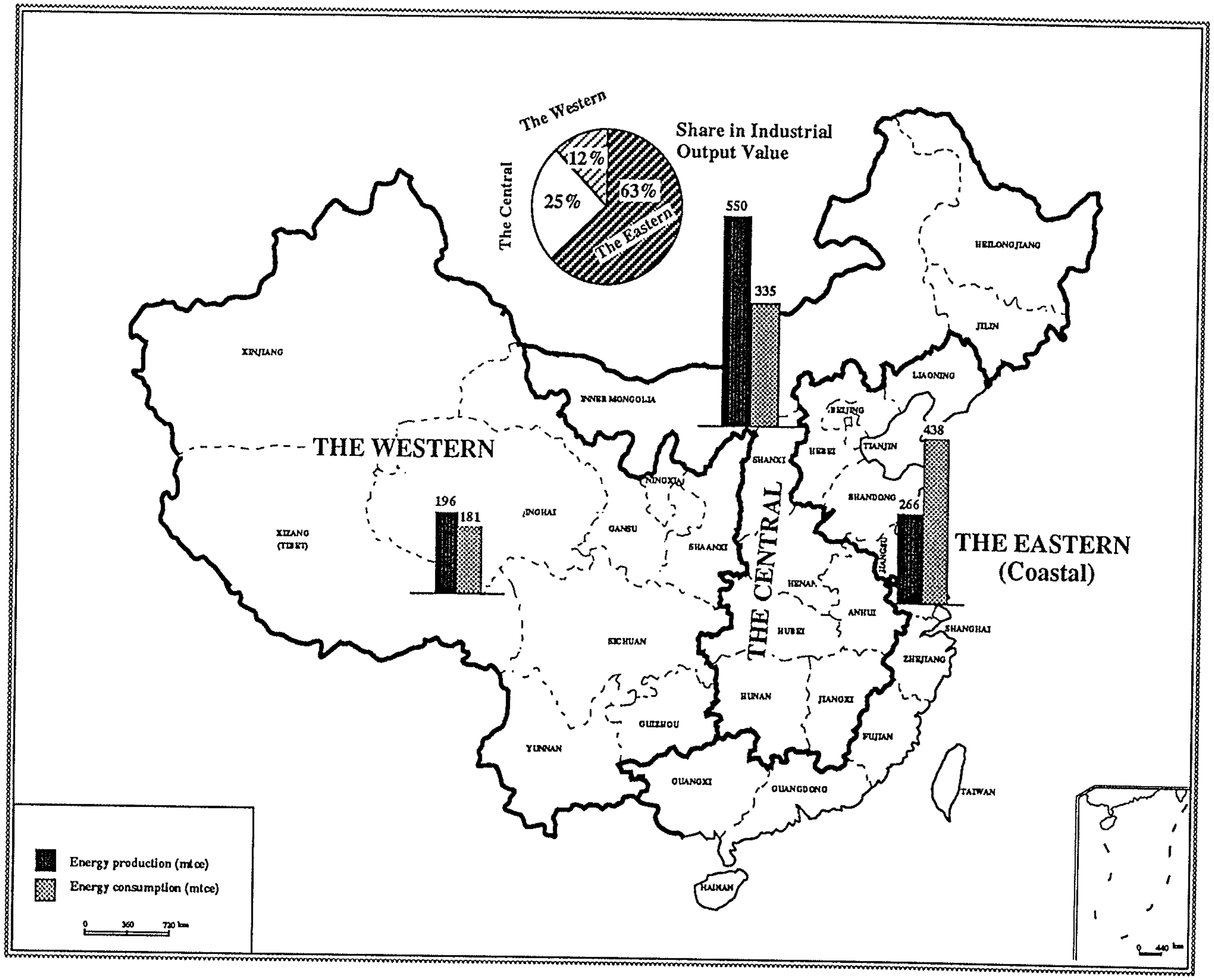


Figure 1.2 Energy Production and Consumption Among Three Big Regions, 1990

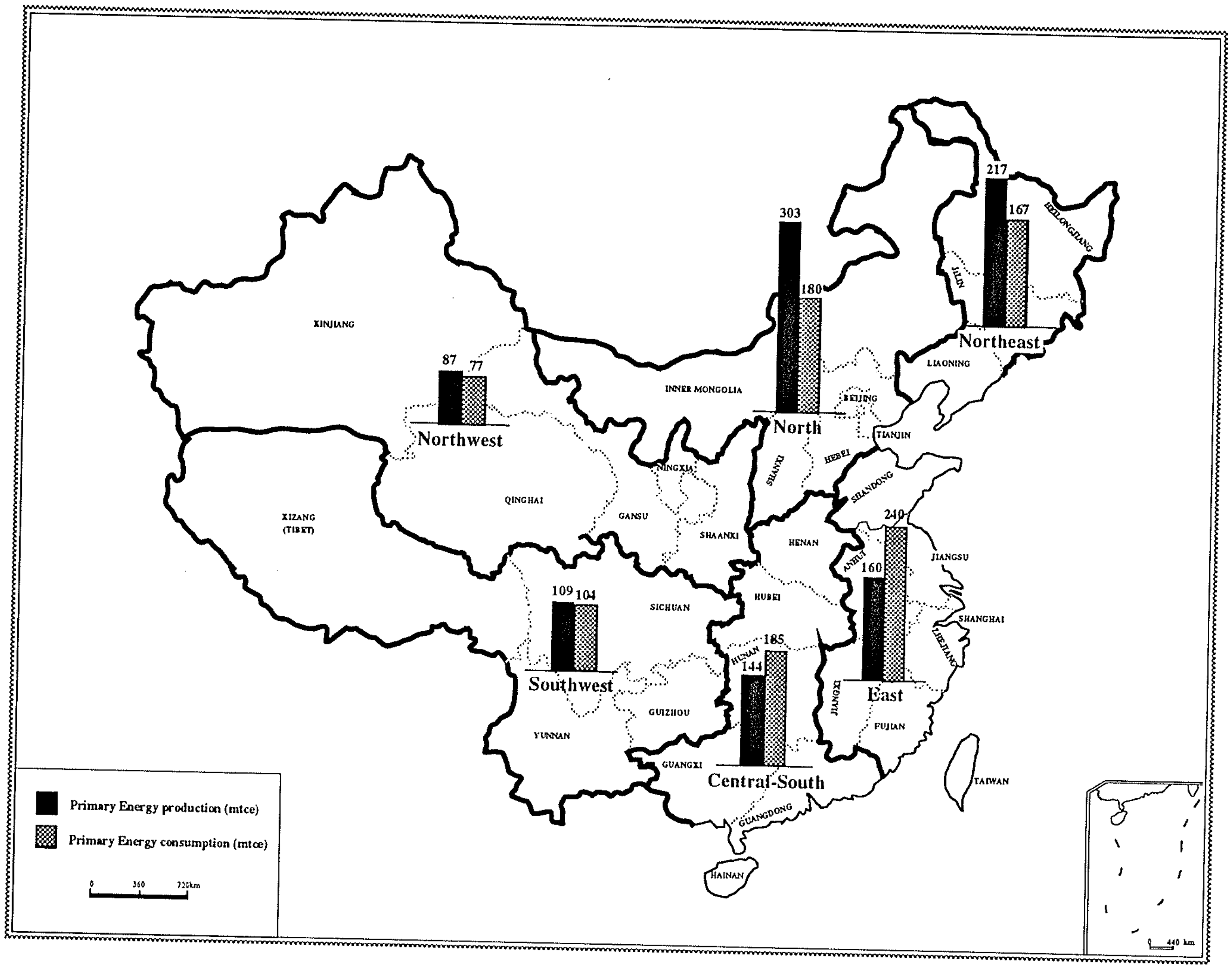


Figure 1.3 Primary Energy Supply and Consumption in Six Divisions, 1990

COAL

Coal remains the backbone of China's energy economy, though development of its petroleum and natural gas resources is emphasized. For coal, the most immediate obstacle facing China is not that of exploration for new sources but its location. Most coal is mined at locations far from where it is consumed. Coal supply is never sufficient in China's ten coastal provinces and municipalities, where the nation's industry and population are concentrated and coal consumption is high. The coal deposits of coastal regions amount to only 5.5 percent of the national total, in contrast with 76 percent in the North and North-West (Ledic, 1989).

As Table 1.12 shows, the regional imbalance between coal supply and demand is particularly acute in the East, but appreciable shortfalls occur in parts of the North-East and South as well. Significant coal surpluses emerge in the North, transforming this region into the principal supply source for the rest of the country. Most of the North's advantage is gained by Shanxi, an interior province which can truly claim to be the heart of China's coal industry (Todd and Zhang[2], 1994). Over one-quarter of China's coal production came from Shanxi province in 1990. The balance indicator can be calculated, one in which coal production minus coal consumption for a given province provides a picture of regional coal self-supply. In 1990 there were 19 provinces which fell into the category of net coal importer.

Jiangsu and Liaoning were by far the largest, with net import requirements that amounted to 38 MT and 31 MT respectively. Shanghai, Hubei, Zhejiang, Guangdong, Tianjin, Hebei, Beijing, Jilin and Shandong, each demanding imports in the 10-30 MT range, accounted for more than 160 MT or over 60 percent of total regional coal imports (Todd and Zhang[2], 1994). At the same time, only nine provinces can be identified as net coal exporters, and they are led by Shanxi. Its net coal exports reached 209 MT in 1990, a level far in excess of the second largest exporter, Henan, which registered nearly 30MT. The third largest exporter, Heilongjiang, recorded net exports of 17.4 MT. Six others--Guizhou, Inner Mongolia, Shaanxi, Ningxia, Xinjiang and Sichuan--achieved export levels of less than 10 MT each. It is abundantly clear, then, that the interior presents higher coal self-sufficiency than the coast. Also in the wake of the adoption of the "Open Door" and further economic development along the coast, the demand for coal has increased even more dramatically in this part of the country and its import dependency has been rising steadily in consequence. For instance, the most dependent area, Shanghai-Jiangsu-Zhejiang, relies on other regions to overcome its net shortfall of 89 MT as a corollary of its self-supply ratio (coal production/coal consumption) of only 0.32. Beijing-Tianjin-Hebei was in a more fortunate position in 1990, thanks to a 0.60 ratio, and called for 48.3 Mt of net imports (Todd and Zhang[2], 1994).

Table 1.12 Regional Coal Production and Consumption, 1990

Region	Production (MT)	(%)	Consumption (MT)	(%)	Balance (MT)	(%)
North	406.1	37.6	236.9	22.4	+169.2	+15.2
Beijing	10.1	0.9	24.1	2.3	-14.0	-1.4
Tianjin	--	--	17.9	1.7	-17.9	-1.7
Hebei	62.4	5.8	78.8	7.5	-16.4	-1.7
Shanxi	286.0	26.5	76.6	7.3	+209.4	+19.2
Inner Mongolia	47.6	4.4	39.5	3.8	+8.1	+0.6
North-east	159.7	14.8	187.8	17.8	-28.1	-3.0
Liaoning	51.0	4.7	82.5	7.8	-31.5	-3.1
Jilin	26.1	2.4	40.1	3.8	-14.0	-1.4
Heilongjiang	82.6	7.7	65.2	6.2	+17.5	+1.5
East	147.0	13.6	257.1	24.4	-110.1	-10.8
Shanghai	--	--	27.4	2.6	-27.4	-2.6
Jiangsu	24.1	2.2	62.2	5.9	-38.1	-3.7
Zhejiang	1.4	0.1	24.9	2.4	-23.5	-2.3
Anhui	31.2	3.0	34.3	3.2	-3.1	-0.2
Fujian	9.5	0.9	13.1	1.2	-3.6	-0.3
Jiangxi	20.3	1.9	22.7	2.1	-2.4	-0.2
Shandong	60.0	5.6	72.6	6.9	-12.6	-1.4
South	152.5	14.1	180.2	17.1	-27.7	-0.3
Henan	90.8	8.4	61.0	5.8	+29.8	+2.6
Hubei	9.2	0.9	33.4	3.2	-24.2	-2.3
Hunan	33.7	3.1	39.6	3.8	-5.9	-0.7
Guangdong	8.9	0.8	29.9	2.8	-21.0	-2.0
Guangxi	9.8	0.9	15.6	1.5	-5.8	-0.6
Hainan	--	--	0.7	0.1	-0.7	-0.1
South-west	127.1	11.8	115.5	10.9	+11.6	+0.9
Sichuan	67.9	6.3	66.5	6.3	+1.4	0.0
Guizhou	37.0	3.4	27.1	2.6	+9.9	+0.8
Yunnan	22.3	2.1	21.9	2.1	+0.4	0.0
Xizang	--	--	--			--
North-west	87.5	8.1	77.8	7.4	+9.7	+0.7
Shaanxi	33.3	3.1	27.3	2.6	+6.0	+0.5
Gansu	15.6	1.5	18.6	1.8	-3.0	-0.3
Qinghai	3.2	0.3	4.7	0.5	-1.5	-0.2
Ningxia	14.4	1.3	8.9	0.8	+5.5	+0.5
Xingjiang	21.0	1.9	18.4	1.7	+2.6	+0.2
Total	1079.9	100.0	1055.2	100.0	+24.7	0.0

Source: China Energy Statistical Yearbook, 1991.

This imbalance has its historical and natural reasons. During the First Five-Year Plan, most of the coal output came from the coalfields closest to coastal markets, mainly from the medium and large-sized mines in the North-East, North and East, which accounted for 80 percent of the nation's coal investment. As a result, coal output in the North and North-East contributed 38 percent and 33 percent, respectively, to country-wide production (Li[1], 1990). During the Great Leap Forward (1958-60), feverish construction of primitive, small, open outcrop mines was started throughout the country, bolstering the steel-making expansion campaign. The coal industry, led by the steel mania, spread to the South where an ambitious plan was launched to establish seventeen coal bases in the South notwithstanding the scarcity of suitable geological data. A labour force of 30,000 had to be moved from the North to the South. The coal-mining investment in the South increased 1.5 times during the course of the Second Five-Year Plan. By contrast, the traditional heavy industrial centre, the North-East, received less attention, and its share of coal-mining investment fell from 40 percent to 22 percent in the same period. By the end of 1958, there were reportedly some 110,000 small pits in operation. However, many of the disorganized pits proved shortlived and were closed down in 1961 (Cheng, 1984). After the three years restoration that followed, the emphasis of the coal industry shifted to the remote interior provinces as industrial investment was steered away from the coastal regions into the "Third Front" Zone so as to enhance national security. Guizhou (Liupenshui), Sichuan and Shaanxi were singled out for development. The share held by the South-West and North-West in the nation's coal-mining investment rose dramatically, from the First Five-Year Plan's 4.2 and 6 percent to the Third Five-Year Plan's 28.6 and 13 percent respectively. Following this, the directive to "reverse coal movement from north to south" came on stream during the Fourth Five-Year Plan (1971-75). Coal mines in the nine provinces in the Central-South and East were initiated, strengthened by the fact that 32.5 percent of the total coal-mining investment was sunk in these regions in order to allow them to achieve self-sufficiency, and thereby reducing their dependence on northern shipments. Ten years' exploration, investment, and promotion of southern mining, while pursued with vigour and great expense, still failed to assuage the energy needs of growing regional economies, much less to correct the supply-demand imbalance.

Since 1980, both the North-east region and the Beijing-Tianjin-Hebei region have experienced acute coal shortage owing to their depleted out-dated mines and long-term neglected investment. At the same time, the coastal regions, stimulated by rapid economic growth due to the "Open Door" policy and economic reform in 1978, were gasping for energy supplies. New policy thereafter switched attention back to the North and Central regions, reverting with renewed vigour to the development of large, fully-mechanized coalfields with low production cost and high output. Combined with huge deposits and qualitative superiority, the northern coalfields were confirmed in their supremacy. In 1990, the North contributed 37.6 percent of the nation's output; its leading producer, Shanxi, being dubbed China's "Ruhr". Of the fourteen large coal-mining areas with annual outputs of more than 10 MT, half of them are located in the North. The most notable is the giant Datong site with a capacity of about 30 MT (Table 1.13 and Figure 1.4).

Table 1.13 Distribution of Major Coal Mines, 1990

Region	Total capacity (MT) and its share (%)	Raw coal output of major mines >10 MT		5-10 MT		2-5 MT	
North	406.1 (37.6%)	Datong	29.9	Fenxi	6.9	Wuda	4.6
		Kailuan	17.8	Beijing	6.0	Huoxian	4.5
		Yangquan	16.2			Xingtai	3.8
		Xishan	15.2			Huolinhe	3.7
		Fengfeng	11.5			Handan	3.2
		Jincheng	10.4			Xuangang	2.5
		Luan	10.1			Haibowan	2.0
North-East	159.7 (14.8%)	Hegang	15.7	Tiefa	8.6	Tonghua	4.3
		Jixi	15.7	Qitaihe	8.0	Liaoyuan	3.7
		Fuxing	11.0	Fushun	7.6	Shulan	3.6
		Shuang-yashan	10.6	Shenyang	5.3	Nanpiao	2.5
						Beipiao	2.4
East	147.0 (13.6%)	Huaibei	14.2	Yanzhou	9.7	Feicheng	3.9
		Xuzhou	13.2	Xinwen	7.4	Datun	3.7
		Huainan	10.1	Zaozhuang	6.0	Pingxiang	3.2
				Zibo	5.5	Fengcheng	2.0
Central-South	152.5 (14.1%)	Pingdingshan	17.5	Xingmi	5.7	Jiaozuo	4.3
		Yima	10.7	Hebi	5.1		
South-West	127.1 (11.8%)			Liupan-shui	9.8	Dukou	3.7
						Furong	2.9
						Nantong	2.4
North-West	87.5 (8.1%)			Shitan-jing	7.2	Hancheng	4.0
				Tongchuan	6.1	Yaojie	3.2
						Jingyuan	3.2
						Shizuishan	3.1
						Urumqi	2.1

Source: China Energy Statistical Yearbook, 1991.

Indeed, about one-half of China's total proven reserve is concentrated in the North, mostly clustered in Shanxi and Inner Mongolia (Table 1.14). The North-West region, next best endowed, is responsible for about 30 percent of the national coal reserves. Significantly, the 13 provinces composing the South and East, the two most populous regions, only account for 8 percent of the total. Moreover, coal resources in the north of China are of much better

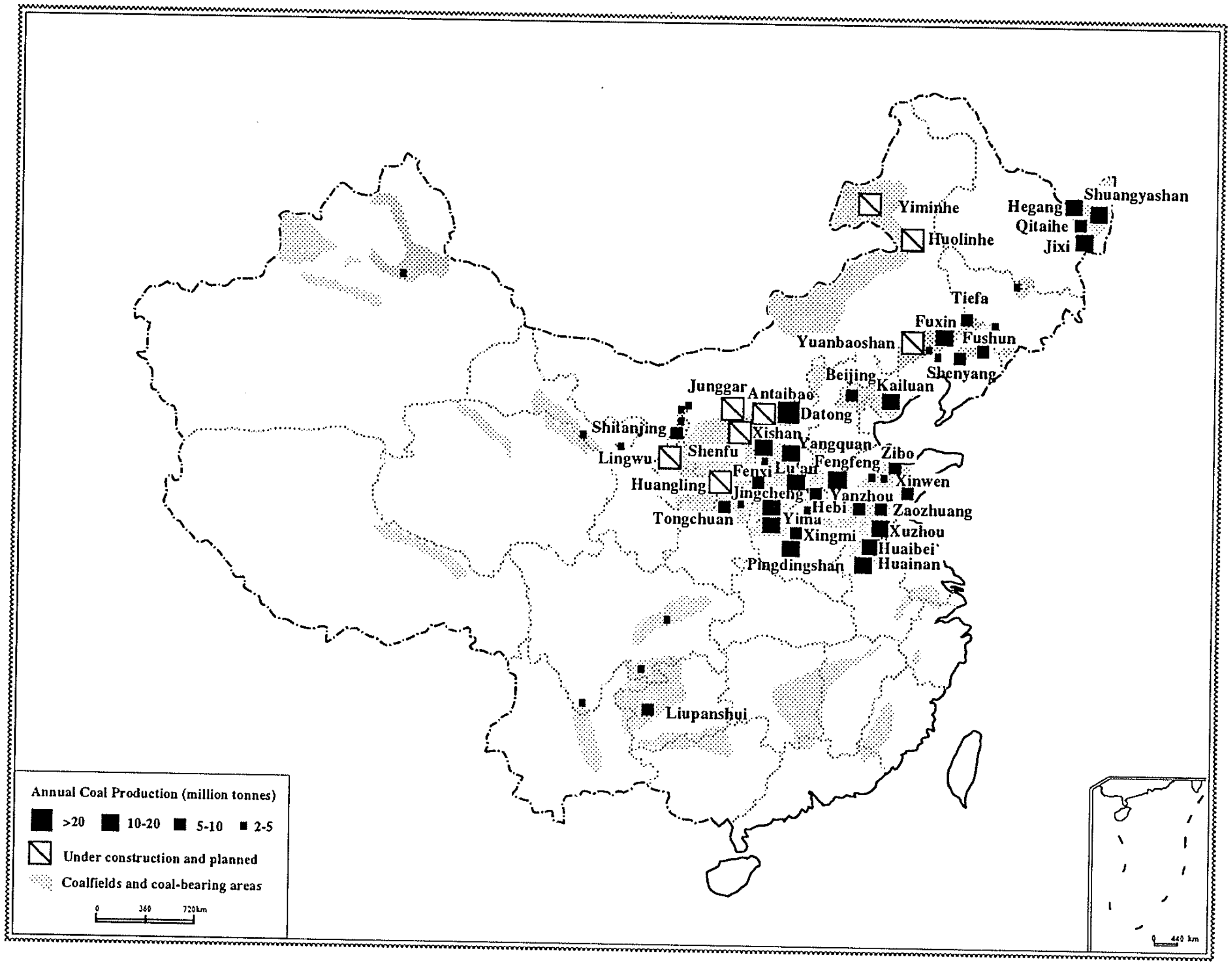


Figure 1.4 Distribution of Coalfields and Major Coal Mines in China

quality than those in the south. Furthermore, the provinces in the Central-South and East have a high degree of coal reserve extraction, thanks to the large-scale development in the 1960s and 70s; while the northern and north-western provinces, especially Shanxi, Shaanxi and Inner Mongolia are endowed with immense potential, a potential that remains largely intact. To ensure continued growth in the industry, China's Ministry of Energy (MOE) is now attempting to centre coal production in these three coal-rich provinces. Under a development programme worked out by the MOE, this base should produce 600 MT of coal in the year 2000, or 43 percent of the country's output of 1.4 BT planned for that year. At that time, nearly three-quarters of the base's output, 450 MT, will be sent to other provinces. If this base is extended to embrace Henan province and Ningxia Hui autonomous region, coal reserves at its disposal amount to 69.7 percent of the nation's total, and it is estimated that this huge production base will account for about half of the coal output by 2000. The plan is to build the area into the country's biggest energy production and supply base.

Table 1.14 Regional Coal Reserves and Extraction Potential

Region	Coal reserve/ nation's total (%)	Extraction/ reserve (%)	Region	Coal reserve/ nation's total (%)	Extraction/ reserve (%)
Beijing	0.26	--	Henan	2.11	39
Tianjin	0.05	--	Hubei	0.06	40
Hebei	1.62	62	Hunan	0.32	57
Shanxi	26.97	18	Guangdong	0.07	63
Inner Mongolia	21.05	14	Guangxi	0.23	--
Liaoning	0.72	68	Hainan	0.01	--
Jilin	0.23	59	Sichuan	1.00	38
Heilongjiang	1.91	56	Guizhou	5.14	7
Shanghai	0.00	--	Yunnan	2.43	7
Jiangsu	0.44	69	Xizang	0.01	--
Zhejiang	0.01	80	Shaanxi	16.29	2
Anhui	2.63	28	Gansu	0.91	--
Fujian	0.11	86	Qinghai	0.45	--
Jiangxi	0.15	56	Ningxia	3.25	8
Shandong	1.77	39	Xinjiang	9.83	--

Source: Song, 1992.

During the Eighth Five-Year Plan (1990-95), the government persists in giving coal the highest priority in its overall energy and industrial development strategies. Coal production is scheduled to increase to 1.23 BT by 1995. Construction will highlight the production of important coal bases, such as the Huolinhe, Yimin, Yuanbaoshan, and Jungar opencast coal-mines in Inner Mongolia, the Datong coal-mining area in Shanxi province, the Shenfu-Dongsheng mining area of Shaanxi, the Tiefa and Shuangyashan coal-mining areas in North-East China, and the Yanzhou, Huainan and Yongcheng coal-mine areas in East and South-Central China. The construction of new projects will also start in the Huangling coal-mining area in Shaanxi, the Lingwu coal-mining area in Ningxia, and the Anjialing opencast mine at Pingshuo in Shanxi province. Emphasis will be given to the mechanization of production, the expansion of large opencast mines, and the building of new ones with large volumes and high-grade deposits, low production costs and economically-viable operations (Table 1.15, Figure 1.4).

Table 1.15 China's Five Large Surface Mines Under Development

Surface mines	Province	Mining area (km^2)	Coal reserves (Bt)	Stripping ratio[a]	Annual production capacity (Mt/year) Initial	Ultimate
Huolinhe	Inner Mongolia	540	12.9	3.5-5.0	3	50
Yiminhe	Inner Mongolia	545	5.0	1.8-2.5	3	55
Yuanbaoshan	Inner Mongolia	13	5.4	5.5	3	8
Junggar	Inner Mongolia	1723	3.4	3.1-6.0	25	60
Antaibao	Shanxi	376	12.7	5.0-8.0	15	45

Note: [a] The unit amount of overburden or waste that must be removed to gain access to a similar unit amount of mineral material.
Source: Smil, 1988

OIL

Like coal, oil is unevenly distributed in China. Its distribution favours the North-East, East, and North-West. The North-East represented the largest share of 48.3 percent in the nation's oil reserve in 1990, followed by the 18.2 percent obtaining in the East, and the 14.2 percent applying in the North-West. These three regions together accounted for 80.7 percent of the total oil reserves (Song, 1992). Nevertheless, the distribution of oil reserves is more commensurate with consumption than is the case with coal. Of the accumulated proved reserves by 1987, the Eastern, Central and Western regions possessed 40.05 percent, 45.40 percent and 12.60 percent respectively. Similarly, oil consumption has the same order with the East responsible for 58.71 percent, the Central for 24.79 percent and the West 10.33 percent (Table 1.10). By adding the offshore resources, China's oil distribution is much more congruent with economic development in the Northeast and East than is coal.

When the People's Republic was founded in 1949 only three small oilfields were active in the Northwest----Laojunmiao in Gansu, Yanchang in Shaanxi and Dushanzi in Xinjiang----and their total output was merely 100,000 tonnes a year. During the 1950s the emphasis of China's oil production was still in the west, although oil exploration and development began on a broad scale with the receipt of Soviet aid. By 1959, 98 percent of crude oil output came from the western regions, such as Xinjiang, Qinghai, Shaanxi and Gansu provinces. Meanwhile, China was becoming increasingly dependent on oil imports from the USSR. The exploration achievements in the East, spearheaded by China's first, and still by far the largest, discovery, the giant Daqing oilfield in the Songliao basin (1959) and the Shengli field near the mouth of the Huang He (1962-64), led increasingly to an eastward shift in the centre of gravity of China's petroleum production. The successes of the Shengli field encouraged offshore development and the discovery of the Dagang field in 1964. By 1965, the crude oil outputs of Daqing in Heilongjiang, Dagang in Tianjin and Shengli in Shandong province combined to account for 88.2 percent of the national total (Petroleum Economist, 1981). Since then, the distribution of the oil industry has scarcely altered, despite a little southward shift with the development of Liaohe, Huabei, Zhongyuan and Jianghan oilfields.

