Supplement of

Dynamic projection of anthropogenic emissions in China: methodology and 2015-2050 emission pathways under a range of socioeconomic, climate policy, and pollution control scenarios

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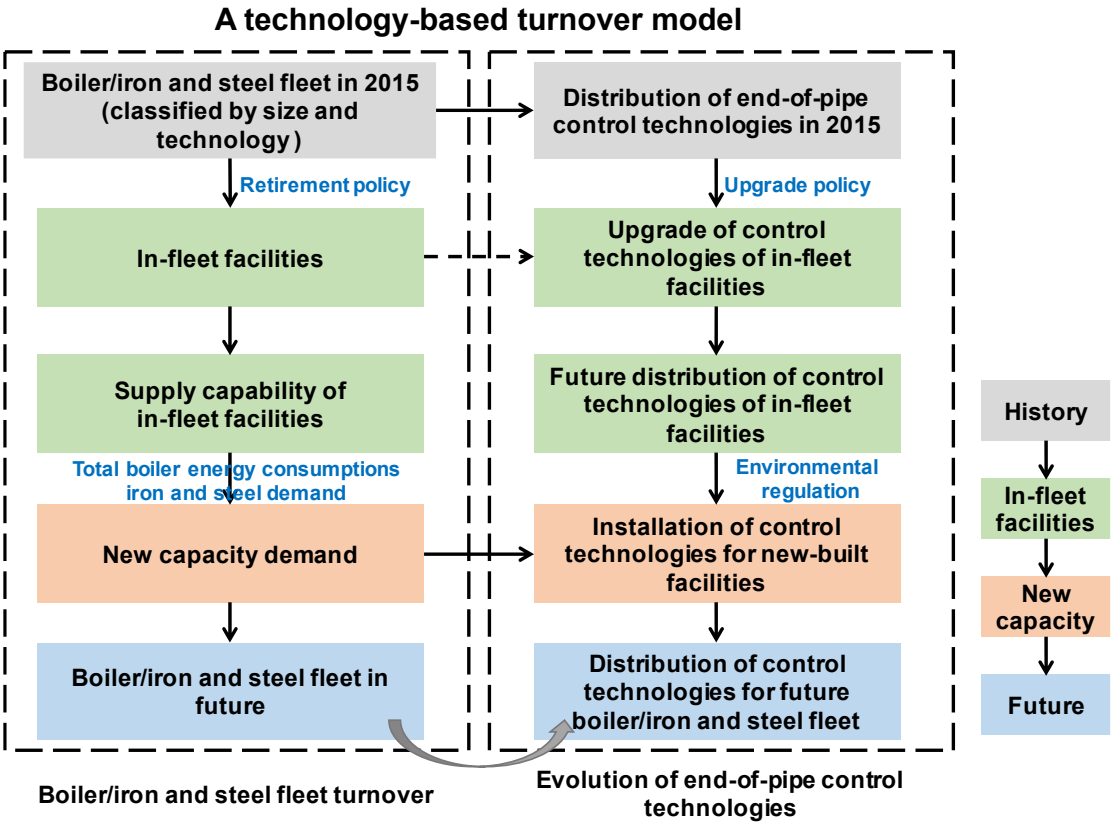

Figure S1: The framework of technology-based turnover emission projections model for coal-fired industrial boilers and iron and steel plants.

