

1 *Supplemental Material for:*

2 Regional Production Shift and Increased Utilization Dampen Coal Mine Methane
3 Emissions in China

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Table S1. Distribution of coal mines based on ownership and methane gas levels within each province reported in SACMS's National Coal Mine Methane Level Identification Database (2011).¹

Province	Total	Ownership			Methane gas level		
		State-owned	Local state-owned	Township	Low-gas	High-gas	Outburst
Beijing	4	4	-	-	4	-	-
Hebei	72	67	1	4	50	15	7
Shanxi	1012	314	398	300	780	192	40
Mongolia	284	37	247	-	255	20	9
Liaoning	498	30	39	429	438	43	17
Jilin	224	35	-	189	193	29	1
Heilongjiang	672	114	33	525	613	51	8
Jiangsu	21	12	9	-	18	1	2
Zhejiang	1	-	1	-	-	1	-
Anhui	126	56	5	65	73	13	40
Fujian	303	-	36	267	303	-	-
Jiangxi	598	37	71	490	367	213	18
Shandong	196	54	142	-	191	3	2
Henan	494	378	37	79	387	33	74
Hubei	376	-	19	357	326	21	16
Hunan	991	56	80	855	557	148	271
Guangxi	77	-	14	63	75	2	-
Chongqing	747	47	-	700	494	101	88
Sichuan	1143	38	29	1076	702	328	113
Guizhou*	1104	30	89	985	414	345	345
Yunnan	1032	14	5	1013	780	159	42
Shaanxi*	456	49	14	393	439	13	4
Gansu*	135	-	31	104	132	3	-
Qinghai†	11	-	5	6	11	-	-
Ningxia	41	21	11	9	34	4	3
Xinjiang	166	19	147	-	145	11	1
Total	10,784	1,412	1,463	7,909	7,781	1,749	1,101

* No production capacity is available but average monthly or daily output is reported for mines in these provinces.

† No production capacity or emission factor is available for mines in Qinghai.

16 Table S2. Coefficients and model performance of multi-linear regression by considering varying numbers
 17 of variables.

Variables		Cases				
		(1)	(2)	(3)	(4)	(5)
Number of Observations		8186	8186	3948	3948	3938
Provinces [†]	Anhui	-35.80*** § (1.32)	-35.00*** (1.44)	-42.16*** (1.59)	-41.73*** (2.11)	-41.29*** (2.79)
	Beijing	-31.39*** (1.71)	-31.54*** (1.97)	-31.08*** (1.79)	-30.77*** (1.52)	-30.36*** (2.15)
	Chongqing	-24.97*** (1.32)	-23.43*** (1.43)	-24.47*** (1.02)	-22.85*** (1.29)	-22.98*** (1.77)
	Fujian	-28.77*** (1.71)	-27.43*** (1.75)	-28.23*** (1.66)	-26.74*** (1.71)	-26.75*** (1.82)
	Gansu	-30.59*** (1.67)	-29.40*** (1.70)	0.00 (.)	0.00 (.)	0.00 (.)
	Guangxi	-27.39*** (1.61)	-26.40*** (1.62)	-27.12*** (1.57)	-26.37*** (1.45)	-26.27*** (1.39)
	Guizhou	-22.55*** (0.93)	-21.06*** (1.05)	0.00 (.)	0.00 (.)	0.00 (.)
	Hebei	-31.86*** (1.29)	-31.86*** (1.63)	-31.50*** (1.08)	-31.16*** (1.01)	-30.94*** (1.47)
	Heilongjiang	-29.36*** (1.56)	-28.13*** (1.60)	-28.69*** (1.44)	-27.38*** (1.39)	-27.38*** (1.45)
	Henan	-32.36*** (1.47)	-32.18*** (1.68)	-31.95*** (1.14)	-31.62*** (1.03)	-31.49*** (1.13)
	Hubei	-28.46*** (1.55)	-26.98*** (1.63)	0.00 (.)	0.00 (.)	0.00 (.)
	Hunan	-26.98*** (1.28)	-25.52*** (1.35)	-26.74*** (0.68)	-25.43*** (0.95)	-25.48*** (1.12)
Provinces	Jiangsu	-32.52***	-32.62***	0.00	0.00	0.00

