XIANGTAN GREENHOUSE GAS EMISSIONS SCENARIOS AND PROGRAM IMPACTS ANALYSIS

A. Executive Summary

1. To assess the greenhouse gas (GHG) reduction impacts of the Xiangtan low-carbon transformation sector development program (XSDP), results of Integrated Assessment Models (IAMs) presented by the Intergovernmental Panel on Climate Change (IPCC) for the global worst case (Representative Concentration Pathway [RCP] 8.5) and the global best case (RCP 2.6) emission scenarios were used to bracket potential future emissions for Xiangtan and to provide a context for the impacts of Asian Development Bank (ADB)-funded interventions.[1] IAM results for the grid cell containing Xiangtan were scaled to the Xiangtan city level and harmonized to one another. IAM results are available for industrial, energy, and transport sectors and all relevant Xiangtan emissions were lumped into those categories for comparison. Worst case and best-case emission trajectories for the period 2020 to 2045 from these IAMs bracketed potential emissions in Xiangtan. RCP 2.6 represents an optimistic pathway that provides a reasonable chance of keeping global temperature rise to no more than 2°C above pre-industrial temperatures. Results of IAMs for Xiangtan show that Xiangtan's ambitious target of carbon peaking by 2028 would be unrealistic, as Xiangtan's carbon peaking year could be in 2032 under the most optimistic scenarios (RCP 2.6).

2. Impacts of project and policy actions on GHG emission reductions are summarized as follows. In the first year after project completion, low-carbon, resilient, inclusive infrastructure and information and knowledge platforms would result in over 337 $ktCO_2e$ of GHG emission reduction. Combined project and policy actions are expected to reduce emissions more than 770 $ktCO_2e$ in 2026. The total amount of GHG reduction over the project lifetime up to 2045 would be over 7 $MtCO_2e$ with an annual average of 378 $ktCO_2e$. During the program lifetime up to 2045, a total GHG reduction would be over 48 $MtCO_2e$ with annual average of 2.4 $MtCO_2e$. The cumulative abatement gap between the best case and worst case for Xiangtan exceeds 167 $MtCO_2e$, ranging from a 1.6 $MtCO_2e$ annual abatement gap in 2026 to a 16.6 $MtCO_2e$ gap in 2045. The best-case scenario from the IAMs shows that Xiangtan carbon peaking could be possible in 2032 under the assumption that Xiangtan implements all possible low-carbon measures, policies and technologies in all sectors. In terms of the XSDP's impacts, the results show that the project component alone could result in only a 5% contribution to the necessary abatement, ranging from 2% to 21% annual contribution to necessary yearly abatement. The combined project and PBL, on the other hand, could lead to a 29% contribution to the cumulative abatement need, ranging from 19% to 49% annual contribution to necessary abatement per year.

B. Developing the Xiangtan GHG Emissions Scenarios

3. In the absence of the official GHG inventory and reliable projections on the GHG emissions in Xiangtan, an expert was engaged to develop defensible GHG scenarios to project Xiangtan's business-as-usual and best possible GHG reduction projections in Xiangtan.[2]

4. **Global GHG Models.** Anthropogenic GHG emissions are mainly driven by population size, economic activity, lifestyle, energy use, land use patterns, technology and climate policy. The IPCC working group developed the 'Representative Concentration Pathways (RCPs)',

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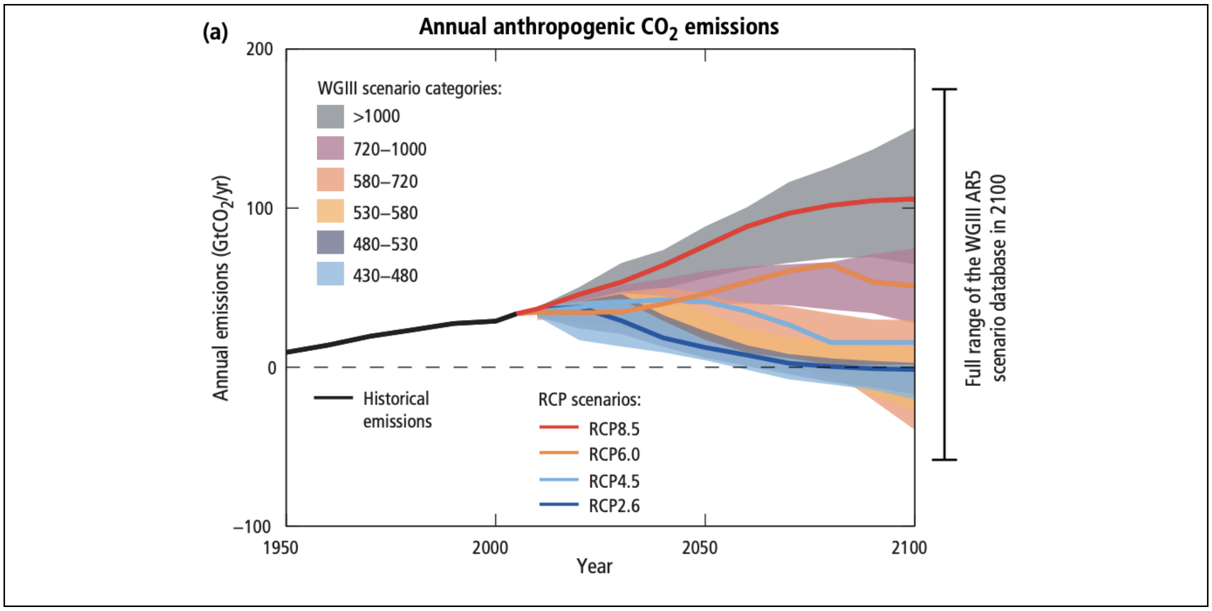
[1] IPCC. 2014. *Fifth Assessment Report* by Working Group I. Available at: https://www.ipcc.ch/assessment-report/ar5/

[2] Rachael Jonassen(Ph.D. The Pennsylvania State University, PMP) is Professor at Sustainable Urban Planning Program, who directs the Greenhouse Gas Management Online Certificate Program in the Environmental and Energy Management Institute at George Washington University.

describing different They developed four pathways, spanning a broad range of forcing in 2100 (2.6, 4.5, 6.0, and 8.5 watts per meter squared). The RCPs are used for making projections based on these factors, describe four different 21st century pathways of GHG emissions and atmospheric concentrations, air pollutant emissions and land use. The RCP is expressed in the greenhouse gases and other radiative forcing that might occur in the future.[3] The RCPs include a stringent mitigation scenario (RCP2.6), two intermediate scenarios (RCP4.5 and RCP6.0) and one scenario with very high GHG emissions (RCP8.5). Scenarios without additional efforts to constrain emissions ('baseline scenarios') lead to pathways ranging between RCP6.0 and RCP8.5.). RCP2.6 is representative of a scenario that aims to keep global warming likely below 2°C above pre-industrial temperatures.

Figure 1: RCP scenarios



Source: IPCC. 2014. Fifth Assessment Report.

5. After the IPCC first assessment report, so-called 'Shared Socioeconomic Pathways (SSPs)' were developed, modelling how socioeconomic factors including population, economic growth, education, urbanization, the rate of technological development, drivers of demand such as lifestyles may change over the next century. The SSPs are based on five narratives describing broad socioeconomic trends that could shape future society: (i) SSP1: Sustainability – Taking the Green Road (Low challenges to mitigation and adaptation); (ii) SSP2: Middle of the Road (Medium challenges to mitigation and adaptation); (iii) SSP3: Regional Rivalry – A Rocky Road (High challenges to mitigation and adaptation); (iv) SSP4: Inequality – A Road Divided (Low challenges to mitigation, high challenges to adaptation); (v) SSP5: Fossil-fueled Development – Taking the Highway (High challenges to mitigation, low challenges to adaptation). The SSPs are part of a new framework that the climate change research community has adopted to facilitate the integrated analysis of future climate impacts, vulnerabilities, adaptation, and mitigation. The framework is built around a matrix that combines climate forcing on one axis (as represented by

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[3] Radiative forcing is a measure of the influence a factor has in altering the balance of incoming and outgoing energy in the Earth-atmosphere system and is an index of the importance of the factor as a potential climate change mechanism. In this report radiative forcing values are for changes relative to preindustrial conditions defined at 1750 and are expressed in Watts per square meter (W/m^2)

the RCPs) and socio-economic conditions on the other. Together, these two axes describe situations in which mitigation, adaptation and residual climate damage can be evaluated.

6. Integrated assessment models (IAMs), which are computer models, can translate the socioeconomic conditions of the SSPs into estimates of future energy use characteristics and GHG emissions. Six IAMs are: AIM-CGE, GCAM, IMAGE, MESSAGE-GLOBIOM, REMIND-Magpie, and WITCH-GLOBIOM.[4] The socio-economic information of the SSPs has been used as input for the development of the IAM scenarios. The IAM data set includes both reference (baseline) and mitigation scenarios.

7. **Methodology**. To develop BAU scenario, the RCP 8.5 scenario, which describes an evolution of the global economy along a pathway of emissions that leads to GHG concentrations at the year 2100 corresponding to a Radiative Forcing (RF) of 8.5 Watts per square meter (W/m^2), was chosen considering the economic, social, and environmental conditions as well GHG emission trends. Note that the RCP 8.5 scenario was developed by The RCP 8.5 is developed by the 'Model for Energy Supply Strategy Alternative and their General Environmental Impact (MESSAGE)' modeling team of the IPCC working group 1.[5] Solutions of MESSAGE for RCP 8.5 are available for a global network of grid cells at a spacing of 30 arc minutes.[6] For best-case scenario development, the RCP 2.6, is selected, as it is the only one among RCPs that can possibly show an early peaking of GHG emissions followed by a rapid decline. Note that the RCP 2.6 was developed by the 'Integrated Model to Assess the Global Environment (IMAGE)' modeling team of the Netherlands Environmental Assessment Agency.[7] Solutions of IMAGE for RCP 2.6 are also available for a global network of grid cells at a spacing of 30 arc minutes. As the grid cells (Figure 2) used for Xiangtan do not include Changsha, Zhuzhou, and other cities, it is reasonable to believe that the results primarily represent emissions due to activities in Xiangtan. These grid cells data can be previewed at the Royal Netherlands Meteorological Institute (KNMI) Viewer site.[8]

[4] K. Riahi et al. The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview. Global Environmental Change Volume 42, January 2017, Pages 153-168

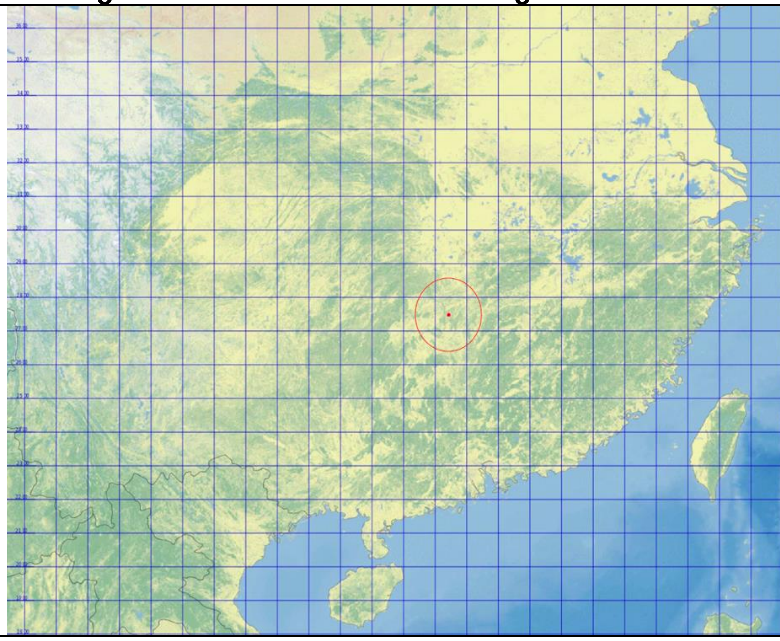
[5] The MESSAGE a linear programming energy engineering model including all GHG-emitting sectors, including energy, industrial processes as well as agriculture and forestry with global coverage. It is designed to formulate and evaluate alternative energy supply strategies consonant with the user-defined constraints such as limits on new investment, fuel availability and trade, environmental regulations and policies, and diffusion rates of new technologies. Environmental aspects can be analyzed by accounting, which helps to evaluate the impact of environmental regulations on energy system development.

[6] Arc minute is a unit of angular measurement equal to 1/60 of one degree. Since one degree is 1/360 of a turn (or complete rotation), one minute of arc is 1/21600 of a turn.

[7] IMAGE is an ecological-environmental model framework that simulates the environmental consequences of human activities worldwide. It represents interactions between society, the biosphere and the climate system to assess sustainability issues such as climate change, biodiversity and human well-being. The objective of the IMAGE model is to explore the long-term dynamics and impacts of global changes that result from interacting socio-economic and environmental factors.

[8] Available at: https://data.knmi.nl/wms-preview/viewer

Figure 2: Grid cell used for Xiangtan GHG Scenarios



Source: The Royal Netherlands Meteorological Institute (KNMI) data center.

8. Tables below provides description of step by step procedures to develop the BAU and the best-case scenarios.

Table 1: Description on the Xiangtan BAU Scenario Development

	Description of Steps for the Xiangtan BAU Projections
1	Download MESSAGE projections

	CO2 Emission Rate		
Year	**IND**	**TRA**	**ENE**
2000	2.796E-12	2.058E-12	2.21696E-10
2005	3.443E-12	2.854E-12	4.25158E-10
2010	4.236E-12	3.706E-12	5.74945E-10
2020	4.625E-12	6.878E-12	7.93877E-10
2030	4.767E-12	1.0037E-11	7.64214E-10
2040	3.698E-12	1.193E-11	1.00813E-09
2050	3.072E-12	1.4059E-11	1.34886E-09
2060	2.264E-12	1.1386E-11	1.70183E-09
2070	1.404E-12	9.917E-12	2.01093E-09
2080	8.65E-13	7.842E-12	2.2986E-09
2090	5.88E-13	6.243E-12	2.67661E-09
2100	3.35E-13	5.031E-12	2.73131E-09

Definition of Variables

ENE	Power plants, energy conversion, extraction CO2
IND	Industry (combustion and processing) CO2 emissions
TRA	Surface transportation CO2 emissions

Units = kg m-2 sec-1
kgm-2s-1

Source: MESSAGE IAM RCP 8.5 CH4 for grid cell containing Xiangtan
Accessed: 31 March 2020

2 Record the observed emissions

Summary of Xiangtan's Total GHG Emissions				
	ktCO2e	2005	2015	2016
Total net emissions		24,357.50	38049.4	39694.4
		24357.5	38049.4	39678.8
	Energy industry	5,520.40	6419.3	6456.5
	Biomass combustion (for energy use)	96.10	36	33.5
	Fugitive emissions from oil and gas systems	218.70	16.7	0
	Electricity transfer emissions	1.00	726.5	830.9
	Building - Construction		332.5	369.2
	Building - Service Industry	204.70	1728.9	1849.6
	Building - Residential	902.10	2432.1	2536.5
	Manufacturing industries and construction	14,573.50	16168.6	16797.8
	Industrial processes	1,776.70	3342.4	3672.8
	Transportation	635.8	3057.1	3166.5
Agriculture				
	Agriculture, forestry, animal husbandry, fishery	185.40	832.2	844.3
	Agriculture		3031.3	3364.8
Waste		243.1	323.7	221.6
LUF		0	-397.9	-465.2

	2005	2015	2016
ENE	6,943.00	11,692.00	12,076.20
IND	16,350.20	19,511.00	20,470.60
TRA	635.8	3057.1	3166.5

3 Set the years for which projections are desired: 2020-2045

4 MESSAGE projections

5 Mean and Standard Deviation of MESSAGE projections

6 Standardize values of years for better precision estimates of regression coefficients; and

7 Standardize values of MESSAGE projections

Year	ENE	Observed	Year	ENE	Standardized Year	Standardized ENE	Yearly Standardized
2000	2.21696E-10		2000	2.22E-10	-1.00	-1.30840238974949	-1.334057095
2005	4.25158E-10		2001		-0.98		-1.257544191
2010	5.74945E-10		2002		-0.96		-1.19026242
2020	7.93877E-10		2003		-0.94		-1.131304151
2030	7.64214E-10		2004		-0.92		-1.079818329
2040	1.00813E-09	6,943.00	2005	4.25E-10	-0.90	-1.07851131510528	-1.035008274
2050	1.34886E-09		2006		-0.88		-0.996129519
2060	1.70183E-09		2007		-0.86		-0.962487694
2070	2.01093E-09		2008		-0.84		-0.933436446
2080	2.2986E-09		2009		-0.82		-0.908375404
2090	2.67661E-09		2010	5.75E-10	-0.80	-0.90926745434636	-0.886748188
2100	2.73131E-09		2011		-0.78		-0.868040453
			2012		-0.76		-0.851777983
			2013		-0.74		-0.837524821
			2014		-0.72		-0.824881443
		11,692.00	2015		-0.70		-0.813482971
		12,076.20	2016		-0.68		-0.802997437
			2017		-0.66		-0.793124074
			2018		-0.64		-0.783591661
			2019		-0.62		-0.774156905
			2020	7.94E-10	-0.60	-0.66189687529962	-0.764602868
			2021		-0.58		-0.754737425
			2022		-0.56		-0.744391783
			2023		-0.54		-0.733419023
			2024		-0.52		-0.721692692
			2025		-0.50		-0.709105442
			2026		-0.48		-0.695567697
			2027		-0.46		-0.681006379
			2028		-0.44		-0.665363658
			2029		-0.42		-0.648595758
			2030	7.64E-10	-0.40	-0.69541300581624	-0.630671798
			2031		-0.38		-0.611572676
			2032		-0.36		-0.591289994
			2033		-0.34		-0.569825028
			2034		-0.32		-0.547187735
			2035		-0.30		-0.523395805
			2036		-0.28		-0.498473754
			2037		-0.26		-0.472452062
			2038		-0.24		-0.445366342
			2039		-0.22		-0.417256569
			2040	1.01E-09	-0.20	-0.41981308365428	-0.388166329
			2041		-0.18		-0.358142132
			2042		-0.16		-0.327232745
			2043		-0.14		-0.295488587
			2044		-0.12		-0.262961151
			2045		-0.10		-0.229702474

