Recent Trends in Automotive Development and Innovative Experimental Equipment for Enhancing Capital Efficiency in Diversified Vehicle Engineering

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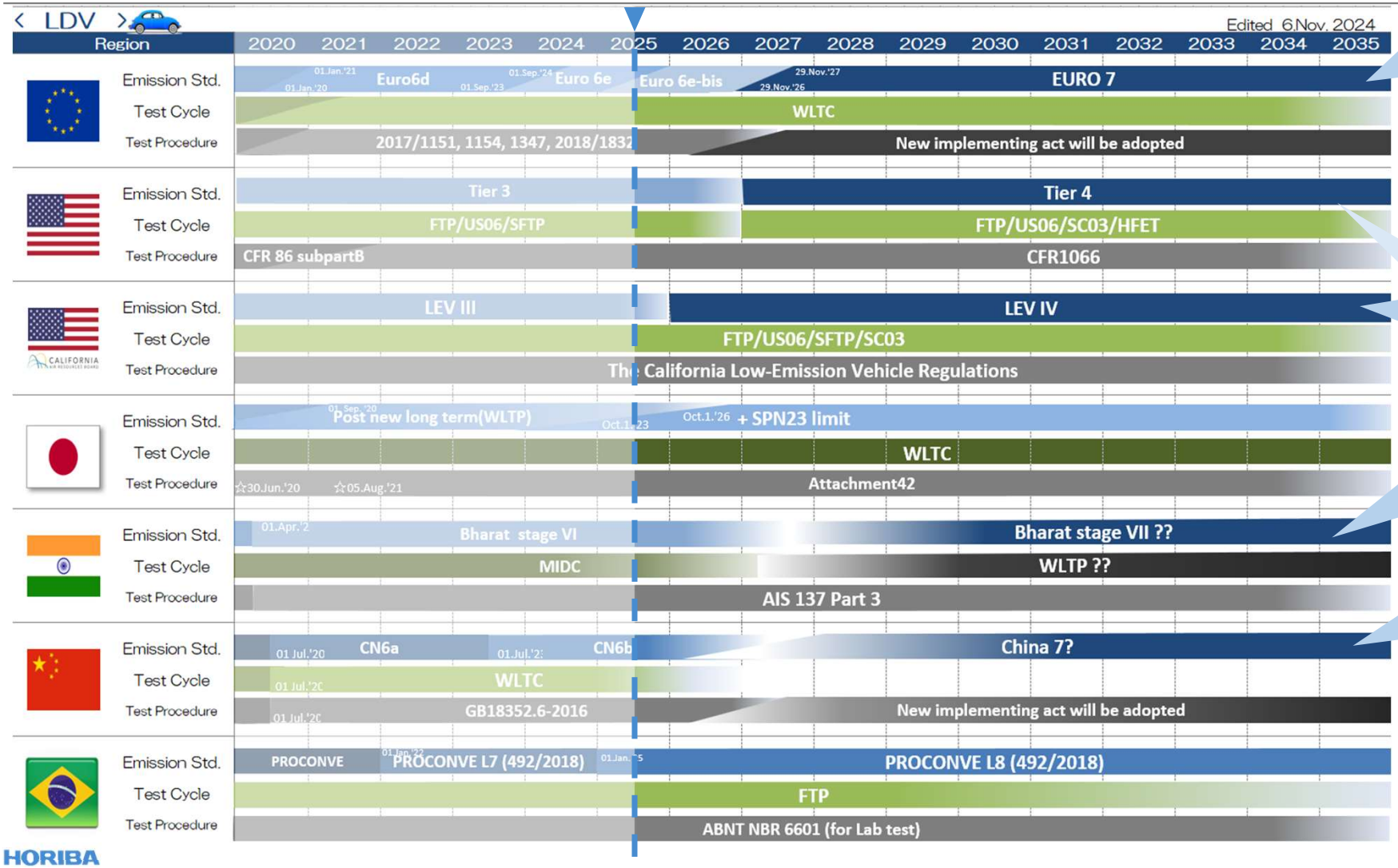
Agenda

1. Global Trends in Clean Mobility Policies
2. Struggles in the Future Test Requirement
3. Multi-Purpose Exhaust Emission Analyzer
4. Test Data
5. Conclusion

1. Global Trends in Clean Mobility Policies Engine Exhaust Regulation and Multi Fuels

Timeline of LDV Emission Standards



Regulation finalized in May 2024.
Implementing regulation for the first stage finalized in September 2025.

Under review by the Trump administration.

WLTP cycle adoption scheduled for April 2027
Research on BS VII has started.

NH_3, SPN10, Non-exhaust Particle Emissions are under consideration.

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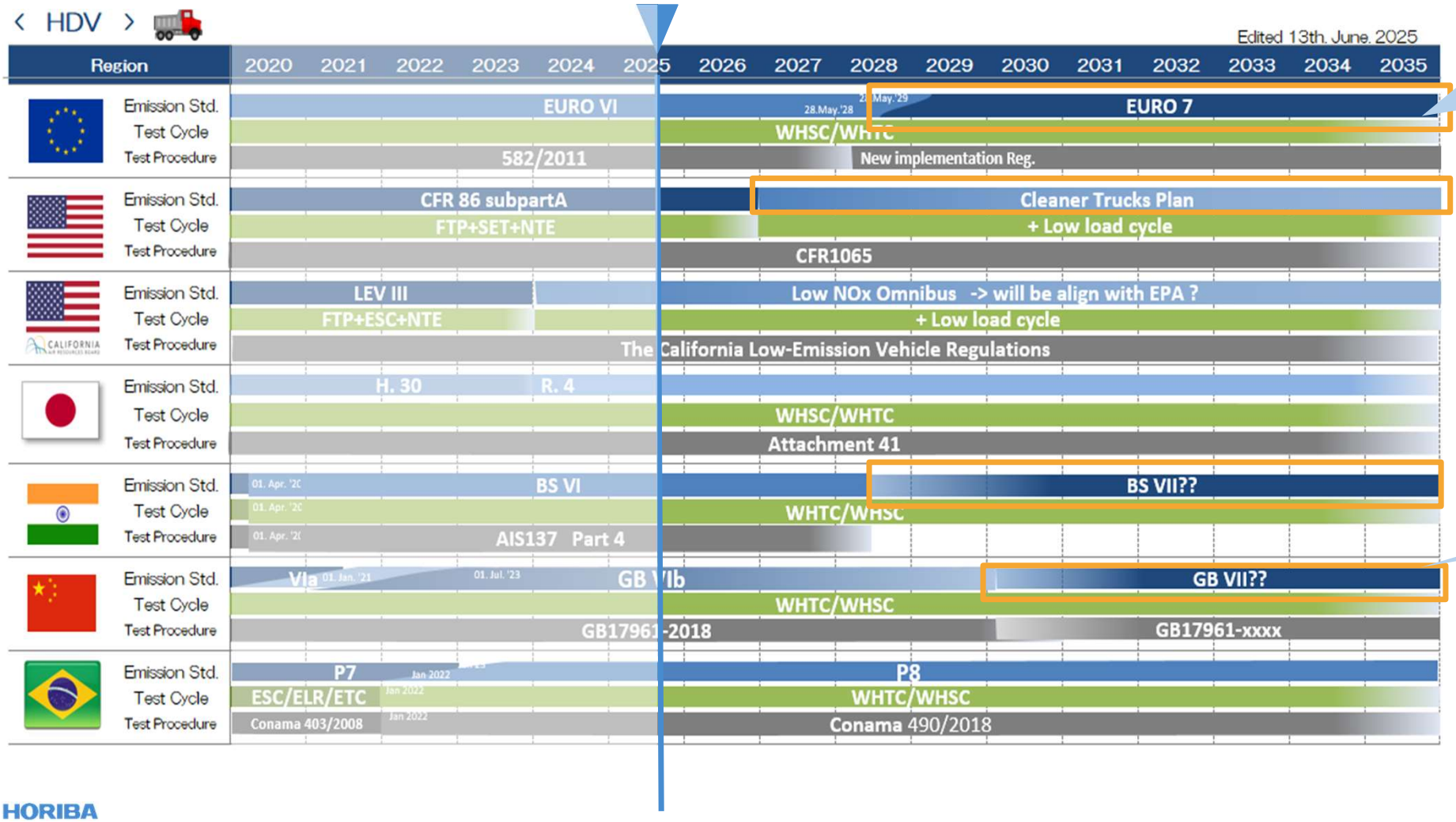
Timeline of HDV Emission Standards



Discussion of implementing rules has started.

Discussions have started for GB VII but still early stages.

R49-07 amendment to add new measurement principles

- Amendment of UN Regulation 49-07 will be voted on Nov 2025.
- QCL-IR and FTIR are allowed as raw exhaust measurement methods for Lab and RDE tests

Standard Analyzers in UNR 49		Alternative methods
Components	Principle	Principle
CO and CO_2	NDIR	**FTIR, QCL-IR**
THC	FID	-
CH_4	GC-FID or NMC-FID	**FTIR, QCL-IR**
NOx	CLA or NDUV	**FTIR, QCL-IR**
NH3	LIA(TDL, QCL), FTIR	-
H2O	FTIR, QCL-IR	-

To use alternative analyzer, there are some conditions, e.g.

1) the analyzer type shall be type-examined by an international or national metrological institute,

2) For RDE test, The portable analyzers shall be assessed according to CEN EN 17507:2021

NDIR : Non-dispersive infrared absorption
FID : Flame ionization
GC-FID : Gas chromatograph combined FID
NMC-FID : Non-methane cutter combined FID
CLA :Chemiluminescent
NDUV : Non-dispersive ultra-violet resonance absorption
LIA : Laser Infrared Analyser

TDL: Tunable Diode Laser
QCL: Quantum Cascade Laser
FTIR : Fourier Transform Infrared

Source)World Forum for Harmonization of Vehicle Regulations 197th session, Meeting document of WP29, ECE-TRANS-WP29-2025-94e.pdf

Biofuel Trends (As of November 13, 2024)

Target : E20 by 2025

Target : E10 by 2030
E20 by 2040

E5 ~ E10 **

B5 ~ B7 **

**Not mandatory but commonly used

E10*

*Not mandatory but commonly used

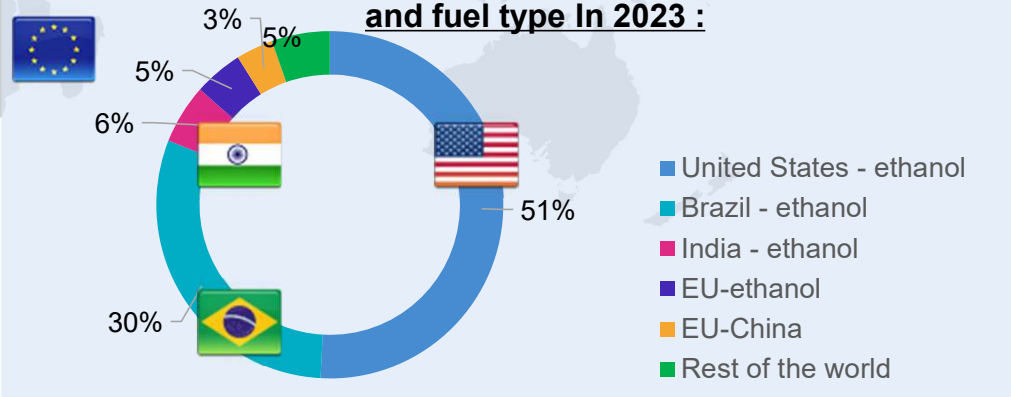
B30 from 2020
Target : B40

Target : B30 by 2030

E27.5 as of 2023
Target : E30

B12 as of 2023
Mandatory :
B14 from Mar 2024
B15 from 2025

Bioethanol production by country/region and fuel type In 2023 :



