The EANET webinar workshop for emission inventory of VOCs and its application for policy consideration

VOCs Emissions from Road Transport

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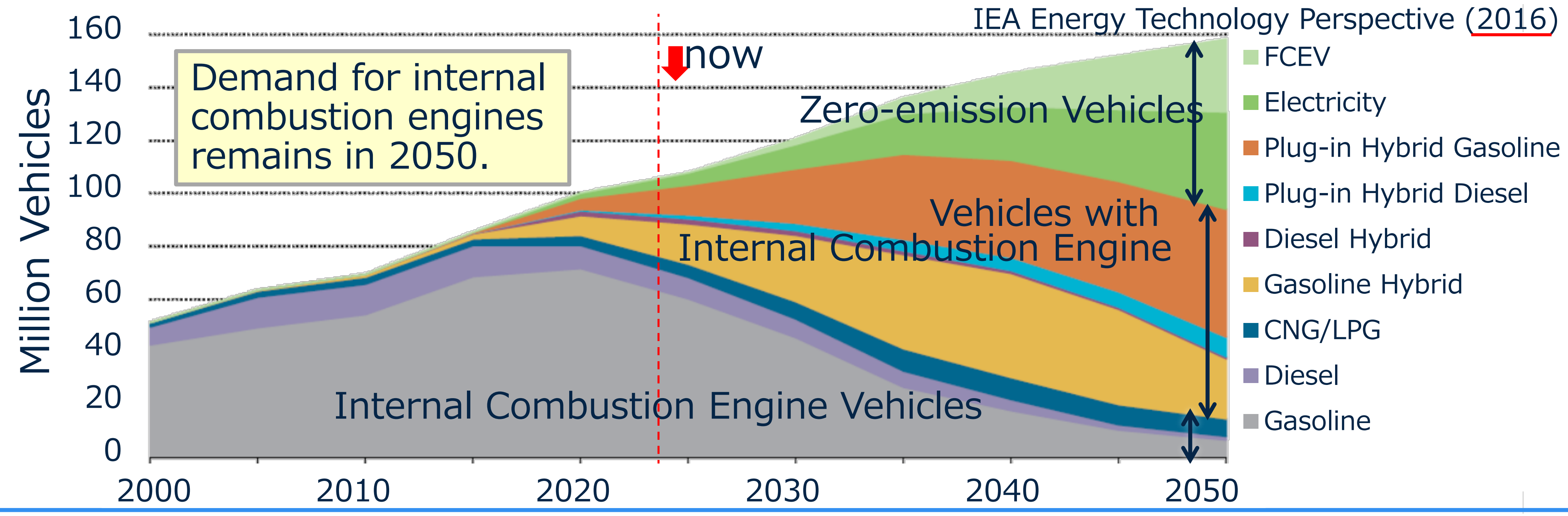
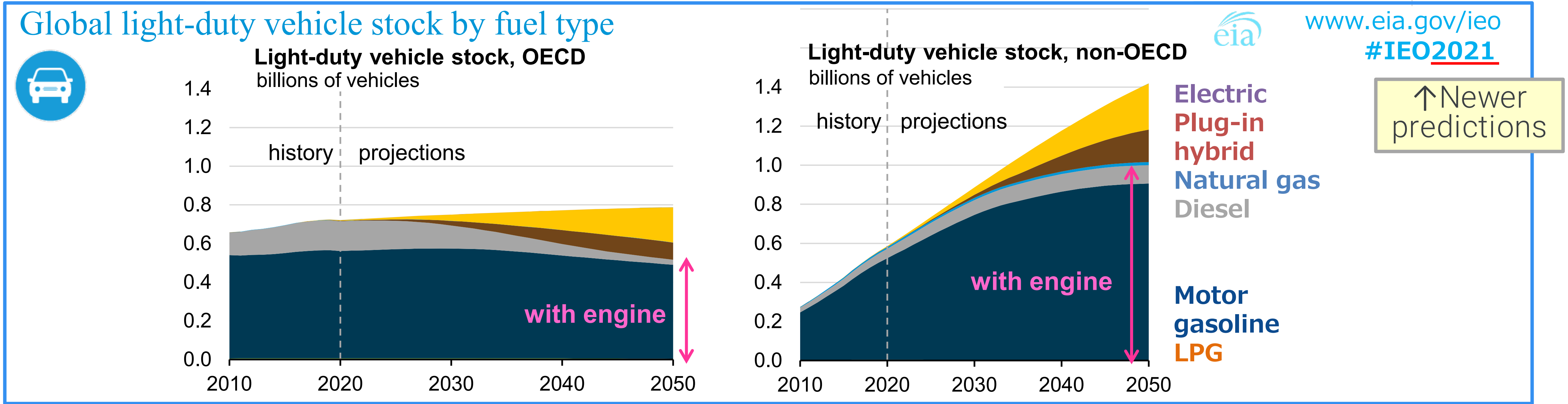
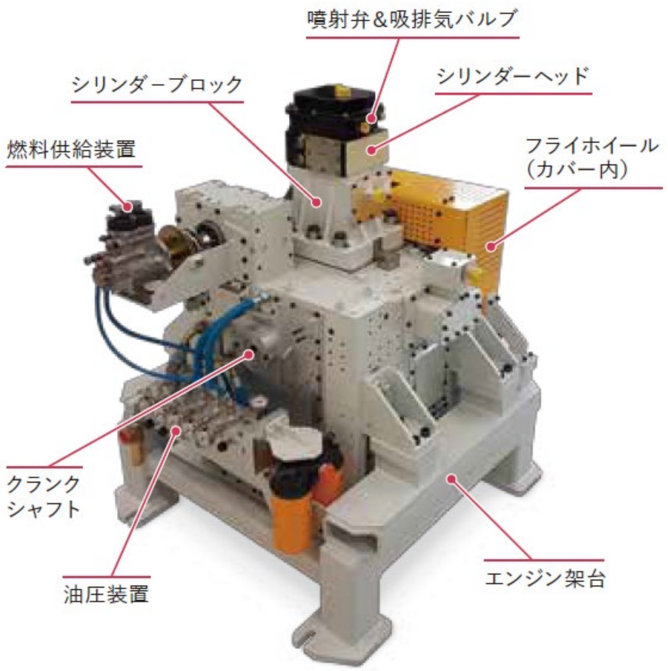
Global Changes in Passenger Cars





Global Changes in Heavy Duty Vehicles

- Electric Vehicle (EV)
- Fuel Cell Vehicle (FCV)
- Hybrid or Plug-in Hybrid Electric Vehicle
- Natural Gas or H_2
- e-fuel, bio-fuel
- High Efficiency New Diesel Engine



What is the best?

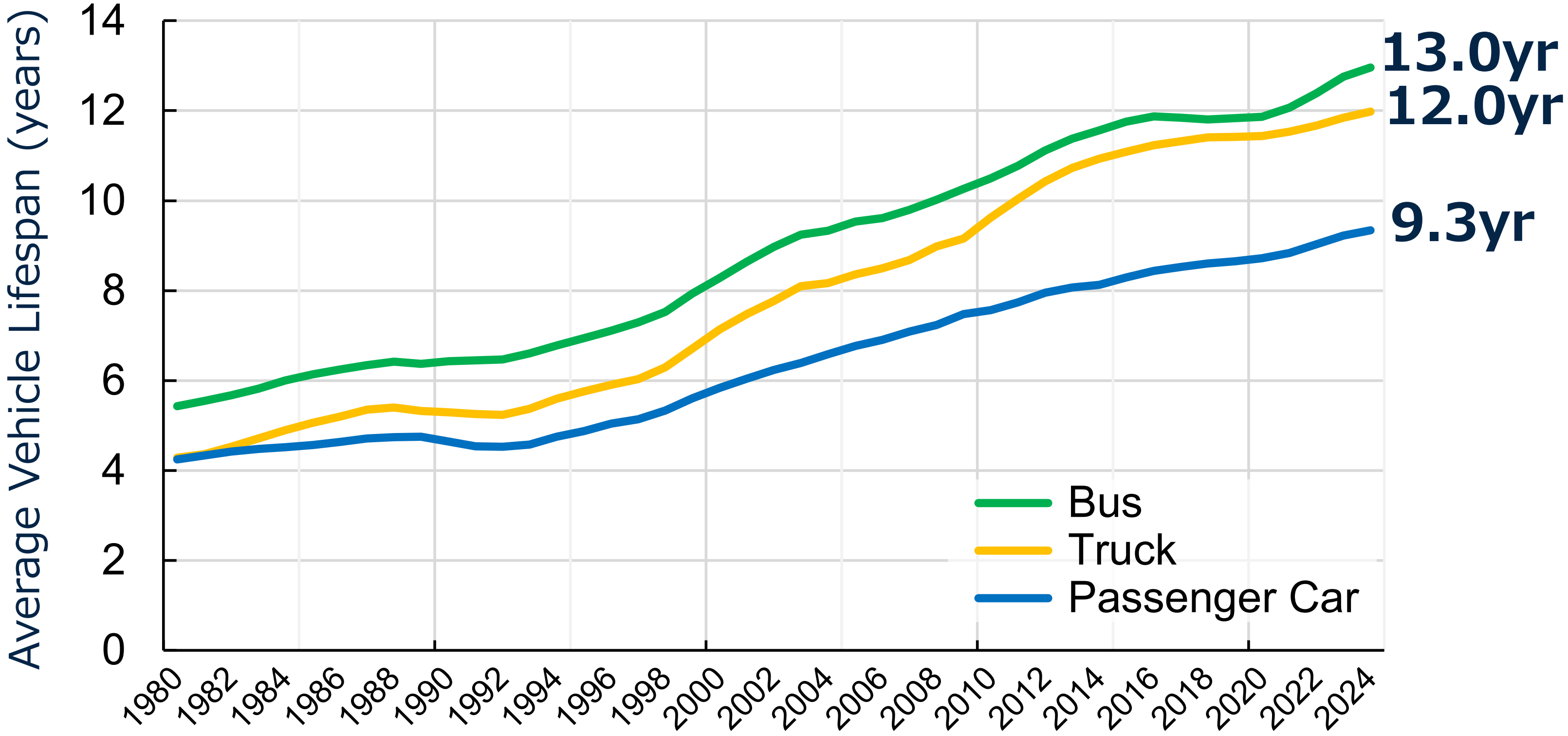
Passenger Car Electrification Targets of Various Countries

Japan: 100% electrified vehicles in passenger LDV sales by 2035 (2021 announcement)
Thailand: 100% share of ZEVs in new car sales by 2035. (2021 announcement)

⋮

Even after the end of internal combustion vehicle production or sale, vehicle equipped with engines will continue to exist and emissions of CO_2 and air pollutants will continue for some time.

