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Report, Recommendations and Workplan of the

Working Group on Energy Strategies and Technologies

15 July 2000

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1. The Rationale and Objectives

The rationale for the Working Group on Energy Strategies and Technologies remain unchanged, and were elaborated in the Annual Report to CCICED last year.

2. Report on Activities in 1999/2000.

2.1 General Status of Activities

This year has proven to be an active one for the Working Group, in all its main areas of activity, namely studies, workshops, demonstration projects and capacity building. In all these aspects, work is in progress and will continue for some time. Specific progress during the past year is summarized below, and ongoing and planned work is outlined in section 5.

The Working Group has appointed Professor Mao Yushi as Ambassador of the Working Group to other Working Groups of the CCICED. In this capacity, Professor Mao has attended meetings of the Working Groups on Trade and Environment, Cleaner Production, Environmental Economics, and Transportation. This has resulted in better communication among the Working Groups.

2.2 Studies and Research Work

The Syngas Strategy for Coal:

The Working Group has outlined a strategic, "syngas" strategy for coal utilization in China in its 1998 and 1999 Reports to the CCICED. There have been some formal publications that relate directly to deliberations of the Working Group and workshops convened by the Working Group to explore this approach.

The long-term vision of a hydrogen economy based on syngas derived from coal and characterized by near-zero emissions of both air pollutants and greenhouse gases, one of the foci of a January 1999 workshop,[1] was further elaborated in an Italian conference paper.[2] A near-term syngas strategy for coal based on oxygen-blown gasification and "polygeneration" that would facilitate an evolution over the longer term to such a coal-based hydrogen economy is a major focus of the energy supply chapter of the forthcoming World Energy Assessment report.[3]

Enhanced Coal Bed Methane Recovery:

An important element in the Working Group's recommended syngas strategy for coal involves the use of CO_2 generated as a byproduct of hydrogen manufacture for enhanced recovery of methane from deep beds of unminable coal. This was discussed in the Working Group's 1999 report to the CCICED, and the focus of a January 1999 workshop convened by the Working Group.[4] This topic is the focus of a paper presented at and published in the proceedings of the 4th International Conference on Greenhouse Gas Control Technologies.[5]

Concessions for Large Wind-Power Plants:

The Working Group has reported earlier of its evaluation of prospective competitive wind power deliverable as baseload electricity to major load centers if in regions of good wind resources large wind farms are built using domestically manufactured modern wind turbines.

Work has been concluded, with UNDP funding, to develop the institutional framework for the *Wind Resource Concession Approach to Wind Energy Development*. The project consists of two collaborative elements: *(i)* concept development in the context of international analogues and with consultation with potential bidders, and *(ii)* relating the concept to the realities of concrete opportunity to develop large wind resources in China.

Renewable Portfolio Standards:
A study was prepared for the workshop on Renewable Portfolio Standards (RPS) in January 2000. The content is summarized in section 4.4.

The Energy Situation in China:
A paper reviewing the energy situation and the challenges ahead was presented to the Working Group in May 2000.

Village-Scale Biomass Energy Systems Involving Electricity Generation:
As a direct result of the workshops convened by the Working Group on Small-Scale Power Generation from Biomass (Changchun, Jilin Province, January 1998) and on Mechanisms for Commercialization of Modernized Biomass Technologies (Changchun, July 1999), a project has been launched in Jilin Province. This project will demonstrate a village-scale trigeneration system providing from gasified residues electricity, hot water for heating, and cooking gas (see Section 3.2). Following an inception meeting to formally initiate the demonstration project (Changchun, March 2000) an Inception Report was prepared to describe the objectives, organization, work plan, and schedule for this project.[6]

If the Jilin demonstration project is successful, it will be desirable for China to have the capacity to innovate in this area, so as to be able to improve technical performance and reduce costs continually. As a result of discussions at the January 1998 Workshop, the Working Group organizers made the preliminary judgment that the microturbine is one promising future ("second-generation") technology option for providing electricity and hot water for heating based on gasifiying crop residues. A study co-authored by one Working Group member, with much input from Jilin Provincial officials regarding crop residue availability and cost as well as energy demand and price data, indicates that the initial 1998 judgments are probably correct: microturbines are likely to be able to provide electricity from crop residues at about 1/3 less cost than with the first-generation technology that will be demonstrated in the Jilin project.[7]

2.3 Workshops

Renewable Portfolio Standards, January 2000
In October 1999, the State Development and Planning Commission expressed interest at the Working Group meeting in learning more about international experience in applying the RPS framework to encourage the development of renewable energy. At the request of

SDPC, a workshop on the subject was organized by the Working Group in Beijing, January 2000. Some 70 attendees from 15 institutions participated.

A paper which was prepared for the workshop by Trent Berry and Mark Jaccard entitled *The Renewable Energy Portfolio Standard: Relevance to the Chinese Electricity Sector* was presented by the latter author, who is a member of the Working Group. The study addressed key considerations in designing a renewable portfolio standard; the main issues and impacts on the energy sector found by experience of RPS in the United States, the European Union and in Australia; and finally what appeared to be relevant considerations relating to an RPS from a Chinese perspective.

Feedback from attendees and others concerning this workshop was positive and follow-up review has culminated in a number of recommendations which are included in this report under section 4.4.

The Working Group understands that this Workshop was very well received, with many senior Chinese officials attending. The State Development and Planning Commission has given explicit attention to the RPS in the draft 10th Five Year Plan, and is now exploring next steps.

Polygeneration Strategies Based on Oxygen-Blown Gasification--Strategic Energy Thinking for the 10th 5-Year Plan

A workshop on polygeneration strategies based on oxygen-blown gasification was convened by the Working Group at Tsinghua University, 11-12 May 2000. The workshop explored the technology, economics, and environmental aspects of coproducing various combinations of electricity, process heat, liquid and gaseous fuels, and chemicals ("polygeneration") from coal and petroleum residuals (e.g., petroleum coke, pitch) via oxygen-blown gasification.

More than 70 persons attended the workshop, representing various Ministries and agencies, universities and research institutes, and foreign companies, as well as Working Group members. Thirteen technical papers were presented, 7 by Chinese experts and 6 by international experts (including two papers presented by Working Group members).

The Workshop showed the potentially large benefits to China of pursuing efforts to advance polygeneration strategies based on oxygen-blown gasification. The Working Group's recommendations in this area appear in Section 4.2 below.

2.4 Demonstration Projects

No new demonstration project was proposed this year. An update on developments in demonstration project that were proposed earlier appears in the next section.

2.5 Progress on Capacity Building

Integrated Resource Planning (IRP) was introduced by the Working Group in its first report to CCICED in 1993. The *Integrated Resource Planning Promotion Network*, initiated by the Working Group, is continuing its work. The next Workshop is planned for the fall of 2000. After a short gap, funding has now been secured for the continuation of the valuable IRP work. The Working Group believes that given the importance of IRP's potential contribution to solving the modernization problems being addressed in the 10th

Five-Year Plan, IRP should be pursued actively and its network greatly expanded.

A discussion paper, "Environmental Tax Shift" written by Working Group member Mark Jaccard has been translated into Chinese by the WG. To introduce economic instruments in environmental protection is an essential issue in China. In energy sector tax incentive has been widely adopted in developed countries, it is becoming recognized that tax incentive will be important for China too. This paper explains why and how environmental tax can replace some of the taxes.

The volume "Renewable Energy – Sources for Fuels and Electricity" was first published in 1993 and later reprinted. Three of the four editors are members of the Working Group. The book deals with wide range of renewable energy, solar, wind geothermal, hydro, biomass, etc. The Working Group has arranged for the translation of the book into Chinese, as it will be useful for the future development of renewable energy in China. The Chinese version will be published in the fall of 2000.

3. Update on Developments from Earlier Recommendations of the Working Group

This update is intended to inform the CCICED about developments from some of the proposals made by the Working Group in earlier Reports. The Working Group does not have a role as implementer of these projects but keeps informed.

3.1 Deep Coal Bed Methane Recovery/Carbon Dioxide Sequestration

As a direct result of discussions at its January 1999 workshop on the prospects for enhanced recovery of methane from deep beds of unminable coal, a proposal was developed jointly by the China United Coal Bed Methane Co. (CUCBM) and a North American consortium led by the Alberta Research Council (ARC, the largest provincial research and development organization in Canada) for carrying out a demonstration project in China of enhanced coal bed methane (CBM) recovery via CO_2 injection coupled to sequestration of the injected CO_2 in the coal bed.

The Technology Development Program, as Phase I of this project is called, is estimated to cost 10 million Canadian dollars. The CUCBM has pledged to contribute the equivalent of 5 million Canadian dollars to this project if the other participants can come up with the other half of the needed support.

In September 1999 a Concept Paper on this project was submitted to the Canadian International Development Agency (CIDA), seeking 5 million Canadian dollars for partial support of Phase I. Following technical and departmental reviews, the Concept Paper was favorably received by CIDA. CIDA indicated that this project would be funded under the Climate Change Fund. The mechanism for resource allocation from this fund has not yet been identified.

In December 1999 the CUCBM and members of the North American consortium signed the China Coal Bed Methane Technology Development Agreement. In January 2000 CUCBM signed a letter of support together with the signed Agreement to CIDA.

