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Study on the Distribution of Carbon Emission Reduction Potential of Urban Transformation Development under the "Dual Carbon" Goal--Taking Guangzhou as an Example

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Introduction

- *Action Plan for Carbon Peaking Before 2030*, formulated by the Central Committee of the Communist Party of China (CPC) and the State Council, requires regions with stabilized carbon emissions to further reduce their carbon emissions on the basis of taking the lead in achieving carbon peaking.
- Regarding how to further reduce carbon emissions after reaching the peak, most of leading regions in China merely proposed framework at the macro level, lacking detailed sectoral and equipment-level countermeasures.
- To further decompose the sectoral carbon reduction tasks and propose targeted recommendations, it is necessary to identify the main emission sources at the equipment level and to assess the emission reduction potential of various measures.
- The main tasks of this research are as follows: (1) assess the emission reduction potential of each sector in the case city; (2) identify the main emission sources and the emission reduction potential various measures at the sectoral level; (3) propose a carbon emission reduction pathway after peaking from the sectoral equipment perspective.

Methods

MCEE Model

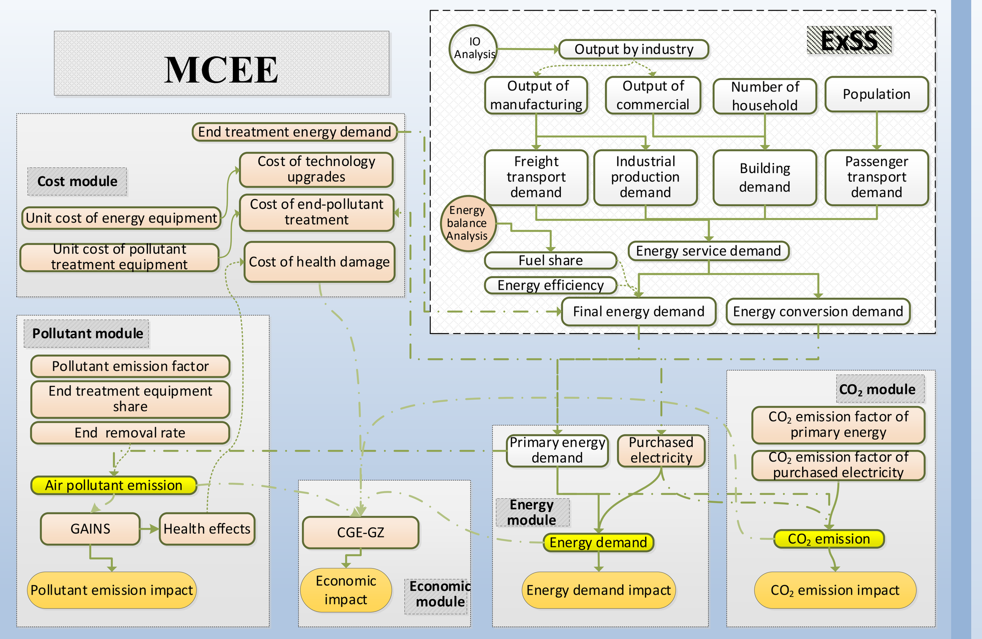
The model adopted in this poster is the multi-objective comprehensive assessment model for energy consumption, CO_2, and pollutant emission, referred to as MCEE. MCEE is constructed based on the ExSS model, and it contains the following sub-modules or functions.

1.Air pollutant Module:
A module for calculating air pollutants from energy combustion

2.Health Impact Module:
Quantifies morbidity and mortality as well as derived medical expenditure, work time loss and premature death

3.Cost Module:
A module used to estimate the cost of technology upgrading, air pollution treatment and health of the whole society

4.Economy Module:
Estimate the economic impact of changes in costs



5. Measure's contribution assessment function:
Assess the energy saving and emission reduction contribution of each measure based on the accounting segment in which it is located

Settings

- All the datasets are converted to the base year of 2015.
- It is assumed that the controlled amount of energy demand and Carbon dioxide intensity per unit GDP in each of the following FYP is the same as the 13th FYP, and the air pollutant emissions decrease by 20% per five years.

