

*Supplement of*

**Modeling fuel, vehicle- type, and age specific CO<sub>2</sub> emissions from  
global on-road vehicles during 1970-2020**

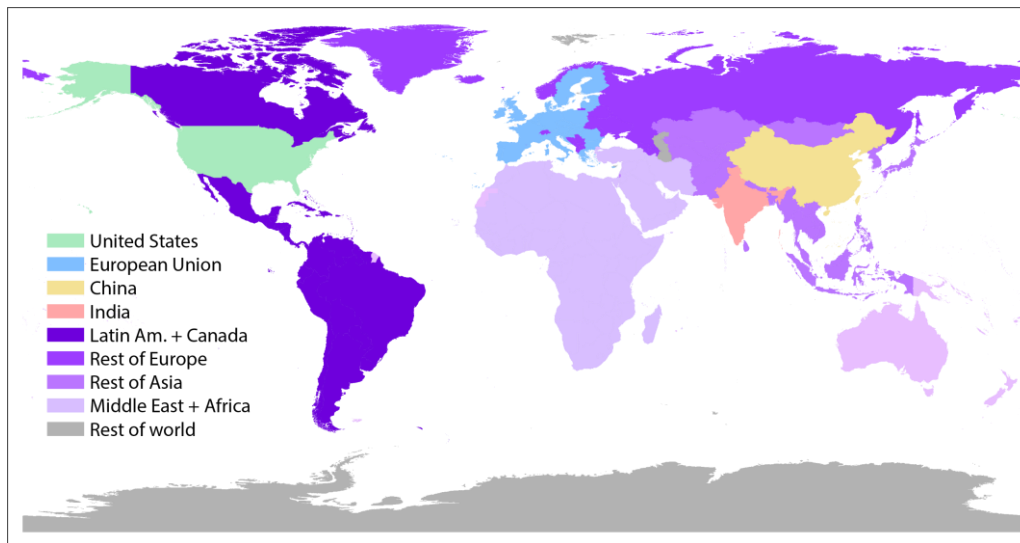
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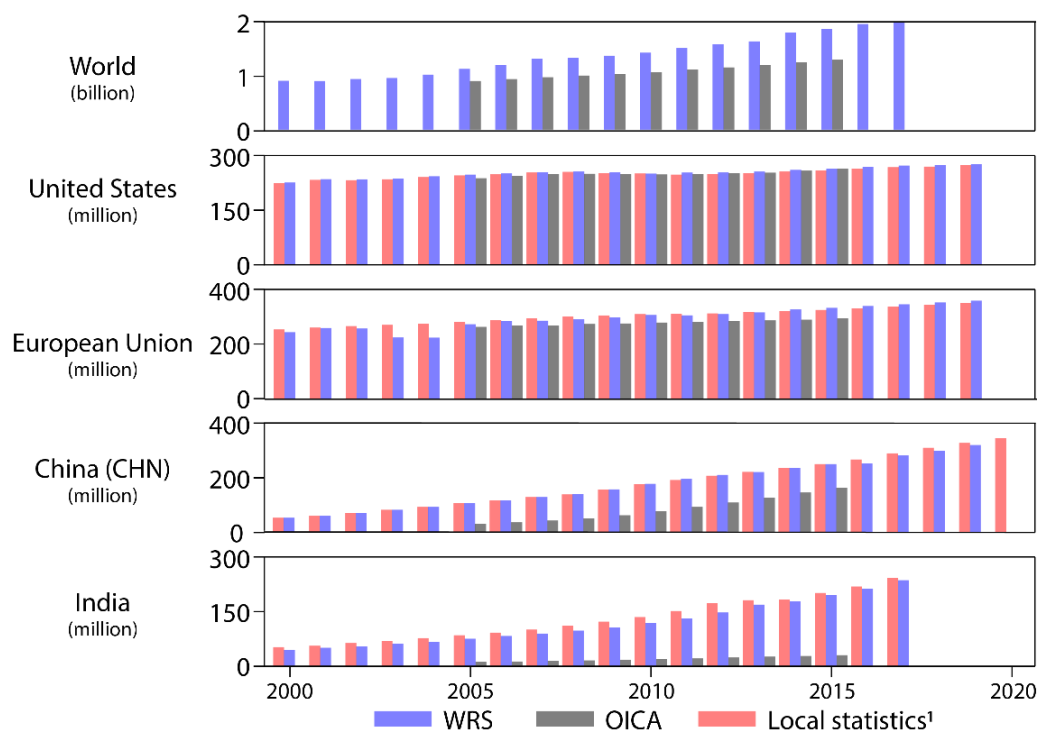
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**Figure S1. Region definition**

