

Document of
The World Bank

FOR OFFICIAL USE ONLY

Report No: ICR00005412

IMPLEMENTATION COMPLETION AND RESULTS REPORT

TF-18479

ON A

GRANT FROM THE GLOBAL ENVIRONMENT FACILITY

IN THE AMOUNT OF US\$12 MILLION

TO THE

PEOPLE'S REPUBLIC OF CHINA

FOR THE

MUNICIPAL SOLID WASTE MANAGEMENT PROJECT

September 24, 2021

Environment, Natural Resources, and Blue Economy Global Practice
East Asia and Pacific Region

This document has a restricted distribution and may be used by recipients only in the performance of their official duties. Its contents may not otherwise be disclosed without World Bank authorization.

CURRENCY EQUIVALENTS

(Exchange Rate Effective March 31, 2021)

Currency Unit = Chinese Yuan (CNY)

US\$1 = CNY 6.55

FISCAL YEAR

July 1 – June 30

ABBREVIATIONS AND ACRONYMS

BAT	Bast Available Technique
BEP	Best Environmental Practice
CPF	Country Partnership Framework
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
EPB	Environmental Protection Bureau
ESIA	Environmental and Social Impact Assessment
ESMP	Environmental and Social Management Plan
FECO	Foreign Environmental Cooperation Center
FM	Financial Management
GEF	Global Environmental Facility
GRM	Grievance Redress Mechanism
ICR	Implementation Completion and Results Report
IEP	Integrated Emission Permit
M&E	Monitoring and Evaluation
MEE	Ministry of Ecology and Environment
MoHURD	Ministry of Housing and Urban-Rural Development
MSW	Municipal Solid Waste
OEPA	Operations and Environmental Performance Audit
OIP	Operational Improvement Program
PAD	Project Appraisal Document
PCDD	Polychlorinated Dibenzo-p-Dioxin
PCDF	Polychlorinated Dibenzofuran
PDO	Project Development Objective
PMO	Project Management Office
POP	Persistent Organic Pollutant
RF	Results Framework
SC	Stockholm Convention
TEQ	Toxic Equivalent
ToC	Theory of Change

TTL	Task Team Leader
UMB	Urban Management Bureau
WBG	World Bank Group

Regional Vice President: Manuela V. Ferro

Country Director: Martin Raiser

Regional Director: Benoit Bosquet

Practice Manager: Ann Jeannette Glauber

Task Team Leader(s): Daniel Mira-Salama

ICR Main Contributor: Zijing Niu

TABLE OF CONTENTS

DATA SHEET	1
I. PROJECT CONTEXT AND DEVELOPMENT OBJECTIVES.....	5
A. CONTEXT AT APPRAISAL.....	5
B. SIGNIFICANT CHANGES DURING IMPLEMENTATION	10
II. OUTCOME	12
A. RELEVANCE OF PDOs	12
B. ACHIEVEMENT OF PDOs (EFFICACY).....	12
C. EFFICIENCY.....	18
D. JUSTIFICATION OF OVERALL OUTCOME RATING.....	19
E. OTHER OUTCOMES AND IMPACTS	20
III. KEY FACTORS THAT AFFECTED IMPLEMENTATION AND OUTCOME.....	21
A. KEY FACTORS DURING PREPARATION	21
B. KEY FACTORS DURING IMPLEMENTATION	22
IV. BANK PERFORMANCE, COMPLIANCE ISSUES, AND RISK TO DEVELOPMENT OUTCOME ..	23
A. QUALITY OF MONITORING AND EVALUATION (M&E)	23
B. ENVIRONMENTAL, SOCIAL, AND FIDUCIARY COMPLIANCE	24
C. BANK PERFORMANCE	26
D. RISK TO DEVELOPMENT OUTCOME	27
V. LESSONS AND RECOMMENDATIONS	27
ANNEX 1. RESULTS FRAMEWORK AND KEY OUTPUTS.....	30
ANNEX 2. BANK LENDING AND IMPLEMENTATION SUPPORT/SUPERVISION.....	41
ANNEX 3. PROJECT COST BY COMPONENT	43
ANNEX 4. EFFICIENCY ANALYSIS.....	44
ANNEX 5. BORROWER COMMENTS TO ICR.....	48
ANNEX 6. SUPPORTING DOCUMENTS	49
ANNEX 7. PROJECT TECHNICAL SUMMARY.....	51
ANNEX 8. PROJECT MAP AND IMAGES	56



DATA SHEET

BASIC INFORMATION

Product Information

Project ID	Project Name
P126832	CH GEF Municipal Solid Waste Management Project
Country	Financing Instrument
China	Investment Project Financing
Original EA Category	Revised EA Category
Full Assessment (A)	Full Assessment (A)

Organizations

Borrower	Implementing Agency
People's Republic of China	Foreign Environmental Cooperation Center (FECO)

Project Development Objective (PDO)

Original PDO

The projects objective is to build capacity and demonstrate best available techniques (BAT) and best environmental practices (BEP) in municipal solid waste incineration in accordance with the Stockholm Convention.



FINANCING

	Original Amount (US\$)	Revised Amount (US\$)	Actual Disbursed (US\$)
World Bank Financing			
TF-18479	12,000,000	11,439,698	11,439,698
Total	12,000,000	11,439,698	11,439,698
Non-World Bank Financing			
Borrower/Recipient	20,910,000	20,910,000	31,140,000
Total	20,910,000	20,910,000	31,140,000
Total Project Cost	32,910,000	32,349,698	42,579,698

KEY DATES

Approval	Effectiveness	MTR Review	Original Closing	Actual Closing
14-Nov-2014	29-May-2015	02-Feb-2018	31-Dec-2019	31-Mar-2021

RESTRUCTURING AND/OR ADDITIONAL FINANCING

Date(s)	Amount Disbursed (US\$M)	Key Revisions
10-Dec-2019	7.93	Change in Results Framework Change in Loan Closing Date(s) Change in Implementation Schedule Other Change(s)

KEY RATINGS

Outcome	Bank Performance	M&E Quality
Highly Satisfactory	Satisfactory	Substantial

RATINGS OF PROJECT PERFORMANCE IN ISRs

No.	Date ISR Archived	DO Rating	IP Rating	Actual Disbursements (US\$M)
01	06-Apr-2015	Satisfactory	Satisfactory	.21
02	04-Aug-2015	Satisfactory	Moderately Satisfactory	.21



03	06-May-2016	Satisfactory	Moderately Satisfactory	3.21
04	10-Dec-2016	Moderately Satisfactory	Moderately Satisfactory	4.33
05	21-Feb-2017	Moderately Satisfactory	Moderately Satisfactory	4.33
06	21-Oct-2017	Moderately Satisfactory	Moderately Satisfactory	2.07
07	22-May-2018	Moderately Satisfactory	Moderately Satisfactory	6.23
08	30-Nov-2018	Moderately Satisfactory	Moderately Satisfactory	6.57
09	27-Jun-2019	Moderately Satisfactory	Moderately Unsatisfactory	7.59
10	21-Dec-2019	Moderately Satisfactory	Moderately Unsatisfactory	8.14
11	15-Jun-2020	Satisfactory	Moderately Satisfactory	9.36
12	21-Dec-2020	Satisfactory	Satisfactory	11.46

SECTORS AND THEMES

Sectors

Major Sector/Sector (%)

Water, Sanitation and Waste Management 100

Waste Management 100

Themes

Major Theme/ Theme (Level 2)/ Theme (Level 3) (%)

Private Sector Development 100

Jobs 100

Environment and Natural Resource Management 101

Environmental Health and Pollution Management 51

Air quality management 17

Water Pollution 17

Soil Pollution 17

Environmental policies and institutions 50



ADM STAFF

Role	At Approval	At ICR
Vice President:	Axel van Trotsenburg	Manuela V. Ferro
Country Director:	Bert Hofman	Martin Raiser
Director:	John A. Roome	Benoit Bosquet
Practice Manager/Manager:	Iain G. Shuker	Ann Jeannette Glauber
Project Team Leader:	Tijen Arin	Daniel Mira-Salama
ICR Co Author:		Zijing Niu



I. PROJECT CONTEXT AND DEVELOPMENT OBJECTIVES

A. CONTEXT AT APPRAISAL

Context

1. The rapid economic development in China since 1978 had led to significant environmental pollution and ecological degradation. Committed to reversing this downward environmental trend, the Government made environmental protection a national policy. At the time of appraisal, rapid urbanization and increasing per capita incomes were reflected in a growing trend in municipal solid waste (MSW) generation—the quantity of MSW collected increased from about 85,000 tons per day (t/d) in 1980 to about 430,000 t/d in 2009 and was projected at the time to reach 1.6 million t/d by 2030. A set of national policies that encouraged energy recovery from waste, together with shortage of urban land for landfills and other incentives (value added tax refunding, favorable feed-in tariff for electricity sale, and so on), created an incentive to choose incineration as the disposal method of choice. Projections at the time envisioned the number of MSW incinerators in China to increase from 93 in 2009 to 200 in 2015, with a corresponding increase in daily disposal capacity from 55,400 tons to 140,000 tons.

2. MSW incineration is a well-known source of dioxin and furan¹ emissions, and the projected increase in incineration capacity in the country called for increased attention to minimizing the conditions under which these highly toxic chemicals are unintentionally produced. Dioxins are a group of substances that persist in the environment, can be transported far from their sources, and can lead to serious health effects. Due to their extreme stability, they tend to accumulate in the food chain and remain in the environment for a long time, so that efforts to reduce their emissions have a global benefit. Cognizant of these issues, and as part of its commitment to reversing environmental degradation, the Government of China ratified a range of international conventions on pollution control, including the Stockholm Convention (SC) in 2004, a global treaty aimed at protecting human health and the environment from persistent organic pollutants (POPs), including dioxins and furans. According to a 2007 inventory, MSW incineration was the 3rd largest source of dioxin and furan release in China, following ferrous and nonferrous metal production and heat and power generation.

3. At the time of Project preparation, few MSW incinerators in China applied the best available techniques (BAT) or best environmental practices (BEP) defined by the SC (BAT/BEP provide guidance to SC parties to minimize POP releases). In 2014, as Project preparation was nearing completion, the Ministry of Ecology and Environment (MEE) carried out an ambitious review of the standards regulating dioxin emissions for MSW incineration, reducing the emission limit tenfold, from 1.0 to 0.1 ng TEQ/m³,² effective January 1, 2016. Although new facilities in large cities were generally designed to comply with the new standard, older facilities were challenged to meet the target, and incinerator operators often lacked the knowledge and skills to manage operations—a key shortcoming being the inadequate ability to monitor and control the combustion process, leading to unstable conditions in the furnace resulting in dioxin

¹ Dioxins and furans are short forms for polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs), a group of chemically similar compounds. In this document, unless otherwise specified, the word 'dioxins' refers to both dioxins and furans.

² TEQ: Toxicity equivalent units. Dioxins and furans include various forms of PCDDs and PCDFs that present different levels of toxicity. Chinese and international standards use TEQ to measure the toxicity of dioxins and furans collectively based on a conversion methodology developed by the World Health Organization.



formation. In addition, as the country implemented improved waste segregation programs at source, the moist fraction reaching the incinerators was projected to slowly decline over time, a fact that would require further assessments and tests on how to adjust incineration conditions to the new feedstock.

4. In addition, regulatory weaknesses existed in the sector:

- (a) Key regulations for the establishment and operation of MSW incinerators were essentially technical requirements for combustion temperature and residence time, with no specifics for non-stationary combustion regimes during start-up and shutdown of incinerator units, and no regulatory provision for corrective actions against noncompliant incinerators.
- (b) There was no legal requirement for regulators to monitor dioxin emissions on a continuous basis or, in the absence of capacity to monitor these continuously, to monitor incineration operating conditions to infer emission estimates.
- (c) Requirements and conditions specified in the Environmental Impact Assessment (EIA) needed for the establishment of an incinerator were not held as regulatory requirements or site-specific operating conditions after the incinerator is commissioned.
- (d) Sampling and analysis of dioxin emissions were carried out once a year by institutes contracted by the incinerator, and the few institutes with capacity to do so were concentrated in eastern provinces. Sampling was mandated to be carried out during normal operating conditions, but local Environmental Protection Bureaus (EPBs) could not ensure that the requirement was met as they did not have access to operating conditions on a continuous basis.
- (e) There was no requirement for public disclosure of dioxin emission test results.

5. Two demonstration cities were selected during appraisal: Kunming and Ningbo. Kunming (capital of Yunnan Province and a typical growing city in China) had decided to rely entirely on incineration for MSW disposal and had been designated by the Central Government as the MSW segregation demonstration city for Yunnan. Four incinerators were under operation (Dongjiao, Wuhua, Xishan, and Konggang, employing either the 'fluidized bed' or the 'grate bed' technology, the two most representative technologies around China), and a fifth incinerator was about to be completed. Kunming was in the process of preparing a citywide MSW segregation plan and was looking for models to learn from. Ningbo (Zhejiang Province) had an advanced MSW system, including waste segregation and recycling programs, and was an example of how solid waste composition in less advanced cities would evolve over time as they implement segregation programs. Ningbo had three incinerators under operation. There was a World Bank-financed project under implementation³ and was therefore considered a good candidate to test continuous sampling technologies as well as serve as a model in studies on the effects of segregated feedstock on incineration conditions and related emissions.

6. The Project was prepared under the framework of World Bank Group (WBG) Country Partnership Strategy for FY2013–FY2016 (Report No. 67566-CN), which included "Strategic Theme One: Supporting Green Growth," Outcome 1.2: Enhancing Urban Environmental Services by "improving sanitation, solid waste and other basic urban services in selected second-tier cities, while reducing pollution," and Outcome 1.6: Demonstrating Pollution Management Measures, achieved among others by "supporting efforts to reduce hazardous waste, by continuing to support the reduction of POPs from the regulatory

³ Ningbo Municipal Solid Waste Minimization and Recycling Project (P123323).



level to emissions control and to urban site cleanup.” The World Bank’s involvement was also the result of a 15-year-long partnership with China in the implementation of the SC, through a series of operations financed by the Global Environment Facility (GEF) aimed at curbing POP emissions in key sectors (paper and pulp, firefighting and pesticides, polluted soils, iron and steel, and others). The World Bank’s support was needed to identify good international BAT/BEP and facilitate their implementation to the rapidly evolving Chinese context.

Theory of Change (Results Chain)

7. While an explicit Theory of Change (ToC) was not required in the Project Appraisal Document (PAD) at the time of preparation, figure 1 illustrates a ToC developed for this Implementation Completion and Results Report (ICR) that aligns with the conceptual framework described in the PAD along with underlying assumptions.

Project Development Objectives (PDOs)

8. The PDO, as stated in the Grant Agreement and the PAD, is to build capacity and demonstrate best available techniques and best environmental practices in MSW incineration in accordance with the Stockholm Convention.⁴

Key Expected Outcomes and Outcome Indicators

9. **The Project included one PDO-level results indicator:** “Regular and reliable monitoring data show operating practices that lower dioxin levels to 0.1 ng TEQ/m³ at selected demonstration incinerators.”

10. **The indicator was complemented by two supplemental indicators that further defined and developed the PDO indicator:** (a) a planned schedule of improvements in operating procedures established after measuring and evaluating the baseline situation and (b) achievement of milestones set for the improvement of operating procedures as identified in the schedule of improvements in operating procedures.