Source) Global Bioenergy Statistics Report published by World bioenergy Association

Forecast of Fuel Usage by Transportation in the EU Region

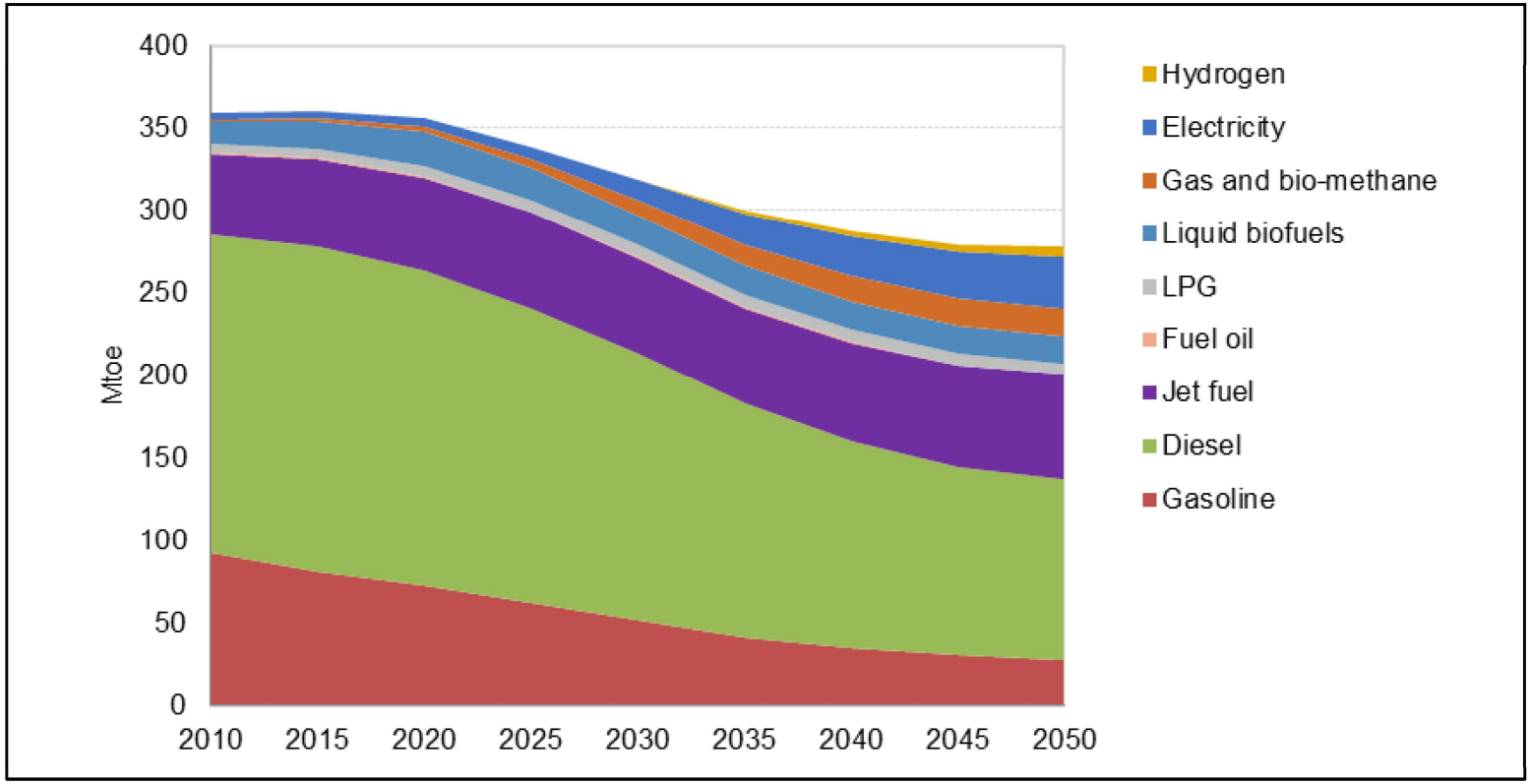
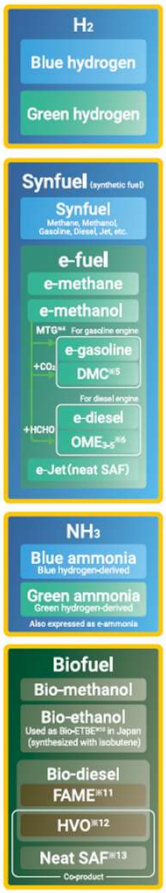


Figure 2-3. Energy use in transport (including international aviation and excluding international maritime) under current trends and adopted policies by 2050 (EU28)
Source: Baseline scenario, PRIMES-TREMOVE model, E3-Modelling[11]

Source: State of the art on alternative fuels transport systems in the European Union - Publications Office of the EU (europa.eu)

Measurement of Unconventional Components

CN fuels



H_2

Synfuel
(Methane, Methanol, Gasoline, Diesel, Neat SAF etc.)

Synfuel (e-fuel)
(e-methane, e-methanol, e-gasoline, e-diesel, Neat SAF etc.)

NH_3

Biofuel
(Alcohols, Biodiesel, Neat SAF)

Measuring components

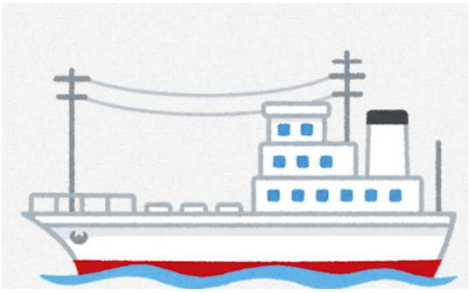
H_2 R&D	For H_2-ICE (unburned H_2 fuel from Engine)
H_2O R&D	For H_2-ICE, NH_3 Engine (to check combustion efficiency)
CH_4 R&D/Reg.	For Synfuel (Methane) combustion (Produced by Methanation)
NH_3 R&D/Reg.	For NH_3 Engine (unburned NH_3 from Engine)
N_2O R&D/Reg.	For NH_3 Engine (Produced by oxidation of NH_3)
Alcohols R&D/Reg.	For Biofuel (Alcohol) Engine (unburned alcohol fuel from Engine)
Aldehydes R&D/Reg.	For Biofuel (Alcohol) Engine (Produced by oxidation of alcohols)

Many special components need to measure in addition to the conventional components

Diversification of Measurement Applications

CN fuel utilization

Automobile
- Gasoline (Synfuel/Biofuel)
- Diesel (Synfuel/Biofuel)
- CNG (Synfuel/Biofuel)
- H_2



Ship
- Heavy oil + Diesel
- LNG (Synfuel/Biofuel)
- Methanol (Synfuel/Biofuel)
- NH_3
- H_2

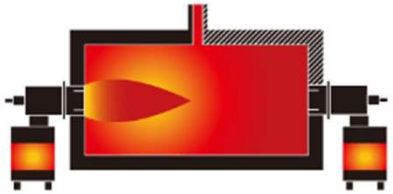
Motorcycle
- Gasoline (Synfuel/Biofuel)
- H_2

Aircraft
- Jet
- SAF (Jet+neat SAF)

Mix ratio of SAF: 10~50%

+

Industrial furnace



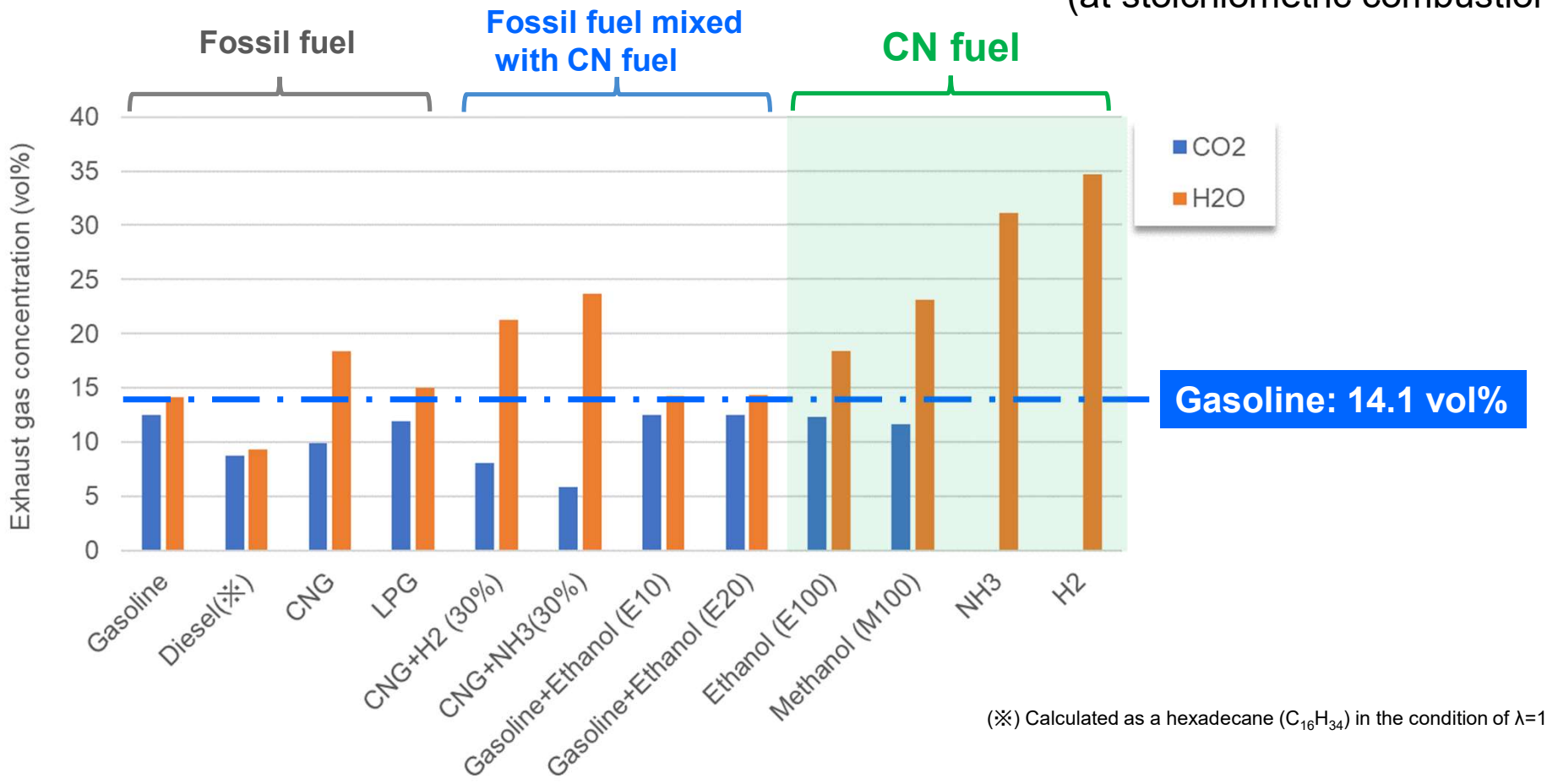
Burner reactor
NH_3, H_2 fuel

https://www.jifma.or.jp/recruit-lp/

Requires to measure combustion exhaust gas from various industries

High Water Concentration in the Exhaust Gas

(at stoichiometric combustion)



