1. The Energy-Development-Environment Context

China is faced with finding a balance between the needs of socio-economic development and environmental protection. As in other developing countries, the priority in China must be for development. Therefore, this creates an urgent need for a strategy to integrate development and environmental issues, and to define policies for implementation that will be effective at municipal, provincial and national levels.

Economic Growth. Economic growth in China averaged 7.9% through 1988/92 and over 10% 1993. Energy consumption has also grown, but at a considerably lower rate due to a shift towards less energy-intensive industries and to more energy-efficient technologies. Population growth and improving standards of living will foster a steady growth in energy services for the foreseeable future.

Rural Development. Socio-economic growth in the rural areas raises important problems which must be addressed as a priority, because two-thirds of the population live there. Economic loss and environmental damage is being caused by the unsustainable use of biomass. Rural development needs to be supported by provision of clean, low cost energy.

Urban Growth. The rapid growth of cities calls for the creation of infrastructure in which energy and transport services can be supplied efficiently. One key concern is air pollution, which is a problem in most large cities, now caused chiefly by coal-burning for cooking and heating, and liable in the near future to be added to by vehicle emissions. Coordinated planning is clearly vital to ensure that every opportunity is taken to increase the use of clean energy sources such as electricity and gaseous fuels.

Environment. The extraction, conversion and use of energy leads to local, regional and global problems, such as urban air pollution, acid rain and climate change.

Energy consumption is projected to grow dramatically in China, from 1 billion to 1.5 billion coal equivalent (Btce) in 1990, to 1.5 Btce in 2000, 2.4 Btce in 2020 and 3.7 Btce in 2050. If this more than tripling were to be based in fossil fuels alone, and especially on coal, already serious environmental problems would deteriorate further, even with the development of more efficient and cleaner technologies. Modern non-fossil fuel energy sources could also play a bigger part, and, in so doing, help lessen the constraint on development now caused by the huge capital needs of conventional energy systems.

The Working Group (WG) attempts, therefore, a scientifically based approach to the provision of energy services, using modern technologies which are suitable to China’s conditions. The WG recognizes the demanding geographic, financial and demographic realities, but also sees a great opportunity for a rapid advance by China, which can avoid some of the environmental pitfalls experienced in many industrialized nations.

2. The Approach

The key energy issues addressed by the WG are strategic, in that they are aimed at integrated energy systems compatible with sustainable development over the long term. Such systems will integrate cost-effective improvements in efficiency (on the supply and the demand side), with both renewable and cleaner conventional sources of energy.
The integrated approach embraces also the institutional capacity and human resource aspects needed to realize sustainable development. The primary emphasis is on cost-effective development, in terms which include conventional, social and environmental costs.

First, the steps that can be taken immediately to improve the current situation are identified. Secondly, measures are shown which will expand the option portfolio in the near and longer term, and which will have a more regional impact. In the case of the latter, actions are identified which are required now to make this possible.

Good environmental policies and practice will aid development, while the reverse will hinder it by allowing constraints to develop. It is common experience that environmentally positive technology benefits the economies of both enterprise and society. Therefore, a key goal is to find the right technologies and other measures which will provide a win-win situation for China, at all levels, from local to global. Success in this will highlight China's commitment to the aims of Agenda 21.

In pursuing the above, the focus on the performance of new investments in terms of energy and the environment must remain central in such a fast-growing economy. At growth rates of 10% per year, the capital stock approximately doubles in a 7-year period. This illustrates the overwhelming, influence of the performance of new investments on how the Chinese economy performs in the future.

Energy needs in China are different from those of the industrialized countries. In China the satisfaction of basic human needs and infrastructure building still takes priority, while in industrialized countries this phase is generally over. Where opportunities for innovation exist, particularly in the energy-intensive basic-materials industries, China should take the lead, since industrialized countries will be slow in bringing forward innovations, because demand is no longer growing there.

In summary, the WG approach has four elements: (i) technological leapfrogging supported by human capacity building; (ii) efficient use of energy; (iii) cleaner sources of energy; (iv) "least cost" energy demand/supply options.

2.1 Technological and Institutional Leapfrogging

Technological and institutional innovation is needed to sustain economic growth in the long term. In some cases, China may need to follow the same path as industrialized countries, but where technical capacity, financial and security factors allow, China can move more quickly to the latest, most advantageous technologies and institutional arrangements, by "leapfrogging". At the same time, adaptation to China's specific conditions will be called for, because most of the latest technologies, for example, will have been developed for industrialized countries.

In industrialized countries, where labour is expensive and capital relatively cheap, new technology is labour-saving and capital intensive. In China, the reverse is true, which will affect the way new technology is realized.

The crucial importance of technological leapfrogging is not well understood in the energy sector. This is especially true in developing countries, where energy planners find it difficult to accept the risk of innovation in exchange for what appear to be only medium-term payoffs, and particularly the many who have had a disappointing experience in new technology-transfer. The sheer size of some conventional energy projects also argues for caution, and this attitude is reinforced by the major lending-agencies who insist on a proven track record in industrialized countries before financing.