Components

11. **Component 1: Capacity Building for Improved Operation and Regulation of MSW Incinerators** (Total cost at appraisal: US\$27.44 million, including GEF grant of US\$9.83 million; Actual cost: US\$34.94 million, including GEF grant of US\$9.38 million)

12. **Subcomponent 1A. Building Capacity for Improved Incinerator Operations and Emission Control.** This subcomponent financed selected demonstration incinerators to improve operations and reduce dioxin and other pollutant emissions in line with SC BAT/BEP. Kunming’s four functioning incinerators at the time (Dongjiao, Xishan, Konggang, and Wuhua)⁵ were the initial candidates, of which three were to be selected during implementation, based on operational and environmental performance audits (OEPAs), financial eligibility criteria, and the operator’s commitments to a tailor-made operational

⁴ The extra characters in the spelling of the word ‘project’ in the datasheet PDO statement are system generated and could not be easily removed.

⁵ Of the four candidate incinerators, in 2017, the Yunnan government decided to relocate the Wuhua incinerator outside Kunming; thus, the final number of incinerators initially selected for Project investments was three (Dongjiao, Xishan, and Konggang).



improvement program (OIP). Activities in this subcomponent included (a) OEPAs to fill the information gap on operating conditions at the selected incinerators; (b) dissemination of lessons learned from the audits in Kunming, tailored to regulators and incinerator managers in cities across China, on the link between operating conditions and environmental performance of the two widely employed incineration technologies⁶ in the country; (c) OIPs, including capital investments in dioxin-reducing equipment based on the OEPAs, to be governed by operational improvement agreements signed by Kunming Municipality and the demonstration incinerators; and (d) training to incinerator managers and operators in Kunming, Ningbo, and other incinerators across China.

13. Subcomponent 1B. Capacity Building for Improved Regulation of MSW Incinerators. This subcomponent included (a) piloting of integrated permits to support regulators in Kunming to develop and implement an integrated permitting system—a facility-specific license for incinerators to reduce environmental impacts, especially the emission of dioxin and other pollutants, which would include the requirements set out in the facility’s EIA, thus effectively operationalizing it;⁷ (b) capacity building for improved monitoring by regulators to allow EPBs and Urban Management Bureaus (UMBs) to improve monitoring of waste incineration through online access to real-time operating and emission data and dioxin stack testing and Ningbo EPB’s dioxin laboratory capacity enhancement; (c) training of regulators through international study tours to cities where BAT/BEP for MSW incineration are implemented; (d) updating and developing of four national-level technical standards for MSW incinerator operations; and (e) public awareness raising and disclosure of incinerator operating and emissions data.

14. Component 2: Capacity Building for Improved MSW Management Planning (Total cost at appraisal: US\$1.75 million, including GEF grant of US\$1.57 million; Actual cost: US\$3.66 million, including GEF grant of US\$1.26 million). This component included (a) study on regional planning of MSW disposal, aimed at identifying cost-effective disposal options at a regional scale; (b) study on the system of statistical indicators and MSW classification; (c) twinning Kunming and Ningbo on MSW segregation; and (d) assessment of the impact of MSW segregation on dioxin emissions in Ningbo.

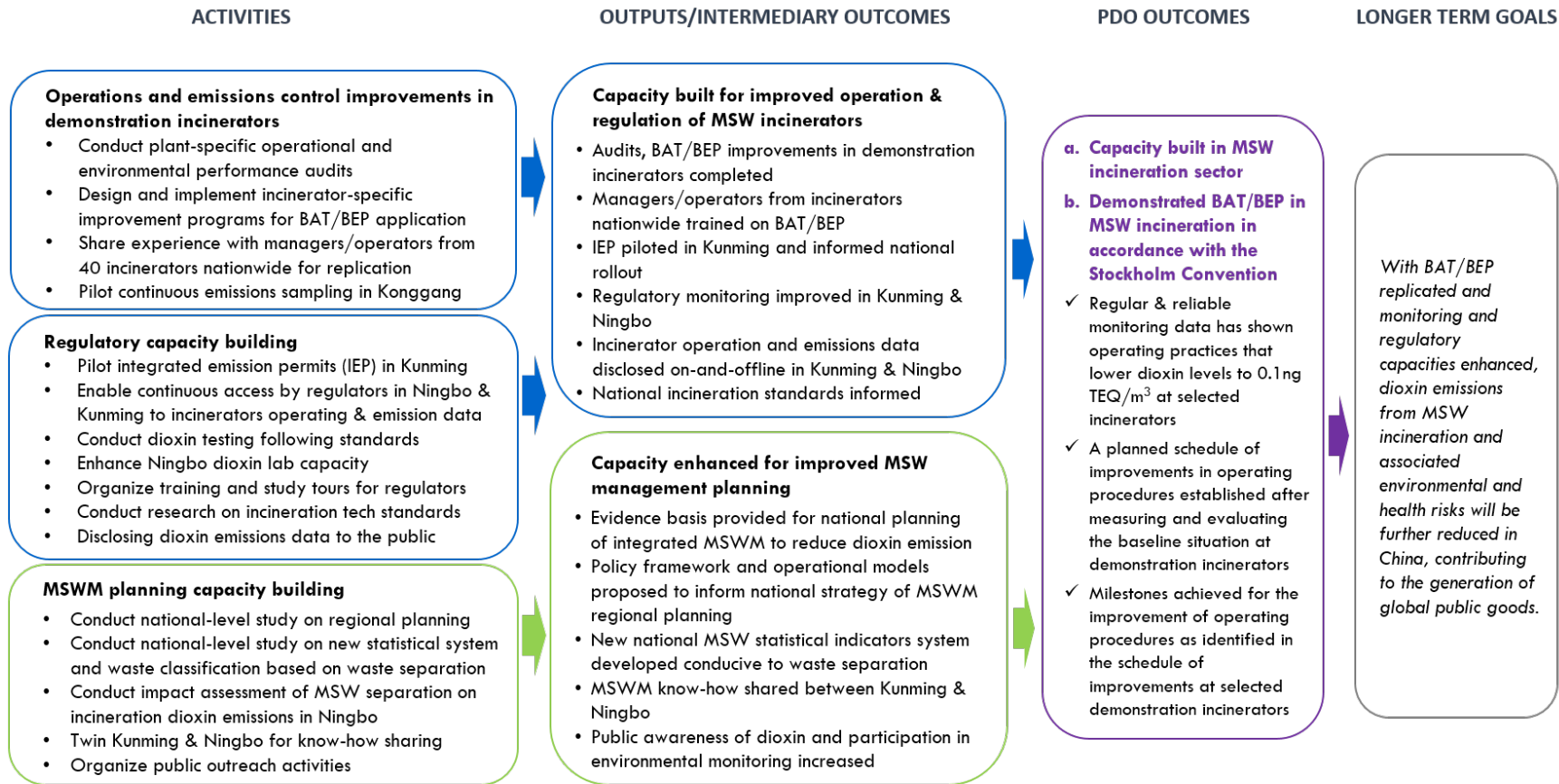
15. Component 3: Project Management (Total cost at appraisal: US\$3.72 million, including GEF grant of US\$0.6 million; Actual cost: US\$3.98 million, including GEF grant of US\$0.8 million), to fund incremental operating costs and consultancy costs associated with project management.

⁶ Circulating fluidized bed and grate bed technologies in MSW incinerators.

⁷ The operating and performance requirements in the integrated permit would include feedstock management, combustion unit performance and emission limits, database management, record keeping, information disclosure, training, contingency planning, and others. It also includes all requirements set out in the EIA, hence operationalizing the conditions under which the facility was approved.



Figure 1. Theory of Change



Key Barriers: (a) Baseline of MSW incinerators operating and emissions status and gaps with SC BAT/BEP unknown, (b) no instant emissions monitoring and online data accessibility in MSW incineration sector, and (c) limited capacity of integrated MSWM planning

Main Assumptions: (a) China is shifting to incineration to meet soaring demand of waste disposal, (b) regulatory enforcement for incineration pollution control is much strengthened, and (c) incinerators have multiple drivers to adopt BAT/BEP, i.e. compliance, better operating stability, and cost savings.

Note: MSWM = Municipal solid waste management.



B. SIGNIFICANT CHANGES DURING IMPLEMENTATION

Revised PDOs and Outcome Targets

16. No change was made.

Revised PDO Indicators

17. A Level-2 Project restructuring was approved in December 2019, through which the PDO indicator was adjusted and the previously missing baseline and target were added (see details below).

Revised Components

18. No revision was made.

Other Changes

19. **Change in the Results Framework (RF).** The following changes were made:

Table 1. Change in the RF

Original Indicator	Revised Indicator	Original/Revised Baselines	Original/Revised Targets
Regular and reliable monitoring data show operating practices that lower dioxin levels to 0.1 ng TEQ/m ³ at three demonstration incinerators	Regular and reliable monitoring data show operating practices that lower dioxin levels to 0.1 ng TEQ/m ³ at selected demonstration incinerators	Original: "TBD based on first year audits" Revised: "Baseline dioxins emissions: Xishan 0.059; Dongjiao 0.46; Konggang 0.093"	Original: "TBD based on first year audits" Revised: "Dioxin emission: at least meets 0.1 ng TEQ/m ³ "
Achievement of milestones set for the improvement of operating procedures as identified in the schedule of improvements in operating procedures at three demonstration incinerators	Achievement of milestones set for the improvement of operating procedures as identified in the schedule of improvements in operating procedures at selected demonstration incinerators	Original: "TBD based on first year audits" Revised: "Operational Baselines: Xishan 72% compliance with Stockholm Convention BAT/BEP; Dongjiao 69%; Konggang 70%"	Original: "TBD based on first year audits" Revised: "Operational practice targets: Xishan 90% compliance with SC BAT/BEP; Konggang 94%"
Dioxin emission test results for five incinerators in Kunming posted on the web ^a	Dioxin emission monitoring results for five incinerators in Kunming posted on the web	No change	No change
Public awareness of incinerator information disclosed	Public awareness of incinerator information increased	No change	No change
N/A	New: Continuous sampling of emissions is tested in at least one selected demonstration incinerator	Original: N/A New baseline: 'No'	Orig: N/A New target: 'Yes'

Note: a. Four incinerators were under operation during Project preparation, and a fifth was about to be completed. The Project facilitated the disclosure of monitoring results for all five incinerators during implementation.

20. **Change in closing date.** The original grant closing date of December 31, 2019, was extended by 15 months to March 31, 2021.



21. **Change in implementation schedule.** The Project implementation schedule was extended in line with the extension of the grant closing date.

22. **Other changes.** New activities were added in Konggang: (a) installation and testing of continuous dioxin emissions sampling and (b) additional improvements to complement its approved OIP.

Rational for Changes and Their Implication on the Original Theory of Change

23. Rationale for the abovementioned changes is discussed in the following paragraphs, and none of these changes affected the Project ToC.

24. **The changes to the PDO-level indicator and RF** were motivated by the shutdown of the Dongjiao incinerator. During the development of the OEPA for Dongjiao, it was realized that the facility was not compliant with the emissions standards set out by Chinese regulations. Accordingly, an improvement plan was prepared to address the shortcomings, agreed and approved, with procurement set to begin shortly thereafter. However, the Government of China carried out inspections and decided to shut down the facility due to noncompliance with emissions standards. For many months it remained unclear if this was a temporary closure, until its permanent closure was communicated in August 2019, leading to its withdrawal from the Project. Other changes were needed because the main PDO indicator (and the second PDO supplemental indicator) did not initially include a baseline or a target, as these were pending the completion of the OEPAs. The restructuring was carried out after OEPAs were completed, and baselines and targets were thus formally included. Other revisions were made to reflect the change from three demonstration incinerators to two and to adjust minor language issues. None of the end target values for the intermediate indicators were changed, and a new intermediate indicator was introduced to capture the results of the additional activities that were carried out with the savings resulting from the Dongjiao shutdown.

25. **The Dongjiao shutdown has not negatively affected the Project or the ToC:** (a) the OEPA for Dongjiao and the design of its OIP were both carried out through the Project (thus achieving the first PDO supplemental indicator), providing a good opportunity for on-the-job learning; (b) the two remaining incinerators are based on the two main incineration technologies prevalent in China, which allowed for the demonstration value of the Project to be fully realized as the improvement programs were implemented; (c) the Project's objective is to demonstrate BAT/BEP for replication not to reduce the absolute amount of dioxin emissions per se; and (d) although the closure discussion created significant delays to accommodate extensive negotiations, it served, overall, as an example of assertive environmental management and enforcement of regulations, sending an important, strong signal to the incineration sector.

26. **The change in the closing date and implementation schedule was also mostly motivated by the Dongjiao closure.** The process leading to the decision by Chinese authorities to shut down the incinerator was protracted and caused uncertainties along the way. The final decision was made in August 2019 (with less than six months to Project closure, leaving no time to find alternatives). An extension was needed to provide sufficient time for the completion of all activities, including new activities that were added to utilize Project savings and strengthen the sustainability of Project objectives, as well as monitoring and verification, training, and extraction of lessons learned under the Project.

27. **Other changes were made during the restructuring to strengthen Project outcomes.** The Konggang incinerator implemented a new batch of improvements as identified in its OIP and was used as demonstration to test equipment able to continuously sample dioxin emissions. The latter is an important



contribution with potential national application. Whenever the environmental controller needs to carry out an inspection of dioxin emissions, the standard practice is to collect a sample over a limited period. This process is extremely costly, and it is not representative of the incinerator's real emissions (a manual sample taken over a few hours, for example, will not capture the start and stop of the furnace, when dioxin emissions are typically the highest). Continuous sampling tests at Konggang are providing additional insights to MEE's plans to roll out the technique to MSW incinerators nationwide as a more reliable and cost-effective monitoring tool.

II. OUTCOME

A. RELEVANCE OF PDOs

Rating: High

Assessment of Relevance of PDOs and Rating

28. The relevance of the PDO is rated as High. This Project spanned two WBG Country Partnership Strategies/Frameworks for FY2013–FY2016 (Report No. 67566-CN) and the current Country Partnership Framework (CPF) for FY2020–2025 (Report No. 117875-CN). The Project objectives and activities remained highly relevant throughout this period and at the time of its closing. In fact, the current WBG-China CPF contemplates three areas of engagement, with Area 2 devoted to “promoting greener growth, by facilitating the transition to a lower carbon energy path, reducing air, soil, water, and marine plastic pollution.” The CPF highlights the importance of supporting China to implement the SC on POPs and the demonstration approach to be adopted. Another measure of the high relevance of the Project at closing is given by its direct contribution to the WBG's evolved focus of collaboration with China, centered around delivering global public goods such as global pollution reduction (dioxins are persistent pollutants able to travel long distances and accumulate throughout the food chain) and plastic pollution reduction (improved collection and adequate disposal of plastic waste is fundamental to reducing plastic leakage into the ocean).

29. The Project activities have also directly contributed to China's 13th and 14th Five-Year Plans (2016–2020 and 2021–2025), both of which included provisions for the improvement and strengthening of pollution prevention and control, integrated solid waste systems, and improved monitoring capacity. A final measure of the Project's relevance relates to the vertiginous incineration construction development witnessed in China over the past years. In 2010, during the Project preparation phase, China had 104 incinerators in operation in cities with total capacity of 23.2 Mt/d. Nine years later, by 2019, this number more than tripled to 389, and capacity increased fivefold to 121.2 Mt/d. China's 14th Five-Year Plan sets an incineration target of 65 percent for all MSW from the current level of 45 percent. The objectives of the Project and the impacts of its demonstration potential are, therefore, more relevant than ever before in the country.

