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Impact Assessment of Energy Transition Policy on Air Quality over a Typical District of the Pearl River Delta Region, China

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ABSTRACT

Energy transition policies have been proposed for the two imperative tasks of carbon dioxide (CO_2) emissions peaking and air pollution control in the Pearl River Delta (PRD) region in China. This study assesses the impact of the policies on CO_2 emissions mitigation and air quality improvements and provides recommendations for policy implementation. Using Shunde District as a case study, we developed the emission inventories of CO_2 and air pollutants, projected the trend of CO_2 emissions, and estimated the air quality under three energy transition scenarios using the Long-range Energy Alternatives Planning (LEAP) model and the Weather Research and Forecasting-Community Multiscale Air Quality Modeling (WRF-CMAQ) system. The emission inventory revealed that the power, transportation and industry sources were three key sectors of CO_2 and energy-related air pollutant emissions, with a combined contribution of more than 90%. The simulation results of energy transition policy demonstrated that CO_2 emissions in Shunde would be unable to peak under the current "business as usual" (BAU) policy, while it could peak at 21.58 million tons (Mt) and 21.18 Mt under the energy transition (ET) and the enhanced energy transition (EET) policies, respectively. The concentrations of all index pollutants could meet the Grade II national standards for air quality in 2025, and the Comprehensive Air Quality Index (CAQI) in 2030 could also significantly decrease by 27.0% relative to the 2019 base year under the most stringent energy transition policies. Our study suggests that the local government should consider taking the power, transportation and industry sources as the priority sectors and implementing a stricter energy transition policy as soon as possible in Shunde District of the PRD region in China.

Keywords: Energy transition policy, CO_2 emissions peaking, Air quality, LEAP model, WRF-CMAQ model

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1 INTRODUCTION

Achievements of carbon dioxide (CO_2) emissions peaking and air quality improvements are currently two major environmental priorities in China (Tong *et al.*, 2020; Shi *et al.*, 2021; Yang *et al.*, 2021). The State Council of the People's Republic of China has issued the "Action Plan for Carbon

Dioxide Peaking Before 2030", in which the energy transition policy, a key pathway of CO_2 mitigation, was proposed in particular (The State Council of the People's Republic of China, 2021a). The implementation of energy transition policy can remarkably reduce related air pollutant emissions and bring air quality benefits (Gi *et al.*, 2019; Jiang *et al.*, 2019; Peng *et al.*, 2020; Sim *et al.*, 2020). Therefore, to reach the two national environmental goals more effectively, it is imperative for the local government to estimate the CO_2 and associated air pollutant emissions and assess the corresponding air quality improvements under the re-formulated energy transition policies in China.

The CO_2 emissions have been typically predicted with the top-down, bottom-up and hybrid models (Cheewaphongphan *et al.*, 2017; Helgesen *et al.*, 2018; Liu and Xiao, 2018; Yan *et al.*, 2020). The top-down models, such as the Emissions Prediction and Policy Analysis (EPPA) (Jacoby *et al.*, 2006; Paltsev *et al.*, 2012) and China in Global Energy Model (C-GEM) (Qi *et al.*, 2016; Zhang *et al.*, 2016), can analyze the relationship between the energy system and macroeconomic factors from a holistic perspective and then forecast the future carbon emissions (Babiker *et al.*, 2009; Huo *et al.*, 2021). However, top-down models usually simulate the carbon emissions at a macro-level and lack technological details of the energy system (Böhringer and Rutherford, 2009). The bottom-up models like the Integrated MARKAL-EFOM System (TIMES) (Gerbelova *et al.*, 2014; Li *et al.*, 2017) and Long-range Energy Alternatives Planning (LEAP) (Emodi *et al.*, 2017; Zhang *et al.*, 2019; Kuylenstierna *et al.*, 2020), are based on available technologies or policies to analyze the activity level of various emission sources and predict the carbon emissions. Therefore, the bottom-up models can more specifically predict CO_2 emissions affected by the policy due to their consideration of detailed technologies in the process of energy production, conversion or consumption (Böhringer and Rutherford, 2008; Liu *et al.*, 2009; Dai *et al.*, 2016). The hybrid models are developed based on both the top-down and bottom-up approaches, which can forecast CO_2 emissions with detailed consideration of macroeconomic and energy technology factors (Dai *et al.*, 2016; Xie *et al.*, 2018). The Global change assessment model (GCAM) is a typical hybrid model, where the interaction between the detailed energy system and the macroeconomic module is taken into account, and then the CO_2 emissions can be predicted from regional to national scale, or for the sectors (Ou *et al.*, 2021).

The effects of carbon mitigation policies on air quality in China have been extensively studied (Liu *et al.*, 2017; Li *et al.*, 2019b; Xing *et al.*, 2020; Shi *et al.*, 2021). For example, Peng *et al.* (2017) found that the population-weighted concentration of $PM_{2.5}$ in China could be further reduced by 15% under a combined sectoral carbon mitigation scenario compared to the base $PM_{2.5}$ levels. Zhang *et al.* (2021) estimated that the $PM_{2.5}$ concentration in Sichuan province is expected to decrease by as much as 2.8 µg m^{-3} due to the implementation of carbon mitigation policy. Wu *et al.* (2021) indicated that Guangzhou could meet local $PM_{2.5}$ ambient air quality standards (34 µg m^{-3}) under the most stringent carbon mitigation strategies. Whereas previous studies mostly focus on the national, provincial or urban scale and lack attention to the district or county level, which is the basic administrative unit in China (Wang *et al.*, 2019). Moreover, most of these studies consider only the changes in $PM_{2.5}$ concentration, but the local government is more concerned about the improvement of overall air quality that includes all index pollutants: SO_2, NO_2, PM_{10}, $PM_{2.5}$, O_3, CO.

