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Accelerating Hainan's transition to new energy vehicles to hit its target for peak CO_2 emissions by 2030

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Keywords: new energy vehicles (NEVs), peak CO_2 emissions, Hainan, on-road transportation

Background

In March 2019, Hainan province of China released a roadmap to phase out all sales of new gasoline and diesel vehicles by 2030.[1] This is hereafter referred to as "the 2019 roadmap." Starting from 2030, all new vehicles sold in Hainan will have to be either new energy vehicles (NEVs) or natural gas-powered vehicles, and these are collectively referred to as clean energy vehicles (CEVs) in the 2019 roadmap. NEVs include battery electric vehicles, plug-in hybrid electric vehicles, and fuel cell electric vehicles, while natural gas-powered vehicles include compressed natural gas vehicles and liquefied natural gas vehicles.

As shown in Table 1, Hainan classified all on-road vehicles into 11 categories and in the 2019 roadmap proposed a timeline for each category to progressively shift to either 100% NEVs or 100% CEVs. For passenger vehicles (except taxis) and buses, Hainan recognized NEVs as the only clean technology pathway and aimed to hit 100% NEVs for new sales no later than 2030. For coaches and trucks, Hainan also indicated that it favored NEV technologies, but did not propose NEV sales share targets except for sanitation trucks; this was due to the limited understanding of the feasibility of electrifying these vehicles in the near-to-mid term when the targets were being formulated. At that time, the province saw natural gas-powered vehicles as an alternative clean technology pathway for coaches and trucks and aimed to achieve 100% new CEV sales no later than 2030.

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1 Hainan Provincial People's Government, "海南省清洁能源汽车发展规划[Development Plan of Clean Energy Vehicles in Hainan Province]," March 6, 2019, https://www.hainan.gov.cn/hainan/szfwj/201903/51856f7e3b3d4fa6b4efc4a0ffdf98e8.shtml

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Table 1. Hainan's targets for new sales shares of new energy vehicles (NEVs) and clean energy vehicles (CEVs) by vehicle category and actual new sales shares in 2021

Vehicle category		Targets for new sales share						Actual new sales share in 2021	
		2021		2025		2030			
		NEV	CEV	NEV	CEV	NEV	CEV	NEV	CEV
Passenger vehicles	Private cars	40%	40%	80%	80%	100%	100%	26%	26%
	Government vehicles	100%	100%	100%	100%	100%	100%	84%	84%
	Taxis	80%	100%	80%	100%	80%	100%	96%	100%
	Ride-hailing vehicles	100%	100%	100%	100%	100%	100%	100%	100%
	Rental cars	100%	100%	100%	100%	100%	100%	100%	100%
Buses	Buses	100%	100%	100%	100%	100%	100%	100%	100%
Coaches	Tour coaches		40%		100%		100%	37%	51%
	Inter-city coaches		40%		100%		100%	18%	71%
Trucks	Sanitation trucks	50%		50%		50%	100%	36%	36%
	Light-duty trucks[a]						100%	14%	15%
	Heavy-duty trucks[b]						100%	0.2%	15%

[a] Light-duty trucks refers to trucks with a gross vehicle weight (GVWR) of up to 4,500 kg, excluding sanitation trucks.

[b] Heavy-duty trucks refers to trucks with a GVWR of at least 4,500 kg, excluding sanitation trucks.

Three years have passed since the release of the 2019 roadmap. During this period, there were two major developments that call for further accelerating the transition to NEVs in Hainan. For one, Hainan province announced in August 2022 that it would follow China's national carbon emissions reduction strategy and aim to achieve peak CO_2 emissions at the provincial level by 2030.[2] An accelerated transition to NEVs will be essential if Hainan's on-road transportation sector is to hit peak CO_2 emissions on that same timeline. Second, as NEV technologies and products have evolved, so too has our understanding of the feasibility of coach and truck electrification. New research is shedding light on the performance and cost effectiveness of NEV coach and truck models, and governments around the world are beginning to set coach and truck electrification targets based on this new progress.[3]

In this context, this paper evaluates the necessity of accelerating Hainan's transition to NEVs beyond the ambition of the 2019 roadmap and considers a feasible pathway for achieving this. We performed a detailed CO_2 emissions modeling exercise to determine the pace of vehicle electrification needed to ensure that CO_2 emissions from Hainan's on-road transportation sector peak no later than 2030. We considered the feasibility of electrifying different vehicle categories when developing policy scenarios for the modeling exercise. Based on the modeling results, we conclude with policy recommendations for Hainan's NEV transition.

