Opportunities for Controlling Evaporative Emissions in Japan

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Main Factors Affecting Controls and Emissions

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Parking patterns (duration, end time)
Ambient Temperatures
Fuel RVP and ethanol %
Vehicle kilometers traveled
Average fuel economy
Elevation above sea level</td><td>Number of diurnals or Refueling control req’t</td><td>∝ Canister Capacity</td><td rowspan="6">Parking (diurnal)
Running Loss
Refueling
Hot Soak
Permeation</td></tr>
<tr><td>Duration of shortest series of test drive cycles</td><td>$\propto \frac{1}{Purge\ Rate}$</td></tr>
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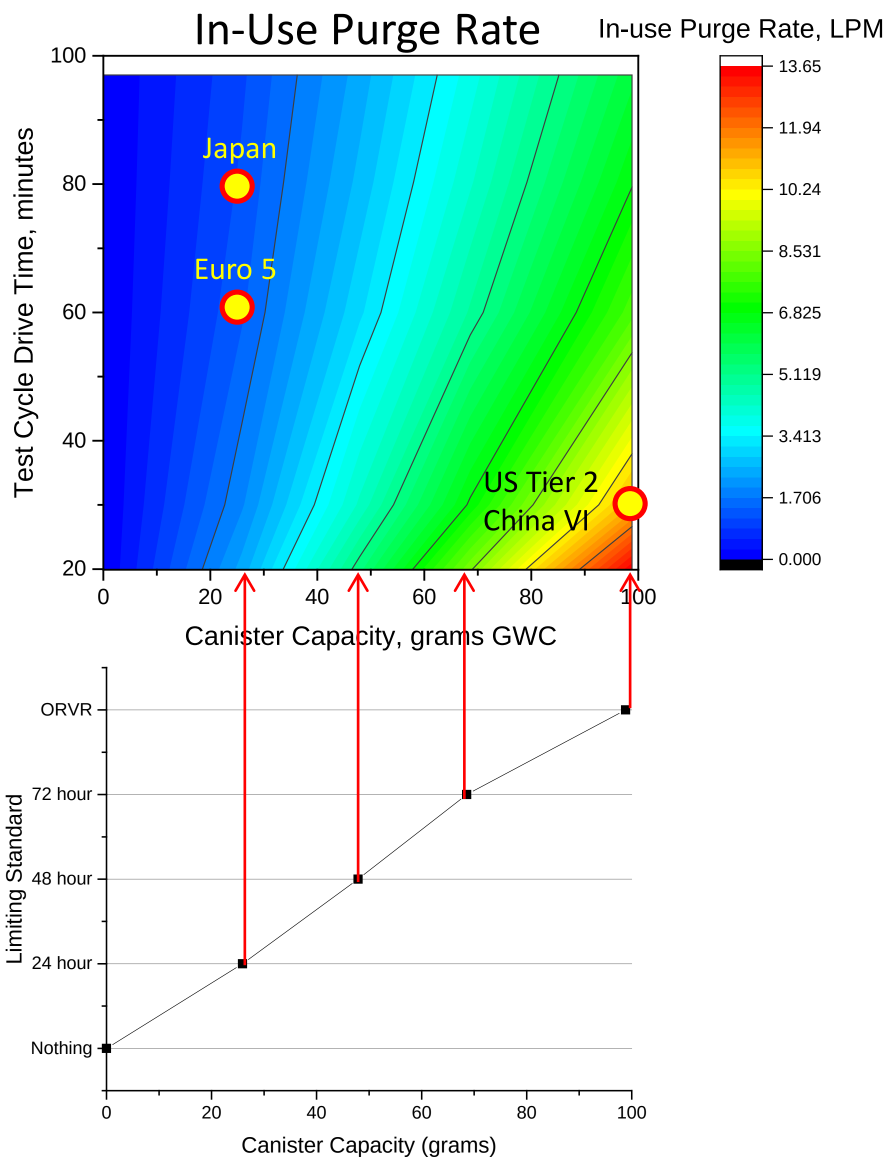
Base Canister Capacity and Purge Rates Result from Certification Procedures



<u>Example: 50 L Fuel Tank</u>

- Greatest certification vapor load establishes base canister capacity
  - US: ORVR @ 99 grams GWC
  - JP: 24hr @ 26 grams GWC
- Purge rates calibrated by shortest drive cycle used for purge-down
  - US: 30 minutes in 48hr test
  - JP: 80 minutes in 24hr test

