The above-captioned Staff Appraisal Report for China: Sichuan Gas Development and Conservation Project is a revised version of the report prepared following the approval of the Project by the Executive Directors of the Bank and does not include information deemed confidential by the Government of the People's Republic of China.
STAFF APPRAISAL REPORT

CHINA

SICHUAN GAS DEVELOPMENT AND CONSERVATION PROJECT

June 22, 1994

Industry and Energy Operations Division
China and Mongolia Department
East Asia & Pacific Regional Office
**ABBREVIATIONS AND ACRONYMS**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>bcm</td>
<td>billion cubic meter</td>
</tr>
<tr>
<td>CNOOC</td>
<td>China National Offshore Oil Corporation</td>
</tr>
<tr>
<td>CNPC</td>
<td>China National Petroleum Corporation</td>
</tr>
<tr>
<td>E&amp;P</td>
<td>Exploration and Production</td>
</tr>
<tr>
<td>EA</td>
<td>Environmental Assessment</td>
</tr>
<tr>
<td>ESMAP</td>
<td>Energy Sector Management Assistance Program</td>
</tr>
<tr>
<td>GEF</td>
<td>Global Environment Facility</td>
</tr>
<tr>
<td>GET</td>
<td>Global Environment Trust Fund</td>
</tr>
<tr>
<td>ICB</td>
<td>International Competitive Bidding</td>
</tr>
<tr>
<td>IOCs</td>
<td>International Oil Companies</td>
</tr>
<tr>
<td>JGF</td>
<td>Japanese Grant Facility</td>
</tr>
<tr>
<td>LCB</td>
<td>Local Competitive Bidding</td>
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<tr>
<td>mcm</td>
<td>thousand cubic meters</td>
</tr>
<tr>
<td>MOE</td>
<td>Ministry of Energy</td>
</tr>
<tr>
<td>MOPI</td>
<td>Ministry of Petroleum Industry</td>
</tr>
<tr>
<td>PMO</td>
<td>Project Management Office</td>
</tr>
<tr>
<td>PRIF</td>
<td>Pre-Investment Facility</td>
</tr>
<tr>
<td>SAA</td>
<td>State Audit Administration</td>
</tr>
<tr>
<td>SOE</td>
<td>Statements of Expenditures</td>
</tr>
<tr>
<td>SPA</td>
<td>Sichuan Petroleum Administration</td>
</tr>
<tr>
<td>T&amp;D</td>
<td>Transmission and Distribution</td>
</tr>
<tr>
<td>TCC</td>
<td>Technical Cooperation Credit</td>
</tr>
<tr>
<td>tce</td>
<td>ton coal equivalent</td>
</tr>
<tr>
<td>UNDP</td>
<td>United Nations Development Programme</td>
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</table>
CURRENCY EQUIVALENTS
(as of January 1994)

Currency Name = Renminbi (RMB)
Currency Unit = Yuan (Y)
1 Yuan = 100 fen
Y 1.00 = $0.11
$1.00 = Y 8.7

FISCAL YEAR
January 1 - December 31

WEIGHTS AND MEASURES

1 millimeter (mm) = 0.039 inches
1 meter (m) = 3.28 feet
1 square meter (m²) = 10.76 square feet
1 cubic meter (m³) = 35.3 cubic feet
1 kilometer (km) = 0.62 miles
1 hectare (ha) = 10,000 square meters = 15 mu
1 kilogram (kg) = 2.204 pounds
1 megawatt (MW) = 1,000,000 watts
1 gigajoule (GJ) = 1 billion (10⁹) joules
CHINA

SICHUAN GAS DEVELOPMENT AND CONSERVATION PROJECT

LOAN AND PROJECT SUMMARY

Borrower: People’s Republic of China

Beneficiaries: China National Petroleum Corporation (CNPC) and Sichuan Petroleum Administration (SPA)

Amount: $255 million equivalent

Terms: 20 years, including 5 years of grace, at the Bank’s standard variable interest rate

Onlending Terms: $250 million and $5 million would be onlent to SPA and CNPC, respectively, on the same terms and conditions as the Bank loan. SPA and CNPC would bear the foreign exchange risks.

Project Description: The project would comprise three main components: (a) a restructuring component: implementation of the first phase of restructuring the upstream oil and gas sector, based on the recommendations of an ongoing restructuring study, including commercialization and corporatization of CNPC/SPA through their transformation into joint-stock companies, introduction of a commercial accounting system and implementation of productivity enhancement and related human resources development programs; (b) an investment component: gas field development in Eastern Sichuan through the drilling of about 100 wells, seismic survey and interpretation, and construction of related surface facilities; gas field stimulation and rehabilitation of about 90 wells in Eastern Sichuan and 100 wells in Central Sichuan; and expansion as well as rehabilitation and environmental upgrade of SPA’s gas transmission and distribution system; and (c) an institution building component: technical assistance and training for the implementation of the above two components as well as for national petroleum education to upgrade the teaching and research capabilities of the local petroleum institutes and develop exchange programs between the local and foreign institutes.
**Project Benefits:**

The proposed project has been designed to promote sustainable development through institutional restructuring and alleviation of energy shortages in an environmentally sound manner. The investment component would result in incremental gas production which would help offset the natural decline of aging fields in Sichuan. The economic rate of return has been conservatively estimated at 24 percent. In addition to quantifiable economic benefits, the project would lend added momentum to policy and enterprise reforms as well as human resources development in the sector. Further, environmental degradation and health concerns (notably respiratory diseases) would be mitigated under the project through the substitution of coal (2.9 million tons per annum) by gas, which would, in turn, reduce emissions of $SO_2$, $CO_2$ and particulates. Moreover, the gas transmission rehabilitation component would enhance safety, minimize gas leakages and reduce the emissions of methane and related global warming impact.

**Project Risks:**

Gas field development in Sichuan faces relatively high geological and technical risks mainly due to complex geology and difficult operating conditions. These risks would be mitigated by the provisions of appropriate modern technology and equipment under the project. Further, to minimize the risks related to the uncertainties of economically recoverable gas reserves, a techno-economic preinvestment study on gas reserve assessment and development plan optimization has been undertaken with the assistance of international consultants. In addition, assurances have been obtained from the government on the implementation of a reform action plan for the rationalization of gas pricing and allocation criteria to ensure the financial sustainability of the proposed gas supply component. To reduce the risks of delay in implementation of the project, the Chinese authorities have agreed to maintain satisfactory arrangements for project management. Moreover, the requisite technical assistance and training in project implementation would be provided under the project.

**Poverty Category:**

Not applicable.
### Estimated Costs:

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<tr>
<th>Description</th>
<th>Local ($ million)</th>
<th>Foreign ($ million)</th>
<th>Total ($ million)</th>
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<tr>
<td>Gas Field Development</td>
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<tr>
<td>- Drilling</td>
<td>195.4</td>
<td>130.6</td>
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<td>- Seismic surveys</td>
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<td>- Surface facilities</td>
<td>22.0</td>
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<td>Gas dehydration &amp; desulfurization</td>
<td>32.2</td>
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<td>Technical assistance &amp; training</td>
<td>0.7</td>
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**Base Cost**

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<td></td>
<td>400.2</td>
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<td>Price contingency</td>
<td>60.2</td>
<td>43.6</td>
<td>103.8</td>
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**Total Project Cost /a**

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<td>500.4</td>
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<tr>
<td>Interest during construction /b</td>
<td>0.0</td>
<td>67.3</td>
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**Total Financing Required**

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<tr>
<td></td>
<td>500.4</td>
<td>444.7</td>
<td>945.2</td>
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### Financing Plan:

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<td>SPA/CNPC</td>
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**Total /c**

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<tbody>
<tr>
<td></td>
<td>500.4</td>
<td>444.7</td>
<td>945.2</td>
</tr>
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</table>

/a Project-financed goods are exempt from import duties and taxes.

/b Interest during construction (IDC) is based on onlending rates for projected disbursement of loan proceeds. Foreign exchange portion of IDC is based on the Bank’s standard variable interest rate.

/c Figures may not total exactly due to rounding.
Estimated Disbursements:

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<tr>
<td>Annual</td>
<td>25.0</td>
<td>50.0</td>
<td>55.0</td>
<td>45.0</td>
<td>35.0</td>
<td>25.0</td>
<td>20.0</td>
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<tr>
<td>Cumulative</td>
<td>25.0</td>
<td>75.0</td>
<td>130.0</td>
<td>175.0</td>
<td>210.0</td>
<td>235.0</td>
<td>255.0</td>
</tr>
</tbody>
</table>

Economic Rate of Return: 24 percent
This report is based on the findings of an appraisal mission in June 1993. The report was prepared by the following: S. Shum (Senior Financial Analyst, Task Manager), J. Fritz (Environmental Engineer), S. Khwaja (Senior Gas Specialist), H. Morsli (Senior Petroleum Engineer), C. Amana (Young Professional), D. Caplin (Energy Conservation Consultant) and J. Warren (Geophysical Consultant). The peer reviewers include: Messrs. R. Batstone (Principal Environmental Specialist), N. Berrah (Senior Energy Economist), R. Heath (Principal Chemical Engineer), C. Khelil (Petroleum Group Leader) and B. Svensson (Energy Economist). The Division Chief is R. Newfarmer and the Acting Department Director is Z. Ecevit.
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MAPS

IBRD No. 25137 China Oil and Gas Resources
1. THE ENERGY SECTOR

A. OVERVIEW

Energy and the Environment

1.1 China is the third largest producer of energy in the world. In 1991, the country's primary commercial energy supply and consumption amounted to 1,048 and 1,023 million tons of standard coal equivalent (tce), respectively. Coal is the most important source of energy, accounting for about 74 percent, and oil for 19 percent of the total production. Hydroelectric power (4.6 percent), natural gas (2 percent), and small quantities of shale oil and geothermal power make up the balance. Details of the primary commercial energy production during the period 1949-91 are given in Annex 1.1.

1.2 Few countries are as dependent on coal as China, with annual consumption of about 1 billion tons. However, increased generation of coal-based energy is both a corollary of economic growth and a major source of pollution. In particular, the combustion of bituminous coal is causing serious atmospheric pollution from airborne particulates, and emissions of sulfur dioxide (SO\(_2\)) and carbon dioxide (CO\(_2\)). Rising coal consumption in China has contributed to increasingly serious environmental ramifications, both at the local and global levels. The Chinese authorities are aware of the need to address environmental problems and recent official policy calls for economic development to proceed in tandem with environmental protection.

1.3 China has one of the world's fastest growing industrial economies. Over the past decade, its GNP growth has averaged 13 percent per annum and economic growth is expected to remain robust for this decade. Since the growth of energy supply has not kept pace with demand, energy shortages are acute in the country. With a view to sustaining both economic development and reduction of air pollution, efforts to enhance both the supply of cleaner energy resources and the efficiency of energy use have been a cornerstone of the country's energy and environmental policy.

1.4 It is commonly accepted that China has no realistic alternatives to depending heavily on coal as its primary source of energy. Nevertheless, at the margin, rational exploitation of natural gas would provide a cleaner and more efficient fuel and feedstock option to meet the growing needs of an industrial economy. However, despite China's high gas potential, gas exploration and development have been inadequate mainly due to past neglect, financing constraints, and limited access to advanced technologies. Thus, a coherent development strategy integrating energy with environmental considerations calls for an increased emphasis on economic and efficient exploitation of natural gas. It is in this context that the government has placed high priority on the proposed project.
Energy Resources

1.5 Coal. China has large coal deposits of which 30 percent are proven. In 1991, the country produced 1.1 billion tons of raw coal. By the year 2000, China aims to produce 1.4 billion tons of coal a year. The best quality coals are found in North China, particularly Shanxi and Inner Mongolia. However, insufficient transport capacity makes it extremely difficult to move coal to the large consuming centers in Central and East China.

1.6 Hydroelectric Potential. China is rich in water resources and has a long tradition of harnessing them for energy and other uses. Of the country's hydroelectric potential, only about 9 percent of it has been developed. Most of the potential is located in the southwest, notably Sichuan (70 percent), about 1,500 km away from the main demand centers. The long gestation period for hydroelectric projects has also inhibited the rapid development and utilization of hydroelectric resources.

1.7 Crude Oil. China's cumulative oil production has reached 2.3 billion tons. Crude oil production was 142 million tons in 1992.

1.8 Natural Gas. In 1992, China produced 15.6 billion cubic meters of natural gas. About 44 percent of the current gas production is nonassociated gas, mostly from Sichuan Province. The remaining production is associated with onshore oil production.

1.9 Biomass. Noncommercial biomass energy use currently amounts to about one quarter of total energy consumption in China. Fuelwood and agricultural straw and stalks are the chief biomass fuels, and they are consumed almost entirely by rural households. China is promoting a variety of measures to achieve environmentally sustainable biomass supply and consumption levels, including more efficient use of biomass, tree planting, and substitution of other fuels for traditional biomass fuels.

Institutions of the Energy Sector

1.10 Until 1988, the Ministry of Petroleum Industry (MOPI) was in charge of all the upstream activities in the oil and gas subsector, while the Ministry of Water Resources and Power and the Ministry of Coal oversaw the respective subsectors of power and coal. As part of the administrative reform in 1988, the responsibility for overseeing the entire energy sector was consolidated under the Ministry of Energy (MOE). As a first step in its major restructuring policy, the government transformed the former MOPI into a state-owned enterprise, the China National Petroleum Corporation (CNPC), which has continued to report directly to the State Council. In May 1993, MOE was disbanded during a broad government reorganization, and a new Ministry of Electric Power was established, along with a Ministry of Coal. The newly established Economic and Trade Commission oversees the overall national economic policy. The State Planning Commission, on behalf of the State Council, has the responsibility for review and approval of the strategic plans, investment programs and pricing policy of the energy sector.
Energy Investments

1.11 Energy investments in the 1980s were planned based on an expected economic growth rate of 7.5 percent a year. Actual economic growth rates exceeded this target by a significant margin, which has exacerbated energy shortages already existing at the outset. Under the Eighth Five-Year Plan (1991-95), the Government has continued to place high priority on infrastructure sectors, notably energy and transport, which are key bottlenecks in economic development. In 1992, China dedicated 3.4 percent and 1.7 percent of its Gross National Product (GNP), respectively, to develop infrastructure for energy production and transportation.

B. ENERGY SECTOR ISSUES

1.12 In addition to the already noted shortages, the main energy sector issues in China are: (a) the efficiency of energy supply and use; (b) the dominance of coal and associated environmental problems; (c) improvement in scale and technology in energy industries; (d) rationalization of energy pricing policies; and (e) institutional, regulatory and enterprise reform.

Efficiency of Energy Use

1.13 China’s energy consumption per capita is low, but consumption per unit of GNP is high compared with other countries. The high share in GNP of industrial output, the structure of industry, the use of inefficient technology, and inadequate energy management practices are major factors that contribute to this. Efforts to improve the efficiency of energy use have been a cornerstone of China’s energy policy. Particular progress has been made in building a strong institutional framework for energy conservation. During 1980-92, China’s energy intensity per unit of GNP fell by about 30 percent in real terms, and the elasticity of growth in energy use relative to GNP growth was about 0.57 (Annex 1.2). Nevertheless, further improvements in energy efficiency are crucial. Economic growth and energy supply targets for the 1990s imply that only about one half of the increased energy services required will come from new energy supplies, while the other half must come from energy efficiency improvements. This will require major progress in addressing structural and systemic issues, especially in industry, as well as still stronger programs to upgrade inefficient technology and strengthen energy management.

Dominance of Coal and Associated Environmental Problems

1.14 Many of China’s air pollution problems are related to the heavy use of coal and its dispersed, small-scale application in industry and households. Unlike the situation in most other countries, the electric power subsector is not the largest consumer of coal in China (about 25 percent of the total). Environmental problems occur at every stage of the coal chain; mining and disposal of mine waste, coal washing, transport and handling, processing and combustion, and ultimately ash disposal. The ambient concentration of particulates is the most serious problem; it is largely related to the dominant small-scale
use of coal, its high-ash content (20-30 percent), and the often incomplete combustion. The average sulfur content of the coal is relatively low (about 1.5 percent), but because coal is used so extensively sulfur emissions are increasing.

1.15 The environmental implications of continued increases in coal use highlight the need for the strict enforcement of environmental regulations and more investment to conserve coal and mitigate its environmental effects. Incorporation of modern technology, achievement of suitable scale economies, and elimination of backward small-scale capacity is a key to improving coal utilization in many subsectors such as thermal power generation. The scope for substituting cleaner fuels remains limited. The country has insufficient proven natural gas resources; its production of oil is increasingly absorbed by transport and petrochemicals; and large hydropower resources are located far away from major consuming centers.

Scale and Technology in Energy Industries

1.16 Coal Subsector. Over half of the coal produced in China comes from small-scale mining operations. Exploitation of large coal reserves through uncoordinated small-scale mining has often led to inefficiencies in production and a waste of coal resources. In the larger mines, productivity and safety could be increased by making greater use of mechanized systems and applying more efficient designs.

1.17 Power Subsector. Large-scale power development in China is beneficial from the standpoint of both energy conservation and environmental protection. Modern thermal power plants, with unit capacities of 600 MW, are about 20 percent more efficient than smaller units. The boilers of the modern utilities also support better pollution control, thus raising the efficiency of particulate removal.

1.18 Petroleum Subsector. In the petroleum subsector, there is a need to employ more modern equipment and technology at all stages of exploration and development; seismic survey and related data processing, exploratory drilling, and enhanced oil recovery in order to increase production from aging fields. Improvements in operating and maintenance practices are also needed to increase the efficiency of the subsector.

Energy Pricing

1.19 Energy price reform has proceeded steadily during recent years, resulting in substantial increases in real energy prices. In the mid-1980s, dual-track energy pricing was developed, whereby energy supplies allocated under the national plan were priced at "in-plan" prices, at levels well below incremental production costs or border prices, while higher, market-based prices were charged for energy supplied through the market ("outside of the plan"). Over the years, in-plan prices have increased in real terms, and perhaps more importantly, the portion of energy allocated at in-plan prices has greatly declined.

1.20 By early 1993, the Government had declared its commitment to abolish low, in-plan prices for all the chief forms of energy by the end of 1995, with the exception of
a few consumer categories (e.g., ammonia-based fertilizer producers). The country is now in the process of completing this transition to market-driven prices. In general, average consumer energy prices are now close to the economic costs of supply in the principal demand centers. Distortions remain, however, in both the structure of prices and inequitable treatment of different producers and consumers, requiring further concerted action to complete the transition to a truly efficient pricing system suitable for the emerging market economy.

1.21 Coal supplied at market-driven prices now accounts for over three quarters of coal consumption. In January 1993, the Government announced its intention to decontrol in-plan prices over the next three years, and followed through by cutting the amount of coal supplied at in-plan prices by about one half. Market prices are generally in line with the economic costs of domestic production and distribution and, in East China, local market coal prices are close to or even above international price levels. Further action is required, however, to fully remove production subsidies and reduce the substantial losses still incurred by the coal industry.

1.22 While the average price levels of light petroleum products are close to international prices, average prices of crude oil and heavy fuel oil have been kept substantially lower. The Government's intention is to complete the liberalization of crude oil prices within the next three years. Producer prices for natural gas remain distorted and should be adjusted to provide better incentives to find and develop more resources. Further discussions on oil and gas pricing are in paras. 2.5-2.7.

Economic System and Enterprise Reform1/

1.23 The process of transformation from a command economy to a market-based economic system was initiated in China in the late 1970s. In recent years, it has gained momentum, fueled by past successes and the strong economic performance of the more liberalized sectors of the economy. Considerable progress has been made in putting in place the appropriate macroeconomic policy framework for the transition to a market-based economy, from trade to price liberalization, to encouragement of foreign investment and nonstate enterprise development, to decreased involvement of government agencies in the management and operations of state enterprises. However, the process of reform has tended to lag in the designated strategic sectors, including energy, which has continued to operate under a highly centralized financial system. These sectors are dominated by large state-owned enterprises, many of which are relatively inefficient and high-cost operations. They are also burdened by social obligations and government policies which are inconsistent with efficient and competitive company performance in a market-based economy.

1.24 To address the above systemic issues in the country, enterprise reform has been accorded high priority by the government in the latest initiatives to promote efficiency

gains through increased competition and market orientation. In this connection, the policy framework governing the state-owned enterprises has been greatly improved by the recently promulgated "Regulations on Transforming the Management Mechanisms of State-Owned Industrial Enterprises" and "Regulations on Enterprises' Shareholding System Experiment". Further, critical complementary efforts for financial sector, pricing, fiscal, housing and social security system reforms have recently been launched by the government, with active support by the Bank. These reform efforts are indicative of the government's resolve to gradually transform the state enterprise system into a full-fledged independent corporate structure. However, given the complexity and multi-dimensional nature of enterprise reform, it will take time to complete the process.

C. ENERGY SECTOR STRATEGY

1.25 Sector reform now plays a central role in China's energy development strategy. To reduce the prevailing energy shortages in today's environment of rapid economic growth will require further major improvements in the efficiency of the supply system, in domestic and foreign capital mobilization, and in energy use. The government is committed to the reforms needed to make these improvements, including the commercialization of enterprises, the achievement of greater enterprise autonomy with respect to the government, regulatory and legal reforms to provide the framework for more market-oriented enterprises, promotion of competition, completion of price reforms, and adoption of a variety of new means to mobilize financing.

1.26 Efforts to improve the efficiency of energy use remain a cornerstone of China's energy policy; it is well recognized that China's economic development goals cannot be attained without further major efficiency gains. Focus on environmental issues in China's energy policy also has increased sharply in recent years. While heavy reliance on coal is an unescapable necessity in China, improvements in the efficiency of coal use and reduction of pollution from coal are recognized as critical. The Government's strategy in this area focuses on (a) strengthening environmental policy and regulation of emissions; (b) restructuring and renovation of inefficient, polluting industrial capacity; (c) achievement of greater efficiency and enhanced pollution control through development of large-scale power and industrial plants which properly capture scale economies; (d) transfer and development of more efficient and cleaner industrial process and coal utilization technology; (e) promotion of cleaner fuels, notably gas, as alternatives to coal; (f) further rationalization of energy prices and investment funding; and (g) deepening economic policy and enterprise reforms in the sector.

D. BANK ROLE IN THE ENERGY SECTOR

1.27 The Bank has supported 13 projects in electric power development, 5 in petroleum (including two natural gas projects), and one in coal. In all three subsectors, Bank-financed operations have included support for technology transfer, modern management practices, and the development of efficient, large-scale energy production. In support of China's gradual transformation toward a market-based economy, the Bank's assistance in the energy sector would continue to focus on the design and implementation
of institutional and regulatory reforms, rationalization of energy pricing policy, economic
energy resource development in an environmentally sustainable manner, energy conserv-
ervation, transfer of appropriate modern technology and human resources development. The
Bank has also launched a program of technical assistance and sector work on institutional
development, regulatory and enterprise reforms for power and the oil and gas subsectors
(Chapter 2). Stepped up since 1992, the Bank's assistance program for power subsector
reform includes the successful completion of technical assistance on reform options
sponsored by the Bank's Institutional Development Fund, a Power Sector Strategy Paper
which is under preparation, and reform-oriented lending operations.

1.28 A continuing dialogue (on energy efficiency and the environment) with the
Government has been established through the completion of three joint studies, Efficiency
and Environmental Impact of Coal Use (Report No. 8915-CHA, 1991), the China Energy
Conservation Study (Report No. 10813-CHA, 1992) and an Environmental Strategy Paper
for China (Report No. 9669-CHA, April 1992). Further follow-up technical assistance and
preinvestment work is currently under way with support from the Global Environment
Facility, including a national strategy of greenhouse gas emissions reduction. Because the
issues involved concern the use of energy across the economy, assistance through the
lending program would continue to involve operations in a variety of sectors.
2. OIL AND GAS SUBSECTOR

A. BACKGROUND

2.1 China has had remarkable success in the development of its hydrocarbon resources; it has been a net oil exporter for over two decades. The growth of its petroleum production during the period 1949-92 is presented in Annex 2.1. However, most of the major oil and gas producing fields in China are considered mature and many of these fields have already experienced natural production decline. Moreover, certain Chinese techniques, equipment and practices in hydrocarbon exploration and production have become outmoded, and less efficient and effective than international industry standards. Consequently, after three decades of continued increase in production, both oil and gas production started to decline in 1980. It was at this critical juncture in the early eighties that the Government of China first requested Bank assistance in the petroleum sector. Following the implementation of various remedial measures, notably an intensive campaign of infill drilling and well stimulation as well as development of new fields, oil and gas production started to increase again, albeit slowly, in 1983. By 1992, oil and gas production reached 142 million tons and 15.7 billion cubic meters (bcm), respectively. The production of major oil and gas fields during the period 1988-92 is set out in Annex 2.2.

2.2 In recent years, oil and gas production growth (1 percent per annum) has been outpaced by the growth in domestic demand (4 percent per annum) fueled by rapid economic development in the country. As a result, increasing efforts in energy conservation notwithstanding, net oil/product export decreased sharply from 25 million tons in 1987 to about 9 million tons in 1992 (Annex 2.3). The decline in net oil export is expected to continue (to an estimated 4 million tons in 1993) and China would likely become a net oil/product importer in the near term. Separately, in the wake of increasing environmental concerns and continued shortages of natural gas (a far cleaner fuel than coal), the Chinese authorities are actively pursuing various options to augment gas supply, including both domestic production and possible import of natural gas.

B. INVESTMENT STRATEGY

2.3 The government's latest oil and gas production targets (which have been revised downward by some 20 percent from earlier targets) are to reach 165 million tons and 20 bcm, respectively, by the year 2000. Continuing to increase production of oil and gas will require a very large and sustained effort in exploration and development in the country. This calls for a three-pronged approach in the sector's investment strategy:
(a) to continue exploration and development around the presently producing oil and gas fields (including the Sichuan basin) and undertake a series of well-balanced infill drilling, rehabilitation and enhanced recovery programs in these fields to ensure recovery rates comparable to those obtained in the international industry;

(b) to formulate and promote major new initiatives in exploration, notably in the largely unexplored Tarim basin, to identify new reserves which could be brought into production in the longer term; and

(c) to promote diversification of nonassociated gas supplies beyond Sichuan, including improved assessment of the potential of gas prone areas and promote gas market development in those areas where reserves have already been discovered, including the offshore Yacheng gas field in the South China Sea (operated by an international joint venture partner, ARCO) and the recently discovered Changqing gas field (Ordos Basin in Central China).

C. SECTORAL POLICY

2.4 In order to accelerate hydrocarbon exploration and development in the country, critical sectoral constraints which exist in various aspects of technology, management and financing need to be overcome. Toward this end, significant progress has been made in improvements of the sectoral policy environment, including recent reform initiatives toward (a) rationalization of energy pricing policy; and (b) further opening up of petroleum concessions for foreign direct investment. In addition, with a view to enhancing efficiency and competitiveness in an increasingly market-based economy that is increasingly integrated into the world economy, the Chinese authorities are committed to the implementation of a far-reaching program of institutional restructuring in the oil and gas sector.

Pricing

2.5 Crude Oil. Despite recent efforts to increase crude oil prices (Annex 2.4), the average level of crude oil has remained low, with some 28 percent of the production in 1993 sold at state-controlled "low prices" [currently about Y 201-265/ton, depending on the quality of oil ($3.2-4.2/bbl equivalent at the current exchange rate of Y 8.7 to $1)]. Moreover, with the multiple tier state-controlled and market pricing system, the present structure of crude oil pricing is unduly cumbersome to administer. As part of the ongoing efforts to deepen price reform, all the "low prices" of crude would be increased to the same levels as "high prices" [currently about Y 520-595/ton ($8.2-9.4/bbl equivalent)] by 1994. Further, the government has announced its intention to complete the liberalization of crude oil prices by 1995 to international price levels [currently about $16/bbl (Y 1,000/ton equivalent)]. In this connection, free market pricing has already been effected for all the crude production from foreign joint ventures and a very limited portion
(5 percent of production in 1993) from CNPC. Market-based pricing also applies to joint stock companies.

2.6 Petroleum Products. Unlike crude oil prices, most of the petroleum product prices in China are at or higher than export parity prices, with the exception of state-controlled low prices (some 34 percent of total production) for selected consumer categories (notably diesel fuel for farmers and fuel oil for certain enterprises in the strategic sectors). Indeed, prices for gasoline and diesel fuel for transportation purposes are now substantially higher than export parity prices.

2.7 Natural Gas. In recent years, the well-head prices of natural gas have been inadequate to cover the full cost of exploration and production. In 1992, the average well-head prices of gas were increased by some 40-50 percent to about Y 254/mcm and Y 230/mcm, respectively, in Sichuan (nonassociated gas) and other regions (mainly associated gas). In order to mobilize the necessary resources for sector development and to provide adequate incentives for efficient supply and consumption of gas, further improvements in both the levels and structure of gas pricing are indicated. Under the proposed project, an assurance would be sought from the government on the implementation of a time-bound action plan to reform gas pricing in Sichuan (para. 3.16).

Foreign Direct Investment

2.8 In the early 1980s, the government opened offshore petroleum concessions to international oil companies (IOCs). During the last decade, 56 offshore petroleum contracts have been concluded; foreign direct investment in exploration and development has totalled $3.2 billion by end-1991. In 1986, the IOCs were also invited to explore and develop onshore basins in eleven southern provinces. However, only five contracts have thus far been concluded mainly because these areas appear to have relatively low prospects. In early 1993, the government has renewed efforts to attract foreign direct investment; the areas opened for onshore exploration and production increased to a total of 21 provinces, autonomous regions and cities. Specifically, the IOCs have been invited to bid for concessions in south eastern Tarim Basin (in March 1993) and eleven areas surrounding major producing oilfields in ten northern and eastern provinces (in end-1993). Thus far, 64 IOCs have registered to bid for concessions in the Tarim. The second round of international competitive bidding for additional concessions in the Tarim and other basins was announced in early 1994. Expanded involvement of the IOCs in the sector would augment the infusion of much needed capital resources and the transfer of technology and management expertise.

2.9 However, gas is typically less attractive than oil to the IOCs. Further, gas exploration and development in Sichuan involves complex geology, difficult production conditions, and relatively high costs. Moreover, in order to promote private sector participation, the regulatory framework must provide for transparent and rational pricing policy. Thus, the provisions for rationalization of gas pricing policy under this project would help lay the ground for attracting IOC investments in the future. As a first step, gas field development of the Datianchi structure in Sichuan is planned to be opened up for
joint venture with IOCs. The proposed project would include technical assistance for the promotion of petroleum concession offers to international investors (Annex 5.4).

D. Sector Organization

2.10 The organization of the petroleum industry in China has been in a state of continuous change. The former Ministry of Petroleum Industry (MOPI) was first created as a Bureau in the Ministry of Fuel in 1949. MOPI became a full ministry in 1955 and oversaw all aspects of hydrocarbon exploration, development and transportation. In 1970, MOPI was merged with the Ministry of Coal and the Ministry of Chemical Industry; these ministries were split again in 1978. In 1988 MOPI was transformed into a state-owned corporation, CNPC (para. 1.10), which continues to report directly to the State Council.

2.11 CNPC is in charge of all the onshore petroleum exploration and development activities in China, including negotiations and administration of agreements with international oil companies (through its subsidiary, the China Oil and Natural Gas Exploration and Development Corporation). The China National Offshore Oil Corporation (CNOOC), created in 1982, is responsible for all the offshore petroleum operations. The Ministry of Geology is in charge of geological work. The Petrochemical Corporation of China (SINOPC), established in 1983, is responsible for most petroleum refining and petrochemical production based on liquid petroleum feedstocks. The Ministry of Chemical Industry (MCI) is responsible for petrochemical plants using natural gas and coal as feedstocks. The China Chemical Industry Import/Export Corporation (SINOCHEM) is in charge of oil and products trading. As part of a recent reform initiative, China United Oil Company (SINO-OIL), a shareholding company with limited liability, has been established by CNPC and Sinochem (each with 50 percent ownership). Sinoil's operations cover import/export of oil and refined products as well as overseas investment in oil/gas ventures. Separately, the shares of Shanghai Petrochemical Corporation started listing on the Hong Kong Stock Exchange in July 1993.

2.12 CNPC Organization. CNPC is a large state-owned enterprise; its charter was issued by the State Council in 1988. It has 36 subsidiaries operating as separate legal and accounting entities. Amongst this group, 22 are regional petroleum administrative bureaus which are responsible for petroleum exploration and production, and 3 for oil/gas transport. In addition, CNPC is affiliated with eight enterprises in the sector. The organization chart of CNPC is presented in Chart 1.

2.13 CNPC is headed by a President who is appointed by the State Council. He is assisted by four Vice Presidents. The total staffing of CNPC and its subsidiaries is in the order of 1.4 million, of which about one million are employed in provision of auxiliary services for oilfield support (including geophysical and geological service companies, drilling and other oilfield auxiliary service companies, petroleum engineering and construction companies, and petroleum research and educational institutes) and social welfare (including employee housing, schools and hospitals).
E. Sectoral Restructuring

2.14 Within the broad framework of economic and enterprise reform in the country, the oil and gas sector is faced with the challenge to implement a far-reaching program of restructuring which would be basically completed by the year 2000. The major objective of the reforms in the oil and gas sector is to improve productivity and economic efficiency and to promote the development of the sector. The major elements of the restructuring program include (a) separating the governmental function from the management of the enterprises, (b) commercializing and corporatizing the petroleum administrative bureaus, (c) establishing the market for oil and gas exploration and development compatible with international practices, (d) improving the legal and regulatory system, and (e) transforming the oil and gas fields and other petroleum enterprises into independent legal entities bearing full rights and obligations in the market competition. Implementation of the first phase of restructuring the upstream oil and gas sector is a component of the proposed project. The government’s intention to carry out the restructuring program was confirmed in a policy letter to the Bank from the Ministry of Finance (Annex 2.5). As part of project supervision, the Bank will review the progress in implementation of the restructuring program.

2.15 CNPC Restructuring. CNPC has established system reform units at headquarters and in all of its operating subsidiaries, including the Sichuan Petroleum Administration (SPA), the major beneficiary of the proposed project. Further, CNPC has sought out the advice of the international community, notably the Bank, through such vehicles as a workshop on petroleum sector management and reform held in China in July 1992 under the joint sponsorship of CNPC and the Bank/Energy Sector Management Assistance Program (ESMAP). Consistent with the recommendations of this workshop, remarkable progress has recently been made in resolving key policy issues in the sector, including rationalization of energy pricing policy and further opening up of petroleum concessions for foreign direct investment.

2.16 To build on and accelerate the reform momentum, CNPC is in the process of preparing a comprehensive action plan within the framework of sectoral restructuring noted above (para. 2.14). CNPC’s reform program is being developed along the following direction:

(a) Transparency in the Separation of Government from Enterprise Management. CNPC will transfer its administrative function to the government, and operate as a national state-owned company to manage and supervise the state assets in its subsidiaries. As a first step, the administrative function formerly assumed by CNPC with respect to the approval of petroleum concessions for domestic oil companies is in the process of being transferred to the government. The government departments concerned will focus on policymaking, regulatory formulation and long term planning. The operations of CNPC will be free from direct interference by government agencies.
(b) Commercialization and Corporatization of Public Enterprises. Oil/gas exploration and production units, auxiliary service units and social welfare units of the petroleum administrative bureaus will be transformed into independent legal entities. In accordance with the Chinese Company Law, the aforementioned units will be restructured into limited liability companies with different ownership structures, including state-owned and joint-stock companies.