		(1.55)	(1.65)	(.)	(.)	(.)
	Jiangxi	-29.80***	-28.66***	-27.30***	-26.23***	-26.32***
		(1.11)	(1.18)	(1.05)	(1.15)	(1.38)
	Jilin	-29.00***	-27.67***	-28.37***	-26.88***	-26.80***
		(1.46)	(1.53)	(1.36)	(1.44)	(1.36)
	Liaoning	-32.45***	-31.11***	0.00	0.00	0.00
		(1.52)	(1.58)	(.)	(.)	(.)
	Inner Mongolia	-31.51***	-30.17***	-31.93***	-31.64***	-31.11***
		(1.63)	(1.68)	(1.27)	(1.10)	(2.27)
	Ningxia	-28.50***	-28.24***	-27.93***	-27.57***	-27.13***
		(1.50)	(1.59)	(1.24)	(1.01)	(1.76)
	Qinghai	0.00	0.00	0.00	0.00	0.00
		(.)	(.)	(.)	(.)	(.)
	Shaanxi	-31.09***	-29.74***	0.00	0.00	0.00
		(1.65)	(1.70)	(.)	(.)	(.)
	Shandong	-31.34***	-31.46***	-30.78***	-30.92***	-30.63***
		(1.67)	(1.68)	(1.61)	(1.50)	(1.78)
	Shanxi	-28.60***	-28.89***	-28.06***	-28.29***	-27.87***
		(1.29)	(1.39)	(1.14)	(1.04)	(1.83)
	Sichuan	-22.23***	-20.78***	-21.28***	-19.80***	-19.77***
		(0.95)	(1.12)	(0.65)	(1.09)	(1.05)
	Xinjiang	-30.14***	-30.25***	-28.94***	-29.32***	-29.24***
		(1.58)	(1.58)	(1.43)	(1.42)	(1.44)
	Yunnan	-25.91***	-24.32***	0.00	0.00	0.00
		(1.40)	(1.51)	(.)	(.)	(.)
	Zhejiang	0.00	0.00	0.00	0.00	0.00
		(.)	(.)	(.)	(.)	(.)
Gas-level †		18.02***	17.91***	18.25***	18.17***	18.28***
	High-gas	(1.71)	(1.71)	(1.84)	(1.82)	(1.83)
	Outburst	25.47***	25.16***	26.23***	26.07***	26.20***

		(1.90)	(1.81)	(3.47)	(3.38)	(3.36)
	State-owned		-0.71 (0.62)		-0.95 (0.52)	-0.84 (0.49)
Ownership [†]	Local-state		-0.74 (0.52)		-0.50 (0.36)	-0.52 (0.32)
	Township		-2.44* (1.02)		-2.47 (1.61)	-2.59 (1.31)
Depth	Log-depth [‡]			0.30 (0.31)	0.14 (0.27)	0.17 (0.33)
Production capacity	Log-production capacity [‡]				-0.22 (0.73)	
	Constant (α)	32.83*** (1.71)	33.69*** (1.88)	30.51*** (1.90)	32.21*** (1.68)	32.51*** (1.47)
	Adjusted R ²	0.617	0.618	0.609	0.610	0.610
	RMSE	8.529	8.514	8.345	8.332	8.340

[†] Coefficients for categorical variables are derived relative to the omitted comparison group. The omitted comparison groups for province, gas-level, and ownership are Zhejiang, low-gas level, and unidentified ownership mines in Shanxi province.

[‡] Log-depth and log-production represent natural logarithm of depth and production-capacity, respectively.