Table.1 Scenario Setting

No.	Scenario	Description
1	BaU	The baseline scenario. It is based on the trend of 2015 development, does not consider any measures. As a reference scenario, it does not actually exist.
2	HD(high-quality transition)	The HD scenario includes the following measures: restructuring the energy structure in the power generation sector, increasing the proportion of renewable energy generation, cleaning the purchased power, improving the energy efficiency of equipment, replacing oil with electricity in the transportation sector, electrification in the industrial sector, improving the energy efficiency level of electrical equipment inside buildings, optimizing the industrial structure, reducing the demand for industrial activities, optimizing travel modes, reducing the demand for transportation activities and reducing the demand for construction activities.

Classification of equipment:
The model is set up for 20 industries and 29 equipment types , as shown in Tab. 2.

Classification of measures:
The carbon emission processes caused by production or living are simplified into four stages, as shown in Fig.1. The measures are summarized into five categories according to the stages: demand scale optimization measures (DSO), lower intensity of demand measures (LID), energy efficiency improvement measures (EEI), end-use energy restructuring measures (EER), and power generation energy restructuring measures (PER), as shown in Tab. 3.

Tab.2 Industry and equipment settings

Code	Sectors	Code	Equipment
pts	Passenger transport	tpsv	Passenger small vehicles
fts	Freight transport	tplv	Passenger Large Vehicles
hht1	Household of towns	tpcv	Commercial vehicle
hht2	Household of country	tpbs	Bus
pd1	Extractive Industries	tptr	Passenger train
pd2	Food and tobacco	tptw	Two wheeler
pd3	Textile	tpsh	Passenger ship
pd4	Wood processing and furniture	tpar	Passenger aircraft
pd5	Paper printing, cultural and educational	walk	Walk
pd6	Petroleum, coking products	bike	Bike
pd7	Chemical industry	tfsv	Small freight vehicle
pd8	Nonmetal manufacturing	tflv	Large freight vehicle
pd9	Ferrous metal processing manufacturing	tftr	Freight train
pd10	General Equipment Manufacturing	tfsh	Freight ship
pd11	Transportation Equipment Manufacturing	tfar	Freight aircraft
pd12	Other manufacturing industries	cl	Air conditioner
pd13	Power, heat, gas and water supply industries	ht	Heating equipment
pd15	Construction industry	hw	Hot water heaters
pd17	Wholesale and retail trade	kt	Kitchen facilities
pd18	Transportation	ke	Cooking Appliance
		lg	Lighting
		rf	Freezer cabinet
		em	Other electrical equipment
		dh	Furnaces
		st	Steam (boiler)
		mt	Motor
		ot	Other equipment
		cstl	Smelting of iron and steel
		kln	Clinker production

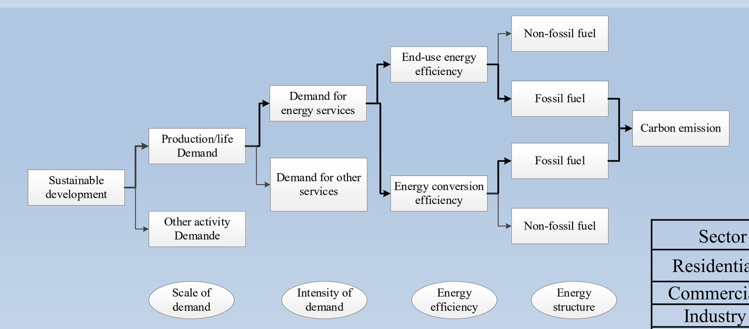


Fig.1 A brief view of the carbon emissions process

Tab.3 Measure Setting

Sector	DSO	LID	EEI	EER	PER
Residential	Population and households	Population, buildings, value of output Energy Service Intensity	End-use equipment energy efficiency, energy conversion efficiency	Electrification of buildings, electrification of transportation and end-use energy transition	Electricity emission factors
Commercial	Building area				
Industry	value of industry				
Passenger	Passenger turnover	Energy services per unit of turnover			
Freight	Freight turnover				