RESULTS:
- Capacity: US 4x higher than JP
- Purge: US 10x higher than JP

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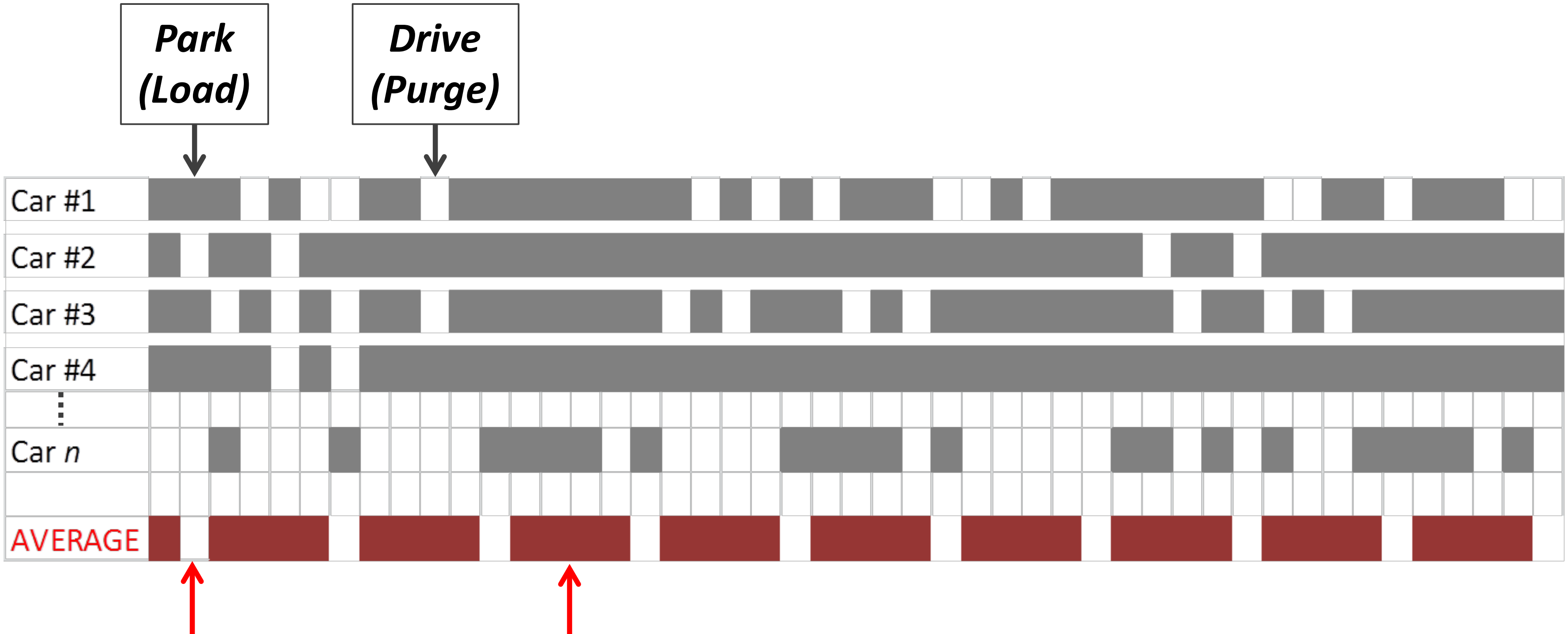
In-use canister capacity is ƒ(base capacity, fleet activity)

Vapor load and purge are almost random, so a SS modeling approach is needed to establish average canister capacity

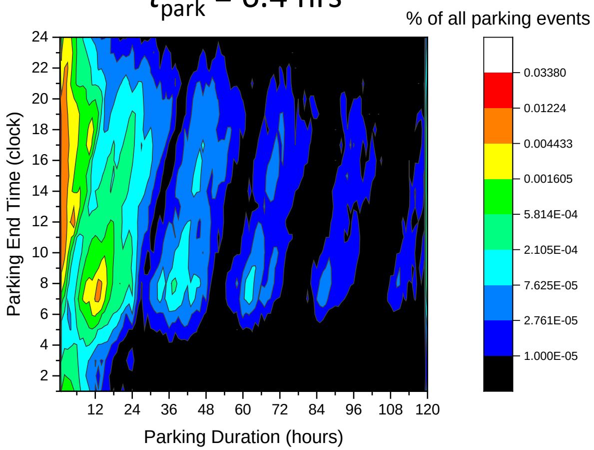


Baseline Data: Average Drivetime = 15 minutes
Average Parktime = 7 hours

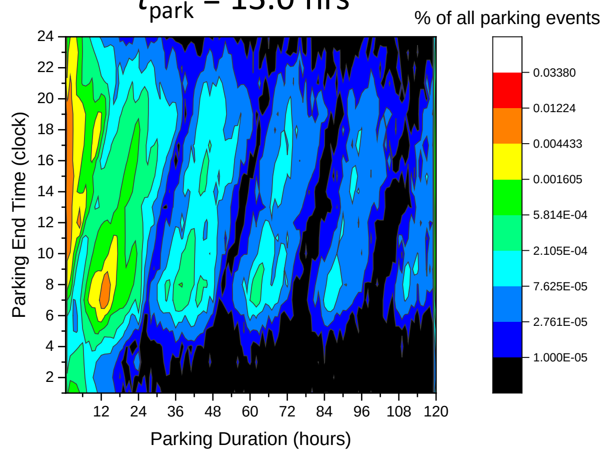
These will adjust based upon average km/hr, VKT, and any Activity Data changes

Baseline activity data (Florence) can be rescaled to better match local conditions or can be replaced with local activity data

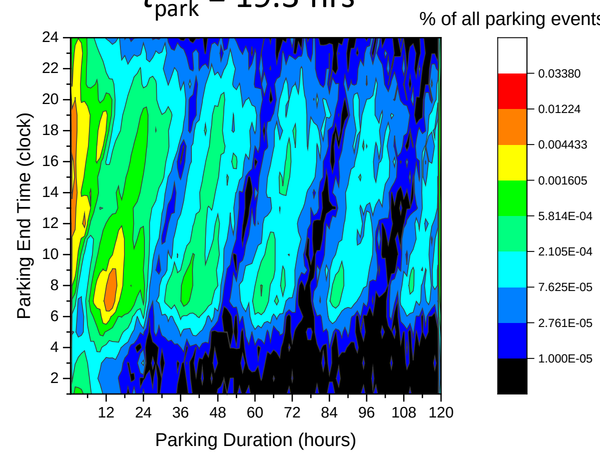
Baseline (Florence)
Parking Distribution
$\overline{t}_{park}$ = 6.4 hrs

