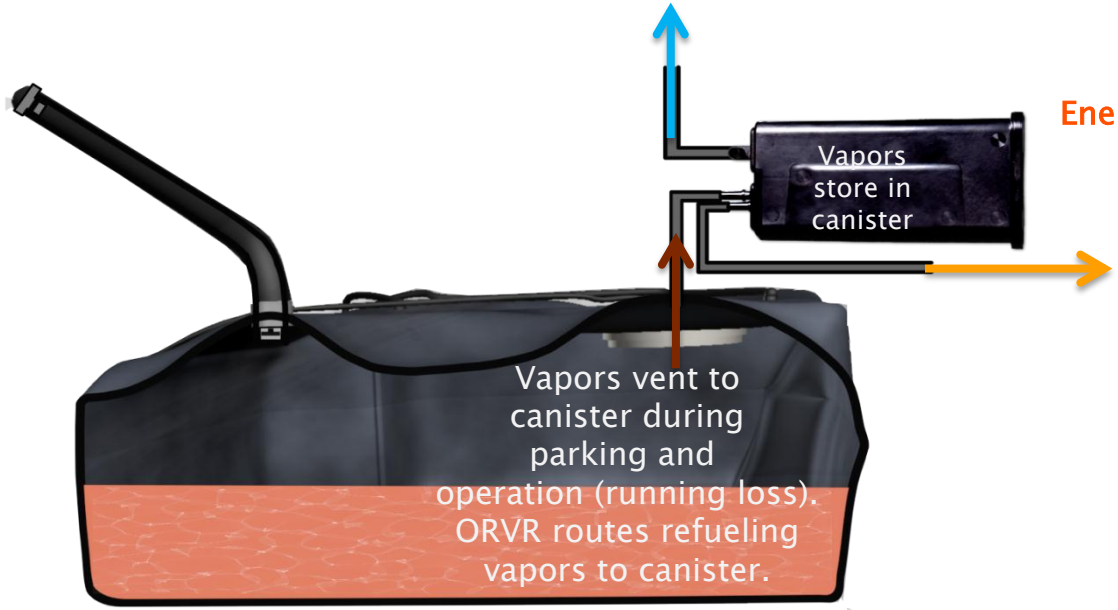
India's hot climate requires greater attention to evaporative emissions

Dr. Michael Tschantz

Canister capacity and purge rate are key to minimizing in-use evaporative emissions

– Control technology package results from emissions standard

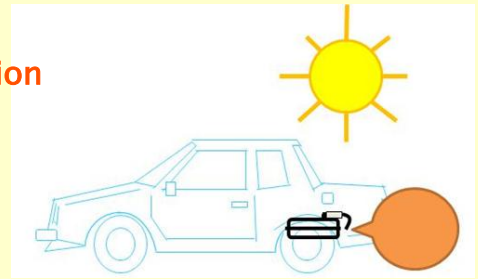
Emissions Control
Purified air vents to the environment until capacity is exceeded



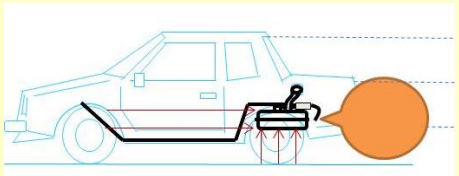
Energy Conservation
Stored vapors sent to engine when driving