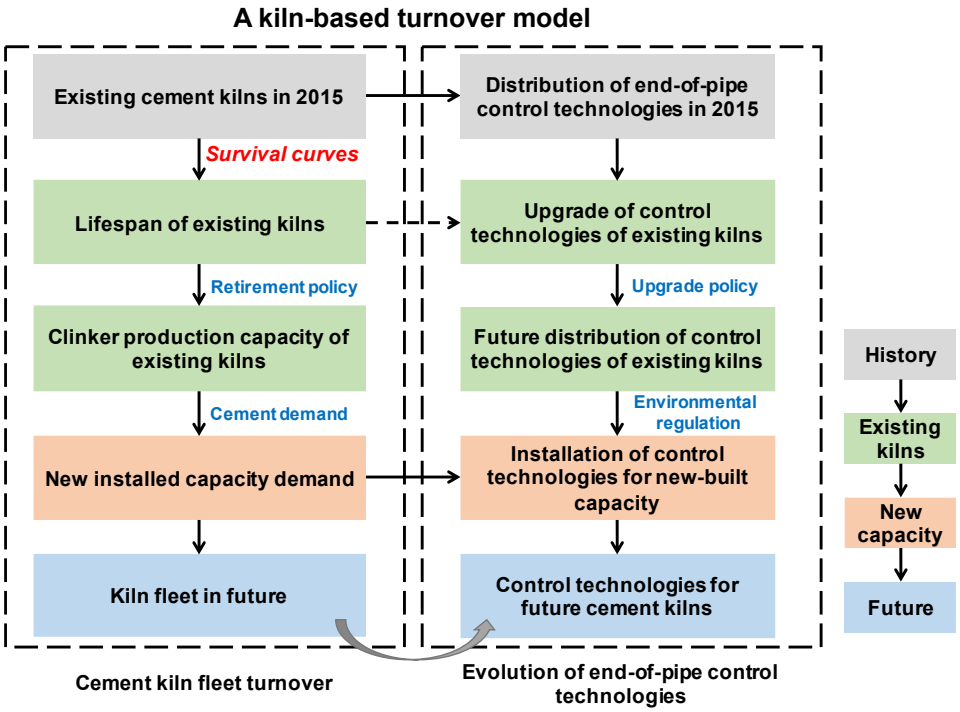

Figure S2: The framework of kiln-based turnover model for the cement industry.

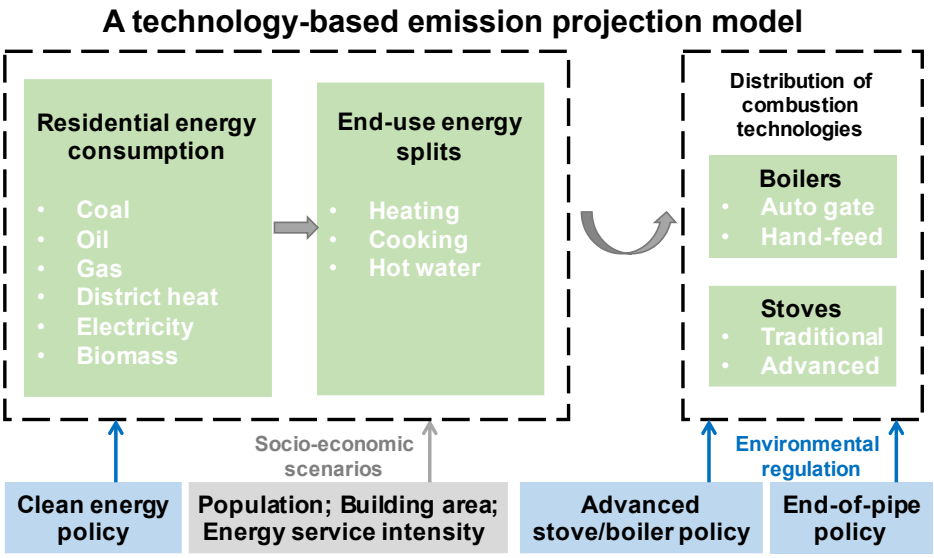

Figure S3: The framework of technology-based model for the residential sector.

