Appendix for the manuscript:
Pathways to achieve the dual targets of carbon neutrality and air quality in Southern China

The appendix includes the following contents:

1. The integrated modeling framework

1.1 Model framework

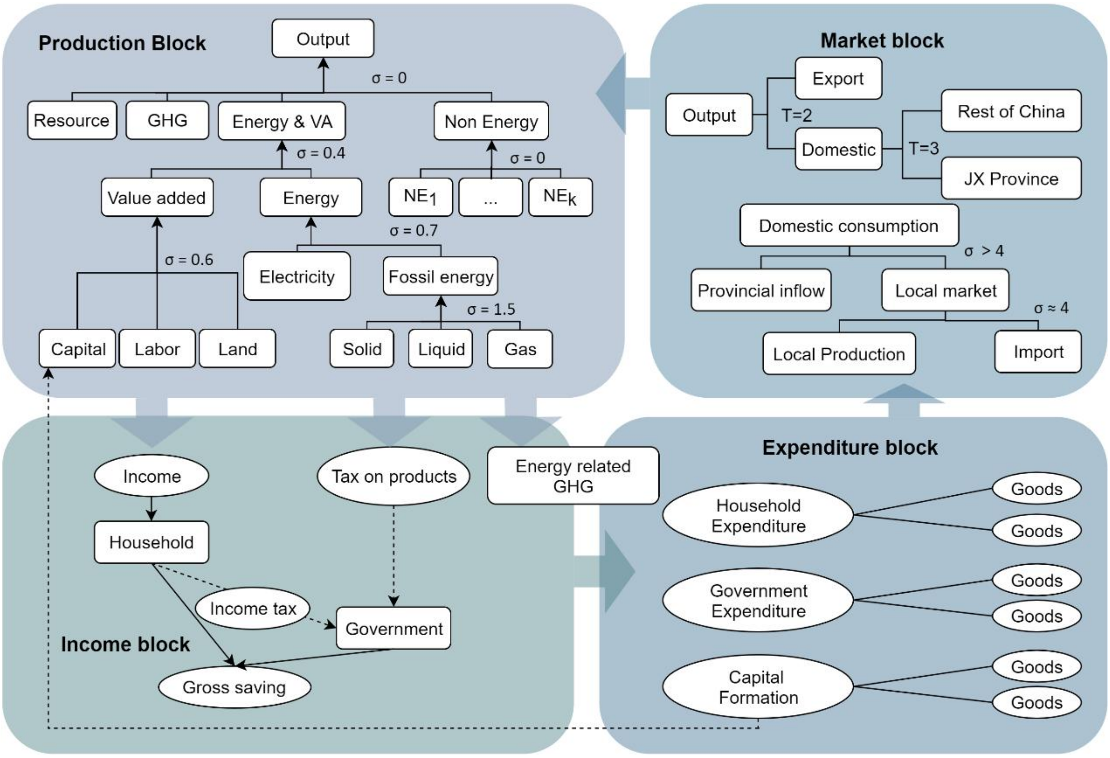

Figure S1. The IMED|CGE framework

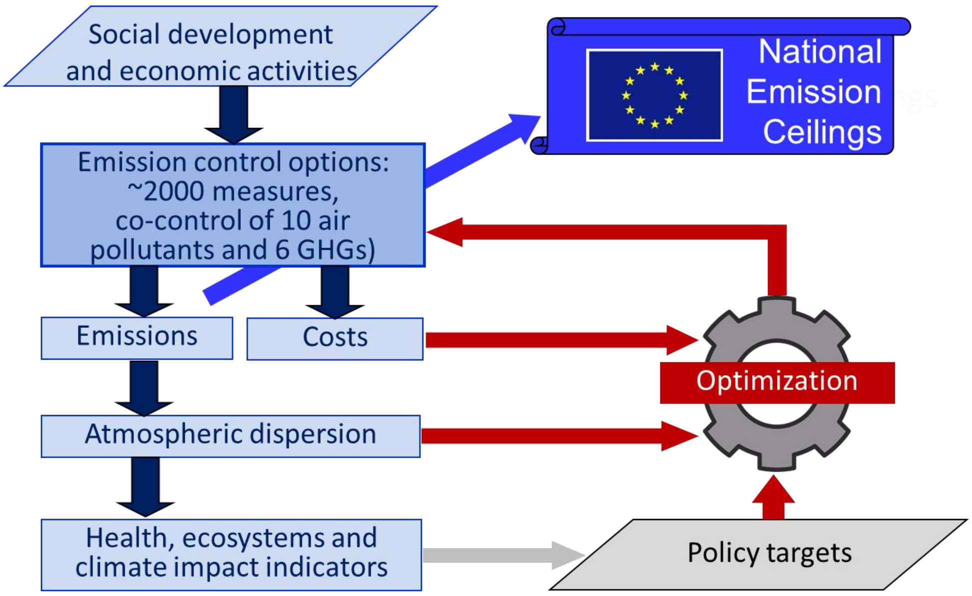

Figure S2. GAINS model and its optimization module

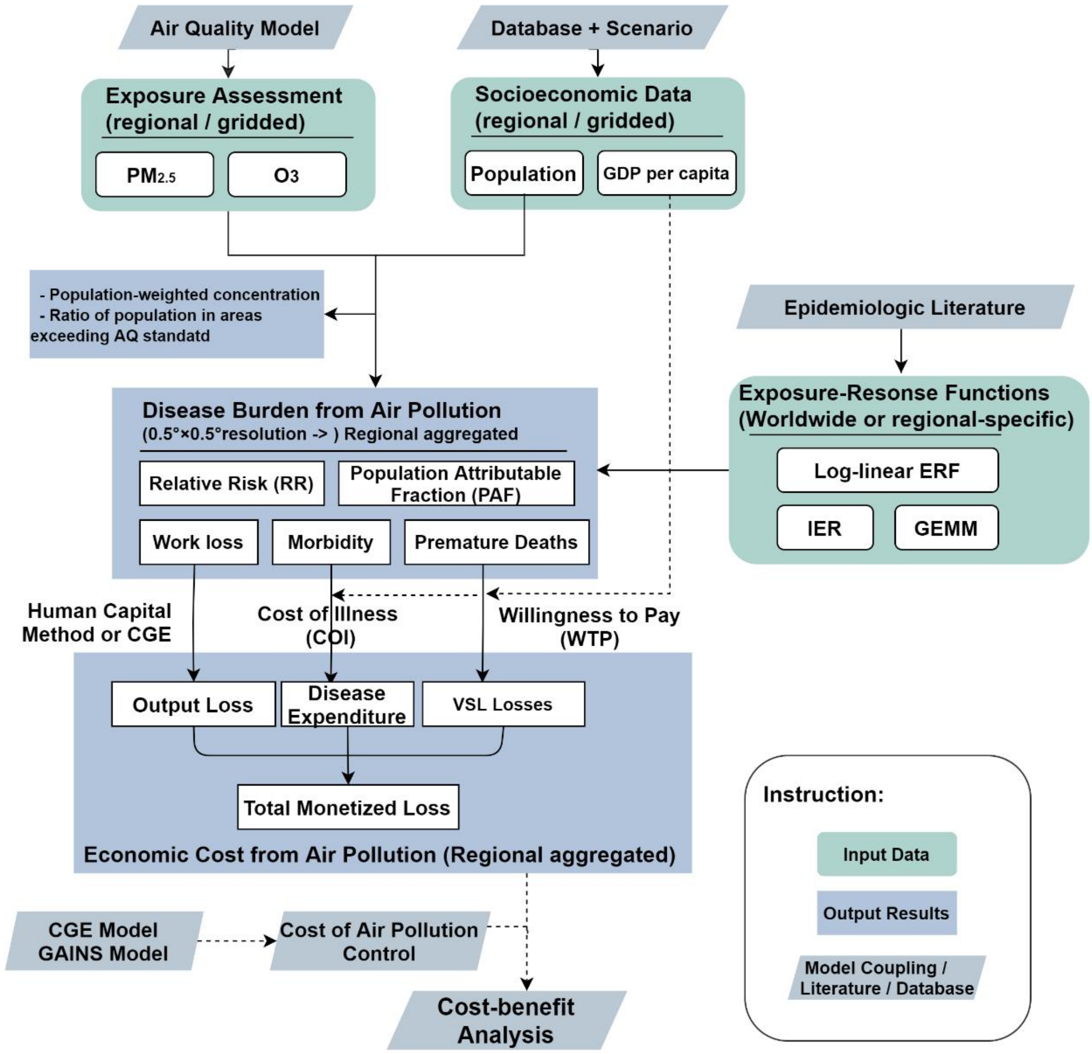

Figure S3. The IMED|HEL framework

Table S1. Sectoral classification and aggregation rules in IMED|CGE

Number	Abbr.	Sector	Aggregated sector
1	AGR	Agriculture	Agriculture
2	COA	Coal mining	EneSuply
3	COL	Crude oil	EneSuply
4	Gas	Natural gas	EneSuply
5	Cok	Coke	EneSuply
6	MMN	Other mining	EneSuply
7	FOD	Food production	Manufact
8	TEX	Textile	Textile
9	PAP	Paper	Manufact
10	PET	Petrol oil	EneSuply
11	CHM	Chemicals	Chemicals
12	NMT	Nonmetal	Nonmetal
13	MET	Metal smelting	MetalSmlt
14	MPD	Metal product	Manufact

15	MCN	Machinery	Manufact
16	TPQ	Transportation Equipment	Manufact
17	ELP	Electrical product	Electronics
18	OMN	Other Manufacture	Manufact
19	ELE	Power generation	Power generation
20	GDT	Manufactured gas	EneSuply
21	WTR	Water supply	Service
22	CNS	Construction	Construction
23	TSP	Transport	Transport
24	SVC	Service	Service

Table S2. Adjustment of direct consumption factor

Output / Input	Power generation	End-use sectors					
	ELE	PAP	CHM	MCN	SVC	household	…
Gas	-	-	-	-	-	0	
COA	-	-	-	-	-	-	
COK	-	-	-	-	-	-	
PET	-	-	-	-	-	-	
ELE	-	+	+	-	+	+	
GDT	-	-	-	-	-	-	
capital	+	+	+	+	+	0	

Note: "+" represents an increase in input parameter values, "-" represents a decrease.

In the BaU scenario, we adjust the direct input coefficients in the Input-Output table for the power generation and end-use sectors. Specifically, we reduce the share of fossil energy inputs and increase the share of electricity and capital inputs to mimic the autonomous energy efficiency improvement process and accelerated electrification trends through enhanced capital input. Consequently, the baseline results could match the NDC targets of peaking carbon emissions around 2030. In the climate policy scenarios, we assume a faster rate of electricity substitution and a higher level of technological progress (i.e., increased capital inputs), given that there may be spontaneous shifts in the energy mix when the whole societies face low carbon constraints by the middle of this century.