MAJOR CLASSES OF EVAPORATIVE EMISSIONS

Refueling



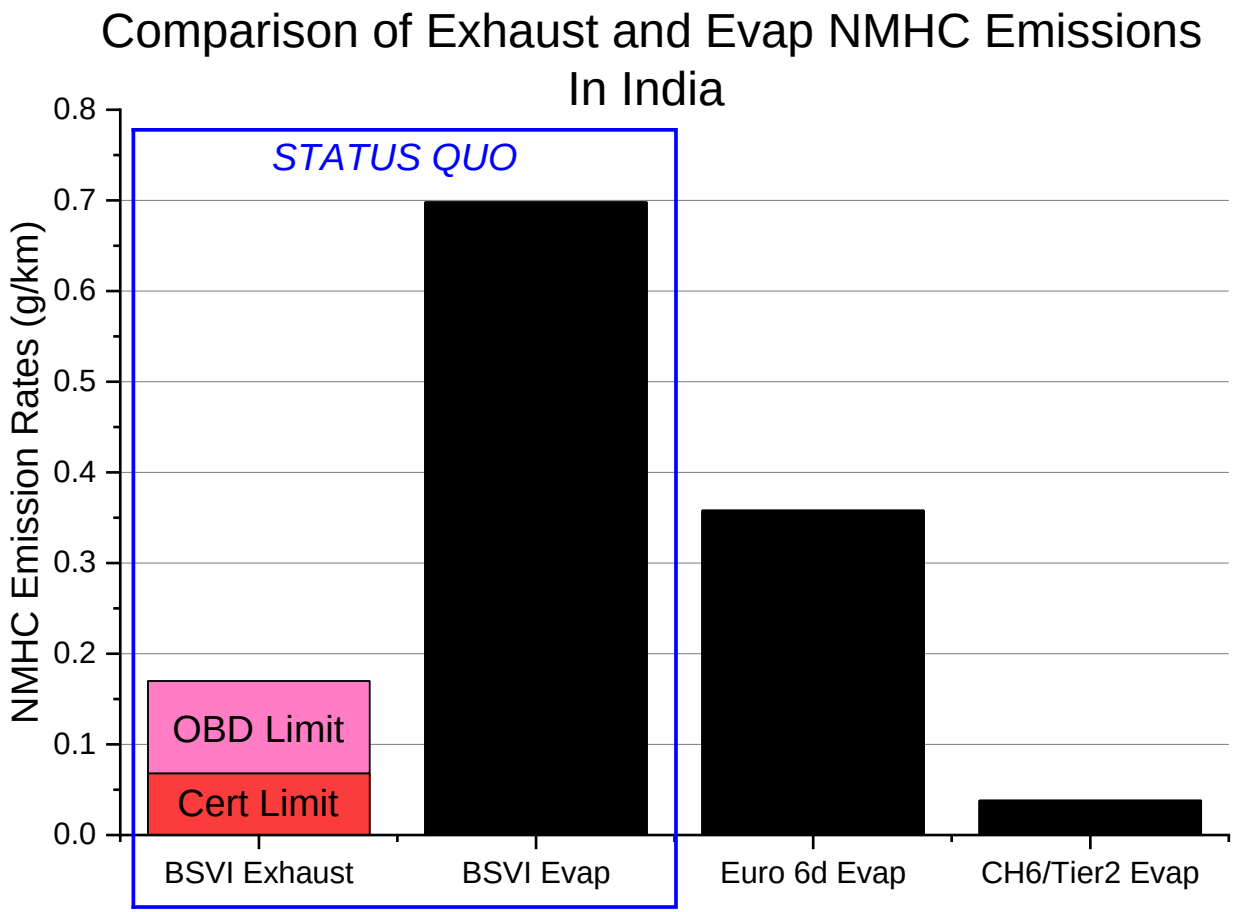
Diurnal Parking



Running Loss

ingevity

Evaporative emissions are 4-10 times higher than exhaust NMHC emissions with Bharat VI

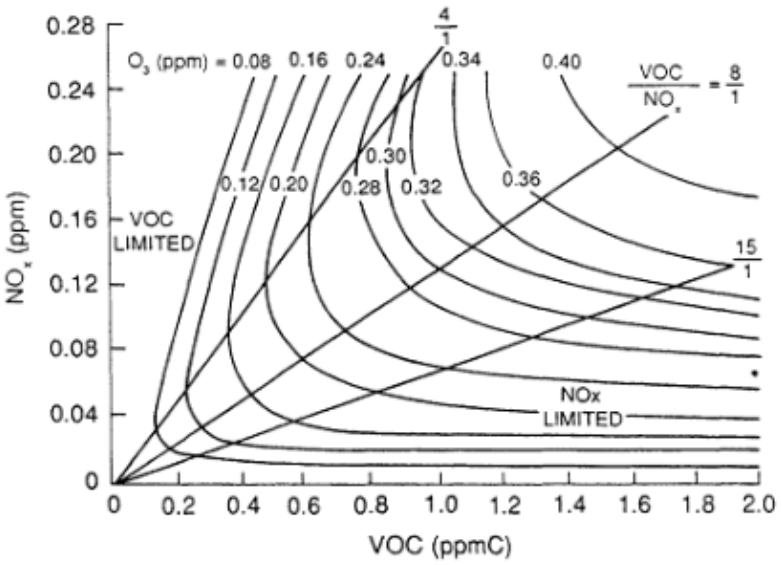


ingevity

Ozone from VOCs

- Ozone production potential is dependent on the amount of vapor emitted and the concentration and reactivity of each vapor component