Example: Trends in the Average Lifespan of Vehicles in Japan



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Air Pollutants Emitted from Vehicles

Diesel Vehicles

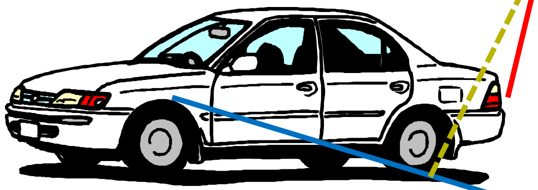
Tailpipe Emissions

- **Running Emissions**: Emissions from tailpipe during vehicle operation. **RE**
- **Start Emissions**: Increased exhaust emissions from engine start to warm up. **SE**

Non-exhaust Emissions (PM)

Brake dust, Tire wear, Re-suspension Emissions

Gasoline Vehicles



Evaporative Emission

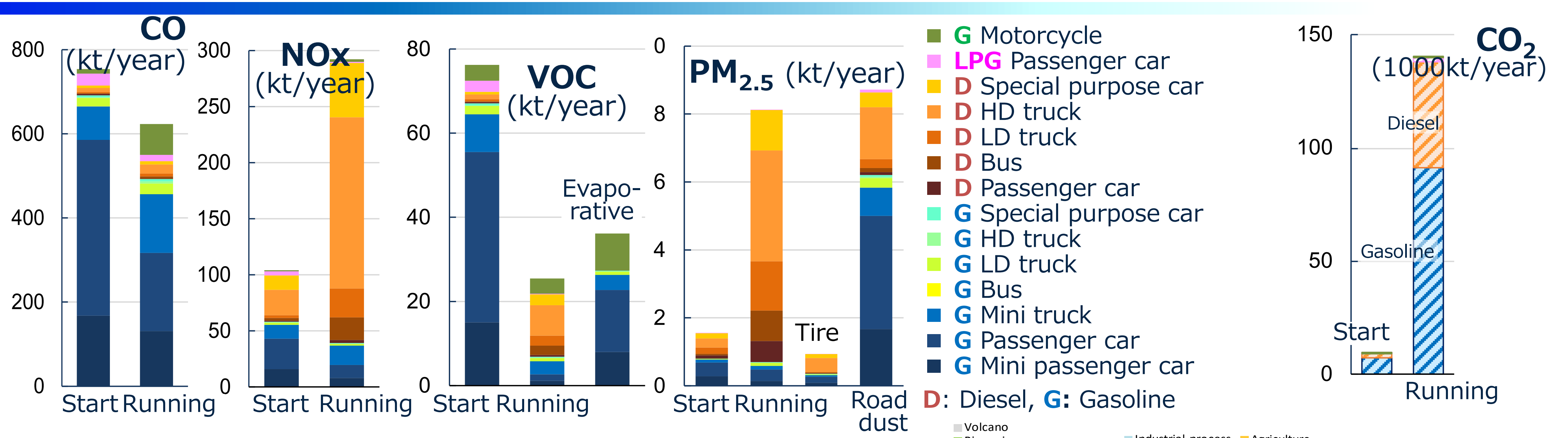
- **Hot Soak Loss**: **HSL**
- **Diurnal Breathing Loss**: **DBL**
- **Running Loss**: **RL**

Emissions are calculated by multiplying the basic Emission Factor(**EF)** by the amount of activity, but various correction factors are needed to bring emissions closer to those in the real environment.

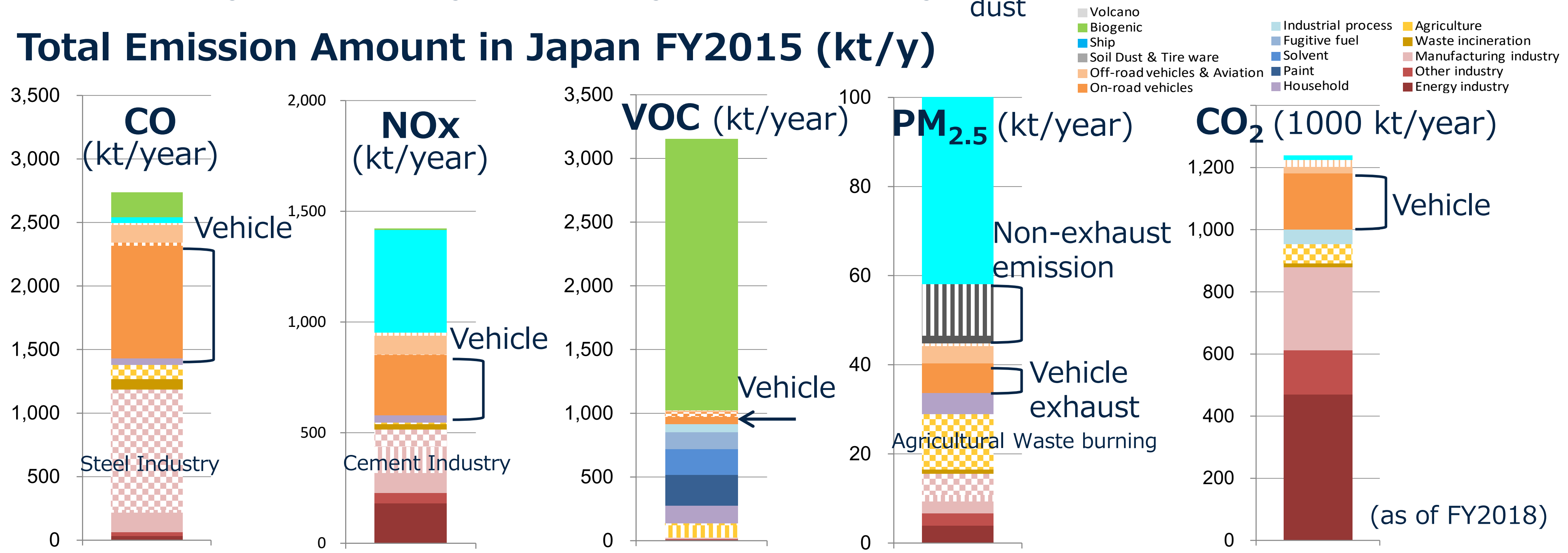
Characteristics of the Gasoline and Diesel Vehicles

	Gasoline Vehicle	Diesel Vehicle
Fuel and its characteristics	Gasoline, Flash point -40℃, ignition point 300℃, easy to evaporate and need to pay attention to evaporative emission.	Light Oil, Flash point +45~70℃, Ignition point 250℃. Low vapor pressure, no evaporative emission.
Combustion mechanism to extract power	Compress air/gasoline mixture and ignite with spark (Premixed combustion, 2000 °C).	Compresses only air and directly injects light oil to self-ignite (diffusion combustion, 800-1000 °C).
Characteristics of combustion and raw exhaust gas	Stoichiometric combustion, air:fuel = 1:1. O_2 is not included in the exhaust gas. Prone to incomplete combustion, high CO concentration. High NOx emissions due to high combustion temperature, but most are NO.	Lean burn, air is excess than fuel. O_2 is included in the exhaust gas. There is nonuniformity in the mixed state of fuel and air, and unburned fuel tends to be PM. CO is low. NOx emissions are lower than gasoline vehicles. Exhaust gas includes 10% NO_2 because O_2 is in the exhaust gas.
After treatment device	Three-way catalyst can be used because there is no O_2. CO and VOC → Using O of NOx, CO and VOC are oxidized to CO_2 and H_2O. NOx → NOx is reduced to N_2.	Three-way catalyst cannot be used because of O_2 included in exhaust gas. EGR is used to reduce O_2 in the air and reduce NOx production. Oxidation catalyst oxidizes VOC and PM. NOx is reduced by SCR and PM is collected by DPF.
Power	High speed, compact engine, easy to control, suitable for passenger cars.	Low speed torque is large and suitable for trucks.

Estimated Emissions from Vehicles in Japan (as of FY2015)



Total Emission Amount in Japan FY2015 (kt/y)



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Japanese Emission Factors for Running Emission

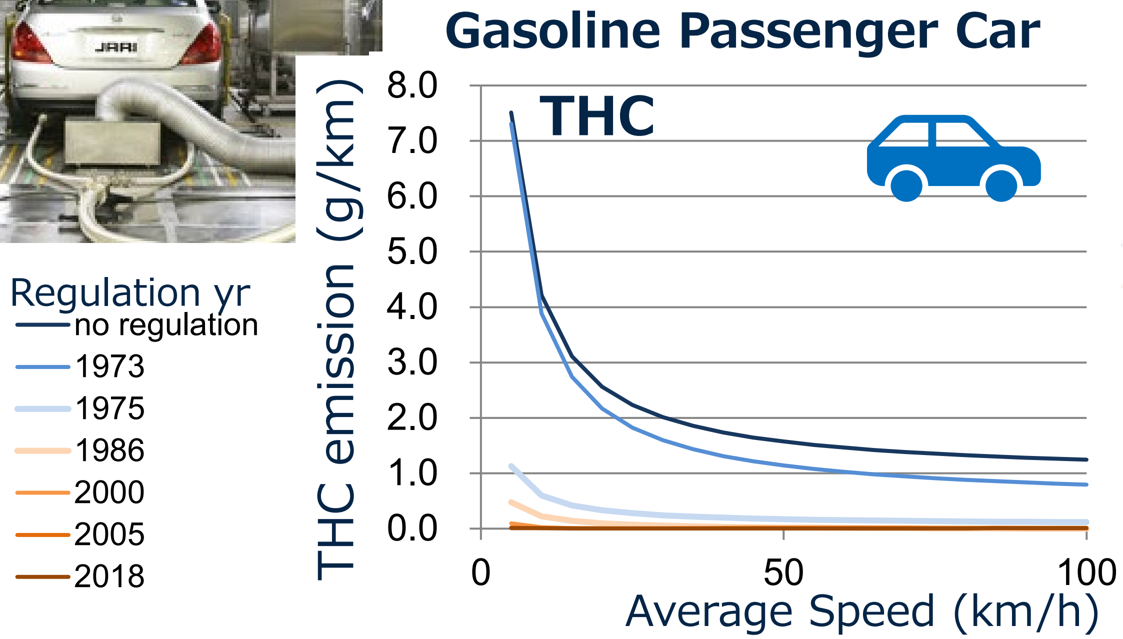
All Emission Factor EF is expressed by the function of average speed:

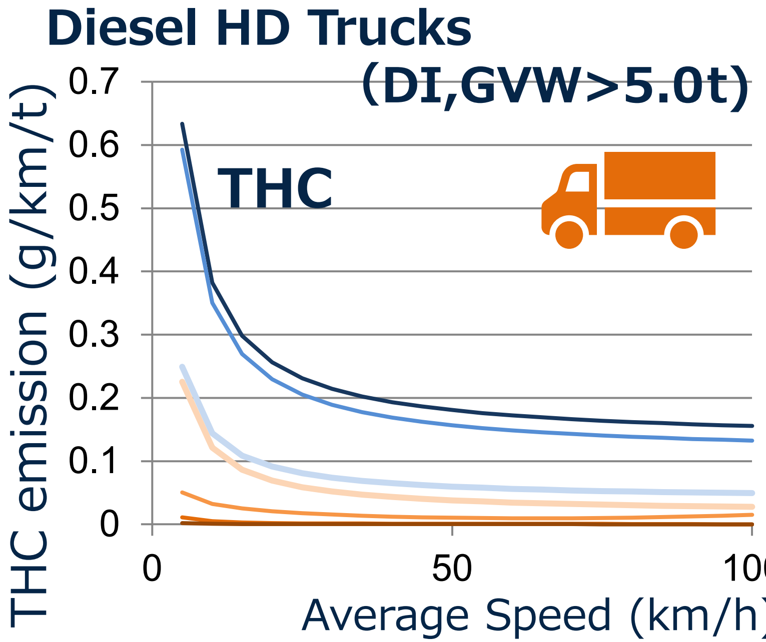
$$EF = a + b/V + c \cdot V + d \cdot V^2$$

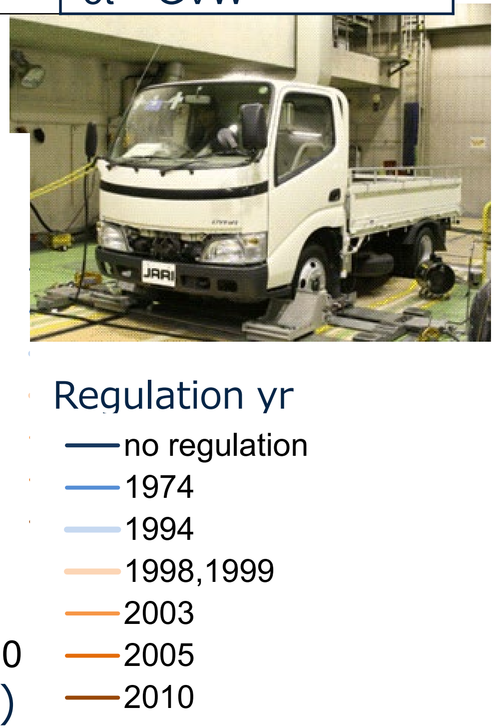
V: Vehicle average speed for short trip
a,b,c,d: Constants

Velocity-dependent emission factors for CO, NOx, PM, THC (NMHC), NH_3, and CO_2 are provided by 13 Vehicle types and regulation years.

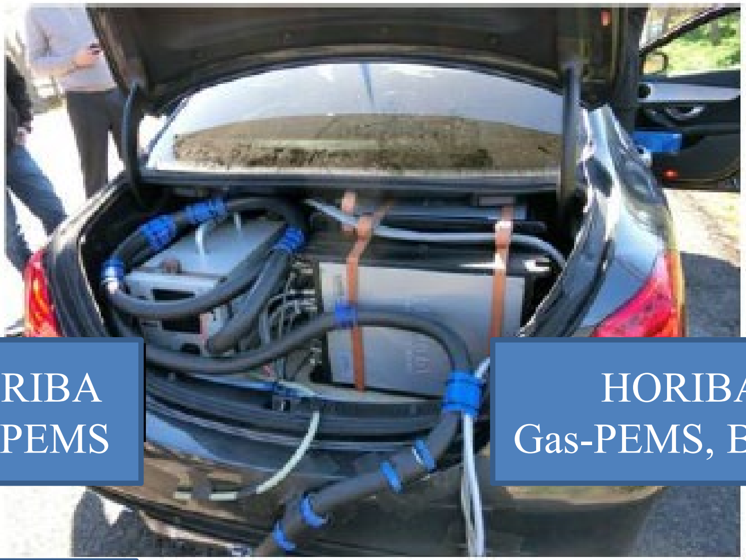
Vehicle type	Fuel Type	Vehicle weight
Mini-Passenger-Cars	Gasoline/LPG	
Small Passenger-Cars	Gasoline/LPG, Diesel	IW <= 1.25t
Middle Passenger-Cars	Gasoline/LPG, Diesel	IW >1.25t
Mini-Cargos	Gasoline/LPG	
Light-Duty-Trucks	Gasoline/LPG, Diesel	GVW <= 1.7t
Medium-Duty-Trucks	Gasoline/LPG, Diesel	1.7t < GVW <= 3.5t
Heavy-Duty-Trucks	Gasoline/LPG, Diesel	3.5t < GVW
Heavy-Duty-Trucks	Diesel	3.5t < GVW <= 5t
Heavy-Duty-Trucks	Diesel	5t < GVW

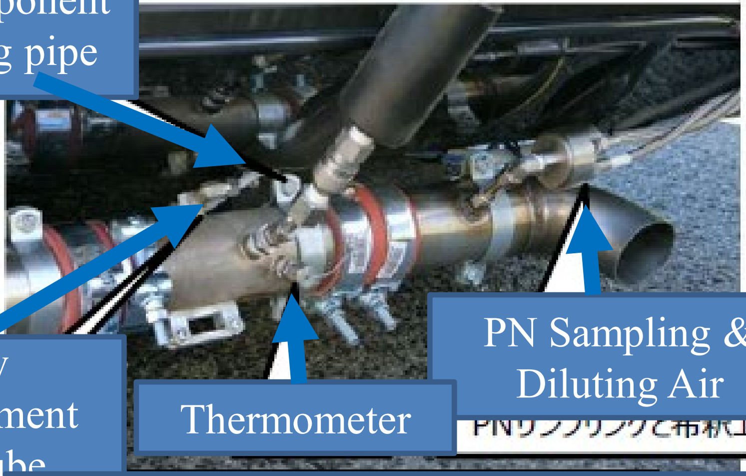




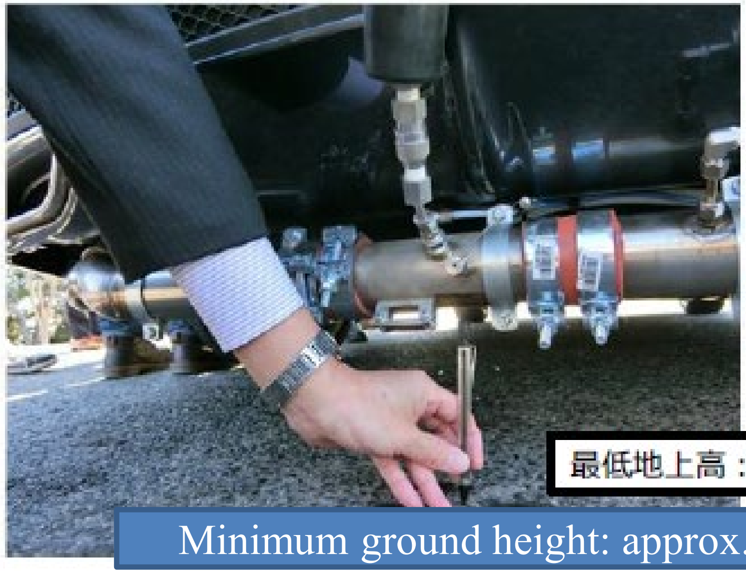


Real Driving Emission Exams





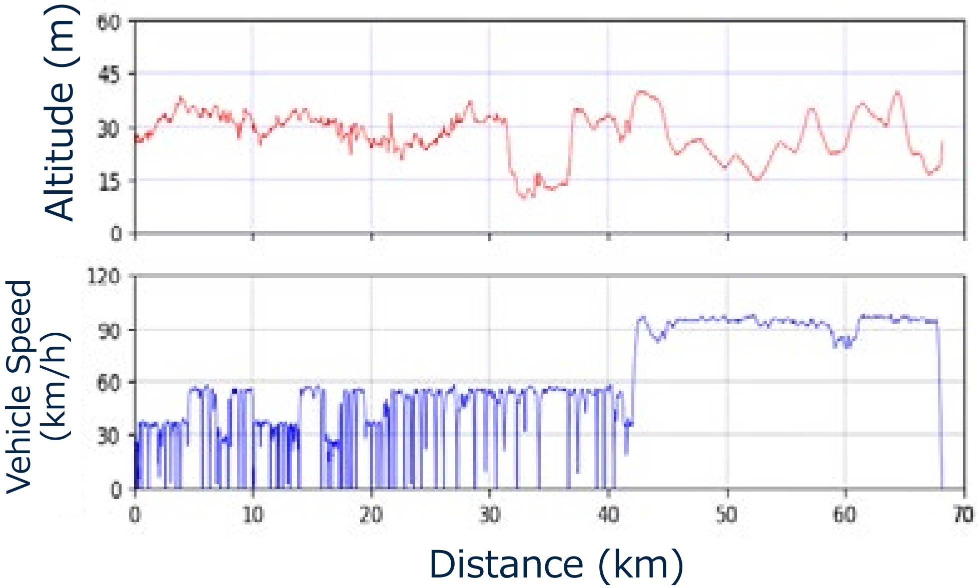
Made by PEMS manufacturer: Select diameter depending on exhaust flow rate