(c) Setting up the Market for Oil and Gas Exploration and Development and Creating a Competition Mechanism for Enterprises. Under the proposed competition policy: (i) oil companies would compete for concessions under a "licensing system"; these companies could sell their reserves to nonstate investors (foreign or local); and (ii) service companies would engage in bidding for contracts across provincial boundaries. This would, in turn, promote efficiency gains through competition and arm’s-length (commercial) transactions between the oil/gas producers and the service companies. The large number of service companies are expected to be reduced gradually through mergers and closing down of companies which are not competitive.

2.17 A local study team (comprised of CNPC and other relevant government agencies) are collaborating with the Bank and international consultants financed under the Japanese Grant Facility (JGF) to carry out a study which would provide an analytical framework for building consensus on the detailed reform program. This study, which is scheduled for completion in end-1994, would focus on the following aspects: (a) the establishment of an appropriate legal and regulatory framework for the oil and gas sector; in addition to existing laws, such as the Mining Law and laws on international cooperation for petroleum concessions, joint ventures and foreign direct investment, a petroleum law will be developed as part of the sectoral reform; (b) competition policy and market development; and (c) CNPC institutional restructuring, including commercialization and corporatization of CNPC entities, and diversification of ownership and financing. The first phase of the study will develop pilot reform programs for the restructuring of two of CNPC’s subsidiaries, SPA and Dagang Petroleum Administration. These pilot programs would be implemented during the second phase of the study, and the recommendations emerging from this study would take into account the experience of the pilot programs. The Terms of Reference for the restructuring study are in Annex 2.6.
3. GAS SUBSECTOR IN SICHUAN

A. BACKGROUND

3.1 Sichuan Province is located in southwestern China (see Map IBRD No. 25137). It is the most populous province in the country, with about 110 million people (representing some 10 percent of the country’s population) for an area of about 570,000 km². Its Gross Value of Industrial and Agricultural Output (GVIAO) amounted to Y 180 billion in 1990, accounting for about 6 percent of the national GVIAO. With limited land and some 88 percent of its population being farmers, Sichuan is one of the poorest provinces in the country; its per capita income of Y 896 ($180) was only 50 percent of the national average in 1990. Indeed, in part due to the government’s earlier focus on a "coastal development" strategy, the pace of development in inland provinces, including Sichuan, has lagged considerably behind that in the coastal provinces. The government is aware of the issues relating to increasing disparity of regional income and the latest official plan points to greater concern to achieve more balanced regional development. The proposed operation to support sustainable economic development in Sichuan is consistent with the above regional development policy.

B. ENERGY AND THE ENVIRONMENT

3.2 Sichuan is endowed with the country’s largest potential for hydropower and natural gas; however, both of these resources are underdeveloped (paras. 1.6, 1.8). By contrast, the recoverable coal deposits in the province amount to only 1 percent of the country’s total. By 1990, 45 percent of the coal deposits in Sichuan had been exploited; coal production was about 70 million tons in that year. However, coal in the province is generally of low quality, with a high content of sulfur (3 percent) and ash (33 percent). The reserves of crude oil (about 10 million tons) are too small to be developed economically.

3.3 The consumption of primary commercial energy in Sichuan totalled about 63 million tce in 1990. Recent economic growth in the province has averaged about 10 percent p.a. Since the growth of energy supply has not kept pace with demand, energy has continued to be a key bottleneck sector. As a result of severe gas shortages, industrial production has been curtailed and an increasing number of industrial boilers have been converted to burn coal instead of gas. The share of natural gas in the commercial energy consumption of the province decreased from 19 percent in 1979 to 11 percent in 1990, while the share of coal increased from 68 percent to 74 percent. During the same period, the share of hydropower increased slightly from 8.5 percent to 10 percent while that of
petroleum products has remained stable at about 4 percent. The commercial energy balance in Sichuan during the period 1970-90 is set out in Annex 3.1.

3.4 As a result of rising coal consumption, the already serious environmental ramifications (notably acid rain/smog and global warming) and related health problems have been exacerbated. In particular, there are reports of serious respiratory problems and a high incidence of lung cancer in Chongqing Municipality (Sichuan) which has some of the highest ambient concentrations of particulates and SO₂ in the world. In this connection, the environmental advantages of natural gas render its development and targeted use a cost-effective strategy to mitigate environmental degradation at the regional and global levels. As part of a coherent energy and environmental strategy in the province, both the ongoing Bank-financed Ertan Hydroelectric Project (Loan 3387-CHA) and the proposed Sichuan gas operation aim at supporting economic and efficient supply and use of cleaner energy resources, hydropower and natural gas, respectively.

C. NATURAL GAS PRODUCTION

3.5 Since the 1960s, Sichuan province has been a significant gas producing area; its gas production reached 6.5 bcm (representing 42 percent of the total gas production in the country) in 1992. Currently, about 83 producing gas fields spread over a sedimentary basin of approximately 180,000 km². The total proven and probable reserves are presently estimated at about 400 bcm and 140 bcm, respectively. Sichuan basin is divided into five major gas producing regions: east, south, southwest, northwest and central. The gas field development component of the project is located in Eastern Sichuan, which is the largest gas producing region in the province, accounting for about 3 bcm (or 47 percent) of the total gas production in 1992. The total proven and probable reserves of Eastern Sichuan are presently estimated at about 200 bcm and 94 bcm, respectively.

3.6 SPA is the predominant gas producer in Sichuan, accounting for 6.4 bcm or 98 percent of the gas production in 1992. Separately, the South West Petroleum Geological Bureau (under the Ministry of Geology) and the Shallow Gas Company (under the Sichuan provincial government) together account for most of the balance (2 percent) of the gas production. In addition, there are a few small scale gas companies that belong to the counties.

3.7 Mainly due to complex geology and difficult operating conditions, coupled with outmoded technology and equipment, operating problems and inefficiencies exist in a broad spectrum of gas field activities (Annex 5.1). In particular, production problems, notably severe water incursion, have become increasingly serious. Further, many of the producing fields in Sichuan are aging and declining in production. Consequently, in the early eighties, gas production in Sichuan fell by some 20 percent from its 1979 peak level (6.5 bcm). Recent remedial measures have slowed the natural decline and, coupled with the development of new gas fields, gas production has increased steadily, reaching the previous peak level in 1992.
3.8 Gas Resources Conservation. Under the recently completed Weiyuan Gas Field Technical Assistance Project (Loan 2580-CHA), a diagnostic study on the rehabilitation of the Weiyuan field was carried out with the assistance of international consultants. This study concluded that a major lesson learned from the development experience of Weiyuan is that suboptimal development schemes with excessive flow rates (over-production) have resulted in extensive reservoir damage and consequently lost opportunities for recovering gas resources from these reservoirs. To enhance ultimate gas recovery and resources conservation at the field level, the proposed project would support the adoption of sound reservoir management practices. Separately, it is common international practice to safeguard against wastage of energy resources through the establishment of maximum well rate limits by an independent regulatory agency. This aspect will be addressed by the ongoing JGF-financed study on oil/gas sector restructuring (para. 2.17).

D. GAS TRANSMISSION AND DISTRIBUTION

3.9 The five main gas producing regions in Sichuan are linked together by SPA's transmission and distribution (T&D) system which comprises a closed loop pipeline grid and a number of spurs (totalling about 2800 km in length). SPA supplies about 5.8 bcm of natural gas per year directly to about 600 large industries and fifteen major city gas companies (which account for 90 percent of city gas consumption). About one million households, small industries and commercial entities are supplied through 59 city gas companies.

3.10 Most of SPA's T&D system is 12-20 years old. Largely due to financing constraints and inadequate economic/financial incentives, there is a large backlog of investments required to rehabilitate the transmission and distribution system. Thus, it is operating under precarious condition and is prone to breakdowns, accidents and gas leakages. Based on the results of a recently completed diagnostic study financed under the Preinvestment Facility (PRIF) of GEF, the proposed project would include support for priority investments to rehabilitate SPA's T&D system (paras. 5.11-5.14).

3.11 Safety Regulation. SPA, in its capacity as an administrative bureau, is responsible for the enforcement of design and operational standards as well as safety regulations for the gas sector. However, as an operating agency, SPA is not best suited to enforce these standards. As part of the ongoing sector restructuring, it is envisaged that an independent regulatory agency would be established to oversee the enforcement of standards and safety regulations in Sichuan Province. This aspect will be addressed under the aforementioned oil/gas sector restructuring study.

E. GAS CONSUMPTION

3.12 The consumption pattern of gas in Sichuan has remained stable over the past five years (Annex 3.2). In 1992, about 54 percent of the gas was used as feedstocks/fuels for fertilizer production in Sichuan (40 percent) and two of its neighboring provinces, Yunnan (7 percent) and Guizhou (7 percent). In addition, about 11 percent of the gas was
used for other chemical industries. The balance of the gas was mainly used as an industrial fuel, of which the metallurgical sector (11 percent) and the machinery sector (7 percent) were the major users. The share of residential uses was about 6 percent while that of commercial uses was less than 1 percent.

3.13 China is the world's largest consumer and importer of chemical fertilizers. Thus, in rationing the use of scarce natural gas resources, the government has placed first priority on fertilizer production. Under the Eighth Five-Year Plan (1991-95), two large fertilizer plants, which are under construction, will consume some 60 percent of the planned increase of gas supply (1 bcm) in Sichuan. The balance of the increased gas supply would be allocated mainly to other chemical industries and residential uses.

F. GAS PRICING AND ALLOCATION POLICY

3.14 Gas Pricing. Over the past few years, escalations of exploration and production costs have outpaced the increases of well-head prices of gas. As a result, SPA, the major gas producer, has increasingly suffered operational losses for its exploration and production activities (para. 6.10). A significant step has recently been taken toward the rationalization of gas pricing; in 1992, the average level of well-head prices in Sichuan increased by about 50 percent (from Y 160/mcm to about Y 254/mcm). Further, the pricing and allocation of a limited portion of the total gas production (12 percent in 1993) has been deregulated; the current market price is about Y 400/mcm. However, to mobilize the necessary resources for sector development and to provide adequate incentives for efficient supply and consumption of gas, the average levels of well-head prices in Sichuan would have to be increased further.

3.15 Gas Allocation. There is a wide disparity in the economic value of current major gas uses. While the major gas uses yield positive economic benefits, the allocation of the scarce gas resources have not always been optimized on the basis of economic and environmental considerations. In particular, the allocation of existing gas supply has not covered power generation even though gas offers the prospect of both cheaper power generation and less pollution in many countries. Thus, there is scope for improvements in the criteria for gas allocation with a view to enhancing both the economic and environmental benefits of gas.

3.16 Reform Action Plan. To provide an analytical framework for the formulation of a reform program, a study on Sichuan gas allocation and pricing was recently completed with the assistance of international consultants financed under the United Nations Development Programme (UNDP). Broad agreement has been reached on the study's recommendations for economic-efficient principles that the Sichuan authorities would apply in the allocation and pricing of natural gas. Specifically, gas allocation criteria should reflect the relative economic values and environmental considerations of different gas uses. In this connection, new allocations of gas would include peak power generation and residential uses. The above gas uses are expected to yield relatively high economic benefits as well as significant reduction in air pollution. Separately, the minimum average levels of gas supply price should be no less than the average incremental
cost. In addition, with a view to fostering end-users’ efficiency, the structure of gas pricing would be improved through gradual reduction, if not removal, of cross subsidies between different categories of consumers. Based on the above principles, an agreement has been reached with the government on a reform action plan. Since project appraisal, the government has approved an average well-head price increase by Y 200/mcm in 1994 (representing some 80 percent increase from the 1993 average price level). However, in light of the recent changes in exchange rates and higher projected local inflation rates than anticipated at the time of project appraisal, further gas price adjustments would be required to ensure the financial soundness of the project and SPA overall (Chapter 6). An understanding has been reached with the government that it would annually send a rolling gas pricing reform action plan to the Bank and exchange views with the Bank on this plan. During negotiations, an assurance has been obtained from the government that it would implement the agreed reform action plan for gas pricing and allocation, in a manner satisfactory to the Bank.

G. Energy Conservation

3.17 Acute gas shortages are expected to continue in Sichuan in the foreseeable future. The pressing need for promoting energy conservation is thus compelling both from the economic and environmental viewpoints. Since the early 1980s, effective institutional arrangements, for encouragement and implementation of energy conservation measures in industry and in other sectors, have been established in Sichuan. Particular emphasis has been placed on energy conservation in the three most energy-intensive industrial subsectors, chemicals (including fertilizers), metallurgy and machine building. The strategy followed was the classical sequence of (a) improvements in housekeeping; (b) retrofitting; and (c) process modernization. The program has been successful. It is estimated that over 70 million tce have been saved since 1981. Nevertheless, considerable potential still exists for further energy conservation in the province, particularly in industry, although larger investments are likely to be required to maintain the rates of savings previously achieved. An essential element in ensuring continuing success for the program will be the raising of energy prices to their economic levels as rapidly as possible. Detailed discussions on energy conservation in Sichuan are set out in Annex 3.5. An understanding has been reached with the government that it would exchange views with the Bank, from time to time, on the progress in the implementation of energy conservation measures in Sichuan.

H. Lessons Learned From Earlier Bank Involvement

3.18 Bank participation in the gas sector in China has thus far included two operations which were completed recently: Weiyuan Gas Field Technical Assistance Project (Loan 2580-CHA) and Liaodong Bay Petroleum Appraisal and Technical Assistance Project (Loan 2708-CHA). The lessons learned from these projects include: (a) fragmentation of responsibilities among various Chinese agencies, coupled with cumbersome internal clearance procedures, contributed to significant delays in initial procurement activities of the Weiyuan Project; in contrast, the streamlined procurement arrangements under the Liaodong Bay Project contributed to the timely implementation of the project; (b) delays
in the implementation of institution building components could be mitigated through reaching agreements on the training program and the Terms of Reference for consultant services no later than negotiations; and (c) strong project management offices with adequate staff to provide requisite coordination among multiple agencies are crucial for efficient project implementation.

3.19 In addition, according to "A Review of World Bank Lending for Natural Gas" (Report No. 10828), the principal lessons learned included: (a) the Bank’s assistance has had most impact on improving the technical capacity of gas institutions, particularly where there were twinning arrangements with an internationally experienced foreign operating company or gas utility; and (b) a major weakness of the Bank’s institutional development approach was its strategy of trying to do everything at once; a more long term view was needed, given that the goals of institutional development generally will not be achieved within the time span of one project. The design of the proposed project has built on the above lessons learned from earlier Bank operations.
4. THE BENEFICIARY

A. INTRODUCTION

4.1 SPA, the major beneficiary of the proposed project, is responsible for the implementation of the investment component. Separately, CNPC is responsible for the implementation of the national petroleum education component. In addition, both SPA and CNPC are responsible for the implementation of the restructuring and institution building components. The organization of CNPC is discussed in paras. 2.12-2.13.

B. SICHUAN PETROLEUM ADMINISTRATION

Legal Status and Organization

4.2 The Southwest Petroleum Exploration Department (SPED), the predecessor of the Sichuan Petroleum Administration (SPA), was established in 1952. After the discovery of three gas fields, SPED was renamed SPA in 1958. SPA is a state-owned enterprise under the leadership of its parent company, CNPC. It is a separate legal and accounting entity. Its main business includes petroleum exploration, production, storage, transportation, processing, as well as production and sale of other minerals encountered during well drilling. Its ancillary business includes the manufacturing and repairing of specialized oil and gas machinery and instruments. SPA’s charter, which was first issued by CNPC in 1990, has been revised in May 1993 to reflect the deepening of enterprise reforms in China. In particular, consistent with the guiding principle of the ongoing reforms to separate government administration from enterprise management, a Board of Directors would be established to oversee the operations of SPA. The Board would comprise a chairman and seven members.

4.3 SPA is headed by a President appointed by CNPC. He is assisted by a Senior Vice President and five Vice Presidents. Hitherto, SPA has operated as a single legal entity with no subsidiaries. Its headquarters has 24 departments to oversee its broad spectrum of activities which are carried out by 30 subunits. Its core operational subunits include five exploration and production (E&P) companies, namely the East Sichuan Gas Production Company (the major subunit responsible for the implementation of the proposed investment component), the Central Sichuan Mining District (responsible for the proposed rehabilitation project component in Central Sichuan), the South West Mining District (the beneficiary of the Weiyuan Gas Field TA Project), South Sichuan Mining District and the North West Mining District. In addition, SPA has subunits which are specialized service companies, including seismic surveys, well drilling, logging, surface facility construction, down-hole service, design and research. Further, SPA is also engaged in machinery
manufacturing and repairing as well as a wide array of social obligations (notably employee housing, schools and hospitals). The company's organization chart is in Chart 2.

4.4 **Gas Transmission Reorganization.** Until recently, the responsibility for planning and operation of SPA's transmission and distribution system was divided between the five gas producing subunits, notably the East Sichuan Gas Production Company, and headquarters' Transmission and Distribution Department. This led to a lack of coordination and procedural consistency in the operation and maintenance of the system. It also resulted in a lack of accountability at the senior management level. This, in turn, contributed to the release of nonspecification gas into the system. Similarly, long-term plans for the operation and development of the system have never been drawn up and its maintenance and capacity expansion have remained underfunded. SPA recognizes that without an efficient transmission and distribution system, linking the gas resources with the markets, efficient development of the gas sector would not be possible. Thus, SPA recently established the Gas Transmission and Distribution Company (GTDC), consolidating all the transmission and distribution operations into a single subunit which will be fully accountable for efficient transportation of gas from the fields to major consumers and the city gas companies. The organization chart of GTDC is in Chart 3.

**Restructuring Framework**

4.5 Consistent with CNPC's overall reform direction (para. 2.16), the organization of SPA will be restructured as part of the process to enhance efficiency and productivity. As noted above (para. 2.17), the first phase of the ongoing JGF-financed study will develop a comprehensive pilot program for the restructuring of SPA; the pilot program would be implemented during the second phase of the study.

4.6 The broad areas of SPA's reform efforts required would cover both the external policy (enabling) environment and the internal organization and management of SPA, including: (a) rationalization of gas pricing and allocation; (b) improvements of SPA's productivity; (c) commercialization and corporatization of SPA; and (d) diversification of ownership and financing.

4.7 SPA is presently overstuffed, particularly in its auxiliary service operations. Its output per employee is about 60 ton oil equivalent (toe) or 40 percent below the national average (100 toe). In order to improve productivity to at least 200 toe per employee (the target set by CNPC), SPA is faced with a formidable challenge to reduce its staff from the present level of 108,000 to about 75,000 and 50,000 targeted for 1995 and the year 2000, respectively. Toward this end, SPA has planned to gradually spin off its auxiliary service companies. Further, as part of the process to commercialize SPA, housing reform will be launched shortly and other social functions of the enterprise will also be gradually spun off. During the transitional period, SPA would continue to provide active support for surplus workers in identifying job opportunities and/or setting up their own businesses (notably in the service sector).
4.8 Separately, with a view to diversifying ownership and financing, SPA is seeking the approval of CNPC and the government to: (a) transform six SPA subsidiaries into joint-stock companies; and (b) open up petroleum concessions in Sichuan for direct foreign investment. As a first step, gas field development of the Datianchi structure is planned to be opened up for joint venture with international oil companies. In this connection, rationalization of gas pricing policy is critical for promoting both foreign and domestic investment in the gas sector.

Staff Training

4.9 With a view to enhancing the operational, managerial and financial capabilities of SPA, the proposed project would include an institution building component for the implementation of the components for oil and gas sector restructuring and for gas production and transmission (paras. 5.15-5.18).
5. THE PROJECT

A. RATIONALE FOR BANK PARTICIPATION

5.1 The proposed project is part of the Bank's multidimensional assistance to China designed to promote efficiency gains and sustainable development through economic policy and enterprise reforms as well as alleviation of energy shortages in an environmentally sound manner. During the course of project preparation, the Bank has engaged in an active policy dialogue with the Chinese authorities who are committed to a far-reaching reform program in the oil and gas sector. In particular, the Bank was instrumental in effecting up-front actions in improvements of the sectoral policies for pricing and foreign direct investment. Further, as a first step toward corporatization and transparency in separation of ownership and management, a board of directors would be established at SPA. Moreover, Bank participation in the conceptualization of this project has contributed to growing appreciation of the Chinese authorities for an increased emphasis on natural gas development and conservation on both economic and environmental grounds. The Bank has also contributed to improvements in the project design through the initiation and monitoring of various policy and preinvestment studies. Finally, the proposed operation would support the implementation of the first phase of restructuring the upstream oil and gas sector. The good practices learned under this project would have a significant demonstration effect for the reforms of other public enterprises in China.

B. RATIONALE FOR GEF FUNDING

5.2 Based on the results of a recently completed diagnostic study financed under the GEF (Global Environment Facility) Preinvestment Facility (PRIF), an amount of SDR 7.3 million ($10 million equivalent) grant from the Global Environment Trust Fund (GET) would help finance the much needed rehabilitation of SPA's transmission and distribution system. The environmental benefits of this project component are clear in that reductions in natural gas leaks will reduce fugitive methane emission, a potent greenhouse gas. Global warming concerns are directly addressed since fugitive methane enters the atmosphere where its global warming potential is some 20 times that of CO₂. Successful implementation of this project component would have a significant demonstration effect for other gas transmission and distribution systems in China and other developing countries.

C. PROJECT OBJECTIVES

5.3 The proposed project aims to: (a) support the implementation of the upstream oil and gas sector restructuring; (b) rationalize both the levels and structure of
gas pricing; (c) promote rational gas allocation; (d) reduce acute gas shortages and environmental degradation in Sichuan through increased gas production (and avoidance of coal consumption) and energy conservation, including reduction of gas leakages (which would, in turn, reduce the emissions of methane and greenhouse gas effect); (e) improve the efficiency of gas production and enhance the ultimate gas recovery and resources conservation through sound reservoir management and state-of-the-art enhanced gas recovery technology; (f) enhance the safety, reliability and operational efficiency of the gas transmission and distribution system; and (g) strengthen the institutional capabilities of CNPC and SPA.

D. PROJECT DESCRIPTION

5.4 The project design is based on various policy and preinvestment studies carried out with the assistance of international consultants financed with funds from the international community, including Technical Cooperation Credit (TCC) II (Credit 1664-CHA), $1.9 million; Japanese Grant Facility (JGF), $1.2 million; United Nations Development Programme (UNDP), $250,000; and Preinvestment Facility (PRIF) of the Global Environmental Facility (GEF), $1.4 million.

5.5 The project would comprise the following three main components:

(a) A Restructuring Component. Implementation of the first phase of the upstream oil and gas sector restructuring program, based on the recommendations of an ongoing restructuring study, including commercialization and corporatization of CNPC/SPA through their transformation into joint-stock companies, introduction of a commercial accounting system and implementation of productivity enhancement and related human resources development programs (paras. 2.14-2.17).

(b) An Investment Component (98 percent of project cost).

(i) development of proven gas reserves in about 14 selected gas fields in East Sichuan through drilling of about 100 infill development wells; seismic survey and interpretation; and construction of surface facilities consisting of gas gathering systems, gas dehydration and desulfurization plants, and appropriate scheme for disposal of produced formation water (62 percent);

(ii) rehabilitation of old gas wells, about 90 in East Sichuan and 100 in Central Sichuan, through work-over, reservoir stimulation and well recompletion techniques (15 percent);

(iii) expansion of SPA's gas transmission system (9 percent); and

(iv) rehabilitation and environmental upgrade of SPA's gas transmission and distribution systems (12 percent).
An Institution Building Component (2 percent of project cost).
Technical assistance and training for the implementation of the above two
components as well as for national petroleum education.

Gas Field Development/Rehabilitation Subcomponent

5.6 During the last decade, several small to medium size gas fields were
discovered in Eastern Sichuan. However, these discoveries are deep and contain
substantial quantities of hydrogen sulfide (H\textsubscript{2}S). As a result, development of these fields
has been hampered by SPA's lack of specialized modern technology and equipment.
Unless these fields are developed adequately, Sichuan's gas production could start to
decline as early as 1995 at a rate of about 10 percent per year. To delay and reduce its
production decline, SPA would require significant increases of investments for gas field
development and rehabilitation and induction of appropriate modern technology and
equipment. The proposed upstream component would support SPA's priority investment
in this endeavor. Detailed discussions of the proposed upstream components are in Annex
5.1.

5.7 The reserve estimate has been confirmed by an independent gas reserve
assessment study which was recently completed by TCC-financed international consultants.
Separately, geological and geophysical work carried out over recent years indicates that
Sichuan basin's gas resource base could be much larger than now projected, particularly
in East Sichuan where about 80 potential structures have not yet been fully explored.
However, these structures are in deep complex geological formations where drilling and
production conditions are becoming increasingly more difficult and costly. Exploring and
developing these structures would require enormous incremental investments and would
entail exploration related risks. In this connection, SPA is in the process of seeking CNPC
and government approval for opening up concessions for direct foreign investment. The
proposed project would include technical assistance to SPA for petroleum development
promotion to potential international investors (Annex 5.4).

5.8 The main objectives of the proposed upstream components are to:

(a) delay overall gas production decline in Sichuan and yield a total incremental
gas production of about 68 billion cubic meters (bcm) over a 20-year period
(1995-2015);

(b) improve field productivity (by 10 to 30 percent) and enhance the ultimate
gas recovery (from the current level of about 40 percent to 70 percent) and
conservation of gas resources at the field level; and

(c) enhance overall field environment and safety through adequate purification
of sour gas and efficient treatment and disposal of produced formation water
and other field wastes.

5.9 Toward these ends, the proposed project would assist SPA in:
Toward these ends, the proposed project would assist SPA in:

(i) acquiring state-of-the-art technology, equipment and materials (for geophysical surveys and gas well drilling, completion and production) which are highly critical for some of the most operationally difficult gas fields;

(ii) installing efficient gas treatment facilities for the incremental gas production particularly with regard to gas desulfurization and dehydration;

(iii) installing adequate subsurface injection systems and treatment facilities for disposal of produced formation water and other field wastes;

(iv) introducing effective field operating techniques such as high pressure hydraulic fracturing of tight gas reservoirs, multiwell pad directional and horizontal drilling and infill seismic for new well locations; and

(v) enhancing the institutional capability of its personnel through technical assistance and training.

Gas Transmission Expansion Subcomponent

SPA’s gas transmission and distribution system in the eastern region would be expanded for additional gas supply from field development. To ensure safety and system integrity and to increase the life expectancy of the gas transmission and distribution system, only dry and sweet gas (in accordance with the specifications) would be allowed to enter the pipelines. Toward this end, appropriate locations of the gas purification plants and other arrangements to ensure the safety of the system will be determined through an ongoing study being carried out by SPA with the assistance of international consultants. During negotiations, an agreement has been obtained that arrangements to ensure the safety of the expansion of the gas transmission and distribution system, satisfactory to the Bank, would be required prior to the disbursements for this component.

Gas Transmission Rehabilitation Subcomponent

A PRIF-financed diagnostic study has evaluated the gas transmission and distribution system’s integrity, efficiency and reliability and determine the most efficient measures for its rehabilitation, including measures to reduce methane emission reduction. The main findings of the study are summarized as follows: (a) the integrity of the system is threatened; 110 pipe failure accidents were reported during the past two decades. In the absence of adequate remedial measures, further deterioration of the system would result in an increasingly high risk of accidents which would jeopardize the safety of the general public, disrupt gas supply to customers and increase greenhouse gas emissions; (b) internal corrosion in the pipelines due to release of sour gas into the transmission system is the
most serious problem; (c) almost all of the methane emissions from the SPA gas system are due to fugitive equipment leaks, notably control and block valves; (d) in emergencies, the grid control system cannot efficiently respond to rapid changes in the operating conditions; and (e) until recently, the responsibility for the operation of the system was divided between several departments and there was a lack of accountability at senior management level.

5.12 To address the above issues, a risk-averse, least cost rehabilitation program has been formulated under above the diagnostic study. The remedial measures would include (a) installation of adequate gas treatment facilities and only dry and sweet gas (in accordance with the specifications) would be allowed to enter the pipelines, (b) rehabilitation and environmental upgrading of the transmission and distribution system that would mitigate the risk and would enable optimal upgrading and expansion for safe and efficient operation as well as environmental protection over the next 20 years, (c) enhancement of safety regulation, and (d) institution building through technical assistance (TA) and training. Moreover, as recommended by the study, all the functions relating to gas transmission and distribution operation has recently been consolidated into a single subunit (SPA T&D Company) which is fully accountable for efficient transportation of gas from the fields to the consumers. Further discussions on the findings and recommendations of the study, and the proposed project component along with the Terms of Reference for TA in project implementation, are set out in Annex 5.2.

5.13 Under the proposed project, measures which would enhance both the safety and operational efficiency of the transmission and distribution system would include (a) rehabilitation and upgrading of pipelines, measurement, corrosion control, corrosion inhibition, telecommunication, gas control, gas quality monitoring and emergency response facilities of SPA’s entire gas transmission and distribution system; (b) deterioration monitoring and evaluation of the transmission and distribution system; (c) provision of a supervisory control and data acquisition system (SCADA) for the whole transmission and distribution system; and (d) technical assistance and training.

5.14 In addition, the project would include cost-effective measures for reduction in gas leakages. The program of environmental upgrades would include (a) installation of additional valves at the vent stacks of both the gas gathering and transmission systems; (b) installation of chained caps or plugs on open ended pipelines; (c) upgrading or replacement of the seals of control valves; (d) replacement of high performance compressor seals; (e) upgrading of the seals of block valves; and (f) the implementation of comprehensive gas leak detection and repair programs, including repairs or replacement of leaking valves (including control valves, block valves and pressure relief valves); plugging of open-ended lines; and provision for methane emission monitoring equipment.

Institution Building Component

5.15 In connection with the various preinvestment studies for gas reserve assessment, gas transmission and distribution rehabilitation, as well as environmental assessment, transfer of technology and human resources development have been augmented
through overseas study tours and on-the-job training by international consultants. In addition, the project would include a comprehensive program of technical assistance and training for the implementation of the components for oil and gas sector restructuring and for gas production and transmission, as well as for national petroleum education. The draft training program and related cost estimates are shown in Annex 5.3. An assurance has been obtained from SPA and CNPC that training would be carried out in accordance with a program agreed with the Bank.

5.16 Oil and Gas Sector Restructuring. This component would include technical assistance to SPA for the promotion of petroleum concession offer to international investors (Terms of Reference in Annex 5.4) as well as training in modern management and tariff setting. In this connection, the JGF-financed study for oil and gas sector restructuring would include identification of staffing and skills required to implement the reform program and preparation of an appropriate training program for CNPC and SPA.

5.17 Gas Field Development and Transmission. The TA and training program for gas production and transmission would include twinning arrangements with international companies, training seminars in China and overseas study tours to cover a broad spectrum of SPA’s operations.

5.18 Financial Management. The project would include overseas training and seminars in China conducted by international consultants; these provisions would complement training by local institutes which is beyond the scope of the project. The scope of training would include accounting principles and practices of international oil and gas companies; corporate financial management, notably cost control/management and modern financing techniques; pricing policy and tariff setting, taxation policy and gas marketing.

5.19 National Petroleum Education. Building on the experience of the national petroleum education component under the recently completed Weiyuan Gas Field TA Project, the main objectives of the proposed petroleum education component ($5 million) are to: (a) upgrade the teaching and research capabilities of the local petroleum institutes; (b) develop exchange programs between the local and foreign institutes; (c) meet a growing demand for highly qualified personnel in technical, managerial and financial skills; and (d) introduce and develop advanced oil and gas field technologies.

5.20 As an immediate first step, a diagnostic review would be carried out by the Education Department of CNPC, with the assistance of international experts, to assess the needs for strengthening the teaching and research programs in a broad spectrum of disciplines (including petroleum geology, geophysics, petroleum engineering, mechanical engineering, chemical engineering, business management, computer science, and general education). Based on the results of the diagnostic review, the details of the proposed education component would be better defined. This component would include: (a) short and medium term overseas training; (b) international experts lecturing in China; and (c) teaching materials and computer software. The Terms of Reference for the diagnostic study are attached in Annex 5.5.
E. PROJECT ORGANIZATION AND MANAGEMENT

5.21 SPA is responsible for the implementation of the gas field development and transmission components and CNPC for the petroleum education component. SPA has established a Project Management Office (PMO) to coordinate the various project components. An assurance has been obtained from SPA that it would maintain the project management office with functions, powers, funds, facilities and staffing satisfactory to the Bank.

F. PROJECT IMPLEMENTATION SCHEDULE

5.22 The proposed project would be implemented over a seven-year period from 1994-2000. The project is estimated to be completed by June 30, 2000, and the loan closing date would be June 30, 2001.

G. PROJECT COST ESTIMATES

5.23 Project cost estimates are based on preinvestment studies prepared with the assistance of local design institutes and international consultants. The unit prices were derived through a reconciliation of data from the following sources: (a) quotations obtained from manufacturers and suppliers; (b) prices of goods and works from recent contracts in China; and (c) construction costs according to prices published by the government, adjusted for inflation. Physical contingencies have been estimated at 10 percent of the base costs (in early 1993 prices). The price escalation for costs expressed in terms of local currency equivalent is calculated according to the following projected local inflation rates: 15 percent per annum in 1993, 12 percent per annum in 1994, 9 percent per annum in 1995, 8 percent per annum in 1996, 7.2 percent per annum in 1997, 6.5 percent per annum in 1998 and 1999, and 6 percent per annum in the year 2000. The price escalation for costs expressed in terms of US dollars equivalent is calculated according to anticipated international price escalation of 2.8 percent per annum.

5.24 The total project cost (excluding interest during construction) is estimated at $877.9 million equivalent, with a foreign exchange component of $377.4 million equivalent (43 percent). The total financing required, including interest during construction ($67.3 million) is $945.2 million equivalent.

H. PROJECT FINANCING

5.25 The financing plan for the overall project is shown in Table 5.2.
<table>
<thead>
<tr>
<th>Description</th>
<th>Local ($ million)</th>
<th>Foreign ($ million)</th>
<th>Total ($ million)</th>
<th>Local (Y million)</th>
<th>Foreign (Y million)</th>
<th>Total (Y million)</th>
<th>Foreign as % of Total</th>
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<tr>
<td>Gas Field Development</td>
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<td>- Well Drilling</td>
<td>195.4</td>
<td>130.6</td>
<td>326.0</td>
<td>1,705.8</td>
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<td>- Seismic Surveys</td>
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<td>30.5</td>
<td>169.4</td>
<td>96.9</td>
<td>266.3</td>
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<tr>
<td>- Surface Facilities</td>
<td>22.0</td>
<td>21.3</td>
<td>43.3</td>
<td>192.0</td>
<td>185.9</td>
<td>377.9</td>
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<td>165.0</td>
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<td>Gas Field Stimulation &amp; Rehabilitation</td>
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<td>24.1</td>
<td>92.2</td>
<td>594.5</td>
<td>210.4</td>
<td>804.9</td>
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<td><strong>Total Base Costs</strong></td>
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<td><strong>303.5</strong></td>
<td><strong>703.7</strong></td>
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<td>Physical Contingencies</td>
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<td>265.0</td>
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<tr>
<td><strong>Total Project Costs /a</strong></td>
<td><strong>500.4</strong></td>
<td><strong>337.4</strong></td>
<td><strong>837.9</strong></td>
<td><strong>4,843.1</strong></td>
<td><strong>3,914.5</strong></td>
<td><strong>8,757.6</strong></td>
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<td>Interest during construction /b</td>
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<td><strong>Total Financing Required /c</strong></td>
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<td><strong>444.7</strong></td>
<td><strong>945.2</strong></td>
<td><strong>6,064.0</strong></td>
<td><strong>5,212.8</strong></td>
<td><strong>11,185.8</strong></td>
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</tr>
</tbody>
</table>

/a The project is exempt from import duties and taxes. Local cost includes Y 241 million ($28 million equivalent) in taxes on local expenditures.
/b Interest during construction (IDC) is based on onlending rates for projected disbursements of loan proceeds. The foreign currency portion of IDC is based on the Bank loan variable rate.
/c Figures may not total exactly due to rounding.
Table 5.2: Project Financing Plan
(in $ million equivalent)

<table>
<thead>
<tr>
<th>Source</th>
<th>Local</th>
<th>Foreign</th>
<th>Total</th>
<th>Percentage of financing</th>
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<td>GET</td>
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<td>10.0</td>
<td>1</td>
</tr>
<tr>
<td>SPA/CNPC</td>
<td>500.4</td>
<td>179.7</td>
<td>680.2</td>
<td>72</td>
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<tr>
<td>IBRD</td>
<td>0.0</td>
<td>255.0</td>
<td>255.0</td>
<td>27</td>
</tr>
<tr>
<td><strong>Total Financing Required</strong> /a</td>
<td><strong>500.4</strong></td>
<td><strong>444.7</strong></td>
<td><strong>945.2</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

/a Includes interest during construction (IDC) of about $67.3 million. Figures may not total exactly due to rounding.

