BS VI Evaporative Standards: Not enough to improve air quality

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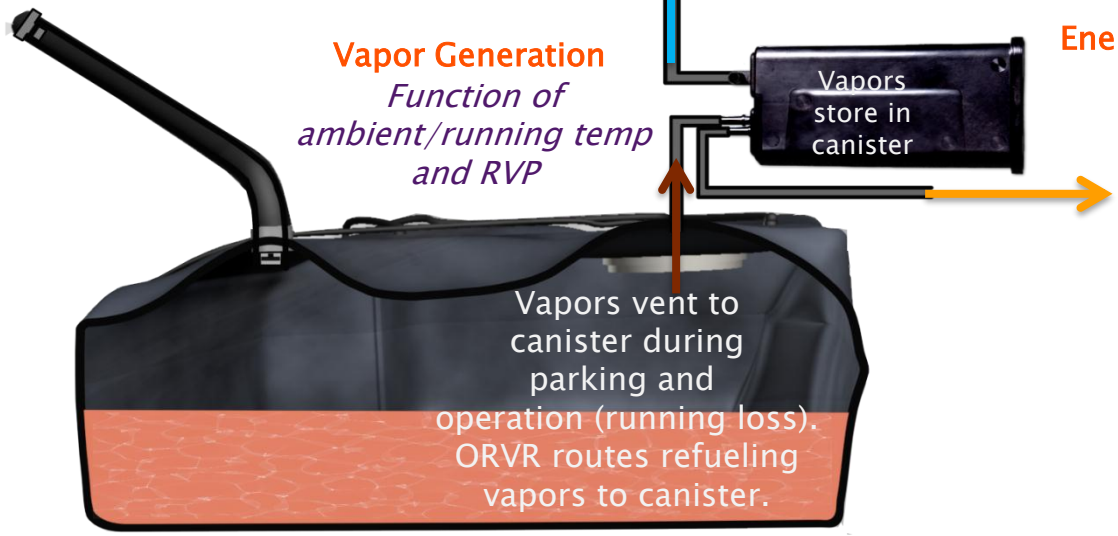
Canister capacity and purge rate are key to minimizing in-use evaporative emissions

- VOCs result in PM2.5, ozone, and hazardous air pollutant exposure
- Control technology package results from emissions standard

Emissions
Function of canister capacity and purge rates

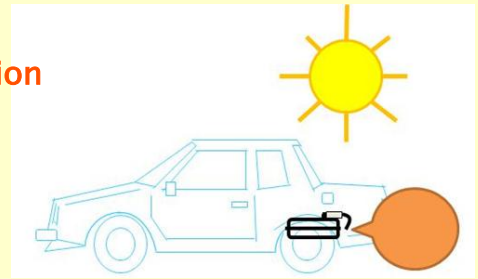
Vapor Generation
Function of ambient/running temp and RVP

Energy Conservation
Stored vapors sent to engine when driving

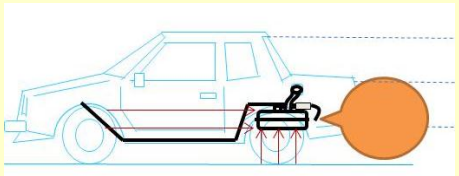


MAJOR CLASSES OF EVAPORATIVE EMISSIONS

Refueling



Diurnal Parking



Running Loss

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The Euro 6c evaporative standards only address one set of operating conditions – a short drive under moderate temperatures.

- No consideration for hot ambient temperatures or long drives under running loss conditions
- US and China standards cover the spectrum of conditions

	MODERATE TANK TEMP (lower purge efficiency)	ELEVATED TANK TEMP (high running loss)
SHORT DRIVE (short purge time)	(US 2DD) Euro6c/WLTP 2DD WORST CASE	(China 2DD)
LONG DRIVE (short purge time) (time for high tank temps)	(US ORVR, China ORVR) (Euro 3,4,5 1DD) BEST CASE	(US 3DD, China 2DD) WLTP Phase 2 ??? WORST CASE