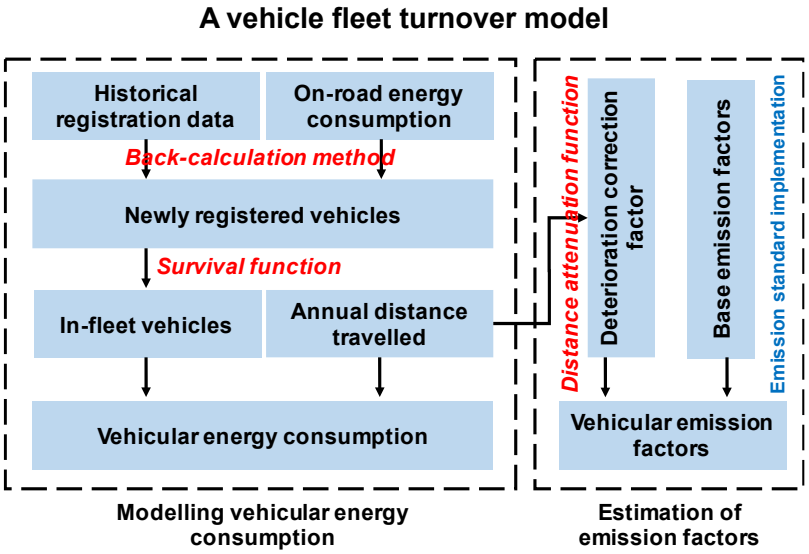

Figure S4: The framework of vehicle fleet turnover model for the on-road transportation.

<table>
<tr><th>Emission source</th><th>Scenario</th><th>Region</th><th>2015</th><th>2016</th><th>2017</th><th>2018</th><th>2019</th><th>2020</th><th>2021</th><th>2022</th><th>2023</th><th>2024</th><th>2025</th><th>…</th><th>2030</th><th>…</th><th>2034</th><th>2035</th><th>…</th><th>2040</th><th>…</th><th>2046</th><th>…</th><th>2050</th></tr>
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Figure S5: Policy evolution under each emission scenarios in the transportation sector during 2015-2050. Policies in each emission source are strengthened in the order of blue, green, orange, yellow, and purple color.

Source sector	Scenario	Region	2015	2016	2017	2018	2019	2020	2021	…	2026	2027	2028	…	2030	…	2045	…	2050
Residential	BAU	All region	No specific regulations																
	ECP	BTH & FW Plain	no specific regulations			cleaner coals and stoves			further reduce the ash and sulfur content in residential coal, and fully applied advanced stoves			relative low emission levels							
		YRD	no specific regulations			cleaner coals and stoves			further reduce the ash and sulfur content in residential coal, and fully applied advanced stoves					relative low emission levels					
		Other regions	no specific regulations			cleaner coals and stoves			further reduce the ash and sulfur content in residential coal, and fully applied advanced stoves							relative low emission levels			
	BHE	All region	no specific regulations			cleaner coals and stoves			further reduce the ash and sulfur content in residential coal, and fully applied advanced stoves			relative low emission levels					Innovation of stoves and residential fuels		
Solvent use	BAU	All region	No specific regulations																
	ECP	BTH & FW Plain	no specific regulations			lower the VOCs content			further improve the water-soluble solvent use; install VOC control faclity in coating and painting industry				relative low emission levels						
		YRD	no specific regulations			lower the VOCs content			further improve the water-soluble solvent use; install VOC control faclity in coating and painting industry					relative low emission levels					
		Other regions	no specific regulations			lower the VOCs content			further improve the water-soluble solvent use; install VOC control faclity in coating and painting industry							relative low emission levels			
	BHE	All region	no specific regulations			lower the VOCs content			further improve the water-soluble solvent use; install VOC control faclity in coating and painting industry				relative low emission levels				Innovation of solvent and VOC control facility		
Agriculture	BAU	All region	No specific regulations																
	ECP	BTH & FW Plain	no specific regulations			promote the use of organic fertilizer and the resource utilization of the poultry excrement and straw			enhance intensive cautivation and grazierty; promote the slow-release fertilizer				relative low emission levels						
		YRD	no specific regulations						enhance the intensive cautivation and grazierty; promote the slow-release fertilizer					relative low emission levels					
		Other regions	no specific regulations						enhance the intensive cautivation and grazierty; promote the slow-release fertilizer							relative low emission levels			
	BHE	All region	no specific regulations						enhance the intensive cautivation and grazierty; promote the slow-release fertilizer				relative low emission levels				Innovation of cautivation and grazierty		

Figure S6: Policy evolution under each emission scenario in the residential, solvent use, and agriculture sectors during 2015-2050. Policies in each emission source are strengthened in the order of blue, green, orange, and yellow color.

