Leaping to Cleaner Air with Refueling Emissions Control

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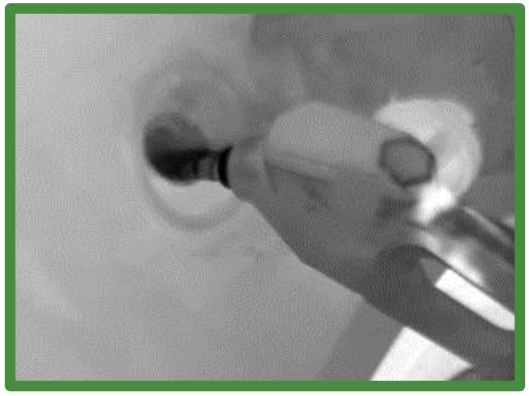
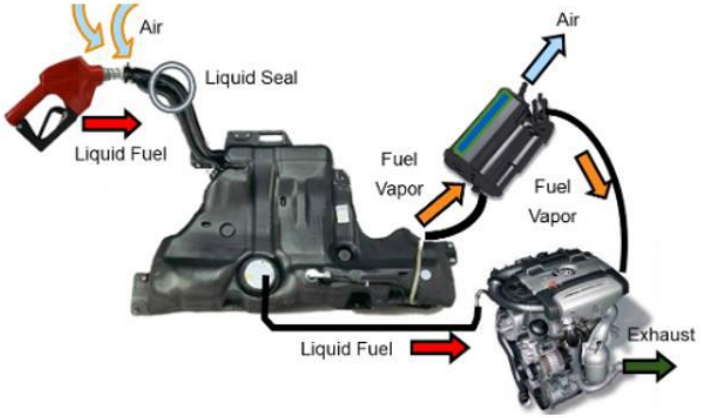
What are Refueling Emissions?

Refueling emissions are non-methane volatile organic compounds (NMVOCs) emitted during the refueling of conventional, hybrid, and plug-in hybrid electric vehicles with petrol.

Refueling with No Control
1.4 g/L

Refueling with Onboard Refueling Vapor Recovery (ORVR)
0.03 g/L (98% control)





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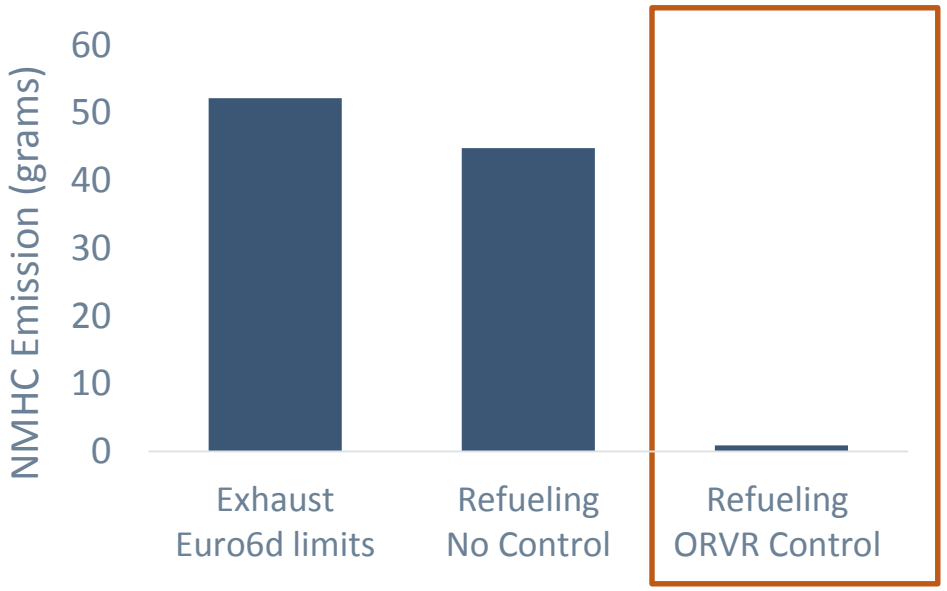
How do Refueling Emissions Compare with Exhaust?

The amount of refueling emission from a single refueling event is comparable to the exhaust emissions over the full range of driving between refills of the fuel tank.



98% of the refueling emissions can be controlled!