In 1990, 52.7 percent of crude oil production came from the North-East region and almost 25 percent came from the East. Currently, China has four major oil production bases: Song Ji (Daqing, Jilin), Bohai Bay Rim (Liaohe, Huabei, Dagang, Shengli), Zhongyuan (Zhongyuan, Henan, Jianghan) and Qing Xin (Qinghai, Xinjiang) (Figure 1.5). With 132.7 MT of crude oil produced in 1990, or 96 percent of the nation's total, these oilfields are the major crude oil suppliers for refineries and crude export. The three largest oilfields, Daqing (40 percent), Shengli (24 percent) and Liaohe (10 percent) together accounted for three-quarters of the output registered for 1990. Seldom in the history of world oil exploration and extraction has a single oilfield affected the national oil production of a nation to the extent that Daqing has affected China's. In 1980 Daqing accounted for 48.6 percent of the national crude total; in 1990, though a declining field, it was still responsible for 40.2 percent. The need for source diversification is obvious, but none of the operating onshore fields can supplant Daqing and, at the same time, provide additional output growth. The Chinese concede that from 30-40 percent of oil in place at Daqing has already been extracted. Obviously, to maintain the present reserves-to-production ratio will require a greatly stepped-up exploration effort.

As for offshore resources, because China has nearly 1.4 million square kilometres of continental shelf at a water depth of less than 200 metres, prospects for offshore oil discoveries are

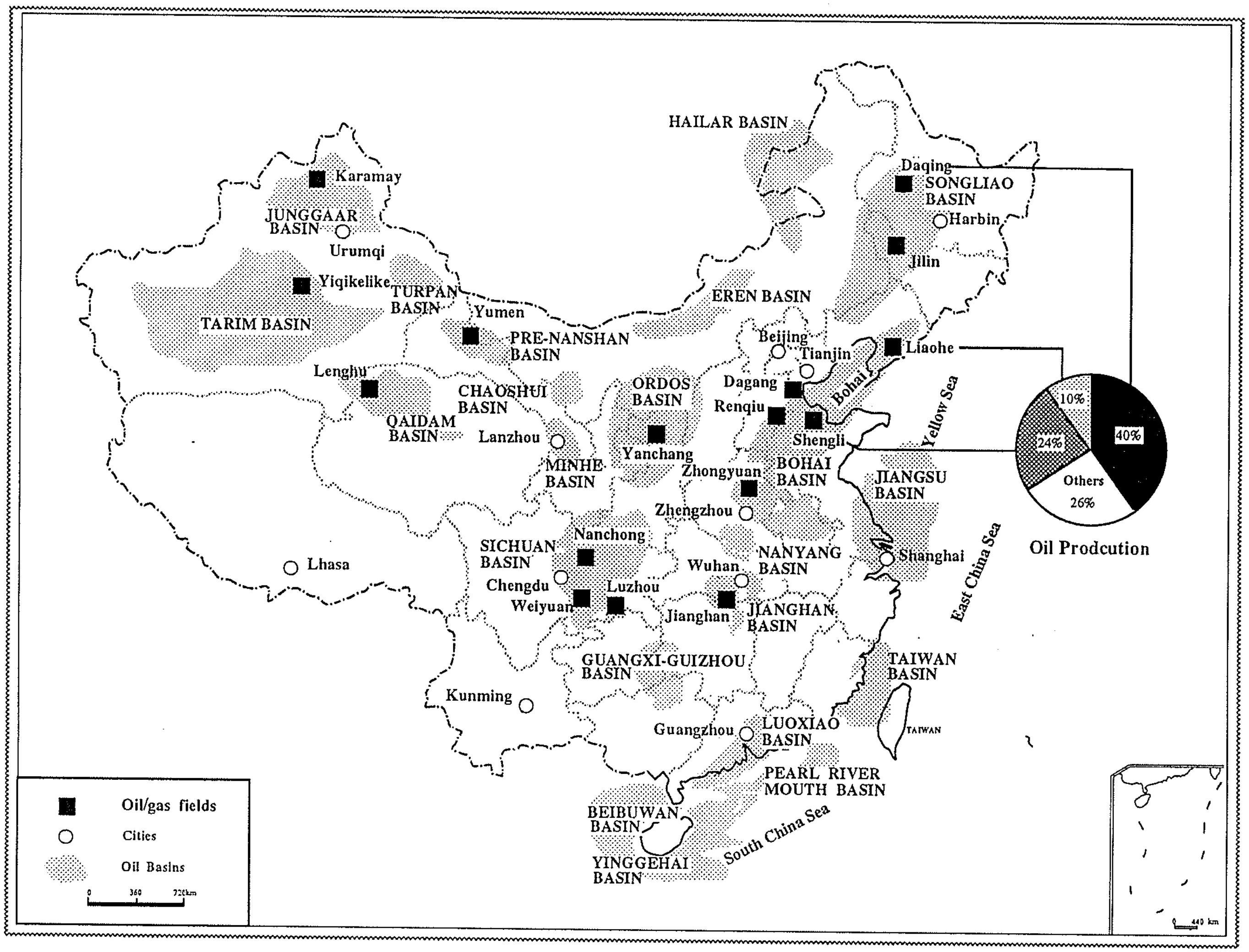


Figure 1.5 China's Oil Basins and Major Oilfields

somewhat promising despite disappointing results in early commercial exploration activities. China possesses a very large coastline, with the Bohai Sea in the north, the Yellow Sea and the East China Sea in the east, and the South China Sea in the south (see Figure 1.5). During the early 1980s, China's offshore oil regions were considered among the most promising in the world. However, by 1986 many oil companies had come to realize that the South China Sea----on which exploration activities were focused----was unlikely to contain large oil reserves because of less-than-favourable geological conditions and low gas content of the oil. During the years following the first and second rounds of bidding for offshore oil (held in 1982 and 1985 respectively), total investments amounted to $2.42 billion and 400 million yuan (Owen and Neal, 1989). Despite such concerted investment, oil discoveries to date have been only modest, and offshore production may rise to around 8 million tonnes per year by the late 1990s.

China's greatest geological potential for discovering oil deposits is in the western and northern onshore basins, particularly in Gansu, northern Qinghai, and central Xinjiang. Their remote location, however, makes these basins extremely costly to work owing to the enormous infrastructure investment that is required to bring them on stream. Petroleum exploration and development will continue to focus on eastern regions for the remainder of this century, but in the long term both western and northern China hold promise of major oil discoveries. In view of the exploration results of the past two decades, it can be concluded that the best prospects can be expected in basins overlying old, stable platforms with thick unmetamorphosed carbon sections, such as the Bohai Sea basin complex, the Sichuan, Jungar, and Tarim basins. Present onshore drilling is concentrated in the Shengli-Gudong, Liaohe, Dagang, Jungar, Tarim and Qaidam basins. Whether China's oil industry will shift back to the western region is contigent both upon the change in transportation conditions and whether exploration is so promising as to offset the huge infrastructure costs.

China's oil prospecting and development brought about a rebirth of the oil-refining industry. In 1949, there were only three small refineries and two oil-shale processing plants in China. The nation's processing capacity of crude oil was only 170,000 tonnes, with the annual output of gasoline, diesel oil, kerosene and lubricating oil amounting to only 35,000 tonnes (Anonymous, Oct.31-Nov.6 1994). In the 1950s, many refineries were built near the oilfields, such as Lanzhou, Yumen and Dushanzi refineries, in tandem with the exploration and opening up of the western basins. At the same time, refineries were set up in the coastal region, such as in Southern Liaoning and Shanghai, to process crude oil shipped by railway from the western oilfields to the major eastern ports of Dalian and Shanghai, thereby providing petroleum products to the consuming regions. In 1959, the country's processing capacity for crude oil jumped dramatically to 5.79 MT, a 34-fold increase over 1949. However, the Soviet withdrawal in 1960 did deliver a severe blow to the Chinese petroleum-refining industry, because Soviet refinery experts and blueprints went back to the USSR. The Chinese turned to alternative sources of aid in Romania, Italy, West Germany, France and Japan (Petroleum Economist, 1981).

With the discovery and large-scale production of Daqing oilfield in the 1960s, oil refineries shifted to East China, closer to the country's industrial and population centres. Most of them were erected in the North-East; for example, Daqing, Fushun No.1, Fushun No.2, Fushun No.3, Jinzhou No.6, Jinxi No.5 and Dalian No.7. These refineries were located near both the source of raw materials and the places of consumption. The Shengli refinery (later styled the Qilu petrochemical complex), built in proximity to the Shengli oilfield, was a similar case. Another kind altogether are those refineries far from the oilfields, but close to the consumption centres, such as Maoming oil refinery in Guangdong province, which imported crude oil all the way from the Daqing fields. The nation's refining capabilities expanded greatly in the 1960s, helped greatly by a reliable domestic oil supply, and Nanjing, Dongfanghong (later expanded as Yanshan petrochemical complex), Jingmen and Changling were subsequently constructed to alleviate the shortage of petroleum products in the North, Central-South and South-West.

From 1970 China's refining industry developed at an even faster pace with large-scale pipeline construction and waterway development. A host of new refineries were built along the coast, the Yangtze river, the major oil pipelines or near the interior oilfields, while old refineries underwent expansion. A few of them were envisaged as cores for petrochemical complexes. Nevertheless, it was not until the end of the 1970s, with imports of advanced machinery from Japan, and to a lesser extent from Western Europe, that China was prepared to enter petrochemicals on a large scale. A rapidly developing chemical industry registered large production increases, and the demand for petroleum as raw material for the chemical industry grew strongly. Gaoqiao, China's first petrochemical complex, appeared in Shanghai in 1981, grouping refining, thermal power, chemical fibre and chemical plants led by different ministries as an entity. It was followed by the establishment of several large petrochemical complexes, most notably, those at Jinglin (including Nanjing refinery), Fushun (including Fushun refineries), Jinzhou (including Jinzhou and Jinxi refineries), Tianjin (including Tianjin refinery), Dalian (including Dalian refinery) and Baling (including Changling refinery) (Li[1], 1990).

In 1982 China's State Council initiated a working group to negotiate with the major players involved in petroleum-refining in China, namely, the industries of petroleum, textiles, chemicals, and various local governments. The negotiations resulted in the establishment of a new ministerial-level economic entity, the China National Petrochemical Corporation (SINOPEC). Today Sinopec manages nearly 95 percent of China's petroleum-refining industry and is responsible for domestic product and petroleum distribution. It has 30 refineries, each with crude distillation capacity above 2.5 MT, and a total crude distillation capacity of 139 MT, accounting for 89.8 percent of the country's output . The secondary processing capacity[1] is over 62 MT. There are five ethylene production bases located in Beijing, Daqing, Shandong, Nanjing and Shanghai, each having an annual production capacity of over 300,000 tonnes, and a total capacity of 1.802 million tonnes, accounting for 87.1 percent of the country's total (China Petrochemical Corporation, 1991).

By 1990, China had 18 large refineries with individual refining capacities in excess of 3 MT, 22 middle refineries with refining capacities of between 1-3 MT, and 58 small refineries with unit refining capacities of less than 1 MT. Their share of the country's total refining capacity amounted to 64 percent, 29 percent and 7 percent respectively. The major oil refining bases in China are Heilongjiang-Jilin (15 MT), the central-south of Liaoning (30 MT), Beijing-Tianjin-Hebei (17 MT), Shandong (12 MT), Guangdong (14 MT), Shanghai-Jiangsu-Zhejiang (29 MT), and the refining bases

---

[1] The capacity of secondary treatment of oil needs clarifying. Unlike the primary process, a physical process which separates crude oil into different fractions by distillation, the secondary processes are all chemical processes, which change the structure of the various oil fractions. The two important processes are: cracking, used to adapt the distillation yield to the structure of demand; and reforming, a process used mostly to improve the quality of the products, in particular of gasoline.

along the middle course of the Yangtze River (16 MT) and in the North-west of China (17 MT) (Fang, 1993) (Figure 1.6). In terms of the six-region partition of the country, in 1990 almost one-third of the nation's oil-refining capacity was concentrated in the North-East, followed by 27 percent in the East and 20 percent in the Central-South, composing three-quarters altogether. Of 18 large refineries, 14 are located in the above regions where supply of petroleum products is compatible with consumption. Leading the second rank are the North and North-West which together accounted for roughly 22 percent of the total refining capacity. The South-West, with only 0.15 MT, or 0.1 percent of the total, occupied the bottom position (Table 1.16).

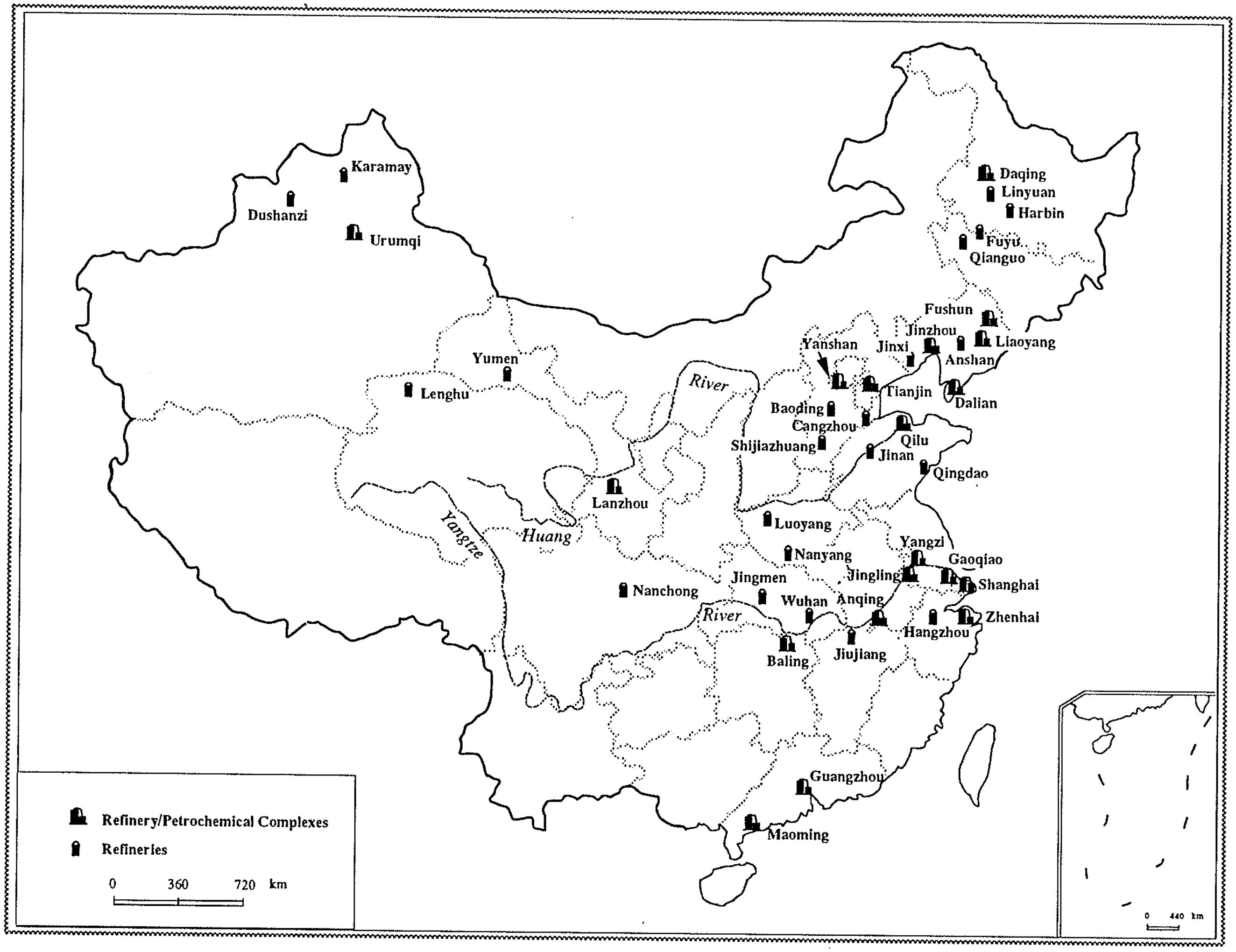


Figure 1.6 China's Major Refineries and Petrochemical Complexes

Table 1.16 Regional Crude Oil Production and Refining Capacity, 1990

Region	Production (MT)	Production (%)	Refining Capacity (MT)	Refining Capacity (%)	Balance (%)	Large Oil Refineries (capacity > 3MT)
North	10.4	7.5	15.5	10.7	-3.2	
Beijing	0.0		7.0	4.8	-4.8	Yanshan
Tianjin	4.7	3.4	4.2	2.9	+0.5	
Hebei	5.7	4.1	4.3	3.0	+1.1	Shijiazhua
Shanxi	0.0					
Inner Mongolia	0.0					
North-East	72.9	52.7	45.1	31.0	+21.7	
Liaoning	13.7	9.9	30.3	20.9	-11.0	Fushun, Dalian, Jinzhou, Jinxi
Jilin	3.6	2.6	7.3	5.0	-2.4	
Heilongjiang	55.6	40.2	7.5	5.2	+35.0	Daqing
East	34.4	24.9	39.9	27.5	-2.6	
Shanghai	0.0		7.6	5.2	-5.2	Gaoqiao
Jiangsu	0.9	0.7	8.5	5.9	-5.2	Jinling, Yangzi
Zhejiang	0.0		5.7	3.9	-3.9	Zhenhai
Anhui	0.0		2.8	1.9	-1.9	
Fujian	0.0					
Jiangxi	0.0		2.5	1.7	-1.7	
Shandong	33.5	24.2	12.8	8.8	+15.4	Qilu
Central-South	10.3	7.4	29.3	20.2	-12.8	
Henan	8.8	6.4	5.5	3.8	+2.6	Luoyang
Hubei	0.8	0.6	7.6	5.3	-4.7	
Hunan	0.0		5.0	3.4	-3.4	Baling
Guangdong	0.5	0.4	11.2	7.7	-7.3	Guangzhou, Maoming
Guangxi	0.1	0.1	0.1	0.0	+0.1	
Hainan	0.0					
South-West	0.2	0.1	0.2	0.1	0.0	
Sichuan	0.2	0.1	0.2	0.1	0.0	
Guizhou	0.0					
Yunnan	0.0					
Xizang	0.0					
North-west	10.2	7.4	15.3	10.5	-3.1	
Shaanxi	0.7	0.5	0.7	0.5	0.0	
Gansu	1.5	1.1	7.7	5.3	-4.2	Lanzhou
Qinghai	0.8	0.6	0.3	0.2	+0.4	
Ningxia	0.3	0.2	0.1	0.1	+0.1	
Xinjiang	7.0	5.0	6.5	4.4	+0.6	Dushanzi
Total	138.3	100.0	145.2	100.0		

Source: China Energy Statistical Yearbook, 1990

The crude oil supply-demand gap can be observed from Table 1.16, where refining capacity is assumed to be closely related to crude consumption because China's crude oil output largely goes to the refineries. So the volume of regional refining capacity can be regarded as a corresponding measurement of regional crude consumption. As the table exhibits, China's crude oil production is heavily dominated by two provinces, Heilongjiang and Shandong, which held 40.2 percent and 24.2 percent, respectively, of the country's total in 1990, owing to the contribution of the Daqing and Shengli oilfields. By adding the provinces of Liaoning, Henan, Xinjiang, Hebei and Tianjin, these seven contain 93.3 percent of the nation's total. In contrast, 12 provinces and municipalities are devoid of oil production (Beijing, Shanxi, Inner Mogolia, Shanghai, Zhejiang, Fujian, Jiangxi, Hunan, Hainan, Guizhou, Yunnan and Xizang). As to be expected, crude oil flows mainly from the oil-rich regions to the oil-destitute provinces in the North, East and Central-South, or along the Yangtze River. Key recipients are Liaoning, Guangdong, Shanghai, Jiangsu, Beijing, Zhejiang, Hubei and Hunan, which hold a large share of the refining industries seeking crude supply and are far removed from the oil-producing regions of Heilongjiang, Shandong, Henan and Xinjiang. Usually the length of haulage of domestic oil is not as long as that of coal, since the distribution of oil production is more congruent with oil consumption. However, remote north-eastern Daqing's oil reaches as far as the south-eastern coastal refineries by virtue of coastwise shipping. In 1990 the net export oil flow from Heilongjiang, Shandong, Henan and Xinjiang reached 80.3 MT, comprising 69.9 percent of the nation's petroleum consumption (Song, 1992).

The supply-demand mismatch of petroleum products is characterized by the large supply surplus in the North-East, about

8-9 MT annual net export flow on the one hand, and the South-West, almost a blank paper in refining, on the other. The North, despite possessing refining capacity, is also in sharp deficit. The East and Central-South seem capable of achieving local balance, while the North-West can demonstrate a small surplus (Fang, 1993)(Table 1.17).

Table 1.17 Regional Shares in Petroleum Products' Production and Consumption, 1990 (%)

Region	Production (%)	Consumption(%)	Balance (%)
North	10.7	13.9	-3.2
North-East	31.0	20.3	+10.7
East	27.5	29.1	-1.6
Central-South	20.2	20.1	+0.1
South-West	0.1	3.2	-3.1
North-West	10.5	7.2	+3.3

Source: Song, 1992.

In 1990, China's total oil-refining capacity ranked fourth in the world, behind the Soviet Union, the United States and Japan. The capacity continued to rise to 177 MT in 1993 and will be boosted to over 200 Mt by 2000 to meet the rising demand for petroleum products, especially light products and petrochemical feedstocks. The high wax content of Chinese domestic crudes, and the fact that they yield an average of 70 percent of heavy products, has led to the need for widespread use of secondary processing to upgrade the heavy ends into gasoline and diesel fuel. Despite an average of 30 percent of underutilized capacity, China's secondary-processing equipment and technology have become outdated and inadequate, leading to increased imports of petroleum-based products, and this trend is being exacerbated by limited internal transport of crude, intermediate and final products. China's refined product demand is growing by more than 10 percent per year, but the country's ageing transport network is incapable of moving large volumes from refineries in northern China to the fast growing regions in the south. As a result, some southern Special Economic Zones were permitted to import urgently needed oil products in 1988, bypassing the central oil trading company SINOCHEM (China National Chemical Import and Export Corporation). Moreover, in mid-1992 the government allowed state refiner SINOPEC's four main coastal refineries----Maoming, Guangzhou, Zhenhai and Gaoqiao----to import crude oil from abroad. In the government plan, revamping and upgrading older refineries will continue to be emphasized, but, crucially, new large, advanced refineries will be established in favourable coastal locations. There, they will benefit from foreign investment, deep-draught port infrastructure and economies of scale in sea shipping, with a view to processing partly imported oil to assuage the chronic shortage of domestic oil supply. Meanwhile, renovation and expansion of existing coastal refineries is receiving some attention.

In conclusion, the high energy demand of recent years resulting from rapid economic growth, especially in industry, has highlighted the acute need to tackle regional energy imbalances. This regional pattern raises severe problems for energy transportation, an issue which is going to be explored in the next chapter.

CHAPTER 2 ENERGY TRANSFER WITH RESPECT TO COAL AND OIL

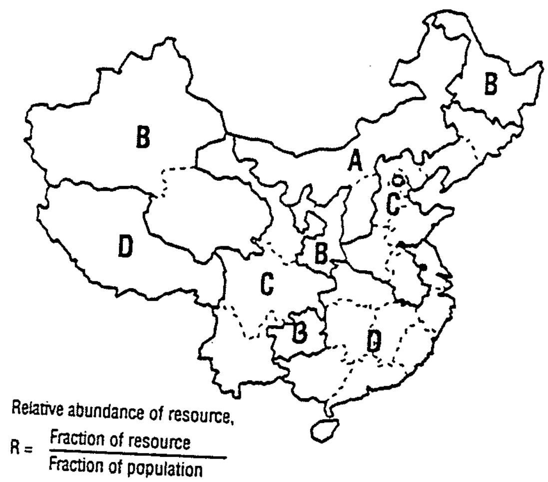
If energy vital for the national economy is recognized, by analogy, as blood essential for the body, energy flows, just like blood arteries, are indispensable for the movement of energy resources from origins to destinations and between producing, processing and consuming centres. Owing to the vastness of Chinese territory and the large regional imbalances in energy supply and demand, as elaborated in Chapter 1, there is a need for very large movements of all fuels, both within and among regions. Indeed, China's domestic energy flows (across regions and provinces) are very significant. Total energy inflows to all energy-importing provinces in 1989 reached 250 million tonnes of coal equivalent, representing 41 percent of the total consumption of those provinces (Tang and Croix, 1993). China's energy flows are generally coal flows from north to south and from west to east, oil flows from north to south, and electricity flows from west to east. Of them, coal movements, typically, from China's western and northern inland provinces to its relatively developed coastal provinces, are much more notable in terms of the huge volumes, long-haul distances and various carriers involved. The increasing long distance of energy transportation is placing a heavy burden on the existing already taxed transport system. Transportation bottlenecks are most severe in the energy sector. This chapter will describe the general pattern of coal and oil transfer, and identify the major problems posed by them.

COAL TRANSFER

Background. As already seen in Chapter 1, most of the coal resources are concentrated in northern China, and most centres of consumption are located in eastern and southern China. The implementation of the government's recent "Open Door" policy will further accelerate the economic development of coastal regions and thus will further increase this discrepancy. Early in 1980, a coal-resource distribution zone map based on the per capita reserve of each region was issued (Figure 2.1). A forecast based on such zoning was then made, which predicted the pending energy shortage in Northeast China, in contrast with the prevailing opinion at that time that this region was an important energy production base. Later on, in the mid-eighties, energy shortages struck Northeast China exactly as forecasted. About 24 million tonnes of coal had to be imported from Shanxi to this region in 1985, and the amount is steadily increasing (Lu, 1993).