Fortunately, not all technological leapfrogging involves high-risk innovation, but it may involve the application of technology that has not hitherto been used in China. The risk attached to a specific leapfrog project need to be set against the potential reward to the industry and to the society as a whole. This approach will help in quantifying the justifiable scale of resource to be invested.

Also important is the definition of conducive corporate structures, for example public/private sector joint ventures, to stimulate activity. The key challenge will continue to be that of obtaining sufficient financial backing, under acceptable terms. The role and needs of lenders, be they international, national, multilateral, or bilateral, must be integrated into the total innovation package in any successful solution.

Technological innovation will only be effective in parallel with an upgrading of institutional management and entrepreneurship. These in turn can only come about when the human capacity is up to the necessary standard. When the means for simultaneous human capacity building are indeed found, there will be immediate value to the economy in the better use that can be made of capital, human, and natural resources.

China has embarked upon the introduction of market principles in the economy. Unlike the situation in industrialized countries, where supply is efficient and consumption wasteful, in China the chief scope for improvement is on the supply side. Although the market outlook is
already showing a shift towards efficiency, much remains to be done. The task is now to find ways to maintain the momentum toward supply-side efficiency, but without introducing demand-side waste.

2.2 Efficient Use of Energy

Efficiency can be improved at each step in the energy chain from extraction and collection, through conversion, transmission/distribution to end use. Many relevant and cost-effective means to do this exist today, and there are more improvements on the way. Overall, the greatest scope seems to lie at the point of end use, as discussed in Section 3.

2.3 Cleaner sources of Energy

Coal dominates the energy supply today, and is also the biggest single contributor to China's environmental problems. To use coal more cleanly and more efficiently is a clear priority. Increasingly in the future, cleaner alternatives to coal, such as natural gas, renewable energy and nuclear energy, when used in an environmentally sound manner, could help reduce energy-related environmental problems, as further discussed in Section 4.

2.4 Analytic Methods

Where resources are limited, priorities must be set. Integrated Resource Planning (IRP) is a powerful analytic method that has proven its ability to provide cogent answers to this problem.

The aim of an energy system is to deliver the energy services for end uses such as illumination, a comfortable indoor climate, cold storage, transport and cooking, to take a few examples. This takes a complete "energy chain", which extracts/collects the primary energy, and converts it to carriers suitable for end-use(s), that in turn are used in end-use equipment to provide the energy service(s).

The scientific IRP analysis is based on the chain as a whole, and therefore the potential for efficiency improvement of all realistic supply and demand side alternatives must be included in the analysis. Demand and supply alternatives can then be ranked according to cost (including social and environmental cost), in order to find the true least-cost options. A prerequisite is a rational energy pricing system.

The WG has organized two IRP workshops with the cooperation of the Energy Research of the State Planning Commission, the International Energy Initiative and Tsinghua University.

3. Energy Demand

Long term energy demand is determined by the growth and structure of the economy and by energy efficiency (specific energy use). However, the overall development of the economy is not a task for this WG. This discussion therefore addressed the specific energy use of the major activities which contribute to total energy demand.

Long term energy demand will be influenced by specific energy use and by structural changes in economy. Experience in industrialized countries is that increasing affluence shifts consumption patterns towards more knowledge intensive products and away from energy and materials-intensive products.

A few decades hence, energy demand in China will be dominated by new equipment yet to be put in place. There will be a myriad of new applications in industry, in commercial and residential buildings, and in transportation systems and vehicles. It is vital, therefore, in discussing energy efficiency, to focus on the energy performance of new investments.

3.1 Potential Impact

Considerable progress in rationalizing the use of energy in China has been made in the past 15 years. Consumption has grown at only half the rate of GNP growth. This is a remarkable achievement for an industrializing country whose prime need is for an energy intensive infrastructure and a durable goods manufacturing sector.

Much still remains to be done, and large margins for improvement still exist in all sectors. The energy consumption for major products in China is still some 40% higher than the corresponding figure in industrialized countries. Similar differences exist in electricity generation, and in the household and transportation sectors.
Up front it is important to assess the relative merits of retrofit versus new investment. It is noteworthy that the technical and economic potential for energy saving is typically 20-50% in the case of efficiency improvements in existing installations and 50-90% in the case of new installations (as compared with the present stock average specific energy use in industrialized countries). Form the point of view of basic thermodynamics, the limits to efficiency improvements are far away.

The use of new technology is always associated with a cost for new equipment. This cost has to be added to the cost of the energy used and the total compared to that of the alternatives that could also provide the desired energy service. It is worth noting that the cost of achieving a saving in energy use is often lower than the cost of supplying a similar amount of energy. In all cases, least cost solutions should be sought.