B. ACHIEVEMENT OF PDOs (EFFICACY)

Rating: High

Assessment of Achievement of Each Objective/Outcome

30. The PDO has two elements: (a) build capacity (in MSW incineration in accordance with the Stockholm Convention) and (b) demonstrate best available techniques and best environmental practices



in MSW incineration in accordance with the SC. Both objectives have been fully achieved, and all PDO-level and intermediate indicators as set in the RF have been met (annex 1).

PDO(a): Build capacity in MSW incineration

31. The Project was designed to devote plenty of attention and resources to build capacity and address all the main challenges identified during Project preparation and summarized in section I, with all corresponding intermediate results indicators achieved (annex 1). Capacity has been built at various levels: incinerator operators, regulatory agencies, communities and general public, and the broader MSW incineration sector.

32. **Incinerator operators.** Tailored BAT/BEP training was designed and delivered to MSW incinerator managers and operators nationwide, in three phases: (a) development of training materials based on experiences in Kunming; (b) training of trainers (eight in total); and (c) training to 281 managers and operators from 67 incinerators across China, through six training events in Ningbo, Xi'an, Chengdu, Shenzhen, Wuhan, and Beijing. The learning materials describing the experience and lessons learned in Kunming were disseminated to experts across the country.

33. **Regulatory agencies.** Capacity to monitor and enforce regulations was enhanced in various ways:

- (a) **Real-time monitoring of operating conditions and emissions enabled.** Continuous access to operating and emissions data of incinerators in Kunming was enabled for Yunnan provincial EPB and Kunming EPB/UMB and of incinerators for Ningbo EPB/UMB, thus delivering an important part of the PDO indicator. Access to operating conditions in real time, and to emission data, has made enforcement easier, according to feedback from regulators. Moreover, and as a result of the Project's experience, Kunming and Ningbo have made real-time data disclosure a mandatory feature for new incinerators under construction. This initiative has triggered a series of actions by enterprises to have real-time monitoring equipment installed and connected to the local and national regulatory platforms. These results contributed to the national-level dialogue, and since 2020, MEE discloses noncompliant incinerators nationwide on its website.
- (b) **IEP piloted.** The pilot included inspection manuals for regulators and know-how exchanges and contributed as a learning platform toward the adoption of the IEP as an effective regulatory mechanism countrywide—a national IEP preparatory team visited Kunming to learn from the experience in 2018, and in the following year, China officially launched the permitting standards and procedures for MSW incinerators (HJ1039-2019). The positive experiences of the pilot also led to the preparation of four directives within the permitting procedures system, from application and verification to approval, issuance, and monitoring and inspection of incinerators.
- (c) **National and local regulators trained.** A total of 36 regulators from the Ministry of Housing and Urban-Rural Development (MoHURD) and Kunming and Ningbo EPBs/UMBs participated in six international study tours for advanced MSW incineration experiences.⁸ These exchanges resulted in cross-tier interaction among policy makers and regulators at

⁸ The study tours visited cutting-edge companies and experiences such as AEB MSW in the Netherlands, Covanta in Canada, Spittelau in Austria, and good practices in compliance regulation from environmental departments in the US and Japan.



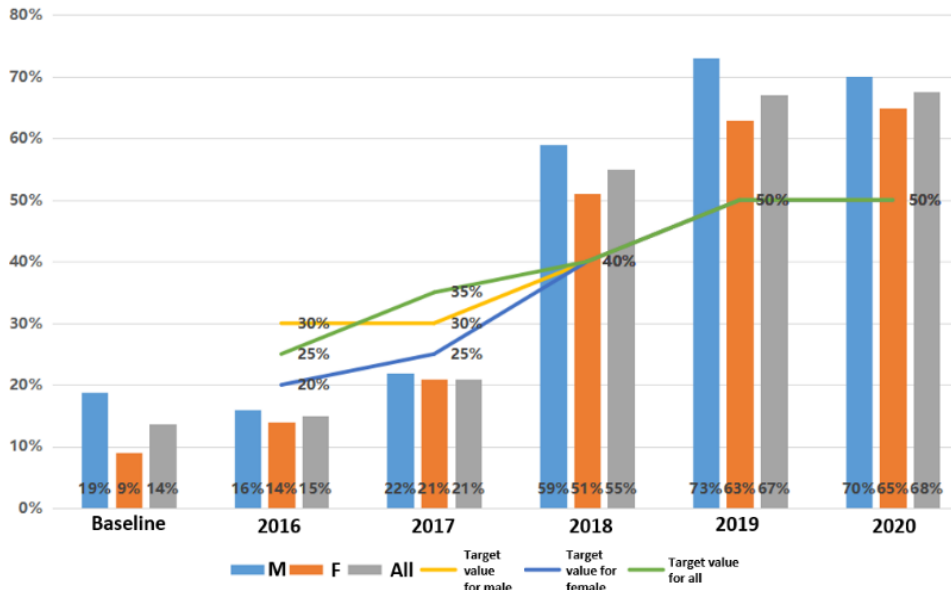
the central ministries and in Kunming and Ningbo, contributing to enhanced technical and regulatory capacities.

- (d) **Ningbo EPB dioxin lab capacity enhanced.** Strengthening this lab was important since the number of labs in the country able to monitor dioxins is limited and geographically skewed. A continuous dioxin emission sampler was purchased and tested, standard operations procedures of the lab were updated, and participation in domestic and international quality assessment and quality control exercises, training, and study tours for lab staff were completed, thus strengthening lab capacity to monitor dioxin emissions and better support Ningbo EPB with compliance verification.
- (e) **Sector standards and technical specification developed or updated in line with the SC.** The Project experience directly informed the formulation and updating of national standards and specifications. Three existing technical specifications and standards were updated: (i) Technical Specifications for Operation, Maintenance, and Safety of MSW Incinerators (CJJ128-2017), (ii) Technical Specifications for MSW Incineration Facilities (CJJ90-2009), and (iii) MSW Incinerator and Heat Recovery Boiler (GB 18750-2008). A new 'Standards for the Solidification and Disposal of Fly Ash after Waste Incineration (CJJ XXX-20XX)' was formulated and is in the final stages of clearance by MoHURD.

34. **Communities and general public.** An important, new approach to the way public awareness raising and community outreach are carried out was promoted by the Project, through online disclosure of operating and emissions data of incinerators (see details on online platforms in annex 6) and bulletin boards in public areas in Kunming and Ningbo. This led to increased public participation in environmental monitoring (EPBs received phone calls from time to time from citizens who had questions on incinerator emissions) and served to streamline communications channels and grievance redress mechanisms (GRMs). Publicity messaging was also delivered through news coverage, TV programs, videoclips played in buses, and project documentaries. A specialized institution was hired to carry out yearly surveys of a representative set of households in the vicinity of the Project incinerators to assess the change in public awareness about incineration as a result of Project activities. Final data show awareness raising consistently and beyond Project targets, reaching 67.5 percent at Project closure compared to the 2015 level of 13.7 percent. Gender-disaggregated data also showed female awareness significantly rising, from an initial 9 percent in 2015 to a final 65 percent (figure 2).



Figure 2. Public Awareness of Incinerator Information (2016–2020)



Source: Foreign Environmental Cooperation Center (FECO) Project Management Office (PMO). Awareness is measured based on a composite index built upon answers received to a questionnaire and interviews and participatory observation determined by a specialized team of experts hired by the Project.

35. **Contribution to the wider MSW incineration sector.** The Project delivered several analytical studies aimed at covering knowledge gaps in national and provincial MSW capacity, all of which delivered additional information and data that contributed to the wider dialogue on improved MSW incineration planning:

- (a) **Study on regional planning of MSW disposal.** The study strengthened the operational and financial case for integrated regional MSW management planning and the identification of regional facilities that can serve several municipalities/cities. A framework and technical specifications were developed in April 2020 to provide guidance for MoHURD to inform regional MSW management planning and improve regulations.
- (b) **Study on statistical indicators and MSW classification system,** to improve the type and quality of data utilized to inform and better manage MSW segregation. A new set of statistical indicators was established through the Project, and a recommendation for adoption was prepared with MoHURD to contribute to the review of this complex system.
- (c) **Twinning Kunming and Ningbo on MSW segregation.** Four visits were organized for exchange between regulators and incinerators and received highly positive feedback from participants (a total of 92).
- (d) **Impact assessment of waste separation on dioxin emissions (Ningbo).** Three studies were completed: (i) sampling and analysis of waste composition under different segregation conditions, (ii) detection and analysis of dioxin emissions from incinerators, and (iii) relationship between waste segregation and dioxin emissions. These studies helped regulators and policy makers better understand the anticipated effect of waste segregation on dioxin emissions, contributing to national-level planning.



PDO(b): Demonstrate BAT/BEP in MSW incineration in accordance with the Stockholm Convention

36. **To be able to demonstrate the BAT/BEP approach, the first step is to improve the ability to collect regular and reliable monitoring data.** Significant efforts and technological development were devoted to improving the ability to manage and better monitor the combustion process inside the incinerator furnaces—being able to measure and control the variables of this process (such as residence time, temperature, oxygen content, and others) is key to avoiding dioxin formation. This included, for example, the installation of state-of-the-art process control tools, such as a new SCADA⁹ system and the elements needed to grant continuous access, by regulators, to the real-time operating and emissions data of Kunming and Ningbo incinerators. Facilitating access to operating conditions by regulators adds a layer of control and oversight to the process and an incentive for continuous improvement. Using the lessons learned through this activity, the Project also funded the development of national guidelines and a standard framework for harmonizing online monitoring systems of incinerator operations for EPBs and UMBs at the national, provincial, and city levels.

37. **The implementation of “regular and reliable monitoring data showing operating practices that consistently lower dioxin levels to 0.1 ng TEQ/m³ at selected demonstration incinerators” was successfully carried out in both Konggang and Xishan incinerators.** This single PDO-level results indicator has thus been achieved (table 2). On the one hand, Project-financed improvements in operating practices were ascertained through the continuous and reliable access to incinerators’ operating conditions granted to regulators, as mentioned in the previous paragraph. On the other hand, whereas dioxin levels are traditionally measured only once a year (it is a costly and complex process), the Project implemented quarterly dioxin emission sampling and analysis of participating incinerators by a certified lab, to better characterize emission levels. Success in emission reductions was measured both directly and indirectly. The direct quarterly sampling provides information on dioxin levels during the sampling period (conducted in stationary state), whereas the monitoring of operating practices illustrates how stable and optimized the combustion process is, thus providing an indirect assessment of potential dioxin formation and emission (longer stationary state periods lead to less dioxin formation). In addition to improved monitoring and quarterly sampling, both participating incinerators implemented the BAT/BEP improvements recommended by the OEPAs supported by the Project and carried out (with own financing) additional renovations in line with the SC (see annex 7).

38. **According to third-party monitoring and verification of dioxin levels, in January 2021, both incinerators outperformed the 0.1 ng TEQ/m³ target** (final dioxin levels were 0.03 ng TEQ/m³ [Konggang line 2], 0.0046 ng TEQ/m³ [Xishan line 1], and 0.0052 ng TEQ/m³ [Xishan line 3]).¹⁰ Both incinerators also significantly improved their operations owing to BAT/BEP implementation, reaching 94 percent compliance¹¹ with the SC compared with the baseline level of 70 percent (Konggang) and 90 percent

⁹ Supervisory Control and Data Acquisition, a system able to gather and analyze real-time data to monitor and control equipment.

¹⁰ Both baseline and end-of-project dioxin levels were measured by an accredited third-party monitoring agency hired by the Project.

¹¹ Operational compliance with SC BAT/BEP is measured by analyzing a range of processes in an incinerator and assessing if they are in line with SC BAT/BEP guidance. Table 7.1 shows that, for Konggang, 71 processes were assessed, of which 48 were compliant (70 percent of total) and 21 were not (30 percent). Some of these processes were upgraded through the Project, and the end-of-project values went to 67 processes compliant (94 percent). The same approach was followed for Xishan. Final compliance was verified by a panel of experts from government and qualified environmental service companies in China. The BAT/BEP compliance levels that Konggang and Xishan reached under the Project are within the best of the sector in China—achieving higher compliance would require other improvements that are more technically complex, resource demanding, and costly than most incinerators can manage at this stage.



compliance compared with the baseline level of 72 percent (Xishan) and reducing the number of start-stop cycles considerably (64 percent reduction in Konggang and 44 percent in Xishan; see section on Other Unintended Outcomes and Impacts).

39. **The “planned schedule of improvements in operating procedures established after measuring and evaluating the baseline situation” was successfully carried out.** This supplemental PDO-level results indicator has thus been achieved (table 2). The OEPAs carried out at the onset of the Project laid a solid basis for both incinerators to implement successful renovations. Based on baseline data and the weaknesses identified through the OEPA, plant-specific improvements in hardware and operations were proposed and programed into OIPs, with targets and milestones for implementation. The OEPAs, by themselves, proved to be valuable tools for diagnostic, prioritization, and sequencing of actions.

40. **The “achievement of milestones set for the improvement of operating procedures as identified in the schedule of improvements in operating procedures” was completed at the demonstration incinerators.** This supplemental PDO-level results indicator was thus achieved (table 2 and annex 7). All physical and operational improvements to Konggang and Xishan were completed before Project closing, substantially increasing the level of SC BAT/BEP operational compliance and contributing to the demonstration value of the investments.

Table 2. PDO-Level Indicators

PDO Indicator	Baseline Dioxin Levels (ng TEQ/m ³) ^a	End Target	Actual (at closing)
Regular and reliable monitoring data show operating practices that lower dioxin levels to 0.1 ng TEQ/m ³ at selected demonstration incinerators	<ul style="list-style-type: none"> Konggang line 2: 0.093 (July 2018) Xishan line 1: 0.094 Xishan line 3: 0.059 (December 2019) 	At least meets 0.1 ng TEQ/m ³	<ul style="list-style-type: none"> Konggang line 2: 0.03 (68% reduction) Xishan line 1: 0.0046 (95% reduction) Xishan line 3: 0.0052 (91% reduction)
Supplemental PDO Indicators	Baseline ^b	End Target	Actual (at closing)
A planned schedule of improvements in operating procedures established after measuring and evaluating the baseline situation at demonstration incinerators	No	Yes	Yes
Achievement of milestones set for the improvement of operating procedures as identified in the schedule of improvements in operating procedures at demonstration incinerators	<ul style="list-style-type: none"> Konggang 70% compliance with SC BAT/BEP Xishan 72% compliance with SC BAT/BEP 	<ul style="list-style-type: none"> Konggang 94% Xishan 90% 	<ul style="list-style-type: none"> Konggang: 94% compliance Xishan: 90% compliance

Note: Although baseline levels at Konggang and Xishan were below the 0.1 ng TEQ threshold, it was important to further reduce them and implement BAT/BEP improvements because (a) baseline levels were a one-off measure, over a nonrepresentative period; (b) baselines were quite close to the 0.1 ng TEQ limit; and (c) operating performance of both incinerators was, respectively, only 70 percent and 72 percent compliant with the SC, suggesting challenges in managing combustion and guaranteeing conditions that prevent dioxin formation.

a. See footnote 10; b. see footnote 11.