8 Fit 6th order polynomial

9 Extract coefficients of equation to 16 significant figures

10 Use equation to solve annual values of scaled MESSAGE projections

11 Rescale solutions using same mean and standard deviation used for scaling

12 Compare to known MESSAGE values to check calculation results

13 Solve MESSAGE values for same years as observations

14 Plug the observed emissions

15 Fit linear polynomial to scale MESSAGE values to observations

16 Extract coefficients of equation to 16 significant figures

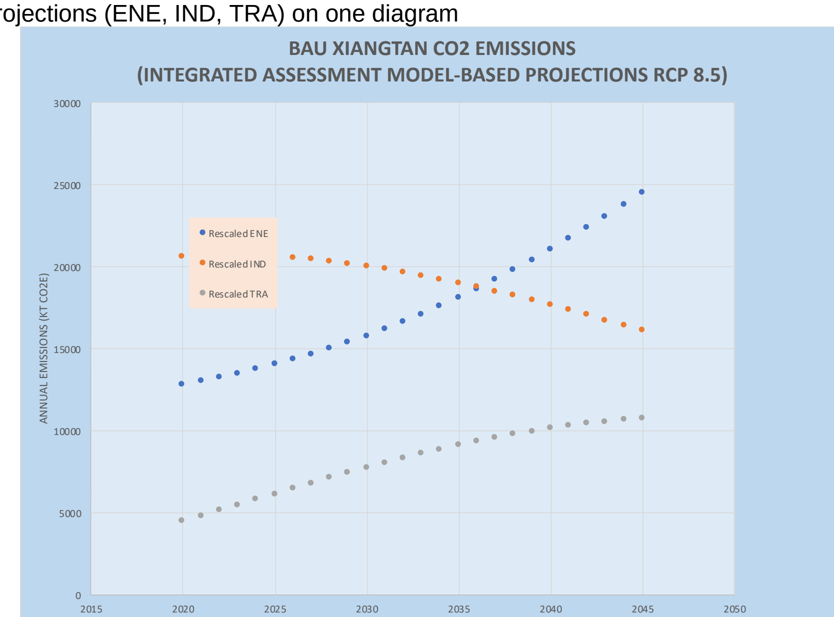
17 Use equation to solve annual values of rescaled MESSAGE projections, as the MESSAGE projections are not

18 for a specific location but for a grid cell. Rescaling allows direct comparison to Xiangtan values; and Compare to known observed values to check calculation results

Year	ENE (6th Order)	ENE (MESSAGE)	ENE (6th Order)	Observed	Year	Rescaled ENE	Observed
2000	1.99E-10	2.22E-10	4.64E-10	6,943.00	2000	416	
2001	2.67E-10		6.60E-10	11,692.00	2001	2085	
2002	3.26E-10		6.69E-10	12,076.20	2002	3553	
2003	3.78E-10				2003	4839	
2004	4.24E-10				2004	5962	
2005	4.64E-10	4.25E-10			2005	6939	6,943
2006	4.98E-10				2006	7787	
2007	5.28E-10				2007	8521	
2008	5.54E-10				2008	9155	
2009	5.76E-10				2009	9702	
2010	5.95E-10	5.75E-10			2010	10173	
2011	6.11E-10				2011	10581	
2012	6.26E-10				2012	10936	
2013	6.38E-10				2013	11247	
2014	6.50E-10				2014	11523	
2015	6.60E-10				2015	11772	11,692
2016	6.69E-10				2016	12000	12,076
2017	6.78E-10				2017	12216	
2018	6.86E-10				2018	12424	
2019	6.95E-10				2019	12629	
2020	7.03E-10	7.94E-10			2020	12838	
2021	7.12E-10				2021	13053	
2022	7.21E-10				2022	13279	
2023	7.31E-10				2023	13518	
2024	7.41E-10				2024	13774	
2025	7.52E-10				2025	14048	
2026	7.64E-10				2026	14344	
2027	7.77E-10				2027	14661	
2028	7.91E-10				2028	15002	
2029	8.06E-10				2029	15368	
2030	8.22E-10	7.64E-10			2030	15759	
2031	8.38E-10				2031	16176	
2032	8.56E-10				2032	16618	
2033	8.75E-10				2033	17086	
2034	8.95E-10				2034	17580	
2035	9.16E-10				2035	18099	
2036	9.39E-10				2036	18643	
2037	9.62E-10				2037	19210	
2038	9.86E-10				2038	19801	
2039	1.01E-09				2039	20414	
2040	1.04E-09	1.01E-09			2040	21049	
2041	1.06E-09				2041	21704	
2042	1.09E-09				2042	22378	
2043	1.12E-09				2043	23071	
2044	1.15E-09				2044	23780	
2045	1.18E-09				2045	24506	

19 Plot resulting rescaled MESSAGE projections for the years for ADB program lifetime

20 Plot all three projections (ENE, IND, TRA) on one diagram



Source: R. Jonassen. 2020. MESSAGE Xiangtan CH4 8.5 data

Table 2: Description on the Procedure for the Xiangtan Best-Case GHG Scenario

Description of Steps for the Xiangtan BAU Projections

1 Download IMAGE RCP 2.6 CO2 projections from the grid cell containing Xiangtan

	CO2 Emission Rate				
Year	**ENE**	**IND**	**TRA**	**AGR**	**AWB**
2000	1.18E-08	9.58E-09	1.59E-09	0	0
2005	1.56E-08	1.14E-08	1.78E-09	0	0
2010	2.17E-08	1.40E-08	1.91E-09	0	0
2020	3.43E-08	1.90E-08	2.33E-09	0	0
2030	4.19E-08	2.04E-08	2.51E-09	0	0
2040	4.63E-08	2.01E-08	2.54E-09	0	0
2050	4.69E-08	1.81E-08	2.55E-09	0	0
2060	4.62E-08	1.79E-08	2.48E-09	0	0
2070	4.70E-08	1.87E-08	2.56E-09	0	0
2080	4.87E-08	1.96E-08	2.28E-09	0	0
2090	5.21E-08	1.98E-08	1.56E-09	0	0
2100	5.63E-08	1.94E-08	8.35E-10	0	0

Definition of Variables

ENE	Power plants, energy conversion, extraction CO2
IND	Industry (combustion and processing) CO2 emissions
TRA	Surface transportation CO2 emissions
AGR	Agriculture (animals, rice, soil)
AWB	Agriculture (waste burning on fields)

Units are kg/m2/sec
kgm-2s-1

Source: IMAGE RCP 2.6 CO2 for grid cell containing Xiangtan

2 Record the observed emissions (*same as Table 1*)

3 Set the years for which projections are desired: 2020-2045

4 Plug IMAGE projections number in relevant year;

5 Check Mean and Standard Deviation of IMAGE projections;

6 Standardize values of years for better precision estimates of regression coefficients; and

7 Standardize values of IMAGE projections

Year	TRA	Observed	Year	TRA	Standardized Year	Standardized TRA	Yearly Standardized
2000	1.59E-09		2000	1.59E-09	-1.00	-0.89452890566192	-0.85001043
2005	1.78E-09		2001		-0.98		-0.837606614
2010	1.91E-09		2002		-0.96		-0.808497761
2020	2.33E-09		2003		-0.94		-0.765312784
2030	2.51E-09		2004		-0.92		-0.710460125
2040	2.54E-09	635.80	2005	1.78E-09	-0.90	-0.54198700747884	-0.646138227
2050	2.55E-09		2006		-0.88		-0.574345793
2060	2.48E-09		2007		-0.86		-0.496891823
2070	2.56E-09		2008		-0.84		-0.41540542
2080	2.28E-09		2009		-0.82		-0.331345391
2090	1.56E-09		2010	1.91E-09	-0.80	-0.30273603146131	-0.246009609
2100	8.35E-10		2011		-0.78		-0.160544169
			2012		-0.76		-0.075952307
			2013		-0.74		0.006896885
			2014		-0.72		0.087259982
		3,057.10	2015		-0.70		0.164510961
		3,166.50	2016		-0.68		0.23813316
			2017		-0.66		0.307711455
			2018		-0.64		0.372924668
			2019		-0.62		0.433538186
			2020	2.33E-09	-0.60	0.45940456143199	0.489396807
			2021		-0.58		0.540417806
			2022		-0.56		0.586584223
			2023		-0.54		0.627938373
			2024		-0.52		0.664575578
			2025		-0.50		0.696638114
			2026		-0.48		0.724309393
			2027		-0.46		0.74780835
			2028		-0.44		0.767384067
			2029		-0.42		0.783310607
			2030	2.51E-09	-0.40	0.78622428316082	0.795882076
			2031		-0.38		0.805407903
			2032		-0.36		0.812208344
			2033		-0.34		0.816610206
			2034		-0.32		0.818942793
			2035		-0.30		0.819534075
			2036		-0.28		0.818707073
			2037		-0.26		0.816776473
			2038		-0.24		0.814045458
			2039		-0.22		0.810802758
			2040	2.54E-09	-0.20	0.84633410276391	0.80731993
			2041		-0.18		0.803848849
			2042		-0.16		0.800619433
			2043		-0.14		0.797837574
			2044		-0.12		0.795683306
			2045		-0.10		0.794309184

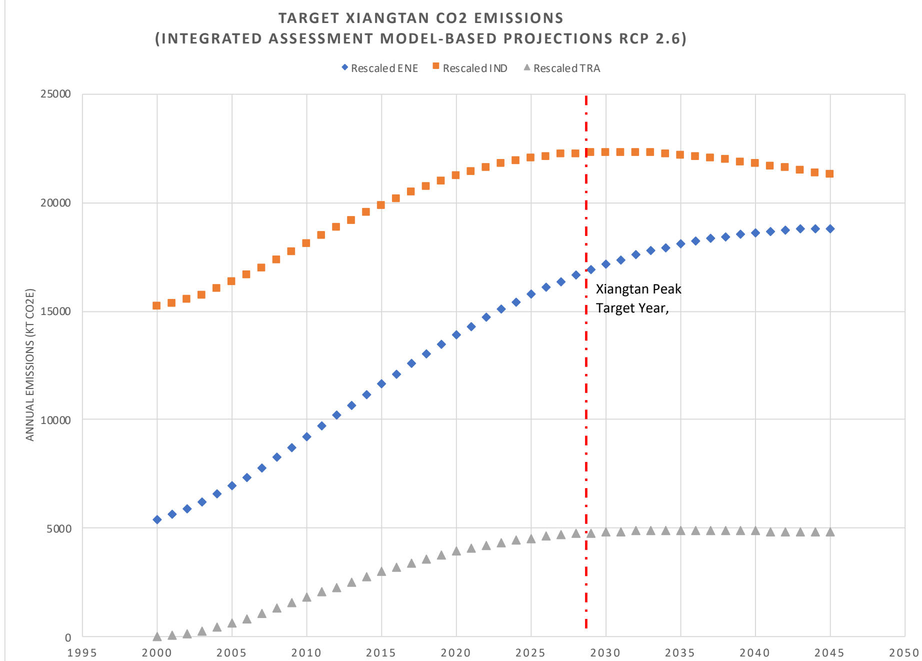
(Extracted from transport emissions calculation sheet)

8	Fit 6th order polynomial to columns F and G
9	Extract coefficients of equation to 16 significant figures
10	Use equation to solve annual values of scaled IMAGE projections
11	Rescale solutions using same mean and standard deviation used for scaling
12	Compare to known IMAGE values to check calculation results
13	Check IMAGE values for same years as observations
14	Check the observed emissions
15	Fit linear polynomial to scale IMAGE values to observations
16	Extract coefficients of equation to 16 significant figures
17	Use equation to solve annual values of rescaled IMAGE projections
18	Compare to known observed values to check calculation results

Year	TRA (6th Order)	IND (IMAGE)	TRA (6th Order)	Observed	Year	Rescaled TRA	Observed
2000	1.61E-09	1.59E-09	1.72E-09	635.80	2000	43	
2001	1.62E-09		2.17E-09	3,057.10	2001	79	
2002	1.63E-09		2.21E-09	3,166.50	2002	163	
2003	1.66E-09				2003	289	
2004	1.69E-09				2004	449	
2005	1.72E-09	1.78E-09			2005	636	636
2006	1.76E-09				2006	846	
2007	1.80E-09				2007	1071	
2008	1.85E-09				2008	1309	
2009	1.89E-09				2009	1553	
2010	1.94E-09	1.91E-09			2010	1802	
2011	1.99E-09				2011	2051	
2012	2.03E-09				2012	2297	
2013	2.08E-09				2013	2539	
2014	2.12E-09				2014	2773	
2015	2.17E-09				2015	2998	3,057
2016	2.21E-09				2016	3212	3,167
2017	2.24E-09				2017	3415	
2018	2.28E-09				2018	3605	
2019	2.31E-09				2019	3782	
2020	2.34E-09	2.33E-09			2020	3944	
2021	2.37E-09				2021	4093	
2022	2.40E-09				2022	4228	
2023	2.42E-09				2023	4348	
2024	2.44E-09				2024	4455	
2025	2.46E-09				2025	4548	
2026	2.47E-09				2026	4629	
2027	2.48E-09				2027	4697	
2028	2.50E-09				2028	4754	
2029	2.50E-09				2029	4801	
2030	2.51E-09	2.51E-09			2030	4837	
2031	2.52E-09				2031	4865	
2032	2.52E-09				2032	4885	
2033	2.52E-09				2033	4898	
2034	2.52E-09				2034	4904	
2035	2.52E-09				2035	4906	
2036	2.52E-09				2036	4904	
2037	2.52E-09				2037	4898	
2038	2.52E-09				2038	4890	
2039	2.52E-09				2039	4881	
2040	2.52E-09	2.54E-09			2040	4871	
2041	2.52E-09				2041	4860	
2042	2.51E-09				2042	4851	
2043	2.51E-09				2043	4843	
2044	2.51E-09				2044	4837	
2045	2.51E-09				2045	4833	

(extracted from transport emissions calculation sheet)

19	Plot resulting rescaled IMAGE projections for the years of interest to ADB
20	Plot all three projections (ENE, IND, TRA) on one diagram



Source: R. Jonassen. 2020. IMAGE Xiangtan RCP 2.6 data

9. **Xiangtan BAU (Worst-case) and the Best-Case GHG Scenarios.** After rescaling the global models for Xiangtan, the harmonization process was carried out to make consistency in GHG emissions values between the RCP 8.5 and the RCP 2.6. After discovering some odd projections of industrial GHG scenarios under RCP 8.5 and RCP 2.6., the decision was made to readjust the sector-based projections to determine the BAU under the assumption that it would be the worst-case scenario, and the best-case scenario for Xiangtan.