3.2 Creating an Environment Conducive to Energy Efficient Development

A prerequisite for markets to deliver the most efficient use of resources is access to information, education and training. This involves a cost (technically known as "transaction cost"). Transaction costs will only be kept at a reasonable level if implementation is properly designed. Experience has shown that transaction costs associated with retrofits are higher for new installations.

It is vitally important that the communication effort is directed at the points of greatest leverage, in particular at manufacturers of widely used products and equipment, and to decision-makers at national or provincial level. Massive campaigns to educate all potential users are impractical and would result in high transaction costs.

Some concrete suggestions for projects demonstrating energy efficient technologies are made in Sections 3.4 and 4.11, for demand and supply-side installations.

Energy prices are the key to creating a climate conducive to energy efficiency. In order that the full costs within the energy chain can be covered, and at the same time be controlled by competition, the market should be allowed to set prices. These will in consequence become rational. This innovation will create a climate of thrift in energy use, and promote incentives for efficient production. External costs of energy production and use, such as those implicit in environmental destruction, should be reflected in final prices by specific taxes and/or through regulations. Where energy prices rise because of deregulation, to the extent of causing problems to consumers, non-price related measures can be taken to mitigate such effects.

Direct subsidies in conventional technologies obstruct the dissemination of new technologies and are economically inefficient. If used to make possible high priority pilot and demonstration projects, and to help create the capacity to market the technologies involved, subsidies can have a useful, temporary role.

Market-based energy prices will not on their own bring about least-cost supply of energy services. Removal of non-price barriers to the diffusion of energy efficient technologies is usually necessary, by the use of macro-economic measures, legislation, fiscal means, education and promotional campaigns. Some of these barriers can be grouped under the heading "market imperfections", for example the limited access by many consumers to accurate and relevant information, landlord/tenant problems, access to capital on terms comparable to those for energy supply investments.

Energy efficiency will only come about permanently when there is a clear accountability of those responsible to the owners. Thus ownership structure reform is an integral part of the process of achieving energy efficiency.

Demand side management (DSM) should be reinforced in overall energy planning. Experience shows that the institutional and regulatory setting determines the rationale for engaging in least cost energy services. Central and provincial governments need continually to attend to these issues.

Financial means can increase energy efficient investment. For example, the current bias against providing capital to demand side projects, at the favorable rates that are frequently available to supply side projects, is holding back responsible innovation in the former. This is not logical considering that the value of the net saving in energy consumed often exceeds the additional cost of the concessional finance.

Regulatory processes are effective in getting inefficient products and practices off the market. Mandatory standards of energy efficiency can be set for all kinds of devices, appliances, vehicles, buildings, and supply side technologies. The procedure is complex, since it depends upon defined specifications, tests, labeling, certification, verification and control. The emphasis must, however, remain on the performance rather
than on the desire to establish a particular technology.

The complementary issue is to get the energy efficient technologies into the market. Government and private sector procurement, in cooperation, has proven a very effective route to achieve this. The procurement conditions will set the performance goals and the incentive for participation.

Fiscal measures present another effective tool for implementing energy conservation and other policies to protect the environment. Differential fiscal loading can steer the market toward demand side products with lesser environmental impact. For example, highly efficient equipment of buildings can attract lower taxes, and the highly inefficient examples much higher taxes, a "carrot and stick" policy that can result in winners all around.

Energy consumption should be metered and results compared with national best practices. International benchmarking will become possible, enabling better macroeconomic planning. Measurement makes possible target-setting for continuous improvement, aids promotion and the cultivation of a social climate where energy efficiency is the norm.

Environmental auditing will strongly reinforce the drive for efficiency. Performance in achieving environmental goals can be judged both against national standards and against the short term goals that an enterprise sets itself. Environmental audits will complement financial audits, and should be made regularly, e.g. annually by the internal audit departments of the enterprises, and bi- or tri-annually by external auditors. Professional auditors would need to be developed and would be drawn from central firms or Institutes, and from the National Environmental Protection Agency.

Enterprises in which energy consumption exceeds a certain threshold should, by law, appoint a professional energy manager. His duty is to ensure that all decision-makers are fully aware of the energy efficiency implications of their decisions, and also that they are informed in a timely fashion of the full array of options that exist to improve the energy efficient performance of the enterprise before key decisions are taken. Typically, he acts as a channel for the diffusion of energy efficiency knowledge throughout the organization, and would normally play a major role, personally, as the key educator and trainer on this subject to staff.

Energy management companies should be encouraged. Typically, they will offer specialist advice to consumers, especially the larger ones, and the remuneration for their service is set at an agreed proportion of the energy saving that they achieve for the client company. To be paid, they must deliver. Such companies may be subsidiaries of an energy supplying company. If so, they have an opportunity of developing good long term relationship with their key clients. This relationship can flourish particularly well in a regulatory setting that is focussed upon encouraging the provision of least cost energy services.

3.3 Energy Use in the Transportation Sector

Energy use in transportation took only 4.6% of the total 1990 energy consumption in China, a much smaller proportion than in developed countries. This proportion will increase in coming decades.