1.2 Rules for soft linking between models

Table S3. Sector mapping rules between IMED|CGE and GAINS

Sectors in IMED|CGE	Sector abbreviations in IMED|CGE	Sectors in GAINS
Agriculture	AGR	DOM_OTH
		TRA_OT_AGR
Coal mining	COA	TRA_OT_LB
Coke	COK	CON_COMB
Crude oil	COL	TRA_OT_LB
Natural gas	GAS	TRA_OT_LB
	Gas works	TRA_OT_LB
Mining	MMN	TRA_OT_LB
Food production	FOD	IN_BO_OTH
		IN_BO_OTH_L
		IN_B_OTH_S
Textile industry	TEX1	IN_OC_OTH
Manufacture of leather, fur, feather and related products	TEX2	IN_OC_OTH
Paper and printing	PAP	IN_OC_PAP
		IN_BO_PAP
Chemicals	CHM	IN_OC_CHEM
		IN_BO_CHEM
Nonmetal	NMT	IN_OC_NMNI
Metal smelting	MET	IN_OC_ISTE
Metal product	MPD	IN_OC_NFME
Machinery	MCN	IN_OC_OTH
Transportation Equipment	TPQ	IN_OC_OTH
Electrical product	ELP	IN_OC_OTH
Other Manufacture	OMN	IN_OC_OTH
Manufactured gas	GDT	IN_OC_ISTE
Construction	CNS	TRA_OT_CNS
Water supply	WTR	DOM_COM
Service	SVC	DOM_COM
Power generation	ELE	PP_EX_OTH
		PP_EX_S
		PP_EX_L
		PP_NEW
		PP_NEW_L
		PP_MOD
		PP_MOD_CCS
		PP_IGCC
		PP_IGCC_CCS
		PP_ENG

Transport	TSP	TRA_RD_HDB
		TRA_RD_HDT
		TRA_RD_LD2
		TRA_RD_LD4C
		TRA_RD_LD4T
		TRA_RD_M4
		TRA_OTS_L
		TRA_OT_AIR
		TRA_OT_RAI
		TRA_OT_INW
		TRA_OT_LD2
household	resident	DOM_URB
		DOM_RES
		DOM_LIGHT

2. Emission calculation principle of the GAINS model

2.1 Air quality impacts of $PM_{2.5}$

The Unified European Monitoring and Evaluation Program (EMEP) Eulerian model was used with the GAINS model to link marginal changes in emission precursors of various sources to changes in impact-relevant air quality[1, 2]. For the GAINS model, it has been found that the almost linear response in annual mean $PM_{2.5}$ toward changes in annual emissions of $PM_{2.5}$ and SO_2, as well as changes in seasonal NO_x and NH_3 emissions, can be represented as follows.

$$PM_j = k_{0,j} + \sum_i pm_i PP_{ij}^A + \sum_i s_i S_{ij}^A + C_0\left(\sum_i a_i A_{ij}^S + \sum_i n_i N_{ij}^S\right) + (1 - C_0)$$
$$\times \ \min\left\{\max\left\{0, k_{1,j} + c_1 \sum_i a_i A_{ij}^W - c_2 \sum_i s_i S_{ij}^W\right\}, k_{2,j} + c_3 \sum_i n_i\, N_{ij}^W\right\} \quad (1)$$

where:

PM_j = annual mean concentration of $PM_{2.5}$ at receptor point j.

s_i, n_i, a_i, and pm_i = emissions of SO_2, NO_x, NH_3, and primary $PM_{2.5}$ in country i.