(※) Calculated as a hexadecane ($C_{16}H_{34}$) in the condition of λ=1.5

Requires to take measures against high water concentration measurement

H_2-ICE related UN/ECE Regulations Trend

LDV

- Requirement for H_2 mono fueled vehicles has already included in UN Regulation 154*.
  - ✓ Only NOx Emission measurement is required if vehicle run only hydrogen.
  - ✓ No request of evaporative emission and OBFCM

NRMM

- UN Regulation 96-05*** series of amendment regulation for H_2 100% fueled engines has been adopted in June 2024

HDV

- UN Regulation 49-07** series of amendment regulation for H_2 100% fueled engines came entry into force in Jan 2024
  - ✓ NOx, CO, THC or NMHC, NH_3, PM and PN
  - ✓ Lambda sensor can be used for exhaust flow calculation

<u>Regarding to UN Regulation 49-07 series</u>

Additional amendments are under consideration

- Water measurement
- Water-based formula for dry/wet correction
- FTIR and QCL-IR as analyzer for NOx,CO,CH_4, and/or CO_2

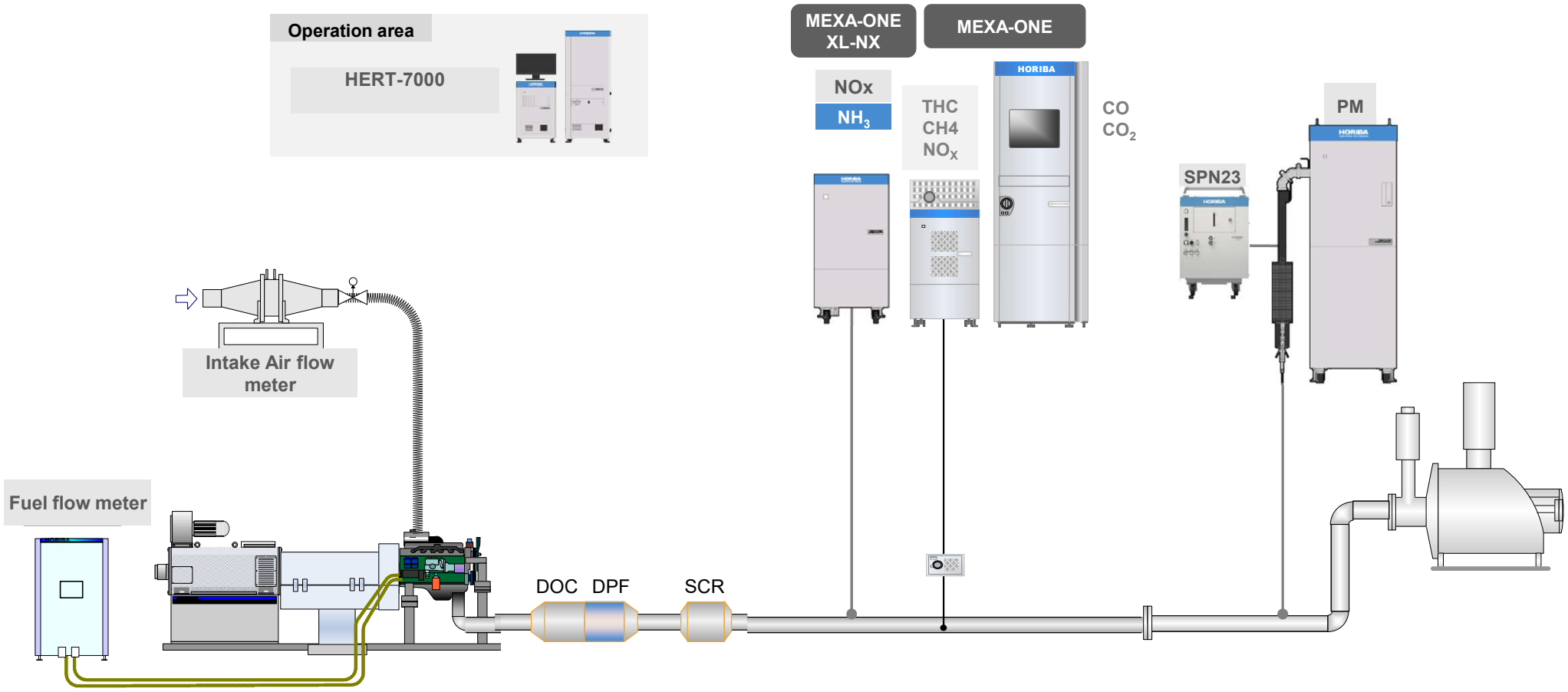
*UN Regulation 154 : Uniform provisions for the approval of light-duty vehicles on emissions, etc. based on the World Harmonized Light Vehicle Test Procedure

**UN Regulation 49 : Uniform provisions concerning the measures to be taken against the emission of gaseous and particulate pollutants from compression-ignition engines and positive ignition engines for use in vehicles

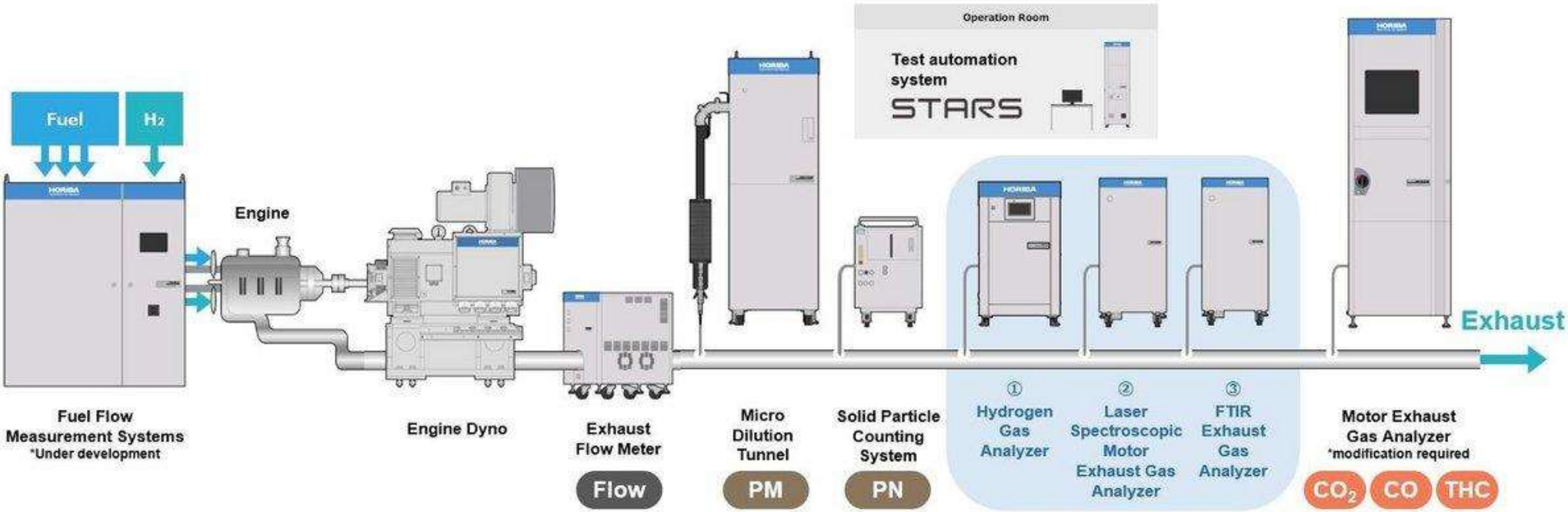
***UN Regulation 96 : Uniform provisions concerning the approval of compression ignition (C.I.) engines to be installed in agricultural and forestry tractors and in non-road mobile machinery about the emissions of pollutants by the engine

2. Many Struggles to Comply Regulations in Different Test Different Engine and Different Fuels

UN Regulation 49 compatible HDV Engine Test system (Direct)

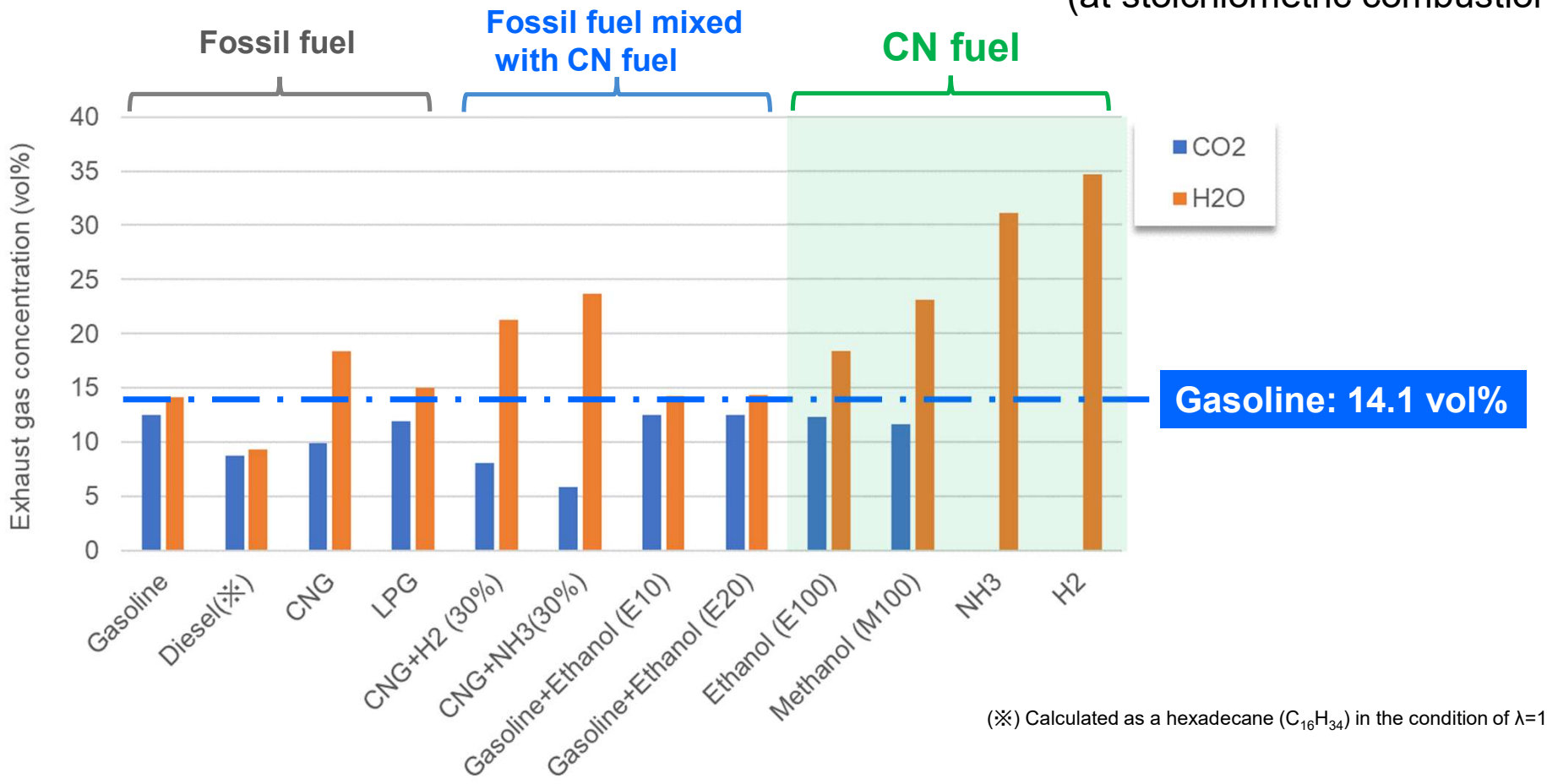


Examples of development and evaluation facilities for hydrogen ICE



High Water Concentration in the Exhaust Gas

(at stoichiometric combustion)