41. The Project has thus managed to improve the ability to regularly monitor operational data, implement a program of improvements to increase the incinerator’s BAT/BEP compliance, and successfully demonstrate that the approach manages to reduce dioxin levels, with results significantly



lower than the 0.1 ng TEQ/m³ threshold. The Project also financed the documentation and publication of the demonstration experiences through several articles on domestic journals, a book titled ‘Exploration and Innovations in the Environmental Management of MSW Incineration in China’ authored by FECO and Yunnan EPB (published in August 2021), and a training textbook on MSW incineration technologies and applications, in addition to knowledge exchange events, training and study tours, and other dissemination efforts (described in the previous section). The Project has thus demonstrated the approach and fully achieved the corresponding PDO statement.

Justification of Overall Efficacy Rating

42. The overall efficacy is rated as High, as both parts of the PDO have been fully delivered. The PDO was achieved with direct attribution to the Project activities. The achievement of the PDO-level indicators and all intermediate results indicators directly contributed to the Government’s capacity to lower dioxin emissions and ensure compliance with operating technologies and environmental practices in accordance with the SC.

C. EFFICIENCY

Rating: Substantial

Assessment of Efficiency and Rating

43. **Economic and financial analysis.** As in most environmental projects focusing on capacity building, financial viability and sustainability of involved Project beneficiaries is key. Therefore, the economic and financial analysis carried out at appraisal was focused on the financial ability of the demonstration incinerators to participate in the Project and raise needed counterpart funds. A post-Project financial analysis carried out by government counterparts indicates that both Konggang and Xishan have (a) reported overall profitability and positive returns to their BAT/BEP investments due to operational efficiency gains and cost savings and (b) proved their ability to co-finance the technical renovations—Konggang invested US\$7.6 million which is twice the GEF grant received, and Xishan invested US\$5.2 million or 3.8 times the GEF grant received. Based on counterpart financial analysis, it is estimated that Konggang would recover its BAT/BEP investments within three years after Project closing, and Xishan could recover its investments within five years.

44. **GEF grant resources were needed for this demonstration Project.** With no experience applying SC BAT/BEP in China, individual incinerators would not invest the up-front costs needed to improve their processes and increase their compliance, since costs would be borne by them but not the benefits. GEF resources provided the additionality needed to demonstrate the validity and efficiency of the approach.

45. In the absence of a reliable method to estimate the cost-benefit of dioxin reduction,¹² efficiency gains are estimated from a number of angles:

- (a) At appraisal, the economic justification was driven by the potential benefits in reducing the severe health impacts that dioxin emissions would cause as a result of improper management of MSW incinerators. These pollutants are not only a risk to nearby populations but also known to be persistent in the environment for a long time, making

¹² Dioxins have multiple, complex interactions with the environment and human health, causing impacts that are hard to fully characterize and monetize.



cleanup after emission expensive or impossible. The SC approach reflects these issues and proposes a BAT/BEP package that balances minimizing the risk of emissions release with the cost and feasibility of reducing these emissions. Thus, core principles of technical and economic efficiency were already embedded along the implementation of SC BAT/BEP.

- (b) In an evolved context where environmental regulations in China are tightening around an expanding MSW incineration sector, driving noncompliance costs higher than ever before, the Project and its demonstration effect make an even greater economic sense at closing than during its design. Emitters in violation of emission limits face stringent corrective requirements or even shutdown, and the economic loss associated with these measures can be multiple times that of compliance requirements.
 - (c) Significant private sector investments in BAT/BEP were leveraged by the Project through co-financing from the incinerators (US\$12.74 million). Counterpart funding proved to result in savings through other unintended benefits (see paragraph 53 and annex 7), including in materials, energy, and others.
 - (d) The economic benefits of the Project go beyond Kunming and Ningbo cities, with a national and global demonstration potential to the MSM incineration community and its stakeholders.
46. Design and implementation aspects that contributed to the efficiency include the following:
- (a) **Well-designed and budgeted Project activities.** All activities were completed by the closing date, and all goals were achieved within budget. The US\$12 million GEF grant was 96 percent disbursed, with a small balance of US\$560,000 due to exchange rate fluctuation and the Dongjiao withdrawal.
 - (b) **Timely and effective Project restructuring.** Delays were experienced mainly with the demonstration activities, due to procurement difficulties (identifying and securing international expertise), several revisions to the BAT/BEP investment plans given their deeply technical complexities, shutdown of Dongjiao, and the COVID-19 pandemic in China (approximately four months of delay in completing the investments in Xishan and Konggang). The restructuring mitigated the risk of not achieving Project outcomes on time and introduced new, relevant activities implemented before the closing date.
 - (c) **Administrative efficiency.** There were dedicated and stable teams by the implementing agencies and strong technical support by the World Bank as an experienced partner in SC implementation. The total administrative cost utilized by the World Bank was relatively low, spread over 10 fiscal years (annex 2).

D. JUSTIFICATION OF OVERALL OUTCOME RATING

Rating: Highly Satisfactory

47. The overall outcome of the Project is rated **Highly Satisfactory**, based on the High rating for relevance of PDO, High rating for efficacy, and Substantial rating for efficiency.



E. OTHER OUTCOMES AND IMPACTS

Gender

48. The public outreach and community engagement activities pursued by the Project were designed with a gender perspective. Social assessments carried out during the preparation phase showed that women were less knowledgeable than men about hazardous emissions from incinerators; less aware than men of information disclosed by incinerators, more concerned about incinerators' impact on health and quality of life, and significantly more interested in information on health impacts than men. All these differences were reflected in an updated information disclosure plan in Kunming, and household surveys were carried out to determine how awareness was being raised among men and women in surrounding communities. Results showed that female awareness rose as a result of the Project team efforts, reaching levels comparable to those of men (figure 2), demonstrating the validity of the gender-informed approach to information disclosure.

49. The Project had an overall positive social benefit, as it managed to drastically reduce dioxin emissions, minimizing health impacts associated with these very toxic pollutants, including potential for prenatal exposure of children through women exposed to POPs, which is of particular concern.

Institutional Strengthening

50. The Project has strengthened the institutions involved in MSW incineration at the city, provincial, and national levels: (a) with online real-time access to operational and emissions data and city-province-central monitoring platforms established, regulatory efficiency has greatly improved and costs lowered; (b) hardware and capacity for dioxin sampling and monitoring were greatly enhanced to support enforcement; (c) the piloting of IEP in Kunming informed the adoption of the IEP as an effective regulatory mechanism in China; (d) the BAT/BEP demonstration led to the development and updating of four national standards and technical specifications for MSW incineration following the SC standards; (e) knowledge gaps were bridged on regional planning of MSW disposal, contributing to a wider policy-relevant dialogue; and (f) regulator capacity was built and coordination improved, through a tailored training program.

Mobilizing Private Sector Financing

51. The GEF grant has leveraged co-financing by the participating incinerators. The Xishan incinerator (privately owned) co-financed US\$5.2 million in additional voluntary renovations following the SC BAT/BEP, and the Konggang incinerator (state-owned) leveraged US\$7.6 million.

Poverty Reduction and Shared Prosperity

52. The Project contributed to the generation of global public goods, through a demonstration approach that also supported Yunnan, one of the less-developed provinces in China, to acquire technology, hardware, and capacities to mitigate environmental and health risks. The Project also promoted access to information by the public, regardless of background and incomes, and enabled them to be part of the economic development and voice their concerns through established channels. As the urban poor usually reside in areas of higher pollution exposure, replication of the BAT/BEP across China, especially to regions where gaps exist and compliance is imperative, will bear more significance in improving livability and shared prosperity.



Other Unintended Outcomes and Impacts

53. Both Konggang and Xishan carried out assessments after BAT/BEP implementation and reported operating benefits beyond dioxin emission reduction—better stability of the operation, better feedstock quality due to pretreatment, less start-stop cycles, savings in energy, less use of combustion additives, and other inputs, leading to economic returns and additional environmental benefits. Unwanted start-stop cycles were reduced by 64 percent in Konggang and 44 percent in Xishan, the use of a range of additives in Konggang was reduced by 5–55 percent, and fly ash amount dropped by 14 percent. Emission of other air pollutants such as SO₂, HCl, and dust was also reduced, and the monthly energy recovery increased by 14 percent in Konggang and 6 percent in Xishan.

III. KEY FACTORS THAT AFFECTED IMPLEMENTATION AND OUTCOME

A. KEY FACTORS DURING PREPARATION

54. Project preparation was challenging as this was the first BAT/BEP demonstration attempt in China for a complex sector.

55. **Project scoping.** The process of defining the Project scope and identifying the participating pilot cities was lengthy, given the different approaches and expectations of the demonstration. The scope was narrowed down from broader MSW life-cycle management issues to incinerator management and emissions control. Following a detailed evaluation of options that considered the demand, readiness, and geographic balancing, Kunming and Ningbo were selected. Kunming was to implement BAT/BEP renovations given the city's full reliance on incineration, and Ningbo was to improve regulatory monitoring and enforcement and conduct research leveraging the experience of an ongoing World Bank lending project in Ningbo to promote waste separation at source. The selection of two cities turned out to be efficient and cost-effective, and the differentiated activities have effectively used their strengths and addressed respective needs.

56. **Comprehensive identification of challenges.** During the preparation phase, detailed work was carried out in identifying gaps at the technical, operational, regulatory, and policy levels in the sector. The identification of challenges to be addressed was accurate, with government attention and demand remaining high throughout the Project toward obtaining responses and suggestions to the identified challenges.

57. **Design of technical methodology.** Agreeing on the right methodology and approach required, intensive and innovative work by the World Bank team and all stakeholders before a viable technical pathway emerged. The final agreed approach “pre-audit -> OEPA -> dioxin baseline monitoring -> OIP -> BAT/BEP investment plan -> implementation -> verification” proved useful to identify gaps in incinerators' operations and tailor investment plans, with end targets and implementation milestones. This stepwise design has significantly contributed to the Project's success and the proactive engagement of incinerator operators.

58. **Risks were adequately identified and mitigation activities were appropriately defined.** Stakeholder risks, associated with the not-in-my-backyard syndrome, were mitigated by increased, gender-informed outreach and awareness-raising initiatives, which resulted in high levels of awareness. Capacity gaps in MSW incineration were addressed through training activities targeted to multiple



stakeholders (operators, regulators, policy makers, and the public) and by providing expert support to the implementing agencies. Monitoring weaknesses were covered by activities promoting online disclosure and real-time monitoring, online sampling, and others.

B. KEY FACTORS DURING IMPLEMENTATION

59. **Factors under counterpart control: (a) Project implementing entities were fully committed and determined to succeed.** FECO, under MEE, is an experienced and knowledgeable implementing agency and provided overall leadership and coordination. Provincial leadership in Yunnan was also fundamental in linking and maintaining coordination and oversight between central-level agencies, individual incinerators, and the World Bank technical teams. Both Kunming and Ningbo appointed and secured the continued participation of highly skilled staff who contributed to a successful implementation. (b) **The regulatory framework on dioxin emissions and MSW incineration evolved in line with Project goals.** Regulators and policy makers at MoHURD and MEE continued to move the needle into more stringent regulations and frequent and effective enforcement, thus reaffirming the authorizing environment for implementation. Lastly, participating incinerators were committed and flexible, engaging with World Bank missions and members and sharing potentially sensitive information about their operations to facilitate learning. (c) **Fiduciary, environmental and social, and monitoring and evaluation (M&E) functions were well established and maintained throughout.** This facilitated a smooth implementation process, allowing for quality reporting of expenditures, proactive budgeting, overall compliance with safeguard requirements, and proper follow-up of Project progress (see section IV).

60. **Factors under World Bank control: (a) The World Bank's global experience and networks** on MSW management and incineration were useful in identifying potential international consultants to support the OEPA and OIP processes, in identifying and organizing international study tours and in overall guidance and support to counterparts. (b) **The World Bank maintained a stable team, both through continuity of team leaders and by providing key expert consultants from preparation to completion.** Communications with FECO, Kunming, and Ningbo were frequent, with numerous implementation support missions, meetings, and technical discussions. Candor and realism were maintained when evaluating performance, leading to the downgrading of Project ratings when the implementation pace slowed down.

61. **Factors outside the Project control: (a) The relocation of the Wuhua incinerator after Project onset and the shutdown of the Dongjiao incinerator in 2019 responded to government decisions** and caused delays during the protracted government discussions leading to these actions. FECO's request for a 15-month Project extension was influenced by these facts. (b) **COVID-19 delays and renewed commitment.** The unexpected outbreak of COVID-19 in China in January 2020 came at a crucial time, effectively halting all Project activities, paralyzing procurement processes and improvement works at the incinerators. However, Project activities resumed due to commitment and determination by government counterparts, who, with support from the World Bank team, managed to complete all tasks without requiring any additional extension—a measure of the leadership and determination to complete the demonstration successfully.



IV. BANK PERFORMANCE, COMPLIANCE ISSUES, AND RISK TO DEVELOPMENT OUTCOME

A. QUALITY OF MONITORING AND EVALUATION (M&E)

Rating: Substantial

M&E Design

62. The M&E design was solid and able to capture progress and the intended demonstration results. The overall RF was appropriate for measuring attributable success toward achieving the PDO. A comprehensive range of indicators was selected to illustrate the main components and key activities, with clear baseline and target values. The single PDO-level indicator and its two supplemental ones were effective at measuring the complex, interrelated objectives of building capacity, improving the reliance of monitoring systems, improving operating conditions, and reducing dioxin emissions. The single PDO-level indicator managed to capture the two main aspects of capacity building and demonstration; however, a different approach with a few indicators for each aspect of the PDO might have been easier to follow. The supplemental PDO indicators and the intermediate indicators were comprehensive, simple, and straightforward and properly covered all Project achievements, and therefore the RF is considered to be adequate.

M&E Implementation

63. **M&E implementation was carried out as expected and without shortcomings.** The M&E design included appropriate arrangements for data collection, analysis, and reporting, and indicator progress was shared by Project counterparts on a semiannual basis. The M&E methodology remained unchanged during implementation, with minor adjustments to the RF through the 2019 Project restructuring. The FECO, Kunming, and Ningbo PMOs prepared comprehensive monitoring reports following agreed reporting schedules. FECO maintained overall M&E responsibility, reported progress of national-level activities, and collected M&E reports from Kunming and Ningbo PMOs.

M&E Utilization

64. The efficient implementation of the M&E framework offered the three PMOs and the World Bank a solid basis to timely capture and assess progress and achievement of results and informed key decisions such as for Project restructuring. It has been effective in tracking capacity-building activities for regulators, operators, and policy makers. The measurement of baseline and end-of-project dioxin emissions in the incinerators was a complex task, very much at the heart of the Project objectives, and subject to multiple discussions and verification protocols. This facilitated the discussion on how to improve, mainstream, and reduce costs in dioxin sampling and analysis. The addition of an intermediate indicator during Project restructuring to measure the success of continuous sampling testing was carried out to reflect the importance of this activity.

Justification of Overall Rating of Quality of M&E

65. Overall, M&E design was well-defined and comprehensive and provided the basis for assessing PDO achievements. The M&E system was effectively implemented and provided ongoing, timely, and relevant information needed to take corrective action whenever granted. There were only a few minor shortcomings, as described in previous paragraphs, and therefore the Project M&E quality is rated Substantial.