Results

1. Distribution of Emission Reduction Potential

- From the perspective of sectors, industrial sector has the highest potential for emission reduction in the next ten, with an annual emission reduction of 46.94 Mt, accounting for 40.08% of the total reduction, followed by the transportation sector, with an annual reduction of 42.89 Mt, accounting for 38.32%. There is an obvious growth on the emission reduction potential of the transportation sector and the commercial service sector, while that of the industrial sector and the residential sector is declining. (Tab.4)
- From the perspective of measures, EEI has the largest emission reduction potential in the next ten years, with an annual reduction of 44.34 Mt, accounting for 38.00% of the total reduction, followed by PER, with an emission reduction of 29.84 Mt, accounting for 25.00%. The emission reduction potential of EEI continues to decrease over time, while that of the EER and PER continues to increase. (Tab. 5)
- From the perspective of equipment, freight vehicles, cargo ships, petrochemical boilers, water heating equipment of commercial and service sectors, and passenger vehicles have high potential of emission reduction, occupying the top 5 of the equipment with the largest emission reduction potential. (Tab.6)

2. Characteristics of Emission Reduction Potential

- The transportation sector has the largest emission reduction potential and with concentrated emission sources. The largest emission reduction source of passenger transportation is private cars, which accounts for 66.60% of passenger transportation and 4.10% of all. The largest emission reduction source of freight transportation is highway freight transportation, which accounts for 58.69% of freight transportation and 18.87% of all. (Fig.2-Fig.3)
- The industrial sector has a large emission reduction potential, but its emission sources are scattered. The largest emission reduction source of the light industry is boiler equipment in the textile industry, which accounts for 28.65% of the light industry and 3.17% of all. The largest emission reduction source of the heavy industry is boiler equipment in the petrochemical industry, which accounts for 31.62% of the heavy industry and 5.01% of all. The largest emission reduction source of the manufacturing industry is power motors, which accounts for 30.95% of the manufacturing industry and 2.87% of all. (Fig.6-Fig.7)
- The building sector has a small emission reduction potential and its emission sources are dispersed. The largest emission reduction source of the residential living sector is air-conditioning equipment, which accounts for 39.41% of the residential living sector and 1.92% of all. The largest emission reduction source of the commercial and service sector is heating equipment, which accounts for 29.45% of the commercial sector and 4.93% of all. (Fig.4-Fig.5)
- The power generation sector is the largest emission reduction source, accounting for 26.01% of the whole society, and it is key to reduce emission from the electrification of buildings and the electrification of transportation.

3. Conflict of emission reduction measures

- In certain conditions, some of the measures will lead to carbon emission growth, such as excessive growth in the scale of passenger transport demand and poor management of demand intensity (Fig.2b), as well as slow structural transformation of electricity generation with too rapid electrification of freight transport (Fig.3b).

Tab. 4 Sectoral Emission Reduction Potential

Sector	Reduction potential in 2025（$MtCO_2$）	Share in 2025	Reduction potential in 2035（$MtCO_2$）	Share in 2035
pts	3.10	5.40%	7.22	6.16%
fts	18.05	31.45%	37.67	32.16%
ind	23.35	40.68%	46.94	40.08%
com	9.29	16.18%	19.59	16.74%
res	3.61	6.30%	5.7	4.86%

Tab. 5 Measures Emission Reduction Potential

	DSO	LID	EEI	EER	PER
Reduction potential in 2025（$MtCO_2$）	12.54	4.05	26.96	1.36	12.50
Share in 2025（%）	21.85%	7.05%	46.96%	2.37%	21.78%
Reduction potential in 2035（$MtCO_2$）	26.93	7.46	44.34	8.54	29.84
Share in 2035（%）	23.00%	6.00%	38.00%	7.00%	25.00%

Tab. 6 Equipment reduction potential (top 10)

Equipment	Reduction potential in 2025（$MtCO_2$）	Share in 2025	Equipment	Reduction potential in 2035（$MtCO_2$）	Share in 2025
fts-tflv	10.74	18.72%	fts-tflv	22.11	18.87%
fts-tfsh	5.97	10.41%	fts-tfsh	11.96	10.21%
pd17-hw	2.31	4.03%	pd7-st	5.87	5.01%
pts-tpsv	2.21	3.84%	pd17-hw	5.77	4.93%
pd7-st	2.14	3.73%	pts-tpsv	4.81	4.10%
pd13-mt	2.02	3.52%	pd18-em	3.91	3.34%
pd10-cstl	1.98	3.45%	pd4-st	3.72	3.17%
pd18-em	1.97	3.43%	fts-tfar	3.43	2.93%
pd4-st	1.70	2.95%	pd13-mt	3.37	2.87%
pd18-cl	1.54	2.69%	pd15-mt	3.17	2.71%

