

Supplementary Materials

Regional prioritization in vehicle electrification and renewable electricity expansion facilitates decarbonization of China's road transport

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1. Vehicle energy consumption rate

Table S1. Fuel/electricity consumption rate for vehicles in 2020 and 2050

Powertrain technologies for each vehicle type	Fuel or electricity consumption rate (L/100km or kwh/100km)	
	2020	2050
LDPV-G	8.2	6.2
LDPV-BEV	14.7	11.1
LDPV-PHEV (G)	3.8	2.9
LDPV-PHEV (Electric)	13.2	10.3
TA-G	8.2	6.2
TA-BEV	20.5	15.5
TA-EG	9.0	6.8
TA-D	8.2	6.2
TA-CNG	8.0	8.0
HDB-D	27.4	24.0
HDB-BEV	106.2	93.0
HDB-PHEV (CNG)	18.8	18.8
HDB-PHEV (Electric)	9.0	7.9
HDB-HEV (D)	22.1	19.4
HDB-G	31.3	27.4

HDB-CNG	51.0	51.0
HDT-D	27.2	23.3
HDT-BEV	149.0	127.8
HDT- CNG	48.8	41.8
MDT-D /-G	16.5	14.2
MDT-BEV	57.8	49.8
LDT-D	13.4	10.8
LDT-G	11.5	9.2
LDT-CNG	8.2	6.1
LDT-BEV	37.6	30.3
MT-D	8.5	6.9
MT-BEV	17.8	14.3
MT-G	8.6	7.0
MT-CNG	8.6	7.0
MDPV-G	13.6	10.2
MDPV-BEV	24.2	18.3
HDPV-D	31.0	27.1
HDPV-BEV	75.9	66.5
MC-G	2.5	1.9
MC-BEV	2.8	2.1

2. Mileage

In this study, mileage is calculated based on vehicle age by equation (1):

$$\text{Mileage}_{v,f,p,y,t} = \text{Mileage}_{v,f,p,y,n} \times \text{Mileage ratio by ages}_{v,f,p,y-t} \quad (1)$$

Where, $\text{Mileage}_{v,f,p,y,t}$ is the average annual mileage travelled (km) for a vehicle of vehicle type v , fuel type f , vintage t in province p and year y , $\text{Mileage}_{v,f,p,y,n}$ is the average mileage travelled by a new vehicle (denoted by n) in the first year for vehicle type v , fuel type f in province p (see Table S2), Mileage ratio by ages is the ratio that reflects how annual mileage changes with vehicle age (denoted by $y-t$) (see Table S3).

Table S2. Mileage for new vehicles

Vehicle type	Annual mileage for new vehicles/km
LDPV	19,000
MDPV	43,800
HDPV	85,655
MC	6,919
HDB	98,495
TA	134,565
HDT	111,745
MDT	58,834
LDT	47,451
MT	62,539

Table S3. Mileage ratio by ages for different types of vehicles

Age	LDPV, MDPV & MC	TA	HDT, MDT & HDPV	LDT & MT	HDB
0-1	1.00	1.00	1.00	1.00	1.00
1-2	0.98	1.00	0.92	0.87	0.79
2-3	0.95	0.98	0.83	0.75	0.67
3-4	0.93	0.93	0.74	0.65	0.59
4-5	0.90	0.81	0.66	0.56	0.54
5-6	0.85	0.62	0.58	0.49	0.50
6-7	0.80	0.41	0.50	0.44	0.48
7-8	0.67	0.35	0.43	0.44	0.46
8-9	0.52	0.35	0.36	0.44	0.44
9-10	0.45	0.35	0.31	0.44	0.44
10-11	0.40	0.35	0.26	0.44	0.44
11-12	0.37	0.35	0.21	0.44	0.44
12-13	0.35	0.35	0.17	0.44	0.44
>13	0.35	0.35	0.17	0.44	0.44

3. Provincial contributions to national EV and ICEV production for different vehicle types in 2020-2050

The data of provincial vehicle production for different vehicle types is available in China Automotive Industry Yearbook 2021 [10], but the vehicle type in the yearbook is inconsistent with the vehicle classification in this study. The vehicles in the yearbook are classified as car, MPV, SUV, minibus, passenger vehicle, special vehicle, and truck. To eliminate the bias caused by different classification standards, we reclassified the vehicles and assumed that LDPV and TA were in the same category with car, MPV, SUV and minibus, defined as Category 1. MDPV, HDPV and HDB were in the same category with passenger vehicle, defined as Category 2. HDT, MDT, LDT and MT were in the same category with truck, defined as category 3. MC alone was defined as category 4. Provincial EV production share was calculated based on the production data of ICEVs and EVs in China Automotive Industry Yearbook 2021 (see Table S4), then power grid-level EV production share was calculated (see Table S5).

Table S4. The production share of vehicles in different categories and EV's production share of all vehicle types in each province in China in 2020-2050

Province	Vehicle production share (%)				
	Category 1	Category 2	Category 3	Category 4	EV
Beijing	5.156	1.184	3.779	0.000	0.938
Tianjin	4.804	0.056	0.000	0.000	2.426
Hebei	5.016	1.861	7.066	0.000	4.346
Shanxi	0.078	0.169	0.669	0.000	1.285
Inner Mongolia	0.074	0.000	0.296	0.000	0.029
Liaoning	5.008	0.508	0.306	0.000	2.830
Jilin	7.224	0.395	4.066	0.449	2.787
Heilongjiang	0.322	0.000	0.000	0.000	0.159
Shanghai	7.687	1.297	0.000	0.000	15.175