B. ENVIRONMENTAL, SOCIAL, AND FIDUCIARY COMPLIANCE

Environmental and Social

66. **The Project triggered the Environmental Assessment (OP 4.01) policy.** Key environmental risks identified during preparation were associated with the operation of the demonstration incinerators, including air emissions control, solid waste and wastewater management, and health and safety risks. Due to the risk level of potential environmental impacts, the Project was classified as Category A-full assessment. No social safeguards policy was triggered, as the Project involved no land acquisition or resettlement, and there were no ethnic minority groups associated with the Project area or associated with the demonstration incinerators.

67. An environmental audit and an environmental and social management plan (ESMP) for each incinerator and an Environmental Assessment Executive Summary for the entire Project were prepared in compliance with World Bank safeguards policies and Chinese national regulations. These documents became the overarching references for environmental and social management and were proactively implemented and reviewed from time to time. The ESMPs were developed based on the findings of the environmental audits and included detailed information on organizational arrangements and responsibilities for environmental management, mitigation measures, plans for training, monitoring, public engagement and risk management, and budget estimates for ESMP implementation during construction and operation. All draft environmental audits and ESMPs were disclosed locally on March 10, 2014, and on the World Bank website on March 25, 2014, and updates were disclosed on the World Bank website on August 15, 2014. The ESMPs for Konggang and Xishan incinerators were updated in 2018 and 2019, respectively, to integrate the findings of the OEPAs and OIPs.

68. The environmental management system was built into the management structure within FECO, provincial/local EPBs, and participating incinerators, and environmental staff were appointed to coordinate and supervise. Frequent training sessions were organized, and an external environmental monitoring consultant was hired to conduct regular environmental monitoring to the participating incinerators. The ESMPs' requirements were included in the contractor's contracts, and a GRM was established and implemented (see details in annex 6).

69. Project environmental performance was monitored and reviewed by FECO, provincial PMOs, and the World Bank team, based on regular field visits and semiannual environmental monitoring data. The ESMPs for the demonstration incinerators were implemented in a satisfactory manner, with no reported environment, health, and safety incident/accident.

70. In addition to the significant reduction of dioxin emissions, participating incinerators also reported reduced emission levels of other air pollutants such as SO₂, HCl, and dust. Hence, the Project resulted in considerable direct and long-term environmental benefits.

71. A detailed social assessment was carried out during Project preparation, and two main issues were identified: insufficient information disclosure and the absence of GRMs. To address these issues, the Project team facilitated the effective and gender-informed disclosure of information and designed a range of initiatives to raise public awareness, with dedicated results indicators to follow progress. The main methods to improve the awareness of residents in surrounding communities included (a) capacity building for communication teams at the demonstration incinerators, (b) community needs assessment, and (c) screening of effective communication channels and dissemination activities. The Project team also



facilitated the establishment of GRMs to respond to questions and concerns from people in the neighborhood. Yunnan PMO and Kunming UMB also established GRMs to address comments on performance or coverage of Project activities.

72. The Kunming PMO engaged a task force led by a social and community development professor from Yunnan University to support public outreach activities, guide incinerators in community awareness raising, and carry out household surveys to establish the effectiveness of these activities. Through the concerted cooperation of this task force and Project stakeholders, substantial efforts on community work were promoted at the demonstration incinerators, achieving significant results in information disclosure and public participation, in a gender-informed manner. The Project overachieved in all its targets of awareness raising to the general population as well as disaggregated by gender.

73. In addition, the client ICR carefully captures this experience, with a summary of the main methods and results of community work in the project development process, providing guidance for waste incineration information disclosure and public awareness raising to promote good relationships between plants and surrounding residents and alleviate the ‘not in my backyard’ mindset.

Fiduciary Compliance

74. Procurement was carried out in compliance with World Bank policies and procedures. The PMOs at FECO, Kunming, and Ningbo were staffed with designated team members responsible for procurement, and staffing was maintained stable, which was a favorable condition for procurement management. A procurement agent and an external consultant were hired to enhance capacity to procure and manage contracts.

75. In the early stages, procurement delays were observed and attributed to lack of familiarity with procedural requirements. For some contracts, the final pricing received, in excess of what was originally budgeted, also resulted in delays, since there was no counterpart fund allocated for the contracts and the client had to seek other available resources or among the different Project activities. Due to the incompatibility of existing incinerator systems with other products, competitive processes were deemed inapplicable for renovation for the incinerators, and this led to additional time required by PMOs to verify the pricing quoted by suppliers and justify the adoption of noncompetitive methods in procurement.

76. Despite initial delays due to the highly technical nature of activities and limited resources and monitoring during the first part of the Project, the rest of the procurement processes were concluded successfully, supporting implementation and ensuring efficient use of resources. The Procurement Plan was regularly updated, at least every year or as needed, and no major issues came up throughout implementation.

77. The Project agencies maintained an adequate financial management (FM) system that provided, with reasonable assurance, accurate and timely information about the grant and its use for the intended purposes. Accounting and financial reporting were in line with the regulations issued by the Ministry of Finance and the requirements specified in the Grant Agreement. No significant FM issues were noted throughout implementation and any minor weakness raised during supervision was resolved on time. Project audit reports were all with unqualified audit opinions. In addition, the withdrawal procedure and funds flow arrangements were appropriate, and grant proceeds were disbursed timely.



C. BANK PERFORMANCE

Quality at Entry

78. **World Bank performance at entry is assessed as Satisfactory.** Project design was forward-looking and fully aligned with China's compliance commitments and WBG strategy, with a strong focus on global public goods. The PDO was clear, rational, and challenging, to be achieved through a comprehensive mix of technical, institutional, and policy interventions that incentivized change. Preparation work by the World Bank team managed to identify key technical and institutional challenges, and Project design responded to these challenges, engaging a range of MSW incinerator stakeholders, and more broadly on MSW management, across departments and agencies at the city, provincial, and national levels. The Project included important 'soft' elements that were critical to improve the managing environment, through real-time monitoring capabilities, strengthening of enforcement, improving of the permitting system, community outreach, and gender-informed information disclosure, improved policies, and training. All these delivered a comprehensive package of measures that responded to current and emerging needs, all with a relatively modest grant.

79. Given the complex technical challenges addressed by the Project and the difficulty of identifying willing and committed incinerators, it took around two years to move from concept to approval, partly reflecting the need to carry out appropriate environmental and social assessments, identify risks, and design mitigation strategies. This process was needed to strike the right balance of investments and managerial improvements and delivered a valid and robust design. For each of the challenges identified in the PAD, a specific product was identified and included in the Project by the World Bank team and participating agencies, all of which were relevant at the time of their conclusion and were either directly adopted (policies, guidelines, monitoring requirements) or directly used as input to wider processes (statistical classification system, studies on effects of waste segregation on dioxin emissions, and others).

Quality of Supervision

80. **Quality of supervision is rated as Satisfactory.** The World Bank team provided strong technical inputs and effective operational support during implementation, with regular support missions (every six months, for a total of 12, with hardly any interruption during the early stages of the COVID-19 pandemic); desk reviews; training events; and on-demand, frequent guidance to the PMOs. This included a detailed midterm review in 2018, which promptly addressed procurement through an action plan and which was fundamental in reviewing the BAT/BEP investment proposals for participating incinerators, approving the Konggang proposal, and issuing technical feedback to the Xishan and Dongjiao proposals. Throughout implementation, the World Bank team included a good skills mix, with technical, environmental, social, financial, procurement, and policy experts, and managed to mobilize expertise in and outside China. The task team remained relatively stable, with three country-based team leaders in total, and most key team members were not changed throughout. Issues were timely identified and addressed. Each World Bank support mission comprised technical, fiduciary, and safeguards specialists, reviewing progress and preparing detailed aide memoires with action plans and next steps. Although the Project did not trigger social safeguards, a World Bank social specialist was part of the core team, providing guidance on community outreach and awareness raising, GRM, and dissemination work. This proved to be a value added to counterparts, who were less used to this type of upstream engagement work.



81. The World Bank team was candid in assessing progress, rating the Project as Moderately Unsatisfactory for overall implementation progress for 14 months, which led to an agreement for restructuring and a resolution of the causes of implementation delays. The restructuring addressed all key obstacles and turned around implementation progress with strong collaboration by FECO, Yunnan, and Ningbo PMOs.

Justification of Overall Rating of Bank Performance

82. Overall World Bank performance is rated Satisfactory, based on the satisfactory ratings for quality at entry and of supervision.

D. RISK TO DEVELOPMENT OUTCOME

83. The overall risk to development outcomes is Low. The adoption of the 0.1 ng TEQ/m³ dioxin standard and the cost savings reported by participating incinerators have motivated plants countrywide to undertake technical improvements following BAT/BEP. In this sense, the Project has provided a good opportunity for Konggang and Xishan facilities to be the early demonstration among other enterprises in China to avoid future emissions noncompliance and associated costs. The parent company to which Xishan belongs has announced its plans to replicate the BAT/BEP approach to all its facilities (22 incinerators in total in 13 provinces).

84. Technically, the physical and operational improvements by Konggang and Xishan are irreversible. Both incinerators have made significant investments in the technical transformation and have shown the skills and capacity to sustain the operation at a more stable and less polluting level than before the Project. Also, they contributed with substantial own finances. By Project closing, both Konggang and Xishan are operating at capacity, have positive and growing revenues, and have already been financing the recurrent costs—these are all proofs of the financial sustainability of the investments. As a result of the Project, dioxin levels were reduced beyond the targets, thus fulfilling the technical and financial demonstration of the Project.

85. **In relation to capacity building**, significant achievements were made in demonstrating real-time data monitoring and sharing of operational conditions with local and provincial regulators, comprehensive training (including training of trainers), improvements to the policy framework, twinning of Ningbo and Kunming, improvement of dioxin lab and dioxin monitoring approaches, and others. All these point to an enhanced and sustainable capacity at the provincial and national levels.

V. LESSONS AND RECOMMENDATIONS

86. **Project design and the customized BAT/BEP methodology have been key to success.** The Project managed to adopt a robust, logical framework for improvements, agreed with all stakeholders, consisting of “pre-audit -> OEPA -> dioxin baseline monitoring -> OIP -> BAT/BEP investment plan -> implementation -> verification.” This road map, although time-consuming, paid off and managed to facilitate decision-making, customize operational improvements to the incinerators, and ensure ownership (annex 7).

87. **Timing and ownership are key for increased demonstration value.** The Project was prepared at a time when China was considering a tightening of emissions standards. The official announcement of a tenfold reduction in the allowed dioxin levels (from 10 to 0.1 ng TEQ/m³) came in May 2014, only six



months before Project approval, and was to be enforced starting January 2016. This provided a solid framework for the Project to succeed and influence important environmental regulations that the new standard demanded, contributing to mainstreaming dioxin control in the broader framework for environmental protection. The funds available for this grant were relatively modest, but the range of actions and results is quite significant, due to client demand and commitment.

88. Interministerial collaboration needs to be fostered through initiatives with strong institutional ownership. The Project supported technical activities including the development of MSW management planning methodologies and the revision of incineration technical standards. The activities were under the overall coordination of FECO but with active participation and guidance by MoHURD given the relevance to the ministry's ongoing work in modernizing MSW management. MoHURD is the beneficiary of key deliverables under the Project, the findings of which have informed policies, standards, and sector planning. In this way, the Project fostered interministerial exchange and collaboration, leading to greater synergy and efficiency of the regulatory regime. The twinning of Ningbo and Kunming was also helpful in promoting peer-to-peer learning and a sense of healthy competition.

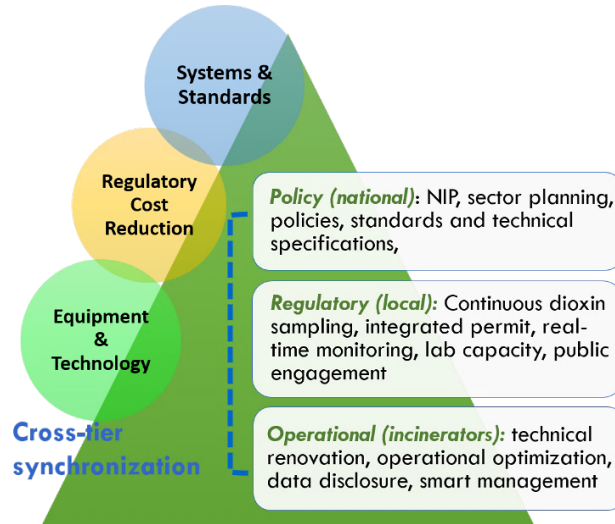
89. Project leadership at the implementation level and PMO staff continuity are needed to achieve Project objectives. The determination of staff, particularly at Kunming where the demonstration work took place and overall at FECO, were fundamental during times of doubt, for example, those that occurred at the early stages due to Project complexity and those caused by the COVID-19 pandemic. The challenge of reaching agreements between privately or state-owned incinerators, local and provincial authorities, central-level ministries, and the World Bank is significant, and the application of the World Bank's safeguards and fiduciary requirements demands commitment and openness. PMOs played a fundamental role in this space, coordinating all parties and providing the needed momentum for success.

90. All stakeholders need to be proactively engaged to achieve sustainable dioxin emission compliance. The Project has demonstrated transformative approaches not only for incinerator operators but also for regulators, communities, and broader policymakers, as emissions compliance requires capacity and skills at all those levels (figure 3). The Project has thus supported a mix of hard and soft interventions to improve the reliability and efficiency of data monitoring and its access by third parties; enable engagement between regulators, policy makers, and the public; and encourage cross-tier collaboration. The combination of investments, capacity building, and tailored training proved to be an effective way to achieve success.

91. Demonstration activities combined with assertive enforcement provide a strong foundation for sustainability. Determined enforcement of standards is key to showing how regulatory and monitoring frameworks work toward protecting people's health and the environment. As an illustrative example, the decision to shut down the Dongjiao incinerator sent a strong, assertive signal within the sector. At the same time, the BAT/BEP improvements funded by the Project at the two selected incinerators not only demonstrated how to reduce dioxin levels to ensure compliance with national standards and the SC but also led to other positive outcomes such as more stable operating conditions and overall cost savings, thus illustrating the benefits of the approach and incentivizing replication of the experiences elsewhere.



Figure 3. Stakeholder Collaboration



Note: NIP = National Implementation Plan.

92. **Community outreach and engagement and data disclosure are game changers in the balance between incinerators and neighbors and need to be gender informed.** Detailed social assessments were carried out during Project preparation, and gaps in previous communication strategies prepared by the participating incinerators were identified. The assessments were gender informed, and this became a crucial element of the effort, as gender disparities were identified in the reception of information, with females reporting lower awareness levels, lower understanding of the processes, and a more proactive interest in health consequences. A specialized team was engaged and worked closely with the social teams appointed by incinerators to tailor outreach messages, with the result of higher levels of awareness at Project end than targeted by both males and females. The disclosure of air pollutant information by incinerators helped build trust and accountability, improved the flow of communications between stakeholders, and allowed for early grievance redress. All these efforts are expected to mitigate the 'not in my backyard' syndrome.

