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Air quality improvement through vehicle electrification in Hainan province, China

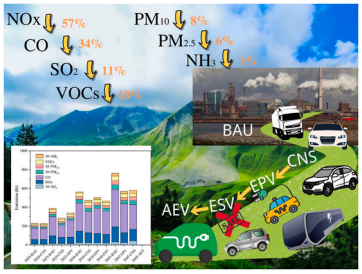
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HIGHLIGHTS

- Anthropogenic emission inventory of air pollutants for Hainan Province was developed.
- Vehicle electrification will improve the air quality in Hainan.
- The success in Hainan might help encourage further promotion of the policy nationally.

GRAPHICAL ABSTRACT



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ABSTRACT

To improve the ecological environment, provinces in China have set ambitious goals for the electrification of fossil-fuel-powered vehicles (FVs) and the promotion of electric vehicles (EVs). Hainan is the first province to propose a clean energy target that schedules the banning of new FVs sales from 2030. Therefore, Hainan is a good case study to illustrate how this policy might improve regional air quality over the coming years. This study first developed an anthropogenic emission inventory of seven major air pollutants in 2017 in Hainan. The total emissions of CO, NOx, NH_3, volatile organic compounds (VOCs), PM_{10} and $PM_{2.5}$ and SO_2 in 2017 were estimated as 247.56, 69.61, 61.87, 41.38, 37.02, 19.82, and 8.55 kt, respectively. Using the developed emission inventory, multiple scenarios of economic development were considered to assess the benefits to air quality from Hainan's goal of electrification. In comparison with 2017, the reductions in emissions of SO_2, NOx, CO, PM_{10}, $PM_{2.5}$, VOCs, and NH_3 by 2045 were projected to be 5.45 (11.11%), 275.07 (57.32%), 675.51 (34.07%), 8.39 (5.73%), 7.73 (8.24%), 81.15 (9.76%), and 4.89 (0.91%) kt, respectively, under the all-electric vehicle scenarios. These results indicate that this policy will not only reduce the emission of air pollutants but also avoid complex O_3 pollution in the future. The findings of this work elucidate the effects of vehicle electrification policies on regional air quality and provide scientific support for policymakers in developing pollution control strategies.

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1. Introduction

Air pollutants emitted from mobile sources are important contributors to overall air pollution in many cities in China (He et al., 2014; Platt et al., 2017). In 2017, transport-related emissions of SO_2, NOx, CO, PM_{10}, $PM_{2.5}$, volatile organic compounds (VOCs), and NH_3 accounted for 3.2%, 35.1%, 18.5%, 5.5%, 7.1%, 16.7%, and 0.42%, respectively, of the total air pollutant emissions in China (Li et al., 2017). In comparison with fossil-fuel-powered vehicles (FVs), electric vehicles (EVs) offer the advantages of benefiting human health and reducing air pollution (Liang et al., 2019; Song et al., 2021). In China, the policy of exempting EVs from purchase tax has been promoted to encourage sales of EVs (Department of Taxation, 2014; 2017, Department of Taxation, 2022). Hainan is the first province to propose a clean energy target and to schedule the banning of new FVs sales from 2030 and has focused efforts on vehicle electrification since 2017. However, there is insufficient knowledge on how proposed policies might reduce air pollutant emissions and benefit local air quality in Hainan (see Table S13 for policies). Therefore, Hainan is a suitable case study of the potential improvement in air quality that China might expect from vehicle electrification in provinces.

The benefits of vehicle electrification for local air quality have been well documented. For example, the emission reductions powered by vehicle electrification in Spain showed that the reduced concentrations of NO_2 in Barcelona and Madrid were up to 30 and 15 $\mu g/m^3$, respectively (Soret et al., 2014). The emission reduction potentials of CO, VOCs, NOx and $PM_{2.5}$ were 1500, 165, 33.9 and 7.2 kt/yr, respectively, with full EV penetration in Taiwan (Li et al., 2016). In addition, a fixed EV combination showed that the average concentration of $PM_{2.5}$ would be reduced by 0.4–1.1 $\mu g/m^3$ annually in the Yangtze River Delta (Ke et al., 2017). Therefore, vehicle electrification in Hainan will improve the regional air quality through a reduction of air pollutant emissions. The Chinese government established a complete industrial system for EVs and formulated a Mid-term and Long-term Development Plan for the Automobile Industry in 2017 (CGPR, 2017), which will help the development of vehicle electrification in Hainan.

The emission of air pollutants in Hainan has been investigated in the petrochemical enterprises (Xie et al., 2019) and using the Multi-resolution Emission Inventory for China (MEIC) model with a low resolution (Cui et al., 2020). However, such studies are not sufficiently comprehensive to fully characterize provincial air pollution. Therefore, a high-resolution, source-specific, integrated and regularly updated inventory of anthropogenic pollutants emitted from multiple sources, together with improved knowledge of their spatiotemporal variations in Hainan, will provide fundamental information on the regional air quality. Such information will not only represent a source of data with which to assess the impact of different policies on air quality, but it will also support the development of guidelines for regions with comparable economic status or for those that might be intending to implement the same policies.

Therefore, this work developed an inventory of pollutant emissions in 2017 in Hainan and identified the spatiotemporal variations of anthropogenic pollutant emissions from multiple emission sources. On the basis of the emission inventory for Hainan province and the declared goal of electrification by 2030, this study established a baseline scenario and four emission reduction scenarios to compare the effects of the policy on the regional air quality. The projected reductions in air pollutant emissions attributable to the transition to EVs showed the potential effectiveness of the policy in Hainan. The findings may encourage further promotion of the policy nationally.