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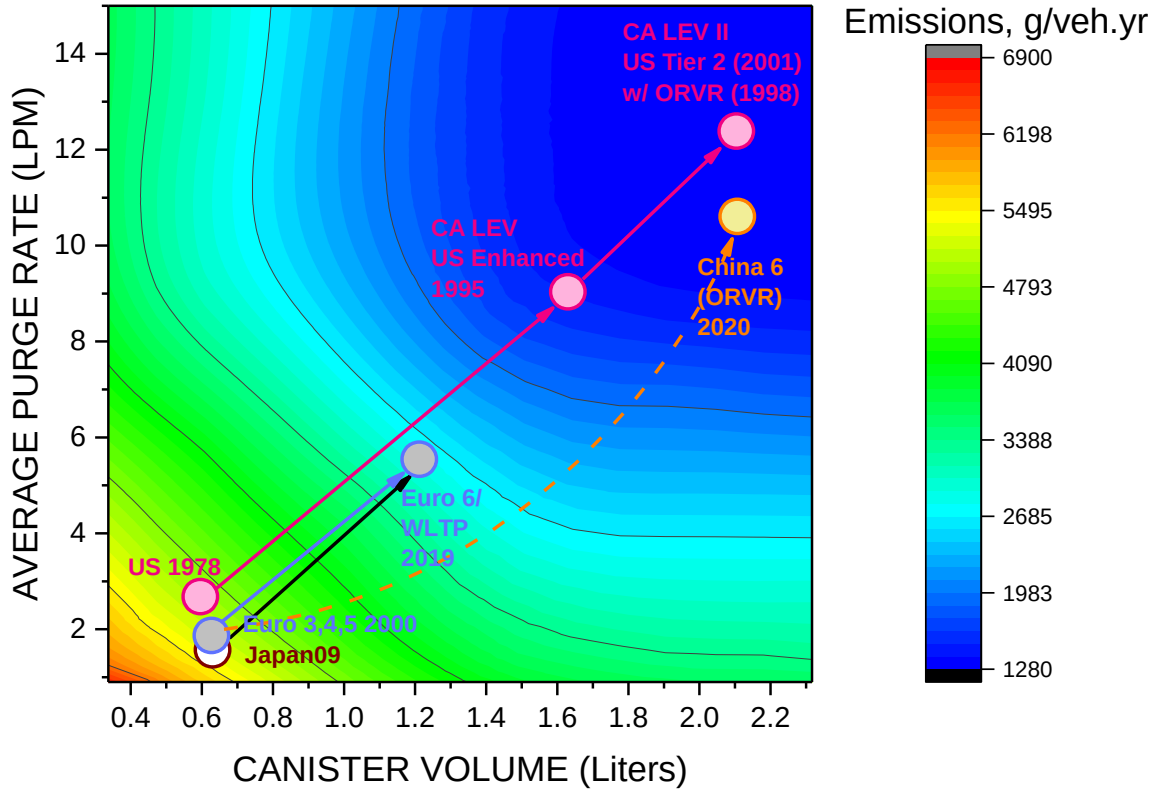
Euro 6C (BS VI) is inferior to US 1990s technology package resulting in higher in-use emissions

-China is responding with China 6 standards that match US Tier 2

RELATIONSHIP BETWEEN CANISTER CAPACITY AND PURGE RATE
ON DIURNAL+HOT SOAK+RUNNING LOSS EMISSIONS IN TOKYO



Other Technology Package impacts to further reduce emissions:

- Tank temp controls
- Low permeation materials
- Canister bleed control

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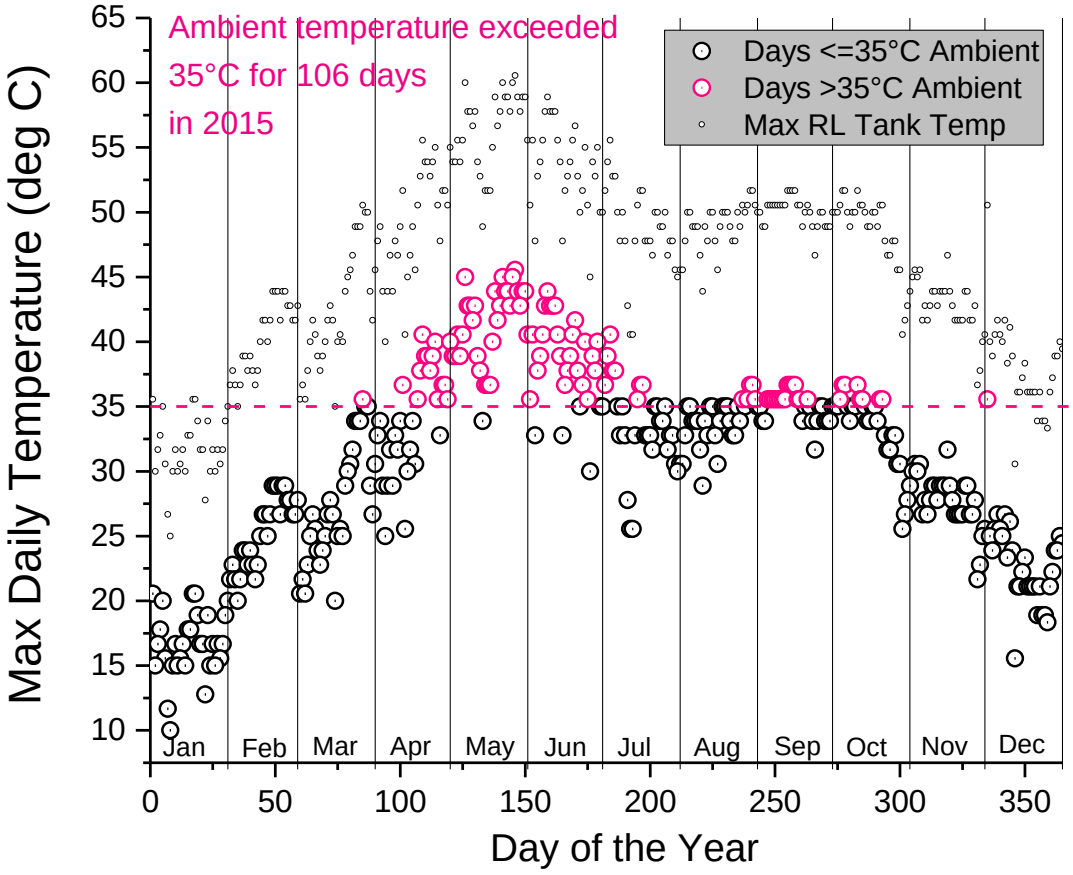
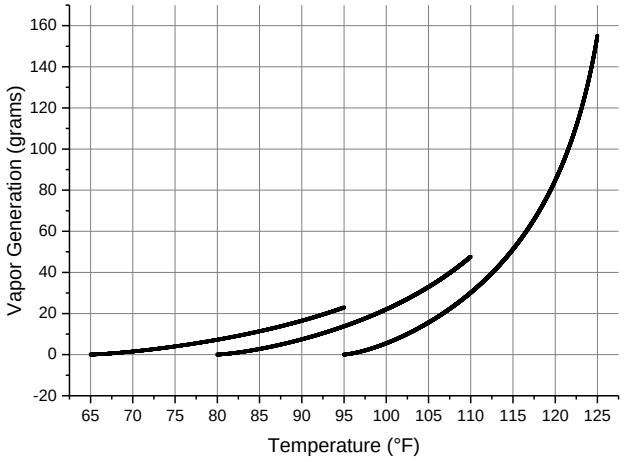
Euro 3,4,5,6 vehicles are not certified for temperatures above 35°C, yet ambient and tank temperatures commonly exceed 35°C and result in high off-cycle vapor generation and emissions

MAXIMUM DAILY AMBIENT TEMPERATURE AT DELHI AIRPORT 2015
AND POTENTIAL DAILY HIGH RUNNING LOSS TANK TEMPERATURE



RUNNING LOSS VAPOR GENERATION AS A FUNCTION OF INITIAL TANK TEMPERATURE FOR A 15 gallon TANK FILLED 40% WITH 60 kPa GASOLINE AND UNDERGOING A 30°F HEAT BUILD