Jiangsu	5.840	25.550	1.749	13.481	7.970
Zhejiang	6.399	0.451	0.000	8.194	5.357
Anhui	3.452	3.046	4.754	0.000	7.595
Fujian	0.286	5.189	0.530	1.015	1.530
Jiangxi	0.358	30.908	4.658	0.000	0.693
Shandong	3.136	8.686	35.340	4.888	9.038
Henan	2.490	11.732	1.586	4.521	3.523
Hubei	8.466	2.538	7.209	0.000	1.617
Hunan	2.917	1.805	1.166	0.000	5.472
Guangdong	15.783	1.805	0.363	33.869	12.099
Guangxi	2.592	0.733	2.050	0.000	3.595
Hainan	0.002	0.000	0.000	0.000	0.000
Chongqing	6.664	0.000	14.467	32.281	4.736
Sichuan	3.983	1.466	3.583	0.000	0.693
Guizhou	0.359	0.338	0.005	0.000	0.231
Yunnan	0.002	0.226	0.492	0.000	0.072
Tibet	0.000	0.000	0.000	1.301	0.000
Shaanxi	1.854	0.056	5.609	0.000	5.775
Gansu	0.002	0.000	0.000	0.000	0.029
Qinghai	0.000	0.000	0.000	0.000	0.000
Ningxia	0.000	0.000	0.000	0.000	0.000
Xinjiang	0.045	0.000	0.253	0.000	0.000
National	100.000	100.000	99.995	100.000	100.000

Table S5. EV's production share at provincial and power grid levels between 2020 and 2050

Power grid region	Province	EV production share at provincial level (%)	EV production share at power grid level (%)
North	West IM*	0	
	Hebei	4	
	Beijing	1	9
	Tianjin	2	
	Shanxi	1	
Northeast	Shandong	9	
	Heilongjiang	0	
	Jilin	3	15
	Liaoning	3	
	East IM*	0	
Northwest	Shaanxi	6	
	Gansu	0	
	Qinghai	0	6
	Ningxia	0	
	Xinjiang	0	
	Tibet	0	

Central	Henan	4	17
	Sichuan	1	
	Chongqing	5	
	Hubei	2	
	Jiangxi	1	
	Hunan	5	
East	Shanghai	15	38
	Jiangsu	8	
	Zhejiang	5	
	Anhui	8	
	Fujian	2	
South	Guangdong	12	16
	Guangxi	4	
	Yunnan	0	
	Guizhou	0	
	Hainan	0	

*Due to the geographical characteristics of Inner Mongolia, it is divided into two parts: West Inner Mongolia (West IM) and East Inner Mongolia (East IM), as referred to hereafter.

4. Provincial contributions to national battery production for different vehicle types in 2020-2050

Lithium-ion NMC811 battery was selected as the mainstream battery type for EVs in China. According to the White Paper On the Development of China's Lithium-ion Battery Industry published in 2020 [13], 10 provinces (Henan, Anhui, Jiangsu, Tianjin, Jiangxi, Guangdong, Fujian, Chongqing, Hubei, and Sichuan) reported 88.8% of China's total Li-ion battery production in 2020, Hong Kong, Macau, and Taiwan were not considered. The remaining 11.2% of battery production came from regions except these 10 provinces in China, but the specific location information for these regions was unavailable. Therefore, we evenly distributed the 11.2% of battery production among these 10 provinces. As we assumed the distribution of battery production industry remains unchanged between 2020 and 2050. The adjusted battery production shares at the provincial and power grid levels in China for 2020-2050 are summarized in Table S6.

Table S6. Battery production share at provincial and power grid levels in 2020 and 2050.

Power grid region	Province	Battery production share at provincial level (%)	Battery production share at power grid level (%)
North	West IM	0	5
	Hebei	0	
	Beijing	0	
	Tianjin	5	
	Shanxi	0	
Northeast	Shandong	0	0
	Heilongjiang	0	

Northwest	Jilin	0	0
	Liaoning	0	
	East IM	0	
	Shaanxi	0	
	Gansu	0	
	Qinghai	0	
	Ningxia	0	
	Xinjiang	0	
Central	Tibet	0	35
	Henan	10	
	Sichuan	6	
	Chongqing	5	
	Hubei	7	
East	Jiangxi	7	33
	Hunan	0	
	Shanghai	0	
	Jiangsu	16	
	Zhejiang	0	
South	Anhui	5	27
	Fujian	11	
	Guangdong	27	
	Guangxi	0	
	Yunnan	0	
	Guizhou	0	
	Hainan	0	

5. Weight of vehicle and battery for each vehicle type/technology

Table S7. The weight of vehicle components for each vehicle type with different fuel/technology types

	Fuel/powertrain type	Weight without battery (kg)	Battery weight (kg)	Curb weight (kg)
LDPV	Gasoline	1,340	0	1,340
	PHEV	1,534	116	1,650
	BEV	1,271	354	1,625
MDPV	Gasoline	3,510	0	3,510
	PHEV	3,510	265	3,775
	BEV	3,598	1,002	4,600
HDPV	Diesel	10,900	0	10,900
	BEV	9,073	2,527	11,600
LDT	Gasoline	2,120	0	2,120
	Diesel	4,300	0	4,300
	CNG	4,365	0	4,365
	BEV	2,315	680	2,995

MDT	Diesel	7,880	0	7,880
	BEV	6,101	1,699	7,800
HDT	Diesel	10,515	0	10,515
	CNG	10,600	0	10,600
	BEV	8,760	2,440	11,200
MT	Gasoline	1,500	0	1,500
	Diesel	1,500	0	1,500
	CNG	1,500	0	1,500
	BEV	1,212	338	1,550
HDB	Gasoline	12,900	0	12,900
	Diesel	12,900	0	12,900
	CNG	12,900	0	12,900
	PHEV	11,993	907	12,900
	BEV	10,090	2,810	12,900
TA	Gasoline	1,340	0	1,340
	CNG	1,340	0	1,340
	BEV	1,271	354	1,625
MC	Gasoline	94	0	94
	BEV	74	20	94