2. Methods and data

2.1. Study domain

Hainan province, which is located in South China (18°10′–20°10′ N, 108°37′–111°37′ E), includes 27 regions (cities and counties) covering an area of approximately 35,354 km^2 (Fig. 1). In 2017, the permanent population of Hainan was 9.26 million. The population density is shown in Fig. S2. In terms of GDP, Hainan ranked 28th among China's provinces in 2017 (NBSC, 2018), and tourism accounted for 56% of its total secondary industry. Hainan has a tropical monsoon climate with multiple natural resources such as rainforests, grasslands, beaches, and sunshine, which attracted tens of millions of tourists from China and internationally in 2017. The recent rapid development of tourism and the increase in the number of FVs (with a vehicle density of 207 vehicles per thousand people) have placed considerable pressure on the regional atmospheric environment.

2.2. Emission inventory

The Emission sources were divided into nine sectors in accordance with the socioeconomic characteristics of Hainan, consistent with other recent studies in China (Zheng et al., 2020, 2021; Zhou et al., 2021). Each sector was then subdivided on the basis of fuel type, consumption of the product, and the control technology applied in production. Compared with previous studies (Liu et al., 2017; Zhou et al., 2021), the sectors of fugitive dust, storage and transportation, waste disposal, road dust (recorded as PM_{10} and $PM_{2.5}$), and agriculture were also considered in this study. The details of the emission source sectors are shown in Table S1.

Activity data were obtained from the 27 regions of Hainan. The analysis considered anthropogenic sources (6353 sources were classified in Table S1) that emitted substantial volumes of air pollutants, such as power plants, the cement industry, the oil industry, and sewage treatment plants. Some marine and natural emissions such as those from shipping and biogenic air pollutants were not included in this study. Field investigations (shown in Section S6), surveys of local pollution sources, and information extracted from appropriate literature sources were used to collate activity data. The calculation methods, data sources, and emission factors are listed in Sections S1 and S2. The spatial allocation and the temporal variation of the emission sources are presented in Section S3.

2.3. The methodology for Monte Carlo simulations

Monte Carlo simulations were applied to estimate the uncertainties in the derived emissions, and the probability distribution data are presented in Tables S3–S10. Further details on the uncertainty analysis can be found in (Zhao et al., 2011). To determine the ranges of uncertainty in the estimated pollutant emissions, 10,000 Monte Carlo simulations were performed (with a confidence interval of 95%).

2.4. Emission reduction scenarios

In accordance with the EV-related policy to reduce air pollutant emissions in Hainan, this study established five scenarios (one baseline scenario and four emission reduction scenarios) and selected 2017 as the base year and 2045 as the end year. According to the Plan for Population Development in Hainan (PGHP, 2018), the population will grow over the coming decades (see Fig. S7), which could increase the consumption of vehicles. The assessment of vehicle pollutant emissions was limited to the pollutants directly emitted by the fuel combustion of vehicles rather than road dust. The five scenarios are described in the following sections.

2.4.1. Business-as-usual (BAU) scenario

The BAU scenario, presented as a non-intervention scenario in which no further mitigation measures were implemented, was regarded as the annual emission ceiling for a certain year. No countermeasures to control vehicles were considered in this BAU scenario, which assumed normal rates of renewal and scrappage of vehicles (in accordance with