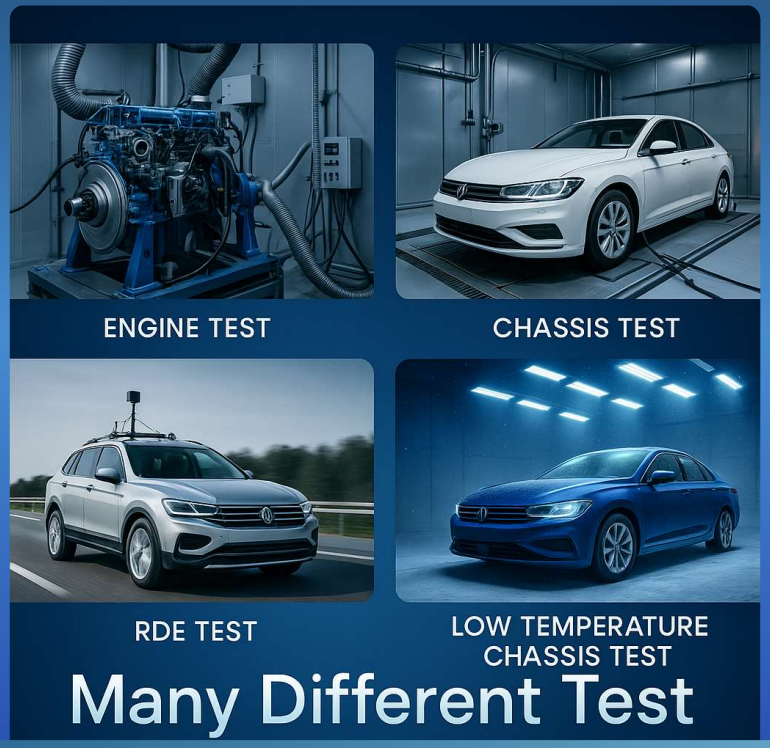
(※) Calculated as a hexadecane ($C_{16}H_{34}$) in the condition of λ=1.5

Requires to take measures against high water concentration measurement

Struggling

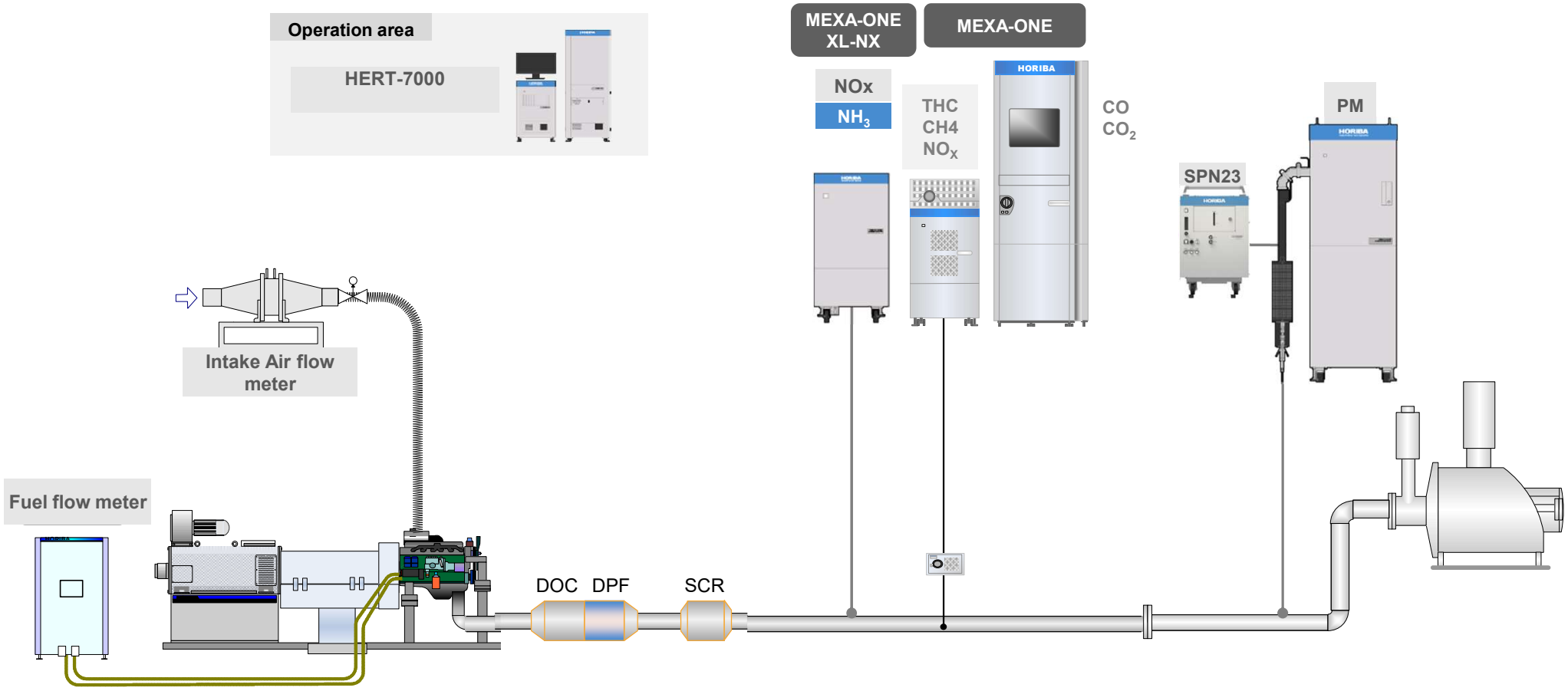
With Many Different Application

With Many Different Equipment

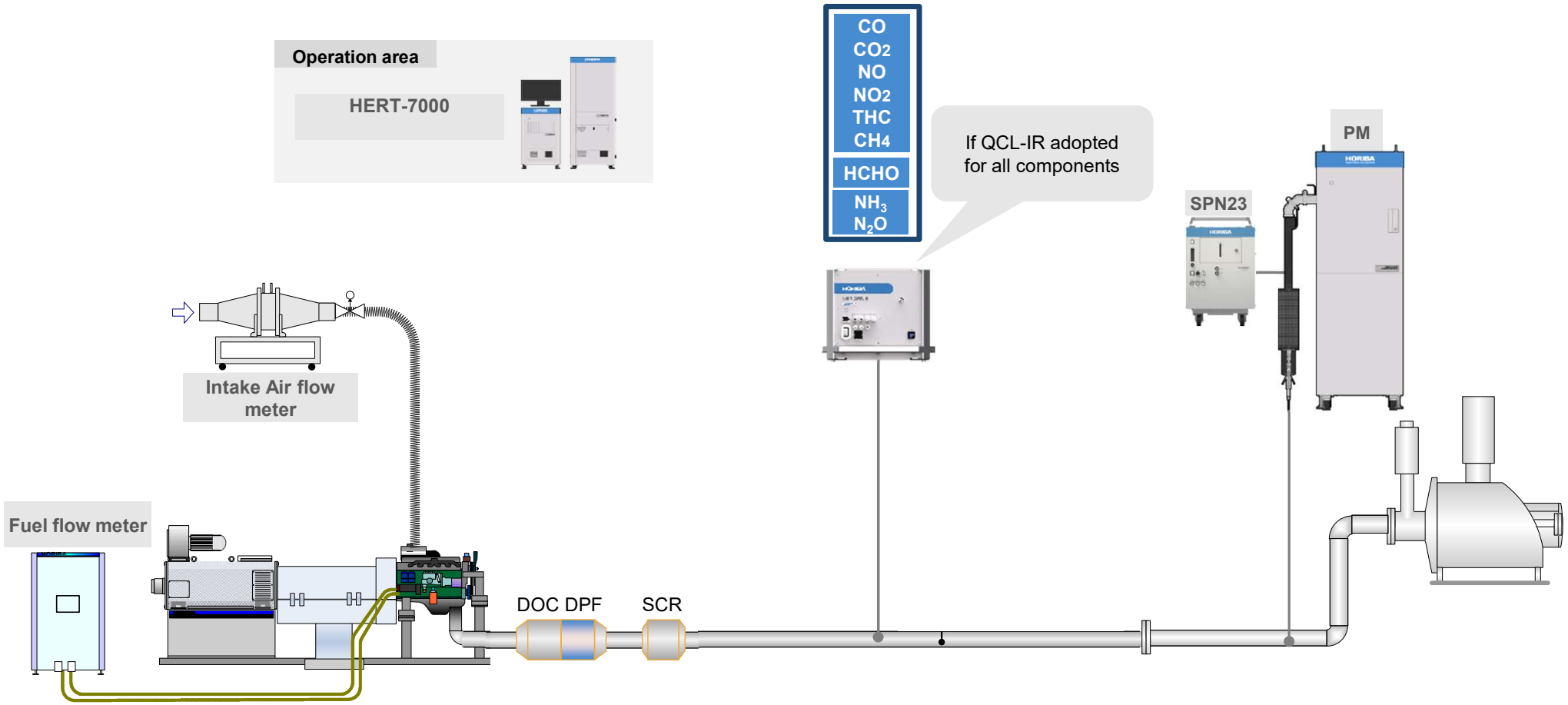


3. Multi Purpose Exhaust Emission Analyzer Designed for Reducing Investment Cost for the Future Mobility Development

UN Regulation 49 compatible HDV Engine Test system (Direct)

