Short-lived Greenhouse Gas Emission Scenarios in China

Jiang Kejun, Hu Xiulian

Energy Research Institute

AIM International Workshop 2021

Research Methodology

Using IPAC-AIM/technology model：CH4，BC，NOX，VOC

Air-Pollution model: by inputing NOX，VOC，to get O3

Using GCM: calculate warming before 2050

Scenarios：1.5℃ as target, two scenarios:

1.5 ℃ scenario
1.5 ℃ low Nature Gas Scenario

Source of CH4 emission from IPAC

Energy Combustion
Oil exploitation
Natural gas exploitation
Oil transport
Natural gas transport
Coal mining
Coal Bed Methane expoitation
Waste treatment: landfills
Waste treatment: burning
Agriculture： rice field
husbandry
straw burning and bury

Black carbon emission sources

Energy combustion

coal: large sources

coal: scatted burning

diesel engine： generators， others

Transport: diesel vehicle, ship, air plane, trains

Vehicles not for transport purposes： agriculture use, engineering

Biomass use： Agriculture

rural household

NOx Emission sources

Energy combustion
- Large sources
- Scatted burning
- Transport

Process：
- Ammonia
- Other chemical
- Metal manufactures

VOC Emission sources

Energy Combustion
Gas station
Chemical industry
Biomass burning
Daily life material use
Natural sources

Technology List

Classification	Technologies (equipment)
ɛ Steel	Coke oven, Sintering machine, Blast furnace, Open hearth furnace (OH), Basic oxygen furnace (BOF), AC-electric arc furnace, DC-electric arc furnace, Ingot casting machine, Continuous casting machine, Continuous casting machine with rolling machine, steel rolling machine, Continuous steel rolling machine, Equipment of coke dry quenching, Equipment of coke wet quenching, Electric power generated with residue pressure on top of blast furnace (TRT), Equipment of coke oven gas, OH gas and BOF gas recovery, Equipment of co-generation.
errous metal	Aluminum production with sintering process, Aluminum production with combination process, Aluminum with Bayer, Electrolytic aluminum with upper-insert cell, Electrolytic aluminum with side-insert cell, crude copper production with flash furnace, crude copper production with electric furnace, Blast furnace, Reverberator furnace, Lead smelting-sintering in blast furnace, Lead smelting with closed blast furnace, Zinc smelting with wet method, Zinc smelting with vertical pot method.
ng materials	Cement: Mechanized shaft kiln, Ordinary shaft kiln, Wet process kiln, Lepol kiln, Ling dry kiln, Rotary kiln with pro-heater, dry process rotary kiln with pre-calciner, Self-owned electric power generator, Electric power generator with residue heat; Brick & Tile: Hoffman kiln, Tunnel kiln; Lime: Ordinary shaft kiln, Mechanized shaft kiln; Glass: Floating process, Vertical process, Colburn process, Smelter.
ical industry	Equipment of synthetic ammonia production: Converter, Gasification furnace, Gas-making furnace, Synthetic column, Shifting equipment of sulphur removing; Equipment of caustic soda production: Electronic cell with graphite process, Two-stage effects evaporator, Multi-stage effects evaporator, Equipment of rectification, Ion membrane method; Calcium Carbine production: Limestone calciner, Closed carbine furnace, Open carbine furnace, Equipment of residue heat recovery; Soda ash production: Ammonia & salt water preparation, limestone calcining, distillation column, filter; Fertilizer production: Equipment of organic products production, Equipment of residue heat utilization
hemical Industry	Facilities of atmospheric & vacuum distillation, Facilities of rectification, Facilities of catalyzing & cracking, Facilities of cracking with hydrogen adding, Facilities of delayed coking, Facilities of light carbon cracking, Sequential separator, Naphtha cracker, de-ethane separator, diesel cracker, de-propane cracker, facilities of residue heat utilization from ethylene.
-making	Cooker, facilities of distillation, facilities of washing, facilities of bleaching, evaporator, crusher, facilities of de-water, facilities of finishing, facilities of residue heat utilization, facilities of black liquor recovery, Co-generator, Back pressure electric power generator, condensing electric power generator.
e	Cotton weaving process, Chemical fiber process, Wool weaving & textile process, Silk process, Printing & dyeing process, Garment making, Air conditioner, Lighting, Facilities of space heating.
inery	Ingot process: Cupola, Electric arc furnace, fan; Forging process: coal-fired pre-heater, Gas-fired pre-heater, Oil-fired pre-heater, Steam hammer, Electric-hydraulic hammer, Pressing machine; Facilities of heat processing: Coal-fired heat processing furnace, Oil-fired heat processing furnace, Gas-fired heat processing furnace, Electric processing furnace; Cutting process: Ordinary cutting, high speed cutting.
ion	Diesel engine, Electric induct motor
ng works	Tractor, Other agricultural machine
ultural products process	Diesel engine, Electric induct motor, processing machine, coal-fired facilities.
y	Diesel engine, Electric induct motor.
al husbandry	Diesel engine, Electric induct motor, Other machines.
heating in resident	Heat supplying boiler in thermal power plant, Boiler of district heating, Dispersed boiler, Small coal-fired stove, Electric heater, Brick bed linked with stove (Chinese KANG).
g in resident	Air conditioner, Electric fan.
ng in resident	Incandescent lamp, Fluorescent lamp, Kerosene lamp.
ng & Hot water in nt	Gas burner, bulk coal-fired stove, briquette-fired stove, Kerosene stove, Electric cooker, cow dung-fired stove, firewood-fired stove, methane-fired stove.
ic Appliance	Television, Cloth washing machine, Refrigerator, others.
heating in service sector	Heat supplying boiler in the thermal power plant, Boiler of district heating, dispersed boiler, Electric heater.
ng	System of central air conditioner, Air conditioner, Electric fan.
ng	Incandescent lamp, fluorescent lamp.
ng & Hot water	Gas burner, Electric cooker, Hot water pipeline, Coal-fired stove.
ic Appliance	Duplicating machine, computer, Elevator, others.
nger & freight transport	Railway (passenger & freight): Steam locomotive, Internal combustion engine locomotive, Electric locomotive.; Highway (passenger & freight): Public diesel vehicle, Public gasoline vehicle, Private vehicle, Large diesel freight truck, Large gasoline vehicle, small freight truck. Waterway (passenger & freight): Ocean-going ship, Coastal ship, Inland ship. Aviation (passenger & freight): Freight airplane, passenger airplane.

Sectors in IPAC/AIM

No.	Industries	Sectors	Subsctors
1	Agriculture	Grain	
2		Rice	
3		Husbandry	
4		Forest	
5		Fishing	
6	Industry	Coal mining	
7		Oil and N.Gas exploitation	
8		Other mining	
9		Steel making	
10		Non-ferrous	Aluminum
11			Copper
12			Zinc and Lead
13		Building materials	Cement
14			Glass
15			Lam
16			Brick
17		Petrochemical	Ethylene
18			Chemical fiber
19			Plastic
20		Chemical industry	Ammonia
21			Fertilizer
22			Soda Ash
23			Caustic soda
24			Calcium carbide
25			Organic chemical products
26			Other chemical products
27		Paper making	
28		Textile	Cloth
29			Printing and Dyeing
30			Cloth making
31		Other manufactures	
32		Other industry	
33		Construction	

39	Transport	Freight transport	
40		Passenger transport	
41	Tertiary		
42	Urban resident		
43	Rural resident		
44	Waste	Municipal waste landfill	
45		Building waste	
46		Municipal waste power generation	
47		Recycling	
48	Coal based chemical industry	CTL	
49		CTG	
50		Coal to chemical	
51	Waste water treatment		
52	Non-energy sources	Construction site	
53		Road	
54		Ammonia from agriculture land	
55		Cooking	

