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Greenhouse gas inventory at sub-national level using CIRIS tool: a case study in Quang Tri Province, Vietnam

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Abstract. This study presents the first comprehensive greenhouse gas (GHG) inventory for Quang Tri Province, Vietnam, using the City Inventory Reporting and Information System (CIRIS) tool at the BASIC level. The inventory covers the stationary energy, transportation, and waste sectors, utilising 2022 activity data and nationally approved emission factors. The total GHG emissions were estimated at 1,987,208 tons of CO_2 equivalent (CO_2e), with the stationary energy sector contributing the largest share (76.4%), followed by transportation (16.2%) and waste (7.4%). The per capita emissions were 3.1 tons CO_2e, comparable to neighbouring provinces. The results highlight key emission sources, including electricity use in residential and industrial buildings, and road transport fueled with gasoline and diesel. A mitigation scenario with improved building energy efficiency and rooftop solar systems could cut emissions by approximately 274,000 tons CO_2e annually. Although the CIRIS tool does not require a full uncertainty analysis, this study nevertheless identifies potential data limitations related to informal energy use and under-reported waste flows. It recommends incorporating sensitivity or Monte Carlo simulations in future inventories to quantify uncertainties. By establishing a reliable GHG emissions baseline, we provide a critical input for developing targeted climate mitigation strategies and support Vietnam's broader commitment to achieving net-zero emissions by 2050.

Keywords: CIRIS, greenhouse gas inventory, BASIC level, Quang Tri Province

1 Introduction

Vietnam is among the countries most vulnerable to the effects of climate change. To address greenhouse gas (GHG) emissions and secure international support, the country ratified the Kyoto Protocol and the United Nations Framework Convention on Climate Change (UNFCCC). According to the prerequisites set by UNFCCC, Vietnam has conducted national GHG emission inventories in 1994, 2000, 2010, 2013, and 2016. Since then, it has provided National Communications and Biennial Update Reports on GHG emissions, adhering to the Intergovernmental Panel on Climate Change (IPCC) [1].

Several provinces and cities in Vietnam have also undertaken GHG inventories to identify high-emission sectors and propose targeted mitigation measures. Examples include inventories in Da Nang, Hoi An, and Dong Ha in 2017, Vinh and Dong Hoi in 2019, and Ho Chi Minh City, Can Tho, and Tam Ky in 2021 [2]. However, as of 2023, Quang Tri has not yet conducted any GHG inventories across its entire territory. Such inventories are essential for developing strategies and solutions to reduce emissions, contributing to Vietnam's commitment to achieving net-zero emissions by 2050, as announced by the Prime Minister at the 26th

Conference of the Parties (COP26) in Glasgow, United Kingdom.

The City Inventory Reporting and Information System (CIRIS), developed by the C40 Cities Climate Leadership Group and its partners, is based on the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC). Though mainly developed for cities, CIRIS can also be adapted for other administrative levels, such as provinces like Quang Tri [3].

While previous provincial-level greenhouse gas inventories primarily relied on IPCC emission factors and aggregated activity data, this study is the first in Vietnam to develop a bottom-up provincial-level GHG inventory for Quang Tri Province. It utilises national emission factors with locally reported electricity and fuel consumption data, as well as information on informal energy use and transmission losses. The Scope 3 boundary was also expanded to include inter-provincial waste flows—a factor often overlooked in previous studies—and applied the CIRIS methodology to create a detailed sectoral picture for the stationary energy, transportation, and waste sectors.

The conducting of a 2022 GHG inventory using CIRIS in Quang Tri is a practical and necessary step to establish a provincial emissions baseline. The findings will provide critical data for local authorities to formulate effective strategies and solutions for reducing GHG emissions, supporting Vietnam's broader efforts to mitigate climate change and fulfill its international commitments.

2 Materials and methods

2.1 Materials

City inventory reporting and information system (CIRIS)

The CIRIS offers a structured, template-based approach for cities and provinces to enter data and utilise it across various processes. It enables transparent calculation and reporting of emissions across all sectors, including stationary energy, transportation, waste, industrial processes and product use (IPPU), and agriculture, forestry, and other land use (AFOLU) [4]. CIRIS allows localities to choose one of the two GHG inventory levels:

Advanced level (BASIC+): A more complex level, typically used for regional or national GHG inventories. However, localities are also encouraged to adopt this level. BASIC+ accounts for all five sectors mentioned above and includes Scopes 1, 2, and 3 (see Table 1 and Fig. 1).