5.26 The total foreign exchange requirements are estimated at $444.7 million, of which $255 million and $10 million would be financed by the proposed Bank loan and GET grant, respectively. The balance of the foreign exchange financing requirements would be financed by CNPC's own resources. Local counterpart funding would be financed by SPA's internal cash generation.

5.27 The Bank loan of $255 million equivalent would be made to China for a 20-year term, including a 5-year grace, at the Bank's standard variable interest rate. An assurance was obtained from the borrower that $250 million and $5 million would be onlent to SPA and CNPC, respectively, on the same terms and conditions as the Bank loan. SPA and CNPC would bear the foreign exchange risks. Execution of the subsidiary loan agreements between the Government and SPA/CNPC, satisfactory to the Bank, would be a condition of loan effectiveness.

5.28 International procurement under the project would be carried out by a qualified government authorized agent that has been recently appointed by SPA. Model bidding documents specifically prepared for China in accordance with Bank Procurement Guidelines will be used for all procurement activities under the project. In addition, SPA recently established a procurement unit (PU) as part of the aforementioned PMO. The PU unit will coordinate with the international procurement agent and the relevant SPA departments to manage the procurement process under the project, including procurement schedules, preparation of tender documents, technical specifications, bid evaluation, contract administration and monitoring. In addition, in view of SPA's relative inexperience with the international competitive bidding process, an experienced consultant would be hired to assist SPA in international procurement. The Terms of Reference for...
this consultancy are set out in Annex 5.6. The procurement arrangements for the project are summarized in Table 5.3.

5.29 Most of the equipment, materials and spare parts to be imported for well drilling and rehabilitation, field production, seismic data acquisition, construction of surface facilities, and rehabilitation of gas transmission and distribution system would be packaged for international competitive bidding (ICB) in accordance with the Bank’s Procurement Guidelines. About 80 packages, with an estimated total value of $205.9 million, would be procured under ICB. Each package is expected to cost $1 million or more. Local bidders participating in ICB would receive a preference in bid evaluation of 15 percent of the CIF price or the prevailing customs duty applicable to nonexempt importers, whichever is less, provided the local value added to the goods is not less than 20 percent of the ex-factory bid price.

5.30 Contracts for highly specialized equipment and services (including specifically designed drilling and coring bits, \( \text{H}_2\text{S} \) resistant wellhead assemblies and seismic data processing equipment, and services for high pressure \( \text{H}_2\text{S} \) drilling, directional drilling, electric logging, well cementing, production and stimulation) which can only be supplied by a limited number of international manufacturers and contractors, would be procured by limited international bidding (LIB) on the basis of bids obtained from at least three suppliers, up to an aggregate value of $25.5 million. About 15 packages, each with a value of about $0.5 million or more, would be procured under these procedures. Small value readily available off-the-shelf equipment and materials (fittings, thread dope, servicing and production unit tools, some fluid treatment chemicals and additives, etc.) would be procured through international shopping by comparing price quotations obtained from at least three suppliers to ensure competitiveness. Shopping procedures, which do not require formal bidding, would be limited to items or groups of items estimated to cost less than the equivalent of $200,000 per contract, up to an aggregate amount equivalent to $2 million. Proprietary items (including a limited number of laboratory instruments and spare parts for existing electric logging tools and seismic data processing centers) would be procured on a direct purchase basis, up to an aggregate value of $4 million.

5.31 Additional equipment and materials would be procured through local competitive bidding (LCB). The LCB procedures recently promulgated by the Government have been reviewed and found satisfactory to the Bank. The nature of equipment, materials and works entailed under LCB procedures is unlikely to attract foreign bidders; however, interested foreign bidders will be allowed to bid for LCB contracts. About 120 packages, each with a value of about $1 million or more, consisting of drilling materials, low pressure line pipes and gas treatment plant components with an estimated total value of $219 million would be procured under LCB. No procurement under LCB would be financed by the proposed Bank Loan.

5.32 Construction of well access roads and locations, surface facility sites, field transmission and gathering lines, along with some basic field services such as seismic survey and well drilling and rehabilitation operations, with an estimated value of $224.2 million, would be carried out by SPA’s own operating departments on a force
Table 5.3: PROCUREMENT ARRANGEMENTS
(in $ million)

<table>
<thead>
<tr>
<th>Project component</th>
<th>Procurement method</th>
<th></th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>ICB</td>
<td>Other/a</td>
<td>NBF/b</td>
<td>Total</td>
<td></td>
</tr>
<tr>
<td>Civil Works</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Well access road/drilling sites</td>
<td>-</td>
<td>-</td>
<td>30.4</td>
<td>30.4</td>
<td></td>
</tr>
<tr>
<td>Field surface facilities</td>
<td>-</td>
<td>-</td>
<td>38.2</td>
<td>38.2</td>
<td></td>
</tr>
<tr>
<td>Gas transmission &amp; dist. system</td>
<td>-</td>
<td>-</td>
<td>63.3</td>
<td>63.3</td>
<td></td>
</tr>
<tr>
<td>Equipment and Materials</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Field development drilling &amp; rehabilitation</td>
<td>102.1</td>
<td>18.7</td>
<td>145.8</td>
<td>266.6</td>
<td>(102.1)</td>
</tr>
<tr>
<td></td>
<td>(18.7)</td>
<td>(18.7)</td>
<td>(120.8)</td>
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<tr>
<td>Seismic survey</td>
<td>8.0</td>
<td>5.8</td>
<td>2.0</td>
<td>15.8</td>
<td>(8.0)</td>
</tr>
<tr>
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<td>Gas treatment and field surface facility</td>
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<td>-</td>
<td>82.2</td>
<td>101.7</td>
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<td>Gas transmission &amp; dist. system</td>
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<td>-</td>
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<td>(76.3)</td>
<td>(76.3)</td>
<td>(76.3)</td>
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<td></td>
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<tr>
<td>Technical Services /c</td>
<td>-</td>
<td>7.0</td>
<td>224.2</td>
<td>231.2</td>
<td>(7.0)</td>
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<tr>
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<td>(7.0)</td>
<td>(7.0)</td>
<td>(7.0)</td>
<td></td>
<td></td>
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<tr>
<td>Consultancy and Training</td>
<td></td>
<td></td>
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<tr>
<td>Capacity building</td>
<td>-</td>
<td>4.3</td>
<td>0.3</td>
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<tr>
<td>Project implementation support</td>
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<td>0.5</td>
<td>0.2</td>
<td>0.7</td>
<td>(0.5)</td>
</tr>
<tr>
<td></td>
<td>(0.5)</td>
<td>(0.5)</td>
<td>(0.5)</td>
<td></td>
<td></td>
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<tr>
<td>Training</td>
<td>-</td>
<td>12.8</td>
<td>0.3</td>
<td>13.1</td>
<td>(12.8)</td>
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<td></td>
<td>(12.8)</td>
<td>(12.8)</td>
<td>(12.8)</td>
<td></td>
<td></td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>205.9</strong></td>
<td><strong>49.1</strong></td>
<td><strong>622.9</strong></td>
<td><strong>877.9</strong></td>
<td><strong>255.0</strong></td>
</tr>
<tr>
<td></td>
<td>(205.9)</td>
<td>(49.1)</td>
<td>(255.0)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note:  (1) Figures in parentheses are amounts to be financed by the Bank.
       (2) Figures may not total exactly due to rounding.

/a Other procurement methods include limited international bidding, direct purchase, shopping and consultant services (recruited in accordance with the Bank's Guidelines) and training.
/b NBF denotes non-Bank financing.
/c Technical Services include directional drilling, electric logging, well connecting, production and stimulation.
account basis, for which Bank-financing would not be provided. The performance of SPA operating departments has been satisfactory.

5.33 The consultants retained under the project will be recruited in accordance with the Bank's Guidelines for the Use of Consultants by its Borrowers.

5.34 To ensure economy and efficiency in the project execution, equipment and materials with an estimated total value of $179.7 million, not financed by the Bank, would also be imported for the project following procedures similar to the model bidding documents to be used for Bank-financed procurement.

5.35 **Bank Review.** The Bank's prior review would be required for each contract for goods and technical services, estimated to cost no less than $1 million equivalent to be procured under ICB and LIB procedures; this represents about 80 percent of procurement of the Bank-financed portion of the project.

**J. DISBURSEMENT**

5.36 The Bank loan would be disbursed against: (a) 100 percent of foreign expenditures or 100 percent of local expenditures (ex-factory cost) of goods procured through ICB or, as appropriate, LIB, direct purchase and shopping; and 75 percent of local expenditures for other items procured locally; and (b) 100 percent of consulting services and training. To facilitate efficiency of disbursements, two special accounts, in US dollars (based on four months average disbursements) would be established, one for SPA and the other for CNPC, with authorized allocations of $10 million and $0.5 million, respectively. The special accounts would be replenished monthly or whenever the account amounts are drawn down to 50 percent of their initial deposit, whichever occurs first. Disbursements for training and goods contracts not exceeding $400,000 equivalent would be made on the basis of statements of expenditure (SOEs). The PMO of SPA and the Education Department of CNPC would retain documents supporting the SOEs; these documents would be made available for inspection and review by the Bank supervision missions. All other disbursements will be made against fully documented expenditures. Retroactive financing of up to $10 million is provided for expenditures incurred after September 30, 1993 covering urgently needed technical assistance and training required for detailed project design, including the diagnostic study for national petroleum education (para. 5.19). The disbursement schedule is projected to be largely consistent with the standard disbursement profile for power projects in China.

**K. ENVIRONMENTAL MANAGEMENT**

5.37 The proposed project would result in significant environmental benefits; increased gas supply and utilization would reduce coal consumption, which would in turn reduce emissions of SO₂, CO₂, and particulates. In addition, reduced gas leakages in the transmission and distribution systems would reduce emissions of methane, a potent greenhouse gas (para. 7.7).

5.38 No residents will have to be relocated as a result of this project. However, about 700 hectares and 190 hectares of agricultural land would have to be acquired on a
temporary and permanent basis, respectively. Public consultation has been built into the process of project preparation and implementation; site selection may be changed according to the preferences of the local residents. Procedures for compensation and resettlement have been established in both national and provincial legislations, with compensation payment based on the productivity of occupied land in recent years. These procedures are satisfactory.

5.39 Chinese regulation requires the preparation of an environmental assessment (EA) report at the time of project design. The EA report of the project, which was prepared with the assistance of TCC-financed international consultants, was satisfactory. As part of the environmental assessment process, mitigating measures for possible environmental impacts have been developed. In this connection, various preinvestment studies have been carried out with the assistance of international consultants, and the project design and implementation will conform with international engineering and safety standards as well as sound environmental management practices. The agreed environmental management program, including the implementation of a sound monitoring system and regular gas leak detection and maintenance program as well as appropriate disposal of produced formation water and other field wastes, is summarized in Annex 5.7. An assurance has been obtained from SPA that it would carry out an agreed environmental management program, in a manner satisfactory to the Bank.

L. PROJECT MONITORING, REPORTING AND SUPERVISION

5.40 The implementation schedule of the proposed project is in Chart 4. Reports on project progress would be sent to the Bank on a quarterly basis. The format and content of project progress reports have been discussed and agreed during negotiations. Following up on the project progress reports, the Bank would normally field two supervision missions per year. Given the complexity of this project, the supervision requirements are likely to be higher than the Bank-wide average. An indicative Bank supervision plan is shown in Annex 5.7. Various measures would be taken to help contain supervision costs, including (a) an agreement with SPA regarding satisfactory arrangements for project management, (b) provisions for technical assistance and training in project implementation, and (c) adding supervision for this project in the terms of reference of other project missions as well.

M. PROJECT SUSTAINABILITY

5.41 The sustainability of the proposed gas supply component is critically dependent on the quantities of gas reserves and rationalization of pricing policy. The quantities of commercially recoverable gas reserves expected to be derived from the project have been certified by an independent international consultant under the gas reserve assessment study. Further, assurances have been obtained from the government on the implementation of a reform action plan for the rationalization of gas pricing and allocation criteria. In addition, the Chinese authorities are committed to the implementation of the restructuring component under the project. Finally, the project would provide for technical assistance and training for project implementation. All these measures will contribute toward the project's sustainability.
6. FINANCIAL ASPECTS

A. INTRODUCTION

6.1 Since 1978, state-owned enterprises in China has operated within a financial system which is evolving with the economic reforms in the country. Starting from the early 1980s, government grants have been replaced by loans. The contract responsibility system was introduced in the mid-1980s to increase the autonomy and accountability of public enterprises in China. Insofar as the oil and gas sector is concerned, the offshore petroleum enterprises, which were established during the last decade, have enjoyed both operational and financial autonomy. However, as in the case of most energy entities in China (para. 1.25), the long established onshore petroleum enterprises, including SPA, have continued to operate under a highly centralized financial system. Specifically, gas pricing and allocation are largely set by the government; its operational and investment budgets as well as production targets are approved by the government. CNPC, its parent company, has continued to mobilize a portion of its investment financing and provide subsidy to cover "policy losses" within approved limits.

6.2 The present financial arrangements in the oil and gas sector have a number of shortcomings, notably the inadequacy of resource mobilization for sector development and inadequate financial accountability and discipline. The ability of the sector to increase the level of resource mobilization has been hampered by a number of factors, including inadequacy in tariff adjustments, the lack of diversification of financing and ownership, underdeveloped domestic capital markets, inexperience of most enterprises in modern financing techniques, as well as inadequate cost control and management. In the absence of deepened enterprise and fiscal reforms, the gap in financing the required sector investment would continue to increase in the 1990s.

6.3 The Chinese authorities are aware of the above systemic issues and, as noted above, they are committed to the implementation of a far-reaching reform program in the oil and gas sector within the overall framework of economic and enterprise reform in the country. Since the details of such reforms are still being formulated, there are considerable uncertainties relating to the specific parameters affecting the enterprises' future finances. Nevertheless, consistent with the guiding principles of the recently promulgated regulation on enterprise management (para. 1.26), the integrated measures of the economic reform would be directed at enhancing the commercial orientation of the petroleum enterprises.

6.4 SPA is undergoing a difficult transitional period of restructuring its internal organization and management. The proposed project is a vehicle for the Bank to effect its
development objective of strengthening SPA's financial capability and increasing its efficiency and effectiveness in carrying out the ongoing economic reforms. During the course of project preparation, the Bank was instrumental in effecting up-front actions for gas price adjustments. Further, the project would provide for: (a) a reform action plan to further rationalize both the levels and structure of gas tariffs; (b) implementation of the first phase of oil/gas sector restructuring, including commercialization and corporatization of SPA; (c) training in financial management; and (d) financial covenants which would establish a framework for greater financial discipline.

**B. ACCOUNTING**

6.5 All the state-owned enterprises in China follow a unified enterprise accounting system on an accrual basis. The current accounting standards were developed in the context of a highly centralized planned economy. With a view to complementing the ongoing efforts to deepen reforms in the financial sector and enterprise management, the accounting system in China needs modernization to permit satisfactory financial management in an increasingly decentralized and market-oriented environment. As a first step, the general principles of enterprise accounting have recently been revised by the Ministry of Finance (MOF). These revised principles are generally consistent with those of international accounting standards. Within this broad framework, specific accounting standards would be developed with the assistance of the Bank under the Financial Sector Technical Assistance Project (Credit 2423-CHA).

6.6 However, mainly due to the lack of distinction between financial reporting and tax accounting, significant anomalies remain in the accounting practices of the oil and gas producers which reflect their unique funding arrangements with the government. In particular, exploration costs, which are major expenditures for SPA, are not reflected in its operating cost. On the other hand, the revenues derived from the difference between quota and above-quota prices are not considered as income. In view of the foregoing, the financial reports of SPA continue to present a distorted view of the company's financial position and operating results. During negotiations, an assurance has been obtained from the government that sector specific accounting standards for the oil and gas sector would be revised and adopted consistent with international accounting standards. Training in modern financial management, including international accounting practices, would be provided to SPA under this project (para. 5.18).

**C. AUDITS**

6.7 **Internal Audit.** The present institutional capabilities of SPA in internal auditing appear to be inadequate both quantitatively and qualitatively. In this connection, CNPC has recommended an increase of internal auditing staff from 12 to 30 at SPA's headquarters. An assurance has been obtained from SPA that it will provide the Bank, by December 31, 1994, with an action plan to strengthen its internal audit function and thereafter take into account the Bank's comments in the implementation of this plan.
6.8 **External Audit.** As with other Bank-financed projects in China, the Foreign Funds Utilization Bureau of the State Audit Administration (SAA) will have the responsibility for auditing accounts concerning the project. This arrangement is satisfactory. Technical assistance for SAA will continue to be financed under the Planning Support and Special Studies Project (Credit 1835-CHA). *An assurance has been obtained from SPA and CNPC that the following annual audited financial reports would be submitted to the Bank within six months after the end of the financial year: (a) project accounts, including the auditor's opinion on the use of the Special Account and statements of expenditures (SOEs); and (b) SPA's financial statements.* In the case of SOEs, the audit report would contain a separate opinion by the auditors as to whether the SOEs submitted during the fiscal year, together with the procedures and internal controls involved in their preparation, can be relied upon to support the related withdrawals.

**D. Finances of SPA**

**Past Finances and Present Financial Position**

6.9 Hitherto, SPA has operated as a single legal entity with no subsidiaries (para. 4.3). Each of its major activities is a separate accounting subunit and is managed along the lines of profit or cost centers, although intercompany transactions may not always be conducted on a strictly commercial basis. SPA's activities include, inter alia, (a) gas exploration and production (E&P), the dominant business; (b) gas purification; (c) gas transmission and distribution; and (d) other activities, including operation of a small oil refinery, sales of various petroleum products and by-products (e.g., sulphur) as well as headquarters administration.

6.10 **Revenue Position.** Over the past few years, SPA's E&P operations have increasingly suffered operational losses. This was mainly attributable to rapidly rising operating costs which increased at an average of 14 percent per annum during the period 1988-92. Meanwhile, gas sales volume increased slowly at an average rate of 2 percent per annum. Further, adjustments of well-head prices and city-gate price averaged 6 percent and 9 percent, respectively; these adjustments were not adequate to cover the cost escalations. As a result, SPA's consolidated net income declined sharply from a peak of Y 301 million in 1989 to Y 58 million in 1992. As a first step in the right direction, the average well-head price was increased by some 50 percent in 1992 (para. 3.14).

6.11 **Investment Financing.** SPA has thus far maintained a very low debt position with debt/equity ratio of 12/88 by end-1992. This reflects mainly the conservative financing policy of the Chinese authorities to rely mainly on self-financing for the gas sector. However, as noted above, natural gas prices have thus far remained inadequate. As a result of financing constraint, SPA was unable to complete the original work program and related gas production target under the Seventh Five-Year Plan. Over the past five years, SPA's capital expenditures increased by 53 percent, reflecting SPA's efforts to enhance gas production through increased investment. Its self-financing ratio increased from 52 percent in 1988 to 70 percent in 1992, mainly as a result of the aforementioned gas price adjustment.
6.12 Liquidity Position. SPA’s overall liquidity position has remained satisfactory, as indicated by its current ratio of no less than 1.6 times during the period 1988-92. However, there were two areas of special concern:

(a) Accounts Receivable Collection. SPA supplies directly to some 600 large industrial customers and to fifteen major city gas companies. All the customers are charged once a month according to the meter readings. With the onset of domestic credit squeeze in 1988, intercompany indebtedness among the state-owned enterprises has become a serious problem in China. Since 1991, the government has increased the credit availability for settlement of intercompany indebtedness. Consequently, SPA’s average collection period was reduced from a peak of 72 days in 1988 to 48 days in 1992.

(b) Stock Management. SPA has maintained a high level of inventory which comprises mainly material supplies for both operations and capital construction. Its inventory reached a record high level of Y 1.2 billion by end-1992. This was, in part, due to inadequate stock management and control.

Future Finances

6.13 Financial Performance Targets. SPA’s management is aware of the need to strengthen the company’s finances, and, in addition to tariff adjustments, would pursue other remedial measures. In particular, these measures would include making improvements in operational efficiency and cost controls; the proposed project would assist SPA in the attainment of its financial objectives. During negotiations, assurances have been obtained from SPA that it would:

(a) take all measures, including but not limited to tariff adjustments and improvements in operational efficiency, to ensure that the revenues of its overall operations and of each of its major operations in gas production, purification and transmission are sufficient to cover all operating costs, and the greater of depreciation or debt service requirements;

(b) maintain a self-financing ratio of no less than 50 percent for its future investments;

(c) achieve a financial rate of return of no less than 12 percent (in real terms) under the proposed project; and

(d) by September 30 of each year, starting from September 30, 1994, annually furnish the Bank with a rolling long-term financial plan (including projected income statements, sources and uses of funds and balance sheets for a period of no less than eight years) and exchange views with the Bank on the companies’ finances, focusing on comparison of actual financial
6.14 The future finances of SPA, including major assumptions and projected financial statements over the period 1993 to 2000, are in Annex 6.2. Based on the assumption that the minimum average tariffs would be set at levels which would allow SPA to achieve the above financial performance targets, its finances are forecast to be satisfactory.

6.15 Revenue Position. Over the period 1993-2000, SPA's gas production is projected to increase, by an average rate of 3 percent per annum, to 8 bcm by the year 2000. The minimum average well-head prices required to achieve the agreed financial performance targets are projected to increase from Y 254/mcm in 1993 to Y 620/mcm in the year 2000, representing an average of 14 percent per annum (about 4 percent in real terms). Given the capital-intensive nature of gas production and transmission, SPA's cost structure and resultant impact on its profitability are particularly sensitive to the depreciation rates of its assets. In forecasting the future finances of SPA, it has been conservatively assumed that the present depreciation rates for major categories of its assets, which are considerably faster than the average economic life of these assets, would remain (Annex 6.2). On this basis, SPA's gas production operations and consolidated finances are forecast to become profitable starting from 1994 onwards. Its consolidated net income is projected to turn around from a net loss of Y 190 million in 1993 to Y 507 million in the year 2000.

6.16 Liquidity Position. In the wake of inflationary concerns in China, domestic credit has been increasingly tightened in 1993. Thus, the aforementioned problems relating to intercompany indebtedness are emerging again. To ensure the financial soundness of the company, SPA would need to monitor closely its sizable accounts receivable and inventory turnover and maintain them at acceptable levels. To this end, SPA has started to adopt various measures to provide customers with incentives to make timely payment, including (a) imposing penalties on customers with overdue payments; and (b) reducing gas supply by 50 percent for customers who maintain continuous arrears. These measures would allow SPA to maintain a more reliable cash flow from sales. Further, as part of the overall SPA institutional restructuring (para. 4.6), the inventory management function would be reorganized and strengthened with a view to minimizing the working capital requirements.

6.17 Investment Financing. In order to achieve the gas production targets set for this decade, SPA's investment requirements would be increased substantially from the past levels for the following reasons: (a) development of new fields and enhanced gas recovery to arrest natural production decline of aging fields would be increasingly difficult and costly to achieve; and (b) underinvestment in the past in terms of both quantity and quality of SPA's work program.

6.18 During the financial forecast period, SPA's planned investments would total
Y 20 billion ($2.3 million equivalent); SPA’s self-financing ratios for these investments are projected to be no less than 76 percent. The proposed project would account for about 41 percent of the company’s total investment program, and the proposed Bank loan would meet about 11 percent of SPA’s total financing requirements. Separately, as noted above, SPA would seek to diversify its sources of financing and ownership, including the aforementioned opening up of petroleum concessions for direct foreign investment and transformation of selected subsidiaries into joint-stock companies (para. 4.6). However, due to the preliminary nature of these activities, the financial forecast has not reflected these potential sources of financing. SPA is projected to maintain a relatively low debt/equity ratio of no more than 24/76 throughout the forecast period.

6.19 **Project Financial Rate of Return.** The financial rate of return (FRR) based on the discounted cash flow (DCF) over the life of the project is critically dependent on the levels of incremental gas production (para. 7.2) and prices. Based on the agreed financial performance targets in the price reform action plan, gas prices would be adjusted at such levels that the project FRR would be no less than 12 percent (in real terms).
7. PROJECT JUSTIFICATION AND RISKS

A. PROJECT BENEFITS

7.1 The proposed project has been designed to promote sustainable development through institutional restructuring and alleviation of energy shortages in an environmentally sound manner. The investment component would result in incremental gas production which would help offset the natural decline of aging fields in Sichuan. In addition to quantifiable economic benefits, the project would lend added momentum to policy and enterprise reforms as well as human resources development in the sector. Further, the project would result in mitigation of air pollution and related health impact through the substitution of coal by gas. The gas transmission rehabilitation component would also enhance safety, minimize gas leakages and reduce the emissions of methane and related global warming impact. Successful implementation of this project component would have a significant demonstration effect for other gas transmission and distribution systems in China and other developing countries.

B. ECONOMIC BENEFITS

7.2 Incremental Production. The investment component for gas field development and well rehabilitation would result in an incremental production of gas and condensate totalling 68 bcm and 74,000 tons, respectively, over a 20-year period (1995-2015), representing an average annual gas production of about 3.4 bcm. In addition, gas would be saved from the rehabilitation and environmental upgrade of the gas transmission and distribution system, estimated at about 0.17 bcm per annum, totalling about 3.4 bcm over the life of the project.

7.3 Economic Values of Gas. The imputed values of the economic benefits of natural gas are commonly indicated by the price of alternative fuels or netback values [the avoidable cost of alternative fuels adjusted for any capital cost savings and efficiency gains through fuel substitution or, in the case of feedstock applications, the economic value of the final output, net of any incremental costs for conversion, construction and operation]. In the case of Sichuan gas, the lowest values of the alternative fuel is the international price of fuel oil (at about $11.8/bbl, FOB Singapore) which is equivalent to about $60.34/mcm of gas (or Y 543/mcm at the shadow exchange rate of Y 9 to $1). The international fuel oil parity also approximates the economic cost of delivered coal in Sichuan (the long run marginal cost of mine-mouth coal from northern China plus transport cost to the province).
7.4 The UNDP-financed study on gas pricing and allocation has included estimates of netback values as an indication of the relative economic benefits of different gas uses. The study concluded that there is a wide disparity in the estimated netback values of major present gas uses in Sichuan, ranging from Y 1,404/mcm for large urea plants to Y 631/mcm for methanol production. Based on the study's estimates of netback values and the current gas consumption, the weighted-average netback value of Sichuan gas is estimated at Y 1,119/mcm or $124/mcm at the shadow exchange rate. However, the above study is intended to be policy-oriented rather than a detailed empirical assessment of the Sichuan gas sector. Thus, the absolute levels of netback values estimated by the study are only preliminary rough estimates.

7.5 Economic Rate of Return. For purposes of calculating the base case of the economic rate of return (ERR) of the investment component, the economic value of natural gas has been conservatively assumed to be the lowest value of replacement fuel, namely international fuel oil prices. Separately, the economic value of condensate has been estimated at international price of naphtha of about $150/ton. On this basis, the ERR has been estimated at 24 percent and the net present value (NPV, at a 12 percent discount rate) would be about $275 million. The ERR and NPV would be increased to 82 percent and $1.5 billion, respectively, based on the aforementioned netback value of natural gas uses which indicates the maximum imputed value of natural gas in Sichuan.

7.6 Sensitivity Analysis. The results of sensitivity analysis are summarized below:

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<th>ERR</th>
<th>NPV</th>
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<tr>
<td>(a) Base case</td>
<td>24%</td>
<td>275</td>
</tr>
<tr>
<td>(b) Benefits 10% lower</td>
<td>19%</td>
<td>162</td>
</tr>
<tr>
<td>(c) 20% cost overrun</td>
<td>16%</td>
<td>105</td>
</tr>
</tbody>
</table>

7.7 Environmental Subcomponents. The economic values of gas saved under most of the environmental subcomponents for rehabilitation of SPA’s transmission and distribution system would more than offset the capital and operating costs, thus yielding net economic benefits. Four of these subcomponents (replacement or upgrading the packing of block valves, replacement of control valves and plugging open-ended lines) would entail net incremental costs which would be largely financed by the GET grant.

C. ENVIRONMENTAL BENEFITS

7.8 In addition to the quantified economic benefits noted above, the project would also result in mitigation of environmental degradation and health concerns (notably respiratory diseases) through the substitution of coal (2.9 million tons per annum) by gas, which would, in turn, reduce emissions of SO$_2$ (171,080 tons per annum), CO$_2$ (2.3 million tons per annum), nitrogen oxide (6,100 tons per annum), carbon monoxide (64,985 tons per annum) and ash (948,300 tons per annum). However, while the qualitative benefits of these environmental externalities are clear, these impacts cannot be estimated with
precision. Common approaches in quantifying the environmental benefits include: (a) an estimate of the environmental damage avoided through the development of "damage functions" based on studies of the physical impacts and the values that people place on avoiding these impacts; or (b) the avoided cost of pollution abatement using available control technologies; the marginal cost controlling any given pollutant varies significantly depending on the technology and the level of pollution control. In the case of the proposed project, the lack of relevant data has prevented the economic analysis from the inclusion of quantified environmental premium of gas usage. Thus, the economic benefits of the project have been understated.

D. PROJECT RISKS

7.9 Gas field development in Sichuan faces relatively high geological and technical risks mainly due to complex geology and difficult operating conditions. These risks would be mitigated by the provisions of appropriate modern technology and equipment under the project. Further, to minimize the risks related to the uncertainties of economically recoverable gas reserves, a techno-economic pre-investment study on gas reserve assessment and development plan optimization has been undertaken with the assistance of international consultants. In addition, assurances have been obtained from the government on the implementation of a reform action plan for the rationalization of gas pricing and allocation criteria to ensure the financial sustainability of the proposed gas supply component. To reduce the risks of delay in implementation of the project, an agreement has been obtained from the Chinese authorities to maintain satisfactory arrangements for project management. Moreover, the requisite technical assistance and training in project implementation would be provided under the project.
8. AGREEMENTS REACHED AND RECOMMENDATION

8.1 During negotiations, assurances have been obtained from the borrower that it would:

(a) implement a gas allocation and pricing reform action plan, agreed with the Bank (para. 3.16);

(b) onlend the proceeds of the Bank loan to SPA and CNPC for 20 years, including 5 years of grace, at the Bank's standard variable interest rate (para. 5.27); and

(c) revise and adopt sector specific accounting standards for the oil and gas sector consistent with international accounting standards (para. 6.6).

8.2 Assurances have been obtained from SPA that it would:

(a) carry out training in accordance with a program agreed with the Bank (para. 5.15);

(b) maintain the project management office with functions and staffing satisfactory to the Bank (para. 5.21);

(c) carry out an environmental management program satisfactory to the Bank, including the implementation of a regular gas leak detection and maintenance program (para. 5.38);

(d) furnish to the Bank by December 31, 1994 an action plan to strengthen its internal audit function and implement the plan taking into account the Bank's comments (para. 6.7);

(e) ensure that its revenues of its overall operations and of each of its major operations (gas production, purification and transmission) are sufficient to cover all operating costs, and the greater of depreciation or debt service requirements [para. 6.13(a)];

(f) maintain a self-financing ratio of no less than 50 percent for SPA's future investments [para. 6.13(b)];

(g) achieve a financial rate of return of no less than 12 percent (in real terms) under the proposed project [para. 6.13(c)]; and
(h) furnish to the Bank a rolling long-term financial plan by September 30 of each year and review its future finances with the Bank [para. 6.13(d)].

8.3 Arrangements to ensure the safety of the expansion of the gas transmission and distribution system, satisfactory to the Bank, would be a condition of disbursement for this component (para. 5.10).

8.4 An assurance has been obtained from CNPC that it would carry out training in accordance with a program agreed with the Bank (para. 5.15).

8.5 Execution of the subsidiary loan agreements between the Government and CNPC/SPA, satisfactory to the Bank (para. 5.27), and approval of the Loan Agreement by the borrower’s State Council would be conditions for loan effectiveness.

8.6 With the above assurances, the proposed project would be suitable for a Bank loan of $255 million equivalent for a period of 20 years, including 5 years of grace, at the Bank’s standard variable interest rate, to the People’s Republic of China.
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**Notes:**
1. Excluding bio-energy, solar, geothermal and nuclear energy.
2. All fuels are converted into standard coal with thermal equivalent of 7,000 kilocalorie per kilogram. The conversion factors are:
   - 1 kg of coal (5,000 kcal) = 0.714 kg of standard coal
   - 1 kg of crude oil (10,000 kcal) = 1.43 kg of standard coal
   - 1 cubic meter of natural gas (9,310 kcal) = 1.33 kg of standard coal
3. The conversion of hydropower is based on the specific consumption of standard coal for thermal power generation of the year.

**Source:** China Statistical Yearbook 1991.
## China: Oil & Gas Production
(1949 --- 1992)

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<td>1992</td>
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China: Oil & Gas Production
(1949 - 1992)

Gas Production (BCM)

Oil Production (Million ton)
# Major Oil & Gas Field Production

(1988 - 1992)

<table>
<thead>
<tr>
<th>Year Field</th>
<th>Crude Oil (Million Ton)</th>
<th>Natural Gas (BCM)</th>
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</thead>
<tbody>
<tr>
<td>Total</td>
<td>137.0</td>
<td>137.7</td>
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<tr>
<td>A. Onshore</td>
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</tr>
<tr>
<td>Daqing</td>
<td>55.70</td>
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<td>Shengli</td>
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<td>Huabei</td>
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<td>Liaobe</td>
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<td>Xinjiang</td>
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<td>Dagang</td>
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<td>B. Offshore</td>
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<td>CNOOC</td>
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ANNEX 2.3

China Crude Oil Price
(1988 - 1992)

<table>
<thead>
<tr>
<th>Year</th>
<th>High (average)</th>
<th>Low (average)</th>
<th>Weighted Avg.</th>
<th>Growth</th>
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<tbody>
<tr>
<td></td>
<td>Price (Y/T)</td>
<td>Weight (%)</td>
<td>Price (Y/T)</td>
<td>Weight (%)</td>
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<tr>
<td>1988</td>
<td>500</td>
<td>30</td>
<td>115</td>
<td>70</td>
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<tr>
<td>1992</td>
<td>530</td>
<td>50</td>
<td>210</td>
<td>50</td>
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</tbody>
</table>

![Graph showing China Crude Oil Price (1988 - 1992)](chart.png)

- **high** - **Low** - **Weighted Average**
CHINA: Oil /Products Consumption and Exports
(in Million Tons)

<table>
<thead>
<tr>
<th></th>
<th></th>
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<tbody>
<tr>
<td>Production</td>
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<td>137</td>
<td>138</td>
<td>138</td>
<td>140</td>
<td>142</td>
<td>143</td>
<td>1</td>
<td>7</td>
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<tr>
<td>Domestic Consumption</td>
<td>109</td>
<td>112</td>
<td>117</td>
<td>117</td>
<td>123</td>
<td>134</td>
<td>139</td>
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<tr>
<td>Net Exports</td>
<td>25</td>
<td>25</td>
<td>21</td>
<td>21</td>
<td>17</td>
<td>9</td>
<td>4</td>
<td>26 (84)</td>
<td></td>
</tr>
<tr>
<td>Export</td>
<td>27</td>
<td>27</td>
<td>25</td>
<td>24</td>
<td>25</td>
<td>21</td>
<td>19</td>
<td>6 (30)</td>
<td></td>
</tr>
<tr>
<td>Import</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td>8</td>
<td>12</td>
<td>15</td>
<td>43</td>
<td>757</td>
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</tbody>
</table>

CHINA: Oil/Products Consumption & Exports

![Graph showing oil products consumption and exports in China from 1987 to 1993. The graph includes bars for production, domestic consumption, and net exports. The production values range from 134 to 143 million tons, domestic consumption from 109 to 139 million tons, and net exports from 25 to 4 million tons.]
POLICY LETTER ON OIL AND GAS SECTOR REFORMS

Mr. Shahid Javed Burki
Director
China and Mongolia Department
The World Bank
1818 H Street, N.W.
Washington, D.C. 20433
The United States of America

December 30, 1993

Dear Mr. Burki,

Prior to the negotiation of the proposed Bank Financed Sichuan Gas Development and Conservation project, I hereby present, on behalf of the Government of China, a statement on the status of the ongoing reform and next phase of reform program in China’s oil and gas sector and the China National Petroleum Corporation (CNPC).