Sectors in Transport

Subsector	Mode level 1	Mode level 2	Mode level 3
Passenger transport	Road	Car	Private car
			Business car
			taxi
		Buses	Bus for entities own use
			Public transport bus
		Non-mobility transport	
	Railway	Diesel locomotive	
		Electric locomotive	
		High speed train	
	Air		
	Water way	Inner river ship	
		Near sea ship	
Freight transport	Road	Small and medium truck	
		Heavy duty truck	
	Railway	Diesel locomotive	
		Electric locomotive	
	Air		
	Water way	Inland river ship	
		Sea ship	
		Ocean ship	
	Pipeline	Natural gas	
		Oil	

Technology list in transport

Classification	Technologies
Car	Normal gasoline car, normal diesel car, energy efficient gasoline car, energy efficient diesel car, hybrid gasoline car, hybrid diesel car, advanced hybrid gasoline car, advanced hybrid diesel car, super high energy efficiency diesel car, plugin hybrid gasoline car, plugin diesel car, electric car, advanced electric car, hydrogen fuel cell car
Heavy duty Truck	Normal diesel truck, gasoline truck, energy efficient diesel truck, advanced energy efficient diesel truck, LNG truck, high energy efficient LNG truck, hybrid diesel truck, electric truck, hydrogen fuel cell truck
Light duty truck	Normal diesel truck, gasoline truck, energy efficient diesel truck, energy efficient gasoline truck, advanced energy efficient diesel truck, Nature Gas truck, high energy efficient LNG truck, hybrid gasoline truck, hybrid diesel truck, electric truck, hydrogen fuel cell truck
Bus	Gasoline bus, diesel bus, energy efficient gasoline bus, energy efficient diesel bus, hybrid gasoline bus, hybrid diesel bus, advanced diesel hybrid bus, CNG/LNG bus, advanced CNG/LNG bus, electric bus, trolly bus, mini gasoline bus, mini diesel bus, energy efficient mini gasoline bus, energy efficient mini diesel bus, hybrid mini gasoline bus, hybrid mini diesel bus, CNG mini bus, electric mini bus, hydrogen fuel cell bus.
Locomotive	Diesel locomotive, electric locomotive, energy efficient diesel locomotive, energy efficient electric locomotive, heavy duty electric locomotive, high speed train, energy efficient high speed train, hydrogen fuel cell locomotive
Air plane	Normal air plane, 20% higher energy efficient air plane, 35% higher energy efficiency air plane, bio-fuel air plane, electric air plane, fuel hydrogen cell air plane
Ship/vessel	River ship, energy efficient river ship, electric river ship, coastal vessel, high efficiency coastal vessel, cross ocean vessel, advanced energy efficiency cross ocean vessel, bio-fuel vessel, renewable energy utilized vessel, super high efficiency low emission vessel, electric vessel
Pipeline	Electricity driven pipeline, gas driven pipeline, oil driven pipeline
Metro/subway	Subway, energy saving subway
Bicycle	Bicycle, electric bike
Alternative fuel	E10, E15, E25, E85, E100, M3, M15

Emission factors from coal mining Kg/t coal

activities		Emission Factor
Open mouth coal mine		1.34
After mining activities	High methane coal mine	2.01
	Low methane coal mine	0.6
	Open mouth coal mine	0.34

Emission factors from oil ad n.gas facilities

表 2.2 油气系统不同设施 CH_4 排放因子缺省值*

油气系统	设施/设备 CH_4 排放因子	
	设施逃逸	工艺放空
天然气系统		
a).天然气开采		
—井口装置	2.50(吨/年•个)	(吨/年•个)
—集气站	27.9(吨/年•个)	23.6(吨/年•个)
—计量/配气站	8.47(吨/年•个)	-
—储气站	58.37(吨/年•个)	10.0(吨/年•个)
b).天然气处理	40.34(吨/亿 Nm3)	13.83(吨/亿 Nm3)
c).天然气储运		
—压气站/增压站	85.05(吨/年•个)	10.05(吨/年•个)
—计量站/分输站	31.50(吨/年•个)	13.52(吨/年•个)
—管线(逆止阀)	0.85(吨/年•个)	5.49(吨/年•个)
—清管站	0	0.001(吨/年•个)
石油系统		
a).常规原油开采		
—井口装置	0.23(吨/年•个)	-(吨/年•个)
—单井储油装置	0.38(吨/年•个)	0.22(吨/年•个)
—接转站	0.18(吨/年•个)	0.11(吨/年•个)
—联合站	1.40(吨/年•个)	0.45(吨/年•个)
b).原油储运		
—原油输送管道	753.29(吨/亿吨)	-