Therefore, this study aims to predict CO_2 and air pollutant emissions under the energy transition policy and evaluate the overall air quality enhancement in Shunde, which is a leading economic district in the Pearl River Delta (PRD) region listed as one of the top 10 GDP (Gross Domestic Product) districts in China. This research is expected to provide a sound technical route and data support for effectively achieving CO_2 emissions peaking and improving the air quality at a small-area scale of the district or county.

2 METHODS

The process for evaluating the impact of energy transition policy on air quality is shown in Fig. 1. Firstly, the key sectors for emission reductions in Shunde District were identified based on the 2019 CO_2 and air pollutants emission inventories and then linked to energy transition policy to develop energy transition scenarios. Secondly, based on social economy and energy data, the LEAP model was employed to predict CO_2 and energy-related air pollutant emissions under various energy transition scenarios. After that, the total air pollutant emissions of control scenarios

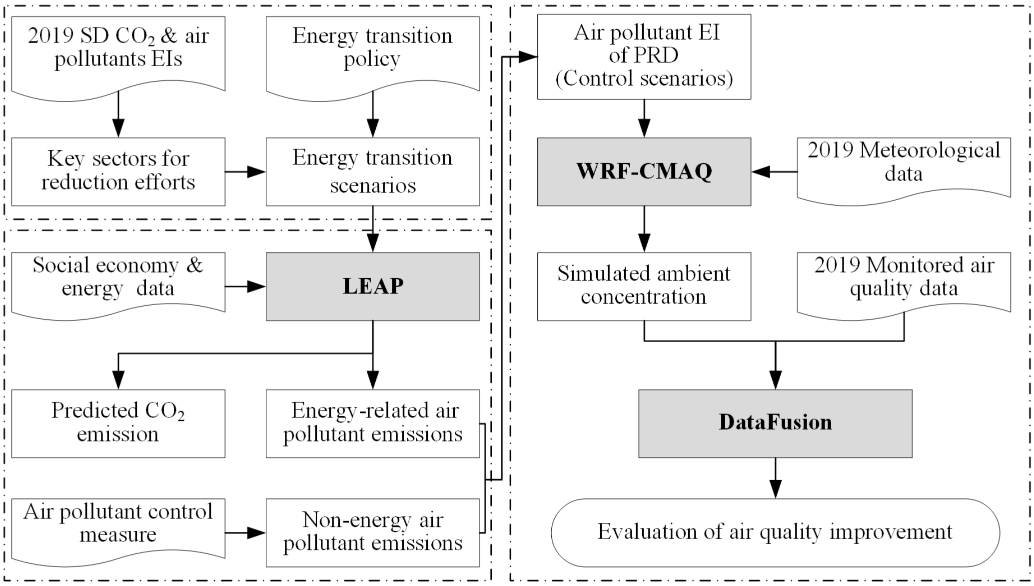

Fig. 1. The framework for impact evaluation of energy transition policy on air quality. SD: Shunde District, EIs: emission inventories, PRD: Pearl River Delta.

were acquired by combining non-energy air pollutant emissions under the implementation of air pollution control measures. Thirdly, the Weather Research and Forecasting-Community Multiscale Air Quality Model (WRF-CMAQ) platform was utilized to simulate the future ambient pollutant concentrations, and the simulation results were furtherly adjusted by the monitor data using the Data Fusion tool for improving the CMAQ simulation accuracy. Finally, the overall air quality improvements in Shunde that benefited from the implemented energy transition policy were evaluated derived from the simulation results.

2.1 Development of CO_2 and Air Pollutant Emission Inventories

The CO_2 emission inventory of Shunde District in 2019 was developed by using the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) (Jia *et al.*, 2018; Lopes Toledo and Lèbre La Rovere, 2018; Sununta *et al.*, 2019). It covered only CO_2 from energy activities which included direct emissions from fossil fuel combustion within urban boundaries (Scope 1) and indirect emissions from electricity imports (Scope 2) (Wattenbach *et al.*, 2015; Jiang *et al.*, 2021). Furthermore, CO_2 emission sectors were classified into five first-level sectors (power, industry, transportation, building and others) and subdivided into several subsectors to match the sectoral characteristics of CO_2 emissions in Shunde (Table S1). The activity level data of various sectors on the CO_2 emission inventory were derived from the statistical yearbook of Shunde District (SDSB, 2019). The CO_2 emission factors of various energy types were adopted from the Guidelines for Greenhouse Gas Inventory of Guangdong City and County (District) published by the Department of Ecology and Environment of Guangdong Province in 2020 (GDEEP, 2020).

The air pollutant emission inventory of Shunde in 2019, which mainly covered six types of air pollutants (SO_2, NO_x, CO, PM_{10}, $PM_{2.5}$, and VOCs) and eleven anthropogenic sources, was estimated by applying the technology-based emission factor method (Gao *et al.*, 2018; Zheng *et al.*, 2018; Yu *et al.*, 2019). Additionally, these eleven anthropogenic sources of air pollutant emissions were divided into two categories: energy-related and non-energy emission sources, and then the energy-related emission sources were matched to the CO_2 emission sectors (Table S2). The emission factors and removal efficiency of air pollutants were acquired from the latest technical guidelines and research (MEE, 2014; Zhong *et al.*, 2018).