The major objective of the reforms in the oil and gas sector and the restructuring of CNPC is to improve the productivity and economic efficiency and to promote the development of petroleum and gas industry by: (a) separating the governmental function from the management of the enterprises; (b) defining clear-cut property relationship; (c) establishing the market for oil and gas exploration and development compatible with international practice; (d) improving the legal and regulatory system for macro-control; (e) transforming the oil and gas fields and other petroleum enterprises into independent legal entities bearing full rights and obligations in the market competition.

1. Separating the governmental function from the management of enterprises.

CNPC shall transfer its administrative function to the departments concerned under the State Council, and operate as a national state-owned company to manage and supervise the state assets in its subsidiaries. The government departments concerned shall focus on policy-making, regulatory formulation and medium and long-term planning. The regular operations of CNPC will be free from direct interference by government agencies.

2. Phasing in the corporatization and restructuring of the oil and gas fields.

Oil company, service company and social welfare units shall be spun off the main body of the oil and gas fields, and become independent legal entities. The existing pattern
of self-contained, self-served petroleum administrative bureaus shall be transformed. Meanwhile, in accordance with the Corporation Law, and based on assets evaluation and property rights verification, oil companies, service companies and some social welfare units shall be restructured, according to their different status, respectively into solely state-owned companies, state-holding companies, and limited liability companies with their stock held by the state, legal persons and employees, thereby establishing the modern enterprise system compatible with the international practice.

3. Setting up the market for oil and gas exploration and development and creating a competition mechanism for enterprises.

After they meet all the necessary requirements, all exploration districts, development and construction projects should subject to open and fair competition in the market, and the enterprises shall compete for oil and gas exploration and development on the basis of qualification. Thus a competitive environment shall be set up in which the well managed enterprises shall survive whereas the badly run ones shall be eliminated.

4. Further expanding the opening up and international cooperation for the on-shore oil exploration and development in China.

CNPC shall cooperate with foreign oil companies to explore and develop the blocks in east and west China endorsed for joint ventures by the government, in accordance with international practice and the relevant regulations. On the other hand, CNPC’s activities shall extend to the outside world and CNPC shall participate more vigorously in competition in the international petroleum market, including concession contract and cooperative development.

5. Improving the state’s macro-control and regulatory system.

The government administrative agencies shall be designated for macro-control and their functions and responsibilities shall be clearly defined. The oil and gas prices shall be rationalized and administrated prices shall be gradually unified with the market prices and converge with the international price. The central-planned production and marketing shall be gradually replaced by the market-based practice with state guidance, so that the enterprises can operate independently with profit-maximizing as their objective. The accounting system shall also be reformed to meet the international practice, and the incidence of taxation be reduced and made more fair. The infrastructure of oil and gas market should be improved and the market supervision and management be strengthened. Those reforms shall be standardized and guaranteed through legislative process.

All the above mentioned reforms are to be implemented as part of the national reforms in the economic system, and shall be basically completed by the end of 1990’s. Since the beginning of this year, great progress have been achieved great progress in implementing CNPC’s restructuring program, formulating regulations on operation mechanism transformation of petroleum enterprises, transferring the operation power to the
level of Petroleum Administrative Bureau, and determining the direction and basic framework for the restructuring of CNPC.

The study for action plan concerning the sector and CNPC restructuring, as you are aware, is being undertaken jointly by C&L Advisory Co. and the specialist group made up of CNPC and government agencies. The final report shall be completed next year and is expected to be put into practice step by step, in the context of the actual situations.

Yours sincerely,

Jin Renqing (signed)
Vice Minister of Finance
People's Republic of China
TERMS OF REFERENCE
RESTRUCTURING OF THE CHINA NATIONAL PETROLEUM CORPORATION

A. BACKGROUND

Economic Reform in China

1. The process of reform of the centrally planned Chinese economy to a market-based economic system was initiated in the late 1970s. In recent years, it has gained momentum, fuelled by past successes and the strong economic performance of the more-liberalized sectors of the economy. Considerable progress has been made in putting in place the appropriate macroeconomic policy framework for the transition to a market-based economy, from trade to price liberalization, to encouragement of foreign investment and nonstate enterprise development, to decreased involvement of government agencies in the management and operations of state enterprises. This is not to say that the process is nearing completion. There is the need for further trade reform if China is to qualify for participation in the GATT. Moreover, there remain important concerns about the relatively slow progress of reform in the financial and strategic sectors of the economy. Further separation of government from enterprise management in the strategic industrial sectors of the economy is required. There is not yet in place an appropriate legal and regulatory framework, nor an effective competition policy, for the efficient functioning and governing of a market-based economy. There has been only relatively modest progress to date in the restructuring of state-owned enterprises (SOEs). Indeed, it will take time to develop the new social systems to replace the present provision of housing, pension, health and education benefits through public enterprises, and to generate the alternative sources of employment opportunity that will be necessary before large levels of excess labor can be shed from the SOEs.

2. The process of reform has tended to lag in the designated strategic industrial and energy sectors of the economy. These are dominated by large state-owned enterprises (SOEs), many of which are relatively inefficient and high-cost operations. They are also burdened by social obligations and government policies which are inconsistent with efficient and competitive company performance in a market-based economy. Of the total industrial enterprise losses, coal accounts for some 21 percent and crude oil a further 14 percent. This is in part due to "policy losses" from underpricing of energy. For the SOEs to achieve financial viability and efficiency, a consensus appears to be emerging that most industrial SOEs will require greater independence from state industrial bureaux and planning commissions than is now the case; that they will need to undertake extensive restructuring of their operations, focusing on their core business activities; and that they...
will need to emphasize productivity enhancement, including change of management, financial and information systems. Furthermore, these actions will need to progress in parallel with reform of the policy framework governing their sectors, including further liberalization of sector markets and prices. In recent months, significant price reforms have been initiated in the energy sector; coal and crude oil prices are planned to be fully liberalized within the next three years. Moreover, average levels of well-head gas prices have been increased by some 50 percent. However, in order to mobilize the necessary resources for sector development and to provide adequate incentives for efficient supply and consumption of gas, further improvement in gas pricing and allocation is indicated. Under the proposed Bank-financed Sichuan Gas Development and Conservation Project, the Sichuan authorities would prepare shortly a time-bound reform action plan based largely on a Sichuan Gas Allocation and Pricing Study recently been completed with the assistance of international consultants.

3. A major task of the ongoing enterprise reform in China is to define and separate the different functions of the various groups concerned with the supervision and operation of the SOEs. During the last decade, various reform measures were introduced to increase the autonomy of state-owned enterprises, most notable among these is the contract responsibility system (CRS) whereby the SOEs are held accountable under performance contracts concluded with the government. However, the CRS has not resolved the confusion of fiscal and investment decisions, and SOEs continue to renegotiate their obligations and benefits with the government. Recent reform initiatives to refine the CRS are linked to tax reform to separate taxes (which are to be rule-based) and profit targets of SOEs.

4. The enterprise policy framework governing the SOEs has been considerably improved by the Regulations on Transforming the Management Mechanisms of State-Owned Industrial Enterprises (NOM) issued in July 1992. The NOM is the core of China's new governance policy towards the SOEs. The guiding principles of the NOM are to separate government administration from enterprise management, increase the autonomy and accountability of state-owned enterprises, increase competition and market-orientation. With the NOM, enterprise management is granted clear authority over most economic decisions, including prices, production, sourcing and employment. As owner, the state retains the right of approval over such important matters as large capital investments, joint ventures, mergers and acquisitions. The NOM does not, however, address certain key issues such as the government oversight function, ownership and the SOE corporate form. In addition to the NOM, Regulations on Enterprises' Shareholding System Experiment were issued in 1992 to promote the restructuring of state enterprises as shareholding companies. In this connection, the government has issued its Views on Standards for Limited Share Companies and Views on Standards for Limited Liability Companies. All these efforts are indicative of the government's resolve to eventually transform the state enterprise system into a full-fledged independent corporate structure.

5. All the state-owned enterprises in China follow a unified enterprise accounting system. As a first step to modernize the accounting system in China, the general principles of enterprise accounting have recently been revised by the Ministry of
Finance (MOF). These revised principles are generally consistent with those of international accounting standards. Within this broad framework, general accounting standards are being developed with technical assistance of international consultants. In addition, specific accounting standards for selected sectors, including oil and gas (notably accounting treatment of exploration costs), would also be revised and developed in accordance with international accounting standards.

Oil and Gas Sector Management and Reform

6. Coal meets approximately three quarters of China's commercial energy needs. The shares of oil and gas in energy consumption are about 17 percent and 2 percent, respectively. China is a net exporter of oil, with annual production in 1991 at 140 million tons and exports of 17 million tons of oil/products (net of imports). China's oil production is largely from onshore fields with production from the Daqing and Shengli oil fields accounting for approximately 64 percent of total production. Most of the major oil and gas producing fields in China are considered mature and many of these fields have already experienced natural production decline. Consequently, total domestic oil production has been increasing relatively slowly in recent years, and not keeping pace with the growth in domestic demand for petroleum products which has been increasing in parallel with the strong growth in the economy. Thus, the recent trend of net oil/product export decline is expected to continue and China could become a net oil importer in the near to medium term.

7. Demand for natural gas has been supply-constrained for a number of years. Gas production has been increasing by 2-3 percent per annum in recent years, to reach 15.4 billion cubic meters in 1991. Of this total, roughly half is nonassociated gas production, ninety percent of which is produced in Sichuan province. The remaining production is associated with onshore oil production. Sichuan gas production is planned to increase from the present level of 6.5 bcm to 8.0 bcm in 2000, to be achieved through increased budgets for exploration and development. The Chinese authorities are also promoting gas-oriented exploration in other regions with the objective of diversifying supply sources and increasing the nonassociated gas portion of domestic supplies.

8. The Government has recognized both the need to accelerate oil and gas explorations and development activity, and the benefits to the nation of involvement of the IOCs in this endeavor (not only from the perspective of capital resources but also the transfer of technology and expertise that accompanies foreign investment). From the early 1980s exploration in offshore basins has been open to foreign investment, although exploration results have been modest. In 1986, the IOCs were also invited to explore onshore basins in eleven southern provinces. In recent months, there has been a renewed effort to involve the IOCs in the onshore exploration and production efforts. Twelve regions in China will be opened for foreign investments, including the prospective Tarim Basin in the northwest and existing oil fields in northern and eastern China.

9. Until 1988, the Ministry of Petroleum Industry (MOPI) generally oversaw all upstream activities in the oil and gas sector. As part of the administrative reform in
1988, the responsibility for overseeing the entire energy sector was consolidated under the Ministry of Energy (MOE). The former MOPI was transformed into a corporation, the China National Petroleum Corporation (CNPC), which continues to report directly to the State Council. Since further administrative reforms in March 1993, MOE has been replaced by the Ministries of Power and Coal. The State Pricing Bureau is responsible for setting energy prices. The State Planning Commission has the responsibility for review and approval of the CNPC strategic plan and investment program, on behalf of the State Council. The newly established Economic and Trade Commission (ETC) oversees national economic policy. The Ministry of Finance approves CNPC's accounting standards, annual budget, tax and profits remittance to the government. CNPC's trade activities require the approval and authorization of the Ministry of Foreign Trade and Economic Relations.

10. The oil and gas sector in China is characterized by the compartmentalization of responsibilities. CNPC is in charge of all onshore exploration and development activities in China. The China National Offshore Oil Corporation (CNOOC), created in 1982, is responsible for offshore operations, including negotiations and administration of production sharing agreements with international oil companies. The Petrochemical Corporation of China (SINOPEC) is responsible for most petroleum refining and petrochemical production based on liquid petroleum feedstocks. The Ministry of Chemical Industry (MCI) is responsible for petrochemical plants using natural gas and coal as feedstocks. The China Chemical Industry Import/Export Corporation (SINOCHEM) is in charge of oil and products trading. As part of a recent reform initiative, China United Oil Company (Sinoil), a joint stock company with limited liability, has been established by CNPC and Sinochem (each with 50 percent ownership). Sinoil's operations cover import/export of oil and refined products as well as overseas investment in oil/gas ventures.

11. There are eight enterprises affiliated with CNPC headquarters in Beijing, each operating as independent economic entities. In addition, there are 36 subsidiaries also operating as separate legal entities. Amongst this group, 22 are regional petroleum administrative bureaus which are responsible for petroleum exploration and production, and 3 for oil/gas transport. Total employment is reported by management to be in the order of 1.4 million, of which about one million are employed in provision of auxiliary services for oilfield support (including geophysical and geological service companies, drilling and other oilfield auxiliary service companies, petroleum engineering and construction companies and petroleum research and educational institutes) and social welfare (including employee housing, schools and hospitals).

12. The Chinese authorities are committed to introducing a far-reaching program of oil and gas sector reform. Reforms are needed both in the organization and management of public enterprises, and in the policy environment in which they operate to offer a "level playing field." The ultimate objectives of the sector reform process for CNPC are set out below:

(a) accelerated growth of oil and gas production in order to support economic development;
ANNEX 2.6

(b) the creation of a competitive domestic oil market;

(c) the development of Chinese exploration and production companies, oil field
supply service companies and specialized petroleum and exploration
consulting firms which will be efficient and competitive both in the domestic
oil market and, over time, will become competitive in the international
market.

13. As an SOE, CNPC is now challenged to implement the NOM and to develop
recommendations on the oil and gas sector policy framework to induce efficiency gains
within the broad framework of the national enterprise reform. To this end, CNPC has
established reform management units at headquarters and in all of its larger operating
subsidiaries. It has encouraged its subsidiaries to explore new management and incentive
systems, and to examine how they might best separate their core business activities from
their ancillary oil field supply, service and construction activities. CNPC has also sought
out the experience and expertise of international oil companies and consultants on subjects
pertaining to oil and gas sector reform and state oil company restructuring, through such
vehicles as a workshop on international Petroleum Management and Reform held in Beijing
in July, 1992 under the joint sponsorship of CNPC and the World Bank. Based on the
recommendations emerging from this workshop, a comprehensive restructuring action plan
would be developed. To provide an analytical framework for building consensus on a
detailed program of action to achieve the transition/ transformation of the sector in line with
the above reform objectives, a local team headed by CNPC would collaborate with
international consultants financed under the Japanese Grant Facility (JGF) to carry out a
restructuring study.

B. STUDY OBJECTIVES AND SCOPE

14. The principal objective of the study is to develop detailed, practical
recommendations on reforms both in the organization and management of CNPC, and in
the policy environment and legal/regulatory framework which are consistent with the
objectives for sector reform (para. 12). In addressing the issue of how best to restructure
CNPC, the study should give highest priority to the operational efficiency and financial
viability of both the existing entities and any new enterprises to be established. In
recommending the creation of new enterprises, emphasis is also to be placed on the
development of competitive markets for the different oil field services, including drilling,
seismic acquisition and processing, as well as for exploration and production.

15. International consultants would work closely with the Chinese study task
force on the following subject matters:

(a) Sector reform strategy and policy reform framework;

(b) Legal and regulatory framework for the sector, including:
(i) separation of government (policy, taxation and regulation) and enterprise (operational) functions,

(ii) the government oversight function and petroleum industry regulation, and

(iii) petroleum law and sector taxation;

(c) Competition policy and market development;

(d) CNPC institutional restructuring (including development of a model of CNPC organization and management toward commercialization and corporatization of CNPC entities);

(e) Detailed implementation plan of the reform program; and

(f) Training.

16. In view of the complexity and multidisciplinary nature of the study, the study is broadly divided into three modules: (a) Module I—commercialization and corporatization of CNPC; (b) Module II—policy and governance: rationalization of relationship between the government and CNPC and the role of a regulatory authority; and (c) Module III—legal framework. The international consultants for carrying out Module I above are also invited to submit proposals for an option to carry out Module II as well. Separate international consultants are expected to be hired to carry out, in parallel, Module III. The consultants for different modules will coordinate closely with each other as the modules are interrelated and there are some obvious overlaps.

17. The study would proceed in two main phases. The first phase will include:

(a) a critical assessment of the present institutional, legal, regulatory and financial framework; identification of the principal issues and factors hampering CNPC’s efficient operation and development and the major areas that will need to be addressed in the restructuring program;

(b) an assessment of different, potentially promising organizational models for CNPC, taking into account relevant international experience and practices; and

(c) development of pilot programs for the restructuring of two of CNPC’s subsidiaries, the Sichuan Petroleum Administration [SPA is a major nonassociated gas producer with gas production of about 6.5 bcm in 1992] and Dagang Petroleum Administration [DPA, Dagang is the sixth largest oilfield in China with oil production of about 3.9 million tons in 1992]. CNPC’s approach to reform is to use these demonstration programs to
explore options, and then build on the lessons learned from the pilot results prior to company-wide implementation.

18. The output of the first phase would be an interim report that would provide the basis for a *workshop in China*. This workshop would be jointly sponsored by the Government and the World Bank. Those selected reform options would then become the focus of a second phase of analytical work.

19. The second phase would include:

(a) implementation of pilot programs for restructuring CNPC's two subsidiaries, SPA and DPA, with the assistance of the international consultant, and

(b) analyses in considerable depth of the scope and pace of implementing these measures with a view to ensuring a smooth transition toward achieving the full reform agenda over the longer term. The output of the second phase of the study would include an evaluation of the results of the pilot programs.

**MODULE I: COMMERCIALIZATION AND CORPORATIZATION OF CNPC**

20. The scope of the module on "commercialization and corporatization of CNPC" would include the following:

For CNPC as a whole,

(a) An assessment of the overall sector management and administrative framework within which CNPC operates.

(b) A critical review of the existing CNPC organizational structure, including the relationships and linkages between CNPC and its eight headquarter affiliates and thirty-six subsidiaries.

(c) An assessment of the need to "simplify" CNPC and concentrate on core business activities, and related benefits.

(d) An analysis of the options/constraints for restructuring its core and auxiliary business activities, with particular attention to be paid to the issues of labor redundancies and social obligations.

(e) An assessment of the merit of establishing one or more vertically integrated petroleum companies. (CNPC wishes to explore if there is merit in moving into downstream petroleum operations).
(f) A detailed analysis of the reform options and constraints for commercializing and corporatizing CNPC core and auxiliary business activities.

(g) A detailed analysis of possible forms of ownership and diversification of financing for CNPC's different businesses and other activities. In this connection, CNPC has expressed an interest in promoting experiments in the joint stock company option. Assess the organizational structure and legal framework required for the transformation of CNPC into a joint stock company, including the establishment of corporate governance instances and functions.

(h) Develop detailed recommendations for restructuring CNPC, including a program for commercialization and corporatization.

(i) Design a detailed multiphase implementation program for CNPC reform, including prioritization and sequencing of actions and a timetable for implementation; and

(j) Identification of staffing and skills required to implement the reform program, and preparation of an appropriate training program.

For CNPC's two subsidiaries, SPA and DPA,

21. Within the above reform framework for overall CNPC, detailed implementation programs for restructuring SPA and DPA would be developed. The scope of work would include the following:

(a) An assessment of the present organization structure, management techniques and procedures, including performance indicators and incentive system, and the impact on managerial accountability and operational efficiency.

(b) An assessment of the present policies and procedures for corporate planning and financial management, including pricing, investment financing, cost controls and financial reporting.

(c) An assessment of present staffing levels, skill mix, employment and compensation programs and procedures.

(d) A review of present supply sourcing policies and procedures.

(e) An assessment of recent operating performance in the principal core business units and auxiliary service units.

(f) An assessment of the potential for improved efficiency within the existing organizational structure.
(g) An analysis of options for restructuring the regional petroleum administrations, assuming spinoff of service companies.

(h) Develop for each regional administration recommendations for commercialization and corporatization, a productivity enhancement program and related human resources development program.

(i) Develop for each regional administration a restructuring strategy and a detailed implementation program, including prioritization and sequencing of actions and a timetable for implementation.

(j) Identification of staffing and skills required to implement the reform program, and preparation of an appropriate training program.

MODULE II: POLICY AND GOVERNANCE

22. The scope of the module on "policy and governance" would include the following, and elaborations of the areas which are of special interest are attached:

Sector Policy Framework

23. In collaboration with the counterpart team, establish what is the present situation for the subjects listed below, and their reform status, and examine what further initiatives are required to achieve sector reform objectives:

(a) energy pricing and the timetable for removing remaining price subsidies;

(b) competition between producers for oil and gas, respectively, including internal and external conditions for companies to enter the market and various forms of ownership, including foreign companies;

(c) organization and various forms of ownership of oil and gas pipelines and storage facilities, including possible separation of pipelines from the production companies and open access to oil and gas pipelines;

(d) restrictions on interprovincial and international trade in oil and gas and oilfield-related supplies and services;

(e) regional barriers to the movement of capital, labor and other factors of production;

(f) discrimination in the fiscal regime, on access to capital, on access to exploration prospects, etc;
(g) policies towards investment (both foreign and local) in the different segments of the oil and gas business; and

(h) state-owned enterprise social service obligations to employee and reform of social service delivery systems.

**Government and CNPC Relationship**

(a) Analyze how CNPC now interfaces with the Government and the Petroleum Administrative Bureau, and examine the ramifications of this for CNPC performance and financial viability, and for achieving in the future a competitive, market-based oil and gas sector.

(b) Assess the reform options with respect to the following aspects, taking into account the experience of other countries which have made the transition from an administered petroleum industry dominated by the state oil company to one that is market-driven and in which there is competition between companies:

(i) enterprise rights and obligations;

(ii) the rights and obligations of shareholders (private or state);

(iii) how best for the state to exercise its ownership rights while staying at arm's length with respect to management of the state enterprise;

(iv) the appropriate role for the board of directors of a state-owned enterprise;

(v) which government policy functions are considered essential to effective governance of the industry, and of these which can be delegated to a regulatory agency; and

(vi) how best to achieve the transfer of authorities in a transitional period.

(c) In consultation with the Chinese study team, develop recommendations for a phased reform program toward rationalization of government and enterprise relationship, focusing on the division of responsibilities between the Government, CNPC and regulator authority.

**The Role of the Regulatory Authority**

(a) Establish in what areas petroleum industry operations are now de facto regulated, by which government agency or department and under what authority, and come to a judgement as to the adequacy of the present system
vis-à-vis a market-based oil and gas industry in which there is competition amongst a number of oil companies.

(b) Define and seek agreement upon the subject areas which require regulation, including safety, environment, commercial and technical aspects; the principles and policies which will govern regulation of the sector, and the status and powers of the regulatory authority(ies) to be established.

(c) Develop a preliminary outline of the powers, responsibilities and structure of the regulatory authority(ies) and assist in defining its role relative to other official bodies, taking into account the experience of alternative approaches to petroleum industry regulation followed in other countries.

(d) Identify the appropriate legal framework and laws needed to establish and empower the regulatory authority(ies).

C. STUDY ORGANIZATION, REPORTING AND TIME SCHEDULE

24. At the request of the Chinese government, the World Bank is providing assistance to the government in executing the study for administrative purposes. In this respect, the Bank will issue a contract to the consultant to provide essential services in carrying out the study. While the Bank and the government will jointly oversee the work of the consultant, the ultimate client is the People's Republic of China and its implementing agencies. A local study team will be involved in the day-to-day supervision and structuring activities of the study. This is a study of the Chinese authorities who have the primary responsibility in the preparation of a reform action plan. The international consultant, who is responsible for providing technical assistance and training to the Chinese counterpart team, must pay particular attention to ensure that the Chinese counterpart is "on board" throughout the study process. In this connection, the international consultants would bring to bear their international experience and facilitate the induction of modern organization and management techniques in the oil and gas industry. To facilitate the exchange of ideas between the international consultants and the local counterpart team, the consultants will conduct workshops in China in conjunction with carrying out the proposed study. It is envisaged that a minimum of three workshops would be conducted during the inception stage, and at the end of phases 1 and 2 of the study.

25. A Leading Group will be established which will oversee the work of the Chinese project team and international consultants. It will provide study direction, review principal study findings and recommendations and guide the consultants on the course to be followed in implementation of the CNPC reform program. The Leading Group will be comprised of senior representatives of CNPC and concerned Chinese government departments and representatives of the concerned World Bank departments.

26. The local counterpart study team, headed by CNPC, is in place. It is comprised of senior officials from CNPC, the Economic and Trade Office and the Development Study
Center of the State Council, State Planning Commission, the State System Reform Commission and the Ministry of Finance. The local task force would collaborate with the World Bank and JGF-financed international consultants in carrying out the studies. The international consultant is directed to collaborate closely with the counterpart team and involve it as much as possible in completion of the study program of work and the analysis of study options, the development of reform strategy recommendations and preparation of the implementation program. To this end, it will provide training seminar(s) at the outset of the project, going into detail on the study methodology and information requirements. The counterpart team will also assist in providing information and arranging meetings with the Chinese authorities. It will also provide translation services.

27. On reporting, the consultant will prepare an interim report on phase 1 of the study and a draft final report on phases 1 and 2. The study final report will be completed incorporating the comments and conclusions of the Leading Group. All the reports will be in English. Five copies of all the reports will be sent to CNPC and ten copies of them to the Bank. In addition, the consultant will prepare monthly progress reports, to be sent to the Bank and CNPC covering the following subjects: the results of the work performed to date, progress on completion of the work program and adherence to the study program schedule and outstanding issues/problems encountered.

28. Study Time Schedule.

<table>
<thead>
<tr>
<th>Period</th>
<th>Description</th>
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<tr>
<td>October 1993 - March 1994</td>
<td>Workshops/fieldwork/issues identification/option analysis</td>
</tr>
<tr>
<td>April 1994</td>
<td>Interim report</td>
</tr>
<tr>
<td>May 1994</td>
<td>Leading Group review, workshop, direction on the Phase 2 program of work</td>
</tr>
<tr>
<td>June/July 1994</td>
<td>Refinement of option analysis, workshops, development of recommendations on reform strategy and implementation</td>
</tr>
<tr>
<td>August 1994</td>
<td>Review and consultation within Leading Group re Phase 2 findings and recommendations</td>
</tr>
<tr>
<td>September 1994</td>
<td>Submission of draft final report and program of action</td>
</tr>
<tr>
<td>October 1994</td>
<td>Submission of study report.</td>
</tr>
</tbody>
</table>
MODULE II: POLICY AND GOVERNANCE

AREAS OF SPECIAL INTEREST

The Chinese study team is responsible for the study and design of policy and regulation under "Module III", taking into account the experience of foreign countries. International Consultants are responsible for providing suggestions to address the following questions mainly based on data gathering and analyses of the relevant policies and regulations in main oil-produced countries (including at least USA, Russia, Mexico, Venezuela, Brazil, Britain, Norway, Saudi Arabia and Indonesia, etc.); the following aspects should be classified into different models with analyses of their relative pros and cons, then develop recommendations.

Governance on Oil/Gas Sector

- Which government agencies or departments are empowered to govern the oil/gas sector. How do they divide their duties and responsibilities and who is responsible for coordination between them?

- What are these regulatory authorities' focus and scope, e.g., to protect domestic resources, oversee the appropriate exploration and development, guarantee stable supply of oil/gas as well as safety, environmental protection or prevent excess profits, etc?

- What ways and means does the government use and at what degree to regulate the petroleum sector?

- Which organ (government agency or nongovernment one) and at what scope and degree governs oil/gas resources, especially which organ and how does it manage risky exploration and who assumes these risks? How are oil/gas reserves managed and who confirms these reserves and how to price them? How are the proven reserves usually transferred to the producers? How to recover the exploration capital investment?

Based on the conditions of the main oil producing countries, the above aspects should be classified into different models with analyses of their relative pros and cons, then develop recommendations.

Government and National Oil Corporation Relationship

- What is the legal basis to establish National Oil Corporations (NOCs) in each country? What are the major types of legal basis?

- Who represents the ownership of state assets in an NOC—is it a government agency (e.g., Ministry of Finance) or some other organs to represent the state? What are the major types of representatives in state asset ownership?
Compare to a non-NOC, what special responsibilities does an NOC have to assume? What special powers and favorable conditions are given to the NOC? If an NOC suffers economic loss through the assumption of special responsibilities, e.g., stabilize price and supply, does the Government compensate the NOC? What are the major types of compensation?

How to allocate profits between Government and NOC. What are the major types of profit allocation?

Do NOC and non-NOC compete on the same level in the same country? Are there any discriminations? How does Government ensure fair market competition, including competition between the subsidiaries of NOCs?

Are there any special government requirements regarding the content, methods and scope of NOC management? And how to achieve these requirements in reality?

Please use actual examples to illustrate and analyze the above aspects, then develop recommendations.

Regulatory Authority

Regarding the necessity and legal basis to set up a regulatory authority between the government and oil companies, what are the major types of such regulatory authority in other countries?

The legal status, power, functions and responsibilities of the regulatory authority.

What ways and means does the authority use to govern?

The relationships between the regulatory authority and other government agencies, (e.g., Ministry of Petroleum or Ministry of Energy) and oil companies.

Analyze the above aspects by citing actual examples and compare them, then develop recommendations to the Chinese team.

Sector Policy

Analyze the petroleum exploration and development policies of major oil producing countries, including the background of policy setting, policy evolution and differences among these countries. The major areas include:

Policy on Resources
(a) What are the appropriate policy reforms to protect oil/gas resources, rationalize development and utilization of resources, prevent adverse resource development and monopoly, abuse, excessive competition and wastage of resources?

(b) Which of these policies are effective and can be applied to China?

- Pricing Policy

(a) Price setting basis for oil/gas

(b) Price setting for transmission by pipelines

(c) Are these prices controlled and regulated by the government? Which of the methods are the most effective?

(d) Are there differences in pricing due to different development stages of oil/gas fields, different oil/gas qualities? If so, how to set prices and on what basis?

- Tax Policy

(a) Are there any special policies to stimulate exploration investment?

(b) Are there any forms of discrimination over the taxation and tax rates due to significant differentials in production cost and profits because of different qualities of oil and gas (e.g., wax content, sulphur content, or viscous oil, sour condensate oil and high-pour-point oil), reservoir depths and development stages?

(c) What are the policies on encouraging the development of fields which have low profits so as to increase the degree of resource utilization?

(d) How about the oil company(ies) which suffer losses due to high cost at the stage of the tertiary recovery? Does the government give them special policy?

(e) Does the government use tax policy to adjust and transfer different profits amongst the oil companies?

Analyze and compare the tax policies in different countries and recommend to the Chinese team practical and effective tax policies.

- Investment Policy
ANNEX 2.6

(a) What investment policies (including foreign capital) for oil/gas exploration and development have been set by the main oil-producing countries? What are the major types of these policies?

(b) What are the differences of these policies? Which of them are the most effective?

- Trade Policy

Are there any policy restraints or restrictions over oil/gas import and export in each oil producing country? What are the differences in these policies? What are their results?

Competition Policy & Market Requirements

- Analyze and provide some facts about the national oil industries (in at least three countries) which have made the transition from a nonmarket system to a market-based one. What are the main difficulties and barriers during the transition? And how to overcome them by means of appropriate policies and measures?

What is the role of Government in developing and governing the oil/gas market mechanisms to protect and encourage oil companies competing at the same level.

- Are there any policies to be used to encourage open and fair competition between oil companies and service ones, and prevent monopoly, unfair competition or illicit behavior.

- Provide the following actual examples on open competition amongst companies following market regulations: one onshore regional exploration project, one onshore concession development project and one competitive bidding for onshore drilling; analyze the different areas of market management in exploration and development and highlight the main issues.

- Organization, operating mechanisms of oil and gas transmission enterprises, their relationships with the producers, marketers (oil companies), and how to prevent monopoly and illicit competition.

- Price and tax policies for service companies (e.g., geophysical prospecting, well drilling, logging, construction, down-hole service, etc.).

In addressing the above questions, the international consultant should include actual examples, statistics, analysis and concrete recommendations (not only conceptual). Chinese study team will put forward more questions on the basis of the answers to the above questions in order to deepen the study gradually.
SICHUAN PROVINCE COMMERCIAL ENERGY BALANCE  
1970-1990  
(in % of total consumption)

<table>
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<th>Year</th>
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Source: Sichuan Statistical Yearbook, 1991

* m tce: in million ton coal equivalent
# Sichuan Gas Consumption

**1987 -- 1992**

**(BCM)**

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<td>%</td>
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<td>%</td>
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<td>0.3</td>
<td>6</td>
<td>0.3</td>
<td>6</td>
</tr>
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</table>
ENERGY CONSERVATION IN SICHUAN

Institutions

1. Sichuan Province has in place an elaborate system of institutions for initiating, evaluating, implementing and monitoring energy conservation activities in the Province. The principal organizations involved in this field of activity at provincial level are:

(a) **The Sichuan Province Planning Commission.** The Commission, which reports to the State Planning Commission (SPC), is responsible for setting overall policy regarding energy conservation activities in Sichuan. In 1992, it set up a Resources Conservation and Comprehensive Utilization Division, responsible for these activities in the fields of water, electricity, coal, oil, natural gas and raw material recycling. They are ultimately responsible for setting energy consumption quotas and (in collaboration with the Provincial Bureau of Standards and Measurement) promulgating equipment and unit energy consumption standards for the various industrial subsectors; and

(b) Offices set up jointly by provincial government departments and bureaux and the energy producers which are responsible for the allocation of their specific energy carriers to each consuming enterprise, as well as overseeing energy conservation activities in the production units under their control. These offices include:

(i) The Three Electricity Office (responsible for power allocation, power conservation, and safety in power production, distribution and utilization),
(ii) Coal Conservation Office,
(iii) Petroleum Products Conservation Office (most petroleum products consumed in Sichuan are imported into the Province),
(iv) Natural Gas Conservation Office,
(v) Water Conservation Office, and
(vi) Raw Material Recycling Office.

(c) There are also, at provincial level, parallel organizations which oversee the activities of the energy consuming enterprises and residential users. Prominent in the energy conservation field are the Provincial Government Departments of Chemical Industry, Metallurgy and Machine Building.
These departments provide annual energy conservation targets to the individual enterprises in their subsectors, and monitor their performance.