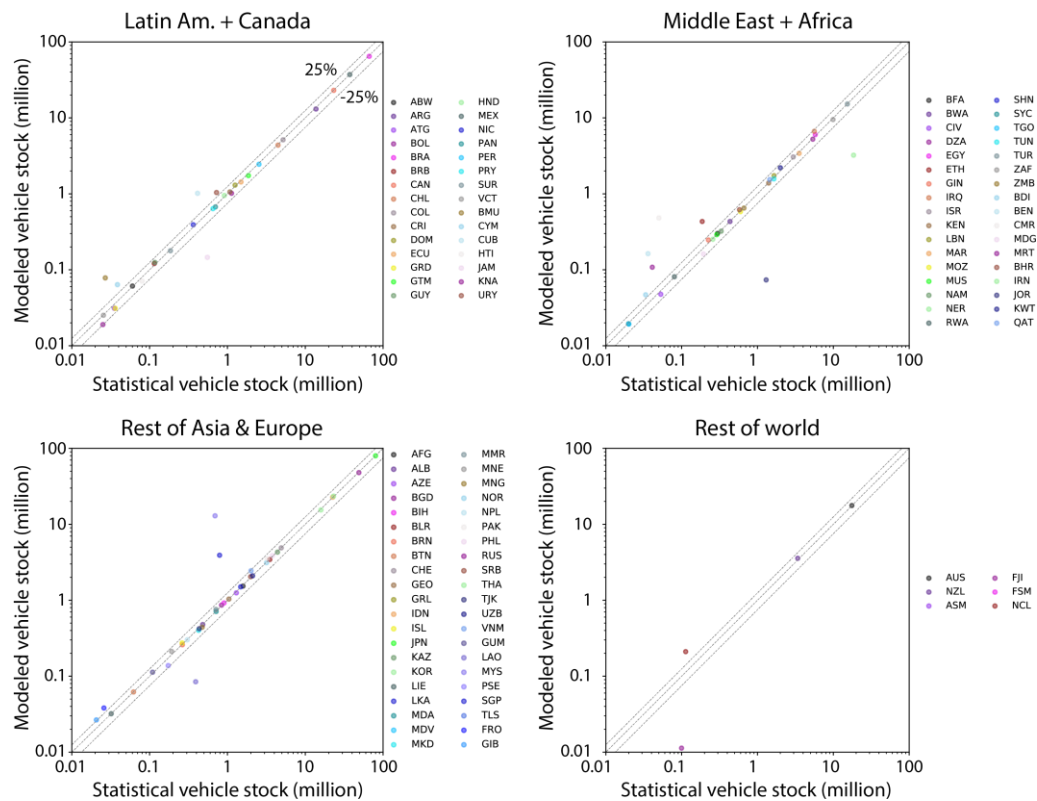


**Figure S2. Comparison of WRS, OICA, and local statistics**

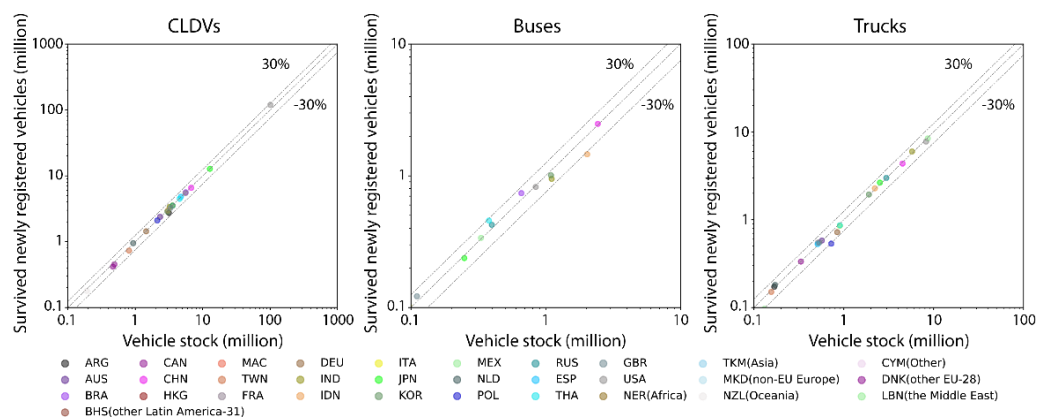


<sup>1</sup> United States: Transportation Energy Data Book, European Union: ACEA/European Commission, China (CHN): NBS, India: Statistical Year Book India.

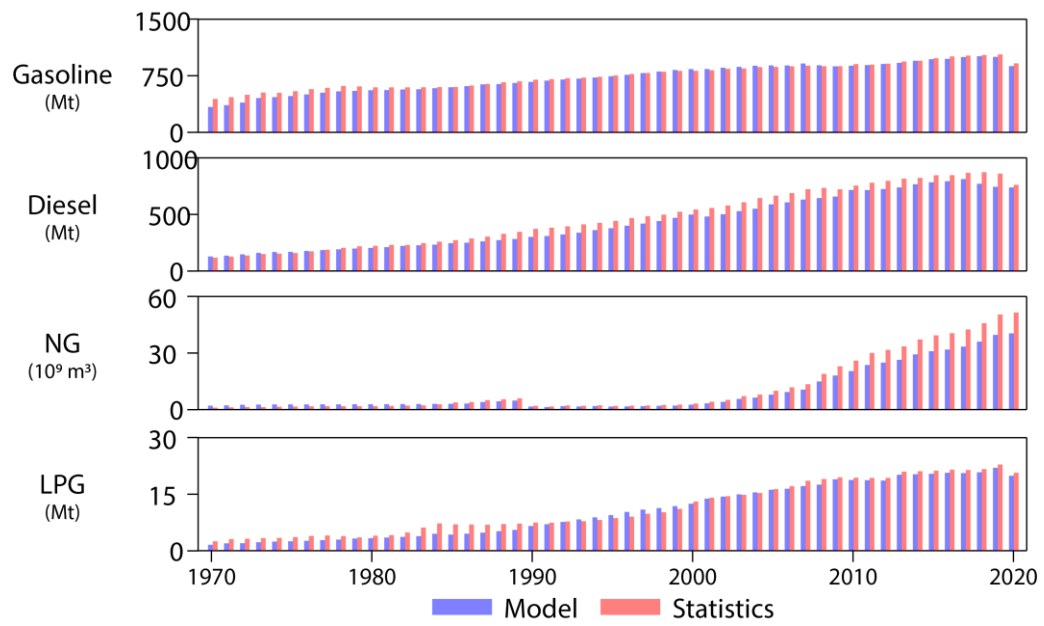
**Figure S3. Verification of the modeled vehicle stock in rest countries in 2015.**



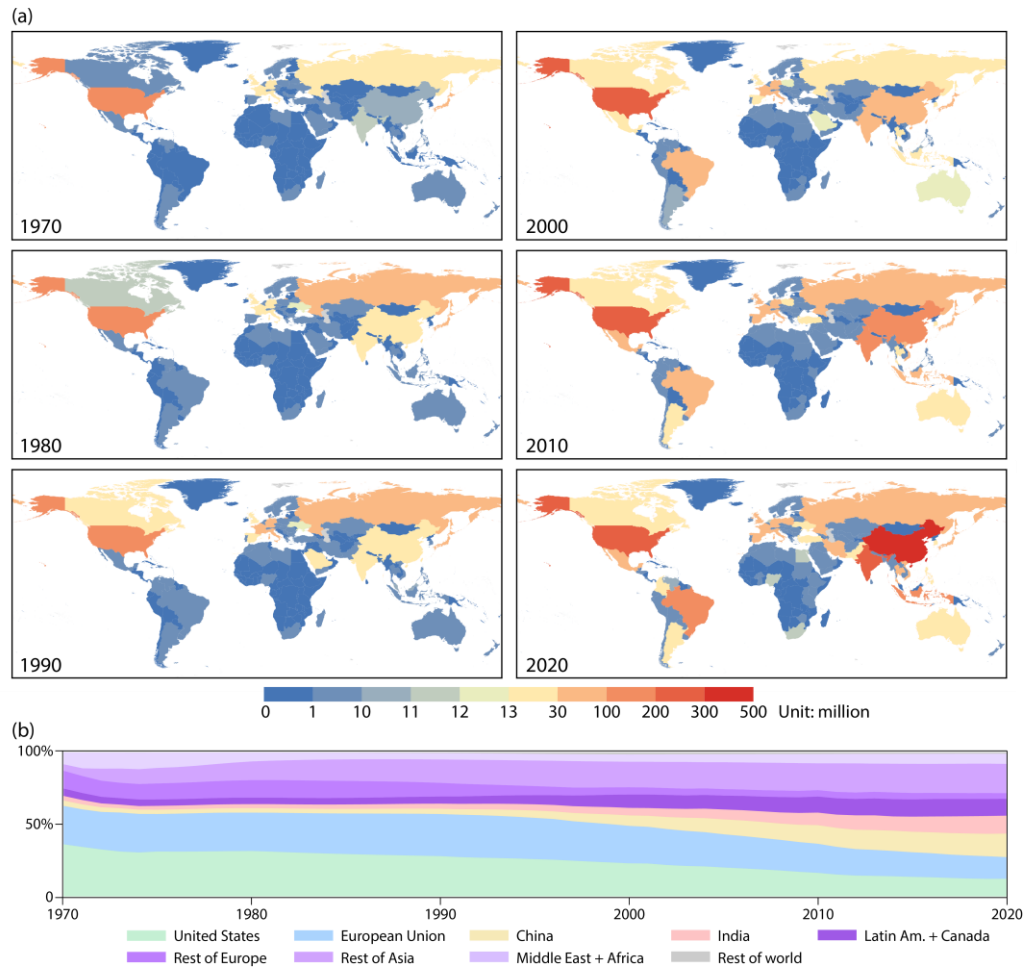
**Figure S4. Verification of the age distribution for CLDVs, buses, and trucks in 2015.**