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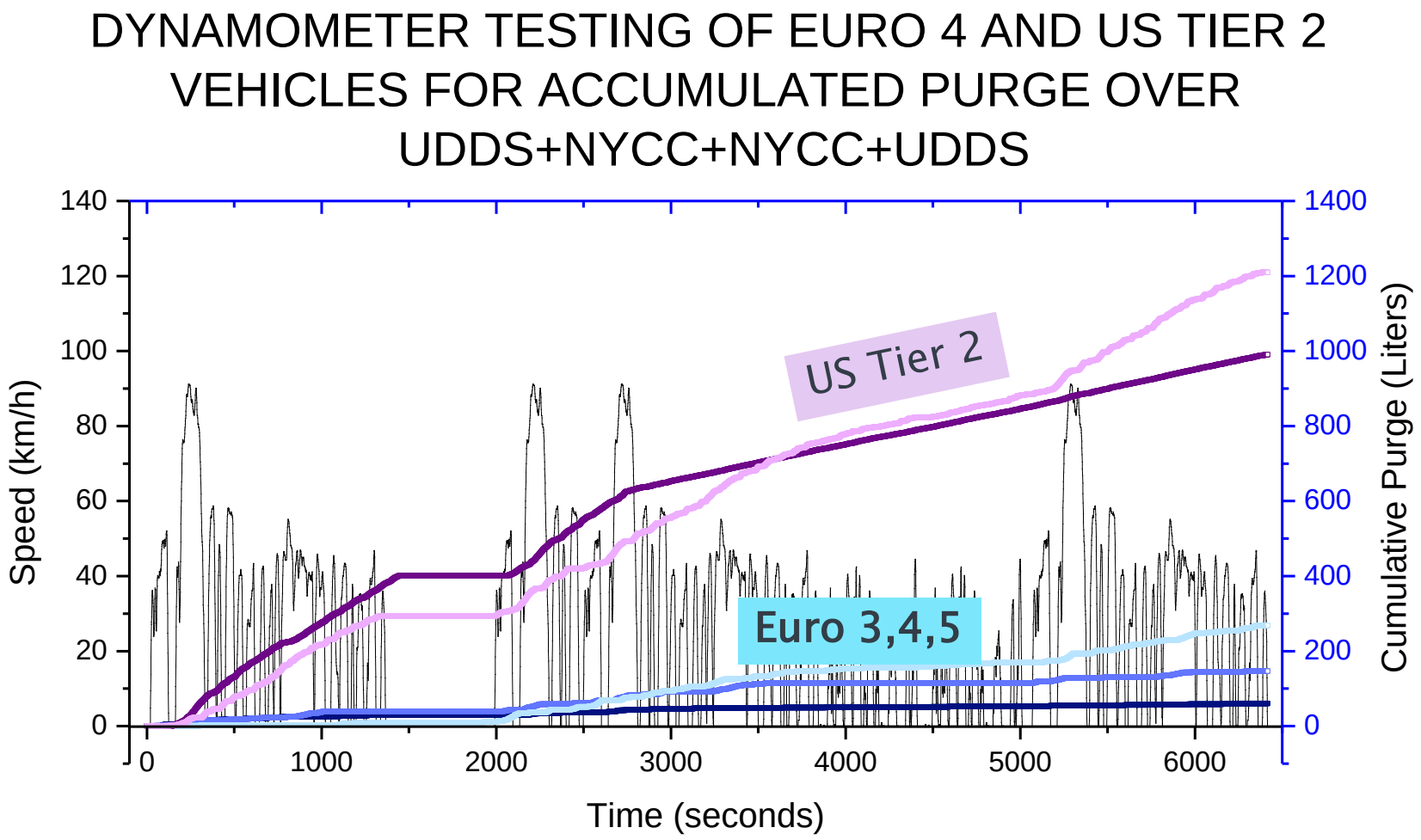
Testing demonstrates that US Tier 2 vehicles purge at rates 8-times higher than Euro 4 vehicles



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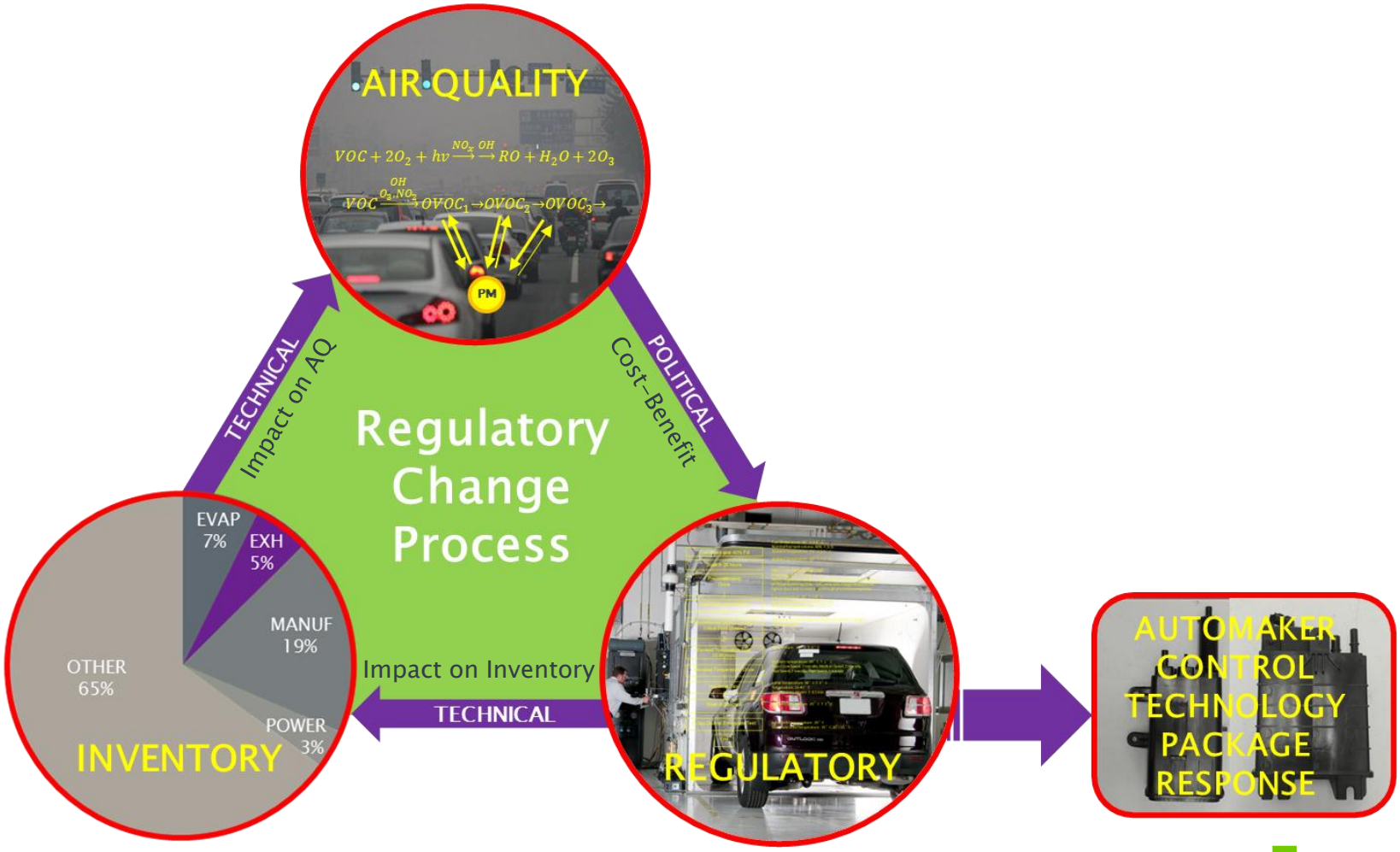
Overcoming the political challenges to upgrading emissions regulations requires an accurate picture of the inventory and its effect on air quality