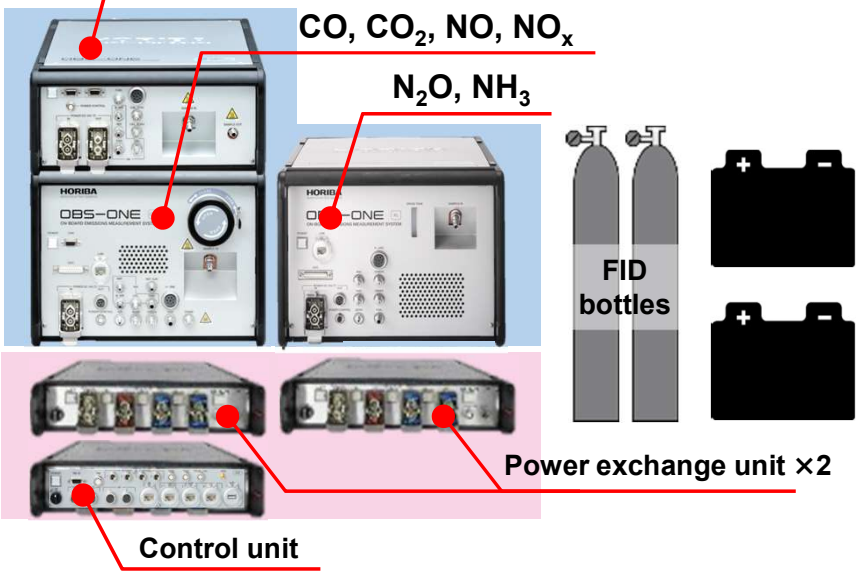


Possible UN Regulation 49 compatible HDV Engine Test system (Direct)

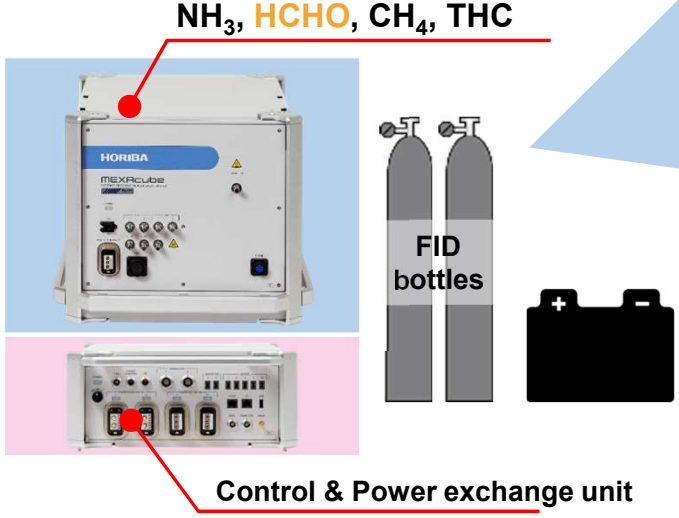


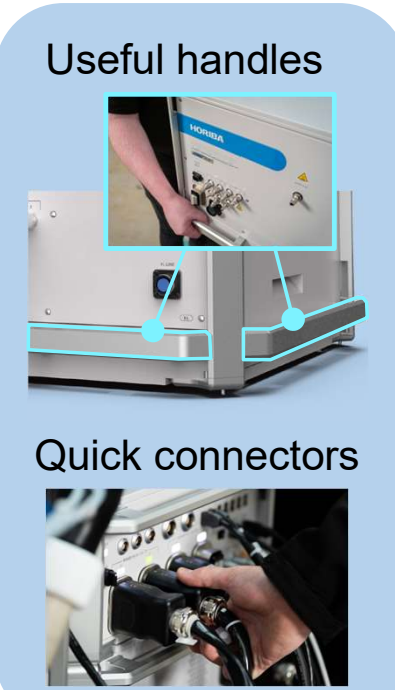
Improve from messy RDE test

Conventional PEMS (OBS-ONE)



MEXAcube





- Reduced number of piping and wiring by **50%**
- Reduced power consumption **80% from MEXA-ONE, 40% from OBS-ONE**
  Scope 1 reduction: CO_2 1200kg/year *
- Reduced consumable parts **30% from OBS-ONE**

※ Estimate condition: On-board: 200 hours/year, Laboratory: 800 hours/year

With MEXAcube , more efficient investment

Compact & High Performance

for CO, CO_2, NO, NO_2, N_2O, NH_3, HCHO, CH_4, THC

Best solution for both laboratory and real-world testing.

4. Data for Moisture from Multi Fuels Laboratory – Read Driving Emission CVS / Dilution Comparison NH3 / NOx Comparison in Vehicle Test

Measurement components

Direct exhaust gas analyzer which can cover upcoming regulations

Meas. component	Meas. principle	Analyzer range	Required component for RDE			
			EU7 LDV	EU7 HDV	CN7 LDV	CN7 HDV
CO	QCL-IR	0 – 8000 ppm 0 – 12 %	✓*	✓	✓	?
CO_2	QCL-IR	0 – 20 %	✓	✓	✓	?
NO	QCL-IR	0 – 2000 ppm	✓	✓	✓	?
NO_2	QCL-IR	0 – 800 ppm	✓	✓	✓	?
N_2O	QCL-IR	0 – 1000 ppm		✓		?
NH_3	QCL-IR	0 – 1500 ppm		✓	TBD	?
HCHO	QCL-IR	0 – 50 ppm		TBD		?
CH_4	QCL-IR	0 – 2000 ppm 0 – 10000 ppm		✓		?
THC	FID	0 – 10000 ppmC	TBD*	✓		?

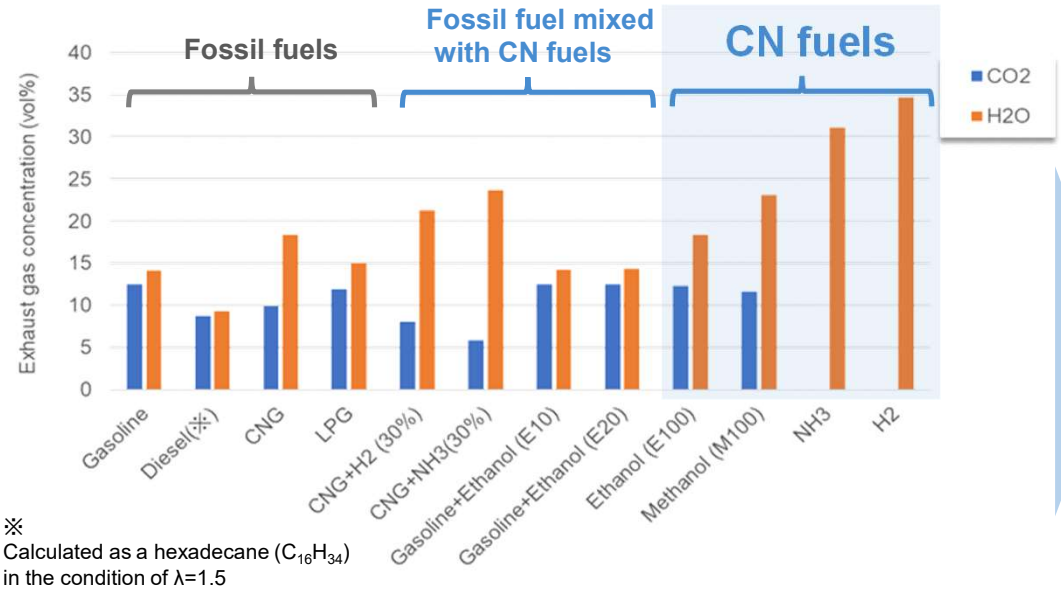
* May be decided in the future.

HORIBA's latest QCL-IR technology "IRLAM™" integrated!

Minimize interference against high moisture emissions

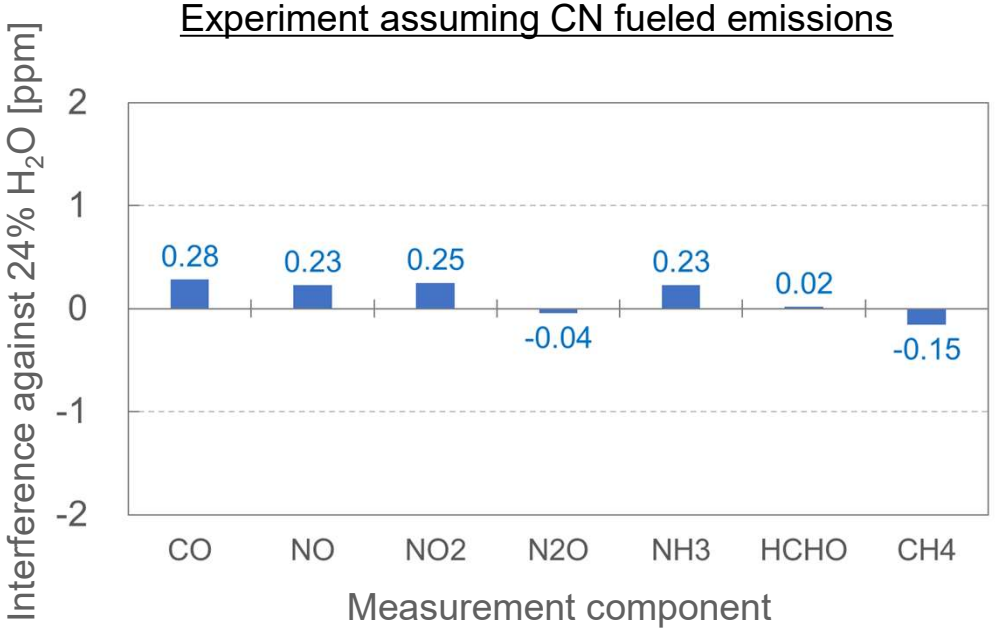
Suitable for carbon-neutral (CN) fueled engines

H_2O concentration under stoichiometric combustion

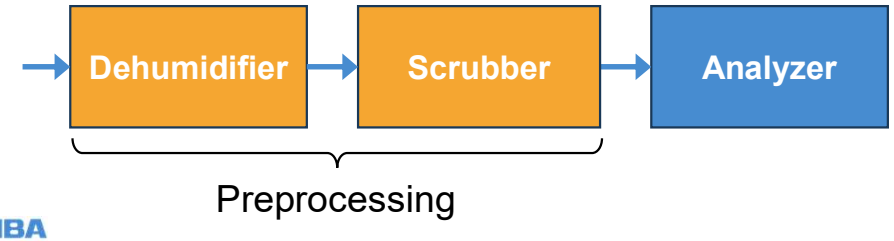


※
Calculated as a hexadecane ($C_{16}H_{34}$)
in the condition of λ=1.5

Experiment assuming CN fueled emissions



Conventional technology against high moisture



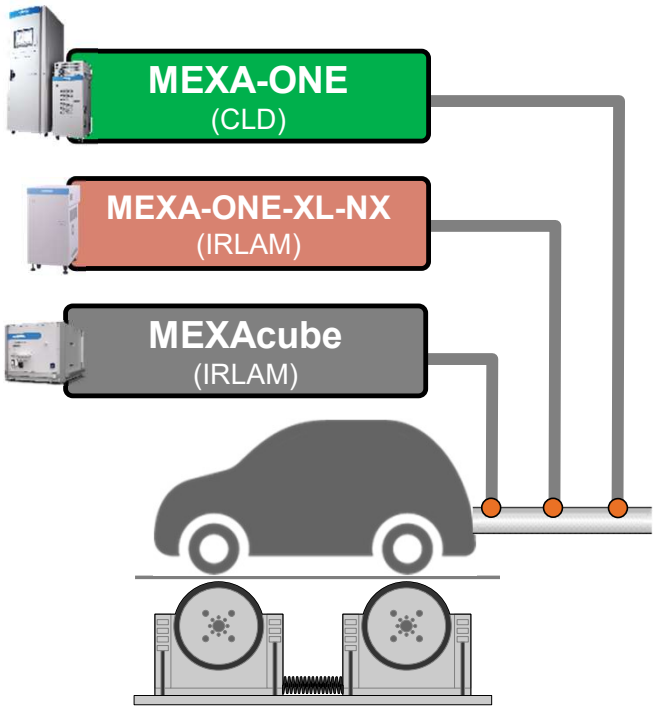
Extreme low interference
even with wet measurement method

