People's Republic of China

FY2018 Ex-Post Evaluation of Japanese ODA Loan

"Gansu Province Lanzhou City Atmospheric Environmental Improvement Project"

External Evaluator: Hiromi Suzuki S., IC Net Limited

## 0. Summary

This project was implemented under the objective to mitigate the burden of air pollution by suppressing pollution emission resources through the removal small coal boilers that are not equipped with dust collectors and desulfurization equipment and developing a centralized heat supply facility in Lanzhou City, Gansu Province of the People's Republic of China, thereby contributing to the improvement of the living environment of the said city. This project was fully consistent with the development and environmental protection plans, and the development needs of China, and Lanzhou City, Gansu Province at the time of the appraisal and the ex-post evaluation, as well as Japan's ODA policy at the time of the appraisal; therefore, the relevance of the project is high. As for the output, there were slight increases and decreases, and since both project cost and project period surpassed the plan, the efficiency of the project is medium. Regarding the project's outcome "to mitigate the air pollution burden through suppression of pollutant emission sources," the main indicators of reduction in the emissions of sulfur dioxide ($SO_2$), nitrogen oxides ($NO_x$), and total suspended particles (TSP), achieved their goals, and all auxiliary indicators show a tendency toward improvement, thus the project was highly effective. Regarding the impact which is "to improve resident's living environment," the project contributed to improve residents' living environment by prompting all small coal-burning boilers to shift to centralized heat supply in the project target area. Land acquisition was less than the area planned at the time of the appraisal, and was conducted appropriately, forcing no resettlement of residents. Regarding impact on the natural environment during the construction and at the time of the ex-post evaluation, appropriate measures were taken, and monitoring was conducted properly, and results indicated that there was no negative impact. Based on the above, the effectiveness and impact of the project is high as the intended project results were achieved. The systems, technology, finance, and maintenance management at Lanzhou West-East Heat Transmission Co., Ltd., and Lanzhou Fanping Thermal Network Co., Ltd, both of which are responsible for the operation and maintenance management of the project, were generally favorable, and the sustainability of effects brought by the project is high.

In light of the above, this project is evaluated to be highly satisfactory.

## 1. Project Description


Project Location

Heat exchange station developed by the project (Qilihe District)

### 1.1 Background[1]

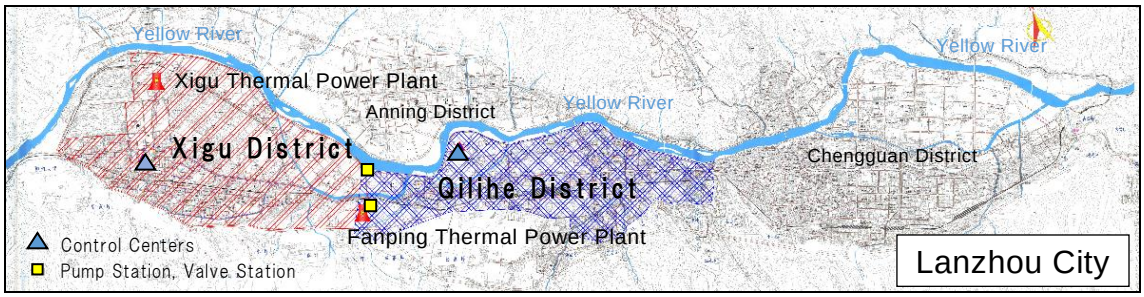
In early 2005, because approximately 69% of China's domestic consumption of energy depended on coal, it was suffering from serious air pollution caused by sulfur oxide (SOx), dust, etc. Taking these circumstances into account, the Chinese government set a goal of reducing emissions of principal pollutants, prohibited construction of new coal-burning thermal power plants in cities, and promoted construction of co-generation and centralized heat supply facilities.

Gansu Province was especially one of the most serious areas of air pollution at the national level, as energy consumption increased rapidly with rapid economic growth and about 70% of its resources depended on coal. In particular, Lanzhou City, the provincial capital, which is the target area of this project, used more than 2,000 small coal boilers for district heating in the winter season. These facilities were a major source of air pollution due to the lack of dust collectors and desulfurizers. Due to the rapid development of the city, if these were left unattended, there were concerns about further pollution caused by the installation of a large amount of small coal boilers every year in addition to the contamination caused by the existing facilities. In addition, the city is located in a valley surrounded by mountains along the Yellow River, which results in a location condition that makes it difficult for the polluted air to diffuse, thus improving the air environment had become an urgent issue. In light of these circumstances, the Lanzhou City People's Government was planning to improve the air environment of the city by improving the spread of centralized heat supply facilities, prohibiting the construction of new small coal boilers, and removing existing small coal boilers. This project aimed to introduce a centralized heat supply facility to replace small coal boilers and was expected to reduce the amount of emissions of air pollutants.

[1] Based on documents provided by JICA and the ex-ante evaluation table.

### 1.2 Project Outline

The objective of this project is to mitigate the burden of air pollution in the district of Xigu and Qilihe (West area and Southeast area[2]) of Lanzhou City, Gansu Province, by mitigating the air pollution load through the suppression of pollution emission resources by removing small coal boilers that are not equipped with dust collectors and desulfurization equipment, and by developing a centralized heat supply facility, thereby contributing to the improvement of the living environment of the said city.




Source: Documents provided by the executing agency.

Fig. 1 Lanzhou City: Central Heating Supply Area of the Project

| | | |
|---|---|---|
| Loan Approved Amount/ Disbursed Amount | 7,400 million yen/7,292 million yen | |
| Exchange of Notes Date/ Loan Agreement Signing Date | December 2007/December 2007 | |
| Terms and Conditions | Interest rate<br>Repayment Period<br>(Grace Period<br>Conditions for Procurement | 0.65%<br>40 years<br>40 years)<br>General Untied |
| Borrower / Executing Agencies | People's Republic of China/People's Government of Gansu Province (Finance Agency), Lanzhou Thermal Power Co. | |
| Project Completion | April 2016 | |
| Target Area | Gansu Province Lanzhou City (Xigu District, West Qilihe District, Southeast Qilihe District) | |
| Main Contractors (Over 1 billion yen) | Jiansu Sainty Machinery Import & Export Corp. Ltd. (People's Republic of China), Haotian Energy Conservation Equipment Co., Ltd. (People's Republic of China) | |
| Related Studies (Feasibility Studies, etc.) | F/S: CSCEC AECOM Consultants Co., Ltd. | |
| Related Projects | Japanese ODA Loan: "Lanzhou Environmental Improvement Project" (L/A signed in 1996) | |

[2] In the appraisal documents including the ex-ante evaluation table, it is referred to as "Dongcheng area." However, officially there is no area under such a name, and it indicates the Southeast area of Qilihe District. According to the executing agency, "Dongcheng area" was used to differentiate it from the West area of Qilihe District, as the development of the centralized heat supply in the Southeast area of Qilihe District was conducted based on the concept of "sending the heat from the west to the east." In this ex-post evaluation, as a result of discussions with the executing agency, the names were unified in "Qilihe District West area" and "Qilihe District Southeast area."

## 2. Outline of the Evaluation Study

### 2.1 External Evaluator

Hiromi Suzuki S., IC Net Limited

### 2.2 Duration of Evaluation Study

This ex-post evaluation study was conducted with the following schedule.

Duration of the Study: February 2019-January 2020

Duration of the Field Study: April 7-30, 2019 and August 17-24, 2019

## 3. Results of the Evaluation (Overall Rating: A[3])

### 3.1 Relevance (Rating: ③[4])

3.1.1 Consistency with the Development Plan of China

A) Development Plans

The national development plan at the time of the appraisal of the project was the *Eleventh Five-Year Plan on National Economic and Social Development (2006-2010)*. The plan aimed to reduce 20% of energy consumption per GDP by 2010 compared to 2005, and similarly 10% of air pollutants $SO_2$ and NOx, respectively, by promoting the replacement of existing energy with renewable energy. The national development plan at the time of the ex-post evaluation, was the *Thirteenth Five-Year Plan on National Economic and Social Development (2016-2020)*. The plan aims to reduce energy consumption per GDP by 15% compared to that of 2010 by 2020, through strengthening construction of urban infrastructure facilities, including combined heat and power systems, clean energy heat supply systems, and centralized heat supply. Specifically, it aimed to cut back emissions of carbon dioxide ($CO_2$) per unit of GDP by 18% compared to the actual value of 2010, and of $SO_2$ and NOx by 15% compared to the actual values of 2015.

