ECONOMIC ANALYSIS

A. Introduction and Background

1. The economic analysis of the Chemical Industry Energy Efficiency and Emission Reduction Project was conducted in accordance with Asian Development Bank (ADB) Guidelines for the Economic Analysis of Projects.[1] The economic cost–benefit analysis of the project was completed for the two subprojects of the first batch of subprojects to be initially supported by the loan. However, the economic benefits of the project will not be limited to these subprojects, but will include those of other similar subprojects to be financed from the repayment flows from the two initial subprojects. The project selection criteria stipulate that future projects will need to have an economic internal rate of return (EIRR) of at least 12%. Such projects are expected to comprise technology replication projects of the two initial subproject technologies or other projects in additional three areas of the chemical industry strategic to its transformation.[2]

B. Rationale for Public Investment

2. The two initial subprojects have been selected to pave the way for solving specific, major environmental issues facing the chemical industry of the People's Republic of China's (PRC). The economic and social impact of the two subprojects include improved energy security, reduction of potential health risk for consumers, and the creation of more environmentally safe and sustainable production within the PRC's chemical industry.

3. The proposed subproject 1, to be implemented at Dezhou Shihua Chemical (DSC), is the larger of the two and accounts for 84% of the combined economic investment cost of both subprojects. The project will support first-of-its-kind demonstration at commercial scale of a new mercury-free catalyst technology that utilizes calcium carbide, together with dichloroethane, to synthesize vinyl chloride monomer, which then can be processed into polyvinyl chloride (PVC).[3]

4. In 2010, the Government of the PRC issued a notice to phase out the use of mercury in the PVC industry. Moreover, the PRC is party to the Minamata Convention on Mercury, which stipulates phasing out conventional mercury-based catalyst by 2020, and completely phasing out mercury use in the industry within 5 years after an alternative catalyst has been proven technically and commercially feasible.[4] As the PRC and the world aim to eliminate intentional use of mercury due to the hazards of dealing with mercury waste, the project can demonstrate a viable approach for gradually eliminating mercury catalysts in PRC's calcium carbide–based

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1 ADB. 1997. *Guidelines for the Economic Analysis of Projects.* Manila.

2 These three areas include applications of pressure swing absorption technology, new approaches for comprehensive reuse of industrial gas emissions, and fractionating chemical separation technologies.

3 PVC is produced by the liquid phase polymerization of the intermediate product vinylchloride monomer, which can be synthesized by several different routes essentially based upon either coal-derived calcium carbide or various petroleum- and/or natural gas-derived ethylene routes as the initial feedstock. Due to scarcity of petroleum resources in the PRC and abundant and cheap coal reserves, the PRC's chemical industry in general is based on coal to avoid straining the country's weak energy security further (Sector Assessment (Summary): Energy, which is accessible from the list of linked documents in Appendix 2 of the main text of the report and recommendation of the President). In the PRC's PVC industry, the calcium carbide-based process is therefore significantly more economical in the PRC than the ethylene-based process. More than 80% of the industry applies this process.

4 Minamata Convention on Mercury. 2013. *Text and Annexes* (Article 5). p.5. http://www.mercuryconvention.org/Portals/11/documents/conventionText/Minamata%20Convention%20on%20Mercury_e.pdf.

PVC plants. A switch to the ethylene-based process by the industry, despite the recent slump in oil prices, is unlikely due to the following reasons (i) coal prices have dropped in tandem with oil prices and are at the lowest price since 2004 in the PRC; (ii) a switch to ethylene-based would leave existing PVC production facilities as stranded assets; and (iii) one strategic objective of the PRC's chemical industry is to maintain feedstock independence. In addition, subproject 1 results in significant energy savings compared to plants that rely exclusively on calcium carbide, which is very energy intensive to produce.

5. Subproject 2, to be implemented at Zhonghao Chenguang Research Institute of Chemical Industry (CGY), includes the implementation of a package of one greenhouse gas (GHG) emission abatement component combined with comprehensive energy efficiency and emission reduction measures. The first component consists of plasma incineration of the unwanted by-product of CGY's fluoropolymer production, the GHG fluoroform (HFC-23). When emitted to the atmosphere, HFC-23 is a particularly damaging GHG, with each ton of emissions exhibiting a global warming potential (forcing power) equivalent to 0.0148 million tons of carbon dioxide equivalent ($MtCO_2e$) over a 100-year period.[5] According to PRC sector statistics, in 2013, nearly 10,000 tons of untreated HFC-23, or 140 $MtCO_2e$, were emitted. Given the PRC's stringent climate change mitigation commitments, there is a strong environmental need for the plasma incineration technology. The subproject would effectively reduce 890 tons of HFC-23 emissions per year, or 13.2 $MtCO_2e$ from this plant alone. Additionally, the plasma pyrolysis technology to be used, which is largely new to the PRC, would show an additional emissions reduction pathway to other HFC-23 emitters in the PRC.