[§] *p*-value significance testing: * indicates $p < 0.05$, ** indicates $p < 0.01$, *** indicates $p < 0.001$.

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24 Table S3. China coal mine methane emission factor based on gas level in each province

Province	Emission Factor (m ³ ton ⁻¹ coal production)		
	Low-gas	High-gas	Outburst
Beijing	1.33 [0.78 - 2.07]	-	-
Hebei	2.16 [1.64 - 2.73]	10.64 [10.10 - 11.20]	16.94 [14.70 - 18.72]
Shanxi	2.84 [2.58 - 3.11]	18.12 [14.99 - 21.35]	38.51 [30.51 - 49.20]
Mongolia	0.63 [0.52 - 0.75]	13.49 [11.87 - 14.84]	21.48 [15.04 - 36.26]
Liaoning	0.25 [0.23 - 0.27]	12.74 [6.23 - 17.27]	61.58 [47.24 - 75.68]
Jilin	4.66 [3.62 - 5.77]	11.59 [10.28 - 13.12]	12.38 [-]
Heilongjiang	3.76 [3.07 - 4.48]	21.45 [17.66 - 26.25]	11.43 [8.53 - 15.83]
Jiangsu	1.91 [0.89 - 3.19]	9.06 [-]	8.55 [2.93 - 12.98]
Zhejiang	-	50.85 [-]	-
Anhui	2.73 [2.06 - 3.42]	6.71 [5.73 - 8.07]	11.40 [8.53 - 14.66]
Fujian	3.82 [3.50 - 4.17]	-	-
Jiangxi	5.89 [5.54 - 6.24]	13.69 [13.15 - 14.25]	33.70 [27.62 - 29.03]
Shandong	1.07 [0.88 - 1.29]	12.12 [9.46 - 15.43]	5.67 [5.30 - 6.46]
Henan	3.26 [2.86 - 3.68]	9.20 [6.52 - 13.24]	13.46 [11.11 - 16.03]
Hubei	5.19 [4.91 - 5.48]	21.46 [15.82 - 27.20]	15.19 [11.47 - 17.94]
Hunan	6.27 [6.02 - 6.50]	18.62 [17.47 - 19.82]	29.54 [27.99 - 31.09]
Guangxi	5.25 [3.90 - 6.76]	22.33 [20.38 - 23.85]	-
Chongqing	6.64 [6.39 - 6.86]	30.17 [25.89 - 34.29]	57.24 [45.02 - 67.65]
Sichuan	5.79 [5.14 - 6.40]	30.02 [26.76 - 33.34]	34.35 [23.75 - 46.16]
Guizhou*	7.61 [7.25 - 7.96]	27.27 [25.11 - 29.42]	37.15 [30.66 - 44.98]
Yunnan	6.08 [5.87 - 6.29]	25.93 [23.62 - 28.19]	32.98 [26.17 - 39.95]
Shaanxi*	0.82 [0.56 - 1.18]	11.22 [7.21 - 15.43]	30.42 [22.71 - 40.57]
Gansu*	1.67 [1.44 - 1.93]	12.24 [10.84 - 13.23]	-
Qinghai†	-	-	-
Ningxia	0.44 [0.31 - 0.63]	17.58 [5.34 - 25.09]	49.70 [21.94 - 75.22]
Xinjiang	1.86 [1.51 - 2.28]	12.69 [11.73 - 15.01]	25.14 [-]

25 * For the provinces with no reported production, the average emission factors and uncertainties are
 26 calculated without weighting factors of production.

27 † There is no emission factor reported in Qinghai.