Gansu Province's development plan at the time of the appraisal was the *Gansu Eleventh Five-Year Plan on Economic and Social Development (2006-2010)*, which aims to improve the air quality of the city through the promotion of centralized heat

[3] A: Highly satisfactory, B: Satisfactory, C: Partially satisfactory, D: Unsatisfactory

[4] ③: High, ②: Fair, ①: Low

supply, so that the air quality of the province will reach Grade 2[5] of the "National Ambient Air Quality Standards (GB3095-1996)." Gansu Province's development plan at the time of the ex-post evaluation is the *Gansu Thirteenth Five-Year Plan on Economic and Social Development (2016-2020)*, which aims to strictly adhere to the "National Ambient Air Quality Standards (GB3095-2012)" Grade 2 (See Footnote 5) and to expand the central heat supply area to 180 million square meters by switching from small coal boilers to clean energy, promoting centralized heat supply facilities, and continuing to develop heating supply business with new energy.

As described above, at the time of both appraisal and ex-post evaluation, the project objective was consistent with both China's and Gansu Province's Economic and Social Development plans.

B) Environmental Protection Plans

The national environmental protection plan at the time of the appraisal was the *Eleventh Five-Year Plan for Environmental Protection (2006-2010)*, which announced five major goals that should be achieved by 2010. In particular, this project was in accord with three of the goals set in the plan: reducing new sources of environmental pollution, suppressing destruction of the environment and ecosystems, and improving the environment in places designated as priority environmental protection regions and cities. In particular, with regard to air pollution countermeasures, construction of coal-fired power plants in cities will be restricted, development of centralized heat supply facilities which is a heat source with a low air pollution load will be developed, and energy conversion from coal to natural gas with a low air pollution load, etc., is promoted. At the time of the ex-post evaluation, the environmental protection plan was the *Thirteenth Five-Year Plan for Environmental Protection (2016-2020)*, and among the main objectives to be achieved by 2020, this project was in accordance with the objectives of establishing an ecological civilization construction model which combined the protection of ecosystems and urbanization and improving it continuously,

[5] The national standards at the time of the appraisal was the *National Ambient Air Quality Standards (GB3095-1996)* formulated in 1996, and the national standards at the time of the ex-post evaluation was the *National Ambient Air Quality Standards (GB3095-2012)* revised in 2012. Grade 2 standards apply to residential districts, commercial, transportation and mixed communities, cultural districts, general industrial and rural districts, and specific industrial districts. The standards for $NO_2$ emissions in the 2012 version is stricter compared to the 1996 version, and in addition to that, instead of TSP, the revised standards required monitoring of PM2.5, fine inhalable particles with diameters that are generally 2.5 micrometers or less, and PM10, ones with diameters that are generally ten micrometers or less. In addition, certain industrial districts, which were more loosely applied as Grade 3 standards in the 1996 version, were included in the Grade 2 criteria in the 2012 version. When Grade 2 standards are compared with those of Japan, the United States, and the European Commission, except for $NO_2$, the standards are either the same level or looser. However, since China continues to strengthen comprehensive measures to improve the air environment, and since there is a system through which national standards are revised in a timely manner based on economic and social development and environmental protection needs, it is highly likely that environmental standards can become stricter in the future (Source: documents provided by the executing agency).

and formulating guidelines to develop ecological civilization construction model districts and environmental protection model cities and guiding each region in building an ecological civilization model.

At the time of the appraisal, Lanzhou City's environmental protection plan was the *Lanzhou City Eleventh Five-Year Plan for Environmental Protection (2006-2010)*, which aimed to reduce $SO_2$ and TSP emissions by 10% from the actual values of 2005 by 2010 through spreading centralized heat supply facilities, prohibiting the establishment of new small coal boilers, and removing existing small coal boilers. More specifically, the plan includes the removal of 715 small coal boilers and the construction of the Fanping Thermal Power Station, which is one of the heat sources for this project. Lanzhou City's environmental protection plan at the time of the ex-post evaluation was the *Lanzhou City Thirteenth Five-Year Plan for Environmental Protection (2016-2020)*, which for urban heat supply, it aims to actively promote mainly cogeneration systems and clean energy heat supply systems, and to completely remove small coal boilers. Also, in addition to the environmental protection plan, the *Lanzhou City Central City Heat Supply Special Plan (2016-2035)* has been formulated as a master plan for heat supply in the city. The said plan specifically aims to increase the centralized heat supply penetration rate in urban areas to 81% by 2020 through the development of combined heat and power system infrastructure and increasing the number of heat exchange stations, and to continue to strengthen the regulations on the total amount of $SO_2$ and NOx, which are highly consistent with this project.

As described above, this project was consistent with the objectives of reducing and improving air and environmental pollution, spread of centralized heat supply, and development of urban heat supply infrastructure which were respectively set in China and Gansu Province's Five-Year Plan on Economic and Social Development , China and Lanzhou City's Five-Year Plan for Environmental Protection Plan both at the time of the appraisal and the ex-post evaluation, as well as Lanzhou City's heat supply plan at the time of the ex-post evaluation.

### 3.1.2 Consistency with the Development Needs of China

Although environmental pollution in China had achieved certain results through strengthening environmental protection policies in the 1990s, the situation as of 2005 was still serious. In particular, the city of Lanzhou, Gansu Province, the target area of this project, had a population of 2.05 million people in an area of 95.4 $km^2$, and the penetration rate of centralized heat supply was as low as 32%. For heating in winter, small coal boilers without dust collectors and desulfurization equipment, and with low energy efficiency were used. These became the main sources of air pollution, ranking

20th among the country's 113 worst air-polluted cities designated as national priority environmental protection districts, making air pollution improvement an urgent issue to address. Faced with this situation, because Lanzhou City set target values for the total amount of major pollutants, and made efforts, annual average concentrations of $SO_2$, $NO_2$, and TSP air pollutants achieved Grade 2 of the National Ambient Air Quality Standards (GB3095-1996) in 2006. However, maximum values during winter, which is the period when heat is supplied, were still not able to meet the said national standards (See Table 1).

Table 1 Changes in the concentration of air pollutants in Lanzhou City and comparison with the National Ambient Air Quality Standards

(Unit: mg/m$^3$)

| | $SO_2$ | | $NO_2$ | | TSP | |
|---|---|---|---|---|---|---|
| | Annual Average | Maximum Value during Winter Season | Annual Average | Maximum Value during Winter Season | Annual Average | Maximum Value during Winter Season |
| 2002 | ***0.085*** | ***0.371*** | 0.055 | ***0.219*** | 0.199 | ***1.523*** |
| 2003 | ***0.085*** | ***0.393*** | 0.049 | ***0.175*** | 0.174 | ***1.003*** |
| 2004 | ***0.073*** | ***0.289*** | 0.045 | ***0.142*** | 0.169 | ***0.739*** |
| 2005 | ***0.069*** | ***0.281*** | 0.037 | ***0.158*** | 0.158 | ***0.729*** |
| 2006 | 0.057 | ***0.216*** | 0.052 | ***0.183*** | 0.193 | ***0.865*** |
| Grade 2 of the National Ambient Air Quality Standards (1996) * | Annual average | Daily Average | Annual average | Daily Average | Annual average | Daily Average |
| | 0.06 or less | 0.15 or less | 0.08 or less | 0.12 or less | 0.20 or less | 0.30 or less |

| | $SO_2$ | | $NO_2$ | | PM10 | | PM2.5 | |
|---|---|---|---|---|---|---|---|---|
| | Annual Average | Maximum Value during Winter Season | Annual Average | Maximum Value during Winter Season | Annual Average | Maximum Value during Winter Season | Annual Average | Maximum Value during Winter Season |
| 2013 | 0.033 | 0.075 | 0.035 | 0.056 | ***0.133*** | ***0.197*** | No data | No data |
| 2014 | 0.029 | 0.049 | ***0.048*** | 0.060 | ***0.123*** | 0.148 | ***0.060*** | ***0.083*** |
| 2015 | 0.023 | 0.045 | ***0.053*** | 0.073 | ***0.120*** | 0.142 | ***0.052*** | ***0.079*** |
| 2016 | 0.019 | 0.037 | ***0.057*** | ***0.101*** | ***0.114*** | ***0.199*** | ***0.054*** | ***0.097*** |
| 2017 | 0.020 | 0.053 | ***0.057*** | ***0.090*** | ***0.111*** | ***0.208*** | ***0.052*** | ***0.083*** |
| 2018 | 0.021 | 0.040 | ***0.055*** | 0.068 | ***0.103*** | ***0.218*** | ***0.044*** | 0.073 |
| Grade 2 of the National Ambient Air Quality Standards (2012) * | Annual average | Daily Average | Annual average | Daily Average | Annual average | Daily Average | Annual average | Daily Average |
| | 0.06 or less | 0.15 or less | 0.04 or less | 0.084 or less | 0.07 or less | 0.150 or less | 0.035 or less | 0.075 or less |

Source: based on materials provided by the executing agency.