6. CO₂ emission factors estimation

6.1 CO₂ emission factors for vehicle energy supply chains, vehicle production, and battery production

Provincial CO₂ emissions emission factors under different RE expansion pathways in 2020-2050 for the vehicle energy supply chain (see Table S8 for gasoline, diesel, and natural gas supply chains and see Table S9 for electricity supply chain), vehicle production (without battery) (see Tables S10-S16), and battery production (see Table S17) were estimated by modelling the corresponding processes based on existing life cycle inventory (LCI) datasets from Ecoinvent V3.8 [48] in the LCA software OpenLCA 1.11 [49]. These emission factors are summarized in the attached excel files, details as below:

Table number	Content
S8	Emission factors of diesel, gasoline, and natural gas production
S9	Emission factors of electricity supply chain under different RE scenarios
S10	Emission factors of diesel vehicle manufacturing
S11	Emission factors of gasoline and natural gas vehicle manufacturing
S12	Emission factors of bus manufacturing
S13	Emission factors of medium-duty truck manufacturing
S14	Emission factors of heavy-duty truck manufacturing
S15	Emission factors of electric vehicle manufacturing
S16	Emission factors of electric motorcycle manufacturing
S17	Emission factors of battery manufacturing

6.2 CO₂ emission factors for ICEVs during vehicle use phase

The CO₂ emission factors by transport fuel use of gasoline, diesel, E-G (E10 ethanol gasoline), and CNG (Other fuels were assumed as CNG due to LPG, LNG and biofuels account for quite small share

compared to CNG in this study) are 2.27kg/L [18], 2.68 kg/L, 2.19 kg /L, and 1.88kg/m³ [19], respectively. Fuel consumption rate refers to Table S1. Therefore, CO₂ emission factors for ICEVs powered by different types of fuels per 100km can be calculated by equation (2), which has been summarized in Table S18.

$$\begin{aligned} \text{CO}_2 \text{ Emission factor}_{v,f,p,y,t} \\ = \text{CO}_2 \text{ Emission factor by fuels}_{v,f,p,y,t} \times \text{Fuel consumption rate}_{v,f,p,y,t} \quad (2) \end{aligned}$$

Table S18. CO₂ emission factors for different types of ICEVs in 2020-2050

Vehicle type	Fuel type	CO ₂ emission factors for ICEVs (kg/100km)						
		2020	2025	2030	2035	2040	2045	2050
LDPV	Gasoline	18.61	17.93	17.48	16.57	15.66	14.76	14.07
	PHEV	8.63	8.40	8.17	7.72	7.26	7.04	6.58
MDPV	Gasoline	30.87	29.74	28.83	27.24	25.88	24.52	23.15
	PHEV	14.14	13.63	13.23	12.52	11.91	11.30	10.69
HDPV	Diesel	83.08	80.94	79.06	77.45	75.84	74.24	72.63
HDT	Diesel	72.90	71.02	69.14	67.00	65.12	63.78	62.44
	CNG	91.73	89.36	87.01	84.37	82.02	80.18	78.62
MDT	Diesel	44.22	43.42	42.88	41.54	40.20	39.13	38.06
	Gasoline	37.46	36.77	36.32	35.19	34.05	33.14	32.23
LDT	Diesel	35.91	35.11	34.30	32.96	31.62	30.28	28.94
	Gasoline	26.11	25.42	24.74	23.84	22.93	22.02	20.88
	CNG	15.45	14.93	14.42	13.63	12.84	12.50	11.52
MT	Diesel	22.78	22.24	21.71	20.90	20.10	19.30	18.49
	Gasoline	19.52	19.30	18.84	17.93	17.25	16.57	15.89
	CNG	16.22	15.72	15.45	14.95	14.42	13.63	13.10
HDB	Diesel	73.43	71.56	69.95	68.34	67.00	65.66	64.32
	Gasoline	71.05	69.46	67.65	66.28	64.92	63.56	62.20
	CNG	98.32	95.88	93.62	91.56	89.68	87.80	86.10
	PHEV-CNG	36.17	35.38	34.33	33.80	33.01	32.24	31.72
	HEV-D	59.23	57.89	56.55	55.21	54.14	53.06	51.99
TA	Diesel	21.98	21.44	20.64	19.56	18.49	17.42	16.62
	Gasoline	18.61	17.93	17.48	16.57	15.66	14.76	14.07
	E-G (E10)	19.71	19.05	18.62	17.52	16.64	15.77	14.89
	CNG	14.95	14.95	14.42	13.16	12.84	12.31	11.52

MC	Gasoline	5.68	5.45	5.22	4.99	4.77	4.54	4.31
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7. Provincial fleet life cycle CO₂ emissions and contributions of each power grid region to national CO₂ emissions for each life cycle stage in 2020 and under various scenarios in 2050

Table S19. CO₂ emissions from China's road transport in different life cycle stages at provincial and power grid levels in the base year 2020 (Mt)