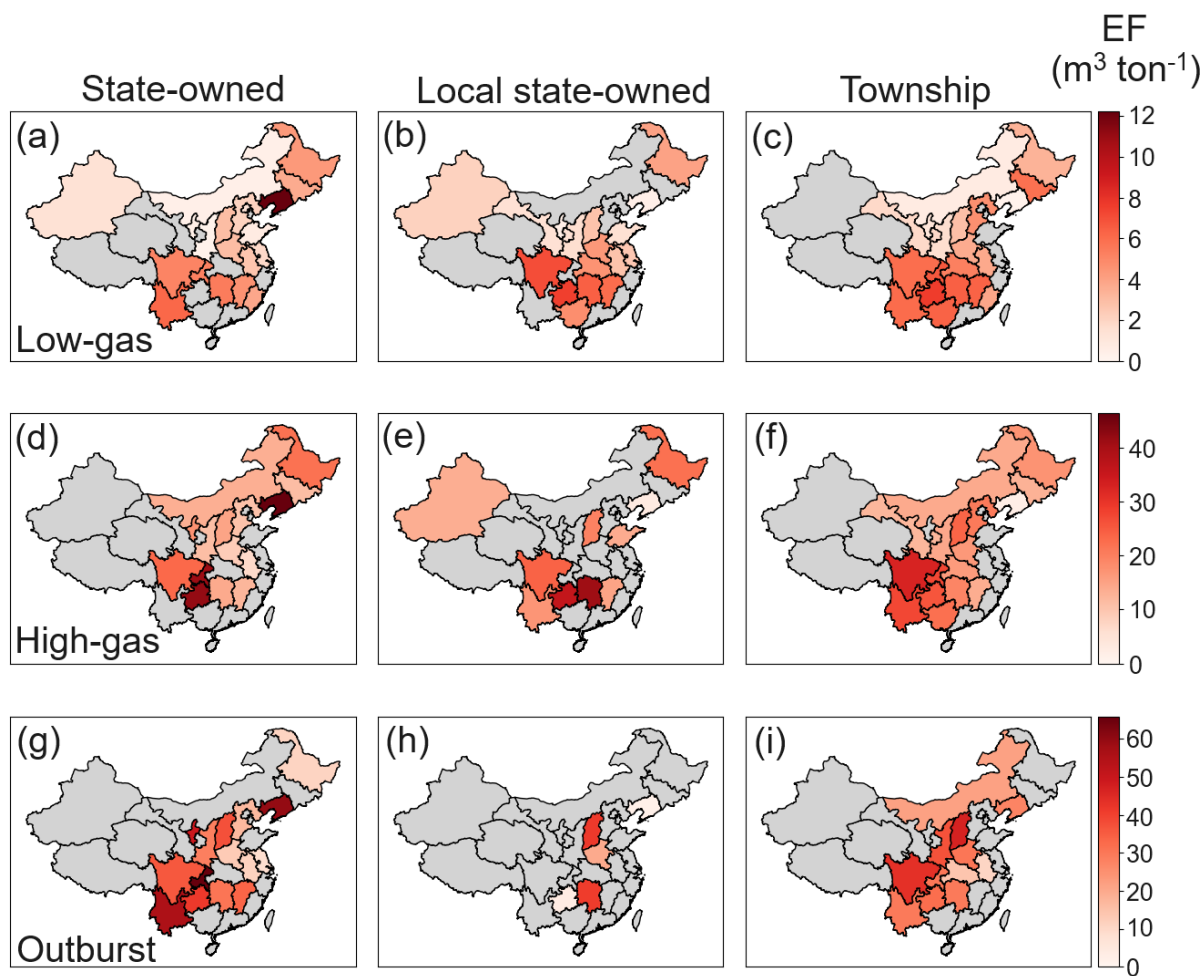
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