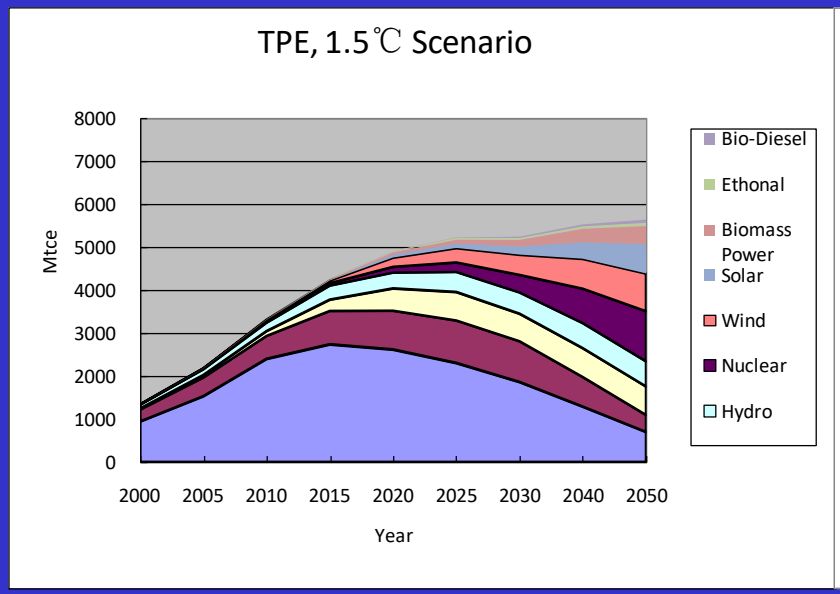
*数据来源：2005年中国温室气体清单研究。

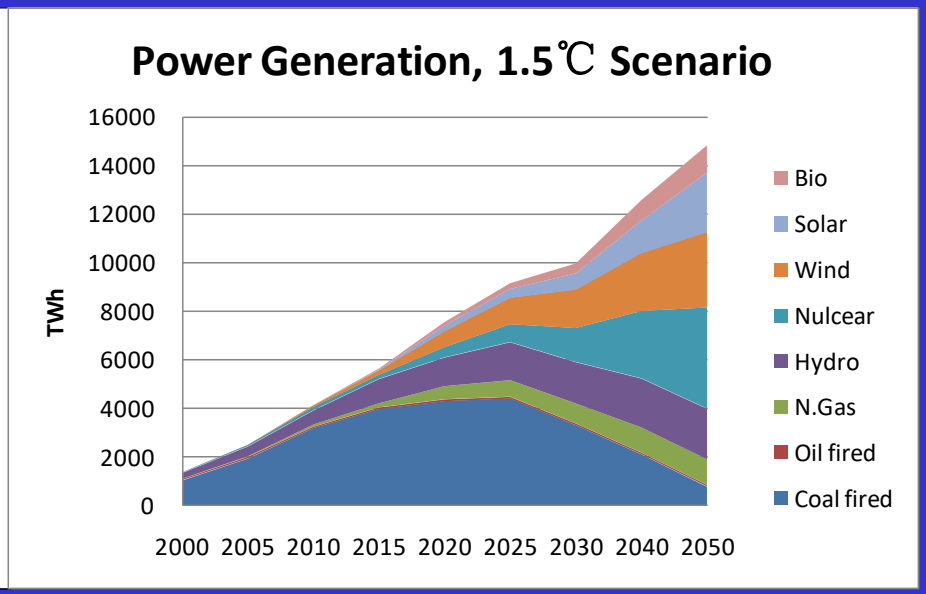
BC emission factors

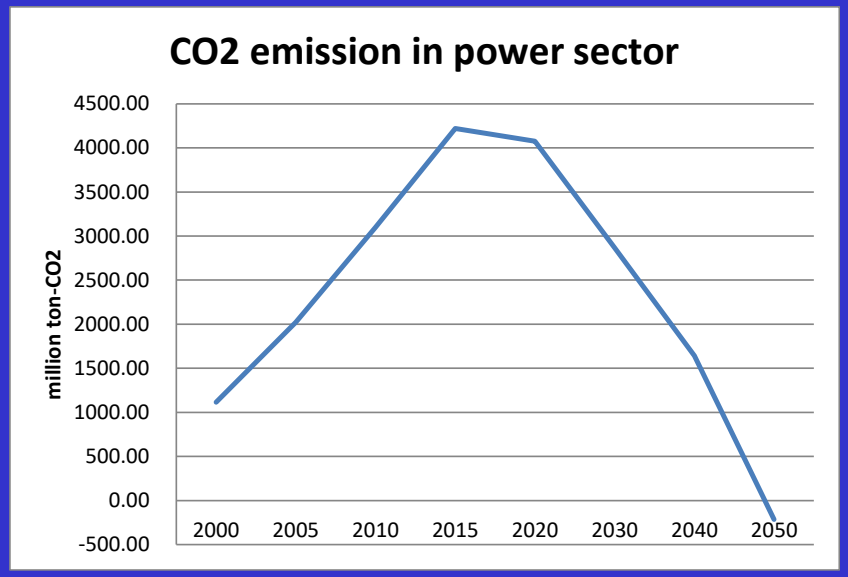
表 2　排放因子汇总表(固定源)(g kg^{-1})

排放源	燃料类型	相关排放因子	本文排放因子
工业源	煤炭	0.003[19], 0.32[19], 0.000062[35]	0.044[a)]
	石油类	0.00012~0.117[18]	0.00012~0.117
	气体类	0.00012[18]	0.00012
	焦炭	0.03136[18]	0.03136
	土法炼焦	3.8[43], 4.8[18]	3.8
	机械炼焦	0.97[18]	0.97
火电 [b)]	煤炭	0.003[19], 0.32[19]	0.0013[a)]
供暖 [b)]	煤炭	0.003[19], 0.32[19]	0.044[a)]
居民生活源化石燃料	原煤-烟煤	3.05[32], 3.7[19], 2.750[35], 3.81[36]	3.05
	原煤-无烟煤	0.007[32], 0.12[19], 0.028[35], 0.007[36]	0.007
	蜂窝煤-烟煤	0.09[32], 0.12[19], 0.082[36]	0.09
	蜂窝煤-无烟煤	0.004[32], 0.004[36]	0.004
	石油类	0.0676~0.117[18]	0.07, 0.117, 0.25, 0.0676
	天然气	0.00012[18]	0.00012
居民生活源生物燃料	秸秆	0.67[39], 0.43[37], 1.38[38]	0.74[c)]
	薪柴	1.49[37]	1.49
	沼气	0.0001[18]	0.0001
生物质燃烧	小麦秸秆	0.52[40], 0.49[42]	0.50[c)]
	水稻秸秆	0.52[40], 0.43[41]	0.47[c)]
	玉米秸秆	0.78[40], 0.35[42]	0.52[c)]
	棉花秸秆	0.82[40]	0.82
	其他秸秆	0.69[44]	0.69
	森林火灾	0.56[44], 0.99[27]	0.99
	草原火灾	0.48[44]	0.48

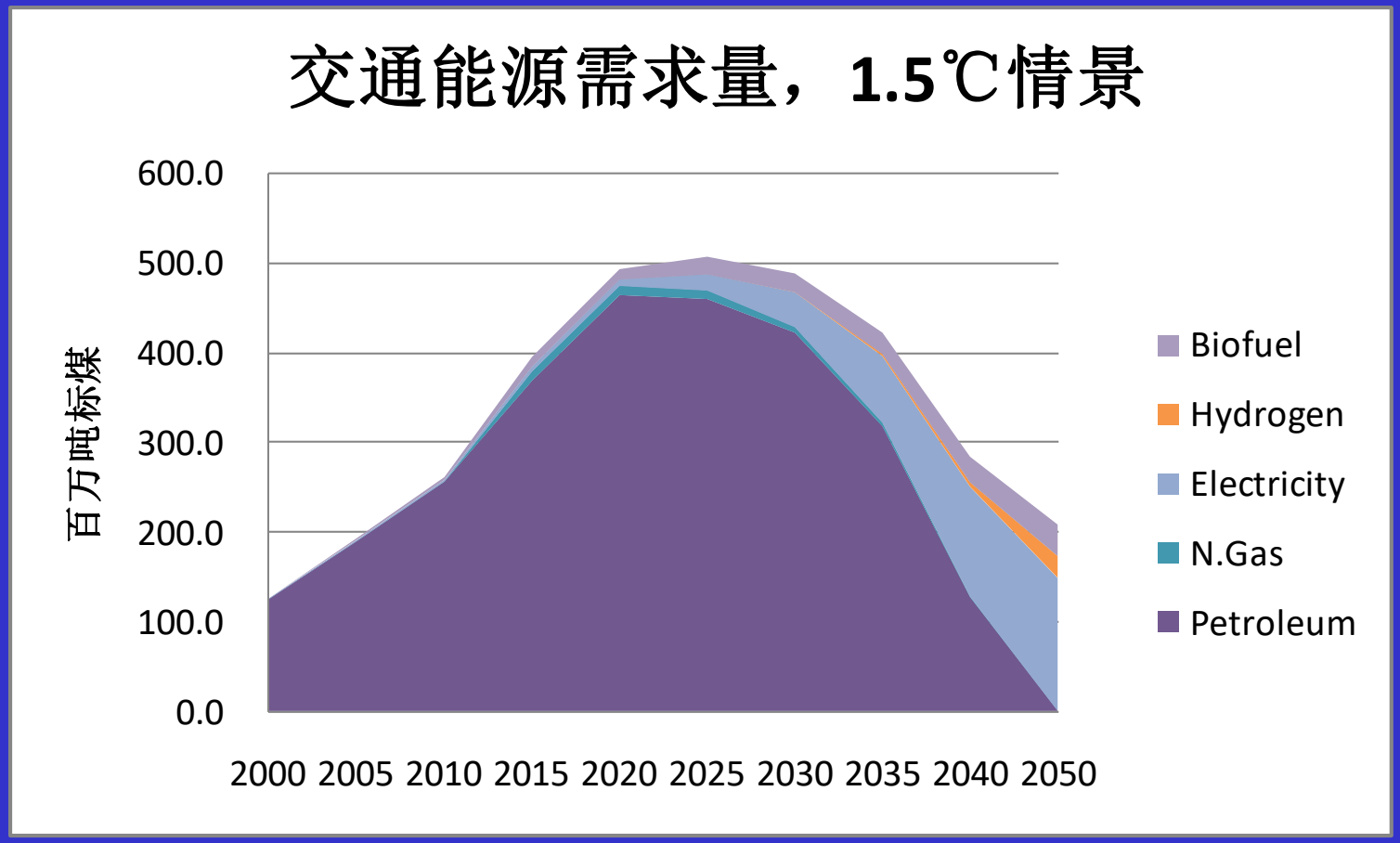
a) 根据原始排放因子、除尘效率、除尘器比例计算得到的最终排放因子; b) 火电及供暖行业石油类和气体类燃料的排放因子与工业源相同; c) 相关排放因子的几何均值