2.2 Prediction for CO_2 and Air Pollutant Emissions

2.2.1 Energy transition scenarios setting

The policy orientation of China's energy transition is "security, green, low-carbon, and efficient", which means shifting the consumption of high-carbon energy toward the use of low-carbon or renewable energy and improving the utilization efficiency of energy (The State Council of the People's Republic of China, 2021a; Wang *et al.*, 2021a). Hence, based on the latest national, provincial, urban and local policies (The State Council of the People's Republic of China, 2021b; GDEEP, 2021; SDPG, 2021), this study mainly considered the energy transition measures in terms of low-carbon or clean energy replacement and energy utilization efficiency improvement and then developed three scenarios: the business-as-usual scenario (BAU), the energy transition scenario (ET) and the enhanced energy transition scenario (EET). The BAU scenario assumed the continuation of current energy transition policies and measures in Shunde District. In the ET scenario, the implementation of energy transition policies focusing on power, transportation and industry sectors was taken into consideration. The EET scenario adopted more aggressive energy transition measures to further reduce CO_2 and air pollutant emissions. Significantly, the differences between scenarios involved the energy transition measures implemented, and the air pollution control measures remained consistent. The assumption of social economy and main energy transition measures of these scenarios were detailed in Table S3, and available air pollution control measures were shown in Table S4. Simultaneously, anthropogenic emissions outside Shunde District in the PRD were assumed to be decreased under three scenarios, which mainly depended on the executive strength of energy transition and air pollution control policies in cities of the PRD.

2.2.2 LEAP model

The bottom-up models contain a wealth of technical information and are appropriate to assess the impact of technology substitution due to energy transition policies. Among bottom-up models, the LEAP model is a relatively popular energy environment simulation platform that can be flexibly designed as various policy models according to the specific policies (Wu and Peng, 2016; Huang *et al.*, 2019). In this paper, 2019 was selected as the base year, because the air quality data in the latest year 2020 and 2021 was relatively unrepresentative resulted from the reduced sectoral emissions during COVID-19 (Wang *et al.*, 2021b; Wang *et al.*, 2021c). With the study period of 2019–2030, LEAP model estimated CO_2 and energy-related air pollutant emissions of Shunde under different energy transition strategies by setting three alternative scenarios. Based on the activity level data of various sectors and emission factors of various energy types, the CO_2 and energy-related air pollutant emissions were calculated by using Eq. (1) and Eq. (2), respectively.

$$E_{CO_2} = \sum_i \sum_j AL_{i,j} \times EF_{i,j} \tag{1}$$

$$E_P = \sum_i \sum_j AL_{i,j} \times EF_{i,j,P} \times \left(1 - \eta_{i,j,P}\right) \tag{2}$$

where *AL* is the activity level, *EF* is the emission factor, *i* is the sector, *j* is the energy type, *P* is the air pollutant type and η is the removal efficiency.

2.2.3 Air quality simulation

The WRF model version 3.9.1 and the CMAQ model version 5.2 were used to simulate air quality under three scenarios. Four-layer nested domains with grid resolutions of 27 km (d01), 9 km (d02), 3 km (d03) and 1 km (d04) were employed for the WRF-CMAQ simulation platform (Fig. 2). The d03 domain mainly included the entire PRD region and the innermost d04 domain covered the whole Shunde District. Tsinghua University provided input emission inventories for d01 and d02 domains. The inventories for d03 and d04 domains were developed by our research team. January, April, July, and October were selected as simulation periods to represent spring, summer, autumn and winter of the year. The simulated results covered the concentrations of SO_2, NO_2, PM_{10} and $PM_{2.5}$, the 95th percentile of daily CO concentration and the 90th percentile of maximum daily 8-hr averaged O_3 concentration in a whole year. Additionally, to improve the CMAQ simulation accuracy, the simulation results were adjusted by the monitor data from the air quality monitor sites using the Downscaler algorithm in the Data Fusion tool developed by

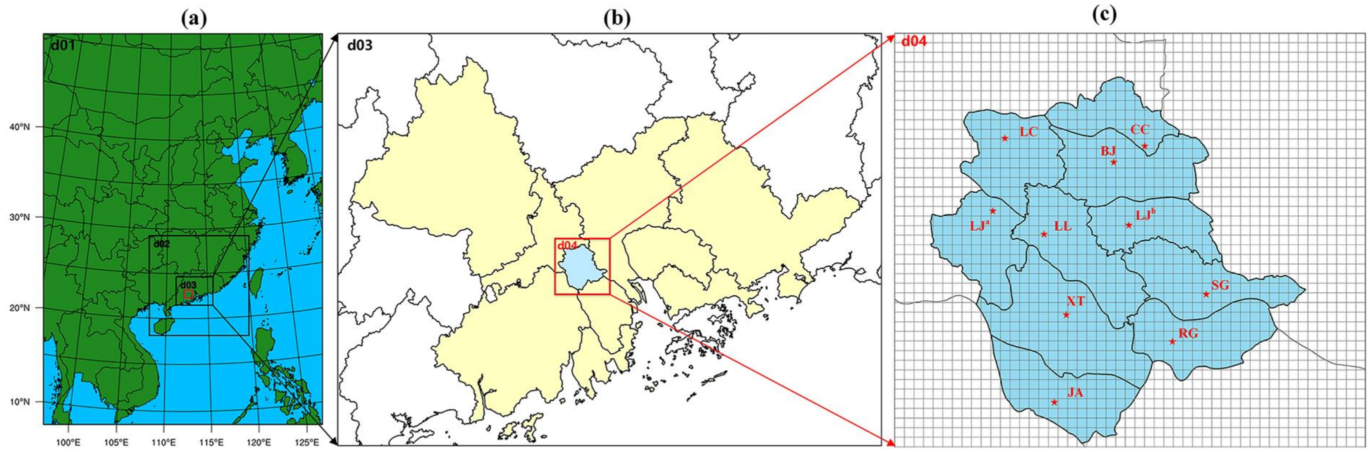

Fig. 2. (a) Four nested domains at 27 km, 9 km, 3 km and 1 km; (b) d03 (3 km) domain; (c) the innermost d04 (1 km) domain and locations of ten air quality monitor sites in Shunde District. LC: Lecong, CC: Chencun, BJ: Beijiao, LJ[a]: Longjiang, LL: Leliu, LJ[b]: Lunjiao, XT: Xintang, SG: Sugang, RG: Ronggui, JA: JunAn.