Minimum ground height: approx. 12cm

Legal requirements for domestic RDE exams

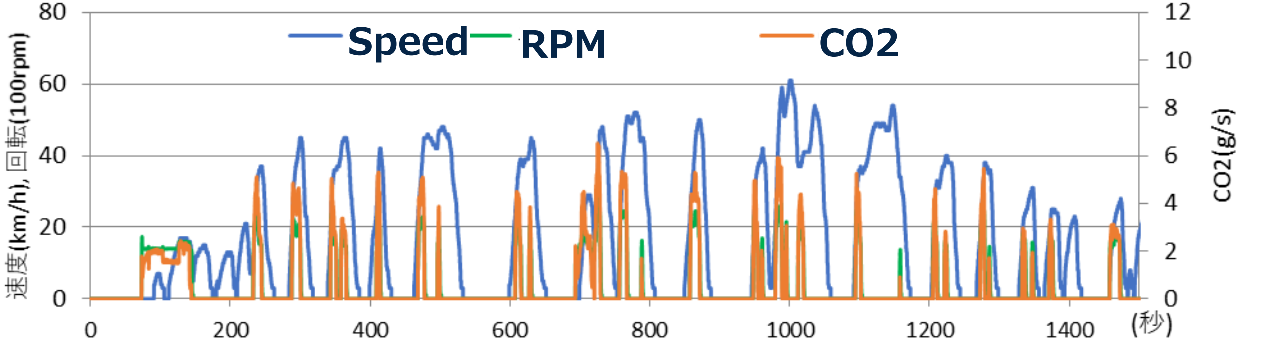
classification	Exam requirements
①Low speed (instantaneous speed **0** to **40km/h**)	**20-35 %**
②Medium speed (instantaneous speed **40** to **60km/h**)	30 ±**10%**
③High speed (instantaneous speed **60km/h** ˜)	45 ±**10%**
Downtime percentage	**7~36%**
elevation	Less than 1000 m

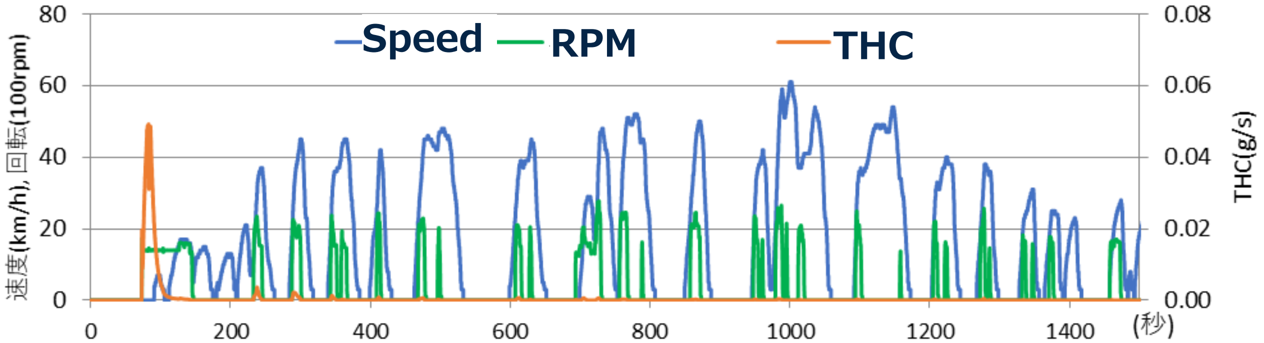


Example of driving route for RDE test

Time series of THC emissions

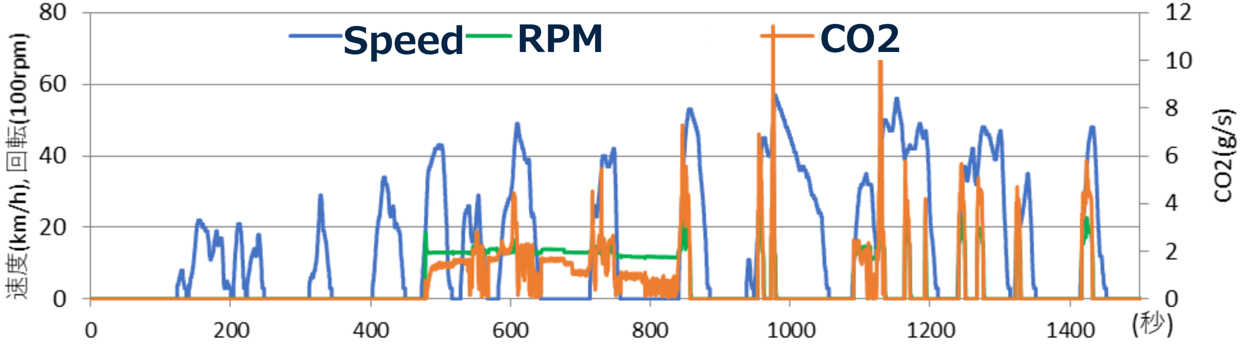
Gasoline Hybrid Passenger Car

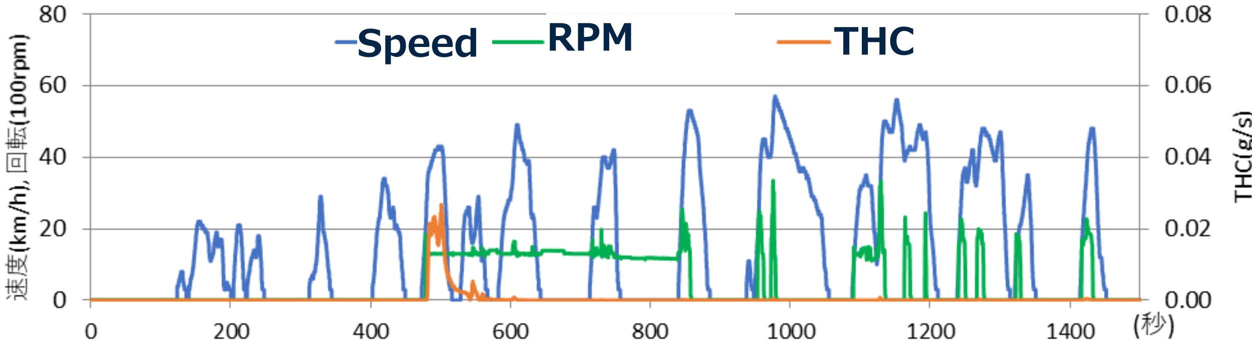




Engine Start

Gasoline Plug-in Hybrid Passenger Car





Motor **Engine Start**

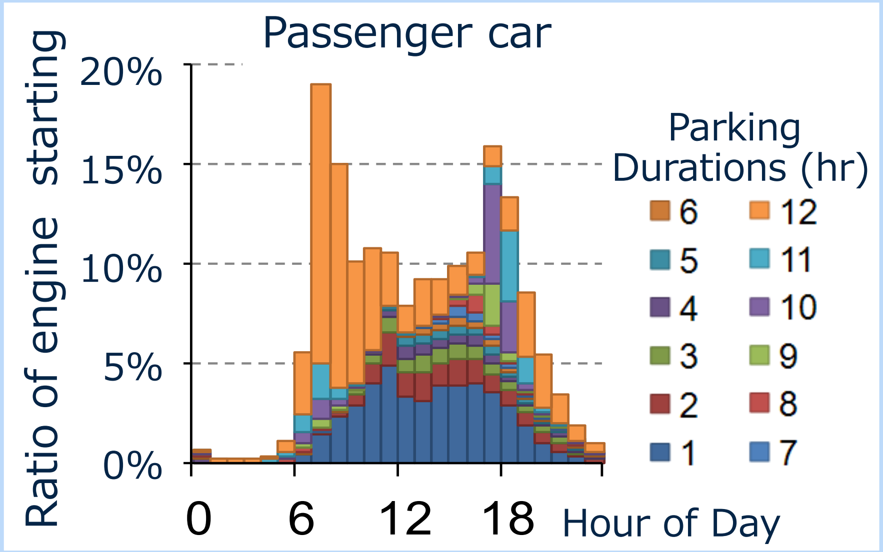
Increased emissions at start-up

Gasoline vehicles emit almost exclusively during start-up

Start-up emissions are affected by engine and Exhaust gas aftertreatment devices' temperatures.

Starting Emission Estimation and Correction Factors

- ✓ Emission factor for ST is defined as emissions per engine start.
- ✓ For engine starting time in a day, the survey results of engine starts by vehicle type is used.