93. **Improving control and stability of the incineration is key for a stable, less-polluting outcome.** Dioxin levels have been significantly reduced at the two demonstration incinerators by improving their operating conditions, including by ensuring better combustion stability (more homogeneous feedstock, more stable furnace temperatures and residence times) and by reducing the overall number of start-stop cycles (often caused by emergency stops due to equipment failure or malfunction). Avoiding unnecessary start-stop of the furnace and increasing combustion stability are thus key to keeping dioxin emissions low. The demonstration of these elements in Konggang and Xishan provides a valuable technical example for other incinerators to improve their processes and increase their control systems, to achieve emissions compliance with the SC.



ANNEX 1. RESULTS FRAMEWORK AND KEY OUTPUTS

A. RESULTS INDICATORS

A.1 PDO Indicators

Objective/Outcome: Demonstrate BAT/BEP in municipal solid waste incineration in accordance with Stockholm Convention

Indicator Name	Unit of Measure	Baseline	Original Target	Formally Revised Target	Actual Achieved at Completion
Regular and reliable monitoring data show operating practices that lower dioxin levels to 0.1 ng TEQ/m3 at selected demonstration incinerators	Text	Baseline was measured at the beginning of project implementation. Baseline operating conditions (ng TEQ/m3): Konggang line 2: 0.093; Xishan line 1: 0.094; Xishan line 3: 0.059 03-Dec-2018	TBD based on first year audits 31-Dec-2019	Dioxin emission: at least meets 0.1 ng TEQ/m3 31-Mar-2021	Both Konggang and Xishan comply with the Protocol. Konggang line 2: 0.03 ng TEQ/m3; Xishan lines 1 and 3 are 0.0046 and 0.0052 TEQ/m3, respectively. 31-Mar-2021
A planned schedule of improvements in operating procedures established after measuring and evaluating the baseline situation at three	Yes/No	N	Y		Yes



demonstration incinerators.					
Achievement of milestones set for the improvement of operating procedures as identified in the schedule of improvements in operating procedures at selected demonstration incinerators	Text	Operational Baselines: Konggang 70% compliance with Stockholm Convention BAT/BEP; Xishan 72%; Dongjiao 69%.	TBD based on first year audits	Operational practice targets: Xishan 90% compliance with SC BAT/BEP; Konggang 94%	Konggang: 94% compliance; Xishan: 90% compliance
<p>Comments (achievements against targets): Targets for PDO indicator and two supplemental indicators were achieved and exceeded.</p> <p>The first supplemental indicator was not revised during the Project restructuring because the planned improvements were also prepared for Dongjiao before its closure, and thus they were completed for a total of three incinerators.</p>					

A.2 Intermediate Results Indicators

Component: Capacity Building for Improved Operation and Regulation of MSW Incinerators

Indicator Name	Unit of Measure	Baseline	Original Target	Formally Revised Target	Actual Achieved at Completion
KEPB and KUMB have continuous access to data on operating conditions and emissions from all five	Yes/No	No 05-Jan-2015	Y 31-Dec-2019		Yes 31-Mar-2021



Kunming incinerators					
<p>Comments (achievements against targets): Target achieved. Regulators in Kunming have gained continuous access to data, thus facilitating monitoring and enforcement activities, and public disclosure. Kunming had four incinerators in operation during Project preparation, and a fifth one became operative after Project implementation. The Project facilitated the access to operating data for all five.</p>					

Indicator Name	Unit of Measure	Baseline	Original Target	Formally Revised Target	Actual Achieved at Completion
NEPB has continuous access to data on operating conditions and emissions from all three incinerators in Ningbo.	Yes/No	No 05-Jan-2015	Y 31-Dec-2019		Yes 31-Mar-2021

Comments (achievements against targets):
 Target achieved. Regulators in Ningbo have gained continuous access to data, thus facilitating monitoring and enforcement activities, and public disclosure.

Indicator Name	Unit of Measure	Baseline	Original Target	Formally Revised Target	Actual Achieved at Completion
Data on operating conditions and emissions disclosed to public in Kunming	Yes/No	No 01-Jan-2015	Y 31-Dec-2019		Yes 31-Mar-2021



Operating conditions of five incinerators posted on the web	Yes/No	N	Y		Yes
Information on environmental impacts of four incinerators posted on community bulletin boards	Yes/No	N	Y		Yes
Dioxin emission monitoring results for five incinerators in Kunming posted on the web	Yes/No	N	Y		Yes
<p>Comments (achievements against targets): Targets achieved. The public in Kunming has now access to both operating conditions and emissions data of all incinerators in the city area. Disclosure of operating conditions and dioxin emissions of all five Kunming incinerators was achieved through the Project. The specific disclosure of environmental impacts applied only to the four incinerators that were screened by the Project (Wuhua, Dongjiao, Xishan and Konggang).</p>					

Indicator Name	Unit of Measure	Baseline	Original Target	Formally Revised Target	Actual Achieved at Completion
Operating conditions of three Ningbo incinerators posted on the web	Yes/No	No 01-Jan-2015	Y 31-Dec-2019		Yes 31-Mar-2021
<p>Comments (achievements against targets):</p>					



Target achieved. The public has now access to operating conditions in Ningbo.

Indicator Name	Unit of Measure	Baseline	Original Target	Formally Revised Target	Actual Achieved at Completion
Public awareness of incinerator information increased	Percentage	13.70 31-May-2013	50.00 31-Dec-2019		67.43 31-Mar-2021
Awareness of females of incinerator information increased	Percentage	9.30 31-May-2013	50.00 31-Dec-2019		64.86 31-Mar-2021
Awareness of males of incinerator information increased	Percentage	18.80 31-May-2013	50.00 31-Dec-2019		70.00 31-Mar-2021

Comments (achievements against targets):

Targets exceeded. Both overall and gender-specific awareness raising activities were successful.

Indicator Name	Unit of Measure	Baseline	Original Target	Formally Revised Target	Actual Achieved at Completion
Kunming district EPBs inspect each of five incinerators once per year on the basis of	Yes/No	No 05-Jan-2015	Y 31-Dec-2019		Yes 31-Mar-2021



integrated permit					
Integrated permit finalized for each incinerator	Yes/No	N	Y		Yes
Comments (achievements against targets): Target achieved.					

Indicator Name	Unit of Measure	Baseline	Original Target	Formally Revised Target	Actual Achieved at Completion
Number of regulators trained through study tours to northern America and Europe	Number	0.00 01-Jan-2015	36.00 31-Dec-2019		36.00 31-Mar-2021
Comments (achievements against targets): Target achieved.					

Indicator Name	Unit of Measure	Baseline	Original Target	Formally Revised Target	Actual Achieved at Completion
Number of incinerators nationwide with at least five supervisors and operators	Number	0.00 01-Jan-2015	40.00 31-Dec-2019		40.00 31-Mar-2021



trained in BAT/BEP

Comments (achievements against targets):

Target achieved. Most of the trained supervisors and operators belong to companies that operate several incinerators nationwide, thus increasing the impact.

Indicator Name	Unit of Measure	Baseline	Original Target	Formally Revised Target	Actual Achieved at Completion
Dioxin emissions from demonstration incinerators	Text	Baseline to be determined at end of first year audits 01-Dec-2018	0.1 ng TEQ/m3 31-Dec-2019		Konggang line 2: 0.03; Xishan line 1: 0.0046; line 3: 0.0052 31-Mar-2021

Comments (achievements against targets):

Target exceeded.

Indicator Name	Unit of Measure	Baseline	Original Target	Formally Revised Target	Actual Achieved at Completion
Ningbo Lab standard operating procedure assessed as consistent with international good practices	Text	No 01-Jan-2015	Yes 31-Dec-2019		Yes 31-Mar-2021



Comments (achievements against targets):

Target achieved.

Indicator Name	Unit of Measure	Baseline	Original Target	Formally Revised Target	Actual Achieved at Completion
Number of standards revised/developed	Number	0.00	3.00		4.00
		01-Jan-2015	31-Dec-2019		31-Mar-2021

Comments (achievements against targets):

Target exceeded.

Indicator Name	Unit of Measure	Baseline	Original Target	Formally Revised Target	Actual Achieved at Completion
Continuous sampling of emissions is tested in at least one selected demonstration incinerator	Yes/No	No	Y		Yes
		05-Jan-2015	31-Mar-2021		31-Mar-2021

Comments (achievements against targets):

Target achieved. The continuous sampling equipment is installed and under operation at Konggang incinerator.



B. KEY OUTPUTS BY COMPONENT

Objective/Outcome 1. Demonstrate BAT/BEP in Municipal Solid Waste Incineration in accordance with the Stockholm Convention	
Outcome Indicators	<ol style="list-style-type: none"> 1. Regular and reliable monitoring data show operating practices that lower dioxin levels to 0.1 ng TEQ/m³ at selected demonstration incinerators. <ul style="list-style-type: none"> • A planned schedule of improvements in operating procedures established after measuring and evaluating the baseline situation at three demonstration incinerators • Achievement of milestones set for the improvement of operating procedures as identified in the schedule of improvements in operating procedures at selected demonstration incinerators
Intermediate Results Indicators	<ol style="list-style-type: none"> 1. KEPB and KUMB have continuous access to data on operating conditions and emissions from all five Kunming incinerators. 2. NEPB has continuous access to data on operating conditions and emissions from all three incinerators in Ningbo. 3. Dioxin emissions from demonstration incinerators. 4. Continuous sampling of emissions is tested in at least one selected demonstration incinerator.
Key Outputs by Component (linked to the achievement of the Objective/Outcome 1)	<ol style="list-style-type: none"> 1. OEPAs and OIPs developed and implemented in Konggang and Xishan. Baseline emissions established. 2. Installation of hardware and software to improve management of the combustion process and to improve emissions monitoring. 3. Dioxin emissions substantially lowered, below the 0.1 ng TEQ/m³ target. 4. Operational SC compliance practices increased (Konggang 94% compliance with SC BAT/BEP, Xishan 90%). 5. Konggang and Xishan post-project dioxin monitoring and verification completed. 6. Online access to operating conditions enabled, online sampling of dioxins successfully tested.
Objective/Outcome 2. Build Capacity	
Outcome Indicators	<ol style="list-style-type: none"> 1. Regular and reliable monitoring data show operating practices that lower dioxin levels to 0.1 ng TEQ/m³ at selected demonstration incinerators.



Intermediate Results Indicators

1. KEPB and KUMB have continuous access to data on operating conditions and emissions from all five Kunming incinerators.
2. NEPB has continuous access to data on operating conditions and emissions from all three incinerators in Ningbo.
3. Data on operating conditions and emissions disclosed to the public in Kunming.
 - Operating conditions of five incinerators posted on the web
 - Information on environmental impacts of four incinerators posted on community bulletin boards
 - Dioxin emission monitoring results for five incinerators in Kunming posted on the web
4. Operating conditions of three Ningbo incinerators posted on the web.
5. Public awareness of incinerator information increased.
 - Awareness of females of incinerator information increased
 - Awareness of males of incinerator information increased
6. Kunming district EPBs inspect each of five incinerators once per year on the basis of integrated permit.
 - Integrated permit finalized for each incinerator
7. Number of regulators trained through study tours to north America and Europe.
8. Number of incinerators nationwide with at least five supervisors and operators trained in BAT/BEP.
9. Ningbo lab standard operating procedure assessed as consistent with international good practices.
10. Number of standards revised/developed.



Key Outputs by Component
(linked to the achievement of the
Objective/Outcome 2)

1. Incinerators in Kunming and Ningbo have disclosed emissions and operating data online to EPBs and UMBs.
2. Incinerators in Kunming have disclosed emissions (including dioxin) and operating data online.
3. Increase public awareness of incinerator information (male/female).
4. Integrated emissions permit issued by EPB to each incinerator in Kunming.
5. Six international study tours organized for regulators.
6. BAT/BEP replication training completed for incinerators nationwide—at least 40 incinerators had at least five supervisions and operators trained.
7. Ningbo lab equipped with continuous dioxin sampling equipment and staff capacity built.
8. Four national standards revised/developed.
9. Continuous dioxin sampling equipment procured for Konggang and sampling conducted.
10. Dissemination and educational activities delivered.
11. Study on regional planning of MSW disposal delivered.
12. Study on statistical indicators and MSW classification system delivered.
13. Kunming and Ningbo twinned for learning purpose.
14. Impact assessment of waste separation on dioxin emission delivered.
15. Results monitored and verified; experience disseminated.

**ANNEX 2. BANK LENDING AND IMPLEMENTATION SUPPORT/SUPERVISION****A. TASK TEAM MEMBERS**

Name	Role
Preparation	
Tijen Arin	Task Team Leader
Sing Cho	Urban Specialist
Laurent Granier	Senior Environmental Specialist
Ning Yang	Senior Environmental Specialist
Chaogang Wang	Social Specialist
Fang Zhang	Financial Management Specialist
Zheng Liu	Procurement Specialist
Minneh Mary Kane	Lead Counsel
Aristeidis I. Panou	Counsel
Lourdes L. Anducta	Program Assistant
Nina Queen Irving	Senior Program Assistant
Supervision/ICR	
Daniel Mira-Salama	Task Team Leader
Zheng Liu	Procurement Specialist
Fang Zhang	Financial Management Specialist
Frank Van Woerden	Team Member
Yan Zhang	Procurement Team
Xieli Bai	Program Assistant
Shuang Zhou	Social Specialist
Bin Xu	Environmental Specialist
Xiaodan Huang	Senior Environmental Engineer
Ning Yang	Senior Environmental Specialist (former TTL)
Zijing Niu	Team Member
Tian Qinghua	Consultant, dioxin specialist



B. STAFF TIME AND COST

Stage of Project Cycle	Staff Time and Cost	
	No. of staff weeks	US\$ (including travel and consultant costs)
Preparation		
FY11	.575	2,471.12
FY12	18.081	86,865.01
FY13	18.976	110,360.10
FY14	15.120	110,586.51
FY15	10.562	68,690.32
FY16	2.551	15,828.88
FY17	0	0.00
Total	65.87	394,801.94
Supervision/ICR		
FY16	6.675	35,962.62
FY17	10.855	54,605.14
FY18	9.825	64,975.43
FY19	6.653	71,979.87
FY20	9.435	99,231.32
Total	43.44	326,754.38



ANNEX 3. PROJECT COST BY COMPONENT

1. The Project cost at approval and closing is shown in table 3.1. By the end of the grace period for disbursement of July 31, 2021, the GEF grant was 95 percent disbursed. A small balance of US\$560,000 was due to the Dongjiao shutdown and related savings, together with lower-than-estimated contract values through competitive bidding, exchange rate fluctuation, and cancellation of some Project events and travel due to the COVID-19 outbreak.

Table 3.1. Project Cost by Component

Components	Total (US\$, millions)			GEF Financing (US\$, millions)		
	Amount at Approval	Actual at Project Closing	Percentage of Approval	Amount at Approval	Actual at Project Closing	Percentage of Approval
1. Capacity Building for Improved Operation and Regulation of MSW Incinerators	27.44	34.94	127	9.83	9.38	95
2. Capacity Building for Improved MSW Management Planning	1.75	3.66	209	1.57	1.26	80
3. Project Management	3.72	3.98	107	0.60	0.80	133
Total	32.91	42.58	129	12.00	11.44	95

2. The co-financing status is shown in table 3.2. The actual amount of co-finance realized exceeds the amount confirmed at CEO endorsement by 49 percent.