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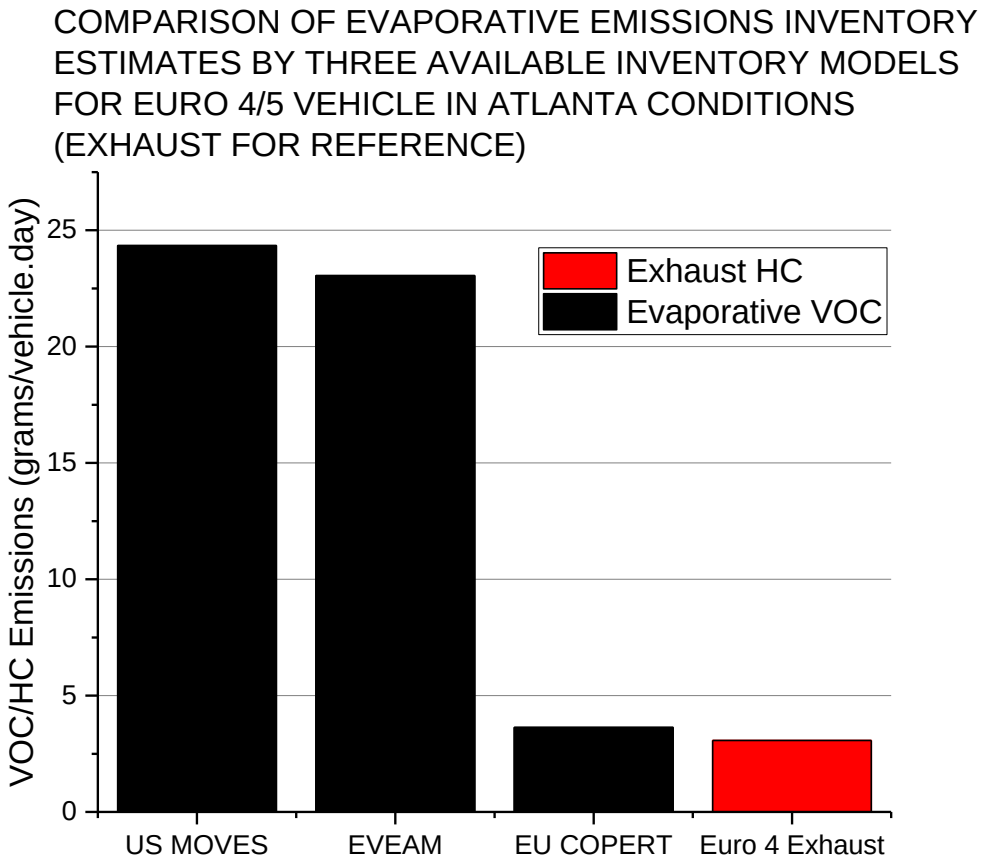
European COPERT inventory model shows evaporative emissions at one-seventh the level estimated by MOVES and new EVEAM global model for Euro 3,4,5 technology package

- Generally, countries/regions relying upon COPERT model have been very slow to upgrade evap standards
- How are evaporative emissions accounted for in India inventory?