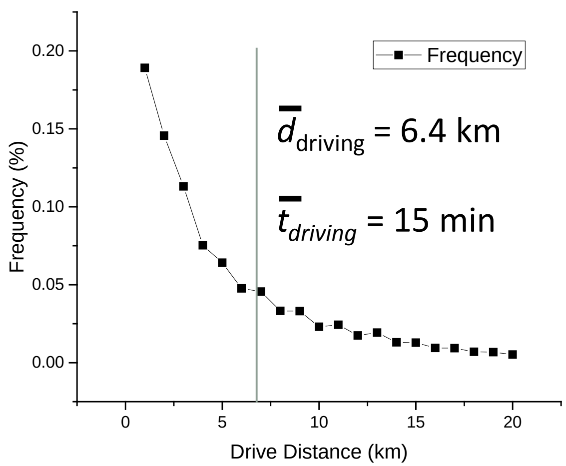


Rescaled
Parking Distribution
$\overline{t}_{park}$ = 13.0 hrs



Rescaled
Parking Distribution
$\overline{t}_{park}$ = 19.3 hrs

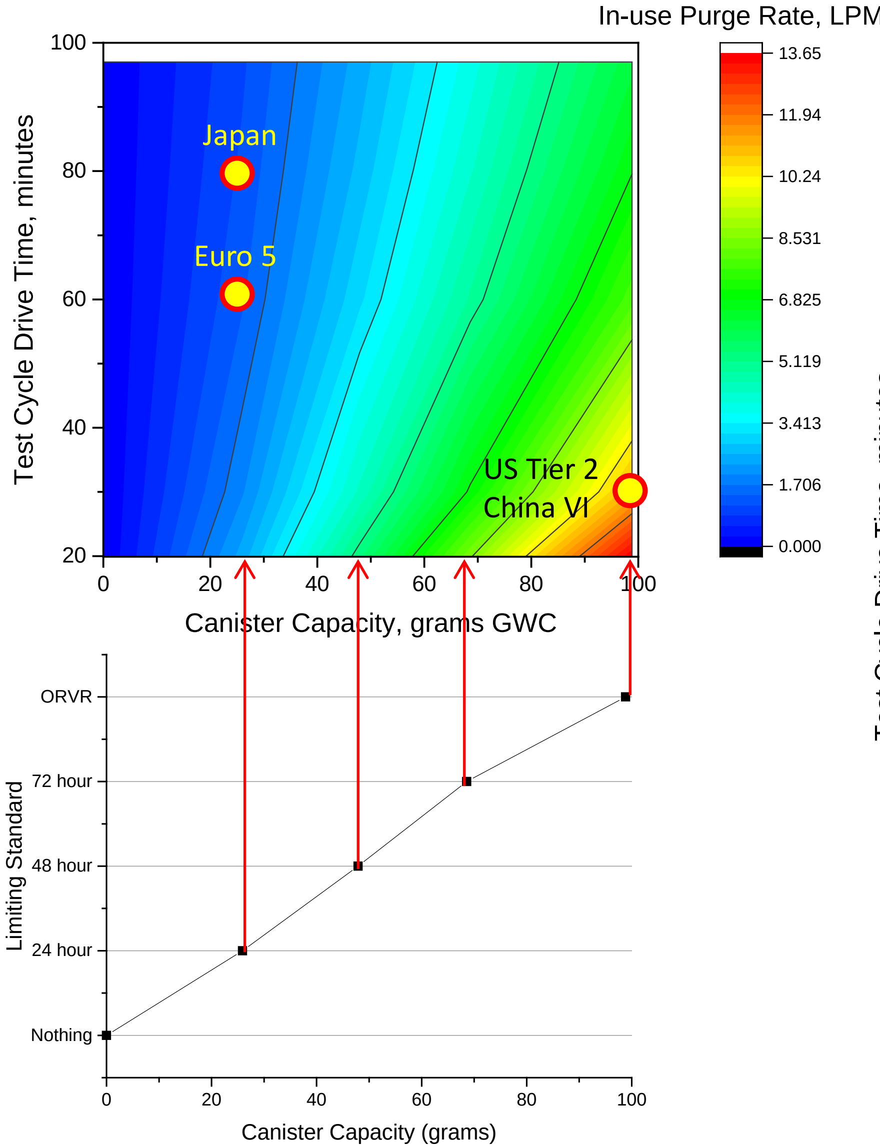




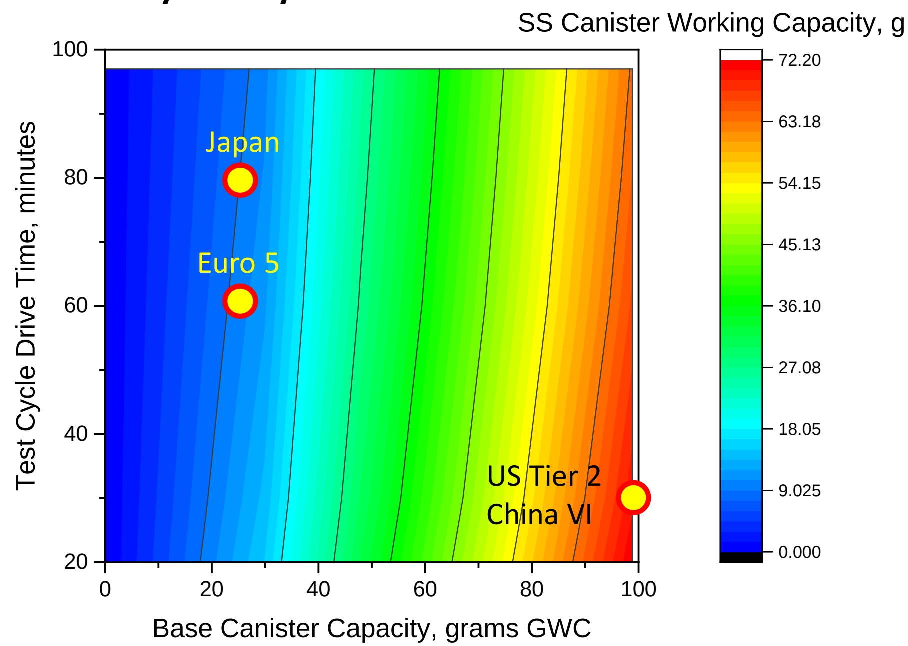
Adjusting the parking distribution affects diurnal emissions.