If Phase I is successful, it is hoped by those involved in Phase I that it will be followed by Phase II, which is aimed at conducting a semi-commercial-scale demonstration project, which is estimated to cost about 60 million Canadian dollars.

3.2 Biomass Energy Demonstration Projects in Jilin Province

Biomass demonstration project

In total, Jilin Province has initiated 6 demonstration projects on gasification of agricultural residues. The producer gas obtained is used for cooking, replacing direct combustion of the residues.

One project at Baicheng, Jiling Province, which was initiated by the WG, involves a pyrolysis process producing combustible gas with high heating value, 15MJ/m^3. The raw materials are farm residuals, of which there is with ample supply. The gasification plant supplies 700 households (July 2000) and will expand to serve 1,500 households at the end of this year. The gas is used for cooking and space heating. More than 90% households have paid their gas bills, which are based on the rates of RMB0.8 (for urban households) or 0.6 (for rural households)/m^3. This price is much lower than the price of LPG in terms of energy content. The by-products charcoal and tar are further processed to pro, duce fertilizer and chemicals, which can be sold at the domestic market. With no cost of land and a favorable tax policy, the project could be marginally profitable. Central and local government funds the project, which is also partly supported by private capital. Currently, there are other two plants using similar technology.

The Government of Jilin has launched a three-year project to demonstrate, at village scale, an energy system based on gasification of crop residues. This system will provide the village, via "trigeneration", all its cooking gas, heating and electricity needs and will sell excess electricity into the electric grid.

This project is being supported by a $1.24 million grant from the United Nations Foundation (UNF), provided via the United Nations Development Programme (UNDP), and by 27.02 million Yuan RMB in additional funds from the government of Jilin Province. This is the first project in China to be funded by the UN Foundation. The project will be administered by the China International Center for Economic and Technical Exchange (CICETE) under UNDP guidance. The Jilin Environmental Protection Board (EPB) will be responsible for implementing the project.

The provision of cooking gas from village-scale gasifiers has already been demonstrated in several projects in Jilin (described above) and other provinces as a stand-alone activity. It is expected that the economics of cooking gas will be markedly improved by coupling the gasifier also to an engine/generator set that provides electricity and hot water for heating.

Biomass gasifier engine/generator systems are commercially available in some countries (e.g., India) based on gasification of wood chips and finely divided feedstocks (e.g., rice husks).. Biomass gasification of bulkier crop residue feedstocks (e.g., corn stalks, the dominant crop residue in Jilin) has been successfully demonstrated in China for cooking gas applications. However, gasification of such bulkier feedstocks for engine/generator applications has not yet been demonstrated.

The major technical task will be to demonstrate the production of gas from various biomass feedstocks with a tar content low enough to meet the technical requirements for the engine/generator set. The major institutional task will be to facilitate the export of electric power into the grid, as there are sufficient residues available to export large quantities of electricity into the grid. A major objective of the project is to build the necessary institutional, human, and technical capacities in Jilin to design, install, operate, and disseminate such trigeneration systems both domestically and abroad.

The site of the demonstration will be Hechengli Village, in Yanbian Korea Prefecture—a 224 household village near the North Korean border. The village has ample crop residues and wood wastes, a relatively high standard of living and a strong economy—conditions that are conducive to a successful demonstration project.

The Project Inception meeting was held in Changchun, Jilin Province, China on 24 March 2000. This event attracted high-level government participation, and generated extensive discussion on both technical and policy issues.

3.3 The Fuel Cell Bus Project

The Fuel-Cell Bus demonstration project has moved on from its stage of direct promotion by the Working Group, through the feasibility study (funded by UNDP) to the bidding stage, the closing date for which was June 30, 1998. The Government of China (GOC) issued a request for proposals for a demonstration project, and negotiations between Skoda/Ballard and the GOC were initiated. The demonstration project for the fuel cell powered bus (FCPB) in China is supported by UNDP and is being implemented by the Ministry of Science and Technology of China.

The Working Group believes that it is in the mutual advantage of China and the technology developer that a reasonable solution be found for financing the early prototype technology.

The Ministry of Science and Technology (MOST) will shortly submit a report of the project to UNDP that will include following:

- Summary of fuel cell bus development around the world,
- Analysis on potential social-economic & environmental benefits of the development and commercialization of the FCPB in China,
- Analysis on funding requirements for development and commercialization of FCPBs in China, Development of and potential demand for the FCPB in Chinese markets & analysis on its commercialization in China,

The Working Group will continue to follow the progress of this initiative.

4. Recommendations to CCICED

In accord with the request of the CCICED secretariat that specific recommendations suggested by the Working Group be presented in a standard format (whenever appropriate) for the CCICED to consider in making its recommendations to the Government of China

(GOC); the Working Group puts forward below specific proposals in six areas:

4.1 Recommendations for the Development of Western China

The strategy for development of Western China has its emphasis on improving the living standards of the people in Western China and to foster a productive economy and to protect the environment. New opportunities arise by taking into account major energy developments and experiences from other provinces and neighboring countries. How the resources of Western China can be brought to bear on the development objectives should be seen through the lens of what is now technologically and economically practical.

Some 50M people in Western China have no access to electricity, and clean cooking fuels are scarce. Decentralized electricity generation can be a key complement to grid extension in socio-economic development and should be a high priority. Wherever there are significant quantities of agricultural wastes, the experiences from biomass gasification for multiple purposes (e.g., for simultaneously providing electricity, clean cooking fuels, and hot water , as will be demonstrated in Jilin Province) should be carefully evaluated and applied as appropriate in Western China.

Some of the resources of oil and natural gas and in especially the Tarim basin have been considered to be too far from major markets to be economic to develop. Therefore the development for local use has also not occurred. In addition, developing the oil resources can lead to flaring of large quantities of associated natural gas in high gas-to-oil-ratio oil fields. There are two potential developments that may change the outlook, however. First, if plans to transport gas from the huge reserves in Central Asia to Eastern markets materialize, natural gas from Tarim could be less expensive to transport, either in the same pipeline or in a separate pipeline in the same corridor. Second, Xinjiang Province has a tremendous wind energy resource but scant potential local electricity demand to consume it. Previous Working Group work has shown good economic prospects for exploiting such resources if developed at large scale using domestically manufactured wind turbines--if the wind power so produced can be exported from the region as baseload power. In particular, High Voltage Direct Current (HVDC) transmission technology makes it possible to bring large quantities of baseload electricity to very distant markets economically. There is a potential synergy between developing the gas and wind resources, in that they could be combined to "baseload" l a HVDC line to the East. Electricity would be generated from the associated gas to fill in when wind electricity is not available. The Working Group recommends that a study be commissioned on this topic.

Clean cooking fuels and possibly also transport fuels for Western regions could also be provided from associated gas in the Tarim Basin. In addition to recovery of naturally occurring propane and butane (the constituents of LPG) from associated gas for cooking and other purposes, Dimethyl ether (DME) could be manufactured as a synthetic fuel from associated gas. DME is both an attractive low-polluting fuel for use in Diesel engine vehicles and a clean fuel suitable for cooking with properties similar to LPG. Particular attention should be given to the prospects for making DME using near-commercial liquid-phase reactors in once-through configurations that involve producing electricity as a coproduct (see related discussion in Section 4.2: A Syngas Strategy for

Coal), possibly in conjunction with the production of electricity from both natural gas and wind power for export from the Tarim Basin via HVDC transmission lines. (Electricity production might be maximized during periods of low wind-power availability, and DME production might be maximized during periods of high wind-power availability to obtain the most favorable overall system economics). The Working Group recommends that a study be commissioned on this topic.

HVDC can also be used to transport hydropower from Western China to markets. For the development of hydro, wind, and biomass electricity in Western China, the Renewable Portfolio Standard (see Recommendation 4.4) might be an important instrument that will generate significant additional income to the Western Provinces, especially if inter-Provincial trading of renewable energy credits is allowed under an RPS.

4.2 A Syngas Strategy for Coal

Background

Over the last three years, the Working Group has shown, and discussed in its 1998 and 1999 Reports to the CCICED, that an especially promising strategy for coal in China would be to pursue technologies based on the production of synthesis gas—a gaseous mixture consisting largely of carbon monoxide and hydrogen. Synthesis gas, or “syngas” as it is often called, is made by partial oxidation of coal using modern oxygen-blown coal gasifiers--technology that is well established in the chemical process industry of China. Syngas-based energy strategies make it possible to extract useful energy services from coal, with very low levels of pollutant emissions.

During the past year the Working Group has made considerable progress in articulating near-term syngas strategies and policies that would both provide major near-term economic and local environmental benefits while simultaneously putting China on a path that would lead over the long-term to widespread use of hydrogen derived mainly from coal. The May 2000 Workshop on Polygeneration Strategies Based on Oxygen-Blown Gasification (see Section 4.3) was especially helpful in advancing the thinking of the Working Group relating to syngas strategies for coal.

Theoretical Basis and Feasibility

Gasification is key to a clean and cost-effective energy future for China based on coal and other low-value feedstocks (e.g., petroleum coke, biomass, municipal solid waste). However, electric utility-based coal integrated gasification combined cycle (IGCC) power generation demonstration projects in Europe and the US have all had higher costs and lower availability (on-stream factor) than conventional coal steam power plants.

China could avoid the problems that have been encountered in coal IGCC demonstration plants in industrialized countries by building on China's already strong gasification expertise that exists in the oil and chemical industries.

