ECONOMIC ANALYSIS

A. Introduction and Background

1. The Air Quality Improvement in the Greater Beijing–Tianjin–Hebei Region—Regional Emission-Reduction and Pollution-Control Facility (the facility) is the third in a set of multiyear projects by the Asian Development Bank (ADB) that seek to support air quality improvement in the greater Beijing–Tianjin–Hebei (BTH) region.[1] The facility will leverage financing and scale up investments in advanced technologies to reduce air pollution in areas such as agriculture, transport, and industry. China Energy Conservation and Environmental Protection Group (CECEP) will act as the executing agency. CECEP's majority-owned subsidiary, CECEP Huayu Fund Management Co., Ltd., will manage the facility.

2. The greater BTH region is one of the most important economic regions in the People's Republic of China (PRC), generating around one-third of the country's gross domestic product.[2] However, the region's economic growth has been based on energy-intensive and highly polluting industries and transport modes.[3] This led to substantially increased burning of fossil fuels such as coal and diesel, which emit particulate matter ($PM_{2.5}$). Coal-based energy-intensive industries are responsible for an estimated 54% of $PM_{2.5}$ emissions in the region.[4] The region's cities rank highest in the country for $PM_{2.5}$.[5] $PM_{2.5}$ poses severe health risks and contributes to more than one million premature deaths annually in the PRC.[6] Other pollutants emitted from coal and diesel burning—such as nitrogen oxides (NO_x), sulfur dioxide (SO_2), methane (CH_4), carbon dioxide (CO_2), and volatile organic compounds (VOCs)—pose a threat to human health, the local environment and to climate stability. Therefore, it is imperative that continued economic growth rely on clean, low-pollution technologies.

3. Six subprojects were selected as representative to be funded under the facility. These subprojects use advanced pollution-reduction technologies that have the potential to be scaled up across their respective industries. The subprojects' economic impact includes reduction of pollutants harmful to health and the human environment as well as reduced use of energy- and emission-intensive fuels and processes. The six subprojects are:

(i) **Advanced biogas and organic fertilizer**. The subproject plant will use anaerobic fermentation technology to digest livestock manure and straw to create biogas. The plant will divert agricultural waste away from environmentally harmful practices, such as open burning of straw and applying manure, which contribute to air pollution, eutrophication, and the potential for zoonosis. The biogas created will be used to replace diesel and petroleum in transport. Biogas residue and

[1] The greater BTH region refers to Beijing and Tianjin municipalities; Hebei, Henan, Shandong, Shanxi, and Liaoning provinces; and Inner Mongolia Autonomous Region.

[2] The greater BTH region accounts for more than 32% of national gross domestic product (CNY23.5 trillion in 2016).

[3] The region accounts for more than half of the PRC's highly energy- and pollution-intensive steel and cement production capacity, about one-third of PRC's cars and other automobiles, and heavy concentration of urban and rural housing and energy use because about 370 million of the PRC's 1.3 billion population live in the region.

[4] Bloomberg Philanthropies and Green Finance Committee of China Society for Banking and Finance. 2016. *Green Finance for Low Carbon Cities.* China.

[5] Air Quality Index (AQI) is a common measure of the quality of air and its potential health impacts. AQI includes consideration of six atmospheric pollutants: SO_2, NO_x, suspended particulates smaller than 10 micrometers in diameters (PM_{10}), $PM_{2.5}$, carbon monoxide, and ozone. In the PRC, the AQI is categorized from 50 (excellent) to 500 (severe pollution).

[6] G. Yang, et al. 2013. Rapid Health Transition in China, 1990–2010: Findings from the Global Burden of Disease Study. *The Lancet, Vol. 381.* Amsterdam, Netherlands: Elsevier.

slurry will be used to produce organic fertilizer, which will replace chemical fertilizer, a key contributor to soil denitrification and eutrophication.