C. General Assumptions for the Economic Analysis of the Project

6. Incremental costs and benefits are estimated by comparing with-project and without-project scenarios for each subproject and then for the project as a whole. The project life for both subprojects is assumed to be 15 years because of the technical useful life of the installations. The residual value at the end of project life is assumed to be zero. All prices and costs are expressed in 2015 prices. A discount rate of 12% is assumed. Physical contingencies are included with an allowance of 5%. Key tradable commodities are valued at constant 2015 border prices. The share of non-tradables is less than 3% of project costs. As undertaken in other recent ADB project assessments, non-tradable commodities are valued by applying a standard conversion factor of 0.987,[6] and the following specific conversion factors: 1.0 for equipment and 1.0 for skilled labor.[7]

D. Economic Costs

7. Capital investment costs are adjusted to eliminate price contingencies, interest during construction, and taxes. The investment costs will occur during the first 3 years of the subprojects. Operation and maintenance (O&M) costs, appropriately shadow priced, are assumed to remain constant in real terms. The incremental O&M costs in the two analyzed subprojects mainly include costs for maintenance, raw materials, fuel, and electric power. The

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[5] The Fourth Assessment Report of the International Panel on Climate Change assessed the global warming potential of HFC-23 over a 100-year period to amount to 14,800 tons of carbon dioxide (CO_2) equivalent. https://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-10-2.html

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

[7] It has been assumed that the projects will not involve unskilled labor.

economic value for fuel and electric power includes a conservative valuation of local environmental costs of energy use. The plasma gasification of HFC-23 will create incremental electricity use.

E. Economic Benefits

8. Incremental economic benefits for subproject 1 consist of mercury-free, energy efficient production, and the sale of 360,000 tons of PVC to be implemented by 2018. This is based on the assumption that the high mercury content, polluting calcium carbide–based production process would be shut down, if not transformed.[8] A prudent assumption has been made on the sales price: while mercury-free PVC is expected to be sold at a premium, the economic benefits have nonetheless been valued at the observed January 2015 constant price of CNY5,486 per ton of PVC.[9] Additional economic benefits include the sale of slag valued at CNY9 million.

9. In the case of subproject 2, benefits include direct net energy savings of 8,905 tons of coal equivalent (tce) per annum.[10] A conservative proxy for the environmental and energy security externality benefits of energy savings was developed to derive a minimum economic value for energy savings for base-case analysis. During the current 12th Five-Year Plan, 2011–2015, the government has demonstrated a willingness to pay at least CNY300 per tce of energy savings capacity to all qualifying large energy savings projects, given its interest in the positive effect of such savings on the environment and energy security. Assuming a project lifetime of 7 years, including 2 years of construction, this equates to CNY60 tce in present value terms. This was added to the nonsubsidized financial costs of energy faced at the project locations to derive an estimate of the minimum value of energy saved.

F. Environmental and Social Benefits

10. Only the environmental benefits from effective climate change mitigation have been incorporated in the economic analysis. The PRC is already experimenting with seven regional carbon market pilots, which have been operational since 2012. Therefore, carbon prices exist, which can serve as indicative prices.[11] In addition, the government has announced that it will launch a nationwide carbon market in 2016.[12] Moreover, the draft guidelines of the nationwide carbon market do not exclude other GHG than carbon dioxide (CO_2). Thus, GHG emission reductions from both subprojects were included in the economic analysis.

11. Subproject 1 will lead to CO_2 emissions reductions, predominantly through the reduction in calcium carbide consumption of 1.359 $MtCO_2e$; subproject 2 will lead to the effective abatement of 890 tons of HFC-23 emissions, or 13.1 $MtCO_2e$, per year. The benefits were evaluated at CNY 22 tCO_2e, the lowest of the observed carbon prices among the operating carbon pilot markets to date in 2015 (footnote 10).

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8 It is expected that in the future, the application of high mercury content catalysts will not be allowed.

9 This is the lowest observed price since 2004. After a sudden drop in prices, the PVC recovered to return to its average price of CNY6,000 per ton of PVC.

10 Energy efficiency components of this subproject result in energy savings of 10,888 tce per annum, while the plasma pyrolysis entails an energy penalty of 1,983 tce per annum.

11 The seven pilot carbon markets cover the major cities of Beijing, Tianjin, Shanghai, and Shenzhen, and the provinces of Chongqing, Guangdong, and Hubei. Carbon prices range from CNY120 per ton of CO_2 equivalent in Shenzhen to CNY22 per ton of CO_2 equivalent in Hubei. The average observed price is about CNY50.