In 1990, ten provinces and autonomous regions emerged in the category of net coal exporters and eighteen in the category of net coal importers. All the export regions are concentrated in the interior, centred on the Shanxi-core energy base. No less than 71.8 percent of the total net coal export flows came from Shanxi alone. The import regions are mainly located in south-eastern China, especially the eleven municipalities and provinces constituting the coastal area. Their net import coal reached 212.78 MT in 1990, or 80 percent of the total import flows. Furthermore, the dependency

Figure 2.1 Distribution of Coal Resources in China



A	$10<R$	Extremely abundant	Shanxi, Inner Mongolia;
B	$1<R<10$	Relatively abundant	Shaanxi, Ningxia, Heilongjiang, Guizhou, Xinjiang, Qinghai;
C	$0.1<R<1$	Relatively poor	Jilin, Liaoning, Beijing, Tianjin, Hebei, Henan, Shandong, Anhui, Gansu, Sichuan, Yunnan;
D	$R<0.1$	Extremely poor	Shanghai, Jiangsu, Zhejiang, Fujian, Jiangxi, Hubei, Hunan, Guangdong, Guangxi, Hainan, Xizang.

of the coastal regions on the shipment of the northern coal is growing dramatically. Between 1980 and 1990, the coal transferred out of Shanxi rose from 57.9 percent to 71.9 percent of the total coal export flows, while the net coal flow into the coastal regions increased from 69.1 percent to 80 percent of the total coal import flows (Hou and Wang, 1995). For example, during 1981 to 1990, coal consumption in the coastal region of Shanghai-Jiangsu-Zhejiang grew by an impressive 296 percent in comparison with only slightly under 6 percent registered for the interior Gansu-Qinghai region (Table 2.1) (Zhang, 1995). In particular, two coastal provinces, Hebei and Shandong, once important coal-producing regions, converted from being net exporters to becoming net importers in 1984 and 1985 respectively. Anhui also assumed net importer status in 1990 (Figure 2.2). It is estimated that Sichuan will fall into the coal-deficit category in the near future. During the five years from 1986 to 1990, coal production in China has achieved the annual growth rate of 4.8 percent, whereas the interprovincial net coal flow reached 6.4 percent and the coal shipment into the coastal regions 9.9 percent; that is, twice the nation's coal production growth. More and more, the source or the origin of the coal flow will converge in northern and north-western China, and the end or the destination of the flow will focus on southern and eastern China. The massive coal movement across the vast area (e.g. the average distance involved in moving coal from Northern China is 1362km to the North-East, over 1000km to the East, and over 2000km to the South) poses an enormous challenge for the various

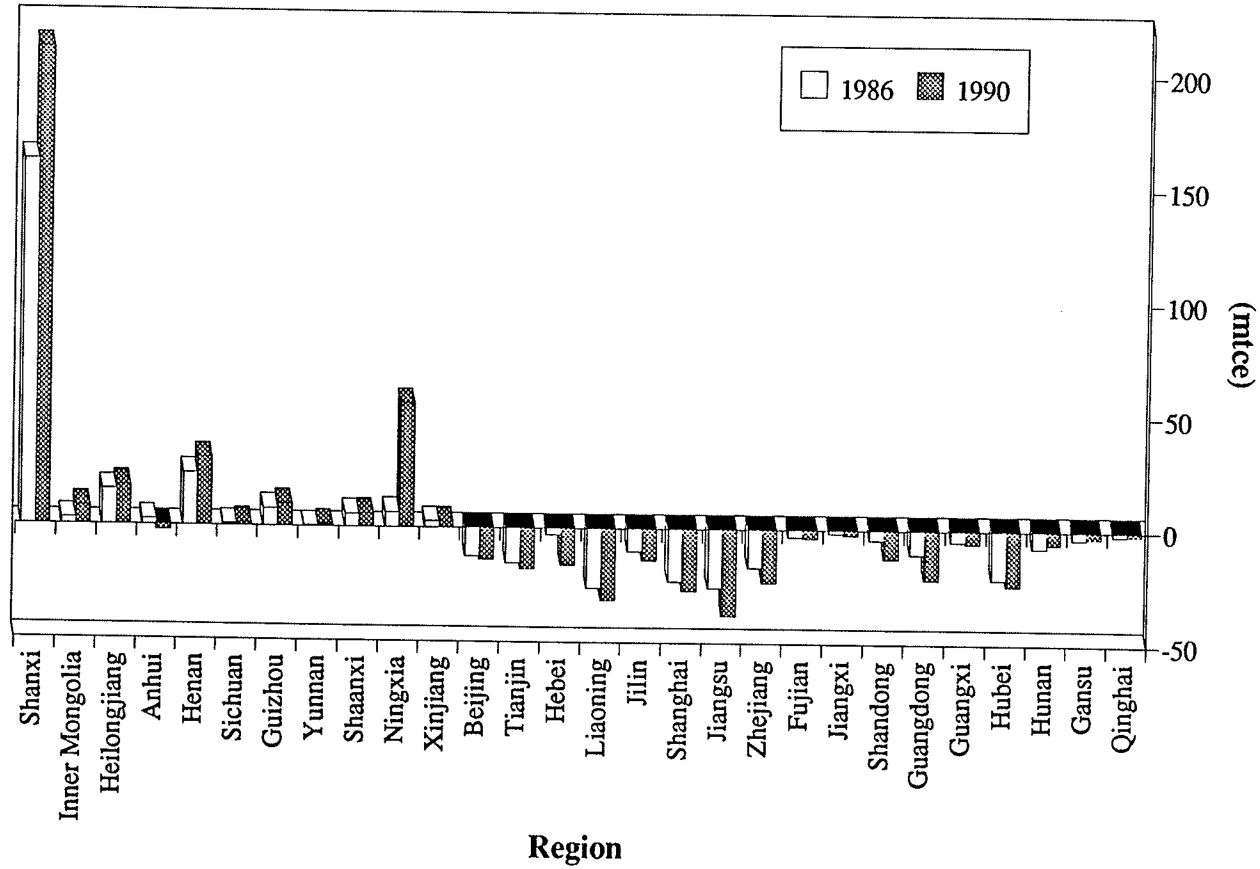


Figure 2.2 Transported Coal Across Regions (+Export, -Import)

transportation systems involved, as they must bear the burden for resolving China's spatial imbalance in energy supply.

With the establishment and operation of coal bases in Shaanxi and Inner Mongolia, the so-called "Three West (San Xi)" zone including Shanxi, Shaanxi, and Mengxi (the western part of Inner Mongolia), will become China's biggest coal hub earmarked to assure the energy supply. It is estimated that Shanxi's share in coal output of these three regions will decline from 83.7 percent in 1990 to 72.9 percent in 2000 and 55.2 percent in 2020, while Shaanxi's share will rise from 9.7 percent to 27.4 percent from 1990 to 2020 and Mengxi's share will grow from 6.6 percent to 17.3 percent in the same period (Hou and Wang, 1995). The share of coal production in Northern China between 1980 and 2000 is expected to increase from 33 percent to 46 percent of the national total. More than 400 million tonnes of coal will have to be shipped from the "Three West" base to the East and South China in the year 2000 (see Table 2.2). Thus the growing trend of a westbound shift in coal supply will exacerbate the problem of coal transfer.

Table 2.1 Selected Years of Net Coal Imported for Seven Regions (million tonnes)

Region	1957	1967	1975	1981	1985	1990
Shanghai-Jiangsu-Zhejiang	6.56	13.93	19.71	30.10	39.93	89.06
Beijing-Tianjin-Hebei	4.38	4.55	5.64	16.58	26.36	48.27
Liaoning-Jilin	1.04	10.20	6.09	23.38	32.32	45.56
Hubei-Hunan-Jiangxi	-	4.13	11.25	15.76	23.64	32.43
Guangdong-Guangxi-Fujian	1.17	2.40	5.77	8.25	12.22	31.33
Gansu-Qinghai	0.77	1.94	4.41	4.21	5.72	4.55
Sichuan-Yunnan	-	-	-	1.54	1.61	-

Sources: Li, 1990 and China Energy Statistical Yearbook, 1992.

Table 2.2 Estimated Coal Production and Transportation by Region

Region	Measured reserves (%)	1985 (actual), MT			2000 (forecast), MT		
		Production	Consump- tion	Trans- portation	Production	Consump- tion	Trans- portation
Shanxi, Shaanxi, Inner Mongolia	62.4	257	130	127	600	150	450
Northeast	8.3	147	171	-24	240	315	-75
East	6.1	127	181	-54	200	390	-190
Beijing, Tianjin, Hebei	2.3	71	101	-30	90	195	-105
South-Central	3.0	131	153	-22	160	235	-74
Southwest	9.7	95	88	-7	140	148	-7
Northwest	8.2	43	41	-2	70	60	8
Total	100.0	871	865	--	1500	1453	--

Source: Lu, 1993.

Coal Flows. China has long been confronted with a choice between concentrating coal production in the north where costs were lowest or developing more expensive coal resources closer to consumption centres so as to reduce transport costs. During the First Five-Year Plan, the priority of investment was placed on the coal mines in the North-East and North China. Subsequently, coal-mining activities flourished widely all over China as a result of the "Great Leap Forward" mania. During the Third Five-Year Plan, the emphasis of coal mining switched to Southwestern China. However, it switched back to the coastal area in the Fourth Five-Year Plan when efforts were directed to searching for coal deposits in resource-poor provinces south of the Yangtze River in an attempt to reverse the coal movement from north to south. During the Fifth Five-Year Plan, attention was reverted to the East and North-East, focusing on "Liang Huai (Huainan, Huaibei)". The shift of coal development orientation reflected the dilemma between energy and transportation facing China. Since the Sixth Five-Year Plan, the emphasis has swung back to North China so as to address the persistent energy shortage. The Office for Planning the Energy Resources Base of Shanxi was founded in 1982 as an agency responsible for the overall development of the province and its contiguous areas of western Inner Mongolia, northern Shaanxi and western Henan. Large-scale coal-mining construction started in Shanxi, and resulted in substantial increases in newly-added capacity of coal production (Table 2.3).

However, restoring priority to the exploitation of the more favourable resources in northern China does not imply a solution of the problems accompanying the uneven distribution of coal reserves. On the contrary, as coal production increases, the transportation difficulties become more and more acute, and this may eventually turn out to be a major restraint on Chinese energy supply and coal exploitation.

Current major coal flows are illustrated in Figures 2.3 and 2.4. A clear picture can be elicited from these figures; one endorsing the general pattern of coal flows from north to east and from north to south in a pattern which is more like a sector with Shanxi as a centre and the coastline as a rim. Coal transfer "corridors" are formed to penetrate the North and Central-South and radiate to the Southeast. In general, after highlighting the

Table 2.3 Newly-added Capacity of Coal Production in the State-Run Enterprises of China by Provinces, 1952-90 (%)

Province	1 FYP	2 FYP	1963-65	3 FYP	4 FYP	5 FYP	6 FYP	7 FYP
Beijing	2.24	2.64	1.39	0.43	1.15	0.00	0.18	0.00
Tianjin	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hebei	8.08	9.52	9.79	5.22	3.64	3.23	5.91	4.64
Shanxi	15.20	8.50	9.74	8.10	10.23	12.01	24.39	28.58
Inner Mongolia	1.55	2.48	4.87	5.31	1.61	2.63	11.09	4.75
Liaoning	10.71	6.87	15.59	4.16	5.65	6.65	4.59	7.38
Jilin	5.66	5.83	6.13	1.78	4.21	4.02	5.55	2.99
Heilongjiang	12.39	7.11	4.78	2.26	5.13	5.54	5.29	10.38
Shanghai	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jiangsu	0.56	3.62	3.20	2.70	2.46	10.72	1.23	3.18
Zhejiang	0.00	0.31	0.00	0.30	0.31	0.82	0.00	0.38
Anhui	7.59	3.74	6.96	3.83	2.77	1.94	8.54	3.61
Fujian	0.03	0.06	2.41	1.00	3.32	2.28	0.59	0.66
Jiangxi	2.67	1.96	1.67	6.32	1.70	1.19	1.70	1.35
Shandong	3.31	10.23	3.48	1.52	6.86	5.33	9.93	10.35
Henan	6.03	14.01	11.37	6.46	10.73	10.93	8.01	5.26
Hubei	0.03	0.03	1.39	1.58	1.71	2.11	0.68	0.29
Hunan	2.51	3.01	3.34	10.87	3.88	2.53	1.99	1.62
Guangdong	0.72	0.83	0.56	2.39	3.56	1.57	0.37	0.55
Guangxi	0.50	1.24	0.00	1.43	2.84	4.14	1.07	0.66
Hainan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Sichuan	3.56	7.04	7.52	8.92	8.60	4.14	3.10	3.88
Guizhou	0.22	2.12	1.90	7.00	6.90	0.46	1.48	1.56
Yunnan	1.27	0.37	1.67	1.49	1.53	1.93	0.15	1.56
Xizang	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17
Shaanxi	1.33	2.55	2.46	6.06	3.50	10.77	2.55	1.44
Gansu	2.92	1.25	0.00	2.73	3.03	1.76	1.00	3.48
Qinghai	0.91	0.22	0.00	0.56	0.85	0.79	0.00	0.36
Ningxia	0.00	2.85	0.00	3.50	4.30	0.46	0.37	0.64
Xinjiang	0.00	1.34	0.00	4.06	0.18	2.05	0.26	0.24
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Total (MT)	**63.76**	**96.76**	**21.55**	**69.15**	**81.21**	**64.93**	**81.27**	**126.34**

Source: China's Energy Statistics Yearbook, 1991

Longhai (Langzhou-Lianyungang) railway as a dividing line, coal movement to the north of the line is primarily from west to east and functions as a rail-port system, while to the south of the line, it is mainly from north to south and is delivered solely by rail or by rail combined with the inland waterway system.

The main rail lines for coal transport from north to south are: (1) Beijing-Xuzhou-Nanjing-Shanghai-Hangzhou-Fuzhou (Jinghu, Zhegan and Yingxia lines); (2) Beijing-Zhengzhou-Wuhan-Guangzhou (Jingguang line); (3) Datong-Taiyuan-Jiaozuo-Zhicheng (Nantongpu and Jiaozhi lines); and (4) Harbin-Shenyang-Dalian (Hada line). Within this network, the two most important track sections are Zhengzhou-Wuhan and Xuzhou-Nanjing: both carrying more than 25 MT of coal per year.

The main railway lines for coal transport from west to east are: (1) Baotou-Datong-Beijing-Qinhuangdao (Jingbao and Daqin lines); (2) Taiyuan-Shijiazhuang-Dezhou-Qingdao (Shitai and Jiaoji lines); (3) Jiaozuo-Xinxiang-Yanzhou-Shijiusuo (Jiaoxin and Yanshi lines); (4) Zhengzhou-Xuzhou-Lianyungang (Longhai line); (5) Beijing-Jinzhou-Shenyang (Jingshen line). Without question, the most important of these is the Datong-Qinhuangdao line: its eminence is so great, indeed, that with the recent double-tracking and electrification completed, it can carry 40-50 million tonnes of coal per year in the first stage (Zhang, 1995).

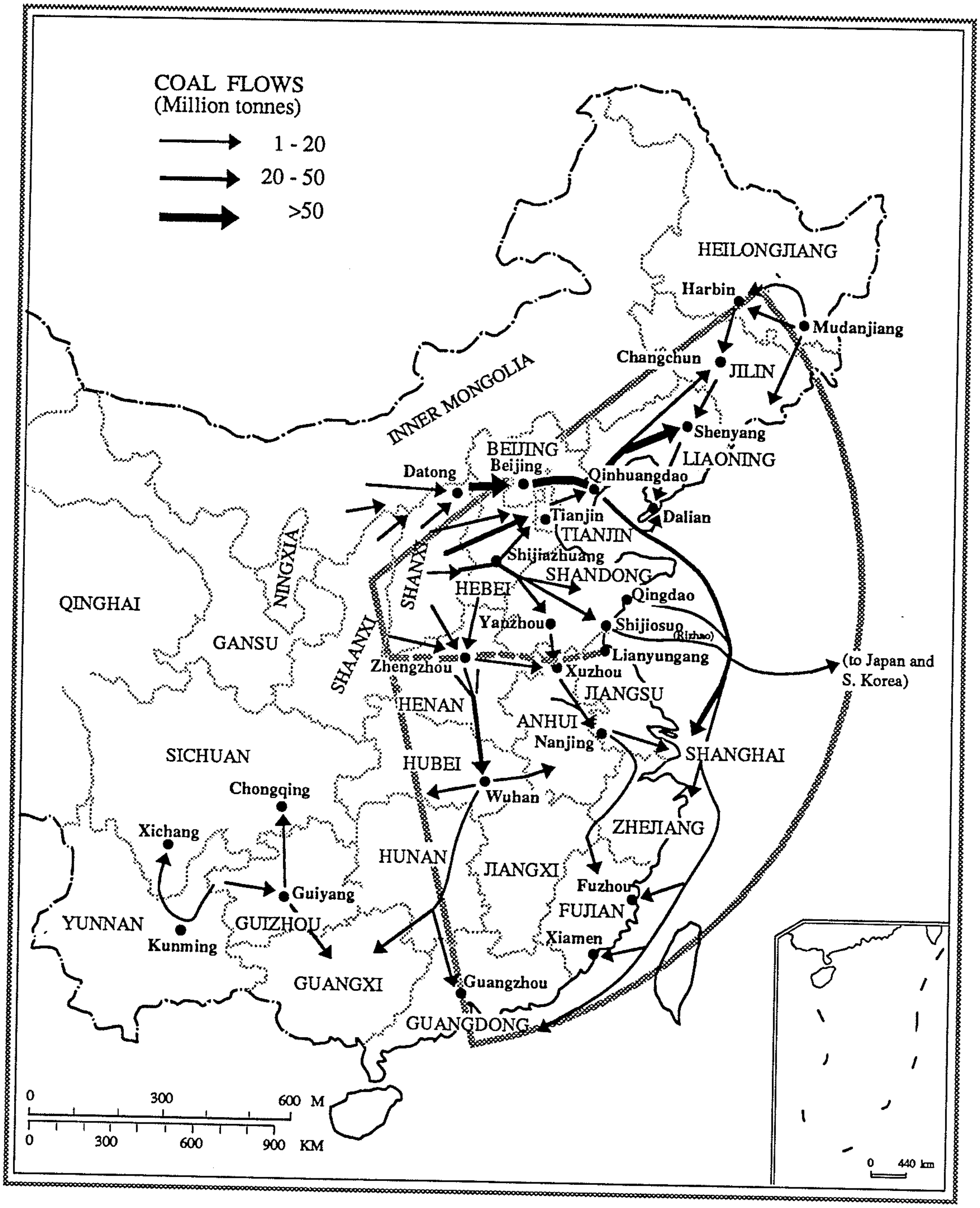


Figure 2.3 Major Coal Flows, 1990

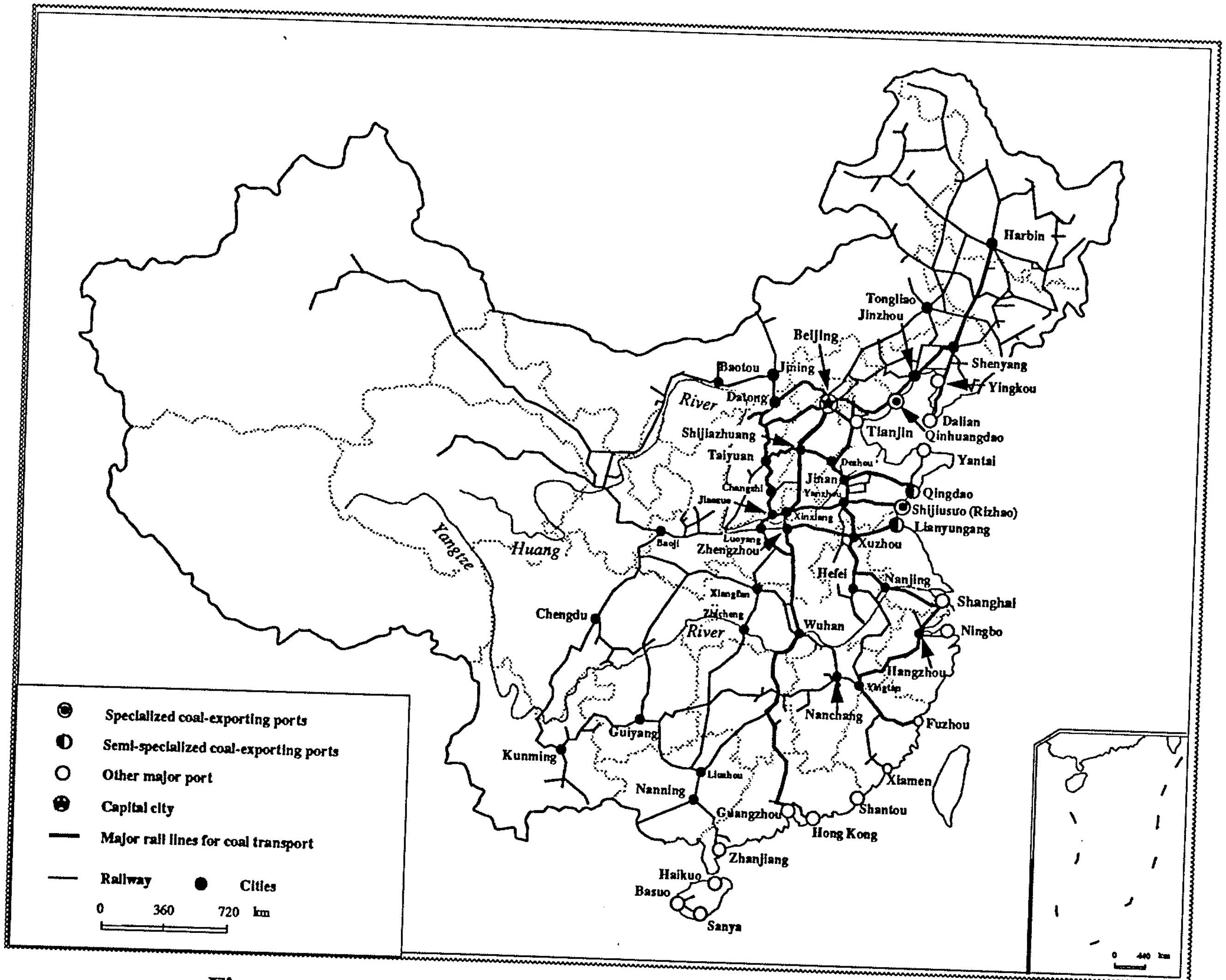


Figure 2.4 Coal-Transport and Rail-Port System in China, 1990

Coal Flows Out Of Shanxi. All the major coal flows originate in Shanxi, which provided one-fourth of the country's coal production and engendered 80 percent of coal deliveries throughout China. The area abounds in all kinds of coal, including coal to generate electricity, coking coal for metallurgical purposes, anthracite for making chemical fertilizers and peat coal for domestic usage. Shanxi coal generally is high heat grade (average 6000 kilocalories per kilogram, Datong coal registering 7800 kilocalories) while low in ash, sulphur and phosphorus; indeed, the huge Shanghai Baoshan iron and steel complex has relied on coal extracted from Gujiao since its inception. The coal seams are thick, display little faulting, and have a simple geological structure, all of which make for cost-effective extraction. Generally costs in other regions are one-third to two times higher than those obtaining in Shanxi. Even more advantageous, Shanxi is strategically placed, just a moderate 400-600 km from both the Beijing-Tianjin market and the ports earmarked for onward shipment to coastal markets in the south (Todd and Zhang[1], 1994). Of 26 coal-producing provinces, Shanxi, Guizhou and Xinjiang are only one-way coal exporters without coal importing; nevertheless, the amount of coal exported by Guizhou and Xinjiang is only 9.36 MT, less than 5 percent of that emanating from Shanxi. Owing to the long lead times required to bring new mining capacity on stream in Inner Mongolia, Shaanxi and Ningxia, by 2000 Shanxi will still remain the biggest province for coal production and export. Beyond 2000, however, coal-mining activities will tend to shift westward, as noted above.

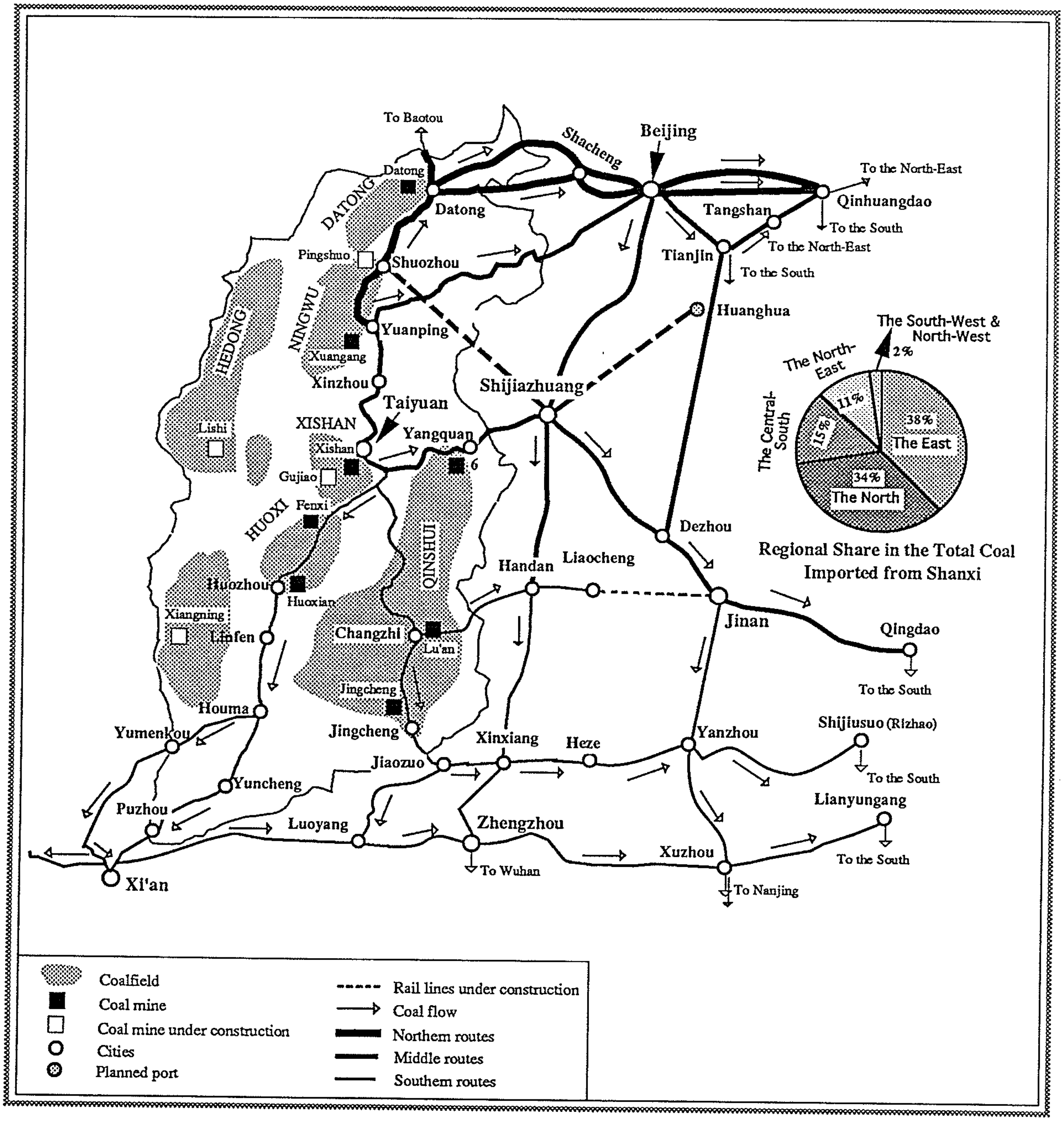


Figure 2.5 Shanxi Coal Mines and Major Coal Flows

The major coal flows out of Shanxi are conveyed along three routes, north, middle and south, which all stem from the important coal sites within Shanxi. Datong-based northern coal mines supplied 43 percent of Shanxi's coal output in 1993, and transferred over 90 MT outside, or about 45 percent of the total coal shipment out of the province that year, utilizing the Daqin (Datong-Qinhuangdao) and Fengsha (Fengzhen-Shacheng) rail lines. The major destination is Liaoning-Jilin in the North-East, Beijing-Tianjin-Hebei in the North and the largest coal port of Qinhuangdao through which a large amount of coal was carried to the southern provinces by coastal shipping. Xishan- and Yangquan-based coal mines in the middle of Shanxi provided 35 percent of the coal output in 1993. Sixty MT, or some 34 percent of the total coal exports, moved eastward over the Jingyuan (Beijing-Yuanping) and Shitai (Shijiazhuang-Taiyuan) rail lines to the regions of Liaoning-Jilin, Beijing-Tianjin-Hebei, Shandong and Anhui. Most of coal was transferred through the ports of Shijiusuo (now known as Rizhao) and Qingdao to the South. The southern coal mines in Jingcheng, Changzhi, Linfen and Yuncheng provided 27 percent of the coal production in 1993. Forty MT of their output, or about 21 percent of the Shanxi's coal exports, were hauled over the Taijiao (Taiyuan-Jiaozuo), Hanchang (Handan-Changzhi), Nantongpu (Datong-Puzhou) and Houxi (Houma-Xi'an) rail lines to the sea ports of Shijiusuo and Lianyungang as well as the river ports of Nanjing and Huhan along the Yangtze River, supplying the Central-South and the East by the rail or combined system. Their anthracite coal was even transferred as far as the Southwest and Northwest. These three routes, despite the different outlets, all cement eastbound connections with the ports in order to remove the congestion on the north-south rail lines (Figure 2.5).