Example:
A BS VI light-duty vehicle with a fuel tank of 32 Liters and a fuel economy of 24 kilometers per Liter.

- This vehicle can travel 768 kilometers on a full tank of petrol.
- This vehicle could emit a maximum of 52.2 grams of exhaust NMHC over 768 km of driving (using the Euro 6 NMHC emission limit of 68 milligrams per kilometer).
- This vehicle would emit 44.8 grams during the refueling event (using an uncontrolled refueling emissions rate of 1.4 grams per Liter of fuel dispensed)
- 98% of refueling emissions could be controlled if the vehicle has ORVR

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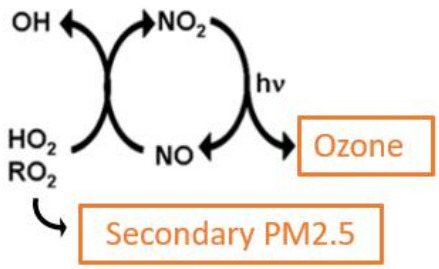
How do Refueling Emissions Impact Air Quality?

Refueling emissions contain Volatile Organic Compounds (VOCs), which are important contributors to smog and haze (Ozone and $PM_{2.5}$) and contain toxic compounds (benzene)



1. Vehicle Emissions

NO (Exhaust)
+
VOC (Exhaust, Refueling, Evaporative)
+
Primary PM
(Exhaust, tires, brakes)

2. Atmospheric Chemistry

VOCs react in sunlight with NOx

Ozone and $PM_{2.5}$ are formed

Detailed analysis from U.S. shows potential formation of 3 grams of ozone for each gram of VOC

3. Air Quality Exceedances

Air Stagnation
Heat Waves
Increased Emissions
Lack of Precipitation
Health Exposure

Refueling emissions are about 1% benzene by mass
Benzene is a known carcinogen

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How are Refueling Emissions Regulated?

A vehicle refueling emission standard was first implemented in the United States starting with the 1998 model year, China implemented starting in 2018 and Brazil in 2023.

Emission Standard	India BS 6	Europe Euro 6d	USA Tier 3	Brazil PL 7	China 6b
On-board Refueling	None (Stage II)	None (Stage II)	0.05 g/L	0.05 g/L	0.05 g/L
Evaporative (hot soak + diurnal)	1-day 2.0 g	2-day 2.0 g	3-day 0.300 g	2-day 0.50 g	2-day 0.70 g

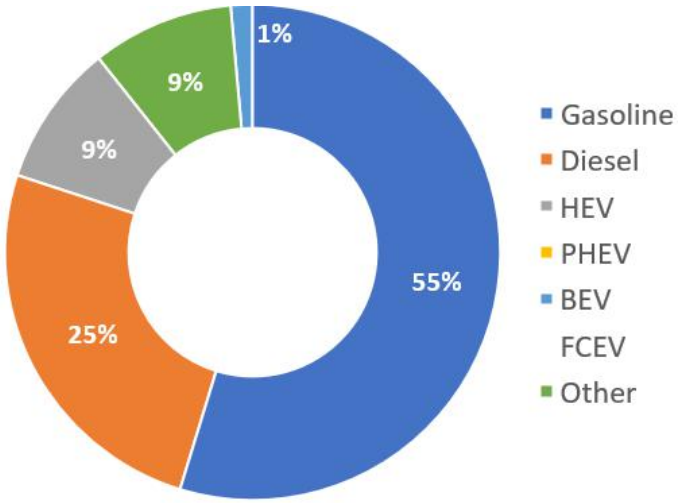
The on-board refueling emission standard and test procedures are consistent across regions