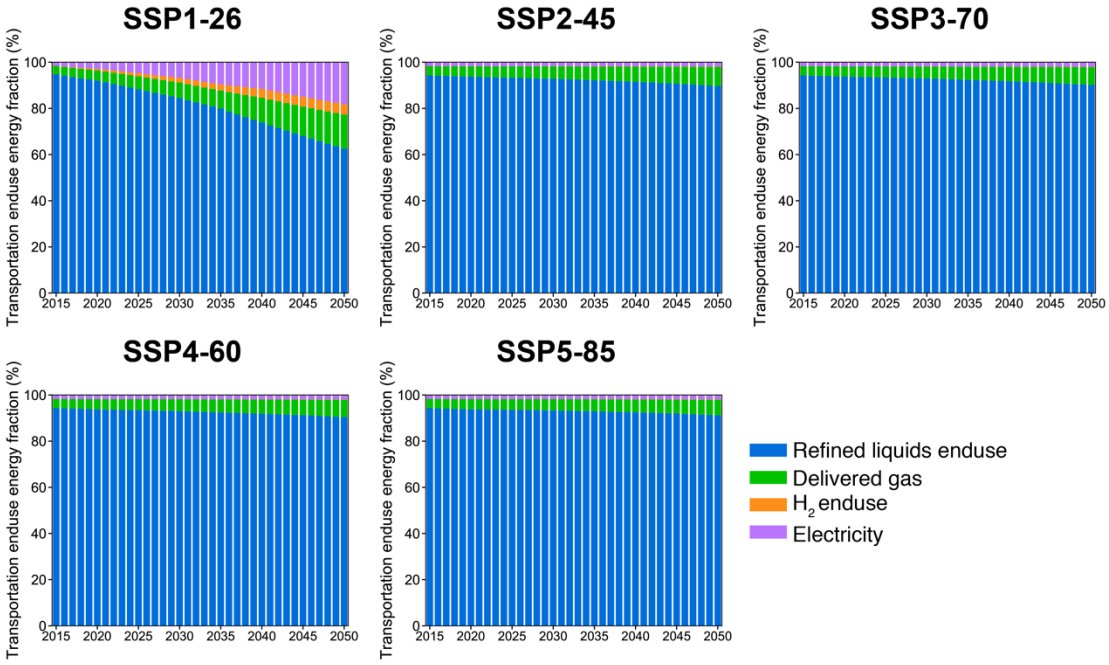

Figure S7: The evolution of future on-road transportation structure under each energy scenario during 2015-2050.