This alternative approach would emphasize polygeneration strategies in which the gasification process is <u>not</u> highly integrated with combined cycle power generation. The oil and chemical industries would convert coal and other low-value feedstocks into clean syngas that would be used in liquid-phase once-through reactors to produce clean synthetic fluid fuels [Fischer-Tropsch (F-T) liquids, methanol, dimethyl ether (DME), town gas]. Syngas not converted to usable fluid fuels in a single pass through these reactors could be:

- Used for power generation in combined cycle power plants in these oil or chemical process industries, or
- sold to the electric power industry who would use this syngas in central-station combined cycle power plants, or
- distributed to residential apartment buildings, commercial buildings, and small factories for cooking, heating, and/or small-scale combined heat and power (CHP) applications.

China already has considerable experience with oxygen-blown gasification, the single most important *enabling technology* for this coal strategy. Another *important enabling technology* is liquid- phase reactor technology for producing clean synthetic fuels in once-through processes where electricity or electricity + process steam are coproducts of the synthetic fuels. Liquid-phase reactor technology is currently commercially available for producing both F-T liquids and methanol from coal. Liquid-phase technology for making DME from coal or other fossil fuels can be commercialized soon; the same reactor already developed for methanol manufacture can be used for DME manufacture.

Box A: Polygeneration via Oxygen-Blown Gasification--Key to an Attractive Future for Coal

The oxygen-blown coal gasification route for making electricity from coal [usually considered in conjunction with coal integrated gasifier/combined cycle (IGCC)] is just *one option* for improving efficiency, environmental performance in coal power generation. Competing advanced technological options include ultra-supercritical steam (USCS) generation, pressurized fluidized bed combustion (PFBC), and air-blown IGCC. All four options offer, with current technology, efficiencies greater than 40% for stand-alone power and improved environmental performance. But not all four options offer the same benefits. Shifting from present coal steam-electric plants to coal-based USCS, PFBC, or air-blown IGCC technology for power can be likened to *shifting from manual typewriters to alternative variants of electric typewriters.* But *shifting to oxygen-blown coal gasification*, is, by analogy, *like shifting from manual typewriters to laptop personal computers.* Just as it makes no sense to limit laptop computer use to word processing, it makes no sense to limit oxygen-blown gasification technology to power generation via IGCC--rather *this technology should be used for polygeneration.*

Expected Economics and Environmental Benefits

Polygeneration based on oxygen-blown gasification offers benefits that greatly surpass what can be provided with alternative coal technologies and strategies (see Box A). Polygeneration is the *key enabling strategy* that will enable China to make a transition to superclean energy carriers (electricity, superclean synthetic fuels, process steam) for meeting energy needs.

Polygeneration strategies based on gasification greatly improve the economics of coal utilization compared to single-product strategies (e.g., electricity only via IGCC, or methanol only via gasification) and will often be economic today--i.e., no technological advances are needed to make gasification-based conversion competitive with direct combustion technologies.

Polygeneration strategies based on gasification make it possible to produce fluid fuels (liquids, town gas), electricity, and essential chemicals at higher efficiencies and much lower emissions than are possible with other approaches to coal conversion..

Towngas produced in near-urban sited polygeneration facilities and used for cooking, heating, and CHP (e.g., via reciprocating engines or microturbines) would do more to reduce urban air pollution than any other energy strategy China might pursue in the near term.

DME has enormous potential as a clean synthetic fuel: for Diesel engine applications it offers high Cetane number and much lower emissions of particulates (e.g., DME combustion leads to zero soot formation) and NO_x than petroleum-derived Diesel fuel. It can also be used as a super

clean cooking fuel--with properties very similar to LPG. Moreover, the LPG infrastructure can be readily adapted to DME. *The high CO content of coal-derived syngas makes coal an ideal feedstock for DME manufacture*--with much greater syngas conversions in a single reactor pass than is feasible for methanol, which indicates a potential for low cost when it is manufactured in liquid-phase reactors in once-through configurations, where the syngas unconverted in a single pass through the reactor is burned to provide coproduct electricity in a combined cycle.

Near-term polygeneration strategies coupled to the development of hydrogen-compatible towngas distribution infrastructure in the near-term would facilitate an evolution to an energy system for the long term in which the main energy carriers are electricity and hydrogen that are produced and used with near-zero air pollutant emissions.

This energy system for the long-term could also be characterized by near-zero emissions of greenhouse gases as well, if the CO_2 generated as a byproduct of hydrogen and electricity generation[8] were sequestered in depleted oil or gas wells, deep beds of unminable coal, or deep saline aquifers. The incremental energy costs associated with CO_2 disposal in such ways in conjunction with coal gasification strategies are typically far less than with any strategies based on direct coal combustion. These incremental energy costs associated with CO_2 disposal will be especially low (and zero in some instances!) if the CO_2 disposal is coupled to enhanced resource recovery--e.g., if the CO_2 is used for enhanced oil recovery or enhanced recovery of methane from deep beds of unminable coal.

The greenhouse gas emissions mitigation and enhanced resource recovery benefits of injecting CO_2 underground do not have to await the introduction of hydrogen as an energy carrier. China already produces hydrogen from coal for ammonia and fertilizer manufacture and could use the streams of relatively pure CO_2 produced essentially "free" as a coproduct for enhanced resource recovery, as pointed out in our 1999 annual report. Locating planned ammonia/fertilizer factories at sites where there are opportunities for enhanced resource recovery by CO_2 injection could provide significant near-term economic and climate change mitigation benefits.

Essential Measures for Implementation
The main obstacles to such polygeneration strategies are institutional, not technological. Key to favorable economics will often be the ability to sell the electricity coproduct into electric grids at competitive rates. Reforms that encourage competition and market pricing in electricity generation would be powerful incentives for such polygeneration strategies.

The transition to polygeneration would be further accelerated if the health and environmental costs of air pollution were fully valued in market prices.

On the technical side, liquid-phase reactor technology is the single most important technology needed in the near term that China currently does not have. For the longer term, advanced technologies for hydrogen production and use are also needed, as well as technologies and strategies for CO_2 disposal in geological formations.

Recommendations
The Working Group recommends that China consider:

1. Making a decision soon relating to strategies for developing, demonstrating, and deploying advanced coal conversion technologies. The Working Group believes that a syngas strategy based on oxygen-blown gasification is far superior to all other strategies. Initial emphasis should be given to polygeneration.

2. Building on its experience with oxygen-blown gasification in the chemical industry to initiate polygeneration strategies. The GOC might begin by encouraging the conversion of planned oxygen-blown gasification projects for the production of chemicals into polygeneration projects that would involve adding to these chemicals projects extra syngas production for providing various combinations of coproduct synthetic fluid fuels (including towngas), electricity, and process steam. For polygeneration projects in which electricity is a key coproduct, emphasis should be given to systems for which the gasification process is not highly integrated with combined cycle power generation. Emphasis should be given initially to using low-cost petroleum residuals (e.g., petroleum coke, pitch) in polygeneration facilities. Subsequently high-Sulphur coals (the prices of which are expected to fall) should be emphasized.

3. Moving quickly to acquire liquid-phase synthetic fuel reactor technology and encourage its deployment in once-through configurations that involve electricity or electricity and process heat production along with synthetic fluid fuels.

4. Giving serious attention to introducing DME as a major energy carrier for serving both transportation and cooking needs (especially rural cooking), in light of the outstanding environmental characteristics of this energy carrier, its good match to coal as a feedstock, and its potential attractive economics when produced via polygeneration strategies involving liquid-phase reactors used in once-through configurations. Pioneering work on DME as an energy carrier has already been carried out in China, as

was highlighted at the polygeneration workshop convened by the Working Group in May 2000.

5. Involving, for *polygeneration plants sited near urban centers,* the manufacture of town gas as a polygeneration coproduct for serving distributed CHP cooking fuel, and heating markets in these urbain centers.. If the polygeneration facility were to produce synthetic middle distillates via the F-T process in a once-through configuration, this town gas would contain some high energy content gases (e.g., methane) as well as CO and hydrogen, which would enhance the energy value of the town gas and make it possible to provide the town gas at a lower distribution cost per unit of contained energy. Towngas infrastructure put into place in the near term should be designed to be compatible with conversion to hydrogen later.

6. Pricing towngas to be both viable as an energy carrier produced profitably by private-sector entrepreneurs and competitive as an energy carrier--both of which would be feasible if towngas were produced via polygeneration.

7. Enacting market reforms that enable both polygenerators and distributed CHP generators to sell electricity into electric grids at competitive market prices. Just as the Working Group has identified oxygen-blown gasification as the key enabling technology for polygeneration, it has identified *market reform that enables selling coproduct electricity into the grid at competitive prices as the key enabling policy for polygeneration.*

8. Selecting as the dominant coproducts, electricity (transported by wire to markets) and easily transported clean synthetic fluid fuels (e.g., methanol, DME) for *polygeneration plants sited near coal minemouths.*

9. Giving high priority to introducing policies that would facilitate the creation of "syngas parks," at which various industrial parties could collaborate in polygeneration strategies. Syngas producers at such syngas parks should be encouraged to focus on use of the less costly quench designs for gasification, since the more costly syngas cooler gasifier designs are not needed to achieve high performance in polygeneration facilities. Syngas producers at these syngas parks might sell syngas "over the fence" to chemicals/synthetic fuels manufacturers. And, both electricity or CHP producers and town gas producers strategies might in turn take syngas "over the fence" from these chemicals/synthetic fuels manufacturers who would use liquid phase reactors in once-through configurations. Electricity and CHP producers at such syngas parks should be encouraged to deploy the latest gas turbine-based power cycles (e.g., combined cycles).