Table 3: Harmonized IMAGE RCP 2.6 and MESSAGE RCP 8.5 Results Versus the Final Xiangtan Best and Worst-Case Scenarios (unit: KTCO$_2$e)

	MESSAGE IAM - RCP8.5			HARMONIZED IMAGE IAM - RCP2.6		
Year	Worst Case ENE	Best Case IND	Worst Case TRA	Best Case ENE	Worst Case IND	Best Case TRA
2020	12838	20594	4505	12838	20594	4505
2021	13053	20648	4832	13245	20802	4654
2022	13279	20676	5162	13636	20988	4788
2023	13518	20677	5493	14009	21151	4909
2024	13774	20654	5824	14364	21292	5016
2025	14048	20607	6155	14700	21410	5109
2026	14344	20536	6483	15017	21507	5190
2027	14661	20443	6808	15315	21583	5258
2028	15002	20328	7128	15594	21639	5315
2029	15368	20193	7442	15853	21675	5362
2030	15759	20039	7748	16093	21693	5398
2031	16176	19866	8045	16315	21695	5426
2032	16618	19677	8333	16518	21680	5446
2033	17086	19471	8609	16703	21651	5459
2034	17580	19249	8873	16870	21608	5465
2035	18099	19014	9125	17021	21554	5467
2036	18643	18766	9362	17155	21489	5465
2037	19210	18506	9584	17273	21416	5459
2038	19801	18235	9790	17377	21334	5451
2039	20414	17954	9980	17467	21246	5442
2040	21049	17665	10152	17544	21153	5432
2041	21704	17368	10307	17608	21057	5421
2042	22378	17064	10443	17660	20959	5412
2043	23071	16754	10561	17702	20859	5404
2044	23780	16439	10660	17735	20760	5398
2045	24506	16121	10739	17758	20662	5394

TOTAL EMISSIONS ENE+IND+TRA IAM XT SCENARIOS		
Year	Worst Case	Best Case
2020	37,937	37,937
2021	38,687	38,547
2022	39,428	39,100
2023	40,162	39,595
2024	40,890	40,034
2025	41,613	40,416
2026	42,334	40,743
2027	43,052	41,016
2028	43,769	41,237
2029	44,485	41,408
2030	45,200	41,531
2031	45,916	41,607
2032	46,631	41,640
2033	47,346	41,632
2034	48,062	41,585
2035	48,778	41,502
2036	49,494	41,386
2037	50,210	41,239
2038	50,925	41,063
2039	51,640	40,863
2040	52,355	40,640
2041	53,068	40,397
2042	53,780	40,136
2043	54,491	39,860
2044	55,200	39,572
2045	55,907	39,273

Source: R. Jonassen. 2020.XSDP GHG Emissions Summary Model.

C. GHG Reduction Impact Analysis

1. GHG Emission Reduction by the Project

10. The project contains several multi-sector transformational solutions in the mobility, building, and energy infrastructure and also information and knowledge platforms that would complement the physical infrastructure and create synergy effects, including impacts on the GHG emissions reduction. Table below summarizes the assumptions used for the GHG reduction calculation of each component. As for the mobility system, the project intervention is reinforced by the PBL, it is not feasible to split the GHG reduction impacts. Also, assessing the impacts on mobility transformations is rather complex, a separate model was developed. GHG emission factor is calculated based on the Central Grid System. The Central China Grid run by the State Grid covers six provinces, including Hunan, Hubei, Henan, Jiangxi, Sichuan, and Chongqing provinces. The energy sources of the Central China Grid are composed of 55% coal, 42% hydro, 3% wind and solar energy. CO_2 emission factor of 462 g/kWh is calculated reflecting the energy composition (Table 5). Note that GHG reduction is automatically calculated through the EDGE certification, which uses CO_2 emission factor of 494 g/kWh.

Table 4: Assumptions and baseline scenarios of energy and GHG emission reduction projection.

Output	Assumptions	Baseline Scenario
Output 1: Low-Carbon and Resilient Transportation Infrastructure Demonstrated		
Mobility transformation, clean vehicles and e-charging facilities	City-wide bus priority system, integrated with pedestrian and cyclist's safety and accessibility improvements, will lead to mode shift from cars to public and non-motorized transport modes. *A separate transport model was developed and a 40% of reduced GHG emissions will be allocated under the project, while 60% under the PBL impacts.*	Business-as-usual
EDGE-certified Xiangtan First Traditional Chinese Medicine Hospital	Total building floor area and number of beds are the same with baseline scenario	Original design of the hospital
EDGE-certified Asia Pacific Low-Carbon Development Training Center	Total building floor area is the same with baseline scenario	Business-as-usual scenario*
Low-carbon communities improvement	Activities relevant to energy efficiency and cleaner energy supply were counted, including building insulation, LED lighting, and improved access for natural gas	Business-as-usual scenario
Output 2: Information and Knowledge Platforms for Informed Decision Making and Behavior Changes		
City-Wide ICT Platform	--	--
ITS reprogramming for mobility transformation	- Support mode shift from cars to public and NMT. - ITS induced fuel efficiency improvement: 10%	Business-as-usual scenario
BEMS- 200 public buildings	- Average floor area of a public building: 4500 m^2; - Equivalent Hour of full capacity for heating / cooling per year: 1321h / 1373h;	Business-as-usual scenario

	- heating / cooling load indicator: 60 / 80 w/m^2; - coefficient of performance for air-conditioner: 2.7 - BEMS induced Energy efficiency improvement: 20%	
CEMS at Jiuhua Industrial Zone	- Number of Companies in 2020: 1333; - Installed capacity to meet energy demand in 2020: 309 MW; - Energy demand in 2021: 1,419,837 MWh/a; - Installed capacity to meet energy demand in 2025: 561 MW; - Energy demand in 2025: 2,577,763 MWh/a; - CEMS induced Energy Saving: 20%	Business-as-usual scenario

Source: Emission Projection and Reduction Calculations, Xiangtan Low-Carbon Transformation Sector Development Program. ADB, 2020.

Table 5: Central China Grid Analysis and GHG emission factor calculation

	Hunan Power Generaiton (100 million kWh)				
Year		2016	2017	2018	
hydro power		530.0	516.8	447.8	31.56%
thermal power		722.6	786.0	912.5	64.31%
nuclear power		0.0	0.0	0.0	0.00%
wind power		31.6	43.5	51.0	3.59%
solar power		0.064	2.9	7.4	0.52%
total		1284.0	1349.2	1418.8	100%

	Hubei Power Generaiton (100 million kWh)				
Year		2016	2017	2018	
hydro power		1379.3	1459.2	1449.8	52.28%
thermal power		1012.0	1042.0	1237.0	44.61%
nuclear power		0.0	0.0	0.0	0.00%
wind power		27.7	41.0	54.3	1.96%
solar power		4.167	6.7	31.9	1.15%
total		2423.1	2549.0	2773.0	100%

Source: http://data.stats.gov.cn/adv.htm?m=advquery&cn=E0101 National Bureau of Statistics of China

	Henan Power Generaiton (100 million kWh)				
Year		2016	2017	2018	
hydro power		88.6	96.6	138.3	4.74%
thermal power		2516.2	2564.9	2708.3	92.87%
nuclear power		0.0	0.0	0.0	0.00%
wind power		14.1	29.2	38.7	1.33%
solar power		3.659	12.8	30.8	1.06%
total		2622.5	2703.5	2916.2	100%

	Jiangxi Power Generaiton (100 million kWh)				
Year		2016	2017	2018	
hydro power		82.0	84.5	67.6	5.67%
thermal power		832.3	939.1	1056.3	88.58%
nuclear power		0.0	0.0	0.0	0.00%
wind power		6.4	15.6	43.0	3.61%
solar power		2.191	7.4	25.7	2.16%
total		922.9	1046.6	1192.5	100%

	Sichuan Power Generaiton (100 million kWh)				
Year		2016	2017	2018	
hydro power		2721.8	2909.9	2982.2	85.24%
thermal power		397.8	380.5	447.9	12.80%
nuclear power		0.0	0.0	0.0	0.00%
wind power		17.9	37.8	53.8	1.54%
solar power		4.062	11.7	14.7	0.42%
total		3141.6	3340.0	3498.6	100%

	Chongqing Power Generaiton (100 million kWh)				
Year		2016	2017	2018	
hydro power		217.6	215.5	197.1	26.05%
thermal power		448.6	468.5	539.1	71.25%
nuclear power		0.0	0.0	0.0	0.00%
wind power		4.6	5.9	7.2	0.95%
solar power		0.000	0.6	0.6	0.08%
total		670.8	690.5	756.6	100%

	Central China Grid Power Generaiton (100 million kWh)				
Year		2016	2017	2018	
hydro power		5019.3	5282.5	5282.8	42.07%
thermal power		5929.5	6181.0	6901.1	54.96%
nuclear power		0.0	0.0	0.0	0.00%
wind power		102.3	173.0	248.0	1.98%
solar power		14.1	42.1	111.2	0.89%
total		11064.9	11678.8	12555.7	100%

Reflecting the share of thermal power in Central China Grid

National wide factors	Emission factors of thermal power generation (g/kWh)		Emission factors of power generation (g/kWh) in Central China Grid reflecting the share of thermal coal power	
Year	2017	2018	2017	**2018**
CO2	844	841	446.69	462
PM	0.06	0.04	0.03	0.02
SO2	0.26	0.20	0.14	0.11
NOx	0.25	0.19	0.13	0.10

Source: 2018 Yearly Report of Power Sector in China
2019 Yearly Report of Power Sector in China

Source: ADB TRTA energy expert.

11. Table below shows the detailed calculation of project components that are relevant to the GHG reduction impacts.

Table 6: GHG reduction calculation of the relevant project components

Output 1: Low-Carbon and Resilient Infrastructure Transformation Demonstrated.

Xiangtan First Traditional Chinese Medicine Hospital

Basic Assumptions/Information	Floor area (m2)
Total	103,632
Inpatient Building	41,300
outpatient Building	46,443
Technical dormitory building	4,234
Chinese Medicine production building	11655

Benefit Calculation	Original Design		Project Design	Savings	Unit	Efficient Improvement
Energy Savings Total	**16,819**		**12,352**	**4,459**	MWh/a	**26.51%**
Inpatient Building	5,347		4,059	1,278	MWh/a	23.90%
outpatient Building	8,417		6,065	2,353	MWh/a	27.96%
Technical dormitory building	2,758		2,002	757	MWh/a	27.43%
Chinese Medicine production building	298		226	71	MWh/a	23.99%
Embodied Energy in Materials Savings	**251,396**		**181,326**	**70,071**	GJ	**27.87%**
Inpatient Building	116,328		75,823	40,506	GJ	34.82%
outpatient Building	96,995		77,286	19,709	GJ	20.32%
Technical dormitory building	27,348		20,030	7,318	GJ	26.76%
Chinese Medicine production building	10,725		8,188	2,538	GJ	23.66%
Water Saving/Total	**127,680**		**99,851**	**27,820**	m³/a	**21.79%**
Inpatient Building	72,657		58,199	14,458	m³/a	20.13%
outpatient Building	23,732		18,977	4,746	m³/a	20.02%
Technical dormitory building	16,191		12,372	3,819	m³/a	23.58%
Chinese Medicine production building	15,100		10,304	4,797	m³/a	31.47%
CO2 reduction/total				**3,243**	TCO2e	
Inpatient Building				755	TCO2e	
outpatient Building				1,843	TCO2e	
Technical dormitory building				533	TCO2e	
Chinese Medicine production building				112	TCO2e	
Annual Utility Cost	**18,505,259.88**		**14,042,127.96**	**4,463,132**	CNY/a	
Inpatient Building	5,885,046		4,319,427.84	1,565,618	CNY/a	
outpatient Building	9,603,623		7,566,138.36	2,037,485	CNY/a	
Technical dormitory building	2,775,763		1,976,249.76	799,514	CNY/a	
Chinese Medicine production building	240,828		180,312.00	60,516	CNY/a	
Incremental Cost	**17,584,919**	CNY		**2,520,413**	USD	
Inpatient Building	5,643,615	CNY		808,888	USD	
outpatient Building	7,865,537	CNY		1,127,352	USD	
Technical dormitory building	2,930,852	CNY		420,073	USD	
Chinese Medicine production building	1,144,916	CNY		164,099	USD	
Payback period						
Inpatient Building	3.6	year				
outpatient Building	3.86	year				
Technical dormitory building	3.67	year				
Chinese Medicine production building	18.92	year				

Xiangtan Government Buildin Retrofit (Asia Pacific Low-Carbon Development Training Center)

Basic Assumptions/Information						
Floor area (m2)	6,347.8					
Benefit Calculation						
	Before		**Project Design**	**Savings**	**Unit**	**Efficient Improvement**
Energy Savings Total	**1,597.05**		**1,223.42**	**373.63**	MWh/a	**23.39%**
Embodied Energy in Materials Savings				**4,606.54**	GJ	**31.14%**
Water Saving/Total	**10,505.40**		**7,884.00**	**2,621.40**	m³/a	**24.95%**
CO2 reduction/total				**566.23**	TCO2e	
Annual Utility Cost	1,120,934.40		858,273.12	262,661.28	CNY/a	
Incremental Cost	1,753,817.69	CNY		**251,371.32**	USD	
Payback period	6.68	Year				

Output 2: Information and Knowledge Platforms for Informed Decision-Making and Behavioral Change Enabled.

Building Energy Management for 200 Public Buildings

Basic Assumption/Information		
Average floor area of a public building	4,500 m2	
Equivalent Hour of full capacity for heating per year	1,321 h	
heating load indicator	60 W/m2	
Equivalent Hour of full capacity for cooling	1,373 h	
Cooling load indicator	80 W/m2	
coefficient of performance	2.00	(note: 1 kWh electricity will produce 2 kWh energy for cooling or heating)
BEMS induced Energy efficiency improvement	20%	~30%
Benefits Calculation		
Total floor area of 200 public buildings	900,000 m2	
Total energy consumption for heating	35,667 MWh/a	
Total energy consumption for consumption	49,428 MWh/a	
Energy Savings	**17,019 MWh/a**	
Savings in terms of Standard Coal Equivalent	**3,336 TCE/a**	
CO2 emission reduction (CO2e)	**7,863 ton/a**	

Jiuhua Industrial Zone- Power Distribution Expansion and CEMS

Basic Information		(in 2045)
Number of Companies in 2020	1333	
Energy intensive manufacturing plants are currently on negotiation		
Installed capcity to meet energy demand in 2020	309 MW	
Energy demand in 2021	1,419,837 MWh/a	
Installed capcity to meet energy demand in 2025	561 MW	
Energy demand in 2025	2,577,763 MWh/a	9,902,100 MWh/a
Future Energy Demand		
CEMS induced Energy Saving	20%	~30%
Benefit Calculation		(in 2045)- PBL impacts
Energy Saving in 2025	**515,553 MWh/a**	**1,980,420 MWh/a**
Energy Saving in Standard Coal Equivalent	**87,128 TCE/a**	**334,691 TCE/a**
GHG Reduction (TCO2e)	**238,185 ton/a**	**914,954 ton/a**

20 Urban Low-Carbon Communities Improvement

Benefit Calculation

	Yuhu District			Yuetang District		
Activities	Scale of Activitities	Energy Saving	GHG Reduction (CO2e)	Scale of Activitities	Energy Saving (MWh/a)	GHG Reduction (CO2e)
External wall insulation (m2)	350650	5,152 MWh/a	2,380 ton/a	77548	1,139 MWh/a	526 ton/a
Roof insulation (m2)	79880	866 MWh/a	400 ton/a	74830	811 MWh/a	375 ton/a
Building light bulbs to LED (piece)	2382	18 MWh/a	8 ton/a	6844	51 MWh/a	24 ton/a
Windows and doors replacement for better insulation (m2)	71088	6,415 MWh/a	2,964 ton/a	16346	1,475 MWh/a	682 ton/a
Installation of solar hot water panel system (piece)	-	-	-	1053	885 MWh/a	409 ton/a
Installation of rooftop solar PV (m2)	-	-	-	298563	3,761 MWh/a	1,738 ton/a
LED Street lighting (pole)	96	18 MWh/a	8 ton/a	609	111 MWh/a	51 ton/a
Electric bike charging unit (piece)	47	-	-	204	-	-
E-charging unit for vehicle	-	-	-	116	-	-
Installation of water saving facets/toilers (piece)	-	-	-	4097	-	-
Rainwater harvesting pool (m3)	-	-	-	1460	-	-
Rainwater collection pipes	-	-	-	4850	-	-
Natural gas pipeline network	-	-	-	3621	6,159 Nm3/a	12 ton/a
Sewage pipe upgrade (different pipe size) (m)	6165	-	-	15325	-	-
Underground power cable (m)	-	-	-	7000	-	-
Parking space upgrade with EbA for resilience (m2)	5730	-	-	15300	-	-
Community parks resilience improvement with EbAs (m2)	-	-	-	8900	-	-
Sidewalks/cycling ways improvement (m)	3967	-	-	6923	-	-
Community counseling center improvement (m2)	-	-	-	2200	-	-
Sub-Total		*12,469 MWh/a*	*5,761 ton/a*		*8,234 MWh/a*	*3,816 ton/a*
Total Energy Saving		**20,703 MWh/a**				
Total Energy Saving in Standard Coal Equivalent		**4,058 TCE/a**				
Total GHG Reduction (TCO2e)		**9,577 ton/a**				

2. Xiangtan Transport Model and GHG Emissions

12. The transport model is developed to assess GHG emissions reduction induced by the project intervention and transport related policy actions. Due to the nature of the PBL on low-carbon mobility, reinforcing and complementing the project, it is not feasible to segregate the impacts. Thus, 40% of combined results are allocated to the project impacts and 60% allocated to the PBL impacts. The ITS reprogramming to complement the low-carbon mobility was estimated at a 10% efficiency improvement in terms of traffic flows, reduction of accidents, mobility service improvement, and others.

13. The XLCTSDT Transport GHG Calculation Model is an excel-based model. The model is organized with navigation tabs. It shows detailed assumptions, logical flow to explain interconnectivity of different measures, description of interventions and their effects, detailed calculations, and summary calculation. Here, the following shows the structure of the model, assumptions, and summary of GHG reduction results.