$Á^x_{ij}$, N^x_{ij}, S^x_{ij}, and PP^x_{ij} = matrices with coefficients for reduced (A) and oxidized (N) nitrogen, sulfur (S), and primary $PM_{2.5}$ (PP) for season X, where X = W (*winter*), S (*summer*), and A (*annual*)

c_0, c_1, c_2, and c_3 = model parameters derived by regression analyses.

$k_{0,j}$, $k_{1,j}$, and $k_{2,j}$ = constants to take background concentrations into account.

Furthermore, a simpler formulation has been used in the GAINS IV Asia model to perform reasonably well when only marginal changes in emissions around a reference point are considered (Equation 2).

$$PM_j = \sum_i pm_i PP_{ij}^A + \sum_i s_i S_{ij}^A + \sum_i a_i A_{ij}^A + \sum_i n_i N_{ij}^A + k_{0,j} \qquad (2)$$

2.2 Emission control measures and their costs

The GAINS model estimated emission control costs from the perspective of a social planner, with a focus on resource costs of emission controls to societies. Emission control costs are influenced by the allocation of emission control measures, which were calculated based on the assumption that, in a free market for emission control technologies, the same technology will be available to all regions at the same cost. Technological progress was also assumed with respect to the performance and cost data based on literature estimates. For each of the 3,500 emission control options, this model estimated the costs of local application considering annualized investments (I^{an}) as well as fixed (OM^{fix}) and variable (OM^{var}) operating costs, and how they depend upon technology m, country i, and activity type k. Unit costs of abatement (ca), related to one unit of activity (A), were calculated as:

$$ca_{i,k,m} = \frac{I^{an}_{i,k,m} + OM^{fix}_{i,k,m}}{A_{i,k}} + OM^{var}_{i,k,m} \quad (3)$$

The cost per unit of abated emission (cn) of a pollutant p was calculated as:

$$cn_{i,k,m,p} = \frac{ca_{i,k,m}}{ef_{i,k,0,p} - ef_{i,k,m,p}} \quad (4)$$

where $ef_{i,k,0,p}$ is the uncontrolled emission factor in the absence of any emission control measure (m = 0).

2.3 Linear optimization of air pollution control strategies in GAINS

The GAINS optimization, which is solved by GAMS, could minimize the costs of air pollution control strategies, such that environmental effects (e.g., $PM_{2.5}$ concentration) do not exceed pre-defined limits. There are additional technology constraints, e.g., maximum application rates and vintage structure.

$$\text{Objective:} \quad \text{minimize (Costs)} \quad (5)$$
$$\text{s.t.} \quad \text{EnvironmentalEffect} < \text{Limit}$$

To ensure that the model has a solution, the target for pollutant concentrations in POLICY scenarios must be greater than or equal to the concentrations under the MTFR and less than or equal to above the CLE. Therefore, in practice, the model needs to be run once to calculate the $PM_{2.5}$ concentrations for the MTFR and CLE scenarios before determining the targets for the POLICY scenario.

3. Scenario setting and key data

3.1 Detailed scenario setting

The formulas for the three carbon neutrality scenarios set according to different principles are shown below.

(1) Net Zero

The carbon emissions of each province in the 2060 carbon emission scenario are allocated according to the principle that each province's per capita carbon emissions will be the same by 2060. Provinces with larger populations have higher carbon credits to meet the carbon emission needs of development brought about by larger populations. Specifically, when China's total carbon emissions under the 2060 carbon neutral target are 3 billion tonnes, the per capita carbon emissions are 2.3 tonnes.

$$C_{i,2060} = C_{\text{china},2060} \times \frac{POP_{i,2060}}{\sum_{i=1}^{30} POP_{i,2060}} \tag{6}$$

Where, $C_{i,2060}$ is the carbon emissions allocated by province i in 2060;

$C_{china,2060}$ is the total carbon emissions of China under the 2060 carbon neutrality target;

$POP_{i,2060}$ is the predicted population of province i in 2060.

(2) Net Zero_CO2Intensty

This scenario indicates that each province's carbon emissions per unit of GDP will reach approximately the same level by 2060, meaning that regions with higher GDP are allowed to emit higher levels of carbon dioxide. Here, this study multiplies the GDP of each province in the BaU scenario simulated by the IMED|CGE model with the average carbon intensity of China under the carbon neutrality target to obtain the carbon emissions of each province in 2060. Then, interpolation is used to obtain the annual carbon emissions, which are used as carbon emission constraints for each province in this scenario. Specifically, when China's total carbon emissions under the 2060 carbon neutrality target are 3 billion tons, the carbon intensity is 50 tons per million US dollars. As a reference, China's carbon intensity in 2017 was approximately 746 tons/million US dollars.

$$C_{i,2060} = CI_{China,\ 2060} \times GDP_{i,2060} \tag{7}$$

Where, $CI_{China,2060}$ is the national average carbon emission intensity under the 2060 carbon neutrality target;

$C_{i,2060}$ is the carbon emissions allocated by province i in 2060;

$GDP_{i,2060}$ is the GDP of the province i under the BaU scenario in the IMED|CGE model for 2060.

(3) Net Zero_SameRate

Based on China's carbon-neutral emission pathway, a year-by-year rate of carbon emission decline is calculated, with each province maintaining an equal rate of carbon emission decline. Specifically, for China's total carbon emissions of 3 billion tonnes under the 2060 carbon neutrality target, carbon emissions are maintained at an annual rate of decline of 1%-7% after 2025, and the rate of decline gradually increases.

$$V_{i,t} = V_{China,t} \tag{8}$$

Where, $V_{i,t}$ is the rate of decline in carbon emissions for province i in year t;

$V_{China,t}$ is the rate of decline in China's carbon emissions in year t.

3.2 Key data

The social accounting matrix used to establish the IMED|CGE model is constructed based on the input-output tables of Guangdong, Guangxi, Hunan, Hainan, Jiangxi, and Fujian provinces in 2017[3]. The future population for each province is estimated from the results of provincial projections under the SSP2 pathway in the literature[4], which is exogenous parameters given to the CGE model.