Figures in italics indicate that they exceeded Grade 2 of the national air environment standards.

＊: The National Ambient Air Quality Standards at the time of the appraisal are the GB3095-2012, and those at the time of the ex-post evaluation are the GB3095-2012 (for details of the National Ambient Air Quality Standards see footnote 5).

At the time of the ex-post evaluation, Lanzhou City's urban district population has grown to 2.54 million people and the area has grown to 186 km$^2$. All small coal boilers were removed, and heating is covered by centralized heat supply including this project, and natural gas, and the penetration rate of centralized heat supply has increased to

71%[6]. The ranking among the country's worst air-polluted cities designated as national priority environmental protection districts has improved to 70th place among 169 cities. As shown in Table 1, regarding the concentration of air pollutants in urban areas, since 2016, annual average concentrations and winter concentrations of $SO_2$, $NO_2$, PM2.5 and PM10 have respectively achieved Grade 2 of the national standards existing at the time of the appraisal (GB3095-1996). However, when compared to the national standards revised in 2012 (GB3095-2012), only $SO_2$ was able to achieve both the annual average value and the maximum winter value. According to the executing agency, the main reason for $NO_2$ not achieving the national standard is that the number of vehicles has increased significantly in recent years, and the amount of $NO_2$ emissions has increased with it. Furthermore, the reason why the annual average values of PM2.5 and PM10 exceed the standard is that, especially in winter, the days when there are no winds often exceed 40 days, and the exhaust gas from automobiles becomes difficult to diffuse. Lanzhou City is still being urbanized and heat demand is expected to increase in the future. The city government plans to revise the urban heating plan according to the heat load of the heating area in order to cope with the future population growth, thus the development needs for this project continue to be high at the time of ex-post evaluation.

3.1.3 Consistency with Japan's ODA Policy

Japan's ODA policy at the time of the appraisal consisted of the *Economic Cooperation Plan for China (2001-2006)* as well as JICA's *Medium-Term Strategy for Overseas Economic Cooperation Operations (2005-2007)* and the *FY2006 Country Assistance Strategy*. The goal set by the *Economic Cooperation Plan for China (2001-2006)* [7] was to emphasize areas centered on protecting the environment and ecosystems as pollution and destruction became serious, improving the lives of people in inland areas and developing their societies, developing human resources, establishing systems, and transferring technology, and six priority areas were listed. In particular, in the priority area regarding the cooperation to cope with environmental and other global issues the plan clearly stated that Japan would support China's efforts to introduce new types of renewable energy and conserve energy consumption, and this was highly consistent with this project. The *Medium-Term Strategy for Overseas Economic Cooperation Operations (2005-2007)* considered support for poverty reduction, infrastructure development for

[6] At the time of the ex-post evaluation, there are three heat sources in Lanzhou City: (1) Xigu Thermal Power Plant (330MWx2), (2) Fanping Thermal Power Plant (300MWx2), and (3) Second Thermal Power Plant (110MWx2). The heat sources for the heat exchange stations and the heat supply grid developed by the project are (1) and (2) and covers Xigu and Qilihe Districts out of Lanzhou City's four administrative districts (Anning District, Xigu District, Qilihe District and Chengguan District). The centralized heat supply penetration rate in these districts have achieved 100% in Xigu District and 80% in Qilihe District.

[7] Ministry of Foreign Affairs' *Economic Cooperation Plan for China (2001-2006)*.

sustained growth, support for solving global issues and peace building, and support for human resource development as its four priority areas. In particular, it stated that Japan would actively use its technology to address global issues, cope effectively with environmental problems in developing countries, assist in improving the lives of people, and at the same time contribute actively to global warming, which were highly consistent with the project. *The FY2006 Country Assistance Strategy*[8], stressed environmental protection and stated that JICA would place emphasis on public projects such as supporting air pollution measures in which the government was required to play a part and provide intangible support such as improving environmental administration abilities. It also stated that JICA would work more closely with local governments in Japan to transfer their know-how in the environmental area. With regards to the atmospheric sector, it aimed to install stack gas desulfurization systems in existing thermal power plants; develop centralized heat supply facilities; promote natural gas projects; introduce air quality monitoring equipment; and step up support in the intangible aspects of these undertakings, all of which were highly consistent with the project.

Based on the above, this project has been highly relevant to China, Gansu Province, and Lanzhou City's development plans and development needs, as well as Japan's ODA policy. Therefore, its relevance is high.

### 3.2 Efficiency (Rating: ②)

#### 3.2.1 Project Outputs

The output at the time of the appraisal were the development of heat supply facilities and training in Japan. In real terms, the following three changes occurred regarding the heat supply facilities. These were based on a detailed analysis performed at the time of the detailed design, and all of them were appropriate changes from the viewpoint of operational safety, reliability, reduction of operation costs, and the procedures for change.[9] As for the trainings in Japan, which was planned twice, there was a change in their implementation periods, but the contents, the number of participants, and the targeted participants were mostly implemented as planned (For details on the output at the time of the appraisal and ex-post evaluation, see Comparison of the Original and Actual

[8] Based on documents provided by JICA.

[9] Based on interviews with the executing agency, in China, normally, after obtaining the approval of the F/S by the city government, a more detailed survey of the current situation is conducted based on the F/S, and a detailed design is elaborated based on the results of the survey. Therefore, some changes occur from the F/S to the detailed design stage. In the case of this project, it was confirmed that these changes were not significant changes related to the consistency with the logic leading to the achievement of the project purpose and the development effects, and there were no problems in the changing procedures as well.

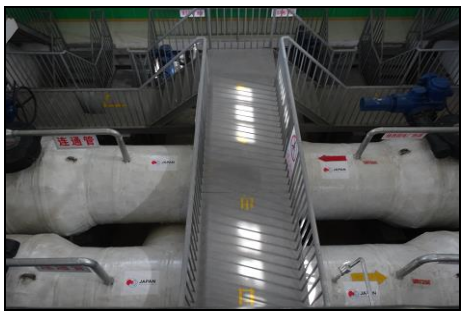
Scope of the Project).

(1) Increase in the construction of heat supply pipeline: As a result of the survey conducted at the time of the detailed design, the length of heat supply pipes to be constructed increased from 115.45 km at the time of the appraisal to 131.15 km, which was 113% of the plan.

(2) Reduction in the number of heat exchange stations: At the time of the appraisal, 220 heat exchange stations were planned to be constructed, but the executing agency took measures to consolidate geographically close heat exchange stations in order to improve efficiency, 170 heat exchange stations were actually constructed (77% of plan). However, in terms of heat exchange capacity, the total capacity at the time of the appraisal, which was 910 MW, increased to 1,049 MW, 115% of the plan.

(3) Change from pump station to valve station: At the time of the appraisal, construction of two pump stations were planned. However, in real terms, one pump station and one valve station were constructed. With the construction of a valve station, it became possible to connect the heating pipes of the two heat sources of the project, which are the power plants in Xigu District and Qilihe District. As a result, the heat supply pipe grid in Xigu District and Qilihe District, which were independent, can now be complement each other, strengthening the heat supply system in Lanzhou City even more.


Lanzhou Fanping Thermal Network Co., Ltd.'s control station developed by the project



Valve station developed by the project

3.2.2 Project Inputs

3.2.2.1 Project Cost

The total project cost at the time of the appraisal was 15,160 million yen (foreign currency 7,899 million yen, domestic currency 7,261 million yen, project cost covered by Japanese ODA was 7,400 million yen of the foreign currency). The actual total project cost was 18,146 million yen (foreign currency 7,293 million yen, domestic currency 10,853 million yen, project cost covered by Japanese ODA was 7,293 million yen of the foreign currency), 120% of the plan, exceeding the plan.