Basic level (BASIC): Preferred for ease of comparison between localities. Currently, both the C40 Cities Climate Leadership Group and the Global Covenant of Mayors for Climate and Energy permit the use of this BASIC level. It includes only Scope 1 and 2 for stationary energy: Scope 1 for transportation and Scopes 1 and 3 for waste (see Table 1 and Fig. 2).

Table 1. Three GHG emission scopes according to the CIRIS tool [3]

Scope	Definition	Example
1 (Direct)	GHG emissions from sources within the provincial/city	– Fuel consumption within the provincial/city – Waste generated and treated within the provincial/city

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Scope	Definition	Example
2 (Indirect)	GHG emissions from the use of the national grid electricity	Electricity consumption of the provincial/city
3 (Indirect)	GHG emissions occurring outside the provincial/city area but resulting from activities within the area	– Waste generated within the area but treated outside – Transmission and distribution losses of the grid electricity

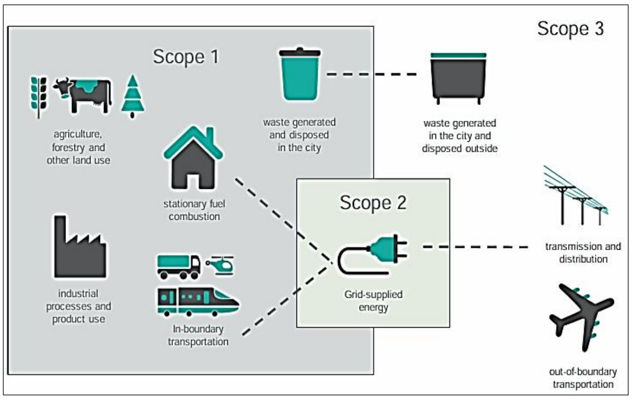

Fig. 1. Reporting level - BASIC+ sources [4] (© C40 Cities, 2022. All rights reserved)

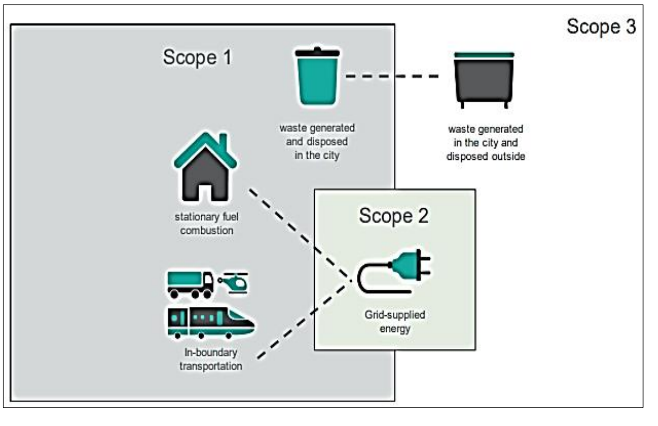

Fig. 2. Reporting level - BASIC sources [4] (© C40 Cities, 2022. All rights reserved)

Emission factors

In Vietnam, the Ministry of Natural Resources and Environment has developed and officially issued a comprehensive list of emission factors to support the preparation of GHG inventories. These emission factors are applicable across five related sectors, including stationary energy, transportation, IPPU, AFOLU, and waste [5]. Specifically for the national electricity grid, its emission factor was estimated at 0.6766 tons of CO_2e/MWh in 2022 [6].

2.2 Greenhouse gas inventory method

The calculation of GHG emissions using the CIRIS tool is based on the scale of emission sources and emission factors (Fig. 3). The CIRIS tool uses Excel-based templates with pre-established calculation and conversion formulas. The users of this tool only need to select the correct type of emission source, input the scale data into appropriate cells with the correct units, and choose additional conditions [4].

The GHG inventory for determining emission levels in the province was conducted at the BASIC level, covering three sectors: stationary energy, transportation, and waste. The three commonly calculated GHGs at this level are CO_2, CH_4, and N_2O.