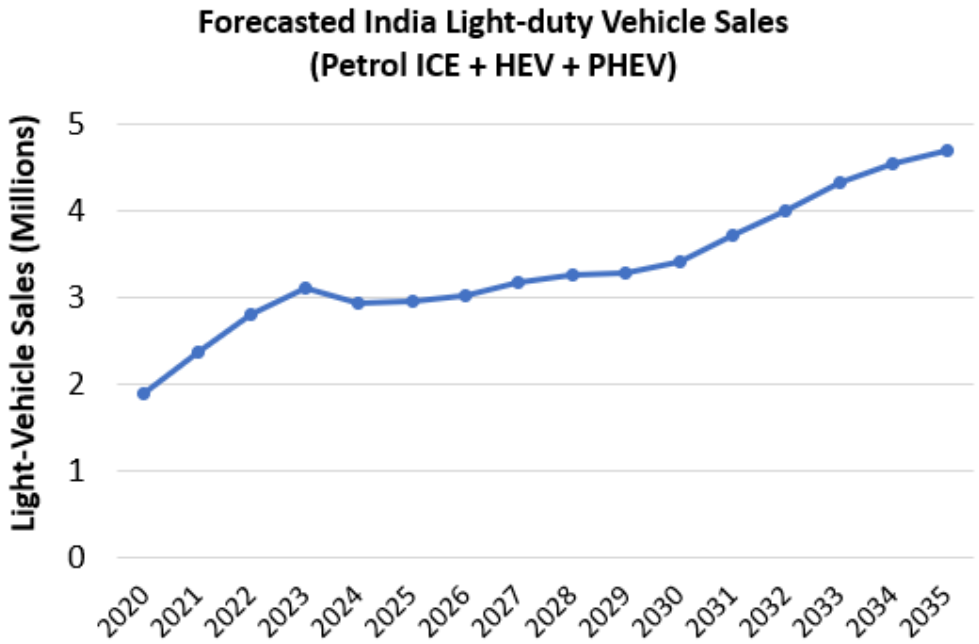
Regulatory updates in progress:

- India;
  - Draft AIS-175 (October 2022) proposes to adopt the evaporative emission limits and test procedures of Euro 6d. *This standard does not propose to adopt a refueling limit.*
- Europe;
  - In 2022, the European Commission proposed Euro 7, including a 0.05 g/L refueling emission limit and a 2-day 0.5 g evaporative emission limit. *Euro 7 is still under review by Parliament and Council.*
- China;
  - U.S. Tier 3 evaporative limits are being evaluated for China 7.

Why is Refueling Emission Control Important For India?

Petrol-engine vehicles are the largest fraction of light-duty vehicle sales in India. India currently has no on-board refueling emissions control. Additionally, India is aiming to promote E20 petrol and flex-fuel vehicles.





Source: S&P Global; Mobility and Energy Future Inflections Scenario, August 2023

- In 2022, **64%** of new passenger car sales in India have petrol engines (ICE + HEV)
- **40 M** petrol-engine vehicles are projected to be sold in India from 2025 to 2035
- By 2035, petrol sales are projected to double, meaning greater refueling-related VOC and benzene emission inventories.

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How are Refueling Emissions Being Controlled Today?

The India Central Pollution Control Board is responsible for requiring petrol stations in cities with 1M+ population and turnover larger than 300 KL/month install Stage I and II vapor recovery systems with a minimum 80% recovery efficiency.

Challenges with Stage II:

- Stage II vapor recovery is not effective without full Stage I vapor recovery.
- The implementation of Stage I and II requires comprehensive administrative and enforcement programs, including new expertise in system installation, performance testing, system operation, and government oversight of performance at installation and in use.
- Stage II requires lead time to establish these new programs and to allow for phase-in of hardware installations.
- While certification efficiency may be required to be 80%, the in-use efficiency of Stage II can be much less. Systems can be faulty due to mis-installation, lack of maintenance, and misuse.
    - Experience in U.S. with Stage II suggests the in-use efficiency is at best 71% with strong certification and enforcement[1,2]
    - In the Euro 7 impact assessment, the European Commission determined in-use efficiency of Stage II is uncertain and could be as low as 55%. Early U.S. values were as low as 56%.
- The long-term durability of Stage II components with higher ethanol fuels is unknown.
- Special attention is needed on underground storage tank vent stack emissions
    - The European Commission chose to not regulate vent stack emissions from Stage II systems, but acknowledged if they are included, they would reduce the Stage II efficiency[4].

1 https://ww3.arb.ca.gov/vapor/gdf-emisfactor/gdfumbrella.pdf
2 https://www.meca.org/wp-content/uploads/resources/Refueling_Vapor_Recovery_WhitePaper_Final.pdf
3 SAE, 2017 - https://saemobilus.sae.org/content/2017-01-5008/
4 https://publications.europa.eu/en/publication-detail/-/publication/2fce37c3-d154-11e5-a4b5-01aa75ed71a1, pages 78-79.

How can Refueling Emissions Control be Improved?