The main reason for the total project cost exceeding the plan was an increase in civil engineering work costs (187% of the plan), especially due to soaring prices of materials and equipment and personnel costs.[10] Other expenses were as planned or within the plan. In particular, since the land acquisition cost was 65% of the plan, further increase in the total project cost could be suppressed. Although the project planned to reuse the sites of small coal boilers free of charge, for new land acquisitions, it was assumed that payments such as land guarantee fees etc., to residents that were using these lands to cultivate vegetables and the like, would occur. However, due to the efficient implementation of the project which actually reduce the number of heat exchange stations through consolidation, new land acquisition was no longer necessary, and it became possible to significantly reduce land acquisition costs.

In sum, the total project cost exceeded the plan, but efforts to reduce the increase in output deserves recognition.

3.2.2.2 Project Period[11]

The project period at the time of the appraisal was from December 2007 to October 2015 (7 years and 11 months, 95 months). The actual project period was from December 2007 to December 2016 (9 years and 1 month, 109 months), 115% of plan, exceeding the plan. The main reasons are that it took time to elaborate the detailed design, which delayed the starting of equipment and installation work by seven months, and the changes and adjustments in the output that occurred in the process from the F/S to the detailed design extended the period of equipment and installation work by eight months.

As for training in Japan, the first one was scheduled to be held for 10 days in June 2008 and the second one in June 2009 respectively, but it took time to adjust the training contents in both the first and second courses. In addition, since the second training was implemented with delay in consideration of the Great East Japan Earthquake, the first training was held for 11 days in January 2010 and the second training was held for 10 days in January 2016.

[10] According to the executing agency, especially personnel expenses increased 152% from 2010 to 2016.

[11] In this project, at the time of the appraisal the following two points were noted as requiring attention due to their possible impact on the project period: (1) delay in the conclusion and effectuation of sub loan contracts by the central government to the project execution department, and (2) the completion of construction in October 2009 of Lanzhou City Thermal Power Company's Fanping Thermal Power Plant (capacity 300MWx2) which would be the heat source of the project's Qilihe District (West area and Southeast area). As for the former, it was confirmed from the questionnaire as well as interviews to the executing agency that there was no delay in the conclusion and effectuation of the sub loan contracts. As for the latter, there was a delay and it was completed in November 2012. However, since period of starting of operations of the project's heat exchange stations were 2010 for Xigu District and 2012 for Qilihe District (West area and Southeast area), the delay in the starting of operations of the Fanping Thermal Power Plant have no effect to the project.

In sum, the project period exceeded the plan.

3.2.3 Results of Calculations for Internal Rates of Return (Reference Only)[12]

The Financial Internal Rate of Return (FIRR) for this project at the time of the appraisal was 8.4%. FIRR at the time of the ex-post evaluation was 8.2%, which was good almost the same as at the time of the appraisal. Although the project cost increased in this project, the efficiency was improved by various methods as described in "3.4.3 Financial Aspect of Operation and Maintenance," and the fact that the operation and maintenance costs are being covered by income from fees is significant.

Although there were slight changes in output in this project, which were mainly increases in the installation of heat supply pipes and heat exchange capacity, all these changes were reasonable from the perspective of operational safety, reliability, and reduction of operating costs. Due to the change in output, the project cost was 120% of the plan and the project period was 115% of the plan, both exceeding their respective plans, but these increases were appropriate considering the change in output. Based on the above, both the project cost and project period exceeded the plan. Therefore, efficiency of the project is fair.

**3.3 Effectiveness and Impacts[13] (Rating: ③)**

The outcome of this project is "to mitigate the burden of air pollution by suppressing pollution emission sources such as small coal boilers" and the impact is "to improve the living environment in Lanzhou City." Analysis of the former was conducted in the quantitative effect under "3.3.1 Effectiveness," and the analysis of the latter was conducted in "3.3.2 Impacts" respectively. As the $CO_2$ emissions that would be reduced by the completion of this project which was described as a quantitative impact at the time of the appraisal, is the basis for the effectiveness indicators, it was included as an auxiliary indicator of the quantitative effects described in "3.3.1 Effectiveness."

3.3.1 Effectiveness

3.3.1.1 Quantitative Effects

The outcome of this project is "to mitigate the burden of air pollution by suppressing pollution emission sources such as small coal boilers," which was evaluated using main indicators ((1) $SO_2$ emission reduction amount, (2) $NO_X$

[12] FIRR at the time of the appraisal was calculated based on the following assumptions: costs are project costs and operation and maintenance costs, while benefits are income from fees. Project life is 30 years. The same assumptions were used for the ex-post evaluation, but for increase in future costs and fee revenues items for which no clear information could be obtained, estimations were made based on the information obtained from interviews.

[13] Sub-rating for Effectiveness is to be put with consideration of Impacts.

emission reduction amount, (3) TSP emission reduction amount) and auxiliary indicators ((4) $CO_2$ emission reduction amount, (5) Coal consumption reduction amount, (6) Number of small coal boilers removed, (7) Number of beneficiaries, (8) Heat supply area ($m^2$), (9) Penetration rate of centralized heat supply).

Main indicators (1) to (3) and auxiliary indicator (4) are all calculated based on indicator (5) Coal consumption reduction amount, which in addition changes according to the increase or decrease of indicator (6) Number of small coal boilers removed (see note in Table 2 for details). In this project, indicator (6) Number of small coal boilers removed increased from 715 at the time of the appraisal to 850[14] in actual terms, which also resulted in a significant increase of indicator (5) Coal consumption reduction amount, which was to 152% of the plan. As a result, indicators (1) $SO_2$ emission reduction amount, (2) $NO_X$ emission reduction amount, (3) TSP emission reduction amount, and indicator (4) $CO_2$ emission reduction amount were 115%, 116%, 114%, and 171% of the plan respectively, exceeding the target values. With the removal of small coal boilers that were not originally included in the plan, indicator (7) Number of beneficiaries increased from 780,000 to 830,000 (106% of the plan), and similarly, indicator (8) Heat supply area increased from 1,820 $m^2$ originally planned, to 1,850 $m^2$ in actual terms (106% of the plan). This project has made it possible to achieve an average of 80% in indicator (9) Penetration rate of centralized heat supply in the target districts at the time of project completion.

[14] The reason for the increase in the number of small coal boilers to be removed was that the size of small coal boilers that needed to be registered with the city government at the time of the appraisal was 100,000 $m^2$ or more. Since there were 715 units with this capacity, this number was set as the target value for the number of small coal boilers to be removed. However, at the time of the detailed design, it became clear that there were small coal boilers with a smaller capacity, and because these were also removed and construction of centralized heat supply by the project was carried out, 850 units were eventually removed.

Table 2 Operation and Effect Indicators: Target, Actual and Target Achievement Degree

| | Indicator * | Target At the moment of Project completion | Actual | |
|---|---|---|---|---|
| | | | At the moment of Project completion 2016 | Target Achievement Degree (%) |
| Main Indicators | (1) $SO_2$ emission reduction amount (t/year) | 9,000 | 10,340 | 115% |
| | (2) $NO_X$ emission reduction amount (t/year) | 7,800 | 9,012 | 116% |
| | (3) TSP emission reduction amount (t/year) | 5,000 | 5,722 | 114% |
| Auxiliary Indicators | (4) $CO_2$ emission reduction amount (t/year) | 933,000 | 1,600,000 | 171% |
| | (5) Coal consumption reduction amount (t/year) | 513,000 | 780,000 | 152% |
| | (6) Number of small coal boilers removed (units) | 715 | 850 | 119% |
| | (7) Number of beneficiaries (10 thousand) | 78 | 83 | 106% |
| | (8) Heat supply area ($m^2$) | 1,820 | 1,850 | 102% |
| | (9) Penetration rate of centralized heat supply (%) | No information | 79.9% | — |

Source: Targets are from the ex-ante evaluation table and documents provided by JICA. Actual figures are from documents provided by the executing agency.

* : Definition and method of calculation of the indicators are as follows:
As for indicators (1) to (4), they are obtained using the calculation methods (which consists of conversion factors, annual boiler working days, etc., based on the reduction amount of coal consumption) indicated in China's "National Technical Measures for Design of Civil Construction: Heating, Ventilation and Air Conditioning (2009)."
Indicator (5) Coal consumption reduction amount: values obtained by subtracting the "coal consumption amount of the thermal power plant that is the heat source of this Project" from the "coal consumption amount of small coal boilers removed by this project."
Indicator (6) Number of small coal boilers removed: number of small coal boilers removed by the development of central heat supply by the Project.
Indicator (7) Number of beneficiaries: number of the Project's direct beneficiaries.
Indicator (8) Heat supply area: area directly supplied with heat by the Project.
Indicator (9) Penetration rate of centralized heat supply: total heat supply population of the project target area divided by the total population.