Modeling by Dr. Joshua Fu
University of Tennessee

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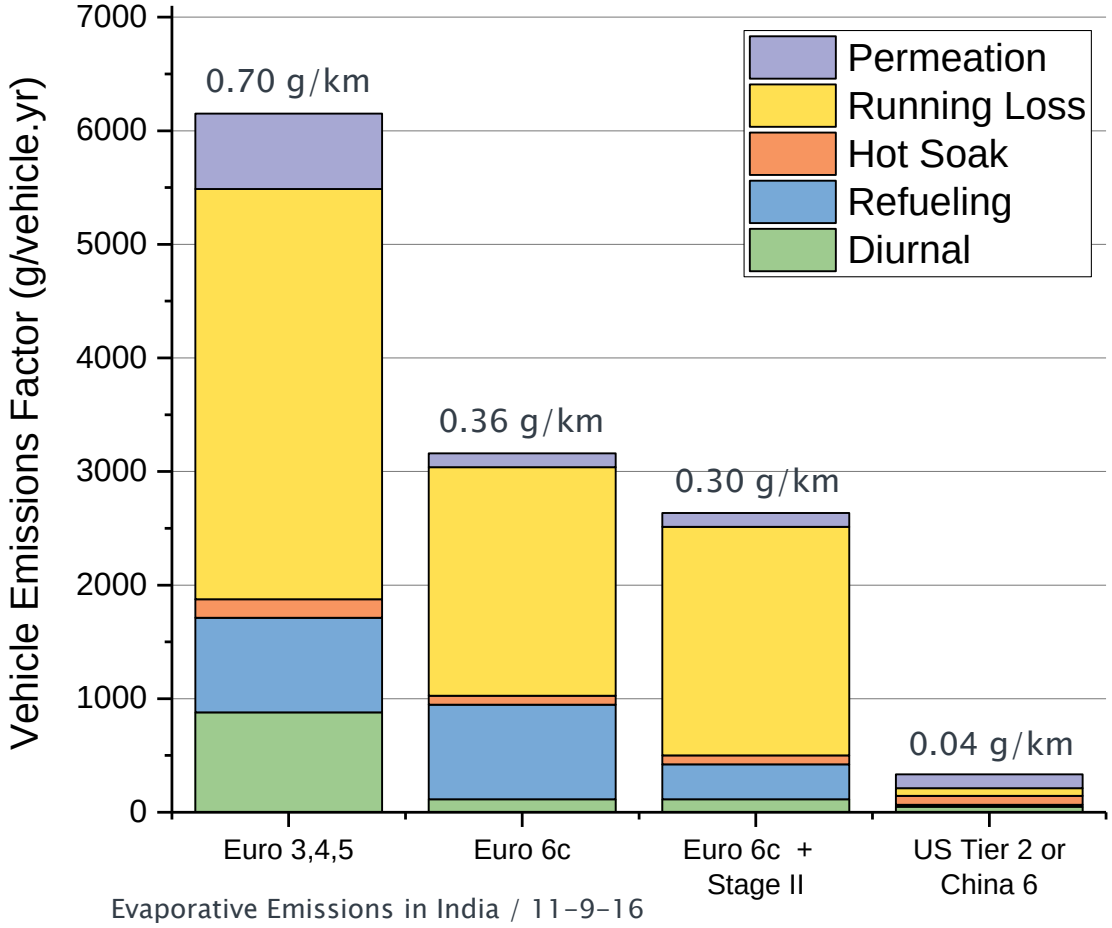
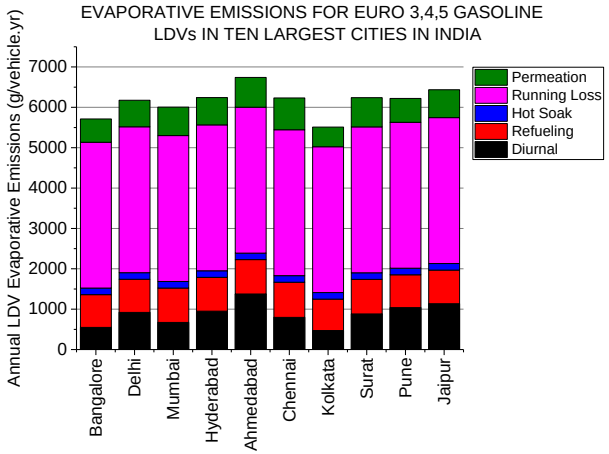
MOVES (EVEAM) methodology shows large effect of standard-level on emissions

- Evaporative emissions factor in India now 6 kg/vehicle·yr, reducing to 3 kg/vehicle·yr with BS VI
- US Tier 2 and China 6 at 0.3 kg/vehicle·yr
- Stage II would be costly and provide little reductions; ORVR should be considered