TPE, 1.5℃ Scenario
Mtce
8000
7000
6000
5000
4000
3000
2000
1000
0
2000 2005 2010 2015 2020 2025 2030 2040 2050
Year
Bio-Diesel
Ethonal
Biomass
Power
Solar
Wind
Nuclear
Hydro

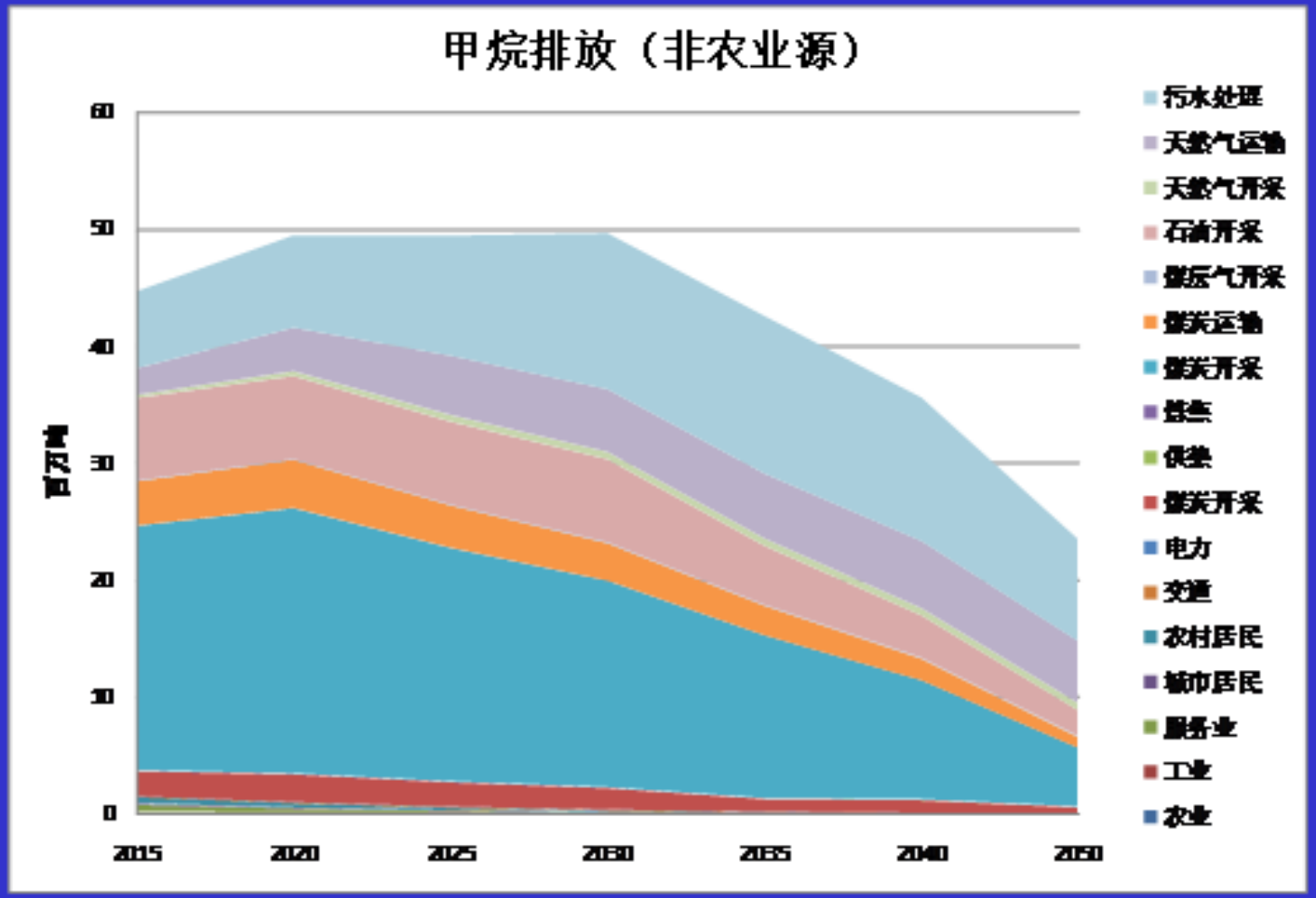

Power Generation, 1.5℃ Scenario
TWh
16000
14000
12000
10000
8000
6000
4000
2000
0
2000 2005 2010 2015 2020 2025 2030 2040 2050
Bio
Solar
Wind
Nulcear
Hydro
N.Gas
Oil fired
Coal fired


CO2 emission in power sector
million ton-CO2
4500.00
4000.00
3500.00
3000.00
2500.00
2000.00
1500.00
1000.00
500.00
0.00
-500.00
2000 2005 2010 2015 2020 2030 2040 2050

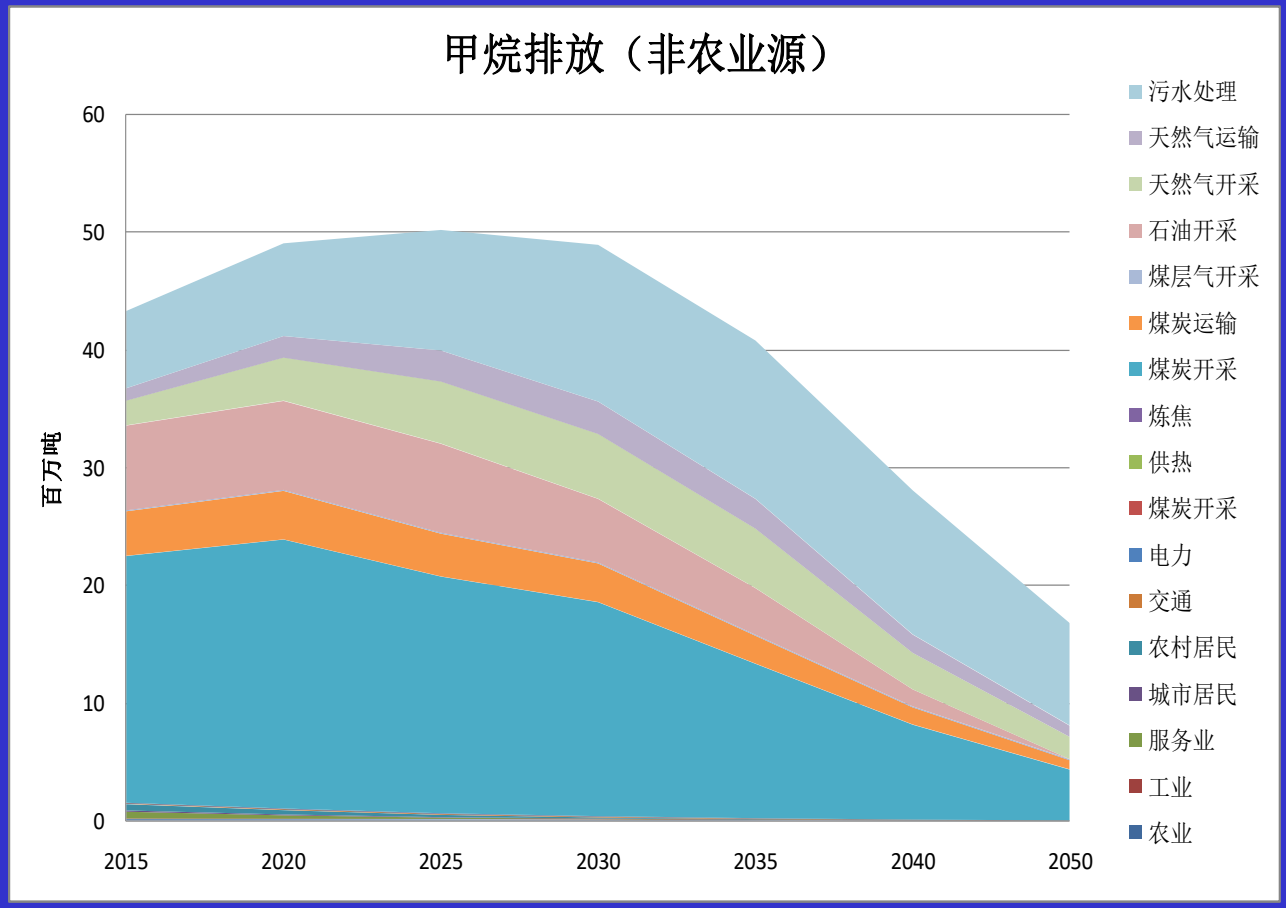
Final energy demand in transport in China