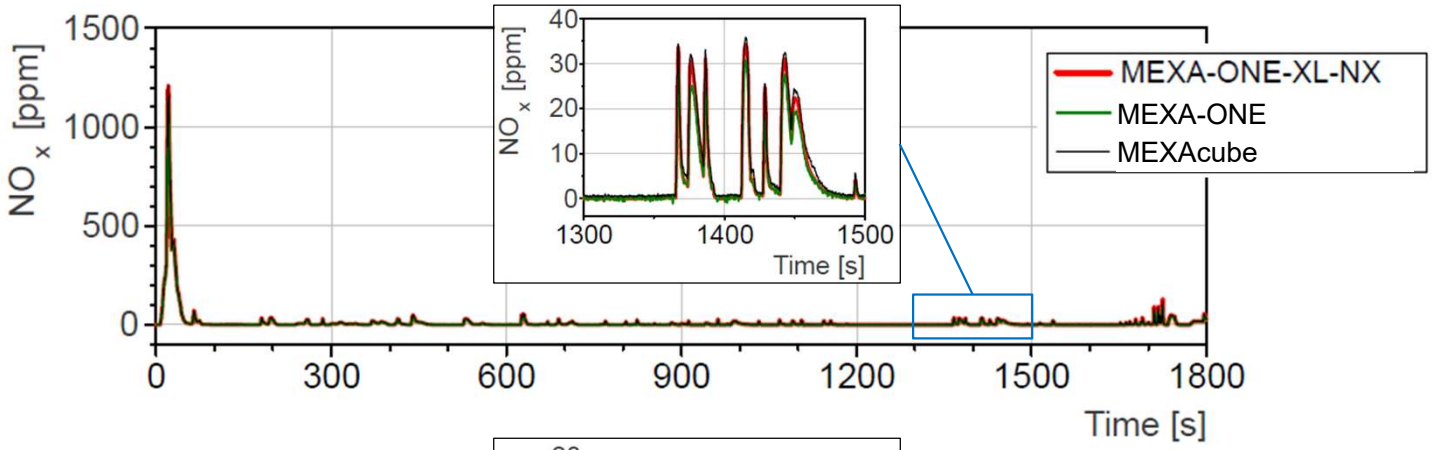
Good agreement with laboratory-grade analyzers

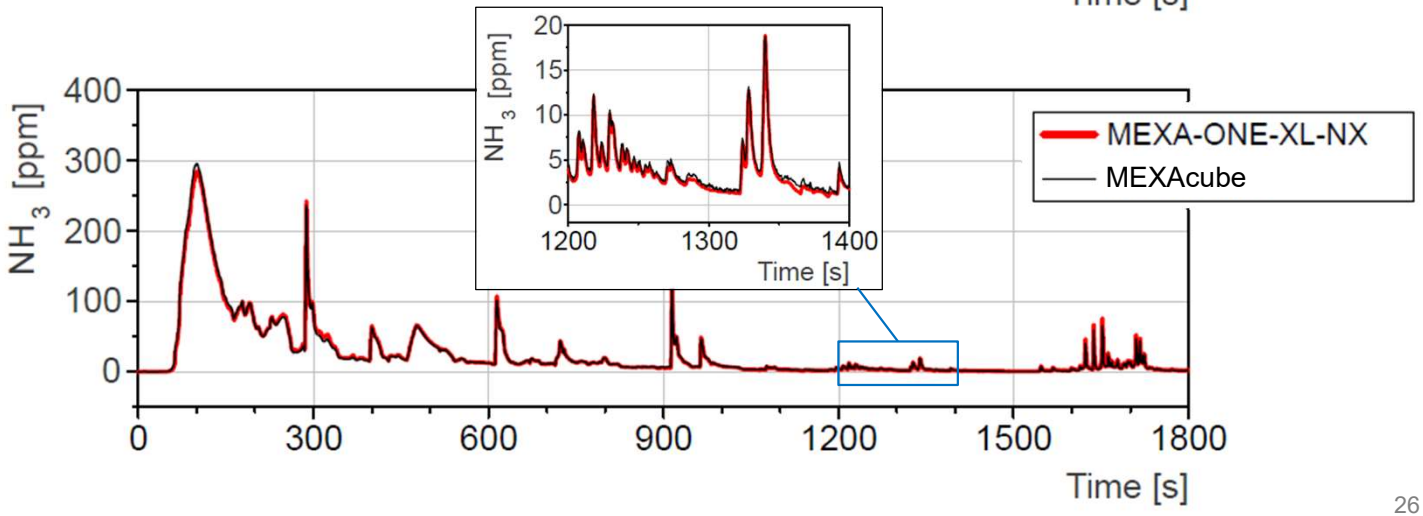
Secure data continuity with MEXA-ONE series

Test vehicle
DI gasoline vehicle

Test cycle
WLTC with cold start



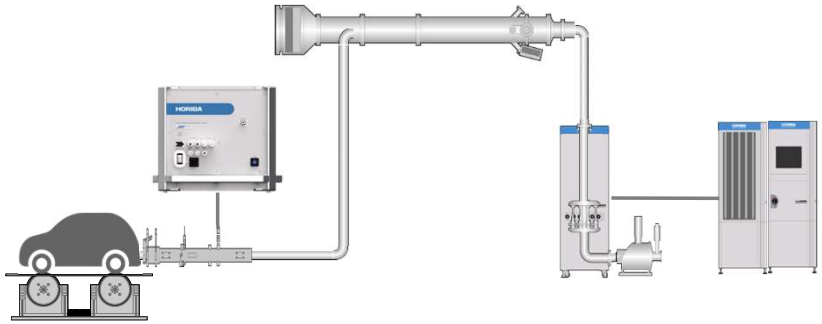


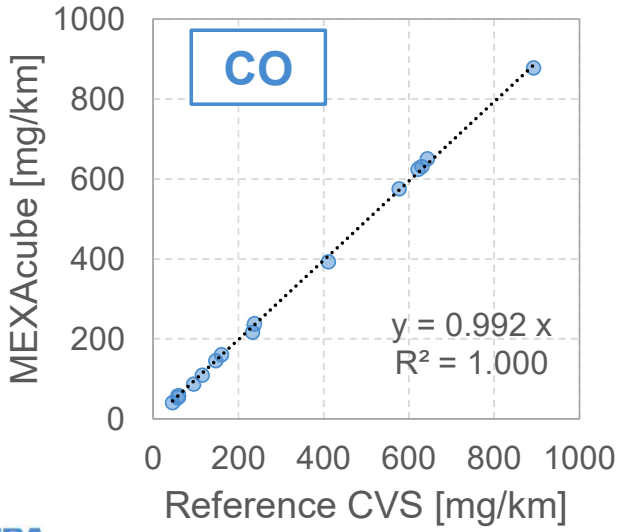


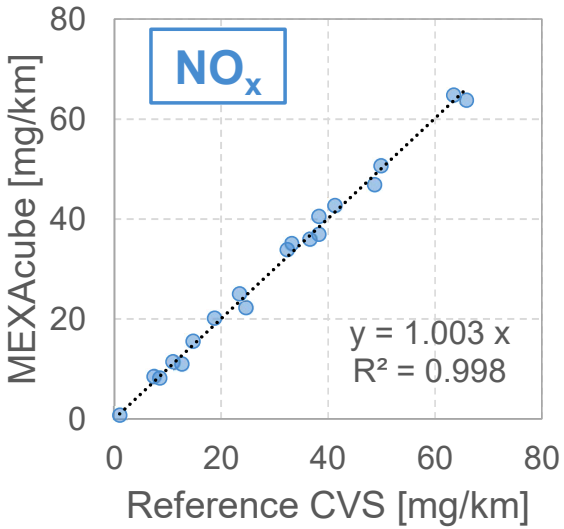
Good agreement with “CVS method”

Contribute front-loading of R&D

MEXAcube (direct modal mass) vs. CVS / MEXA (bag mass)





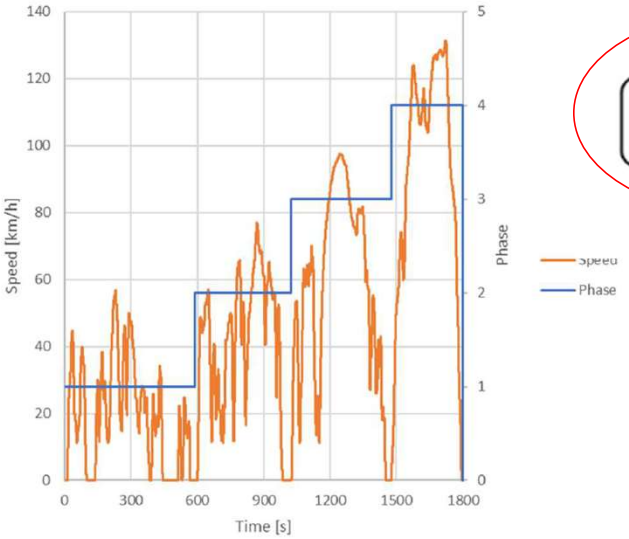


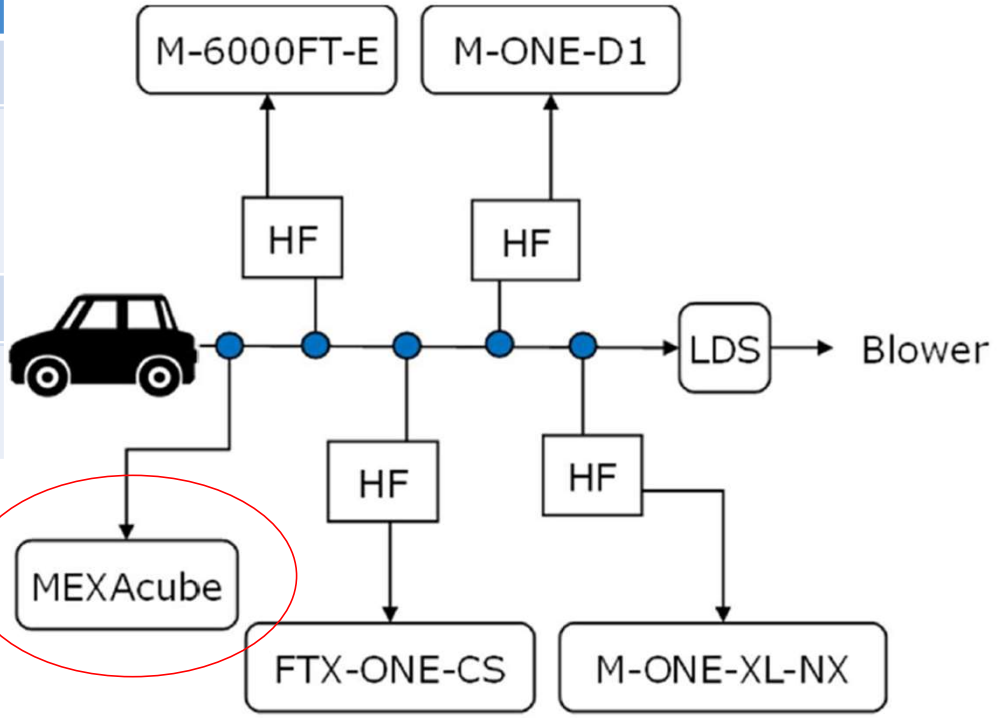
Suitable to evaluate emissions as “mass” in upstream processes