Table S4. Total population in southern China from 2017 to 2050

Unit: million person

Region \ Year	2017	2020	2025	2030	2035	2040	2045	2050
Fujian	39.1	39.9	40.7	40.8	40.6	40.3	39.8	38.9
Jiangxi	46.2	47.2	48.4	49.2	49.7	49.9	49.8	49.4
Hunan	68.6	69.8	70.9	71.3	71.4	71.2	70.8	69.9
Guangdong	111.7	115.6	119.4	120.9	121.1	120.8	120.2	119.0
Guangxi	48.9	50.3	52.4	54.0	55.3	56.5	57.5	58.4
Hainan	9.3	9.6	10.1	10.5	10.8	11.0	11.3	11.5

This study adjusts total factor productivity (TFP) and capital growth rate to achieve the expected GDP growth rate in each province. Regarding the potential for future economic growth in China, the weakening of traditional economic growth drivers will lead to a continued slowdown in China's economic growth rate[5]. The potential economic growth rate will decrease to below 5% between 2020 and 2030, and below 4% between 2030 and 2040, as shown in Table S5. The GDP growth rate for 31 provinces is set as follows. First, we divide China into six regions: North China, Central China, South China, Northeast China, East China, Southwest China, and Northwest China, and calculate the proportion of each region's GDP from 1978 to 2019. Second, the Autoregressive Integrated Moving Average model is used to forecast the GDP share of each region from 2021-2060. Taking into account the relevant policies for the revitalization of Northeast China, appropriate adjustments have been made to the trend of the low GDP ratio in the Northeast, while maintaining the sum of the regional ratios to be 1. Third, based on the calculated GDP ratio of each region and the overall growth rate of China, which is referred to from the research of the Economic Research Centre of the State Council, the GDP growth rate of the six regions can be obtained (Table S6).

Table S5. Expected GDP growth rate and capital growth rate in China

	2020~2025	2025~2030	2030~2035	2035~2040	2040~2045	2045~2050	2050~2055	2055~2060
GDP growth rate	6.5	4.5	4.0	3.4	3.4	2.9	2.8	2.5
Capital growth rate	7.2	5.7	4.5	3.5	3.2	2.9	2.6	2.3

Table S6. Expected GDP growth rate in southern China from 2021-2050

Region	2021-2025	2026-2030	2031-2035	2036-2040	2041-2045	2046-2050
Jiangxi	7.4%	5.8%	5.2%	4.5%	4.2%	3.9%
Fujian	6.7%	5.1%	4.5%	3.8%	3.5%	3.2%
Hunan	6.4%	4.8%	4.1%	3.5%	3.1%	2.8%
Guangdong	5.6%	4.1%	3.4%	2.7%	2.2%	1.8%
Guangxi	7.1%	5.6%	4.8%	4.1%	3.7%	3.3%
Hainan	10.6%	9.1%	8.3%	7.5%	7.1%	6.7%

Table S7. Total factor productivity (TFP) in southern China

Region \ Year	2017	2025	2030	2035	2040	2045	2050
Fujian	0.030	0.033	0.028	0.024	0.021	0.020	0.019
Jiangxi	0.035	0.030	0.028	0.024	0.023	0.022	0.021
Hunan	0.039	0.034	0.028	0.022	0.021	0.020	0.020
Guangdong	0.042	0.026	0.025	0.024	0.023	0.023	0.021
Guangxi	0.039	0.034	0.027	0.022	0.019	0.017	0.015
Hainan	0.035	0.053	0.043	0.039	0.035	0.033	0.030

Carbon neutrality refers to the emission of carbon dioxide equal to the absorption of carbon dioxide, which can be divided into two categories: ecological carbon sequestration and carbon capture and storage. The former includes ecosystem carbon sequestration, while the latter includes traditional capture and storage technologies (CCUS), bioenergy and carbon capture and storage (BECCS), and direct air capture and carbon storage (DACCS)[6]. Studies have shown that China's average ecosystem carbon sink from 2006 to 2100 was approximately 0.43-1.34 billion tons of CO_2[6, 7], and the potential for CCUS in 2060 was 1.22-2.92 billion tons[8]. In summary, this study sets CO_2 emissions at 3 billion tones in 2060 under the carbon neutral scenario.

