Technical Assistance Report

Project Number: 42074
Policy and Advisory Technical Assistance (PATA)
August 2009

People's Republic of China: Recycling Waste Coal for Power Generation

Asian Development Bank

CURRENCY EQUIVALENTS
(as of 15 June 2009)

Currency Unit	–	yuan (CNY)
CNY1.00	=	$0.1465
$1.00	=	CNY6.82

ABBREVIATIONS

ADB	–	Asian Development Bank
CFBC	–	circulating fluidized bed combustion
EA	–	executing agency
FYP	–	five-year plan
GW	–	gigawatt
IA	–	implementing agency
MW	–	megawatt
PCC	–	pulverized coal combustion
ppm	–	parts per million
PRC	–	People's Republic of China
TWh	–	terawatt-hour
TA	–	technical assistance

TECHNICAL ASSISTANCE CLASSIFICATION

Type	–	Policy and advisory technical assistance (PATA)
Targeting classification	–	General intervention
Sector (subsector)	–	Energy (energy efficiency and conservation)
Themes (subthemes)	–	**Environmental sustainability** (eco-efficiency) economic growth (knowledge, science, and technological capacities)
Location impact	–	Urban (high)

NOTE

In this report, "$" refers to US dollars.

Vice-President	C. Lawrence Greenwood, Jr., Operations 2
Director General	K. Gerhaeusser, East Asia Department (EARD)
Director	A. Bhargava, Principal Energy Specialist and Officer-in-Charge, Energy Division, EARD
Team leader	T. Oi, Energy Specialist, Energy Division, EARD
Team member	P. Dungca, Administrative Assistant, EARD
	C. Wang, Economics Officer, People's Republic of China Resident Mission, EARD

I. INTRODUCTION

1. During the December 2008 country programming mission of the Asian Development Bank (ADB), the Government of the People's Republic of China (PRC) requested technical assistance (TA)[1] to study recycling waste coal for power generation at the Pingshuo coal mine in Shanxi Province. ADB conducted a fact-finding mission from 4–5 June 2009 and reached an understanding with the Shanxi provincial government on the TA's objective, scope, cost estimates, financing plan, implementation arrangements, and consultants' terms of reference. The design and monitoring framework is in Appendix 1.

II. ISSUES

2. In 2008, coal-fired power stations generated 81% of total 2,779.3 terawatt-hour (TWh) electricity in PRC.[2] The power sector consumed 1.3 billion tons of raw coal, or about 50% of total coal produced in PRC.[3] Every year, waste coal is generated during coal production as the largest solid waste discharged by industry, accounting for about 25% of industrial solid waste. Its large stockpiles damage mining areas' ecology and occupy valuable land. In addition, spontaneous combustion within these heaps causes air pollution and safety hazards, and leaching of trace elements with rainwater causes groundwater contamination.

3. Currently, annual waste coal generation in PRC is around 200 million tons, which is almost equivalent to the coal production in the Russian Federation, the sixth-largest coal producer in the world. Accumulated waste coal in PRC was about 4.5 billion tons in 2008. Shanxi Province, the largest coal-producing province, has accumulated about 1.1 billion tons of waste coal, and its annual waste coal production is around 100 million tons.[4] The utilization level of waste coal in Shanxi Province is only 50%, so environmental issues related to waste coal are more acute here than in other provinces. Although waste coal use for power generation has been increasing due to government policies, technical and regulatory barriers still exist, which may delay or impede large-scale waste coal use.

4. The 11th Five-Year Plan (FYP) for Energy Development in PRC requires that waste coal use should increase to 390 million tons in 2010 from 150 million tons in 2005. Both the 11th FYP for Economic and Social Development and 11th FYP for Energy Development emphasize building large-scale circulating fluidized bed combustion (CFBC) boilers to control pollution from waste coal heaps. According to the State Council's Opinion on Accelerating Development of a Recycling Economy and Shanxi Recycling Economy Development Plan under the 11th FYP, there is an urgent need to develop the integrated use of waste coal from coal production for thermal power-generation.