U.S. EPA (Li *et al.*, 2019a). The performance evaluations of the WRF and the CMAQ are provided in supplementary material Section S1. Then, the Comprehensive Air Quality Index (CAQI), which is an indicator that considers concentrations of six index pollutants and represents the overall regional air quality, was adopted to reflect the air quality improvements driven by energy transition policy, and the specific calculation method was detailed in Section S2.

3 RESULTS AND DISCUSSION

3.1 CO_2 and Air Pollutant Emission Inventories

The CO_2 emissions result and the contributions of various sectors to the local direct emissions are shown in Figs. 3(a) and 3(b). The amount of the total CO_2 emissions for Shunde in 2019 was 19.87 million tons (Mt), of which the direct emissions from local fossil fuel combustion emissions and the indirect emissions from electricity import accounted for 51.92% and 48.08%, respectively. In the local emission sources, the transportation sector was the largest contributor that contributed 43.88% to the overall local CO_2 emissions. This was followed by the power and industry sectors, with proportions of 30.52% and 19.69% of the local CO_2 emissions, respectively. The building sector made a small contribution (4.81%) to the local CO_2 emissions since its major energy consumption type is electricity.

The anthropogenic emissions of SO_2, NO_x, CO, PM_{10}, $PM_{2.5}$, and VOCs of Shunde District in 2019 were 2.4 kilotons (kt), 22.1 kt, 29.6 kt, 13.2 kt, 5.6 kt, and 53.7 kt, and the proportions of air pollutant emissions from various anthropogenic emission sources were shown in Fig. S1. From the energy category perspective, the energy-related emission source dominated SO_2, NO_x and CO emissions (88.85%, 97.64% and 92.91%, respectively) but accounted for a small share of PM_{10}, $PM_{2.5}$ and VOC emissions (13.78%, 19.67% and 20.21%, respectively) (Fig. 3(c)). Regarding the local emission sectors, the power, transportation and industry sectors collectively accounted for more than 90% of energy-related emissions of each air pollutant (Fig. 3(d)). Synthesizing the analysis for CO_2 and air pollutant emission inventories, Shunde should focus emission reduction efforts on the power, transportation and industry sectors.

3.2 Emissions under Three Scenarios

3.2.1 CO_2 emissions analysis

To assess whether the Shunde District could achieve its CO_2 emissions peaking goal, the trends of CO_2 emissions under three selected energy transition scenarios were analyzed as shown in Fig. 4(a). Under the BAU scenario, CO_2 emissions would maintain a growing trend and increase to 23.14 Mt until 2030 due to the increasing energy consumption driven by the development of power, industry, transportation and building sectors, indicating that Shunde District was not