Structure of the XSDP Transport Emissions Calculation Model

Navigate Using These Buttons

v

- Read Me
- Logical Flow
- Dashboard
- Assumptions
- Abbreviations
- Interventions and Effects
- Intervention Representation
- Demographics
- BAU Bus Scenario
- Bus Fuel Switch
- Weighted Bus EFs
- Bus EF Interventions
- Bus LOS EFs
- BAU Mode Preference
- Mode Shift Interventions
- Modal Shift
- More EV POVs
- POV Efficiency Interventions
- Car Pooling
- ICE Fuel Standards
- ICE Emission Standards
- MC Emission Standards
- POV LOS
- Vehicle Numbers
- Environmental Impact
- Example Growth Equations
- References

EXHIBIT A

Greenhouse Gas (GHG) Implications of TA-9437 PRC: Supporting Project Preparation-Hunan Xiangtan Low Carbon City Development

PURPOSE:

This spreadsheet accompanies a report to ADB summarizing projected impacts of Low Carbon (LC) City Development in the municipality (county) of Xiangtan, China.

The report summarizes each of the project-based and policy-based actions that will be undertaken as a result of the requested loan and indicates the ways in which those actions can be expected to influence the trajectory of GHG emissions over the lifetime of the loan (to 2045).

This spreadsheet calculates these effects for each of the project-based and policy-based actions related to transport and determines the net impact of each by comparison to a baseline scenario.

The baseline scenario represents a 'Business as Usual" (BAU) case where the composition of the bus fleet and all incentives for use of the various modes of transport available do not change from today (2019).

Under the BAU scenario, all factors that could be influenced by the project-based and policy-based loans are held constant at 2019 values. Only external factors such as population change in the BAU scenario.

The "ADB Scenario" represents the case where each project-based and policy-based action is fully implemented.

The ADB Scenario examines the effect of five project-based actions and six policy-based actions. These actions are:

Project-based modifications examined:

1. Change in bus fleet engine types - and corresponding switch in fuel types.
2. Change in bus lane placement, features, and operating characteristics.
3. Changes in availability of charging piles and charging stations.
4. Changes in availability and characteristics of bicycle lanes.
5. Changes in availability and characteristics of pedestrian walkways.
6. Improvements in interconnectivity of low carbon transport modes.

Policy-based modifications examined:

1. Changes in parking fees, parking availability and rule enforcement.
2. Improvements in accessibility of public bicycles.
3. Enforcement of restrictions on electric motor bikes.
4. Improvements in operation of multi-modal hubs.
5. Promotion of LC transport (e.g. bus operation, bicycle use and parking, car sharing, pedestrian safety, clean private vehicles).
6. Discouraging the use of fossil fuel transport options (vehicle emissions).

Policy-based actions are designed to occur in two tranches with different implementation dates and the effects of policies on human behavior are also phased over time as they reach greater numbers of the relevant population.

EXHIBIT B

Organization of This Spreadsheet

This spreadsheet is organized into 27tabs as listed below. Each tab develops one aspect of the total picture of GHG emission reductions projected as a result of implimentation of the ADB project-based and policy-based loans to the Xiangtan municipal government beginning in 2020. The section below explains the purpose of each tab.

Navigation in the Spreadsheet	Use the blue navigation pane at the left side of this spreadsheet to easily move to tabs of interest. You will find similar buttons on each tab, at the left side of the page.

#	Tab Name	Contents and Purpose of Tab
1	Read Me	THIS TAB - Explains the purpose and organization of the spreadsheet.
2	Logical Flow	Presents a graphical representation of the entire spreadsheet and the relations between the various tabs. Click on a box to go to that tab.
3	Dashboard	Summary of results of the key calculations. Presents results for base year, 2028, loan end year (2045), and overall total.
4	Assumptions	Lists in one place the various assumptions that are needed to complete the calculations on each tab. Assumptions are repeated on relevant tabs
5	Abbreviations	Provides definitions for every abbreviation used in this sheet.
6	Interventions and Effects	Lists, codes, and explains each intervention that results from the two loans.
7	Intervention Representation	Indicates what modes are affected by each intervention and what equation represents it.
8	Demographics	Develops, documents, and presents a scenario of population change during the loan lifetime.
9	BAU Bus Scenario	Describes the current bus fleet in XT and calculates CO2 emissions to 2045 under the assumption of no change.
##	Bus Fuel Switch	Presents the scenario and GHG reduction where bus fleet composition changes as proposed in the loan
##	Weighted Bus EFs	Summarizes the net effect on GHG emissions as the bus fleet composition changes and cleaner busses come online
##	Bus EF Interventions	Presents interventions not covered in the bus fuel switch scenario that effect emission factors and what tab presents the detailed calculations.
##	Bus LOS EFs	Calculates the effect on bus operating efficiency of improvments in "Level of Service" where improvements increase bus speed.
##	BAU Mode Preference	Summarizes survey data on transport mode preference, extrapolated to 2045 and shows how bus passengers are allocated to bus types.
##	Mode Shift Interventions	Presents interventions that have the effect of encouraging residents to use cleaner modes of transport and how each is represented.
##	Modal Shift	Examines the effect of all policies that focus on encouraging shift from fossil fuel transport options to low carbon options.
##	More EV POVs	Represents the effect on GHG emissions of increasing proportion of electric vehicles (EVs) in the POV fleet.
##	POV Efficiency Interventions	Summarizes policy-based interventions for standards enforcement and car-pooling.
##	Car Pooling	Calculates the effect of policies that encourage car pooling in an optimal manner and compares that to a BAU scenario of GHG emissions.
##	ICE Fuel Standards	Examines the effect of all policies that focus on improving POV adherence to existing and planned fuel economy standards.
##	ICE Emission Standards	Examines the effect of all policies that focus on improving POV adherence to existing and planned emission standards.
##	MC Emission Standards	Examines the effect of all policies that focus on improving MC adherence to existing and planned emission standards.
##	POV LOS	Calculates the effect of reduced service on the lanes used by POVs when a lane is switched to only bus use.
##	Vehicle Numbers	Summarizes the effects of relevant interventions upon the number and type of vehicles and emissions of each mode in Xiangtan through 2045.
##	Environmental Impact	Computes various metrics of safety and cost of living that relate to quality of life as reliance on POVs decreases.
##	Example Growth Equations	Provides an overview of the four types of equations used to represent changes induced by the project-based and policy-based loans.
##	References	Lists all sources used in this analysis, including relevant project documents, documents provided by the XTMG, and professional literature.

Assumptions

Key Assumptions of Spreadsheet

BAU Bus Scenario Tab:

1. Assume Gui'an EFs scale to unknown fuel sources as observed in all-China data.
2. Assume bus annual VKT is as reported for Gui'an and remains constant throughout the loan period.
3. This value (55,000) agrees closely with the all-China value for 10-12m busses (56,000).
4. Assume all busses are 12 m in length and eBusses are 100% electric battery powered.
5. Assume 8 years lifetime for eBus.
6. Assume bus batteries are reused (stationary) after the bus no longer uses them, lowering lifetime GHG emissions drastically.
7. Emissions are calculated as the no. of busses of each type x distance travelled per year (for the average bus) x emissions per km travelled.
8. For the purposes of this analysis, we assume that when busses are replaced, the replacements use the same fuel and have the same emission profile as the original.

Bus Fuel Switch Tab:

1. All replacements occur over a five-year period 2020-2024.
2. The new busses will be 10.5m eBusses.
3. Busses must be replaced every eight years (all-China regulation).
4. For the purposes of this analysis, we assume that when busses are replaced, the replacements use the same fuel and have the same emission profile as the original.
5. GHG emissions are calculated using well-to-wheels (WTW) emission factors that are averages for China.
6. Emission factors represent average total kilometers travelled by busses in China.
7. These EFs assume 56,000 annual VKT constant throughout the loan period.
8. Assume 8 years lifetime for eBus.
9. Assume bus batteries are reused (stationary) after the bus no longer uses them, lowering lifetime GHG emissions drastically.
10. Emissions are calculated as the no. of busses of each type x emissions per year.

Weighted Bus EFs Tab:

1. For the purposes of this analysis, we assume that when busses are replaced, the replacements use the same fuel and have the same emission profile as the original.
2. GHG emissions are calculated using well-to-wheels (WTW) emission factors that are averages for China.
3. Emission factors represent average total kilometers travelled by busses in China.
4. These EFs assume 56,000 annual VKT constant throughout the loan period.
5. Assume 8 years lifetime for eBus.
6. Assume bus batteries are reused (stationary) after the bus no longer uses them, lowering lifetime GHG emissions drastically.

Bus LOS EFs Tab:

1 Consider only China 4 emissions standards since even those are dated.
2 Assume a two-level improvement in LOS from "saturated traffic" to "free flow" traffic.
3 Assume bus EFs scale to LOS in direct linear relation to the relative values for automobiles conforming to China 4 emission standards.
4 All replacements occur over a five-year period 2020-2024.
5 The new busses will be 10.5m eBusses.
6 Busses must be replaced every eight years (all-China regulation).
7 For the purposes of this analysis, we assume that when busses are replaced, the replacements use the same fuel and have the same emission profile as the original.
8 GHG emissions are calculated using well-to-wheels (WTW) emission factors that are averages for China.
9 Emission factors represent average total kilometers travelled by busses in China.
10 These EFs assume 56,000 annual VKT constant throughout the loan period.
11 Assume 8 years lifetime for eBus.
12 Assume bus batteries are reused (stationary) after the bus no longer uses them, lowering lifetime GHG emissions drastically.
13 Emissions are calculated as the no. of busses of each type x distance travelled per year (for the average bus) x emissions per km travelled.
14 Assume number of busses operating on enhanced LOS lanes is proportional to the km upgraded busways vs total km busways in XT.
15 Assume the fraction of busses operating in the dedicated lanes are proportional to the relative length of those lanes compared to the system length.
16 The BAU case assumes no change in the bus fleet composition.
17 These calculations ignore the embedded GHG emissions from construction of bus lanes.
18 Assume the fraction of busses of each fuel type operating on the enhanced LOS lanes is the same as in the general fleet.

Modal Shift Tab:

1 Apportion trips per year according to percentages in transition calculations each year.
2 Divide those by load factor of each mode. Multiply by average trip distance. Multiply by emissions per km.
3 EFs are WTW, gCO2e/km Source: ADB - "Emission calculation 21 Feb_final, Gui'an.xlsx" Asssumptions tab, cells G5:G13.
4 Bike EF is value for "non-motorized transport"
5 Bus EF is average across fuel types, weighted by bus type numbers. See "Weighted BUS EFs tab.
6 Assume that the trip km are one-way, and so we multiply all these by two (2.0) to determine the total distance travelled during a trip.
7 365 Assumed number of days with trips each year
8 Trip VKT Source: General report on XT urban comprehensive transportation system planning (for 2015).
9 They were provided by Zhou Lin of the Shenzen Urban Transport Planning Center in a spreadsheet titled "XT average distance travelled_2015" on 22 Oct 2019.
10 *Load Factor* calculated by dividing passenger kilometers by place kilometers, shows the average load on a bus route throughout the day.
11 BAU case represents absence of additional policy interventions.
12 Assume modal preference is as reported in ADB survey of XT commuters performed in August 2019. This applies for 2019 and throughout the loan period for the BAU case.
13 Assume changes in modal preference occur on an annual basis and can be represented by a Markov Transition Matrix for all modes of interest.
14 Assume policy interventions target specific mode transitions and can be represented by a percentage change in preference of one mode over another.
15 Assume commuters remain "loyal" to the prior year mode unless influenced by specific policy interventions.
16 Assume this "loyality" can be represented by a percent value (usuall nearly 100% but may be lower and that lower amounts imply an equal chance of shifting to any mode).
17 Assume EVs are initially 2% of the automobile fleet, as reported in the ADB survey from August 2019 and as consistent with all-China statistics.
18 Assume no commuters in XT use the train. This assumption is inconsistent with the expenditures planned in the loan to improve train-bus transfers.
19 Assume the number of commuter trips each year is proportional to the population that year as projected in the "Demographics" tab.
20 1.93 Assumed number of trips per day. Assume this number remains constant throughout the loan period.
21 2 Assume that each trip is in-fact a two-way trip so we double the km travelled to represent the round-trip distance of each trip.
22 Emissions are calculated as the no. of vehicles of each type x distance travelled per year x emissions per km travelled.
23 Number of vehicles of each type are calculated from number of commuters x percent in commute mode / load factor.

More EV POVs Tab:

1 Assume the share of EVs in the XT fleet follows the intervention scenario recommended in the "Modal Shift" tab.
2 Accept all assumptions of the "Modal Shift" tab.
3 14100 Assumed number of km travelled per year by POVs An alternative scenario is available as an option that reflects declining VKT consistent with Chinese literature.
4 462 g/kWh Assumed EF for electricity. Source: Electricity related emissions factors_for Xiangtan SDP use
5 Assume the number of diesel vehicles rapidly declines following a logistic curve. This decline is in response to national, regional, and local policies to remove diesel vehicles.
6 This calculation assumes sales of new diesel cars and LDVs are banned in XT beginning in 2021.
7 Assume the number of charging stations and charging piles of each type conforms with current XT policy throughout the loan period.
8 Assume the energy needs of EVs for each km travelled declines accoring to the scenario of Huo et al 2010.
9 BAU assumes no additional adoption of EVs

Car Pooling Tab:

Assume the number of passengers in a POV follows a Poisson Distribution.
Assume the parameter of the Poisson, lambda, increases yearly in response to policy interventions and following a logistic equation form.
Assume the maximum value of lambda is set by the average capacity of a vehicle and when lambda increases too far unsafe numbers of riders occurs.
12,500 Annual increase in population for Xiangtan County is as specified by the XT Health and H Comm.
300% The proportion of people in XT County living in Yuetang and Yuhu relative to the entire XT County will remain as reported in the 2015 GHG Assessment
62.1% Assumed fraction of the population that is working age (and in the workforce)
Assume that the entire working age population commutes each day and that there are no other users of transport. This ignores children.
Assume the share of POVs in the XT fleet follows the intervention scenario recommended in the "Modal Shift" tab.
365 Assume number of days per year of commute / car pooling
22.4% Percent commuting by car in BAU scenario remains constant throughout the period.
13.1 VKT/d for commuting vehicles remains constant throughout the loan period.

ICE Fuel Standards Tab:

1 Assume that the REF scenario of Wang, et al., 2017 represents the BAU scenario without ADB-funded intervention

ICE Emission Standards Tab:

1 Standards enforcement refers to existing standards for automobiles and motorcycles.
2 The focus is to ensure existing automobiles and motorcycles conform to the pollution control standards now in force.
3 Such standards of concern that are relevant to GHG emissions include: criteria pollutant emissions, efficiency (L/100km), and durabilty.
4 The focus on this tab is enforcement of criteria pollutant emission standards and durability (scrappage rates). For efficiency see the "ICE Fuel Standards" tab.
5 Currrent regulations require that all vehicles conform to China-5 criteria pollutant emission standards.
6 Efforts at enforcement will tend to move vehicles now confoming to lower standards to the China-5 level (see transition matrix in Exhibit C).
7 Without enforcement, vehicles tend to conform to the standard in place when they were assembled.

MC Emission Standards Tab:

1 Standards enforcement refers to existing standards for automobiles and motorcycles.
2 The focus is to ensure existing automobiles and motorcycles conform to the pollution control standards now in force.
3 Such standards of concern that are relevant to GHG emissions include: criteria pollutant emissions, efficiency (L/100km), and durabilty.
4 The focus on this tab is enforcement of criteria pollutant emission standards and durability (scrappage rates). For efficiency see the "ICE Fuel Standards" tab.
5 Currrent regulations require that all vehicles conform to China-5 criteria pollutant emission standards.
6 Efforts at enforcement will tend to move vehicles now confoming to lower standards to the China-5 level (see transition matrix in Exhibit C).
7 Without enforcement, vehicles tend to conform to the standard in place when they were assembled.
8 We consider only four-stroke engines and do not include calculations for two-stroke engines.
9 We consider only twp-wheeled vehicles and do not include calculations for three-wheeled vehicles.
10 We consider only motorcycles (engine displacement >50cc) and these calculations do not include mopeds.
11 Derogation rules are unknown and for the purposes of this analysis derogation is assumed to be not allowed.

POV LOS tab:

1 We assume that only the traffic on roads directly modified by the bus lane designation
2 is affected by the change.
3 This ignores any effect of bus lane change on the number of POVs (i.e. mode shift).
4 We assume that traffic is load is evenly spread across all roads considered.
5 This ignores the difference in traffic between different road types.
6 We assume that the length of roads in XT does not change during the entire period.
7 We calculate the case assuming the bus lanes are on major arterial roads.
8 We had assumed in the "Bus LOS EFs scenario that traffic flow began in the "Saturated Traffic" LOS.
9 We use that same assumption here.
10 In this case, traffic LOS switches down two levels (symmetric with our assummption of a two level
11 improvement for busses. Thus, traffic flow becomes "Heavy stop-and-go" for automobiles.
12 Assume that the effect is for more than one trip per day. Use the average number of trips.