Source scale	Emission factor	Emission quantity
X litres of diesel/year (industry)	*F*1 kg CO_2/liter	*X* × *F*1 kg CO_2/year
Y tons.km/year (transportation)	*F*2 kg CO_2/tons.km	*Y* × *F*2 kg CO_2/year
Z m² (construction)	*F*3 kg CO_2/m²	*Z* × *F*3 kg CO_2/year

Fig. 3. Estimation of GHG emissions based on magnitude of sources and emission factors

Similar to other GHG inventory tools like Bilan Carbone, CarbonView, SimaPro, Bamboo, and Cage Carbon, the CIRIS simplifies the calculation process through the following assumptions: The Global Warming Potential (GWP) is calculated based on the 100-year timeframe from the IPCC's Sixth Assessment Report (AR6) (Table 2); Water vapour is negligible because of its short atmospheric lifetime; Ozone is excluded because of its short lifespan, limited direct emission sources, and the difficulty in calculating from indirect sources.

Table 2. GWP of three GHGs over a 100-year timeframe according to IPCC's AR6 [7]

GHGs	Chemical formula	GWP factor
Carbon dioxide	CO_2	1
Methane	CH_4	27-29.8 (depending on fossil or non-fossil fuel)
Nitrous oxide	N_2O	273

In addition to MS Excel spreadsheets, the CIRIS tool provides guidance documents explaining related terms used in the spreadsheets and detailed instructions on inputting data for each module [8].

3 Results and discussion

3.1 Greenhouse gas emissions in the stationary energy sector

For the stationary energy sector, the CIRIS tool requires the inventory of GHG emission sources from the oxidation process during the combustion of fossil fuels in buildings, industrial production, agriculture, electricity generation, etc., as well as direct emissions from the use of fuels (Table 3). These include both intentional and unintentional outputs due to leaks during extraction, processing, storage, and transportation of fuels.

Quang Tri Province has negligible activities related to coal extraction, oil refining, or liquefied petroleum gas (LPG) processing, resulting in zero direct emissions from fuel leaks during extraction, processing, storage, or transportation. Table 4 presents data on the electricity and fuel consumption within the province in 2022.

Table 3. GHG emission sources in stationary energy sector according to CIRIS tool [4]

Sub-sector	Explanation
Residential buildings	Emissions from energy use in households
Commercial and service buildings	Emissions from energy use in commercial buildings, schools, hospitals, government offices, etc., and specialised equipment within them
Industry and construction	Emissions from energy use in industrial and construction facilities (excluding the energy industry)

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Sub-sector	Explanation
Energy industries	Emissions from energy use in the energy industry, including primary fuel production and electricity generation for the grid
Agriculture, forestry, and fisheries	Emissions from energy use in agriculture, forestry, and fisheries
Other sources	Other emissions from energy production or consumption facilities, not classified in the above sub-sectors
Electricity losses	Electricity losses during transmission and distribution
Coal mining, processing, storage, and transportation	Intentional and unintentional emissions from coal mining, processing, storage, and transportation within the province/city*
Oil refining and natural gas systems	Emissions from oil refining and natural gas activities within the province/city. Main sources include equipment leaks, evaporation losses, etc.

**The formation of coal releases seam gases. When coal is exposed and broken during mining, processing, storage, and transportation, methane is released to the outside.*

Table 4. Electricity and fuel consumption in stationary energy sector of Quang Tri in 2022 [9, 10]

No	Sub-sectors	Consumption/production/ loss level	Data sources
1	***Electricity***		Quang Tri Power Company
	Total electricity consumption	776,850 MWh	
	Electricity loss on transmission and distribution	2.66%	
2	***Energy industries***		
	Hydropower production	354,812.2 MWh	
	Solar power production	183,861.5 MWh	
	Wind power production	1,772,092.8 MWh	
3	***Fuels***		Quang Tri Department of Industry and Trade
	Gasoline	31,309 tons	
	Oil (all types)	44,055 tons	
	LPG	122.5 tons	
	Coal (all types)	90,706 tons	

The results of the GHG inventory obtained by using the CIRIS tool, presented in Table 5, show that in the stationary energy sector, the energy consumed by the residential segment has the highest emission share (847,689 tons of CO_2e, accounting for 55.8% of the total GHG emissions in this sector). This high share stems from widespread electricity and liquid-fuel use for cooking, water heating, space cooling, and household appliances. Moreover, every kilowatt-hour of grid electricity carries a relatively high emission factor (0.6766 tons CO_2e/MWh), amplifying the carbon impact of even basic residential energy services.