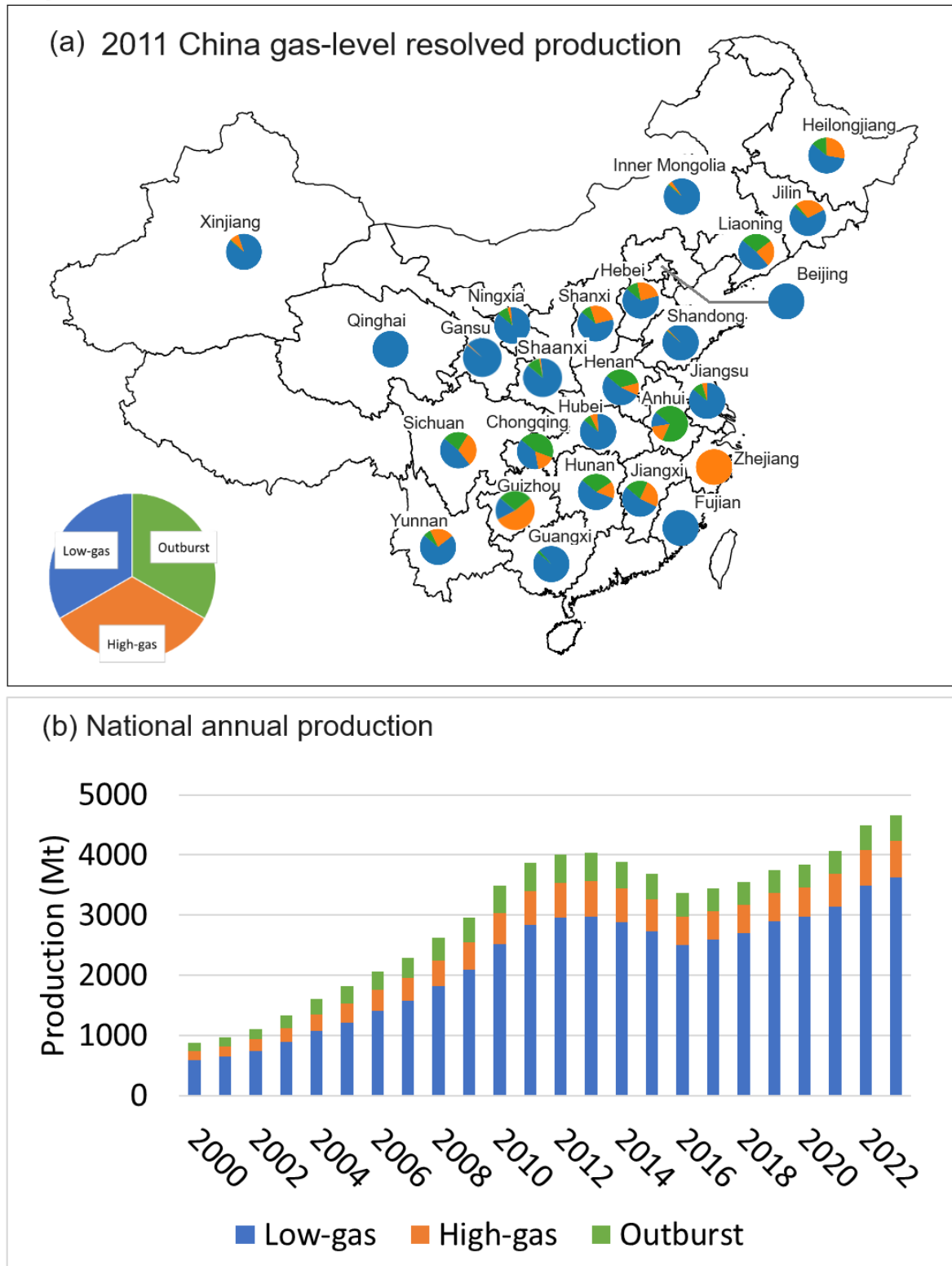
31 Table S4. Comparison of emission patterns between 2011 and 2023 in Shanxi and Guizhou