Vehicle Numbers Tab:

1	12,500	Annual increase in population for Xiangtan County is as specified by the XT Health and H Comm.
2	0%	The proportion of people in XT County living in Yuetang and Yuhu relative to the entire XT County will remain as reported in the 2015 GHG Assessment
3	62.1%	Assumed fraction of the population that is working age (and in the workforce)
4		Assume that the entire working age population commutes each day and that there are no other users of transport. This ignores children.
5	1.93	Assumed number of trips per day for commuters.
6	2	Assume that each trip is in-fact a two-way trip so we double the km travelled to represent the round-trip distance of each trip.
7	25	Bus Load Factor
8	200.2	Bus VKT/d 73073 Bus km/yr
9	5.9	Bus trip length (km)
10		Assume mode preference for BAU corresponds exactly to that reported in the ADB survey performed in August 2019
11		Assume transport mode load factors are as reported in "Emission calculation 21 Feb_final, Gui'an.xlsx" Traffic Load tab

Transport Model Results

	BAU SCENARIO	(kt CO2e)				
Year	Bus	Auto - Gas	Auto - Diesel	Auto - EV	MC	eBike
2026	35	429	62	4	7	131
2027	35	431	62	4	7	131
2028	35	432	63	4	7	132
2029	36	434	63	4	7	132
2030	36	436	63	4	7	133
2031	36	438	63	4	7	133
2032	36	439	64	4	7	134
2033	36	441	64	4	7	134
2034	36	443	64	4	7	135
2035	36	444	64	4	7	135
2036	37	446	65	4	7	136
2037	37	448	65	4	7	136
2038	37	449	65	4	7	137
2039	37	451	65	4	7	137
2040	37	453	66	4	7	138
2041	37	455	66	4	7	138
2042	37	456	66	4	7	139
2043	38	458	66	4	8	139
2044	38	460	67	4	8	140
2045	38	461	67	4	8	140
	731	**8904**	**1290**	**79**	**146**	**2711**

	INTERVENTION SCENARIO	(kt CO2e)				
Year	Bus	Auto - Gas	Auto - Diesel	Auto - EV	MC	eBike
2026	38.7	405	61	12	10	100
2027	41.9	375	59	18	13	77
2028	44.7	344	56	22	15	59
2029	47.3	314	52	25	16	46
2030	49.6	286	48	27	17	36
2031	51.8	259	43	28	18	29
2032	53.7	235	38	29	18	23
2033	55.6	214	33	30	19	19
2034	57.2	196	27	30	19	15
2035	58.8	180	22	30	19	13
2036	60.3	166	16	30	19	11
2037	61.7	154	11	30	19	9
2038	63.0	143	8	30	19	8
2039	64.2	132	5	30	19	7
2040	65.4	122	3	29	19	6
2041	66.5	112	2	29	19	6
2042	67.6	104	1	29	19	5
2043	68.6	96	1	30	19	5
2044	69.6	88	0	30	19	4
2045	70.5	81	0	30	19	4
TOTALS	**1157**	**4006**	**487**	**546**	**358**	**482**

											POV LOS		Delta GHG
CHANGE IN EMISSIONS - Mode Shift, More Evs, Car-Pooling (kt CO2e)							**Improved km/l**	(kt CO2e)			Roads w or wo Bus Lanes		(kt CO2e)
Year	Bus (incl. LOS)	Auto - Gas	Auto - Diesel	Auto - EV	MC	eBike	Auto - Gas	Auto - Diesel	MC	Total	With	Without	Net Effect
2026	3.3	-24	-1	8	3	-31	-38	-6	0	-44	56	-151	-95
2027	6.3	-56	-3	14	6	-54	-40	-6	0	-47	55	-148	-93
2028	9.0	-88	-7	18	8	-72	-42	-7	0	-50	54	-144	-91
2029	11.5	-120	-11	21	9	-86	-45	-8	0	-52	53	-141	-88
2030	13.7	-150	-15	23	10	-96	-47	-8	0	-55	51	-138	-86
2031	15.7	-178	-20	24	11	-104	-48	-8	0	-57	50	-134	-84
2032	17.5	-204	-25	25	11	-111	-50	-8	0	-59	49	-131	-82
2033	19.2	-227	-31	26	12	-115	-52	-8	-1	-61	48	-127	-80
2034	20.7	-247	-37	26	12	-119	-55	-8	-1	-63	46	-124	-78
2035	22.2	-264	-43	26	12	-122	-58	-7	-1	-65	45	-122	-76
2036	23.5	-280	-48	26	12	-125	-61	-6	-1	-68	45	-119	-75
2037	24.7	-294	-53	26	12	-127	-64	-5	-1	-70	44	-117	-73
2038	25.9	-307	-58	26	12	-129	-66	-4	-1	-71	43	-115	-72
2039	27.0	-319	-61	26	12	-130	-68	-3	-1	-72	42	-114	-71
2040	28.1	-331	-63	25	12	-132	-69	-2	-1	-72	42	-113	-71
2041	29.0	-342	-64	25	12	-133	-69	-1	-1	-71	42	-111	-70
2042	29.9	-353	-65	25	12	-134	-69	-1	-1	-70	41	-111	-69
2043	30.8	-362	-66	25	12	-135	-67	0	-1	-69	41	-110	-69
2044	31.6	-372	-66	26	12	-136	-66	0	-1	-67	41	-109	-69
2045	32.4	-380	-67	26	11	-137	-64	0	-1	-65	41	-109	-68
TOTALS	**422**	**-4898**	**-803**	**468**	**212**	**-2229**	**-1138**	-96	-14	-1249	**929**	**-2489**	**-1561**

CJHANGE IN EMISSIONS - Summary of All Transport Intervent		(kt CO2e)						10% ICT Contribution		
									v	
Year	Bus	Auto - FF	Auto - EV	MC	eBike	TOTAL		Policy kt CO2e	ICT Project kt CO2e	Project + Policy
2025	0.00	0.00	0.00	0.00	0.00	0		0	0	0
2026	3.27	-138.80	8.15	3.06	-30.99	-155		155	16	171
2027	6.33	-142.61	14.03	5.49	-54.47	-171		171	17	188
2028	9.04	-146.86	18.23	7.29	-72.29	-185		185	18	203
2029	11.48	-151.34	21.16	8.62	-85.89	-196		196	20	216
2030	13.67	-155.97	23.15	9.59	-96.31	-206		206	21	226
2031	15.66	-160.80	24.44	10.28	-104.34	-215		215	21	236
2032	17.49	-165.92	25.23	10.76	-110.58	-223		223	22	245
2033	19.17	-171.48	25.66	11.08	-115.46	-231		231	23	254
2034	20.72	-177.52	25.85	11.27	-119.34	-239		239	24	263
2035	22.16	-183.90	25.89	11.36	-122.44	-247		247	25	272
2036	23.50	-190.14	25.84	11.37	-124.97	-254		254	25	280
2037	24.75	-195.64	25.76	11.32	-127.06	-261		261	26	287
2038	25.92	-199.87	25.66	11.24	-128.82	-266		266	27	292
2039	27.02	-202.61	25.57	11.12	-130.32	-269		269	27	296
2040	28.05	-203.98	25.50	10.99	-131.63	-271		271	27	298
2041	29.02	-204.23	25.46	10.84	-132.80	-272		272	27	299
2042	29.94	-203.67	25.45	10.69	-133.84	-271		271	27	299
2043	30.81	-202.52	25.47	10.52	-134.80	-271		271	27	298
2044	31.63	-200.98	25.52	10.35	-135.69	-269		269	27	296
2045	32.41	-199.17	25.60	10.17	-136.52	-268		268	27	294
TOTALS	**422**	**-3598**	**468**	**197**	**-2229**	**-4739**		**Total**	**474**	**5213**
									^	
	21.1	-179.9	23.4	9.9	-111.4	-237.0		As modeled in other ADB examples for China		

3. GHG Emission Reduction Induced by the PLB

14. The PBL contains ranges of policy actions that reinforce and complement the project intervention on one hand. Some of policy actions aim to encourage and attract private sector to do low-carbon energy and green building business.

15. **XSDP District Heating GHG Calculation**. As indicated in the Xiangtan low-carbon development challenges, Xiangtan has great potentials to utilize industrial waste heat for district heating system development, replacing household-level electric heating devices. Assessment results show that waste heat from the Xiangtan steel plant along has over 2,530-megawatt (MW) energy that can provide heat to 51 million square meter (m^2) of floor area with full coverage of the base and peak load demands. Yet, the financial viability for long distant heating pipes construction needs to be considered for assessing feasible district heating development and its impacts on GHG reduction. The XSDP District Heating GHG Calculation Model is separately developed, including key assumptions, detailed calculations and the summary of results. Here, overview of the model and key assumptions, and the results are presented.

Table 7: The XSDP District Heating GHG Calculation Model

Structure of the Model

Adoption of District Heating in Xiangtan and the Subsequent Reduction in Carbon Dioxide Emissions

WHAT DOES THIS DOCUMENT SHOW?

1 The urban districts of Xiangtan County, Yuhu and Yuetang, have the potential to be converted from a combination of electric home heating (~90% of homes) and natural gas home heating (a few percent of homes) to using a newly built district heating network
2 The district heating network would be powered by industrial surplus heat (ISH) from the Xiangtan Iron & Steel Co., Ltd. Of Hunan Valin
3 Annual and total emission reductions in (t CO2e) through the year 2045 based on supply from the district heating network services 30% of the homes in YT+YH and replaces their current heating supply. **5378 kt CO2e**
4 Version March 19, 2020 updates the previous calculations and assumes project start date of 2021 and completion by 2025.
5 Version April 2, 2020 incorporates calculation of commercial space, limited service area and optimizes determination of base/peak load decisions and emissions.

TABLE OF CONTENTS

ABBREVIATIONS

ADB	Asian Development Bank
CO2	Carbon dioxide
DH	District heating
EF	Emission factor
GHG	Greenhouse gas
ISH	Industrial surplus heat
XT	Xiangtan
XTMG	Xiangtan Municipal Government
XT PMO	Xiangtan Program Management Office
YT + YH	Yuhu and Yuetang Districts

Key Assumptions

KEY ASSUMPTIONS MADE

1 District Energy Zone is all of Yuetang and Yuhu (see maps below, Figure 1 outlines Yuhu and Figure 2 shows Yuetang (see faint purple line))

Figure 1

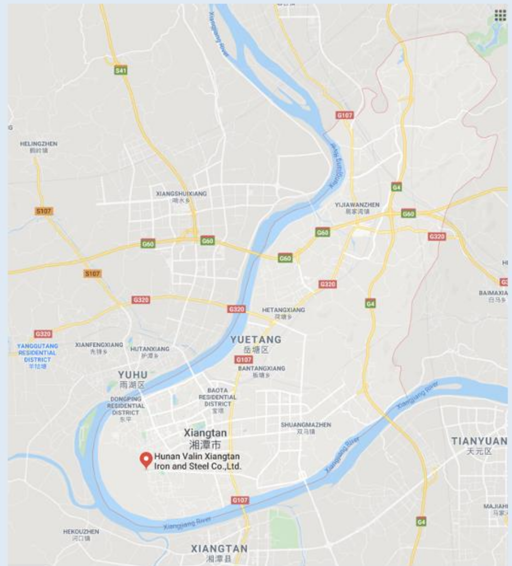


Figure 2

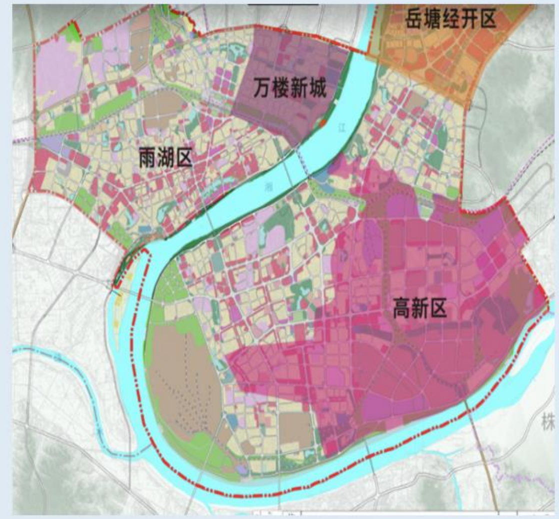


Figure 3

2 Due to existing district heating service in YH + YT, only a certain percentage of the total residential area can be serviced by DH from the steel mill (Figure 3)
3 No additional emissions are created from use of waste heat from steel mill for the district heating network except those created by the heat pump used to expand service area
4 The build out of the district heating modification in the steel plant is completed in one stage by the date specified in Exhibit A-2 through Exhibit A-5. Major components are the heat exchanger unit(s) and (in some scenarios) a heat pump.
5 Build out of the distribution system (pipeline transmission system and residential connections), is a separate effort from the plant modifications. The distribution system is extended to residential units according to the logistic
6 Distribution system costs would be borne by a private enterprise, which would execute a contract with the steel mill to use the available steam.
7 The pipeline transmission system would extend under the XT River to service homes in Yuhu. China has experience with such engineering from N. China.
8 Construction of the distribution network begins very quickly so that some homes can be serviced as early as 2026, when Scenario 1 (shown in Exhibit H) is due to be completed.

LOGISTIC GROWTH EQUATION

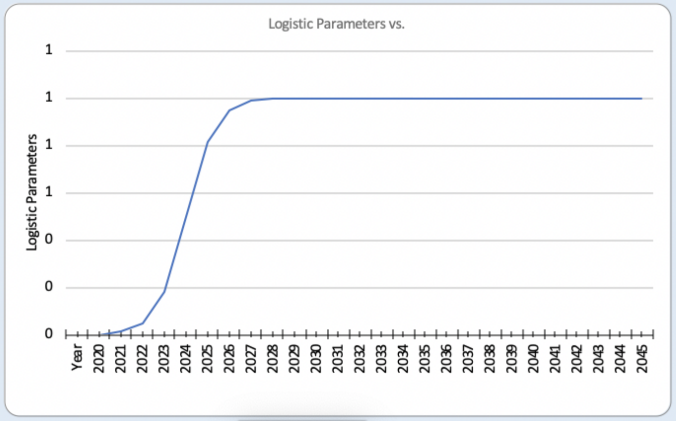


Chart Area

y = L / (1 + e^(k*(x0-x))

100% L = maximum value
150% k = logistic growth rate
2024 x0 = midpoint

Calculating the energy cost of a heat pump to expand DH service

Annual energy savings and emissions reductions for the full serviceable area under each of the four scenarios is calculated using Shaofang's formulas in Exhibit G. This accounts for everything (water pump costs, transmission losses, BAU electricity
Annual savings are converted to energy and emissions savings per square meter served in Exhibit G (cells U36-X36 and U37-X37, respectively). These per square meter values assume DH is expanded to units heated with electricity and natural
Savings per square meter are converted to savings per year based on expansion of the DH distribution system in Exhibit A-2 through Exhibit A-5.
In Exhibit A-3 and Exhibit A-5, the annual energy and emission cost of operating the heat pump assumes that the heat pump is only "turned on" when the residential area served exceeds the area that could be served without the heat pump, and

Foster, Love and Walker (2016) note that costs and COP of heat pumps exhibit a large range of values depending on the operating conditions and the temperature differential betweenheat source and heat sinks. The following table of cost and

Category	Unit	Low	Central	High
COP - central HP	COP @ 10C source, 70C sink	1.5	2.21	3.6
COP - water-to-water building integrated HP	COP @ 10C source, 45C sink	3.86	4.53	5.31

*(from increasing sink T by 5C) * (from decreasing sink T by 5C)

CONSIDERATIONS FOR CREATING A DH SYSTEM THAT CAN MEET PEAK-DEMAND

A DH system that can provide heat during peak load will produce excess heat during times when the load is not at peak demand.
On average, Xiangtan experiences average minimum temperatures below 15C for only six months of the year (Xiangtan City Assessment Report).
Peak demand would likely account for approximately half of the operational life of the DH system and it is necessary to conside excess steam during non-peak operations.

One option for the the use of excess steam is to extend the DH system to demand-flexible commercial uses in the urban core as a supplementary source of heating for them.

Another option is to arrange demand-flexible industrial use of the excess steam during non-peak demand.
A study from the Lawrence Berkeley National Lab found that steam systems are used in nearly every major industrial process (Einstein et al, 2001.)

Xiangtan could approach industrial use of excess steam from the DH system through implementing an eco-industrial initiative in Xiangtan's industrial area.
China's eco-industrial initiative aims to close industrial loops and turn wastes from one industry into inputs for another (Mathews and Tan, 2011).

ADDITIONAL CONSIDERATIONS

1 Imagine a future in which the steel plant is moved out of the city, perhaps to reduce health risks to the population.
In that case, consider transitioning to a 4th Generation DH system, with renewable energy as the primary source.

2 Consider transmission loss from transporting energy from steel plant to unit

3 It is not yet clear whether the calculations in Exhibit G assume that XT homes are primarily heated with electricity, not natural gas. So those calculations may be preliminary.