AVERAGE VEHICLE EVAPORATIVE AND REFUELING EMISSIONS FACTORS FOR INDIA AS A FUNCTION OF REGULATORY LEVEL





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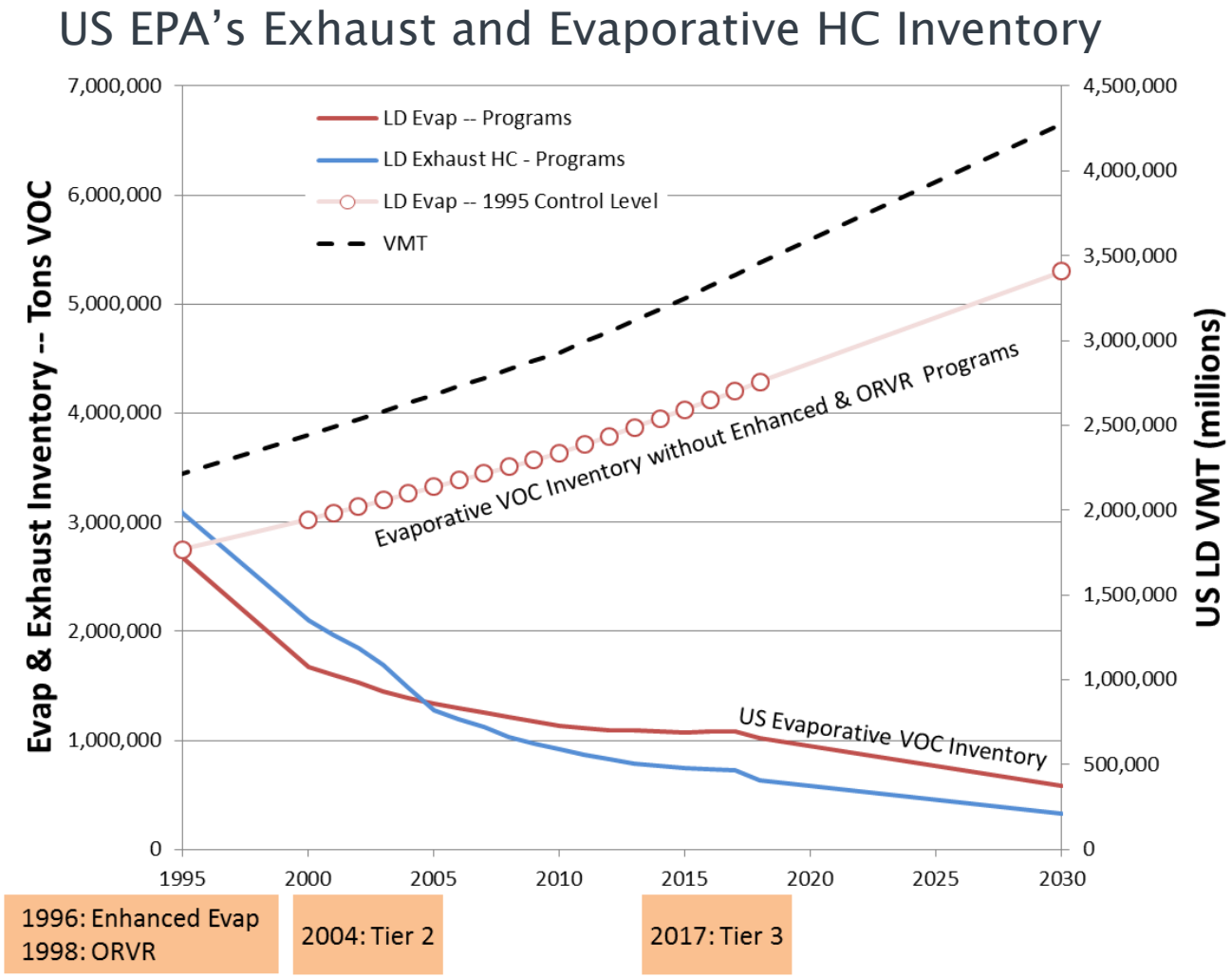
If Enhanced Evaporative & ORVR programs were not implemented, VOC inventories would be 3 million tons higher in US today

Evaporative emissions are still higher than exhaust, which necessitated further Tier 2 and Tier 3 reductions



Source: "Development of Light-Duty Emission Inventory Estimates in the Notice of Proposed Rulemaking for Tier 2 and Sulfur Standards," US EPA, March 1999
Source: "Control of Air Pollution from Motor Vehicles: Tier 3 Motor Vehicle Emission and Fuel Standards Final Rule, Regulatory Impact Analysis," US EPA, March 2014
Source: "Final Regulatory Impact Analysis and Summary and Analysis of Comments, Control of Vehicular Evaporative Emissions," US EPA, February 1993