a. Shanxi	2011	2023
Total capacity (Mt)	1127.16	811.00 (/1560.00)
Total output (Mt)	966.62	NA (/1356.58)
Capacity-Low (Mt)	730.24 (65%)	439.90 (54%)
Capacity-High (Mt)	295.32 (26%)	309.40 (38%)
Capacity-Outburst (Mt)	101.60 (9%)	61.70 (8%)
b. Guizhou	% Output in 2011	% Capacity in 2023
Low	19	5
High	28	12
Outburst	53	83



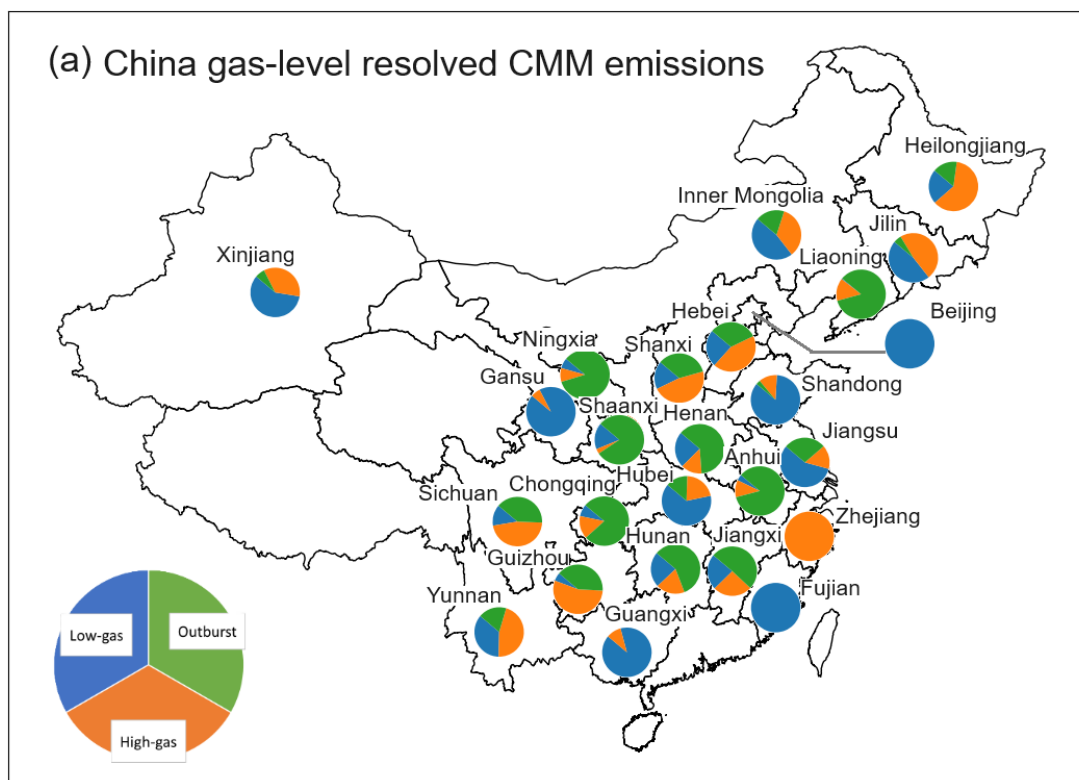
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34 Fig. S1 EF variation due to geological distribution, gas level, and ownership.