Adjusting $d_{driving}$ and *average fleet km/hr* affects how well a canister will purge in-use, the total amount of parking time, and amount of running loss emissions.

High base canister capacity and high purge rates result in high average working capacity entering all parking events



Average In-Use Canister Working Capacity
July in Tokyo with 50 L Fuel Tank



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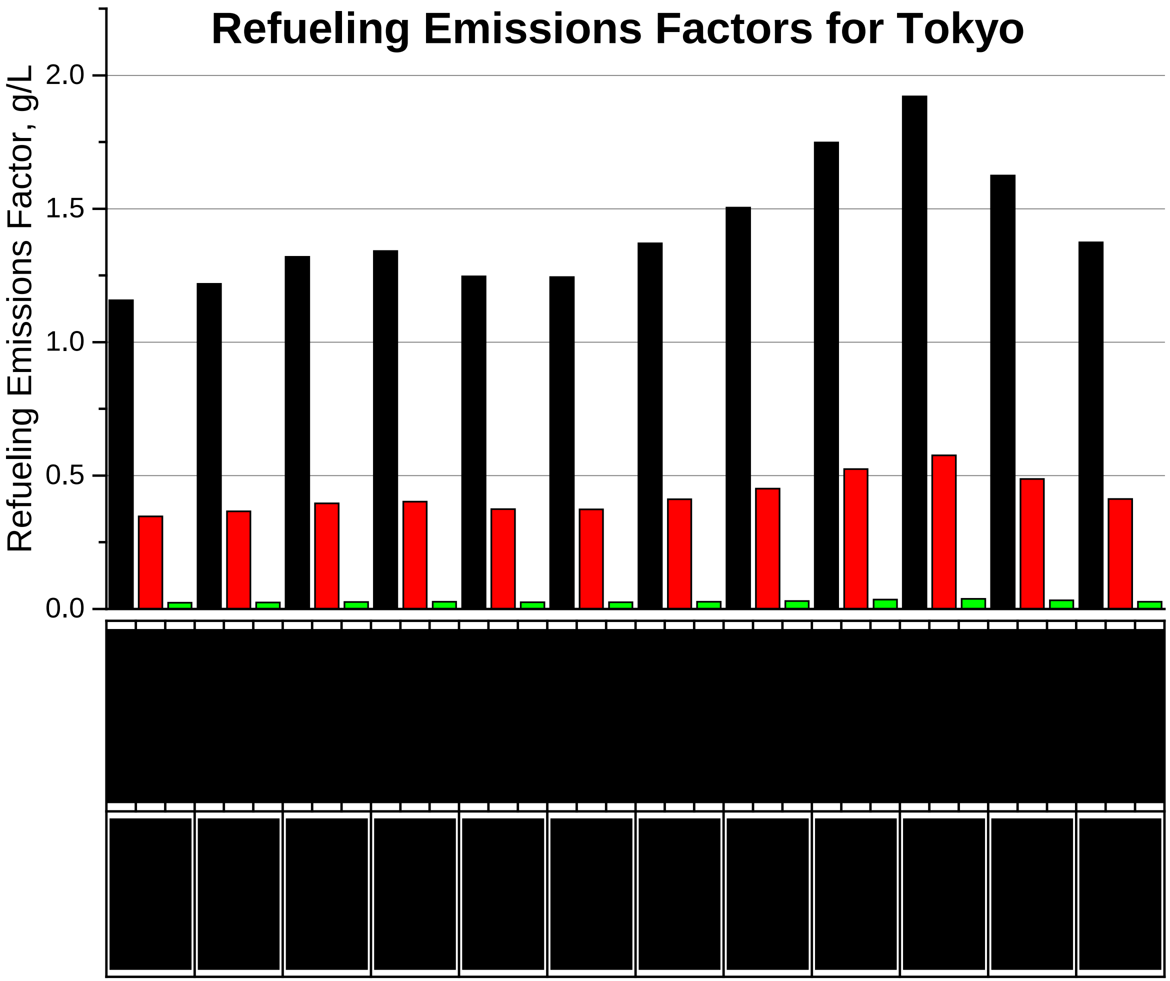
Purge rates and emissions based on empirical relationships

Model Calculated Technology Package Parameters

	Average Certified Canister Capacity for 50-L fuel tank	Average In-Use SS Canister Capacity for Tokyo	Average Purge Rate
Status Quo	26 grams	10.3 grams	1.2 LPM
+ ORVR	99 grams	62.2 grams	6.8 LPM
+ Tier 2 and ORVR	99 grams	75.4 grams	11.1 LPM

Controlling Refueling Emissions

ORVR provides maximum refueling control, canister capacity, and pure rates



ORVR has many advantages over Stage II:

- Better efficiency: 98% vs 70%
- Lower cost: Zero program cost over vehicle lifetime
- Provides maximum canister capacity for improved diurnal and running loss control