- The VOC/NOx ratio is important for ozone formation chemistry



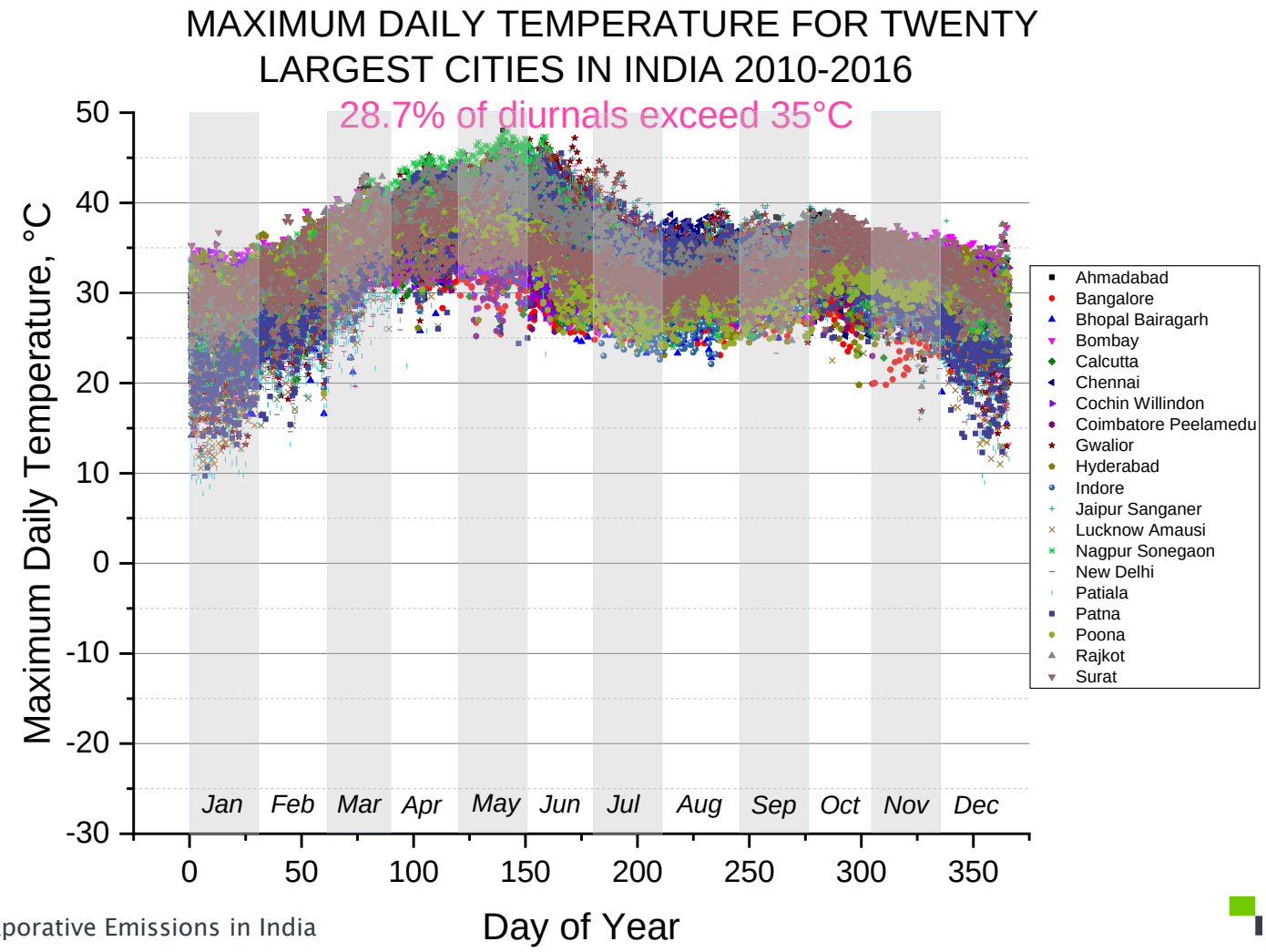
- High VOC/NOx ratio (NOx-limited):
  - Ozone reduced by controlling NOx

- Low VOC/NOx ratio (VOC-limited):
  - Ozone reduced by controlling VOC or NOx+VOC
  - Controlling only NOx could increase ozone

ingevity

In April and May 2017, 64% of the days in Delhi were above the "safe standard" for ozone (The Times of India, June 4, 2017)