As mentioned above, all the indicators exceeded the target values, and this project achieved to "mitigate the burden of air pollution by suppressing pollution emission sources such as small coal boilers," and significant effects are manifested.

3.3.1.2 Qualitative Effects (Other Effects)

Qualitative effects of this project have been considered to be the "improvement of the living environment of Lanzhou city." As this can be understood as an effect at the impact level of this project, it is evaluated in "3.3.2.1. Intended Impacts."

### 3.3.2 Impacts

#### 3.3.2.1 Intended Impacts

(1) Quantitative Impacts

Regarding quantitative changes in the air environment in Lanzhou City, as described in Table 1 in "3.1.2 Consistency with the Development Needs of China," when comparing $SO_2$ and $NO_X$ with the national standards at the time of the appraisal, these have certainly improved. As for the centralized heat supply penetration rate, it has increased from 32% in 2006 to 71% in 2007, and an impact of this project on the air environment in Lanzhou City can be recognized to a certain extent (see "3.1.2 Consistency with the Development Needs Developments of China" for details).

(2) Qualitative Impacts

The impact of the project is "to improve the living environment in Lanzhou City." In order to grasp this impact, group interviews[15] with beneficiaries were conducted to check (1) their level of satisfaction with the current heat supply service and (2) changes in life and health conditions before and after the project due to improved centralized heat supply capacity and services. As indicated in Table 3, satisfaction of residents regarding (1) was very high in all categories such as supply time, service stop time and number of days, customer service and charge setting and pricing, and it became clear that a stable temperature is kept at all times, indicating that a project has a very high overall satisfaction level. Regarding (2) this project has made it possible to supply heat at a stable temperature, greatly improving the living environment (indoor and outdoor hygiene, atmospheric environment), health and lifestyle. It has been confirmed that now, even in the winter, the quality of life has improved because it has become possible to live in a natural way without worrying about the cold and the outside air as before the project.

[15] The overview of the group interviews is as follows. Implementation dates: April 24 and 25, 2019 (2 days in total). Target of the survey: the executing agency convened a total of 28 persons (15 men, 13 women) from the project's target areas (Xigu District, Qilihe District). By age groups were 20s (5 persons), 30s (11 persons), 40s (5 persons), 50s (7 persons). In addition to this, six households (three households respectively from Xigu District and Qilihe District) were visited and interviews were conducted. As for the method of collection the executing agency randomly selected from the customer lists of the target area, informed then on the date of the group interview, and convened residents who could participate. In the case of visits to households, not only the area but also the floor in which the target resident is living was taken into consideration. The average number of people per household was three. Type of residence: prior to the project, all but one who lived in a house lived in apartments provided by the companies where they worked. At the time of the ex-post evaluation, all residents live in apartments that are equipped with centralized heat supply. Heat supply method before the project: small coal stoves were used in houses (1 person), the rest were apartments and were supplied by small coal boilers (27 persons).

Table 3 Project Impact: Main Results Obtained from Group Interviews

**[Satisfaction of current heat supply service]**

- Project satisfaction: All categories such as supply time, service stop time and number of days, customer service and pricing are "highly satisfactory (16 people)" and "satisfactory (6 people)." The main reason for the latter were "although it is a satisfactory service, but we need the company to aim for perfection in the future," "since sensory temperature in lower floors is often lower than higher floors, we would like the heat supply temperature in lower floor to be higher," and "we need the customer service response time to improve."
- Heat supply service stop/customer services: Up to now, there has been no interruption in the heat supply service due to deficiencies in the supply company. There are planned service stoppages once or twice a year due to power or water outages etc., but it does not affect life in general because there is always a notification in advance, and they are completed in a few hours. Before starting heat supply, each household is visited, tests are run, temperature is measured and instructions on how to vent the pipes are given.
- Supply period and pricing: Period of service is from November 1st to March 31st of every year, and supply time is 24 hours. At the time of starting of operations the fee was 4.2 yuan/$m^2$/month, at the time of the ex-post evaluation the fee is 5 yuan/$m^2$/month with almost no change. For residents with smart meters installed, because the valve can be adjusted in each household, it has resulted in a savings of approximately 500 yuan/year in heat bills compared to before the project. Residents who pay a fee based on the residential area pay an average of 300 to 400 yuan/year more than before the project, however thanks to subsidies for heating expenses from the companies where they work in, although in general, the proportion of fuel costs in the household income has increased slightly, it is insignificant, has no impact on their lives and satisfactions levels are very high. Payments can also be made conveniently through various methods such as bank, charge collection offices, mobile phone, elderly households have a collection service, and selection range is wide and very convenient.

**[Changes in lifestyle before and after the project because of the improvement of centralized heat supply capacity/service]**

1. Changes in the usage of small coal boilers, changes in lifestyle after shifting to centralized heat supply

- Living environment has improved. Before the project, the number of people operating small coal boilers was limited, often not working at night, thus temperature at night dropped sharply and was unstable. The room temperature averaged 14 to 15 degrees during the day and 7 to 8 degrees at night. Even during the day, inside the house was cold, thus it was necessary to wear thick clothes and used electric stoves. If there was a boiler room near the house, there was a lot of dust, the air was bad, and in addition to that, there was also other pollution such as noise from the trucks carrying coal. After the project, the room temperature has been kept constant at 18 degrees, and the rhythm of life has changed, and it became possible to live a comfortable life. In the case of centralized heat supply, there is no ash or smoke, so the indoor and outdoor air has also improved significantly.
- Air environment in Lanzhou has improved. In winter, neither the sky nor the sun was visible, and the atmospheric environment was bad, but now it is possible to see the blue sky and the starry sky, and the atmospheric environment is good all year round. In addition, there are no chimneys of small coal boilers and the scenery is good.

2. Opinions on diseases caused by air pollution

- Before the project, mainly children and elderly people had many health problems such as cold, asthma, joint pain, coldness, etc., but now their health has clearly improved. Now it is possible to do outdoor activities such as sports, resulting in mental and physical health.

Source: based on group interviews to beneficiaries.

Overall, it was possible to collect positive opinions related to the project's "contribution to improving the quality of life in Lanzhou City" and results that back the impacts of the project up to a certain point could be obtained.

3.3.2.2 Other Positive and Negative Impacts

(1) Impacts on the Natural Environment[16]

The report on the Environmental Impact Assessment (EIA) was approved in January 2007 by the Gansu Province Environmental Protection Bureau. At the time of the appraisal, Lanzhou City Environmental Protection Bureau was scheduled to be responsible for pollution measures (installation of dust collectors, desulfurization equipment, wastewater treatment, etc.) as well as environmental monitoring during construction and after project completion. Based on environmental status reports and environmental monitoring station data obtained from the Lanzhou City Environmental Protection Bureau at the time of the ex-post evaluation, the environmental pollution measures and environmental monitoring planned at the time of the appraisal were carried out as planned, and it was confirmed that China's domestic environmental regulations and standards were observed and the impact on the environment was minimized.

(2) Resettlement and Land Acquisition

At the time of the appraisal, the project had already acquired the right to use of about 1.83 hectares of the total planned land of 12.83 hectares, and the remaining approximately 11 hectares was planned to be obtained in accordance with China's domestic procedures. In real terms, land whose right of use was necessary to be acquired in this project was a total of 2.3 hectares, which was significantly less than planned. The main reasons were as follows: (1) Many of the heat exchange stations constructed in this project were built on sites where small coal boilers had been removed, making it unnecessary to reacquire the land, and (2) regarding some of the planned heat exchange stations, measures to consolidate those that were geographically close were taken, thus the required land area was reduced. The 2.3

[16] At the time of the appraisal, the project area was not considered to be a sensitive area such as a national park or its surroundings, and the negative impact on the natural environment was assumed to be minimal. At the time of the ex-post evaluation, it was confirmed that it was as planned through interviews with the executing agency and site visits. In group interviews with residents, it was also confirmed that the project had no negative environmental impact during construction and operation. Also, in this project the environmental impact and countermeasures of the Fanping Thermal Power Plant, which is one of the heat sources of this project, were raised as a point to be noted at the time of the appraisal. Regarding this point, at the time of the ex-post evaluation, it was confirmed through interviews and site visits to the power station, that information on air pollutant emissions from the power plant is sent to the Environmental Monitoring Bureau of Lanzhou City Environmental Protection Administration Department through an online automatic monitoring device in real time. And it was confirmed that the Lanzhou Environmental Protection Bureau, monitors correctly the environmental burden of Fanping Thermal Power Plant based on the "Enforcement Measures of Lanzhou City Air Pollution Control Management Act." If an air pollutant emission exceeding the standard value occurs, the Lanzhou City Environmental Protection Bureau will give guidance immediately and there will be penalties as well. Therefore, China's domestic standards are also observed for the environmental impact of the Fanping Thermal Power Plant, and there are no particular problems.

hectares of land was acquired in accordance with China's internal laws, Lanzhou City People's Government allocated the land for construction, and monetary compensation based on the "Lanzhou City Land Acquisition Management Rules" was made. Some of these lands included lands cultivated with vegetables, but the compensation paid to the farmers included land compensation fees, pensions, insurance funds and other related expenses, and it was confirmed from interviews with the executing agency that the content of the compensation was sufficient to guarantee the lives of the farmers. In addition, resettlement was not planned to occur at the time of the appraisal and as a matter of fact did not occur.