10. Engaging in international collaborative efforts to accelerate the introduction of advanced coal-derived hydrogen-production technologies (e.g, hydrogen-separation membrane reactors) and hydrogen-consuming technologies (e.g., fuel cells for both transportation and distributed CHP applications), and strategies for geological disposal

of the CO_2 produced as a byproduct of H_2 manufacture (e.g., use of CO_2 for enhanced oil recovery, enhanced methane recovery from deep beds of unminable coal, and CO_2 disposal in deep saline aquifers).

4.3 Enhanced Coal Bed Methane Recovery

Background

During 1999 the Working Group showed, as discussed in its 1999 Report to the CCICED, that there are potentially large opportunities in China for using CO_2 for enhanced methane recovery from deep beds of unminable coal, while sequestering the injected CO_2. The Working Group pointed out that virtually free streams of nearly pure CO_2 could be available for such purposes using the CO_2 produced as a byproduct of hydrogen manufacture and that some of these opportunities could be exploited in the near term, well before hydrogen becomes established in the market as an energy carrier, if China were to site some of its planned new plants for making ammonia from coal (for which hydrogen is produced as an intermediate product) near prospective sites for enhanced recovery of CBM from deep coal beds.

Theoretical Basis and Feasibility

China has large potential methane resources trapped in coal beds. There is currently considerable industrial activity in the US aimed at extracting this CBM using conventional recovery technologies that are well established. In the US CBM accounts for about 6 percent of total natural gas production. New technology for enhancing production of methane from deep beds of unminable coal by injection of CO_2 into coal beds is being field tested in the US and Canada.

Coal is a porous solid whose pore spaces often contain large quantities of methane. Commercial technology exists for recovering this methane by depressurizing the coal bed, usually by pumping water out of the bed.

Additional methane can often be recovered from deep beds of unminable coal by pumping CO_2 into the bed. Because it is typically about twice as adsorbing on coal as is methane, pumping CO_2 into a coal bed tends to displace the methane in the bed and replace it with CO_2, typically leaving two CO_2 molecules in the coal pores for each molecule of methane recovered.

Expected Economics and Environmental Benefits

The value of enhanced CBM recovery via CO_2 injection relative to conventional CBM recovery technology may well be greater for low-permeability than for high-permeability reservoirs. The economic potential for enhanced CBM recovery by CO_2 injection is site specific—depending on the degree of saturation of the bed with methane, permeability, coal bed thickness, and other factors.

The overall economic attractiveness of CO_2 injection for enhanced CBM recovery depends on the availability of low-cost sources of CO_2. China is currently producing "virtually free" CO_2 as a byproduct of the manufacture of ammonia from coal with modern coal gasifiers. By siting planned ammonia plants near deep beds of unminable coal and using the byproduct CO_2 at these plants for stimulating enhanced CBM recovery, China could potentially improve the economics for CBM recovery in the near term.

Enhanced CBM recovery offers multiple local and global environmental benefits. The environment benefits first by increasing the availability of methane, the cleanest and least carbon-intensive fossil fuel. Moreover, CO_2 injection into deep beds of unminable coal leads to isolation from the atmosphere of amounts of carbon in the form of CO_2 that are typically larger than the carbon content of the extracted methane.

Essential Measures for Implementation

To understand better the prospects for enhanced CBM recovery from deep coal beds, available data on prospective sites for CBM removal should be compiled and analyzed, pilot tests should be carried out at several prospective CBM recovery sites, and this approach to enhanced CBM recovery should be demonstrated.

Recommendations

The Working Group reiterates the essence of its 1999 recommendations that China consider:

1. Encouraging the demonstration of this technology in China, along the lines formulated in the proposal advanced by CUCBM and the consortium headed by the ARC in Canada,

2. Encouraging a strengthening of this proposal by including in the set of participants for the project a potential supplier of low-cost CO_2 (e.g., a firm that produces ammonia from coal), and

3. Insisting that, following a reasonable grace period after project completion, the major results will be in the public domain. Such information would give policymakers a much better understanding of the prospects for recovering methane from deep beds of unminable coal in China.

4.4 Recommendations on Renewable Portfolio Standards in China

Background

The Renewable Portfolio Standard (RPS) is one of a number of policy instruments which might be used to increase roles for electricity generation from commercially-ready renewable energy technologies offering desirable social, economic and/or environmental benefits, but whose costs are not yet competitive with those for mature fossil fuel technologies such as coal and natural gas.

Interest in the international experience of applying RPS policies was expressed by the State Development and Planning Commission, at the Working Group's October 1999 meeting in Beijing. This resulted in the Working Group agreeing to write the report referred to in Section 2, and to convene a RPS Workshop in January 2000. Some 70 delegates attended the Workshop. The SDPC is now exploring the benefits of pushing further toward implementing such a standard during the 10^{th} Five-Year Plan.

Theoretical Basis and Feasibility

RPS is rapidly emerging as a favoured mechanism among energy policy makers interested in promoting a higher share of renewable energy in the energy supply mix. This trend is currently visible among industrialized countries, but is also increasingly of interest to those developing countries needing to reduce the polluting effects of rapidly growing electricity industries based on fossil fuel.

The Chinese electricity sector is currently dominated by coal, yet the country also has significant renewable electricity potential, notably from hydro, wind, biomass, photovoltaic, and solar thermal-electric technologies. The Chinese government already has several policies to support renewables. It is now interested in better understanding how it might use the RPS to further this policy aim.

Support for renewables is currently required since they are often not yet financially competitive with conventional, polluting sources. This is because:

- many jurisdictions provide substantial subsidies to conventional generation sources;
- the full costs of pollution (externalities) are not included in the financial cost of traditional technologies;
- renewables are often associated with newer, higher cost technologies, whose relative costs will only fall when widespread commercialization of renewables occurs through economies of learning and scale in equipment manufacture.

By mandating that each electricity provider include a minimum amount of renewable energy in the generation mix, the RPS can accelerate the rate at which renewable energy costs decline to market-clearing levels, because, for technologies that are amenable to modern manufacturing techniques (as is the case for most renewables), costs tend to decline with cumulative production--typically falling about 20% for each cumulative doubling of production (see Figure 4.4-1).

Countries pursuing the RPS typically hope that it will hasten market development for not just for one renewable energy technology but for a portfolio of commercially ready renewable energy technologies[1]--e.g., some mix of hydro, biomass, wind, photovoltaic, and solar thermal-electric options. Yet at any one time alternative commercially ready technologies are at different points along their experience curves. Thus if policy makers deem that a portfolio approach is desirable, care must be taken in RPS design to ensure that all the major commercially-ready options can benefit.

The RPS is just one of several alternatives available to government to support the increased use of renewables. Other means include:

- direct financial support for renewables

- indirect support to accelerate the commercialization of renewables
- removal of subsidies for fossil fuels
- imposition of taxes on fossil fuels or pollution
- emissions caps on carbon dioxide and acid gases produced.

Ideally, the RPS would be applied in concert with some or all of these measures.

Expected Economics and Environmental Benefits

The RPS is rapidly gaining acceptance as the preferred means of fostering

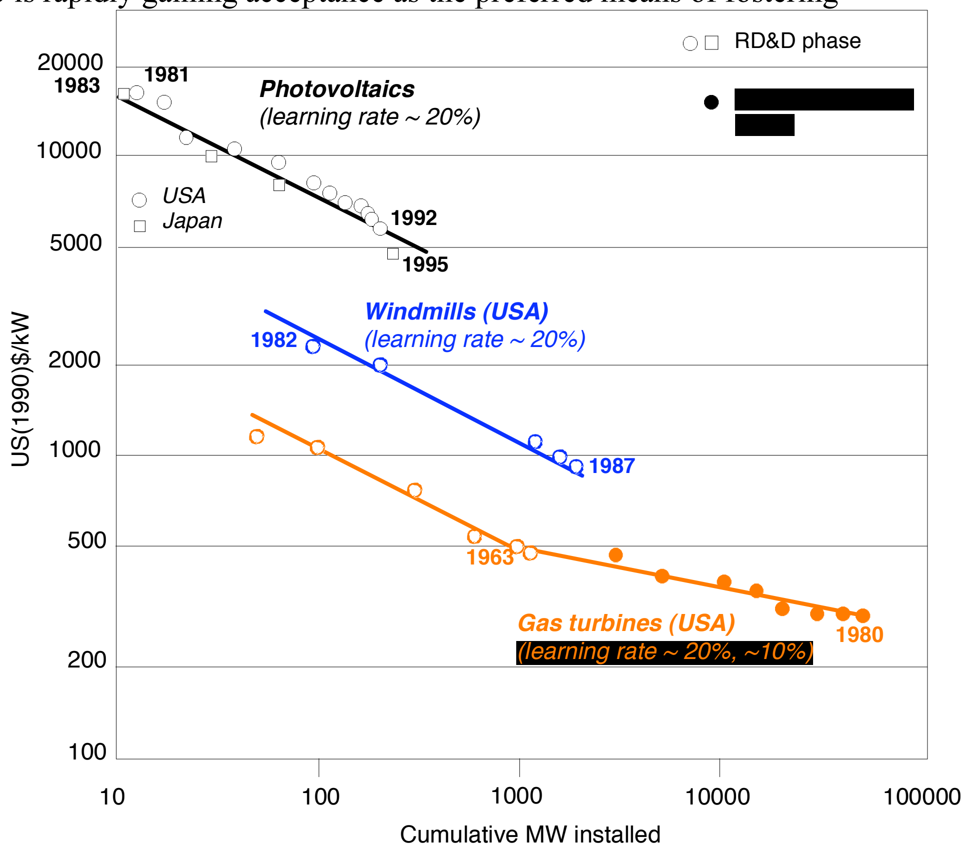

Figure 4.4.1: Experience Curve Relationships for Photovoltaics, Wind Generators, and Gas Turbines. Note that gas turbines also have fuel costs and associated capital investment that are not shown here.