The railway, highway, water, and air transportation systems are overloaded. To improve their performance, it is crucial that congestion bottlenecks are identified and removed, tariffs are normalized, and air pollution and energy waste are reduced. Along with the development of the economy, the urban transport systems are at a crossroad. It must be decided whether the pattern prevailing in western countries should be followed, or whether an entirely new pattern should be created.

Pertinent to this question is the fact that China is the only large country that does not yet have a large petroleum-based transport system in place. Countries that have one face severe internal-combustion (IC) derived urban air pollution, and in many cases are burdened with a heavy oil import dependency. To what extent conventional private car use should be encouraged now needs to be carefully examined in the current generation of transport policy.

China is fortunate in that it has an important opportunity to leapfrog to transport technologies of the future. These are inherently much cleaner than IC engine technologies, and which match well with China's natural resource base. The fuel cell will eventually make it possible to use coal in a clean way for transport, at costs that are competitive with imported oil. This is possible because the higher cost of the coal-derived fuel will be more than compensated for by the much higher efficiency of the fuel cell vehicle compared to that of the IC powered vehicle. Thus, China's fast growing demand for transport services provides a thea ter conducive to innovation in the transport sector.
The WG intends to carry out a study of transportation issues in the next phase.

3.4 Demand Side Demonstration Project

The WG proposes demonstrations of technology leapfrogging in the following selected areas:

1) Iron and steel-making technology.

2) Commercial buildings.

3) Fuel cell buses.

The experience of competitions is encouraging in Sweden, and in the USAA, in bringing more energy efficient products to the market. Joint ventures should be encouraged participants in the competitions. Assistance in funding these projects may be sought from the Global Environment Facility (GEF), and multi- and bilateral sources. Winners would build the facility in China in cooperation with Chinese partners, under Government guaranteed and legally protected intellectual ownership.

Iron and steel technology demonstration: The WG recognizes the great importance of improving energy efficiency in the expanding energy-intensive basic-materials industry. The energy-intensive steel industry was chosen as the first sector for attention. Several international steel-making firms have new, clean and energy efficient technologies, which so far, have only operated at pilot or demonstration scale. Steel demand in industrialized countries is not growing as in the past, due to changes in consumption patterns, and to the development of higher performance steels of which less is needed for a given purpose. They are therefore no good theaters for innovation.

The WG propose that such technologies be introduced into China, as part of the needed 50 Mt/year expansion of steel-making capacity over the next decades. An international tender should be organized by a consortium of Chinese authorities and the steel industry, to select the technologies to be demonstrated. Minimum environmental performance specifications for acceptable technology will be included in the invitation to bid, and these will include, inter alia, maximum energy use and maximum permissible emissions per tonne of steel produced.

Commercial Buildings Demonstration: Commercial buildings are constructed at a rapid rate in China, contributing to total electricity use and to peak utility demand. Energy-efficient technologies exist and are being introduced in many countries. Special areas where attention is needed include cooling/heating, lighting, ventilation, appliances and equipment, and the integration of these into the total energy system of a building. Competitive procurement as discussed above should be considered as one approach also here.

Fuel Cell Buses Demonstration: Transportation is a sector facing rapid expansion, and given its early stage of development an excellent candidate for a technological leapfrog. Recent technology breakthroughs in fuel cell technology has opened the door to new and attractive options in transportation. Fuel cell technology will become widely available to all modes of ground transportation, including trucks and trains.

Urban bus transportation particularly suitable for demonstration project, because refuelling is easy, the of demonstration is low, and the visibility is high. An individual fuel cell bus fleet in Beijing and elsewhere can gradually be replaced and expanded by fuel cell buses.

The fuel cell option offers near zero vehicle emissions (even with coal-derived fuels) and therefore has no need of pollution control technology. It offers independence from oil, and can be economically viable using fuels derived from coal, biomass and natural gas. A preliminary feasibility study has been conducted by the WG. A demonstration project of a fleet of fuel cell buses can be pursued if the funding can be arranged. The capital required for a test fleet of 400 units is about 35 million dollars for the demonstration elements.

3.5 Summary of WG Recommendations on Energy Demand:

1) Energy prices should be market based.

2) External costs of energy production and use should be recovered through taxes and/or controlled by regulatory measures.

3) Performance standards should be developed and applied for energy end-use efficiency.

4) Energy efficiency auditing be institutionalized as part of a broader environmental auditing in the energy sector.
5) Integrated Resource Planning (IRP), and a reshaping of the regulatory structure, to provide incentives for IRP and demand side managements (DSM), are both recommended.

6) Information, education, and training in efficient use of energy should be strengthened.

7) Energy managers should be required by law in all industries and entities using large amounts of energy.

8) Procurement competitions should be organized, with the cooperative participation of the government and the private sector, to bring new, energy-efficient technology into the market, specifically in the iron and steel industry, in the design and construction of commercial and residential buildings, and in the transportation industry.