The industrial and construction sub-sector emits 471,287 tons CO_2e, making it the second-largest source within stationary energy. High emissions stem from energy-intensive processes, reliance on high-carbon fuels (diesel, coal), outdated equipment, and limited use of energy-management or waste-heat recovery systems.

The CIRIS tool considers emissions resulting from the direct operation of renewable energy sources like solar panels and wind turbines. Nevertheless, it excludes GHG releases from their entire lifecycle, including production, transportation, and installation [3]. According to the IPCC (2022), emissions from renewable energy sources such as wind, solar, and hydropower mainly occur during equipment manufacturing and construction, as their operation does not involve burning fossil fuels. Therefore, the GHG emissions from these sources during operation are considered negligible or effectively zero, including those generated in Quang Tri from hydropower, wind, and solar power.

It is crucial to note that the data on electricity and fuel consumption in Quang Tri for 2022 is primarily based on reports from Quang Tri Power Company and Quang Tri Department of Industry and Trade. While this covers most grid electricity and major fuel types (gasoline, diesel, and coal) consumed, gaps still exist. Regarding informal energy consumption, sources such as small generators, agricultural biomass, or self-blended fuels (e.g., waste oil and coal in craft villages) have not been recorded. Additionally, although grid electricity transmission losses (2.66%) have been factored into calculations, losses during the storage and transportation of liquid and gaseous fuels (e.g., LPG leaks) are considered "insignificant" but may be underestimated because of the lack of real-world data.

Table 5. GHG emissions in stationary energy sector

Emission sources	Emission levels (tons of CO_2e)			
	Scope 1	Scope 2	Scope 3	Subtotal
Residential segment	591,936	255,753	0	847,689
Commercial and service segment	38,787	53,768	0	92,555
Industrial and construction segment	248,316	222,970	0	471,287
Agriculture, forestry, and fisheries segment	82,426	24,999	0	107,425
			Total	**1,518,956**

3.2 Greenhouse gas emissions in transportation sector

The GHG emissions from the transportation sector are calculated based on fuel consumption by vehicles on road, waterway, air, rail, and off-road transport (e.g., rollers, cranes, and forklifts) (Table 6). However, intra-provincial air and rail transport, as well as off-road vehicles, were excluded because of their minimal contribution, as confirmed by local transport data. Consequently, only road and waterway transport are included in the GHG emissions calculations. Fuel consumption data for the transport sector in Quang Tri are presented in Table 7.

Road transport dominates the transport sector, contributing 95.3% (306,093 tons of CO_2e) of its total emissions. This is driven by the extensive use of private and commercial vehicles powered by gasoline and diesel, often older models with poor fuel efficiency. Public transport remains underdeveloped, and non-motorised or electric

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alternatives are rare. Consequently, high per-vehicle fuel consumption and an absence of low-carbon mobility options keep transport emissions disproportionately large. The GHG outputs from water transport represent the lowest contribution, only 4.7% (Table 8).

Table 6. GHG emission sources in transportation sector according to CIRIS tool [4]

Sub-sector	Explanation
Road transport	Emissions from motor vehicles running on electricity or liquid fuel on roads
Rail transport	Emissions from all types of electric trains (elevated, street-level, and underground) in urban areas and inter-provincial routes, as well as national or international railway systems passing through the province/city
Water transport	Emissions from all types of ships, boats, ferries, etc., on water bodies within the province/city, or national/international waterway transport passing through the province/city
Air transport	Emissions from helicopters and domestic flights within the province/city
Off-road vehicles	Emissions from off-road vehicles such as rollers, bulldozers, and cranes

Table 7. Fuel consumption in the transportation sector [10]