2 Hainan Provincial People's Government, "海南省碳达峰行动方案[Action Plan of Hainan Province on Peaking CO_2 emissions]," August 22, 2022, https://www.hainan.gov.cn/hainan/szfwj/202208/911b7a2656f148c08e5c9079227103a7.shtml

3 Yihao Xie et al., "Heavy-Duty Zero-Emission Vehicles: Pace and Opportunities for a Rapid Global Transition," (ICCT: Washington, DC, 2022), https://theicct.org/publication/hdv-zevtc-global-may22/; Shiyue Mao and Felipe Rodríguez, "Race to Zero: How Manufacturers are Positioned for Zero-Emission Commercial Trucks and Buses in China," (ICCT: Washington, DC, 2021), https://theicct.org/publication/race-to-zero-how-manufacturers-are-positioned-for-zero-emission-commercial-trucks-and-buses-in-china/; Shiyue Mao et al., "Total Cost of Ownership for Heavy Trucks in China: Battery Electric, Fuel Cell, and Diesel Trucks," (ICCT: Washington, DC, 2021), https://theicct.org/publication/total-cost-of-ownership-for-heavy-trucks-in-china-battery-electric-fuel-cell-and-diesel-trucks/; Hongyang Cui and Dale Hall, "Annual Update on the Global Transition to Electric Vehicles: 2021," (ICCT: Washington, DC, 2022), https://theicct.org/publication/global-ev-update-2021-jun22/

Emissions modeling exercise

Methodology

We used ICCT's Roadmap model to project CO_2 emissions from Hainan's on-road transportation sector through 2035, with 2021 as the baseline year.[4] All passenger vehicles, buses, coaches, and trucks registered in Hainan were included. Following the practice of the European Union, this study defined on-road transportation sector emissions as tank-to-wheel (TTW) emissions, in other words, those emitted directly from the tailpipe.[5] Well-to-tank (WTT) emissions, which are those emitted from processes of producing, storing, and distributing fuels and of producing, maintaining, and recycling vehicles were recognized as emissions from other sectors (e.g., energy, industry) and were excluded from our scope.

The classification of passenger vehicles, buses, and coaches in this analysis was consistent with the 2019 roadmap, but trucks were re-classified into five sub-categories: sanitation trucks, light-duty trucks, yard trucks, distribution trucks, and work trucks. This new classification was developed with local fleet characteristics in mind and highlights the diversity of truck specifications, operations, and ownership. Regarding the feasibility of electrification for each class of trucks, generally trucks with (1) lower gross vehicle weight ratings (GVWRs) and those that (2) typically make shorter trips, (3) have more predictable routes, and (4) are owned or managed by the government are in a better position to transition faster to NEVs. Table 2 describes the five truck sub-categories and presents our qualitative assessment of the feasibility of electrifying different truck categories in Hainan according to the four metrics. Based on these factors, our evaluation is that sanitation trucks and yard trucks are relatively more poised for new energy truck deployment in the next few years; they are followed by light-duty trucks, distribution trucks, and work trucks.

4 International Council on Clean Transportation (ICCT), "Roadmap model version 1.8," (Washington, DC, 2022), https://theicct.github.io/roadmap-doc/versions/v1.8/

5 European Environment Agency, "Transport and Environment Report 2021, Decarbonizing Road Transport – the Role of Vehicles, Fuels, and Transport Demand," (Copenhagen, 2022), https://www.eea.europa.eu/publications/transport-and-environment-report-2021/at_download/file

Table 2. Truck categories and our assessment of the feasibility of electrifying each in Hainan

Truck category	Description of category, operations, and ownership	Factors affecting electrification				Overall feasibility of electrification
		GVWR	Trip length	Route predictability	Public ownership/ management	
Sanitation trucks	Owned by government-affiliated entities and used for garbage collection and city cleaning, with an average daily VKT[a] of around 30 km.	Low	Medium	High	High	High
Light-duty trucks	Owned by logistics companies and used for urban delivery or owned by individuals and used for individual businesses, with an average daily VKT of around 70 km.	Low	Medium	Medium	Low	Average
Yard trucks	Operate within ports, construction sites, industrial parks, and more, with an average daily VKT of around 10 km.	Medium	Short	High	Medium	High
Distribution trucks	Ship goods between major ports and distribution centers in cities, with fixed routes and an average one-way trip length of 200 km. Typical vehicle types are stake trucks and tractors paired with a container/stake trailer. Mostly privately owned.	High	Long	High	Low	Lower
Work trucks	Ship goods with unfixed and ad-hoc routes. Representative routes include transport of ores from mining sites to steel plants, with an average trip length of 100 km, and transport of steel from steel plants to construction sites, with an average one-way trip length of 180 km. Typical vehicle types are dump trucks and tractors paired with a platform/tank trailer. Mostly privately owned.	High	Long	Low	Low	Lower