(ii) **Industrial by-product gas utilization**. This subproject will construct an industrial by-product coke gas oven that converts coking gas from steel production to produce liquefied natural gas for transportation, thereby displacing diesel or petroleum use. Because the project uses an industrial by-product, it also reduces pollution from the combustion of coke gas by flaring.

(iii) **Smart industrial zone development.** The subproject will construct a smart micro-grid that integrates various renewable energies, energy storage, and energy management system technologies for an industrial zone. The smart micro-grid will replace coal-dominated grid electricity. It will comprise the following technologies: solar photovoltaic panels; gas-based tri-generation for heating, power, and cooling; battery storage systems; chilled water thermal storage systems; a linear Fresnal solar thermal heating system; and an air source heat pump. An energy management center will synchronize these technologies.

(iv) **Deep-well geothermal district heating system**. The subproject will construct a geothermal district heating system for certain residential areas in Dezhou City, Shandong Province. The subproject will substitute traditional coal-fired boilers for a centralized system based on a sustainable and renewable resource. It will include reinjection wells to ensure that the geothermal resource is exploited sustainably.

(v) **Hydrogen-based low-emission transport**. A fleet of hydrogen fuel cell buses will displace conventional diesel fuel buses. The subproject will not result in any direct energy savings because the hydrogen will be produced using surplus wind power. However, the hydrogen buses will replace diesel usage.

(vi) **Super energy service company.** A super energy service company (ESCO) will finance energy efficiency improvements and waste heat recovery for the iron and steel industry. The technologies proposed include a waste heat recovery system to reduce energy consumption from steel production; a water-source heat pump to increase the temperature of cooling water for space heating; a dry vacuum degassing system to reduce energy consumption from steel production; a set of magnets to reduce energy consumption of steel production; an annular cooler, heat recovery ventilator, dedusting fan, and main exhauster to reduce energy consumption for pellet production; and energy-efficient water pumps to reduce power consumption in steel production.

4. A complete description of subprojects can be found in Introduction of Technologies Used for Representative Subprojects.[7]

5. ADB and CECEP agreed on various economic viability criteria for the selection of subprojects, such as: (i) the total economic benefits must exceed the total economic costs; and (ii) the economic internal rate of return (EIRR) must be greater than the discount rate of 6%, assumed to be the social opportunity cost of capital, and must be viable under adverse sensitivity scenarios. CECEP will conduct an economic analysis like that done for the representative subprojects shown below for all subprojects selected under the facility.

[7] Introduction of Technologies Used for Representative Subprojects (accessible from the list of supplementary documents in Appendix 2 of the main text of the Report and Recommendation of the President).

B. Quantifying Project Benefits

6. **Economic benefits.** The economic benefits for the subprojects are incremental, non-incremental, and external. Incremental benefits such as better quality and reliability of heat supply (subproject 4) were not included in the economic analysis because it is not yet known how much demand will be truly incremental, and how much will be replaced. Non-incremental benefits included in the economic analysis are savings from less use of coal (subprojects 3, 4, and 6), diesel (subprojects 2 and 5), petroleum (subproject 1), and nitrogenous fertilizer (subproject 1), as well as the external benefits of reducing CO_2 emissions and local pollutants such as SO_2, VOCs, dust emissions, NO_x, and $PM_{2.5}$. Global environmental benefits from CO_2 abatement are valued at the 2016 global social cost of carbon of $36.30 per ton of CO_2, adjusted to 2017 price levels, and increased annually by 2% to reflect the potential increase in marginal social costs of climate change over time. Local environmental benefits from local pollutant emissions abatement is valued by estimating premature mortality effects (labor loss) associated with the pollutant emissions.[8] The cost of technology obsolescence and replacement, and costs associated with the diversion of production inputs were included in the analysis to capture the economic costs and benefits of the subprojects. Detailed supplementary materials that describe the economic analysis conducted for each subproject are discussed in the supplementary document.[9]

7. **External benefits from pollution abatement.** The subprojects reduce the amount of pollution that would have otherwise been caused by burning diesel and coal. These pollutant savings are of considerable benefit to human health and the environment. The pollution benefits are reduced at the same rates assumed for the energy efficiency or fuel efficiency factors. The assumptions for the economic cost of pollution avoided in each subproject is shown in Tables 1 and 2 below.