LIVING SPACE IN XIANGTAN

Multiple estimates of living space in Xiangtan are available.
Two factors enter into determining this value: the number of people in a household and the area available per person.
We have the following sources and estimates for number of people in a household:

1	2.85	XT GHG Inventory (2015), Chapter 2, City Profile lists 2.84 for Yuetang and 2.86 for Yuhu for an average value of 2.85..
2	3.52	ADB Survey of households in August 2019 asked (Question 2) "How many members in your household?" The average of 406 responses is 3.52
3	**3.10**	The Xiangtan 2018 Year book reports the value for urban as 3.10 for the year 2017.

We have the following sources and estimates for the area available per person (or per household):

1	112.88	ADB Survey of households Aug 2019 asked (Q 22) "What is the status of your home? ____m2" The average of 406 responses is 112.88
2	44.8	The Xiangtan 2018 Year book reports the value (per person) for urban as 44.8 for the year 2017.
2	**138.88**	Using that value and the value of household size from the same source, we get 138.88 as the area per household

2. How many members in your household?

option	Frequency	Percent (%)	
1	25	6.2	6.2
2	32	7.9	15.8
3	166	40.9	122.7
4	103	25.4	101.6
5	52	12.8	64
6	28	6.9	41.4
Total	**406**	**100**	**3.52**

22. What is the status of your home? ____m2___bedrooms___living/dining rooms

22.1 **Square meter**

Option(m^2)	Frequency	Percent (%)
Below 50	30	7.4
50-100	170	41.9
100-150	160	39.4
150-200	33	8.1
Over200	13	3.2
Total	406	100

Population growth rate	12500	XT Health and H Comm.
2019 base population	3,050,000	XT Health and H Comm.
Percent of building that are residential	64%	Yi, J et al (2018), pg 21
Percent of buildings that are commercial/public	36%	Yi, J et al (2018), pg 21
% YT + YH	30%	Source: Xiangtan City Assessment Report

WHAT DOES THIS SHEET SHOW?

1 Demographic data and DH distribution network expansion parameters
2 Expansion of the district heating network to residential units within the steel mill service area
3 **Updated April 2**: Optimized service area and total emissions reductions at base load service level and peak load service level.
4 **Updated April 2**: Difference in emissions reduction between optimized base load service scenario and optimized peak load service level
5 **Updated April 2**: Monetized estimate of emissions benefit based on user-specified carbon price

How is this demonstrated here?

1 Expansion of the DH network within the service area of the steel mill (percentage of total YT + YH area specified by user in cell M17) is modeled with user-defined logistic growth parameters. User-defined demographic data is used to estimate population and residential housing
2 Capacity of DH system is estimated in Exhibit G for four scenarios (base load service without heat pump, peak load service without heat pump, base load service with heat pump, and base load service without heat pump) and resulting electricity, natural gas, and CO2 emissions
3 The point at which emissions from additional heating demand met by households exceeds the emissions cost of running the heat pump (Stage 2) is calculated separately for the base load and peak load scenarios (note: it is assumed that the DH system can be designed to meet
4 **Updated April 2**: Heat pump cost assumes that the heat pump, once implemented, is running anytime the system is delivering energy (see Sensitivity Analysis-HP assumptions tab) and uses a COP value of 4.00 (see Sensitivity Analysis-COP tab)
3 **Updated April 2**: Expansion of the DH network assumes all units within a single residential building are connected simultaneously (see Sensitivity Analysis-Connection Level tab)

EXHIBIT A: ESTIMATED GHG EMISSIONS REDUCTIONS RESULTING FROM THE ADOPTION OF A DISTRICT HEATING SYSTEM IN YUHU AND YUETANG DISTRICTS IN XIANGTAN COUNTY

	Logistic Parameters, Stage 1	Total Population + growth (Xiantang County, 2019)	Proportion of people in XT County living in Yuetang and Yuhu	Average Population Per Household (Yuhu and Yuetang)	Average number of units per residential building**	Percentage of buildings classified as residential (%)****	Percentage of buildings classified as public/ commercial	Average floor area of a residential building (m^2)				Average floor area of a commercial/ public building (m^2)*	Per household Living Space in Xiangtan, 2019 (m2)	YH Residential Heating Demand in Service Area in Steel Mill	Total residential space heating area in YT + YH 2021 (m2)
L	100%														
k	150%	12,500													
Xo	2024	3,050,000	33.5%	3.10	120	64%	36%	16,666				4,500	138.88	30%	46,149,600

** data source: Gálvez (2015), pg 5

**** data source: Yi, J et al (2018), pg 21

*Initial parameter values estimated by Shaofang (2020)

Year	Percentage of total units within the steel plant service area connected to DH System	Population (Xiangtan County)	Population (YH + YT)	Number of Household Units (YH + YT)	Number of Residential Buildings (YT + YH)	Number of Commercial Buildings (YT + YH)	Number of residential units within the steel mill service area connected (total)	Number of residential buildings within the steel mill service area connected (total)	Number of commercial buildings within the steel mill service area (total)	Total commercial space within the steel mill service area (total)	Number of commercial buildings within the steel mill service area connected (total)	Total Commercial Space Heating Area within the steel mill service area Connected to DH System	Total Residential Space Heating Area in Yuhu and Yuetang (m^2)	Total residential space heating area within steel mill service area (m^2)	Total Residential Space Heating Area Connected to DH System (m^2)
2020	0%	3,062,500	1,025,938	330,948	2,758	1,551	0	0	465	2,094,278	0	0	45,962,000	13,788,600	0
2021	1%	3,075,000	1,030,125	332,298	2,769	1,558	1,095	9	467	2,102,826	5	23,104	46,149,600	13,844,880	149,990
2022	5%	3,087,500	1,034,313	333,649	2,780	1,564	4,747	40	469	2,111,374	22	100,134	46,337,200	13,901,160	666,624
2023	18%	3,100,000	1,038,500	335,000	2,792	1,570	18,334	153	471	2,119,922	86	386,728	46,524,800	13,957,440	2,549,837
2024	50%	3,112,500	1,042,688	336,351	2,803	1,577	50,453	420	473	2,128,470	236	1,064,235	46,712,400	14,013,720	6,999,552
2025	82%	3,125,000	1,046,875	337,702	2,814	1,583	82,829	690	475	2,137,018	388	1,747,171	46,900,000	14,070,000	11,499,264
2026	95%	3,137,500	1,051,063	339,052	2,825	1,589	96,892	807	477	2,145,566	454	2,043,811	47,087,600	14,126,280	13,449,139
2027	99%	3,150,000	1,055,250	340,403	2,837	1,596	100,999	842	479	2,154,114	473	2,130,447	47,275,200	14,182,560	14,032,435
2028	100%	3,162,500	1,059,438	341,754	2,848	1,602	102,273	852	481	2,162,662	479	2,157,315	47,462,800	14,238,840	14,199,091
2029	100%	3,175,000	1,063,625	343,105	2,859	1,608	102,875	857	482	2,171,210	482	2,170,010	47,650,400	14,295,120	14,282,419
2030	100%	3,187,500	1,067,813	344,456	2,870	1,615	103,324	861	484	2,179,758	484	2,179,489	47,838,000	14,351,400	14,349,082
2031	100%	3,200,000	1,072,000	345,806	2,882	1,621	103,739	864	486	2,188,306	486	2,188,246	48,025,600	14,407,680	14,399,078
2032	100%	3,212,500	1,076,188	347,157	2,893	1,627	104,147	868	488	2,196,855	488	2,196,841	48,213,200	14,463,960	14,465,741
2033	100%	3,225,000	1,080,375	348,508	2,904	1,634	104,552	871	490	2,205,403	490	2,205,400	48,400,800	14,520,240	14,515,738
2034	100%	3,237,500	1,084,563	349,859	2,915	1,640	104,958	875	492	2,213,951	492	2,213,950	48,588,400	14,576,520	14,582,400
2035	100%	3,250,000	1,088,750	351,210	2,927	1,646	105,363	878	494	2,222,499	494	2,222,499	48,776,000	14,632,800	14,632,397
2036	100%	3,262,500	1,092,938	352,560	2,938	1,653	105,768	881	496	2,231,047	496	2,231,047	48,963,600	14,689,080	14,682,394
2037	100%	3,275,000	1,097,125	353,911	2,949	1,659	106,173	885	498	2,239,595	498	2,239,595	49,151,200	14,745,360	14,749,056
2038	100%	3,287,500	1,101,313	355,262	2,961	1,665	106,579	888	500	2,248,143	500	2,248,143	49,338,800	14,801,640	14,799,053
2039	100%	3,300,000	1,105,500	356,613	2,972	1,672	106,984	892	501	2,256,691	501	2,256,691	49,526,400	14,857,920	14,865,715
2040	100%	3,312,500	1,109,688	357,964	2,983	1,678	107,389	895	503	2,265,239	503	2,265,239	49,714,000	14,914,200	14,915,712
2041	100%	3,325,000	1,113,875	359,315	2,994	1,684	107,794	898	505	2,273,787	505	2,273,787	49,901,600	14,970,480	14,965,709
2042	100%	3,337,500	1,118,063	360,665	3,006	1,691	108,200	902	507	2,282,335	507	2,282,335	50,089,200	15,026,760	15,032,371
2043	100%	3,350,000	1,122,250	362,016	3,017	1,697	108,605	905	509	2,290,883	509	2,290,883	50,276,800	15,083,040	15,082,368
2044	100%	3,362,500	1,126,438	363,367	3,028	1,703	109,010	908	511	2,299,431	511	2,299,431	50,464,400	15,139,320	15,132,365
2045	100%	3,375,000	1,130,625	364,718	3,039	1,710	109,415	912	513	2,307,979	513	2,307,979	50,652,000	15,195,600	15,199,027

Summary of GHG reduction Impacts from waste heat recovery for district heating

	Cumulative emission reduction at base load service (tCO2e)	Carbon price (2020USD /tCO2e)		Cumulative emission reduction at peak load service (tCO2e)	Carbon price (2020USD /tCO2e)
	4,428,599	$20.00		5,377,569	$20.00

Optimized base load serviceable area (m^2)	Emission reduction under optimized base load scenario (tCO2e)	Baseload emission reduction valuation (2020USD)	Optimized peak load serviceable area (m^2)	Emission reduction under optimized peak load scenario (tCO2e)	Peak load emission reduction valuation (2020USD)
0	-	$0.00	0	-	$0.00
0	-	$0.00	0	-	$0.00
27,912,000	9,384	$187,675.20	13,956,000	11,400	$227,998.74
27,912,000	35,949	$718,970.19	13,956,000	43,673	$873,456.01
27,912,000	98,722	$1,974,430.73	13,956,000	119,934	$2,398,685.10
27,912,000	162,167	$3,243,344.00	13,956,000	197,013	$3,940,252.17
27,912,000	189,671	$3,793,416.05	50,590,500	230,306	$4,606,114.34
27,912,000	197,867	$3,957,338.24	50,590,500	240,258	$4,805,150.10
27,912,000	200,240	$4,004,806.19	50,590,500	243,140	$4,862,791.37
27,912,000	201,416	$4,028,319.06	50,590,500	244,567	$4,891,341.70
27,912,000	202,346	$4,046,926.69	50,590,500	245,697	$4,913,934.19
27,912,000	203,069	$4,061,375.57	50,590,500	246,574	$4,931,481.48
27,912,000	203,986	$4,079,718.42	50,590,500	247,688	$4,953,750.26
27,912,000	204,705	$4,094,107.96	50,590,500	248,561	$4,971,224.99
27,912,000	205,622	$4,112,437.50	50,590,500	249,674	$4,993,477.51
27,912,000	206,341	$4,126,824.06	50,590,500	250,547	$5,010,948.60
27,912,000	207,061	$4,141,210.50	50,590,500	251,421	$5,028,419.54
27,912,000	207,977	$4,159,539.35	50,590,500	252,534	$5,050,671.22
27,912,000	208,696	$4,173,925.76	50,590,500	253,407	$5,068,142.12
27,912,000	209,613	$4,192,254.60	50,590,500	254,520	$5,090,393.79
27,912,000	210,332	$4,206,641.01	50,590,500	255,393	$5,107,864.68
27,912,000	211,051	$4,221,027.41	50,590,500	256,267	$5,125,335.58
27,912,000	211,968	$4,239,356.25	50,590,500	257,379	$5,147,587.25
27,912,000	212,687	$4,253,742.66	50,590,500	258,253	$5,165,058.15
27,912,000	213,406	$4,268,129.06	50,590,500	259,126	$5,182,529.04
27,912,000	214,323	$4,286,457.91	50,590,500	260,239	$5,204,780.71
	4,428,599	$88,571,974.37		5,377,569	$107,551,388.63

16. **XSDP Green Building GHG Calculation**. While the project demonstrates two green buildings: (i) new construction of IFC-EDGE certified hospital building and (ii) the government building retrofit, which will be used as the Asian Pacific Low-Carbon Training Center, policy actions under the PBL describe active promotion of green buildings construction and retrofit. The XSDP Green Buildings GHG Calculation Model is separately developed, including key assumptions, detailed calculations and the summary of results. Here, overview of the model and key assumptions, and the results are presented.

Table 8: The XSDP Green Buildings GHG Calculation Model

Structure of the Model

EXHIBIT A

Greenhouse Gas (GHG) Implications of TA-9437 PRC: Supporting Project Preparation-Hunan Xiangtan Low Carbon City Development

PURPOSE:

This spreadsheet accompanies a report to ADB summarizing projected impacts of Low Carbon (LC) City Development in the municipality (county) of Xiangtan, China.

The report summarizes each of the project-based and policy-based actions that will be undertaken as a result of the requested loan and indicates the ways in which those actions can be expected to influence the trajectory of GHG emissions over the lifetime of the loan (to 2045).

This spreadsheet calculates these effects for each of the project-based and policy-based actions related to buildings and determines the net impact of each by comparison to a baseline scenario.

The baseline scenario represents a 'Business as Usual" (BAU) case where the composition of the buildings and all incentives for retrofits or green building construction do not change from today (2019).

Under the BAU scenario, all factors that could be influenced by the project-based and policy-based loans are held constant at 2019 values. Only external factors such as population change in the BAU scenario.

The "ADB Scenario" represents the case where each project-based and policy-based action is fully implemented.

The ADB Scenario includes two project-based actions and five policy-based actions. These actions are:

Project-based modifications examined:

1. Green, low-carbon, resilient Xiangtan No. 1 Hospital. This includes IFC-EDGE certification, low-carbon equipment, hospital structural civil works, resilient rain garden/EbA facilities design.
2. Public building retrofitting for low-carbon demonstration. This includes IFC-EDGE certification, building renovation civil works, and procurement of low-carbon green products.

Policy-based modifications examined:

1. Enhancement of green building strategy through quantifiable (EDGE) green building certification
2. Action plan on passive buildings promotion
3. Implementation plan on enhancement of inclusive access to buildings
4. Implementation of a program to increase local capacity for EDGE certified green building
5. Design guidelines and standards on passive building and housing design

Policy-based actions are designed to occur in two tranches with different implementation dates and the effects of policies on human behavior are also phased over time as they reach greater numbers of the relevant population.

Questions:

Contact Rachael Jonassen (rachaelj@gwu.egu) for questions about the contant of this spreadsheet.

EXHIBIT B

Organization of This Spreadsheet

This spreadsheet is organized into 11 tabs as listed below. Each tab develops one aspect of the total picture of GHG emission reductions projected as a result of implementation of the ADB policy-based loans to

#	Tab Name	Contents and Purpose of Tab
1	Read Me	THIS TAB - Explains the purpose and organization of the spreadsheet.
2	Abbreviations	Key for abbreviations used throughout the spreadsheet
3	Assumptions	Describes key assumptions, equations and variables for the following estimates: Building Projections, New EDGE Certified and Passive Buildings, EDGE Certified and Passive
4	Intervention Effects	Lists, codes, and explains each intervention that results from the two loans.
5	Intervention Representation	Indicates which building improvements are impacted by each intervention in the policy-
6	EDGE Certified Hospital	Summary data and information on the project-based intervention for green, low-carbon, and resilient Xiangtan No. 1 Hospital. This includes IFC-EDGE certification, low-carbon
7	EDGE Certified Building Retrofit	Summary data and information on the project-based intervention for retrofitting public buildings for low-carbon demonstration. This includes IFC-EDGE certification, building
8	Building Projections	Shows the estimated total number of residential and commercial/ public buildings built from 1989-2045 in the Yuetang and Yuhu districts. This information is used in other
9	New EDGE Certified and Passive Buildings	Shows the estimated total emissions reduction through new EDGE Certified construction, assuming a total of 200,000 new buildings constructed during the loan period, and estimates future national growth of green building construction to place Xiangtan in context of national efforts.
10	EDGE Certified and Passive Building Retrofits	Shows the total CO_2 emissions anticipated from EDGE Certified building retrofits. The anticipated turnover rates of building stocks are based on population estimates and estimates of the adoption rate of retrofits is based on a logistic growth model.
11	Summary Impacts	Shows the estimated total emissions reduction anticipated from new EDGE Certified construction and EDGE Certified Building retrofits combined, 2020-2045. Total impacts include both project-based and policy-based components.
12	References	Lists all sources used in this analysis, including relevant project documents, documents provided by the XTMG, and professional literature.