–European evaporative standards were written for moderately cool European conditions … not for India's hot environment



ingevity

Secondary organic aerosol (SOA) from VOCs

Volatile Organic Compound

Evaporation,
Combustion,
Biogenic Emissions

\+

Oxidant

- •OH
- •NO_3
- O_3

Yields

Secondary Organic Aerosol

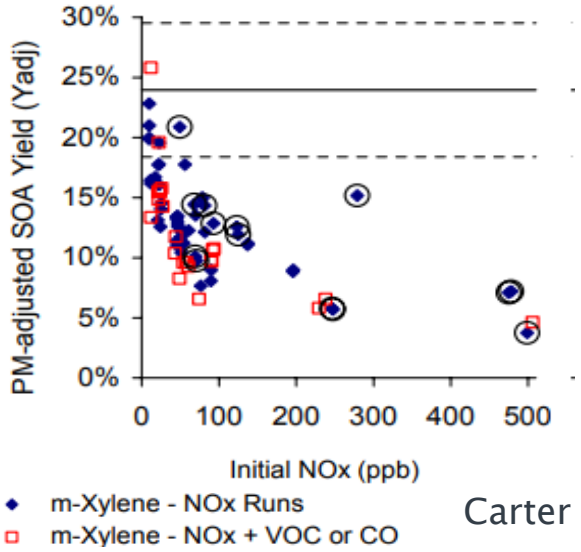
Condensation

New Particle Formation

SOA is a significant fraction of total particulate matter (PM) mass

Secondary organic aerosol (SOA) from VOCs

- SOA production depends upon emission concentrations and atmospheric chemistry (reactivity and SOA yield) of each vapor component.
- Aromatic hydrocarbons are an important class of SOA precursors due to their abundance in urban environments and high SOA yields under certain conditions
  - SOA yields in the literature range from < 5% to >38%



Carter et al., 2012

- The large variability in SOA yields result from a non-linear sensitivity to NOx
  - SOA yields can increase as NOx is reduced
  - **Control strategies focused only on reducing NOx may lead to increases in SOA from VOCs**

Bharat VI and Evaporative Controls
– How do the regulatory requirements translate into in-use control?

- Development of evaporative standards are different from tailpipe … consideration of the local climate conditions must be taken into account

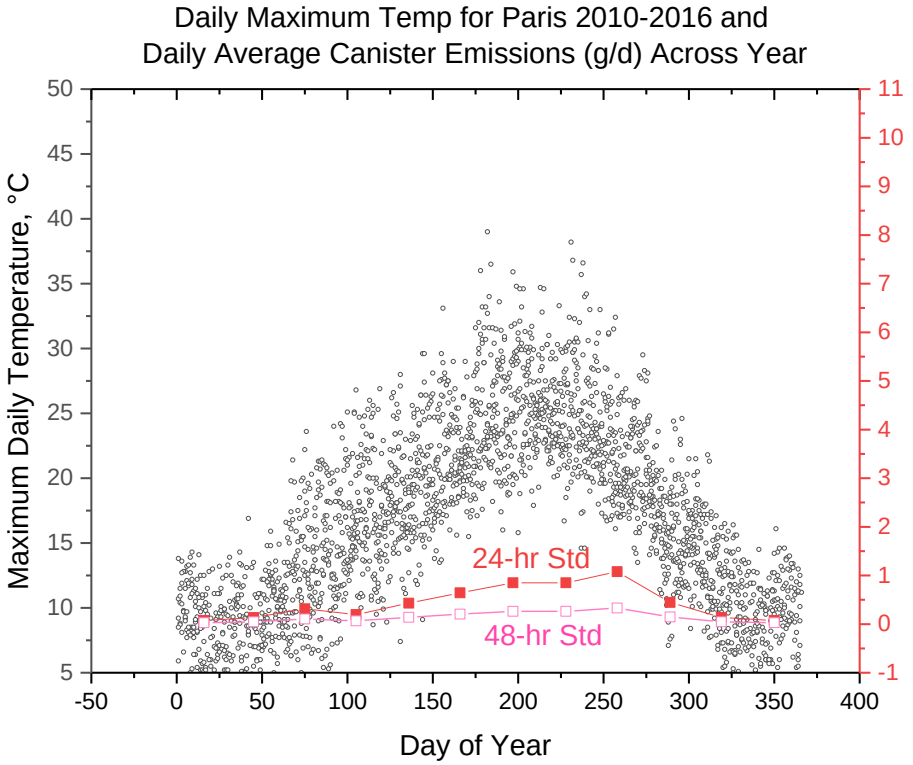
- It is simply too hot in India for European-based evaporative controls to be effective