No.	Sub-sectors	Volume (tons)	Data source
1	***Road transport***		Quang Tri Department of Industry and Trade
	Gasoline (all types)	3,113	
	Diesel (all types)	1,186	
2	***Waterway transport***		
	Gasoline (all types)	34	
	Diesel (all types)	215	

Table 8. GHG emissions in the transportation sector

Emission sources	Emission levels (tons of CO_2e)			
	Scope 1	Scope 2	Scope 3	Subtotal
Road	306,093	0	0	306,093
Railway	0	0	0	0
Waterway	14,907	0	0	14,907
Air	0	0	0	0
Off-road	0	0	0	0
			Total	**321,001**

Similar to stationary energy, it is worth noting that while the transportation emissions data in Quang Tri's GHG inventory are quite detailed for road and waterway vehicles, they still lack comprehensive coverage for all transport types, as noted above. It also does not account for potential systematic biases, such as refueling in border areas or missed indirect emissions. Consequently, actual emissions may be underestimated, particularly for activities involving off-road vehicles, aviation, and transit transportation.

3.3 Greenhouse gas emissions in waste sector

In Vietnam, provinces and cities may process their solid waste and wastewater at treatment facilities located either within their administrative boundaries or in other localities. The waste treatment process generates GHG emissions through aerobic or anaerobic decomposition or direct incineration of waste (Table 9). The data on waste collected and treated in 2022 in the province are shown in Table 10.

At present, domestic waste in the province is primarily managed through landfilling. Wastewater treatment in industrial zones and clusters is limited, with numerous facilities discharging untreated or partially treated wastewater, contributing to water pollution. Urban areas such as Dong Ha City and Quang Tri Town have wastewater treatment plants or stations, but their capacity is limited. Consequently, many residential areas still discharge domestic wastewater directly into surrounding water bodies (e.g., Hieu River and Thach Han River).

Table 9. GHG emission sources in waste sector according to CIRIS tool [4]

Sub-sector	Explanation
Solid waste treatment	Emissions from solid waste disposed of in landfills or open dumps. In this case, please note: – Waste generated and treated within the province/city – Waste generated within the province/city but treated outside – Waste generated outside but treated within the province/city
Biological treatment of solid waste	Emissions from composting and anaerobic decomposition of organic waste. In this case, please note: – Waste generated and biologically treated within the province/city – Waste generated within the province/city but biologically treated outside – Waste generated outside but biologically treated within the province/city
Waste incineration and open burning	Waste incinerated either in controlled incinerators or through open burning. In this case, please note: – Waste generated and burned within the province/city – Waste generated within the province/city but burned outside – Waste generated outside but burned within the province/city
Wastewater treatment and untreated wastewater discharge	GHG emissions related to centralised wastewater treatment and untreated wastewater discharge. In this case, note: – Wastewater generated and treated within the province/city – Wastewater generated within the province/city but treated outside – Wastewater generated outside but treated within the province/city

Table 10. Waste volume generated in 2022 [11]

No.	Sectors	Volume/ quantity	Data source
1	***Wastewater***		Quang Tri Department of Natural Resources and Environment
	Wastewater generated in Quang Tri	50,044 m^3	
	Wastewater collected and treated (including septic tank treatment) in Quang Tri	7,506 m^3	

No.	Sectors	Volume/ quantity	Data source
2	***Solid waste***		
	Solid waste generated in Quang Tri	139,488 tons	
	Volume of solid waste collected and treated in Quang Tri	120,927 tons	
	Volume of solid waste (hazardous industrial solid waste) collected and treated outside Quang Tri	561 tons	

The GHG inventory results obtained by using the CIRIS tool show that GHG emissions from solid waste are 3.2 times as high as those from wastewater (Table 11). The solid waste emission is primarily caused by the breakdown of domestic waste in landfills, which contributes 64.5% of GHG emissions in the waste sector. Emissions from hazardous industrial waste, which is collected and then treated outside the province's boundaries, have the lowest share, at only 0.33%.