[a] VKT means vehicle kilometers traveled.

We projected CO_2 emissions from Hainan's on-road vehicle fleet during 2021–2035 under two scenarios. While both scenarios reflect Hainan's actual NEV sales shares in 2021, they represent different NEV transition pathways in the following years. Under the **Baseline** scenario, passenger vehicles and buses achieve the NEV sales share targets proposed in the 2019 roadmap; meanwhile, as there were no NEV sales share targets for coaches and trucks in the 2019 roadmap, those two categories maintain the 2021 sales shares throughout the period (Table 3).

Table 3. Assumptions for the Baseline scenario

Vehicle category			Actual new sales in 2021	Actual new sales share for NEVs in 2021	Future assumptions regarding new sales share for NEVs		
					2025	2030	2035
Passenger vehicles	**Private cars**		187,267	26%	80%	100%	100%
	Government vehicles		574	84%	100%	100%	100%
	Taxis		1,754	96%	96%	96%	96%
	Ride-hailing vehicles		11,097	100%	100%	100%	100%
	Rental cars		0	100%	100%	100%	100%
Buses			476	100%	100%	100%	100%
Coaches	**Tour coaches**		392	37%	37%	37%	37%
	Inter-city coaches		113	18%	18%	18%	18%
Trucks	**Sanitation trucks**		400	36%	50%	50%	50%
	Light-duty trucks		22,006	14%	14%	14%	14%
	Heavy-duty trucks	**Yard trucks**	1,674	0%	0%	0%	0%
		Distribution trucks	2,580	3%	3%	3%	3%
		Work trucks	3,422	0.4%	0.4%	0.4%	0.4%

The **Accelerated** scenario in Table 4 reflects a faster transition to NEVs for coaches and trucks that is ambitious but feasible. This NEV transition pace was based on the most recent research on the availability and cost-effectiveness of NEV models in China; on regulations and targets for coach and truck electrification in leading markets like California; and on the qualitative assessments in Table 2.[6] A recent ICCT study estimated that the total cost of ownership (TCO) of battery-electric dump trucks, straight trucks, and tractor-trailers will be superior to their diesel counterparts in three representative Chinese cities before 2030.[7] The favorable economic outlook aside, there is already an abundance of both manufacturers and zero-emission coach and truck models available in the Chinese market.[8] (Zero-emission vehicles are battery electric and fuel cell electric vehicles.) Additionally, in California, the Advanced Clean Trucks regulation already in place requires manufacturers to sell an increasing share of zero-emission medium- and heavy-duty trucks from 2024 onward, up to 75% of all sales for rigid trucks and 40% of all tractor-trailers in 2035.[9] California's proposed Advanced Clean Fleets regulation would take further steps to mandate zero-emission-only truck purchases across publicly and privately owned fleets, and this would begin as early as 2024 for certain priority fleets.[10]

Table 4. Assumptions for the Accelerated scenario

Vehicle category			Actual new sales in 2021	Actual new sales share for NEVs in 2021	Assumptions for new sales share of NEVs		
					2025	2030	2035
Passenger vehicles	Private cars		187,267	26%	80%	100%	100%
	Government vehicles		574	84%	100%	100%	100%
	Taxis		1,754	96%	100%	100%	100%
	Ride-hailing vehicles		11,097	100%	100%	100%	100%
	Rental cars		0	100%	100%	100%	100%
Buses			476	100%	100%	100%	100%
Coaches	Tour coaches		392	37%	70%	100%	100%
	Inter-city coaches		113	18%	50%	100%	100%
Trucks	Sanitation trucks		400	36%	100%	100%	100%
	Light-duty trucks		22,006	14%	50%	100%	100%
	Heavy-duty trucks	Yard trucks	1,674	0%	100%	100%	100%
		Distribution trucks	2,580	3%	20%	40%	60%
		Work trucks	3,422	0.4%	15%	30%	45%