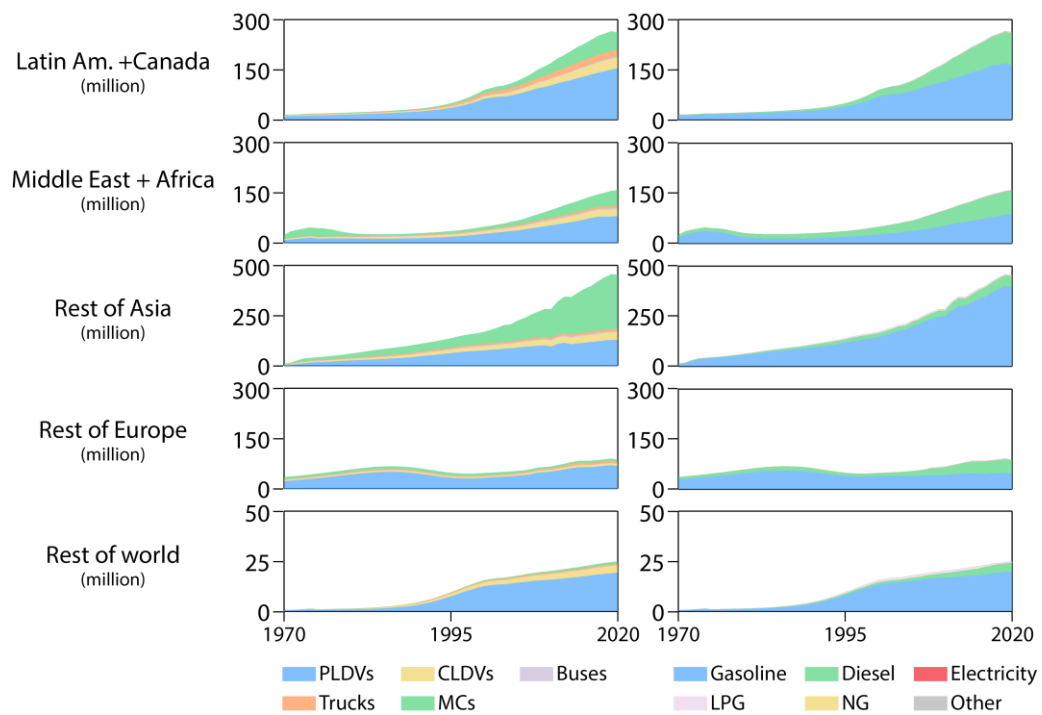
**Figure S5. Comparison of modeled and statistical fuel consumption of global on-road vehicles.**



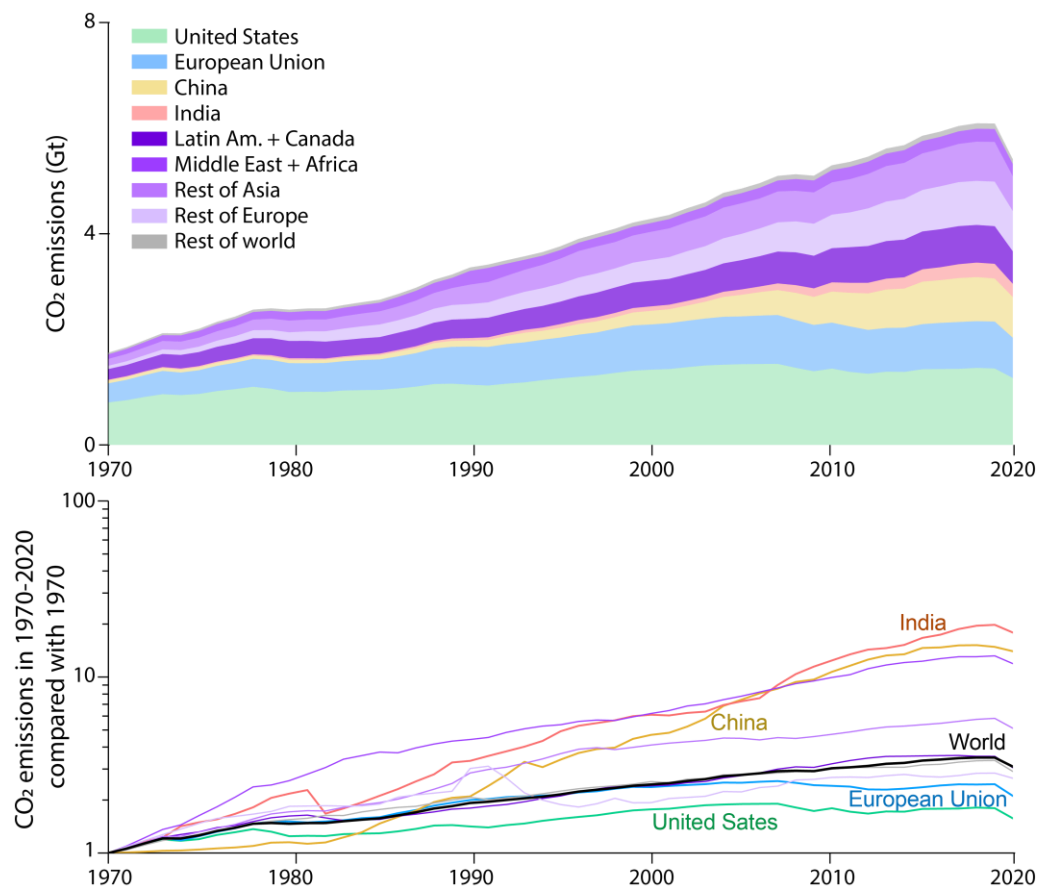
**Figure S6. Spatial distribution of vehicle stock (a) and regional contribution to global vehicle ownership (b) during 1970-2020.**