Region	Province	Vehicle energy supply chain	Vehicle production	Battery production	Vehicle use	Total
North	West IM	1.1	0.3	0.0	17.6	308.2
	Hebei	6.9	24.0	0.0	108.2	
	Beijing	2.3	19.1	0.0	29.9	
	Tianjin	2.6	14.9	2.8	17.9	
	Shanxi	6.4	13.3	0.0	41.0	
Northeast	Shandong	11.8	52.0	0.0	151.0	412.7
	Heilongjiang	4.2	1.0	0.0	33.4	
	Jilin	2.5	27.3	0.0	27.2	
	Liaoning	14.3	16.1	0.0	52.7	
	East IM	1.1	0.3	0.0	17.6	
Northwest	Shaanxi	6.4	13.3	0.0	41.0	155.1
	Gansu	3.8	0.0	0.0	24.0	
	Qinghai	0.3	0.0	0.0	8.2	
	Ningxia	1.8	0.0	0.0	12.3	
	Xinjiang	4.5	0.4	0.0	32.9	
	Tibet	0.2	0.0	0.0	5.8	
Central	Henan	4.1	11.4	5.4	98.0	506.1
	Sichuan	4.3	16.2	3.3	69.4	
	Chongqing	1.5	41.7	2.8	31.1	
	Hubei	4.1	33.4	3.9	54.7	
	Jiangxi	2.9	8.1	3.7	41.6	
	Hunan	2.9	11.5	0.0	50.2	
East	Shanghai	5.8	26.9	0.0	22.9	442.6
	Jiangsu	8.3	24.7	9.0	97.4	
	Zhejiang	5.0	21.6	0.0	82.0	
	Anhui	3.3	17.6	2.9	62.5	
	Fujian	3.9	2.3	6.2	40.4	
South	Guangdong	7.1	55.3	15.1	125.8	361.5
	Guangxi	5.0	10.9	0.0	42.7	
	Yunnan	4.6	0.6	0.0	48.7	
	Guizhou	1.2	1.1	0.0	32.7	
	Hainan	2.1	0.0	0.0	8.6	
National total		136.2	465.4	55.1	1529.6	2186.2

Table S20. CO₂ emissions from China's road transport in different life cycle stages at provincial and power grid levels under the Baseline RE-Baseline EV scenario in 2050 (Mt)

Region	Province	Vehicle energy supply chain	Vehicle production	Battery production	Vehicle use	Total
North	West IM	1.6	0.2	0.0	18.2	295.0
	Hebei	10.3	19.4	0.0	111.1	
	Beijing	2.9	15.6	0.0	22.4	
	Tianjin	3.1	12.3	2.4	15.5	
	Shanxi	6.9	10.6	0.0	42.4	
Northeast	Shandong	15.6	40.4	0.0	147.6	411.6
	Heilongjiang	5.4	0.8	0.0	39.9	
	Jilin	3.4	22.3	0.0	30.0	
	Liaoning	16.8	13.4	0.0	56.1	
	East IM	1.6	0.2	0.0	18.2	
Northwest	Shaanxi	6.9	10.6	0.0	42.4	159.1
	Gansu	4.0	0.0	0.0	27.0	
	Qinghai	0.4	0.0	0.0	8.6	
	Ningxia	2.0	0.0	0.0	12.7	
	Xinjiang	4.8	0.3	0.0	31.1	
Central	Tibet	0.4	0.0	0.0	7.9	530.9
	Henan	4.5	9.5	4.7	109.0	
	Sichuan	4.0	13.2	2.8	78.5	
	Chongqing	1.1	32.0	2.4	33.4	
	Hubei	4.3	27.2	3.3	62.9	
East	Jiangxi	3.0	7.3	3.2	50.1	436.2
	Hunan	3.2	9.6	0.0	61.6	
	Shanghai	6.2	22.5	0.0	31.8	
	Jiangsu	10.3	20.7	7.7	93.9	
	Zhejiang	6.3	17.6	0.0	74.3	
South	Anhui	4.4	14.4	2.5	67.1	364.0
	Fujian	4.8	2.0	5.3	44.2	
	Guangdong	6.4	44.5	12.9	128.3	
	Guangxi	4.6	8.9	0.0	49.3	
	Yunnan	4.0	0.5	0.0	55.0	
	Guizhou	0.8	1.0	0.0	36.0	
	Hainan	2.1	0.0	0.0	9.7	
National total		156.3	377.1	47.2	1616.2	2196.8

Table S21. CO₂ emissions from China's road transport in different life cycle stages at provincial and power grid levels under the Baseline RE-Fast EV scenario in 2050 (Mt).

Region	Province	Vehicle energy supply chain	Vehicle production	Battery production	Vehicle use	Total
North	West IM	18.7	0.1	0.0	0.0	294.2
	Hebei	113.4	17.2	0.0	0.0	
	Beijing	14.8	3.6	0.0	0.0	
	Tianjin	13.7	9.5	42.4	0.0	
	Shanxi	37.9	22.9	0.0	0.0	
Northeast	Shandong	151.8	36.3	0.0	0.0	372.8
	Heilongjiang	57.5	5.2	0.0	0.0	
	Jilin	27.8	11.2	0.0	0.0	
	Liaoning	53.0	11.2	0.0	0.0	
	East IM	18.7	0.1	0.0	0.0	
Northwest	Shaanxi	37.9	22.9	0.0	0.0	136.4
	Gansu	21.4	0.1	0.0	0.0	
	Qinghai	7.5	0.0	0.0	0.0	
	Ningxia	12.6	0.0	0.0	0.0	
	Xinjiang	28.3	0.0	0.0	0.0	
	Tibet	5.8	0.0	0.0	0.0	
Central	Henan	96.0	14.2	82.6	0.0	698.1
	Sichuan	69.9	2.8	50.0	0.0	
	Chongqing	33.7	21.0	42.5	0.0	
	Hubei	50.4	6.3	59.1	0.0	
	Jiangxi	42.0	2.7	56.6	0.0	
	Hunan	46.8	21.5	0.0	0.0	
East	Shanghai	32.3	59.4	0.0	0.0	692.2
	Jiangsu	82.9	32.3	136.1	0.0	
	Zhejiang	63.0	21.6	0.0	0.0	
	Anhui	55.7	29.7	44.1	0.0	
	Fujian	34.7	6.1	94.3	0.0	
South	Guangdong	101.6	49.9	229.0	0.0	519.0
	Guangxi	38.6	14.1	0.0	0.0	
	Yunnan	50.8	0.3	0.0	0.0	
	Guizhou	26.6	0.9	0.0	0.0	
	Hainan	7.2	0.0	0.0	0.0	
National total		1452.7	423.1	836.9	0.0	2712.6

Table S22. CO₂ emissions from China's road transport in different life cycle stages at provincial and power grid levels under the Fast RE-Medium EV scenario in 2050 (Mt).