In 1990, of the total coal deliveries from Shanxi to the other regions, the North-East accounted for 11 percent, the North for 34 percent, the East for 38 percent, the Central-South for 15 percent, and the South-west and the North-west together for 2 percent. In addition to Liaoning, six other municipalities and provinces importing more than 10 MT of Shanxi coal are located in northern and eastern China (Beijing, Tianjin, Hebei, Shanghai, Jiangsu and Shandong). It is thus obvious that the combined North and East is the major destination of Shanxi's coal flows (together accounting for 72 percent), which further underscores Shanxi's dominant role in domestic coal transfer since the country's principal urban-industrial centres are reliant on it.

Transportation Bottlenecks and Integrated System. Historically, coal movement in China relied on an integrated transport network, particularly the dovetailing of rail and coastal shipments. But this tradition changed after the 1950s when the development of the railway system was stressed at the expense of coastal shipping. The latter was neglected on three grounds: the westward extension of mining activities made the coasts more remote, the planners of national defence envisaged the coasts as vulnerable, and the appearance of regional self-reliance policy downgraded resource exports. As a result, the share of total tonnages handled by the waterway system in the long-distance transport sector (that is, combining railway and waterway) was reduced from over 31.3 percent in 1949 to 27.2 percent in 1970 (Zhang, 1995). In the beginning, this development seemed to work well, since the total demand was not big and coal production was encouraged to exploit the accessible coal deposits near the consumer areas. Accordingly, only small-scale interregional coal flows were generated (Table 2.1). The other reason for neglecting integrated coal transport derives from a phase during the 1960s and early 1970s when the attention of energy production was diverted to petroleum. Blind optimism regarding an oil boom led to petroleum development at the expense of coal production. Coal development actually slowed down. From the mid-1970s, however, circumstances began to spin out of control as industrial activities spread far and wide. Energy shortage began to prevail in the eastern and southern regions. Decisions were taken to resume and expand coal production in North China. Large volumes of coal were pressed on the inland transport infrastructure, particularly on the key north-south arteries of East and Central China----the Beijing-Guangzhou and Tianjin-Pukou railways----which were already overtaxed and patently unable to cope with the demands of the continually expanding output of heavy industry.

During the 1952-78 period, the length of railway track in China was extended by only 1.1 times, yet the freight volume increased 7-fold, and coal freight rose 7.8-fold. Most major rail lines reached their saturation points at this time or shortly after (Cheng, 1984). The transport capabilities of many basic sections of track in the coastal areas can only meet 50 percent of the demand for coal carriage. As the transportation system has failed to keep pace with coal production, it has become a major stumbling block for energy development. A large state-owned mine in Pinglu County at Shanxi Province, for example, is restricted to producing 1.5 MT a year instead of the 2.5 MT that could be produced at full capacity, and even then its own stockpile is still growing. Coal backlogs and deterioration in stockpiles became regular problems for lack of transport during the late 1970s, while, perversely, industry in southern and coastal areas remained short of energy.

Since 1979 the key transport priority has been the facilitating of coal transport out of Shanxi. Though affected by the cutbacks in investment during 1981-82, several transport projects----notably high-capacity rail links from Shanxi to the surrounding provinces----were incorporated in the Sixth Five-Year Plan (1981-85). Railway lines in the Taiyuan-Datong-Beijing-Qinhuangdao corridor were targeted for double-tracking and electrification, as was the central access line from Taiyuan (the capital of Shanxi) to Shijiazhuang and Dezhou, connecting with the north-south Tianjin-Pukou railway. A southern corridor was opened up by building a line from the Yanzhou coalfield in Shandong to the new coal shipment port of Rizhao. A further connection from Jiaozuo in western Henan to Jining and Yanzhou was initiated so that coal from Southern Shanxi could also travel over this route (Howard, 1989). Accordingly, west-to-east-oriented rail lines were favoured for connecting to the ports.

The initial impulse for the construction of those particular routes seems to have been the need foreseen in 1978 to export coal to Japan, but an important consideration since that time has been the need to free the north-south rail corridors of as much coal traffic as possible by substituting coastal shipping. Transport constraints in the interior have therefore contributed to enhancing the importance of the coastal ports (Howard, 1989).

Since the end of the 1970s, coastal shipping has grown faster than both inland shipping and rail, and the waterway mode in the long-distance transport sector raised its share to nearly 37 percent of the total volume of cargo moved in 1989. This change is particularly well-suited to serving the needs of the nine coastal provinces which, together with Beijing, Tianjin and Shanghai, accounted for over 53 percent of the total GNP and nearly 45 percent of the total coal consumption. In 1990, modern vessels carried over 700 million tonnes on domestic waters, a 13-fold increase on 1952. The freight volume of inland and coastal shipping in 1990 even exceeded modestly the railway's freight volume (Figure

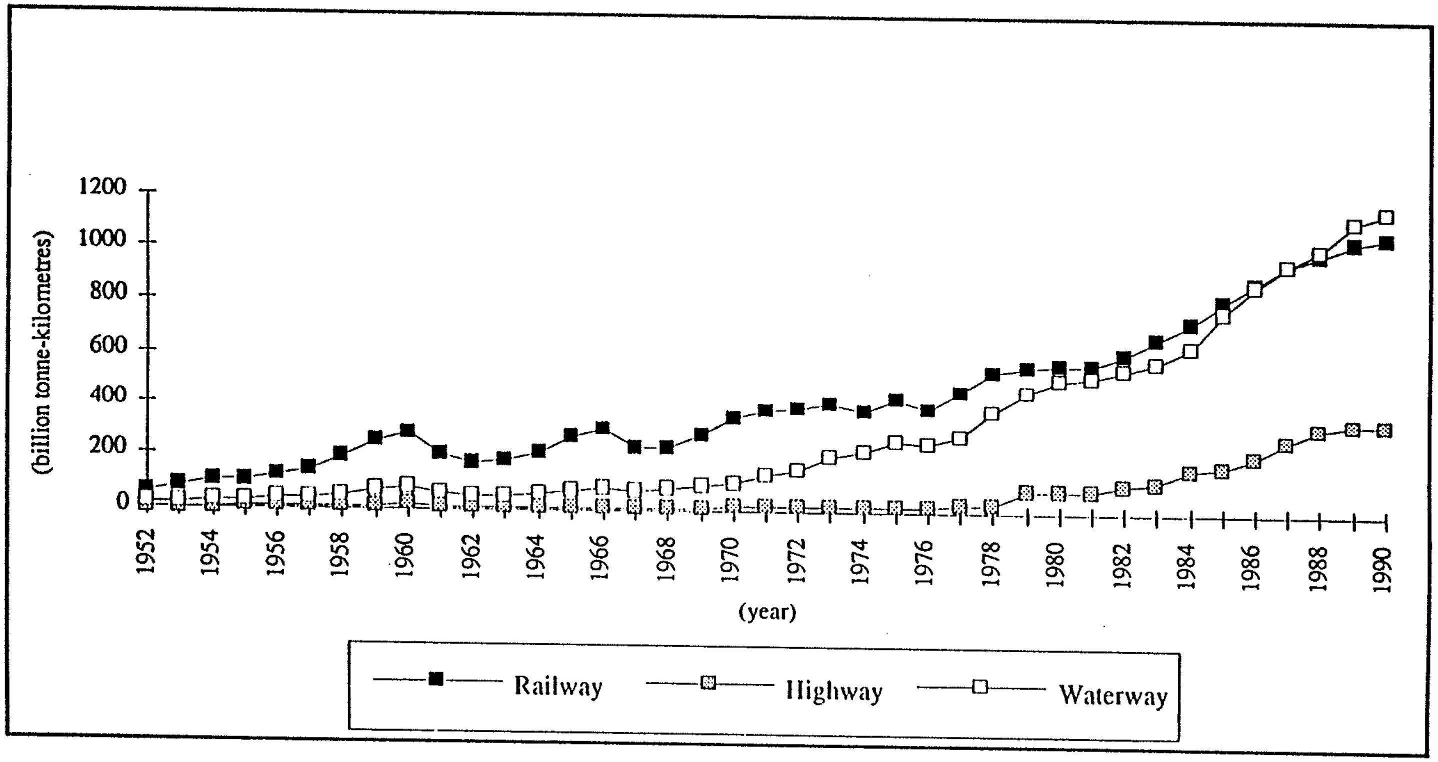


Figure 2.6 A Changing Composition of Freight Traffic in China by Volume

2.6). More to the point, coal cargoes amounted to 52 percent of all centrally-controlled (Ministry of Communications) and 55 percent of all locally-controlled coastal shipping traffic (Zhang, 1995).

The evolution of the integrated transport network has shaped the coal flows prevailing today. More coal is hauled over west-to-east lines to the ports prior to carriage down to the south by sea than ever before. In 1993, Shanxi transferred out 224.3 MT of coal, of which railways accounted for 88 percent; nevertheless, about 130MT (58 percent) were transferred to the ports and then shipped southbound by sea to the consuming centres.

Future coal flows in China will generally conform to the current pattern of an integrated transport system. With bolstered traffic on the lines out of Shanxi province and surrounding areas, increased use can be made of coastal shipping from northern ports to southern destinations, but the needs to move coal from the mines to the ports will continue to place heavy burdens on the transport systems.

Given the existence of bottlenecks, the northern rail network has been highlighted as the portion most in need of improvement. Large infrastructure investments are in progress and planned, including the construction and renovation of railway lines leading to ports. In the meantime, improvement and expansion of port facilities is undertaken in order to move coal along the coast by sea. Underlining this need is the central government's commitment to developing this region as the major supplier of coal to other regions. The details of these ventures will be expounded in the next chapter. In the meantime, the question of oil transfer is considered.

OIL TRANSFER

While the most serious long-term problem in China's oil prospects probably concerns the uncertain oil security, the situation is not improved by a transportation problem which arises from the great distances separating oil producing, processing and consuming centres on the one hand, and the overconcentration of petroleum production and refining capacities on the other. Let us examine these issues from the vantage of crude oil and refined products, beginning with crude.

Crude Oil. Transportation of crude oil does not appear to face significant bottlenecks at present, since 61 percent of oil is transported by pipelines to the major refineries. Crude oil flows are regulated in accordance with changes in the geography of petroleum production and refining. Before the exploitation of the Daqing oilfield in the 1960s, crude oil movements were mainly from the west to the east, and were dependent on the railways. In the First Five-Year plan, the important Zhengzhou-Lanzhou rail line from the Capital of Henan to the Capital of Gansu received attention so that it could transfer crude oil from the Yumen oilfield to the coastal areas. The completion of Lanzhou-Urumqi rail line in the period of the Second Five-Year Plan also served the same purpose, conveying crude oil from the Karamai oilfield to the oil refinery centre at Lanzhou. The surplus went to Lianyungang, then up to the Dalian port and down to the Shanghai port by sea, supplying the refineries in the Northeast and the Shanghai area. Since the large-scale production of Daqing oilfield commenced, and the subsequent discoveries of the eastern and central oilfields were rendered viable, the new pattern of crude flows has emerged. The shift of oil production can be seen from Table 2.4 . Many refineries have been established in the North, Central-South and the East near the consumer markets. Sizeable volumes of crude oil and petroleum products moved from Daqing to the south, mainly through the rail lines of Tongrang (Tongliao-Ranghulu), Jingtong (Beijing-Tongliao) and Jingshan (Beijing-Shanhaiguan), before continuing south either by the Jingguang line (Beijing-Guangzhou) or through the Hada line (Harbin-Dalian) to Dalian port for onward shipment by sea. In 1966, crude oil shipped by rail accounted for 66 percent of the total crude transportation. However, after the end of the 1960s, oil production grew rapidly, and crude transfer was subjected to bottlenecks on some sections of the railways.

Waterborne deliveries were boosted to relieve the railway congestion. After 1970 the government invested in oil-port

Table 2.4 Newly-added Capacity of Crude Oil Production in the State-Run Enterprises of China by Provinces, 1952-90 (%)

Province	1 FYP	2 FYP	1963-65	3 FYP	4 FYP	5 FYP	6 FYP	7 FYP
Beijing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tianjin	0.00	0.00	0.00	5.60	9.40	1.47	3.71	3.92
Hebei	0.00	0.00	0.00	0.00	0.62	44.78	9.11	2.85
Shanxi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Inner Mongolia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13
Liaoning	0.00	0.00	0.00	1.08	7.90	10.12	10.47	14.37
Jilin	0.00	0.37	0.25	5.46	22.98	0.81	1.54	2.74
Heilongjiang	0.00	49.66	88.20	57.82	45.34	14.82	34.46	25.27
Shanghai	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jiangsu	0.00	0.00	0.00	0.00	0.00	0.63	0.47	0.64
Zhejiang	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Anhui	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fujian	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jiangxi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Shandong	0.00	0.00	7.41	19.15	29.30	14.06	24.51	2.87
Henan	0.00	0.00	0.00	0.00	0.00	5.76	12.06	29.22
Hubei	0.00	0.00	0.00	3.61	1.08	0.00	0.30	8.44
Hunan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20
Guangdong	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Guangxi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hainan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sichuan	0.00	0.00	0.00	0.15	0.23	0.00	0.00	0.00
Guizhou	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Yunnan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Xizang	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Shaanxi	0.23	0.20	0.03	0.03	0.06	0.04	0.23	0.47
Gansu	85.37	12.17	0.00	0.70	0.07	0.83	0.21	0.02
Qinghai	0.00	9.61	0.58	0.54	0.26	0.38	0.00	1.34
Ningxia	0.00	0.00	0.00	0.00	0.00	1.42	0.00	0.00
Xinjiang	14.41	28.00	3.53	5.85	3.20	4.87	5.00	7.52
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Total (MT)	**1.31**	**8.16**	**6.75**	**27.67**	**40.65**	**39.41**	**49.76**	**25.16**

Source: China's Energy Statistics Yearbook, 1991 construction in Qinhuangdao in Hebei, Zhanyuwan in Dalian, Huangdao in Shandong, Zhanjiang in Guangdong and Yizheng in Jiangsu. Long-established seaports such as Dalian, Shanghai, Qingdao, Zhenhai and Guangzhou as well as river ports along the Yangtze were also rehabilitated for river, coastal, or ocean shipping. Concurrently, large-scale pipeline construction got under way during the 1970s, using the precedents of the 147km pipeline from Karamai oilfield to Dushanzi refinery (1958) and the 80km pipeline from Dongying (Shengli oilfield) to the Shengli refinery (1965). The approximately 12,000 km of pipelines in use today are mainly located in the Central, North and North-East Regions. The major pipelines----Daqing-Tieling-Dalian, Daqing-Tieling-Qinhuangdao-Beijing (Yanshan petrochemical complex)-Tianjin, Beijing-Renqiu-Cangzhou-Lingyi-Dongying-Zibo (Qilu petrochemical complex), Dongying-Qingdao, Cangzhou-Puyang (Zhongyuan oilfield)-Luoyang and Lingyi-Yizheng (Luning)----together form the biggest pipeline network in China (Figure 2.7). This network links the major oilfields (Daqing, Dagang, Huabei, Zhongyuan and Shengli) with the major petrochemical centres (Yanshan, Qilu and Yangtze), as well as with the northern seaports (Dalian, Qinhuangdao and Qingdao) and the river ports (Yizheng) along the Yangtze. The growth of the combined intermodal system rendered feasible the growth of the refineries along the southern coast and the Yangtze River. Other pipelines include Yumen-Lanzhou and Zhanjiang-Maoming. By the end of 1989, the share of railways in the total of crude oil movements declined to 16 percent, while waterways rose to 23 percent and pipeline shipment retained a comfortable lead among the three modes, thanks to its share of 61 percent. Crude oil movements have crystallized into the pattern which is dominated by the flows from north to south and northeast to southeast (Figure 2.7). Table 2.5 provides a listing of explicit destinations of crude oil shipments.

Table 2.5 The Destination of the Crude Oil Flows

Oil Fields (Origin)	Destination
Daqing	Heilongjiang, Jilin, Liaoning, Beijing, Shanghai, Guangdong, Zhejiang, Refineries along the Yangtze River and export
Jilin	Jilin
Liaohe	Liaoning and export
Huabei	Beijing, Hebei
Dagang	Tianjin, Hebei
Shengli	Shandong, Guangdong, Shanghai, Zhejiang, Refineries along the Yangtze River and export
Zhongyuan	Henan, Jiangsu, Anhui
Henan	Hubei, Henan
Jianghan	Hubei
Changqing	Gansu
Qinghai	Gansu, Qinghai
Xinjiang	Xinjiang,Gansu

Source: the Integrated Transportation Institute, 1993.

It is still too early to see the future pattern of crude oil flow. Owing to the stagnant oil production since the 1980s, oil supply has become a pressing problem. Some of the pipelines are operated below their designed capacity; for instance, crude oil moved through the Luning (Linyi-Yizheng) line dropped recently, and the trend is for more underutilization. Also limited port facilities make it inefficient to transport oil from the North-East to the far-away southeastern region. Insufficient crude supply has led to a situation of surplus refining capacity in China. Some of the coastal refineries have started to import oil from abroad,

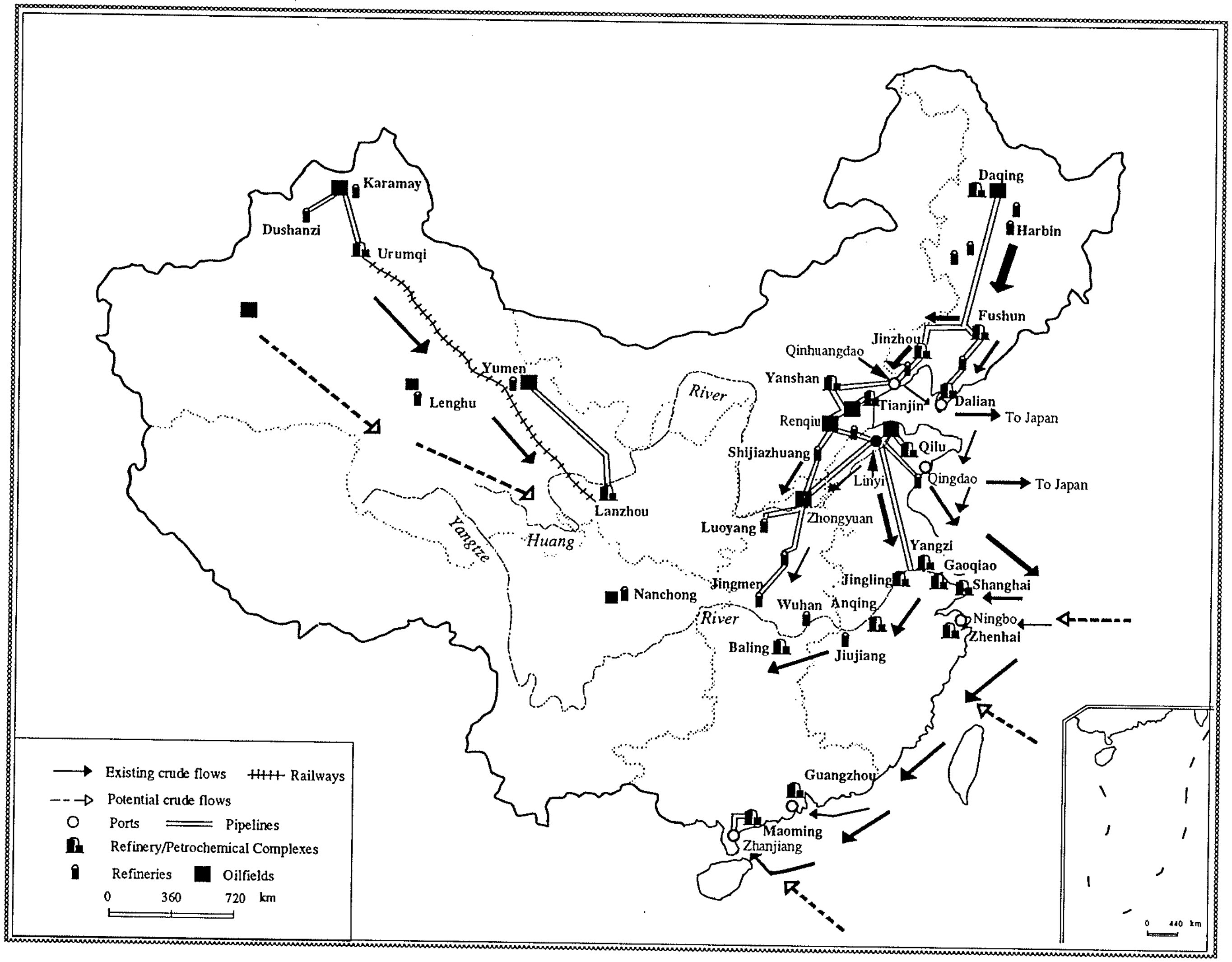


Figure 2.7 Major Crude Oil Flows and Transport System

increasing China's import bill. It can be seen that the future pattern of crude flow will depend upon any changes that may occur in the position of accessible oil reserves. The current flow will only alter significantly if the government were to free the control of oil imports into the coastal regions. The best prospects for China's oil finds are in the West and North-west regions, more than 2,000 km from the main consumption areas. Whether the crude flow reverts to the former pattern (from west to east) will depend on whether the discoveries in the Tarim basin are large enough to justify the transportation costs.

Refined Products. China's refining industry is heavily concentrated in the North-East, which has almost one-third of the nation's oil-refining capacity. It reflects both the earlier intensive development in the older refining regions close to the source of raw material as well as market orientation. In contrast, the South-West only registered 0.13 percent of the total refining capacity. The large surplus of refined products in the North-East and the shortage of refining capacity and production in the North and South-West led to a considerable volume of cross-hauls from the North-East to the North, and finally to the Southwest. In 1990, about 9 MT of petroleum products were transported from the Northeastern region. Of this amount, 2 MT were exported abroad from the port of Dalian, 1 MT were shipped by sea to the southern coastal cities, and another 5.4 MT were moved to the North by railways (Integrated Transportation Institute, 1993). Though the

East and Central-South seem capable of achieving local balance, the transportation of refined petroleum products is, like relay running, a stepped process, going from the North-East to the North, then to the Central-South, and finally from there to the South-West. The surplus of the refined products from the North-West is also destined for the South-West. The Southwestern region, altogether, imported about 4 MT of refined products from the other regions in 1990. The breakdown of the interregional petroleum products volume carried by rail is given in Table 2.6.

Table 2.6 Inter-Regional Petroleum Product Flows by Rail, 1990 (Million Tonnes)

Origins	Destinations						
	N-E	N	E	S-C	S-W	N-W	Total
North-East	22.36	4.38	0.37	0.51	0.10	0.08	27.80
North	0.03	6.70	0.26	1.38	0.39	0.61	9.37
East	0.00	0.09	8.19	0.62	0.01	0.10	9.01
South-Central	0.00	0.04	0.13	7.81	2.36	0.30	10.64
South-West	0.00	0.00	0.00	0.07	0.32	0.04	0.43
North-West	0.02	0.48	0.13	0.31	0.94	6.18	8.06
Total	22.41	11.69	9.08	10.70	4.12	7.31	65.31

	N-E	N	E	S-C	S-W	N-W
Sent to other regions(+)	5.44	2.67	0.82	2.83	0.11	1.88
Received from other regions(-)	0.05	4.99	0.89	2.89	3.80	1.13
Net flows	+5.39	-2.32	-0.07	-0.06	-3.69	+0.75

Source: Ministry of Railways, 1991.

Although the commodity creating the heaviest burden for the railways is undeniably coal, petroleum contributes to the overall strain imposed on transport infrastructure in China. Unlike crude oil, which is mostly transported by pipeline, 77 percent of China's petroleum products are handled by rail; a proportion comparable to the figure of 79.2 percent applying to the former Soviet Union. To date, China only has one product pipeline from Qinghai to Tibet, although another product line from Fushun to Dalian is under construction. The intention to build more product pipelines has been reported and this should be actively pursued to relieve the railways in congested corridors such as Shenyang to Dalian and Beijing to Shijiazhuang and points south.

Because of the extremely limited information on oil refining and its transportation, the general description of refined products' transfer given here has been pieced together from fragmentary data. The planned expansion of refining capacity in the Southeastern region, in Guangdong and Fujian provinces, with the associated oil import from abroad might increase the product flow from the Central-South to the South-West to alleviate the long cross-haul strain on railways. The next chapter confronts such problems from the broader perspective of national and regional planning.

CHAPTER 3 INFRASTRUCTURE OF ENERGY TRANSFER

Effective energy supply cannot be maintained without an adequate and efficient transport system. The serious interregional energy imbalance in China resulted, as discussed earlier, in significant transport bottlenecks, especially with respect to coal transfer. Such bottlenecks may eventually impose critical constraints on further development of a coal-dominant energy structure and hold down the overall speed of economic growth. The Chinese government has therefore decided to confront this daunting challenge by undertaking an enormous transport infrastructure programme to remedy this situation. Heavy demands are placed on the infrastructure consistent with energy transfer, particularly coal transfer--characteristically on the railways as well as ports, since prime energy sources such as coal and oil are bulky commodities of low value-to-weight ratios which rely on these facilities for transport. Ports and their attendant railway connections in northern China are central to these efforts.

Although the first railway line fully opened to traffic in China (built completely by British capital) dated from 1881, China's transport system was marked by extreme backwardness before 1949. In fact, at a density of 2.3 kilometres (km) of railways per thousand square kilometres of territory, China was less well provided with transport facilities than any other large country in the world. There was a particularly marked dichotomy between the few areas of ready accessibility and the vast areas of limited or no accessibility, and about 60 percent of the total 21,800 km of railways of different gauges and types were concentrated in Northeast China and along the coast. More specifically, more than 50 percent of the provincial capitals had no rail connections with the national capital--Beijing (see Figure 3.1). Also in 1949 there were only 80,768 km of highways, a network which was characterized by roads with little or no surfacing and by bridges and ferries of low capacity. In addition, there were only 73,615 km of navigable inland waterways in China in 1949 despite their historical and geographical significance, and many rivers were still in their natural states with a depth of less than one metre, rendering them useless for commercial traffic on any scale. This aggregate transportation network in China was the result of long historical development where the area of greatest transportation accessibility became the core or central area. The accessibility of this early core area was further reinforced by the colonial establishment of trading ports (Comtois, 1990).