(d) Every industrial enterprise in the Province has an Energy Conservation Engineer who is responsible for ensuring that energy conservation activities are carried out according to the guidelines issued by the above organizations, to ensure that the energy consumption quotas are not exceeded and to carry out effective housekeeping measures on the plants. In the larger enterprises, energy conservation groups have been established which are capable of carrying out energy audits and developing their own energy conservation programs. They frequently pass on energy conservation know-how to the smaller companies, using the Provincial Government Industrial Departments as the conduits.

(e) A Provincial Energy Conservation Service Center and a number of municipal service centers have been established to provide technical consultancy and energy audits to the enterprises in their geographical areas. The main functions of the Provincial Center are:

(i) to provide to the provincial government recommendations and background information for energy conservation policies and regulations; and
(ii) to give technical guidance to the Energy Conservation Service Centers at municipal and county levels.

(f) The Municipal Service Centers are the core of the system, providing practical implementation of energy conservation policies; they provide a bridge between the planning and monitoring functions of the Government and the practical issues faced by the enterprises. Their principal functions are:

(i) performing energy audits for small and medium-size enterprises;
(ii) monitoring energy consumption;
(iii) designing equipment;
(iv) introducing innovative equipment and procedures for energy conservation;
(v) providing information dissemination;
(vi) through training courses, seminars, etc., enhancing the understanding of enterprise managements about the potentials of energy conservation. In accordance with the plans elaborated by the Energy Conservation Offices, the Center carries out energy audits and may also implement the installation of the required equipment, processes and procedures for energy conservation. The Center may also undertake similar activities commissioned by an individual enterprise and receive a fee for its services.
Incentives

2. There are three main forms of incentives for enterprise managements to conserve energy. All are based on energy consumption of the enterprise compared to the norms and allocations decreed by the state and provincial authorities.

(a) A two-tier energy pricing system has been in operation for some time and is currently being improved. In the new system for natural gas, which began on June 1, 1993, enterprises will have to sign contracts to take a contractual amount of gas every month; this quantity is based on a quota allocation, (a quota which in general will be less than in previous contracts). Except when the enterprise is shutdown for planned maintenance or is operating on a reduced level of gas offtake contractually agreed, the enterprise will pay for the total amount of gas stipulated in the contract, regardless of the actual offtake up to the quota granted. The unit gas price will be based on a wellhead price which is expected to average out at about Y 0.24 per cubic meter, to which must be added transport and purification costs. Typical wellhead prices (in Yuan per cubic meter) are as follows:

<table>
<thead>
<tr>
<th>Category</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>For fertilizer plants</td>
<td>0.22</td>
</tr>
<tr>
<td>Other industrial users</td>
<td>0.24</td>
</tr>
<tr>
<td>Residential users</td>
<td>0.28</td>
</tr>
<tr>
<td>Commercial users</td>
<td>0.42</td>
</tr>
</tbody>
</table>

If quantities of gas in excess of the quota are consumed, a higher price will be charged, (subject to contract negotiations). For such excess quantities delivered, it is expected that industrial users will pay about Y 0.40 per cubic meter and commercial users about Y 0.62 per cubic meter for quantities supplied over and above the quota. This arrangement is expected to be in force for about a year. Substantial price increases will take place in 1994 and thereafter.

(b) At times when there is a constraint on the supply of a particular energy carrier (due to production unit malfunction or other causes) those enterprises currently consuming more than their quota would find their supply of energy cutoff.

Effectiveness of Energy Conservation Activities

3. Three main criteria have been used to measure the effectiveness of energy conservation activities over time:

(a) Global energy consumption (measured in tons of coal equivalent (tce) per Y 100 million GNP;
(b) Industrial power consumption (in kWh) per Y 10,000 of industrial output; and

(c) Industrial energy consumption (in tce) per Y 10,000 of industrial output.

The following table shows the actual figures for Sichuan Province in 1992 and the planned targets for 1993:

<table>
<thead>
<tr>
<th></th>
<th>1992</th>
<th>1993</th>
<th>% Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global Energy Consumption</td>
<td>51,500</td>
<td>50,500</td>
<td>1.94</td>
</tr>
<tr>
<td>Industrial Power Consumption</td>
<td>2,100</td>
<td>2,040</td>
<td>2.86</td>
</tr>
<tr>
<td>Industrial Energy Consumption</td>
<td>3.0</td>
<td>2.96</td>
<td>1.33</td>
</tr>
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In 1992, 1.9 million tce was conserved (compared to the 1991 energy consumption; the planned saving in 1993 (over the 1992 consumption level) is 2.0 million tce.

Historical Perspective

4. In the early 1980s, a national campaign of energy conservation was initiated. Since there was a shortage of indigenous energy resources in Sichuan, the conservation campaign was taken up intensively by the Provincial Government. As a result, in the period 1981-89, a total of Y 10 billion was invested in Sichuan for energy conservation projects. This investment had led by 1990 to a cumulative saving of 18 million tons of coal equivalent (tce) per year. Thus the total energy saved through these conservation efforts over the period 1981-89 was over 70 million tce. This savings momentum has been maintained in the early 1990s, so that today, an extra 2 million tce are saved every year, representing a saving of about 20 million tce per year over the 1980 energy consumption level. To put these figures in perspective, it should be noted that the total energy consumption today in Sichuan amounts to 80 million tce in industrial and urban areas and 20 million tce in rural areas, making a total of about 100 million tce per year.

5. At the beginning of this period, there was a rapid and significant decline in natural gas availability in the Province, with production dropping from 6.4 billion cubic meters per year to 5.2 cubic meters per year. To meet this challenge, (i) salt boilers in the Province were converted to use coal as the heating medium instead of natural gas and (ii) bitumen was substituted for natural gas in the production of carbon black, an essential ingredient in the manufacture of rubber. Altogether, an annual saving of about 1.5 billion cubic meters of natural gas were obtained by this fuel switching.

1/ In many cases, these projects had concomitant benefits, including capacity expansion and product quality improvement.
Subsectoral Energy Savings

6. There are three principal energy-consuming industrial subsectors in Sichuan Province—Chemicals (including fertilizers), Metallurgy and Machine Building. Together they account for more than half of total industrial energy consumption. It is therefore natural that a significant proportion of energy conservation activities should have been focussed on these subsectors.

(a) Chemical Industry. The Chemical Industry consumes about 40 percent of industrial energy consumption. A large part of this is as feedstock for fertilizer production. About 50 percent of natural gas consumed is for fertilizer production, with about 10 percent being utilized for the manufacture of other chemicals. Since 1980 the Chemical industry has shown impressive savings in energy usage, as the following table shows:

<table>
<thead>
<tr>
<th>Year</th>
<th>tce</th>
</tr>
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<tbody>
<tr>
<td>1980</td>
<td>12.68</td>
</tr>
<tr>
<td>1984</td>
<td>10.43</td>
</tr>
<tr>
<td>1985</td>
<td>9.67</td>
</tr>
<tr>
<td>1989</td>
<td>8.97</td>
</tr>
<tr>
<td>1991</td>
<td>8.39</td>
</tr>
<tr>
<td>1992</td>
<td>8.28</td>
</tr>
<tr>
<td>1995 (Estimate)</td>
<td>7.00</td>
</tr>
<tr>
<td>2000 (Estimate)</td>
<td>&lt;6.00</td>
</tr>
</tbody>
</table>

(b) Metallurgy. In 1992, the metallurgical sector consumed about 8 million tce, which was made up of 6 million tons of coal, about 5 TWh of electricity, 40,000 tons of petroleum products, and 660 million cubic meters of natural gas, representing about 11 percent of natural gas utilized in the Province. The main areas where energy conservation efforts have been successful have been in the BOF steel making furnaces, and in the electrical steel furnaces, which were originally heated by alternating current instead of the more energy efficient direct current. As a result, the industrial energy consumption per Y 10,000 of output has been reduced from 12.0 in 1980 to 7.34 in 1992, a reduction of almost 40 percent.

(c) Machine Building. The Sichuan Machine Building Industry (which includes the electronics industry) consists of about 300 enterprises.
Together, they consume about 1 million tce of energy, of which 23 percent is in the form of coal and oil, 37 percent is in the form of electric power and 40 percent as natural gas, representing some 5 percent of the natural gas consumed in the Province. The principal uses of direct energy in the subsector are for driving prime movers and heating furnaces and kilns. Natural gas is used by some 60 enterprises, mainly for process preheating.

There have been two main phases of activity in the field of energy conservation:

(i) **Phase I (from 1982-88)**, when the emphasis was on improvements in housekeeping, and achieved a reduction of 20-25 percent in energy consumption; and

(ii) **Phase II (from 1989 onwards)**, when the emphasis switched to energy-saving process modifications, which have so far achieved a further 15 percent energy savings. At the beginning of this phase, most of the subsector's equipment was almost 40 years old and was consequently energy intensive. In the course of this phase of the energy conservation program, modifications included improved furnace insulation, modernized combustion nozzle technology, and changes in furnace configuration. In order to reduce consumption of natural gas, many gas fired furnaces were converted to coal fired units. In addition, power consumption was reduced by the installation of less power intensive equipment such as transformers, electric motors and fans.

As a result of the activities in these two phases, the Subsector's IEC per Y 10,000 has been reduced from 4.5 tce in 1980 to 1.0 tce in 1992.

**Potential Savings from Energy Conservation in the Future**

7. A common pattern in energy savings over time has been observed in many countries which have undertaken energy conservation programs. In the first phase, there is an initial buildup when organizational problems are overcome, surveys carried out and information disseminated. In a second phase, high energy savings are obtained when housekeeping measures are introduced and the obvious retrofitting projects (requiring low capital investment and short implementation times) are identified. In a third phase, more complex and higher capital cost projects (often requiring process changes) are identified and implemented. Thus, after an initial buildup, the annual incremental savings reach a peak and then begin to decline, although, of course, the absolute level of energy savings continues to increase from year to year.
8. In the industrial sector, the greatest potential savings are likely to continue to be found in the three energy intensive subsectors—chemicals (including fertilizers), metallurgy and machine building.

(a) Chemicals and Fertilizers. Intensive studies have been carried out in the fertilizer sector to achieve greater energy savings. Such savings are critical to the economics of production of nitrogenous fertilizers, since natural gas is used not only as an energy source but forms the principal raw material for ammonia and urea. Investment programs which are currently being developed are estimated to lead to savings in the consumption of natural gas of 15-25 percent in medium and large scale production units and 25-30 percent on the smaller units.

The electrolysis of sodium chloride brines to produce caustic soda and chlorine is an important operation in the Sichuan Basic Chemicals industry. Some of the electrolysis cells have already been modified to reduce electricity consumption, and the process of modernization will be continued in the future. Modernization can be expected to reduce the power requirements per ton of caustic soda from 2,700 kWh to 1,900-2,000 kWh, a saving of up to 30 percent.

(b) Metallurgy. The trend to convert the electric steel furnaces from alternating current supply to direct current supply will be continued, resulting in further significant reductions in power consumption in the subsector.

(c) Machine Building. Future plans for energy conservation in this subsector are likely to be concentrated on the Second Sichuan Heavy Machine Building Works which is the largest energy consumer in the industry, and one of the largest machine building complexes in Asia. In 1992 it consumed 170,000 tce, including 70,000 million cubic meters of natural gas. Preliminary estimates indicate that some 40 percent of current energy consumption could be cut by appropriate energy conservation investments and programs (e.g., redesign of furnaces and kilns for process preheating). It is tentatively estimated that the cost of these programs could amount to Y 300 million, of which $20 million would be the foreign exchange cost.

(d) Residential. A vigorous program to indoctrinate the public in energy conservation awareness is to be pursued. This will include a special "Energy Conservation Week", encouragement of the marketing of energy saving domestic appliances, and conversion to natural gas use of coal- and briquette-fired cooking stoves and boilers, in order to improve energy efficiency and to reduce pollution.
Future Role of Government Energy Conservation Institutions

9. As the country's program of economic reform develops, many of the functions currently carried out by government institutions in the field of energy conservation will be superseded by the interplay of market forces. The Provincial Planning Commission has already begun to examine what would be the appropriate role for these institutions to play under these circumstances. The following list of items represent preliminary thoughts which could usefully be subject to further examination. Most of these activities would best be performed through the Energy Conservation Service Centers at different levels.

(a) Initiation and monitoring of projects in the field of renewable energy.

(b) Providing guidance to enterprise managements and government officials in determining reasonable energy conservation targets.

(c) Exercising influence on manufacturers to phase out the product of energy inefficient equipment.

(d) Providing low interest loans for pilot and demonstration projects in the field of energy conservation.

(e) Leasing energy saving equipment and energy monitoring instrumentation.
GAS FIELD DEVELOPMENT AND REHABILITATION SUBCOMPONENT

A. SICHUAN NATURAL GAS UPSTREAM SECTOR

1. Geological Summary. The Sichuan Basin, located in the eastern part of Sichuan province, covers a sedimentary area of about 180,000 km\(^2\). It is surrounded by high mountains composed of Paleozoic and Proterozoic formations. The remainder of the basin consists of low mountains and hills with a relief of about 300 to 500 m with outcrops of Jurassic and Cretaceous formations. The stratigraphic sequence in the basin consists of relatively thick (0.8 to 11 km) sedimentary sequence from the Precambrian (Sinian) crystalline basement through the Quaternary system. Structurally, the basin may be divided into four major parts: (a) the Central High (an uplifted zone with about 6 km of sediments in the central part of the basin), (b) the Southeast Depression (a folded zone with about 9 km of sediments), (c) the Western Depression (a depression zone with about 11 km of sediments), and (d) the Southwest fold-Belt (a series of southwest trending anticlines). Most of the hydrocarbon (essentially natural gas) bearing formations encountered are carbonates (limestones and dolomites located generally below the Lower and Middle Triassic intervals). Very limited quantities of oil have been found in some of the Jurassic sandstone formations in the north central part of the basin.

2. Hydrocarbons in general, and natural gas in particular, in Sichuan are found in sediments of Sinian, Carboniferous, Permian and Triassic age. The Sinian (Precambrian) consists mainly of thick dolomites, up to 650-m thick, with a permeability consisting largely of fractures restricted to the crestal portions of structures. The Carboniferous, which is about 2,000-m thick, consists mainly of dolomites and limestones and has much better developed fractures and pores. The Carboniferous reservoirs appear to be limited to the eastern part of the basin which has been so far the most prospective area. The Permian Yangsin limestone (400 to 500 m in thickness) is widely distributed throughout the basin and is generally quite tight. Large gas reservoirs have been encountered in the Permian where the formation has been fractured. Multiple reservoirs generally have separate gas-water contacts and production is determined by degree of fracturing. Finally, the Triassic rocks, more than 1,000-m thick, consist of dolomites, limestones, anhydrites and shales and are widely distributed throughout the basin. Production from the Triassic is slightly better than the underlying formations but remains highly dependent on fracture development.

3. Structurally, all of the gas fields addressed by this project appear to be closely related to an arcuate thrust fault zone which strikes north-south in the southern portion and nearly east-west in the northern portion of the zone. The age of the faulting and hence, the structures, would appear to be quite young by virtue of the shallow deformation as evident on the seismic sections as well as suggested by the rather high
topographic relief associated with crestal positions of the structures. As such, the migration of the gas probably occurred fairly recently, hence one would expect the smallest closures, even if located well down the flanks of the structures, to be productive. Gas accumulations have been found in both the hanging wall and foot-wall positions on the structures.

Reserves, Production and Prospects

4. Systematic oil and gas exploration and development started in Sichuan in the 1950s. Most of the discoveries were natural gas with practically no oil. Since then, more than 300 surface structures have been identified, of which, some 83 commercial gas fields have been confirmed. Total proven and probable reserves are estimated at 400 bcm and 140 bcm, respectively, of which more than one half is in the eastern part of the basin. Cumulative production reached about 120 bcm in 1992. Annual delivery rate increased progressively over the years to reach about 6.0 bcm (17 mmcm/day) in 1980, after which it declined by about 15 percent during the 1980-85 period. To counter the decline, SPA stepped up its exploration activities and carried out several field rehabilitation programs. Bank support has included the recently completed Weiyuan Gas Field Technical Assistance Project (Loan 2580-CHA). The exploration efforts have been successful in increasing the basin's resource base by more than 150 bcm of proven reserves and has identified several geological prospects, that could not be fully developed, due to the lack adequate equipment and materials. The field rehabilitation programs and the development of some of the newly discovered fields enabled SPA to arrest the decline and slightly increase its production, which reached about 6.4 bcm in 1992 (18 mmcm/day). The production is expected to continue increasing slightly, to reach about 6.7 bcm in 1995, after which it would again start declining, by about 10 percent a year, unless some of the major fields recently discovered are developed.

5. Suboptimal Recovery. The production decline experienced in the mid-1980s, while less than one half of the proven reserves was produced, is an indication of poor gas recovery from the field reservoirs. The problem is generally associated with inadequate development schemes consisting of a limited number of wells by which no production plateau can be achieved. This is often caused by insufficient investment programs, which characterize several of SPA's gas fields. These fields have been operated for years under suboptimal development schemes, with a limited number of wells. To meet an ever increasing gas demand, the wells have been produced at excessive flow rates, which has caused in many cases, severe water influx, with a subsequent substantial production decline, while the reserve recovery is as low as 40 to 50 percent. In similar fields developed under optimum schemes, such a decline would normally start when the reserve recovery reaches 70 to 80 percent. Increasing the recovery level now, would be much costlier than under an optimum development scheme. In fields with very active water drives, substantial quantities of gas may be irremediably lost into the reservoirs. This has been the case for the Weiyuan field, where the reservoir has been completely flooded by formation water, causing the production to fall considerably, while only about 13 bcm of gas has been recovered out of an estimated proven reserves of 40 bcm. The problem could be worse for several of the newly discovered fields, where reservoir depth, geological complexity and H₂S content are much greater than in the older fields, and
where, due to the lack of financial resources, only few appraisal and delineation wells have been drilled.

6. **Inadequate Gas Conservation.** The exploitation of gas fields for several years under suboptimal development schemes, becomes a serious gas conservation problem at the field level. In this regard, a major lesson learned from the development of the Weiyuan gas field is that, substantial quantities of gas have been irremediably lost into the reservoir, due to overproduction and subsequent reservoir flooding. As mentioned earlier, Weiyuan gas field development was not optimized. The field was drilled over several years, at a low pace, following a large well spacing pattern, and the wells put on production at their maximum flow rate as soon as completed. As the Bank financed study concluded, the reservoir has been completely flooded, which renders it highly unlikely that it can be economically rehabilitated, although only about 30 percent of the gas has been recovered. All resuscitation pilots have resulted in a continuously increasing water production and very little gas. While gas reservoir damage to this extent is rare, in the case of Weiyuan, the major cause can be associated with inadequate field development and production schemes, particularly: (a) excessive well flow rates which affected the ultimate recovery; (b) excessive water-gas ratio from the beginning of the field production; and (c) inappropriate well completion techniques as well as a limited number of wells on a large spacing grid by which no production plateau could be achieved. This production technique, which appears to be driven by high production targets, is still being applied in several gas fields. Although, all gas reservoir aquifer properties are not similar to the Weiyuan field reservoir, the technique entails, nevertheless, a substantial loss of gas, as generally reflected by the low gas recovery in most of the Sichuan gas fields.

7. **Lack of Gas Treatment Capacity.** SPA's gas contains significant quantities of \( \text{H}_2\text{S} \), which is extremely corrosive. Of the 6.4 bcm produced in 1992, about 6 bcm contained 0.001 to 6.5 percent of \( \text{H}_2\text{S} \). SPA owns and operates 8 desulfurization plants with a total design capacity of about 5.6 bcm/yr. Of these plants, 5, with a total design capacity of about 4 bcm/yr, are operated between 10 percent and 70 percent of their capacity. Of the 5 plants, 4, built between 1966 and 1973, require complete refurbishing. Due to the lack of foreign exchange, SPA could not adequately maintain these plants, much less refurbish the old ones and add new capacity to minimize the growing shortage in gas treatment. As a result, SPA is able to adequately treat only 3.5 to 4 bcm/yr. Remaining sour gas is mixed with "sweet" gas, to lower its percentage of \( \text{H}_2\text{S} \) content, before entering the transmission and distribution systems. By mixing the 2 types of gas, SPA obtains an \( \text{H}_2\text{S} \) content varying between 200 and 500 mg. per cu.m. of gas compared to 20 to 25 mg. per cu.m. recommended by the international gas industry.

8. The \( \text{H}_2\text{S} \) contained in the gas becomes highly corrosive in the presence of water as can be observed in SPA's gas transmission and distribution systems and other surface facilities, which are highly corroded. SPA produces a large quantity of formation water with the gas from the field reservoirs. The bulk of this water should normally be removed at the wellhead level before the gas is completely dehydrated in specially conceived plants. In SPA's gas fields, most of the wellhead primary water separation stations are old and inefficient. Thus, significant quantities of water are left in the gas,
hampering the gas treatment operations and overloading the field gathering lines. With regard to dehydration, most of the gas produced in the south and southeast districts, about one third of SPA's total production, is not dehydrated at all because of the lack of surface facilities. In the other districts, the dehydration is also inadequate due to poor performance of existing facilities, which are old and lack the necessary spare parts. Several of these facilities, originally designed for lower water volumes, require complete refurbishing. As a result, the quantity of water which is carried out with the gas in the transmission and distribution system is 10 to 15 times greater than levels recommended by the industry. The water also forms slugs of acidic solutions, which are extremely corrosive restricting the flow of gas in many parts of the transmission and distribution network and gas treatment plants.

9. Inadequate Treatment and Disposal of Produced Formation Water. Most of the reservoirs in the Sichuan gas field reservoirs contain substantial quantities of water (formation water) underlying the gas (water drive reservoirs), often in the form of thick water bearing intervals. To avoid or minimize water production, the number, spacing and deliverability of the production wells should normally be carefully determined. High gas flow rates often result in water influx, which is also called water coning. Once the coning has occurred, reduction in gas production rates would not necessarily eliminate the water influx, which often continues to increase to the point where the wells have to be shut-in and abandoned. This phenomenon has apparently affected a number of the Sichuan gas fields, particularly those that have been produced with a limited number of wells. About 2 million tons of formation water has been produced in 1993, most of which comes in the form of streams with the gas. As gas fields mature, the quantity of water increases substantially for the last few years. The water is then removed at the wellhead level through primary separation. On average, 80 percent of produced water is disposed of through subsurface injection into porous formations. The remaining water is saline, often salt-saturated and generally contains substantial quantities of other chlorides, sulfur, hydrocarbons, and heavy metal ions, which are harmful (corrosive) to the injection equipment. This water, therefore, is treated along with some well drilling, work-over and stimulation liquid wastes in earthen pits and, occasionally, in tanks built above-ground before subsurface injection or discharge into rivers and off-site natural drainage. Most of the existing water treatment facilities were developed a number of years ago when production of formation water was lower than now. As a result, the treatment, which is limited to gravity settlement of particles and addition of some chemicals, is inefficient. A limited quantity of the saline water is also processed by the local industry for extraction of salts (sodium chloride/NaCl, and potassium chloride/KCl).

10. Not all subsurface injection is carried out through deep off-site disposal wells. Large quantities of formation water are injected in depleted gas reservoirs through old gas wells. In one area (Zigong), the water is injected into fractured carbonate formations at a depth of about 300 m. Although reportedly these formations (of Triassic age) do not contain groundwater aquifers, injecting formation water at a such shallow depth, without treatment such as addition of corrosion inhibitors, could possibly become a source of long-term contamination of shallower groundwater zones through fluid migration and channelling behind well casings. SPA is aware of such a risk, hence efforts
have been made over recent years to develop a better subsurface injection scheme. However, the lack of necessary equipment and financial resources compounded with the overall external pressure for more gas delivery, have prevented SPA from drilling deep off-site disposal wells. Monitoring movement of injected fluids and integrity of injector wells and old wells that intersect the injection zones is not effectively carried out due to the lack of equipment. Similarly, the chemical treatment is inadequate.

Other Operational Problems in Sichuan

11. The most significant operational problems constraining SPA’s upstream activities are associated with: (a) use of inadequate equipment to produce sour gas; (b) insufficient formation water removal and gas dehydration capacity; (c) low well productivity; (d) inadequate field drilling and production equipment; (e) insufficient seismic data to properly locate development wells; and (f) lack of coordination and overlapping responsibilities particularly between the operating enterprises.

12. To effectively address these problems, SPA would need to: (a) introduce appropriate seismic data acquisition, processing and interpretation equipment; (b) introduce improved well drilling and completion equipment and materials for operating in severe environments of H_2S, CO_2, high pressure and high temperature; (c) build the necessary field gas treatment facilities to bring the project’s incremental gas production to pipeline specifications, (particularly adequate gas desulfurization, wellhead gas water primary separation, and gas dehydration); (d) adopt optimum field development techniques before bringing fields on production, consisting of conclusive reservoir delineation and appraisal and a well advanced initial development phase with the aim of maximizing the ultimate gas recovery; (e) introduce adequate equipment and materials to enhance gas well productivity, particularly with regard to high pressure hydraulic fracturing of tight gas reservoirs and horizontal drilling; (f) rehabilitate some of existing drilling rigs with provision for adequate well materials including equipment which would allow multiwell pad drilling, thus minimizing the use of land particularly in highly cultivated areas; (g) upgrade seismic data acquisition, processing and interpretation, reducing the risks of drilling dry or poor productivity development wells; (h) acquire the necessary seismic data for more reliable selection of well locations and use as a field development tool; and (i) strengthen management and field operational technical and institutional capability through specialized technical assistance covering all aspects of the gas sector activity and extensive training.

13. Lack of Dehydration Capacity. In addition to formation water, Sichuan natural gas generally contains a high level of solution water in a form of gaseous mixture and vapor. This type of water condenses into liquid as the gas is cooled from the high reservoir temperature to the cooler ground surface temperature. Its inadequate removal at the wellhead level, which is the case in several of SPA’s fields, results in serious operational problems. The water seriously overloads the gathering lines and hampers follow-up gas treatment operations such as desulfurization, transmission and distribution. Removal of this water or water vapor from the gas, also called dehydration, is essential for protecting equipment and surface facilities of SPA as well as of the consumers. The industry has developed three dehydration methods, which are used worldwide. Depending
on the gas composition, these involve the use of either a liquid desiccant, solid desiccant, or refrigeration in specially conceived plants located in the fields before the gas transmission and distribution network. Sichuan gas is generally dehydrated using the liquid desiccant with a concentrated solution of trimethylene glycol.

14. SPA fields are not equipped with sufficient and efficient gas dehydration facilities; existing facilities are old and lack the necessary spare parts. Some of the facilities have suffered severe corrosion problems and could be the source of operational hazards if they are not overhauled in the near future. Most plants are not equipped with adequate monitoring of gas dehydration quality and plant configuration and operations are often not appropriate for Sichuan gas. Glycol concentration is generally less than the design of the plants suggesting that excessive water is being carried out in sales gas. Furthermore, most of the natural gas produced in the south and southwest districts, about one third of SPA’s total production, is not dehydrated at all due to the lack of facilities. Reportedly, only glycol is being injected into gathering lines at the well sites. While this may remove some water, it is still insufficient and the gas contains an excessive level of water vapor. As a result, significant quantities of water overload the gas transmission and distribution system, condensing into liquid and forming slugs of water restricting the flow of gas. The problem is further exacerbated by the presence of H₂S, which forms acidic solutions, further accelerating corrosion. This is noticeable in most of the field surface facilities as well as in the transmission and distribution system, all of which now requires extensive repairs and maintenance.

15. Inadequate Seismic Coverage. Although much of the basin has been covered by a fairly detailed seismic grid, data quality of some parts of the basin has been poor. Highly fractured formations, particularly in crestal areas of the gas fields, appear to distort seismic signal, resulting in unreliable data interpretation. In addition, extremely difficult terrain has limited the coverage of several potential areas, particularly on the flanks of structures. This problem has been frequently encountered in East Sichuan, including the fields to be developed under the proposed project, where only dip lines have been surveyed. Because of this, the seismic interpretation is dependent on line-to-line correlations and thus is unreliable. As a result, the number of non productive development wells has been relatively high. New structures and some appraisal wells are drilled using minimum seismic data. Although present data interpretation might suggest favorable structural configurations, additional detailed seismic would conceivably optimize the field development drilling program. Fields with thinning gas reservoirs in structurally high positions, such as Wubaiti, Mingda and Woxinshuang, have not been accurately mapped due to poor seismic quality and inadequate coverage.

16. Inadequate Drilling and Production Equipment. SPA drills 100 to 105 wells per year, of which 70 percent are development and appraisal with the remaining, exploration. Drilling activity consumes about 60 percent of SPA’s total upstream budget. To drill and service its wells, SPA owns and operates 87 drilling and work-over rigs with a drilling depth capacity varying from 4,000 to 6,000 meters. Compared to international standards, SPA’s drilling performance is low with a drilling efficiency about one-third less than it should be. One of the main reasons is that rig design, concept and equipment are
no longer adequate for current drilling conditions (increasing depth with hard and fractured formations, $H_2S$, $CO_2$ and high pressure). The rig fleet consists of about two-thirds Chinese and one-third Rumanian manufacture. Most of the rigs are old and worn out resulting in about 30 percent of the drilling time being devoted to rig repairs. Mechanical and hydraulic power availability is insufficient causing excessive rig breakdowns. Solids control equipment on most of the rigs is inefficient leading to substantial reservoir formation damage, which is one of the main causes of the low well productivity. All of this leads to lengthy drilling time, which in turn causes excessive hole enlargement, invasion of gas-bearing formations by large volumes of drilling fluid losses, and poor casing cement bonding, all of which contribute to an overall poor quality well.

17. With regard to production equipment, the size of tubing being used by SPA in wells with high flow rates could be a problem affecting not only the well productivity but also overall gas recovery. SPA produces most of its well through a 2-7/8 inch size tubing, which is rather small. A review of wells with flow rates higher than 0.30 mcm per day of gas shows an excessive wellhead flowing pressure, which is inconsistent with the reservoir characteristics and production parameters. This generates high back pressures within the reservoir and excessive gas flow velocities. Back pressures accelerate the decline of well flow rates over the reservoir life contributing to the low productivity of the wells and to a reduced ultimate gas recovery. High velocities of gas flow develop erosion problems for the tubing, wellheads and surface facilities. Another problem associated with the tubulars being used by SPA is the casing policy. In this respect, SPA’s current casing program is based on a minimum engineering design criteria with the view of using as little tubulars as possible. While the formula is acceptable for shallow fields with homogeneous and well known geology, its application for Sichuan gas fields and particularly in East District, has proved to be highly detrimental to the overall well quality and subsequently, to the well productive life. Given the complexity of the geology of SPA’s fields, the high pressure deep wells require a revised casing design with introduction of some high grade casing. Other inadequacies in production equipment relate to safety aspects of the wells. In this regard, wellheads are not equipped with remotely operated master valves. Similarly, there are no subsurface safety valves in the wells. These valves are standard equipment for gas fields, particularly those containing $H_2S$.

18. Lack of Coordination. The field activities are carried out by various operating enterprises of SPA. These enterprises are organized on a functional basis and operate generally in a safe and workmanlike manner but appear too compartmentalized. This makes field operational coordination difficult to establish. The overall level of communications between field operational sites and enterprises is poor and the response time is reportedly very slow when special field operations are needed. For example, well completion and production testing which determine the drilling of offset wells, are excessively delayed due to the lack of readiness of the relevant enterprises. As a result, the well drilling proceeds without taking full advantage of recent drilling results. Variations and lack of integration of field operational practices within the different enterprises seem also to affect field coordination and more importantly hamper the overall operational performance. In this regard, some of the enterprises continue to apply practices developed by SPA many years ago during the initial stage of the field development while few others
have successfully revised them in light of recent improvements in technology. In general, improvements have been noticeable in areas where foreign specialized assistance has been used such as in electric logging, low pressure reservoir stimulation and to some extent in seismic. Due to the lack of resources, however, SPA has not been able to benefit from the new technology. For example, contrary to many oil and gas operating companies, for selection of infill well locations, SPA does not use seismic to full advantage, which has proved to be highly reliable technique for reducing the risk of drilling non productive wells in the development of known fields.

B. THE PROPOSED UPSTREAM COMPONENTS

19. **Components’ Objectives.** The proposed upstream components constitute a portion of SPA’s Eighth and Ninth Five-Year Plan (1990-2000) investment program. They would assist SPA in delaying the anticipated production decline, increasing gas deliveries and addressing current major operational problems, particularly those associated with field production optimization and subsequent long-term gas conservation at the field level and with overall gas purification. They consist of: (a) development of 14 gas fields in East Sichuan and rehabilitation of about 190 existing potential wells in East and Central Sichuan. Field development and well rehabilitation are expected to yield a total gas production of about 70 bcm to be produced at an average of 3.4 bcm/yr from 1996 to 2015 assuming a project implementation start-up in 1994. This would increase SPA’s gas production from the current level of about 6.7 bcm/year to about 8 bcm/year in the year 2000. This production level would be sustained for 6 to 7 years after 2000; (b) introduction of modern gas production technology which would improve the field productivity (by 10 to 30 percent), and substantially enhance the overall gas recovery (to about 70 to 75 percent), would become an important gas conservation measure at the field level; and (c) enhancement of field environment and safety through adequate purification (dehydration and desulfurization) of sour gas, and efficient treatment and disposal of waters produced from gas reservoirs.

20. **Description of the Upstream Components.** The upstream components to be financed under the proposed project constitute about 40 percent of SPA’s 1993-2000 investment program, which is part of the Eighth and Ninth Five-Year Plan (1991-2000) and about 70 percent of SPA’s East District Eighth and Ninth Five-Year Plan investment program. These components consist of:

- **(a) Seismic Survey.** Acquisition of about 8,800 line-km of seismic, including data processing and interpretation in the field to be developed under the project;

- **(b) Field Development.** Development of proven gas reserves in 14 selected gas fields in East Sichuan through: (i) drilling of about 100 infill development wells; and (ii) construction of surface facilities consisting of gas gathering systems, gas dehydration and desulfurization plants;
(c) **Well Rehabilitation.** Rehabilitation of old gas wells, about 90 in East Sichuan and 100 in Central Sichuan, through work-over, reservoir stimulation and well recompletion techniques;

(d) **Improvement of Field Environmental Management.** Development of formation water injection schemes to be supplemented by construction of water and other liquid waste treatment facilities and installation of mobile solid waste process units; and

(e) **Consultancy and Training.** Institution building through technical assistance and training in modern petroleum technology and management.

21. **Seismic Survey.** The seismic surveys to be carried out under the proposed project would delineate the extent of the gas fields as well as minimize the risks of drilling dry development wells as a result of poorly chosen well locations. To achieve these objectives, the data quality requires substantial improvement through advanced data acquisition, processing and interpretation equipment and technology. The surveys would consist of about: (a) 3,570 line-km of infill seismic to be acquired as early as possible during the project start-up phase in order to precede the development drilling; (b) 2,550 line-km of appraisal seismic, to be acquired during the 1995 and 1996 field seasons to define the field boundaries, both down the flanks and also along the strike of the fields; and (c) 2,680 line-km of extension seismic, to be acquired during the 1997 and 1998 field seasons to delineate structural culminations adjacent to the project's fields. The new seismic would enable SPA to achieve a fairly dense reliable coverage, which would eliminate some of the existing ambiguities associated with the interpretation of data on complex faulted and fractured structures, where any proved closure could be gas bearing. A limited amount of high quality seismic would also be used, on a trial basis, to determine the viability of direct hydrocarbon indicators, such as bright and flat spots. These indicators may be indicative of less dense formations due to possible increased porosity and gas-filled pore spaces. These techniques have proved to be successful in fields with subsurface geology similar to the Sichuan gas fields. The seismic coverage of the project's fields would be as follows: Wubaiti 2,200 line-km, Fengjiawan 1,700 km, Mingda 800 km, Tanmuchang 700 km, Shuangjiaba 700 km, Yunhegai 600 km, Teishan 570 km, Shaguanping 450 km, Wanshunchang and Longtou 430 km, Mobanchang 420 km, and Woxinshuang 230 km. The seismic program, including supply of 5 telemetry acquisition systems and 2 processing and interpretation systems has been estimated at US $38.6 Million equivalent.