On-board Refueling Vapor Recovery (ORVR) systems have been developed and there is over 25 years of successful implementation in global markets. ORVR technology is cost-effective and controls 98% of refueling emissions.

Bharat VI vehicles contain a 1-function canister. ORVR is a 2-function canister that also will capture the petrol NMVOC vapors from refueling.

Petrol vapors are stored in the canister until the vehicle operates, they are then used by the engine during combustion.

ORVR captures 98% of petrol vapors from refueling[1], preventing them from going to the atmosphere. *No ORVR maintenance is needed for life of vehicle.*

830 – 1,660 INR per vehicle cost for ORVR[2]. This cost is recovered by the consumer in fuel savings – refueling vapors are captured and re-used as fuel.

activated carbon canister (ORVR)

[1]SAE, 2017 - https://saemobilus.sae.org/content/2017-01-5008/
[2]€10-20, MECA, 2020 - http://www.meca.org/resources/Refueling_Vapor_Recovery_WhitePaper_Final.pdf

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On-board Refueling Vapor Recovery (ORVR) has Superior Control Efficiency and Cost-Effectiveness Compared to Stage II

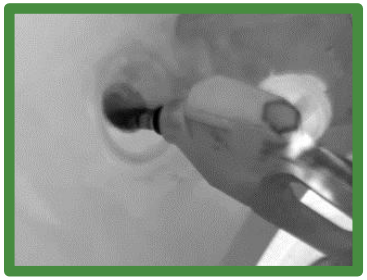
	STAGE 2	ORVR
Certification efficiency	80%	98%
Average typical real-world efficiency	50-60%	97-98%
Maintenance required	replace every 8-10 years	none
Control device location	Fuel pump	Vehicle
Captured emissions	Sent to underground storage tank which must be controlled	Recirculated to engine to be combusted as fuel
Costs	€1,200 - 1,600 per dispenser annually*	€10 - 20 / vehicle for lifetime**

*Based on European Commission Impact Analysis and Evaulation for Stage II useful life of 8-10 years
**MECA estimate based on incremental component costs relative to Euro6d canister

Stage II

Vent Stack Emissions

ORVR

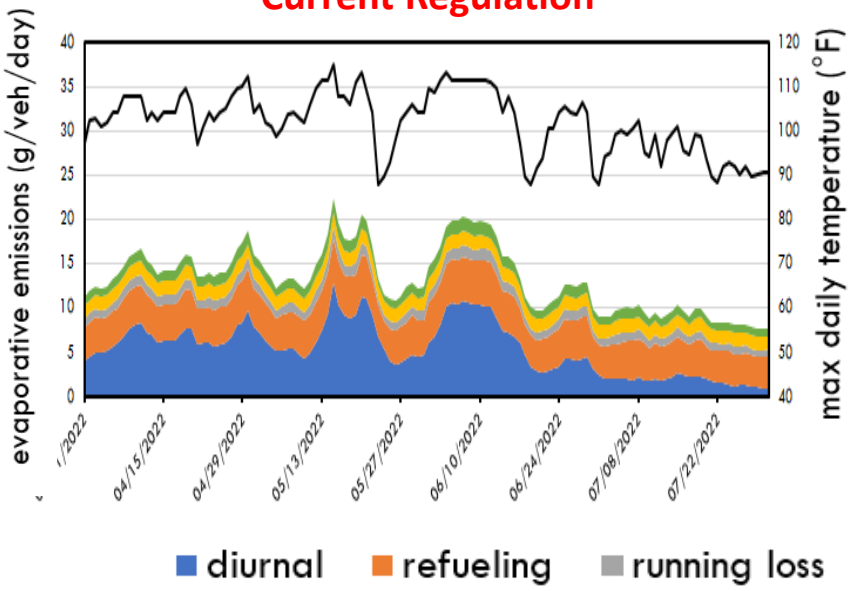


- The U.S. Congress and U.S. EPA determined ORVR has superior efficiency and mandated ORVR in the US Clean Air Act. The U.S. EPA withdrew Stage II when ORVR reached widespread use.
- The European Commission proposed ORVR in Euro 7, finding ORVR would be complementary to Europe's existing Stage II.