Equations

Equations

Tab Name	Description of Equation	Definition of variables	Notes	
New Green Buildings	Adoption of green building guidelines by the construction industry	% of new buildings implementing green building standards in year *x*	The 13th 5 year plan requires new green building to be 50% of new construction by 2020, Additionally, there isn't expected to be a large ramp up of replacing buildings for some time, Chinese buildings generally have a useful life of 50 years and the vast majority of the city was built less than 40 years ago. From the intervention representation tab there are 9 Items in the polices that impact the adoption of green buildings one of which seems to slow down adoption while the other 8 promote it. Without information on how those policies will be shaped, a conservative estimate of a 3.5% growth rate beyond the incentives from the central governments goal (we conjecture this to be 3%) which will start at 50%, the goal for 2020. We will assign a maximum of 85% to	WRI estimates that China's national commitment for 50% new buildings certified green by 2020 will cause the country's green building sector to grow from 5 - 28% by 2030 https://www.wri.org/blog/2017/05/how-can-china-s-green-building-sector-grow-fivefold-2030-3-cities-show-us-way
Green Building Retrofits	Adoption of green building guidelines for retrofits of existing buildings by owners	% of existing building stock retrofitted to green building design standards in year *x*	Following from the central government support, but no specific goal we are adding a base 10% to the model and 3% to the growth factor to reflect the impact of the push for new green building on refits.	
New Passive Buildings	Adoption of passive building guidelines by the construction industry	% of new buildings implementing passive building standards in year *x*	The Central government hasn't placed a specific goal on passive buildings so the central government influence is not built into the model as it is in the Green building model.	
Passive Building Retrofits	Adoption of passive building guidelines for retrofits of existing buildings by owners	% of existing building stock retrofitted to passive building design standards in year *x*	The Central government hasn't placed a specific goal on passive buildings so the central government influence is not built into the model as it is in the Green building model.	
BEMS	Adoption of BEMS by building owners/managers	% of building owners (municipal and large commercial) utilizing BEMS in their buildings		
Energy Audits	(Growth in) Building energy audits of large public and commercial buildings per year	# of audits per year	This is a niche profession, and can be more significantly impacted by focused training. Given that it seems that there will be strong growth in the fields with concerted government effort. With out data for the quantity of buildings in the county boundaries. We will assume for the time being a maximum number of buildings to be audited in a given year at 5000.	
Accessibility	Improved accessibility	% Change in enrergyi use for accessibility	Use of automatic door openers and additng elevators for access are examples of increased energy use.	

Assumptions

- Building quantity assumes no future change in ratios of residential to commercial/public buildings, numbers of residents per household, number of household units per residential building, and a constant population growth rate into the future.
- Starting the adoption of green buildings near 0% of evidence of new construction on lists (only one building found) within the databases of existing certifications (LEED, EDGE, 3 Star)

• The national goal of 50% of new buildings certified as "green" in 2020 is presented for context and it is not plausible that the goal will be exceeded. We assume there will be a new national goal in the upcoming 14th 5-year plan the projection here is just following a logistic growth model that includes data on known points 2% in 2011 and 50% in 2020.
• Energy and emissions savings only account for electricity consumption and do not account for energy or emissions associated with household natural gas or other fuel use.
• We assume a constant emissions factor for electricity and for materials
• There is a huge range of housing types. Starting in 2000, 80% of all residential buildings fell under this description. 4-8 units per floor in various heights up to 34 floors. The are usually built in communities with a mix a mid and hi rise buildings, so assuming an equal mix of buildings (mad and Hi rise) we will assume 6 units per floor and as mid-rise have between 4 and 12 stories we will assume an average floor count to be 20 (to account for a few low rise building a well). Which means an average of 120 units per building
• Average annual energy savings for commercial and public buildings assume energy savings per unit floor area for both new and retrofitted public and commercial buildings will mirror annual energy savings calculated for the project-based component, retrofitting 200 buildings for low-carbon demonstration (see EDGE Certified Building Retrofit tab). Average annual energy savings for residential buildings assume energy savings per unit floor area for both new and retrofitted residential buildings will mirror annual energy savings calculated for the project-based component, EDGE Certified Hospital dormitory building (see EDGE Certified Hospital tab).
• Average reductions in embodied emissions of building materials for new commercial/ public buildings are assumed to mirror average percentage reductions in embodied emissions achieved or anticipated for EDGE Certified warehouse, office, retail, and education buildings in China in the EDGE project database as of April 2020. Average reductions in embodied emissions per unit floor area are calculated as this percentage multiplied by the average embodied energy of public and commercial buildings reported by Azari and Abbasabadi (2018). Average reductions in embodied emissions of building materials for new residential buildings are assumed to mirror average percentage reductions in embodied emissions achieved or anticipated for EDGE Certified homes and hotels in China in the EDGE project database as of April 2020. Average reductions in embodied emissions per unit floor area are calculated as this percentage multiplied by the average embodied energy of residential buildings reported by Azari and Abbasabadi (2018). Average reductions in embodied emissions of building materials for retrofitted commercial/ public buildings are assumed to mirror embodied emissions reductions per unit floor area calculated for the project-based component, retrofitting 200 buildings for low-carbon demonstration (see EDGE Certified Building Retrofit tab). Average reductions in embodied emissions of building materials for retrofitted residential buildings are assumed to mirror embodied emissions reductions per unit floor area calculated for the project-based component, EDGE Certified Hospital dormitory building (see EDGE Certified Hospital tab). The emissions factor for electricity in China is applied to these embodied energy reduction estimates, but this emissions factor can be updated based on emissions factors for building materials used in the EDGE software.
• Each year after 2019, a certain number of existing buildings reach the end of their expected lifetime and become prime candidates for retrofit. The number of eligible buildings is based on historic building rates 1989-2019 and average expected lifetime of buildings (Building Projections tab). Of these buildings, a certain percentage each year will be retrofitted based on a logistic growth model for adoption of green building practices and standards. All other existing buildings are assumed to undergo any modifications or upgrades necessary to continue operating at the same energy efficiency level.
• Buildings built before 1989 are not considered for BEMS retrofit, due to uncertainties in the quality of older building stock and any impediments to sustainability upgrades that may exist. See Paradis (2016) for examples and further discussion of potential barriers to sustainability upgrades in older buildings.
• Total annual emissions reductions (Summary tab) are calculated as the sum of emissions reductions achieved by the project-based components and policy-based components

Summary of PBL Green Buildings GHG Calculation Results

	Policy-Based Component								
Year	National Goal for Fraction of New Buildings that are "Green"	Total Number of EDGE Certified and Passive Buildings (New Construction) (YT + YH)	Embodied CO2 Savings in construction materials for all new buildings (tCO2e)	Annual Emissions Savings from new EDGE Certified and Passive Buildings, Residential (tCO2e/year)	Total Annual Emissions Savings from construction and operation of new EDGE Certified and Passive Buildings, All Buildings (tCO2e/year)	Annual Number of EDGE Certified and Passive Building Retrofit Projects	Embodied CO2 Savings in construction materials for all building retrofits (tCO2e)	Total Annual Emissions Savings from All Retrofitted EDGE Certified and Passive Buildings (tCO2e/year)	Total Annual Emissions Savings from Policy-Based Component (tCO2e/year)
2020	50%	0	0	0	0	9	23,438	32,060	32,060
2021	61%	0	0	0	0	10	23,857	41,225	41,225
2022	72%	0	0	0	0	10	23,857	49,970	49,970
2023	80%	0	0	0	0	11	27,554	63,788	63,788
2024	86%	1	4,803	881	5,727.44	12	31,250	78,982	84,709
2025	91%	2	4,803	1,761	6,652.10	12	31,250	90,479	97,131
2026	94%	3	4,803	2,642	7,576.76	13	31,669	102,517	110,094
2027	96%	4	4,803	3,522	8,501.42	14	35,366	119,209	127,711
2028	98%	5	4,803	4,403	9,426.07	15	39,063	137,277	146,703
2029	98%	7	6,351	6,164	12,823.67	16	39,482	152,190	165,014
2030	99%	9	6,351	7,925	14,672.98	0	0	112,708	127,381
2031	99%	11	6,351	9,687	16,522.30	0	0	112,708	129,230
2032	100%	14	11,154	12,328	24,099.06	0	0	112,708	136,807
2033	100%	17	11,154	14,970	26,873.03	0	0	112,708	139,581
2034	100%	21	15,957	18,493	35,374.45	0	0	112,708	148,082
2035	100%	26	17,505	22,896	41,546.02	0	0	112,708	154,254
2036	100%	32	22,308	28,179	51,896.75	0	0	112,708	164,605
2037	100%	39	23,856	34,344	59,917.64	0	0	112,708	172,626
2038	100%	47	28,659	41,388	72,117.68	0	0	112,708	184,826
2039	100%	56	33,462	49,314	85,242.39	0	0	112,708	197,950
2040	100%	65	33,462	57,239	93,564.32	11	27,554	150,383	243,947
2041	100%	75	35,010	66,045	104,359.18	11	27,554	160,504	264,863
2042	100%	86	39,813	75,732	119,333.20	12	31,250	175,698	295,031
2043	100%	98	44,615	86,299	135,231.89	12	31,250	187,195	322,426
2044	100%	111	46,164	97,747	148,800.72	12	31,250	198,692	347,492
2045	100%	125	50,966	110,076	166,548.72	13	31,669	210,730	377,279
Totals:		**125**	**457,150**	**752,037**	**1,246,808**	**193**	**487,313**	**3,004,692**	**4,324,785**

17. **XSDP Industrial Energy Efficiency GHG Calculation**. As indicated in the Xiangtan GHG profile, emissions from industries occupied more than 50% of total Xiangtan emissions. While the project introduce a community-based multi-energy and utility management system at Jiuhua Industrial Zone to demonstrate the impacts of the CMEUMS in energy and resource efficiency improvement, the policy actions under the PBL introduces the autonomy of industrial zones in developing effective measures such as CMEUMS. This policy action specifies a mandatory connection of companies within the zones to the available CMEUMS. The PBL impacts from CMEUMS deployment is assessed and presented below. The assumption, which is a 20% of energy efficiency improvement, is used and the gradual increase in the CMEMMS coverage applied as below. Table below shows the summary of calculation.

Table 9: CMEUMS impacts on the Industrial GHG Emissions (unit: $kTCO_2e$)

BAU and Goal - IND				ADB Pro		ADB Pro	CMEUMS at	CMEUS expansion	CMEUMS at two other
Year	Worst Case	Best Case	Pct. Goal	Contr.	ADB Traj.	Contr.	Jiuhua (Pj)	at Jiuhua (PBL)	industrial zones (PBL)
2020	20,594	20,594	0%	-	20,594	-	0	0	0
2021	20,802	20,648	0%	-	20,802	-	0	0	0
2022	20,988	20,676	2%	336	20,652	336	0	0	0
2023	21,151	20,677	2%	508	20,643	508	0	0	0
2024	21,292	20,654	3%	681	20,610	681	0	0	0
2025	21,410	20,607	4%	856	20,554	856	0	0	0
2026	21,507	20,536	5%	1,032	20,475	1,032	238	0	0
2027	21,583	20,443	6%	1,209	20,374	1,209	238	0	0
2028	21,639	20,328	6%	1,385	20,254	1,385	238	0	98
2029	21,675	20,193	7%	1,561	20,114	1,561	238	0	269
2030	21,693	20,039	8%	1,735	19,958	1,735	238	0	443
2031	21,695	19,866	9%	1,909	19,786	1,909	238	22	596
2032	21,680	19,677	10%	2,081	19,599	2,081	238	47	747
2033	21,651	19,471	10%	2,252	19,399	2,252	238	74	897
2034	21,608	19,249	11%	2,420	19,188	2,420	238	103	1044
2035	21,554	19,014	12%	2,587	18,968	2,587	238	135	1188
2036	21,489	18,766	13%	2,751	18,739	2,751	238	170	1327
2037	21,416	18,506	14%	2,913	18,503	2,913	238	208	1463
2038	21,334	18,235	14%	3,072	18,262	3,072	238	250	1593
2039	21,246	17,954	15%	3,229	18,017	3,229	238	296	1718
2040	21,153	17,665	16%	3,385	17,769	3,385	238	346	1836
2041	21,057	17,368	17%	3,538	17,520	3,538	238	401	1947
2042	20,959	17,064	18%	3,689	17,270	3,689	238	461	2052
2043	20,859	16,754	18%	3,838	17,021	3,838	238	526	2148
2044	20,760	16,439	19%	3,986	16,774	3,986	238	598	2236
2045	20,662	16,121	20%	4,132	16,530	4,132	238	677	2314
	449,160	413,799		35,901	413,259	35,901	3,573	1,650	13,218
								PBL TOTAL	14,869

4. Total GHG Emission Reduction Induced by the Program

18. **XSDP GHG Calculation Summary.** The combined project and program induced GHG reduction impacts across sectoral inventions are compiled in a separate excel file. The structure, demographic input data, BAU (worst-case) and the best-case scenarios, compiled GHG reduction impacts from various interventions and policy actions, comparison of project, PBL, and the program impacts against the BAU and the best-case scenarios are presented here. The excel summary file is also provided.

Table 10: The XSDP GHG Emissions Scenarios and the Program Impacts Summary

Structure of the Summary Excel File

EXHIBIT A

Greenhouse Gas (GHG) Implications of TA-9437 PRC: Supporting Project Preparation-Hunan Xiangtan Low Carbon City Development

PURPOSE:

This spreadsheet accompanies a report to ADB summarizing projected impacts of Low Carbon (LC) City Development in the municipality (county) of Xiangtan, China.

The report summarizes project-based and policy-based actions that will be undertaken as a result of the requested loan and indicates the ways in which those actions can be expected to influence the trajectory of GHG emissions over the lifetime of the loan (to 2045). This spreadsheet reports these effects for each of the project-based and policy-based actions and presents the net impact of each by comparison to a baseline scenario.

The baseline scenario represents a 'Business as Usual" (BAU) case where the operation of the economy and all incentives for use of the various available means of reducing GHG emissions do not change from today (2020).

Under the BAU scenario, all factors that could be influenced by the project-based and policy-based loans are held constant at 2020 values. Only the external factor of population changes in the BAU scenario.

The "ADB Scenario" represents the case where each project-based and policy-based action is implemented over time.

The ADB Scenario examines the effect of project-based actions and policy-based actions. These actions are:

Project-based and Policy-based modifications examined:

1. Change in transportation systems and policies.
2. Change in industrial activities to reduce use of energy per unit of industrial production.
3. Changes in energy use in residential and commercial buildings through district heating using available waste heat.
4. Changes in energy use in residential and commercial buildings through monitoring and optimization systems.
5. Changes in energy use in residential and commercial buildings using green and passive building intervantions.

Policy-based actions are designed to occur in two tranches with different implementation dates and the effects of policies on human behavior are also phased over time as they reach greater numbers of the relevant population.

Scenarios for BAU and Goal come from two Integrated Assessment Models (IAMs) as reported by the IPCC in the Fifth Assessment.

These IAMs provide a global representation of emission trajectories that are used by the international climate chanage community.

At the global scale, these are called Representative Concentration Pathways (RCPs).

IAMs create projections of global emissions by socio-economic modeling using a grid-cell descritization of the earth.

The solutions used in this spreadsheet are derived from the IAM grid cell containing Xiangtan.

The scenario used here as BAU is the RCP 8.5 scenario developed by the MESSAGE modeling system.

The scenario used here as Goal is the RCP 2.6 scenario developed by the IMAGE modeling system.

These are the two most extreme RCP scenarios. Thus, movement from one to the other represents the most ambitious goal.

Questions about this spreadsheet and the underlying calculations should be directed to: Rachael Jonassen at rachaelj@gwu.edu

EXHIBIT B

Organization of This Spreadsheet

This spreadsheet is organized into 28 tabs as listed below. Each tab develops one aspect of the total picture of GHG emission reductions projected as a result of implimentation of the ADB project-based and policy-based loans to the Xiangtan municipal government beginning in 2020. The section below explains the purpose of each tab.