Table 1: External Environmental Benefits of the Subprojects

Subproject	Subproject Name	CO_2 Reduction (t)	SO_2 Reduction (t)	NO_x Reduction (t)
1	Fengqiu biomass	11,569.0	17.9	7.8
2	Liheng coke to gas plant	580,964.0	691.2	1,942.0
3	Jinan smart industrial zone	76,846.4	366.2	198.7
4	Luhai geothermal	35,237.9	140.5	122.0
5	Hydrogen fuel cell buses	16,663.7	0.5	197.8
6	An Steel ESCO	100,135.0	8,668.6	272.2
	Cost of pollutant (CNY/ton)	255	1,188	1,294

CO_2 = carbon dioxide, ESCO = energy service company, NO_x = nitrogen oxide, SO_2 = sulfur dioxide, t = ton.
Source: Pollution reduction—Asian Development Bank estimates; economic cost of pollutant—Asian Development Bank estimates, adjusted to 2017 prices.

[8] The estimated costs of premature mortality are calculated by multiplying the estimated mortality reduction effect of single pollutant emissions reductions by the net present value of lost wages per person and divided by total emission reductions. Reference emission levels were derived from EDGAR 4.3 and the Fast Scenario Screening Tool was used to evaluate the impact of pollutant dispersion on human health (effect of single pollutant emission reductions). The age of premature mortality was derived from the Global Health Data Exchange tool.

[9] Detailed Economic Analysis on the Representative Subprojects (accessible from the list of supplementary documents in Appendix 2 of the main text of the Report and Recommendation of the President).

Table 2: External Environmental Benefits of the Subprojects Continued

Subproject	Subproject Name	PM Reduction (t)	CO Reduction (t)	HC Reduction (t)
1	Fengqiu biomass	0.12	114.2	6.1
2	Liheng coke to gas plant	48.6	29.7	15.8
3	Jinan smart industrial zone	385.5	0	0
4	Luhai geothermal	4.9	0	0
5	Hydrogen fuel cell buses	7.7	59.4	3.2
6	An Steel ESCO	1,464.6	0	0
	Cost of pollutant (CNY/ton)	1,292	0	30

CO = carbon monoxide, ESCO = energy service company, HC = hydrocarbon, PM = particulate matter, t = ton.
Note: Air pollution valuation estimates revealed no mortality effect from CO reduction.
Source: Asian Development Bank estimates.

C. Economic Costs

8. Financial cost estimates were adjusted to economic costs by eliminating price contingencies and transfer payments such as taxes and financial charges (interest during construction and working capital), and applying shadow pricing. The life of all subprojects (except subproject 6) ranges from 8 to 35 years, consistent with the installations' technical useful life. The residual value at the end of their project life is assumed to be zero. The estimated economic life of subproject 6 is 10 years. Because the value of this subproject's assets will not be fully worn out by the estimated technical life of the subproject (15 years), the residual value at the end of its project life was calculated and included as a negative investment cost. All prices and costs are expressed in real values at the domestic level–2017 prices. Physical contingencies are included for civil works with an allowance of 10%.

9. Most capital costs (90%) and operating costs were assumed to consist of traded goods or services. The financial costs of traded goods were adjusted to economic costs by adjusting domestic prices with a shadow exchange rate factor of 1.01371, the multiplicative inverse of standard conversion factors used for recent ADB projects in the PRC.[10] Most labor inputs (80%) were assumed to come from skilled labor. A shadow wage rate factor of 0.8 was applied to unskilled labor, given the PRC's surplus of unspecialized labor (a factor of 1 was used for skilled labor).