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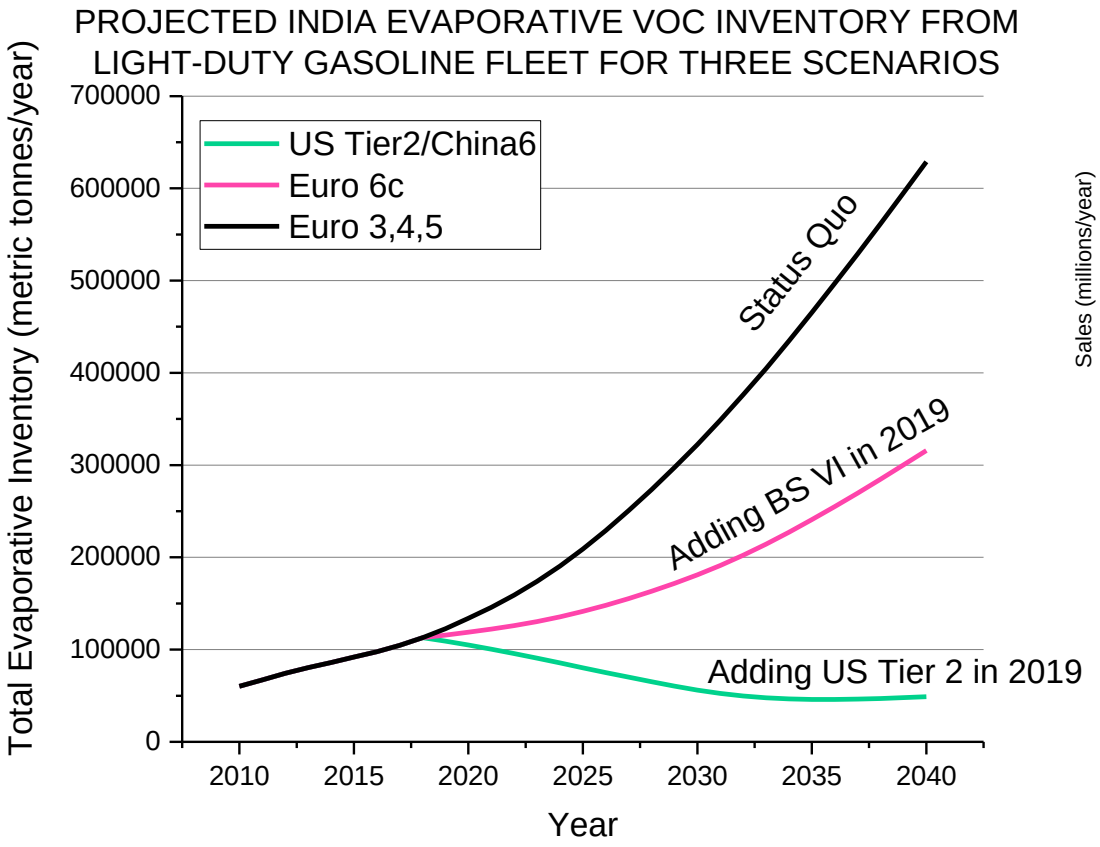
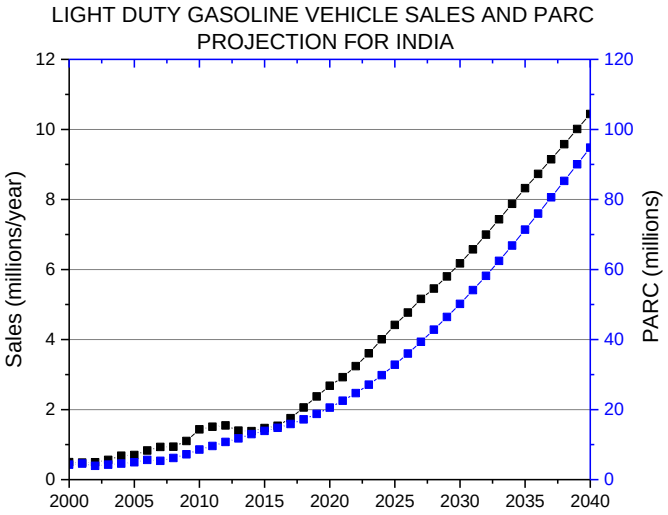
India's VOC inventory is estimated at 100,000 mt/yr and will continue increasing with BS VI

– Enhanced evaporative measures and ORVR would cause inventory to drop while vehicle population and VKT continues increasing





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SUMMARY

1. India's hot climate results in high year-round evaporative VOC emissions
2. VOCs from evaporative emissions are significant contributors to ground level ozone and SOA (PM2.5) formation
3. While significant reductions in exhaust emissions are expected with Bharat/Euro VI, the evaporative VOC inventory will continue rising above the current 100,000 mt/yr
    - Bharat VI still lags behind 1995 standards in the US
    - China has modified WLTP procedures to address running loss and refueling, and China 6 will be equivalent to US Tier 2
4. India should work towards an accurate evaporative and refueling emissions inventory and consider a more effective control program like those in the US, Canada, S. Korea, and China.