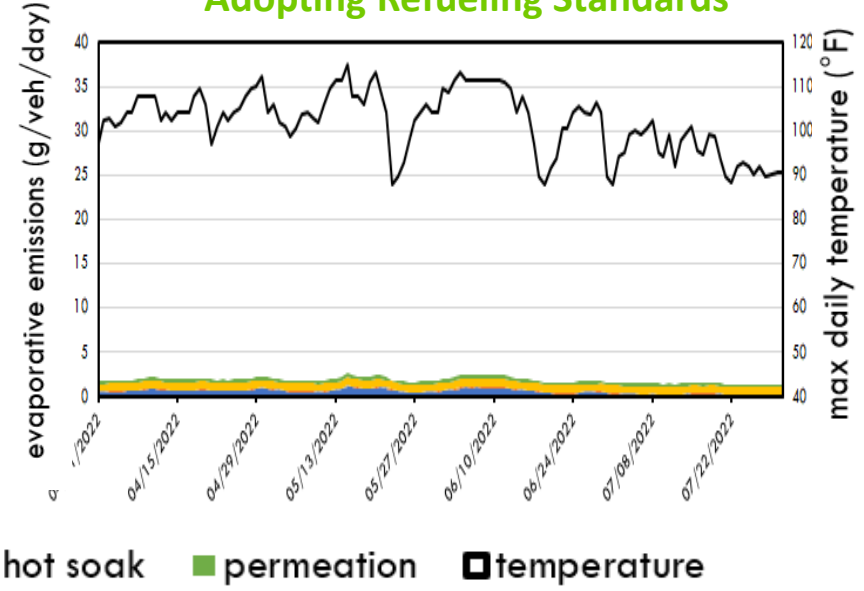
Why is Refueling Emission Control Important For India?

Daily Evaporative Emissions (grams per vehicle per day)

Current Regulation



Adopting Refueling Standards



diurnal | refueling | running loss | hot soak | permeation | temperature

- For evaporative emissions, Bharat VI is equivalent to **Euro 5** – petrol vehicles have **no refueling control and certify to a 1-day diurnal limit of 2 g/test**.
- During heatwaves, up to **20 grams per vehicle per day** of evaporative emissions is emitted.
- This is an estimated **113 tons/day of evaporative emissions** for all Delhi petrol vehicles.

- Adopting refueling standards would **reduce the daily evaporative emission rate by 80%** compared to current levels.
- During heatwaves, **< 2.5 grams per vehicle per day** of evaporative emissions would be emitted.

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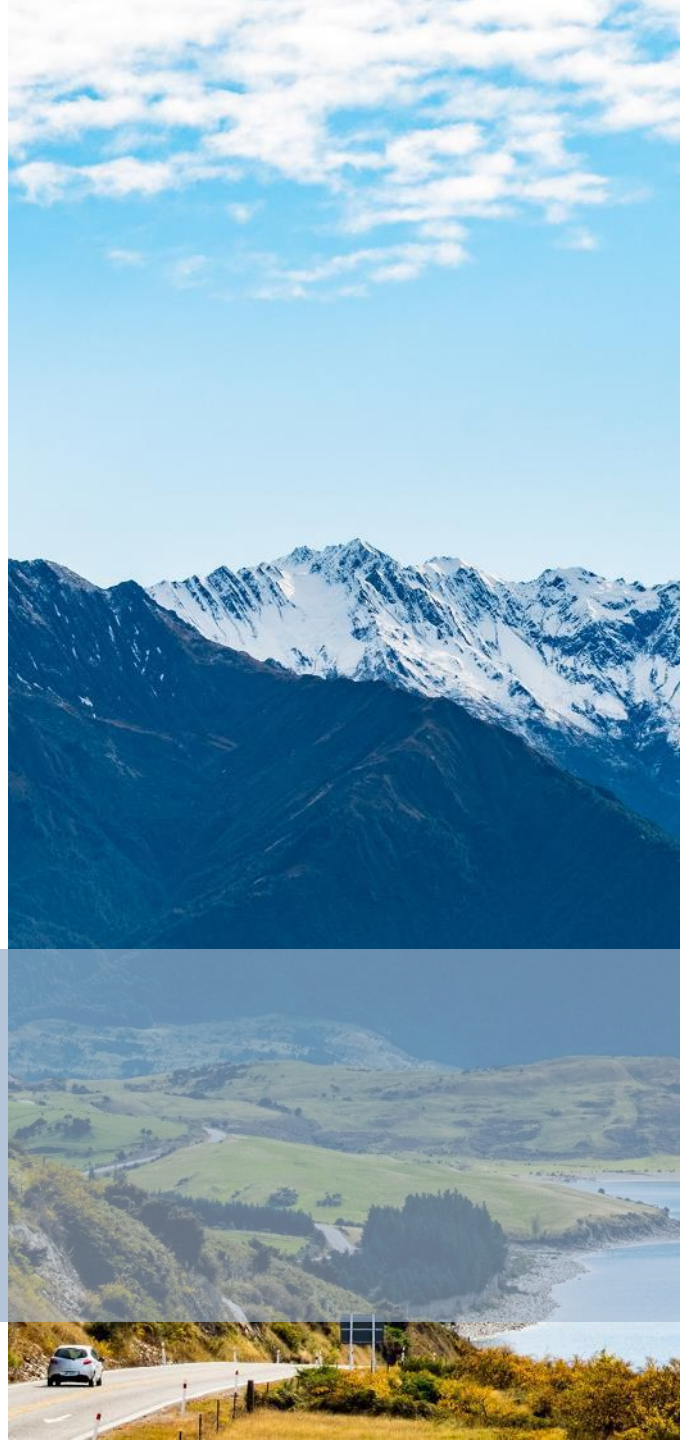
Conclusion: On-board refueling emissions control is needed and is feasible to implement quickly in India