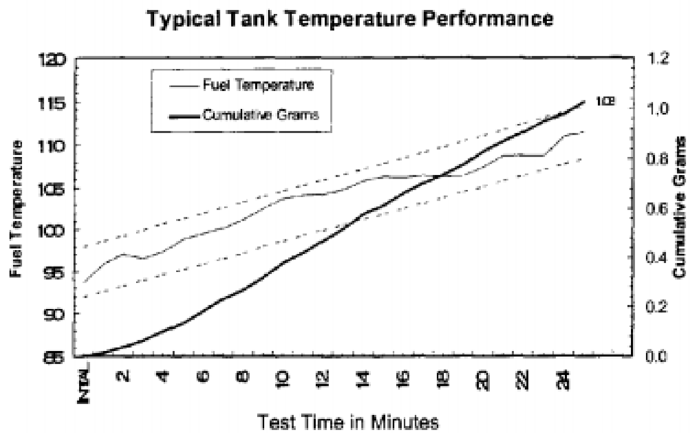
Running Loss vapor generation occurs from fuel tank heating while driving

Fuel tank temperature profile is influenced by a number of factors, including:

- Road surface temperature
- Distance from road surface to tank and spatial arrangement of tank
- Fuel tank material of construction
- Volume of fuel in tank
- Rate of heat generation from in-tank fuel pump
- Proximity of exhaust to fuel tank
- Arrangement of heat shielding
- Volume and speed of air flowing under tank

EPA data show that tank temperature profiles have not changed greatly between Pre-Enhanced and Enhanced but EFs have dropped significantly

- For the majority of vehicles, increased purge and canister capacity are the most significant control factor
- For some vehicles that generate very high temperatures, some additional shielding is necessary
- Procedures ensure that purge system and canister capacity can handle the variable vapor generation



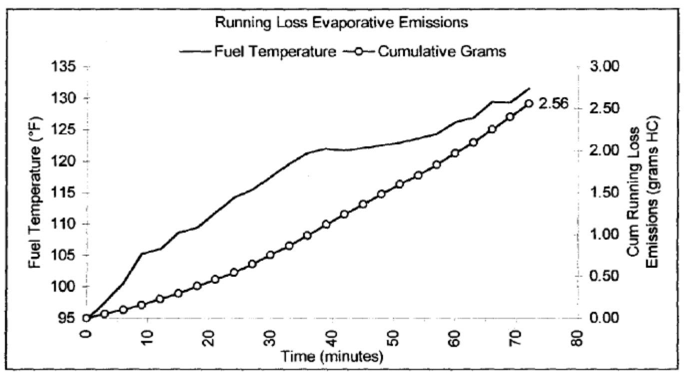
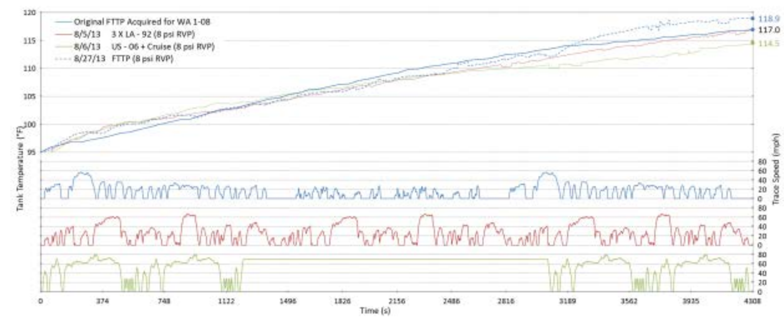


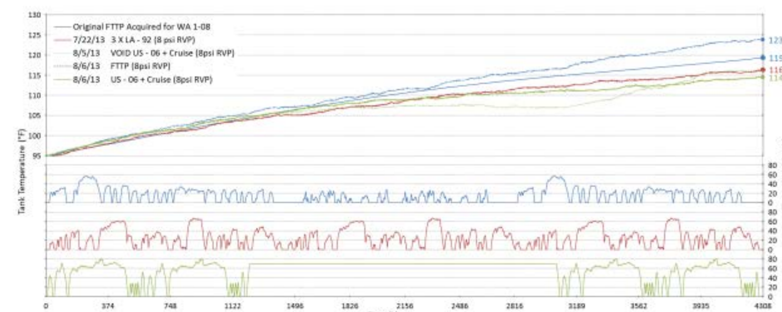
Table 7 - Final average running loss tank vapor venting emission rates

Model year group	TVV mean [g/hr]	
Pre-1971	12.59	
1971-1977	12.59	
1978-1995	11.6	-- Pre-Enhanced (Euro, JP)
1996-2003	0.72	-- Enhanced
2004 and later	0.234	-- Tier 2