5. In 2004, ADB provided a TA to promote waste coal use in Shanxi Province.[5] The resulting study was completed in November 2006, and its main recommendations included promoting waste coal power generation and further study to determine the techno-economic feasibility for large-scale (i.e., 600 MW and higher) waste coal power generation plants.

---

1 The TA first appeared in the business opportunities section of ADB's website on 12 May 2009.
2 China Electricity Council. 2009. *Annual Development Report of China's Power Industry*. Beijing.
3 National Bureau of Statistics, China. 2008. *Statistical Communiqué of the People's Republic of China on the 2008 National Economic and Social Development*. Beijing.
4 The annual raw coal production in Shanxi Province is about 600 million tons.
5 ADB. 2004. *Technical Assistance to the People's Republic of China for Waste Coal Utilization Study*. Manila.

6. In the mid-1980s, waste coal power plants were established in PRC in sets of 6 MW. By 2004, more than 200 waste coal power plants were built with an aggregate capacity of 4 gigawatts (GW), utilizing 40 million tons of waste coal to produce 24 TWh of electricity annually. The largest plant, however, is only 300 MW. Looking ahead, to utilize even 50% of annual waste coal (i.e., 150 million tons), a total capacity of 45 GW is needed. Therefore, more power plants are required—located at every large coal mine—that have the largest capacity that is technically possible. When the unit size is large, it is cost-effective to include designs that control pollution, comply with national emission standards, and enable higher efficiency to increase financial returns and reduce carbon dioxide emissions. Moreover, new emission standards of air pollutants for thermal power plants (GB13223-2003) stipulate stricter emission standards for waste coal power plants, and only large waste coal power plants of about 600 MW range can achieve them.[6]

7. Most modern coal-based power plants use (i) pulverized coal combustion (PCC), in which coal is finely ground so it can burn efficiently, and (ii) supercritical and ultra-supercritical steam parameters. The most efficient units convert 42%–45% of the heat in coal to electricity.[7] The main drawbacks of PCC coal-based power plants are that their transformation and pollution control efficiencies are sensitive to changes in coal quality, the cost of pollution control equipment is high, and waste coal cannot be used efficiently because of variations in quality. Supercritical and ultra-supercritical coal-based power plants also require superior grade steel tubes, which result in higher boiler costs. Therefore, the appropriate design is CFBC. Although development of CFBC technology has been slow (presently, only 2% of the world's coal-based power plants use it), it is particularly suited for coal with lower heat content and high sulfur. The efficiency of its large-sized units (i.e., over 300 MW) can be similar to that of PCC units.

8. Although national policies encourage waste coal power plants, the policies can be improved to simplify exemptions and reductions in income and value-added taxes for power generated from waste coal power plants. The State Council stipulates that such power plants should get preference in selling power and the power sale price; power plants with capacities of 12 MW or less are exempted from the grid load management and related fees.[8] Still, coal mining companies and other power producers face obstacles in selling power to grids. Various fees are involved in power sale transactions,[9] and there is a lack of a transparent and fair structure. Presently, the power generated by waste coal power plants can only be purchased by provincial power distributing companies, which are wholly owned subsidiaries of just two national grid companies.[10] A prolonged and laborious process in negotiating power sales agreements with off-takers is also a serious barrier.

---

[6] Smoke emission limit of 200 parts per million (ppm), sulfur dioxide emission limit of 800 ppm, and nitrogen oxide emission limit of 659 ppm.

[7] The efficiency range reflects different turbine designs and temperature of cooling water that is available at the site. It requires 0.273 tons of standard coal (heat content 29.3 MJ per kilogram or 7,000 kcal per kilogram) to produce 1 megawatt-hour of electricity when the efficiency is 45%, and the carbon dioxide emission will be 0.8 ton. In terms of pollution control, it is possible to limit emissions to 200 ppm of sulfur dioxide (using flue gas desulfurization plants), 200 ppm of nitrogen oxide (using selective catalytic converters), and 30 ppm of particulate matter.

[8] Due to the large size of PRC provincial power grids, smaller units (i.e., 100 MW and less) are technically incapable of influencing the system's frequency to short-term load changes.