In the economic growth of underdeveloped countries a critical factor has been the improvement of internal accessibility through the expansion of a transportation network. China is no exception on this score. The new government of 1949 attempted to accomplish the task through investment in a combination of modern and traditional transport modes. The Chinese government invested more than 220 billion yuan in the transportation sector between 1953 and 1990,

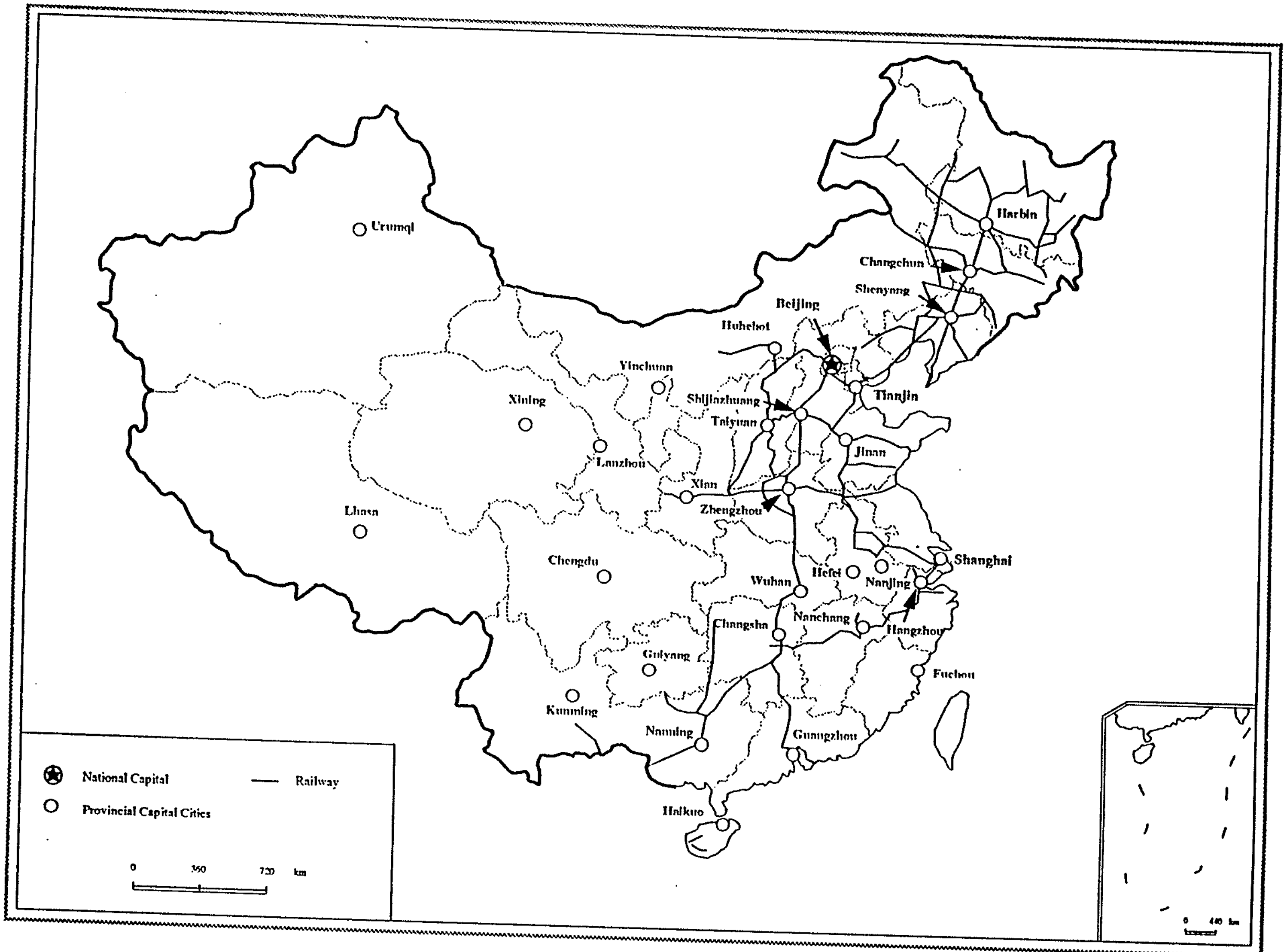


Figure 3.1 Railway Network in China, 1949

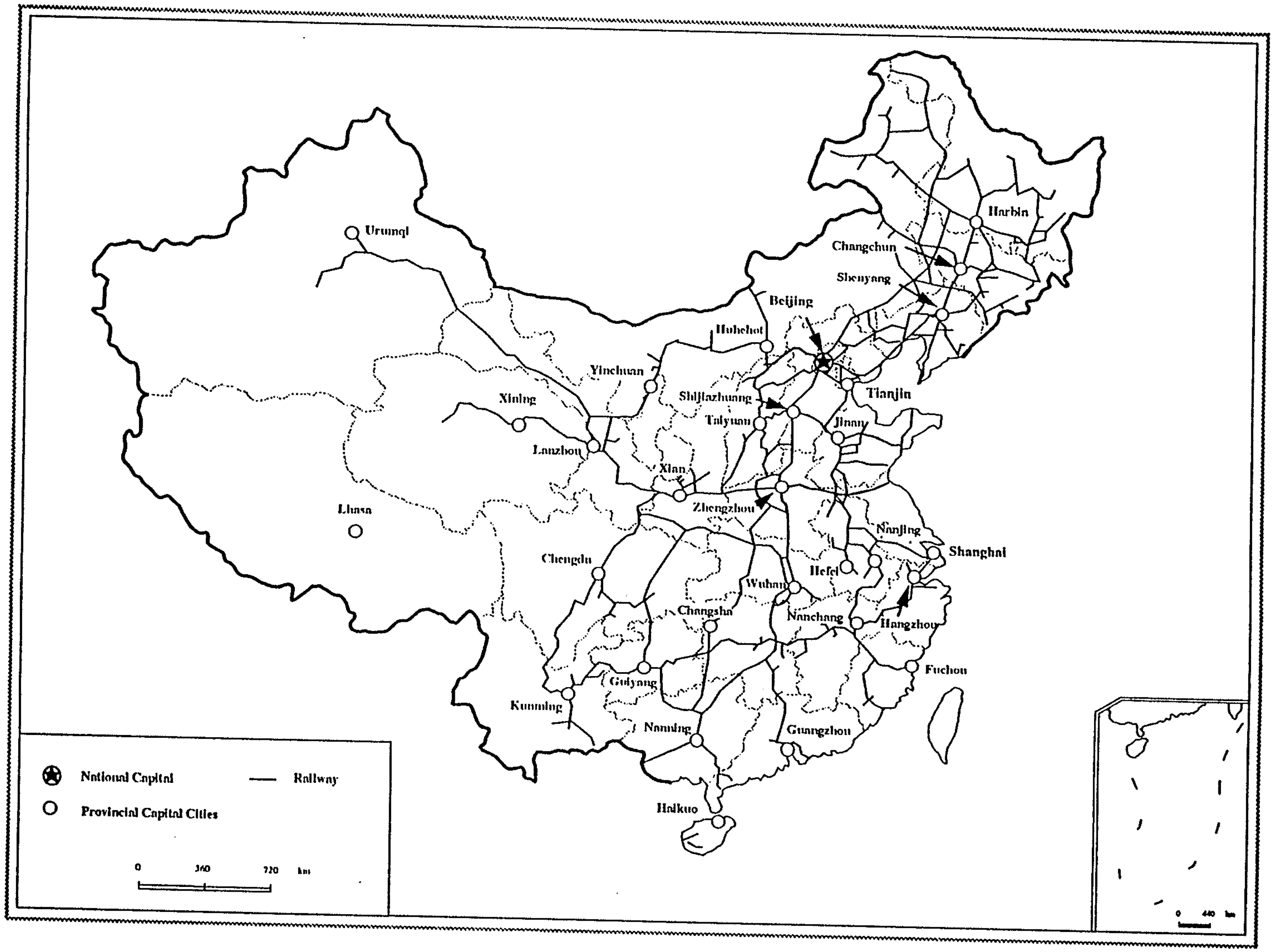


Figure 3.2 Railway Network in China, 1990

and evidence of the ensuing remarkable growth since 1950 can be found in Table 3.1 as well as Figure 3.2 (Zhang, 1995).

Table 3.1 The Development of the Transport Network in China, 1949-90

	Length in operation (km)						
	Railways				Airways		
Year	Total	(E)[a]	Highways	Waterways	D[b]	I[c]	Pipelines
1949	21,800		80,768	73,615			
1952	22,900		126,675	95,025	8,023	5,100	
1957	26,700		254,624	144,101	22,145	4,300	
1962	34,600	100	463,500	161,900	30,900	4,400	100
1965	36,400	100	514,500	157,700	34,900	4,500	100
1970	41,000	300	636,700	148,800	36,200	4,400	400
1975	46,000	700	783,600	135,600	47,100	37,100	5,300
1980	49,940	1,700	888,250	108,508	110,500	81,200	8,600
1985	52,100	4,500	942,400	109,100	171,200	106,000	11,700
1990	53,378	6,900	1,028,300	109,200	340,400	166,400	15,900

Source: China Statistical Yearbook, 1991
Note: [a] E=Electrified lines; [b] D=Domestic Routes; [c] I=International Routes.

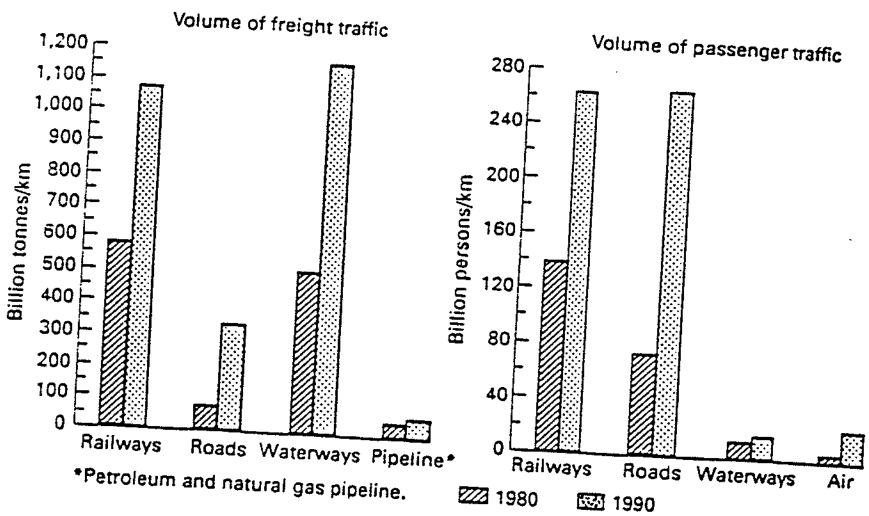
Freight traffic in China has grown from 315 MT in 1952 to 9,706 MT in 1990, attaining an average growth rate of 9.4 percent per annum. Comparing this rate with that of the total tonne-kilometre ratio in the same period--a rate of increase at the level of 9.8 percent per annum--means that while the transport system has experienced remarkable development since the 1950s, more expansion in fact has been achieved in highly-intensive freight transport as a direct result of the development of the long-distance routes, notably with respect to the railway system (Zhang, 1995). China now stands high in the world regarding freight intensity, higher than in any country except the former Soviet Union. Expressed in tonne-km of freight per dollar of GNP, China's ratio (3.17 tkm/$GNP) is almost twice as intensive as that of the United States (1.87), India (1.67) and Brazil (1.40) (World Bank, 1985). Clearly, country size and location of resources and population are decisive factors in the high intensity recorded by China. While the country is as large as the United States, its population is far more concentrated. Over 70 percent of the population lives east of the Beijing-Guangzhou line, while in the United States both the east and west coasts are highly developed. Regarding energy resources, the most common, such as coal and oil, are spread throughout the country. However, as remarked in earlier chapters, the conditions for exploitation of coal and oil in the North and the Northeast are more favourable than in the other regions. Concentrating on these resources will increase transport intensity more than would the development of local production closer to demand areas.

Although significant use is made of waterways and shipping, as well as road and pipelines, China's transport system is based predominantly on rail, which is the result of the long-term development of the modern transport system to serve heavy industry's need to move large quantities of coal, oil, timber, mineral ores, construction and industrial materials. Efforts have concentrated on developing the railways first and to a much lesser extent inland waterways and coastal shipping. Nevertheless, these efforts have not kept pace with economic growth, which is largely attributable to the relatively low priority given to transport investment before 1979, and the concentration of resources on "productive" sectors, particularly heavy industry. For instance, over the three decades to 1980, rail freight turnover increased more than thirtyfold, while the length of the network only grew by 130 percent. What is more, the number of locomotives in operation increased by a fairly modest 150 percent, and the number of wagons by a more impressive, but still inadequate 460 percent. The result has been a chronic deficiency of capacity, exacerbated by low running speeds and incompetent marshalling stations (Howard, 1989). Under transport development, water transport particulary had received little attention before 1978. Ports have been congested. Berth shortage and long delays resulted in large demurrage charges. These inadequacies have had regional repercussions, and thus may constrain the overall economic growth, which, in any event, is aggravated by the imbalance of regional energy demand-supply and the necessity of long-distance energy transfer. Given the length of time needed to construct new railways, ports and other infrastructure, efforts have to be made to accelerate the construction tempo. The focus of attention is now directed to the energy-related transport infrastructure, namely, railways and ports.

RAILWAYS

In China as a whole, past concentration of development strategy on heavy industry and reliance on coal as the primary source of energy have been coupled with a transportation strategy focused to a

Figure 3.3 Recent Transportation Usage in China



unusual degree on the rail mode. The rail network, as the backbone of China's transportation system, accounted for about half of total traffic (Figure 3.3). By the end of 1992, national railways had stretched 53,890.4 km, and included 13,704 km (25 percent) of double-track lines and 8,742.8 km (16 percent) of electrified railways (Wu, 1993).

From a chronic perspective, nearly 75 percent of the tonnage carried by the railway system revolves around coal, construction materials, materials for the iron and steel industry and petroleum. The share of coal freight in the total tonnage increased from 25 percent in the late 1950s to 34 percent in the early 1980s, and reached 38 percent by the middle years of the 1980s. Since 1990, coal alone has accounted for more than 40 percent of the total tonnage, whereas petroleum and gas composed only 4.5 percent (Figure 3.4). On the major rail lines of Beijing-Guangzhou, Beijing-Shenyang, Harbin-Dalian, Beijing-Shanghai and Lanzhou-Lianyungang, coal freight shipment accounted for over 50 percent of the total tonnage hauled (Hou and Wang, 1995). From Table 3.2 it is possible to elicit not only the fact that Shanxi reports greater rail freight traffic than other leading coal producers, but that far more of its traffic is coal related than is the case elsewhere (recall, also, the previous chapter). "If the spillovers of Shanxi railborne coal traffic were to be taken into account, the ramifications could be extended to Liaoning, Shandong and Hebei, where much of the railway development occurring in the 1980s was

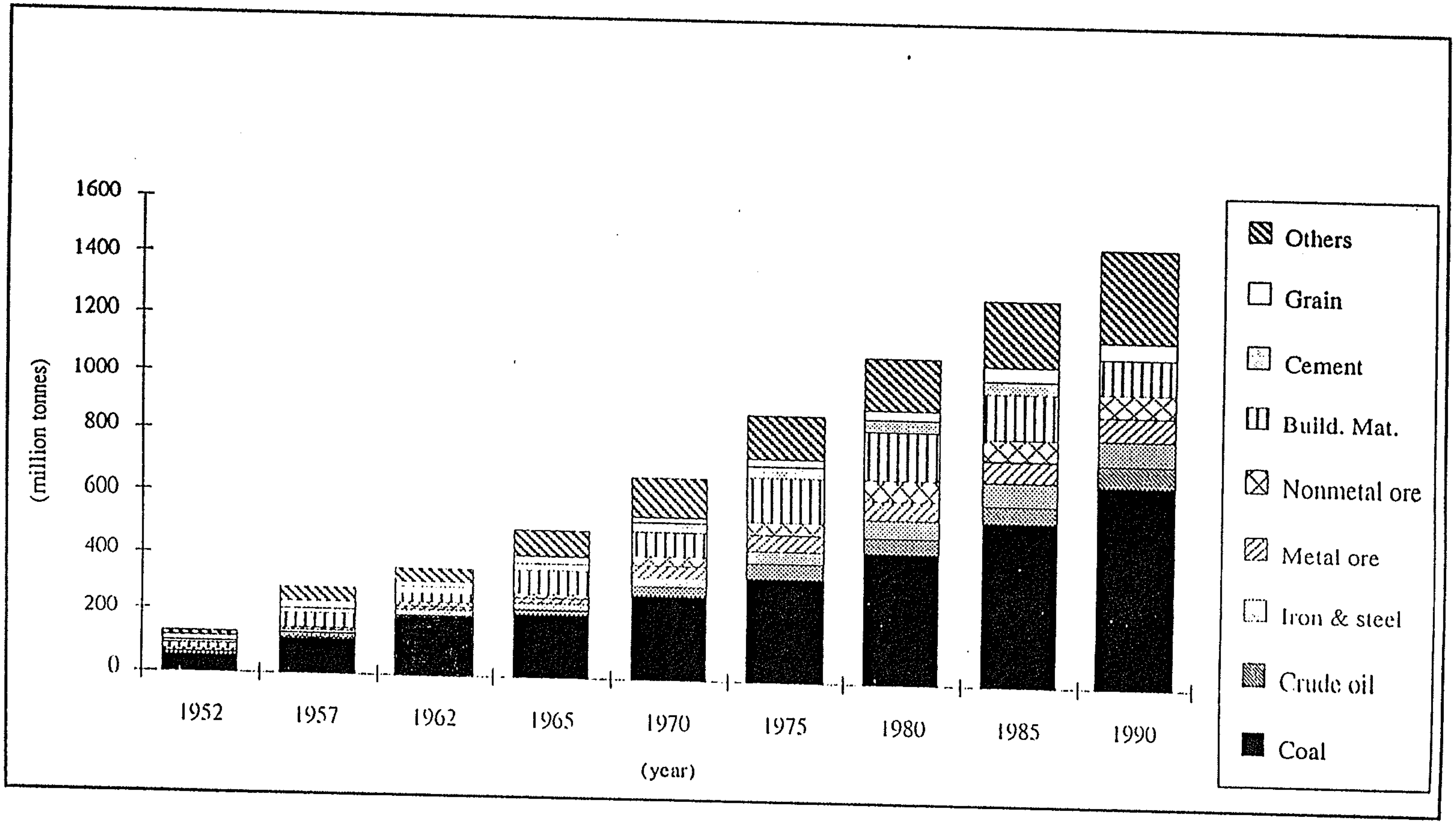


Figure 3.4 Composition of Railway Freight in China, by Selected Year

bound up with transferring Shanxi coal to ports for coastwise distribution" (Todd and Zhang[1], 1994). Moreover, the average distance for coal movement from the North to the Northeast is 1300 km by rail, and 1500-2000 km to the East and South by rail-via-sea. Allocation of resources to the transport sector is therefore likely to be governed by energy policy and the location of exploitable coal reserves. Coal flow, at the same time, acted as a contributor to, and a corollary of, rapid industrialization in general, and the development of transport networks in particular.

Table 3.2 Railway Dependence on Coal Traffic, 1990

Province	Rail density (km/km^2)	Annual increase in system extension (%, 1981-1990)	Freight traffic (MT)	Coal (% of traffic)
Shanxi	1.488	1.4	230.82	87
Hebei	1.576	1.6	110.97	34
Liaoning	2.427	0.9	141.00	22
Heilongjiang	1.009	0.0	131.26	47
Shandong	1.293	2.3	80.12	38
Henan	1.260	0.1	84.13	62
Sichuan	0.509	0.0	61.79	37
China	0.558	0.7	1462.09	43

Source: China Communications and Transportation Statistics Yearbook, 1990

The railways have been roundly blamed for the country's inability to move enough coal out of the mining areas to feed the industrial centres in east and south China. It is not surprising that railway transport is more of a constraint on energy supplies than coal-mine development; a situation occasioned by insufficient railway investments in the past and the slow replacement of inefficient steam locomotives by electric or diesel traction. For instance, between 1952 and 1978, the average industrial annual growth rate was 10 percent and rail freight turnover 6.8 percent, but railway facilities grew at only 3-5 percent per annum. Many industries report a shortage of railcars. The railway network density is still very low in terms of both capacity per area and population. The former is 56.1 km per 10,000 km^2, ranking 70th in the world, while the latter is as low as 4.5cm per capita, placing the system at well beyond the 100th place in the world (Wu, 1993).

Since increased energy requirements in China will have to be met largely by coal, the amount of coal transported by rail will continue to grow. Though increased use of coastal shipping from northern ports to southern destinations can help meet the demand, coal will still need to be moved via rail from the mines to the ports. The Ministry of Railways expects that the percentage of coal production transported by rail will not change greatly by the year 2000. Rail transport distances for coal are also likely to continue to increase, as coal mining will be increasingly concentrated in the North, and in particular in Shanxi province, though some of the short-distance traffic will be shifted to the roads.

To handle this traffic and relieve the severe bottleneck, China's coal transport sector is in need of urgent improvement. Construction of new railway lines and revamping of existing lines are in full swing. During the Eighth Five-Year Plan, China intended to build 4,100 km of multiple-tracked lines, 5,600 km of electrified lines and 6,600 km of single-tracked lines with a total investment of 100 billion yuan (Wu, 1993).

The greatest construction and upgrading of the rail network has occurred in recent years between those provinces where coal-mine development has taken place and four northern coal ports: Qinhuangdao, Qingdao, Shijiusuo (or Rizhao as it is now styled) and Lianyungang. The most prominent achievement is the building of the 653-kilometres' long Datong-Qinhuangdao railway in North China. The Daqin line is China's first double-track, electrified and heavy-duty coal transport line, linking the cities of Datong, a major coal producer in Shanxi, and Qinhuangdao, the world's largest marine coal terminal. The International Heavy Load Transport Association defines a heavy-load train as one weighing over 10,000 tonnes, or as a train unit carrying over 5,000 tonnes while operating on a railway which has an annual freight volume exceeding 20 million tonnes. This, China's first 10,000-tonnes heavy-load railway, was constructed in two phases which opened to traffic in December 1988 and late 1992 respectively. It cost a total of 6.6 bn yuan, including 18.4 bn Japanese yen ($147m.) in loans (Hua, 1989). It has the capacity to move about 55 MT of coal annually. Its long-term handling capacity will approach 100 MT per year, earning it the title "China's energy lifeline."

A southern corridor was opened up during the Seventh Five-Year Plan by connecting the Jiaozuo-Xinxiang-Heze rail line with the Yanzhou-Shijiusuo line so that coal from southern Shanxi could travel over this route to the coal shipment port of Rizhao. Near completion is the new electrified railway extending 252 km from

Houma in southern Shanxi to Yueshan in western Henan. With a designed annual transport capacity of more than 20 MT, it will open up a new coal transport link. Another electrified railway under construction is that from Baoji on the Longhai railway to Zhongwei in Ningxia with an annual transport capacity of 15 MT. Cutting across Shaanxi, Ningxia and Gansu provinces, the railway connects the Lanzhou-Lianyungang, Baotou-Lanzhou and Lanzhou-Xinjiang lines, becoming a new conduit to move coal from the "San Xi" coal base to other parts of the country (Figure 3.5).

With the westward shift of energy production, development of the Shenfu-Dongsheng Coalfield has become one of the largest ongoing energy projects. The coalfield, located in northern Shaanxi Province and the southern part of the Inner Mongolian Autonomous Region, has one-fourth of the nation's total verified coal reserves. The past decade of construction has formed an annual production capacity of 20 MT. However, the port and railway construction has lagged behind the inception of mining capacity. Now only 5 MT of coal is transported outside per year, calling for the shift of the emphasis of the development strategy from production to transportation. The integrated infrastructure project includes construction of an electrified railway line extending from Baotou through Shenmu and Shuozhou to Huanghua, a planned specialized coal port, to say nothing of the coal fields with two affiliated plants and the Huanghua port. The first stretch, a 171 km-long line from Baotou in Inner Mongolia to Shenmu in Shaanxi

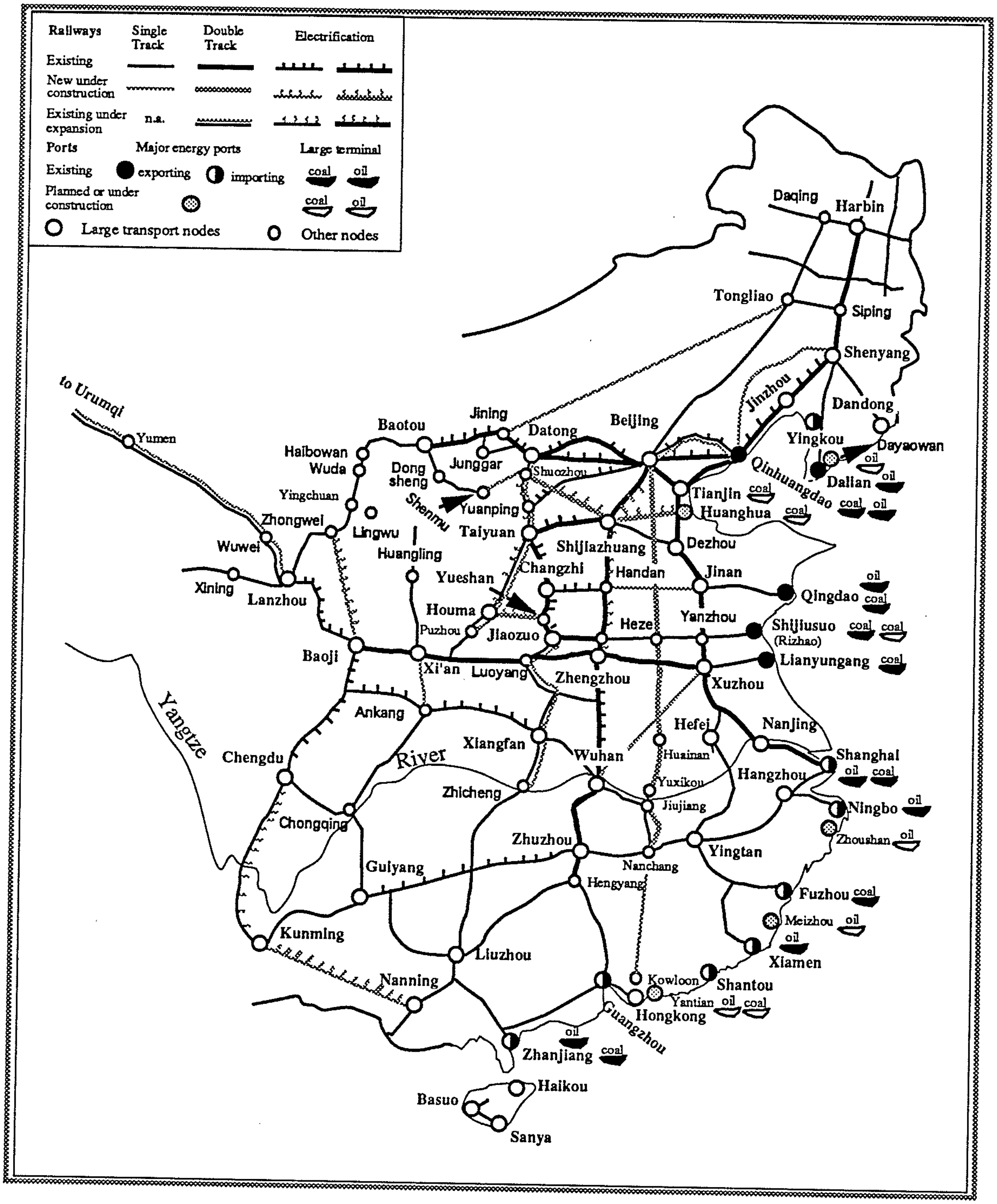


Figure 3.5 Railway and Port Construction Projects

province has been completed, and the second stretch, from Shenmu to Shuozhou in Shanxi province is now under construction(Figure 3.5). Upon completion in the year 2000, the Baotou-Huanghua railway will be capable of moving 100 MT of coal from Inner Mongolia, Shaanxi and Shanxi to the port for onward shipment.

The above new railway construction projects mainly are envisaged as opening up new conduits to move coal to the ports for coastwise shipping. In addition to these, the north-south rail capacity will also need bolstering to ease the worst bottlenecks in the north-south arteries. As a result, construction of the Xian-Ankang railway started in 1994, and will be completed during the Ninth Five-Year Plan (1996-2000). It is a section of China's new alternative north-south artery. The 18.4-km tunnel being bored through the Qinling Mountains will be China's longest railway tunnel. The line will aid the shipping of coal from Shanxi, Shaanxi and the Inner Mongolia region to the Southwest (Figure 3.5).