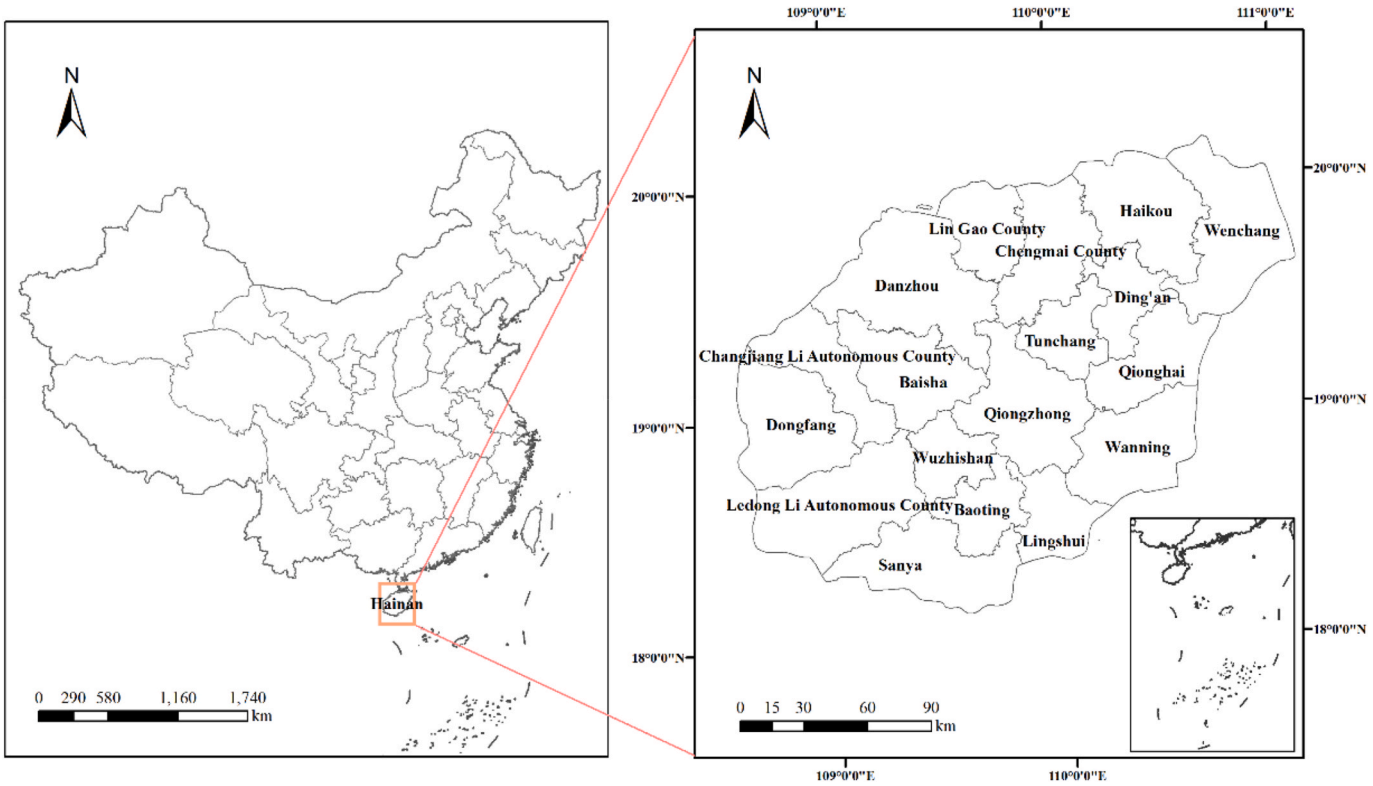


Fig. 1. Map showing the study domain (Hainan province) and its localization within China.

GDP, as shown in Section S4).

2.4.2. China VI emission standards (CNS) scenario

Hainan carried out the Limits and measurement methods for emission from light-duty vehicles (China VI) (Ministry of Ecology and Environment of the People's Republic of China, 2016) in 2019. The policy was divided into "China VI A″ and "China VI B". In Hainan, China VI A was introduced in 2019. China VI B will be introduced in 2023 and contains further emission limits for air pollutant compared with China VI A. China VI B is considered the most stringent policy for limiting the air pollutant emitted from vehicles (the details were shown in Table S16). Thus, the vehicle emissions from 2020 were accessed and compared with the scenarios of EVs (methods are shown in Section S4).

2.4.3. Eliminating public service vehicles (EPV) scenario

In 2022, the People's Government of Hainan issued an ambitious version of the Plan for Peak Carbon Dioxide Emissions in Hainan, which declared that the proportion of clean energy vehicles in public services and social operations should increase to 100% by 2025 (PGHP, 2022).

2.4.4. Eliminating the sale of FVs (ESV) scenario

On the basis of the plan for 2025, the goal of achieving peak pollutant emission reductions in Hainan dictates that no new FVs will be available for sale in the market from 2030, and that all new and exchanged vehicles must be EVs.

2.4.5. All-electric vehicles (AEV) scenario

Under the AEV scenario, all vehicles will be electrified and no air pollutants will be emitted directly from electric vehicles by 2045. This is based on the final FVs being sold at the end of 2029 and scrapped by 2045. Therefore, pollutant emissions in 2045 are considered to show the greatest benefits for air quality from Hainan's vehicle electrification.

The scenarios mentioned above also considered the decline in pollutant emissions associated with a reduction in the number of gas filling stations because of the sale of EVs. This information is presented in Table S12.

3. Results and discussion

3.1. Spatiotemporal characteristics of air pollutant emissions

The emission inventory for Hainan in 2017 is summarized in Table 1. Apart from NH_3, point sources emitted approximately 41.7%–98.1% of the corresponding pollutants. As shown in Fig. 2, subcategory attribution was performed for each major pollutant. The details of the contributions from each region can be found in Fig. S1. Stationary combustion of fossil fuel was regarded as the largest contributor to the emission of SO_2, accounting for 45.3% of the total. Power plants, mining and manufacturing industries, and cement factories were considered the major contributors to SO_2 emissions, accounting for 22.5%, 20.5%, and 19.0% of the fossil-fuel-related SO_2 emissions, respectively.

Mobile sources made a marked contribution to NOx emissions (57.6% of the total), followed by stationary combustion of fossil fuel sources (22.1%) and industrial processes (20.3%). On-road mobile sources emitted 45.7% of the mobile NOx. Trucks comprised only 7% of the total number of on-road vehicles, but they made a substantial contribution to NOx emissions (66.1% of the total). This reflects the fact that trucks burn diesel fuel, which emits large amounts of NOx. Thus, it is vital to promote the use of commercial EVs to reduce NOx emissions.

Both PM_{10} and $PM_{2.5}$ were emitted mainly by industrial process sources, accounting for 69.2% and 77.6% of the total, respectively. The sources of fugitive dust contributed 0.35% and 4.3% of the total emission of $PM_{2.5}$ and PM_{10}, respectively. Road dust, which has been shown to be a significant part of PM (PM_{10} and $PM_{2.5}$) (Hua et al., 2019), contributed 25.00% and 9.33% of the total emission of $PM_{2.5}$ and PM_{10}, respectively.