A review of Hainan's recent NEV market trends showed a marginal share for plug-in hybrid technology. In 2021, only the private car segment registered new sales of plug-in hybrid electric vehicles, and those accounted for 7% of new NEV sales in that segment. In this modeling exercise, we assumed the plug-in hybrid share of new NEV private car sales gradually decreases from 7% in 2021 to 5% in 2025, and then to 0% in 2030. For all the other vehicle categories, a 0% plug-in hybrid sales share was assumed throughout the analysis period. As both battery electric and fuel cell electric vehicles

6 Hongyang Cui and Dale Hall, "Annual Update on the Global Transition to Electric Vehicles: 2021," (ICCT: Washington, DC, 2022), https://theicct.org/publication/global-ev-update-2021-jun22/

7 Shiyue Mao et al., "Total Cost of Ownership for Heavy Trucks in China: Battery Electric, Fuel Cell, and Diesel Trucks," (ICCT: Washington, DC, 2021), https://theicct.org/publication/total-cost-of-ownership-for-heavy-trucks-in-china-battery-electric-fuel-cell-and-diesel-trucks/

8 More detail will be provided in a forthcoming ICCT publication, Shiyue Mao et al., "Race to Zero: How Manufacturers are Positioned for Zero-Emission Commercial Trucks and Buses in China, A 2021 Update."

9 Claire Buysse and Ben Sharpe, "California's Advanced Clean Trucks Regulation: Sales Requirements for Zero-Emission Heavy-Duty Trucks," (ICCT: Washington, DC, 2020), https://theicct.org/publication/californias-advanced-clean-trucks-regulation-sales-requirements-for-zero-emission-heavy-duty-trucks/

10 California Air Resources Board, "Proposed Advanced Clean Fleets (ACF) Regulation Workshop," May 2, 2022, https://ww2.arb.ca.gov/sites/default/files/2022-04/220502acfpres_ADA.pdf

are zero emissions at the tailpipe, assumptions on the sales mix between them have no impact on the TTW CO_2 emissions modeling results. Based on a recent ICCT report, the TCO of fuel cell electric trucks is many times higher than their battery electric counterparts.[11] Considering that there are few long-haul transportation needs in the island province of Hainan, it is estimated that the market share of fuel cell electric vehicles will be very limited.

The vehicle sales and stock in Hainan from 2022 to 2035 were projected using ICCT's Roadmap model. Key inputs for the projection include Hainan's actual vehicle sales and stock data for the baseline year (2021), vehicle survival curves by vehicle category, and key socioeconomic indicators influencing vehicle sales growth such as population, vehicle stock per capita, and gross domestic product growth rate. Assumptions on annual vehicle kilometers traveled (VKT) and energy efficiency by vehicle category were made by combining the best available data from interviews with local fleets, vehicle fuel efficiency simulation, and various public sources.

Modeling results

Although Hainan's vehicle stock is still relatively small, it is likely to increase significantly in the coming decade. By the end of 2021, there were 1.7 million vehicles registered in Hainan and it ranked third from last among all Chinese provinces. As shown in Figure 1, passenger vehicles were the majority of Hainan's vehicle stock with a share of 87%; they were followed by light-duty trucks (10%) and heavy-duty trucks (2%). Hainan's passenger and freight transport demand is expected to increase rapidly and continuously in the coming decade as the province undergoes development to become China's new icon for economic openness and the world's largest free trade port.[12] Based on our modeling results, the growth in economic activity will lead to a doubling of Hainan's vehicle stock by 2030 compared with 2021. Given this, a quick and substantial reduction of fleet-average emissions, measured in grams of CO_2 per kilometer, will be needed for Hainan's on-road transportation sector to hit peak CO_2 emissions on schedule, and achieving this hinges on an accelerated transition to NEVs.