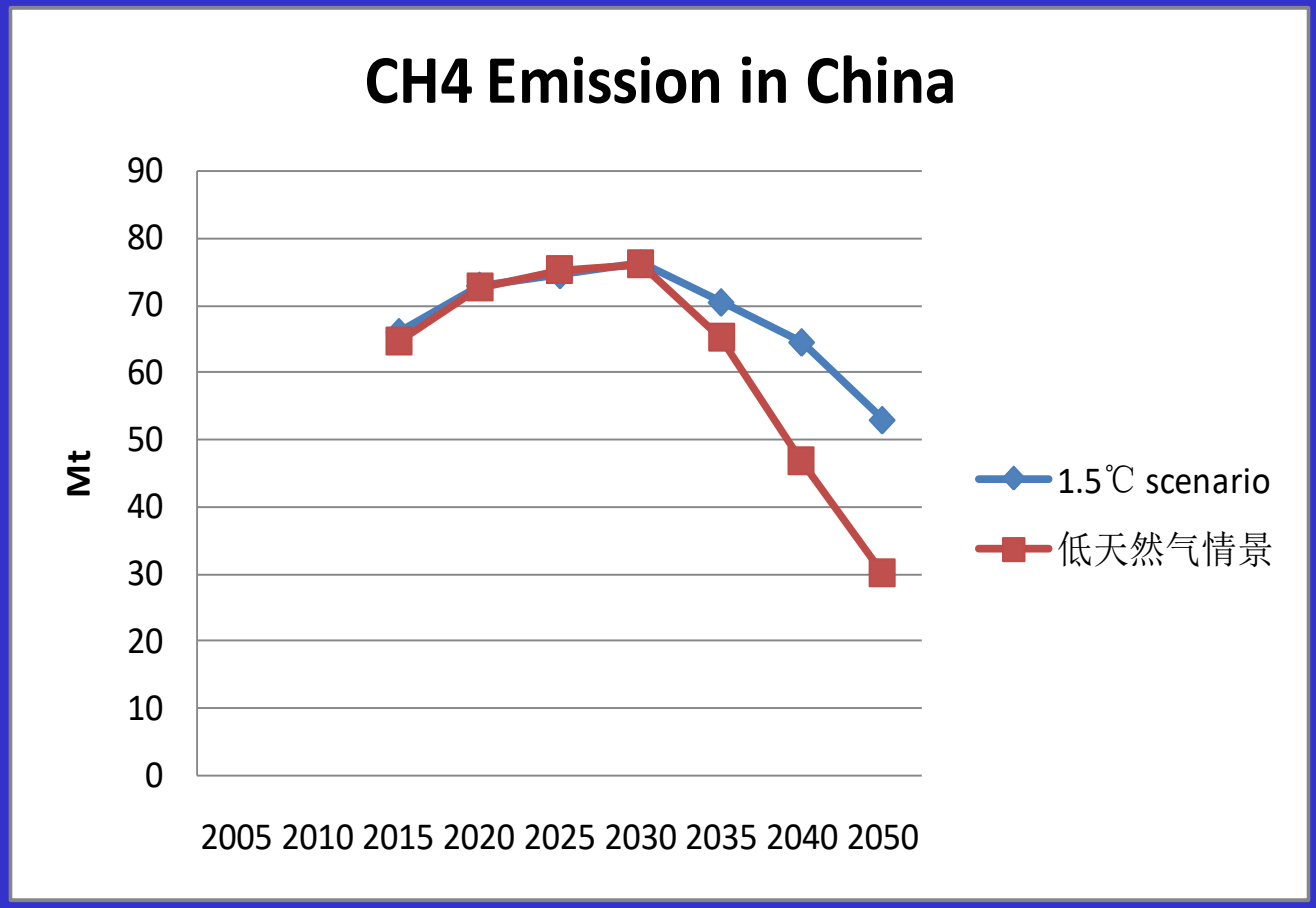


Methane emission: 1.5C scenario, not including agriculture sources

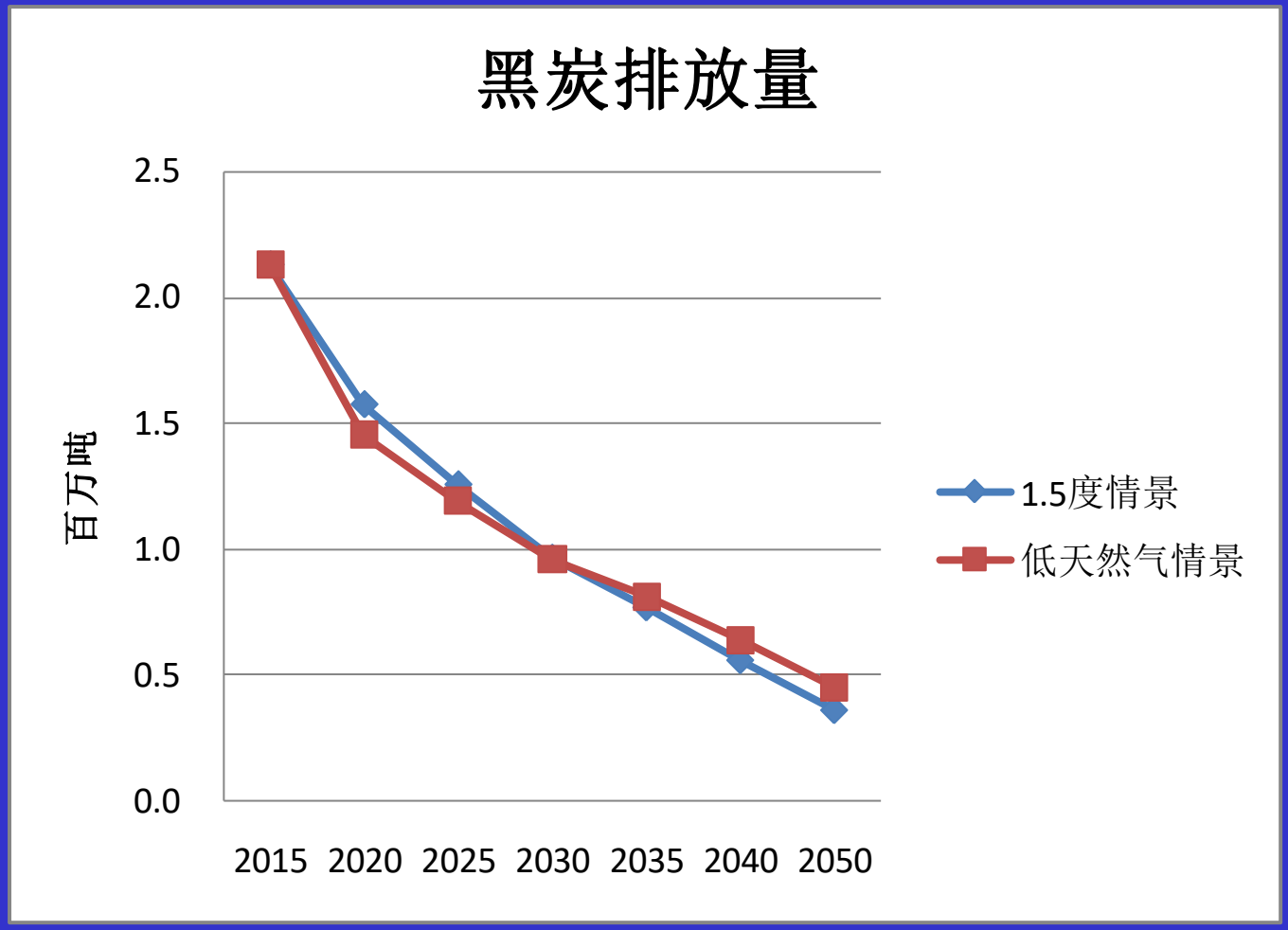


Methane emission: low natural gas scenario