The major contributors to CO emissions were industrial processes (48.0% of the total), mobile sources (34.1%), and stationary combustion of fossil fuel (18.0%). Overall, 38.6% of VOCs were emitted by industrial processes, followed by solvent use (22.9%) and mobile sources (22.0%).

Table 1
Emission inventory for Hainan province in 2017 in kilotonnes (kt).

Category	SO_2	NOx	PM_{10}	$PM_{2.5}$	CO	VOCs	NH_3
Stationary combustion of fossil fuel	3.88	15.26	0.42	0.25	44.34	4.74	1.63
Industrial processes	3.72	14.46	25.62	15.38	118.87	19.95	6.16
Solvent use						11.27	
Mobile sources	0.95	39.90	1.59	1.48	84.35	1.80	0.56
Agriculture							52.27
Fugitive dust			0.13	0.85			
Storage and transportation						2.24	
Waste disposal						1.39	1.25
Road Dust			9.25	1.85			
Total	8.55	69.62	37.01	19.81	247.56	41.39	61.87

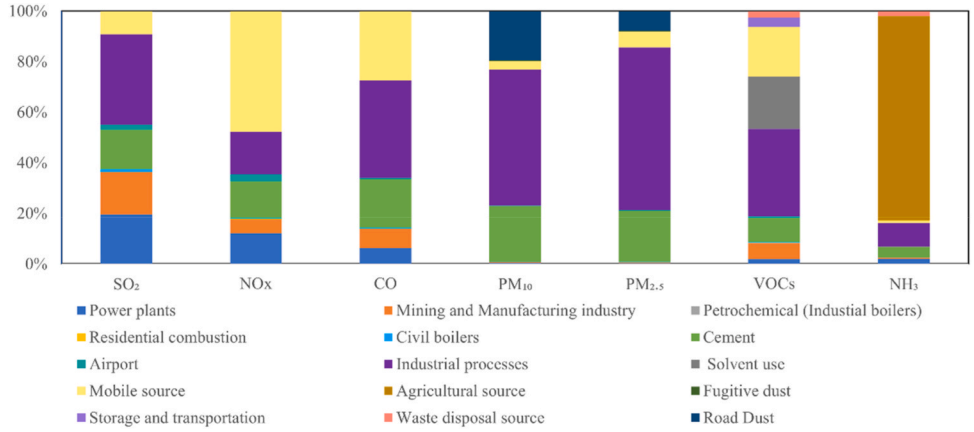


Fig. 2. Emission contributions by subcategory for Hainan province in 2017.

The remaining contributors were passenger cars, transportation and storage, and other industrial waste gases, which jointly accounted for 29.9% of the total emission of VOCs. Emissions of NH_3 were mainly contributed by agriculture, which accounted for 84.5% of the total NH_3 emissions. Livestock contributed 63.7% of the total NH_3 emissions, followed by the subcategory of nitrogen-based fertilizer (11.1%).

The spatial distributions of the seven air pollutants in 2017 in Hainan on a 0.05° × 0.05° grid are shown in Fig. 3. Apart from NH_3 and NOx, high-level emissions were mainly located in areas along the coast, especially in Haikou, Changjiang Li Autonomous County, and Sanya. These cities have well-developed industries, heavy traffic, and high-density populations (as shown in Fig. S2).

Monthly production data from different sectors were used to understand the temporal distribution of the emission characteristics from various industrial processes. The results are shown in Section S7. For example, monthly emissions from power plants were assessed using data on electricity generation.

3.2. Emission analysis under the five scenarios

The air pollutants emitted from FVs under the BAU scenario are shown in Fig. 4. The emissions of the seven air pollutants will continue to increase during 2017–2045, which can be attributed to the growth of FVs and the development of Hainan's economy. The total emissions in 2020, 2025, 2030, and 2045 will be 1.5, 2.6, 3.9, and 5.1 times greater, respectively, than those in 2017. To assess the effect of the emission reduction policy on pollutant emissions from vehicles, the vehicle emission inventories of the rest scenarios for 2020, 2025, 2030, and 2045 are also illustrated in Fig. 4.

Under the CNS scenario, in comparison with the BAU scenario in 2020, reductions in emissions were contributed by CO (0.44 kt), and the other emissions were the same as the BAU scenario in 2020. This can be attributed to the similarity between China VI A and China V. In 2025, China VI (A and B) will both be operating at the same time so that the emissions from CNS were lower than those in the BAU scenario and the EPV scenario (carried out in 2025 with less development). The CNS emissions scenario in 2030 was lower than the EPV scenario and close to the ESV scenario. In 2045, the emissions of the CNS scenario were lower than the BAU scenario and close to the EPV scenario. Therefore, in terms of emissions, the CNS scenario seems to have the same effect as the incomplete EV scenarios (EPV and ESV). However, compared with the EV scenarios, it still emitted substantial air pollutants and consumed fossil fuels.

Under the EPV scenario, in comparison with the BAU scenario, reductions in vehicle emissions of SO_2, NOx, CO, PM_{10}, $PM_{2.5}$, VOCs, and NH_3 by 2025 were projected to be 0.19, 14.42, 22.01, 0.42, 0.38, 1.82, and 0.07 kt, respectively, with vehicle emissions reduction rates of 11.69%, 17.53%, 10.90%, 16.87%, 16.51%, 7.55%, and 4.51%, respectively.