**Figure S7. Vehicle ownership by category and fuel type in rest regions**



**Figure S8. Trends in on-road CO<sub>2</sub> emissions from 1970 to 2020.**



**Figure S9. Category distribution of CO<sub>2</sub> emissions.**

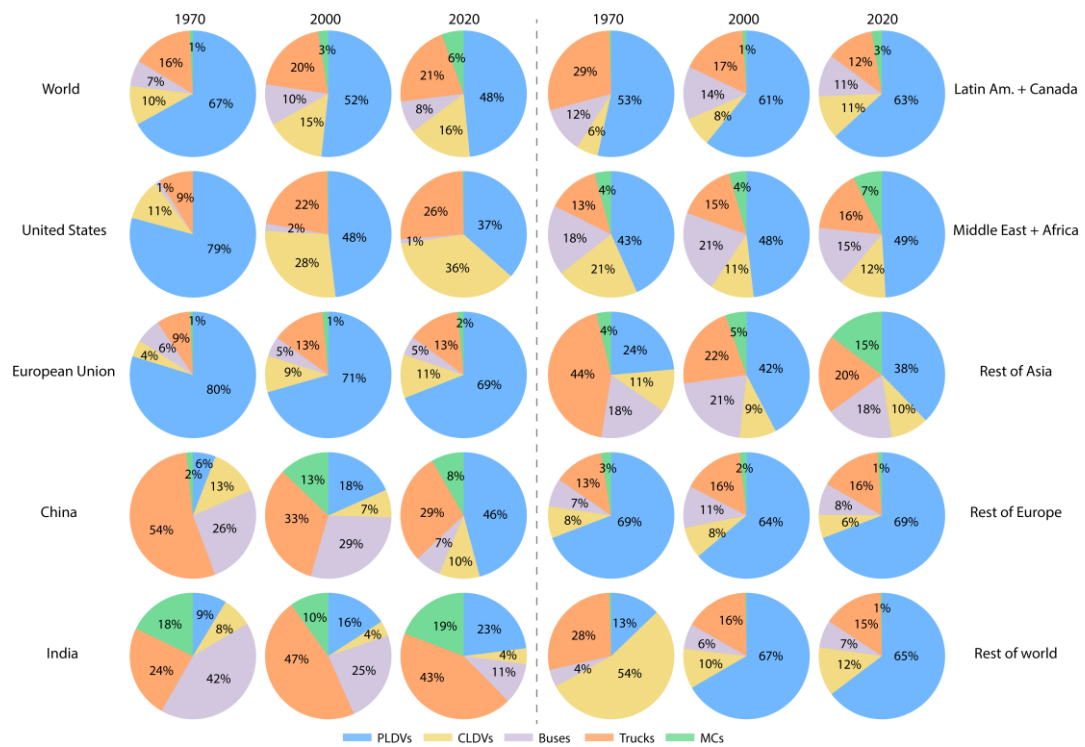
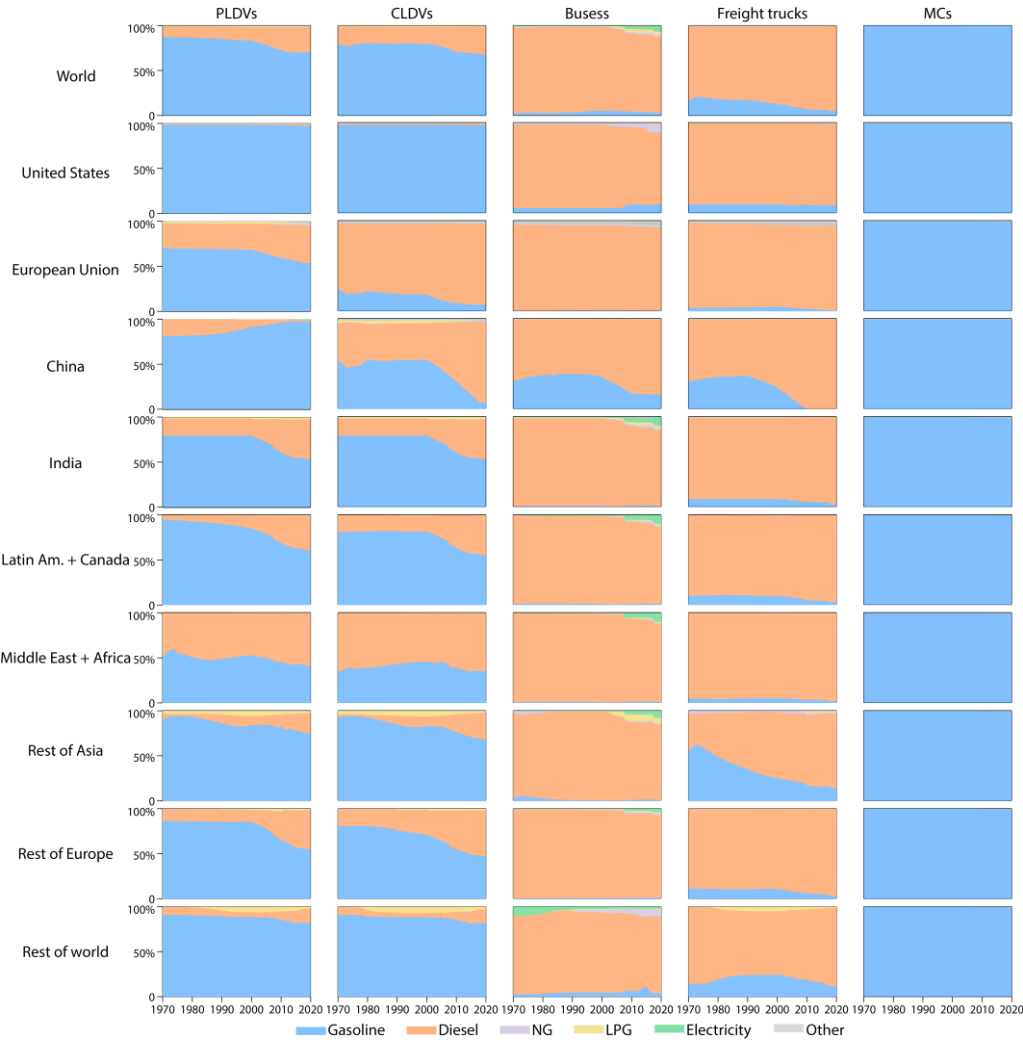
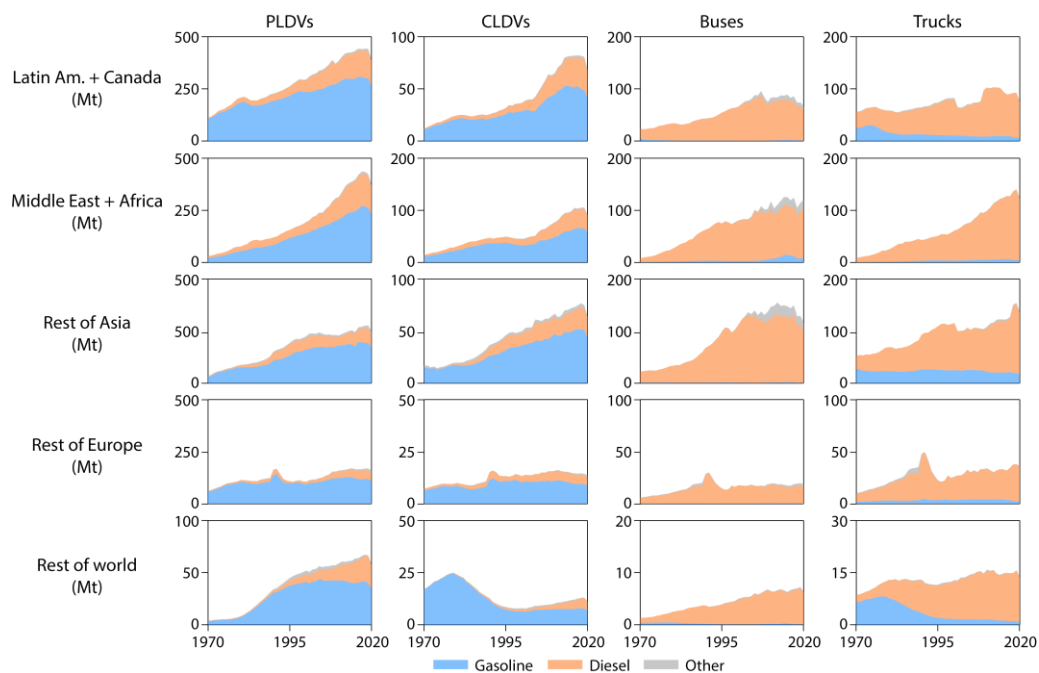