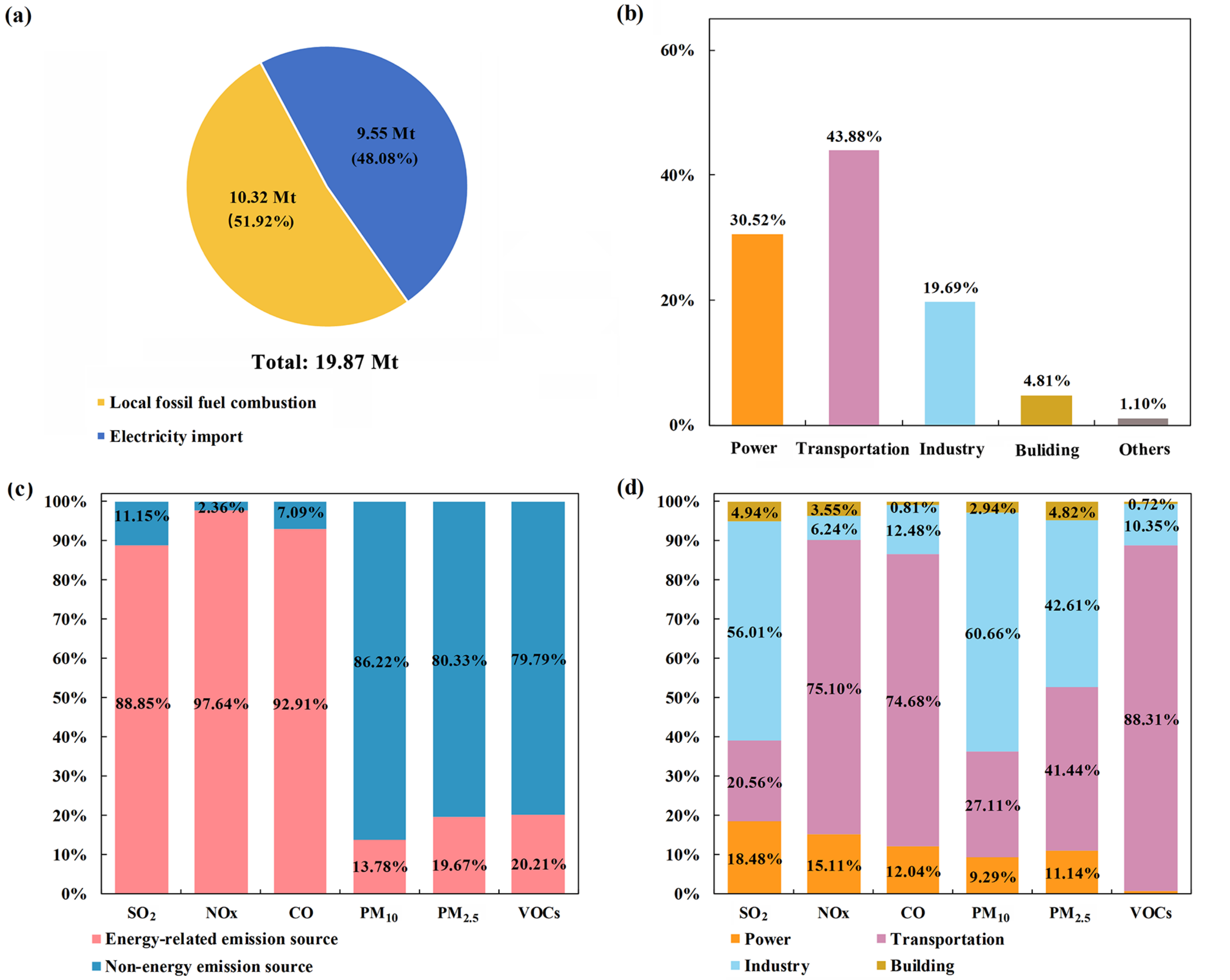

Fig. 3. (a) Contributions of local fossil fuel combustion and electricity import to the total CO_2 emissions; (b) Contributions of various sectors to the local fossil fuel CO_2 emission; (c) Contributions of energy-related and non-energy emission sources to each air pollutant; (d) Contributions of various sectors to energy-related air pollutant emissions.

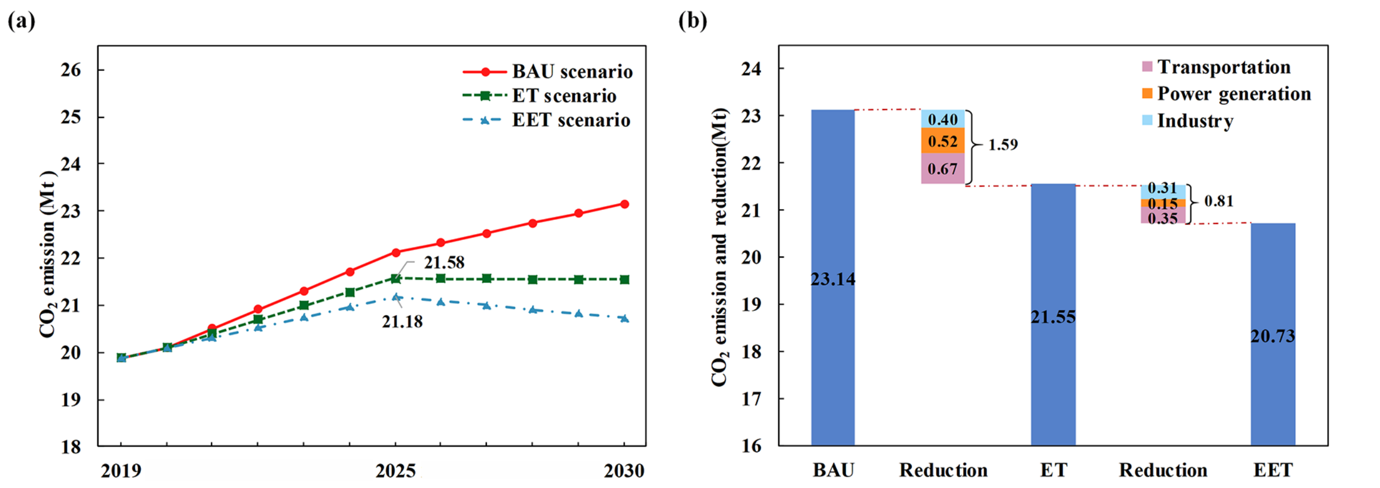

Fig. 4. (a) The trends of CO_2 emissions in Shunde District under three scenarios; (b) The CO_2 emission reduction potential of various sectors in 2030.

sufficient to reach its CO_2 emissions peaking through the implementation of current energy transition policies and measures alone. However, with the sectoral emission reduction efforts on clean energy replacement and energy utilization efficiency improvement in the ET scenario, CO_2 emissions of Shunde District would peak in 2025 at 21.58 Mt and then experience a slightly declining plateau period till 2030. Compared to the ET scenario, the more stringent energy transition measures of the EET scenario could achieve an additional 0.4 Mt reduction on Shunde's peak value of CO_2 emissions in 2025 and further decrease CO_2 emissions to 20.73 Mt by 2030.