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Evaporative Emission from Gasoline Vehicles

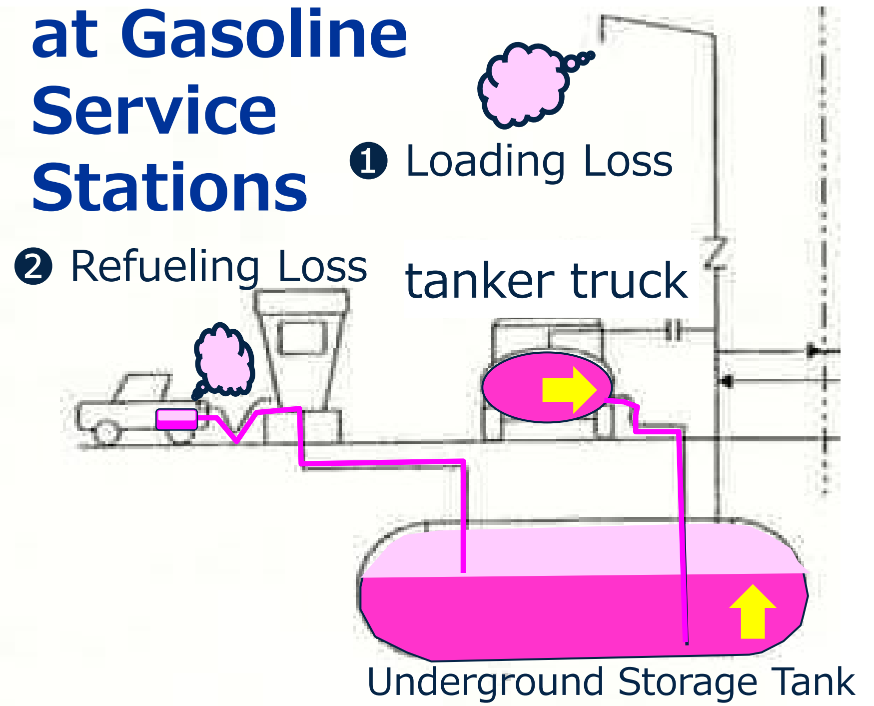
From Gasoline Vehicles

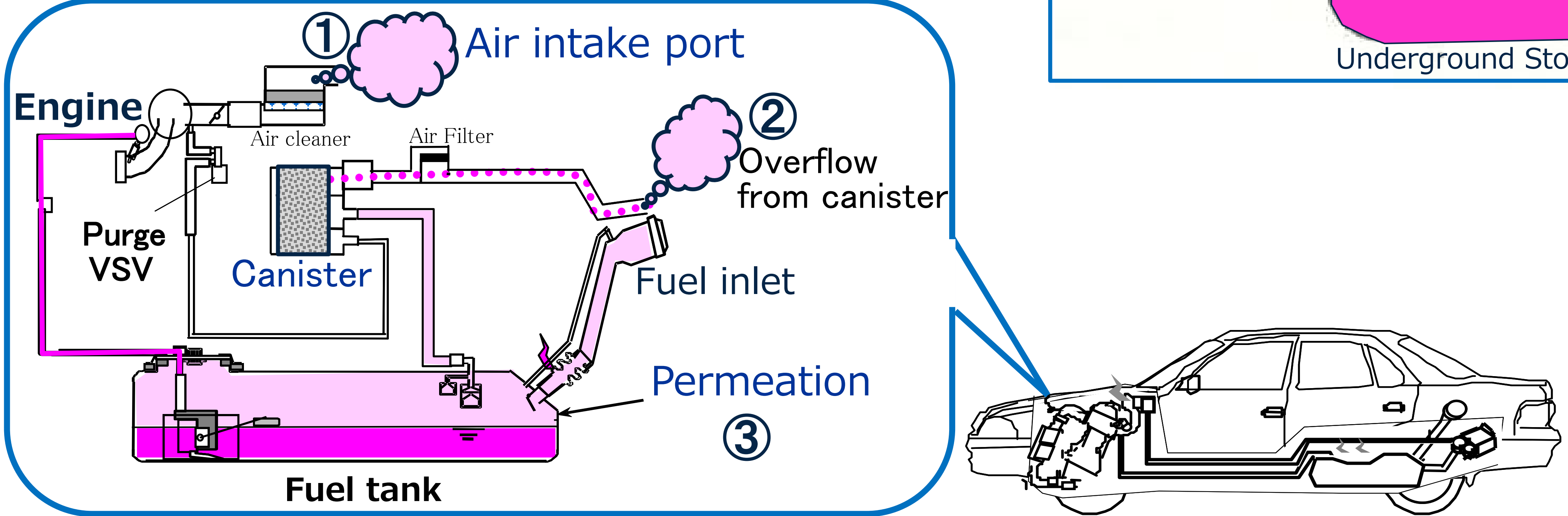
① **Hot Soak Loss** VOC emissions from within 1 hour after engine stop

② **Diurnal Breathing Loss** VOC emissions from fuel tank breathing

③ **Running Loss** VOC emissions while driving

at Gasoline Service Stations



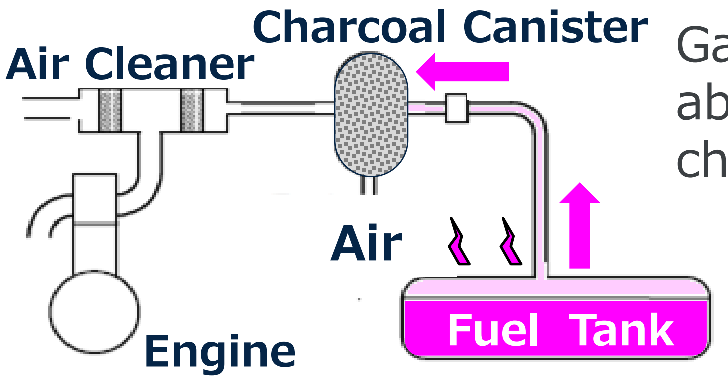


DBL (Diurnal Breathing Loss) Mechanism

①Before charcoal canister "Breakthrough" **Emission is Low**
: permeation from fueling system

②After charcoal canister "Breakthrough" **Emission is High**
: direct evaporation from fuel tank

① Before "Breakthrough"

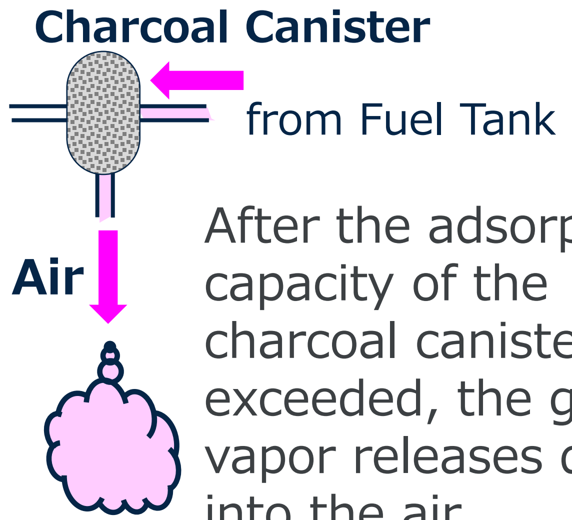


Gasoline vapor is absorbed into the charcoal canister.

Gasoline vapor generated during the daytime.

The leakage of fuel from the fuel tank and piping is continuous.

② After "Breakthrough"

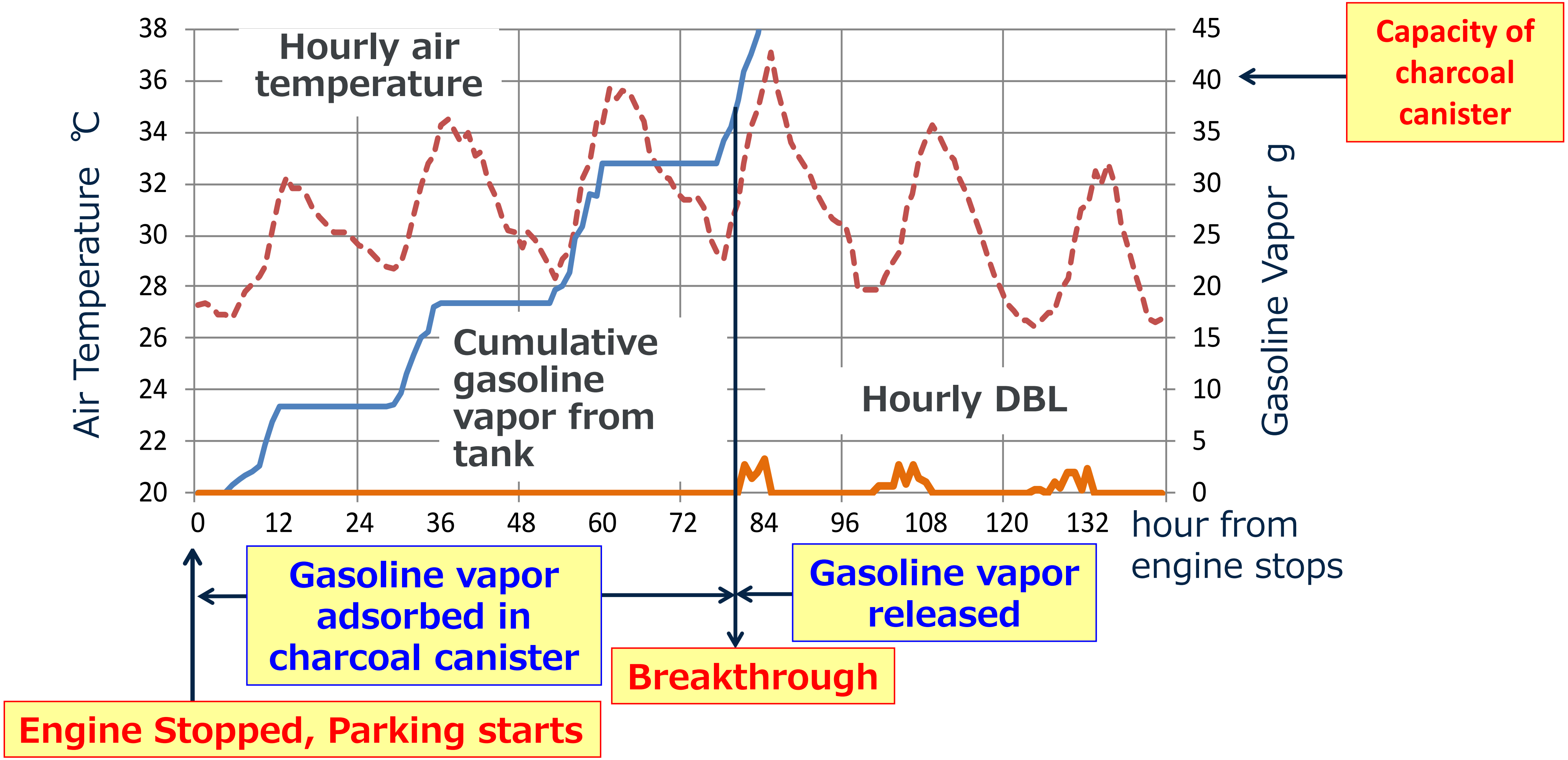


After the adsorption capacity of the charcoal canister is exceeded, the gasoline vapor releases directly into the air.