(3) Unintended Positive/Negative Impacts

Lanzhou City had a heat supply tariff reduction measure for the poor since the time of the appraisal, and this project also planned to apply it as a measure to promote poverty reduction. At the time of the ex-post evaluation, the measure taken by Lanzhou City People's Government in relation to the poor and vulnerable people is the "Opinion on Implementation of Promoting the Welfare Society for Persons with Disabilities (Lanzhou City People's Government No. 63, 2016)," with which heating facilities are constructed for facilities for people with disabilities, welfare and nursing care, and heat supply charges are reduced as well.

Example of reusing the former site of a small coal boiler that no longer was required due to implementation of this project: sharing bicycle maintenance factory

Regarding other unintended impacts at the time of the appraisal, in addition to the fact that some of the sites from which small coal boilers were removed were reused for public facilities (parks, green spaces, bicycle parking lots, etc.), leading to improvements in the living space of residents, the fact that Lanzhou City's efforts to improve the air environment, which includes this project, were recognized at the United Nations Climate Change Conference held in Paris in 2015, and won the "Award for Today's Transformative Step" as an example of good practice in and out of the country can also be pointed out.

**【Column】Impact of Lanzhou City's efforts to improve the air environment, including this project: Winning the United Nations Climate Change Conference "Award for Today's Transformative Step"**

Lanzhou City was given the "Award for Today's Transformative Step" at the United Nations Climate Change Conference held in Paris in 2015. The Lanzhou City People's Government formulated the *Lanzhou City Blue Sky Project* as a comprehensive measure to prevent air pollution in the city based on the aforementioned five-year plans such as the *Environmental Protection Plan,* and by using the *Lanzhou Model* consisting of "Everybody into Action, Science Policy, and Iron Fist Management" as the pillar of its implementation policy, it set the goal to mobilize all resources and control air pollution. The objectives of Lanzhou City Blue Sky Project were (1) Fundamental control of air pollution by coal fired power, (2) Control of industrial pollutants, (3) Control and reduction of exhaust gas pollution by automobiles, (4) Effective reduction of dust and dust pollution, and (5) Implementation of measures to prevent ecosystem pollution so asto expand and protect ecosystem areas in urban areas. From these, regarding the target (1), the Lanzhou City People's Government decided to dismantle all small coal boilers in urban areas and to fundamentally control the air pollution caused by coal combustion, by which the number of days of good air during winter in urban areas has increased significantly, a fact that has been highly evaluated. It can be said that this project, which aimed at "reducing air pollution load by controlling pollution emission sources such as small coal boilers," also contributed greatly. These efforts have reduced GDP energy consumption by 20%, and Lanzhou City has been steadily withdrawn in the worst ranking of domestic polluted cities, being recognized as the city with the clearest results in improving air quality in the country. This comprehensive approach as an environmental pollution prevention model has now been recognized as the "Lanzhou model." The relevant ministries and agencies have extended the experience of pollution prevention in Lanzhou City to the whole of China, and further recommended it to the United Nations Climate Change Conference, which resulted in winning the "Today's Change and Progress Award.".


Diploma and trophy of the "Award for Today's Transformative Step" given to Lanzhou City People's Government (Source: executing agency)

Source: based on documents provided by the executing agency and interviews.

Regarding the project outcome which is "to mitigate the burden of air pollution by suppressing pollution emission sources such as small coal boilers," emission reductions of air pollutants ($SO_2$, NOx, TSP, $CO_2$) all exceeded the target due to the increase in the number of small coal boilers removed and the reduction in coal consumption. In addition, the number of beneficiaries and heat supply area set as auxiliary indicators exceeded the

target, and significant effects were recognized. From the above, project outcomes were achieved, and effectiveness of the project is high. Regarding the impact "improvement of living environment in Lanzhou City," based on the air quality indicators for $SO_2$, NOx, and TSP in Lanzhou City obtained, and when comparing them with the national standards at the time of the appraisal, $SO_2$, NOx, and TSP achieved the National Standard Grade 2. As for qualitative impacts, through group interviews with residents, a large improvement in the living environment has been recognized due to the fact that all small coal boilers have been able to shift to centralized heat supply in the project target area, and the level of satisfaction with the project is also very high. As for land acquisition, it was less than the area planned at the time of the appraisal, and it was confirmed that the land acquisition was carried out appropriately based on the procedures established by the country. There was no resettlement and no negative impacts were observed. As for the impact on the natural environment, it was confirmed that the Environmental Protection Bureau monitored the project appropriately both at the time of project construction and after the starting of operations.

This project has largely achieved its objectives. Therefore, effectiveness and impacts of the project are high.

**3.4 Sustainability (Rating: ③)**

3.4.1 Institutional / Organizational Aspects of Operation and Maintenance

The entities in charge of the operation and maintenance of the infrastructure facilities provided by the project (hereinafter referred to as "Project executing department") are Lanzhou West-East Heat Transmission Co., Ltd., and Lanzhou Fanping Thermal Network Co., Ltd., both of which were established as subsidiaries of Lanzhou City Thermal Power Company in order to achieve a more efficient and effective operation and maintenance of this project. At the time of the ex-post evaluation, the former oversees 100% of the centralized heat supply area of Xigu District, whereas the latter oversees 80% of the of the centralized heat supply area of Qilihe District (West area and Southeast area). Each subsidiary consists of a total of 14 departments, including the heat supply network/pump stations, heat exchange stations, control center, operation services, and the administrative labor department, all of which work under a president and a vice president. Regarding the operation and maintenance of the heat exchange stations, each district is divided into three areas, and each area is assigned four groups that work in three shifts, and each group consists of three to four people. In the same way, the control center consists of three groups that work in two shifts, and each group consist of three to four people. The heat supply network/pump station consists of three groups that work in

three shifts, and each group consist of three to four people.

Table 4 Scale of the Project Executing Departments at the time of the ex-post evaluation (number of people)

| Department | Lanzhou West-East Heat Transmission Co., Ltd.* | Lanzhou Fanping Thermal Network Co., Ltd.* |
|---|---|---|
| Heat supply network/ pump station | Total 23 persons: technical personnel 6 persons, production operation personnel 16 persons, clerk 1 person | Total 21 persons: technical personnel 6 persons, production operation personnel 14 persons, clerk 1 person |
| Heat exchange station (Branches 1, 2 and 3) | Total 142 persons: technical personnel 40 persons, production operation personnel 86 persons, clerks 6 persons | Total 136 persons: technical personnel 52 persons, production operation personnel 78 persons, clerk 6 persons |
| Control Center (Production safety, production technology) | Total 21 persons: technical personnel 19 persons, clerks 2 persons | Total 11 persons: technical personnel 10 persons, clerk 1 person |
| Electric facility maintenance and inspection | Total 14 persons: technical personnel 4 persons, production operation personnel 6 persons, clerks 4 persons | Total 17 persons: technical personnel 8 persons, production operation personnel 7 persons, clerks 2 persons |
| Operation Services (Sales, customer services) | Total 85 persons: managers 3 persons, clerks 82 persons | Total 70 persons: managers 4 persons, clerks 66 persons |
| Administrative Labor Department (Management, Human Resources, Finance, Communist Party related department) | Total 19 persons: managers 2 persons, clerks 17 persons | Total 21 persons: managers 3 persons, clerks 18 persons |
| Total | 314 persons | 276 persons |

Source: documents provided by the executing agency.
*: Technical personnel are personnel who have special qualifications issued by the country or province, while production operation personnel are personnel who have qualifications issued by the company.