4. Result

4.1 Economic impact of climate policy

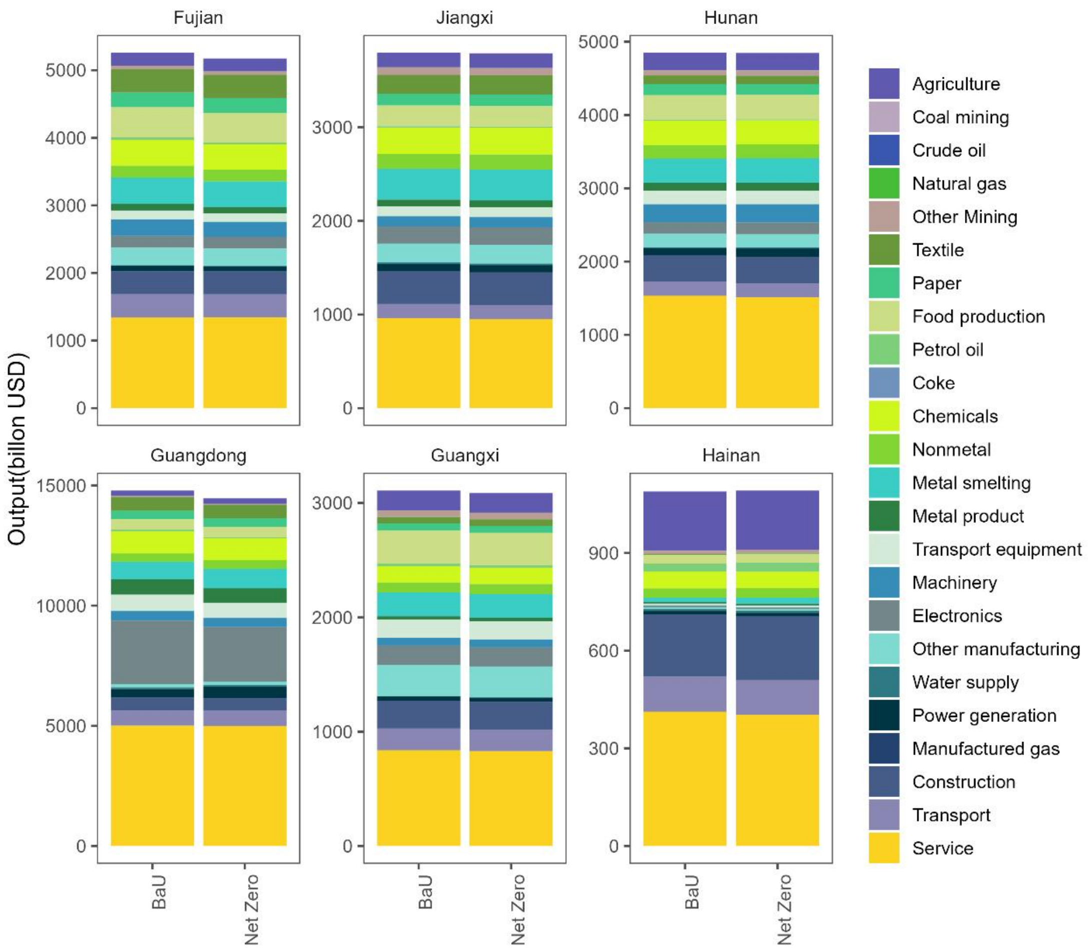

Figure S4. Sectoral output in 2050

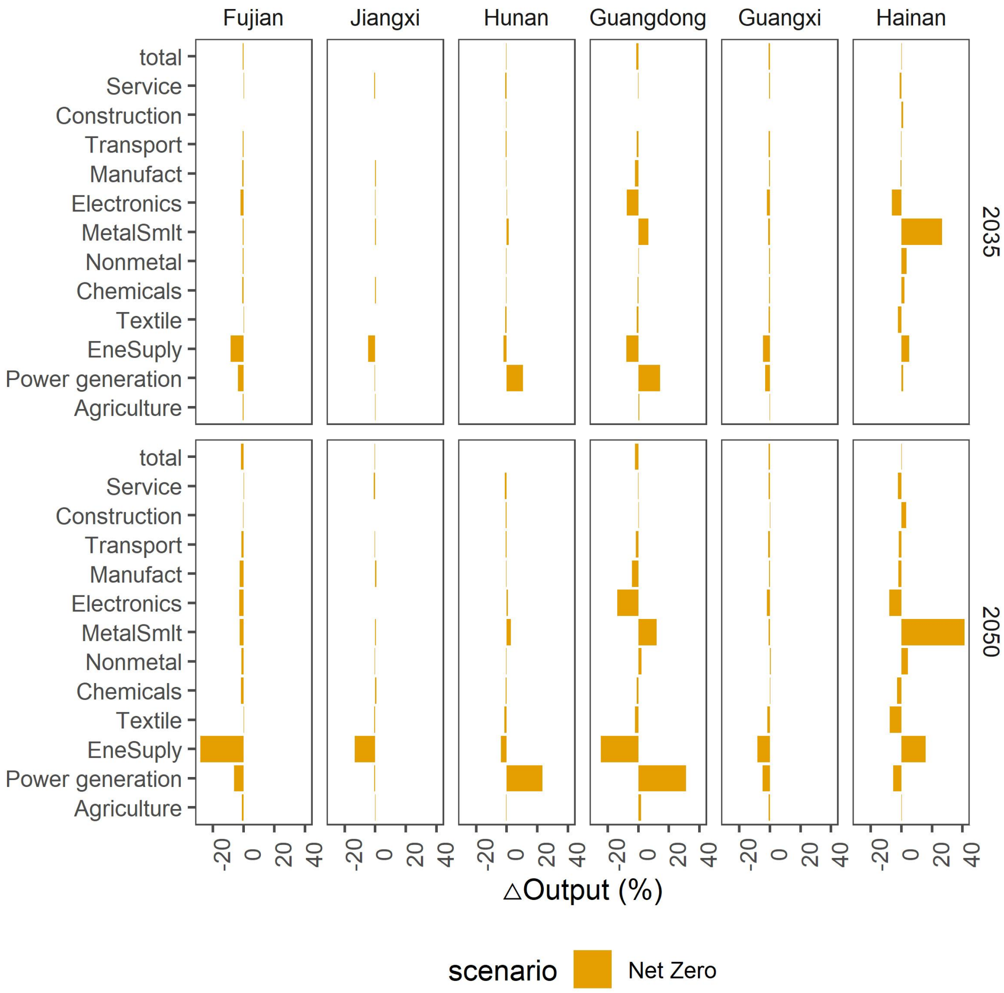

Figure S5. Relative output changes in Net zero scenario compared to BaU in 2035 and 2050