- In India, refueling emissions are as significant as exhaust emissions and contribute to poor air quality, smog and haze. These emissions also contain toxic compounds (benzene).
- Refueling emissions can be controlled 98% with ORVR, which is cost-effective and provides fuel savings. ORVR also provides increased control of vehicle diurnal and running loss emissions.
- ORVR is a mature technology implemented in global markets, including the U.S., Canada, Brazil and China. ORVR works with ethanol fuels and flex-fuel vehicles. No new technology development is necessary.
- ORVR test procedures exist and are consistent across all regions – no new test procedure development is necessary. Draft procedures were developed for Euro 7 that could be used. There is minimal need for additional government resources.
- If India adopted ORVR, daily vehicle evaporative emission rates could be reduced by 80%, including during heatwaves when evaporative emissions are highest.
- Reliance on Stage II vapor recovery is not the best long-term decision. It is less efficient and requires a resource intensive and costly long-term commitment to maintain and enforce.



Contact

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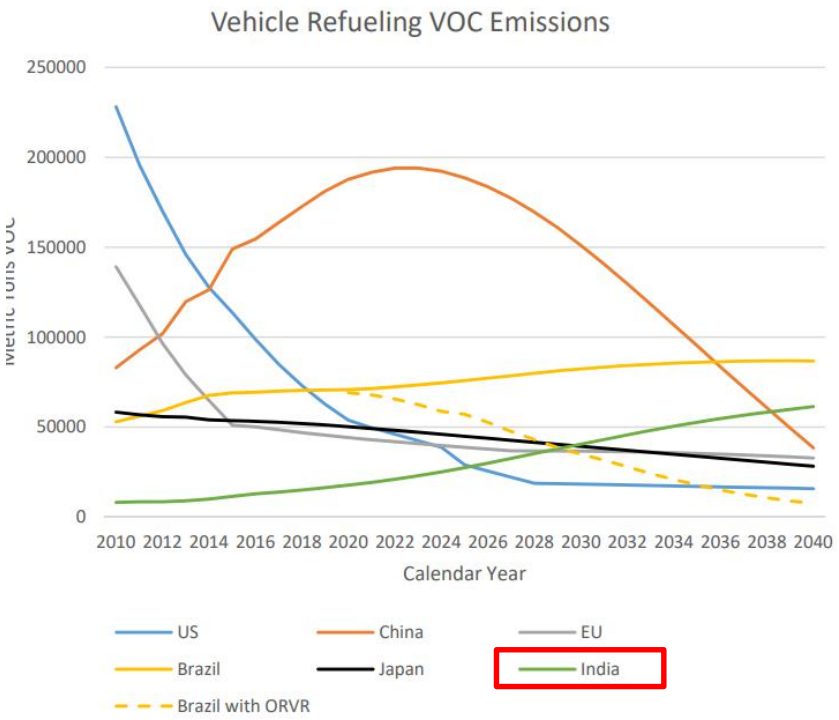
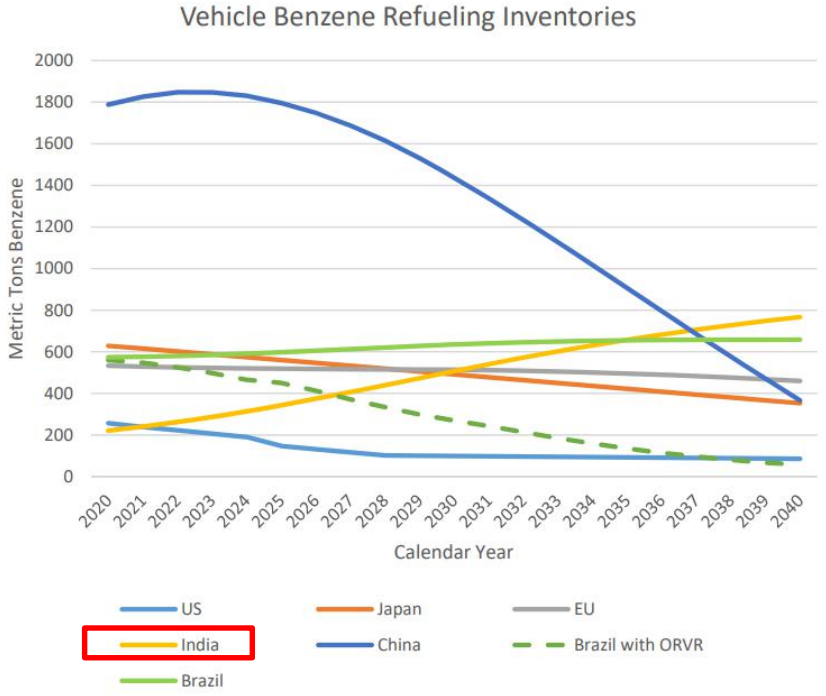
THANK YOU

Refueling Emission Inventory Trends





Source: www.epa.gov/sites/default/files/2017-11/documents/vehicle_refueling_emissions.pdf