Source: N. Nakicenovic, A. Grubler, and A. McDonald, eds., *Global Energy Perspectives*, Cambridge University Press, Cambridge, UK, 1998.

commercialization of renewables because it:

- sustains incentives for renewable producers to seek cost reductions (economic efficiency) over a specified period and can be designed to ensure that these cost reductions are passed on to consumers (equity);

- ensures the attainment of a specific market share for renewable energy and thus can be directly linked to environmental and economic development targets;
- requires no government finance;
- minimizes government involvement relative to other measures.

China could give focussed attention to renewable energy technologies, which have evolved to where they are beginning to be choice technologies on a worldwide scale. Adoption of a RPS could not only hasten a transition to renewables in China but also minimize dependence on imported equipment by accelerating the development of domestic manufacturing activities. Western China has abundant renewable resources the exploitation of which could be accelerated by a national RPS policies that allows trading of renewable energy credits across provinces and regions, thereby creating new sources of prosperity for less well-off provinces. At the same time, renewable energy has potentially a major part to play in relieving urban air pollution throughout China since renewables are typically characterized by zero or near-zero emissions.

Essential Measures for Implementation

If China were to implement a RPS, such a policy would be designed to meet the unique situation and needs of China. This would require research and policy development in several areas:

1. The government needs to establish explicit policy objectives for renewables (including specification of whether a portfolio approach is to be adopted), linked to environmental and economic development objectives. This will help in setting targets and establishing the details of the mechanism.

2. The definition of eligible renewable supplies needs to be determined. This will depend on environmental and economic development objectives as well as on considerations of commercial readiness of alternative technologies.

3. If a portfolio approach to renewables is to be adopted, care must be given in RPS design to ensure that the eligible alternative technologies are given the opportunity to compete. One way this might be done (without getting the government involved in attempting to "pick winners") would be to specify maximum shares in the RPS that are allowed for any particular renewable energy technology.

4. The renewable energy resource endowment of China should be better assessed on a regional basis. This has already been done to a some extent by agencies responsible for renewable energy. These resources should be assessed in terms of their relationship to the different electricity grids in the country, different levels of government and different administrative jurisdictions. This will help in setting regional targets of opportunity that might be given focused attention under an RPS and help catalyze industrial activities aimed at meeting these targets.

5. Prospective costs of renewable electricity supplies in different grid regions should be

estimated in relation to cumulative production levels to help define production targets on a regional basis.

6. The likely development of the electricity sector in the absence of a RPS needs to be established. This will help in determining impacts of the program on electricity prices and in establishing reasonable targets.

7. RPS options need to be researched to determine their likely effect on electricity prices as well as environmental and economic development targets.

8. This will lead to the final analysis and selection of the preferred option by the government.

Recommendations
The study envisages a number of steps leading to a decision on whether to introduce a RPS policy in China:

1. Establish a RPS research group.

2. The RPS research group carries out research steps 1 - 7 above and makes a recommendation (8) to government in time for possible inclusion in the 10^{th} Five-Year Plan.

3. Consider what national entity should be created to apply the RPS.

4. Consideration would be given how to introduce a RPS policy, whether immediately to apply RPS to certain regional grids or to the country as a whole.

5. A legal framework for RPS legislation should be drafted for enactment. There may be scope to link this to the Clean Production Law.

4.5 Recommendations on Wind energy Concessions in China

Background
China's existing programme for wind energy development
In the UNDP report *Energy After Rio: Prospects and Challenges, 1997,* it is stated that there are good prospects for introducing renewable energy technologies (RET's) over the next couple of decades, when the conventional fossil fuel use is held to progressively higher local environmental standards, and where commercialisation incentives are adequate.

Scenarios reviewed illustrate the possibility that renewables could be contributing at least 200 EJ per annum world-wide by the year 2050 (equivalent to about half of global energy use at present), provided certain actions are taken to support the necessary R&D and to develop incentives to help launch new renewable energy industries.

China has promoted wind energy development since the early '70's, initially for remote rural communities, more lately wind-farms whose total capacity reached 166.7MW in 1997. The largest of these are in Xinjiang, Guangdong, Liaoning, Inner Mongolia and Hebei. Despite encouragement from the former MOE, now the SPC and SETC, installed capacity is a tiny fraction of China's energy supply, and an even smaller fraction of the abundant available wind resource, estimated to be of the order of 253 GW. Consideration of the exceptional cleanliness of the wind resource as regards both air pollutants and climate damaging greenhouse gases, advances the case for redoubling efforts in China to unlock this valuable national resource, as a matter of urgency.

Current strategies for promoting wind energy technologies are inadequate to meet the challenge posed by its potential

Today's institutional frameworks, funding routes and corporate arrangements have not yet developed in scale and nature sufficiently to support an industry contributing the proportion of the world's or China's energy needs envisaged in the UNDP scenario. This is to be expected in an industry which has yet to overcome the formidable economic and institutional barriers posed by the massive dominance of fossil fuels.

Wind energy penetration is slow. New ideas are needed

The Working Group has completed two studies which support adoption of a new method to help accelerate wind energy development in China. These reports are:

Concessions for Wind-Power Plants; a New Approach to Sustainable Energy Development in China by Timothy P. Brennand, and A New Approach for Wind Power Development – Wind Resource Concession by Ni Weidou, Yin Lian and Guo Yuan et al.

These papers concern a specific initiative to achieve a better relationship between risk and reward in the wind energy industry, namely the idea of applying the time-honoured *concessionary approach*, for the exploitation of this renewable energy. The focus here is on large centralised schemes. The paper considers how in general terms a government might offer for competitive bidding concession areas for developing large wind-farms, delineated within a region of highly prospective wind energy resource.

Barriers in China to build world scale wind energy industry

The reports highlight the economic and institutional barriers to the effective harnessing of China's wind energy resource, barriers similar to those which have been confronted and surmounted in other countries, by practical measures acceptable to industry and society.

Theoretical Basis and Feasibility

Wind energy Concessions or Licences

The idea of applying a *concessionary approach* to the development of wind energy is quite logical given that wind is a geographically constrained resource. Wind is different from a mineral resource by being dynamic rather than static and above ground rather than below. However, much of the regulatory logic can apply equally to both. Certain areas are more "prospective" than others are and there needs to be a period of exploration and appraisal to confirm the economic potential, and to establish the dimensions and methods for development and off-take. A concession is a designated area within which a developer enters into a commitment to commercialize and develop a wind resource over the period of the licence, usually, in the case of minerals, 20 years or more.

How large concession should be will depend on a) the overall size of the wind energy resource area, b) the quality of the wind and its power generating potential, and c) the strategy of the issuing authority as regards factors such as the national target for renewable energy per annum, and d) the ability of the regional grid to accommodate power from new wind-farms.

Concession areas must be large enough to attract the interest of wind energy development companies (WEDCs),. The most appropriate area for a concession is a parameter that will only emerge by trial and error and may well vary from region to region. In the extractive industries already mentioned there is no standard concession size. Timing of successive concession "rounds," that is, the successive issuing of invitations to bid for licences, is entirely a matter of government policy which will be guided by prior target setting, and the extent to which initial round(s) are supported by applicant bidders.

Concessions under production sharing contracts (PSCs), such as apply in China's offshore oil concessions, in themselves confer no equity rights by the investor over the national resource. Modern petroleum legislation uses the term "licence" rather than "concession." Thus the successful bidder would be granted a licence to develop wind energy for electricity in the licensed area for a set period of time, subject to his fulfilling diligently certain work commitments agreed at the outset.

Compliance with published terms regulating the conduct of licensees, and with the terms of the power purchasing agreement (PPA), would also be conditions of retaining the rights to the licence. Land for wind turbine sites, for buildings, and offices and for other technical installations, such as may be needed for storage of energy and transmission way-leaves, would be rented from the local community and/or authority as appropriate.

Various corporate configurations can be considered for WEDCs, but the international joint venture involving as partners either local companies or authorities or some combination of both, stands out as especially appealing--combining ready access to world state-of-the art technologies and foreign capital and good prospects for low cost wind electricity as a result of maximizing use of local capabilities for both wind equipment manfacturing and wind farm management, as appropriate. All partners would share potential earnings in accord with their willingness to share financial obligations and assume risk. Arrangements can be factored into the partnership agreement to ensure any desired level of technology transfer.

