

ECONOMIC ANALYSIS

1. The economic analysis of the Shanxi Energy Efficiency and Environment Improvement Project was conducted in accordance with the Guidelines for the Economic Analysis of Projects (1997) of the Asian Development Bank (ADB). The analysis was done for the four district heating subprojects under part A and one coal-mine methane (CMM) gas supply and distribution subproject under part B.

A. General Assumptions for Economic Analysis

2. Incremental costs and benefits are estimated by comparing with-project and without-project scenarios for each subproject and the project as a whole. For each subproject, economic analysis was conducted for the project lifespan of 25 years, including the construction period of 4–5 years. The residual value at the end of the project life is assumed to be zero. All prices and costs are expressed in 2011 prices and in the domestic currency. A discount rate of 12% per annum is assumed. The capital costs are adjusted to eliminate price contingencies, interest during construction, and taxes,¹ but physical contingencies are included. Tradable commodities are valued at border prices at the prevailing exchange rate. Non-tradable commodities are valued by applying a standard conversion factor of 0.987 and the following specific conversion factors: 1.0 for equipment, 1.0 for skilled labor, and 0.67 for unskilled labor.²

3. For the economic analysis, the baseline scenario (without project) was defined for the district heating subprojects as follows: existing small boilers and single-family stoves will remain in use to serve existing heating demand, and new and small heat-only boilers will be installed to serve the incremental heating demand. For the CMM subproject, under the baseline scenario, the customers use coal as fuel for domestic use and space heating, and electricity for chillers.

B. Economic Costs

4. The financial capital costs are converted to the relevant economic values after deducting taxes, subsidies, and price contingencies, then applying the respective conversion factors as specified in the general assumptions. The capital costs of district heating include costs related to boilers, pipelines, heat exchange stations, other associated costs, and physical contingency. The capital costs of CMM supply include costs related to the construction and installation of the gas supply system and gas storage station, gas distribution pipelines, and other capital investments. These costs occur primarily during the construction period within the first 4–5 years of the project. The operation and maintenance (O&M) costs, assumed to remain constant in real terms, comprise costs for maintenance, raw materials, energy inputs, salaries, overhead, and administration expenses. The O&M costs occur throughout the lifespan of each subproject.

C. Economic Benefits

5. The economic benefits for the four district heating subprojects include (i) improvements in heating efficiency from coal savings after conversion from small boilers and single-family stoves to large boilers, multiplied by the economic coal price, for the existing heating area;³ (ii) incremental heating revenues (willingness to pay) due to expansion of the heating area; and (iii) environmental benefits, which are reflected in the reduction of environmental costs from the

¹ The taxes are assumed to be 25% for income tax, 17% for local value-added tax, and 5% for construction tax.

² These conversion factors were consistently used for recently approved energy projects in the PRC.

³ Jinzhong, Licheng and Qin District Heating subprojects will use pulverized coal-fired boilers with combustion efficiency assumed at 88%, which is higher than that of the existing boilers (65%). Zhongyang District Heating subproject will use the chain-grate stoker boiler, which has about 80% combustion efficiency.

new boilers relative to the old boiler system (the baseline scenario). For the CMM subproject (Part B), the economic benefits include reduction of coal consumption for the existing heating area, incremental CMM use for new heating areas, cooking and space cooling in buildings, and environmental improvement through reduction of environmental costs from pollutant emissions.

6. The project will generate considerable environmental benefits through the reduction of pollutant emissions. The total energy saved from all subprojects (part A and part B) is estimated at 85,390 tons of standard coal equivalent per year, which translates to an annual emission reduction of 254,379 tons of carbon dioxide, 4,121 tons of sulfur dioxide, 1,942 tons of nitrogen oxides, and 6,494 tons of particulate matter. The capture of CMM for use in the project will avoid its release into the atmosphere. This is equivalent to an additional 764,568 tons per year of carbon dioxide emissions. However, this benefit has not been considered in the benefit valuation as the associated costs for the CMM capture are not known, this not being a part of the project scope. The economic evaluation of the environmental impact is based on the benefits transfer method described in ADB's *Workbook on Economic Evaluation of Environmental Impacts (1996)*. The consolidated economic net present value (ENPV) of the emission reduction is estimated at CNY142.6 million for the whole project.