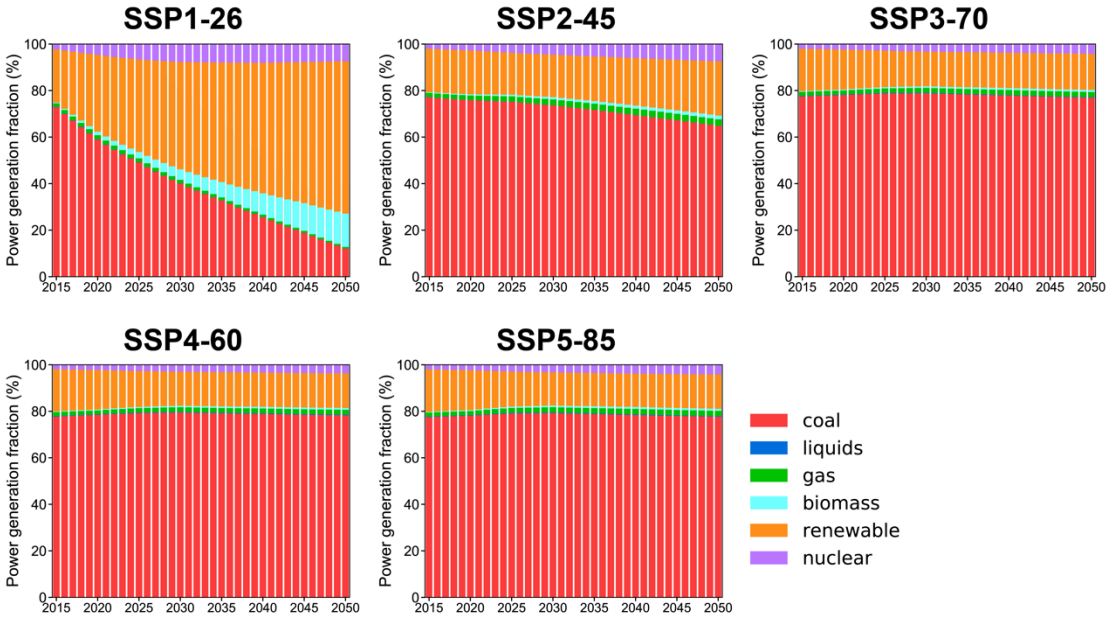

Figure S8: The evolution of future power structure under each energy scenario during 2015-2050.

Table S1: The mapping table between the DPEC model and the GCAM-China model.

Activity rate of DPEC			Driving factors from GCAM-China			Methods note
Sector	Subsector	Fuel/production type	Sector	Subsector	Fuel/production type	
Power	Power generation	-	Electricity	Electricity generation by technology	-	Trend-adopted
	Power fuel	Raw coal Cleaned coal Other washed coal Briquettes Coke Other coking products		Electricity fuel consumption	Regional coal	Distributed by the base-year proportion (heat values) of coal-related fuels (from power sector) in DPEC model
		Nature gas Coke oven gas Other gas			Wholesale gas	Distributed by the base-year proportion (heat values) of gas-related fuels (from power sector) in DPEC model
		Crude oil Gasoline Kerosene Diesel oil Fuel oil LPG Refinery gas			Refined liquids industrial	Distributed by the base-year proportion (heat values) of liquids-related fuels (from power sector) in DPEC model

		Other petroleum products				
		Biofuel			Regional biomass	Trend-adopted
Heating	Heating industrial	Raw coal Cleaned coal Other washed coal Briquettes Coke Other coking products	Heat (national output); Industry (provincial output)	Energy consumption of heat sector (national output); Industry final energy by technology and fuel (provincial output)	Delivered coal (national output); District heat (provincial output)	Distributed by the base-year proportion (heat values) of coal-related fuels (from heating industrial sector) in DPEC model; downscaled to provincial level with district heat proportion
		Nature gas Coke oven gas Other gas			Wholesale gas (national output); District heat (provincial output)	Distributed by the base-year proportion (heat values) of gas-related fuels (from heating industrial sector) in DPEC model; downscaled to provincial level with district heat proportion
		Crude oil Gasoline Kerosene Diesel oil Fuel oil LPG Refinery gas Other petroleum products			Refined liquids (national output); District heat (provincial output)	Distributed by the base-year proportion (heat values) of liquid-related fuels (from heating industrial sector) in DPEC model; downscaled to provincial level with district heat proportion

		Biofuel			Delivered biomass (national output); District heat (provincial output)	Trend-adopted and downscaled to provincial level with district heat proportion
	Heating residential	Raw coal Cleaned coal Other washed coal Briquettes Coke Other coking products	Heat (national output); Building (provincial output)	Energy consumption of heat sector (national output); Building final energy by service and fuel (commercial heating + residential urban heating) (provincial output)	Delivered coal (national output); District heat (provincial output)	Distributed by the base-year proportion (heat values) of coal-related fuels (from heating industrial sector) in DPEC model; downscaled to provincial level with district heat proportion
		Nature gas Coke oven gas Other gas			Wholesale gas (national output); District heat (pro-vincial output)	Distributed by the base-year proportion (heat values) of gas-related fuels (from heating industrial sector) in DPEC model; downscaled to provincial level with district heat proportion
		Crude oil Gasoline Kerosene Diesel oil Fuel oil LPG			Refined liquids (national output); District heat (provincial output)	Distributed by the base-year proportion (heat values) of liquid-related fuels (from heating industrial sector) in DPEC model; downscaled to provincial level with