An initial "exploratory and appraisal" period will be required in all concession agreements. Experience will dictate how long this period will tend to be, but it is safe to assume that for very large schemes step-by-step confirmation will take at least one and half to two years. The initial period of the concession term would involve risk for the "explorer" because it may be that detailed surveys show that wind quality is not good enough to justify investment in long term development. Thus the front-end "exploration" and "appraisal" money could be lost. As it is the objective to enable wind energy projects in the multi-hundred MW class, sizeable risk-money will be involved.

WEDCs would be invited to bid for previously designated and published areas, and their bids would be compared and allocations made subject to a number of factors. These would include companies up-front "exploratory and appraisal" work programmes of surveys, measurements and studies during the initial period (to be defined), at a certain minimum cost at their own risk.

For the second, or "development and production" phase, there would also be work commitments offered in the bids, to be accomplished within a stipulated time frame. There may be requirements for relinquishment of any areas not to be included in the development plan. The amount and timing of these relinquishments will vary depending on the work programmes, the resource realities and the degree of competition.

The duration of the second phase will be long enough for the resource within the concession area to be fully productive and for the investors to achieve a sufficient economic return to keep the industry motivated and growing. Assuming a second phase, including the building of a transmission line to a probably distant market it is likely that the concession lifetime, including both first and second phases will be for a period of not less than 20 years, and possibly longer.

China's abundant wind energy resource

Regional surveys confirm the existence of huge wind energy resources in China yet to be tapped. These are not uniformly distributed, but are located in prime areas with relatively continuous and high wind-speed, such as parts of Xinjiang, Inner Mongolia, Jilin, Heilongjiang, and coastal areas of eastern and southern provinces. Because much of this resource lies far from markets it is necessary that large wind-power farms (several hundred MW or even GW+) are built and grid connection made at nearest points. Such large wind farms will often require, and can sustain the extra cost of investments in appropriate storage facilities or other strategies for enabling electricity export from wind-rich region as baseload power, which is necessary to keep costs low.

Economic barriers; relative high cost, capital shortage

The wind power industry has struggled world-wide and also in China to compete with low-priced coal, for up to now its environmental cleanliness has attracted no premium. Moreover, coal has generally not had to accept the external costs of its uncleanness. Shortage of capital investment for wind projects reflects in large part the lack of interest by investors in this status quo situation

This situation is beginning to be partially redressed by Renewable Portfolio Standard (RPS) policies, which require, for specified renewable energy shares in total generation, that the cost gap between renewables and conventional energy be covered by a charge on all grid users. As noted in Section 4.4, the RPS is under consideration in China.

Institutional barrier; many authorities involved; reluctance of grid to accept wind energy; insufficient competition

Five governmental organizations, each of which have other more important priorities, are separately in charge of wind energy development. Moreover within the industry R&D is separated from manufacture. There is no central wind energy body to promote the industry and push development onwards. The regional grids are not truly supportive of the wind energy strategy since in the more market oriented world they are now in, they have a heightened sensitivity to higher costs.

The reliance on bilateral funding in the past has also hindered effective development. It has led to construction and running of wind-power plants as a government activity rather than a business. This has inhibited competition as the selection of the equipment is often predicated upon the nationality of the donor. Maintenance of equipment and follow-up service suffers in bilaterally funded schemes.

Risk and reward

Ventures that succeed in getting off the ground are those that strike an acceptable balance between the possibility of losing up-front pre-feasibility and feasibility cost, and the expectation of reward in a successful development. The concessionary approach allows, through the bidding process, different perceptions of that balance held by different companies in competition to drive down the cost of involving private capital in renewable energy development.

Successive bidding rounds establish the going rate for expectations on both sides, the issuing authorities and the investing companies. In this way, industry norms become established quite quickly and strategic planning for all parties becomes possible on a surer footing.

The risks for government is chiefly that licensees fail to deliver on the contractual terms, primarily work programmes, either through non-diligence or *force majeure*. In such cases, the remedy is to revoke the licence assuming that any re-negotiation proves unsuccessful.

The two chief risks for the investor are a) that the phase 1 pre-feasibility survey fails to prove up a commercially viable project, and that phase 1 costs are non-recoverable. And b) that the terms of the PPA are overridden by other considerations such as temporary oversupply in the power sector requiring shut-ins of supply capacity, such has been the case in China during recent years. However, no commercial venture is without risk, and the essential counterbalance is that there are solid expectations for a return of sufficient magnitude to justify accepting the risks.

Expected Economics and Environmental Benefits

Overcoming economic barrier by the Concession approach combined with RPS

The concession approach will move towards overcoming the economic barrier by encouraging much larger, therefore more cost effective, wind-power plants. Unit capital and operating costs will rapidly come down when local manufacture of large numbers of large wind turbines is in place and standardisation is more common. Competitive bidding will also bring downward pressures on costs in ways that bilateral soft loan financing cannot.

As costs decline in the bigger projects the regional grids will become more supportive. Furthermore, as larger supply inputs become available from wind-power plants, the industry will assume greater importance to the grids. Wind energy is of domestic origin, and requires no imported commodity nor technology once local manufacture is built up.

Environmental benefits
The environmental benefits of wind-energy are linked to its absolute cleanliness and absence of climate-damaging emissions. The resource is open ended, continuous and free in itself.

Need for price support in formative years
Developing wind energy calls for some electricity price support in the formative years. This can be achieved by a charge on all consumers. Later, as wind energy equipment costs decline through expanded use, and fossil fuel costs rise as external costs are increasingly allocated to where they belong, wind energy and coal prices should converge and price support should taper to zero.

Rural economy benefits
Developing wind energy under RPS legislation with trading permits will provide impoverished remote communities and provinces such as Western China new sources of income from wealthier provinces.

Essential Measures for Implementation
A successful major nation-wide wind energy industry using the concessions approach will develop in conjunction with the following:

1) A national authority, a Wind Energy Development Authority, for example, legally commissioned by government to issue licences and to regulate a wind energy industry, is the first essential to bring about an expansion of the use of this energy form. It would, for example, define and promulgate "Wind Energy Development Regulations" which would spell out rules for the designation, issuing, working retention and relinquishment of wind development concession areas. It would define the fiscal framework, the payment of royalties and to whom, and ground rules for developing a constructive relationship among energy producers, transmitters and distributors.

2) The commitment of consenting authorities (government) to seeing renewable energy as a long term, commercially viable and significant contributor to a diversified energy supply mix. This will be visibly realised in the setting of targets for renewable energy supply, together with a pricing and regulatory framework for accommodating renewable energy within the established conventional energy supply system. A *Renewables Portfolio Standard (RPS)* enactment is an effective means of setting clear targets and also obligations for a proportion of renewable energy to be purchased by the regional networks.

3) Equipment manufacturers competing on quality, performance and price for supply contracts to projects from local manufacturing ventures.

4) The existence of technically competent, financially sound WEDCs willing and capable of routinely exposing risk and development capital in long term, major wind energy projects. Projects that are larger in scale than have up to now been built, e.g. multi-hundred MW to GW+, at the same time smaller scale schemes that will have benefited from the cost reductions achieved in the mega-schemes.

5) Grid-access for independent power producers (IPPs) within a commercially acceptable framework. Wind energy supply companies will require negotiated robust long-term supply contracts, in which a fair balance is achieved between the amount of risk to be borne by venture capital and amount of reward to be earned by the risk taker in the event of a successful contract.

6) An updated survey of China's wind energy resource is called for since the national estimates of the total resource were compiled in the early '90's.

7) Designated areas and planned accommodation of targets of wind energy in the relevant regional power grids. Prime areas should be selected for locating wind energy resource concessions (WERCs). These will take into account the amount of the wind power electricity the authority wishes to accommodate into the specific regional grid over a certain period.

8) The drafting of a Model Wind Energy Development Agreement is required before issuing invitations to the industry to bid for concessions. Bidders will need to know what are the terms and conditions of the concession they are bidding for.

9) The enactment of a Renewable Portfolio Standard (RPS) provides the power grid organizations responsible for accepting the wind power generated in the concessions, the legal framework for their obligation. It also provides bidders with an assurance of their right to sell wind power generated to these designated off-takers.

10) Invitation to bid and award licences:

Following a similar practice already established in China for the award of oil and natural gas concessions in the petroleum industry, concession areas are put out to tender. These are bid for and awarded to those companies whose technical expertise, financial strength and work commitment offered is the most attractive to the issuing authorities. The up-front risk of confirmatory surveys and studies remains with the licensee.

An important consequence is that under the concession approach, no government funding is called for, unless, a government company chooses to co-venture as a joint venture partner in the concession development.

Recommendations

The Working Group recommends that China considers

1) Adopting a concession approach to develop successive large-scale wind power-plants in China to furnish a wind energy component of the national renewable energy target.

2) Encouraging development of wind power plants in concessions with 500 MW potential and higher.

3) Encouraging joint venture development of wind energy resource concessions involving the most capable of international companies.

4) Encouraging immediate local manufacture of world scale and quality large wind turbines in the range of 750kW – 1.5MW.

5) Establishing grid access for Independent Power Producers (IPPs)

6) Enacting a Renewable Portfolio Standard (RPS) legislation for China to ensure national targets for renewable energy are met within a defined time-frame.