D. Estimation of the Economic Internal Rate of Return

7. Results of the economic analysis have been presented in the key economic indicators, such as the economic internal rate of return (EIRR) and the ENPV of each subproject, and the consolidated result for all subprojects. The projected EIRRs are high but regarded as conservative, as they take into account only the main benefits of different components and include all project-related costs. The EIRRs for the subprojects range from 13.0% to 22.6% without the environmental benefits. The EIRR of the whole project without environmental benefits is 15.0%, which is greater than the 12% economic cost of capital (discount rate). The ENPV of the whole project is CNY146.1 million without environmental benefits. The combined economic benefits and costs of the five subprojects are in Table 1.

Table 1: Economic Internal Rate of Return for the Overall Project
(CNY million)

| Year | Capital Cost | Operating Cost | Economic Benefits | Environmental Benefits | Net Economic Benefits without Environmental Benefits | Net Economic Benefits with Environmental Benefits |
|------|--------------|----------------|-------------------|------------------------|--|---|
| 2012 | (181.0) | 0.0 | 0.0 | 0.0 | (181.0) | (181.0) |
| 2013 | (328.1) | (47.4) | 96.7 | 8.2 | (278.9) | (270.6) |
| 2014 | (299.5) | (84.9) | 190.8 | 15.3 | (193.6) | (178.3) |
| 2015 | (181.4) | (111.3) | 244.9 | 20.1 | (47.9) | (27.8) |
| 2016 | (22.1) | (124.7) | 272.6 | 23.4 | 125.8 | 149.2 |
| 2017 | 0.00 | (124.7) | 272.6 | 23.4 | 147.9 | 171.3 |
| 2018 | 0.00 | (124.7) | 272.6 | 23.4 | 147.9 | 171.3 |
| 2019 | 0.00 | (124.7) | 272.6 | 23.4 | 147.9 | 171.3 |
| 2020 | 0.00 | (124.7) | 272.6 | 23.4 | 147.9 | 171.3 |
| 2021 | 0.00 | (124.7) | 272.6 | 23.4 | 147.9 | 171.3 |
| 2022 | 0.00 | (124.7) | 272.6 | 23.4 | 147.9 | 171.3 |
| 2023 | 0.00 | (124.7) | 272.6 | 23.4 | 147.9 | 171.3 |
| 2024 | 0.00 | (124.7) | 272.6 | 23.4 | 147.9 | 171.3 |
| 2025 | 0.00 | (124.7) | 272.6 | 23.4 | 147.9 | 171.3 |
| 2026 | 0.00 | (124.7) | 272.6 | 23.4 | 147.9 | 171.3 |
| 2027 | 0.00 | (124.7) | 272.6 | 23.4 | 147.9 | 171.3 |
| 2028 | 0.00 | (124.7) | 272.6 | 23.4 | 147.9 | 171.3 |
| 2029 | 0.00 | (124.7) | 272.6 | 23.4 | 147.9 | 171.3 |
| 2030 | 0.00 | (124.7) | 272.6 | 23.4 | 147.9 | 171.3 |
| 2031 | 0.00 | (124.7) | 272.6 | 23.4 | 147.9 | 171.3 |

| Year | Capital Cost | Operating Cost | Economic Benefits | Environmental Benefits | Net Economic Benefits without Environmental Benefits | Net Economic Benefits with Environmental Benefits |
|------|--------------|----------------|-------------------|------------------------|--|---|
| 2032 | 0.00 | (124.7) | 272.6 | 23.4 | 147.9 | 171.3 |
| 2033 | 0.00 | (124.7) | 272.6 | 23.4 | 147.9 | 171.3 |
| 2034 | 0.00 | (124.7) | 272.6 | 23.4 | 147.9 | 171.3 |
| 2035 | 0.00 | (124.7) | 272.6 | 23.4 | 147.9 | 171.3 |
| 2036 | 0.00 | (124.7) | 272.6 | 23.4 | 147.9 | 171.3 |
| | | | Base Case | EIRR (%) | 15.0 | 17.9 |
| | | | | ENPV | 146.1 | 288.6 |

() = negative, CNY = yuan, EIRR = economic internal rate of return, ENPV = economic net present value.