4. Energy Supply

On 2nd March, 1994, the State Planning Commission, the State Science and Technology Commission, and the State Environmental Technology Commission published a list of priority areas and technologies for government support. In the energy and environmental area, nuclear power, oil extraction and coal industries were identified. The WG suggests that, in addition, natural gas (including liquefied natural gas—LNG, for Combined Cycle power generation, in suitable coastal areas), hydropower, cogeneration (in oil refineries, sugar cane industries and district heating), wind energy (small to medium sized wind farms), and long distance HVDC transmission technology should also be given comparable priority.

China's vast coal resources are mainly located in the north, and economic growth is largely elsewhere, in coastal areas and the south. Transportation bottlenecks are serious, underlining the attraction of finding new ways to transport coal. Use of coal-water mixtures (CWM), moved by pipeline and coastal tanker, is an innovative example. Another way to reduce coal transport is HVDC electricity transmission from mine-mouth power plants. Carrying less non-combustibles, by deferring the use of high ash coals, will also reduce the transport burden.

The support mix is likely to change in response to the problems caused by increased coal utilization. Oil reserves are comparatively small, and China is now adjusting to life as a net oil importer. Natural gas reserves are presently limited, but with prospects for large increases, especially of natural gas is allowed to compete on a market basis with coal.

Renewable sources of energy already provide a significant fraction of total energy supply, and there are prospects for increased contributions. To realize this potential, biomass use must be modernized, and new technologies for using wind and solar energy need to be mobilized. The use of hydropower should also be expanded. In every case, activities should be integrated, in harmony with environmental and socio-economic conditions. Again, every activity should be founded in the consistent logic of least-cost solutions.

Acidification of the atmosphere, rivers and lakes is now a reality requiring immediate countermeasures, as an increasing toll is being taken in terms of quantifiable loss to GNP. Southern China is more affected, because of sensitive soils, and by the use there of the more sulfur-bearing coals, the cleaner northern coals being largely out of reach for transport reasons. The technologies needed to combat acid rain are well proven, and are readily available.

4.1 Cleaner and More Efficient use of Coal

Coal now contributes 76% of commercial energy, 30% is used for power generation, which is a very low share in comparison with coal's share in other major coal-using countries. China, is and will remain in the long term, a coal-dominated economy.

The overall efficiency of coal use stems from the existence of a large legacy of what are, by modern standards, highly inefficient industrial boilers. The coal-fired electricity supply industry, also, has great scope for an efficiency upgrade, to bring it to the international standard of 320 grams coal/KW produced.

Measures to achieve the above include selective retrofitting of simple, proven equipment to a larger number of substandard plants (e.g. there are over 400,000 coal-fired boilers in this category) that cannot, for the time being, be phased out because of the intense demand, in the current economic climate, for the electrical and heat energy they produce. In larger plants, new low NOx burners, convective pulverized coal burning and desulfurization technology can bring immediate benefits of better fuel economy and cleaner air quality.

Attention should be focussed on the 10-20,000 new boilers that are taken into operation each year. Boiler manufacturers should combine
forces to set higher efficiency standards for new equipment.

In the longer term, oxygen-blown coal gasification offers important opportunities: (i) integrated coal gasification/combined cycle (IGCC) power generation; (ii) technology to make methanol and/or hydrogen from coal for transport applications; (iii) the provision of synthesis gas for direct gasoline and/or diesel manufacture, and a wide variety of industrial chemicals.

Direct coal liquefaction seems to have limited economic potential and there are environmental impacts yet to be resolved. Further development of magnetohydrodynamics (MHD), seems to have been preempted by recent advances in gas turbine/combined cycle technologies, that now offer better performance at lower cost than appear attainable by MHD. Fluidized bed combustion technologies, now entering the market in some industrialized countries do not show the long term strategic advantages of oxygen-blown gasification, and is potentially problematic as regards ozone depletion and global warming, because of N2O emissions.

4.2 Oil

Oil now caters for 19% of commercial energy. Production growth is curtailed by geological realities. The most rewarding areas for exploring are likely to be the proven, oil producing basins. In these areas, ever improving exploration technologies will reward re-exploration more or less indefinitely, albeit with individual discoveries of decreasing size. The expanding production infrastructure will permit the commercialization of large numbers of small fields that are usually present.

Less explored basins exist, such as the intriguing Tarim Basin, in which there are prospects for large discoveries. However, the hostile nature of this terrain and its huge distance from the market make this at best a medium term benefit, and one requiring major inputs of capital and other resources.

A strategic question presents itself with regard to the Tarim Basin. Given that petroleum reserves of China will always be low, on a per capita basis, self-sufficiency cannot be a realistic national goal, even with Tarim production.