4.6 Recommendations on Mechanisms for Commercialization of Modernized Biomass Technologies

Background

Crop residues have historically been the dominant cooking/heating fuel in rural areas of China. However, gathering, storing, and preparing residues for fuel are tedious tasks, and indoor air pollution associated with direct biomass-burning stoves poses serious indoor air pollution problems. The World Bank has estimated that adverse health effects of indoor air pollution (mostly from biomass and coal stoves) cost $10-$11 billion per year in rural areas of China.

With the rapid development of the rural economy and increasing farmer incomes there has been a shift away from crop residues to commercial energy forms (e.g., coal briquettes and LPG) for rural residential purposes. As a result, crop residues are increasingly being burned off in the fields. The pollution from such field burning has become so severe as to lead to airport and highway closings near harvest time in some provinces.

This situation is leading to growing interest in finding new productive uses for crop residues. China has already begun to implement village-scale crop residue gasification projects to provide cooking gas that can be distributed via plastic pipes to individual homes. While so doing is highly desirable in that it provides a clean, easy-to-use cooking fuel, this strategy by itself would actually aggravate the growing “excess residue problem,” because the overall efficiency of cooking via gasification plus gas stoves is about twice the efficiency of cooking by burning biomass directly in stoves. Thus there is interest in complementing the current strategy of making gas from residues for cooking with approaches that would also use residue-derived gas for electricity generation or for CHP in small village-scale engine/generator sets.

Theoretical Basis and Feasibility

Analyses presented at the January 1998 workshop on small-scale biopower generation and subsequently have convinced the Working Group that crop residue gasification to provide clean cooking fuel plus electricity or CHP represents a major opportunity for China to simultaneously meet basic energy needs in rural areas, provide significant electricity supplies in advancing rural industrialization, and meet environmental objectives.

In 1995 China generated 605 million tonnes of crop residues, of which 335 million tonnes (about 190 Mtce) were available for energy purposes. Gasification in small village-scale gasifiers offers a promising approach for utilizing these residue resources to provide clean energy. The China-wide available residues are enough to meet all rural cooking needs and generate, via small (~ 100 kW_e) engine/generator sets, 135 TWh/y of electricity (~ 22 GW_e of baseload power—about 20% more than the capacity being planned for the Three Gorges plant). Moreover, for northern China, where winters are severe, hot water produced via CHP from engine exhaust could be provided for heating purposes without having to burn extra fuel.

Expected Economic and Environmental Benefits

Village-scale crop residue gasification systems designed to satisfy cooking, heating, and electricity needs offer the potential to provide clean energy cost-effectively for rural villages in many instances if the electricity produced in excess of village needs can be sold into the electric grid at competitive prices. Although eventually electricity generated from residues can be used for supporting rural industries, in the early years, before such industries can be put into place, the ability to export electricity into electric grids at competitive prices is key to the economic viability of such rural energy systems.

Such small-scale bioenergy systems could make such economic benefits available to many western provinces and other poor regions having abundant crop residues but that heretofore have not fully benefited from the dramatic economic growth that has taken place in China.

Successfully launching such technologies in the market in areas were adequate crop residues are available could virtually eliminate the serious indoor air pollution problems associated with direct burning of biomass or coal for cooking and heating, eliminate the outdoor air pollution problems associated with burning excess crop residues in the field, and provide electricity with much less air pollution than via conventional coal-fired power plants. Moreover, crop residues are a renewable energy source characterized by zero net lifecycle CO_2 emissions.

Essential Means for Implementation

Several hurdles must be overcome in order to convert the potential offered by small-scale power or CHP or trigeneration technologies based on gasified crop residues into commercial success.

A key first step is commercial-scale demonstration of power or CHP or trigeneration systems, building on the experiences China has accumulated in recent years with gasification of crop residues for cooking gas applications. The technology has advanced to the point where commercial demonstrations can be carried out with gasifiers, engine/generator sets, and ancillary equipment that are commercially available on the world market as separate components. What needs to be demonstrated is the viability of the integrated systems. The recently launched Jilin demonstration project (see Section 3.2) provides the opportunity to do this.

As Working Group research has shown, there are advanced technologies (e.g, microturbines) that could become available in the 2005-2010 time frame that offer the potential for energy costs that are lower than costs that can be expected with the first generation technology (e.g., reciprocating internal combustion engines) that will be demonstrated in Jilin. In order to seize such opportunities, China will have to develop a capacity to innovate continually in this area. Advances are not likely to flow naturally from industrialized countries, where the market prospects for such technologies are not bright because of the inherent labor intensity of these technologies and high labor costs in industrialized countries.

Most of the barriers to small-scale biopower or CHP or trigeneration technologies are institutional rather than technological. Attention must be given in Jilin and China generally to building the needed institutional, human, and technical capacities to design, install, operate, and disseminate these technologies throughout China and eventually for export markets. The single most important policy reform needed is to enable village-scale power systems to sell electricity into electric grids at competitive prices. Grid interconnection will be a key aspect of the Jilin demonstration project, as planned.

Implementation of a suitably designed Renewable Portfolio Standard (RPS) in China (see Section 4.4) could provide a powerful incentive for launching these technologies in the market and quickly "buying down" their costs.

A major challenge relates to the fact that transaction costs and maintenance costs per unit of energy provided tend to be high for any small-scale systems, unless ways can be found to spread these costs over many individual systems. Institutional arrangements that facilitate such activities are needed. One possibility is a rural energy concession in which a single supplier wins the right (e.g., via an auction) to provide energy services in a geographically delineated region for a specified period, in exchange for an obligation to deploy energy systems to serve all customers in that region.

Other important supporting policies include pricing conventional electricity to reflect full costs, including environmental damage costs, and pricing electricity provided by small-scale power systems to reflect the full market value of such energy—including various "distributed benefits" that make electricity generated near users inherently more valuable than electricity generated in central-station power plants.

Recommendations

In its 1999 report to the CCICED the Working Group set forth a substantial list of recommended policy reforms for advancing small-scale bioenergy technologies—measures that are as important for China's consideration today as they were then. But in light of all that has happened since then—especially the inception of the Jilin biomass trigeneration demonstration project and China's development of a comprehensive framework for renewable policy in its draft 10th Five-Year Plan, the present set of recommendations is focused on a small number of measures that stand out as being paramount. The Working Group recommends that China consider:

1) Launching a comprehensive program for exploiting crop residues to provide electricity and other modern energy services to rural reas. This activity should aim to exploit opportunities for performance improvement and cost reduction via various coproduction strategies—such as CHP and trigeneration, as discussed above. The activity should give attention to the entire energy innovation chain—including fundamental research, development, demonstration, early deployment (involving "technology cost buy down"), and widespread deployment—and critical links among different elements of this energy energy innovation chain. The renewables policy discussion in the draft 10th Five-Year Plan provides a strong framework for doing just this.

2) Enacting market reforms that enable small-scale biopower producers to sell electricity into electric grids at competitive market prices. Just as the Working Group has identified gasification as the key enabling technology for CHP or trigeneration, it has identified *market reform that enables selling coproduct electricity into the grid at competitive prices as the key enabling policy for implementing these small-scale biomass energy technologies.*

3) Adopting an RPS, as discussed in the draft 10th Five-Year Plan, and crafting the details of an RPS in such a way that would make it possible to deploy and, via rapid market expansion, buy down the costs of the more promising biopower technologies as they become commercially ready.

4) Testing alternative institutional arrangements such as rural energy concessions for market aggregation that make it possible to overcome the high transaction cost/high maintenance cost features that are inherent in small-scale energy systems deployed on a "one-off" basis.

5. Workplan for 2000/2001

5.1 General considerations

The following workplan is based on the approach outlined in last year's Report. In the overall context outlined there, the Working Group will contribute to the development of ***market rules for sustainable energy development*** in China, including contributions to the discussion of the role of government in shaping these rules. Further, the Working Group will identify and analyze important ***new technologies for sustainable energy, propose demonstration projects*** for new technologies and new institutional arrangements**,** and discuss the ***institutional and human capacity issues that are required to make full use of sustainable energy options*** in China.

There are two meetings per year, at which studies are reported, technological and capacity-building workshops are convened and demonstration projects are followed up. With this time limitation, it is necessary to be selective in what the Working Group plans to achieve each year. In the next year (2000-2001), the Second Phase of the CCICED will conclude. Human resources and funding also exert constraints upon what can be effectively tackled.

As workshops stem from mature studies, and the choice of studies is arrived at through an ongoing discussion of priorities, it follows that the portfolio of these activities remains dynamic. The Working Group's attention will continue to be directed into those areas and themes that seem most important to Chinese members. Its work aims always to ensure a balance between the twin concerns of socio-economic development and the environment. The international members strive to ensure that the most appropriate, clean and efficient technologies, and the most efficient institutional arrangements experienced worldwide, are brought to the attention of the Working Group.

The Working Group will produce a brochure summarizing its work for publication, based on its self-evaluation report of Spring 2000.