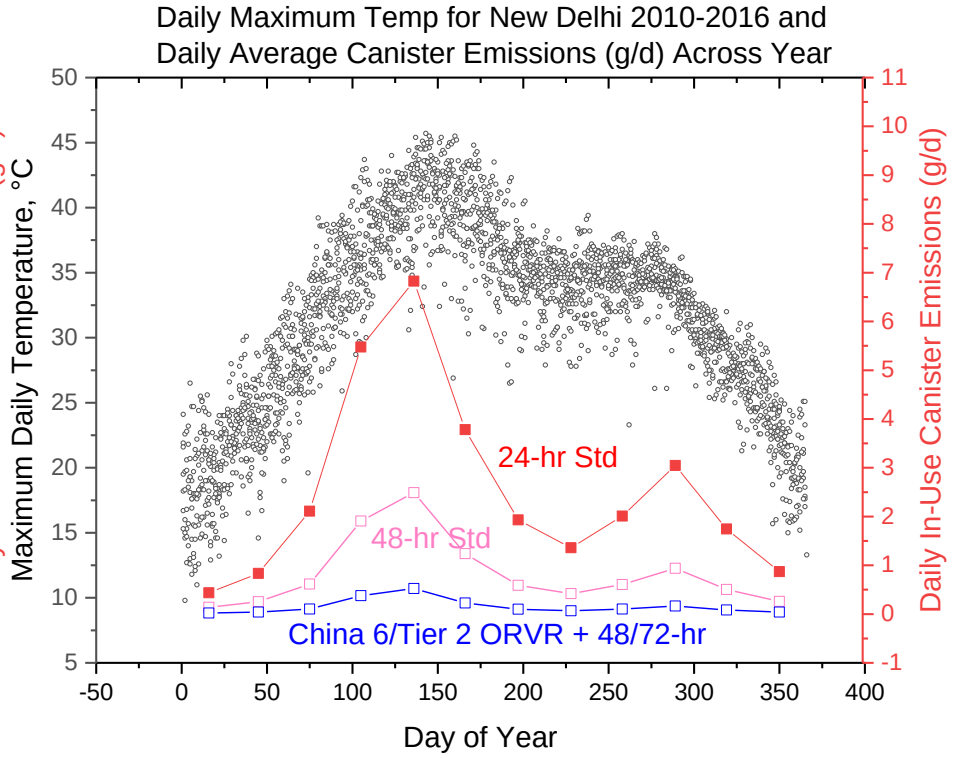
NEW DELHI, INDIA - MAY 24: A road melt near Safdarjung Hospital after the Temperature rise to 45 degree Celsius during a hot weather as Delhi/NCR experienced yet another scorching day, on May 24, 2015 in New Delhi, India. The national capital sizzling today as heat wave-like conditions prevailed across the city with mercury hovering above 45.3 degree Celsius, making life tough for the Delhiites.

Photo by Sanjeev Verma/Hindustan Times via Getty Images

Diurnal canister emissions are seven times higher with the same evaporative standard in India compared with Europe

– Only by adopting US or Chinese standards can India bring diurnal emissions down to levels in Europe





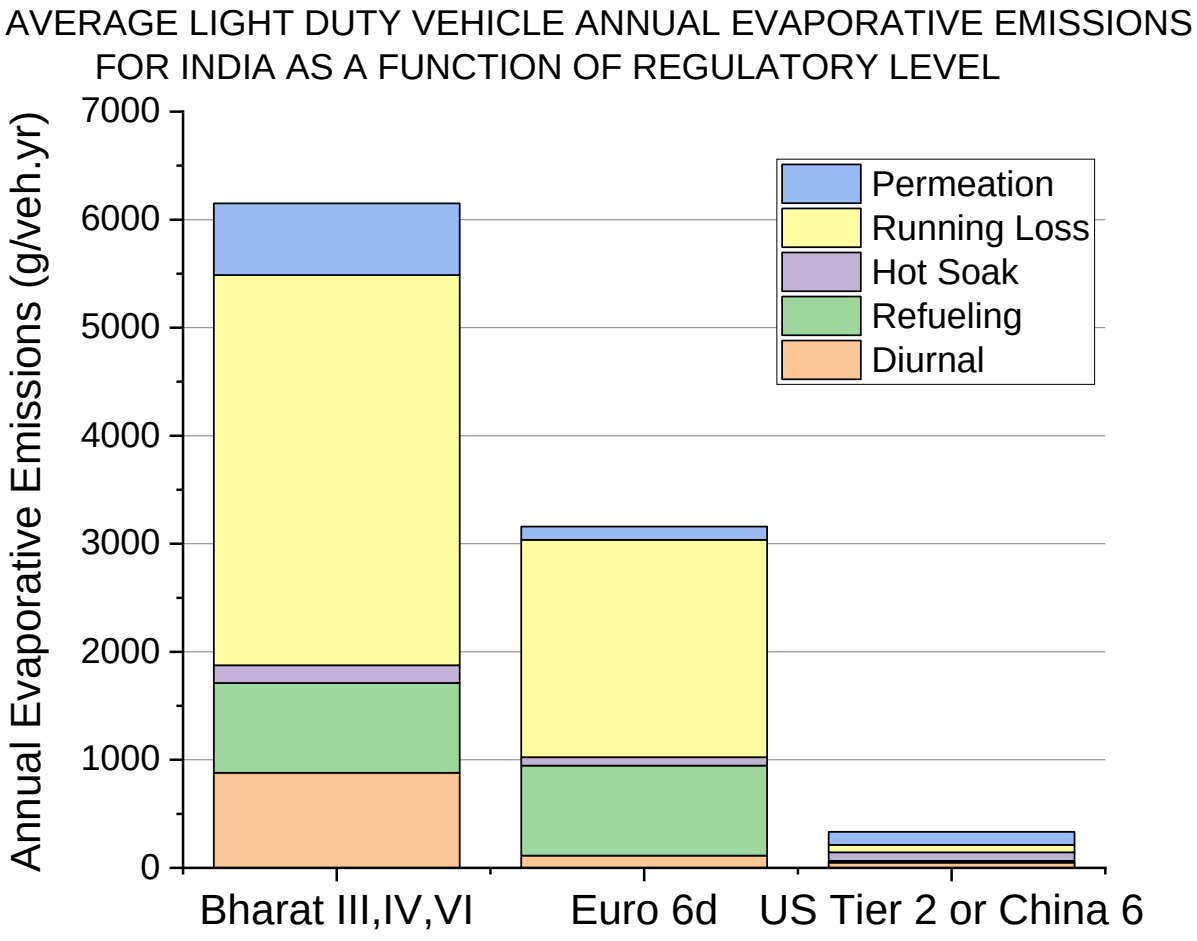
- Vapor generation is exponential with temperature.
- Canister capacity and purge are unable to keep up with vapor generation in India