Tarim production will always be costly, both in capital and operating terms, and there could be merit in regarding such high cost national assets as a potential national reserve, to be prudently kept to offset external dependence on oil imports in any future oil emergency. While enormous stocks of competitively-priced international oil are readily available, these should be the chief source of filling the gap between low-cost domestic oil production and demand. China should not hesitate to import oil and other energy carriers, to the extent that these offer least-cost solutions.

4.3 Natural Gas

Natural gas (NG, otherwise known as methane) now furnishes 2% of commercial energy. It has not played a role anywhere near its geological potential so far in China. On any international comparison, there is scope for a large increase in the share it can command. Increased exploration should therefore be a priority, but because there is much still to find, and the fuel is particularly attractive in its low environmental impact.

Natural gas prices are very low, in comparison with world market prices. Price relaxation would allow a gas market to develop with competitive pricing, and this will stimulate exploration for new reserves. Even with much higher natural gas prices, the fuel will still compete successfully with coal in power generation, when coal plants are designed to meet tough environmental regulations.

Natural gas is an excellent fuel for power generation. There are distinctive advantages inherent in gas turbines and combined cycle technology, which is a clean highly efficient process at low unit capita cost. In the longer term, gas turbines will be commonly used in coal IGCC plants, and in biomass integrated gasification/gas turbine facilities. China can establish a know-how and infrastructure base needed for such later applications by first introducing gas turbines and combined cycles with natural gas. Well-heated power plants can help in revenue-generation to assist in developing a natural gas infrastructure (transporting electricity is cheaper relative to the cost of gas transport by pipeline).

In addition to natural gas, liquid petroleum gas (LPG, sometimes known as refinery gas), is clean and flexible fuel for domestic use in small homes, and on larger scale for large apartment complexes, and light industry. Expansion of its use can be immediate, there being abundant supplies from neighboring countries (e.g. the Philippines), and some domestic sources.
Hand in hand with the development of natural gas resources, imported liquefied natural gas (LNG) provides clean fuel for power generation and the possibility of piped gas fuel for thermal use both for residential and industrial use in coastal provinces and cities. There is a lead time required, given the need for upstream investments and construction of LNG storage facilities.

Natural gas imports, chiefly overland, from the vast gasfields of Siberia are of great long term interest to China, and would harmonize with joint goals of economic development protection.

4.4 Hydropower

Hydropower contributes 5% of commercial energy, and 17% of electricity. The total hydropower generation is 130 TWh per year. The resources are about 2,000 TWh per year, most of which is located in the South-West of China. Development of small-scale hydropower should be encouraged together with carefully integrated large-scale hydropower installations. Because of the geographical location, long range HVDC transmission lines have to be built. This is established technology, which may also be used in bringing energy from distant coal reserves to demand centers.

4.5 Biomass for energy

Biomass sources include rural and urban waste, agricultural and forestry waste, and biomass plantations dedicated for energy. Biomass plays an important role, especially in the rural areas. The efficiency of its use is typically low, although improved cooking stoves have improved the situation significantly. Further improvements using modern biomass conversion technologies producing electricity in the near term and liquid and gaseous fuels in the longer term would enhance the role of biomass. Here, we will only discuss two areas that the WG considers to be particularly important, namely biogas and the use of sugar cane by-products for cogeneration of heat and electricity.

4.5.1 Biogas

Biogas is a valuable fuel that can be generated at little cost in different sectors of the community. Particularly important opportunities exist for:

- the rural / farm sector;
- the treatment of industrial wastes (such as distillery wastes);
- the treatment of municipal wastes;
- landfills.

It is estimated that the national biogas resource could provide a significant contribution to China's energy needs, without the disadvantage of long range transport since the biogas potential is already dispersed throughout the community.

It is noteworthy that biogas in the rural areas provides not only fuel but also good sewage treatment (by the biodestruction of pathogens by anaerobic-cum-aerobic fermentation), ecologically sound agriculture (derived from fertilizer output of biogas plants), and generation of electricity (based on biogas-driven generator sets).

In order to revitalize investment and penetration in the rural sector, attention should now be given to: location-specific solutions (paying heed to the variations in the north and south of China); technological advances in the design and materials of biogas plants; local participation; the software (policies, management, economics, financing, and training); widening the feedstock to all agricultural residues; the pricing of alternative fuels and of alternative products (such as fertilizer); and information campaigns at the community level.

It is also important that the cocal-craft approach to the dissemination of biogas technology should now give way to a more industrial approach in which both larger scale schemes are planned and implemented and quality is enhanced.

In future, biogas must not be seen as separate from biomass-based energy. For instance, the same engines-cum-generator sets that can be run on biogas can also be run with gas obtained by gasifying woody biomass.

4.5.2 Exploiting the Sugar Cane Cogeneration Potential
Modern technology could open up the large potential for biomass fired electricity generation. This can supply low cost electricity for supporting rural industrialization and income generation in areas where coal is not easily available. The key process will be biomass integrated gasification coupled with gas turbine power generation (BIG / GT).