The CO_2 emission reduction potential of various sectors from the BAU to ET scenario and from the ET to EET scenario was furtherly identified as shown in Fig. 4(b). The transportation sector contributed the largest share to the total CO_2 emission reductions either from the BAU to ET scenario (42.14%, 0.67 Mt) or from the ET to EET scenario (43.21%, 0.35 Mt), illustrating it was the key sector which strongly affected the achievement of CO_2 emissions peaking task. From the BAU to ET scenario, the power sector, which reduced not only the local direct emissions by decreasing the installed capacity of coal but also the indirect emissions by increasing local power generation to reduce the demand for electricity imports, contributed 32.70% (0.52 Mt) to the total CO_2 emission reductions (1.59 Mt). However, the emission reduction potential of the power sector decreased to 0.15 Mt from the ET to EET scenario, because Shunde District has the limitation in the development of renewable energy of hydropower and wind due to geographical conditions constraints. Therefore, it is suggested for Shunde to increase the subsidies for solar power and garbage power generations, improve power generation efficiency and raise the proportion of purchased electricity from renewable energy. The emission reduction potential of the industry sector was also essential, accounting for 25.16% and 38.27% of the total emission reductions from the BAU to ET scenario and from the ET to EET scenario, respectively. The industry sector in Shunde District will continue to reduce coal consumption and increase the electrification of industrial equipment, such as electric boilers instead of traditional coal-fired boilers. So it will still have the potential to reduce CO_2 emissions in the future.

3.2.2 Air pollutant emissions analysis

The air pollutant emission reductions that benefited from the energy transition policies are shown in Fig. 5. Under the BAU scenario, the emissions of SO_2, NO_x, CO, PM_{10}, $PM_{2.5}$ and VOCs would be 1.74 kt, 18.47 kt, 25.88 kt, 9.11 kt, 3.71 kt and 42.14 kt in 2030. Deep energy transition

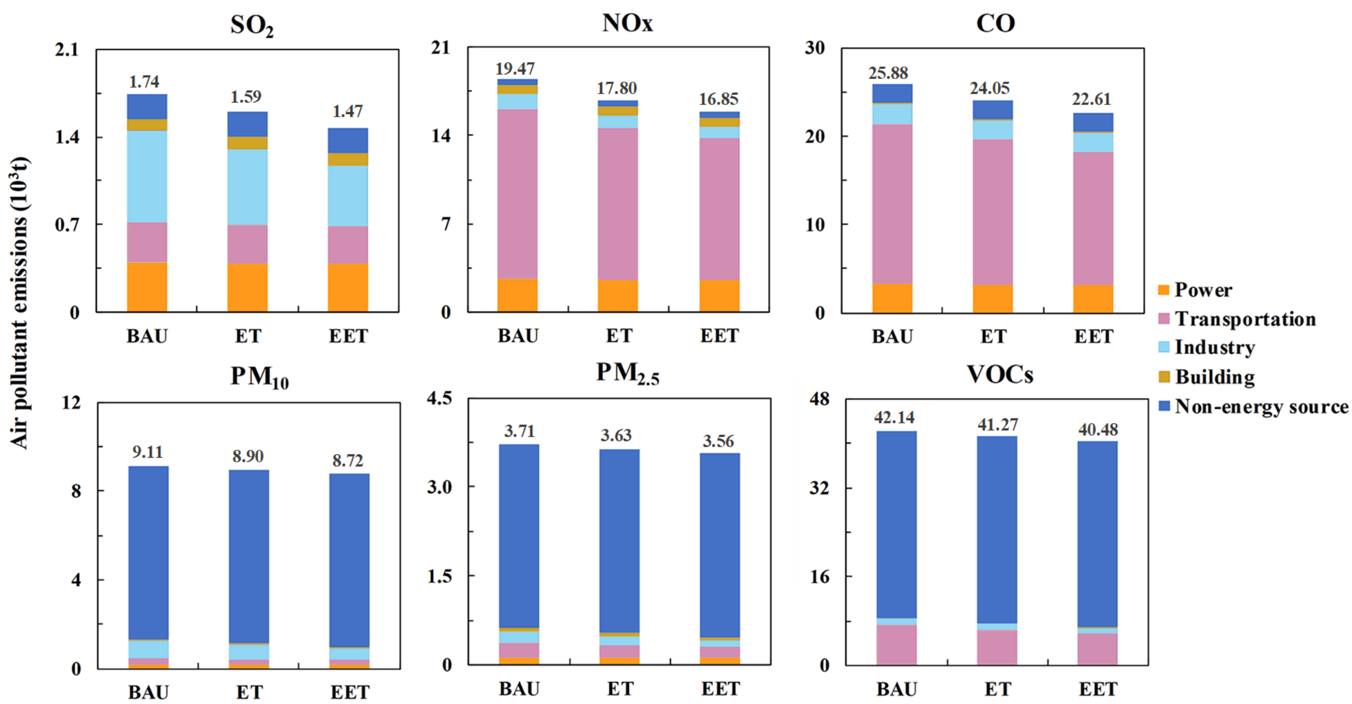

Fig. 5. The air pollutant emissions under three energy transition scenarios in 2030.

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policies would lead to further air pollutant emission reductions. By the implementation of energy transition measures under the EET scenario, the emissions of SO_2, NO_x, CO, PM_{10}, $PM_{2.5}$ and VOCs would be further declined in 2030 and reduced to 1.47 kt, 15.85 kt, 22.61 kt, 8.72 kt, 3.56 kt and 40.48 kt, respectively. From the BAU to ET and EET scenarios, SO_2 and NO_x experienced the greater emission reductions among all air pollutants, with the reduction ratio of 8.62% and 9.04% respectively under the ET scenario and 15.52% and 14.19% under the EET scenario. For SO_2, the industry sector made the largest contribution to the overall emission reductions from the BAU to EET scenario. The SO_2 emission reduction potential from the power sector was relatively small due to the implementation of the Ultra-Clean Emissions Work Plan for power plants in Shunde (SDEP, 2014). From the BAU to EET scenario, the transportation sector (especially in terms of vehicle electrification) contributed the largest emission reductions of NO_x and CO, while the emission reduction ratios of PM_{10}, $PM_{2.5}$ and VOCs were relatively small because their emissions were mainly attributed to the non-energy category source.