KEY WORDS: Gasoline vapor pressure, Daily temperature range, Parking duration

Example of DBL Estimation of a Passenger Car

Example: Charcoal canister capacity: 40 g



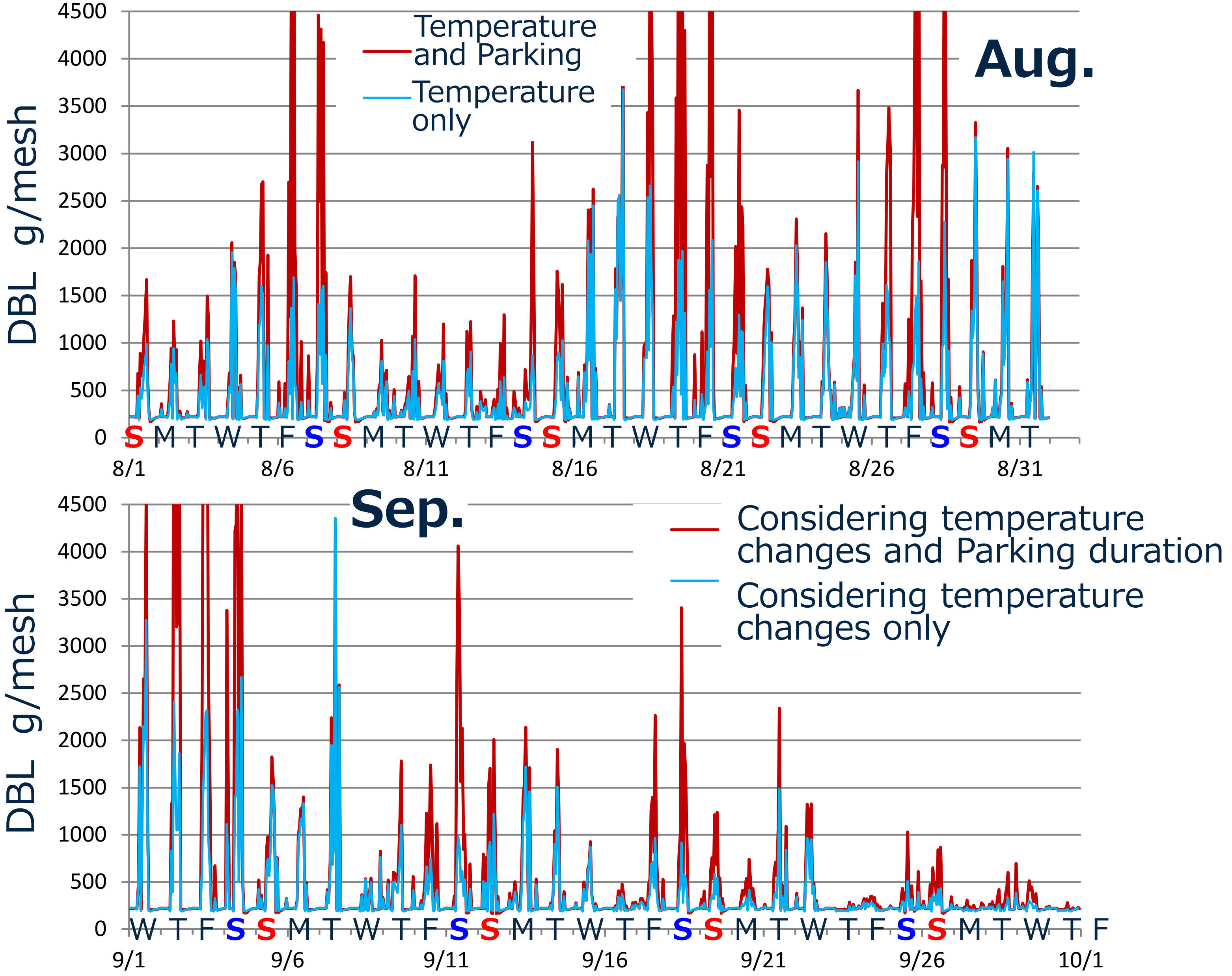
DBL Estimation Considering Parking Duration Hours

In Tokyo, many families do not drive on weekdays but use their cars on weekends.

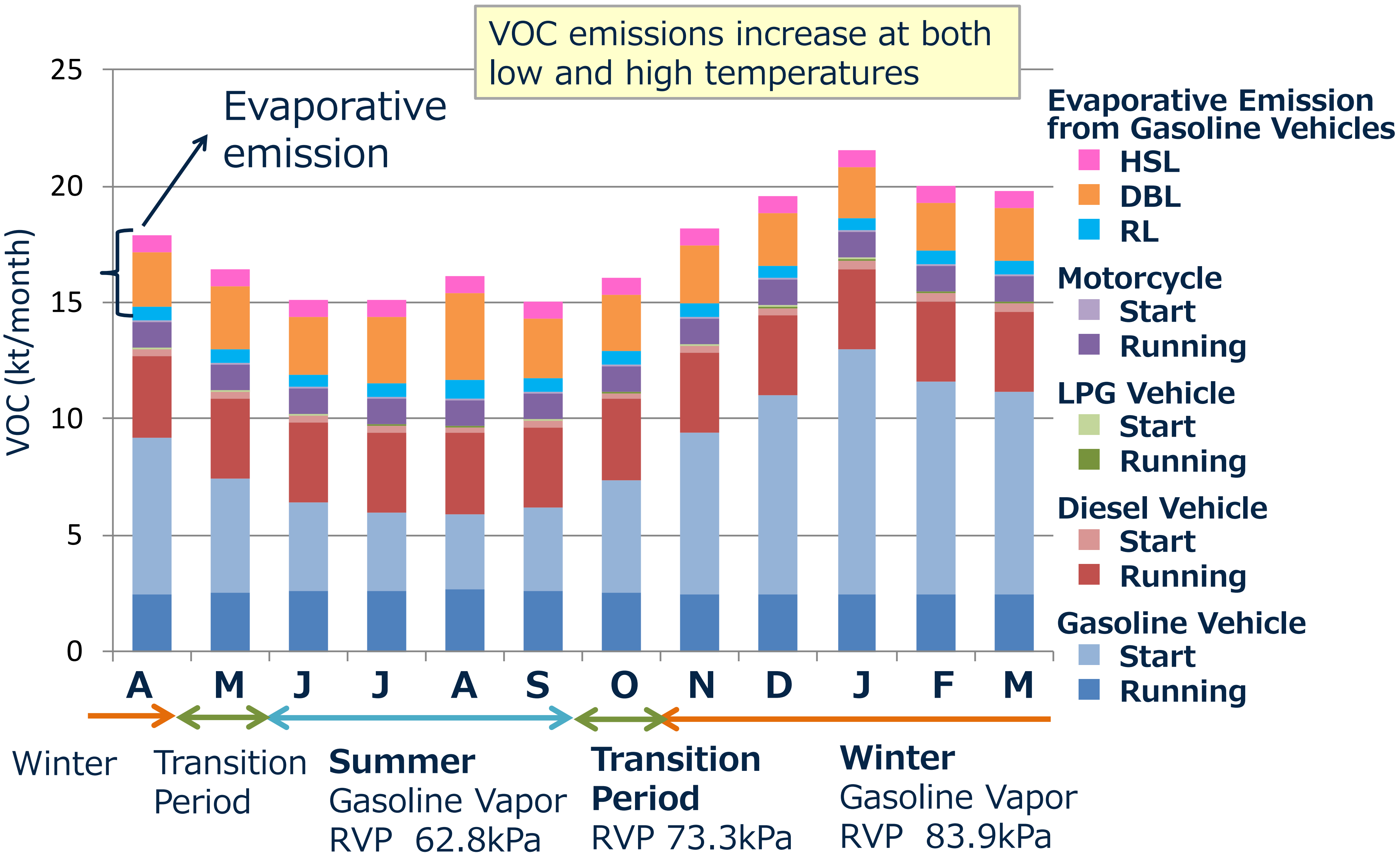
DBL emissions especially increase over the weekend in Tokyo.

However, this trend does not exist in suburban areas where people use their cars every day.

Time dependent DBL emission (in the Center of Tokyo, ca. 1km x 1km)