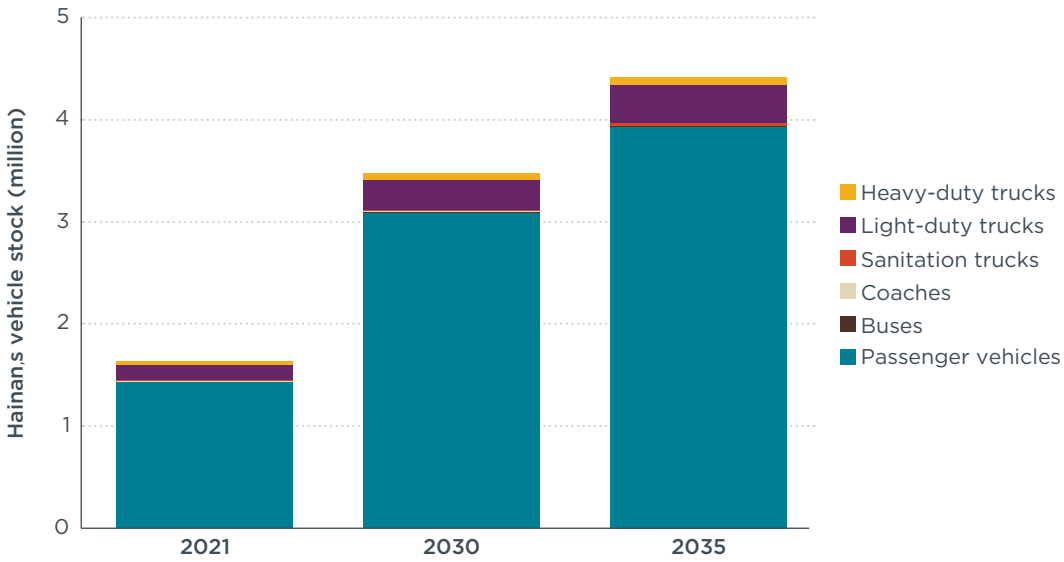

Figure 1. Vehicle stock in Hainan by vehicle category in 2021 and projections for 2030 and 2035.

11 Shiyue Mao et al., "Total Cost of Ownership for Heavy Trucks in China: Battery Electric, Fuel Cell, and Diesel Trucks," (ICCT: Washington, DC, 2021), https://theicct.org/publication/total-cost-of-ownership-for-heavy-trucks-in-china-battery-electric-fuel-cell-and-diesel-trucks/

12 Central Committee of the Communist Party of China and China State Council, "关于支持海南全面深化改革开放的指导意见[Guidance on Supporting Hainan on the Comprehensive Deepening of Reform and Opening-Up]," April 11, 2018, http://www.gov.cn/zhengce/2018-04/14/content_5282456.htm; Central Committee of the Communist Party of China and China State Council, "海南自由贸易港建设总体方案[Master Plan for the Development of Hainan Free Trade Port]," June 1, 2020, http://www.gov.cn/zhengce/2020-06/01/content_5516608.htm

The accelerated transition is particularly important for trucks, which are responsible for a disproportionate share of CO_2 emissions in today's fleet in Hainan and will play a crucial role in peaking the province's on-road transportation CO_2 emissions. Although trucks represented just 12% of Hainan's vehicle stock in 2021, they were 51% of CO_2 emissions from Hainan's on-road transportation sector that year. This was mainly due to their higher emission factors, measured in grams of CO_2 per kilometer, and larger annual VKTs, measured in kilometers per year. Based on the targets set in the 2019 roadmap, Hainan's passenger vehicle and bus fleets will embrace a rapid transition to NEVs and their CO_2 emissions will taper off as NEVs are adopted. However, under the Baseline scenario, the emissions reductions from passenger vehicles and buses would be undermined by a substantial increase in truck emissions and Hainan would fail to peak its on-road transportation CO_2 emissions by 2030 (left side of Figure 2).

Note, too, that the CO_2 emissions reduction potential of natural gas-powered vehicles is limited and insufficient to help Hainan achieve peak CO_2 emissions on schedule.[13] This is mainly due to the much lower thermal efficiencies of natural gas engines compared to their diesel counterparts. Though natural gas has a lower carbon intensity than diesel fuel, this advantage is largely offset by diesel vehicles' strength in efficiency. Additionally, the production and transport of natural gas frequently comes with methane leakage. Given the strong short-term climate impact of methane, natual gas is inferior to diesel when we consider the life-cycle greenhouse gas emissions based on 20-year global warming potential.[14] Continuing to favor natural gas-powered vehicles could lock Hainan into a regulatory and infrastructure pathway that is not compatible with its carbon emissions reduction goals. Only NEVs are worth investing in for all categories of vehicles in Hainan, including coaches and trucks.