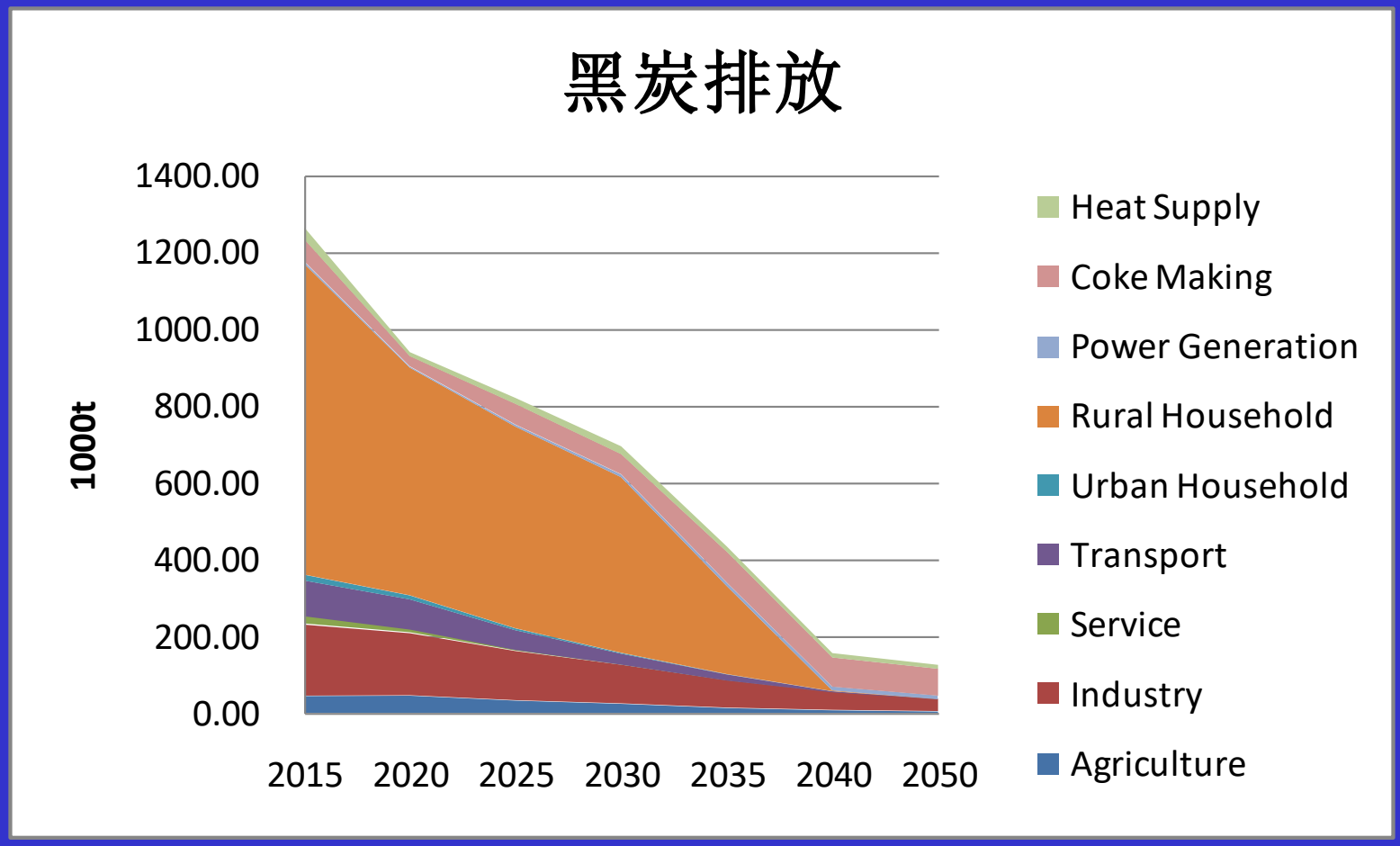



CH4 Emission in China
Mt
90
80
70
60
50
40
30
20
10
0
2005 2010 2015 2020 2025 2030 2035 2040 2050
1.5℃ scenario
低天然气情景