[9] The fees include the grid modification and connection fee, grid support fee, generation capacity fee, grid management fee, and grid connection technical support fee. The local power authorities have the flexibility to define these fees.

[10] The alternative is to build waste coal power plants for captive use of the coal mine, but this would restrict growth and fail to resolve the problem of accumulating waste coal heaps.

9. Waste coal use will bring social and environmental benefits to local residents and coal mine workers such as (i) creating new jobs during power plant construction, operation, and associated economic activities; (ii) eliminating harmful environmental contamination; and (iii) improving public health, including quality of water and air in and around the Pingshuo mining area.

III. THE TECHNICAL ASSISTANCE

A. Impact and Outcome

10. The impact of the TA will be reduced negative environmental impacts from waste coal heaps in Shanxi Province. The outcome of the TA will be a set of recommended policy measures to increase waste coal use in Shanxi Province.

B. Methodology and Key Activities

11. The TA will (i) provide a comprehensive utilization plan and policy recommendations for waste coal, (ii) introduce advanced energy-efficient technologies for waste coal power generation and a technical due diligence report for a 600-MW waste coal power plant utilizing CFBC technology with supercritical steam parameters, and (iii) disseminate knowledge on advanced energy-efficient technology for waste coal power generation.

12. The activities consist of two components.

(i) **Component A: Development of a comprehensive plan for waste coal use and policy recommendations, and introduction of advanced energy-efficient technologies.** This component will prepare a comprehensive utilization plan for waste coal for the Pingshuo coal mine in Shanxi Province. It will analyze existing policy and regulatory frameworks and make recommendations on policy measures to promote waste coal power generation. It will analyze (a) existing technology of 600-MW supercritical CFBC and its key components; (b) thermal design methods, hydrodynamic force calculation methods, technical feasibility of outside-sets of heat exchangers, and antirubbing technology for 600-MW supercritical CFBC chambers; and (c) boiler auxiliary equipment, its arrangement, and system for 600-MW CFBC within supercritical steam parameters.

(ii) **Component B**: **Management and knowledge dissemination.** This component will manage implementation of components A and B, prepare a policy note by ADB, and organize workshops with major provincial coal producers and government officials for knowledge dissemination.

C. Cost and Financing

13. The total cost of the TA is estimated at $650,000 equivalent. ADB's TA funding program (Technical Assistance Special Fund-Others) will finance, on a grant basis, $500,000. The Government will finance the remaining $150,000 equivalent through in-kind contributions. The proceeds of the TA will be disbursed in line with ADB's *Technical Assistance Disbursement Handbook.* [11] The cost estimates and financing plan are in Appendix 2.

[11] ADB. 2008. *Technical Assistance Disbursement Handbook*. Manila.

D. Implementation Arrangements

14. The TA will be implemented over a period of 11 months, from October 2009 to August 2010.

15. The Executing Agency (EA) will be the Shanxi Provincial Finance Bureau, and the implementing agency (IA) will be Pingshuo Waste Coal Power Generation Co. Ltd. Both the EA and IA will provide access to relevant data, reports, and information, and provide logistical support[12] and office space. For component B—a critical knowledge-sharing component of the TA design—all workshops, seminars, and conferences will be organized by the EA and IA in close consultation with ADB.

16. The TA will require 48 person-months of national consulting services. Required experts include a (i) coal engineer, (ii) economist, (iii) environment specialist, (iv) boiler design specialist, (v) thermodynamics specialist, (vi) dynamics specialist, (vii) clean combustion specialist, (viii) material specialist, (ix) CFBC boiler debugging specialist, and (x) CFBC boiler operation specialist. Since waste coal utilization for large-scale power generation is a unique local problem to PRC—especially Shanxi Province—there is abundant local knowledge and availability of national experts to undertake TA tasks. The outline terms of reference for consultants are in Appendix 3.