ingevity

95+% emissions reduction to Tier 2/China 6 levels at a cost of less than 2200 INR/vehicle

Not Regulated in BS VI
- Running losses
- Refueling

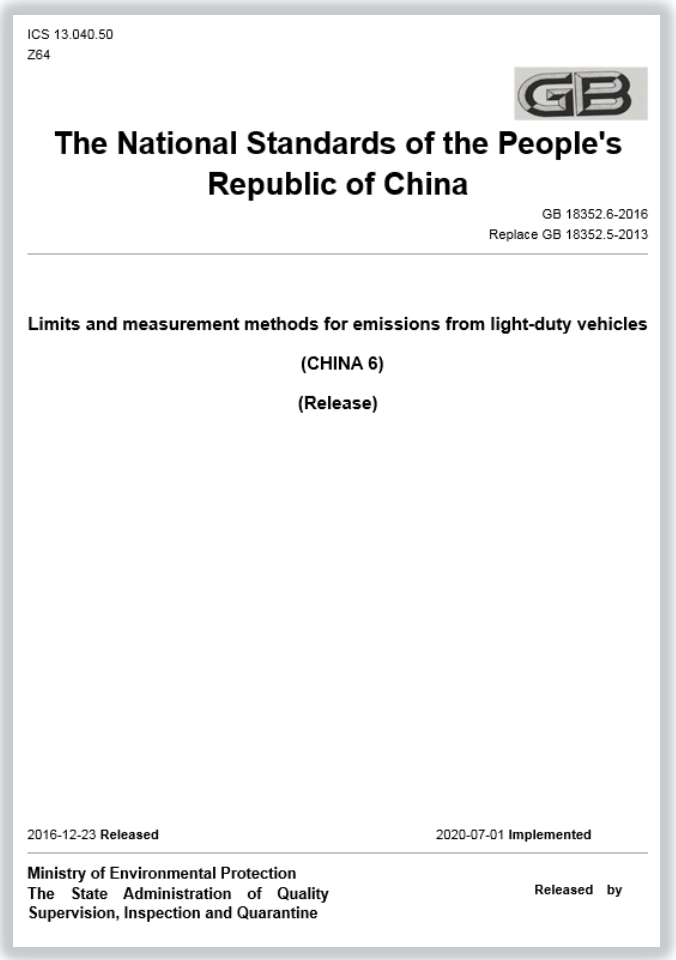
Marginally Regulated
- Diurnal
- Permeation



ingevity

China 6 completed in December 2016

– Includes ORVR, High Temp Running Loss Drive, and 48-hour Diurnal+HS using modified Type IV diurnal test and new Type VII refueling test



ICS 13.040.50
Z64

GB

The National Standards of the People's Republic of China

GB 18352.6-2016
Replace GB 18352.5-2013

Limits and measurement methods for emissions from light-duty vehicles

(CHINA 6)

(Release)