Region	Province	Vehicle energy supply chain	Vehicle production	Battery production	Vehicle use	Total
North	West IM	0.6	0.0	0.0	2.3	117.3
	Hebei	3.8	13.9	0.0	13.9	
	Beijing	0.3	3.0	0.0	2.4	
	Tianjin	0.3	7.7	41.7	1.9	
	Shanxi	1.8	18.5	0.0	5.1	
Northeast	Shandong	5.0	29.3	0.0	18.4	102.0
	Heilongjiang	1.8	4.1	0.0	5.7	
	Jilin	1.0	9.0	0.0	3.9	
	Liaoning	4.3	9.1	0.0	7.5	
	East IM	0.6	0.0	0.0	2.3	
Northwest	Shaanxi	1.8	18.5	0.0	5.1	38.6
	Gansu	1.0	0.1	0.0	3.4	
	Qinghai	0.0	0.0	0.0	1.1	
	Ningxia	0.6	0.0	0.0	1.5	
	Xinjiang	0.6	0.0	0.0	3.9	
	Tibet	0.0	0.0	0.0	1.0	
Central	Henan	5.1	11.7	81.2	14.4	403.5
	Sichuan	0.6	2.2	49.1	11.1	
	Chongqing	1.8	17.5	41.7	3.3	
	Hubei	1.8	5.2	58.1	8.0	
	Jiangxi	0.4	2.2	55.6	6.5	
	Hunan	0.5	17.4	0.0	8.0	
	East IM	0.6	0.0	0.0	2.3	
East	Shanghai	1.6	48.6	0.0	3.1	440.6
	Jiangsu	2.5	26.4	133.8	12.6	
	Zhejiang	3.7	17.9	0.0	8.8	
	Anhui	2.0	24.3	43.3	8.4	
	Fujian	0.6	4.9	92.6	5.4	
South	Guangdong	5.6	41.3	225.2	15.9	321.6
	Guangxi	0.6	11.4	0.0	6.4	
	Yunnan	0.6	0.2	0.0	6.8	
	Guizhou	0.8	0.7	0.0	4.4	
	Hainan	0.5	0.0	0.0	1.2	
National total		52.1	345.4	822.4	203.7	1423.6

Table S23. CO₂ emissions from China's road transport in different life cycle stages at provincial and power grid levels under the Fast RE-Fast EV scenario in 2050 (Mt)

Region	Province	Vehicle energy supply chain	Vehicle production	Battery production	Vehicle use	Total
North	West IM	0.6	0.0	0.0	0.0	90.5
	Hebei	3.7	13.9	0.0	0.0	
	Beijing	0.1	3.0	0.0	0.0	
	Tianjin	0.1	7.7	41.7	0.0	
	Shanxi	1.2	18.5	0.0	0.0	
Northeast	Shandong	4.8	29.3	0.0	0.0	62.4
	Heilongjiang	1.7	4.1	0.0	0.0	
	Jilin	0.8	9.0	0.0	0.0	
	Liaoning	2.9	9.1	0.0	0.0	
	East IM	0.6	0.0	0.0	0.0	
Northwest	Shaanxi	1.2	18.5	0.0	0.0	21.2
	Gansu	0.7	0.1	0.0	0.0	
	Qinghai	0.0	0.0	0.0	0.0	
	Ningxia	0.4	0.0	0.0	0.0	
	Xinjiang	0.2	0.0	0.0	0.0	
	Tibet	0.1	0.0	0.0	0.0	
Central	Henan	5.5	11.7	81.2	0.0	351.9
	Sichuan	0.4	2.2	49.1	0.0	
	Chongqing	1.9	17.5	41.7	0.0	
	Hubei	1.7	5.2	58.1	0.0	
	Jiangxi	0.3	2.2	55.6	0.0	
	Hunan	0.3	17.4	0.0	0.0	
	East IM	0.6	0.0	0.0	0.0	
East	Shanghai	1.1	48.6	0.0	0.0	400.9
	Jiangsu	2.0	26.4	133.8	0.0	
	Zhejiang	3.7	17.9	0.0	0.0	
	Anhui	1.9	24.3	43.3	0.0	
	Fujian	0.2	4.9	92.6	0.0	
South	Guangdong	5.9	41.3	225.2	0.0	286.4
	Guangxi	0.2	11.4	0.0	0.0	
	Yunnan	0.3	0.2	0.0	0.0	
	Guizhou	0.9	0.7	0.0	0.0	
	Hainan	0.2	0.0	0.0	0.0	
National total		45.5	345.4	822.4	0.0	1213.3

Table S24. Contributions of different life cycle stages to CO₂ emissions for each power grid region in the base year 2020.

Region	Contributions of power grid regions to national CO ₂ emissions for each life cycle (%)			
	Vehicle energy	Vehicle production without	Battery	Vehicle
	supply chain	Battery	production	use
North	6.3	23.2	0.7	69.6
Northeast	8.2	23.4	0.0	68.3
Northwest	11.0	8.8	0.0	80.2
Central	3.9	24.2	3.8	68.2
East	5.9	21.0	4.1	68.9
South	5.5	18.8	4.2	71.5

Table S25. Contributions of different life cycle stages to CO₂ emissions for each power grid region under the Baseline RE-Baseline EV scenario in 2050.