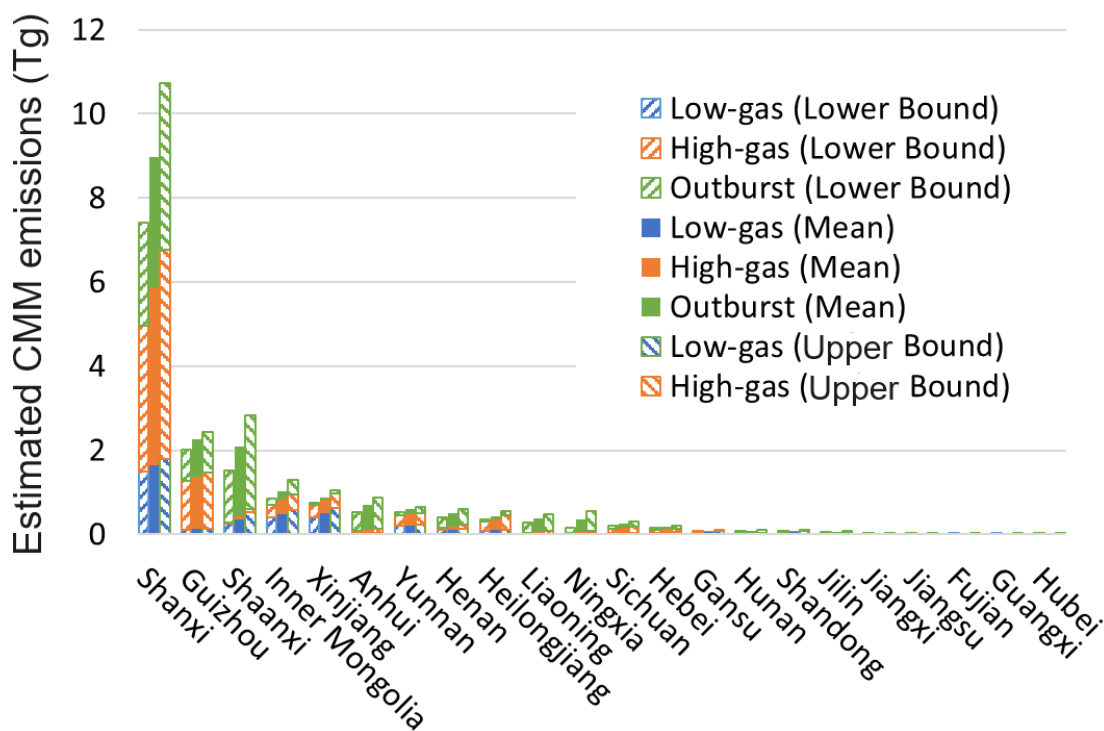


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36 Fig. S2 (a) Distribution of coal mine production capacity for each gas level in each province based on the
 37 2011 database; (b) National coal mine production at each gas level 2000-2023, assuming the proportions
 38 in each province remain constant.

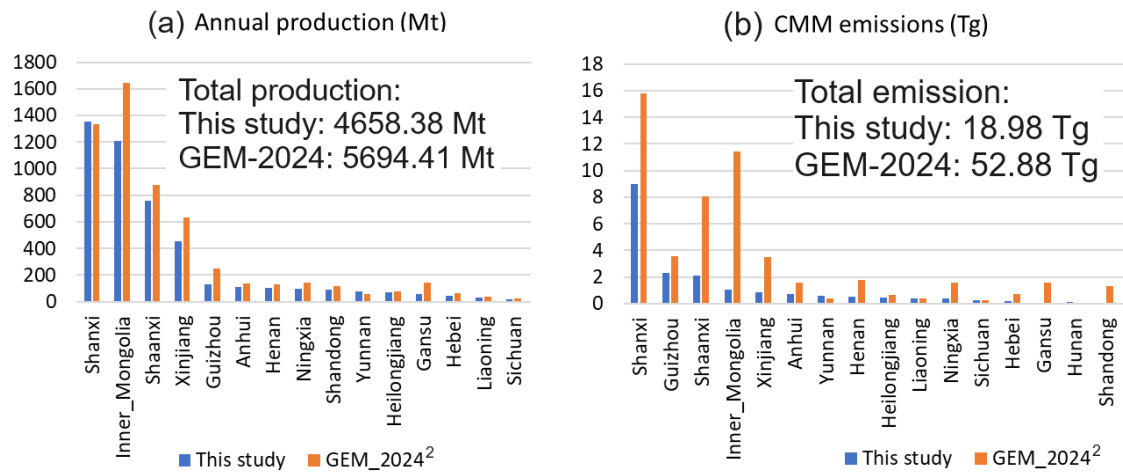


(b) Estimate of provincial CMM emissions in 2023



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40 Figure S3. (a) The provincial CMM emission fractions at each gas level derived from the production-
 41 weighted average EF. (b) Estimate of provincial CMM emissions and associated uncertainties in 2023.