3.3 Evaluation of Air Quality Improvements

3.3.1 Reduction of air pollutant concentrations

The air pollutant concentrations under three scenarios are shown in Fig. 6. Under the normal BAU scenario with the implementation of current energy transition policies and available air pollution control measures, the annual average concentrations of SO_2, NO_2, PM_{10}, $PM_{2.5}$, O_3 and CO in Shunde would be 6.9 µg m^{-3}, 33.5 µg m^{-3}, 46.9 µg m^{-3}, 22.0 µg m^{-3}, 168.3 µg m^{-3} and 1.2 mg m^{-3}, respectively in 2025. More stringent energy transition policies would bring air pollutant concentration reductions. Under the ET scenario, the air quality in Shunde would be further improved and the concentrations of SO_2, NO_2, PM_{10}, $PM_{2.5}$, O_3 and CO in 2025 would be reduced by 0.5 µg m^{-3} (7.2%), 1.7 µg m^{-3} (5.1%), 1.1 µg m^{-3} (2.3%), 0.92 µg m^{-3} (4.2%), 4.9 µg m^{-3} (2.9%)

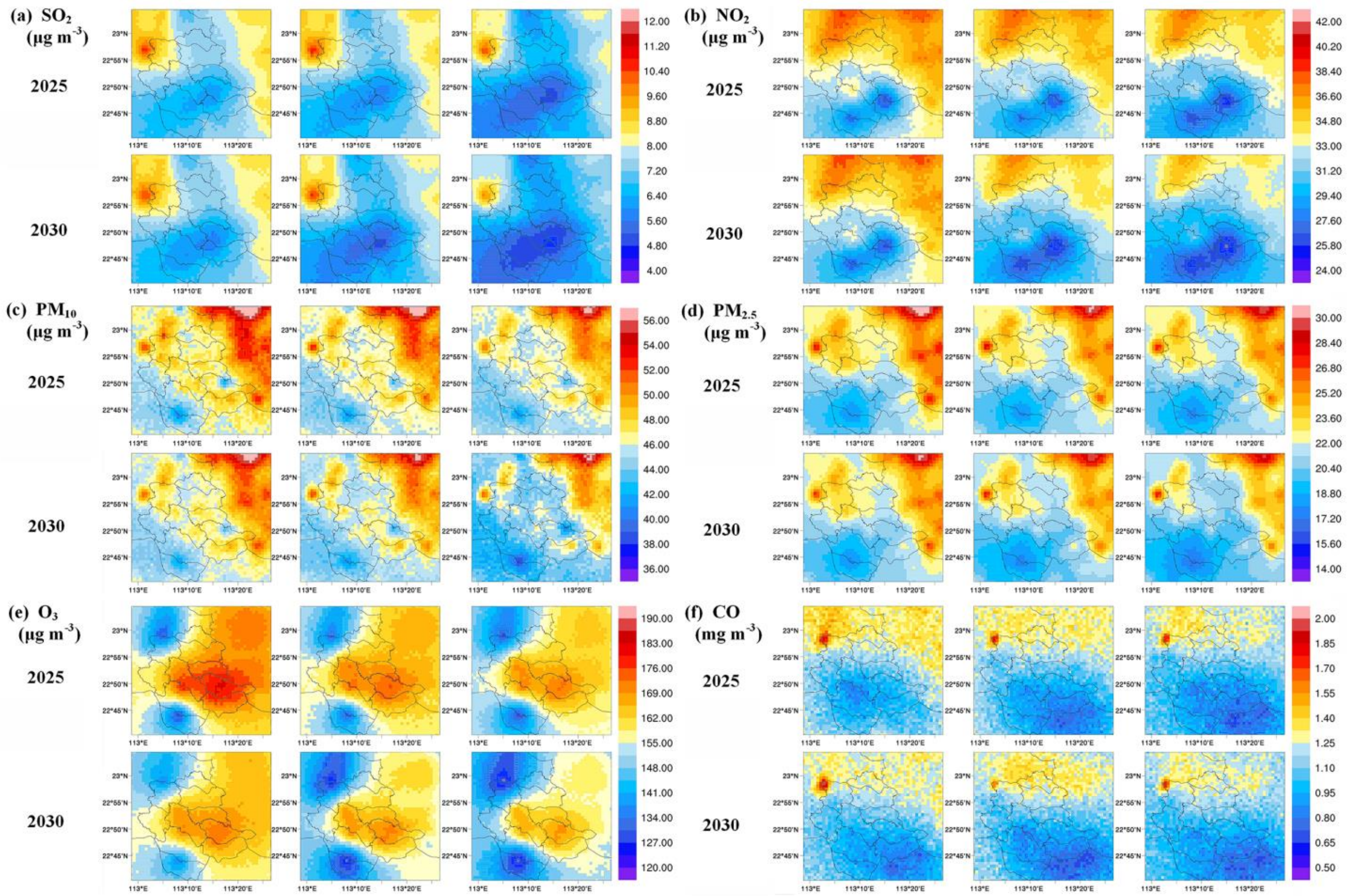

Fig. 6. The concentrations of SO_2, NO_2, PM_{10}, $PM_{2.5}$, O_3 and CO under three scenarios in 2025 and 2030.

Table 1. The single index of each air pollutant and CAQI under various scenarios.