22. **Field Development.** SPA's operation includes about 83 producing gas fields with a total proven and probable reserves presently estimated at about 400 bcm and 140 bcm respectively. Twenty-two fields are located in East Sichuan District, spread over an area of about 50,000 km², with total proven and probable reserves presently estimated at about 200 bcm and 94 bcm, respectively. Geological and geophysical work carried out over recent years indicates that the basin's gas resource base could be much larger than now projected, particularly in East Sichuan where about 80 potential structures have not yet been fully evaluated. However, these structures are in deep complex geological
formations where drilling and production conditions are becoming increasingly more
difficult and costly. Exploring and developing these structures would require enormous
incremental investments and would entail exploration related risks. In this regard, SPA
would seek government approval for opening up concessions for direct foreign investment.
The project will include technical assistance to SPA for petroleum development promotion
to potential international investors. The draft Terms of Reference are in Annex 5.4

23. The proposed gas development program was designed as a result of a gas
reserve assessment followed by a field-by-field evaluation; the above study was carried out
with the assistance of TCC-financed international consultants. A program of geological
and geophysical studies will be followed by a program of development and extension
drilling. This program will consist of drilling about 100 development wells in 14 fields
selected on the basis of their gas potential. These fields, which are located in East Sichuan
(see Map IBRD No. 25138), are Wubaiti with 37 wells, Mingda with 7, Tieshan 2,
Yunhenzai 5, Shuangjiaba 6, Fuchengzai 1, Tanmuchang 4, Shaguaping 8, Wanshunchang
2, Longtou 7, Mopanchang 6, Gaofenchang 6, Woxinshuang 5, and Fengjiawan 4. Their
original proven and probable reserves have been estimated, by the aforementioned
independent reserve assessment study, at about 184 bcm and 10 bcm respectively, of which
about 15 bcm has been produced. Based on a projected 80 percent rate of recovery, their
current proven recoverable reserves are estimated at about 135 bcm. The fields have been
discovered over the last 10 years, except one (Woxinshuang), which has been producing
for about 30 years with substantial remaining reserves. There are five other fields
(Shaguaping, Wanshunchang, Longtou, Shuangjiaba and Fuchengzai) that have been
producing since they have been put on stream during the period of 1985-90. To be put on
production, the remaining fields require production wells and wellhead connection
facilities, which will be provided under the proposed project. Some of the recent appraisal
drilling results have indicated that the Wubaiti field, for example, would be much larger
than previously thought, proven and probable reserves estimated at 33 bcm and 10 bcm
respectively. These estimates are expected to increase as more is known about the extent
of the field as a result of project implementation.

24. About two thirds of the proposed drilling program, would be infill
production wells and the remaining would be development and extension production wells.
To ensure higher productivity, the wells would be located following an optimum spacing
pattern and on the basis of field reservoir performance and the most recent drilling,
geological and geophysical data. The wells would be drilled, stimulated and completed
using modern techniques, equipment and materials. Well completion would involve
bottom-hole assemblies including packers. Drilling locations that might fall near populated
areas and cultivated land would be grouped and directionally drilled from multiwell pads.
This cluster drilling is expected to reduce substantially the use of land, the risks of any
environmental degradation, which might be associated with drilling wastes and the overall
field development cost. The total incremental gas production to be achieved from the
proposed field development component would be 58 bcm at an estimated cost of
$394.6 million equivalent.
25. **Well Rehabilitation.** This program consists of restoring production in wells, which have ceased producing or their flow rates have declined considerably, due to hole mechanical problems or changes in reservoir characteristics. The bulk of the wells to be rehabilitated under the proposed project, appears to have been affected by the lack of reservoir permeability and subsequent decline in bore-hole gas drainage. Corrosion of bottom-hole equipment and sand influx have also caused some wells to cease production. The 90 East Sichuan wells have been selected from more than 15 gas fields, in areas with substantial recoverable reserves and 100 Central Sichuan wells are within Moxi and Bajiaochang field with 25 bcm and 20 bcm of proven reserves respectively. A limited quantity of gas has been produced from Moxi and no production has started yet in Bajiaochang. The well rehabilitation work program would consist of a detailed technical review of SPA's previous stimulation and well completion techniques. Based on the review results, field pilots involving propped and fracture acidizing treatments would be carried out with the objectives of containing the fractures within the targeted interval (extended vertical fractures generally lead to serious problems of water influx) and selecting adequate proppants and fracturing liquids. New well recompletion design, including permanent production packers and perforating techniques, would also be field tested and used. One or two wells would be selected in Central Sichuan fields for sidetracking (horizontal well), which could improve the well productivity. Side-tracking could be based on a limited seismic survey to identify gas-filled high porosity zones by use of hydrocarbon indicators. Because of the uncertainty about the magnitude of problems associated with idle wells, work-over cost estimates and production to be gained are difficult to predict. However, based on SPA's previous experience and taking into account the new equipment and technology to be used, the proposed well rehabilitation program is expected to yield about 5 bcm and 7 bcm of gas in East and Central Sichuan respectively along with about 75,000 tons of condensate from Bajiaochang field at an estimated total cost of about $135.2 million equivalent.

26. **Improvement of Formation Water Injection Scheme.** In addition to displacing a significant quantity of coal, which would otherwise worsen the air quality in Sichuan, as already indicated in the project's environmental impact assessment, the proposed project would also assist SPA in its efforts to develop an appropriate scheme to dispose of its huge quantities of produced formation water and other liquid and solid wastes in a proper manner. The scheme would first be limited to the project's fields and then extended by SPA, on its own, to other gas producing areas in Sichuan. It would consist of developing effective subsurface injection programs for formation water and other liquid wastes. A large part of the scheme would be carried out in selected areas of the fields to be rehabilitated as no formation water is expected to be produced in the fields to be developed under the project in the near future. As these fields are new and are not yet in production, their development would be designed following appropriate reservoir management techniques by which no influx of formation water would be expected until after 12 to 15 years from now. Even then, water influx would be much less than what has been experienced by SPA in the past. However, some of the fields would be provided with facilities of a limited capacity, which can first be used for disposal of well drilling and stimulation waste waters and then increased later if required.
27. The scheme’s subsurface injection program would consist of identifying deep geological formations, in off-site locations nearby the fields where large capacity wells would be drilled and adequately equipped for disposal of significant quantities of formation water and other liquid wastes. Selected injection formations should be of a low pressure to avoid vertical fractures through which disposed liquid could channel to other horizons. The wells would be drilled away from and deeper than any known hydrocarbon bearing intervals to ensure that injected water would not move into any previously or currently gas producing formations. Injection zones would be tested and selected based on their capacity to hold large quantities of waste liquids. Groundwater aquifers intersected by disposal wells would be isolated by 2 and possibly 3 casings adequately cemented and periodically checked. Bottom hole section casing would be at least 60-m deeper than the lowermost known aquifer and adequately sealed by cement to avoid any waste water channelling upward behind the casings. No injection would be carried out through multiple casings. The wells would be adequately equipped and field operators provided with the best practical technology to carry out continuous monitoring of injected waste water and well integrity. Well drilling, work-over and stimulation waste water would also be disposed of through subsurface injection. Hazardous liquids, such as drilling, work-over and stimulation fluids, would be treated before injection to avoid deterioration (corrosion) of the disposal well facilities.

28. Improvement of Liquid and Solid Waste Treatment Facilities. The project's formation water injection scheme would be supplemented by adequate liquid waste treatment facilities. Limited to the fields to be rehabilitated under the project, these units would allow SPA to select the most appropriate process technology, which would then be used to upgrade existing units throughout Sichuan Basin and develop new ones. The treatment process to be selected would be based upon field proven technology, efficiency, ease of operation and maintenance, capable of continuous operations with minimal no sludge generation. It would process contaminated formation water and other field waste liquids. It would be integrated into the facility configuration, which in turn would be based on the most effective mechanical treatment (gravity separation by skimming and hydrocyclone centrifuging or enhanced coalescence by precipitation and filtering) including chemical treatment to enhance the process efficiency. Chemical treatment would also be taken into account and limited to field-proven products such as surface active agents (surfactant, foaming agents, demulsifiers and emulsion breakers), coagulating agents and polyelectrolyte. Complete chemical feed piping and pumps together with solution dosing tanks will be provided with each unit.

29. Most of the solid wastes consist of drilled cuttings and associated sludge contained in earthen pits. These pits are now causing some concern to SPA as a large part of the drilling activity is within cultivated lands. About 130,000 cu.m. of drilled cuttings, mud and sludge are produced each year within the well locations, which cover a total area of about 120 hectares. Pits are active for the duration of the drilling operations, which last between 6 and 12 months. Those pits located in cultivated lands are generally closed after the wells are completed, by conventional methods, such as dispersing, pumping and burial. Others are simply abandoned or converted to formation water reserve slumps. In many cases, however, these non concrete lined pits become a source of contamination, suggesting
that such wastes should be treated. Drilling waste is best treated onsite while well drilling is in progress. In this regard, the project would assist SPA in introducing new equipment and techniques to tackle these problems. First, multiwell pad directional and horizontal drilling would limit the number of well locations. Second, the drilling rigs would be equipped with adequate mud solids control systems with mobile drilling fluid and cuttings processing units. The units, which are now field proven and extensively used in North America and Western Europe, separate solids from liquids through a closed loop mechanical process, which is supplemented by flocculants. The fluids are totally recovered for reuse (recycled within the drilling rig fluid circulation system) and the drilled cuttings and associated sludge are rendered harmless for the environment and solidified for use in field civil works. The units also would eliminate or considerably reduce the size of the drilling site pits, which constitute substantial space consuming constructions in well locations. The units are self contained trailer or skid mounted and can be used by any type of drilling rig.

30. Upstream Components' Impact on Ultimate Gas Recovery and Gas Conservation. To achieve an ultimate gas recovery and subsequently an adequate gas conservation at the field level, the project will introduce, through the proposed upstream components, appropriate techniques in well spacing, well completion design, surface facility configuration and operating and maintenance. Well spacing will be based on reservoir characteristics and gas volumetric displacement parameters, which will be derived from conclusive production testing of appraisal and delineation wells and from other reliable bottom-hole data, thus ensuring uniform reservoir drainage. It will be the focal point of the field development scheme and designed with the possibility of a phased implementation through infill drilling. Well completion design will be based on a bottom-hole assembly configuration that allows controlled production flow rates, ensuring a uniform reservoir depletion. It will include equipment that eliminates sand production, thus reducing equipment wear and shutdowns for surface facility cleanout. It will involve adequate casing and tubing strings, minimize risks of well damage and facilitate well preventive maintenance and repairs.

31. Surface facility configuration will be based on a multiyear-production plateau taking into account accurate determination of reserves for an optimal recovery. This will result in larger gas treatment units and water removal vessels than generally conceived by SPA. Larger field based self contained modular facilities will be preferred to several small ones which are added during the field production life. Larger units provide more treatment flexibility and handling of a significant gas/water ratio. The plants' operating pressure will be as low as possible in order to delay or eliminate compression allowing maximum gas recovery at least cost. Some of the plants' modules can be removed as the gas reservoirs are depleted, hence operating and maintenance will be based much more on reservoir management rather than production targets. To optimize exploitation and as a routine reservoir management aid, fields will be developed using reservoir simulation with cross-sectional model. Reserve depletion will be managed through simulation with the aim of maximizing gas recovery. Reservoir behavior will be monitored through periodic downhole pressure and temperature measurements using modern equipment including bore-hole televiewer. Updating and improving reservoir data will be continuous and part of field
development plans. Reservoir vertical permeability and fractures will be particularly studied in order to continuously quantify the nature and magnitude of water encroachment into gas wells. Field development plans will be made flexible to incorporate new reservoir data continuously as they become available. Multilayer reservoirs will be selectively completed to avoid watered-out intervals and control watercut levels. Commingling production from more than one reservoir will be avoided except for those intervals that have the same reservoir characteristics and production parameters. Production stimulation, particularly high pressure fracturing, will be based on ultimate recovery using cross-sectional simulation studies and taking into account the risk of water encroachment.

32. An Independent Regulatory Agency. In order for SPA to develop and implement a sound reservoir management policy with the aim of recovering 70 to 80 percent of in-place reserves and achieving an adequate gas conservation at the field level, usual field development and production plans driven by demand considerations designed essentially for present needs will have to be altered to encompass long-term considerations, particularly with regard to production optimization. However, as in many developed and developing countries, particularly those that are energy supply constrained, setting the production level without any government influence or company quick payout consideration, has proved to be difficult. Rules and regulations governing the sector in general and field-operating practices in particular are especially ill-defined and inadequately implemented by state owned companies. This is a major obstacle to sound field management. Many countries have successfully addressed this problem by establishing an independent agency whose main role is to regulate the sector. Independent of any political interference and operating separately from any government ministry and other politically oriented organizations, the agency proved to be an efficient tool for separating resource ownership from regulation. Some countries entrust both, ownership and regulations to their state companies which has proved to be a problem for countries that now are opening up their petroleum sector to private-sector participation.

33. In the case of the gas sector in Sichuan, a role for a such a regulatory agency would be approving, monitoring and regulating the physical aspects of exploration, development and production of oil and gas. The agency would deal with gas conservation issues, ensure the integrity of gas field development plans and that hydrocarbon resources are maximized using sound technical and economic principles and taking into account safety and environmental practices established by the international industry. Monitoring gas production volumes would be one of the first tasks of the agency. In this regard, the agency would evaluate each field separately and an appropriate production rate set by taking into account the available reserves, the ultimate recovery potential, the reservoir depletion plan, the presence of an active water drive, the potential for reservoir damage, the production capability of the wells and other reservoir characteristics and gas volumetric displacement parameters. A maximum well rate limitation (MWRL) would be established for fields where the agency believes that reservoir damage or gas losses into the reservoir may result from excessive production flow rates. MWRL are usually set annually with the view of achieving a maximum gas recovery from the reservoirs taking into account specific reservoir parameters such as formation pressure, temperature, compressibility, porosity, permeability, recovery life and other relevant characteristics derived from well production
tests. The agency could also specify maximum gas flaring limits to accommodate genuine mechanical breakdowns in gas processing plants, field power failures and production testing of offset wells. To encourage field preventive maintenance, penalties should be applied for flaring gas beyond the set limits.

34. Other Roles for the Agency. The agency could also act as an instrument of the Government policy in issuing petroleum exploration, development and production licenses. It could prepare petroleum licensing promotional material and data packages, determine bidding documents and conditions, administer access to technical data, receive and evaluate proposals, negotiate and execute agreements and check that the licensee conforms with the license conditions. With regard to monitoring and regulating the petroleum operations, while the operational decisionmaking is the responsibility of the operating companies, the agency could develop rules and regulations establishing minimum standards for well drilling operations, production, gas processing and transmission, water disposal operations and other technical field practices. Furthermore, the agency could also develop and enforce oil and gas field operating safety codes covering all aspects of petroleum exploration, development, production, processing, transmission and marketing. Another important role for the agency would be monitoring, auditing production, oil and gas revenues, royalties, taxes and other Government's financial interests in both Chinese and foreign operating companies. Once established, the agency could also deal with oil and gas related pricing, costing including review of operating companies' investment programs for economic regulation. The establishment of such an agency would be in phases, over two to three years. The regulatory framework will be addressed under the JGF-financed study on oil and gas sector restructuring.
GAS TRANSMISSION AND DISTRIBUTION SUBCOMPONENT

A. BACKGROUND

1. The gas transmission and distribution system (T&D) of the Sichuan Petroleum Administration (SPA) comprises a pipeline grid and a number of spurs, totaling about 2,800 km in length. It transports about 16 million cubic meters of natural gas per day from five gas producing regions (Northwest, Southwest, South, Central and East) to about one million, commercial entities and small industries through the city gas companies and directly to about 600 large industries. This system is about 12-20 years old, except for the north loop linking East and Southwest regions, which was built about five years ago. Its maintenance and expansion plans have been underfunded, mainly due to financial constraints. It is prone to breakdowns (110 since 1978), gas leakages and accidents. A preinvestment study (called the Diagnostic Study) of the system was recently completed with the assistance of PRIF-financed international consultants to evaluate the capability, efficiency and reliability of SPA’s T&D system and to determine the most efficient measures for its rehabilitation, environmental upgrade and expansion to transport an additional 4 million cubic meters of natural gas per day expected to be produced in the East region.

B. DIAGNOSTIC STUDY FINDINGS AND RECOMMENDATIONS

2. The recently completed Diagnostic Study concluded that:

(a) the integrity of the system is uncertain and the safety of the operating personnel and the general public is being put at risk;

(b) the standards and safety regulations for system operation have been frequently disregarded and internal corrosion in the pipelines due to release of nonspecification gas (wet and sour gas) into the transmission system is the most serious problem;

(c) in emergencies, the grid control system cannot efficiently respond to rapid changes in the operating conditions;

(d) the responsibility for the operation of the system is divided between several departments, and there is a lack of accountability at senior management level; and

(e) the expertise of the staff requires upgrading.
Major Issues

3. Major issues in gas transmission and distribution are: a) damage control and rehabilitation of transmission and distribution system; b) optimal expansion of the system to meet the enhanced gas supply targets; and c) efficient and safe operation.

4. To address the above issues, the strategy formulated by SPA, which has taken into account the recommendations of the diagnostic study, include the following:

   (a) installation of gas dehydration and purification facilities at identified sour gas locations to ensure that only dry, sweet gas (in accordance with specifications) will enter the transmission and distribution system;

   (b) implementation of a rehabilitation and capacity expansion plan, for the transmission and distribution system, as recommended by the diagnostic study, that would mitigate the risk and optimize the upgrading and expansion for safe and efficient operations over the next 20 years;

   (c) reorganize the gas transmission and distribution operations to clearly focus the responsibility for efficient planning and operation of the system;

   (d) upgrading the staff expertise; and

   (e) enhancement of safety regulation.

Gas Purification

5. To ensure system integrity and to increase the life expectancy of the gas transmission and distribution system, only dry and sweet gas (in accordance with the specifications) would be allowed to enter the pipelines. Gas dehydration and purification facilities will be installed at a central location at each gas field producing nonspecification gas. If this is not feasible, then the facilities will be installed at the receipt stations for gas entering the transmission pipelines. Actual locations will be determined through site feasibility studies.

Rehabilitation and Expansion of Gas Transmission and Distribution

6. The plan, as formulated under the Diagnostic Study, has the dual purpose of (a) upgrading the reliability and capability of the system; and (b) deterioration monitoring and evaluation so that the best rehabilitation and capacity expansion decisions can be made during the next 20 years. In system upgrading, emphasis has been on (a) improvement of control, communication and, maintenance capability and (b) rehabilitation through replacement of parts/components rather than outright substitution of the whole plants/sections. Deterioration monitoring and evaluation of the system will be an ongoing process. Once set in motion, this process will provide early warning of any trouble
brewing in the system and will enable appropriate and timely remedial measures to be undertaken.

Upgrading the Reliability

7. It will take an estimated year and a half under the best possible conditions to set up the gas purification subcomponent under the project. Meanwhile, the mainlines will be pegged clean and dry as required and where sour conditions are present or suspected, inhibition by continuous injection and batching will be utilized to mitigate the internal corrosion process. Gas quality monitoring instrumentation will be installed on the system and monitoring will determine the ongoing need for inhibition operations. Once the network has been cleaned and operating according to the newly upgraded standards and procedures, the drying and inhibition operations can be phased out. The exception will be any local short sections which continue to see wet/sour service.

8. External corrosion protection will be upgraded in one section near Well Wei-6 and thermal electric generators will be installed to replace existing rectifiers at nine stations where the power reliability has been identified as being low. However, the most important consideration for the future is to monitor increased current requirements which may be indicative of wide spread coating deterioration in the future.

9. A total of eleven river crossings have been identified, which need to be carefully examined to determine if they can withstand probable flood conditions. SPA has identified these rivers only as high risk and high consequence locations. The plan assumes all eleven will need to be replaced using modern mechanized methods as a cost-effective precaution against flood failure.

10. The plan recommends the implementation of a supervisory control and data acquisition system (SCADA) system tailored to SPA’s needs which includes mainline measurement and automation at selected locations and a supporting telecommunications system. These systems will provide SPA with basic control and data gathering capability which will make their operation more efficient in routing gas to supply customers and in responding to emergency shut downs and maintenance situations.

11. All meter runs will be inspected and replaced as required. Metering accuracy is a key business consideration for SPA. All mainline valves will be operationally checked and replaced as required with valves which are easy to maintain and fully compatible with the operators required for SCADA. Scrubbers and valves at stations will be upgraded to and overpressurization protection will be provided for the mainlines. Equipment, procedures, and training will be upgraded to provide SPA with enhanced maintenance and construction capability at the district level.

Deterioration Monitoring

12. The plan will also initiate a program designed to determine the extent of deterioration which has already occurred on the pipeline system. This program consists
of hydrostatic testing of three to four representative sections of pipeline which have been exposed to a potentially severe corrosive environment inside the pipe. These sections can be removed from service for extended periods of time without a major business disruption to SPA and will provide a good basis for assessing overall system condition. The second important data gathering means put forward in the plan is the in-line inspection (ILI) of the 173-kilometer Lianglu pipeline. This will involve extensive modifications to the existing pipeline but will establish the actual pipeline condition and will provide future ILI capability, as well as increase the efficiency of all pigging operations. The Lianglu pipeline is a major transmission section which moves the gas to the urban centers of Sichuan province from the primary fields in the east region.

Capacity Expansion

13. SPA’s plan provides for expansion of SPA’s pipeline network in the east region in order to move reserves out of the Wubaiti, Fengjiawan, and Mingda areas. In order to meet the forecast supply and demand requirements, approximately 211 kilometers of NPS 18 pipeline will be constructed and commissioned by year end 1996. An additional 72-km of NPS 10 and NPS 16 will be installed by year end 1999. In order to handle the maximum supply through Lianglu forecast by Sproule Associates, facilities expansion is required on the south trunkline of the system. The expansion consists of looping the existing Naxi to Fuying pipeline with 35 km of NPS 20 pipe by 1994 and adding a compressor station at Hejiang (West) by 1996. The station will consist of two centrifugal compressor units (5,000 HP each) to begin with, one of which is backup, and a third unit of the same size to be added by the year 2000.

Customer Pipeline

14. It was determined at the outset of this project, during the data gathering and confirmation stage, that detailed consideration of customer pipelines was outside the scope and would therefore not be considered in the rehabilitation planning. These pipelines are not owned by SPA, the majority are not operated by SPA, and no data is available for consideration. Nevertheless, they are the downstream recipient of problems generated by the producers and SPA with respect to gas quality. The diagnostic study report has emphasized not merely a cost-effective approach to pipeline rehabilitation but has also put in considerable effort to explain the reasoning for the approach. Volume III, "Assessment of System Integrity," in particular describes the concerns and evaluation process used to formulate a plan. This information should be presented by SPA to its customers in the interest of public safety and avoidance of business disruptions.

15. SPA will be forming a task force to implement the rehabilitation plan. This task force should take the responsibility to inform and educate the customers and, if necessary, work with them to review and upgrade existing construction practices and procedures. If agreement with individual customers can be reached, SPA may extend its cleaning, drying, and inhibition programs to major customer lines. Cleaning and drying runs will give an indication of possible conditions inside the pipeline and gas composition
into the customer line should be estimated by SPA prior to recommending any inhibition program.

16. In addition, SPA should advise its customers that no major expenditure such as hydrostatic testing or in-line inspection (if feasible) should be undertaken without the task force first determining the need by evaluating the risks and consequences of failure for the specific pipeline(s). If the decision is made to proceed with such an operation, the standards developed by SPA (with outside consultant assistance) for their rehabilitation program should be adopted for customer use.

Environmental Upgrades

17. In examining control options for reducing methane emissions from fugitive equipment leaks, there are three basic types of leaks: random, chronic and normal operational. Random leaks are those that may be expected to occur due to normal wear and certain irregular effects (improper installation or equipment defects), but that provide little or no trouble once repaired. Chronic leaks are those that require frequent or continuous maintenance due to more persistent and difficult to correct causes such as poor or inadequate designs, demanding process conditions, high usage or abusive environments. Normal operational leaks on the other hand are inherent to the design of some components such as certain pump seals and compressors seals. This type of leak cannot be classed as random or chronic but may become a random leak through wear.

18. Based on observations made by the consultants during the field work, most of the equipment leaks are of the random type. The best, most efficient method of controlling those types of leaks is to implement regular leak detection and repair (LDAR) programs (inspection and maintenance programs). Based on the experience of industry in the United States, it is reasonable to expect a 70 percent reduction in fugitive emissions if LDAR programs are performed on a regular basis in accordance with US EPA leak performance standards.

19. An LDAR program consists of using a portable organic vapor analyzer to check (screen) potential fugitive emission sources for leaks. Those sources that give a maximum screening value above some specified limit (for example, 10,000 ppm) are considered to be in need of repair or replacement and are said to be leaking. Those components that screen below this value are considered to be in an acceptable state of repair and are said to be not leaking. Leaking equipment components are to be tagged and scheduled for repair.

20. If less than two percent of all potential sources are leaking then fugitive equipment leaks are considered to be well controlled. Otherwise, more frequent LDAR programs are required. To apply an ongoing LDAR program for all potential leak points at all facilities on the SPA system could be a onerous task. However, a more selective approach which targets sources with the highest leak frequency may provide a much greater return on control efforts would be much more cost effective. Specifically, efforts should be focused on leakage past valve seats into the vent systems, and on leakage from
valve packing systems since these sources account for 85.2 percent of total fugitive methane emissions. Secondary efforts should focus on compressor seals and packings, open-ended lines and pressure relief devices as these sources are relatively few in number and are prone to leaking; they account for an additional 7.0 percent of fugitive methane emissions.

21. **Recommendations.** Initial efforts to control methane emissions from the SPA natural gas system should be focused on the problem of fugitive equipment leaks. Comprehensive ongoing leak detection and repair programs should be implemented, and that they be conducted at a frequency of at least once annually. If more than two percent of the components are determined to be leaking (that is have a screening value of 10,000 ppm or more) during these programs, then the frequency of the programs should be increased as required. Specific recommendations for the scope of the LDAR program and for some additional control measures are itemized below by type of source. The incremental reductions in methane losses that may result from each option are summarized in the table at the end of this section.

(a) **Valves.** Considerable effect may be required to bring all components into a state of good maintenance. A certain portion of the components will likely be beyond reasonable repair and need to be replaced. Based on discussions with several commercial valve repair and remanufacturing companies and on results of the field inspections, it is estimated that probably 30 percent of leaking valves in use on the SPA system will need to be replaced. With the ban on asbestos packing materials in North America, a variety of options have emerged including die formed graphite, and various types of polymeric materials. Some of these new materials have broader ranges of application and can provide superior leak control. These better packing materials should be installed in all valves that can accommodate them. Maintenance teams may require special training to install these packings.

(b) **Compressor Seals.** Compressor Seals are prone to leaking and can be significant sources of emissions. To repair compressor seals it is usually necessary to have a complete system shutdown unless backup compression facilities are available. Two reasonable solutions to this problem are to either install high performance packing systems which will last the full period between regular shutdowns, or install a small incinerator to dispose of seal gases when they occur until a convenient shutdown can be arranged. It is recommended that better seals be installed to the extent possible. However, this must be coupled with improved alignment and increased maintenance of the packing case to be effective. Where major modifications or repairs are required, it is recommended that small incinerators be installed to dispose of any seal gases.

(c) **Open-Ended Lines.** Where a block valve is connected to a vent system, a second valve should be installed immediately downstream to control
leakage past the valve seat. Where a block valve opens directly to the atmosphere, it should be equipped with a chained cap or plug. In both cases, the existing valve should be repaired or replaced so that it is in good working condition.

(d) Pressure Relief Valves. When pressure relief valves reseat after having been activated, they often leak because the original tight seal is not regained due to damage of the seating surface or a build-up of foreign material on the seat plug. An effective method of controlling this source of emissions is to install a rupture disk immediately upstream of the pressure relief valve. It is recommended that this be done at all SPA facilities. The rupture disk will shield the valve from corrosive process fluids during normal operation. Moreover, if an overpressure condition occurs, replacement of the disk may be delayed until the next scheduled shutdown period. In the interim, protection against overpressuring is provided by the relief valve. A pressure indicator should be installed between the valve and the rupture disk to show when the rupture disk has failed. If frequent replacement of rupture disks is required, it may be appropriate to install a block valve upstream of the rupture disk to facilitate early replacement or repair of the components.

22. For the LDAR program to be effective there needs to be a strong commitment by both site personnel and by administration. Moreover, some central monitoring and enforcement of the program by SPA is required. It is recommended that a dedicated microcomputer, maintenance software package and data management system be purchased to help organize maintenance and inspection activities and track improvements in environmental performance.

23. Methane emissions reductions that are achievable through implementation of the above options are tabulated below:

<table>
<thead>
<tr>
<th>Emissions Reduction Option</th>
<th>Methane Reductions (tons/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installation of Double Valves on Vent Stacks</td>
<td>53,282</td>
</tr>
<tr>
<td>Installation of Plugs on Open-Ended Lines</td>
<td>1,194</td>
</tr>
<tr>
<td>Rupture Disk Installation and Replacement of Leaking PSVs</td>
<td>6,736</td>
</tr>
<tr>
<td>Upgrade Compressor Seals</td>
<td>528</td>
</tr>
<tr>
<td>Upgrade control valve Packing</td>
<td>77</td>
</tr>
<tr>
<td>Upgrade Block Valve Packing</td>
<td>15,257</td>
</tr>
<tr>
<td>Total</td>
<td>77,074</td>
</tr>
</tbody>
</table>
24. A total methane emissions reduction of 77,074 tons per year can be achieved through implementation of all of the above options. An additional 6,377 tons per year reduction on methane can also be realized through the replacement of 832 defective block valves and 34 defective control valves as part of LDAR programs on block valves, and control valves.

Reorganization of Gas Transmission and Distribution Operations

25. Until recently, the responsibility for planning and operation of SPA's transmission and distribution system was divided between the five gas producing sub-units, notably the East Sichuan Gas Production Company, and headquarters' Transmission and Distribution Department. This had led to a lack of coordination and procedural consistency in the operation and maintenance of the system. It had also resulted in a lack of accountability at the senior management level. This has, in turn, contributed to the release of non-specification gas into the system. Further, long-term plans for the operation and development of the system have never been drawn up and its maintenance and capacity expansion has remained underfunded. SPA recognizes that without an efficient transmission and distribution system, linking the gas resources with the markets, efficient development of the gas sector would not be possible. Thus, SPA has recently established the Gas Transmission and Distribution Company (GTDC), consolidating all the transmission and distribution operations into a single sub-unit which is fully accountable for efficient transportation of gas from the fields to major consumers and the city gas companies. The organization chart of GTDC is in Chart 3.

Upgrading of Staff Expertise

26. SPA's transmission and distribution system is quite extensive and requires a broad base of skills to adequately manage, operate and maintain it. In comparing the analysis of skills required to operate and maintain this system to a high level of reliability and accuracy with the skills currently available in SPA, the Diagnostic Study has identified skill deficiencies in key areas which has resulted in severe degradation of the system operations and integrity over the years. SPA would have to place high priority on correcting the skill deficiencies particularly in the management of transmission and distribution operations, project management, long-term planning, demand management, system integrity assessment, pipeline failure investigation, preventive maintenance, measurement engineering, geotechnical engineering, gas control and dispatch, and environmental protection. The program of skill upgrading would include the following:

(a) On-the-job training in parallel with system rehabilitation, deterioration monitoring and capacity expansion with assistance of consultants to be engaged to provide the necessary expertise;

(b) Courses on specialized topics to be held in Chengdu; these courses would be designed and conducted by experts from an experienced gas utility and/or gas technology institute in North America and Western Europe; and
(c) Post-graduate studies (two-year course) in the universities in North America and Western Europe for twenty staff and short courses (4-6 months) for 50 staff in business administration, gas utility management, project management, and the various disciplines of gas technology.

Safety Regulation

27. The standards for design and operation of natural gas transportation systems were compiled by Sichuan Petroleum Administration’s Design Institute and were promulgated in 1980, under a decree of the former Ministry of Petroleum Industry (MOPI). The oil and gas safety regulations were prepared by China National Petroleum Corporation (CNPC) and were approved and promulgated in 1989 by the State Council. SPA, in its capacity as an administrative bureau, is responsible for the enforcement of these standards and safety regulations. However, as an operating agency, SPA is not best suited to enforce these standards, also with the forthcoming enterprise reforms, there will several independent agencies and companies operating in the gas sector and it will be necessary to establish an office of the Regulator (or a Regulatory Commission). The Regulator’s office should be established in the central government with a branch office in Chengdu, to oversee the enforcement of standards and safety regulations in Sichuan Province. This would be addressed under the oil/gas sector restructuring study.

C. GAS TRANSMISSION AND DISTRIBUTION PROJECT COMPONENT

28. Based on the recommendations of the diagnostic study, the gas transmission and distribution component of the project would cover rehabilitation, environmental upgrade and capacity expansion of the system and the necessary technical assistance for project implementation and staff skills upgrading. Specifically it would include;

(a) Rehabilitation and upgrading of pipelines, measurement, corrosion control, corrosion inhibition, telecommunication, gas control, gas quality monitoring and emergency response facilities of SPA’s entire gas transmission and distribution system;

(b) Deterioration monitoring and evaluation of the transmission and distribution system;

(c) Cost-effective measures to reduce methane emissions, including:

   (i) installation of second valves at vent stacks;
   (ii) installation of chained caps or plugs at the open ended lines;
   (iii) upgrading of packing for control valves;
   (iv) replacement of high performance packing of compressor seals;
   (v) replacement of pressure relief valves and control valves;
   (vi) upgrading of packing for block valves;
   (vii) replacement of block valves;
   (viii) plugging of open-ended lines; and
(ix) replacement of control valves which cannot accommodate packing.

(d) System capacity expansion through the construction of:

(i) 20 in diameter x 35-km long loop line from Fuying to Naxi;
(ii) 18 in diameter x 16-km long loop line from Wubaiti to Jiangzhi;
(iii) 18 in diameter x 71-km long loop line from Wulonghe to Daosuiqiao;
(iv) 18 in diameter x 124-km long pipeline from Jiangzhi to Wulonghe; and
(v) 10 in diameter x 40-km long pipeline from Fengjiawan to Wanxian, along with the related corrosion control, measurement and gas control facilities;

(e) Provision of a supervisory control and data acquisition system (SCADA) for the whole transmission and distribution system; and

(f) Technical assistance covering,

(i) consultant services for,
   • system deterioration monitoring and evaluation,
   • training of SPA staff in Chengdu,
   • upgrading the operation and construction manuals, and
(ii) Overseas training of SPA staff.

29. Measures for environmental upgrade (i) through (v) above are expected to result net economic benefits; while measures (vi) through (ix) would result in net economic costs. The proposed GEF funding would finance most of the incremental costs of measures (vi) through (viii).