17. The TA is intended to be delegated to the EA and IA. The consulting firm will be recruited by the IA under the guidance of the EA in accordance with ADB's *Guidelines on the Use of Consultants* (2007, as amended from time to time) following quality- and cost-based selection in a quality–cost ratio of 80:20 for component A. A capacity assessment report was prepared for TA delegation and it concluded that the IA is capable of directly (i) managing the recruitment of consulting services, (ii) supervising the consultants, and (iii) administering the consulting services contract in accordance with ADB's policies, guidelines, and procedures. The capacity assessment report is in a supplementary appendix. Equipment will be procured in accordance with ADB's *Procurement Guidelines* (2007, as amended from time to time). Under Component B, a set of knowledge dissemination activities will be carried out by the EA and IA with prior approval and review by ADB.

18. At the end of the TA, a policy note will be prepared for the Shanxi provincial government. Knowledge dissemination, through workshops with major provincial coal producers and government officials, will be organized. The disclosure and transfer of the technical information regarding the TA should be made only after the review of the Government of the PRC.

IV. THE PRESIDENT'S DECISION

19. The President, acting under the authority delegated by the Board, has approved the provision of technical assistance not exceeding the equivalent of $500,000 on a grant basis to the Government of the People's Republic of China for Recycling Waste Coal for Power Generation, and hereby reports this action to the Board.

[12] Logistical support includes travel from Taiyuan City to the Pingshuo coal mine.

DESIGN AND MONITORING FRAMEWORK

Design Summary	Performance Targets and/or Indicators	Data Sources and/or Reporting Mechanisms	Assumptions and Risks
Impact Reduced negative environmental impacts from waste coal heaps in Shanxi Province	Demonstration project of 600-MW CFBC using waste coal implemented in Shanxi by 2012	Government statistical data Provincial data	**Assumptions** Government priorities are maintained regarding supporting large-scale, efficient, and environmentally friendly power plants that use waste coal. Required investments are made by the Government and enterprises. **Risk** • The 600-MW CFBC technology is not successfully demonstrated in Shanxi.
Outcome Recommend a set of policy measures to increase waste coal use in Shanxi Province	Recommendations accepted by the Shanxi provincial government by October 2010	Minutes of final tripartite meeting	**Assumption** Development of a 600-MW CFBC waste coal power plant with supercritical steam parameters is considered an appropriate approach by the provincial government.
Outputs 1. Comprehensive utilization plan and policy recommendations for waste coal are prepared. 2. Technical due diligence report for a 600-MW CFBC waste coal power plant with supercritical steam parameters is prepared. 3. Knowledge in advanced energy-efficient technology for waste coal power generation is widely disseminated.	The report is submitted to the EA, IA, and ADB in March 2010 The report is submitted to the EA, IA, and ADB in July 2010 A policy note is prepared in July 2010, and workshops are held in February, May, and July 2010	Minutes of tripartite meeting Minutes of tripartite meeting Minutes of final workshop	**Assumptions** The Government and Pingshuo Waste Coal Power Generation Co. Ltd. provide the necessary counterpart funding. Timely access to records, information, and personnel are provided by the EA and IA. Timely recruitment of consultant by the IA. **Risks** • Being the first technical approach for a 600-MW waste coal boiler, it may take longer to obtain stakeholders' support for the technical design. ▪ Being the first of the TAs delegated to Shanxi, the TA implementation and administration is slow.
Activities with Milestones **Component A** **1.1 Development of a comprehensive plan for waste coal use and policy recommendations** (October 2009–November 2009) 1.1.1 Analyze relevant policies and regulatory frameworks and identify barriers. 1.1.2 Identify resource conditions for waste coal use. 1.1.3 Conduct economic analysis of waste coal use.			**Inputs** ADB: $500,000 Government: $150,000

1.1.4 Establish a compliance mechanism for the implementation of the waste coal use plan. 1.1.5 Recommend reforms to remove barriers to large-scale waste coal power plants. **1.2 Introduction of advanced energy-efficient technologies** (October 2009–January 2010) 1.2.1 Analyze (i) existing technology of 600-MW supercritical CFBC and its key components; (ii) thermal design methods, hydrodynamic force calculation methods, technical feasibility of outside-sets of heat exchangers, and antirubbing technology for 600-MW supercritical CFBC chambers; and (iii) boiler auxiliary equipment, its arrangement, and system for 600-MW CFBC within supercritical steam parameters. 1.2.2 Prepare a comprehensive technical recommendation report of 2 x 600-MW supercritical CFBC and air-cooled generating sets. **Component B** **2.1 Management and knowledge dissemination** (October 2009–August 2010). 2.1.1 Manage implementation of component A. 2.1.2 Prepare policy note (February–July 2010). 2.1.3 Organize workshops with major provincial coal producers and government officials (February, May, and July 2010).	