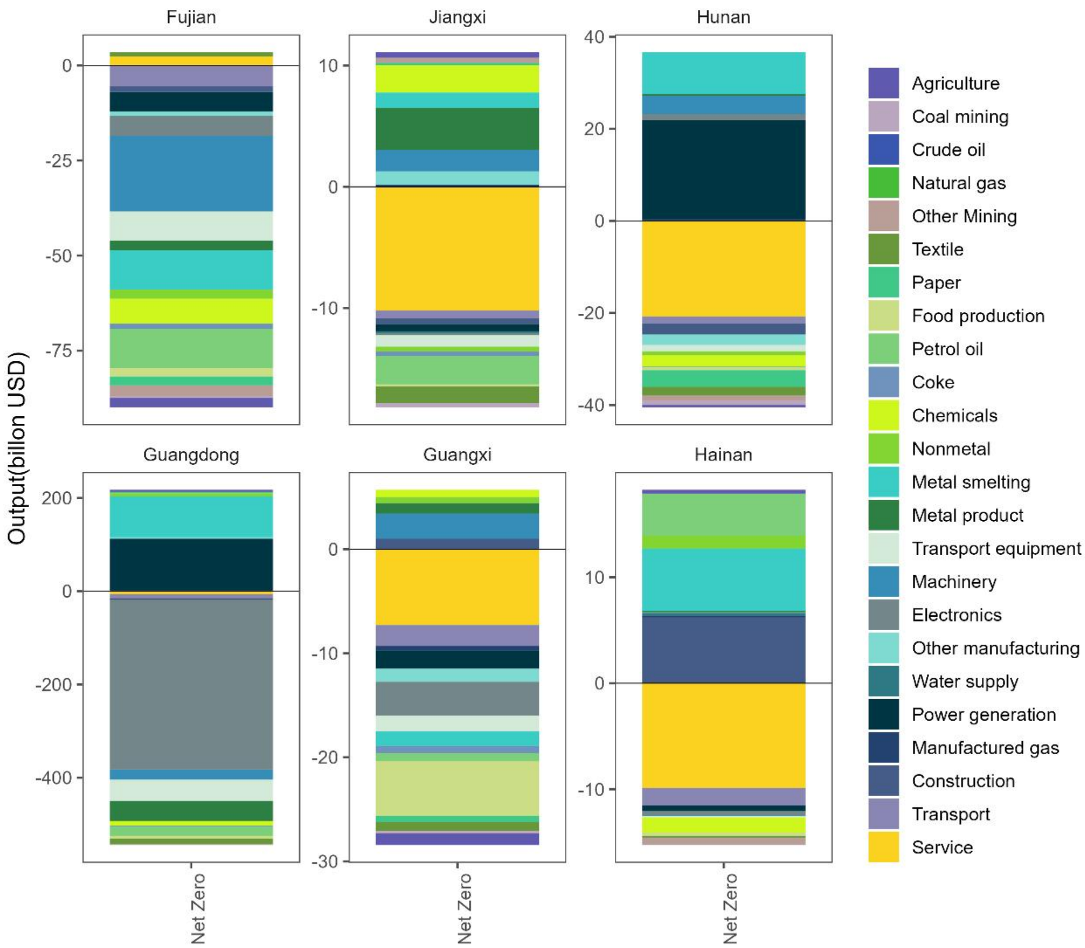

Figure S6. Absolute output changes in Net zero scenario compared to BaU in 2050

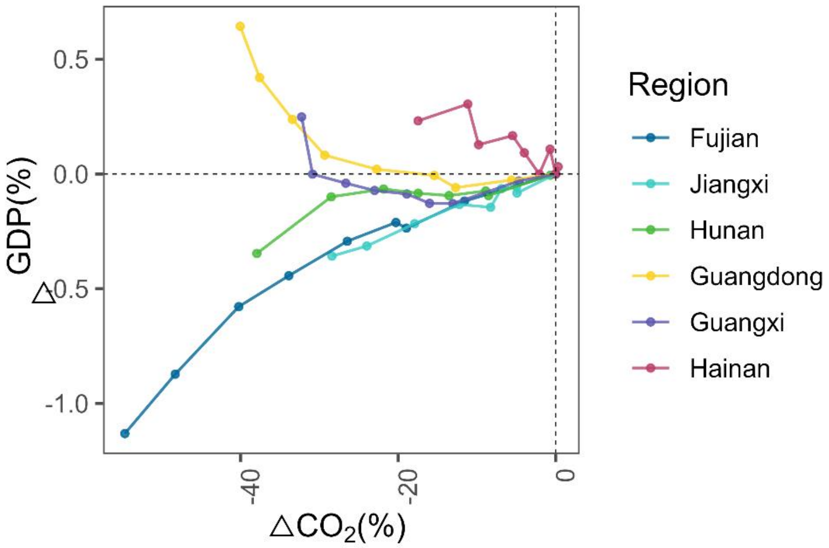

Figure S7. The relationship between carbon reduction and GDP loss under the Net zero scenario compared to BaU (based on data from 2020 to 2050)

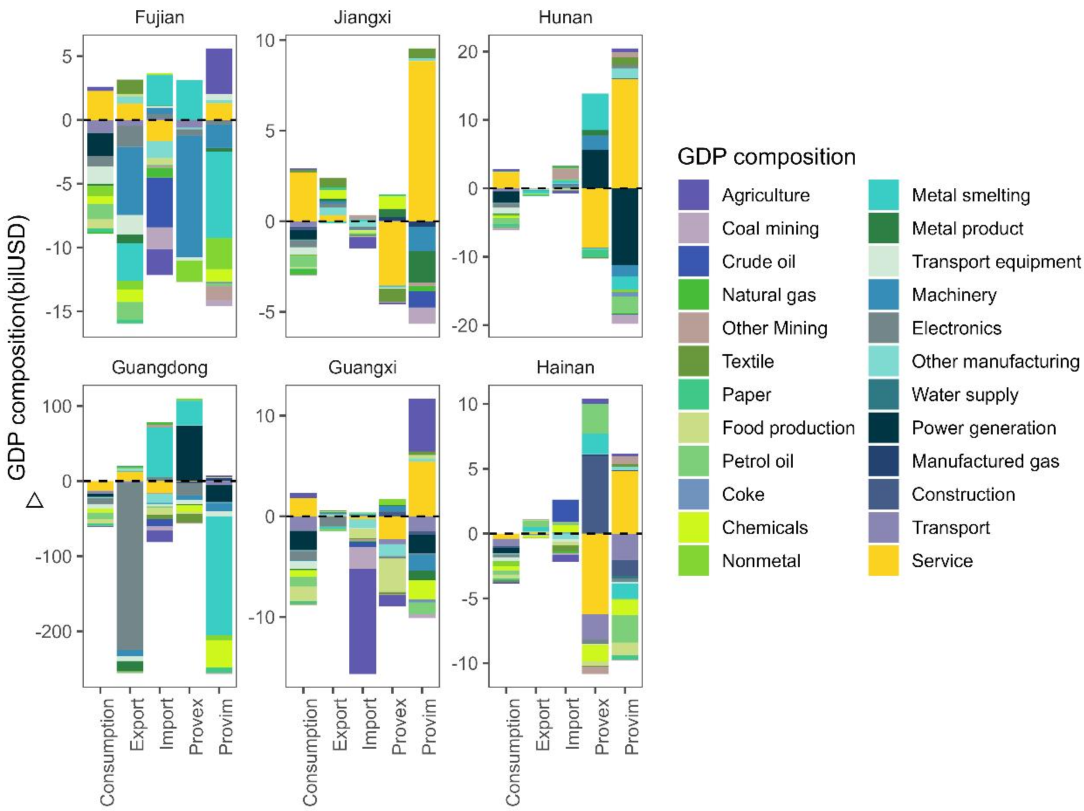

Figure S8. GDP loss under the Net zero scenario relative to BaU in 2050

4.2 Air pollutant emissions and $PM_{2.5}$ concentrations

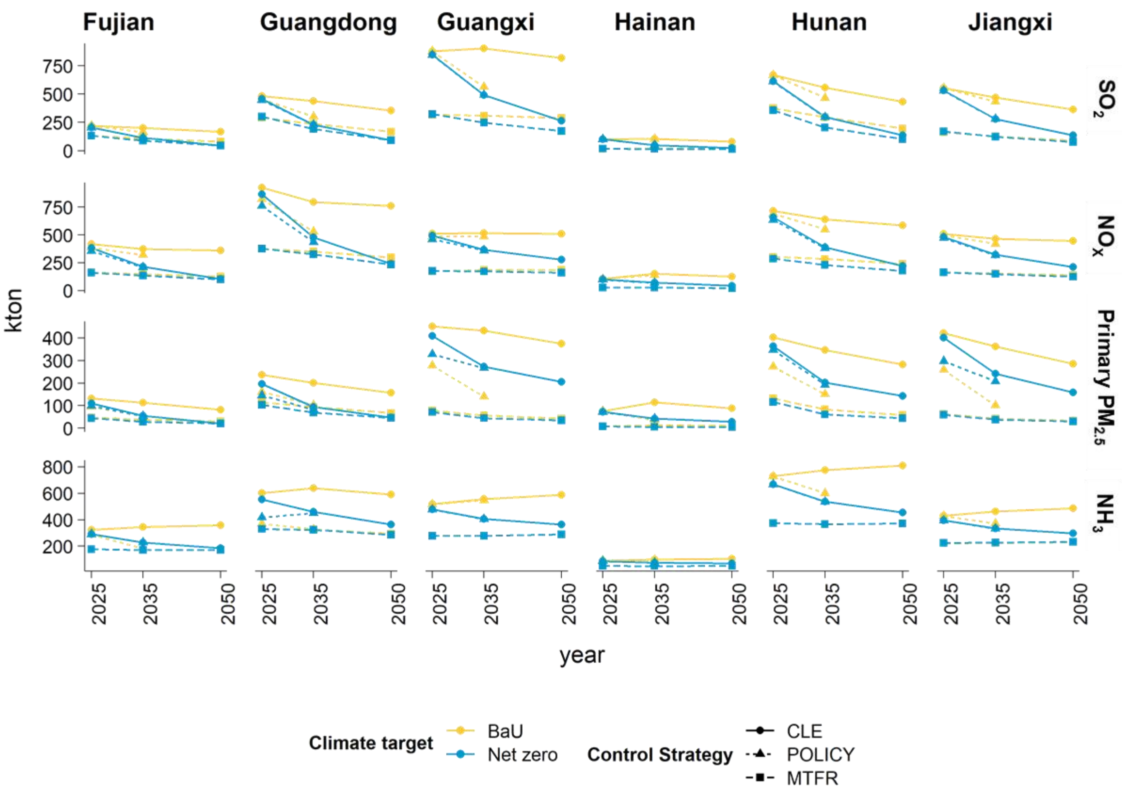

Figure S9. Total air pollutant emissions under different scenarios from 2025-2050

Table S8 shows the $PM_{2.5}$ concentrations in six provinces under different scenarios. Among them, the concentrations in 2020 and 2022 are historical observations. The yellow filling indicates that the concentration in the POLICY scenario is lower than MTFR, and the GAINS model has no solution, which means that even if we try our best, we can only reach the MTFR level and cannot achieve the POLICY goal. The green filling indicates that the concentration in the POLICY scenario is higher than CLE, and the model has no solution, which means that the POLICY goal can be achieved by continuing the current level of control measures.