Region	Contributions of power grid regions to national CO ₂ emissions for each life cycle (%)			
	Vehicle energy	Vehicle production without	Battery	Vehicle
	supply chain	Battery	production	use
North	8.4	19.7	0.6	71.1
Northeast	10.4	18.7	0.0	70.9
Northwest	11.6	6.9	0.0	81.5
Central	3.8	18.6	3.1	74.5
East	7.3	17.7	3.6	71.4
South	4.9	15.1	3.5	76.5

Table S26. Contributions of different life cycle stages to CO₂ emissions for each power grid region under the Baseline RE-Fast EV scenario in 2050.

Region	Contributions of power grid regions to national CO ₂ emissions for each life cycle (%)			
	Vehicle energy	Vehicle production without	Battery	Vehicle
	supply chain	Battery	production	use
North	67.5	18.1	11.4	0.0
Northeast	82.8	17.2	0.0	0.0
Northwest	83.2	16.8	0.0	0.0
Central	48.5	9.8	41.7	0.0
East	38.8	21.5	39.7	0.0
South	43.3	12.6	44.1	0.0

Table S27. Contributions of different life cycle stages to CO₂ emissions for each power grid region under the Fast RE-Medium EV scenario in 2050

Contributions of power grid regions to national CO ₂ emissions for each life cycle (%)				
Region	Vehicle energy supply chain	Vehicle production without Battery	Battery production	Vehicle use
North	5.8	36.8	40.9	21.8
Northeast	12.5	50.5	0.0	37.1
Northwest	10.4	48.2	0.0	41.5
Central	2.5	13.9	70.8	12.7
East	2.4	27.7	61.2	8.7
South	2.5	16.7	70.0	10.8

Table S28. Contributions of different life cycle stages to CO₂ emissions for each power grid region under the Fast RE-Fast EV scenario in 2050.

Contributions of power grid regions to national CO ₂ emissions for each life cycle (%)				
Region	Vehicle energy supply chain	Vehicle production without Battery	Battery production	Vehicle use
North	6.3	47.6	66.9	0.0
Northeast	17.3	82.7	0.0	0.0
Northwest	12.3	87.7	0.0	0.0
Central	2.9	16.0	81.2	0.0
East	2.2	30.5	67.3	0.0
South	2.6	18.7	78.7	0.0

9. Contributions of different power grid regions to national CO₂ emissions for each life cycle in 2020 and under scenarios in 2050

Table S29. Contributions of different power grid regions to national CO₂ emissions for each life cycle in the base year 2020

Contributions of power grid regions to national CO ₂ emissions for each life cycle (%)				
Region	Vehicle energy supply chain	Vehicle production without Battery	Battery production	Vehicle use
North	14.1	15.4	5.1	14.0
Northeast	24.9	20.8	0.0	18.4
Northwest	12.5	2.9	0.0	8.1
Central	14.5	26.3	34.8	22.6
East	19.2	20.0	32.8	20.0
South	14.7	14.6	27.4	16.9

Table S30. Contributions of different power grid regions to national CO₂ emissions for each life cycle under the Baseline RE-Baseline EV scenario in 2050.

Region	Contributions of power grid regions to national CO ₂ emissions for each life cycle (%)			
	Vehicle energy	Vehicle production without	Battery	Vehicle
	supply chain	Battery	production	use
North	15.9	15.4	5.1	13.0
Northeast	27.4	20.5	0.0	18.0
Northwest	11.8	2.9	0.0	8.0
Central	12.9	26.2	34.8	24.5
East	20.6	20.5	32.8	19.3
South	11.5	14.6	27.4	17.2

Table S31. Contributions of different power grid regions to national CO₂ emissions for each life cycle under the Baseline RE-Fast EV scenario in 2050.

Region	Contributions of power grid regions to national CO ₂ emissions for each life cycle (%)			
	Vehicle energy	Vehicle production without	Battery	Vehicle
	supply chain	Battery	production	use
North	13.7	12.6	5.1	0.0
Northeast	21.3	15.1	0.0	0.0
Northwest	7.8	5.4	0.0	0.0
Central	23.3	16.2	34.8	0.0
East	18.5	35.2	32.8	0.0
South	15.5	15.4	27.4	0.0

Table S32. Contributions of different power grid regions to national CO₂ emissions for each life cycle under the Fast RE-Medium EV scenario in 2050.

Region	Contributions of power grid regions to national CO ₂ emissions for each life cycle (%)			
	Vehicle	Vehicle production without	Battery	Vehicle
	energy supply chain	Battery	production	use
North	13.2	12.5	5.1	12.6
Northeast	24.2	14.9	0.0	18.6
Northwest	7.7	5.4	0.0	7.8
Central	19.7	16.2	34.7	25.2
East	19.8	35.4	32.8	18.8
South	15.5	15.6	27.4	17.0

Table S33. Contributions of different power grid regions to national CO₂ emissions for each life cycle under the Fast RE-Fast EV scenario in 2050.