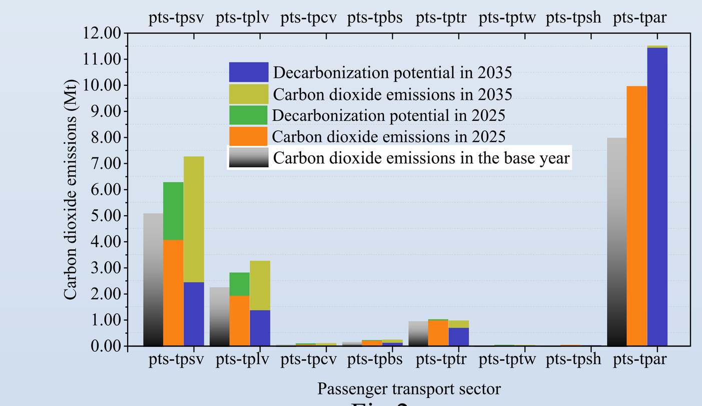


Fig.2a

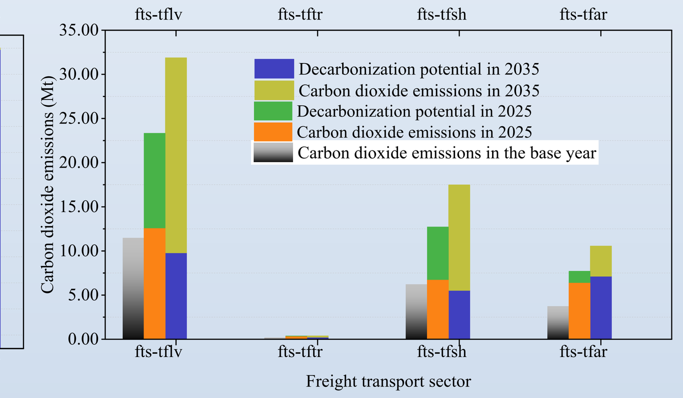


Fig.3a

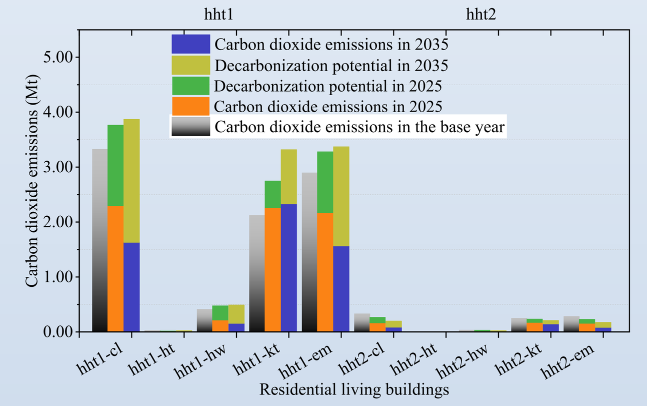


Fig.4a

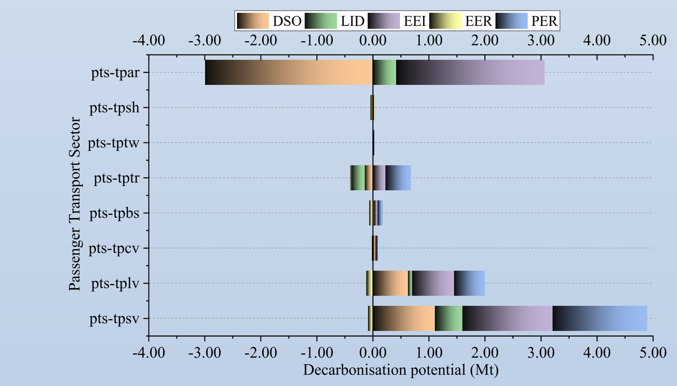


Fig.2b

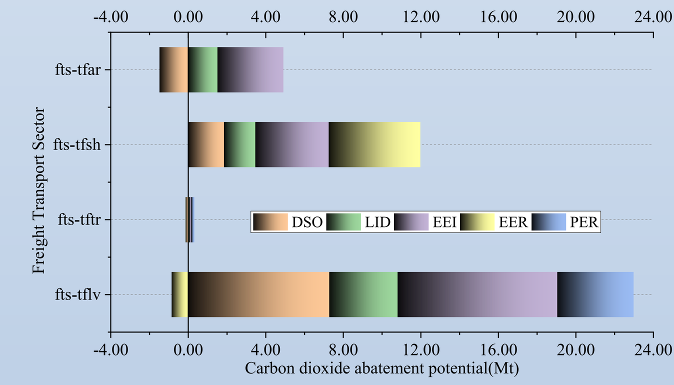


Fig.3b

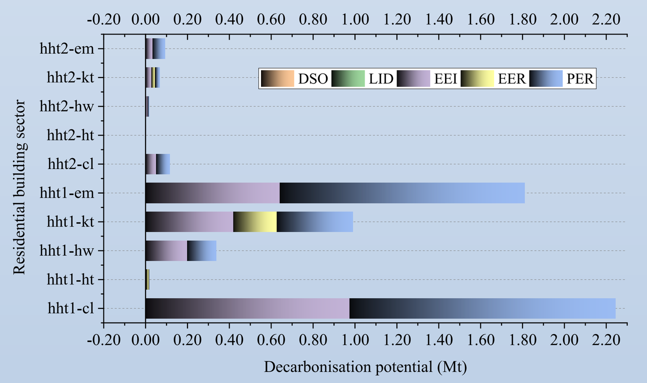


Fig.4b

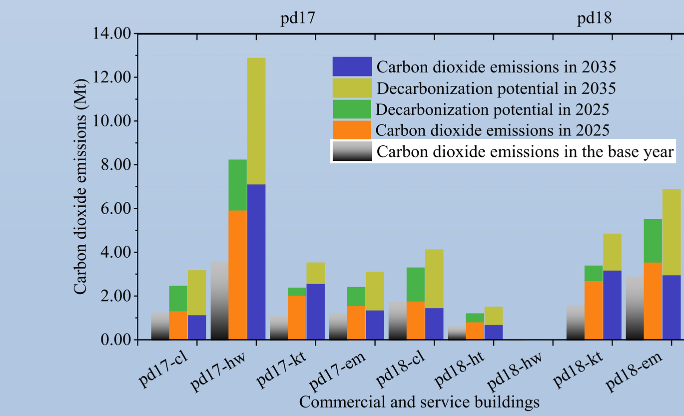


Fig.5a

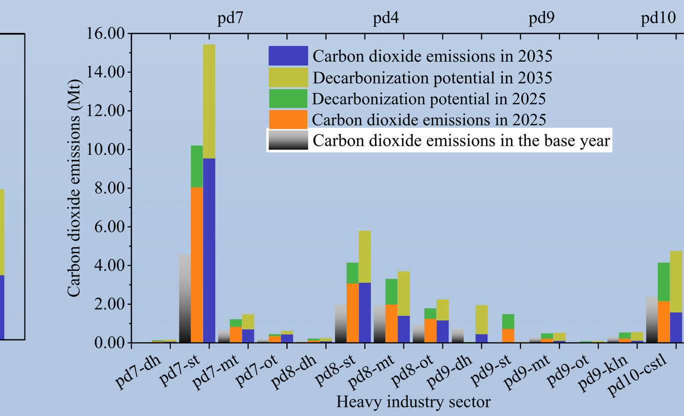


Fig.6a

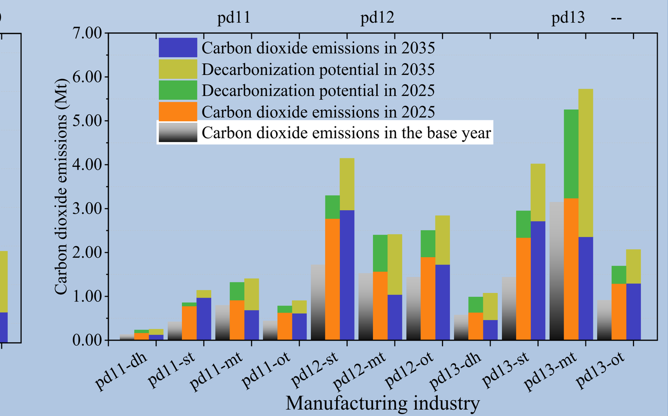


Fig.7a

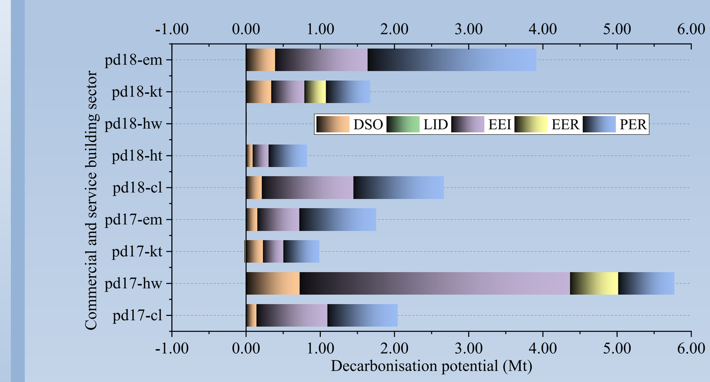


Fig.5b

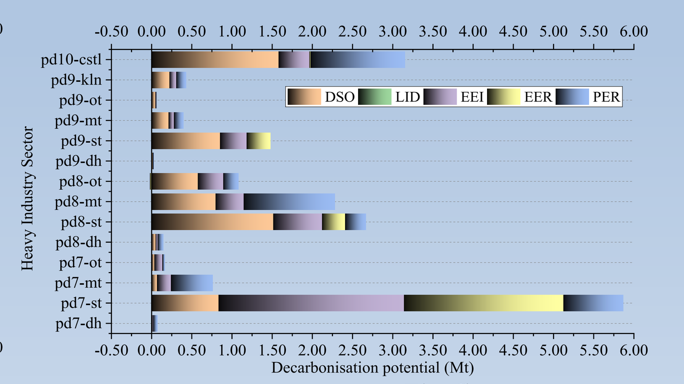


Fig.6b

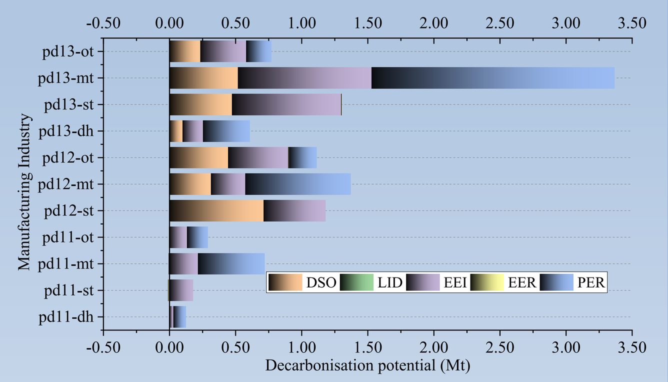


Fig.7b

Conclusion

- Production-driven sectors such as industry and freight transportation are the keys for carbon emission reduction, whose emission reduction potentials accounting for 40.08% and 32.16% respectively. Life-driven sectors such as passenger transportation and residential construction are difficult to reduce carbon emissions, with the reduction potential of 6.16% and 4.84% respectively.