Construction of a main line, that from Beijing to Kowloon, designed to alleviate the constrained north-south railway transportation is in progress. The route runs between the two existing saturated north-south lines, Beijing-Guangzhou and Beijing-Shanghai (Figure 3.5). Extending 2400 km and traversing the nine cities and provinces of Beijing, Tianjin, Hebei, Shandong, Henan, Anhui, Hubei, Jiangxi and Guangdong, the new trunk line encompasses the largest scale and greatest investment over the longest distance in the history of China's railway construction. It can serve as another coal movement passage to the East and the Central-South, particularly for transporting coal from Huainan and Huaibei in Anhui province.

For shipments to the Northeast, plans are being made to increase rail capacity north of Qinhuangdao. Two new lines extending from Qinhuangdao to Shenyang and Jining to Tongliao are planned. Some of the coal can also be shipped to Dalian and Yingkou for coastal uses in Liaoning province. For shipments out of the coal base in Guizhou province, a new line from Nanning in Guangxi to Kunming in Yunnan will be built, linking southwest China with southern coastal areas. It provides a new outlet for transferring Guizhou's coal outside.

With a view to increasing transportation capacity, many efforts are being made not only in constructing new lines, but also in expansion and improvement of the existing lines, especially by double-tracking and electrification.

In the former USSR, a comparable increase in traffic density was achieved between 1960 and 1975 by switching from steam to electric and diesel traction, combined with double-tracking of about one-third of the railway network. Steam traction declined from 85 percent in 1955 to 15 percent in 1975 and has since vanished completely. By contrast, 70-75 percent of total traction in China was still provided by inefficient steam locomotives, and only 18 percent of the rail routes were double-tracked as late as the mid-1980s (World Bank, 1985). By the end of 1992, the total length of China's electrified railways amounted to 8739.2 km on 18 trunk railways, or about 16 percent of the total system, and 40 percent of China's trains were still powered by steam.

Large-scale double-tracking and electrification programmes have revitalized the major coal-carrying lines. The emphasis of this investment was placed on the lines leading from the Shanxi-centred energy base to the east coast, since seven other railways in Shanxi province have been saturated except for the Datong-Qinhuangdao line. The continuing technological transformation includes double-tracking and electrification of the existing lines: Datong-Puzhou, Beijing-Yuanping, Taiyuan-Shijiazhuang and Taiyuan-Jiaozuo (Figure 3.5). After completion of these projects the transport capacity in the coal corridors out of Shanxi will increase significantly. Meanwhile, the current seriously bottlenecked lines are also being transformed; for instance, the electrification of the whole length of the Beijing-Guangzhou line and the renovation of marshalling stations in northern Zhuzhou, Hengyang and Guangzhou is proceeding; as is double-tracking of the Lanzhou-Xinjiang railway and electrification of the Chengdu-Kunming line. According to the plan, if all the targets of railway construction are met, China's railway length will reach 60,000 km, with the share of double-track lines climbing to 30 percent and electrification standing at 23 percent (Wu, 1993).

At the same time, relief is earnestly sought for the hitherto underdeveloped water transport. Under the Sixth Five-Year Plan, the ports were permitted to proceed with expansion programmes necessary to make sure that shipment of coal to the southern coast or foreign markets would no longer be held back by port limitations. How far they have succeeded in this object will be discussed below.

PORTS

The rail effort has been complemented by improvements in the water-borne mode. Alerted to the need to find an alternative to the hard-pressed railways, the planners in the late 1970s found limited relief first in barge haulage on the inland waterways and second, and much more importantly, in coastal shipping. This potential of coastal shipping to act as a useful complement to rail haulage could only be realized, however, with the removal of the problems long besetting the ports.

Port traffic in China was fairly modest for many years, mainly as a result of the sparse development of coastal shipping during the era of self-sufficiency policy and its downgrading in the name of national defence. It was not until 1973 when Premier Chou En-lai personally drew attention to the problems of port inadequacy that serious measures were taken to remedy the situation (Chiu and Chu, 1984). Improvements initially were slow in coming. In 1979 alone, for example, it was estimated that costs incurred as a result of deficient port facilities amounted to US$100 million. Thereafter, the government recognized the importance of having adequate ports to handle the traffic generated by its change in trade policies and, before long, major capacity investments were taking place in many ports. Changes were both striking and immediate. By 1990 cargoes carried on domestic waters, 80 MT, reached a level 16-fold greater than 1952. Moreover, the freight volume of inland and coastal shipping, 1159 MTKM in 1990, was roughly 10 percent more than the railways' freight volume. In that same year, cargo handled at the 16 larger ports reached 432.3 MT, a dramatic increase on the 191.8 million recorded for 1965. Shanghai, as China's gateway port, remained preeminent with 139.6 MT or 29 percent of the total. Significantly, however, the three principal bulk-handling ports--Qinhuangdao, Dalian and Qingdao--together accounted for another 149.3 MT or about 30 percent of the total port throughput. This performance signalled some fundamental changes for the three northern ports, not least a boost in traffic share from the 28 percent arrogated by these three ports in 1965. All in all, aggregate port traffic grew at a rate of 20.8 percent per year between 1978 and 1990, and, correspondingly, the government commissioned 180 berths capable of handling ships over 10,000 dwt during the years 1973 to 1990. Table 3.3 summarizes the port situation obtaining at the beginning of the 1990s (Todd and Zhang[2], 1994).

Table 3.3 Major Chinese Seaports

Port	Throughput (MT pa) 1965	1990	Maximum depth alongside the berth(m)	Total berth length (m)	Total berths	Berths able to take 10,000dwt vessels
Dalian	10.6	49.5	17.5	14,192	75	28
Yingkou	0.3	2.4	-	2,448	22	5
Qinhuangdao	4.8	69.5	14.0	6,151	35	22
Tianjin	5.5	20.6	12.5	9,501	57	32
Yantai	1.0	6.7	9.2	3,324	24	9
Qingdao	4.5	30.3	13.5	7,500	40	16
Shijiusuo	-	9.3	-	1,987	13	5
Lianyungang	2.7	11.4	9.0	3,837	23	14
Shanghai	31.9	139.6	10.5	21,437	215	64
Ningbo	-	25.5	18.2	4,413	45	10
Shantou	1.8	2.8	7.8	1,264	15	-
Guangzhou	4.7	41.6	12.5	10,365	118	22
Zhanjiang	2.2	15.6	12.5	4,601	31	17
Haikou	0.6	2.9	6.0	1,442	13	-
Basuo	1.0	4.3	-	842	5	3
Sanya	0.3	0.3	7.5	715	7	-

Source: China Statistical Yearbook, 1991.

The major efforts to modernize ports, coinciding in part with the adoption of the "open door policy", has focused on two kinds of ports: the container handlers (Tianjin, Shanghai, Guangzhou and the new port of Huangpu) on the one hand and those dedicated to energy (coal and oil) transfers on the other. In accord with the latter, coal ports and oil ports are emphasized in this section.

Coal Ports

Now China has four major coal-loading ports, Qinhuangdao, Rizhao (Shijiusuo), Qingdao and Lianyungang, through which coal is exported to foreign markets or transferred to the domestic southern consuming centres by coastal shipping. Coal-handling capacity of the four ports together had climbed to 65 MT per year by 1985, considerably more than the 45 MT regarded as acceptable by South Africa, one of the world's largest coal exporters. In 1990 the effective coal-handling capacities reached 72 MT pa, breaking down as Qinhuangdao 51 MT per annum, Shijiusuo 15 MT pa, Qingdao 3 MT pa and Lianyungang 3 MT pa (Todd and Zhang[2], 1994).

A potential drawback encroaching on capacity usage can be gleaned from Table 3.4, and that concerns the reliance on relatively small berths. Most berths in the coal terminals are designed to accommodate handysize vessels, those in the 25,000 to 30,000 dwt size class. In fact, the coastal collier fleet is overwhelmingly made up of ships in the 16,000 to 20,000 dwt bracket. While perfectly suited to fairly small consignments in shallow, coastal waters, these vessels forgo the economies of scale enjoyed by bigger vessels of 100,000dwt and greater (the so-called Capesize ships).

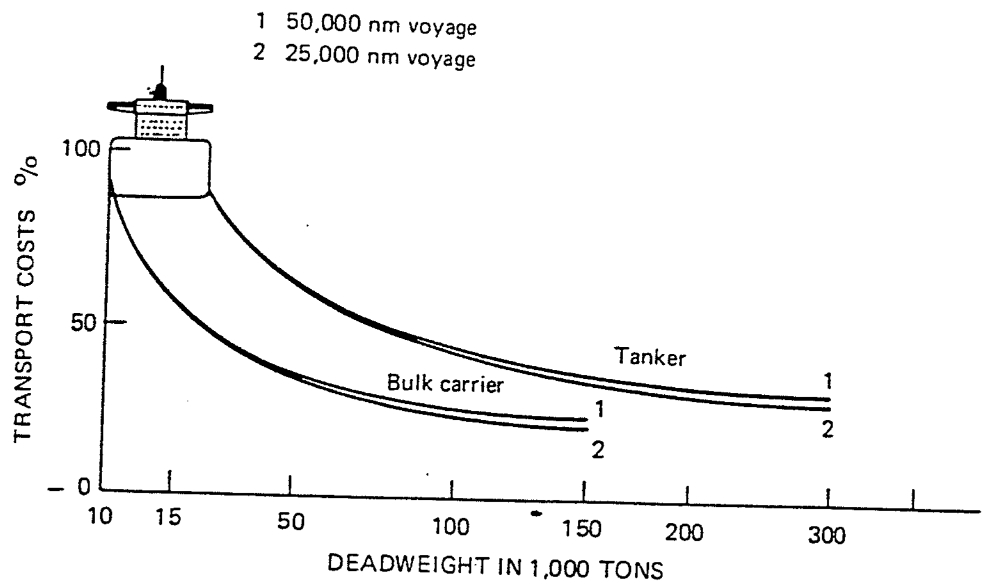
Table 3.4 Port Coal Loading Capacity by Ship Size, 1986

Port	Ship size (000 dwt)				
	<20	20-35	36-60	60-99	>100
Qinhuangdao	4	20	22	0	0
Qingdao	0	3	0	0	0
Shijiusuo	0	0	0	15	0
Lianyungang	10	7	0	0	0
Total Capacity	14	30	22	15	0
Share (%)	17	37	27	19	0

Source: Ministry of Communications, 1990.

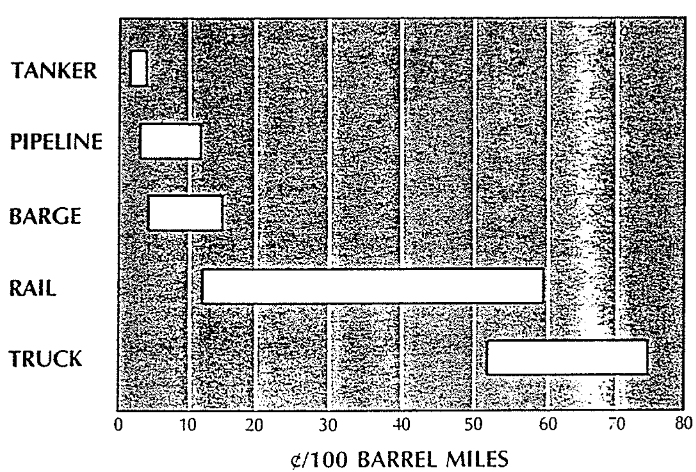
Larger vessels have been a greater concern to ports than smaller vessels in the past two decades around the world primarily because of economies of scale (Figure 3.6). This trend was first

Figure 3.6 Relationship of Tanker and Bulk Carrier Vessel Size to Transport Costs Per Ton of Cargo



Source: Schonknecht et al. (1983).

Figure 3.7 Relationship Between Oil Shipment Costs and Distance for Various Transportation Modes



Source: Wheeler and Muller (1981).

evidenced for tankers, and today 72 percent of the world's oil supplies are carried in tankers 100,000 dwt and larger. Bulk carriers of 100,000 dwt or more increased their share of oceanborne shipments from 6 percent in 1971 to 35 percent in 1980. Large bulk carriers of the Capesize class now carry 80 percent of iron ore shipments, 45 percent of all coal shipments and 10 percent of grain shipments (Cargo Systems Research Consultants, 1982).

Clearly, the primary factor influencing the movement towards larger ships derives from their ability to offer lower unit transportation costs. In general for coal ocean transfer, the largest incremental freight savings were realised on going from 60,000 to 120,000 dwt vessels. It was found that there are also considerable savings on the longer routes in using even larger vessels. However, larger vessels are wider, longer, and have deeper draughts, the last of which requires greater channel and berth depths, which present physical restrictions on existing ports. A close relationship between the draught of a ship and the size of a ship can be derived from the following approximate formula for the full-loaded draught of cargo ships and bulk carriers in metres (Thoresen, 1988):

$$\text{Full loaded draught} = \sqrt{\frac{DWT}{1000}} + 5$$

It thus can be assumed that any change in ship size will have an influence on depth requirement.

In today's world, the Panamax-carrier of 60,000-70,000 dwt can be handled in most major coal ports and is at present the dominating vessel size in the coastal coal trades. In China, however, usage of Panamax vessels is confined to the larger berths of Shijiusuo, a port which has draught limits of 16.2 metres for colliers, generous compared with the 12.5 metres draught limit obtaining in Qinhuangdao. The avoidance of Capesize berths was directly attributable to the severe costs entailed in dredging. Also the relatively short-haul distances of export shipment (most go only as far as Japan) and the relatively small-scale of coal exports are two other reasons for the failure to implement Capesize berths.

Nevertheless, attempts are being made to furnish berths compatible with the most efficient vessels. Much of the impetus is from Japan, a country which is desirous both to acquire Chinese coal for its own markets and to transport it in large, efficient vessels. More to the point, the Japanese were prepared to finance upgraded coal terminals. Shijiusuo, opened to foreign vessels in May 1986, was a major beneficiary, receiving two 100,000 dwt-class berths. Qinhuangdao benefited even more from coal exports and the augmented facilities required to effect them (Todd and Zhang[2], 1994). Its original coal terminal, one berth of 50,000 dwt capacity and one able to take 20,000 dwt vessels, was equipped with Chinese-made facilities with a coal-handling capacity of 10 MT pa. During the Sixth Five-Year Plan (1981-85), with the decision to nominate Shanxi as the leading coal producer, the port was set aside for expansion. Two berths of 50,000dwt were built in Qinhuangdao, equipped with Japanese-made loading and unloading plant, and capable of handling another 20 MT pa of throughput. A succeeding scheme of 1984 envisaged a 100,000 dwt-class berth as well as a 35,000dwt-class berth with a designed capacity of 30 MT pa. Complementing enlarged capacity at the port is the Datong-Qinhuangdao double-track electrified railway mentioned above, construction of which started in 1985 and which will deliver Shanxi coal to the dockside. Conceived on a grader scale, the follow-on phase, destined for completion in 1995, will push up coal throughput to over 100 MT pa. In 1985, 60 percent of the total coal export from China's ports came from Qinhuangdao, and one-quarter of the port's 40 MT pa of coal shipments was cleared for overseas markets, particularly those in Japan(Wang, 1989).

The export incentive helps not only pay for the port infrastructure but also improve the efficiency of port practices: for example, the pre-1983 custom of using small railcars to bring the coal to the stockyard, laboriously transferring it and shovelling it to a storage area by hand before manually loading it into a ship's hold, was replaced by Japanese automated ship loaders capable of transferring coal to the ship directly from the railcars and bypassing the stockyard altogether (Todd and Zhang[2], 1994). By 1991 coal traffic alone in Qinhuangdao had climbed to 54.3 MT, accounting for 75 percent of the port's throughput (Table 3.5). This affirmed its standing as China's principal specialized coal port, a port which is striving to match the demands placed on it by Shanxi coal suppliers. Nevertheless, while the port has grown in concert with the expansion of northern coal production, the enlarged output expected by the turn of the century is likely to stretch its capabilities to the full.

In anticipation of this possibility, development of another new port, Huanghua, received central-government approval in August 1993. This port is designed to meet the need for transferring increased coal flows from the Shenfu-Dongsheng coalfield in the North-West over to the ports for onward shipment. As mentioned in the previous section, port construction is a critical part of the whole project together with the accompanying rail link, given the restricted production of the coalfield owing to lack of transport capacity. Bordering on the Bohai Sea to the east, Shandong province to the south, Beijing and Tianjin to the north, and the Beijing-Shanghai railway to the immediate south, Huanghua has a favourable location. Envisaged is a three-phase construction project with an annual designed capacity of 30 MT. The first phase will begin with four 35,000 dwt berths requiring a 3 billion yuan investment. The second phase will include construction of three additional berths able to take 35,000dwt ships, and one 50,000 dwt-class berth, which will raise the port's handling capacity to 60 MT. Completion of the third-phase construction will raise the port's handling capacity to well over 100 MT, and Huanghua will become the country's second largest east-west coal transportation hub (Anonymous, Jan.17-23 1994). Together, Huanghua and Qinhuangdao will by then be handling in excess of 200 MT of coal; that is, about one-quarter of the total coal traffic volume of the country as a whole.

Table 3.5 Commodity Throughput Shares of Northern Chinese Ports

Commodity	Port (%)					
	Qinhuangdao 1991	Dalian 1990	Qingdao 1985	Tianjin 1985	Yantai 1985	Yingkou 1985
Coal	75.0	5.8	21.7	0.1	13.5	0.2
Petroleum	17.0	51.8	39.7	2.2	0	0
Metallic ores	0.8	3.2	7.4	0.1	0	0.6
Iron & steel	0.3	3.0	7.2	28.4	4.0	13.0
Construction materials	0.2	0.2	4.1	7.2	30.4	0
Cement	0.2	1.4	0.3	2.0	0.5	0
Nonmetallic ores	0.2	2.1	4.0	2.7	2.7	33.7
Timber	2.0	0.8	4.0	2.3	14.9	9.0
Fertilizer	0.8	2.3	2.5	3.0	11.9	3.4
Salt	0	0.8	1.0	11.4	0	1.0
Grain	1.9	13.3	2.4	12.7	6.1	33.0
Others	1.6	15.5	7.7	27.9	16.7	6.1
Total	100.0	100.0	100.0	100.0	100.0	100.0

Source: Gao, 1988, and port authorities of Qinhuangdao and Dalian.
In: Todd and Zhang[2], 1994

Unfortunately, development of the receiving ports seems less advanced. China's major coal receiving ports are Dalian, Yingkou, Shanghai, Ningbo, Zhoushan, Fuzhou, Xiamen, Guangzhou and neighbouring Huangpu, Zhanjiang and Shantou, and the total coal throughput handled by them in 1990 reached 231.6 MT, with one-quarter of that amount attributable to Shanghai. Currently the coal-handling capacities in coal receiving ports falls short of the demand and ships frequently queue up to wait for berths. In Huangpu Port, ships waited an average of 6.8 days in 1986, causing a large compensation cost for demurrage. This problem might be eliminated temporarily when the second World Bank-financed expansion of Huangpu is completed, which is designed to increase port capacity from 15.7 to 22.3 million tonnes/year, including expansion of coal terminals and general cargo terminals with rail connections. However the channel depth, limiting access to 20,000 dwt vessels, is a major constraint on the use of larger vessels for both coastal shipping and foreign trade. Growth in cargo flows again will strain capacity in the near future, especially when coal shipping increases. Other major seaports in Guangdong province, except for the deep-water port at Zhanjiang, are also limited by the depth of approach channels (Guangzhou and its outer ports) or the water depth alongside berths (Shantou).

As a response to the above problems, inauguration of the Yantian Port in Shenzhen was approved as one of the four international deepwater ports envisaged during the Eighth Five-Year Plan. Yantian has 6 km of shoreline available for development with depths of 10-14 m. It plans to construct 40 deepwater berths over the next 15 years, with an annual handling capacity of 80 MT. The total handling capacity of Shenzhen, including that of Yantian, Shekou, Mawan and Chiwan port areas, will surpass the total capacity of Hong Kong. Yantian could become a major transhipment terminal in the region for both coal and containers. Other southern ports like Shanghai, Ningbo, Zhoushan, Xiamen and Shantou are currently being upgraded in readiness for the new influx of coal. To relieve port congestion, large coal users such as steel mills and power plants on coastal locations usually develop their own terminals. Consideration is also being given to simplifying coal-unloading facilities with the use of self-unloading ships, since self-unloading ships can save costly port infrastructure such as berths for alongside mooring, shore equipment and dredging. These upgrading programmes, as well as port expansion plans, not only improve the port development on the one hand but also relieve bottlenecks in coal distribution on the other.

In terms of inland waterways, efforts will be concentrated to dredge 8,000 km of channels capable of handling vessels over 1,000 tonnes, 6,000 km for 500-tonne vessels, and 6,200 km for 300-tonne vessels. Dredging operations will be undertaken along the main steams and large tributaries of the Yangtze, Pearl, Heilongjiang and Huaihe rivers, and the Beijing-Hangzhou Grand Canal (Li, 1993). At present the major inland waterways for coal transfer are concentrated along the Yangtze River. Four coal-loading river ports, Pukou (Nanjing), Yuxikou (Wuhu), Hankou (Wuhan) and Zhicheng, together have a total coal-handling capacity of 20 MT, connecting to the railways on land. In 1990, the coal loaded from these four ports amounted to 14.44 MT. It was generally tranferred from up to down reaches of the Yangtze River, and to the major coal receiving ports of Jiujiang, Jianbi and Chongqing. Undoubtedly, the loading and unloading capacities for the coal river ports will be improved after the dredging programme is completed, which will facilitate joint water and land transport as well as joint river and sea transport, offering another east-west water corridor for coal transfer.

Though coastal shipping--which offers an economic alternative to north-south railways--has likewise grown more rapidly in recent years, the economics in connection with coal transfer over different transport modes should be examined on a case by case basis before the transport infrastructure projects are initiated. Just as coal-mining costs vary considerably in China, depending on the type of deposit, coal transport costs also vary widely depending on the factors related to transport infrastructure such as the available transport mode (rail, ship, road), degree of capacity utilization, and topography. Considering that most rail lines out of the coal-producing areas of North China are operating at or near capacity, the appropriate transport cost to use for the purpose of comparison is the long-run marginal costs (LRMC are total costs including capital construction, operation, and maintenance costs, calculated by using an appropriate factor to reflect the opportunity cost of capital based on construction of new lines). For example, LRMC for transport over a 1000-kilometre distance by double-track railway may be some Y 20 per tonne, but about Y 30 per tonne on a single-track railway line. Coastal shipping over several thousand kilometres may be Y 20-30 per tonne, while road transport cost might be just as high at a distance of only 200-3000 kilometres (see Table 3.6) (World Bank, 1985). The combined use of rail and water transport may be economical on some routes but not necessarily on all. The Government estimates that for Datong-Shanghai, combined rail/water transport (through Qinhuangdao port) could be 20 percent cheaper than direct rail haulage. If several modal transfers (for example, rail to ship to rail to road) are required to transport coal, say, from Shanxi to an inland city in the South, total transport costs could be Y 40-60 per tonne, justifying coal production in the South even under unfavourable conditions and at high costs (up to Y 80-100 per tonne----or 2 to 2.5 times the production costs at the more favourable deposits in Shanxi province). By these lights, local production cost, for example, in Liaoning province approximately 1,000 kilometres away from the Shanxi coal-fields, could still be competitive. So the economic choices need to be thoroughly studied before the trade-offs are made between higher mining costs and the lower transport costs of regional mines on the one hand, and lower mining costs and higher transport costs of concentrated mining on the other. Also economic comparative advantage should be analyzed for different options such as the rail-via-sea, rail-via-river and all-rail routes, and case by case analysis should be performed carefully before traffic is assigned to any particular route and modal combination. Unfortunately, this issue of comparative costs was not emphasized until recent years.

Nevertheless, judging from the point made earlier that the rail system is already overburdened, diversion of the coal traffic from the rail to the sea is needed to relieve congestion on the railway main lines. The ongoing port infrastructure projects attest to the planner's appreciation of this point.

Table 3.6 Indicative Costs of Coal Transport by Modes, 1986

Transport mode	Route	Distance(km)	Cost (Y/t)
Railways	Datong-Beijing	300	6
	-Qinhuangdao	658	12
	-Shenyang	1,000	20
	-Wuhan	1,500	30
	-Guangzhou	2,400	48
	Taiyuan-Shanghai	1,500	30
	-Qingdao	900	10
	-Wuhan	1,200	24
Waterways			
30,000 dwt bulker	Qinhuangdao-Shanghai	1,350	14
10,000 dwt coaster	Qingdao-Shanghai	750	10
3,000 tonne barge	Wuhan-Nanjing	800	12
1,500 tonne barge	Xuzhou-Nanjing	400	7
Roads			
25 tonne truck	Datong-Beijing	300	75

Source: World Bank, 1985.

Oil Ports

Development of oil ports accompanied the large-scale production of eastern oil fields in the 1970s. Much of the impetus, as recorded before, stemmed from the ambition for oil export and the needs for oil transfer from the northeast to the southern oil refineries on the coast or along the Yangtze River. However, the lack of berths and back-up facilities for oil supply, and much worse, the shallow draught afforded by the berths in most ports have restricted the export of oil, which is a major source of foreign exchange. The construction of oil berths in some ports provided an initial spur to China's port development.

Generally speaking, when a direct water route is available for transferring petroleum between supply and demand points, the mode of water transportation may be cheaper than pipeline. This is especially the case for longer-distance movements in which shipping channels are deep enough to accommodate large tankers (Figure 3.7). With excellent harbour conditions and favourable locations (close to Daqing oilfield in the North-East, Huabei and Shengli oil fields in the Bohai Bay Rim), three northern ports, Dalian, Qinhuangdao and Qingdao, were given priority for oil-related infrastructure development.

Dalian is the oldest gateway for oil inflow and outflow of the North-East. Since the discovery of the Daqing field, it has long been an outlet for Daqing's oil and petroleum products. The original oil terminal has been expanded several times over, however, it cannot meet the increasing demand for oil export. Expansion construction started in 1974 in Zhanyuwan, a new port zone with 17.5 metres of water depth. Two years later a deep-water oil wharf able to accommodate 100,000 dwt tankers was put into operation with an annual handling capacity of 15 MT. Meanwhile the oil pipeline laid from Daqing through Tieling to Dalian, directly connecting to the port, was built to provide an easy access to the crude source, and thus augmented oil throughput. In 1990, the share of oil traffic in port throughput accounted for 51.8 percent, and 78.9 percent of 1989 crude oil throughput was export-oriented (i.e. outgoing traffic), especially for the overseas market (Table 3.7).

Table 3.7 Major Seaports Crude Oil Throughput, 1989 (MT)

Ports	Total		Exports		Imports	
		Foreign		Foreign		Foreign
Dalian	18.05	14.24 (78.9%)	17.51	14.16	0.54	0.08
Qinhuangdao	12.10	2.56 (21.6%)	12.10	2.56	0.00	0.00
Yantai	0.78	0.39 (50.0%)	0.39	0.00	0.39	0.39
Qingdao	12.39	6.70 (54.1%)	12.23	6.53	0.17	0.17
Shanghai	7.73	0.14 (1.8%)	0.15	0.00	7.58	0.14
Ningbo	3.91	1.27 (32.5%)	0.62	0.00	3.29	1.27
Shantou	0.13	0.00 (0.0%)	0.00	0.00	0.13	0.00
Guangzhou	3.10	0.46 (14.8%)	0.00	0.00	3.10	0.46
Zhanjiang	6.08	0.62 (10.2%)	0.18	0.00	5.90	0.62
Total	64.28	26.38 (100.0%)	43.18	23.25	21.10	3.13

Source: Ministry of Communications, 1990.