Figure S10. Fuel Structure of vehicle ownership

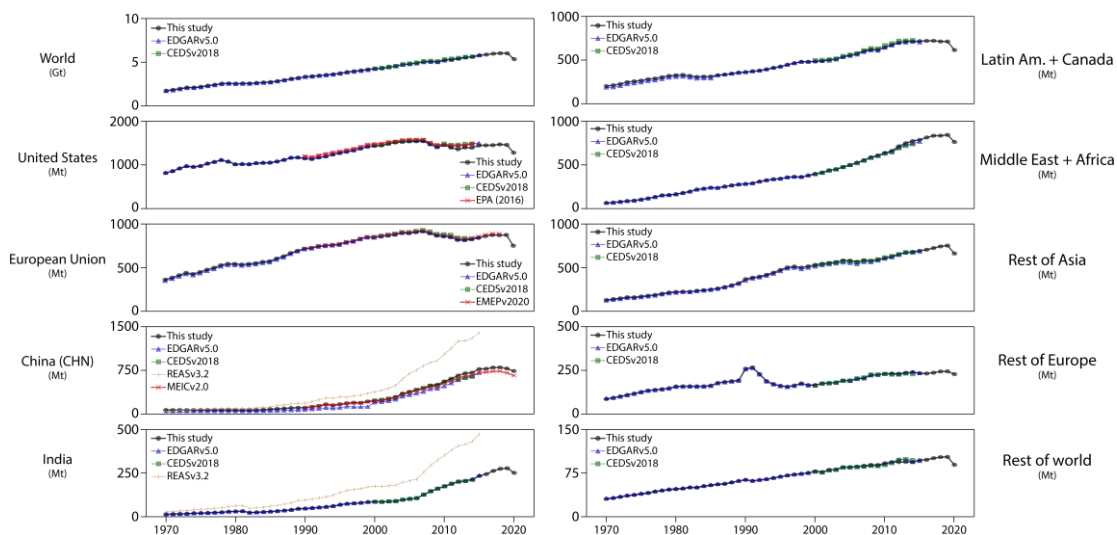




**Figure S11. Transition of diesel vehicles' contribution to CO<sub>2</sub> emissions in rest regions.**



**Figure S12. Comparison of on-road CO<sub>2</sub> emissions between this study and other inventories**



**Table S1. Country list**

Country	Emission estimation group		Uncertainty group
	Name	Note	
Afghanistan	Asia	B <sup>1</sup>	Non-Annex I countries
Albania	non-EU Europe	B	Non-Annex I countries
Algeria	Africa	B	Non-Annex I countries
American Samoa	Oceania	B	Non-Annex I countries
Angola	Africa	B	Non-Annex I countries
Antigua and Barbuda	other Latin America-31	B	Non-Annex I countries
Argentina	Argentina	F <sup>2</sup>	Non-Annex I countries
Armenia	non-EU Europe	B	Non-Annex I countries
Aruba	Other	B	Non-Annex I countries
Australia	Australia	F	Australia
Austria	other EU-28	B	EU15
Azerbaijan	non-EU Europe	B	Non-Annex I countries
Bahamas	other Latin America-31	B	Non-Annex I countries
Bahrain	the Middle East	B	Non-Annex I countries
Bangladesh	Asia	B	Non-Annex I countries
Barbados	other Latin America-31	B	Non-Annex I countries
Belarus	non-EU Europe	B	EIT90
Belgium	other EU-28	B	EU15
Belize	other Latin America-31	B	Non-Annex I countries
Benin	Africa	B	Non-Annex I countries
Bermuda	Other	B	Non-Annex I countries
Bhutan	Asia	B	Non-Annex I countries
Bolivia	other Latin America-31	B	Non-Annex I countries
Bosnia and Herzegovina	non-EU Europe	B	Non-Annex I countries
Botswana	Africa	B	Non-Annex I countries
Brazil	Brazil	F	Non-Annex I countries
British Virgin Islands	Other	B	Non-Annex I countries
Brunei Darussalam	Asia	B	Non-Annex I countries
Bulgaria	other EU-28	B	EIT90
Burkina Faso	Africa	B	Non-Annex I countries
Burundi	Africa	B	Non-Annex I countries
Cape Verde	Africa	B	Non-Annex I countries
Cambodia	Asia	B	Non-Annex I countries
Cameroon	Africa	B	Non-Annex I countries
Canada	Canada	F	Canada
Cayman Islands	Other	B	Non-Annex I countries
Central African Republic	Africa	B	Non-Annex I countries
Chad	Africa	B	Non-Annex I countries