Through the collected data, field visits, and interviews, both project executing departments have clear organizational charts, and adequate operation and maintenance scales. In addition, decision making/line of command, and systems of guidance/supervision, etc. are functioning well. As shown in Table 4, scales of the organization required for safe and secure operation and maintenance are also appropriate, and there is a sufficient system in place to ensure the sustainability of this

project.[17]

3.4.2 Technical Aspect of Operation and Maintenance

Technical aspects of operation and maintenance of the department executing this project were evaluated based on the familiarity of technology adopted by the facility developed by this project, especially the number of people with national certificates, training system, operation and maintenance manuals and status on how they are being used.

Technical training at a heat exchange station developed by the project

Regarding the technical level of staff operation and maintenance, both companies manage strictly those occupations that are required to have national qualifications (national safety officer, chemical analysis worker, machine repair/installation worker, electric welding worker, thermal power operator, and piping worker), and actively promote the acquisition of national qualifications[18] by the employees. In addition, apart from the national qualifications, all employees working in the heat exchange stations and the heat supply network are required to acquire the company's internal qualification of "Production Operator." Both subsidiaries have established an "employee training system" that prepares and implements training plans for the following fiscal year after assessing the training needs of the employees every year. Training is conducted intensively during non-operation periods, and all employees receive some kind of training[19] every month, constantly updating their knowledge and qualifications. For occupations that require

[17] In Lanzhou City, the Lanzhou City Residential Urban Rural Development Bureau and the Lanzhou City Heating Service Center focus on production safety inspection, heating preparation, heating services, etc., and inspect the facilities every year before starting the heat supply period, and if necessary, the project executing department is instructed and emergency plans are confirmed jointly. Meters and other facilities are inspected by the Gansu Province Metrology Institute to ensure accurate measurements. In addition, the Lanzhou Safety Production Supervision and Administration Bureau also conducts safety management personnel training to ensure safe operation, and there is a system to maintain a comprehensive and appropriate operation and maintenance status with not only the project executing departments but also through solid cooperation with the city government.

[18] In order to obtain a national qualification, experience in the field is also required, and there are grades from beginner, intermediate, advanced, and professional engineers. Every year, professional engineers take national occupational qualification examinations and efforts are made to upgrade and increase the number of certificate holders.

[19] The following trainings are examples of regular trainings: Training conducted by Lanzhou Transportation University, Department of Architecture and Environmental Engineering: "Heating system," "Heat transfer" "Selection of heat exchangers, its advantages and disadvantages." Other trainings include "Pipe network operation theory and practice," "On-site operation practice of heat exchange equipment," "Water treatment theory and practice," "Heating network automatic control system, equipment theory and practice," "Safe production knowledge and management skills training," "Client services/quality management," "Production system training."

national qualifications, training is conducted at an external training institutions or external instructors are invited. In addition, in order to acquire the above-mentioned in-house qualification of "production operators," employees receive training (classroom lectures and practical work) on safety management, basic knowledge of centralized heat supply, operation and maintenance management procedures, etc., and evaluations are conducted periodically. In addition, on-the-job training (OJT) is also thoroughly conducted by always teaming experienced production operators and young employees. As for employee evaluation, an evaluation system that considers personality, teamwork, communication skills, business skills, etc. in addition to knowledge and technical skills has been introduced since 2018.

For the purpose of checking the maintenance and utilization status of the operation and maintenance manuals, a total of 50 heat exchange stations, which is about 30% of the total, were visited in this ex-post evaluation, as well as the heat supply network, valve station, and control centers. During the field visit, interviews were also conducted with the personnel responsible for the operation and maintenance at each facility. In addition, manuals and operation records were checked, and the frequency and contents of operation and maintenance were also checked in detail. As for manuals, poster-sized manuals for each equipment were hung on the wall at each facility, and it is devised in such a way that staff can always check. In this project, maps of the areas in charge of each heat exchange station are also prepared so that the number of customers, total heat supply area, etc. can be grasped immediately. Operation records and logs for each facility are properly recorded and managed, and emergency manuals are also kept. In this project, all facilities have been connected to the control centers online since 2017, and basic data such as temperature and pressure are monitored in real time.

In this project, two training visits to Japan were conducted with the aim of "supporting the improvement of air pollution, etc. that Lanzhou City is working on by utilizing the knowledge and know-how of Japan's centralized heat supply." In this project, there were no major concerns about the technical level from the time of the appraisal, and from the interviews with the executing agency, it can be said that the goal and purpose of the training in Japan was to obtain and take home hints that could be applied to the implementation of the project and the operation and maintenance of centralized heat supply in Lanzhou City based on Japan's experience. In particular, for the second training visit to Japan, content requested by the executing agency was also incorporated such as air pollution information analysis systems and the use of exhaust gas from garbage disposal facilities, etc. From interviews with personnel who participated in the training, positive opinions could be heard, such as "it was possible to learn about measures to assure safe production for heating, layout of equipment and piping, and

corporate culture in Japan, and these experiences were combined with the project," "the air pollution analysis system and the effective use of energy in central areas of a city had already been implemented in Japan 10 years ago. China has started to work on these measures only in recent years, and it can be said that it had a 10-year delay. The hints gotten from the training in Japan can finally start to be applied" and it was confirmed that the contents of the training in Japan were utilized in the field to a certain extent. Moreover, in many training that are conducted in Japan, trainees often change jobs or leave their jobs after returning to their countries, but it is noteworthy that in this project, even at the time of the ex-post evaluation, all trainees were working in the project execution departments and the turnover rate was zero. The background is that middle managers and engineers involved in the field were selected as participants in the training, and the Lanzhou City People's Government kept the project implementation office, so that personnel would not be appointed to state-owned enterprises etc., other than the specialized field.

Overall, employees in charge of operation and maintenance in every project executing department have enough level of technical skill. The training system is well organized, the company always works on maintaining and improving technical proficiency, and the technology for sustainability of this project is secured. In addition to human resource development, heating facilities and equipment are designed, installed and operated in accordance with strict national standards, and are regularly tested.

### 3.4.3 Financial Aspect of Operation and Maintenance

Lanzhou City Thermal Power Company, which is the parent company, is in charge of the finance of this project. At the time of the appraisal, the average heat supply fee was 15.7 yuan/$m^2$/year, whereas the average heat production cost was 16.7 yuan/$m^2$/year. As a result, the operation and maintenance costs could not be covered, thus measures for setting the fee structure were raised as a point to keep in mind regarding the financial sustainability of the project.

In Lanzhou City, the fee was adjusted twice[20] from the start of the project to the time of the ex-post evaluation, once in 2008 and once in 2012. As a result, at the time of the ex-post evaluation, the average heat supply fee was 36.8 yuan/$m^2$/year, while the average heat production cost was 23.9 yuan/$m^2$/year, achieving a level where the heat

[20] In Lanzhou City, the Lanzhou Price Bureau has the right to determine the heat supply fees. The price revision process is as follows: once the Lanzhou Pricing Bureau receives the fee revision application from the project executing department, it conducts its own investigation, calculates the appropriate fee, reviews it, and after the examination and approval by the Lanzhou City People's Government, the fee is adjusted. In addition to a system where fees are calculated based on the area of the land, meters have also been introduced in recent years. Invoices are sent to each household on the firs of December every year, and it is required to pay during the heating supply period.

supply fee has exceeded the heat production cost (Table 5).

Table 5 Heat Supply Fee in Lanzhou City: Time of Appraisal and Ex-post Evaluation

| Classification | | Time of Appraisal 2007 | Time of Ex-post Evaluation 2019 |
|---|---|---|---|
| I | Residents | 2.8 yuan/month/$m^2$ | 5 yuan/month/$m^2$ |
| II | Public facilities (schools, hospitals) | 3.3 yuan/month/$m^2$ | 7 yuan/month/$m^2$ |
| III | Services (Hotels etc.) | 3.9 yuan/month/$m^2$ | 8.2 yuan/month/$m^2$ |
| IV | Commercial/Industrial | 4.5 yuan/month/$m^2$ | 9.2 yuan/month/$m^2$ |

Source: Documents provided by JICA for the time of appraisal. Executing agency provided documents for the time of ex-post evaluation.

From the Lanzhou City Thermal Power Balance Sheet, which was available at the time of the ex-post evaluation, the maintenance costs are sufficiently covered by the fee income at the time of the ex-post evaluation, and there is no need to rely on government subsidies. Fee collection rate is as high as 90% and it was confirmed that it has been operating in the black for the past three years (Table 6).