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Global Evaporative Standards		India	Europe	China	Brazil	United States & California
Latest Standard		**Bharat III-VI**	**Euro 6d-TEMP-EVAP-ISC**	**China 6a/6b**	**PROCONVE L7**	**Tier 3/LEV III**
Implementation Dates		2020	2019	2019-2020/2023	2022-2025	2017-2022
Diurnal + Hot Soak	24-hr SHED	2.0 g/test	-	-	-	-
	48-hr SHED	-	2.0 g/test	0.70 g/day	0.50 g/day	0.300 g/day
	48-hr Zero Evap	-	-	-	-	0.020 g/test
	72-hr SHED	-	-	-	-	0.300 g/day
Refueling	Stage II Recovery (controls on gasoline pump)	Future Limited (Delhi)	Phased-in	Phased-out	-	U.S. Phased-out; California Only (EVR)
	ORVR (controls on vehicle)	No	No	0.05 g/L	0.05 g/L	0.20 g/gal (0.05 g/L)
Running Loss		No	No	38°C drive cycle	No	0.05 g/mile
Sealed Tank Requirement		No	Puff Loss Test (0.5 g limit)	Design based requirement	Design based requirement	Design based requirement
In-Use Standard (In-Use Verification Program, In-Use Compliance Program)		In Service Conformity; 5 yrs, 100,000 km	In Service Conformity; 5 yrs, 100,000 km; Type 4 EVAP test is optional	In-use Surveillance ; Low, Medium and High Mileage	Full Useful Life Standard	In-use Verification, Low and High Mileage
Useful Life /Durability Requirement		160,000 km	160,000 km	160,000 km / 200,000 km	160,000 km	150,000 miles (242,000 km)
Certification Fuel Specifications		E10, 56-60 KPa	E10, 56-60 kPa	E0, 56-60 kPa	E22, 60-63 kPa; E100	E10, 62 kPa (US) 48 kPa (CA)
OBD Leak Monitoring		EOBD	EOBD	OBDII (Leak)	OBD BR3	OBDII (Leak) + Leak Standard
Drive Cycle		MIDC	NEDC/WLTP	WLTP	FTP	FTP