Table S8. $PM_{2.5}$ concentration in six provinces under different scenarios

Unit: μg/m^3

Region	Scenario	2020	2022	2025	2035	2050
Fujian	BaU_CLE	20	19	18.2	17.8	17.1
Fujian	BaU_POLICY			16.2	13.1	9.6
Fujian	BaU_MTFR			12.0	11.4	10.9
Guangdong	BaU_CLE	22	20	25.5	24.5	22.1
Guangdong	BaU_POLICY			19.8	16.0	**11.7**
Guangdong	BaU_MTFR			15.9	14.8	12.9
Guangxi	BaU_CLE	26	26	26.3	26.5	25.1
Guangxi	BaU_POLICY			23.4	19.0	13.8
Guangxi	BaU_MTFR			12.6	12.2	11.8
Hainan	BaU_CLE			10.7	12.8	11.3
Hainan	BaU_POLICY	13	12	**11.7**	9.5	6.5
Hainan	BaU_MTFR			5.7	5.9	5.9
Hunan	BaU_CLE			34.3	32.3	30.0
Hunan	BaU_POLICY			31.5	25.5	18.6
Hunan	BaU_MTFR			21.3	19.3	17.7
Jiangxi	BaU_CLE	30	27	30.4	28.9	26.8
Jiangxi	BaU_POLICY			27.0	21.9	15.9
Jiangxi	BaU_MTFR			16.1	15.4	14.9
Fujian	Net zero_CLE	20	19	16.9	13.07	10.5
Fujian	Net zero_POLICY			16.2	13.1	9.6
Fujian	Net zero_MTFR			11.8	10.9	10.3
Guangdong	Net zero_CLE	22	20	23.5	16.8	12.4
Guangdong	Net zero_POLICY			19.8	16.0	11.7
Guangdong	Net zero_MTFR			15.7	13.7	11.5
Guangxi	Net zero_CLE	26	26	25.0	18.8	15.2
Guangxi	Net zero_POLICY			23.4	19.0	13.8
Guangxi	Net zero_MTFR			12.5	11.3	10.6
Hainan	Net zero_CLE			10.4	8.2	6.91
Hainan	Net zero_POLICY	13	12	11.7	9.5	6.5
Hainan	Net zero_MTFR			5.7	5.5	5.4
Hunan	Net zero_CLE			32.1	23.6	19.5
Hunan	Net zero_POLICY			31.5	25.5	18.6
Hunan	Net zero_MTFR			20.6	17.7	16.4

Jiangxi	Net zero_CLE	30	27	29.2	22.7	19.0
Jiangxi	Net zero_POLICY			27.0	21.9	15.9
Jiangxi	Net zero_MTFR			16.1	15.2	14.6

4.3 Costs and health benefits

The Table S9 and S10 shows the avoided premature deaths and VSL loss compared to the BaU_CLE scenario, respectively. The 95% confidence interval is indicated in parentheses. The EF fuction used in this study is non-linear GEMM.

Table S9. Avoided premature deaths compared to the BaU_CLE scenario

Unit: thousand people

Region	Scenario	2025	2035	2050
Fujian	BaU_POLICY	2.35(1.54~3.00)	5.91(3.88~7.60)	6.48(4.25~8.36)
Fujian	BaU_MTFR	7.83(5.14~10.08)	8.22(5.40~10.6)	7.73(5.08~9.98)
Fujian	Net zero_CLE	1.48(0.97~1.89)	5.94(3.90~7.65)	8.25(5.42~10.66)
Fujian	Net zero_POLICY	2.35(1.54~3.00)	6.08(4.00~7.83)	8.25(5.42~10.66)
Fujian	Net zero_MTFR	8.01(5.26~10.32)	8.93(5.87~11.52)	8.59(5.65~11.11)
Jiangxi	BaU_POLICY	3.72(2.50~4.57)	8.14(5.43~10.12)	12.91(8.54~16.28)
Jiangxi	BaU_MTFR	17.53(11.64~21.98)	16.93(11.23~21.31)	14.31(9.47~18.09)
Jiangxi	Net zero_CLE	1.25(0.84~1.52)	7.11(4.75~8.83)	8.95(5.94~11.23)
Jiangxi	Net zero_POLICY	3.72(2.50~4.57)	8.14(5.43~10.12)	12.91(8.54~16.28)
Jiangxi	Net zero_MTFR	17.58(11.68~22.05)	17.18(11.39~21.64)	14.63(9.67~18.5)
Hunan	BaU_POLICY	4.26(2.89~5.15)	10.98(7.39~13.49)	18.97(12.63~23.69)
Hunan	BaU_MTFR	21.56(14.47~26.6)	22.34(14.92~27.76)	20.58(13.69~25.75)
Hunan	Net zero_CLE	3.37(2.29~4.07)	14.26(9.57~17.57)	17.27(11.51~21.53)
Hunan	Net zero_POLICY	4.26(2.89~5.15)	14.85(9.97~18.32)	18.97(12.63~23.69)
Hunan	Net zero_MTFR	22.87(15.33~28.25)	25.52(17.02~31.81)	23.26(15.45~29.17)
Guangdong	BaU_POLICY	16.36(10.86~20.54)	26.54(17.53~33.60)	34.81(22.91~44.57)
Guangdong	BaU_MTFR	29.01(19.18~36.68)	30.93(20.41~39.25)	30.33(19.96~38.76)
Guangdong	Net zero_CLE	5.46(3.64~6.81)	23.95(15.83~30.29)	32.07(21.11~41.01)
Guangdong	Net zero_POLICY	16.36(10.86~20.54)	26.54(17.53~33.60)	34.81(22.91~44.57)
Guangdong	Net zero_MTFR	29.69(19.63~37.55)	34.97(23.07~44.47)	35.73(23.51~45.77)
Guangxi	BaU_POLICY	3.63(2.42~4.53)	9.69(6.43~12.16)	14.53(9.59~18.45)
Guangxi	BaU_MTFR	19.46(12.85~24.73)	20.23(13.36~25.72)	17.68(11.66~22.54)
Guangxi	Net zero_CLE	1.63(1.09~2.02)	9.95(6.60~12.49)	12.54(8.28~15.88)
Guangxi	Net zero_POLICY	3.63(2.42~4.53)	10.22(6.78~12.83)	14.53(9.59~18.45)
Guangxi	Net zero_MTFR	19.58(12.93~24.88)	21.66(14.3~27.57)	19.66(12.96~25.11)
Hainan	BaU_POLICY	0.01(0.01~0.02)	0.84(0.56~1.10)	1.28(0.85~1.68)
Hainan	BaU_MTFR	1.53(1.02~20)	1.97(1.31~2.57)	1.49(1.00~1.95)
Hainan	Net zero_CLE	0.07(0.05~0.10)	1.23(0.81~1.60)	1.16(0.77~1.51)
Hainan	Net zero_POLICY	0.09(0.06~0.12)	1.25(0.82~1.62)	1.28(0.85~1.68)
Hainan	Net zero_MTFR	1.54(1.03~2.01)	2.13(1.42~2.78)	1.66(1.11~2.17)