Table 6 Profit and Loss Statement of Lanzhou City Thermal Power Co. (2016-2018)

(Unit: thousand yuan)

| | 2016 | 2017 | 2018 |
|---|---|---|---|
| Operating revenue (income from fees) | 400,062 | 434,113 | 457,845 |
| Operating costs (personnel expenses, general administrative expenses/selling expenses etc. including operation and maintenance expenses | 383,963 | 401,577 | 435,007 |
| **Operating Profit / Ordinary Profit** | **16,099** | **32,536** | **22,837** |
| Fee collection rate | 95% | 94% | 95% |

Source: documents provided by the executing agency.
Note: Income tax and business tax are exempt.

In addition to the subsidy system for heat supply infrastructure development projects, the Lanzhou City People's Government has a subsidy system[21] that apply in emergency cases, for enterprises that provide social infrastructure services including heat supply, thus a system is in place to ensure stable heat supply even when the financial situation of the project execution department deteriorates. As described above, in addition to continuing a stable profit management, an emergency subsidy system is also in place, ensuring enough financial sustainability.

[21] The "Notice for the use of city heating supply funds in Lanzhou City" General Directorate of the People's Government of Lanzhou City [2016] No. 9, and the "Lanzhou Municipal People's Government's Comprehensive Emergency Plan for Public Emergencies" [2005] 45, among others states that the funds needed in case of emergency are guaranteed by Lanzhou City.

3.4.4 Status of Operation and Maintenance

The operation of this project is strictly formulated and executed according to the safe production and operation plan and heating technology specifications, and parameters such as pressure, temperature, and flow rate of the entire system are controlled by the automatic control system, and stable operation is always within the range of the design parameters. The whole process that goes from the heat source factory to the end user can be grasped in real time at the control center of each subsidiary, and the center and each of the sites are coordinated as well. The temperature of the water sent from the heat exchange station to each household is kept between 38 and 41 degrees, and the temperature and pressure are adjusted according to the number of floor and the type of heating. Just before the starting of operations and during the operation period, each home is visited once a month to check the temperature and equipment, and if necessary, maintenance advice is also given.

Periodic maintenance of the heat transfer plates at a heat exchange station developed by the project

Maintenance of the heat supply pipes developed by the project

Basic daily inspections of facilities and equipment are conducted four times daily during the heat supply period, twice daily during the non-heat supply period, and periodic inspections are performed based on the manual for each facility. In the daily inspection of the heat exchange stations, the condition of the building, the smell in the building, the sound of the motor and circulation pump, water leakages, and the temperature are confirmed using all five senses; numeric values of temperature and pressure are checked from the control panel and recorded; and oil and filters are changed on a daily basis. As for spare parts, there are representative offices of the manufacturers in China, and there are no problems such as unavailability or delay in delivery. Expansion of facilities, and devices for improving efficiency and stability (for example, covering the heat supply pipes with insulation, installing new automatic expansion valves every 200 meters, increasing the introduction of uninterruptible power

supply equipment, etc.) are conducted constantly, and efforts are being made to promote research including energy-saving technologies.

As mentioned above, it was confirmed through questionnaires to the project executing departments, interview surveys, site inspections, checking of operation and maintenance records, and interviews to staff members in an unannounced manner, that in general terms, the maintenance of the facilities constructed and equipment installed by the project are being carried out in a strict manner and further upgrade efforts by the company are being made constantly, and no particular problems were observed.

In light of the above, no major problems have been observed in the institutional, organizational, technical, financial aspects and current status of the operation and maintenance system. Therefore, sustainability of the project effects is high.

## 4. Conclusions, Lessons Learned and Recommendations

### 4.1 Conclusion

This project was implemented under the objective to mitigate the burden of air pollution by suppressing pollution emission resources through the removal small coal boilers that are not equipped with dust collectors and desulfurization equipment and developing a centralized heat supply facility in Lanzhou City, Gansu Province of the People's Republic of China, thereby contributing to the improvement of the living environment of the said city. This project was fully consistent with the development and environmental protection plans, and the development needs of China, and Lanzhou City, Gansu Province at the time of the appraisal and the ex-post evaluation, as well as Japan's ODA policy at the time of the appraisal; therefore, the relevance of the project is high. As for the output, there were slight increases and decreases, and since both project cost and project period surpassed the plan, the efficiency of the project is medium. Regarding the project's outcome "to mitigate the air pollution burden through suppression of pollutant emission sources," the main indicators of reduction in the emissions of $SO_2$, $NO_2$, and TSP, achieved their goals, and all auxiliary indicators show a tendency toward improvement, thus the project was highly effective. Regarding the impact which is "to improve resident's living environment," the project contributed to improve residents' living environment by prompting all small coal-burning boilers to shift to centralized heat supply in the project target area. Land acquisition was less than the area planned at the time of the appraisal, and was conducted appropriately, forcing no resettlement of residents. Regarding impact on the natural environment during the construction and at the time of the ex-post evaluation, appropriate measures were taken, and monitoring was conducted properly, and results indicated that there was no negative impact. Based on the above, the effectiveness and impact of the

project is high as the intended project results were achieved. The systems, technology, finance, and maintenance management at Lanzhou West-East Heat Transmission Co., Ltd., and Lanzhou Fanping Thermal Network Co., Ltd, both of which are responsible for the operation and maintenance management of the project, were generally favorable, and the sustainability of effects brought by the project is high.

In light of the above, this project is evaluated to be highly satisfactory.

### 4.2 Recommendations

#### 4.2.1 Recommendations to the Executing Agency

None.

#### 4.2.2 Recommendations to JICA

None.

### 4.3 Lessons Learned

Dissemination of the project as a good practice example of the organization and technical aspects of the executing agency that can lead to the enhancement of sustainability

This project has had a remarkable effect. The fact that the organizational aspects of the executing agency and the project execution departments have been very stable since the time of project appraisal to the time of ex-post evaluation can be stated as a reason. In the case of this project, the project implementation office, which is normally dismantled upon completion of the project, continues to exist and still functions at the time of ex-post evaluation as a policy of the city government, and is closely linked with the project executing departments. Furthermore, the fact that personnel changes were extremely limited to ensure the sustainability of the project led to a solid accumulation of knowledge and experience. In addition, as the human resource development policy of the project execution department place emphasis on the ability of their personnel to make proposals for work improvement while each carrying out their daily work, as well as on working with awareness and pride as a member of the local community. These policies are increasing the quality of the operation and maintenance. Since this project can be considered as good practice regarding the system and technical aspects of the project executing department, which are suitable systems for ensuring the sustainability of the project in similar projects of JICA, it is desirable that it will be shared in the future.

End

**Comparison of the Original and Actual Scope of the Project**

| Item | Plan | Actual |
|---|---|---|
| (1) Project Outputs<br>I. Development of heat supply facilities | Xigu District, Qilihe District | Xigu District, Qilihe District |
| 1) Construction of heat supply pipelines | West area: 70.34 km<br>Qilihe District Southeast area: 45.11 km | West area: 74.32 km<br>Qilihe District Southeast area：56.83 km |
| 2) Construction of heat exchange stations | Xigu District, Qilihe District<br>West area: 108 places<br>Qilihe District Southeast area: 112 places<br>(Total heat exchange capacity: 910MW) | Xigu District, Qilihe District<br>West area: 80 places<br>Qilihe District Southeast area: 90 places<br>(Total heat exchange capacity: 1,049MW) |
| 3) Construction of pump station | 2 places | 1 pump station, 1valve station |
| 4) Construction of heat supply control centers | 2 places | As planned |
| II. Training | | |
| • Content | Technical training on air quality improvement in Japan | As planned |
| • Number of times (period) | 2 times (June 2008, June 2009) | As planned (January 2010, January 2016) |
| • Number of participants (maximum) | First: 9 persons<br>Second: 12 persons | First: 8 persons<br>Second: as planned |
| • Target Participants | Staff from project executing departments | As planned |
| (2) Project Period | December 2007-October 2015 (95 months) | December 2007-December 2016 (109 months) |
| (3) Project Cost<br>Amount Paid in Foreign Currency | 7,583 million yen | 7,293 million yen |
| Amount Paid in Local Currency | 7,577 million yen<br>(486 million yuan) | 10,853 million yen<br>(728 million yuan) |
| Total | 15,160 million yen | 18,146 million yen |
| ODA Loan Portion | 7,400 million yen | 7,293 million yen |
| Exchange Rate | 1 yuan=15.6 yen<br>(As of June 2007) | 1 yuan=14.9 yen<br>(Average between December 2007 to December 2016) |
| (4) Final Disbursement | April 2016 | |

End