Country	Emission estimation group		Uncertainty group
	Name	Note	
Chile	other Latin America-31	B	Non-Annex I countries
China	China	F	China
Hong Kong, China	China	F	China
Macao	China	F	China
Chinese Taipei	China	F	China
Colombia	other Latin America-31	B	Non-Annex I countries
Comoros	Africa	B	Non-Annex I countries
Democratic Republic of Congo	Africa	B	Non-Annex I countries
Congo	Africa	B	Non-Annex I countries
Costa Rica	other Latin America-31	B	Non-Annex I countries
Cote d'Ivoire	Africa	B	Non-Annex I countries
Croatia	other EU-28	B	EIT90
Cuba	other Latin America-31	B	Non-Annex I countries
Curacao	Other	B	Non-Annex I countries
Cyprus	other EU-28	B	EIT90
Czech Republic	other EU-28	B	EIT90
Denmark	other EU-28	B	EU15
Djibouti	Africa	B	Non-Annex I countries
Dominica	other Latin America-31	B	Non-Annex I countries
Dominican Republic	other Latin America-31	B	Non-Annex I countries
Ecuador	other Latin America-31	B	Non-Annex I countries
Egypt	the Middle East	B	Non-Annex I countries
El Salvador	other Latin America-31	B	Non-Annex I countries
Equatorial Guinea	Africa	B	Non-Annex I countries
Eritrea	Africa	B	Non-Annex I countries
Estonia	other EU-28	B	EIT90
Swaziland	Africa	B	Non-Annex I countries
Ethiopia	Africa	B	Non-Annex I countries
Faeroe Islands	non-EU Europe	B	Non-Annex I countries
Fiji	Oceania	B	Non-Annex I countries
Finland	other EU-28	B	EU15
France	France	F	EU15
Gabon	Africa	B	Non-Annex I countries
Gambia	Africa	B	Non-Annex I countries
Georgia	non-EU Europe	B	Non-Annex I countries
Germany	Germany	F	EU15
Ghana	Africa	B	Non-Annex I countries
Gibraltar	non-EU Europe	B	Non-Annex I countries
Greece	other EU-28	B	EU15
Greenland	non-EU Europe	B	Non-Annex I countries
Grenada	other Latin America-31	B	Non-Annex I countries

Country	Emission estimation group		Uncertainty group
	Name	Note	
Guam	Asia	B	Non-Annex I countries
Guatemala	other Latin America-31	B	Non-Annex I countries
Guinea	Africa	B	Non-Annex I countries
Guinea-Bissau	Africa	B	Non-Annex I countries
Guyana	other Latin America-31	B	Non-Annex I countries
Haiti	other Latin America-31	B	Non-Annex I countries
Honduras	other Latin America-31	B	Non-Annex I countries
Hungary	other EU-28	B	EIT90
Iceland	non-EU Europe	B	OECD90
India	India	F	India
Indonesia	Indonesia	F	Non-Annex I countries
Islamic Republic of Iran	the Middle East	B	Non-Annex I countries
Iraq	the Middle East	B	Non-Annex I countries
Ireland	other EU-28	B	EU15
Israel	the Middle East	B	Non-Annex I countries
Italy	Italy	F	EU15
Jamaica	other Latin America-31	B	Non-Annex I countries
Japan	Japan	F	Japan
Jordan	the Middle East	B	Non-Annex I countries
Kazakhstan	Asia	B	Non-Annex I countries
Kenya	Africa	B	Non-Annex I countries
Kiribati	Asia	B	Non-Annex I countries
Democratic Peoples Republic of Korea	Asia	B	Non-Annex I countries
Republic of Korea	South Korea	F	Non-Annex I countries
Kuwait	the Middle East	B	Non-Annex I countries
Kyrgyzstan	Asia	B	Non-Annex I countries
Laos	Asia	B	Non-Annex I countries
Latvia	other EU-28	B	EIT90
Lebanon	the Middle East	B	Non-Annex I countries
Lesotho	Africa	B	Non-Annex I countries
Liberia	Africa	B	Non-Annex I countries
Libya	Africa	B	Non-Annex I countries
Liechtenstein	non-EU Europe	B	Non-Annex I countries
Lithuania	other EU-28	B	EIT90
Luxembourg	other EU-28	B	EU15
Madagascar	Africa	B	Non-Annex I countries
Malawi	Africa	B	Non-Annex I countries
Malaysia	Asia	B	Non-Annex I countries
Maldives	Asia	B	Non-Annex I countries
Mali	Africa	B	Non-Annex I countries
Malta	other EU-28	B	EIT90