Region	Contributions of power grid regions to national CO ₂ emissions for each life cycle (%)			
	Vehicle energy	Vehicle production without	Battery	Vehicle
	supply chain	Battery	production	use
North	12.4	12.5	5.1	0.0
Northeast	23.8	14.9	0.0	0.0
Northwest	5.6	5.4	0.0	0.0
Central	22.0	16.2	34.7	0.0
East	19.6	35.4	32.8	0.0
South	16.6	15.6	27.4	0.0

10. National fleet life cycle CO₂ emissions in 2050 with regional prioritization in vehicle electrification and RE expansion

Table S34. Fleet life cycle CO₂ emissions with different regional prioritized RE expansion and EV development strategies in 2050 (Mt)

Prioritizing vehicle electrification in the North, Northeast, and Northwest (NNN) regions	Scenarios in the NNN regions in 2050	CO ₂ emissions	Scenarios in the CES regions in 2050	CO ₂ emissions	Total CO ₂ emissions
Prioritizing vehicle electrification in the Central, East, and South (CES) regions	Baseline RE-Fast EV	778	Baseline RE-Baseline EV	1,331	2,109
	Fast RE-Medium EV	239	Baseline RE-Baseline EV	1,331	1,570
	Fast RE-Fast EV	155	Baseline RE-Baseline EV	1,331	1,486
	Baseline RE-Fast EV	778	Fast RE-Medium EV	1,166	1,944
	Fast RE-Fast EV	155	Fast RE-Medium EV	1,166	1,321
Synchronizing vehicle electrification in all regions	Baseline RE-Baseline EV	862	Baseline RE-Fast EV	1,909	2,771
	Baseline RE-Baseline EV	862	Fast RE-Medium EV	1,166	2,028
	Baseline RE-Baseline EV	862	Fast RE-Fast EV	1,039	1,901
	Fast RE-Medium EV	239	Baseline RE-Fast EV	1,909	2,148
	Fast RE-Medium EV	239	Fast RE-Fast EV	1,039	1,278
	Fast RE-Fast EV	155	Baseline RE-Fast EV	1,909	2,064
	Baseline RE-Fast EV	778	Fast RE-Fast EV	1,039	1,817
	Fast RE-Fast EV	155	Fast RE-Fast EV	1,039	1,194
	Fast RE-Medium EV	239	Fast RE-Medium EV	1,166	1,405
	Baseline RE-Fast EV	778	Baseline RE-Fast EV	1,909	2,687

Table S35. Fleet CO₂ emissions for each life cycle stage in 2020 and different regionally prioritized EV and RE development strategies in 2050

Regional prioritized EV development and RE expansion strategies		Vehicle energy supply chain	Vehicle production	Battery production	Vehicle use
Base year 2020		136.2	465.4	55.1	1529.6
Synchronizing vehicle electrification in all regions with different RE expansion pathways in 2050	NNN:Baseline RE-Fast EV + CES:Baseline RE-Fast EV	1453	423.1	836.7	0
	NNN:Fast RE-Medium EV + CES:Fast RE-Medium EV	52.2	345.1	822.3	203.7
	NNN:Fast RE-Fast EV + CES:Fast RE-Fast EV	45.6	345.1	822.3	0
	NNN:Baseline RE-Fast EV + CES:Fast RE-Fast EV	647.3	372.2	823	0
	NNN:Fast RE-Fast EV + CES:Baseline RE-Fast EV	851.3	396	836	0
Prioritizing vehicle electrification in the Central, East, and South regions with different RE expansion pathways in 2050	CES:Baseline RE-Fast EV + NNN:Baseline RE-Baseline EV	918.3	428.9	796.7	631.1
	CES:Fast RE-Medium EV + NNN:Baseline RE-Baseline EV	114.8	378	783	755.4
	CES:Fast RE-Fast EV + NNN:Baseline RE-Baseline EV	112.6	378	783	631.1
	CES:Baseline RE-Fast EV + NNN:Fast RE-Medium EV	855.7	396	836	79.4
	CES:Fast RE-Fast EV + NNN:Fast RE-Medium EV	50	345.1	822.3	79.4
Prioritizing vehicle electrification in the North, Northeast, and Northwest regions with different RE expansion pathways in 2050	NNN:Baseline RE-Fast EV + CES:Baseline RE-Baseline EV	690.8	371.2	87.2	985.1
	NNN:Fast RE-Medium EV + CES:Baseline RE-Baseline EV	93.5	344.1	86.5	1064.5
	NNN:Fast RE-Fast EV + CES:Baseline RE-Baseline EV	89.1	344.1	86.5	985.1
	NNN:Baseline RE-Fast EV + CES:Fast RE-Medium EV	649.5	372.2	823	124.3
	NNN:Fast RE-Fast EV + CES:Fast RE-Medium EV	47.8	345.1	822.3	124.3

Table S36. Fleet life cycle CO₂ emissions from different vehicle types when prioritizing vehicle electrification in the North, Northeast, and Northwest regions in 2050 and the base year 2020

Regional prioritized RE and EV development strategies	CO ₂ emissions from vehicle types (Mt)										
	LDPV	MDPV	HDPV	HDB	TA	HDT	MDT	LDT	MT	MC	Total
Base year 2020	1,087	11	80	35	25	508	32	359	0	48	2,186
NNN: Baseline RE-Fast EV + CES: Baseline RE-Baseline EV in 2050	986	7	65	51	25	679	24	269	0	30	2,136
NNN: Fast RE-Medium EV + CES: Baseline RE-Baseline EV in 2050	854	6	53	39	16	364	19	209	0	28	1,589
NNN: Fast RE-Fast EV + CES: Baseline RE-Baseline EV in 2050	813	6	50	38	16	338	18	198	0	28	1,505
NNN: Baseline RE-Fast EV + CES: Fast RE-Medium EV in 2050	1,018	7	46	34	16	563	24	237	0	23	1,969
NNN: Fast RE-Fast EV + CES: Fast RE-Medium EV in 2050	846	6	32	21	7	222	18	166	0	22	1,340

Note: NNN refers to the North, Northeast, and Northwest power grid regions, while CES refers to the Central, East, and South power grid regions, as used hereafter.