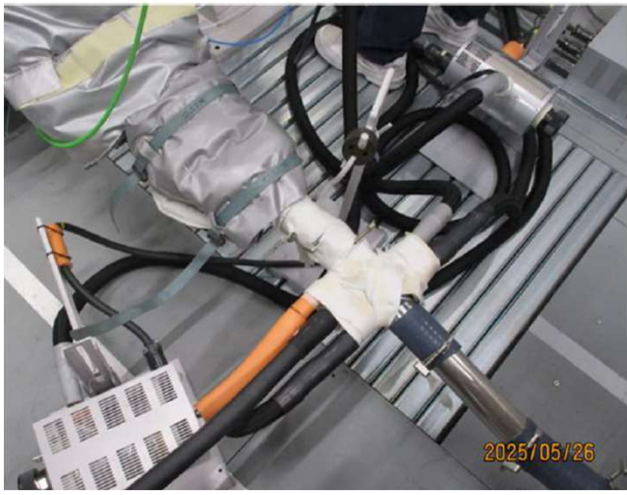
e.g.) Transient operated engine test cell

NH3 / NOx Comparison Test by Vehicle Emission

Model, Make	Nissan Juke
Type	MR16DDT
Engine Size, Type	1.618(L) 4 Cylinder Gasoline DI
Power	140kW @5600rpm
Torque	240Nm @1600-5200rpm







NH3 Comparison over WLTC Cold

High range [6kFT/FTX:1000ppm, XL-NX:3000ppm, MEXAcube:1500ppm]

	Cum.	Err.	Slope.
6kFT	67488.79	0.00%	-
LDS	33653.19	50.14%	-
FTX	67659.06	-0.25%	1.0135
NX	71560.81	-6.03%	1.0074
MC	70932.45	-5.10%	1.037

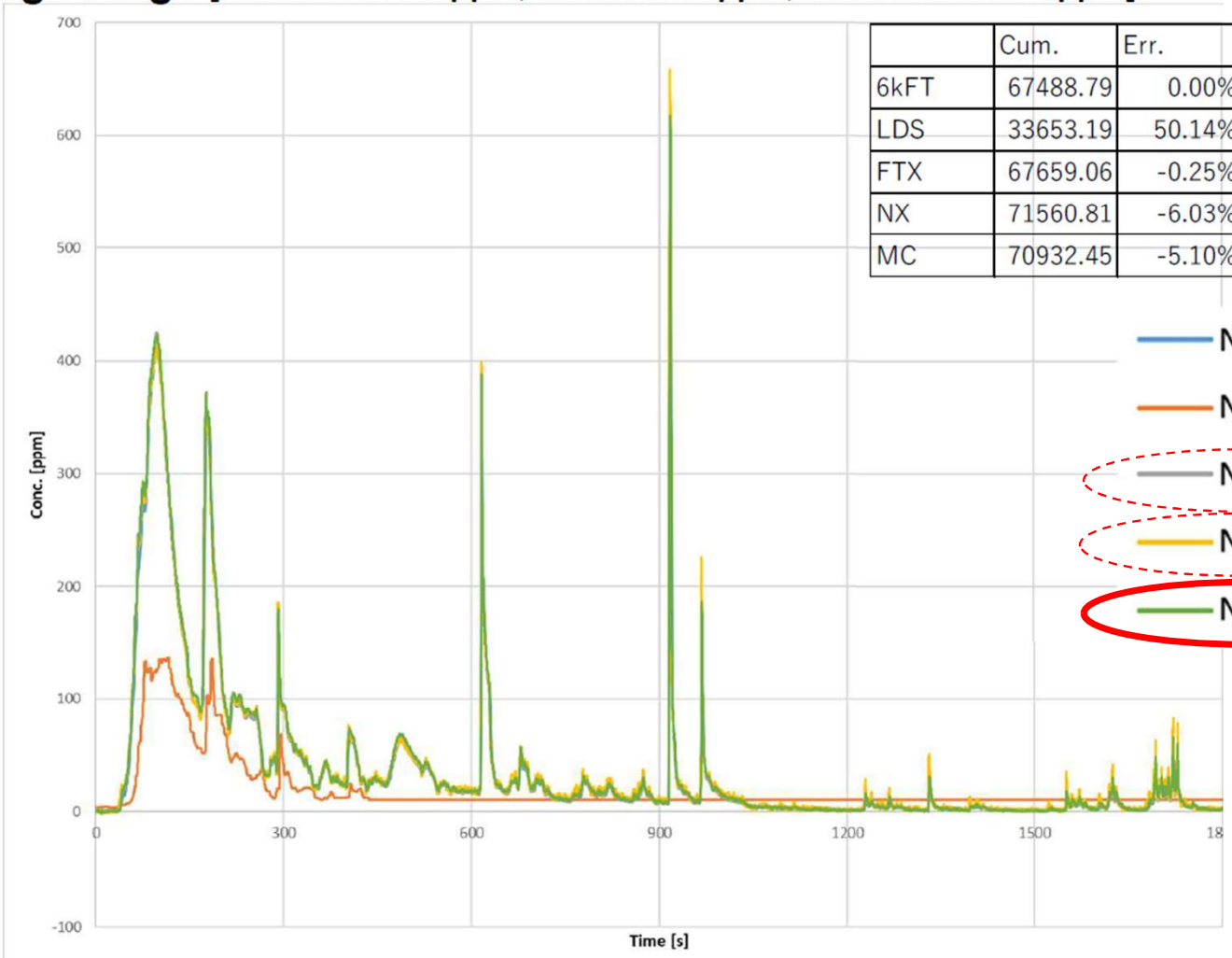
NH3[6kFT] Not Used

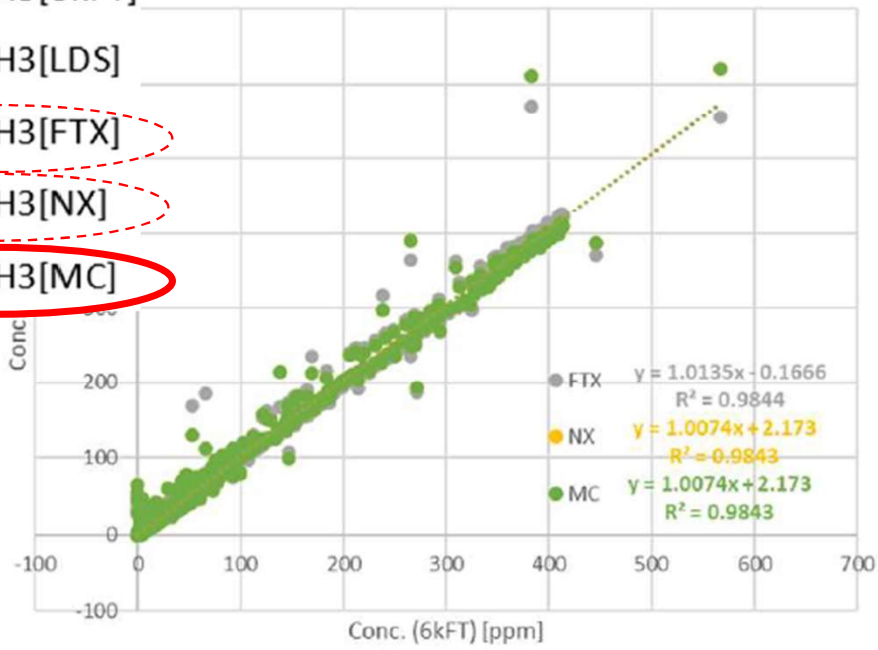
NH3[LDS] Not Used

NH3[FTX] FT Analyzer

NH3[NX] Stationary QCL

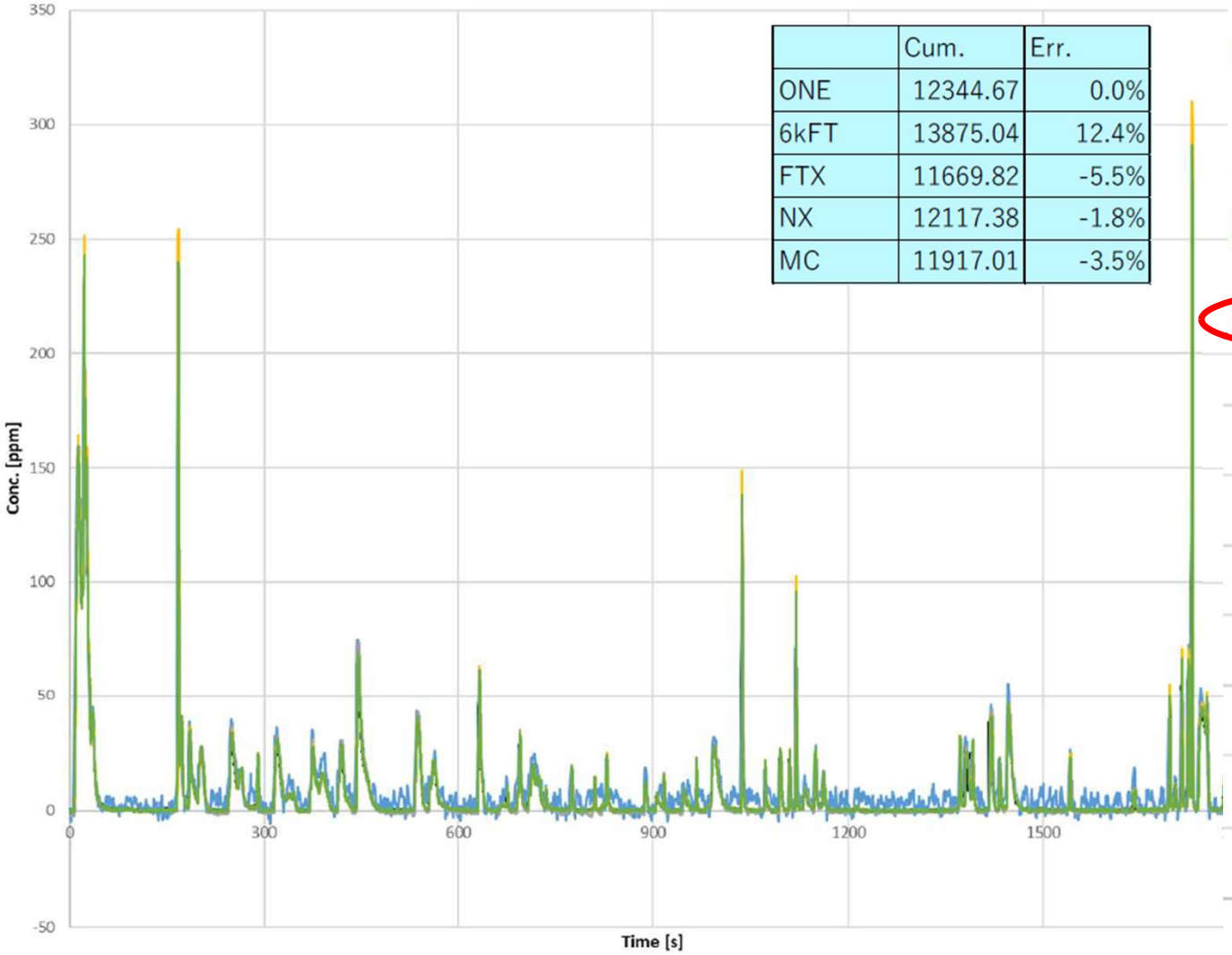
NH3[MC] MEXAcube





NOx Comparison over WLTC Cold

	Cum.	Err.
ONE	12344.67	0.0%
6kFT	13875.04	12.4%
FTX	11669.82	-5.5%
NX	12117.38	-1.8%
MC	11917.01	-3.5%