The logical place to start a biomass power development strategy is with cogeneration in the sugar cane industry. The resource is available in the form of biomass residues that are either not presently used, or used very inefficiently. Chinese manufacturers can supply high-pressure steam turbine technology for cogeneration in the initial phase. In the next phase, integrated biomass gasification, with gas turbine power generation, should be developed. This technology is being tested in a demonstration project in Brazil, supported by the Global Environment Facility (GEF).

A preliminary assessment shows that the potential for cane power is large and that at the local conditions for overcoming barriers and exploiting the potential are not obviously detrimental. The WG recommends that (i) an assessment be carried out, on a county by county basis, to determine the cogeneration potential exportable to the utility grid with currently available technology for both improved steam utilization and power generation, (ii) an assessment be made of the alternative options for producing power in the off-season, (tops and leaves of the sugar cane plant, plantation biomass, other), including an assessment of land availability for growing additional biomass, if needed, (iii) a detailed economic analysis be carried out of the costs of cogeneration during the milling season and during the off-season, as well as the value of this electricity to the utility, and (iv) an assessment should be made of the institutional barriers to cane power generation and of alternative options for overcoming them. Especially the rules regulating small-scale generators’ sale of electricity to the grid are important.

These assessments should be carried out by teams organized like our Working Group, with both Chinese and international members who are experts in the relevant sugar cane / power generating technologies, and in the financial and institutional issues that must be dealt with. The international members of these teams should include representation from those developing countries with the most experience in this area.

The technologies for sugar cane cogeneration and BIG / GT should now be demonstrated.

4.6 Wind electricity

China has vast wind resources, both close to the demand centers in the south-east, and in distant areas. Modern wind technology (500 kW units) supplies wind electricity at costs comparable to conventional power sources. Steps should be taken to demonstrate and introduce modern wind energy technology.

In the longer term, the large-scale exploitation of distant wind resources is becoming of interest, coupling wind energy to hydropower or using compressed air energy storage to baseload HVDC transmission.

Detailed wind maps should be developed to facilitate an evaluation for exploiting near and remote wind energy cost-effectively.

4.7 Photovoltaics

Photovoltaic (PV) power is presently much too expensive for grid-connected applications. Actions are needed to reduce costs. The present strategy in other parts of the world is to exploit niche markets, such as stand-alone systems for illumination and water pumping. This contributes to volume market build-up and learning curve cost reductions.

At present, PV applications in rural areas for lighting and water pumping are important niche markets with a high development profile. The financing arrangement, not the cost per se, constitute a major barrier at present. Demonstration parks in major cities for PV and other renewable energy technologies would help bridge the information gap and reduce transaction costs.

It is also attractive to consider the investment needed for a faster market expansion, and compare it to the benefits obtained through a much earlier cost reduction of PV power than could otherwise be expected. China would benefit from working together with the international community to expand PV markets.

4.8 Solar energy

Active and passive solar heating and cooling should be further encouraged.

4.9 Nuclear energy
The prospects for nuclear power in China are still uncertain. It is presently too expensive per kWh, as compared to other energy supply alternatives. Successful development of nuclear energy will require cost reductions and a well coordinated programme to deal with safety and waste issues.

The cost of nuclear energy in China in the future will to some extent depend on the future of nuclear energy worldwide. There is uncertainty with respect to scale and choice of nuclear technology, safety, waste, and cost issues. In the year s ahead these issues should be clarified as ongoing projects move ahead. In the meantime, there are risks in going ahead with major programmes.

Successful nuclear energy programmes in the world are large scale, e.g. the French programme, and nuclear energy requires an infrastructure of regulation and control, that is difficult to put in place effectively on a small scale. In addition, capital costs are high.

The WG observes that there is presently no convincing rationale in pursuing more speculative nuclear ideas, such as plutonium recycling and fusion, as there are large reserves of low-cost uranium, available, and plutonium recycling is expensive and brings no advantage from the point of view of nuclear waste management.

4.10 Energy conversion and transmission

The conversion of primary energy resources to higher quality energy carriers offers opportunities for higher overall energy efficiencies and less costly transportation of energy. The latter is particularly important in China, as coal and hydro reserves by and large are located far from demand centers, as are future power generation options as wind and natural gas.

With respect to coal, there exist three main options: (i) pulverization and mixing with water to a coal-water-mixture (CWM) that can be pumped in pipelines and burned with higher efficiency. CWM have been transported both in pipelines and by tanker from Shandong to Japan. Considering China's shape, piping CWM to the coast and then distributing the fuel southward by sea to coastal provinces appears to be an interesting idea warranting further study; (ii) electricity generation at mine-mouth and HVDC transmission; (iii) gasification followed by the production of liquid or gaseous fuels. This route is spearheaded by highly efficient combined weight by the prospect of clean liquid fuels, when cost barriers are overcome.

4.11 Supply-side demonstration projects

In order to bring new, efficient supply side technologies to the China market, the WG recommends the establishment of three demonstration projects for key technologies:

Sugar Cane Cogeneration, as discussed in section 4.5.2.