Table 11. GHG emissions in waste sector

Emission sources	Emission levels (tons of CO_2e)			
	Scope 1	Scope 2	Scope 3	Sub-total
Uncollected and untreated wastewater	28,241	0	0	28,241
Collected and treated wastewater	7,060	0	0	7,060
Uncollected and untreated solid waste	16,761	0	0	16,761
Solid waste treated within the province	94,977	0	0	94,977
Solid waste treated outside the province, i.e., hazardous industrial waste	0	0	482	482
			Total	**147,251**

The data on solid waste and wastewater were collected from Quang Tri's Department of Natural Resources and Environment, including the volume of waste generated, collected, and treated. However, these data primarily reflect the amount of waste that has been collected or sent to landfills/treatment plants. Numerous rural residential areas and industrial clusters still discharge directly into the environment or burn household waste, leading to an underestimation of these sources. Additionally, although 561 tons of hazardous industrial waste were reported as being sent for off-site treatment, this figure might be lower than the actual amount because of limited oversight and the possibility of under-reporting by businesses.

According to the summary of results in Fig. 4, the total GHG emissions for Quang Tri Province at the BASIC level in 2022 were 1,987,208 tons of CO_2e. The stationary energy sector accounts for the largest share (76.4%), mainly because of high electricity use. Most buildings, especially homes, rely heavily on grid electricity, which has a high emission factor. Although Quang Tri produces significant renewable energy (hydro, solar, and wind), this type of energy does not count toward local emission reductions in the inventory, as they are fed into the national grid. In addition, limited adoption of energy efficiency measures, like LED lighting or insulation, means energy demand remains high. Together, these factors make stationary energy the largest emission source in the province.

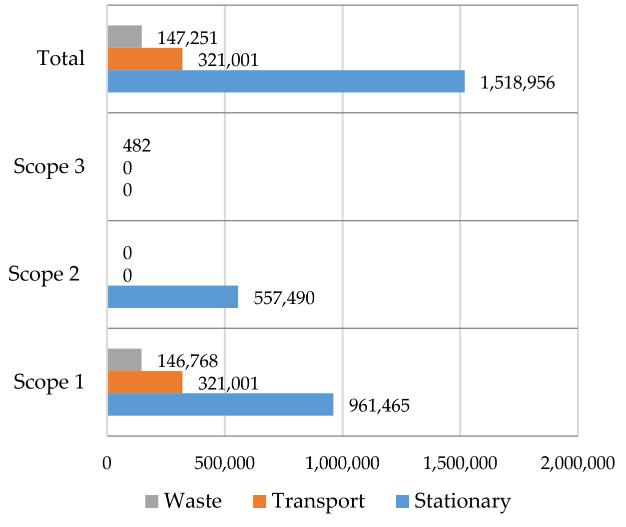

Fig. 4. GHG emissions of Quang Tri Province in 2022 at BASIC level

With a population of 649,708 and a GDP of USD 1,742,179,487 in 2022 [12], Quang Tri had the BASIC-level GHG emissions per capita and unit of GDP at 3.1 tons of CO_2e per person and 1,141 tons of CO_2e per million USD. These emissions are close to those of Thua Thien Hue (currently Hue City), which stand at 3.2 tons of CO_2e per capita and 1,278 tons of CO2e per million USD, and Quang Binh (3.15 tons of CO2e per capita and 1,241 tons of CO_2e per million USD) [2]. This small variation is understandable, as the socio-economic development conditions of the three provinces—Quang Tri, Thua Thien Hue, and Quang Binh—are relatively comparable.

If Quang Tri wants to effectively contribute to Vietnam's goal of reaching net-zero emissions by 2050, it should make the first great effort on GHG reduction for stationary energy. According to the 2022 Quang Tri GHG inventory, stationary energy accounts for the vast majority (76.4%) of emissions, totalling 1,518,956 tons of CO_2 equivalent. A significant and rapid way for rapid reductions is improving end-use efficiency in buildings. By implementing measures like upgrading to LED lighting, improving insulation, and installing smart energy systems, a targeted 20% reduction scenario in electricity use over five years across all sectors could save approximately 155,370 MWh annually. This would prevent around 105,200 tons of CO_2e from being released each year.

Simultaneously, increasing the use of distributed solar power can replace a substantial amount of energy generated from fossil fuels. The installation of 200 MW of solar panels on rooftops and in community projects could generate about 250,000 MWh of clean energy yearly. This would avert an additional 169,150 tons of CO_2e of emissions annually. Moreover, the province is already at the forefront of wind power development. Therefore, it is advisable to build on this success and continue expanding renewable energy capacity.