ADB = Asian Development Bank, CFBC = circulating fluidized bed combustion, EA = executing agency, IA = implementing agency, MW = megawatt, TA = technical assistance.

COST ESTIMATES AND FINANCING PLAN
($'000)

Item	Total Cost
A. Asian Development Bank Financing[a]	
Component A	
1. Consultants	
a. Remuneration and Per Diem	
i. National Consultants	373.0
b. Local Travel	22.0
c. Reports and Communications	6.0
2. Equipment[b]	5.0
3. Miscellaneous Administration and Support Costs[c]	10.0
4. Contingencies	50.0
Component B[d]	
5. Training, Seminars, and Conferences	34.0
Subtotal (A)	**500.0**
B. Counterpart Financing	
1. Office Accommodation and Transport	30.0
2. Remuneration and Per Diem of Counterpart Staff	120.0
Subtotal (B)	**150.0**
Total	**650.0**

[a] Financed by the Asian Development Bank's technical assistance funding program (Technical Assistance Special Fund-others).

[b] Equipment includes computers and printers.

[c] Support costs include transportation costs.

[d] Component B is not part of consulting services. The executing and implementing agencies will plan and implement the conferences, subject to prior review and approval by the Asian Development Bank.

Source: Asian Development Bank estimates.

OUTLINE TERMS OF REFERENCE FOR CONSULTANTS

1. The study on recycling waste coal for power generation will require a total of 48 person-months of national consulting services for component A. The consultants will be recruited in accordance with the *Guidelines on the Use of Consultants* (2007, as amended from time to time) of the Asian Development Bank (ADB) and will work in close collaboration with the Shanxi provincial government to ensure effective knowledge transfer. The terms of reference will include, but not be limited to, the following.

A. Scope of Work

1. Comprehensive Plan for Waste Coal Use and Policy Recommendations

2. The team of consultants for this component will consist of (i) one coal engineer and team leader, (ii) one power economist (financial management), and (iii) one environment specialist. Each will be needed for 2 person-months on an intermittent basis. The team must have at least 5 years of experience in studying coal-based power generation. The consultants will

(i) identify resource conditions for waste coal use, including (a) physical-geographic conditions at the Pingshuo coal mine; (b) geologic features in the area (e.g., coal seams, coal quality, coal reserves, and coal mining); and (c) waste coal resources (e.g., outputs and grade of the waste coal);
(ii) identify key aspects of waste coal use, including (a) power generation at the Pingshuo coal mine, (b) construction materials, (c) chemical products, and (d) land reclamation;
(iii) conduct a benefit analysis of waste coal use, taking into account social benefits (e.g., employment generation and health impacts) and environmental benefits (e.g., reduction of waste coal heaps, raw coal production, carbon dioxide, sulfur dioxide, and nitrogen oxide, and improvement of ground water quality);
(iv) establish a compliance mechanism for the implementation of the waste coal use plan that includes (a) compliance with laws and regulations, (b) reinforcing implementation guidelines, (c) emphasizing technology innovation and advancement, and (d) improving incentives to comply with laws and regulations;
(v) recommend reforms to remove barriers to large-scale waste coal power plants; and
(vi) prepare a comprehensive plan and/or guidelines for waste coal use at the Pingshuo coal mine, and make the necessary policy recommendations.