Table S10. Avoided VSL loss compared to the BaU_CLE scenario

Unit: billion USD

Region	Scenario	2025	2035	2050
Fujian	BaU_POLICY	3.04(2~3.89)	10.95(7.19~14.09)	17.75(11.66~22.89)
Fujian	BaU_MTFR	10.14(6.66~13.06)	15.24(10.01~19.65)	21.17(13.91~27.35)
Fujian	Net zero_CLE	1.91(1.26~2.44)	11.02(7.24~14.18)	22.59(14.85~29.2)
Fujian	Net zero_POLICY	3.04(2~3.89)	11.28(7.41~14.51)	22.6(14.85~29.21)
Fujian	Net zero_MTFR	10.38(6.82~13.37)	16.55(10.87~21.36)	23.53(15.47~30.43)
Jiangxi	BaU_POLICY	5.03(3.38~6.18)	15.96(10.65~19.84)	39.26(25.99~49.53)
Jiangxi	BaU_MTFR	23.7(15.75~29.72)	33.19(22~41.78)	43.53(28.79~55.02)
Jiangxi	Net zero_CLE	1.68(1.14~2.06)	13.93(9.31~17.3)	27.23(18.08~34.16)
Jiangxi	Net zero_POLICY	5.03(3.38~6.18)	15.96(10.65~19.84)	39.26(25.99~49.53)
Jiangxi	Net zero_MTFR	23.78(15.8~29.82)	33.69(22.33~42.41)	44.5(29.43~56.27)
Hunan	BaU_POLICY	5.57(3.79~6.74)	20.56(13.84~25.26)	52.46(34.93~65.52)
Hunan	BaU_MTFR	28.21(18.93~34.8)	41.82(27.93~51.96)	56.92(37.87~71.2)
Hunan	Net zero_CLE	4.40(3.00~5.32)	26.69(17.92~32.9)	47.76(31.83~59.53)
Hunan	Net zero_POLICY	5.57(3.79~6.74)	27.8(18.66~34.29)	52.46(34.93~65.52)
Hunan	Net zero_MTFR	29.91(20.06~36.95)	47.78(31.86~59.55)	64.32(42.73~80.67)
Guangdong	BaU_POLICY	19.86(13.18~24.94)	45.94(30.35~58.17)	94.73(62.34~121.31)
Guangdong	BaU_MTFR	35.21(23.28~44.53)	53.54(35.34~67.94)	82.54(54.33~105.48)
Guangdong	Net zero_CLE	6.63(4.42~8.27)	41.47(27.41~52.43)	87.28(57.44~111.63)
Guangdong	Net zero_POLICY	19.86(13.18~24.94)	45.94(30.35~58.17)	94.73(62.34~121.31)
Guangdong	Net zero_MTFR	36.04(23.83~45.59)	60.54(39.93~76.98)	97.24(64~124.57)
Guangxi	BaU_POLICY	4.59(3.06~5.71)	17.3(11.48~21.71)	36.26(23.93~46.05)
Guangxi	BaU_MTFR	24.57(16.22~31.22)	36.12(23.84~45.9)	44.15(29.11~56.28)
Guangxi	Net zero_CLE	2.06(1.37~2.56)	17.76(11.78~22.29)	31.29(20.67~39.64)
Guangxi	Net zero_POLICY	4.59(3.06~5.71)	18.23(12.1~22.9)	36.26(23.93~46.05)
Guangxi	Net zero_MTFR	24.72(16.32~31.41)	38.66(25.52~49.22)	49.07(32.35~62.68)
Hainan	BaU_POLICY	0.02(0.01~0.03)	1.97(1.30~2.57)	5.11(3.4~6.68)
Hainan	BaU_MTFR	2.17(1.45~2.84)	4.61(3.06~6.01)	5.95(3.96~7.77)
Hainan	Net zero_CLE	0.11(0.07~0.14)	2.87(1.90~3.74)	4.61(3.06~6.01)
Hainan	Net zero_POLICY	0.13(0.08~0.16)	2.91(1.92~3.79)	5.11(3.4~6.68)
Hainan	Net zero_MTFR	2.18(1.45~2.84)	4.97(3.31~6.48)	6.61(4.41~8.63)

Table S11. Net benefits compared to the BaU_CLE scenario in 2050

Unit: billion USD

scenario	region	VSL_China_High	VSL_China_Low	VSL_China_Medium
BaU_POLICY	Fujian	21.49	14.00	17.75
BaU_POLICY	Jiangxi	47.55	30.97	39.26
BaU_POLICY	Hunan	63.55	41.38	52.46
BaU_POLICY	Guangdong	114.74	74.72	94.73
BaU_POLICY	Guangxi	43.92	28.60	36.26

BaU_POLICY	Hainan	6.19	4.03	5.11
BaU_MTFR	Fujian	25.64	16.70	21.17
BaU_MTFR	Jiangxi	52.72	34.34	43.53
BaU_MTFR	Hunan	68.94	44.90	56.92
BaU_MTFR	Guangdong	99.97	65.11	82.54
BaU_MTFR	Guangxi	53.47	34.82	44.15
BaU_MTFR	Hainan	7.21	4.69	5.95
Net zero_CLE	Fujian	16.55	7.00	11.77
Net zero_CLE	Jiangxi	29.94	18.44	24.19
Net zero_CLE	Hunan	56.50	36.33	46.42
Net zero_CLE	Guangdong	118.76	81.90	100.33
Net zero_CLE	Guangxi	37.44	24.23	30.83
Net zero_CLE	Hainan	6.21	4.27	5.24
Net zero_POLICY	Fujian	16.56	7.01	11.78
Net zero_POLICY	Jiangxi	44.51	27.93	36.22
Net zero_POLICY	Hunan	62.21	40.05	51.13
Net zero_POLICY	Guangdong	127.79	87.78	107.78
Net zero_POLICY	Guangxi	43.46	28.14	35.80
Net zero_POLICY	Hainan	6.83	4.67	5.75
Net zero_MTFR	Fujian	17.68	7.74	12.71
Net zero_MTFR	Jiangxi	50.86	32.06	41.46
Net zero_MTFR	Hunan	76.57	49.40	62.99
Net zero_MTFR	Guangdong	130.83	89.76	110.29
Net zero_MTFR	Guangxi	58.98	38.25	48.61
Net zero_MTFR	Hainan	8.64	5.85	7.24

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