Table 3.2. Co-financing Realization

Source of Co-finance	Amount Confirmed at CEO Endorsement (US\$, millions)	Actual Amount Realized at Closing (US\$, millions)	Actual as % of Approval
MEE and environmental protection authorities in Kunming and Ningbo	7.61	18.40	242
Demonstration enterprises	13.30	12.74	96
Other	—	—	—
Total	20.91	31.14	149



ANNEX 4. EFFICIENCY ANALYSIS

1. Project efficiency is assessed to be Substantial, in terms of both the financial sustainability of demonstration incinerators after Project investments and achievement of all capacity building and demonstration goals of the Project within budget and with cost-effectiveness principles embedded into the SC BAT/BEP process.
2. At appraisal, the economic justification was driven by the Project's potential benefits in reducing the severe potential health impacts of the emission of dioxin, a toxic and persistent chemical into the environment, as a result of improper management of MSW incinerators. As a signatory of the SC, China is committed to minimizing dioxin emissions from its growing MSW incineration sector, hence the selection of this Project to help demonstrate the adoption of the BAT/BEP to the local context, by testing the approach at demonstration incinerators in Kunming for further replication across China. The Project had identified some 25,000 people living in the vicinity of the pilot incinerators as direct beneficiaries, who would be exposed to lower dioxin emissions due to the Project interventions.
3. At closing, the Project makes significant economic sense in the evolved sectoral context. MSW incineration is expanding in China, with current installed capacity doubling the estimates made for this Project at appraisal. China's MSW incineration capacity is now close to the European Union level and is around 40 percent of the world's total. Moreover, in the recently released 14th Five-Year Plan (2021–2025) for MSW Separation and Treatment Facility Development, China has set ambitious targets for 2025 of 800,000 t/d, by when 65 percent of waste would end up in incinerators.¹³ These facts make China's capacity to reduce negative environmental impacts of incineration very relevant. Although the final emission reduction achieved owing to Project improvements is known in each of the two demonstration incinerators, a specific cost-effectiveness analysis was not carried out, since dioxin levels are measured through a short period, on steady state, thus not capturing the full incineration cycle (which includes start-stop). The reduction in start-stop cycles is a key outcome of the Project; however, the emission reduction value does not capture this benefit, and thus the cost-effectiveness analysis would not be sufficiently illustrative of all Project results.
4. Since 2017, MEE has made monitoring and enforcement on MSW incineration more stringent than ever, notably by carrying out 'unannounced on-site monitoring' and coordinated enforcement with local governments. The tightening regulatory environment is driving noncompliance costs much higher—as shown by the shutdown of the Dongjiao incinerator during Project implementation. Emitters in violation of emission limits face severe correction actions, including shutdown for physical improvements and corrections that would lead to significant income loss as well as potential damage to the public at large due to the corresponding reduced incineration capacity. Under this perspective, the economic loss associated with the enforcement measures can be multiple times that of maintaining or meeting compliance requirements.
5. Against this backdrop, the Project has laid a solid basis for China to scale up SC compliance efforts and thus minimize economic costs by reducing the environmental and health risks of MSW incineration with a modest grant, with large potential for greater impact: (a) replication of the tested BAT/BEP and technical methodologies to other cities will transform the MSW incineration in China and reduce the health risk related to dioxin emissions to local people (millions of habitants); (b) a real-time online

¹³ Issued by the National Development and Reform Commission and MoHURD, May 2021.



monitoring system connecting enterprises and local and central regulators, as tested in Kunming and Ningbo, would greatly enhance the regulatory efficiency and reduce administrative cost; (c) more stable operating conditions, as demonstrated by the Project, would lead to lower emissions (and related human health and environmental impact reduction) and more efficient processes (related to less energy use, less additives, and thus higher revenue); (d) sector standards following the SC BAT/BEP provide an incentive toward compliance actions along the value chain and in the longer run; and (e) raised public awareness and participation in pollution control will catalyze transitions in and beyond MSW incineration.

6. The economic benefits of the Project also need to be gauged at a global scale. The goals set in the SC cannot be achieved without China, given its size and commitment. This Project has achieved the objective of supporting China to acquire the necessary equipment, technologies, and capacity to generate global public goods on its own.

Financial Viability of Demonstration Incinerators

7. At appraisal, the financial viability of the demonstration incinerators focused on two aspects: (a) the general financial health of the participating enterprises to be able to finance the recurrent costs of implementing BAT/BET in a continuous manner, which is a precondition for reducing dioxin emissions, and (b) their ability to secure counterpart funding for the technical renovations. Given the pilot nature of this Project, no ex-ante cost analysis of specific technical options adapted to the participating incinerators was warranted, as the investments were to be determined on the basis of OEPA. However, cost-effectiveness was factored during the OEPA and the subsequent OIP process, when technical transformation actions were programmed for each demonstration enterprise. Furthermore, the BAT/BEP approach was implemented following the SC recommendations, which embed cost-effectiveness principles within its framework.

8. At Project closing, the two demonstration incinerators of Konggang and Xishan have (a) reported being overall profitable with positive returns from their BAT/BEP investments, due to efficiency gains and cost savings, and (b) proved their ability to co-finance the technical renovations—by completion of all Project activities, Konggang has invested twice as much as the GEF grant it has received, and Xishan has invested 3.8 times the GEF grant it received. The full picture of both enterprises' post-Project cashflows including the recurrent costs associated with the BAT/BEP adaptation will become fully available after a full year of operational data are available. Konggang, the first incinerator to complete its renovations, reported that it was already covering the recurrent costs for BAT/BEP upgrading and in the meantime investing in a second phase of improvements. At Project closing, both Konggang and Xishan were reported to be operating at capacity.

9. Konggang has voluntarily reported to the Project: (a) increase in on-grid electricity generation, which has led to increased revenue; (b) fewer inputs including lime, urea, and diesel to the flue gas purification system, which has led to lower recurrent costs; and (c) less fly ash production which lowers the cost of disposal. No significant increase in recurrent costs as a result of the BAT/BEP implementation was reported. As of 2021, Konggang is operating at capacity with stable feedstock. This sum of increased revenues and input cost savings ('return on investment') amounted to CNY 8.3 million in 2019 and CNY 14.6 million in 2020, compared to the 2018 baseline year.

10. BAT/BEP implementation in Konggang was funded by the Project (US\$3.6 million) and by co-finance (US\$7.6 million). The revenue for 2021–2023 is expected to be no lower than the 2020 level.



Conservatively assuming that the revenue increase and cost savings relative to the 2018 baseline will also be maintained in 2021 and 2022, Konggang could recover its BAT/BEP investment by 2022¹⁴ (table 4.1).

Table 4.1. Konggang: Investment Costs and Returns (CNY, millions)

Year	Investment Costs (CNY, millions)			Return on Investment ^a (CNY, millions)
	Grant	Co-finance	Total	
2019	11.30	21.49	32.79	8.30
2020	9.62	27.77	37.39	14.59
2021	2.60	—	2.60	14.60
2022	—	—	—	14.60
Total	23.52	49.26	72.78	52.09
Production and Inputs				
	Item	2018 (baseline)	2019	2020
1	On-grid energy (10,000 kwh)	107.52	118.48	122.22
2	Hydrated lime (t)	66.34	60.66	42.09
3	Urea (t)	4.70	5.04	2.67
4	Diesel (t)	3.48	3.19	2.81
5	Fly ash (t)	212.64	202.08	174.83
Return on Investment 2019				
	Item	Price	Computing method	Actual incremental
1	On-grid energy	Grid purchase = CNY 0.65 per kwh	$(118.48 - 107.52) \times 0.65$	7.12
2	Hydrated lime	Hydrated lime = CNY 730 per ton	$(66.34 - 60.66) \times 0.073$	0.41
3	Urea	Urea = CNY 2,450 per ton	$(4.70 - 5.04) \times 0.245$	-0.08
4	Diesel	Average diesel = CNY 7,300 per ton	$(3.48 - 3.19) \times 0.73$	0.21
5	Fly ash treatment	Disposal of fly ash = CNY 600 per ton	$(212.64 - 202.08) \times 0.06$	0.63
Total				8.29
Return on Investment 2020				
1	On-grid energy	Grid purchase = CNY 0.65 per kwh	$(122.22 - 107.52) \times 0.65$	9.56
2	Hydrated lime	Hydrated lime = CNY 730 per ton	$(66.34 - 42.09) \times 0.073$	1.77
3	Urea	Urea = CNY 2,450 per ton	$(4.70 - 2.67) \times 0.245$	0.50
4	Diesel	Average Diesel = CNY 7,300 per ton	$(3.48 - 2.81) \times 0.73$	0.49
5	Fly ash treatment	Disposal of fly ash = CNY 600 per ton	$(212.64 - 174.83) \times 0.06$	2.27
Total				14.59

Source: Counterpart ICR 2021.

Note: a. Represent the sum of incremental revenues and cost savings relative to the 2018 levels.

¹⁴ In fact, in January–June 2021, Konggang handled on average around 33,000 tons of waste per month, with better economic return than the previous year.



11. The technical improvements in Xishan were funded by the Project (US\$1.4 million) and by co-finance of US\$5.2 million. At Project closing, the incinerator reported (a) more stable operation, (b) increase in boiler evaporation leading to higher electricity generation and thus larger revenues, and (c) energy savings following BAT/BEP implementation. The more stable operation also led to less use of coal and diesel. The plant is currently operating at capacity. Estimates carried out by the Xishan operator indicate the plant would recover its BAT/BEP investment within five years of its completion.



ANNEX 5. BORROWER COMMENTS TO ICR

1. We are writing to express our sincere appreciation to you for your sustained attention and support to the fulfillment of the Stockholm Convention (SC) in China, especially to your task team and specialists assisting and supporting us in implementing the GEF China Municipal Solid Waste Management Project. With the strong technical and management support, we jointly achieved a successful completion of the demonstration project and its objectives.
2. The design and implementation of the abovementioned project has been effective in demonstration of the best available techniques and best environmental practices (BAT/BEP) in MSW incineration in accordance with the Stockholm Convention. The GEF grant project has contributed to the performance of the Stockholm Convention in China's waste-to-energy industry, to enhance the supervision and management capacity of government authorities and promote the sustainable development of municipal solid waste management industry in China. The practice and lessons learnt in the BAT/BEP demonstration, monitoring capacity building and public awareness raising have been officially concluded and published as a key tool to further replicate the valuable influence of the project in China.
3. The GEF municipal solid waste management project has addressed the issue of dioxin emissions from incinerators, which is important at the local, national and even global level because it affects the health of both human being and environment. The successful completion of the demonstration project has been another good example of the partnership of China and the World Bank on pollution control and environment management, in pursuit of a green and better world of national and global significance.
4. We look forward to further collaboration with the Bank in more fields in the near future.¹⁵

¹⁵ These comments by FECO, Yunnan PMO, and Ningbo PMO, were received on September 22, 2021.



ANNEX 6. SUPPORTING DOCUMENTS

Project and Financing Documents

- Project Appraisal Document
- Project Restructuring Paper
- Aide-Memoires of Implementation Support Mission and Implementation Status and Results Reports
- Recipient's Implementation Completion Results Report (August 2021)

Environmental and Social Safeguards Documents

- Environmental Assessment Executive Summary
- Environmental Audit Report for Wuhua Municipal Solid Waste Incineration Power Plant
- Environmental Audit Report for Dongjiao Municipal Solid Waste Incineration Power Plant
- Environmental Audit Report for Xishan Municipal Solid Waste Incineration Power Plant
- Environmental Audit Report for Konggang Municipal Solid Waste Incineration Power Plant
- Environmental Management Plan for Wuhua Municipal Solid Waste Incineration Power Plant
- Environmental Management Plan for Dongjiao Municipal Solid Waste Incineration Power Plant
- Environmental Management Plan for Xishan Municipal Solid Waste Incineration Power Plant
- Environmental Management Plan for Konggang Municipal Solid Waste Incineration Power Plant

Project Technical Documents

- Operational and Environmental Performance Audit Report
运行及环境绩效审计报告（中英文）
- Kunming MSW Incinerators Dioxin Emission Baselines Report
昆明生活垃圾焚烧厂二恶英排放基线报告（中英文）
- Kunming MSW Incinerators After-Project Dioxin Emissions Assessment Report
昆明生活垃圾焚烧厂二恶英排放技改后评估报告（中英文）
- Financial Analysis Report for GEF-MSW Management Project (Konggang, Xishan, Dongjiao, Wuhua)
城市生活垃圾焚烧改造项目财务分析报告（空港、西山、东郊、五华）
- Technical Specifications for MSW Incineration and Energy Utilization (GB 5XXXX-20XX)
生活垃圾焚烧处理与能源利用工程技术标准
- Technical Specifications for MSW Incineration Operation, Maintenance, and Safety (CJJ 128-2017)
生活垃圾焚烧厂运行维护与安全技术规程
- MSW Incinerator and Boiler (GB 18750-20XX)
生活垃圾焚烧炉及余热锅炉



- Technical Standard for Solidification/Stabilization Treatment of MSW Incineration Fly Ash (CJ XXX-20XX)
生活垃圾焚烧飞灰固化/稳定化处理技术标准
- Study on the Regional Integrated MSW Management Models Final report
生活垃圾区域统筹管理模式研究最终报告
- Study Report on China's MSW Management Index System
中国生活垃圾统计指标体系研究报告
- Technical Guide for Online Supervision on the Operation of Municipal Solid Waste Incineration Facilities
生活垃圾焚烧设施运行在线监管技术指南
- Framework of Three-Tier (National-Provincial-Municipal) MSM Incineration Operation Supervision System
国家-省-市三级生活垃圾焚烧设施运行监管网络系统框架

Incinerator Information Disclosure

Official Website	Information Online	Link
Ningbo EPB	Operating and emissions data of Ningbo incinerators	http://sthjj.ningbo.gov.cn/col/col1229051659/index.html
MEE Monitoring Center	Incinerator data nationwide (five pollutants daily average emissions)	https://ljgk.envsc.cn/index.html
Yunnan EPB (Yunnan PMO)	Operating and emissions data of Kunming incinerators. Project information, news coverage	http://sthjt.yn.gov.cn/ljfs/
Sanfeng Environment (Konggang)	Konggang operating and emissions data, ESIA, permits, emergency response plan	http://hjgk.cseg.cn/hd/?company_id=23
Zheneng Jinjiang Environmental Group (Xishan)	Real-time operating and emissions data of Xishan incinerator, EMP	http://www.jinjiang-env.com/406.html http://www.jinjiang-env.com/Environmentalmanagementpublicity.html

Grievance Redress Mechanism**Key Grievance Redress Contacts**

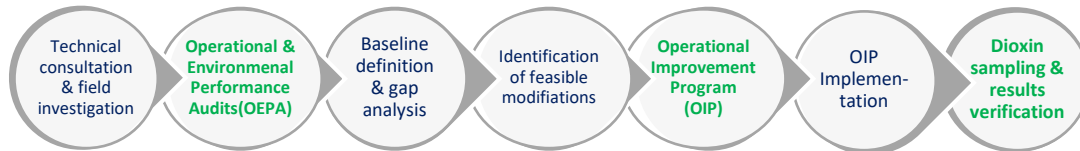
Agency	Contact	Telephone
Project Office		0871-64166316
Kunming UMB	Point person	0871-63190771
Waste Incineration Power Plant in Wuhua	Plant office	0871-68307396
Dongjiao Waste Incineration Power Plant	Plant office	0871-67396512
Xishan District Waste Incineration Power Plant	Plant office	0871-68599896
Konggang Incineration Power Plant	Plant office	0871-68017385



ANNEX 7. PROJECT TECHNICAL SUMMARY

I. Operational and Environmental Performance Audit, Baseline Definition, and Operational Improvement Program

Figure 7.1. Technical Methodology



1. **OEPAs.** This methodology was established and implemented for the BAT/BEP demonstration under the Project (figure 7.1). It started with the OEPAs to participating incinerators (demonstration sites), all in Kunming of Yunnan Province, to measure emissions and other operating conditions before the Project. The objectives of the OEPA were to find out the baseline status of each incinerator, identify gaps with the SC BAT/BEP, and recommend physical and operating improvements to each plant to reduce dioxin emissions in compliance with the SC standards.