Together, the energy efficiency and solar power initiatives could cut stationary energy emissions by approximately 274,350 tons of CO_2e per year, representing a nearly 18% decrease from current levels. In addition to mitigating climate change, these actions would also lead to lower electricity costs for consumers and stimulate local job growth in the solar and retrofitting industries. By prioritising the largest source of emissions, Quang Tri can make significant strides toward its decarbonisation targets and prepare for future emission reduction efforts.

3.4 Recommendations for future uncertainty analysis

While this study provides a robust baseline GHG inventory for Quang Tri Province, a formal assessment of uncertainty was not performed. Such an analysis is crucial for understanding the confidence level of the emission estimates and for

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prioritising future improvements in data collection. Conducting a formal uncertainty analysis in future studies would be a valuable next step, enhancing the credibility of these findings and guiding efforts to improve the accuracy of future GHG inventories for Quang Tri Province.

Regarding the GHG inventory for the province, it relies on activity data (like fuel and electricity consumption) and emission factors drawn from national statistics and standardised sources. However, these numbers are not always perfect, and that is where uncertainty appears. There exist three main reasons.

1) *Activity data quality*: The figures for provincial fuel and electricity consumption can have reporting errors, mismatches when aggregating them, or even gaps in time. This is especially true in informal industrial sub-sectors where operations might not always be fully documented.

2) *Emission factor variability*: The standard emission factors currently applied do not always capture the full picture. They might not account for the specific mix of power generation in a local area, the efficiency of individual plants, or even seasonal changes in fuel quality.

3) *Methodological choices*: The assumptions made can also introduce biases. This includes the methods used to estimate transmission and distribution losses, the way emissions are assigned to different end-use categories, and the treatment of renewable energy generation as having zero operational emissions.

To better handle these uncertainties, a sensitivity analysis should be conducted. This involves adjusting key parameters within reasonable ranges (e.g., ±10% for consumption data or ±20% for emission factors) to observe the resulting variation in total estimates. For instance, if industrial diesel use is under-reported by just 10%, it could shift stationary energy emissions by roughly 50,000 tons of CO_2e.

For an even more robust assessment, a Monte Carlo simulation can be used. Probability distributions—such as normal distributions centred on the reported values with standard deviations reflecting data confidence—are assigned to each uncertain input. The inventory is then run thousands of times, generating a full distribution of possible total emissions. The resulting confidence interval (e.g., 95%) offers decision-makers more than just a single number; it provides a quantified range. This range helps pinpoint exactly where improving data collection or refining emission factors would be most effective in narrowing down the uncertainty.

By integrating these analytical approaches—such as sensitivity analysis and Monte Carlo simulation—future mitigation scenarios can be developed with greater confidence, supported by clearly defined and evidence-based uncertainty bounds that enhance the credibility and transparency of the results.

4 Conclusion

This study establishes a baseline GHG inventory for Quang Tri Province in 2022 using the CIRIS tool at the BASIC level, revealing total emissions of 1,987,208 tons of CO_2e. The stationary energy sector dominates with 76.4% (1,518,956 tons of CO_2e), followed by transportation (16.2%, 321,001 tons of CO_2e) and waste (7.4%, 147,251 tons of CO_2e). Per-capita emissions of 3.1 tons CO_2e align with neighbouring provinces, providing a robust baseline for local climate strategies. The findings highlight the urgent need to prioritise stationary energy reductions through enhanced energy efficiency and expanded renewable energy adoption, such as solar and wind, to align with Vietnam's net-zero goal by 2050. Despite data limitations, including unrecorded informal energy use and potential under-reporting in waste, this inventory offers actionable insights for policymakers. Future inventories should incorporate uncertainty analyses and expand to BASIC+ levels to include additional sectors like IPPU and AFOLU, ensuring a more holistic approach. By leveraging these results, Quang Tri can develop targeted mitigation measures, contributing significantly to Vietnam's climate commitments while fostering sustainable development.

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Conflict of Interest

The authors declare no conflicts of interest related to the publication of this article.

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