12 The government announced that it will launch a national emissions trading scheme in 2016 to be operational in 2017.

12. Additional expected environmental benefits from first batch subprojects include avoidance of (i) direct intentional use of 35 tons of mercury per year at the DSC plant, (ii) 600 kilograms of mercury emissions per year from the PVC production at the DSC plant, and (iii) 1,200 tons of organofluorine emissions per year from chlorodifluoromethane production at the CGY plant. Moreover, in the medium term, it is expected that public health costs for treating affected people suffering from mercury intoxication may be significantly reduced as a result of eliminating the polluting PVC production process.

Table 1: Summary of Economic Benefits of First Batch Subprojects

	Economic Benefits (Annual)		**Value of Economic Benefits per year** (CNY million / year)
	Energy Saving and Incremental Outputs	**Others**	
DSC	PVC output: 360,000 tons	Calcium carbide slag sales: CNY9 million ($1.359\ MtCO_2e$)	1,983.1
CGY	On-site energy savings: 8,905 tce	HFC-23 emissions reduced: ($13.1\ MtCO_2e$)	225.6

( ) = negative, CGY = Zhonghao Chenguang Research Institute of Chemical Industry, DSC = Dezhou Shihua Chemical, HFC-23 = fluoroform, $MtCO_2e$ = million tons of CO_2 equivalent, PVC = polyvinyl chloride, tce = ton of coal equivalent.
Source: Asian Development Bank estimates.

G. Estimation of the Economic Internal Rate of Return

13. Key economic indicators, including the EIRR and the economic net present value, resulting from the combined ADB investment in the first batch are presented in Table 2. The EIRR, calculated at very conservative assumptions and taking only direct economic benefits into consideration, is equal to 20.3%. It will increase significantly to reach 41.0% after incorporating environmental benefits, because of the massive climate change-mitigating benefits from plasma incineration of HFC-23. The EIRR of the plasma incineration component alone is equal to 321.6%.[13] The combined economic benefits and costs of the two subprojects are summarized in Table 2.

Table 2: Economic Results of Subprojects 1 and 2
(CNY million)

Year	Capital Cost	Operating Cost	Economic Benefits	Environmental Benefits	Net Economic Benefits without Environmental Benefits	Net Economic Benefits with Environmental Benefits
2015	(431.0)	0.0	0.0	0.0	(431.0)	(431.0)
2016	(672.4)	(342.4)	413.4	7.1	(601.4)	(594.3)
2017	(136.0)	(760.7)	913.4	215.4	16.7	232.1
2018		(1,529.4)	1,795.4	313.3	266.0	579.3
2019		(1,717.6)	2,015.7	315.5	298.1	613.6
2020		(1,717.6)	2,015.7	315.5	298.1	613.6
2021		(1,717.6)	2,015.7	315.5	298.1	613.6

[13] Due to the very large GHG emissions abatement from subproject 2, the economic viability of the project as a whole is highly sensitive to the carbon price. Subproject 2 is economically viable at a carbon price of CNY1.25.

Year	Capital Cost	Operating Cost	Economic Benefits	Environmental Benefits	Net Economic Benefits without Environmental Benefits	Net Economic Benefits with Environmental Benefits
2022		(1,717.6)	2,015.7	315.5	298.1	613.6
2023		(1,717.6)	2,015.7	315.5	298.1	613.6
2024		(1,717.6)	2,015.7	315.5	298.1	613.6
2025		(1,717.6)	2,015.7	315.5	298.1	613.6
2026		(1,717.6)	2,015.7	315.5	298.1	613.6
2027		(1,717.6)	2,015.7	315.5	298.1	613.6
2028		(1,717.6)	2,015.7	315.5	298.1	613.6
2029		(1,717.6)	2,015.7	315.5	298.1	613.6
2030		(1,717.6)	2,015.7	315.5	298.1	613.6
2031		(1,299.7)	1,513.4	307.2	213.7	520.8
2031		(853.1)	992.1	123.6	139.0	262.6
			Base Case	EIRR	20.3%	41.0%
				ENPV	539.4	2,200.4

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

H. Sensitivity Analysis

14. Estimated economic viability indicators were tested through sensitivity analysis, as assumptions used in the base-case analysis are subject to uncertainty. Since the first two subprojects were mainly selected due to their large environmental co-benefits resulting from the energy efficiency measures, the sensitivity analysis was performed on the viability including the environmental benefits. The economic viability of the project remains valid under various adverse scenarios. The sensitivity analysis showed that the EIRR with environmental benefits would decrease to (i) 38.1% if both subprojects' investment costs overrun by 10.0%, (ii) 33.1% if the O&M costs are increased by 10.0%, and (iii) 29.0% if the economic benefits are reduced by 10.0% (Table 3).

Table 3: Sensitivity Analysis of the Economic Internal Rate of Return

Case	Case 1 Investment Cost +10%	Case 2 O&M Cost +10%	Case 3 Economic Benefits –10%
Sum of Subprojects 1 and 2	38.1%	33.1%	29.0%

O&M = operation and maintenance.
Source: Asian Development Bank estimates.