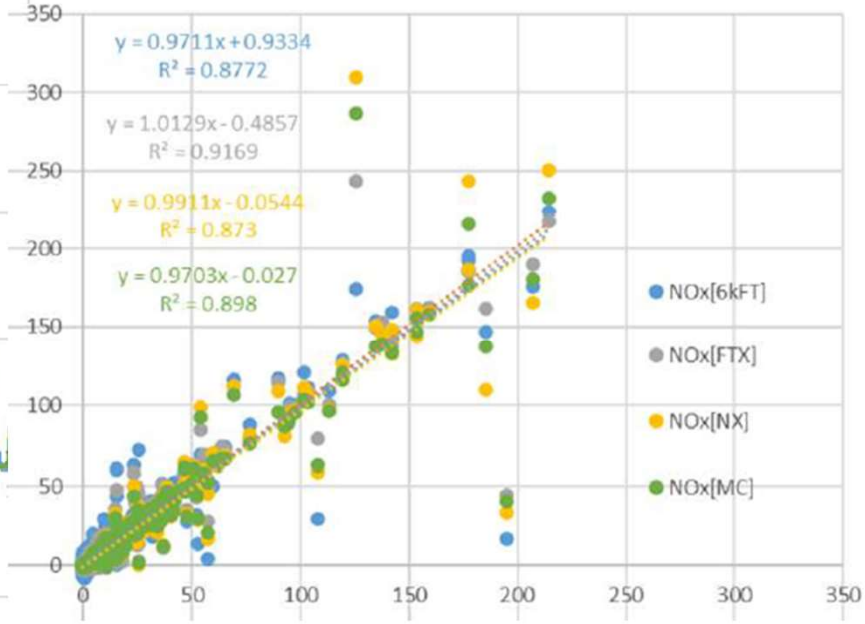
NOx[M-ONE] MEXA (CLD)

NO+NO2[6kFT] Old type FTI-R

NO+NO2[FTX] New FT-IR

NO+NO2[NX] Stationary QCL

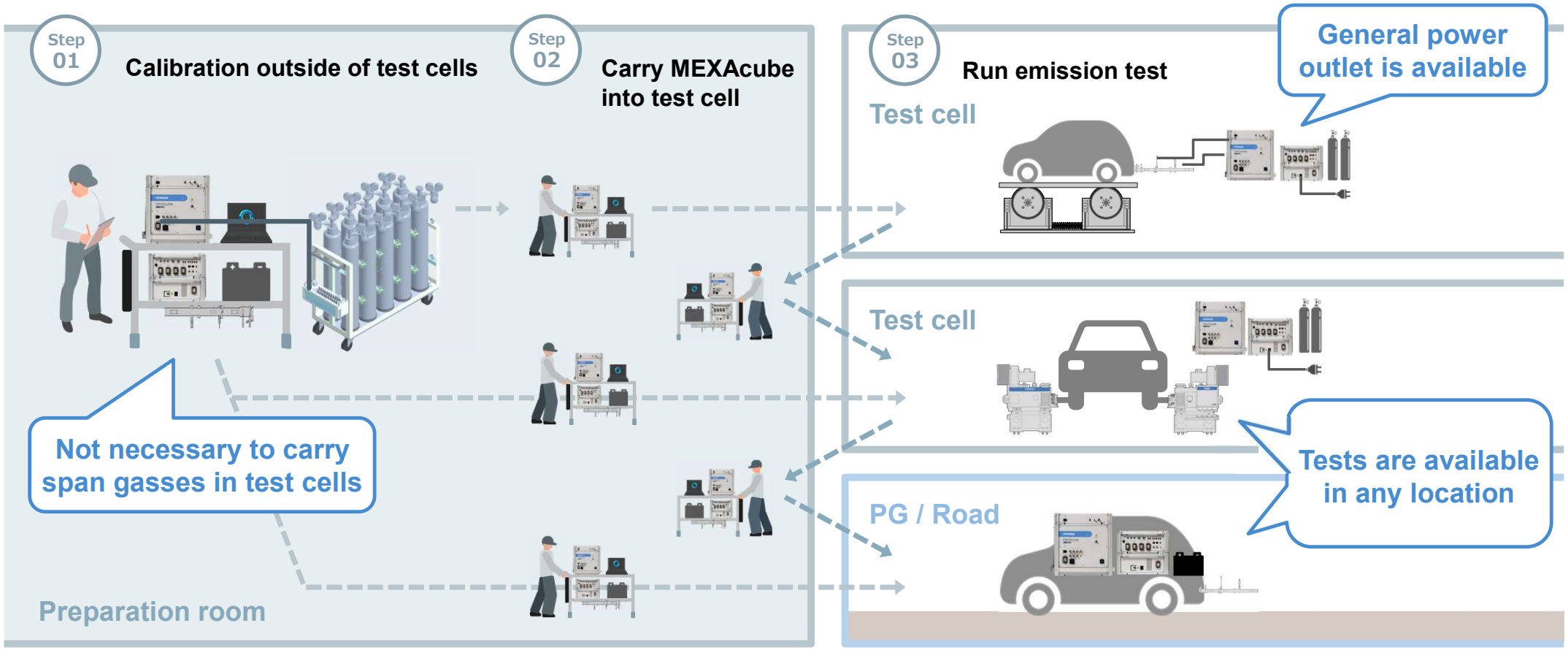
NO+NO2[MC] MEXAcube

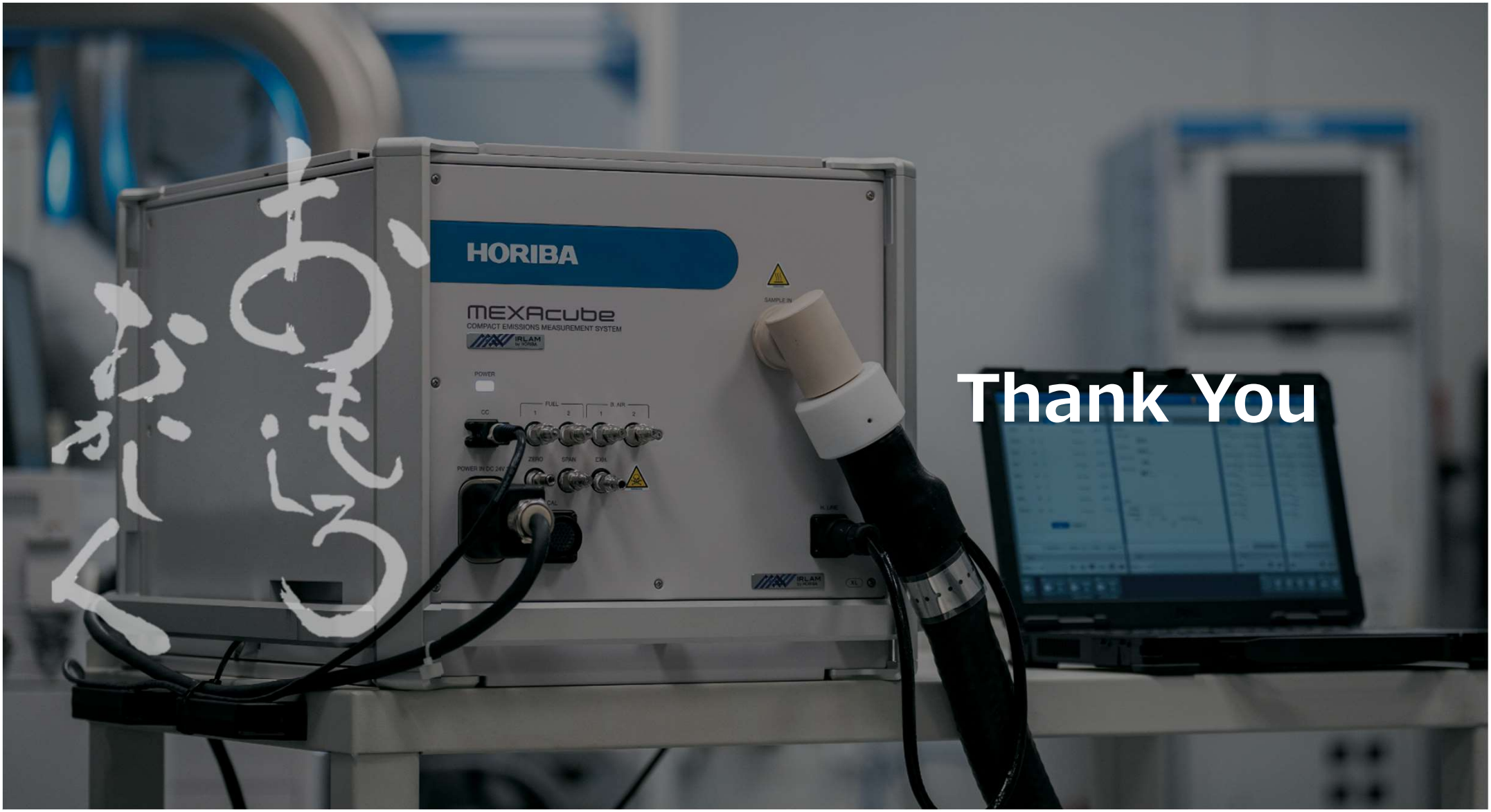


5. Conclusion for Multi Purpose Analytical System For the Reduction of Investment Cost

The new operations with investment reduction

Reviewing conventional operations, and contributing cost-effective solution




HORIBA
MEXAcube
COMPACT EMISSIONS MEASUREMENT SYSTEM
IRLAM
POWER
FUEL
B. AIR
ZERO
SPAN
SAMPLE IN

Thank You