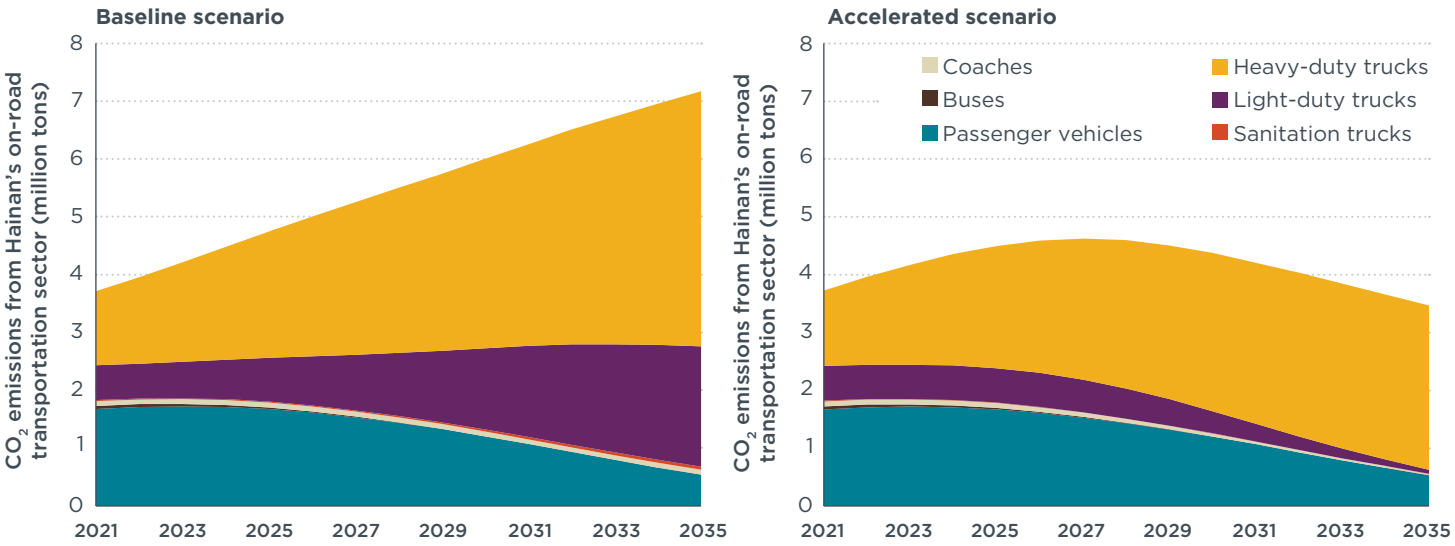

Figure 2. Projected CO_2 emissions from Hainan's on-road vehicles from 2021 to 2035 under the Baseline scenario (left) and the Accelerated scenario (right).

An accelerated transition to NEVs, especially for trucks, is the key for Hainan's on-road transportation sector to achieve peak CO_2 emissions by 2030. As shown in the right side of Figure 2, the Accelerated scenario results in an early peaking of CO_2 emissions in 2027. The different emissions trajectories between the Baseline and Accelerated scenarios can be explained by a faster transition of light- and heavy-duty trucks to

13 Pierre-Louis Ragon and Felipe Rodríguez, "CO_2 Emissions From Trucks in the EU: An Analysis of the Heavy-Duty CO_2 Standards Baseline Data," (ICCT: Washington, DC, 2021), https://theicct.org/publication/co2-emissions-from-trucks-in-the-eu-an-analysis-of-the-heavy-duty-co2-standards-baseline-data/

14 Felipe Rodríguez, "LNG Trucks: A Bridge to Nowhere," (blog), International Council on Clean Transportation, May 12, 2020, https://theicct.org/blog/staff/lng-trucks-bridge-nowhere.

NEVs in the latter's assumptions, described previously in Table 4. Compared with the Baseline scenario, the Accelerated scenario will cut CO_2 emissions from Hainan's on-road transportation sector by 30% in 2030 and 53% in 2035 (Figure 3). Considering that the other transportation modes, such as marine and aviation, are much more difficult to decarbonize than on-road transportation, an early peaking of on-road transportation emissions will be essential for the transportation sector of Hainan province as a whole to achieve peak CO_2 emissions no later than 2030.