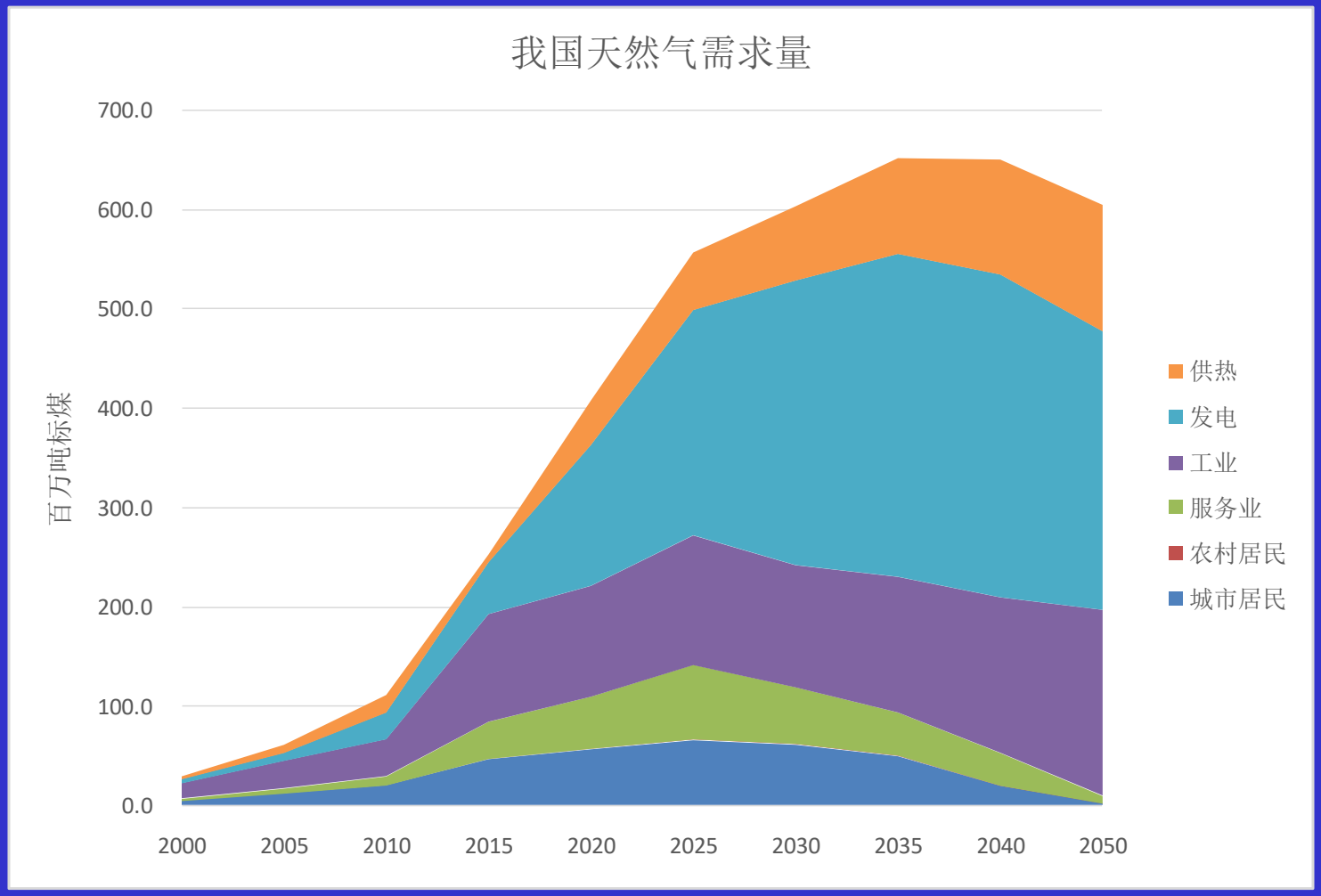
Black Carbon Emission



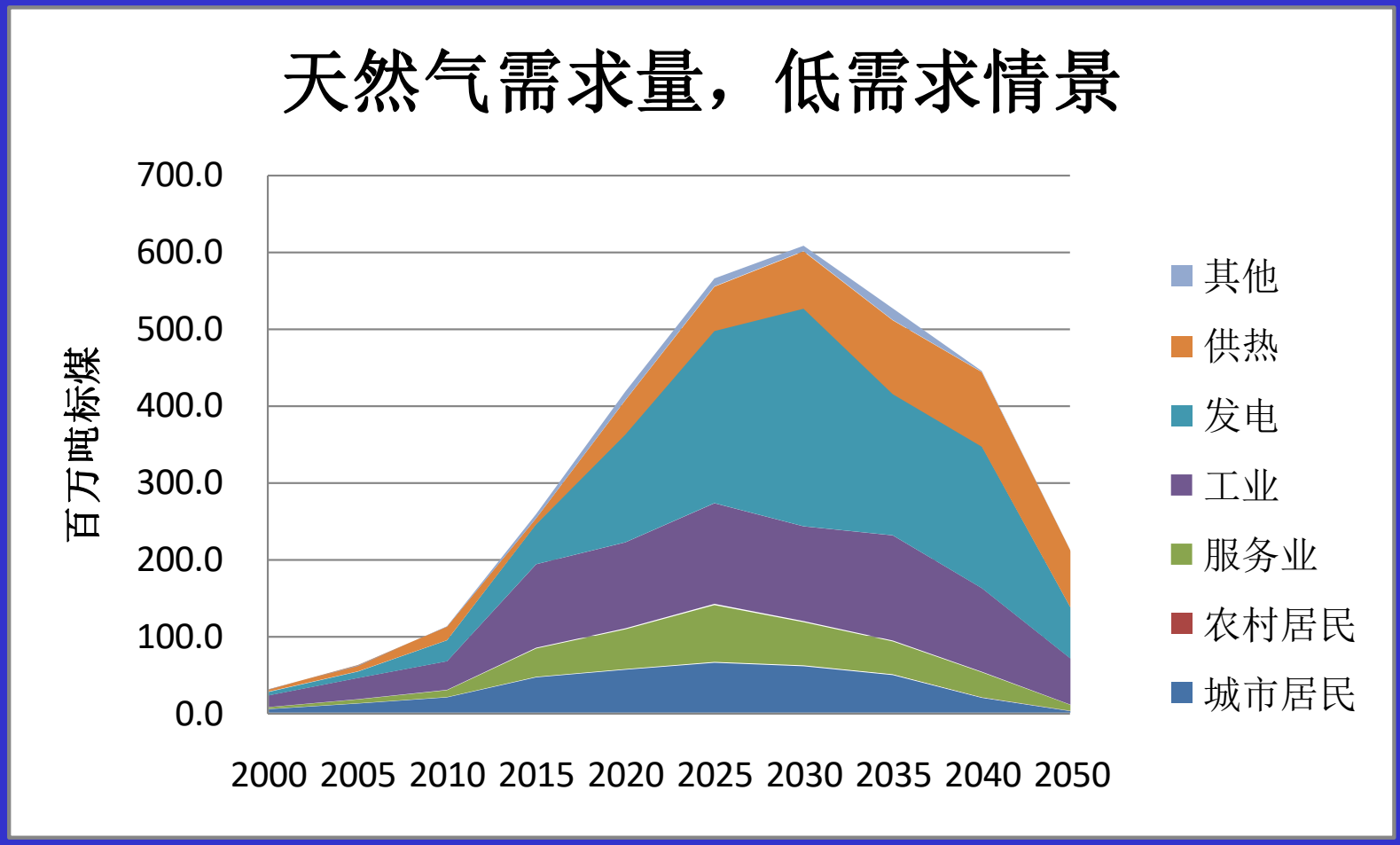
BC Emission

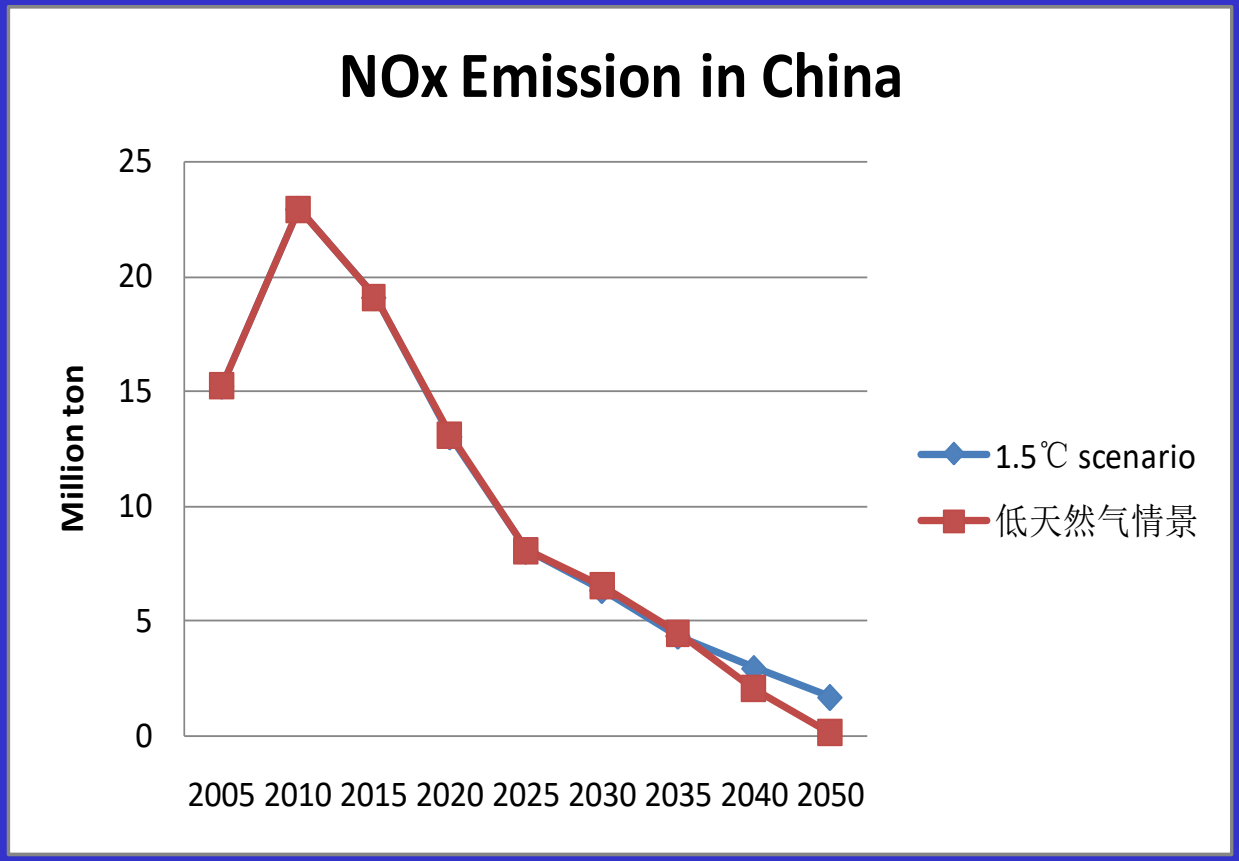

黑炭排放
1400.00
1200.00
1000.00
800.00
600.00
400.00
200.00
0.00
1000t
2015
2020
2025
2030
2035
2040
2050
Heat Supply
Coke Making
Power Generation
Rural Household
Urban Household
Transport
Service
Industry
Agriculture

Natural gas scenario: 1.5C



Natural gas scenario: low demand



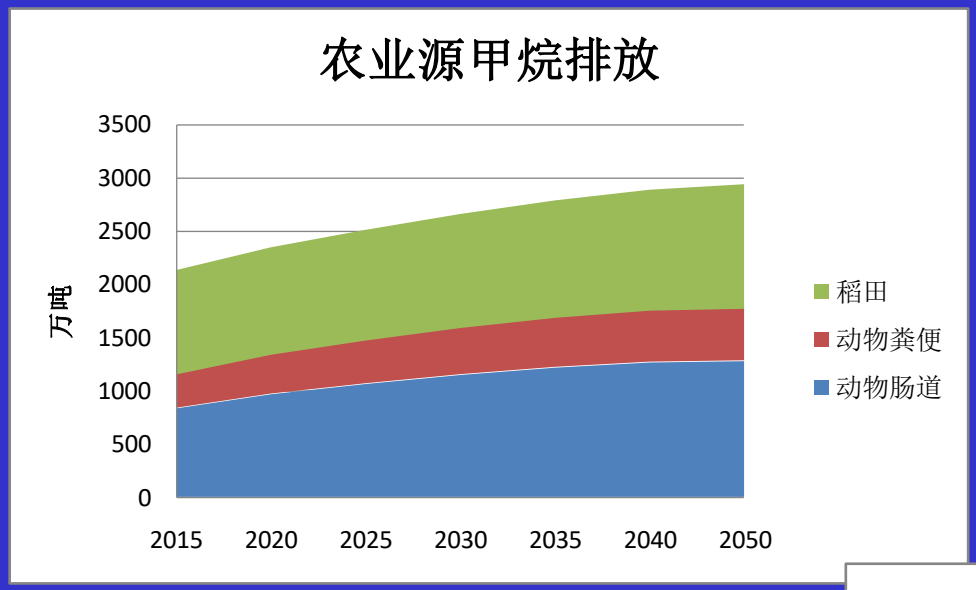

NOx Emission in China
Million ton
25
20
15
10
5
0
2005 2010 2015 2020 2025 2030 2035 2040 2050
1.5℃ scenario
低天然气情景

O3 concentration

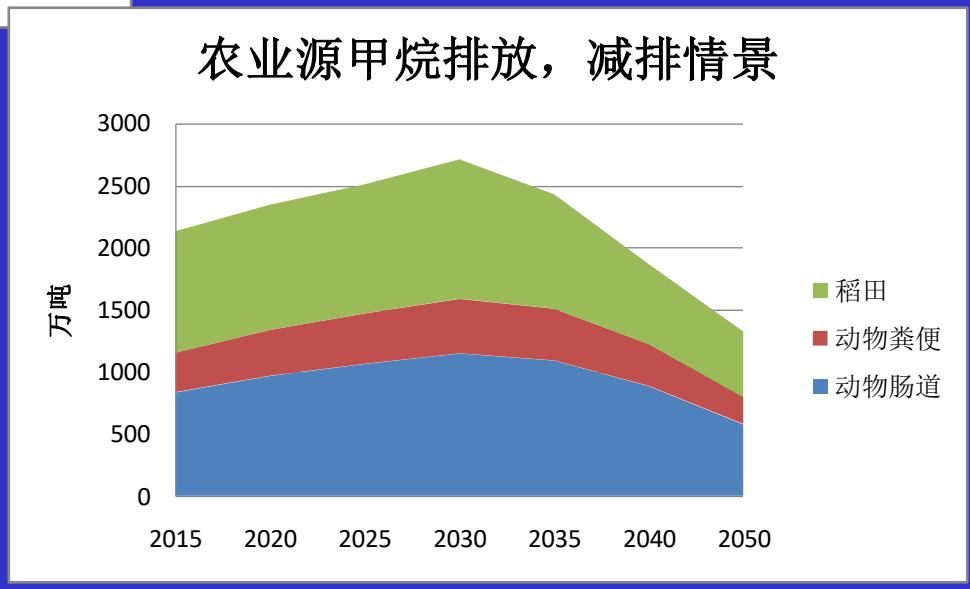
(ηg/m3)	MDA8				
	2015	2020	2030	2040	2050
Beijing-Tianjin-Hebei	154.9	136.7	102.2	91.2	81
Yangzi River Delta	118.3	95.4	66.4	58.6	51.1
Pearl River Delta	163.5	132	93.1	81.1	71.1
ChengDu-Chongqing	130.2	99.6	69.6	61.3	54
Fenwei Plateau	123.2	100.7	73.9	65.7	58

Emission, ton	Nox	VOC
2015	21927361	30568708
2020	11534398	29571405
2030	5097161	21293515
2040	3750767	19211343
2050	2714551	17348648

Methane emission: agriculture



Methane emission: agriculture mitigation



Future Agriculture

- Manmade protein
- Agriculture without soil
- No cotton future
- Well fit food
- Agriculture revolution?

Next step

Using GCMs to simulate temperature rise in China

Specify temperature rise due to SLCPs

Analyze impact on energy by temperature rise using HDD and CDD

Policy recommendation