D. Estimation of the Economic Internal Rate of Return

10. Tables 3–5 show the EIRRs for the representative subprojects, all of which exceed the economic opportunity cost of capital of 6% when global environmental benefits are considered. Table 3 shows the results of the analysis.

Table 3: Net Economic Benefits of Subprojects
(CNY million)

	Subproject					
	1	2	3	4	5	6
ENPV – with global environmental benefits	88.28	1,581.62	64.91	39.30	30.82	298.06

[10] ADB. 2011. *Report and Recommendation of the President to the Board of Directors: Proposed Loan to the People's Republic of China for the Hebei Energy Efficiency Improvement and Emission Reduction Project.* Manila; and ADB. 2011. *Report and Recommendation of the President to the Board of Directors: Proposed Loan to the People's Republic of China for the Shandong Energy Efficiency and Emission Reduction Project.* Manila.

ENPV – without global environmental benefits	66.49	498.38	(169.96)	(75.67)	3.24	98.38
EIRR (%) – with global environmental benefits	22.07	43.16	7.49	9.23	14.86	44.00
EIRR (%)– without global environmental benefits	18.86	28.58	1.05	(6.88)	7.01	20.52

() = negative, EIRR = economic internal rate of return, ENPV = economic net present value.
Source: Asian Development Bank estimates.

E. Sensitivity Analysis

11. Estimated EIRRs were tested in a sensitivity analysis because the assumptions used in the base case analysis are subject to uncertainty. The EIRRs of the subprojects are most sensitive to increases in the expected capital expenditure and operating costs, and the expected value of emission reductions. As Table 4 shows, the subprojects' EIRRs are well above the social opportunity cost of capital even with substantial increases in capital expenditure and operation and maintenance costs, and substantial reductions in the value of CO_2 emission reductions. The exceptions are (i) subproject 3, whose EIRR falls below the social opportunity cost of capital when capital costs are increased; and (ii) subproject 5, whose EIRR falls below the social cost of capital when there is a large increase in operating costs. Table 5 shows the sensitivities of the subprojects' EIRRs when global environmental benefits (CO_2) are excluded. The EIRRs for subprojects 1 and 6 remain above the 6% social cost of capital under both sensitivity scenarios. The EIRR for subproject 1 falls below the threshold when operating costs are increased, and the EIRRs for subprojects 2 and 5 fall below the threshold with increases in either capital or operating costs. The EIRR for subproject 4 is negative when global environmental benefits are excluded.

Table 4: Sensitivity Analysis of the Economic Internal Rate of Return, Including Global Environmental Benefits (%)

Subproject	Subproject Name	Base Case	Case 1: CAPEX +20%	Case 2: OPEX +20%	Case 3: Price of CO_2 –20%
1	Fengqiu biomass	22.07	15.88	10.23	22.01
2	Liheng coke to gas	43.16	36.94	41.04	40.55
3	Jinan smart industrial zone	7.49	5.72	7.32	7.03
4	Luhai geothermal	9.23	7.22	7.07	7.40
5	Hydrogen fuel cell buses	14.86	6.06	1.47	13.37
6	An Steel ESCO	44.00	36.02	42.02	39.57

CAPEX = capital expenditure, CO_2 = carbon dioxide, ESCO = energy service company, OPEX = operating expenditure.
Source: Asian Development Bank estimates.

Table 5: Sensitivity Analysis of the Economic Internal Rate of Return, Without Global Environmental Benefits (%)

Subproject	Subproject Name	Base Case	Case 1: CAPEX +20%	Case 2: OPEX +20%
1	Fengqiu biomass	18.86	12.92	3.60
2	Liheng coke to gas	28.58	22.97	25.38
3	Jinan smart industrial zone	1.05	(0.32)	0.78
4	Luhai Geothermal	(6.88)	(8.56)	(6.14)
5	Hydrogen fuel cell buses	7.01	(0.70)	(9.89)
6	An Steel ESCO	20.52	15.52	18.17

() = negative, CAPEX = capital expenditure, ESCO = energy service company.
Source: Asian Development Bank estimates.