Source: Asian Development Bank estimates.

8. The consolidated economic result of the four subprojects under part A is in Table 2. The consolidated EIRR for part A without environmental benefits is 14.6%.

Table 2: Economic Internal Rate of Return for Part A
(CNY million)

| Year | Capital Cost | Operating Cost | Economic Benefits | Environmental Benefits | Net Economic Benefits without Environmental Benefits | Net Economic Benefits with Environmental Benefits |
|------|--------------|----------------|-------------------|------------------------|--|---|
| 2011 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 2012 | (167.6) | 0.0 | 0.0 | 0.0 | (167.6) | (167.6) |
| 2013 | (295.0) | (27.2) | 70.5 | 3.6 | (251.7) | (248.1) |
| 2014 | (266.1) | (56.3) | 151.6 | 8.4 | (170.8) | (162.5) |
| 2015 | (146.4) | (74.4) | 192.5 | 10.9 | (28.3) | (17.4) |
| 2016 | (22.1) | (79.3) | 207.2 | 11.9 | 105.8 | 117.7 |
| 2017 | 0.0 | (79.3) | 207.2 | 11.9 | 127.8 | 139.7 |
| 2018 | 0.0 | (79.3) | 207.2 | 11.9 | 127.8 | 139.7 |
| 2019 | 0.0 | (79.3) | 207.2 | 11.9 | 127.8 | 139.7 |
| 2020 | 0.0 | (79.3) | 207.2 | 11.9 | 127.8 | 139.7 |
| 2021 | 0.0 | (79.3) | 207.2 | 11.9 | 127.8 | 139.7 |
| 2022 | 0.0 | (79.3) | 207.2 | 11.9 | 127.8 | 139.7 |
| 2023 | 0.0 | (79.3) | 207.2 | 11.9 | 127.8 | 139.7 |
| 2024 | 0.0 | (79.3) | 207.2 | 11.9 | 127.8 | 139.7 |
| 2025 | 0.0 | (79.3) | 207.2 | 11.9 | 127.8 | 139.7 |
| 2026 | 0.0 | (79.3) | 207.2 | 11.9 | 127.8 | 139.7 |
| 2027 | 0.0 | (79.3) | 207.2 | 11.9 | 127.8 | 139.7 |
| 2028 | 0.0 | (79.3) | 207.2 | 11.9 | 127.8 | 139.7 |
| 2029 | 0.0 | (79.3) | 207.2 | 11.9 | 127.8 | 139.7 |
| 2030 | 0.0 | (79.3) | 207.2 | 11.9 | 127.8 | 139.7 |
| 2031 | 0.0 | (79.3) | 207.2 | 11.9 | 127.8 | 139.7 |
| 2032 | 0.0 | (79.3) | 207.2 | 11.9 | 127.8 | 139.7 |
| 2033 | 0.0 | (79.3) | 207.2 | 11.9 | 127.8 | 139.7 |
| 2034 | 0.0 | (79.3) | 207.2 | 11.9 | 127.8 | 139.7 |
| 2035 | 0.0 | (79.3) | 207.2 | 11.9 | 127.8 | 139.7 |
| 2036 | 0.0 | (79.3) | 207.2 | 11.9 | 127.8 | 139.7 |
| | | | Base Case | EIRR (%) | 14.6 | 16.2 |
| | | | | ENPV | 111.9 | 185.0 |

() = negative, CNY = yuan, EIRR = economic internal rate of return, ENPV = economic net present value.