Country	Emission estimation group		Uncertainty group
	Name	Note	
Marshall Islands	Oceania	B	Non-Annex I countries
Mauritania	Africa	B	Non-Annex I countries
Mauritius	Africa	B	Non-Annex I countries
Mexico	Mexico	F	Non-Annex I countries
Federated States of Micronesia	Oceania	B	Non-Annex I countries
Moldova	non-EU Europe	B	Non-Annex I countries
Mongolia	Asia	B	Non-Annex I countries
Montenegro	non-EU Europe	B	Non-Annex I countries
Morocco	Africa	B	Non-Annex I countries
Mozambique	Africa	B	Non-Annex I countries
Myanmar (Burma)	Asia	B	Non-Annex I countries
Namibia	Africa	B	Non-Annex I countries
Nepal	Asia	B	Non-Annex I countries
Netherlands	Netherlands	F	EU15
New Caledonia	Oceania	B	Non-Annex I countries
New Zealand	Oceania	B	OECD90
Nicaragua	other Latin America-31	B	Non-Annex I countries
Niger	Africa	B	Non-Annex I countries
Nigeria	Africa	B	Non-Annex I countries
Macedonia (former Yugoslav Republic of Macedonia)	non-EU Europe	B	Non-Annex I countries
Norway	non-EU Europe	B	OECD90
Palestine	Asia	B	Non-Annex I countries
Oman	the Middle East	B	Non-Annex I countries
Pakistan	Asia	B	Non-Annex I countries
Panama	other Latin America-31	B	Non-Annex I countries
Papua New Guinea	Oceania	B	Non-Annex I countries
Paraguay	other Latin America-31	B	Non-Annex I countries
Peru	other Latin America-31	B	Non-Annex I countries
Philippines	Asia	B	Non-Annex I countries
Poland	Poland	F	EIT90
Portugal	other EU-28	B	EU15
Puerto Rico	Other	B	Non-Annex I countries
Qatar	the Middle East	B	Non-Annex I countries
Romania	other EU-28	B	EIT90
Russia	Russia	F	Russia
Rwanda	Africa	B	Non-Annex I countries
Samoa	Oceania	B	Non-Annex I countries
Sao Tome and Principe	Africa	B	Non-Annex I countries
Saudi Arabia	the Middle East	B	Non-Annex I countries
Senegal	Africa	B	Non-Annex I countries

Country	Emission estimation group		Uncertainty group
	Name	Note	
Serbia	non-EU Europe	B	Non-Annex I countries
Seychelles	Africa	B	Non-Annex I countries
Sierra Leone	Africa	B	Non-Annex I countries
Singapore	Asia	B	Non-Annex I countries
Slovakia	other EU-28	B	EIT90
Slovenia	other EU-28	B	EIT90
Soloman Islands	Oceania	B	Non-Annex I countries
Somalia	Africa	B	Non-Annex I countries
South Africa	Africa	B	Non-Annex I countries
Spain	Spain	F	EU15
Sri Lanka	Asia	B	Non-Annex I countries
Saint Helena	Africa	B	Non-Annex I countries
Saint Kitts and Nevis	other Latin America-31	B	Non-Annex I countries
Saint Lucia	other Latin America-31	B	Non-Annex I countries
Saint Vincent And Grenadines	other Latin America-31	B	Non-Annex I countries
Sudan	Africa	B	Non-Annex I countries
Suriname	other Latin America-31	B	Non-Annex I countries
Sweden	other EU-28	B	EU15
Switzerland	non-EU Europe	B	OECD90
Syria	the Middle East	B	Non-Annex I countries
Tajikistan	Asia	B	Non-Annex I countries
Tanzania	Africa	B	Non-Annex I countries
Thailand	Thailand	F	Non-Annex I countries
Timor-Leste	Asia	B	Non-Annex I countries
Togo	Africa	B	Non-Annex I countries
Tonga	Oceania	B	Non-Annex I countries
Trinidad and Tobago	other Latin America-31	B	Non-Annex I countries
Tunisia	Africa	B	Non-Annex I countries
Turkey	the Middle East	B	OECD90
Turkmenistan	Asia	B	Non-Annex I countries
Tuvalu	Oceania	B	Non-Annex I countries
Uganda	Africa	B	Non-Annex I countries
Ukraine	non-EU Europe	B	Ukraine
United Arab Emirates	the Middle East	B	Non-Annex I countries
United Kingdom	United Kingdom	F	EU15
United States	United States	F	USA
Uruguay	other Latin America-31	B	Non-Annex I countries
Uzbekistan	Asia	B	Non-Annex I countries
Vanuatu	Oceania	B	Non-Annex I countries
Venezuela	other Latin America-31	B	Non-Annex I countries
Vietnam	Asia	B	Non-Annex I countries

Country	Emission estimation group		Uncertainty group
	Name	Note	
Yemen	the Middle East	B	Non-Annex I countries
Zambia	Africa	B	Non-Annex I countries
Zimbabwe	Africa	B	Non-Annex I countries
Anguilla	Other	B	Non-Annex I countries
Montserrat	Other	B	Non-Annex I countries
South Sudan	Africa	B	Non-Annex I countries
Bonaire, Sint Eustatius and Saba	Other	B	Non-Annex I countries
Cook Islands	Other	B	Non-Annex I countries
Falkland Islands	Other	B	Non-Annex I countries
French Guiana	Other	B	Non-Annex I countries
French Polynesia	Other	B	Non-Annex I countries
Guadeloupe	Other	B	Non-Annex I countries
Isle of Man (under British governance)	Other	B	Non-Annex I countries
Jersey	Other	B	Non-Annex I countries
Martinique	Other	B	Non-Annex I countries
Mayotte	Other	B	Non-Annex I countries
Nauru	Other	B	Non-Annex I countries
Niue	Other	B	Non-Annex I countries
Norfolk Island (under Australian governance)	Other	B	Non-Annex I countries
Northern Mariana Islands	Other	B	Non-Annex I countries
Palau	Oceania	B	Non-Annex I countries
Pitcairn	Other	B	Non-Annex I countries
Reunion	Other	B	Non-Annex I countries
Saint Pierre and Miquelon	Other	B	Non-Annex I countries
Sint Maarten	Other	B	Non-Annex I countries
Tokelau	Other	B	Non-Annex I countries
Turks and Caicos Islands	Other	B	Non-Annex I countries
United States Virgin Islands	Other	B	Non-Annex I countries
Wallis and Futuna Islands	Other	B	Non-Annex I countries
Western Sahara	Other	B	Non-Annex I countries

B<sup>1</sup>: Broader regions, F<sup>2</sup>: Focus countries

**Table S2. Vehicle category**

		PLDV <sub>s</sub>	CLDV <sub>s</sub>	Buses	Trucks	MCs
Global vehicle database						
WRS		Passenger cars	Vans & Pick-ups	Buses & Motor coaches	Lorries & Road Tractors	Motorcycles
ICCT		Passenger cars	Light duty commercial vehicles	Heavy duty commercial vehicles		Motorcycles
OICA		Passenger vehicles	Commercial vehicles			- <sup>1</sup>
IEA: Energy efficiency statistics		Cars/light trucks		Buses	Freight trucks	-
Regional vehicle database						
European Union	ACEA	Passenger cars	Light commercial vehicles	Buses	Medium and heavy commercial vehicles	-
	European Commission	Passenger cars	Light commercial vehicles (<3.5t) Commercial Vehicles (3.5-16t)	Buses and Coaches	Heavy Commercial Vehicles (>16t)	-
United states	TEDB	Cars	Two-axle four-tire & trucks Light Trucks(<10 klb)	Bus	Other single-unit trucks: Class 3-8 Medium Trucks(10-19.5 klb) Light-heavy Trucks(19.5-26 klb) Heavy Trucks	Motorcycl
China	NBS	Mini Passenger Vehicles Small Passenger Vehicles	Medium Passenger Vehicles Large Passenger Vehicles	Mini Trucks Light Trucks	Medium Trucks Heavy Trucks	Motorcycles
India	Statistical Year Book India	Cars, Jeeps, Taxis	Buses	Light Motor	Goods vehicles	Two-wheelers