Port development in Qinhuangdao began with the building of an oil wharf in 1973, a facility rendered viable with the construction of the oil pipeline linking the port to the Daqing oil field. Two 20,000 dwt-class oil berths as well as other ancillary facilities were completed in 1974 to handle 10 MT of oil. This new terminal provided a new sea route for shipping Daqing crude oil southward. At the beginning of 1985, a berth able to take 50,000 dwt oil tankers was commissioned and boosted the oil-handling capacity of the port by another 5 MT annually. Though coal traffic enjoys the biggest share in Qinhuangdao's throughput, oil transfer placed it second among China's oil ports. As a transhipment centre, the port's oil throughput is mainly for domestic use, supplying the refineries in the North through pipelines or the southern coastal refineries by sea. Qinhuangdao has now become China's largest energy export port. For the port of Qingdao, construction of its specialized oil terminal started in 1973 in the area of Huangdao with a view to shipping out Shengli oil. Huangdao, now having an annual handling capacity of 10 MT, is able to accommodate 50,000 dwt and 25,000 dwt tankers. About half of the crude oil handled went to foreign markets, especially Japan. In 1990, about 23.1 MT of crude oil were shipped out of Dalian, Qinhuangdao and Qingdao for overseas markets, while 19.6 MT of crude reached Shanghai (8.0 MT), Guangdong (7.6 MT) and Zhejiang (1.9 MT) provinces (Yan, 1991). Also, as Table 3.7 reveals, Shanghai, Ningbo, Guangzhou and Zhanjiang are receiving ports. Zhanjiang is the most advantaged, possessing deep-water berths for 50,000 dwt tankers, and even allowing 70,000 dwt tankers to enter at high tide.

The existing port infrastructure for crude oil shipping seems not to present obvious strains, partly because most of the crude oil goes through the pipelines, and partly because oil production has been steady and the oil prospect is unpredictable. Export initiatives have to be controlled to satisfy the domestic demand, which might increase the oil flow from the northern ports to the south, therefore requiring expanded port-handling capacities. Construction of Dayaowan deep-water port in Dalian was given the go-ahead in the Eighth Five-Year Plan. Up to 70 berths with an annual handling capacity of nearly 100 MT are in prospect, and one-third of the berths will handle shipments of oil. On the other hand, the ongoing expansion and construction of new refineries on the coast has forced the refiners to seek deep-water oil terminals since their major oil sources are from overseas. As shown in Figure 3.6, deep-water terminals could take the very large crude carriers (VLCCs) necessary to achieve economies of scale, especially those generated over the longer distance hauls. China now lacks the deep-water berths to accommodate oil tankers of over 100,000 dwt, and so is denied most such economies. Nevertheless, several sites for deep-water port construction have been selected.

One project under way during the Eighth Five-Year Plan involved building a deep-water port at Meizhou Bay in Fujian province. Crude oil was transferred partly from the Shengli field and partly from the Middle East to supply the Fujian Oil Refinery. A 100,000 dwt-class crude oil wharf as well as a 10,000 dwt-class product wharf have been built in Meizhou Bay with a total throughput of 6.2 MT. The port is expected to develop a 200,000dwt-300,000dwt oil wharf in tandem with the expansion of the Fujian Oil Refinery from its existing capacity of 2.5 MT to 10 MT during the Ninth Five-Year Plan (1996-2000). Another prominent project, a 200,000-dwt class oil terminal, was constructed and put into use in Aoshan Base of Zhoushan in Zhejiang province in 1993. It successfully unloaded "Lampas", a 270,000dwt British oil tanker and transferred 190,000 tonnes of oil to storage tanks within two-and-a-half days; a marked improvement on the 15-to-30 days previously required for sea-based barging operations for 100,000-tonne tankers. The base, a US$30 million joint venture by the Zhoushan city government, the Sinochem Intertrans Co. Ltd. and the Lee Fong Industrial Ltd. of Hong Kong, now has a 200,000 dwt oil dock, two 100,000-cubic-metre stock tanks and two 50,000-cubic-metre storage tanks. In addition, the base plans to build a 200,000-cubic-metre oil storage tank and a 50,000 dwt oil dock with an annual designed handling capacity of 10 MT.

Meanwhile, a series of joint-venture refinery projects are being planned. In Dalian, a five-million-tonne per year refinery project worth US$800 million was slated to start in 1994, jointly run by Sinochem, the French firm Total and other Chinese partners. The refinery will process crude which is 50 percent Saudi Arabian heavy and 50 percent Saudi light grades with technology and equipment provided by Total. In Qingdao, a joint-venture refinery of 10 MT refining capacity is also coming on line involving the Saudi-US company, ARAMCO, the South Korean refiner Ssangyong and Chinese partners. CNOOC also plans to build an 8 MT per year joint-venture refinery and an ethylene plant with oil major, Royal Dutch Shell, SINOPEC and the provincial government in the city of Huizhou in Guangdong province. The crude oil will come from both Chinese offshore fields and the Middle East. If all these coastal refinery projects come to fruition, they will certainly require big ports to accommodate the long-haul VLCCs consistent with scale economies in transport. Accordingly, considerable investment in deep-water port infrastructure will be needed in the foreseeable future.

The inland waterways for crude oil handling are concentrated on the river ports along the Yangtze River, especially the port of Nanjing (Table 3.8) which is connected with the Luning crude pipeline. At this transhipment point, crude oil is transferred from the pipeline or Shanghai port to the river ports on the lower reaches of the Yangtze River and provided to the refineries along the river in Jiangsu, Anhui, Jiangxi, Hubei and Hunan provinces. In 1990 crude oil shipment through inland waterways reached 14 MT. Dredging operations will increase the port capacities for oil transportation.

Table 3.8 Major Inland River Ports Crude Oil Throughput, 1989 (MT)

Ports	Total		Exports		Imports	
		Foreign		Foreign		Foreign
Nanjing	22.34	0.66	14.19		8.15	0.66
Chenglingji	3.15				3.15	
Wuhan	2.10				2.10	
Jiujiang	1.46				1.46	
Anqing	2.72				2.72	
Total	31.77	0.66	14.19		17.58	0.66

Source: Ministry of Communications, 1990.

Petroleum refined products are mainly carried by rail, which accounted for over 77 percent of the total shipment. In contrast, waterways are responsible for about 14 percent. Most of the coastal refineries have their own wharfs, the recipients of a large flow of petroleum products. Dalian is the port outlet for refined products from the Northeastern refining bases to the East and South. The river ports mentioned above are also responsible for handling the refined petroleum from the refineries along the Yangtze River, distributing products to the Central-South region, and mainly the cities along the river. In 1990, this category's shipment amounted to 4.7 MT, managed by the Yangtze River Petroleum Transportation Corporation. Diversion of petroleum traffic from the railways to the pipelines or ports needs to be increased. In 1990, the total pipeline length for crude oil was 9,700 km, but only 1,100 km for petroleum products.

Alternatives

In addition to substantial improvement and expansion of the transport system to ease existing bottlenecks, several options need to be studied for solving the serious problem related to coal transfer. Options that come to mind include mine-mouth power plants for coal conversion, a pipeline for pumping coal slurry and other measures including improving coal washing rates and reducing the amount of inert material that must be transported, readjustment of industrial distribution and the energy mix, and promotion of energy conservation and management. Yet none of these options seems to present the final answer to meeting the formidable challenge of energy distribution beyond this century. Some comments will be proffered to justify this assertion.

One alternative mode of coal transport is pumping coal slurry through pipelines. Two key technologies involved in this option have been studied seriously----the stability of the coal-water mixture and the dehydration of the slurry before it is used as fuel at the end of the line. It is believed that both problems are technically solvable. Two other uncertainties still remain, however. One is the economic viability of the coal slurry method: the actual investment needed and the operational cost are totally unknown. Another unknown is the availability of water at the coal mine for the production of many billions of tonnes of slurry. More development work is therefore needed before implementation of such a gigantic project can be contemplated.

Another alternative is the conversion of coal into electricity at mine-mouth and transmission of the electricity by high-voltage power lines. According to the analysis from the World Bank, for coal above 5000 kcal/kg, rail transport (on single-track railway lines) would be more economical than electricity transmission (Table 3.9). If double-track lines are used as in the case of Shanxi province, rail transport is economical for coal of even lower calorific value (in fact, most investments to transport coal out of Shanxi are more likely to be for electrification of existing lines, or for additional double-track electrified lines, both with considerably lower (about one half) investment costs per tonne capacity). Though power lines can be built more easily than railways through mountain ranges, another obstacle emerges. The coal mines are located in an arid region already short of water and the availability of cooling water for power plants will present a major constraint. Considering that hundreds of millions of tonnes of coal will need to be converted into electricity, the consumption of cooling water will be enormous, even if advanced cooling towers are used. At the present level of technology, the largest capacity of a single dry-cooled turbo-generator attains only 200 MW, too small for a modern power station. However, the capacity needed to be installed is still moderate at present, thus the water constraint will not be a serious problem at first. Several mine-mouth stations are already under construction or planned. For instance, a 2.4 GW power station has been planned for the vast Junggar coal field. Whether such power stations will be able to digest multi-billion tonnes of coal in the future remains an issue.

Table 3.9 Comparison of Coal Transportation and Electricity Transmission

	Coal transportation	Electricity transmission
Type	Single Track	Nine 500-KV lines
Distance	1,100 km	1,000 km
Cost Basis	1. Railway at Y 3.6 mil/km 2. 330 locomotives at Y 1.2 mil each 3. 14,300 coal cars at Y 36,000 each	1. Transmission line at 0.3 mil/km 2. Substation at Y 120/KVA 3. Power plant Y 260/KW
Total Capital Investment	Y 4.871 billion	Y 5.884 billion
Unit cost of energy transported	30.5 yuan/tonne (5,000 kcal/tonne)	30.9 yuan/tonne (5,000 kcal/tonne)

Source: The World Bank, 1985.

It can be averred that China's coal transfer issues triggered the initiation of a wide range of transport infrastructure projects, though many of these find employment moving other commodities and products as well. At any rate, this point is incontestable: transport infrastructure, led by rail but embracing marine facilities too, has been perceptibly moulded throughout China by coal developments in Shanxi in recent years and will be moulded by developments in Shaanxi and the west of Inner Mongolia in the future. Whether the new plans are adequate to overcome railway bottlenecks and handle more and yet more massive coal movements still remains to be seen. The implications of this state of affairs are the concern of the next chapter.

CHAPTER 4 IMPLICATIONS AND SUMMARY

As evidenced in the previous chapters, China is suffering appreciable energy shortage in general and severe regional mismatch between energy supply and demand in particular. Aiming to address this problem, the central government set about implementing an energy expansion strategy through the establishment of energy production bases in the appropriate areas which was accompanied by large-scale transport infrastructure programmes transferring energy from the producing bases to the consuming centres. Such energy transfer programmes, like any development initiatives in China, were motivated by hard-headed national needs. They will produce broad implications for regional development. On the one hand, the new railways, ports and coastal shipping links will eliminate the energy shortages prevailing in the consuming regions, so ensuring their rapid economic growth, while attaining the national goal of quadrupling the gross value of industrial and agricultural output by 2000. On the other hand, the very existence of these infrastructure facilities will not only better serve the developed regions, but also stimulate the less-favoured regions which host them. Thanks to their ability to handle all manner of goods besides coal and oil, railways and ports promise to unlock the door to industrial development in these regions. It is thus apposite to take a closer look at the implications of energy transfer in these aspects. A brief summary of the issues raised and discussed will be given at the end of this chapter.

Implications Germane to the Coastal Regions

The most striking direct and positive effect of the massive transport programmes is undoubtedly the ability to alleviate transport bottlenecks and increase the accessibility of the eastern regions to energy resources. Development cannot occur without movement, and furthermore, economic growth in the eastern regions cannot be realised without efficient movement of coal and other raw materials. According to the 1985 World Bank report, the transport investment in China was just over 1 percent of GDP, quite a low figure compared with other countries (World Bank, 1985). Fast traffic growth has been accompanied by relatively low investment, at least until very recently. Moreover, the investment in transportation lagged behind that in energy industries. The investment proportion between transport and energy sectors dropped from 1.24 in the First Five-Year Plan to 0.65 in the Sixth Five-Year Plan (State Planning Committee, 1991). The upshot was transportation bottlenecks which partly contributed to the energy shortages in the East and constrained that region's economic development. Spending on transport infrastructure, then, is obviously a response to this hindrance.

Coal transfer is deemed of vital concern since it is the predominant national energy source in the first place, and the cause of serious regional imbalances in energy production and consumption in the second. Having been faced in recent years with the dilemma of placing energy production close to producing sites or near to consuming regions, it is apparent that the government has come down on the side of the former, choosing to focus energy production on the northern interior provinces as a coal supplying base for the consuming regions concentrated in the coastal provinces. Thus a large proportion of the money-consuming transport projects in China is concerned with the transport of coal. Projects aimed at easing coal movement, and at facilitating exports, have taken a large slice of transport and communications funding, which was stepped up in 1987 when capital construction on transport and communications was raised from an originally scheduled 12 percent to 14.8 percent of total state capital construction spending. Construction of new berths----especially large, deep-water berths----and improvement of loading and unloading equipment were simultaneously started at the ports, as seen in Chapter 3.

If alleviation of transport bottlenecks were to be taken as the main investment criterion, the coastal provinces would be the main recipients of this additional investment, both in terms of railways and ports. During the period up to 1978, hardly any significant transport facilities were set up or expanded in the coastal area owing to the shift in the emphasis of regional development towards the interior. As a case in point, during the 1960s construction west of the Beijing-Guangzhou line absorbed over 80 percent of the nation's investment in railways, leading to the further deterioration of the transport system in the coastal zone

(Li[2], 1990). Improvement of the transport sector was thereafter focused on the coastal regions, reflecting the ever-increasing demand for imports and exports confronting the ports and the expansion of the capacity for coal transport. Once established, the railways and ports are open to diversification, as well as serving to distribute coal throughout the domestic economy or to despatch coal overseas to achieve export earnings. They have also provided a solid base for the implementation of the "open-door policy" and the development of foreign trade which by 1985 made up 35 percent of the total throughput of China's seaports.

The new focus for the development of transport is reflected both in the pattern of foreign investment and the location of industry. The willingness of Japan and the World Bank to finance high-capacity rail lines in East and North China has certainly influenced the redirection of investment away from the interior. The arrival of large lending programmes for transport infrastructure has served to increase the emphasis on investment in coal-carrying railways and coal terminals. Japan's interest in assuring supplies of coal accounts, in no small measure, for its willingness to advance such loans. The Beijing-Qinhuangdao and Yanzhou-Shijiusuo lines, together with facilities at the terminal harbours of Shijiusuo (Rizhao), have been financed by a series of Japanese loans since 1979. The World Bank has funded the inland sections of these lines, from Datong to Beijing, and Xinxiang to Heze. Current foreign-currency loans are being made for improvements to the Longhai railway between Zhengzhou and Baoji, and to the Beijing-Guangzhou line between Zhengzhou and Wuhan.

In addition, transport infrastructure had a bearing on the location of industrial activities. The location of China's oil refining and petrochemical industries was a faithful reflection of the effects of transport improvement. The pipeline network is intimately involved with linking oilfields to ports (seaports and river ports), and oilfields to refineries (often one and the same thing). Thus most refineries were established along the coast and the Yangtze River or along the major oil pipelines in the eastern regions. Their refining capacities accounted for 90 percent of the country's total. Recently, large-scale refineries are being accorded priority and placed in coastal locations in conjunction with port expansion. Similarly, various economic activities are clustered in the ports, especially the heavier industries such as iron and steel, thermal power generating, oil refining and petrochemicals. They form port-based industrial complexes in order to take advantage of economies of scale in infrastructure investment, economies in cargo handling and bulk economies in transport as well as of favourable location to attract foreign investment, equipment and management skills. For example, Meizhou Bay in Fujian province is being planned round an industrial complex led by oil refining, an industry intimately associated with a deep-water port. Some other export-oriented development zones or free-trade zones are also centred on the port function of inducing the import and export trade development which is an essential prerequisite for modern economic growth.

Therefore, the provision of improved transportation infrastructure incontestably did have a positive effect on the development process of the coastal regions through expansion in directly productive activities. With other central investment and policy support, the coastal regions were given privileges designed to allow them to realize the full extent of their economic development. Since 1978, the coastal region as a whole has maintained two-digit annual industrial growth rates. Nevertheless, rapid economic growth will necessitate continued and stable energy supply, and hence energy transfer. It is therefore likely to be trapped into a circle such as this: coastal economic development--increased energy supply--expanded coal transfer--rapid economic growth--huge energy demand again... Construction of transport infrastructure will never catch up with the demand of the coastal regions for coal.

Power industry is the largest coal-consuming sector while power supply in the coastal provinces still falls short of demand and power cuts are commonplace. Currently China's per capita energy consumption is only half of the world average, and the share of electricity in the final energy consumption is even less than half of that in the developed countries. The percentage of coal transformed to electricity in China is very low, only 30.5 percent in 1986, low in comparison with the United States (85.1 percent) and England (72.4 percent) (Table 4.1) (State Planning Committee, 1991). Therefore, the continuing consumption of coal for power generation will not change significantly in the short or medium term. Table 4.2 indicates that the eastern power grids ranked first in both installed capacity and power generation. In 1990, the coastal region accounted for 53.7 percent of generating electricity and 58.0 percent of raw steel output, while only possessing 5 percent of coal resource and 21 percent of coal production. From 1986 to 1990, the coastal thermal-electricity increased by 761.8 10^8KWh, or 41.44 million tonnes of coal equivalent (Table 4.3), and was responsible for 62 percent of the increased coal imports into the regions. By comparison, in 1990, the electricity transferred from the interior to the coast was only 115 KWh, amounting to 4.2 percent of the total electricity consumption in the coastal regions. It is therefore evident that the coastal provinces mainly depend upon imported coal for power generation. Significantly, their industrial coal consumption rate was even higher than that of the major coal-producing provinces (Table 4.4).

To ensure transport of coal has been the main point of the railway construction undertaken during the Sixth Five-Year Plan and subsequent periods. The railways and ports being constructed and planned during the Eighth Five-Year Plan are mostly involved with coal transfer. In consequence, the share of net coal imports into the coastal regions in the total coal imports of the country rose from 72.2 percent in 1980 to 74.1 percent in 1985 and 80 percent in 1990. Nevertheless, the increased coal transport has not effectively assuaged the shortage of energy in the coastal regions. The North-East, East and Central-South, the three major industrial regions, will lack 390 MT of coal in 2000. The East will suffer most severely, registering a shortfall of 200 MT (Yan, 1991).

As a result, the economic development in the coastal regions will be markedly constrained by inadequacy of the transport system in general and of the energy transfer network in particular for the foreseeable future. Although considerable investment has been made in transport infrastructure in recent years, much of it represents an attempt to make up for earlier neglect. On account of the long lead-time for transport infrastructure investment (for example, the railways average 5 years, the roads average 3-4 years, the seaport berths average 4 years), the investment input after 1995 will not generate any capacity. In the Eighth Five-Year Plan and Ninth Five-Year Plan respectively, 90 percent and 77 percent of the total transport will remain concentrated on the existing network. Therefore constraints of transport will reshape the space economy. The reconcentration of heavy industry in the energy-rich areas of northern China is largely a product of transport constraints, providing an opportunity to spread economic development inland. Meanwhile, the coastal regions were called upon to transform their industrial structure from heavy to light and from extensive to intensive development. In the recent past there also have been plans for substantial investment in hydropower and nuclear power to help solve energy shortages in the East and South China (for instance, two nuclear power stations have been put into operation, one is Qinshan in Zhejiang, and the other is Dayawan in Guangdong). These plans pushed China towards exploiting alternative energy resources which will eventually have an impact on the space economy.

On the ground, the imbalance of regional economic development is the underlying reason for regional energy supply-demand mismatch. Reluctant to jeopardize the growth impetus of the coast because the well-being of the entire country rests on it, the central government is likely to continue to encourage the western and central regions to serve the eastern coastal region's needs. However, only through large investment in transport infrastructure will it be at all possible to eliminate the situation of transport as a restrictive factor on the coastal economic development. If large, heavy industries continue to concentrate there, the problem is worsened.

Table 4.1 Coal Consumption Structure in China and Some Industrial Countries, 1980, 1985 and 1986

	China			U.S.A.	Japan	England	Poland
	1980	1985	1986	1986	1986	1986	1986
Power industry	20.3	21.5	22.7	85.1	22.4	72.4	27.1
Coke industry	9.8	7.8	7.8	4.5	64.5	10.5	12.2
Railways	4.0	3.2	2.9	---	---	---	1.4
Other industries	45.3	43.9	43.5	9.3	12.4	8.6	30.0
Residential use	20.6	23.6	23.1	1.0	0.7	8.5	18.3
Total (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total (MT)	610.1	816.0	861.9	729.1	103.9	119.5	160.5

Source: State Planning Committee, 1991.

Table 4.2 Chinese Power Grids

	Installed Capacity (10^4kW)			Generation (10^8kWh)		
Region	Total	Hydro	Thermal	Total	Hydro	Thermal
Northeast	1320.7	291.6	1029.1	665.6	112.4	553.2
North	1247.9	75.7	1172.2	694.1	12.5	681.6
East	1414.4	188.9	1225.5	761.9	43.9	718.0
Central	1364.1	524.6	839.5	664.1	223.6	440.5
Northwest	585.2	249.4	335.8	301.2	106.6	194.6
Southwest	577.7	277.5	299.9	275.0	116.8	158.2
South	443.8	215.6	228.2	210.6	78.4	132.2

Source: Lu, 1993.

Table 4.3 Thermal Power Generation and Equivalent Coal Consumption in the Eastern Region, 1986 and 1990

	Power generation 1986(10^8kWh)	Power generation 1990(10^8kWh)	Growth during 1986-1990(10^8kWh)	Equivalent coal consumption (MT)
Beijing	102.3	123.3	21.0	1.00
Tianjin	78.4	94.9	76.5	0.86
Hebei	287.4	361.9	74.5	3.17
Liaoning	300.7	400.4	99.7	5.11
Shanghai	267.6	284.1	16.5	0.86
Jiangsu	263.4	403.9	140.5	8.00
Zhejiang	109.3	152.7	43.4	2.26
Fujian	35.7	58.5	22.8	1.38
Shandong	299.3	445.9	146.6	7.54
Guangdong	119.7	273	153.3	9.74
Guangxi	29.7	56.7	27.0	1.72
Total	1893.5	2655.3	761.8	41.63

Source: Yan, 1991.

Table 4.4 **Comparison of Coal Consumption Rate in the State-Run Enterprises in the Major Provinces, 1979-1988**

Major Coal-Consuming Provinces	Shanghai Jiangsu Zhejiang Guangdong	6.7% 7.8% 9.1% 6.2%	Major Coal-Producing Provinces	Hebei Shanxi Shaanxi Ningxia	3.6% 6.1% 4.9% 5.0%
National Average		4.9%	National Average		4.9%

Source: State Planning Committee, 1991.

Implications for the Interior Regions

The interior regions constitute the Middle and Western regions which have abundant energy resources, coal, oil and hydroelectricity, but are beset by economies which lag behind the Eastern regions. Large-scale expansion and construction of the railways and ports devoted to energy transfer extends an opportunity for the interior's development.

It was discovered from the case studies carried out by the Brookings Transportation Research Program that investments in transportation occurring in low income, relatively static areas failed to have much of a catalytic effect. Such failure appeared to be attributable to the dearth of easily exploitable natural resources in the region, along with a failure to combine other more directly productive investments with the improved transportation (Wilson, 1970). By way of contrast, China's recent transport investment in the interior has mainly been concentrated in the energy-rich regions, such as the North, Northwest and Southwest, especially in the northern coal-rich regions. Thus, discussion of the impacts of the improved transportation on these coal-producing regions cannot be isolated from mining and its related investment in the regions. Regarding this point, the magnitude of required transport investment would become a component of the whole investment essential to regional development. The incidence of coal deposits is certainly a decisive factor accounting for the northern region being the chief recipient of massive investment from outside, simply because coal offers the region an unbeatable bargaining counter (Todd and Zhang[1], 1994). According to the export-base theory, the sale of goods with regional comparative advantages, in turn, directly or indirectly provide resources to the commodity-exporting region, which makes possible future development to the end that multiple gains are attributable ultimately to the original export (North, 1955). Put otherwise, first, it can absorb more investment from outside, and also induced capital formation in the region may take place in the investment-goods industries and services, which usually function in a forward linkage (usually defined as a proportion of an industry's output used as an input by other industries) and backward linkage (which exists when an industry purchases intermediate inputs from suppliers) chain with the export product (Zhang, 1995). Second, it can enhance the accessibility of the region to its markets through improved transport infrastructure and other infrastructural facilities.

It is generally accepted that growth in capital is the single most important factor inducing economic development during the early stages, accounting for 50 percent of average growth. The first goal of any planner charged with inducing regional development, therefore, is to find the best way, either by tapping domestic savings or outside sources, of breaking the vicious circle incident to capital shortages and underdevelopment. To establish an effective means of achieving an optimum rate of capital accumulation is vital for the region's economic development because it promises to be self-sustaining (Todd and Zhang[1], 1994). In fact, Shanxi, the largest coal-producing province, cornered nearly 83 billion yuan of investment between 1952 and 1990, two-thirds of which came from the central government. About one-third of this investment was directly ascribable to mining. The rest, ostensibly independent of mining, is in large part related to it all the same. In 1989 the state invested 2.63 billion yuan in fourteen key provincial projects, with 80 percent of state investment centred on development of the energy industry and transport and communications. It also means that the adjoining regions through which the transport links run will also be earmarked for much investment. From Table 4.5 it can be seen that the railways leading from Shanxi involved intimately with coal movement account for more than 80 percent of the total freight transport.

Table 4.5 Major Railways' Coal Transport, 1990

Railways	Total Transport MT	Coal Transport MT	%
Datong-Qinhuangdao	34.00	34.00	100.0
Datong-Beijing	66.52	54.23	81.5
Yuanping-Beijing	16.97	13.31	78.4
Beijing-Qinhuangdao	42.23	40.95	97.0
Taiyuan-Shijiazhuang	64.23	47.86	74.5
Taiyuan-Jiaozuo	35.10	31.40	89.5
Taiyuan-Fenglingdu	10.12	4.55	45.0
Beijing-Shenyang	87.87	52.30	59.5
Shijiazhuang-Dezhou	95.42	32.29	71.1
Jinan-Qingdao	35.55	19.47	54.8
Xuzhou-Pukou, among Tianjin-Pukou	70.28	38.84	55.3
Zhengzhou-Wuhan, among Beijing-Guangzhou	62.35	33.80	54.2
Luoyang-Baofeng, among Jiaozuo-Zhicheng	25.58	10.83	42.3

Source: Yan, 1991.

In any case, many of China's long-term industrial plans have been built around supplies of coal from Shanxi and "San Xi" (Shanxi, Shaanxi and the west of Inner Mongolia) energy base. In return, of course, the economic development in the coal-producing regions is dependent on export of coal, which will be thwarted without efficient transport networks to move coal out of the regions on a worthwhile scale. Transport bottlenecks plagued these regions, especially Shanxi. Severe problems remain, with every year since 1980 seeing Shanxi's mines producing more coal than the transport system can handle. Eighty-five percent and seventy percent of Shanxi's rail and road freight respectively are involved in coal transport, yet coal stockpiles are growing. Significant investment in transport infrastructure will certainly ease the channels for coal movement to some extent. Also the establishment of an integrated infrastructure system will strengthen the east-west and north-south links, and reinforce the exchange of goods, technology and information besides coal and other raw materials between the interior, coastal and even overseas regions.