Source: Asian Development Bank estimates.

9. Table 3 summarizes the EIRR and ENPV of the CMM subproject (part B). Part B is economically viable since it shows a higher EIRR (18.3%) than the 12% economic cost of capital (discount rate).

Table 3: Economic Internal Rate of Return for Part B
(CNY million)

| Year | Capital Cost | Operating Cost | Economic Benefits | Environmental Benefits | Net Economic Benefits without Environmental Benefits | Net Economic Benefits with Environmental Benefits |
|------|--------------|----------------|-------------------|------------------------|--|---|
| 2011 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 2012 | (13.4) | 0.0 | 0.0 | 0.0 | (13.4) | (13.4) |
| 2013 | (33.1) | (20.2) | 26.2 | 4.6 | (27.2) | (22.6) |
| 2014 | (33.4) | (28.6) | 39.3 | 6.9 | (22.7) | (15.9) |
| 2015 | (35.0) | (37.0) | 52.4 | 9.2 | (19.6) | (10.5) |
| 2016 | 0.0 | (45.4) | 65.4 | 11.5 | 20.1 | 31.5 |
| 2017 | 0.0 | (45.4) | 65.4 | 11.5 | 20.1 | 31.5 |
| 2018 | 0.0 | (45.4) | 65.4 | 11.5 | 20.1 | 31.5 |
| 2019 | 0.0 | (45.4) | 65.4 | 11.5 | 20.1 | 31.5 |
| 2020 | 0.0 | (45.4) | 65.4 | 11.5 | 20.1 | 31.5 |
| 2021 | 0.0 | (45.4) | 65.4 | 11.5 | 20.1 | 31.5 |
| 2022 | 0.0 | (45.4) | 65.4 | 11.5 | 20.1 | 31.5 |
| 2023 | 0.0 | (45.4) | 65.4 | 11.5 | 20.1 | 31.5 |
| 2024 | 0.0 | (45.4) | 65.4 | 11.5 | 20.1 | 31.5 |
| 2025 | 0.0 | (45.4) | 65.4 | 11.5 | 20.1 | 31.5 |
| 2026 | 0.0 | (45.4) | 65.4 | 11.5 | 20.1 | 31.5 |
| 2027 | 0.0 | (45.4) | 65.4 | 11.5 | 20.1 | 31.5 |
| 2028 | 0.0 | (45.4) | 65.4 | 11.5 | 20.1 | 31.5 |
| 2029 | 0.0 | (45.4) | 65.4 | 11.5 | 20.1 | 31.5 |
| 2030 | 0.0 | (45.4) | 65.4 | 11.5 | 20.1 | 31.5 |
| 2031 | 0.0 | (45.4) | 65.4 | 11.5 | 20.1 | 31.5 |
| 2032 | 0.0 | (45.4) | 65.4 | 11.5 | 20.1 | 31.5 |
| 2033 | 0.0 | (45.4) | 65.4 | 11.5 | 20.1 | 31.5 |
| 2034 | 0.0 | (45.4) | 65.4 | 11.5 | 20.1 | 31.5 |
| 2035 | 0.0 | (45.4) | 65.4 | 11.5 | 20.1 | 31.5 |
| 2036 | 0.0 | (45.4) | 65.4 | 11.5 | 20.1 | 31.5 |
| | | | Base Case | EIRR (%) | 18.3 | 31.3 |
| | | | | ENPV | 34.2 | 103.7 |

() = negative, CNY = yuan, EIRR = economic internal rate of return, ENPV = economic net present value.

Note: For the EIRR calculation, a greenhouse gas (GHG) savings amount of 121,021 tons of carbon dioxide per year (tCO₂/yr) was used for the CMM subproject, which is derived based on a comparison of the baseline GHG production from burning coal (189,468 tCO₂/yr) compared with GHG emissions from burning 88.8 million cubic meters of CMM (68,447 tCO₂/yr). The potential impact from the release to the atmosphere of the 88.8 million cubic meters of CMM (764,567 tCO₂/yr) was not included in the EIRR calculation, as the associated costs for the CMM capture are not known.