Under the ESV scenario, in comparison with the BAU scenario, reductions in vehicle emissions of SO_2, NOx, CO, PM_{10}, $PM_{2.5}$, VOCs, and NH_3 by 2030 were projected to be 0.43, 28.42, 51.31, 0.84, 0.77, 5.04, and 0.84 kt, respectively, with vehicle emissions reduction rates of 17.87%, 23.30%, 17.13%, 22.69%, 23.35%, 14.02%, and 7.72%, respectively. According to the Hainan Provincial Air Quality Bulletin (CNEMC, 2018), PM (i.e., PM_{10} and $PM_{2.5}$) is a major pollutant affecting the atmospheric environment in the province. On the basis of the emission inventory established in this study, the priority should be to enhance emission control standards for factories and vehicles. Fortunately, with the development of EVs, the emissions of PM were projected to be reduced by more than 20% in the ESV scenario and by approximately 15% in the EPV scenario. In comparison with the BAU scenario in 2045, the EPV scenario will still contribute to the reduction of air pollutant emissions. Because the target date of the ESV policy was 2030, emissions of air pollutants will reduce continuously until Hainan achieves its AEV goal.

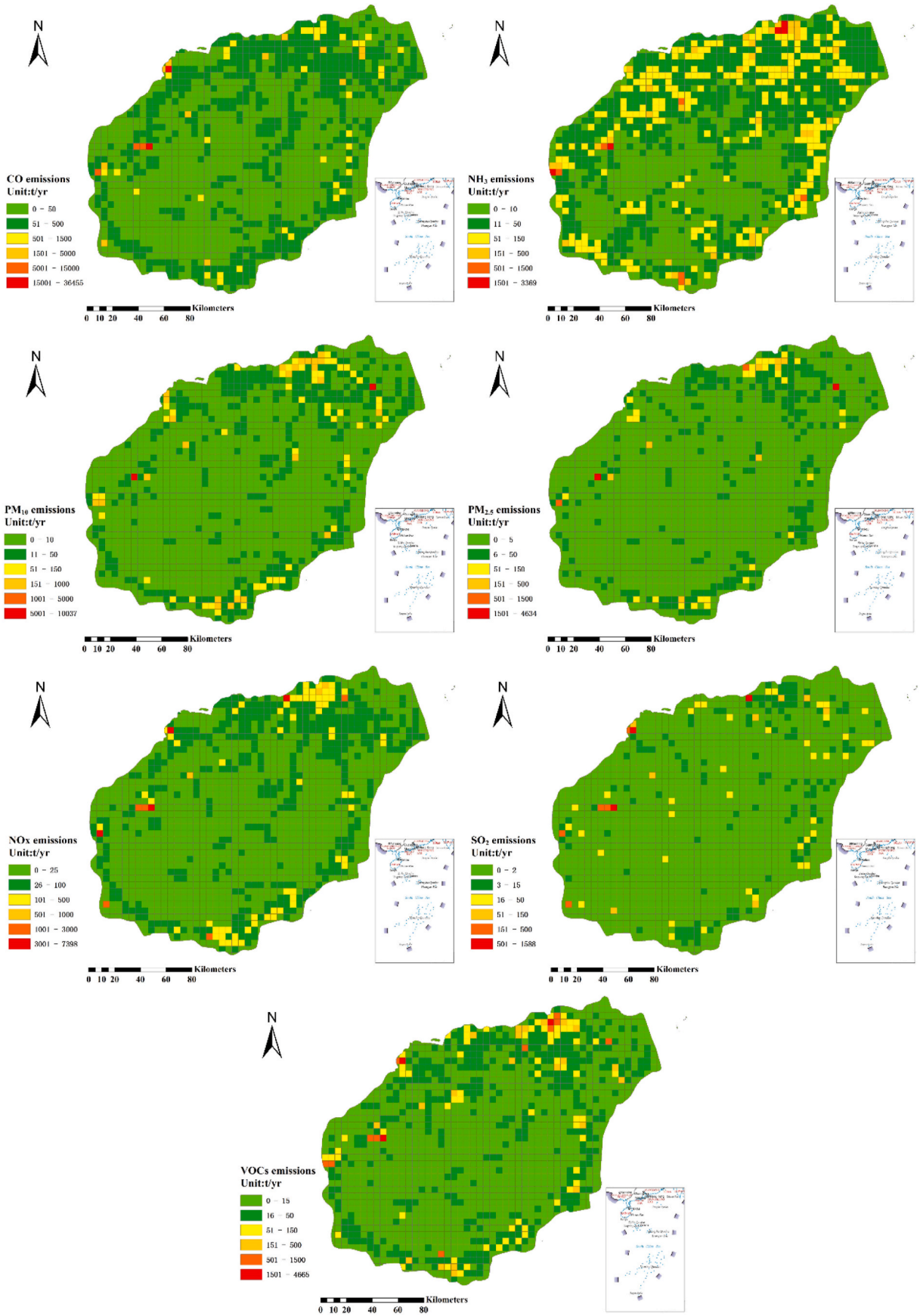


Fig. 3. Spatial distribution of air pollutant emissions in Hainan province in 2017.