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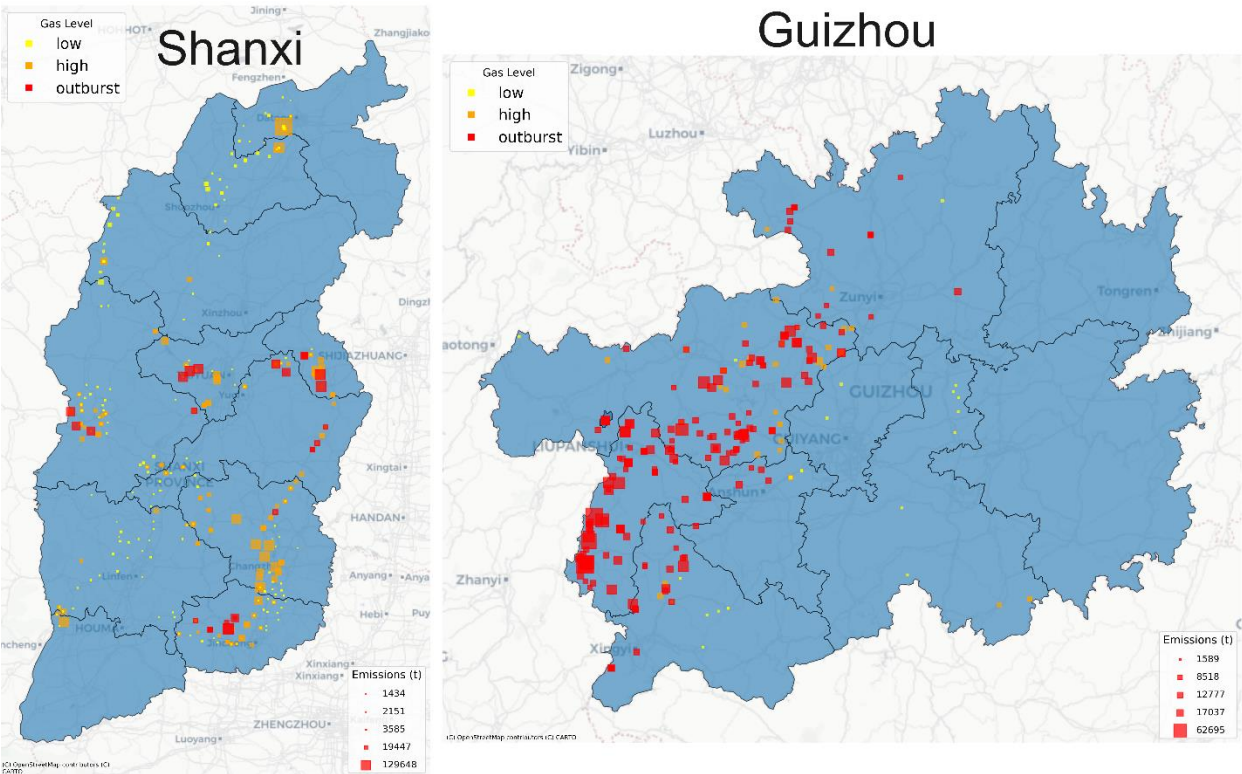
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Figure S4 Comparison of (a) annual production and (b) estimated CMM emissions in this study and GEM database². The provinces with production lower than 20 Mt are not shown in (a). The provinces with CMM emissions lower than 0.1 Tg are not shown in (b).

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Figure S5 Estimated mine-specific methane emissions in Shanxi and Guizhou based on limited data collected in 2023.

52 References

- 53 1 State Administration of Coal Mine Safety (SACMS). Compilation of National Coal Mine Gas Level
54 Identification for 2011. (National Mine Safety Administration Press, 2012).
55 2 Global Energy Monitor. Global Coal Mine Tracker, April 2024 release., (2024).

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