2. Introduction of Advanced Energy-Efficient Technologies

3. The team of national consultants for this component will consist of a (i) boiler design specialist, (ii) thermodynamics specialist, (iii) dynamics specialist, (iv) clean combustion specialist, (v) material specialist, (vi) circulating fluidized bed combustion (CFBC) boiler debugging specialist, and (vii) CFBC boiler operation specialist. Each will be needed for 6 person-months on an intermittent basis. The team will have (i) at least 10 years of experience in designing and implementing CFBC boilers; (ii) grade-A certificates in manufacturing equipment, authorization in designing boilers at the national grade-A level, and designing and manufacturing pressurized containers at the national AR1 grade; and (iii) experience in designing or manufacturing 300-megawatt (MW) CFBC boilers. The consultants will

(i) review existing technology of 600-MW supercritical CFBC; research and develop its key components; and conduct a detailed feasibility analysis on these key components such as wind chambers, cloth air deflectors and wind hats, combustion chambers, separators, loop seals, outside-sets of heat exchangers, and air preheaters;

(ii) study thermal design methods, hydrodynamic force calculation methods, technical feasibility of outside-sets of heat exchangers, and antirubbing technology for 600-MW supercritical CFBC chambers, including (a) based on CFBC thermal design methods, conduct detailed analyses to identify advantages and difficulties of 600-MW supercritical CFBC thermal calculation technology, propose corresponding technical measures, complete thermal calculations for the boiler's technical design, and proof the accuracy of the result; (b) analyze the heat-current density distribution of combined large-scale CFBC, study 600-MW supercritical CFBC hydrodynamic force computational methods, conduct hydrodynamic force calculations to propose a boiler technical plan, and proof the accuracy of the results; (c) proof the technical maturity and feasibility of outside-sets of heat-exchanger technology, and prepare a technical design of outside-sets of heat exchangers; and (d) based on the analysis of the existing antirubbing technology, prepare a feasibility plan;[1]

(iii) research and develop the selection, allocation, and design of key auxiliary equipment[2] of 600-MW supercritical CFBC, including (a) based on the existing slag cooler technology, select design of a slag cooler, confirm its feasibility, and propose a layout plan; (b) propose an arrangement plan for the boiler's air blower system, analyze essential air blowers, select a design proposal for their regulation method, and confirm the feasibility; and (c) confirm feasibility to meet emission standards by adding limestone powder to the boiler for desulphurization, and propose a relevant technology plan;

(iv) prepare a comprehensive technical due diligence report of 2 x 600-MW supercritical CFBC and air-cooled generating sets.

B. Reports

4. The consultants will submit the following reports. One copy will go to ADB in English and two copies to the Government in Chinese.

(i) **Inception report.** It will be submitted within 4 weeks after commencement of services. The report includes a detailed work program plus any major inconsistencies in the terms of reference, staffing problems, or deficiencies in the assistance from the Executing Agency.

---

[1] The result of studies, such as thermal design and hydrodynamic force calculation, has to satisfy the boiler equipment safety in operation and reliability, outside-sets of the bed technology must meet the project application needs, and overhaul time of the antirubbing system for internal heating the chamber surface must be more than 4 years.

[2] Technical selection must meet the following criteria: (i) output per set of slag cooler is 40 tons per hour or more (when the ash-discharge temperature is 150º Celsius or less); (ii) main parameters, such as pressure heat and capacity of high-efficient primary air fans, meet the requirements of running generating set, the full voltage efficiency of the air fan is above 84%, the pressure coefficient is above 0.55, the pressure curve of the air fan is smooth, its high-efficiency area is wider, and the regulating performance is good; and (iii) efficiency of desulphurization is more than 90% (molar ratios of lime to sulfur: Ca/S<2.4).

(ii) **Interim report.** It will be submitted within 6 months after commencement of services. The report includes a preliminary result of activities, updated work program, and any issues and concerns.

(iii) **Draft final report.** It will be submitted within 10 months after commencement of services. Upon submission of the draft final report, a final workshop will be held, attended by relevant stakeholders, to obtain feedback on the report.

(iv) **Final report.** It will be submitted within 4 weeks after the receipt of comments from ADB and the Government on the draft final report. The final report will take into consideration the comments of ADB and the Government. A three-page policy note will also be included.

C. Government Contribution

5. The Government will provide (i) access to relevant data, reports, and information; and (ii) provide logistical support[3] and office space to the consultants.

[3] Logistical support includes travel from Taiyuan City to the Pingshuo coal mine.