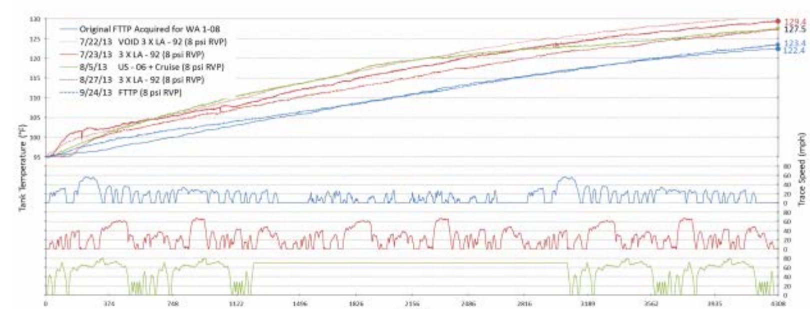
3.4.1 Honda Accord Test Results



3.4.2 Dodge Caravan Test Results

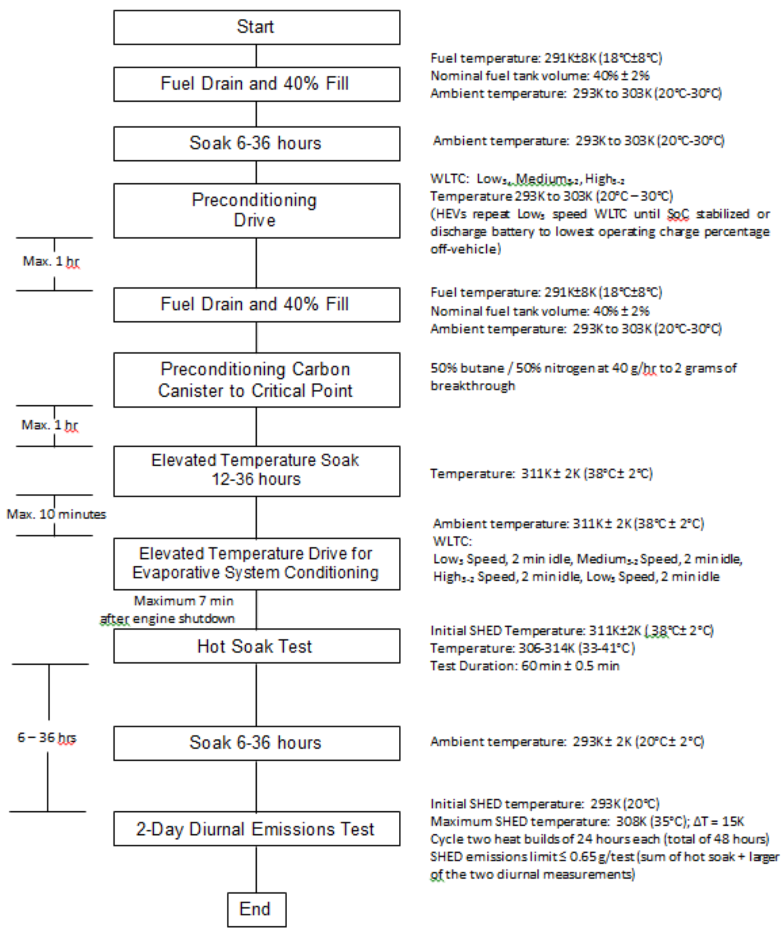


3.4.3 Toyota Corolla Test Results

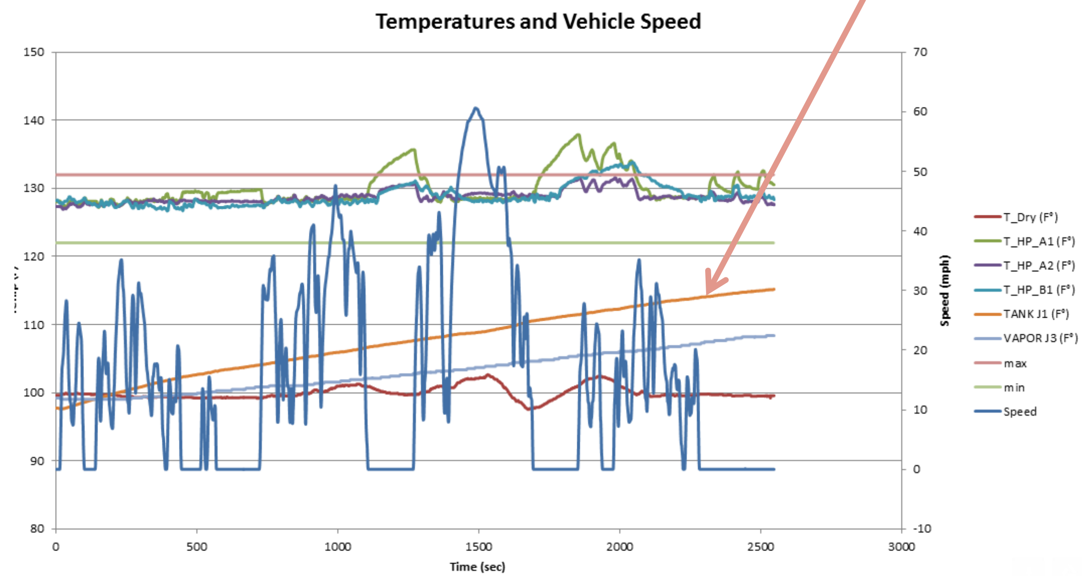


China VI is streamlining by incorporating an elevated temperature soak and drive to indirectly control Running Loss during 30 minute drive-down of 48-hour diurnal + hot soak test with 0.65 g/test limit

Figure F.1a Procedure for determination of evaporative emission for Class 3b vehicles



Fuel tank temperature increased 10 deg C over 30 minutes of WLTC driving at 38 deg C room temperature and over 53 deg C heated road surface



Example: US Tier 2 Toyota Camry

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Permeation and Leak control driven by SHED limit

- Emissions limit value primary factor in reducing permeation and leaks

	Limit
Pre-Enhanced/Japan/Euro 5	2.0 grams/day
Enhanced	2.0 – 2.5 grams/day
Tier 2	0.95 – 1.2 grams/day
LEV II / Tier 2	0.5 – 0.65 grams/day
LEV III / Tier 3	0.300 grams/day