In the case of Shanxi, because it is largely a single-commodity economy, the province has to try to acquire daily necessities and consumer goods by exporting its coal to other provinces within China as well as by attempting to earn much needed foreign currency by exporting coal abroad. No less than 58.8 percent of Shanxi's income from the sale of commodities abroad comes from the export of coal, with Japan and Hong Kong being the main importers. In keeping with the idea of regional specialization, Shanxi exchanges its coal for the commodities it needs in a style of barter that is usually referred to as compensatory trade. Coal has been exchanged for rice, edible oils, building materials and other such essential commodities, as well as Shanghai ready-made suits. The more developed provinces also trade with hard cash, services and expertise. The point to stress is that the improved transport infrastructure provides Shanxi with essential links with other regions, and it was both a consequence and cause of enhanced regional specialization.

In addition, the alternatives to alleviate transport bottlenecks are furnishing energy-producing regions with a new development initiative. As stated above, on account of transport problems, both the energy-intensive industries in the coastal region and the energy-producing centres in the interior cannot operate at full capacity. For instance, Shanxi now has 25 million tonnes of surplus coal, and coal output in Inner Mongolia and Ningxia is fixed according to the tight limits of transportation. But in Liaoning and Jilin provinces, energy-intensive industries are operating 20-50 percent under capacity because electric power and coal are in short supply. At the same time, the demand for goods produced by these industries is rising rapidly. During the period of the Sixth Five-Year Plan, China spent US$29 billion on the import of these goods, exceeding the total foreign exchange earnings from petroleum exports for the corresponding period (Anonymous, 1988). Exacerbated transport bottlenecks have persuaded the government to insist that heavy industrial projects using large quantities of raw materials be built close to the sources of the materials. This trend has accelerated since the beginning of the Seventh Five-Year Plan. Areas which are benefiting from this locational policy are those which permit coal transport to be minimized and those where resources can be found close together. Southern Shanxi and western Henan are good examples. These areas are close to coalfields, but also have mineral resources particularly attractive in making products which are either in short supply or represent import replacements.

A programme for developing aluminium production is under way, with those sites intended to use coal as an energy source located on coalfields----for example, at Jiaozuo in western Henan.

Fertilizer plants, where they are also intended to use coal, have similarly been sited on coalfields----for example, at Lucheng near Changzhi in southern Shanxi. As a large volume of coal will be used to generate electricity, the installation of thermal power plants in mining areas connected by long-distance power lines with the more populous eastern region may, in some cases, prove a viable alternative to the building of new railways. Current preliminary plans are to locate roughly half of thermal power capacity additions during 1986-2000 in coal-mining areas. For example, in Shanxi, a number of power plants are undergoing significant expansion or construction around the major coal-mining areas of Datong, Taiyuan, Pingshuo, Yangquan and Jingcheng as well as along the Huanghe river. When all these power plants are completed, Shanxi will be generating 85,000 million-100,000 million kwh of electricity, as against 12,000 million kwh in 1980. By that time, Shanxi's power will be sent to the industrial areas along the coast. Complementing newly-built or rebuilt railways and ports, power lines will lessen the strain in shipping out Shanxi's coal. Furthermore, coal preparation plants were built in conjunction with mine-mouth power generation to remove rock and impurities (20 to 30 percent of the output) and reduce the waste to be transported. Usually after washing, the percentage of rock and impurities in raw coal will be reduced to around 10 percent. At present the coal washing rate is 18 percent in China and only 7 percent in Shanxi. If this rate rises to 30-40 percent, the savings of transport capacity will average 30-39 MT each year (Yan, 1991).

In this way, recognition of transport constraints is leading to something of a reconcentration of heavy industry in energy-rich areas of the country. This would help the eastern coastland to concentrate efforts towards adjusting the structure of industry and making full use of its advantages in technology. It would also be conducive to the development of the entire economy both by promoting overall energy-use efficiency and by utilising production economies at their optimum rate.

Therefore, energy transfer has contributed profoundly to regional development in both energy-producing regions and energy-consuming regions. It has done so in two respects: first, by attracting outside capital investment (from both domestic and foreign sources) into the region, a phenomenon which in orchestrating a leap in regional income and allowing new investments to be devoted to local needs; and second, by establishing an integrated infrastructure system in the region, which aims not only to relieve the existing transport bottlenecks and reduce the energy supply-demand gap, but also to facilitate energy development in energy-producing regions and satisfy the energy needs of economically-significant regions. However, transport does not work miracles, and integration of transport planning with energy and other economic sectors is essential to development strategy. The transport programmes described in Chapter 3 aim to ease the critical bottlenecks by 2000, but how soon and how much this target will be realized is dependent upon how well such integration is carried out.

Last, but not least, it is recognized that all the patterns of energy production and supply implemented in China since 1949, and the roles played by the different transport modes engaged in energy haulage, are the outcomes of basic policies that have a strong bearing on regional development. "Implicit in these policies is the understanding that decisions made about the scale and location of energy production, the movement of energy resources and the expansion of railways and ports, ultimately aim to attain territorial economic integration, an integration tempered by acknowledgement of the need to reduce the glaring imbalances contained in the coast/interior divisions obtaining in the country" (Todd and Zhang[2], 1994).

The Chinese government has been making strenuous efforts to rectify that regional imbalance since 1949, using industrialization as its root. In 1949, over 70 percent of the industrial assets and output were concentrated in the coastal areas while the rest of the country shared the remainder. From the 1950s, centrally-directed investment was oriented to the interior with the establishment of heavy industry and its accompanying transport infrastructure there (Table 4.6). In terms of the value of fixed assets, the interior was clearly the beneficiary. Nevertheless, the coastal region still produced nearly 60 percent of the national Gross Value of Industrial Output (GVIO) in 1983; and it managed this with only 43 percent of the total fixed assets (Table 4.7). Hence the central government's attempt to spread China's industrial facilities more evenly produced paradoxical results. China's post-1978 regional development strategy has gradually evolved into a coast-oriented one, relying on the coastal region to provide the "engine of growth" for China's economic development. It emphasizes regional comparative advantages, accepts regional disparities as inevitable, encourages foreign investment and international interaction, and seeks to foster technological innovation. It is likened to a "ladder-step doctrine", which describes a situation in which the different regions are equivalent to steps on a ladder and the coastal region is akin to a higher step. Since the three big regions of the country differ considerably in terms of infrastructure, capital, technical level, management skill and economic efficiency, according to the "ladder-step doctrine", national development strategy should first concentrate on developing the more advanced coastal region by providing it with adequate capital, energy and foreign currency. This is necessary if China is to modernize and catch up with its neighbours in economic development. Only after the coastal region has become sufficiently developed will attention be turned to the central region. Eventually the western region will be transformed after the coastal and central regions have been developed. In essence, the "ladder-step doctrine" is analogous to the liberal argument that development will diffuse gradually from the centre to the periphery. Advocates of this doctrine appeal to the national interest. While they emphasize coastal development in the short term, they promise future diffusion or trickle-down for the interior.

However, not all theorists or policy-makers accept the merits of this approach. Those that demur advance the "anti-ladder-step doctrine". Resting on a different understanding of the national interest, the "anti-ladder-step doctrine" argues, firstly, that the interior must receive the same emphasis as the coastal region in industrial development because only in this way will the interior be able fully to exploit its energy and other resources and support the coastal region's outward-orientated economic strategy. Secondly, and perhaps more to the point, the interior already lags behind the coast in the degree of development. As the coastal region receives various special privileges for it to develop first, the coast-interior development gap will further widen. A greater gap will harm the interests of both the interior and the coastal region because the interior's ability to support the coastal region with raw materials and energy will be limited. Hence it is necessary for the coastal and the interior to develop in step.

Table 4.6 State Investment in Fixed Assets (Rmb 100 Million)

Period	Coastal Amount	Coastal % of Total	Interior Amount	Interior % of Total
1 FYP (1953-57)	217.26	44.1	275.57	55.9
2 FYP (1958-62)	462.62	40.6	675.61	59.4
1963-65	147.38	37.5	245.77	62.5
3 FYP (1966-70)	262.85	29.4	631.21	70.6
4 FYP (1971-75)	625.36	39.5	959.34	60.5
5 FYP (1976-80)	988.21	45.8	1,171.59	54.2
including				
1978	200.83	44.0	255.35	56.0
1979	221.09	45.7	262.95	54.3
1980	248.69	47.2	278.46	52.8
1953-80 Total	2,703.68	40.6	3,959.09	59.4

Source: Adapted from State Statistical Bureau, Thirty-Five Glorious Years: 1949-1984, p.40

Table 4.7 Distribution of Industry by Region (1952 and 1983)

	Amount		% of Total	
	1952	1983	1952	1983
Original Value of National Fixed Assets (bn Rmb)	14.88	476.78	100.0	100.0
Coast	10.71	205.97	72.0	43.2
Interior	4.17	270.81	28.0	56.8
National GVIO (bn Rmb)	34.33	616.44	100.0	100.0
Coast	23.81	366.75	69.4	59.5
Interior	10.52	249.69	30.6	40.5

Source: Adapted from State Statistical Bureau, Thirty-Five Glorious Years: 1949-1984, p.40

The Chinese government, therefore, has been caught in something of a dilemma: on the one hand it wishes to correct the interregional disparity by endorsing the development of the interior at the expense of the coast; on the other it is reluctant to slow the "engine" of the coast growth needed as a foundation for the development of the whole country. It is apparent that transport networks provide at best a framework for regional integration, and both the coastal and interior regions are likely to benefit disproportionately from the apparent trends in the development of transport infrastructure. However, the most powerful imperatives still remain those which emphasize the development of the coastal areas. The emerging pattern is one in which coastal areas act as channels for inland ones, developing faster but relying to a large degree on inland provinces for energy and materials. It was anticipated that these coastal dynamos would bring about economic growth elsewhere because of the increased demand for energy and raw materials and because funds, technology, and managerial skills would filter from the coast and spur the exploitation of resources further inland. The upgraded east-west transport links would provide such opportunities. In the interior, the development of transport facilities will be a prerequisite for mining-led economic activities. The alternatives to address transport constraints will also foster the development of energy-intensive industries in the interior. Nonetheless, and significantly, it is unlikely to contribute to narrowing the gap in economic development between the interior and the more developed, coastal regions of China.

Certainly, the increasing disparity between the underdeveloped interior and the rapidly growing coastal areas is a long-term problem to be faced in the process of modernization. It goes well beyond transport infrastructure problems to the very heart of China's future as a viable polity.

Environmental Implications

There is much concern for the environmental problems caused by both energy and transportation in today's world. This concern extends to the interrelated field of energy transportation, which has grave impacts on the environment during the whole process of transportation from loading, unloading to storage and transhipment. Thus discussion of the contribution of energy transfer to regional development cannot be divorced from a consideration of the related environmental implications. The following discussion examines the circumstances in China.

With expanded coal production and limited transportation capacity, a large amount of coal from Shanxi piled up around mining sites or rail yards in the open air, contributing to atmospheric and water pollution owing to spontaneous combustion and coal dust particles carried by wind and water. In addition, of course, it is a waste of energy. It is estimated that the coal wastage rate at the transfer points is 2-3 percent for railways, and 3.6-6.8 percent for waterways. Oil transfer also experienced significant loss, leading to oil pollution in the rivers and oceans.

In the case of the railways, environmental concerns arise from increased air pollution emissions from locomotives and coal dust escaping from open hopper cars. There is also a noise pollution and potential safety problem due to increased traffic. In addition, shipment of increasing volumes of northern coals eastward and southward will necessitate construction of totally new railways or double-tracking of old ones, and these projects will claim relatively large areas of flat land, having marked impacts on the landscape and natural environment.

The impacts of highway movements of coal are already being experienced, most severely in Shanxi and surrounding provinces. Safety problems result from the fact that most highways used to haul coal were not designed for that purpose. The increased coal movements will cause unacceptable deterioration of the roads, making passage in lighter vehicles both difficult and unsafe. By one reckoning, a 28-tonne-truck for coal shipments will generate damage to the roads equivalent to the effect of 2500 cars (Yan, 1991). The coal movements through local communities will also increase noise levels and cause vibrations, increase emission and road dust levels, and increase spillage of coal on local streets and roadsides. Unlike railways which are the sole users and maintainers of their roadbeds, trucks share multi-user roads. This makes the impacts of these issues more severe simply because of the much greater externalities involved.

Increased port traffic also has the potential to create significant environmental problems along the waterway system. These include:

- disposal of the dredge spoil from channel and/or harbour maintenance;

- destruction of the aquatic ecosystem;
- poor water quality on account of coal and oil spills;
- reduction in shoreline property available for other land users; and
- air and noise pollution.

Coal pipelines, though not disruptive to the local community, have to deal with water and other environmental issues. Moreover, there are also concerns about initial temporary disruptions caused by pipeline construction and the potential environmental impact in case of a rupture.

The two principal alternatives to alleviate long-haul coal shipment bottlenecks--hydroelectric power and nuclear power development--carry the burden of considerable environmental problems of their own. Compared with extraction, transportation, and conversion of coal, hydroelectricity generation appears to be environmentally much more benign, but environmental considerations must be of great concern in planning for hydrogeneration capacities. The potential threats to the environment range from common losses of good farmland, disruption of the water ecosystem, change of landscape to rarer but all the more worrisome landslides and reservoir-induced earthquakes. The well-known controversial Three Gorges Dam located in the southwestern provinces along the Yangtze River is receiving widespread attention for the anticipated impacts that it will engender on the environment despite its promise to increase electricity capacity by nearly 50 percent and ease pressure on an overburdened rail transport network by lowering demand for coal.

Under the government's ambitious energy plan, nuclear power has begun to develop to alleviate energy shortage in the coastal regions. However, it is plagued with doubts about the economic viability of fission generation, to say nothing of the concern raised about operating safely and lasting uncertainties about modes of final, environmentally-benign disposal of high-level radioactive wastes. Planned siting of nuclear-power plants in the fuel-deficient but industrialized and very densely-populated eastern, southern, and northeastern locations "will not be looked on with indifference by those who appreciate the relatively high degree of reliability achieved in nuclear generation----but who are also aware of the very real possibilities of accidental malfunctions and human operating errors" (Smil, 1988).

In conclusion, considerable attention needs to be given to the handling of energy on a large scale and especially in an environmentally-acceptable manner. A comprehensive approach to environmental protection in energy transfer requires the integration of environmental criteria with all other aspects and links of energy transportation.

Summary

The aim of this study is to explore the status, causes, problems, solutions and implications of China's energy transfer, particularly in terms of movement of coal and oil, two primary energy resources vital for the country's industrialization. The major findings into China's experiences can be listed in summary form. These findings are qualified, of course, by the observation that they do not take into account the strong possibility of less-than-anticipated energy demand in consequence of vastly improved practices of energy utilisation in manufacturing industry (recollect the mediocre record of China in this respect, noted in the Preface). By the same token, they ignore the real possibility of an explosion in demand for residential uses which may occur in the aftermath of boosted per capita incomes. Since these possibilities work in opposing directions, and cannot be adequately predicted in any event, I feel justified in ignoring them henceforth.

1. Transport and energy have been singled out as the two weak links in the chain of factors that drive the national economy towards the target of bringing China in line with the developed countries by the end of this century. Such weak links are held largely responsible for the inability to implement fully the development plans for the other sectors and economic booming regions. Bottlenecks in transport are further identified as the main constraint on the development of energy resources, and on the ability to pursue policies of

energy import and export as well.

2. Coal transfer is deemed of substantial significance since coal is the predominant national energy source in the first place, the cause of serious regional imbalances in energy supply and demand in the second, and in the third, coal traffic is dominant in various transport modes and creates critical transport bottlenecks.

3. The transportation of crude oil and petroleum products does not appear to face major bottlenecks at present, but the options and costs of future transport systems should be analyzed. Increased use of pipelines could help to reduce the burden on the railways and improve refinery utilization. Also construction of deep-water ports to accommodate larger oil tankers could increase the accessibility of the coastal refineries to the overseas producers of crude. Transport will also be an important factor in developing the oil reserves that may be discovered in the western basins, since transportation costs will be critical in determining the economic viability of such efforts.

4. The major coal flows are from North to South and from North or West to East, while the oil flows are mainly from North to South. The changes of coal flows and oil flows (both crude and products) influence the modes and patterns of transport links. With expansion of coal production concentrated in the North (mainly Shanxi province) at present and in the North-West (mainly Shaanxi and the west of Inner Mongolia) in the future,

the origins of coal flows tend to be geographically confined, with the destinations much more scattered. The average coal-hauling distance will be increasingly longer, which presents the Chinese planners with a problem of major proportions in the future. An integrated transport infrastructure is needed to counter the exacerbated transport bottlenecks. The oil transfer network seems well organized, although product pipelines are wanting. Nevertheless, the transport requirements accompanying the on-going exploitation of western oil basins and the import of oil from abroad are sure to present major challenges.

5. Once it was recognized that transport development lagged behind the promotion of wholesale energy production, transport infrastructure received a significant impetus with the announcement by the government of its intention to resolve the outstanding transport problem on coal. The emphasis is placed on coastal shipping in conjunction with rail transport to the ports; thus west-east links in particular are to be strengthened. North-south links for coal movement are not neglected, but they are mainly accomplished by railways. Long-term investment plans for railways and other transport facilities need to be closely integrated with coal-mining development, and sufficient resources will have to be allocated, especially to ease critical bottlenecks.

6. The economies-of-scale factor is inherent in transport projects and their alternatives. Comparison of relative

economies of different modes (railway alone, rail-via-sea, rail-via-sea-rail, high-voltage power transmission, coal slurry, etc.) is project-specific, as costs vary from project to project. For example, the location of power plants will have to be determined by the relative advantage of development at coal mine sites--requiring high-voltage transmission to major load centres--versus development near load centres and port areas where large quantities of coal would be transported by rail or water. Decision-making should include consideration of factors such as the regional distribution of coal resources, availability of low-grade fuels from coal preparation plants, regional differences in coal development costs, relative costs of coal transportation and power transmission, and environmental implications.

7. Transport constraints pose an economic problem well beyond mere consideration of their effects on the availability of coal or oil. Accordingly, investment in transport infrastructure to relieve the bottlenecks has implications far beyond its impacts on energy transfer. Above all, it has extensive implications for regional development. Transport systems, on the whole, are indispensable to the growth pole instrument, not only in their ability "to render possible an efficient means of transfer from the mine to customer, but in their use as common carriers by all regional activities to boot" (Todd and Zhang[2], 1994). They are also used as a policy tool to achieve regional integration. However, their

negative impacts on the environment cannot be neglected in examining the regional implications, because these implications are directly linked with economic factors.

BIBLIOGRAPHY

Anonymous, "Developing Energy-Intensive Industries in Energy Centre," *Beijing Review*, Jan.18-Feb.2, 1988.

---------- "Excerpts of the Eighth Five-Year Plan (1991-1995)", *Beijing Review*, Vol.34, No.19, 13-19 May 1991, pp.11-16.

---------- "Energy Shortage Hinders Economy," *Beijing Review*, Vol.36, No.1, 4-10 Jan. 1993, pp.5-6.

---------- "Huanghua to Become Transportation Hub," *Beijing Review*, Jan.17-23, 1994, p.29.

---------- "Vigorously Develop Petrochemical Industry," *Beijing Review*, Oct.31-Nov.6, 1994, pp.11-15.

British Petroleum Company, *BP Statistical Review of World Energy*, various editions, London, 1984-93

Cargo Systems Research Consultants, *Large Dry Bulk Carriers-Employment Prospects in the Eighties*, Cargo Systems Research Consultants, Worcester Park, England, 1982.

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

China Energy Statistical Yearbook, China Statistical Press, Beijing, 1989-1991 (in Chinese).

China Statistical Yearbook, China Statistical Press, Beijing, 1989-1991 (in Chinese).

China's Communications and Transportation Statistical Yearbook, China Communications Press, Beijing, 1990 (in Chinese).

Chiu, T.N. and Chu, David K.Y., "Port Development in the People's Republic of China," in Hoyle, B.S., Hilling, D. (eds.), *Seaport Systems and Spatial Change*, John Wiley & Sons Ltd., New York, 1984, pp.199-215.

Chow, Larry Chuen-ho, "The rise and fall of Chinese oil production in the 1980s," *Energy Policy*, Nov. 1991, pp.869-878.

Comtois, Claude, "Transport and Territorial Development in China 1949-1985," *Modern Asian Studies*, Cambridge University Press, Vol.24, Part I, 1990, pp.777-818.

Dunkerley, Ramsay, Gordon and Cecelski, *Energy Strategies for Developing Nations*, Resources for the Future, the Johns Hopkins University Press, Baltimore, 1981.

Fang, Lei (eds.), *Study on China's Industrial Layout*, Ocean Press, Beijing, 1993 (in Chinese).

Fridley, David G.[1], "China's Changing Oil Industry," *Energy Program Petroleum Advisory 77*, East-West Center, Honolulu, 1991.

Fridley, David, G.[2], "China's Energy Outlook," in *China's Energy Dilemmas in the 1990s: The Problem of Reforms, Modernization, and Independence*, Joint Economic Committee report, United States Congress, Washington, DC, 1991b, pp.495-526.

Gao, Xiaozhen, *Study of the Relationship and Economic Development of the Port City in Northern China*, Ph.D. thesis, Peking University, 1988.

General Administration of Customs, PRC, *China's Customs Statistics*, Hongkong, various issues, 1983-1992.

Goldstein, Carl, "Energy: China faces tough choices on oil policy," *Far Eastern Economic Review*, Hongkong, Vol.157, n.14, Apr.7, 1994, pp.66-67

Hou, Bangan and Wang, Fenghong, "Issues of Shanxi's Coal Transportation," *Integrated Transportation*, Institute of Integrated Transportation, State Planning Committee, Beijing, 1995, pp.1-7 (in Chinese).

Howard, Maurice, "Transport and Communications" in D.S.G. Goodman (eds.), *China's Regional Development*, Routledge, London, 1989, pp.77-93.

Hua, Lifang, "New Daqin Coal Railway----Easing China's Energy Crisis," *China Reconstructs*, Vol.38, No.12, April 1989, pp.45-47.

Integrated Transportation Institute, *Report of Energy Transportation Strategy*, State Planning Committee, Beijing, 1993 (in Chinese).

Kambara, Tatsu, "The Energy Situation in China," *The China Quarterly*, London, No.131, Sept.1992, pp.609-635.

Ledic, M., "The Energy Sector," in D.S.G. Goodman (eds.), *China's Regional Development*, Routledge, London, 1989, pp.94-111.

Li, Ning, "Port Construction Stepped Up to Relieve Bottlenecks," *Beijing Review*, Vol.36, No.27-52, Aug.30-Sept.5, 1993, pp.12-15.

Li, Wenyan (eds.)[1], *China's Industrial Geography*, Science Press, Beijing, 1990, pp.57-88 (in Chinese).

Li, Wenyan[2], "Contemporary Spatial Issues," in G.J.R. Linge and D.K. Forbes (eds.), *China's Spatial Economy*, Oxford University Press, Oxford, 1990, pp.59-84.

Lu, Yingzhou, "The Prospect of Energy in the PRC," paper presented at the Training Program on Energy Planning and Management at State University of New York, Stony Brook, October 1980.

Lu, Yingzhou, *Fuelling One Billion, An Insider's Story of Chinese Energy Policy Development*, Washington Institute Press, New York, 1993.

Ministry of Communications, *Collections of Communications Statistical Data*, unpublished material, Beijing, 1990 (in Chinese).

Nef, John V., "An Early Energy Crisis and its Consequences," *Scientific American*, Nov., 1977.

North, D.C., "Location Theory and Regional Economic Growth," *Journal of Political Economy*, Vol. IXIII, June 1955, pp.243-58.

Owen, A.O. and Neal, P.N., "China's Potential as an Energy Exporter," *Energy Policy* 17(5), 1989, pp.485-500.

Pachauri, R.K., *Energy and Economic Development in India*, Praeger, New York, 1977.

Park, Se-Hark and Labys, Walter C., "Divergences in manufacturing energy consumption between the North and the South," *Energy Policy*, Vol.22, No.6, 1994, pp.455-469.

Petroleum Economist, "China's Oil and Energy Industries," London, Nov.1981.

Prasad, K. Krishna and Reddy, A.K.N., "Technological Alternatives and the Indian Energy Crisis," Paper presented at the National Seminar on Energy, Hyderabad, March 1976.

Schonknecht, R. et al., *Ships and Shipping of Tomorrow*, Cornell Maritime Press, Centreville, Md, 1983.

Schurr, Sam, and Joel Darmstadter, "Some Observations on Energy and Economic Growth," prepared for Oak Ridge Associated Universities Conference on Future Strategies for Energy Development, 1976.

Siddayao, C.M., *Energy Demand and Economic Growth*, Westview Press, Boulder, Colo., 1986.

Smil, Vaclav, *Energy in China's Modernization: Advances and Limitations*, M.E. Sharpe, Inc. Armonk, New York, 1988.

Song, Quanqi, *Energy Economy of China*, unpublished Ph.D. dissertation, The Chinese People's University, Beijing, 1992 (in Chinese).

State Planning Committee, Department of Regional Economy, *Regional Balanced Development in Energy Supply and Demand*, China Material Press, Beijing, 1991 (in Chinese).

Tang, Chuanlong and Croix, Sumner J. La, "Energy Consumption and Economic Activity in China," *The Energy Journal*, Vol.14, No.4, 1993, p.21-36.

Thoresen, Carl A., *Port Design, Guidelines and Recommendations*, Tapier Publishers, Trondheim, Norway, 1988.

Todd, Daniel and Zhang Lei[1], "Regional Policy Grounded in Minerals Exploitation, A Chinese Example," *Resources Policy*, 1994, 20(1) 5-13, pp.5-13.

Todd, Daniel and Zhang Lei[2], "Ports and Coal Transfer, Hub of China's Energy Supply Policy," *Energy Policy*, Vol.22, No.7, 1994, pp.609-621.

Wang, Shaowen (eds.), *History of Chinese Coastal Shipping*, People's Communications Press, Beijing, 1989 (in Chinese).

Wang, Xionglin, "Mineral Resources in China: Geological Exploration and Exploitation," in James P. Dorian and David G. Fridley (eds.), *China's Energy and Mineral Industries: Current Perspectives*, Westview, Press, Boulder, Colo., 1988, p.111.

Wheeler, James O., Muller Peter O., *Economic Geography*, John Wiley & Sons Ltd, New York, 1981, pp.249-256.

Wilson, George W., "The Role of Transportation in Regional Economic Growth," in E.W. Tyrchniewicz, O.P.Tangri (eds.), *Transportation and Regional Development, Proceedings of a Conference*, Centre for Transportation Studies, University of Manitoba, Winnipeg, Manitoba, 1970.

World Bank, *The Transport Sector, Annex 6 to China: Long-Term Development Issues and Options*, Johns Hopkins University Press, Baltimore, MD, 1985.

World Bank, *China: Environmental Strategy Paper*, unpublished draft report, September 1991.

World Resources Institute, *World Resources 1994-95*, Oxford University Press, Oxford, 1995.

Wu, Naitao, "China Eases Railway Bottlenecks," *Beijing Review*, Vol.36, No.27-52, Oct. 18-24, 1993, pp.11-19.

Xin Dingguo, "The Present and Long Term Strategy of China," in James P. Dorian and David G. Fridley (eds.), *China's Energy and Mineral Industries: Current Perspectives*, Westview, Press, Boulder, Colo., 1988, pp.43-54.

Yan, Changle, *Report of China's Energy Development*, Economic Management Press, Beijing, 1991 (in Chinese).

Zhang, Lei, *Mineral Industry and China's Regional Development, An Exploratory Analysis*, Ph.D. thesis, Department of Geography, The University of Manitoba, Winnipeg, Manitoba, 1995.