		Refinery gas Other petroleum products				district heat proportion
		biofuel			Delivered biomass (national output); District heat (pro-vincial output)	Trend-adopted and downscaled to provincial level with district heat proportion
Residential	Residential urban	Raw coal Cleaned coal Other washed coal Briquettes Coke Other coking products	Building	Building final energy by service and fuel (residential urban hot water cooking + commercial hot water cooking + commercial heating + residential urban heating)	Delivered coal	Distributed by the base-year proportion (heat values) of coal-related fuels (from residential urban sector) in DPEC model
		Nature gas Coke oven gas Other gas			Delivered gas	Distributed by the base-year proportion (heat values) of gas-related fuels (from residential urban sector) in DPEC model
		Crude oil Gasoline Kerosene Diesel oil Fuel oil LPG Refinery gas			Refined liquids enduse	Distributed by the base-year proportion (heat values) of liquids-related fuels (from residential urban sector) in DPEC model

		Other petroleum products				
		biofuel			Delivered biomass	Trend-adopted
	Residential rural	Raw coal Cleaned coal Other washed coal Briquettes Coke Other coking products	Building	Building final energy by service and fuel (residential rural hot water cooking + residential rural heating)	Delivered coal	Distributed by the base-year proportion (heat values) of coal-related fuels (from residential rural sector) in DPEC model
		Nature gas Coke oven gas Other gas			Delivered gas	Distributed by the base-year proportion (heat values) of gas-related fuels (from residential rural sector) in DPEC model
		Crude oil Gasoline Kerosene Diesel oil Fuel oil LPG Refinery gas Other petroleum products			Refined liquids enduse	Distributed by the base-year proportion (heat values) of liquids-related fuels (from residential rural sector) in DPEC model
		Wood Crop residual			Traditional biomass	Distributed by the base-year proportion (heat values) of biomass-related fuels

						(from residential rural sector) in DPEC model
Industrial combustion	Industrial boilers	Raw coal Cleaned coal Other washed coal Briquettes Coke Other coking products	Industry	Industrial energy use (minus the industrial kilns coal use and off-road transportation energy consumptions)	Delivered coal	Distributed by the base-year proportion (heat values) of coal-related fuels (from industrial boiler sector) in DPEC model
		Nature gas Coke oven gas Other gas			Wholesale gas	Distributed by the base-year proportion (heat values) of gas-related fuels (from industrial boiler sector) in DPEC model
		Crude oil Gasoline Kerosene Diesel oil Fuel oil LPG Refinery gas Other petroleum products			Refined liquids enduse	Distributed by the base-year proportion (heat values) of liquids-related fuels (from industrial boiler sector) in DPEC model
		biofuel			Delivered biomass	Trend-adopted
	Industrial kilns	Cement coal use	Industry	Inputs to cement production	Delivered coal	Trend-adopted
		Lime coal use		1) Projected cement coal use (GCMA-China)		Regression model