#	Tab Name	Contents and Purpose of Tab
1	Read Me	THIS TAB - Explains the purpose and organization of the spreadsheet.
2	Dashboard	Summary of results of the key calculations. Presents results for base year, 2028, loan end year (2045), and overall total.
3	Abbreviations	Provides definitions for every abbreviation used in this sheet.
4	Demographics	Develops, documents, and presents a scenario of population change during the loan lifetime.
5	Plot - Demographics Trends	Displays the assumed changes in Xiangtan poplation throughout the loan period.
6	Reported Emissions	High-level summary of the three GHG emission reports available for Xiangtan (2005, 2015, 2016).
7	Plot - Reported Emissions	Graphical representation of GHG emissions for the three reporting years.
8	IAM Drivers	Presents output of Integrated Assessment Models for RCP2.6 and RCP8.5 for the grid cell containing Xiangtan, scaled to reported XT GHG emissions.
9	Full Summary Data	Summarizes all ADB project and policy based interventions for transport, energy, and industrial emissions as well as IAM output for the same years.
10	Plot - Total Reduction vs IAM	Displays Best Case and Worst Case IAM results and the results of ADB project and policy intervantions on GHG emissions separately for TRA, ENE, IND.
11	Plot - All Reduction vs IAM	Displays Best Case and Worst Case IAM results and the results of ADB project and policy intervantions on GHG emissions summed acrosss TRA, ENE, IND.
12	Transport Data	Summarizes the high-level results of all calculations of emissions impacts of ADB interventions for the transport sector
13	Assumptions - Transport	Lists in one place the various assumptions that are needed to complete the calculations on each tab. Assumptions are repeated on relevant tabs
14	Interventions - TRA	Lists, codes, and explains each intervention that results from the two loans.
15	Plot - TRA ADB Mit. vs. Goal	Displays Best Case and Worst Case IAM results and the results of ADB policy intervantions on GHG emissions separately for TRA.
16	Plot - TRA Mit. Elements	Displays the results of ADB policy intervantions on GHG emissions for each ADB transport intervention.
17	IND Data	Summarizes the high-level impacts of ADB interventions for the industrial sector
18	Plot - IND (ADB Mit. vs. Goal	Displays Best Case and Worst Case IAM results and the results of ADB policy intervantions on GHG emissions separately for IND.
19	Interventions - LC Behavior	Lists, codes, and explains each intervention that results from the two loans.
20	Interventions - Bldgs	Lists, codes, and explains each intervention that results from the two loans.
21	ENE Summary	Summarizes the high-level impacts of ADB interventions for the energy sector
22	Plot - ENE ADB Mit. vs. Goal	Displays Best Case and Worst Case IAM results and the results of ADB policy intervantions on GHG emissions separately for ENE.
23	District Heating Data	Summarizes the high-level results of all calculations of emissions impacts of ADB interventions related to district heating.
24	Green Buildings Data	Summarizes the high-level results of all calculations of emissions impacts of ADB interventions related to green buildings.
25	BEMS Data	Summarizes the high-level results of all calculations of emissions impacts of ADB interventions related to building energy management systems.
26	Assumptions - District Heating	Lists in one place the various assumptions that are needed to complete the calculations related to district heating.
27	Example Growth Equations	Provides an overview of the four types of equations used to represent changes induced by the project-based and policy-based loans.
28	References	Lists all sources used in this analysis, including relevant project documents, documents provided by the XTMG, and professional literature.

Demographic Data Projections

Year	Population XT County	Population YT+YH	Number of Workers
2015	3,000,000	903,246	560,916
2016	3,012,500	907,009	563,253
2017	3,025,000	910,773	565,590
2018	3,037,500	914,536	567,927
2019	3,050,000	918,300	570,264
2020	3,062,500	922,064	572,601
2021	3,075,000	925,827	574,939
2022	3,087,500	929,591	577,276
2023	3,100,000	933,354	579,613
2024	3,112,500	937,118	581,950
2025	3,125,000	940,881	584,287
2026	3,137,500	944,645	586,624
2027	3,150,000	948,408	588,961
2028	3,162,500	952,172	591,299
2029	3,175,000	955,935	593,636
2030	3,187,500	959,699	595,973
2031	3,200,000	963,462	598,310
2032	3,212,500	967,226	600,647
2033	3,225,000	970,989	602,984
2034	3,237,500	974,753	605,322
2035	3,250,000	978,516	607,659
2036	3,262,500	982,280	609,996
2037	3,275,000	986,043	612,333
2038	3,287,500	989,807	614,670
2039	3,300,000	993,570	617,007
2040	3,312,500	997,334	619,344
2041	3,325,000	1,001,098	621,682
2042	3,337,500	1,004,861	624,019
2043	3,350,000	1,008,625	626,356
2044	3,362,500	1,012,388	628,693
2045	3,375,000	1,016,152	631,030

Population Data from Xiangtan City GHG Assessment Report

Districts & Counties	Population	Population per Household	Urbanization Rate
Yuetang District	350,500	2.84	100%
Yuhu District	520,500	2.86	100%
Shaoshan City	118,200	3.30	32.74%
Xiangxiang City	924,100	2.96	28.91%
Xiangtan County	979,600	3.23	17.20%
Amount/Average	2,892,900	3.02	46.51%

Total YT+YH	871,000
% YT + YH	30%

If two people per household work, the fraction that work is:

62% This is consistent with cell Q15.

62.1% Working Age Population (age 15-64)

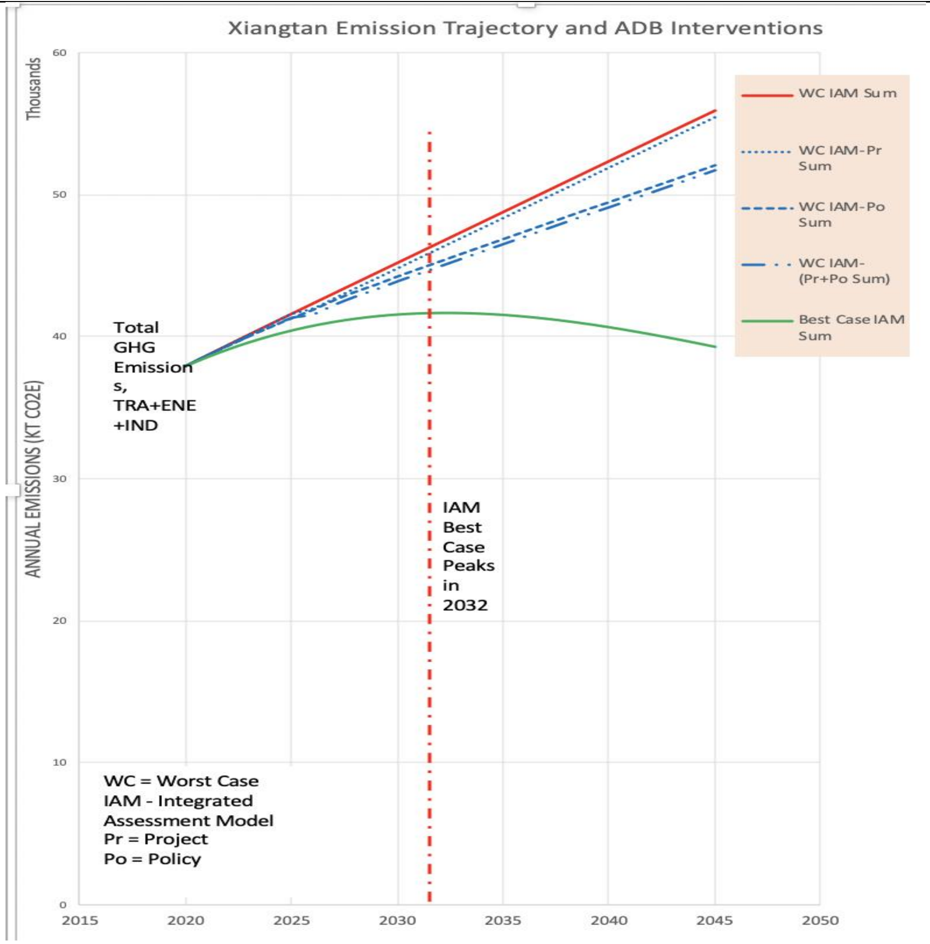
Compiled GHG Emissions Reductions from Each Components under the Project and the PBL

Annual Emissions Reductions (ktCO2e)

	Project-Based Components						Policy-Based Components										
	ENE				IND	TRA	ENE				IND		TRA				
	Output 1			Output 2	Output 2	Output 1	Output 3				Output 3		Output 3				
Year	EDGE-certified Xiangtan First Traditional Chinese Medicine Hospital	EDGE-certified Building Retrofit (Asia Pacific Low-Carbon Development Training Center)	20 Low-carbon communities improvement	BEMS- 200 public buildings	CEMS at Jiuhua Industrial Zone	ITS reprogramming for mobility transformation	Green building Retrofits	New Green Buildings	Waste heat recovery for district heating	Building energy management system to other commercial buildings	Increase in CEMS in Jiuhua industrial zone (assumption: 914,954 ton/a GHG reduction in 2045, based on the long-term growth plan)	CEMS at other industrial zones	Bus	Auto - Fossil Fuel	Auto - EV	MC	eBike
2020	0	0	0	0	0	0.00	0.00	0.00	0.00	0	0	0	0	0.00	0	0	0
2021	0	0	0	0	0	0.00	0.00	0.00	0.00	0	0	0	0	0.00	0	0	0
2022	0	0	0	0	0	0.00	49.85	0.00	11.40	0.46	0	0	0	0.00	0	0	0
2023	0	0	0	0	0	0.00	63.65	0.00	43.67	0.66	0	0	0	0.00	0	0	0
2024	0	0	0	0	0	0.00	78.83	5.73	119.93	0.87	0	0	0	0.00	0	0	0
2025	0	0	0	0	0	0.00	90.31	6.65	197.01	1.09	0	0	0	0.00	0	0	0
2026	3.24	0.57	9.58	7.86	238.19	15.53	102.31	7.58	230.31	1.32	0	0.00	-3.27	138.80	-8.15	-3.06	30.99
2027	3.24	0.57	9.58	7.86	238.19	17.12	118.97	8.50	240.26	1.6	0	0.00	-6.33	142.61	-14.03	-5.49	54.47
2028	3.24	0.57	9.58	7.86	238.19	18.46	137.02	9.43	243.14	1.89	0	97.62	-9.04	146.86	-18.23	-7.29	72.29
2029	3.24	0.57	9.58	7.86	238.19	19.60	151.89	12.82	244.57	2.23	0	269.43	-11.48	151.34	-21.16	-8.62	85.89
2030	3.24	0.57	9.58	7.86	238.19	20.59	112.50	14.67	245.70	2.35	0	443.14	-13.67	155.97	-23.15	-9.59	96.31
2031	3.24	0.57	9.58	7.86	238.19	21.47	112.50	16.52	246.57	2.51	22.36	595.85	-15.66	160.80	-24.44	-10.28	104.34
2032	3.24	0.57	9.58	7.86	238.19	22.30	112.50	24.10	247.69	2.71	46.82	747.32	-17.49	165.92	-25.23	-10.76	110.58
2033	3.24	0.57	9.58	7.86	238.19	23.10	112.50	26.87	248.56	2.94	73.57	896.88	-19.17	171.48	-25.66	-11.08	115.46
2034	3.24	0.57	9.58	7.86	238.19	23.90	112.50	35.37	249.67	3.22	102.83	1043.85	-20.72	177.52	-25.85	-11.27	119.34
2035	3.24	0.57	9.58	7.86	238.19	24.69	112.50	41.55	250.55	3.53	134.84	1187.57	-22.16	183.90	-25.89	-11.36	122.44
2036	3.24	0.57	9.58	7.86	238.19	25.44	112.50	51.90	251.42	3.92	169.86	1327.42	-23.5	190.14	-25.84	-11.37	124.97
2037	3.24	0.57	9.58	7.86	238.19	26.09	112.50	59.92	252.53	4.36	208.16	1462.78	-24.75	195.64	-25.76	-11.32	127.06
2038	3.24	0.57	9.58	7.86	238.19	26.59	112.50	72.12	253.41	4.87	250.06	1593.03	-25.92	199.87	-25.66	-11.24	128.82
2039	3.24	0.57	9.58	7.86	238.19	26.92	112.50	85.24	254.52	5.46	295.89	1717.61	-27.02	202.61	-25.57	-11.12	130.32
2040	3.24	0.57	9.58	7.86	238.19	27.11	150.09	93.56	255.39	6.24	346.03	1835.93	-28.05	203.98	-25.5	-10.99	131.63
2041	3.24	0.57	9.58	7.86	238.19	27.17	160.20	104.36	256.27	7.11	400.87	1947.44	-29.02	204.23	-25.46	-10.84	132.8
2042	3.24	0.57	9.58	7.86	238.19	27.14	175.37	119.33	257.38	8.02	460.86	2051.59	-29.94	203.67	-25.45	-10.69	133.84
2043	3.24	0.57	9.58	7.86	238.19	27.05	186.85	135.23	258.25	9.01	526.47	2147.85	-30.81	202.52	-25.47	-10.52	134.8
2044	3.24	0.57	9.58	7.86	238.19	26.92	198.33	148.80	259.13	10.05	598.25	2235.65	-31.63	200.98	-25.52	-10.35	135.69
2045	3.24	0.57	9.58	7.86	238.19	26.75	210.33	166.55	260.24	11.13	676.77	2314.46	-32.41	199.17	-25.6	-10.17	136.52
	64.8	**11.4**	**191.6**	**157.2**	**4763.8**	**473.9**	**2999.0**	**1246.8**	**5377.6**	**97.6**	**4313.6**	**23915.4**	**-422.0**	**3598.0**	**-467.6**	**-197.4**	**2228.6**

Analysis Summary: The Xiangtan BAU, Best-Case, Project Impacts, Policy Impacts, and the Program Impacts Scenarios

Year	WC IAM Sum	WC IAM-Pr Sum	WC IAM-Po Sum	WC IAM-(Pr+Po Sum)	Best Case IAM Sum
2020	37,937.05	37,937.05	37,937.05	37,937.05	37,937.05
2021	38,687.07	38,687.07	38,687.07	38,687.07	38,547.35
2022	39,428.00	39,428.00	39,366.29	39,366.29	39,100.12
2023	40,161.70	40,161.70	40,053.71	40,053.71	39,595.44
2024	40,889.73	40,889.73	40,684.37	40,684.37	40,033.76
2025	41,613.44	41,613.44	41,318.38	41,318.38	40,415.85
2026	42,333.97	41,996.88	41,899.28	41,562.18	40,742.82
2027	43,052.25	42,707.19	42,580.18	42,235.12	41,016.05
2028	43,769.02	43,417.29	43,169.18	42,817.45	41,237.17
2029	44,484.89	44,127.47	43,686.37	43,328.95	41,408.03
2030	45,200.30	44,837.93	44,258.42	43,896.04	41,530.66
2031	45,915.57	45,548.75	44,790.40	44,423.58	41,607.28
2032	46,630.91	46,259.96	45,315.96	44,945.01	41,640.22
2033	47,346.43	46,971.47	45,846.49	45,471.53	41,631.95
2034	48,062.15	47,683.20	46,371.29	45,992.34	41,585.01
2035	48,778.02	48,395.11	46,899.32	46,516.42	41,502.02
2036	49,493.94	49,107.30	47,424.28	47,037.64	41,385.65
2037	50,209.76	49,819.88	47,952.98	47,563.11	41,238.57
2038	50,925.28	50,532.91	48,479.77	48,087.39	41,063.48
2039	51,640.30	51,246.25	49,007.54	48,613.49	40,863.05
2040	52,354.58	51,959.60	49,504.69	49,109.71	40,639.94
2041	53,067.88	52,672.58	50,028.61	49,633.31	40,396.74
2042	53,779.96	53,384.81	50,544.55	50,149.40	40,136.00
2043	54,490.60	54,095.90	51,064.63	50,669.93	39,860.17
2044	55,199.58	54,805.56	51,587.87	51,193.85	39,571.62
2045	55,906.70	55,513.50	52,106.72	51,713.53	39,272.63



D. Abate Gaps and the Program Contribution

19. Impacts of project and policy actions on GHG emission reductions are analyzed against the BAU and the best-case scenario. The best-case scenario developed using the IMAGE-IAM, then, rescaling and harmonizing it for Xiangtan. As seen in the analysis, even with the best-case scenarios, the Xiangtan's carbon peaking could be possible in 2032. Note that the best-case scenario assumes that Xiangtan implements all possible low-carbon measures, policies and technologies in all sectors.

20. The abatement gap between the BAU and the best-case is also estimated. The cumulative abatement gap between 2020-2045 (the program lifetime) is calculated as 167 $MtCO_2e$. An annual abatement gap would range between 140 ktCO2e and 16.6 $MtCO_2e$. In terms of the XSDP's impacts, the results show that the project component alone could result in only a 5% contribution to the necessary abatement, ranging from 2% to 21% annual contribution to necessary yearly abatement. The combined project and PBL, on the other hand, could lead to a 29% contribution to the cumulative abatement need, ranging from 19% to 49% annual contribution to necessary abatement per year.

Table 11: Abatement Gaps and the XSDP Contributions (unit: $ktCO_2e$)

Abatement Gap	% Project Contribution	% Policy Contribution	% Total Contribution
0	-	-	-
140	0%	0%	0%
328	0%	19%	19%
566	0%	19%	19%
856	0%	24%	24%
1,198	0%	25%	25%
1,591	21%	27%	49%
2,036	17%	23%	40%
2,532	14%	24%	38%
3,077	12%	26%	38%
3,670	10%	26%	36%
4,308	9%	26%	35%
4,991	7%	26%	34%
5,714	7%	26%	33%
6,477	6%	26%	32%
7,276	5%	26%	31%
8,108	5%	26%	30%
8,971	4%	25%	30%
9,862	4%	25%	29%
10,777	4%	24%	28%
11,715	3%	24%	28%
12,671	3%	24%	27%
13,644	3%	24%	27%
14,630	3%	23%	26%
15,628	3%	23%	26%
16,634	2%	23%	25%
167,400	**5%**	**24%**	**29%**