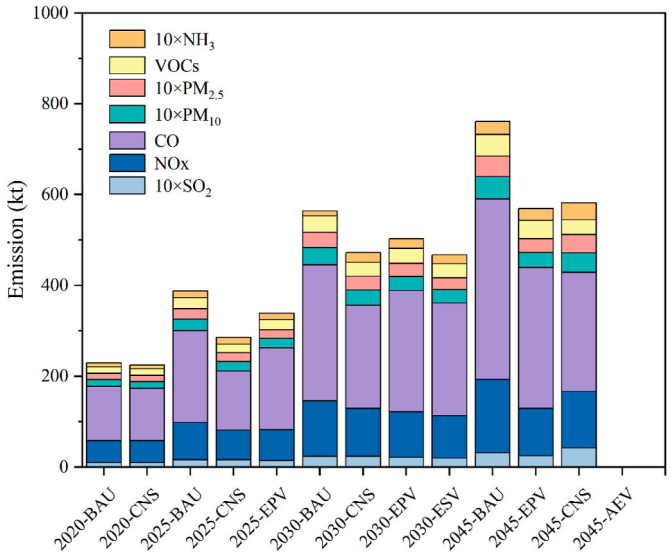


Fig. 4. Emission inventories of vehicles under different scenarios.

Under the AEV scenario, in comparison with the BAU scenario, reductions in vehicle emissions of SO_2, NOx, CO, PM_{10}, $PM_{2.5}$, VOCs, and NH_3 by 2045 were projected to be 3.19, 161.54, 396.71, 4.93, 4.54, 47.66, and 2.87 kt, respectively, with vehicle emissions reduction rates of 100% since all vehicles will be electrified and no air pollutants will be emitted directly from electric vehicles under the AEV scenario. Additionally, emission reductions of SO_2, NOx, CO, PM_{10}, $PM_{2.5}$, VOCs, and NH_3 account for 11.11%, 57.32%, 34.07%, 5.73%, 8.24%, 9.76%, and 0.91%, respectively, of the total anthropogenic emissions in 2045.

The benefits to human health and air quality from the reduction of vehicles will be greater than those related to the reduction of emissions if Hainan's policy is achieved on time between 2030 and 2045. For example, a reduction in emissions of NOx and VOCs, which are important precursors in the process of O_3 formation, could substantially reduce the frequency and harm from O_3 pollution to air quality and human health. According to the study in Taiwan (with similar vehicle density and regional area as Hainan), the researchers evaluated the benefits of a full EV scenario to air quality with a Weather Research and Forecasting Community Multiscale Air Quality (WRF-CMAQ) model, showing that a full EV scenario could reduce annual days of O_3 pollution by ~40% (Li et al., 2016). Studies in other countries also have confirmed that EV scenarios can reduce O_3 pollution (Ke et al., 2017; Schnell et al., 2019). Although the reduction in PM emissions associated with the process of transition to EVs is not as obvious as the reduction in emissions of NOx and VOCs, it would contribute to a reduction in the accumulated O_3 through coordinated control of $PM_{2.5}$ and O_3. Furthermore, during the process of transition to EVs, the emission of VOCs from gas filling stations will diminish; that is, in 2045, approximately 19 kt of VOCs would be emitted by gas filling stations without the transition to EVs (Table S12). Owing to the improvement of regional air quality, Hainan could expect to attract more national and international tourists and achieve a more prosperous tourism industry. The objectives of the policies implemented in Hainan are not only to improve air quality and human health, but also to encourage further economic development.

3.3. Comparisons and uncertainty

To evaluate the quality of our results, we compared the new inventory with the MEIC (Table S14), which also included Hainan in 2017 (Li et al., 2017). The calculated emissions of five pollutants (NH_3, VOCs, CO, NO_X, and SO_2) in the MEIC were higher than in our inventory, which might reflect differences in activity data and emission factors. In terms of activity data, the results of this study, based on city-level information, considered more accurate than either continental-level or national emission estimates. Furthermore, differences in the emission source classification between the MEIC (five source categories) and this study (eight categories) will have caused certain discrepancies. In particular, the MEIC excluded fugitive dust, which was a major source of PM_{10} and $PM_{2.5}$. Therefore, in comparison with the MEIC, we believe that our new emission inventory represents a more comprehensive characterization of pollutant emissions in Hainan.

The results of Monte Carlo simulations were summarized in Table S15. The calculations of residential combustion and non-road mobile sources produced the highest uncertainties. Uncertainty in relation to residential combustion sources was high because of fuel combustion disparities between cities and the limited data available from field surveys. Emission factors and the classification of vehicles might represent the major contributors to the uncertainty in the emissions of non-road mobile sources. Moreover, the parameters selected to calculate the agricultural and construction machinery activity statistics for the non-road mobile sources also included some degree of uncertainty. High levels of uncertainty were also linked with the emission of pollutants related to residential combustion, mobile sources, and industrial processes (e.g., NOx, VOCs, PM_{10}, CO, and $PM_{2.5}$). The emission uncertainty of SO_2 was low because the primary contributors to emissions were point sources with fossil fuel consumption. Finally, uncertainties related to livestock and nitrogen-based fertilizer application, the primary contributors to NH_3 emissions, were attributable to insufficient statistics, uncertainty with regard to fertilization time, and local meteorological conditions.