2. Kunming had five MSW incinerators, with total designed capacity of 6,300 t/d and actual operating capacity of 4,250 t/d:¹⁶ Konggang (owned by Kunming Sanfeng Renewable Energy Power Generation Co Ltd), Xishan (run by Yunnan Green Energy Co Ltd), Wuhua (operated by Kunming Xinxingze Environmental Resources Industry Co Ltd), Dongjiao (operated by Kunming CLP Power Environmental Protection Co Ltd), and Chenggong (run by Kunming Fengde Power Environmental Protection Co Ltd). Of the five enterprises, four plants (Konggang, Xishan, Dongjiao, and Wuhua) undertook the OEPA; Chenggong was then under construction.

3. A key question on the incinerators' operating and environmental performance was if the operating condition of the incinerator meets the requirements of the furnace temperature above 850°C and the residence time no less than 2 seconds. Royal Haskoning DHV Amsterdam and Sheneng Environmental Protection Company were engaged to carry out the audits, identify gaps (table 7.1), and help develop plant-specific OIPs including renovation items, targets, and milestones as well as to update their standard operating procedures.

4. The OEPAs were completed in January 2018. Based on the OEPA operational baseline and improvement recommendations, each participating incinerator proposed a BAT/BEP investment plan, which included an end target of the improvements.

¹⁶ As of Project closing on March 31, 2021, Kunming's total MSW incineration capacity by design is 9,400 t/d, and the actual treatment capacity is 7,150 t/d. Of the five incinerators, Dongjiao reached 4 × 750 t/d (three lines in use and one standby), Konggang reached 2 × 500 t/d, Xishan expanded one line into 750 t/d and reached 3 × 400 + 750 = 1,950 t/d (three lines in use and one standby), Wuhua after relocation and expansion reached 3 × 750 t/d (two lines in use and one standby), and Chenggong after expansion reached 2 × 350 + 500 = 1,200 t/d (two lines in use and one standby).



Table 7.1. Baseline Status of Four Incinerators in Kunming

Content	Aspects assessed	Konggang = Grate Furnace		Xishan = CFB Furnace		Dongjiao = CFB Furnace		Wuhua = CFB Furnace	
		Compliance	Noncompliance	Compliance	Noncompliance	Compliance	Noncompliance	Compliance	Noncompliance
Waste acceptance	8	4	4	5	2	4	4	6	2
Storage, pretreatment, and bunder management	8	4	3	5	3	5	1	5	1
Combustion, boiler, and steam system operation	7	5	1	2	3	0	5	3	4
Process control system	13	13	0	10	1	11	0	11	0
Flue gas treatment system	17	11	6	11	5	13	4	12	5
Online and offline monitoring of emissions	3	2	1	3	0	2	1	3	0
Leachate treatment system	4	3	1	3	1	3	1	0	2
Bottom and fly ash treatment system	5	1	4	2	2	2	3	1	3
Maintenance operations	4	3	1	3	1	3	1	2	2
Communication and training	2	2	0	2	0	2	0	2	0
Total	71	48	21	46	18	45	20	45	19
Percentage		70	30	72	28	69	31	70	30

Source: Counterpart ICR 2021.

Note: CFB = Circulating fluidized bed.



5. **Baseline monitoring** for the BAT/BEP demonstration under the Project was carried out through sampling and analysis of atmospheric emissions from participating incinerators. This process involved three incinerators (Konggang, Xishan, and Dongjiao, since Wuhua was dropped from the Project as it was then being relocated by the Government from the Kunming city to a new site). FECO commissioned Zhejiang Jiu'an Testing Technology Co Ltd (CAIQ Southern Testing Center, a third-party testing institution) to carry out sampling and analysis. A total of 33 samples were collected from nine furnaces at the three incinerators before technical renovation.

II. BAT/BEP Implementation

6. **Dongjiao** withdrew in 2019 after the OEPA was completed and the OIP was designed but not implemented due to its shutdown by the municipal government for emissions noncompliance. Konggang and Xishan implemented the BAT/BEP renovations as set out in the OIP and fully delivered the results. The two demonstration incinerators represent the two mainstream waste incineration technologies that most enterprises in China currently employ: the circulating fluidized bed furnace and grate incinerator.

7. **Konggang** started the technical renovation in March 2018 and implemented 12 OIP items with a focus on upgrading its line 2 incinerator flue gas purification system. The technical upgrading was later extended to its line 1 intelligent combustion control, upgrading of ash removal device, and a pilot of continuous dioxin sampling using the GEF grant savings, as approved in the December 2019 Project restructuring. Konggang also conducted 35 self-funded renovation items following BAT/BEP using co-finance of US\$7.6 million.

8. **Xishan** started the technical renovation in February 2019, a year after Konggang, after its BAT/BEP investment plan underwent several revisions before being approved by the parent company. Based on this plan, Xishan implemented 12 OIP items with a focus on its line 1 and line 3, which included key technical upgrading to waste pretreatment, combustion, and flue gas purification systems. Beyond the OIP, Xishan carried out 16 major renovations using co-finance of US\$5.2 million.

III. Results Monitoring and Verification

9. **Post-Project results monitoring and verification** were carried out by FECO, Yunnan PMO, and a panel of experts on January 21, 2021. FECO commissioned Jiu'an for sampling at Konggang and Xishan for post-Project results monitoring. The verification panel found the technical transformation at Konggang and Xishan compliant with SC standards, completed, and consistent with the OEPA recommendations and items scheduled in respective OIPs. The panel agreed that the two incinerators achieved the PDO through the BAT/BEP demonstration. The grate furnace represented by Konggang and the fluidized bed incineration scheme represented by Xishan have outperformed the dioxin reduction targets at Project closing (table 7.2). The panel also confirmed that, at Project closing, the BAT/BEP compliance of Xishan improved from 72 percent to 90 percent and Konggang from 70 percent to 94 percent (table 7.3).

Table 7.2. Dioxins Emission Reduction Achieved under Normal Operating Conditions

Furnace Line	Emission Concentration (ng TEQ/m ³)			Emission Factor (µg TEQ/m ³)		
	Before	After	Reduction %	Before	After	Reduction %
Xishan 1	0.094	0.0046	95	0.60	0.029	95
Xishan 3	0.059	0.0052	91	0.26	0.036	86



Furnace Line	Emission Concentration (ng TEQ/m ³)			Emission Factor (µg TEQ/m ³)		
	Before	After	Reduction %	Before	After	Reduction %
Konggang1	/	0.024	/	/	0.12	/
Konggang 2	0.093	0.030	67.74	0.38	0.14	63.16

Table 7.3. Post-Project Compliance with the SC

Content	Aspects Assessed	Konggang		Xishan	
		Compliance	Noncompliance	Compliance	Noncompliance
Waste acceptance	8	4	4	7	1
Storage, pretreatment, and bunker management	8	8	0	6	2
Combustion, boiler, and steam system operation	7	7	0	5	2
Process control system	13	13	0	13	0
Flue gas treatment system	17	17	0	15	2
Online and offline monitoring of emissions	3	3	0	3	0
Leachate treatment system	4	4	0	4	0
Bottom and fly ash treatment system	5	5	0	5	0
Maintenance operations	4	4	0	4	0
Communication and Training	2	2	0	2	0
Total	71	67	4	64	7
Percentage		94	6	90.14	9.86

Source: Counterpart ICR, May 2021.

10. In addition to dioxin emission reduction, overall incineration performance improvements at Konggang and Xishan are summarized in table 7.4. Two findings from the demonstration are worth highlighting:

- Monitoring results show that the dioxin emission concentration in non-stationary conditions, that is, at furnace start and/or stop, is much higher than that in normal, stable conditions. This indicates that the process of start and stop has a great impact on dioxin emissions from MSW incineration—thus, dioxin generation and emissions can be effectively reduced by avoiding unnecessary start and stop of the furnace. The Project assessed the change in incinerators’ start/stop cycles before and after BAT/BEP renovation at Konggang and Xishan. The number of start-stop cycles decreased by 44 percent in Xishan, from 50 times (2018) to 28 times (2020), and by 64 percent in Konggang, from 25 times (2018) to 9 times (2020).
- Dioxin levels in flue gas have been significantly reduced after combustion stability was improved in Konggang and Xishan, which indicates that combustion stability is key to keeping dioxin emissions at a lower level. The demonstration provides a valuable technical entry point for other incinerators to introduce new technologies and increase the intelligence level of the control system, to achieve emissions compliance with the SC standards.



Table 7.4. Overview of Overall Performance Improvements

Item		Xishan	Konggang
Environmental performance improvements	Actual measurement	<p>Furnace 1. Dioxin emission concentration lowered by 95%</p> <p>Furnace 3. Dioxin emission concentration lowered by 91%</p> <p>Furnace 3. CO emission concentration lowered by 10%</p> <p>Furnace 3. NOx emission concentration lowered by 40%</p> <p>Furnace 3. HCl emission concentration lowered by 31%</p> <p>Furnace start-stop cycles reduced by 44%</p>	<p>Furnace 2. Dioxin emission concentration reduced by 68%</p> <p>Furnace 2. NOx emission concentration reduced by 5%</p> <p>Furnace 2. Particulate emission concentration reduced by 67%</p> <p>Furnace start-stop cycles reduced by 64%</p>
	Estimated	<p>Dioxin emission reduced from 0.1478 g TEQ per year to 0.0179 g TEQ per year</p> <p>Annual dioxin emission reduction anticipated 0.1299 g TEQ per year</p> <p>Relative reduction rate 88%</p>	<p>Dioxin emission reduced from 0.1265 g TEQ/a to 0.0499 g TEQ per year</p> <p>Annual dioxin emissions reduction anticipated 0.0766 g TEQ per year</p> <p>Relative reduction rate 61%</p>
Operational performance improvements		<p>Average increase in steam capacity 3%</p> <p>Average reduction in secondary fan current 8%</p> <p>Increase in monthly power generation 6%</p> <p>Reduction in power consumption 3%</p> <p>Increase in total running time 310 hours</p> <p>Increase in total amount of waste into the furnace by 5,072 tons</p>	<p>Increase in total running time 6%</p> <p>Increase in total power generation 14%</p> <p>Reduction of fly ash curing material 18%</p> <p>Reduction of lime use 43%</p> <p>Reduction of urea use 52%</p> <p>Reduction of activated carbon use 4%</p> <p>Reduction of cement use 19%</p>

Source: Counterpart ICR, May 2021.



Figures 2–3. Konggang: BAT/BEP Improvements¹⁷

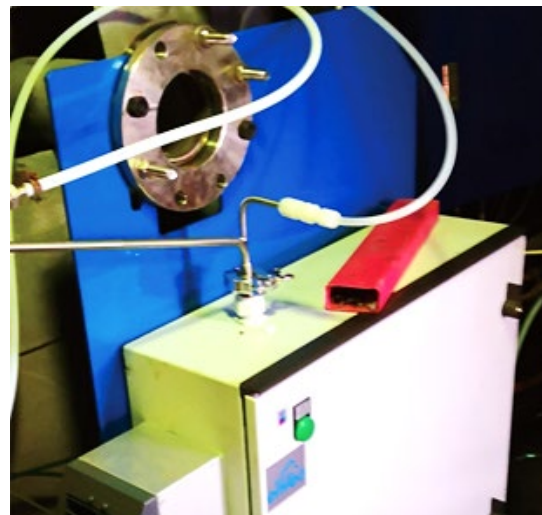


Figures 4–5. Xishan: BAT/BEP Improvements



Figure 6. Continued Dioxin Emissions Sampling at Everbright Incinerator (Ningbo)

Figure 7. Continued Dioxin Emissions Sampling at Konggang Incinerator (Kunming)



¹⁷ All pictures provided by FECO.



Figure 8. Dioxin Emissions Sampling at Konggang before Project Closing

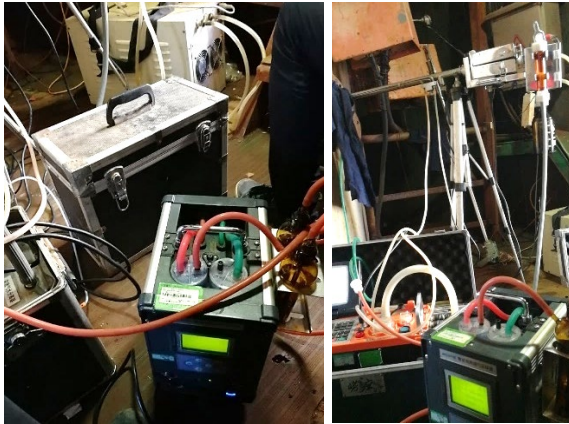


Figure 9. Dioxin Emissions Sampling at Xishan before Project Closing



Figure 10. Ningbo Dioxin Laboratory Capacity Built





Figure 11. Incinerators Operating Data on Kunming Government Website



Image 12. Incinerators Operating Data on Ningbo EPB Website



Figure 13. Ningbo Incineration Operating and Emissions Data Accessible on Mobile App



Figure 14. Monthly Information Disclosure on Community Bulletin Board by Kunming Incinerators



Figure 15. Installation, Display Board Setup, Internet Connection, and Emissions Data Uploaded to National Monitoring System

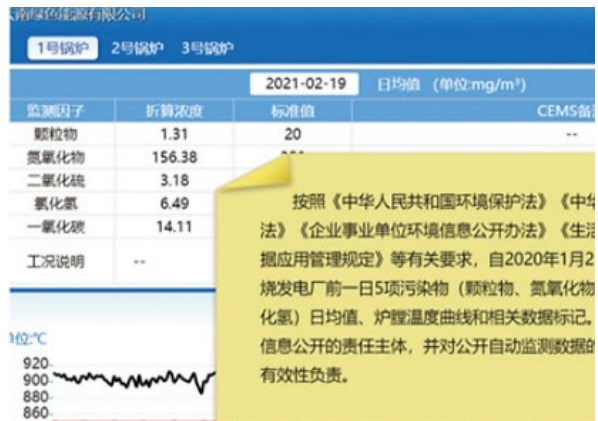




Figure 16. National BAT/BEP Replication Workshop for Regulators and Incinerator Operators/Managers



Figure 17. Kunming Regulators Visited AEB Incinerator (Netherlands), September 2017



Figure 18. Kunming Regulators Visited Covanta Incinerator (Canada), October 2019



Figures 19–20. Public Outreach Events





Figures 21–22. Public Outreach Events