- Permeation reduced from 0.05 g/hr to 0.01 g/hr since Pre-enhanced

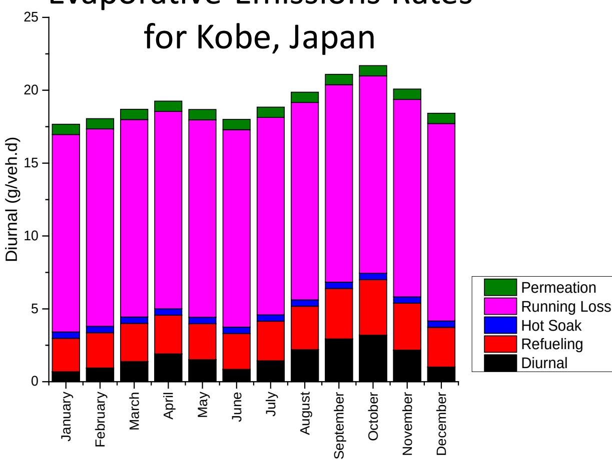
Table 2 - Base permeation rates at 72°F

Model year group	Age group	Base permeation rate [g/hr]
1971-1977	10-14	0.192
	15-19	0.229
	20+	0.311
1978-1995	0-3	0.0554
	4-5	0.0554
	6-7	0.0913
	8-9	0.0913
	10-14	0.124
	15-19	0.148
	20+	0.201
1996	0-3	0.046
	4-5	0.046
	6-7	0.075
	8-9	0.075
	10-14	0.101
	15-19	0.120
	20+	0.163
1997	0-3	0.037
	4-5	0.037
	6-7	0.059
	8-9	0.059
	10-14	0.079
	15-19	0.093
	20+	0.125
1998	0-3	0.015
	4-5	0.015
	6-7	0.018
	8-9	0.018
	10-14	0.022
	15-19	0.024
	20+	0.029
1999 and Newer	0-3	0.0102
	4-5	0.0102
	6-7	0.0102
	8-9	0.0102
	10-14	0.0102
	15-19	0.0102
	20+	0.0102

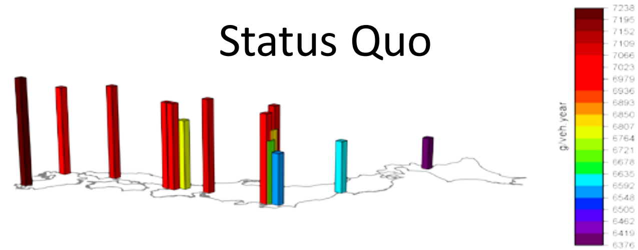
Total Evaporative Emissions in Japan

Status Quo, +ORVR, +Tier 2

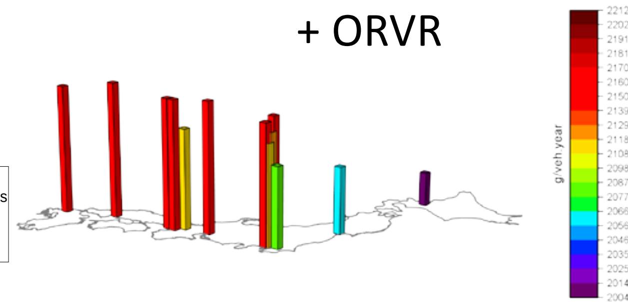
Evaporative Emissions Rates for Kobe, Japan



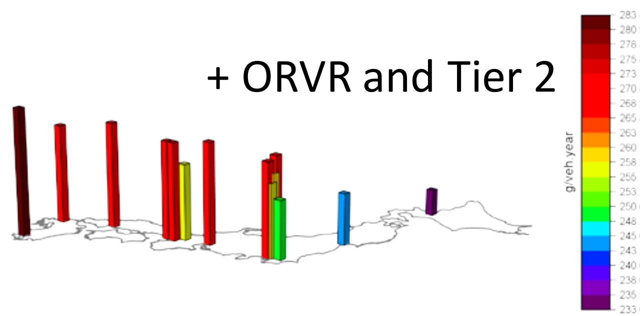
Status Quo



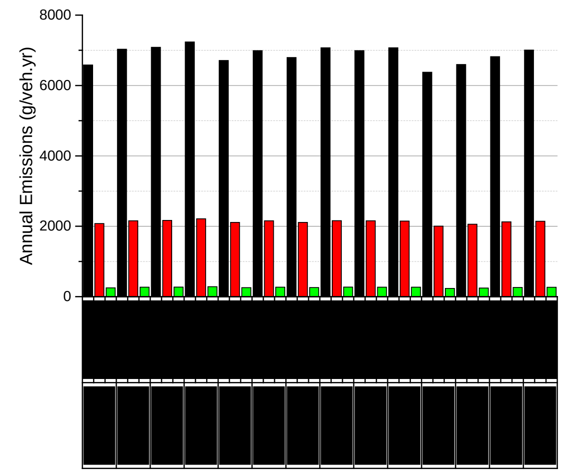
+ ORVR



+ ORVR and Tier 2



Annual Emissions for Japan
Status Quo, +ORVR, +Tier2



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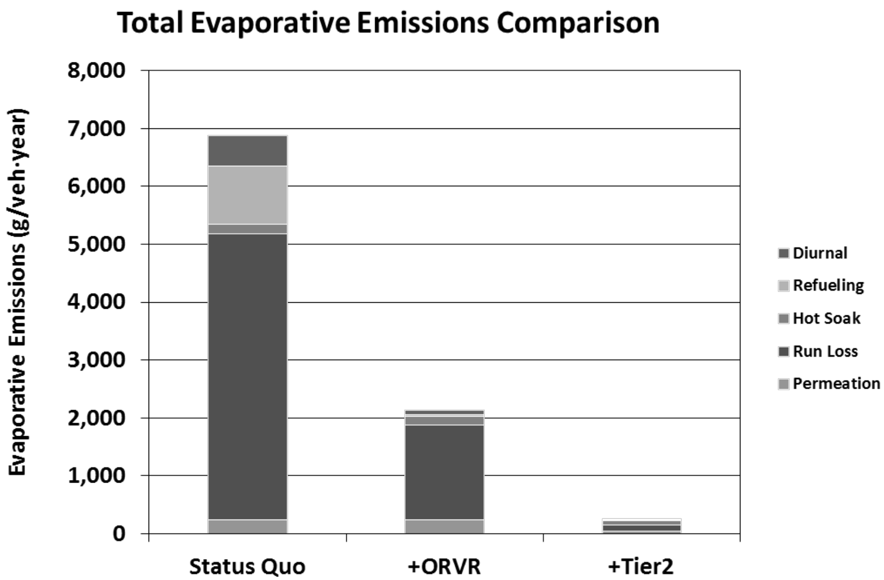
EVA model is consistent with MOVES but does not estimate leaks