- Energy structure transformation measures will gradually replace energy efficiency improvement measures as the main carbon reduction measures in the future. Non-technological emission reduction measures, such as demand management, will become important growth points in emission reduction potential. Reducing carbon reduction not only requires continuous strengthening technological measures, but also attention to management measures, such as reducing demand for production-driven emission sources through management, reducing demand intensity for life-driven emission sources by advocating low-carbon lifestyles and conservation concept.
- According to the distribution law of emission reduction, priority should be given to various types of equipment in the power generation sector and the transportation sector, which have high emission reduction potential and concentrated emission sources, followed by equipment in the industrial sector, which have high emission reduction potential but dispersed emission sources, and finally equipment in the construction sector, which have low emission reduction potential and dispersed emission sources.
- The main paths for the case city to reduce emission include strengthening the management of sectoral demand scale and intensity, continuously upgrading the energy efficiency of key terminal equipment, transforming the transport mode dominated by road transport in the freight sector, reducing heavy industry in the industrial sector and supporting advanced manufacturing, accelerating decarbonization in the power, and promoting the electrification of the transportation sector and the electrification of the building sector in an orderly and timely manner.

References： Gomi, K., Shimada, K., Matsuoka, Y., 2010. A low-carbon scenario creation method for a local-scale economy and its application in Kyoto city. Energy Policy 38, 4783–4796. https://doi.org/10.1016/j.enpol.2009.07.026