Monthly VOC Emissions from Vehicles in Japan



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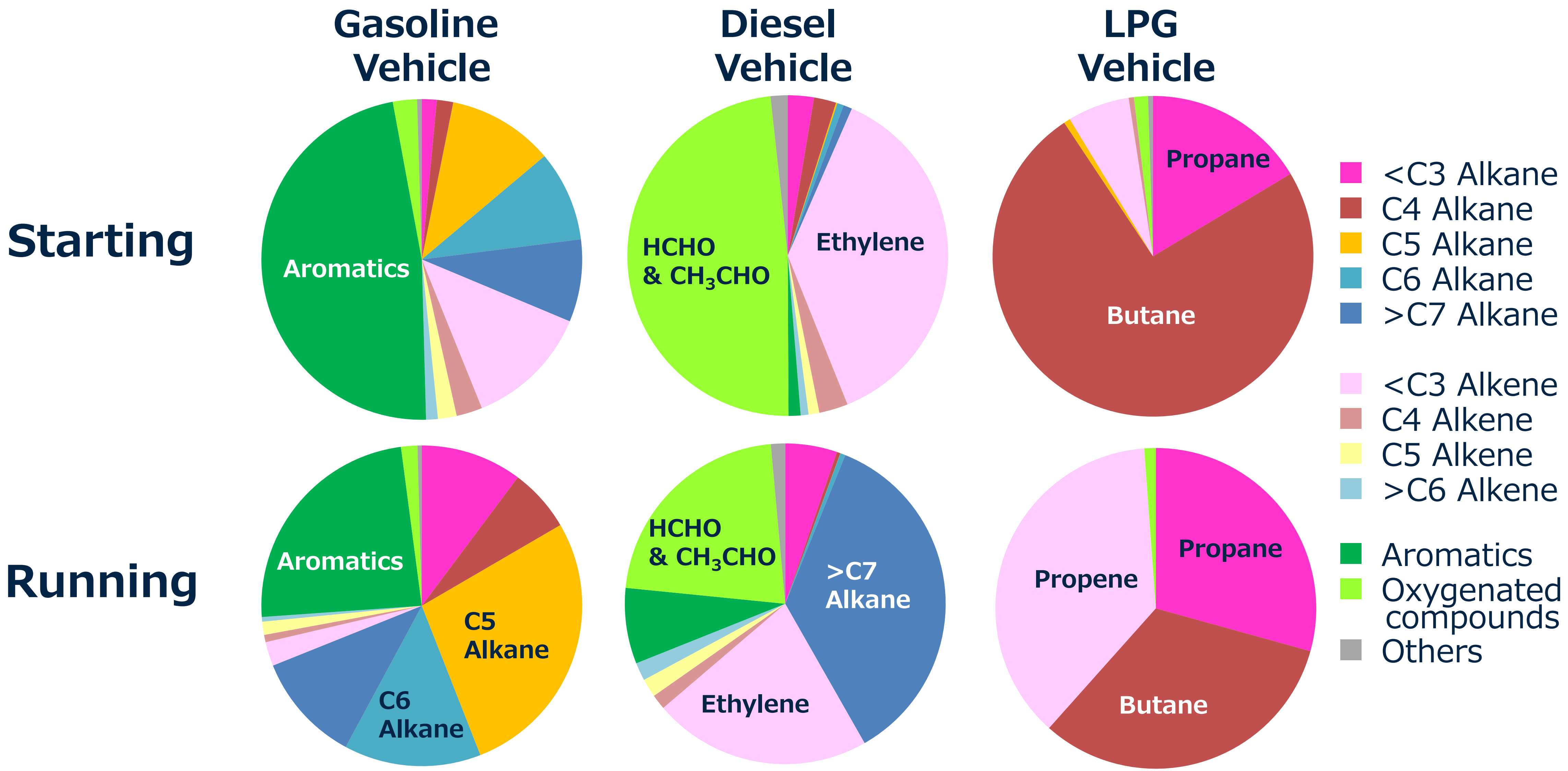
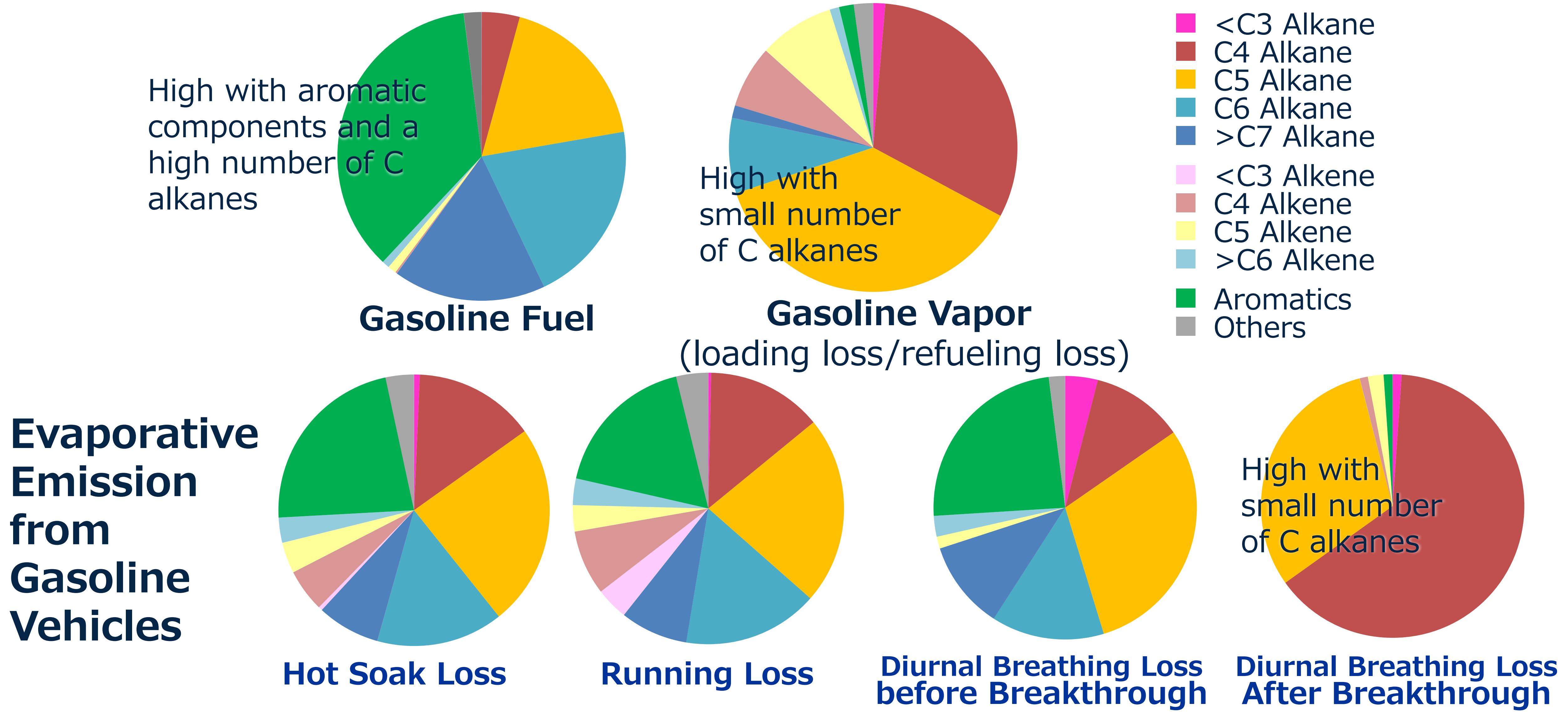
VOC Composition by emission process - 1 Tail Pipe Emission



VOC components vary depending on the fuel and combustion method.

VOC Composition by Emission Process -2 Gasoline Evaporative Emission



Depending on the evaporate process, components of evaporated VOCs are completely different.

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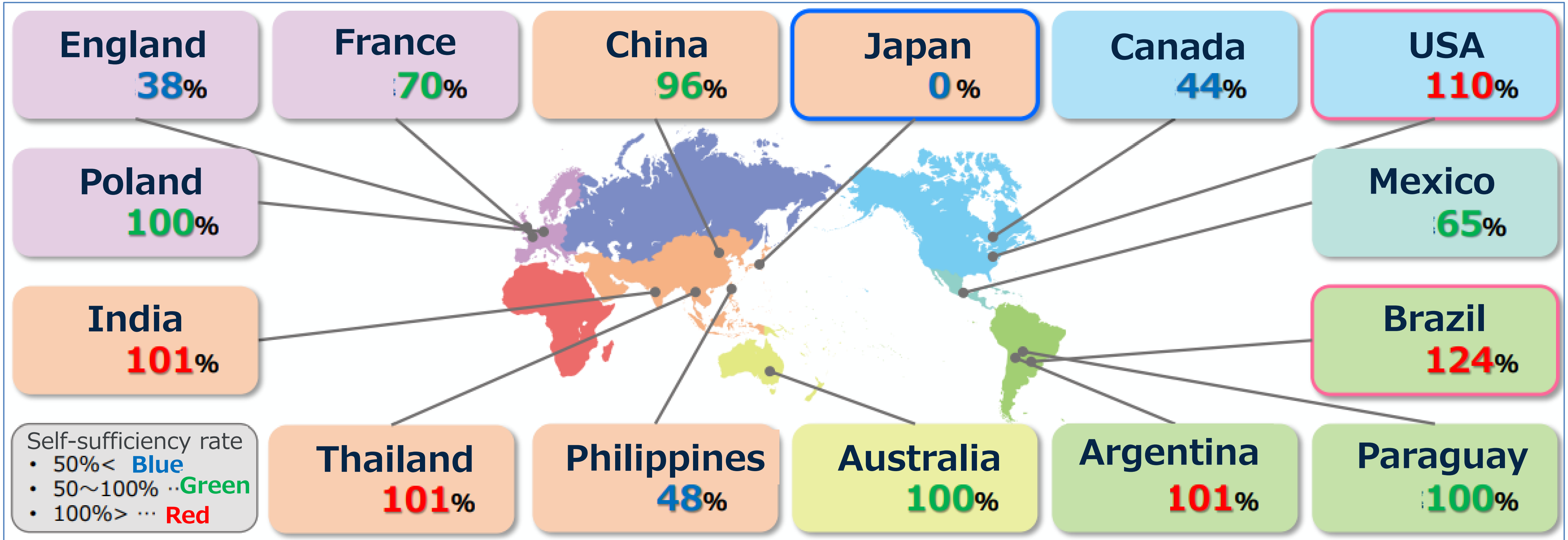
Blending Bioethanol into Gasoline

- ✓ It will take a considerable amount of time before carbon-neutral **e-fuels** are commercially available.
- ✓ Until then, one measure to reduce CO_2 emissions is to mix **bioethanol**.
- ✓ However, there are reports that ethanol blended fuels can increase **vapor pressure** and **formaldehyde** emissions.