Except for the uncertainty of the emission inventory, there were situations that this study did not consider and these may increase the uncertainty of the results. According to the Hainan statistical yearbook (HPSC and NBSC, 2018), the energy structure of Hainan was composed of coal (34%), crude oil (32%), natural gas (15%), and primary electricity (19%). According to our previous research (Han et al., 2019), after the full implementation of ultra-low emission policies, the annual average concentration of SO_2 and $PM_{2.5}$ for each city will be reduced by 57% and 69%, respectively. Furthermore, the research on EVs promotion of air quality co-benefits coupled with power plants emissions confirmed that the additional air pollutant emissions associated with the development of EVs will be acceptable (Lin et al., 2020). Emission reductions would be affected by the migratory people, which reached 1.30 million in Hainan in 2017 (HPSC and NBSC, 2018). However, the use of EVs for migratory people and the resulting air pollutant emissions reductions were not considered in this study.

4. Conclusions

To evaluate the benefits for air quality of the transition to EVs in Hainan over the coming decades, this study established a high-resolution (5 km) emission inventory of seven air pollutants for 2017. On the basis of this emission inventory, four scenarios were adopted to determine the extent to which emissions of air pollutants could be reduced in comparison with the BAU scenario. In terms of the air pollutant emissions, the CNS scenario seemed to be similar to the incomplete EV scenarios (EPV and ESV). However, compared with the AEV scenario, the CNS scenario still emitted substantial amounts of air pollutants and consumed fossil fuels. The results also showed that replacing public service vehicles and private vehicles with EVs would lead to a moderate reduction in the trend of increase in emissions of air pollutants by 2025. Thus, a stricter policy that includes banning the sale of new FVs by 2030 has been proposed in Hainan to reduce emissions levels. Under the ESV and AEV scenarios, the rate of reduction in emissions of NOx would increase from 15% to 55%, which suggests that the goal of reducing air pollutants in Hainan could improve the regional air quality and further stimulate its economic development. Moreover, the success in Hainan with regard to the transition to EVs can be considered an excellent example for promoting the adoption of EVs

nationally.

Author statement

Zhongjun Xu: Methodology, Investigation, Writing-Original Draft. **Shaobo Chen:** Conceptualization, Investigation, Writing- Review and Editing. **Minjie Sang:** Investigation and Methodology. **Zhaotong Wang:** Methodology and Formal analysis. **Xin Bo:** Conceptualization, Methodology, Writing- Review and Editing. **Qian You:** Methodology and Formal analysis.

Declaration of competing interest

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.

Data availability

The data that has been used is confidential.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.chemosphere.2023.137814.

References

China National Environmental Monitoring Centre (CNEMC), 2018. National urban air quality report. Retrieved. http://www.cnemc.cn/. (Accessed 24 October 2022) (in Chinese).

Cui, J., Lei, T., Bo, X., Wu, P., Qu, J., Gao, S., 2020. Studies on air pollutant emission inventory and environmental impact in Hainan province. Environ. Pollut. Contr. 42, 10 (In Chinese with English abstract).

Han, H., Bo, X., Qu, J., Yang, C., Wu, P., Tian, F., Mo, H., Zhao, X., Zhou, X., 2019. Air quality impacts of power plant emissions in Hainan province, 2015. China Environ. Sci. 39, 428–439 (in Chinese with English abstract).

Department of Taxation, Ministry of Finance of the People's Republic of China (DMFP), 2014. Announcement on exemption from purchase tax of new energy vehicles. In: China, Ministry of Finance of the People's Republic of China. Retrieved. http://szs.mof.gov.cn/zhengcefabu/201408/t20140806_1123100.htm. (Accessed 24 October 2022) (in Chinese).

Department of Taxation, Ministry of Finance of the People's Republic of China (DMFP), 2017. Notice on exemption from purchase tax of new energy vehicles. In: China, Ministry of Finance of the People's Republic of China. http://szs.mof.gov.cn/zhengcefabu/201712/t20171227_2788817.htm. (Accessed 24 October 2022) (in Chinese).

Department of Taxation, Ministry of Finance of the People's Republic of China (DMFP), 2022. Announcement on continuation of vehicle purchase tax exemption policy for new energy vehicles. In: China, Ministry of Finance of the People's Republic of China. Retrieved. http://szs.mof.gov.cn/zhengcefabu/202209/t20220926_3842633.htm. (Accessed 24 October 2022) (in Chinese).

Hainan Provincial Bureau of Statistics (HPSC), National Bureau of Stastics of China (NBSC), 2018. Hainan Statistical Yearbook 2017. China Statistics Press, Beijing.

He, H., Wang, Y., Ma, Q., Ma, J., Chu, B., Ji, D., Tang, G., Liu, C., Zhang, H., Hao, J., 2014. Mineral dust and NOx promote the conversion of SO2 to sulfate in heavy pollution days. Sci. Rep. 4, 4172.

Hua, H., Jiang, S., Sheng, H., Zhang, Y., Liu, X., Zhang, L., Yuan, Z., Chen, T., 2019. A high spatial-temporal resolution emission inventory of multi-type air pollutants for Wuxi city. J. Clean. Prod. 229, 278–288.

Ke, W., Zhang, S., Wu, Y., Zhao, B., Wang, S., Hao, J., 2017. Assessing the Future Vehicle Fleet Electrification: the impacts on regional and urban air quality. Environ. Sci. Technol. 51, 1007–1016.

Li, N., Chen, J.-P., Tsai, I.C., He, Q., Chi, S.-Y., Lin, Y.-C., Fu, T.-M., 2016. Potential impacts of electric vehicles on air quality in Taiwan. Sci. Total Environ. 566–567, 919–928.