5.2 Studies

During the next year, the Working Group will undertake studies to address:

1) the potential for cogeneration in China, both with and without a syngas oriented energy future. The study will include cogeneration in district heating networks, industrial cogeneration, and decentralized cogeneration. Modern technologies characterized by high electricity to heat ratios will be explored.
2) continued attention to electricity sector reform
3) renewable portfolio standards
4) capturing the opportunities offered by next-generation technologies to use biomass--including the prospects for the coproduction of DME and electricity based on gasification and use of once-through reactors.
5) the prospects for meeting energy needs at large scale with coal-derived syngas, via a so-called "Syn City Project," planned as a follow-up to the May 2000 polygeneration workshop. In the "Syn City Project" conversion of an entire Chinese city to syngas derived from coal will be modeled. The study will select a city in China for which there are poor prospects for natural gas access, readily available high sulfur coal supplies, and a strong chemical and/or oil refining industry in place that could become home for syngas production for serving city-wide energy needs. The study will model full deployment of syngas technologies at projected energy demand levels for buildings, factories, and transportation in the city for the years 2010 and 2030. The purpose of the study will be to illustrate graphically for policymakers the advantages of syngas strategies and provide the basis for one or more potential Syn City projects as an approach for introducing such energy strategies.

5.3 Workshops

The Working Group is planning one workshop for its October 2000 and one workshop for its May 2001 meeting. The subject of the first workshop will be "Issues Associated with Interconnecting to Electric Grids Power Systems Other Than Utility-Owned Central Station Power Plants", and the topic of the second to be selected at the Working Group meeting in October 2000.

The October 2000 workshop is motivated by consideration of the fact that many of the most promising clean energy technologies the Working Group has identified for playing major roles in providing electricity for China require, in order to be economically viable, that the power generator be able to sell the electricity produced in excess of onsite needs into the electric grid at competitive prices, whereas electricity companies historically have had policies that discourage the sale of electricity into electricity grids by independent power producers. At this workshop both technical issues (e.g., grid stability, safety) and policy issues (e.g, valuation of the power produced by various distributed power sources relative to the value of power produced in central stations, pricing policies, and regulatory issues) will be discussed.

5.4 Demonstration projects

During the coming year, the Working Group intends to focus on the already initiated demonstration projects, the biomass projects in Jilin, the fuel cell bus, the wind resource concession, and the Coal Bed Methane/Carbon Dioxide Sequestration project. By mid-year 2001, it is to be expected that studies/workshops will have generated additional demonstration projects.

5.5 Capacity building

The Integrated Resource Planning Promotion Network is planning the Third Workshop that has had to be postponed until the fall of 2000. This will receive added emphasis in the context of the challenges of the 10th Five-Year Plan.

6. Report on Funding

The costs of meetings of the Working Group have been funded by the Canadian secretariat of the CCICED, covering the participation of the international members and direct local costs. Funding for workshops and other local activities have been identified by the Working Group during Phase I from other sources. For the last year these costs have been covered by the Canadian secretariat of the CCICED, using grants from Canada and Norway. A large number of contributors have been supportive, as acknowledged in the reports of the Working Group to the CCICED. In the judgment of the Working Group, a larger contribution to total activities from CCICED funds would be desirable.

7. List of supporting documents prepared as part of **the** *Working Group activities:*

Formal Publications

Williams, R.H., 1999: Toward zero emissions for coal: roles for inorganic membranes, pp. 212-242, in: *Proceedings of the International Symposium Toward Zero Emissions: the Challenge for Hydrocarbons*, Rome, Italy, 11-13 March 1999, EniTecnologie, Eni Group, Milan, Italy.

Williams, R.H., 2000: "Advanced energy supply technologies," Chapter 8 of the *World Energy Assessment* (a joint project of the UNDP, UN Department of Social and Economic Affairs, and the World Energy Council), in the press.

Timothy P. Brennand: *Concessions for Wind Power Plants – A New Approach to Sustainable Energy Development in China*, UNDP/University of East Anglia, England, 2000.

Ni Weidou, Yin Lian (Project Managers) and Guo Yuan (Executing Manager): *A New Approach for Wind Power Development – Wind Resource Concession,* Report to the UNDP, May 2000.

Mark Jaccard and Trent Lott: *The Renewable Energy Portfolio Standard: Relevance to the Chinese Electricity Sector,* Report for the Working Group on Energy Strategies and Technologies, May 2000.

Papers prepared for the Working Group:

Zhou Fengqi: *Energy Industry in China and Challenges for the 21st Century,* paper presented to the Working Group, May 2000.

Zhou Fengqi: *Natural Gas Transport from West to East,* presentation to the Working Group, May 2000.

Jilin Provincial Environmental Protection Bureau, 2000: INCEPTION REPORT on Modernized Biomass Energy in China: Jilin, report prepared for the United Nations Development Programme (UNDP Project No. CPR/99/H01/A/IV/99) and the United Nations Foundation for International Partnerships (UNFIP No. UDP-CPR-99-051), May.

Henderick, P., and R. Williams, 2000: Trigeneration in a Northern Chinese Village Using Crop Residues, *Energy for Sustainable Development*, **4** (3), October (in the press).

Transparencies for presentations at the Workshop on Polygeneration Strategies Based on

Oxygen-Blown Gasification--Strategic Energy Thinking for the 10th 5-Year Plan (11-12 May 2000)

- An overview of polygeneration based on oxygen-blown gasification (R. Williams, US)
- Gasification: status and polygeneration (D. Simbeck, SFA Pacific, US)
- Liquid-phase reactor technology [R. Moore (retired), formerly Air Products, US]
- Electricity market reforms worldwide: implications for China (M. Jaccard, Canada)
- Institutional issues associated with an IGCC project based on gasification of petroleum residuals at ERG Petroli (Carlo Di Primio, Italy)

Papers prepared for presentation at the Workshop on Polygeneration Strategies Based on Oxygen-Blown Gasification--Strategic Energy Thinking for the 10th 5-Year Plan (11-12 May 2000)

- Technological and economical analysis for Texaco's coal water slurry gasification and relative investigation (Han Wen, Gong Xin, Liu Haifeng, Yu Zunhong, China)
- Shell coal gasification process--a viable alternative for China (M. Williams, Shell, Hong Kong)
- On the polygeneration technology based on "Syngas Park" (Jiao Shujian, China)
- A proposal for electricity, chemicals, and fuels coproduced from coal (Zhu Qiming and Fang Dewei, China, and Song Chunshan, US)
- Chance and challenge in developing Shanghai trigeneration town gas project (Cui Haijun and Sun Songliang, China)
- Utilization of polygeneration based on gasification for retrofitting the Lunan fertilizer factory (Zhou Huaizu, PangG Xicai, Han Mei, and Cai Dalong, China)
- Dimethyl ether (DME)--clean fuel in the 21st century (Niu Yuqin, China)
- Application of DME in Diesel engines (Zhou Longbao, China)

Materials made available by Texaco Power and Gasification to participants in the Workshop on Polygeneration Strategies Based on Oxygen-Blown Gasification--Strategic Energy Thinking for the 10th 5-Year Plan (11-12 May 2000), *but not presented:*

Falsetti, J.S. (Texaco Power and Gasification), D. Brdar and A. Anand (General Electric Power Systems), and J. Paolino (Praxair), 2000: “From Coal or Oil to 550 MW_e via 9H IGCC (paper)

O’Keefe. L.F. (Texaco Power and Gasification), 2000: “Increasing European Refinery Profitability through IGCC Technology,” presented at the IchemE Conference, Noordwijk, The Netherlands, 12 April.

Endnotes

[1] On 18-19 January 1999 the Working Group convened in Beijing a "Workshop on Coal Bed Methane (CBM) Recovery and Prospects for a Hydrogen Economy".

[2] Williams, R.H., 1999: Toward zero emissions for coal: roles for inorganic membranes, pp. 212-242, in: *Proceedings of the International Symposium Toward Zero Emissions: the Challenge for Hydrocarbons*, Rome, Italy, 11-13 March 1999, EniTecnologie, Eni Group, Milan, Italy.

[3] Williams, R.H., 2000: "Advanced energy supply technologies," Chapter 8 of the *World Energy Assessment* (a joint project of the UNDP, UN Department of Social and Economic Affairs, and the World Energy Council), in the press.

[4] On 18-19 January 1999 the WG convened in Beijing a "Workshop on Coal Bed Methane (CBM) Recovery and Prospects for a Hydrogen Economy".

[5] Williams, R.H., 1999: Hydrogen production from coal and coal bed methane, using byproduct CO_2 for enhanced methane recovery and sequestering the CO_2 in the coal bed, pp. 799-804, in: *Greenhouse Gas Control Technologies. Proceedings of the 4th International Conference on GHG Control Technologies, Interlaken, Switzerland, 30 August.— 2 September,.*B. Eliasson, P. Riemer, and A. Wokaun, eds., Pergamon, Amsterdam, 1205 pp.

[6] Jilin Provincial Environmental Protection Bureau, 2000: INCEPTION REPORT on Modernized Biomass Energy in China: Jilin, report prepared for the United Nations Development Programme (UNDP Project No. CPR/99/H01/A/IV/99) and the United Nations Foundation for International Partnerships (UNFIP No. UDP-CPR-99-051), May.

[7] Henderick, P., and R. Williams, 2000: Trigeneration in a Northern Chinese Village Using Crop Residues, *Energy for Sustainable Development*, **4** (3), October (in press).

[8] Using advanced technologies for the co-production of hydrogen and electricity, for which a stream of relatively pure CO_2 is generated as a byproduct. See Williams, R.H., 1999: Toward zero emissions for coal: roles for inorganic membranes, pp. 212-242, in: *Proceedings of the International Symposium Toward Zero Emissions: the Challenge for Hydrocarbons*, Rome, Italy, 11-13 March 1999, EniTecnologie, Eni Group, Milan, Italy.