		PLDV <sup>s</sup>	CLDV <sup>s</sup>	Buses	Trucks	MCs
Japan	Japan Statistical Yearbook	Passenger cars	For freight use (trucks): Small Light motor vehicles	For people transport (buses)	For freight use (trucks): Ordinary	-
South Korea	CEIC	Passenger Car	Truck	Bus	Truck	Motorcycles
Indonesia	CEIC	Passenger Cars	Truck	Bus	Truck	Motorcycle
Russia	CEIC	Passenger Car	Truck	Buses	Truck	-
Canada	CEIC	RMV(<4.5 t)	RMV(4.5-15 t)	Bus	RMV(>15 t)	Motorcycles & Mopeds
Brazil	CEIC	Passenger Cars	RMV: Buses	Light Commercials	Truck	Motorcycle
<b>Regional inventory</b>						
European Union	EMEP	Passenger cars	Light duty vehicles	Heavy duty vehicles and busses		Moped and motorcycles
United states	NEI	Passenger Car	Passenger Truck Light Commercial Truck LDGT, LDGV LDDT, LDDV	Transit Bus Intercity Bus School Bus Motor Home	HDDV Class 2B, 3-7, 8A & B8 Single Unit Short-haul Truck Single Unit Long-haul Truck Combination Short-haul Truck Combination Long-haul Truck	MC
China	MEIC	China-LDB China-MB	China-LDT China-MT	China-HDB China-MDB	China-HDT China-MDT	MC
South Korea	Airemiss	Car, Taxi, Recreation Vehicle	Van, Trucks	Buses	Trucks	two-wheel

<sup>-1</sup>: Not covered

**Table S3. Fuel type**

		Gasoline	Diesel	NG	LPG	Electricity	Other
<b>Global data</b>							
IEA <sup>1</sup>		Motor gasoline	Diesel and light fuel oil	Gas	LPG	Electricity	Other sources
IEA <sup>2</sup>		Motor gasoline excl. biofuels	Gas/diesel oil excl. biofuels	Natural gas	Liquefied petroleum gases (LPG)	-	Natural gas liquids, Other kerosene, Other liquid biofuels, Other oil products, Refinery gas, White spirit & SBP, Biodiesels, Biogasoline, Bitumen, Fuel oil
IPCC		Motor Gasoline	Gas/ Diesel Oil	Natural Gas	Liquefied Petroleum Gases	-	-
<b>Regional data</b>							
European Union	ACEA	Petrol	Diesel	LPG +Natural gas		Battery electric	Hybrid electric, Plug-in hybrid, Other + Unknown
Japan	MVS 2016	-	diesel oil	-	-	-	-
China	Shan et al. (2018)	Gasoline	Diesel oil	-	-	-	-
<b>Regional inventory</b>							
United states	NEI	Gasoline	Diesel	CNG	LPG	Electricity	Ethanol
China	MEIC	G	D	-	-	-	-
South Korea	Airemiss	gasoline	diesel oil	NG	LPG	-	hybrid

**Table S4. The corresponding uncertainty ( $\sigma$ ) of CO<sub>2</sub> emissions for regions.**

<b>Region</b>	<b>1970</b>	<b>1980</b>	<b>1990</b>	<b>2000</b>	<b>2010</b>	<b>2015</b>	<b>2020</b>
World	(-5.5%, 6.2%)	(-5.8%, 6.5%)	(-5.8%, 6.5%)	(-6%, 6.7%)	(-7%, 8%)	(-6%, 6.7%)	(-5.9%, 6.6%)
United States	(-3.8%, 4%)	(-3.7%, 3.8%)	(-3.5%, 3.6%)	(-3.4%, 3.5%)	(-3.2%, 3.3%)	(-3.2%, 3.3%)	(-3.1%, 3.2%)
European Union	(-2.9%, 3%)	(-2.7%, 2.8%)	(-2.5%, 2.6%)	(-2.3%, 2.4%)	(-2.5%, 2.7%)	(-2.5%, 2.6%)	(-2.7%, 2.8%)
China	(-6.8%, 7.3%)	(-7.1%, 7.7%)	(-7.5%, 8.2%)	(-7.9%, 8.5%)	(-11.8%, 13.4%)	(-1.4%, 1.4%)	(-1.2%, 1.2%)
India	(-4.7%, 5%)	(-4.5%, 4.7%)	(-4.3%, 4.5%)	(-4.2%, 4.4%)	(-4.1%, 4.2%)	(-3.9%, 4.1%)	(-3.9%, 4%)
Latin Am. + Canada	(-12.2%, 14.6%)	(-11.9%, 14.1%)	(-12.1%, 14.3%)	(-12.2%, 14.3%)	(-11.9%, 13.9%)	(-11.8%, 13.7%)	(-11.3%, 13.1%)
Middle East + Africa	(-15.4%, 18.3%)	(-15.1%, 18%)	(-14.3%, 16.8%)	(-13.9%, 16.2%)	(-13.6%, 15.8%)	(-13.2%, 15.3%)	(-12.8%, 14.9%)
Rest of Asia	(-7.3%, 8.6%)	(-7%, 8.2%)	(-7.1%, 8.3%)	(-7.4%, 8.6%)	(-8.5%, 9.8%)	(-9.1%, 10.5%)	(-9.3%, 10.7%)
Rest of Europe	(-6.4%, 7.1%)	(-5.9%, 6.5%)	(-5.4%, 5.8%)	(-4.7%, 5.1%)	(-4.9%, 5.3%)	(-4.9%, 5.3%)	(-4.9%, 5.3%)
Rest of world	(-4.5%, 4.8%)	(-4.4%, 4.8%)	(-4.4%, 4.8%)	(-4.3%, 4.7%)	(-4.5%, 5%)	(-4.3%, 4.7%)	(-4.2%, 4.6%)