Implementation

30. SPA will be the agency responsible for the project execution. The implementation of this component will be organized through its subsidiary, the Gas Transmission and Distribution Company, with the manager of the company as the Project Manager. Services of international consultants, in accordance with procedures acceptable to the Bank, will be retained to advise and assist in system rehabilitation. The draft Terms of Reference for the consultancy services are attached.
REHABILITATION AND CAPACITY EXPANSION OF
GAS TRANSMISSION AND DISTRIBUTION SYSTEM

IMPLEMENTATION AND TECHNICAL MANAGEMENT ASSISTANCE

TERMS OF REFERENCE

Introduction

1. The gas transmission and distribution (T&D) system of Sichuan Petroleum Administration (SPA) comprises a pipeline grid and a number of spurs, totaling about 2,800 km in length. It transports about 16 million cubic meters of natural gas per day from five gas producing regions (Northwest, Southwest, South, Central and East) to about one million commercial entities and small industries through the city gas companies and directly to about 600 large industries. This system is about 12-20 years old, except for the north loop linking East and Southwest regions, which was built about five years ago. Its maintenance and expansion plans have been underfunded, mainly due to financial constraints. It is prone to breakdowns (110 since 1978), gas leakages and accidents. A pre-investment study (called the Diagnostic Study) of the system was recently completed with the assistance of international consultants to evaluate SPA’s T&D system’s capability, efficiency and reliability and to determine the most efficient measures for its rehabilitation and for its expansion, if required, to transport an additional 4 million cubic meters of natural gas per day expected to be produced in the East region.

2. The plan, as formulated under the Diagnostic Study, has the dual purpose of (a) upgrading the reliability and capability of the system and (b) its deterioration monitoring and evaluation so that the best rehabilitation and capacity expansion decisions can be made during the next 20 years. In system upgrading, emphasis has been on (a) improvement of control, communication and, maintenance capability and (b) rehabilitation through replacement of parts/components rather than outright substitution of the whole plants/sections. Deterioration monitoring and evaluation of the system will be an ongoing process. Once set in motion, this process will provide early warning of any trouble brewing in the system and will enable appropriate and timely remedial measures to be undertaken.

3. SPA will be the agency responsible for the implementation of the plan which will be organized through its subsidiary, The Gas Transmission and Distribution Company, with the manager of the company as the Project Manager. SPA would like to engage the services of a qualified consultant, hereinafter called "The Consultant" to assist the Gas Transmission and Distribution Company in the implementation of the rehabilitation plan.

Scope

(a) Review of the rehabilitation plan and detailed planning of its implementation.
(b) Review of detailed specifications for the materials and equipment required, procurement documents and bid evaluation.

(c) Organization and planning of system deterioration monitoring and evaluation which, inter alia, include:

(i) hydrostatic testing of the pipelines, establishing appropriate procedures including test pressures and environmental protection measures, and determining practicality of hydrostatic testing approach on the basis of test failures; analysis of failures and correlation of data;

(ii) inline inspection of pipelines, including development of detailed inspection plans, preliminary cleaning/gauging, drying, caliper runs, profile tool and ILI, tracking and handling, evaluation of results;

(iii) drying/caliper pigging; identifying sections which should have priority; sizing/gauging and judging the need for further caliper pig runs; and

(iv) evaluation of data, assessment of integrity and recommendations for repair, preventive maintenance or replacement of the pipelines and related equipment.

(d) Assistance in the planning of internal and external corrosion mitigation.

(e) Assistance in rehabilitation management, formation of taskforce and teams, integrity data gathering, deterioration and mitigation effectiveness assessment, data management and trend analysis, failure analysis and root cause assessment, and relevant counterpart training.

(f) Upgrading of operational and construction manuals.

4. The consultant will closely coordinate his work with the system expansion activities and will advise on the specifications of the materials required for system expansion.

5. On assignment, the consultant will promptly plan and render all necessary advice/assistance to the Gas Transmission and Distribution Company of SPA towards successful completion of the rehabilitation plan. He will be responsible to the manager of the company and will closely liaise with the vice managers. Except for certain backup services from the consultant's headquarters organization to be specified in the contract, the consultant will carry out the assignment in the field, associating the company's staff to the fullest possible extent in order to provide on the job training using modern up-to-date techniques of the industry.
TRAINING AND TECHNICAL ASSISTANCE

1. With 5 major operational districts, 28 subsidiaries, more than 100 drilling rigs, 22 seismic crews, a large gas transmission and distribution network and a total workforce of about 106,000 people, SPA’s training needs are enormous. To bridge the gap and in order for the project to reach its objective of achieving optimal gas recovery, the project would include a comprehensive training program for SPA staff. In addition, workshops and on-the-job training by twinning would also be organized, at no cost, by major equipment suppliers and contractors as part of their sales and field operations service contracts. Further, the project would include a technical assistance program in in project implementation and in addressing specific operational concerns.

Proposed Training Program

2. The objectives of the proposed training program for SPA staff would be to:
(a) ensure the availability of manpower with the aptitude to absorb and effectively utilize the technology to be imported for project implementation; (b) support SPA’s efforts in strengthening its institutional capabilities in enterprise reform, policy formulation and sector management; and (c) provide the basis for continuous development of manpower skills to enhance the sector’s overall performance. Specifically, the project would provide for short and medium-term training in finance, administration, and field operations to improve the managerial performance and optimize the development of the sector. It would also develop and strengthen collaborative relationships between SPA and the international oil and gas industry, training institutions and energy agencies to ensure effective transfer of technology. The program is of relevance to SPA’s overall objective of enhancing the development of its human resources and achieving efficiency. It would cover a broad spectrum of activities in gas production, transmission and distribution along with enterprise reform and environmental protection. This would include in-house training, overseas training and overseas study tours.

3. In-Country Training. In-country training would be specially prepared to meet SPA’s needs and conducted in Sichuan by experts from international training firms and worldwide known petroleum institutes and universities. Some 40 foreign experts would be invited to provide tailor-made courses covering all aspects of natural gas development (Geophysics, Geology, Drilling, Reservoir Testing and Depletion, Surface Facility Construction, Purification, Transmission and Distribution, SCADA, Environmental Protection, Finance, Planning, Administration and Enterprise Restructuring). The courses would be dispensed in classroom sessions, of about 2 week duration each. They would be designed for operating personnel, engineers at all levels as well as for managers. They would be based on the most recent technological developments and focusing on specifically designed problem areas. Technical operational courses would involve, to the extent
possible, field application of some pertinent subjects to real life problems. About 1600 selected staff would attend these courses scheduled for the early part of project implementation. The in-country training would cost about $0.5 million.

4. **Overseas Training.** The proposed overseas training would be a major component of SPA's manpower development program since completion of the Weiyuan technical assistance project in the late 1980s. This type of training is generally organized for the international petroleum industry on a regular basis by international training firms and well known petroleum institutes. The program proposed by SPA covers the same disciplines as the in-house training and consists of 1, 2 and 6-month courses. The 1 and 2-month course sessions, for which SPA is proposing about 580 and 135 selected staff respectively, would be intensive courses. One of the major aspects of these courses, would be focusing on recent technological developments and emphasizing the practical "how to" approach, for which participants would be provided with course materials for practical application. They would be for engineers with some experience and managers at all levels and specially for those in charge of specific programs. The 6-month training program, for which SPA is proposing about 63 selected staff, consists of a combination of university-based oil and gas technology studies and natural gas development management courses. It could be made up of three modules: (a) basic refresher courses in all aspects of oil and gas development; (b) current technological developments in oil and gas in terms of exploration, development, utilization and overall management; and (c) specific projects related to natural gas to be selected by the participants. Some of the courses could be jointly organized by universities and petroleum institutes. The program is intended for young postgraduate professionals, with good performance ratings, to be specialized in their area of activity and for middle managers to be provided with a firm basis for progression to senior management. The overseas training would cost about $5.6 million.

5. **Overseas Study Tour Training.** The proposed overseas study tour training consists of tours specifically organized on the basis of agreements with the parties to be visited, international seminars, conferences and workshops organized by the international petroleum industry and other institutions. SPA proposed study tours would be to develop with other oil and gas companies as well as energy institutions multipurpose collaborative relationships, with the objective of drawing lessons from others' experience. These tours, which can last up to one month, would be for middle and high level management. SPA proposed conferences, seminars and workshops would be selected on the basis of their relevance to its overall development objectives. These training opportunities, which would not take more than 2 weeks, would be for 280 staff consisting of managers and engineers at all levels. The overseas study tour training would cost about $2.0 million.

6. **Technical Assistance.** SPA's proposed studies and consultancy services would include technical assistance in project implementation and in addressing specific field operational difficulties. The studies relate essentially to upstream activities to review problem areas such as seismic data acquisition, processing and interpretation adequacy, geology and particularly petrophysical aspects of relevant fields, drilling engineering to improve rig fleet performance, and introduce new techniques. The consultancy services would cover procurement, promotion of petroleum development to international investors,
environmental protection and construction of gas treatment plants, pipeline and SCADA. They would also assist SPA selecting and operating appropriate gas desulfurization process as well as defining plant locations (centralized vs decentralized). Both the studies and consultancy services have been designed to ensure effective transfer of technology in all aspects of natural gas development, transmission and distribution.

7. Geophysics. SPA has carried out extensive geophysical work over the last 10 years. Most of the work consists of seismic surveys, which often experienced problems associated with extreme changes in surface elevations, variable near surface (weathering problems), complex subsurface structures and lateral velocity variations. Most wells to be drilled under the proposed project would be seismically located. To minimize the risk of offset well locations and assess the seismic performance in general, SPA intends to carry out a seismic study. The objective of the study would be to assess the acquisition, processing and interpretation of selected lines with a special focus on field structures that have been seismically defined. It would include reprocessing some lines using the most recently developed field proven software packages. Based on the reprocessing results, the study would evaluate the adequacy of SPA data processing technology and its impact on defining structural features, stratigraphic traps, near surface variations associated with complex thrusting and folding, and interactive weathering analysis. In addition, SPA intends to conduct about 500 km of 3D seismic surveys on a very selective basis to resolve local structural complexities. In this regard, the study should integrate 2D, 3D and, when available, drilling data and carry out a geophysically-based reservoir evaluation, particularly the extent of the porosity zones. Furthermore, part of the study should evaluate the possibility of improving the database system, such as integrating existing seismic with other geological and drilling data and digitizing it for conversion to computer format. The study would cost about $0.2 million.

8. Geology. Sichuan's natural gas is found in three different geological formations. The first is a series of Sinian to Silurian marine carbonates and clastics, with the Sinian carbonate being the most gas prone. The second is a very thick (2,000 m) interval of Carboniferous, Permian and Triassic carbonates and reef facies, with the carbonates being key gas producing strata. The third is the Upper Triassic clastics and Lower Jurassic limestones, which contain significant gas reservoirs. Most of these gas bearing formations have very low permeability and porosity and with multiple noncommunicating fracture systems. Although, containing substantial gas reserves, their productivity is generally very low. To better understand the geological complexity of the basin, SPA intends to conduct three studies for Wubaiti, Moxi and Bajiaochang fields. The studies would concentrate on the stratigraphy, sedimentation and petrophysics. The scope of the studies would be to establish computer generated isopach, structure, paleostructure, porosity and pore volume maps using available seismic and drilling data. The maps would be used for correlations (well electric logs to seismic data interpretation) between the various data acquisition methods used by SPA, petrophysical analysis, fracture system delineation and reservoir studies to improve field productivity. The three studies are expected to cost about $0.8 million.
9. **Drilling Engineering.** SPA owns and operates 87 Romanian and Chinese made drilling rigs. SPA drills about 100 wells per year, 4,000 to 5,500 m (14,000 to 18,000 ft) deep and of which approximately 70 percent are appraisal and development and 30 percent exploration. Most of the rigs are old and no longer respond to deep drilling requirements, particularly in a complex geology, often leading to excessive overall drilling time. As a result, well quality is seriously affected by numerous problems, of which the most serious are formation damage, which reduces substantially the well deliverability, hole enlargement with subsequent inaccurate electric logging data and inadequate casing cement bonding, both with far reaching implications on well completion and productive life. Excessive drilling fluid losses while drilling also lead to serious reservoir stimulation problems. About 60 percent of SPA's total budget is utilized in drilling and associated operations. Therefore, to improve its drilling operations and reduce overall well drilling cost, SPA intends to carry out three drilling studies.

10. The objective of the first drilling study would be to improve the performance of a selected number of rigs through overhauling. For this the study would assess the mechanical integrity of the rigs and associated major equipment and propose refurbishing only those rigs that can be economically operated for the foreseeable future. As the number of rigs might be reduced, the study should also assess the possibility of redeployment, to other activities, of affected drilling personnel. The objective of the second study would be to improve the drilling fluid technology. SPA's drilling fluid techniques constitute another serious problem area, for which the study would assess the suitability of the chemicals being used and the adequacy of the rig fluid complexes, particularly solids control systems. The study would propose corrective measures including system formulation and design. The objective of the third study would be to introduce multiwell pad (cluster) drilling and horizontal drilling. The study would assess the field areas suitable and equipment requirements for this type of drilling. The study would propose specific parameters to define locations, number of wells and horizontal displacements. It would also evaluate the benefits of such drilling techniques. The three studies are expected to cost about $0.5 million.

11. **Well Production Stimulation and Gas Recovery.** Most of Sichuan gas fields are characterized by very tight reservoirs and low productivity wells. In many fields with substantial reserves, wells cannot be economically produced unless they are systematically stimulated. Effective stimulations in Sichuan fields require complex sequential operations (high pressure acid fracturing and other bottom hole hydraulic treatments), which are designed on the basis of measured reservoir parameters. Accurate measurements depend on conclusive production testings, which are associated with well quality and equipment performance. Deficient well testing leads to inaccurate reservoir definition and inadequate overall reservoir management. To assess to what extent these problems affect SPA operations and how to correct them, SPA intends to carry out 6 different studies.

12. The studies would be on SPA's well testing and stimulation and reservoir management practices in the basin in general and in Wubaiti, Moxi and Bajiaochang fields in particular. These fields have been selected given their different geological setting and
their relevance to field operations. Each of these fields would be subject to 2 studies, one for testing and stimulation and the other for reservoir management. The objective would be to optimize reservoir production using the most economical methods. In well testing and stimulation, the studies should assess current engineering design and field implementation practices and propose: (a) well testing programs taking into account well conditions, drilling and other relevant geological data; and (b) well stimulation modules conceived to assist engineers in the design and analysis of hydraulic fracturing treatments based on various well and reservoir parameters and taken into account uncertainties that can be identified. In reservoir management, the studies should assess SPA's current approach to reserve recovery and evaluate and determine methodologies to enable SPA to categorize its reserves and plan their development on a long-term production to achieve an ultimate recovery rather than on a short-term production to achieve higher volumes. The 6 studies are expected to cost about $1.0 million.

13. **Rehabilitation and Deterioration Monitoring of Gas Transmission and Distribution System.** The plan, as formulated under the Diagnostic Study, has the dual purpose of (a) upgrading the reliability and capability of the system; and (b) its deterioration monitoring and evaluation so that the best rehabilitation and capacity expansion decisions can be made. In system upgrading, emphasis has been on (a) improvement of control, communication and maintenance capability; and (b) rehabilitation through replacement of parts/components rather than outright substitution of whole plants/sections; thus avoiding large scale investments. Deterioration monitoring and evaluation of the system will be an ongoing process. Once set in motion, this process will also provide early warning of any trouble brewing in the system and will enable appropriate, timely and cost effective remedial measures to be undertaken. Successful implementation of this plan would however, depend on the development of high quality of expertise within SPA, for which the services of an appropriate consultant would be required over about three-year periods. The consultant would assist in: (a) the review of detailed implementation plan, specifications of materials and equipment, procurement documents and evaluation; (b) rehabilitation management; (c) capacity expansion, upgrading of operational and construction manuals; and (d) on-the-job training of SPA's staff. The consultant will be responsible to the Manager of SPA Transmission and Distribution Company and will closely liaise with the Vice Managers. Except for certain back up services from the consultant's headquarters organization, the consultant will carry out the assignment in the field in full association with SPA's staff. The type and duration of expertise to be provided by the consultant will match the implementation plan. It is estimated that this consultancy will cost about $2.1 million.

14. **Environmental Protection.** Once the exact locations of wells to be drilled and surface facilities to be constructed under the project are known along with their engineering details finalized, SPA would be assisted by an international consultant to implement a program of mitigation measures (Annex 5.9). The consultancy service is expected to cost about $0.2 million.
15. **Financial Management.** Provisions for training by international consultants under the project would complement training by local institutes which is beyond the scope of the project.

(a) **Training Program Under the Project.** The topics would include, inter alia, accounting principles and practices of international oil and gas companies; corporate financial management, notably cost control and management as well as modern financing techniques; pricing policy and tariff setting, taxation policy and gas marketing. The modality of training would include a combination of training seminars at SPA, overseas training and study tours. The cost of this component estimated at $0.7 million, is included in in-country, overseas and study tour training cost estimates in above paras. 3, 4 and 5.

(b) **Training by Local Institutes.** Topics would include financial and managerial accounting, auditing, statistic principles, financial management and computer applications.

(i) **Short-term (6 months) Professional Training.** Planned schedule: 1993-95; two classes per year; 40 persons per class; total trainees: 240. Trainees would be selected from SPA finance staff with no professional titles but are expected to become professional accountants.

(ii) **Two-year College Program** at the Southwest Finance and Economic University. Planned schedule: 1993-96; 40 persons per class; total trainees: 160. Trainees are high school graduates and are expected to receive a two-year college diploma upon graduation from this program.

(iii) **English Language Training.** Planned schedule: 1993-94; one 1-year class per year; 40 persons per class; total trainees: 80.

(iv) **Other Training.** This would include TV education and correspondence education. Planned schedule: 1993-96; total trainees: 320.

16. **Cost Summary.** SPA's training cost estimates are based on recent price lists published by international training firms for some components and in-house calculations for others. The consultancy services are based on proposals received by SPA in connection with the Project pre-investment studies. These costs (in $ million equivalent) are:
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<td>Capacity Building</td>
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<td>Project Implementation Support</td>
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<td>Environmental Mitigation</td>
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<td>Field Development Promotion</td>
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<td><strong>Subtotal</strong></td>
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SPA Total 13.4
CNPC Petroleum Education 5.0
Total Training & Technical Assist. 18.4

**Total** 48.9
P ETROLEUM DEVELOPMENT PROMOTION
TECHNICAL ASSISTANCE

TERMS OF REFERENCE

1. With a view to accelerating the development of the gas sector in Sichuan, the Sichuan Petroleum Administration (SPA) is considering the opening up of petroleum blocks to international oil companies (IOCs). As a first step, SPA is seeking the approval of its parent company, the China National Petroleum Corporation (CNPC), and the government to open up gas field development of the Datianchi structure for joint venture(s) with IOCs. To manage this process effectively, SPA needs to build up its capability to develop and strengthen its ties to potential international petroleum development partners. To develop this capability, SPA requires technical assistance (TA) from experienced and qualified consultant(s).

2. Objectives. The TA objectives are to assist SPA in: (a) bringing to the attention of the IOCs the hydrocarbon potential of the Sichuan basin; (b) development of appropriate contractual mechanisms to initiate and increase foreign partner willingness to invest; (c) development of SPA's technical capability to deal with the international industry; (d) establishment of effective procedures for mobilization required financial resources; (e) development of recommendations to the government on a legislative and fiscal framework within which the SPA can negotiate contracts; and (f) negotiations with the international investors.

3. Scope of Work. The consultant would act primarily as an advisor and assist SPA in carrying out the following tasks:

(a) assess the potential attractiveness of the Sichuan basin to the IOCs, taking into account (i) current petroleum resource potential; (ii) fiscal (pricing and taxation) terms; and (iii) thorough economic analyses of the areas to be promoted under alternative financing arrangements;

(b) examine existing petroleum exploration and development legal and regulatory framework, evaluate the economic implications of existing tax laws on foreign investment and recommend to the government amendments, if any, to ensure that the petroleum agreements to be negotiated would be in line with the country's legal and regulatory framework and goals;

(c) evaluate different types of petroleum contractual arrangements, including but not limited to joint ventures, production-sharing and service contracts, and
recommend, after consultation with SPA, the most appropriate form of agreements for SPA;

(d) assess SPA's financial resources, skilled personnel and field logistic support as well as any risk factors associated with the exploration and/or development contract being offered in order to determine the appropriate levels of participation and control of SPA and its partners;

(e) determine the obligations of foreign partners in terms of minimum work commitment and implementation timing in order to minimize the risk of delaying economic benefits to be derived from the agreement. With regard to field production rates, which have been subject to frequent controversies between host countries and foreign operators, the agreement should be subject to an independent regulatory agency or a clear statement that the government, jointly with the operator, will determine a maximum efficient production rate;

(f) establish a petroleum data bank where existing geological, geophysical and drilling data of relevant exploration areas and/or development fields, is collated, translated and interpreted into formats and packages commonly used by the international petroleum industry and which should also demonstrate the geological prospectiveness of the Sichuan basin and priorities licensing areas, taking into account the petroleum potential and associated risks;

(g) organize a promotional campaign to present to the international petroleum industry, including the aforementioned data synthesis, legislative framework and model contract; and

(h) organize a core cadre of technical, financial and legal staff that can be trained to effectively negotiate petroleum agreements, coordinate with the private sector, deal with the complexities of petroleum exploration and development promotion, identify priority areas, develop adequate approximate cost estimation using published data in order to properly evaluate the financial commitments of investors, and respond to any level of interest in Sichuan petroleum development by the international industry.

4. Qualifications of the Advisor. The consultant should have extensive professional experience in the international oil and gas industry with a broad exposure to many facets of the business. Basic qualifications should be those of, but not limited to:

(a) Lawyer specialized in the preparation of petroleum laws, regulations and model contracts and in negotiations of international petroleum exploration and development contracts. In addition to petroleum law, the consultant should also possess a broad knowledge of petroleum economics,
engineering, geology, geophysics, infrastructure and new ventures analysis; and/or

(b) **Petroleum economist**, or planner or engineer specialized in negotiations of petroleum exploration and development contracts with in-depth knowledge of petroleum laws and regulations and broad knowledge of petroleum geology, geophysics, infrastructure and new ventures analysis.

5. **Reports.** The consultant will submit the following reports:

(a) a diagnostic report (issues paper), describing the current situation and highlighting the major issues related to SPA's future petroleum exploration and/or development promotion;

(b) a preliminary assessment report based on existing data regarding the hydrocarbon potential of the areas and/or fields to be promoted;

(c) an interim report (at a time to be determined in the advisor's contract) based on the diagnostic report and the information developed from discussions with SPA; the interim report should cover all of the items listed under the above scope of work (para.3), including technical assumptions, economic analyses and prospectiveness of the Sichuan basin. The report should also outline the strategy to be adopted and preliminary actions to be taken for the petroleum exploration and/or development promotion;

(d) an assessment report with regard to the need for a petroleum regulation that clearly defines sound resource conservation principles and an outline of a model contract, taking into account comments on the interim report; and

(e) a final report incorporating agreements comments on all previous reports and a summary of the proceedings/decisions taken during the assignment. In this connection, the advisor's draft reports are to be discussed in detail at all appropriate levels of SPA, CNPC and provincial as well as central governments. Work sessions would be organized to assist designated representatives of the government to fully understand the proposed changes.

6. **Duration of the Assignment.** About twelve months.

7. **Confidentiality and Conflict of Interest.** The contract for this assignment will provide that the consultant shall not accept or perform any services for any of the parties investing or negotiating investment agreements with any of the Chinese public entities with which the consultant will be working. The consultant shall hold strictly confidential all information obtained during the performance of this assignment which is not already in the public domain or otherwise lawfully in the possession of the consultant. The conflict of interest provision will last two years after the end of the assignment, and the confidentiality restriction will be indefinite.
NATIONAL PETROLEUM EDUCATION
DIAGNOSTIC REVIEW

TERMS OF REFERENCE

1. China's oil and gas sector human resource development has been given greater priority since the early 1980s. The China National Petroleum Corporation (CNPC), which is responsible for all onshore exploration and development activities, is entrusted with the task of higher education and training of the sector's manpower. CNPC, which produces through its regional companies about 98 percent of China's oil and all of the gas, has under its jurisdiction five petroleum institutes that aim to supply the sector with professional personnel that possesses a sufficient quality of technical and managerial skills. During the mid 1980s, the educational programs of the 5 institutes were substantially upgraded to achieve an integrated system of higher technical education. The programs were also expanded to cover all disciplines of petroleum technical education. In addition, exchange programs were also initiated and developed with foreign institutions.

2. Since the last two years, however, there has been a legitimate concern about the higher petroleum education responsiveness to the sector's needs. For this purpose, CNPC intends to carry out a diagnostic study of the educational performance of the five petroleum institutes. CNPC would invite about 10 experts from selected foreign petroleum institutes and universities to visit China for about two weeks, to: (a) assess the performance of current fundamental education and training of the institutes; and (b) make recommendations for improvements including developing a comprehensive approach to: (a) upgrading the capability of teaching and training personnel, existing programs and some facilities such as laboratories and libraries; (b) strengthening the institutes' research and development capacity; and (c) developing and strengthening a sustainable collaborative relationship between the Chinese and selected foreign institutes and universities. The experts, each covering a specific petroleum education discipline (Geology, Geophysics, Petroleum Engineering, Mechanical Engineering, Chemical Engineering, Business and Management, Computer Science and Education and Training Technology), would be requested to:

(a) visit the institutes for discussions and inspections of relevant facilities such as laboratories, libraries, research and computer centers, and classrooms as well as examination of curricular and course materials;

(b) discuss with management of the institutes, CNPC and CNPC's regional companies the perceived strengths and weaknesses of current petroleum higher education system;
(c) assess the relationship of the petroleum higher educational programs to the needs of the oil and gas fields in petroleum technologies and managements skills; and

(d) review the institutes' research and development (R&D) performance and associated constraints in scientific and technological manpower, facilities, and equipment as well as the overall impact of R&D on the sector in general and the operating companies in particular;

3. Before leaving China, the experts should convey their preliminary findings, observations and recommendations within the area of their specialization. After leaving China, each expert would submit, within four weeks, a final report providing their assessment, issues, conclusions and recommendations for changes to improve the whole system as well as individual institutes and particularly:

(a) a brief comparison between the Chinese and worldwide higher level petroleum education, particularly institutes, universities and related facilities, with which the experts are associated;

(b) a outline of major problems, and issues facing the petroleum institutes in their efforts of achieving a more highly integrated educational system;

(c) specific programs to upgrade the capability of teaching and training personnel with the objective of producing professional manpower that can be technologically competitive in the international oil and gas industry;

(d) detailed recommendations to update the educational programs to reflect the most recent advanced and sophisticated technological developments;

(e) recommendations for short and medium-term overseas training for about 100 faculty members and 150 teachers, including exchange programs to be associated with relevant Chinese projects;

(f) requirements to initiate, develop and strengthen sustainable collaborative relationship, including specific exchange programs, with worldwide known petroleum institutes and universities;

(g) procedures to revitalize and continuously evaluate R&D programs and projects that would contribute to technology advancements of the end-users qualitatively and quantitatively;

(h) detailed recommendations on developing and strengthening refresher courses for field operational personnel that can be carried out by regional training centers;
(i) suggestions on overall administration and policy of the educational system including allowing the institutes to have more flexibility in program and resource change; and

(j) requirements to upgrade existing laboratory and library facilities in order to achieve an integrated technological development and information resource system that will serve the educational system and the Chinese oil and gas industry;

4. The recommendations and changes to be conveyed by the experts should provide flexibility for their implementation, take into account a minimum disruption, and the resources available to the petroleum institutes.

5. The experts to be invited should be still active, preferably teaching, in worldwide known petroleum institutes and universities. They should have extensive experience in the required specialization. They should also possess adequate general knowledge about higher education and the petroleum industry.
PROCUREMENT IMPROVEMENT TECHNICAL ASSISTANCE

TERMS OF REFERENCE

1. As experienced in other Bank financed petroleum projects in China, procurement could be a major cause of project implementation delays. To minimize this risk, SPA would develop the technical capability to effectively monitor its international procurement. For this purpose, SPA recently organized a Procurement Unit to process necessary documentation for Bank financed procurement. In order for the Unit to operate effectively, SPA would develop adequate internal procedures. The Unit is part of the Project Management Organization and operates independently from SPA’s supply company. It consists of 11 subunits to be specialized in different lines of equipment, materials and services with a total work force of about 70 staff. As of now, the role of the Unit is to: (a) finalize the technical specifications, clear them with SPA management, send them to CNPC for final review and approval and then to the Bank for review and concurrence before transmitting them the procurement agency (PA), which reportedly has not yet been selected and which would be either China Machinery Corporation (CMC) or China International Tendering Corporation (ITC); (b) interact with CNPC and PA to ensure that CNPC’s review is expedited and that PA, which is responsible for preparing the commercial part of the bidding, complete the tender documents and issues them to bidder with no delays; (c) carry out the evaluation of proposals received by PA, clear the evaluation report and award proposal with SPA and then CNPC, obtain Bank’s concurrence and then have PA finalize the contract with the selected bidder; and (d) monitor and ensure the delivery of goods to end users including preparation of necessary customs clearance documentation and inland transportation.

Major Issues

2. Procurement process involves 6 different levels of review and approval and which are the District (Regional), SPA’s procurement unit (Chengdu), SPA’s management (Chengdu), CNPC (Beijing), the State Planning Commission (Beijing), the State Council (Beijing), and the procurement agency (Beijing). Obtaining the various approvals, not including documents preparation, appears to be a lengthy process, requiring, based on recent experience, 6 to 8 months. Separately, SPA has very limited knowledge of international competitive bidding (ICB). Further, the Procurement Unit would be better off to start with a small number of subunits and staff that can be increased as needs arise. If maintained as of now, the Unit management would have difficulties to ensure coordination and clarity of responsibility within the subunits.
3. To develop the necessary procurement capability, SPA would require an individual consultant with adequate experience in procurement for petroleum projects and capable of introducing new skills. The consultant would advise SPA in all matters related to procurement, including assisting SPA to:

(a) organize the procurement unit with definition and description of responsibilities of the subunits;

(b) adapt to SPA’s international procurement requirements (through International Competitive Bidding [ICB] and Limited International Bidding [LIB]) and where appropriate to local procurement requirements (through Local Competitive Bidding [LCB]), the Model Bidding Documents specifically prepared by the Ministry of Finance in accordance with Bank’s Procurement Guidelines;

(c) develop, where necessary, for use with the adapted Model Bidding Documents, bid evaluation criteria specific to gas field equipment;

(d) prepare annual procurement plan and related budget;

(e) develop adequate decision making procedures and delegation of authority by which the number of approval levels is reduced, if possible to one within SPA and to the minimum possible within the other agencies;

(f) prepare equipment technical specifications based on relevant performance and characteristics rather than supplier catalogs in order to attract a maximum of competition;

(g) select appropriate methods of procurement to be used for each package (ICB and LIB) and identify potential bidders for LIB;

(h) develop a procurement schedule allowing reasonable time for each step but resulting in a maximum number of contracts awarded within the first quarter of 1994 calendar year;

(i) monitor progress of the entire procurement process, particularly within the various government agencies in Beijing, respond to requests for clarifications from these agencies as well as from bidders, establish bid evaluations procedures, expedite bid evaluation and following steps leading up to final contract signature, establish L/Cs and prepare customs clearance and inland transportation;

(j) establish quality control criteria and procedures for monitoring standards;

(k) prepare annual procurement training plans, including organization of training courses, seminars and short (1 to 2 days) presentations covering but
not limited to Bank's procurement policies, international petroleum equipment markets and their related developments, sources of information about international market prices and trends are discussed; and

(1) extend the experience gained by the Procurement Unit to SPA's regional and central supply (procurement) companies to ensure quality and uniformity of procurement with due regard to the desirable and necessary degree of decentralization.

Arrangements for the Consultant

4. The consultant is expected to be working on a continuous basis with the Procurement Unit, preferably in the Unit's offices, for at least one and a half years, attending full procurement cycle for the first 4 or 5 major supply contracts and 2 or 3 service contracts.
ENVIRONMENTAL MANAGEMENT

Introduction

1. Environmental benefits of the Sichuan Gas Development and Conservation Project would include the displacement of some 2.9 million tons per year of coal equivalent, thus reducing greenhouse gases, particulate and sulfur dioxide significantly. Nevertheless, there are a range of environmental issues which will be addressed as part of this project. These tend to be site specific confined to areas where the gas is being developed, collected, compressed and purified. There are also a range of environmental issues which affect the system as a whole. These include formation water in some of the old fields, and the presence of hydrogen sulfide which causes corrosion and safety hazards leading to potential leaks. On the one hand, since the SPA gas systems in Sichuan Province are confined to rural or agricultural areas, environmental issues generally do not stress urban areas as does coal burning. Nevertheless, a number of problems have been reported where gas with a hydrogen sulfide content far above the standard has been released into the distribution system and could potentially cause a major accident because of corroded pipes. Current studies carried out under this project have pointed this out and have proposed mitigation measures which will be incorporated into the project.

2. Since the exact locations for construction of the project components have not been finalized, only the basic mitigation measures for each component of the project have been stipulated. Once the specific engineering details are finalized, a detailed program of mitigating measures will be produced along with site-specific environmental assessments. The following list of potential environmental issues will need to be monitored during project implementation and operation. All are addressed in the environmental impact assessment (EIA) report:

(a) Seismic Exploration—storage, transport and handling of explosives and detonators;

(b) Drilling—safety from accidental blowouts, wastewater from drilling mud treatment and equipment and site cleaning, groundwater puncturing and contamination, air pollution from diesel exhaust gases, dewatered waste drilling mud;

(c) Well Gathering Stations—condensate containing volatiles and toxins, formation wastewater;
(d) **Gas Purification**—stack gas containing $\text{SO}_2$, small amounts of wastewaters containing amines and formation wastewater, ashes from sludge treatment, waste oils and lubricants, safety issues;

(e) **Pipelines**—leaks, potential resettlement and compensation issues, cultural and biodiversity issues;

(f) **Compressor Station**—air pollution from engines, gas leakage, small amount of wastewater waste oils; and

(g) **Work-over Operations**—wastewater containing acids and potential safety issues.

**Land Acquisition and Relocation**

3. The project will require about 700 hectares on a temporary basis and 190 hectares on a permanent basis. All of the required land is used for agricultural purposes. A larger area will be required in the vicinity of pipelines as a safety zone, where no houses will be allowed. Site selection is sufficiently flexible to account for safety and social criteria. After public consultation, site selection may be changed according to the preferences of local people. Concentrations of people, small villages, or intensive land use forms such as small industrial facilities, will always be avoided in site selection. Single farm houses will be avoided as much as possible; however, this may be difficult in the safety zones of pipelines in more populated areas. This procedure is outlined in Chapter 12 of the Environmental Assessment (EA) report in the project file.

4. In China, farmers are not legal owners of their land in the sense that they may sell it for market prices. However, their other rights are comparable. There are procedures for compensation and resettlement laid down in national and provincial legislation. In Sichuan, payment is based on the productivity in recent years of the occupied lands. The compensation for assets is negotiated by local or regional authorities. Relocation allowance is provided for farmers moving to other fields but not having to move to another residence and is based on previous income. If insufficient land is available to compensate the farmer, the local government is obliged to employ the former farmer. In the case of resettlement of farmers, SPA will have the legal obligation to construct new houses and find new jobs. After consultation with affected parties and negotiation with the provincial government, and approval of the compensation and resettlement agreement, all payments are made directly to the land owners. Compensation for land is generally made on a land-for-land basis. For temporary land use, compensation is based on previous production. It is estimated that no more than 10 families will be resettled for all project components. SPA has a procedure in place which it has been using for some years to compensate farmers for the permanent and temporary use of their land.
Environmental Assessment

5. Two TCC-financed international consultants helped develop the environmental assessment for the project in cooperation with the Research Institute of Natural Gas Technology and the Environment Department of SPA. The environmental assessment was reviewed and endorsed by the Asia Technical Department of the Bank. As part of the environmental assessment process, mitigating measures for expected impacts have been developed, as well as a component of institution building and training. The detailed environmental action plan is in the project file.