Self-sufficiency rate of bioethanol for vehicles



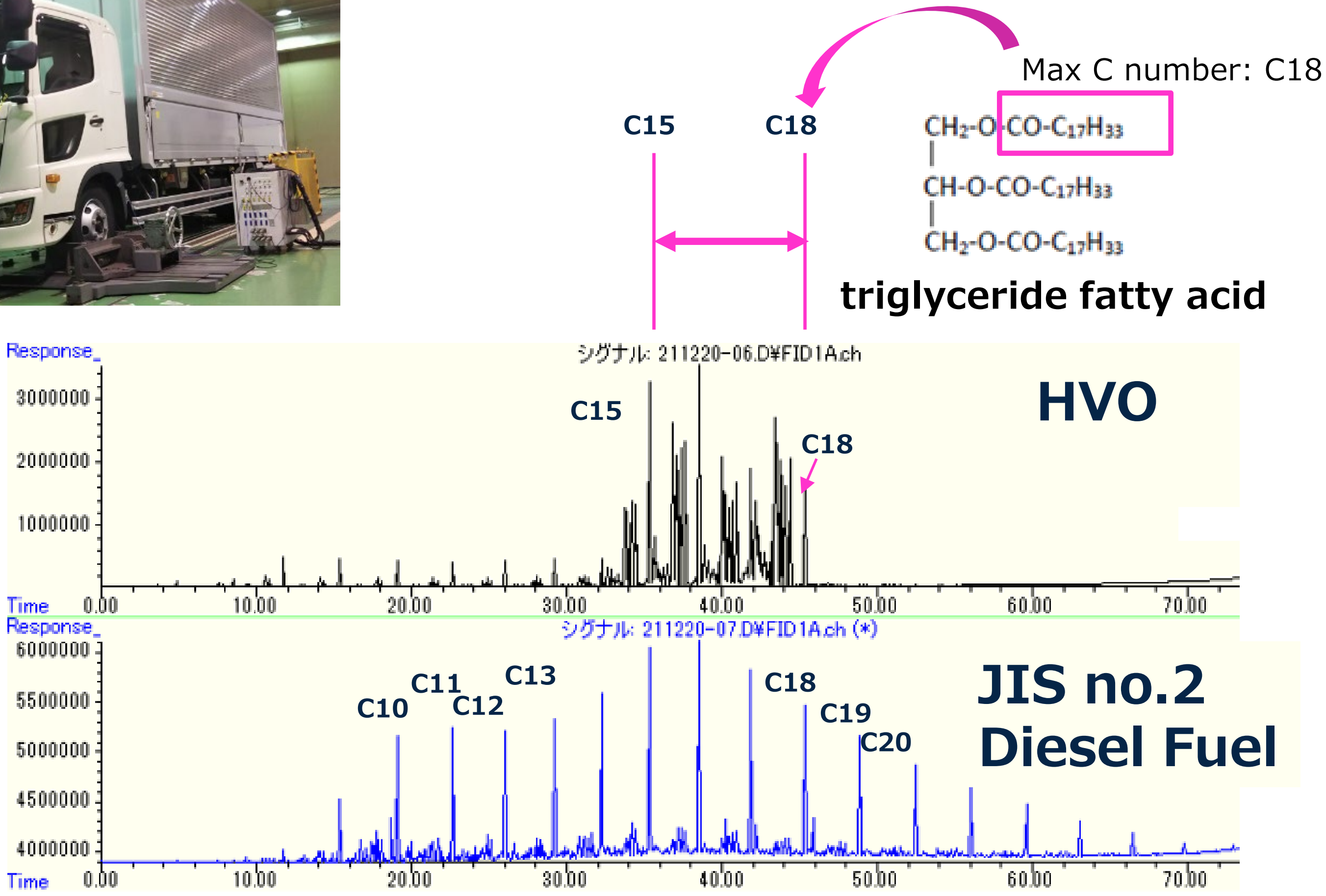
（出典）三菱総合研究所調査データを基に、資源エネルギー庁作成（各種公表データ（主に2023年値）から、①エタノール国内生産量、②エタノール国内消費量をそれぞれ調査し、その割合（①÷②）をエタノール自給率として算出）

Example of Diesel Vehicle Exhaust Gas Using e-fuel

https://www.env.go.jp/air/report/r03_04/page_01.html

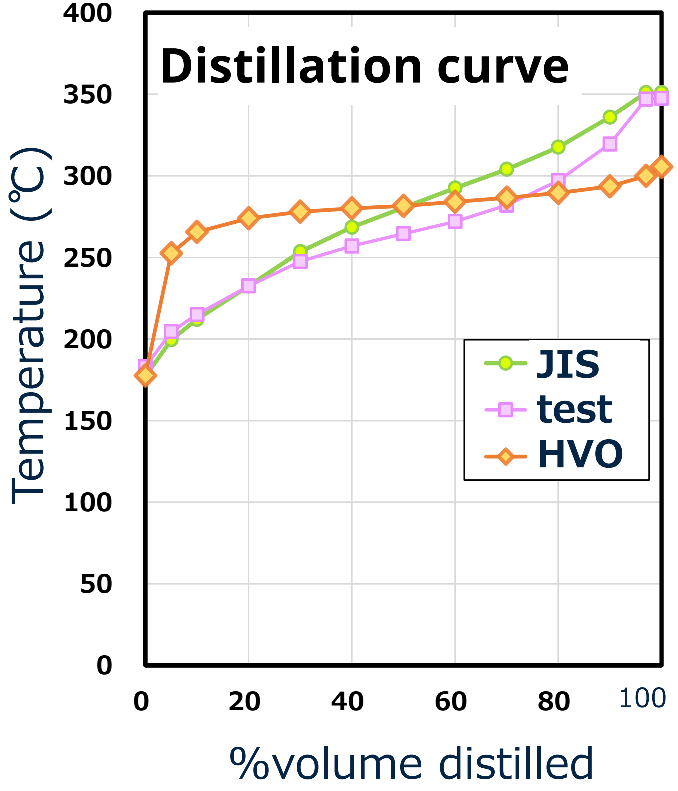
Test Fuels

- ✓ JIS no.2 Diesel Fuel (Commercial Diesel Fuel(Gas Oil)
- ✓ HVO (Hydrotreated Vegetable Oil 100%, Produced by hydrogenolyzing used cooking oil (Euglena Co., Ltd.)

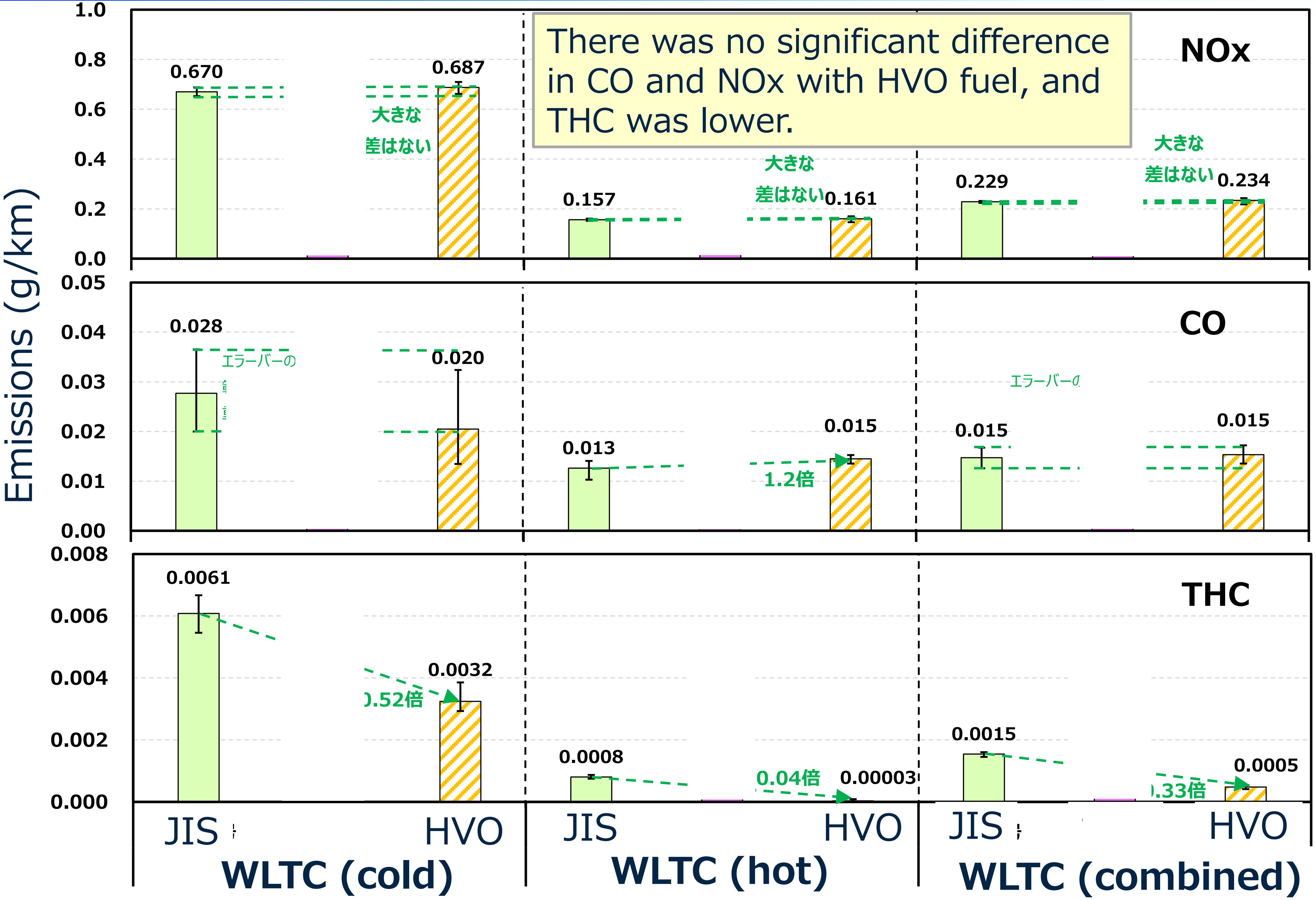


Chromatogram of GC-FID of HVO fuel vs. JIS no. 2 Diesel Fuel

HVO has a lower end point and narrower distillation temperature range because of fewer components over C18.



Exhaust Gas Measurement Results



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In Closing

- ✓ Although the shift to EVs in passenger cars is progressing, it is thought that internal combustion engines will also be used for some time. The path to carbon neutrality for heavy-duty trucks remains unclear.
- ✓ Even though VOC emissions from vehicles are decreasing year by year due to vehicle exhaust gas regulations, air pollutants will still be emitted. It is necessary for us to be aware of that.
- ✓ The composition of VOCs emitted from vehicles varies greatly depending on the fuel type and generation process. If new fuels such as e-fuel are introduced in the future, the VOC composition in exhaust gas is expected to change.
- ✓ Emissions from vehicles are closely linked to people's lifestyles, and it is important to reflect such lifestyles when making emission estimates.

Thank you for your attention !