2016-12-23 **Released** 2020-07-01 **Implemented**

Ministry of Environmental Protection
The State Administration of Quality Supervision, Inspection and Quarantine

Released by

- Full national implementation by July 1, 2020
- Key evaporative provisions:
  - Onboard Refueling Vapor Recovery (ORVR) w/ 0.05 g/L limit and 0.01 g/L DF
  - 48-hr diurnal with 0.70 g/d limit w/ 0.06 g/d DF
  - Includes high temperature running loss drive
  - In-use compliance testing
  - Useful Life requirements:
    - China 6a: 160,000 km/12-year
    - China 6b: 200,000 km/12-year (7/1/23)
  - OBDII leak detection limit of 0.040 inch
- Utilizes WLTP drive cycles and could drop into Bharat VI seamlessly as replacement to 24-hour Type IV test
- Early implementation likely:
  - Hebei Province Announced (January 2019)
  - Guangdong Province Intending (January 2019)
  - Shanghai region intending (January 2019)

Bharat VI will continue to rely upon 1982 technology to control evaporative emissions, which results in low canister capacity and low purge rates

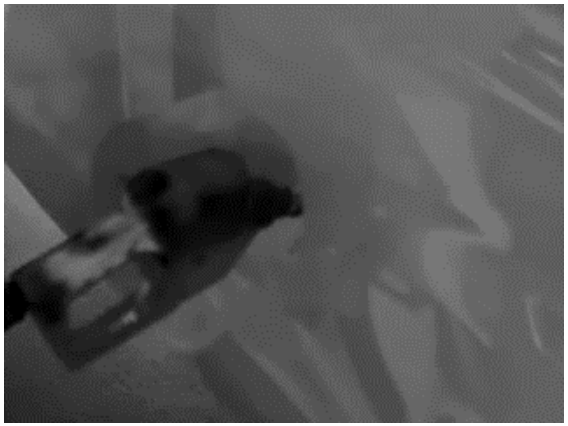
Standard	Canister Capacity* (g GWC)	Average Purge Rate* (LPM)	Typical Canister Emissions in SHED for Certification (g/day)		
			Day 1	Day 2	Day 3
1-Day+HS Euro 3,4,5,6a,6b, Bharat III,IV,VI } 2 g/d limit 2 g/day limit 1982 Technology	37 grams	2.3 LPM	0.60 g	---	---
2-Day+HS Euro 6d, UNECE GTR } ~1 g/d limit KLEVIII } 0.35 g/d limit	62 grams	6.9 LPM	0.10 g	0.24 g	---
ORVR+ 48/72-hr+HS 1995 Technology US Tier 2, China 6 } 0.5-0.7 g/d limit	108 grams	15.2 LPM	0.02 g	0.06 g	0.13 g
US Tier 3 } 0.3 g/d limit 2001 Technology	113 grams	15.2 LPM	0.001g	0.01 g	0.07 g

*Based on 60-liter fuel tank

ingevity

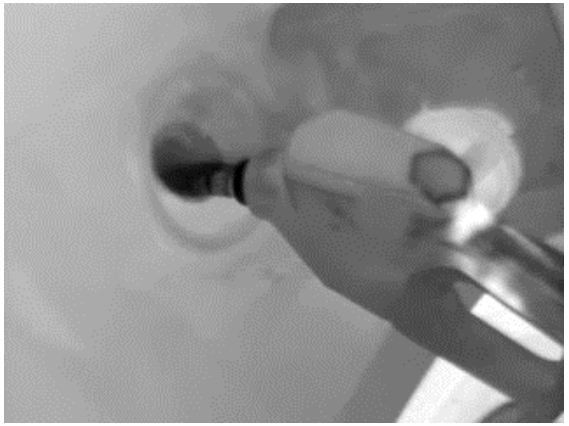
ORVR is the most effective and least costly method for refueling control