Source: Asian Development Bank estimates.

10. The EIRRs and ENPVs of each subproject were also calculated with the environmental benefits. Table 4 summarizes the EIRR and ENPV of each subproject with and without environmental benefits.⁴

⁴ The environmental benefits of reducing CO₂ and SO₂ emissions were estimated using the marginal abatement cost as a proxy for the economic benefits of emission reduction. The marginal abatement cost estimate for CO₂ (\$12/t) is based on the prevailing market price for Clean Development Mechanism credits and the marginal abatement cost of SO₂ (\$160/t) is based on the domestic market price for SO₂ abatement in PRC.

Table 4: Economic Internal Rate of Return and Economic Net Present Value

| Subprojects | Without Environmental Benefits | | With Environmental Benefits | |
|---|--------------------------------|-----------------------|-----------------------------|-----------------------|
| | EIRR (%) | ENPV (CNY million) | EIRR (%) | ENPV (CNY million) |
| Part A | | | | |
| Jinzhong District Heating | 14.4 | 52.4 | 15.6 | 77.8 |
| Licheng District Heating | 15.6 | 25.4 | 19.3 | 51.3 |
| Qin District Heating | 13.0 | 12.4 | 14.4 | 30.2 |
| Zhongyang District Heating ⁵ | 22.6 | 21.7 | 24.6 | 25.8 |
| Part B | | | | |
| Liulin CMM | 18.3 | 34.2 | 31.3 | 103.7 |
| Total (A+B) | 15.0 | 146.1 | 17.9 | 288.6 |

CNY = yuan, EIRR = economic internal rate of return, ENPV = economic net present value.

Source: Asian Development Bank estimates.

11. The environmental benefits improve the overall economic viability of the subprojects considerably. Even without environmental benefits, the subprojects are robust in their economic viability; e.g., at 15.0%, the overall EIRR is still considerably higher than the economic discount factor of 12%.

E. Sensitivity Analysis

12. Sensitivity analysis was performed to test the EIRR's sensitivity to certain changes in parameters. This showed that the EIRR with environmental benefits could fall to (i) 14.5% if all the economic benefits were reduced by 10%, (ii) 15.9% if the subprojects experienced a cost overrun of 10%, (iii) 16.3% if the O&M costs rose by 10%, and (iv) 15.6% if the project implementation was delayed by 1 year (Table 5). Under these sensitivity scenarios, the EIRR will still be greater than the economic discount rate of 12%.

Table 5: Sensitivity Analysis of the Economic Internal Rate of Return

| Case | Base Case with Environmental Benefits | Case 1 Economic Benefits -10% | Case 2 Project Cost +10% | Case 3 O&M Cost +10% | Case 4 1-Year Delay |
|----------------------------|--|--|--------------------------------|----------------------------|---------------------------|
| Part A: | | | | | |
| Jinzhong District Heating | 15.6 | 12.7 | 13.8 | 14.5 | 13.4 |
| Licheng District Heating | 19.3 | 15.4 | 17.1 | 17.4 | 16.7 |
| Qinxian District Heating | 14.4 | 12.1 | 12.9 | 13.6 | 12.5 |
| Zhongyang District Heating | 24.6 | 20.8 | 22.0 | 23.5 | 21.6 |
| Part B: | | | | | |
| Liulin CMM | 31.3 | 23.7 | 28.0 | 25.9 | 27.5 |
| Total (A+B) | 17.9 | 14.5 | 15.9 | 16.3 | 15.6 |

O&M = operation and maintenance.

Source: Asian Development Bank estimates.

⁵ Unlike other subprojects, required civil works were already completed as part of the earlier phase of district heating development in Zhongyang. This subproject will be constructed on existing infrastructure, hence its economic costs are lower than those of other subprojects.