Li, M., Liu, H., Geng, G., Hong, C., Liu, F., Song, Y., Tong, D., Zheng, B., Cui, H., Man, H., Zhang, Q., He, K., 2017. Anthropogenic emission inventories in China: a review. Natl. Sci. Rev. 4, 834–866.

Liang, X., Zhang, S., Wu, Y., Xing, J., He, X., Zhang, K.M., Wang, S., Hao, J., 2019. Air quality and health benefits from fleet electrification in China. Nat. Sustain. 2, 962–971.

Lin, W.-Y., Hsiao, M.-C., Wu, P.-C., Fu, J.S., Lai, L.-W., Lai, H.-C., 2020. Analysis of air quality and health co-benefits regarding electric vehicle promotion coupled with power plant emissions. J. Clean. Prod. 247, 119152.

Liu, M.M., Huang, Y.N., Ma, Z.W., Jin, Z., Liu, X.Y., Wang, H., Liu, Y., Wang, J.N., Jantunen, M., Bi, J., Kinney, P.L., 2017. Spatial and temporal trends in the mortality burden of air pollution in China: 2004-2012. Environ. Int. 98, 75–81.

Ministry of Ecology and Environment of the People's Republic of China (MEE), 2016. Limits and Measurement Methods for Emission from Light-Duty Vehicles (CHINA 6). General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China (GQQ), Beijing, China (in Chinese).

National Bureau of Stastics of China (NBSC), 2018. China Statistical Yearbook 2018. China Statistics Press, Beijing.

Platt, S.M., El Haddad, I., Pieber, S.M., Zardini, A.A., Suarez-Bertoa, R., Clairotte, M., Daellenbach, K.R., Huang, R.J., Slowik, J.G., Hellebust, S., Temime-Roussel, B., Marchand, N., de Gouw, J., Jimenez, J.L., Hayes, P.L., Robinson, A.L., Baltensperger, U., Astorga, C., Prévôt, A.S.H., 2017. Gasoline cars produce more carbonaceous particulate matter than modern filter-equipped diesel cars. Sci. Rep. 7, 4926.

Schnell, J.L., Naik, V., Horowitz, L.W., Paulot, F., Ginoux, P., Zhao, M., Horton, D.E., 2019. Air quality impacts from the electrification of light-duty passenger vehicles in the United States. Atmos. Environ. 208, 95–102.

Song, H., Deng, S.-X., Lu, Z.-Z., Li, J.-H., Ba, L.-M., Wang, J.-F., Sun, Z.-G., Li, G.-H., Jiang, C., Hao, Y.-Z., 2021. Scenario analysis of vehicular emission abatement procedures in Xi'an, China. Environ. Pollut. 269, 116187.

Soret, A., Guevara, M., Baldasano, J.M., 2014. The potential impacts of electric vehicles on air quality in the urban areas of Barcelona and Madrid (Spain). Atmos. Environ. 99, 51–63.

The Central People's Government of the People's Republic of China (CGPR), 2017. Mid-term and long-term development plan for the automobile industry. In: China, the Central People's Government of the People's Republic of China. http://www.gov.cn/gongbao/content/2017/content_5230289.htm. (Accessed 24 October 2022) (in Chinese).

The People's Government of Hainan Province (PGHP), 2018. The plan for population development in Hainan (2030. In: The People's Government of Hainan Province. https://www.hainan.gov.cn/hainan/tingju/201806/1ae20d378fe14a658b5e3eef58f4ef37.shtml. (Accessed 24 October 2022) (in Chinese).

The People's Government of Hainan Province (PGHP), 2022. Hainan province carbon peak implementation plan notice. In: Province, the People's Government of Hainan Province from. https://www.hainan.gov.cn/hainan/szfwj/202208/911b7a2656f148c08e5c9079227103a7.shtml. (Accessed 24 October 2022) (in Chinese).

Xie, D., Zhang, X., Han, Q., He, Q., Zhou, K., 2019. Uncertainty analysis on process organized emission inventory in petrochemical enterprises of Hainan province. IOP Conf. Ser. Earth Environ. Sci. 295, 052052.

Zhao, Y., Nielsen, C.P., Lei, Y., McElroy, M.B., Hao, J., 2011. Quantifying the uncertainties of a bottom-up emission inventory of anthropogenic atmospheric pollutants in China. Atmos. Chem. Phys. 11, 2295–2308.

Zheng, B., Geng, G.N., Ciais, P., Davis, S.J., Martin, R.V., Meng, J., Wu, N.N., Chevallier, F., Broquet, G., Boersma, F., van der Ronald, A., Lin, J.T., Guan, D.B., Lei, Y., He, K.B., Zhang, Q., 2020. Satellite-based estimates of decline and rebound in China's CO2 emissions during COVID-19 pandemic. Sci. Adv. 6, eabd4998.

Zheng, B., Zhang, Q., Geng, G.N., Chen, C.H., Shi, Q.R., Cui, M.S., Lei, Y., He, K.B., 2021. Changes in China's anthropogenic emissions and air quality during the COVID-19 pandemic in 2020. Earth Syst. Sci. Data 13, 2895–2907.

Zhou, M.M., Jiang, W., Gao, W.D., Gao, X.M., Ma, M.C., Ma, X., 2021. Anthropogenic emission inventory of multiple air pollutants and their spatiotemporal variations in 2017 for the Shandong Province, China. Environ. Pollut. 288, 117666.