				2) Historical lime coal use (DPEC)		
		Brick coal use		1) Projected cement coal use (GCMA-China) 2) Historical brick coal use (DPEC)		Regression model
	Energy-related industrial process	Sinter (Capacity)		1) Projected industry final energy use (GCMA-China) 2) Projected sinter production (DPEC) 3) Historical sinter furnace energy structures (DPEC)		Multivariate equation
		Iron (Capacity)		1) Projected industry final energy use (GCMA-China) 2) Projected iron production (DPEC) 3) Historical sinter furnace energy structures (DPEC)		Multivariate equation
		Steel (Capacity)		1) Projected industry final energy use (GCMA-China) 2) Projected steel production (DPEC) 3) Historical sinter furnace energy structures (DPEC)		Multivariate equation
		Petrochemical Industry (crude oil production, crude oil handle, oil depot, oil station)	Socioeconomics, General	1) Projected oil consumption (GCAM-China) 2) GDP per capita at market exchange rates (MER) by region (GCAM-China) 3) Historical production (DPEC)		Regression model
Transportation	On-road	Vehicles gasoline use Vehicles diesel oil use	Transportation	Transportation final energy by fuel	Refined liquids enduse	Distributed by the base-year proportion (heat values) of liquids-related fuels (from on-road transportation sector) in DPEC model
		Vehicles nature gas use			Delivered gas	Trend-adopted

		Vehicles electricity use			Electricity	Trend-adopted
	Off-road	Machines diesel oil use	Transportation and Industry	1) Projected transportation final energy by fuel (GCMA-China) 2) Historical on/off-road energy consumption split ratio (DPEC)	Refined liquids enduse	Trend-adopted
		Machines nature gas use			Delivered gas	Trend-adopted
		Machines electricity use			Electricity	Trend-adopted

Table S2: The description of sector-based emission projection models in the DPEC.

DPEC model sector	Subsector	Model description
Energy supply	Coal-fired power plants	Technology-based turnover model
	Other-fuel-fired power plants	Technology-based model
	Heating plants	Technology-based model
Industrial combustion	Coal-fired industrial boilers and kilns	Technology-based turnover model
	Other-fuel combustion	Technology-based model
Industrial non-combustion	Coke, iron, and steel plants	Technology-based turnover model
	Cement plants	
	Other metals and non-metals (all other metal products, non-ferrous metals, non-metal building materials, and other industrial products)	Technology-based model
	Petrochemical industry (oil and gas production, distribution and refinery; fertilizer production; solvent production; synthetic materials; and other chemical products)	
Transportation	On-road (four types of passenger vehicles: heavy-duty buses, medium-duty buses, light-duty buses, and minibuses; and four types of trucks: heavy-duty trucks, medium-duty trucks, light-duty trucks, and mini trucks; as well as motorcycles)	Technology-based turnover model
	Off-road (agriculture machinery, construction machinery, low-speed truck, 3-wheelers, locomotive, and in-land waterway)	Technology-based model
Residential	/	Technology-based model
Solvent use	Paint use, printing use, pharmaceutical production, vehicle treatment, wood production, pesticide use, and household solvent use	
Agriculture	Fertilizer use and livestock	

Table S3: The projection methods of non-energy related activity rates.

Activity rate of DPEC			Driving factors			Methods note
Sector	Subsector	Fuel/production type	Sector	Subsector	Fuel/production type	
Industrial non-combustion	Coke, iron, and steel	Sinter (production)	-	Driven by GDP with a Resilience factor law		Elastic coefficient method
		Iron (production)				
		Steel (production)				
		Coke		1) Iron production (DPEC)		Trend-adopted
	Cement	Cement	Industry	Cement production by region (GCAM-China)		Trend-adopted
	Other metals and non-metals	Other metal products (foundry products)	-	1) Projected steel production (DPEC) 2) Historical production (DPEC)		Regression model: From the activity levels of above steel production
		Non-ferrous metals (aluminum, copper, zinc, alumina, and other non-ferrous metal)	Socioeconomics	1) GDP at MER by region (GCAM-China) 2) Historical production (DPEC)		Regression model: Line regression
		Glass (flat glass and glass products)	Building	1) New building area (GCAM-China) 2) Historical production (DPEC)		Regression model: From the activity levels of new building area
		lime and brick		Projected cement production (GCAM-China)		Trend-adopted
		Food and drink industry (i.e. bread, cake, biscuit, sugar, beer, wine, and spirits), textile industry (i.e. wool, silk, cloth, and synthetic fiber).	Socioeconomics	1) GDP per capita at MER by region (GCAM-China) 2) Historical production (DPEC)		Regression model: Line regression