Table S37. Contributions of vehicle types to fleet life cycle CO₂ emissions when prioritizing vehicle electrification in the North, Northeast, and Northwest regions in 2050 and the base year 2020

Regional prioritized RE and EV development	Contributions of vehicle types to CO ₂ emissions (%)									
	LDPV	MDPV	HDPV	HDB	TA	HDT	MDT	LDT	MT	MC
Base year 2020	50	0	4	2	1	23	1	16	0	2
NNN: Baseline RE-Fast EV + CES: Baseline RE-Baseline EV in 2050	46	0	3	2	1	32	1	13	0	1
NNN: Fast RE-Medium EV + CES: Baseline RE-Baseline EV in 2050	54	0	3	2	1	23	1	13	0	2
NNN: Fast RE-Fast EV + CES: Baseline RE-Baseline EV in 2050	54	0	3	3	1	22	1	13	0	2
NNN: Baseline RE-Fast EV + CES: Fast RE-Medium EV in 2050	52	0	2	2	1	29	1	12	0	1
NNN: Fast RE-Fast EV + CES: Fast RE-Medium EV in 2050	63	0	2	2	1	17	1	12	0	2

Table S38. Fleet life cycle CO₂ emissions from different vehicle types when prioritizing vehicle electrification in the Central, East, and South regions in 2050 and the base year 2020

Regional prioritized RE and EV development strategies	CO ₂ emissions from vehicle types (Mt)										
	LDPV	MDPV	HDPV	HDB	TA	HDT	MDT	LDT	MT	MC	Total
Base year 2020	1,087	11	80	35	25	508	32	359	0	48	2,186
CES: Baseline RE-Fast EV + NNN: Baseline RE-Baseline EV	1,348	10	75	58	27	814	36	372	0	32	2,771
CES: Fast RE-Medium EV + NNN: Baseline RE-Baseline EV	1,119	8	55	34	19	462	26	278	0	27	2,028
CES: Fast RE-Fast EV + NNN: Baseline RE-Baseline EV	1,047	8	52	33	18	431	25	263	0	25	1,901
CES: Baseline RE-Fast EV + NNN: Fast RE-Medium EV	1,117	8	54	45	16	600	29	271	0	27	2,167
CES: Fast RE-Fast EV + NNN: Fast RE-Medium EV	815	6	30	21	7	217	18	162	0	21	1,297

Table S39. Contributions of vehicle types to fleet life cycle CO₂ emissions when prioritizing vehicle electrification in the Central, East, and South regions in 2050 and the base year 2020

Regional prioritized RE and EV development	Contributions of vehicle types to CO ₂ emissions (%)									
	LDPV	MDPV	HDPV	HDB	TA	HDT	MDT	LDT	MT	MC
Base year 2020	50	0	4	2	1	23	1	16	0	2
CES: Baseline RE-Fast EV + NNN: Baseline RE-Baseline EV	49	0	3	2	1	29	1	13	0	1
CES: Fast RE-Medium EV + NNN: Baseline RE-Baseline EV	55	0	3	2	1	23	1	14	0	1
CES: Fast RE-Fast EV + NNN: Baseline RE-Baseline EV	55	0	3	2	1	23	1	14	0	1
CES: Baseline RE-Fast EV + NNN: Fast RE-Medium EV	52	0	2	2	1	28	1	12	0	1
CES: Fast RE-Fast EV + NNN: Fast RE-Medium EV	63	0	2	2	1	17	1	13	0	2

Table S40. Fleet life cycle CO₂ emissions from different vehicle types when synchronizing vehicle electrification in all regions in 2050 and the base year 2020.

Regional prioritized RE and EV development strategies	CO ₂ emissions from vehicle types (Mt)										
	LDPV	MDPV	HDPV	HDB	TA	HDT	MDT	LDT	MT	MC	Total
Base year 2020	1,087	11	80	35	25	508	32	359	0	48	2,186
NNN: Baseline RE-Fast EV + CES: Baseline RE-Fast EV	1,248	9	66	57	25	915	34	331	0	28	2,713
NNN: Fast RE-Medium EV + CES: Fast RE-Medium EV	888	6	34	22	8	248	19	177	0	22	1,424
NNN: Fast RE-Fast EV + CES: Fast RE-Fast EV	774	5	28	20	6	191	17	151	0	20	1,213
NNN: Fast RE-Fast EV + CES: Baseline RE-Fast EV	1,075	7	51	44	16	574	28	260	0	27	2,083
NNN: Baseline RE-Fast EV + CES: Fast RE-Fast EV	946	7	43	33	15	532	23	222	0	22	1,843

Table S41. Contributions of vehicle types to fleet life cycle CO₂ emissions when synchronizing vehicle electrification in all regions in 2050 and the base year 2020

Regional prioritized RE and EV development	Contributions of vehicle types to CO ₂ emissions (%)									
	LDPV	MDPV	HDPV	HDB	TA	HDT	MDT	LDT	MT	MC
Base year 2020	50	0	4	2	1	23	1	16	0	2
NNN: Baseline RE-Fast EV + CES: Baseline RE-Fast EV	46	0	2	2	1	34	1	12	0	1
NNN: Fast RE-Medium EV + CES: Fast RE-Medium EV	62	0	2	2	1	17	1	12	0	2
NNN: Fast RE-Fast EV + CES: Fast RE-Fast EV	64	0	2	2	1	16	1	12	0	2
NNN: Fast RE-Fast EV + CES: Baseline RE-Fast EV	52	0	2	2	1	28	1	12	0	1
NNN: Baseline RE-Fast EV + CES: Fast RE-Fast EV	51	0	2	2	1	29	1	12	0	1