Hazardous Materials Management

6. Seismic exploration will involve the use of explosives, which could present an explosion hazard. The wells, flow-lines and gathering stations involve handling natural gas, which presents a flammability and explosion hazard as well. Some of the old gas fields, of which two would be rehabilitated under the proposed project produce substantial quantities of formation water, often containing hydrocarbons in the form of emulsion. In addition, a large quantity of the natural gas contains up to 6 percent hydrogen sulfide which is a toxic and explosive gas. Where this danger exists, gas flaring systems will be installed. The vented gas can be ignited and the hydrogen sulfide is burned to produce oxides of sulfur (SOx), which will disperse downwind.

7. In order to avoid accidents a hazard assessment has been performed for each of the elements of the gas system based on a conservative scenario using the largest sizes, highest pressures and maximum effect distances for all possible cases of releases under worst weather conditions, in accordance with the procedures given in the World Bank Technical Paper No.55, *Techniques for Assessing Industrial Hazards*. Safety of the rehabilitation and extension of the transmission line has been addressed by the PRIF-financed preinvestment study.

Safety: Design, Operation and Management

8. SPA has safety groups in several levels of the organization and in all operational units as well as rules and procedures for many of the safety objectives covering operations, explosions, and fire hazards, as well as maintenance. SPA uses Chinese and international codes and standards in the design of processes and equipment. SPA facilities are equipped with hazard detection and disaster management systems such as gas detectors and firefighting equipment at all drilling production and processing locations; hydrogen sulfide detectors at high hydrogen sulfide drilling sites, well sites, gathering stations, and the desulfurization plant. Safety zones for dwellings are maintained around potentially dangerous locations and a cautious selection is made for locations of installations, as well as routing for pipelines and the transportation of explosives.
SPA Environmental Management Organization

9. In 1975, SPA set up an Environmental Protection Department. The SPA subordinate organizations set up their own environmental protection sections and environmental monitoring stations. There are five subordinate organizations involved in the proposed project. All environmental departments operate under the final responsibility of the Environmental Protection Committee, which is organized under a vice president of SPA. Each subordinate organization operates in a specific topographic area or field of operations, usually with many operational sites. On each of these sites, personnel are appointed with responsibilities for environmental affairs.

Environmental Monitoring in SPA

10. In 1975, SPA set up a central monitoring and scientific research station operating under the responsibility of the central environmental protection department. Each subordinate organization also has an environmental monitoring station. Long-term and annual environmental monitoring plans are developed at the central and subordinate level. The monitoring includes regular sampling and documentation of accidental discharges of SPA operations and other relevant environmental quality parameters. The monitored environmental parameters correspond to the environmental regulatory framework. The central environmental monitoring station also carries out environmental impact assessments and measurements to establish baseline conditions. The on-site monitoring stations do the actual sampling at different SPA operation sites, usually with portable equipment. The central SPA monitoring station reports quarterly in writing to the Central Environmental Protection Department of SPA. SPA monitoring facilities consist of one central and 18 on-site monitoring stations which have at their disposal sampling and analysis equipment. The total number of environmental staff in SPA is about 469, with 292 in environmental monitoring. While the available equipment is adequate to monitor the environmental effects of the proposed project, most of the methods are backward and should be updated and automated; these provisions would be included under the project.

11. SPA has been monitoring pollutants in wastewater and waste gas throughout the process of natural gas production (drilling, production, stimulation measures, gas gathering, purification and transmission) since 1978. In addition, ambient air, surface water, soil, noise and ecological parameters near SPA’s natural gas production districts have been monitored as well. The Environmental Monitoring Plan drafted for the project is not significantly different from existing procedures.

Environmental Issues and Mitigation

12. Summaries of mitigation techniques planned for the major environmental issues identified during the EA process follow. More detailed explanations can be found in the EIS, Chapters 7, 8, 9 and the environmental monitoring plan, Chapter 11.

(a) Measures Against Gas Leakage. The first line of action against gas leakage is the quality control and testing of the system as constructed. Next
is the control of the quality of the natural gas entering the trunk line to the requirements of pipeline transmission in order to prevent corrosion of the interior of the lines and associated equipment. Exterior corrosion measures will also be included for the long distance transmission lines and associated systems. The system will be equipped with leak detection instruments and the producing wells, gathering stations, pressure boosting stations, and purification plants will be equipped with methane and hydrogen sulfide detectors and automatic alarm devices. Management guidelines will stipulate complete and detailed operation regulations and maintenance protocols, as well as routine inspections.

(b) **Solid Waste Management.** Solid waste will be generated from drilling, pigging, work-overs, gas production, and gas purification operations. Measures to manage solid waste will include paving of well sites with rock cuttings, use of a secure landfill for cuttings and waste mud, incineration of sludge from wastewater treatment, transfer of condensate and oil from skimmers to a refinery, and solidification of waste drilling muds.

(c) **Groundwater Protection.** Groundwater aquifers can be contaminated during drilling operations. Measures to prevent groundwater contamination include use of casings in wells to seal off aquifer areas, improvement of well completion and cementing processes, paving of well site with cement, selection of appropriate reinjection wells, and transportation of wastewater away from the site with pipelines.

(d) **Wastewater Management.** Wastewater from drilling operations will be treated and the environmental management of operations will be strengthened. Formation water will be reinjected in appropriate injection wells or treated to meet discharge standards for disposal in surface waters.

(e) **Gas Emissions from Pressure Boosting Stations.** Only purified (hydrogen sulfide reduced) natural gas will be used in the system. Air emissions will be via a stack outside the station. Waste gas from the purification plant will be treated for sulfur recovery and an incineration process will be used prior to discharge through a stack with a designed height of 100 meters in order to effect dispersion of the SOx. The wastewater from the gas purification plant will be partially recycled and partially treated by concentration and incineration. The wastewater purification plant will use a biological oxidation process. Management guidelines will be strengthened in order to assure that treated water meets specifications before discharge into the Changjiang (Yangtze River).
### Sichuan Natural Gas Development and Conservation Project Environmental Action Plan Summary

#### 1.0 Site-Specific Regulations of the People's Republic of China concerning new building, reconstruction and extension projects require that SPA execute forms for environmental assessments for new drilling, production, stimulation wells, and natural gas gathering networks. For new natural gas pressure boosting stations, long distance natural gas transmission pipelines, natural gas purification plants, and refinery and petrochemical factories, reports of environmental assessment must be completed before the engineering design phase. The central monitoring and scientific research station of SPA holds a qualification certificate for environmental impact assessment in China. The Environmental Protection Department of SPA carries out the preliminary investigation and then submits to the Sichuan Provincial Environmental Protection Bureau and the local environmental protection department where the construction project is located for approval. Once approval is obtained, design work can begin.

#### 2.0 Air Pollution Control

2.1 Blow-Outs

A system of gas well pressure controlling techniques is employed in order to avoid well blowouts. Well head control techniques including flaring of the open flow have been developed.

2.2 Gas System Leakage

The major production elements in which natural gas leakage is likely to occur are gas transmission and distribution systems, gas gathering stations, and production wells. The causes of leakage are mainly the lack of strict control of natural gas quality, which in turn leads to corrosion of pipelines and equipment, and finally, leakage. The following mitigation measures will be adopted:

- strict adherence to design requirements for quality and gas tightness of all gas handling equipment and piping;
- strict enforcement of engineering quality requirements for pressure tests and leakage tests in the various components of the system;
- control of the quality of natural gas entering the trunk line by regulating hydrogen sulfide content, carbon dioxide content, and free water;
- corrosion prevention of equipment and pipelines will be achieved through cathodic protection and coating of the external walls of long distance transmission lines; corrosion prevention techniques will be used for the internal walls as well, including applications of coatings and injection of corrosion inhibitors;
- corrosion prevention at natural gas producing wells will include injection of gas well corrosion inhibitors;
- corrosion prevention at gathering stations, pressure boosting stations, and purification plants will include coating applied to equipment for corrosion prevention and the injection of corrosion inhibitors into the equipment for internal protection;
- strengthening of management technique. The purification plant must guarantee the quality of the purified gas meeting the requirement of pipeline transmissions. A complete and detailed operation, regulations, and maintenance systems program will be developed for natural gas production, gathering, transmission, and purification. Routine inspections and checks will be included; and
- The equipment necessary for detecting leaks will be installed on the long distance transmission pipelines. The production wells, gathering stations, pressure boosting stations, and purification plants will be equipped with methane and hydrogen sulfide automatic detectors and alarm systems.
### 2.3 Purification Plant Gas Treatment
A modified Claus process for sulfur recovery will be installed. The tail gas from the sulfur recovery unit will be incinerated and discharged through a stack height of 100 m. Accidental discharges will be burned through a flare before being vented. The flare will be equipped with a sensitive, automatic ignition device in addition to the pilot flame. In order to strengthen management, equipment necessary for monitoring and controlling will be obtained.

### 2.4 Gathering Stations and Pressure Boosting Stations
Only purified natural gas will be used to fuel the gas turbines in order to reduce the amount of oxides of sulfur discharged. In case of accidental emergency discharges, the natural gas will be flared prior to discharge. In order to ensure ignition the venting flare will be equipped with sensitive automatic ignition device.

### 3.0 Protection Measures for Surface Water

#### 3.1 Drilling Wastewater
Drilling wastewater consists primarily of washwater from drilling equipment tools and the well site during the drilling operations. The major components are chemical oxygen demand (COD), suspended solids and petroleum compounds. SPA will treat drilling wastewater with oil skimming, sedimentation, oil water separator, flocculation precipitation, and solid/liquid separation. After treatment, the water will be sent to a water storage pond for reuse or discharge. Use of drilling mud systems containing heavy metals will be strictly forbidden. Sludge produced by the wastewater treatment system will be dumped in a lined pond and covered with earth. Since the drilling operations will be of short duration and high mobility, the drilling wastewater equipment will be designed to be skid-mounted.

#### 3.2 Formation Water
Reinjection of formation waters will be reinjected in selected geological formations through specially conceived disposal wells. In field areas where reinjection is not possible, formation water will be treated to meet discharge standards prior to discharge into surface water. Since the chloride content of formation water is high, SPA forbids the discharge of formation water onto farmland. Formation water will be transferred via pipeline to assigned sites for discharge to surface water. Reinjection wells will be chosen for permeability of the formation and isolation from aquifer systems. For formation water that is to be discharged to surface water, treatment will consist of chemical oxidation and precipitation in the case of high sulfide content. Formation waters with high chemical oxygen demand and high levels of other pollutants will require more advanced treatment technologies, which would be provided under the project.

#### 3.3 Wastewater from Natural Gas Purification Plant
Wastewater produced during maintenance functions will be separated from process wastewater. The different wastewater streams will be separated in order that separate appropriate treatment processes can be employed.

#### 3.4 Waste Liquid from Well Work-overs
Work-over fluids will be collected in lined pits and treated by neutralization and sedimentation. Residue and sludge will be disposed in a lined pit on site.
4.0 Soil and Groundwater Protection

4.1 Soil Protection

- Cluster drilling will be adopted in order to reduce the area of occupied land.
- Rock cuttings produced during drilling operations will be washed to remove greasy dirt. Mud caked by solid/liquid separation of the mud which cannot be reused, residue from drilling wastewater treatment, and solid waste from pigging operations will be disposed into a lined pits and covered with earth.
- Sludge from the purification plants will be concentrated, dehydrated, and incinerated.
- Condensate will be sent to a refinery for reprocessing.

4.2 Protection of Groundwater

- Casing will be used in the drilling operation to seal off aquifers.
- Well completion and well cementing processes will be improved to ensure isolation of the well bore and the water bearing strata.
- The ground surface at the well drilling sites and other construction sites will be paved with cement in order to prevent percolation of contaminants to the shallow aquifers.
- Reinjection wells will be selected with greatest depth and best sealing of water bearing layers. Transportation of wastewater from the wastewater drain to the receiving water body will be accomplished with pipelines.

5.0 Safety Measures

5.1 Seismic Explorations

- Explosives will be protected with plastic covers in order to prevent poisoning and other accidents.
- Explosives and detonators will be stored and transported separately.
- Operators must be certified before going on duty and will wear antistatic clothes.

5.2 Drilling and Workover Operations—Safety Measures for Blowout Prevention

- All drilling and work-over rigs will be equipped with adequate blow out preventer (BOP) equipment.
- The density of drilling muds will be carefully controlled. Well controlling facilities, including monitoring and treating equipment and manifolds for gas well pressure control, will be installed.
- The drilling operators will be well trained in individual responsibilities and will be familiar with well control operations, as well as well shut-off procedures.

5.2.2 Fire Prevention

- Strict fire prevention codes will be enforced, diesel exhaust pipes will be water cooled, and maintained clean, exhaust pipes will be set at a safe distance from the well head. Necessary firefighting equipment and materials will be on hand at the drill site.

5.2.3 Hydrogen Sulfide Poisoning Prevention

- Windsocks will be installed at the well sites.
- Automatic monitoring and alarm systems will be installed at the well sites in several directions.
- Drilling operators will be equipped with personal protective apparatus and portable hydrogen sulfide monitoring and alarm instruments.
5.2.4 Producing Wells
- Safety valves above and below the ground surface will be installed at the well head.
- Methane and hydrogen sulfide monitoring and alarm systems will be installed.
- All necessary firefighting equipment and materials will be on hand.

5.2.5 Well Work-overs
- Zoning of the high pressure and low pressure areas will be made before the well work over operations take place.
- Overpressure protection devices will be installed.
- Check valves will be installed to prevent backflow of acid liquid.
- Pressure tests of the high pressure manifold will be carried out prior to each operating cycle.
- A sealed acid injection system will be adopted.
- Operators will be equipped with gas masks and acid protective clothing.
- All necessary firefighting equipment and materials will be on hand at the site.

5.3 Pipelines
- The pipeline will be laid underground to a depth of 0.8 to 1.2 m.
- Protective casings will be installed where pipelines cross highways.

5.3.1 Safety Measures in Pipeline Laying
- Pipelines will be buried below the stable layer of riverbeds at river crossing.
- Routing of the pipeline will avoid zones of dense population and environmentally sensitive areas.

5.3.2 Safety Protection Measures
- Safety valves will be installed between the well head and the first-stage throttle valve.
- Safety valves and check valves will be mounted at the starting ends and the terminals of the connecting pipelines.
- The safety system of the main connecting pipeline will include:
  (a) a valve house sited at each 10 to 15 km interval along the main connecting pipeline; automatic cutoff valves, vent valves, venting flares, will be installed in these houses
  (b) in the case of a pipeline rupture, cutoff valves, both upstream and downstream of the section affected will close automatically; downstream vent valves will be actuated to vent the gas remaining in the fractured section of the pipeline as quickly as possible. All natural gas so vented is sent to the flare for incineration.

5.4 Gathering Stations
- Automatic safety valves and regulating valves will be installed. In the case of a pipeline rupture, the gas supply will be cut off. Gas escape lines will also be installed.
- Fire and explosion prevention measures will include explosion-proof electrical equipment, prohibition of smoking and open flame, methane monitoring and alarm systems, and the maintenance of necessary firefighting equipment and materials.
- Measures to prevent hydrogen sulfide poisoning will include: venting of discharged natural gas to an escape line to be burned prior to discharge and equipping personnel with personnel protection equipment including gas masks, and the installation of hydrogen sulfide monitoring and alarm systems.
5.5 Pressure Boosting Stations

Pressure boosting stations will have the following safety measures installed:

- Pressure release valves.
- Automatic safety valve, cutoff valve, and automatic interlock protection device.
- Air coolers on compressors.
- Natural gas vents in the case of overpressure for maintenance operations through a venting pipeline to a flare of a nearby gathering station to be burned and discharged.
- Fuel gas for gas turbines will be purified natural gas.
- Fire prevention and explosion:
  (a) Area within the wall around the pressure boosting station is a fire and explosion prevention zone.
  (b) Adoption of closed explosion-proof electrical equipment.
  (c) Structure of the compressor room and pressure boosting stations is built open and semi-open.
  (d) Multipoint hydrogen sulfide and methane monitoring and alarm systems.
  (e) The necessary firefighting equipment and materials will be maintained on-hand.
  (f) Operators will be certified through examination before taking up post. Personnel on post must wear working clothes appropriate for explosion hazard areas.

5.6 Purification Plant

- Proper plant siting and a reasonable arrangement of production equipment, zoning of high pressure, high temperature, fire prevention and explosion prevention areas.
- Controlling system and facilities to ensure the safe production will be adopted in the plant design:
  (a) The controlling system will consist of alarms, monitors, automatic controls, interlocking cutoffs, and power-off protection.
  (b) Facilities will include direct reading instruments and explosion-proof electrical equipment, isolation facilities for toxic gases, double source power supply, automatic switch for standby power supply.
- Production management procedures will include detailed technical documents for safe production including operating regulations, operating parameter manual and a safety manual.
- A safe production management system will be adopted including safe production responsibility system, fire prohibition system and firefighting system.

6.0 Noise Mitigation Measures

6.1 Pressure Boosting Station

Control of the noise source at the pressure boosting station will include equipment, design and noise prevention equipment. A sound isolation room for persons on duty will be provided. Pressure boosting stations will be built in districts with comparatively sparse populations, where sound insulation screens could be formed easily.

6.2 Drilling

Noise prevention measures at drill sites will include control of diesel engine noise, sound insulation covers, and a sound proof room for persons on duty.
7.0 Monitoring
Since 1978, SPA has established an environmental monitoring station network at different organizational levels. Monitoring of selected pollutants in wastewater and waste gas discharged through the whole production process of SPA includes drilling operations, production stimulation measures, gas gathering, purification and transmission. Ambient air, surface water, local soils, the noise environment, and ecological parameters have also been monitored by SPA.

7.1 SPA Safety Organization
7.1.2 Safety Measures
In order to mitigate the effects of accidental hazards, the safety department of SPA will carry out the inspections of the following safety measures: seismic exploration, drilling, natural gas well stations, natural gas gathering and transmission, natural gas purification, and natural gas transmission and distribution.

7.2 Environmental Monitoring
Details of existing environmental monitoring equipment are shown in the environmental assessment, page 11-8.

7.2.1 Equipment
Details of environmental monitoring frequencies are shown in the environmental assessment, chapter 11, pages 8 through 11.

7.2.3 Organization for Environmental Monitoring
SPA has established an environmental monitoring organization. SPA organizations at different levels have set up an atmospheric monitoring laboratory, water quality monitoring laboratory, physical monitoring laboratory, ecological monitoring laboratory, technical department and instrument laboratory. Currently, SPA has a group of 469 persons specialized in the environmental field, of which 177 are engaged in environmental protection management and 292 in environmental monitoring.

7.2.4 Reporting
The Environmental Protection Department of SPA submits environmental monitoring reports to the Sichuan Provincial Environmental Protection Bureau quarterly and environmental quality reports on pollutant discharge annually. The subsidiary environmental protection section of SPA submits reports on environmental monitoring work to local environmental protection bureaus quarterly and reports on ambient environmental quality and pollutant discharge annually.

7.2.5 Actions Taken
The Environmental Protection Department of SPA generates environmental protection plans, environmental monitoring plans, and environmental protection mitigation plans on the basis of the reports on environmental work, environmental quality, and pollutant discharge. The Sichuan provincial and local environmental protection bureaus stipulate requirements on environmental protection work for SPA and SPA's subordinate enterprises and also set rewards and penalties.

8.0 Institution Building and Training
The following program for institution building technical assistance and training will be put into effect during the project implementation.
### 8.1 Waste Treatment
Advanced techniques for treating wastewater, solid waste residues (from drilling and well work-over), from oil and gas fields including use of international consultants for techniques in solid/liquid separation of oil and gas wastewater, techniques for nonhazardous treatment of pollutants and solid waste residue disposal, as well as groundwater contamination prevention.

### 8.2.1 Reinjection Techniques
Technical assistance in improved techniques for reinjection of formation water, including international expertise on the techniques and selection of receiving layers for formation water reinjection, the design of reinjection wells, and the pretreatment of formation water before injection.

### 8.2.2 Reinjection Assessment
Improvement of techniques in environmental impact assessment of formation water reinjection, including technical assistance in the selection of calculation models for the effect on groundwater quality caused by the diffusion of pollutants after reinjection.

### 8.3 Groundwater Pollution
Improvement of techniques in environmental monitoring of groundwater pollution, including technical assistance in the selection of optimum sampling points, monitoring process, monitoring instruments and modeling of groundwater contamination caused by formation water reinjection.

### 8.4 High Sulfur Gas Fields
Improvements of techniques for environmental monitoring in exploitation of high sulfur natural gas fields, including technical assistance in creating a regional environmental monitoring network for high sulfur natural gas field exploitation (drilling, gas production, gathering, and transmission), items to be monitored, monitoring processes, selection of monitoring instruments, transmission and processing of monitoring data with computerized techniques.

### 8.5 Purification Plant
Technical assistance in techniques of environmental monitoring of gas purification (desulfurization) plant, including automatic monitoring of tail gas discharge from the purification plant, automatic monitoring of atmospheric pollution, and automatic monitoring system for wastewater discharges.

### 8.6.1 Training
Technical training for qualified personnel to meet the requirements of environmental protection management in a modernized natural gas production system, including training of technical personnel in environmental protection management, environmental pollution prevention, and pollution control engineering, environmental monitoring, environmental impact assessment, and on-site environmental protection management. Technical assistance in state-of-the-art techniques used in oil and gas fields would be required from abroad.

### 8.6.2 Monitoring Equipment
The available equipment in SPA should be augmented in order to undertake the environmental monitoring program. The equipment is currently outdated and insufficient. In order to operate the new equipment, technical assistance will be required in training of personnel.
9.0 **Organizational Arrangements**

9.1 **Mitigation Program**

In order to strengthen environmental protection management in natural gas production and mitigation of environmental impacts, SPA will issue a mitigation program annually on the basis of production schedule, reports on environmental protection work, and the result of environmental monitoring assessments of the previous year. Such programs will include major pollution source control programs, environmental monitoring program, environmental protection, audit program, and environmental management work program.

9.2 **Site Inspections**

Based on the mitigation program, the Environmental Protection Department of SPA will audit subordinate units of SPA at regular intervals (quarterly) each year to inspect progress in the mitigation program and adjust the mitigation program if necessary.

9.3 **Monitoring of the Mitigation Plan**

The Environmental Protection Department of SPA will summarize the accomplishment of the mitigation program and draw up a list for commendation of subordinate units according to progress in accomplishing the mitigation program. Rewards and commendation may be granted after reporting to and being approved by the Environmental Protection Committee of SPA.

10.0 **Resettlement**

In this project, generally, there will be no resettlement. In the case there is, SPA would negotiate with the people affected and make arrangements based on regulations of the government, including the construction of new houses and location of substitute employment. New houses will have the same size but better quality than the old houses.
10.2 Procedures

The project will occupy some land. SPA will confer and negotiate with land owners, based on the following procedures:

- Sites will be selected according to site selection principles and safety standards.
- SPA will solicit opinion of affected parties

Negotiations: SPA will negotiate and confer with local governments (including farmers) on land compensation and resettlement of affected parties.

Department in Charge: The project construction management department of SPA is in charge of resettlement and rehabilitation. The subsidiary production departments of SPA are responsible for the compensation of land acquisition.

Monitoring Agencies: Supervision and examination organizations for land use and land requisition are the local government, the land management departments of both the local government and Sichuan provincial government.

Consultation: The project construction management department of SPA often goes to the subsidiary production departments to examine the land use and acquisition process, and has a special department to collect opinions and views of affected parties.

Reporting: SPA will annually submit land acquisition and compensation summaries to the supervisory and examining departments mentioned above. The supervising and examining departments will conduct regular and unscheduled inspections of land use and acquisition every year. These departments will also collect opinion from affected parties and penalize those people who illegally occupy land as well as confiscating the illegally occupied lands.

Public Opinion: SPA has made investigation into public opinion regarding the environmental impact of the project sites. The local people have fully understood the project. The opinions of people in two counties of east Sichuan area (population 860,000 and 937,000 respectively) are included in the environmental assessment report, Annex 3, Chapter 12.
## INDICATIVE SUPERVISION PLAN

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<thead>
<tr>
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<th>Anticipated Skill Requirements</th>
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<td>1. Review overall project implementation progress, including procurement of goods and services, and consultant mobilization; project cost and financing plan; progress of technical assistance and training program.</td>
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<td>2. Review progress of Sichuan gas pricing and allocation reform action plan.</td>
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<td>3. Review progress of restructuring study/pilot implementation.</td>
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<td>4. Review SPA’s finances.</td>
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Sichuan Petroleum Administration (SPA)
Consolidated Income Statements
(in Million Yuan)

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<td>136</td>
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a/ Net of non-operating income.
### SPA Operating Profit Margin

**Yuan/mcm**

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### Sichuan Petroleum Administration (SPA) Consolidated Balance Sheets (in Million Yuan)

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<td>(2,518)</td>
<td>(2,729)</td>
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<td><strong>Net Fixed Assets</strong></td>
<td>1,918</td>
<td>2,449</td>
<td>2,708</td>
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<td>Construction in Progress</td>
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<td>1,703</td>
<td>2,242</td>
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<td>Unamortized Dryhole Costs</td>
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<td>958</td>
<td>886</td>
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<td><strong>Total Fixed Assets</strong></td>
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<td>5,110</td>
<td>5,836</td>
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<td><strong>Special Assets</strong></td>
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<td><strong>Total Assets</strong></td>
<td>5,535</td>
<td>6,572</td>
<td>7,414</td>
<td>8,383</td>
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<tr>
<td><strong>Liabilities &amp; Equity</strong></td>
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<tr>
<td><strong>Current Liabilities</strong></td>
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<tr>
<td>Working Capital loan</td>
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<td>147</td>
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<td>341</td>
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<td>Accounts payable</td>
<td>171</td>
<td>262</td>
<td>389</td>
<td>374</td>
<td>613</td>
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<td><strong>Total Current Liabilities</strong></td>
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<td>409</td>
<td>600</td>
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<td>954</td>
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<td><strong>Long Term Liabilities</strong></td>
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<td>Domestic loans</td>
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<td>Foreign loans</td>
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<td><strong>Total Long-Term Liabilities</strong></td>
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<td>697</td>
<td>793</td>
<td>1,032</td>
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<td><strong>Total Liabilities</strong></td>
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<td><strong>Equity</strong></td>
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<tr>
<td>Working Capital Fund</td>
<td>218</td>
<td>219</td>
<td>219</td>
<td>223</td>
<td>231</td>
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<td>Fixed Fund</td>
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<td>4,617</td>
<td>5,047</td>
<td>5,876</td>
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<td>Special Fund</td>
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<td>815</td>
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<td><strong>Total Equity</strong></td>
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<td>5,466</td>
<td>6,021</td>
<td>6,736</td>
<td>7,810</td>
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<tr>
<td><strong>Total Liabilities &amp; Equity</strong></td>
<td>5,535</td>
<td>6,572</td>
<td>7,414</td>
<td>8,383</td>
<td>9,948</td>
</tr>
</tbody>
</table>
MAJOR ASSUMPTIONS FOR SPA’S FINANCIAL PROJECTIONS

Income Statement

1. Total gas sales have been assumed to be net of SPA’s self use of 9 percent of gas production.

2. Tariffs are assumed to be adjusted so that the average revenues would be adequate for achieving the minimum financial performance targets (para. 6.15).

   (a) Under the break-even covenant, the minimum operating revenues of each of SPA’s major profit centers, including gas production, purification and transmission would have to cover (i) costs directly chargeable to operations including depreciation, exploration costs and amortization of deferred costs; (ii) operational interest; (iii) sales and income taxes; (iv) debt repayment in excess of the amount repayable from the provisions for depreciation; and (v) required increase in working capital.

   (b) Under the self-financing ratio covenant, earned surplus cash available for financing future investments has been defined as total earned cash less the aggregate of (i) cash operating expenses; (ii) operational interest; (iii) sales and income taxes; (iv) required increases in working capital; (v) and loan repayments. Separately, the average annual investment program has been defined as the average of the previous year’s actual capital expenditures, the current year’s planned capital expenditures, and the next year’s projected capital expenditures.

   (c) For purposes of calculating the project financial rate of return covenant, cash inflow has been defined as total earned cash less sales revenues derived from the incremental production under the project, while incremental cash outflow under the project has been defined as the aggregate of (i) total capital expenditures; (ii) cash operating expenses; and (iii) income tax (if any).

3. General local inflation rates are assumed at 15 percent in 1993, 12 percent in 1994, 9 percent per annum in 1995, 8 percent per annum in 1996, 7.2 percent per annum in 1997, 6.5 percent per annum in 1998/99, and 6 percent in the year 2000.
4. Raw materials, power and fuel costs are projected to increase at 25 percent per annum in 1993, 17.5 percent per annum in 1994, 10 percent per annum in 1995-96, and the same rates as those of general local inflation (6 percent per annum) thereafter.

5. Wages are projected to increase at 25 percent per annum in 1993, 17.5 percent per annum in 1994, and 10 percent per annum thereafter. The number of employees is expected to grow at 3 percent per annum in 1993-95, and remains constant at 1995 level thereafter to reflect the impact of institutional restructuring and streamlining.

6. General and administrative costs are projected to increase with general local inflation rates.

7. Maintenance costs include workover, down-hole services and water injection costs, and are assumed at ¥ 40 per cubic meter of gas produced and an oil field decline rate of 13.53 percent per annum. Maintenance cost of transmission assets is assumed, as a percentage of assets, at 5 percent in 1993 decreasing to 3 percent in 1999-2000. Maintenance cost of gas treatment and purification assets; as a percentage of assets; is assumed at 5 percent in 1993-96, and 3.5 percent in 1997-2000. Maintenance costs of assets used in the production of other products and services is assumed to increase at the general local inflation rate.

8. Exploration cost is based on the successful method whereby dry-holes are expensed during the year of incurrence. All geophysical expenditures and non-well expenditures are fully expensed during the year of incurrence. The success ratio of exploration is assumed to remain at 52 percent (viz. 52 percent of the exploration well drilling expenditures are assumed to be written off during the year of incurrence). Development well drilling, including dry hole costs (with success ratio assumed to be 80 percent), are capitalized and depreciated over the life of the gas reserves.

9. Sales tax is assumed to remain at 5.45 percent of well head gas revenues, 3.27 percent of gas transmission revenues, 5.45 percent for gas purification revenues and an average of 5.4 percent for revenues from other products and services.

10. Depreciation is conservatively assumed to remain at the present rates of 16.17 percent of gas production assets, 7.14 percent annum of gas transmission assets and 10 percent of gas purification assets. However, these depreciation rates for major categories of assets (wells, pipelines and gas purification plants) are considerably faster than the average economic life of these assets.

11. The amortization of pre-1988 dry-hole expenses (deferred cost) is assumed at ¥ 1.14 per thousand cubic meter of gas produced annually.

12. Nonoperating income and nonoperating expenses (include pension-related expenditures, vocational training and other welfare related expenditures) are projected to increase with general local inflation rates.
13. For income tax purposes, the portion of well-head gas price above Y 80/mcm is not considered as SPA’s revenues, but earmarked as Exploration and Development Fund. On the other hand, the actual exploration costs are not included in the deductible expenses. Instead, the deductible expenses include a provision for “resource utilization fee”. Under the present tax rules, which are assumed to remain in the financial forecast period, SPA would continue to report negative taxable income and income tax is thus projected to be zero.

Funds Flow Statement

14. Exploration and Development Special Funds and Loss compensation Special Fund reflect the special funding arrangements between CNPC and SPA, valid until 1995.

15. Remittances to Government represents the Energy and Transportation fund remittance assessed at 15 percent of non-operating income and adjustment fund remittance assessed at 10 percent of non-operating income.

Balance Sheet

16. Accounts receivable is projected at an average collection period of 40 days.

17. Advances to suppliers is projected at 10 percent of operating cost.

18. Inventories are projected at 40 percent of the sum of capital expenditures and operating costs.

19. Accounts payable is projected at 10 percent the sum of capital expenditure and operating costs.

20. Special assets represent funds earmarked for specific uses before the July 1993 change in accounting procedure. A portion (Y 13.5 million) is added to long-term investment and the remainder amortized over a three year period as current assets.


22. Unamortized bonus fund represents the current liability portion of pre-July 1993 item “special fund.” It is projected to be fully amortized in three years.
SELECTED DOCUMENTS AND DATA AVAILABLE IN PROJECT FILE

<table>
<thead>
<tr>
<th>Item No.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Gas Reserve Assessment Study (Sproule Associates Limited)</td>
</tr>
<tr>
<td>2.</td>
<td>SPA Gas Transmission and Distribution Rehabilitation Study (Novacorp International)</td>
</tr>
<tr>
<td>3.</td>
<td>Environmental Assessment Report (SPA and DHV)</td>
</tr>
<tr>
<td>4.</td>
<td>Sichuan Gas Allocation and Pricing Study (NERA)</td>
</tr>
<tr>
<td>5.</td>
<td>Working Papers: Field Geological Data, Field Well Drilling and Completion Programs, Detailed Project Cost Estimates and Procurement Arrangements</td>
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</tbody>
</table>
CHART 1

President

Chief Accountant
- Economic System Reform Office
- Supervision Department
- Auditing Department
- Multiple Operation Department
- Installation & Equipment Dept.
- Refinery & Petro Chemical Dept.
- General Administrative Office
- Enterprise Management Department
- Personnel Department

Chief Engineer
- Foreign Affairs Department
- Payroll Department
- Capital Construction Department
- Operational Marketing Dept.
- Scientific Development Dept.
- Development & Production Dept.
- Exploration Department
- Financial Department
- Planning Department

Chief Economist

Vice President

- Pipeline Department
- Geophysical Explor. Dept.
- Tarim Petroleum Admin.
- Jidong Petroleum E & P
- Yananchang Petroleum Admin.
- Zhejiang Petroleum Admin.
- Anhui Petroleum Admin.
- Dqinggou Petroleum Admin.
- Changqin Petroleum Admin.
- Qinghai Petroleum Admin.
- Yumen Petroleum Admin.
- Xinjiang Petroleum Admin.
- Sichuan Petroleum Admin.
- Henan Petroleum Admin.
- Jiangxi Petroleum Admin.
- Jianghan Petroleum Admin.
- Zhongyou Petroleum Admin.
- Shengli Petroleum Admin.
- Dqing Petroleum Admin.
- Huabei Petroleum Admin.
- Liashe Petroleum Admin.
- Jilin Petroleum Admin.
- Daqing Petroleum Admin.
SICHUAN PETROLEUM ADMINISTRATION
GAS TRANSMISSION AND DISTRIBUTION
COMPANY - ORGANIZATION

CHART 3

- EXPERTISE UPGRADE
- STANDARDS, CODES & MANUALS
- FIELD OPERATION TASK FORCE
- PLANNING RESEARCH & EVALUATION

- BILLING & COLLECTION
- COST ACCOUNTING
- BUDGETING & FUNDS MGT.

- TARIFFS & PRICING
- ECONOMIC ANALYSIS
- STRATEGIC PLANNING

- REPAIRES/OVERHAUL
- MEASURE & PRESSURE REGULATION
- CORROSION CONTROL
- CONSTRUCTION MGT.
- PLANNING & DESIGN

- DISTRICT OPERATIONS
- SAFETY & ENVIRON. PROTECTION
- LAND ADMINISTRATION
- TELECOM
- GAS CONTROL & DESPATCH

- PROCUREMENT
- ADMINISTRATIVE SERVICES
- STAFFING/TRAINING
- PERSONNEL RECORDS

- DEMAND MANAGEMENT
- CUSTOMER SERVICE
- CUSTOMER CONVERSION
- GAS UTILIZATION