Uncontrolled Refueling



Stage II Vapor Recovery

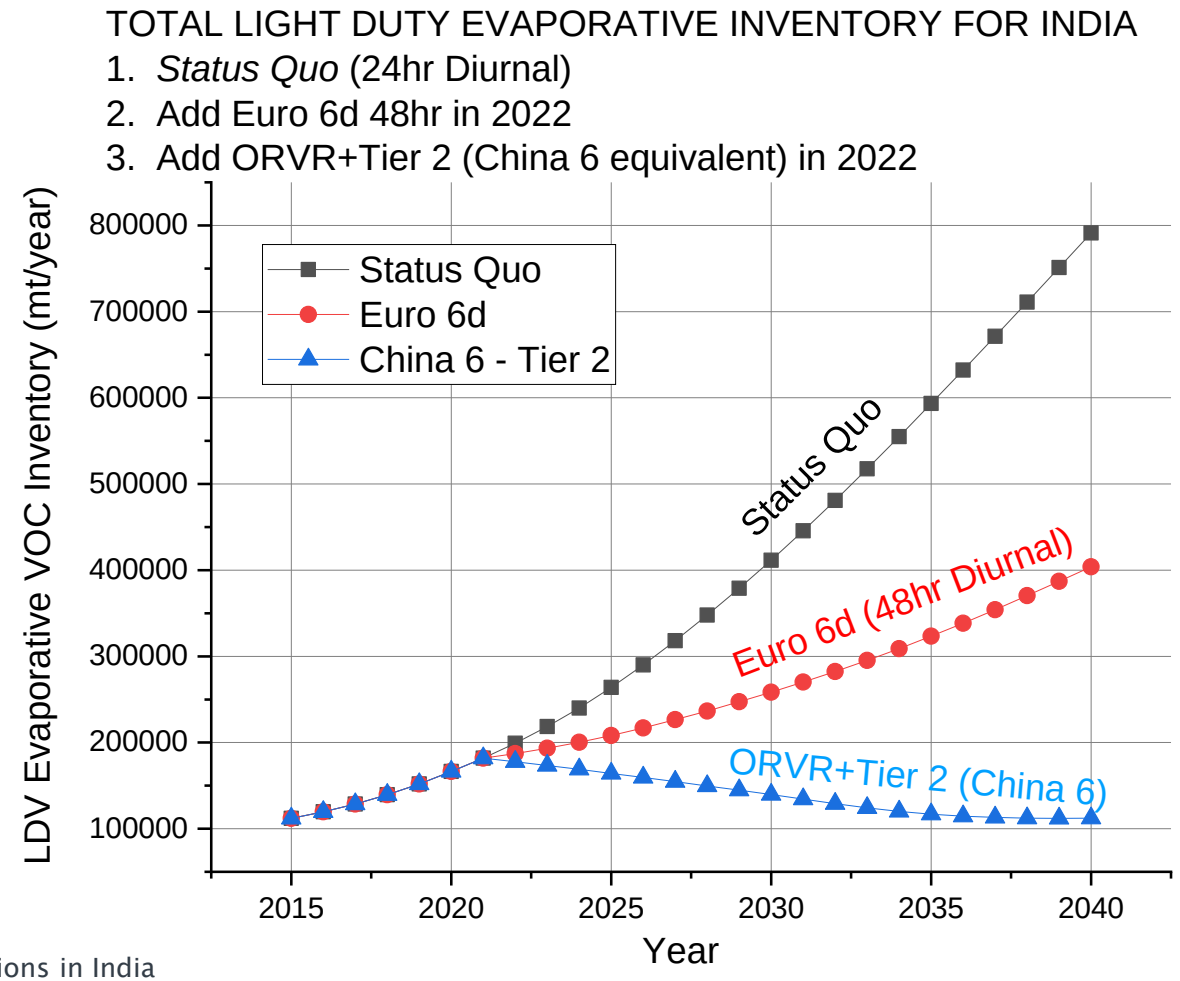
Onboard Refueling Vapor Recovery (ORVR)



	Stage II Vapor Recovery	ORVR
Efficiency	70% Overall	98% Overall
Cost	53 Lakh Rupees/station	1300-2000 Rupees/vehicle
Maintenance	2 Lakh Rupees/year	None

India's VOC inventory is estimated at 150,000 mt/yr and will continue to increase with BS VI

- Only means to reduce inventory with increasing vehicle population is to adopt ORVR, multiday diurnal, and running loss control
- Inventory will continue increasing even if Euro 6d with 48hr diurnal is adopted



ingevity

SUMMARY

1. India's hot climate results in high year-round evaporative VOC emissions. In Europe, only 2% of days exceed 35°C, while 30% of days exceed 35°C in India. European evaporative policy-makers do not take India's hot climate into account, and European evaporative regulations should not be basis for Bharat standards.
2. While significant reductions in exhaust emissions are expected with Bharat/Euro VI, the evaporative VOC inventory will continue rising above the current level of 150,000 mt/yr unless improved norms are enacted.
3. Evaporative standards were not improved in Bharat VI, but VOCs from evaporative emissions are significant contributors to ground level ozone, SOA (PM2.5) formation, and benzene/HAP exposure.
4. New China 6 standards demonstrate that ORVR, multiday diurnals, and running loss control can incorporate the WLTP, streamline for growing automotive markets, and can be quickly implemented. China is implementing with 2-3 years notice! China's evaporative program could serve as a model for India.