Biomass for power. Stand-alone biomass gasification / gas turbine power generation, based on all kinds of biomass resources, including dedicated energy plantations.

Coal Gasification. Gasification of coal is a long-term strategic technology, as discussed in section 4.1.

4.12 Summary of WG Recommendations on Energy Supply:

1) Energy supply projects should only be pursued after rigorous analysis of societal and environmental impact. Least-cost solutions, where cost evaluations include social and environmental aspects, should be sought.

2) Strong efforts should be made by the coal industry to achieve "best practice" international standards for cleaner and more efficient use of coal. Guidelines standards should be agreed with industry and set by central authorities regarding permissible effluent levels and energy efficiency targets.

3) Mandatory requirement for efficiency and environmental audit should be introduced for all enterprises above a threshold level of energy consumption, to be defined, in which performance against the above guidelines standards is examined.

4) In the coal-burning power generation industry pulverized coal technology (PC) should now be pursued as the preferred option, pending its replacement in time, by integrated coal gasification combined cycle technology (IGCC), which has the best identified potential to achieve desired efficiencies.
efficiency and cleanliness goals.

5) Boiler manufacturers for the industrial market should adopt higher efficiency standards.

6) While retrofit has an important role to play in low-cost cleanup technology to reduce air pollution and acid rain, it will not deliver needed efficiency gains at acceptable cost. For the latter, China must look to inherently more efficient technology in new investments.

7) Oil exploration and development in the proven oil producing oil basis will give the fastest and lowest cost return in new reserves.

8) The price barriers to the take off of natural gas should be removed. A growing national gas grid should be aimed at as a long term goal. Imports of Siberian gas could play a major role.

9) LPG should be encouraged to play a larger role in the domestic urban residential and light industry market.

10) The main renewable energy sources should play a growing role for in China - hydropower, biomass (including biogas), wind power, and photovoltaics.

11) The use of biomass must be successively modernized, for example with advanced technologies such as BIG / GT.

12) A proposal for a nuclear programme should be carefully analysed, including comparisons with step-by-step alternatives such as electricity from natural gas, including LNG imports, and biomass, on the grounds of costs, foreign-exchange requirements, and investment requirements.

13) Demonstration projects are especially important for biomass power generation, and coal gasification.

5. Next Steps for the Working Group

A detailed demand and supply scenario analysis for the Chinese energy system by 2030 was considered to be highly desirable in order to be able to illustrate the potential impact of the various options studied by the WG, Scenario analysis will be attempted by the WG, building on the outcome from the IRP workshop organized for May 30-June 8, 1994.

It was greed to organize a workshop on biogas technology and applications. The workshop is scheduled to take place in Beijing, November 28-29, 1994.

A workshop will also be organized on sugar-cane cogeneration in south China, which is the natural starting point for biomass power generation, because the resource exists, and Chinese technology for cogeneration can be employed.

The WG work on the iron and steel industry will be expanded to other energy-intensive industries, including paper and pulp, cement, and the chemical industry.

The WG considers the transportation sector central to the CCICED objectives. China is going to build an extensive infrastructure for transportation. The WG plans to study the sector in an integrated approach, addressing transportation needs, modes of transportation energy carriers and engines, and environmental impacts.

The WG will develop pre-feasibility proposals for the three demand-side demonstration projects and the three supply-side demonstrations projects. This will include a preliminary investigation of the financiability of these projects.

The WG has organized two workshops on Integrated Resource Planning, and will attempt to create a network in China for the IRP methodology.

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List of supporting documents prepared as part of the WG activities:
Energy Consumption and its Efficiency of Iron and Steel Industry in China, by Professor Yang Jike and Mr. Keiichi Yokobori
Energy Conservation in China, by Mr. Xie Shaoxiong and Professor Ugo Farinelli
Renewable Sources of Energy in China: Potential and Policies, by Mr. Xie and Professor Thomas B. Johansson
Development and Utilization of Natural Gas in China, by Professor Qin Tongluo and Dr. Tim Brennand
The Nuclear Energy Program of China: Perspectives and Elements of International Relevance, by Professor Ugo FARINELLI and Professor Zuo Hu
Cleaner Coal Technology, by Professor Zhou Fengqi and Dr. Tim Brennand
A Fuel Cell Bus Demonstration Project for Beijing, by Dr. Robert Williams and Professor Yang Jike
Integrated Resource Planning, by Professor Zhou Fengqi and Professor Amulya Reddy
CCICED-IEI-ITEESA Workshop, by Professor Qiu Daxiong and Professor Amulya Reddy
Integrated Resource Planning, Report on the Workshop in Beijing,

January 21-22, 1994, by Professor Zhou Fengqi and Professor Amulya Reddy

Acknowledgements

The WG would like to acknowledge financial and in kind support from CCICED, ENEA, the International Energy Initiative, the Rockefeller Foundation, and Sarec.