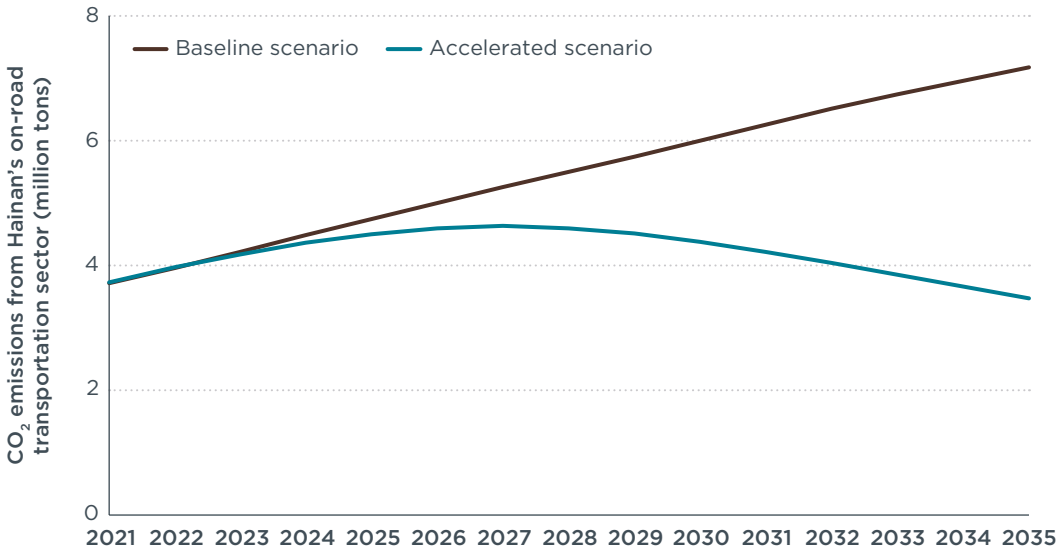

Figure 3. CO_2 emissions from Hainan's on-road transportation sector during 2021–2035 under the Baseline and Accelerated scenarios.

Findings and policy recommendations

The emissions modeling above shows that Hainan's NEV transition pace, as set by the 2019 roadmap, is insufficient to ensure the province's on-road transportation sector hits a CO_2 emissions peak by 2030. The slow transition of trucks, which make outsized contributions to CO_2 emissions, would prevent hitting the CO_2 emissions peak on schedule. Alternatively, an accelerated NEV transition, especially for light- and heavy-duty trucks, would result in an early peaking of Hainan's on-road transportation CO_2 emissions in 2027. Based on these findings, we make the following policy recommendations to Hainan:

Officially propose NEV sales share targets for coaches and trucks by application scenario. Sanitation trucks and yard trucks are well positioned to achieve 100% NEV sales by 2025, and for light-duty trucks, tour coaches, and inter-city coaches, it is feasible to achieve this by 2030. Distribution trucks, and work trucks might need more time to make the transition, and are expected to reach NEV sales share targets of 40% and 30%, respectively, by 2030.

Make NEVs the only preferred technology pathway and stop providing policy advantages to natural gas-powered vehicles. Considering the limited CO_2 emissions reduction potential and methane leakage of natural gas, continuing to favor natural gas-powered vehicles risks putting Hainan on a pathway that is not compatible with the province's carbon emissions reduction goals. Only NEVs are worth investing in for all categories of vehicles in Hainan.

Leverage the resources of multiple government agencies in Hainan, including the Department of Industry and Information Technology, Department of Ecology and Environment, Department of Transportation, Development and Reform Commission, and

more, to explore the most effective policy packages to turn the province's ambitious NEV transition targets, especially for trucks, into reality. There are several policy instruments that have the potential to make this happen:[15]

» Sales requirements that mandate manufacturers to sell an increasing share of NEVs in Hainan.

» Zero-emission zones and/or zero-emission corridors that give unrestricted access only to zero-emission vehicles, to encourage early scrappage of legacy conventional fuel-powered vehicles and stimulate the deployment of NEVs.

» Smartly designed purchase and in-use incentives to close the cost gaps between NEVs and their conventional fuel-powered counterparts.

» Purchase requirements that apply to specific fleets and mandate that a certain percentage of vehicle procurements be NEVs.

» Charging infrastructure action plans that fill the charging gap for an accelerated NEV transition in partnership with industry.

15 Dale Hall et al., "Decarbonizing Road Transport by 2050: Effective Policies to Accelerate the Transition to Zero-Emission Vehicles," (ICCT: Washington, D.C., 2021), https://theicct.org/publication/zevtc-effective-policies-dec2021/