-- Average driving speed range evaluated between 27 km/h (Florence) and 58 km/h (US fleet)

- Average parking duration range evaluated between 6.4 hrs (Florence) and 12.8 hrs

Annual Vehicle Evap Emissions Factors for Japan (averaged from sensitivity analysis)



	US EPA Emissions Factors For Same Evap Control Technology Package as China III, IV, V	Japan Estimated Emissions Factors
Diurnal+HS	0.13 g/km	0.06-0.12 g/km
Refueling	0.14 g/km	0.12 g/km
Running Loss	0.24 g/km	0.20-0.44 g/km
Permeation (Resting)	0.04 g/km	0.03 g/km
Leaks, spillage, other	0.21 g/km	Not Estimated
TOTAL WITHOUT LEAKS, SPILLAGE, OTHER	0.55 g/km	0.41-0.69 g/km
TOTAL ALL	0.76 g/km	0.41-0.69 g/km

$$\textit{Running Loss} \propto \frac{1}{\textit{ave speed}} \text{ because of time on road}$$

$$\textit{Diurnal} \propto \textit{ave speed} \text{ because of time to purge}$$

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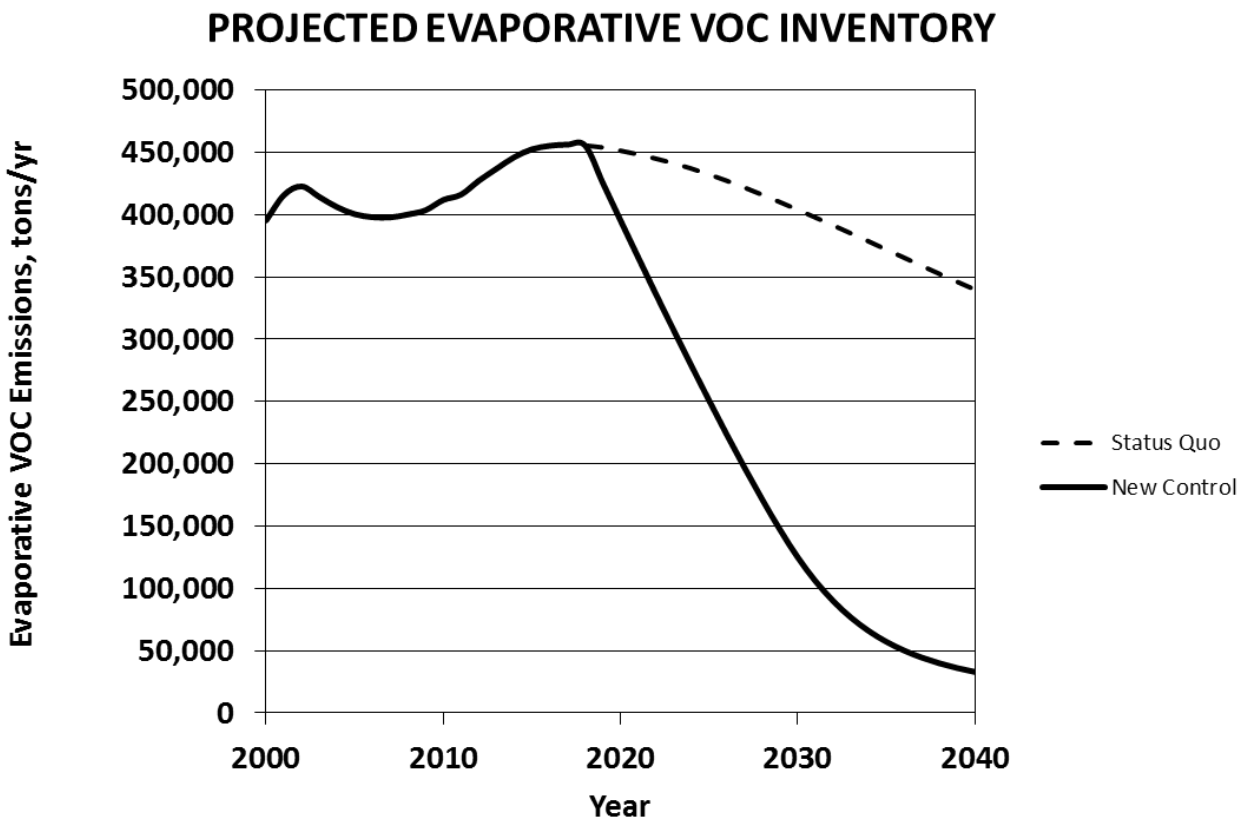
EVA model estimates Japanese vehicles producing 7 kg/yr of VOCs, resulting in an inventory of 425,000 tonnes



Summary

- Primary benefit from increasing purge rate and canister capacity
  - ORVR provides refueling control and maximizes canister capacity for diurnal/running-loss control
  - Purge rates maximized with reduced drive-down time and with increased canister capacity
- Incorporating Running Loss conditions into procedures ensures this large source of emissions is minimized
  - China VI utilizes a streamlined procedure that reduces testing burden
- Permeation and leaks are minimized by reducing SHED diurnal limits
  - US has reduced limits from 2 g/test (1995) to 0.5-0.65 g/test (2004 Tier 2) to 0.3 g/test (2017 Tier 3)
- Opportunity to cut VOC emissions in Japan by 400,000 tonnes/yr

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