Year	Scenario	SI (SO_2)	SI (NO_2)	SI (PM_{10})	SI ($PM_{2.5}$)	SI (O_3)	SI (CO)	CAQI
2019	BASE	0.13	0.98	0.80	0.86	1.19	0.33	4.29
2025	BAU	0.11	0.84	0.67	0.63	1.05	0.30	3.60
	ET	0.11	0.79	0.65	0.60	1.02	0.28	3.45
	EET	0.10	0.76	0.64	0.58	1.00	0.25	3.33
2030	BAU	0.11	0.81	0.64	0.57	1.01	0.28	3.42
	ET	0.10	0.76	0.62	0.54	0.98	0.25	3.25
	EET	0.10	0.71	0.61	0.52	0.96	0.23	3.13

Note: SI: Single Index, CAQI: Comprehensive Air Quality Index, BAU: the business as usual scenario, ET: the energy transition scenario, EET: the enhanced energy transition scenario.

and 0.1 mg m^{-3} (8.3%) compared to the BAU scenario. When the more aggressive energy transition policies under the EET scenario were implemented, the concentrations of SO_2, NO_2, PM_{10}, $PM_{2.5}$, O_3 and CO would decrease to 6.1 µg m^{-3}, 30.4 µg m^{-3}, 45.1 µg m^{-3}, 20.5 µg m^{-3}, 159.2 µg m^{-3} and 1.0 mg m^{-3} by 2025. In addition, under the BAU scenario, the concentrations of SO_2, NO_2, PM_{10}, $PM_{2.5}$, O_3 and CO would only decrease to 6.5 µg m^{-3}, 32.5 µg m^{-3}, 44.9 µg m^{-3}, 20.0 µg m^{-3}, 162.0 µg m^{-3} and 1.1 mg m^{-3} by 2030, while they could be further decreased to 5.9 µg m^{-3}, 28.5 µg m^{-3}, 42.8 µg m^{-3}, 18.4 µg m^{-3}, 153.0 µg m^{-3} and 0.9 mg m^{-3} under the EET scenario. The results indicate that the current policies will be gradually limited in improving the air quality and a deeper energy transition policy is necessary for Shunde in the following decade.

3.3.2 Improvement of comprehensive air quality index

To investigate the overall air quality enhancement in the Shunde District, we also calculated the single index (SI) value of each air pollutant and the CAQI under various scenarios (Table 1). The SI value represents the ratio of the concentration of a pollutant to its concentration limit for the China air quality level II standard (Section S2). When the SI value of a pollutant is lower than 1, its concentration is regarded to meet the China air quality level II standard (Ye *et al.*, 2018). About the CAQI, it is an index that negatively correlates with the air quality level, in other words, a smaller CAQI value represents a better air quality level according to the calculation method of CAQI in Section S2.

As shown in Table 1, although the air quality improved under the BAU scenario compared with the 2019 level, the SI value of O_3 would be still greater than 1 whether in 2025 or 2030, implying that the O_3 concentration was unable to attain the China air quality level II standard under the BAU scenario. Under the most stringent EET scenario, the SI value of each pollutant in 2025 would be less than or equal to 1, indicating that concentrations of all normal pollutants could meet the standard. The CAQI for Shunde would decrease as much as 27.0% by 2030 under the EET scenario compared with the 2019 level. Moreover, the CAQI value was largely contributed by the SI value of O_3 under all scenarios, reflecting that the future air quality would be mainly affected by O_3 while the contributions of NO_2 and $PM_{2.5}$ to CAQI gradually decreased from the BAU to EET scenario.

4 CONCLUSIONS

In this paper, CO_2 emission mitigations and the overall air quality improvements that benefited from three energy transition policies in Shunde District were comprehensively investigated based on the LEAP model and WRF-CMAQ simulation system.

Analysis of the CO_2 and air pollutant emission inventories indicated that the power, transportation and industry sources were three major sectors of CO_2 and energy-related air pollutant emissions. The CO_2 emission trend under three scenarios implied that CO_2 emissions peaking could be hardly achieved by the current policy alone, and a stricter energy transition policy would be more conducive to reaching it, with the peak value of 21.58 Mt and 21.18 Mt under the ET and EET scenarios, respectively in Shunde. From the perspective of sectoral reduction potential, the transportation sector contributed the most to the emission reduction of CO_2 as well as NO_x and

CO. Air quality evaluations suggested that the implementation of energy transition policy would bring a visible air quality improvement in Shunde. Under the most stringent EET scenario, the concentrations of all index pollutants in 2025 would reach China air quality level II standard and the CAQI would decrease the most by 27.0% in 2030 compared with the 2019 level. In addition, the contribution of O_3 to CAQI was the largest under both the current and energy transition policies, indicating a significant effect of O_3 on air quality in Shunde.

Consequently, Shunde can implement the following energy transition strategies to achieve the goals of CO_2 emissions peaking and air quality improvements. First, the construction of a low-carbon energy system can be accelerated by phasing out the backward production capacity of coal-fired power and promoting high-quality development of solar power and garbage power. Second, the inefficient equipment should be eliminated and standards for improving energy efficiency are supposed to be issued to decrease the energy consumption of the industry sector. Third, the application of clean energy should be expanded in the field of transportation. Furthermore, to reinforce the O_3 pollution control, it is needed for Shunde to further reduce NO_x emissions through the implementation of stricter measures on vehicles like accelerating the electrification process.

DISCLAIMER

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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SUPPLEMENTARY MATERIAL

Supplementary material for this article can be found in the online version at https://doi.org/10.4209/aaqr.220071

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