	Petrochemical industry	Fertilizer production(urea, ammonium bicarbonate, other nitrate fertilizers, and NPK fertilizer)	Socioeconomics	1) Fertilizer consumption (DPEC)	Trend-adopted
		Solvent production (varnish paint, architecture paint, printing ink, and glue production)		2) Corresponding solvent use (DPEC)	Trend-adopted
		Synthetic materials (polyvinyl chloride (PVC) products, polystyrene, ethylene, low-density polyethylene (LDPE), high-density polyethylene (HDPE), styrene, polystyrene, vinyl chloride, PVC, propylene, and polypropylene)	Socioeconomics	1) National GDP (GCAM-China) 2) Historical production (DPEC)	Regression model: Line regression
		Other chemical products (carbon black, sulfuric acid, synthetic ammonia by coal, pulp and asphalt production)	Socioeconomics	1) National GDP (GCAM-China) 2) Historical production (DPEC)	Regression model: Line regression
		Other chemical products (Rubber, and tyres)		1) Newly registered vehicles (GCAM-China)	Trend-adopted
Solvent use	Paint use	Architecture interior wall coating	Building	1) Newly-built area (GCAM-China) 2) Historical paint use (DPEC)	Regression model: From the activity levels of newly-built area
		Architecture other paint			
		Decorations wood			
		Wood furniture			

		New car varnish paint	Transportation	1) Newly registered vehicles (GCAM-China) 2) Historical paint use (DPEC)	Regression model: From the activity levels of newly registered vehicles
		Vehicle refurnish paint		1) Total vehicles (DPEC) 2) Historical paint use (DPEC)	Regression model: From the activity levels of total vehicles
		Other industrial coatings		Projected according to the annual growth rate of above paint use	Regression model: From the activity levels of above paint use
	Printing use	Printing ink	Socioeconomics	1) National GDP (GCAM-China) 2) Historical paint use (DPEC)	Regression model: Line regression
		Printing cleaning gasoline solvent			
	Pharmaceutical production	Pharmaceutical production			
	Wood Production Treated	Wood Production Treated			
	Vehicle treatment	Passenger vehicle treated-dewax	Transportation	1) Newly registered vehicles (GCAM-China) 2) Historical paint use (DPEC)	Regression model: From the activity levels of newly registered vehicles
		Passenger vehicle treated-reseal			
	Pesticide use	Pesticide use	Socioeconomics	1) Projected population (GCAM-China) 2) Historical pesticide usage (DPEC)	Regression model: Line regression
	Household solvent use	Domestic solvent	Socioeconomics	1) GDP per capita at MER by region (GCAM-China) 2) Historical solvent use	Regression model: Line regression

		Glue use		(DPEC)	
		Dry clean use	Socioeconomics	1) Urban GDP per capita at MER by region (GCAM-China) 2) Historical domestic dry clean solvent use (DPEC)	Regression model: Line regression
Agriculture	Livestock	Dairy cattle, other cattle, horse, donkey, mule, pig, goat, sheep, broiler, laying hen, other poultry	Socioeconomics	1) Projected population (GCAM-China) 2) Historical amount (DPEC)	Regression model: Line regression
	Fertilizer application	Urea, ammonium bicarbonate, other N fertilizers, NPK	Socioeconomics	Regression model: 1) Historical fertilizer application (DPEC) 2) National crop yield 3) The future national crop yield is estimated using the product of per capita crop yield and population (GCAM-China)	Regression model: Line regression

Table S4: The sector mapping between the DPEC model and the CMIP6 database.

DPEC model sector	CMIP6 database sector
Power, heating industrial	Energy sector
Industry	Industrial sector, peat burning, waste
Residential, heating residential	Residential commercial other
Transportation	Transportation sector
Solvent use	Solvents production and application
Agriculture	Agriculture