New Revolutionary Solutions for Euro 7 Emission Measurement

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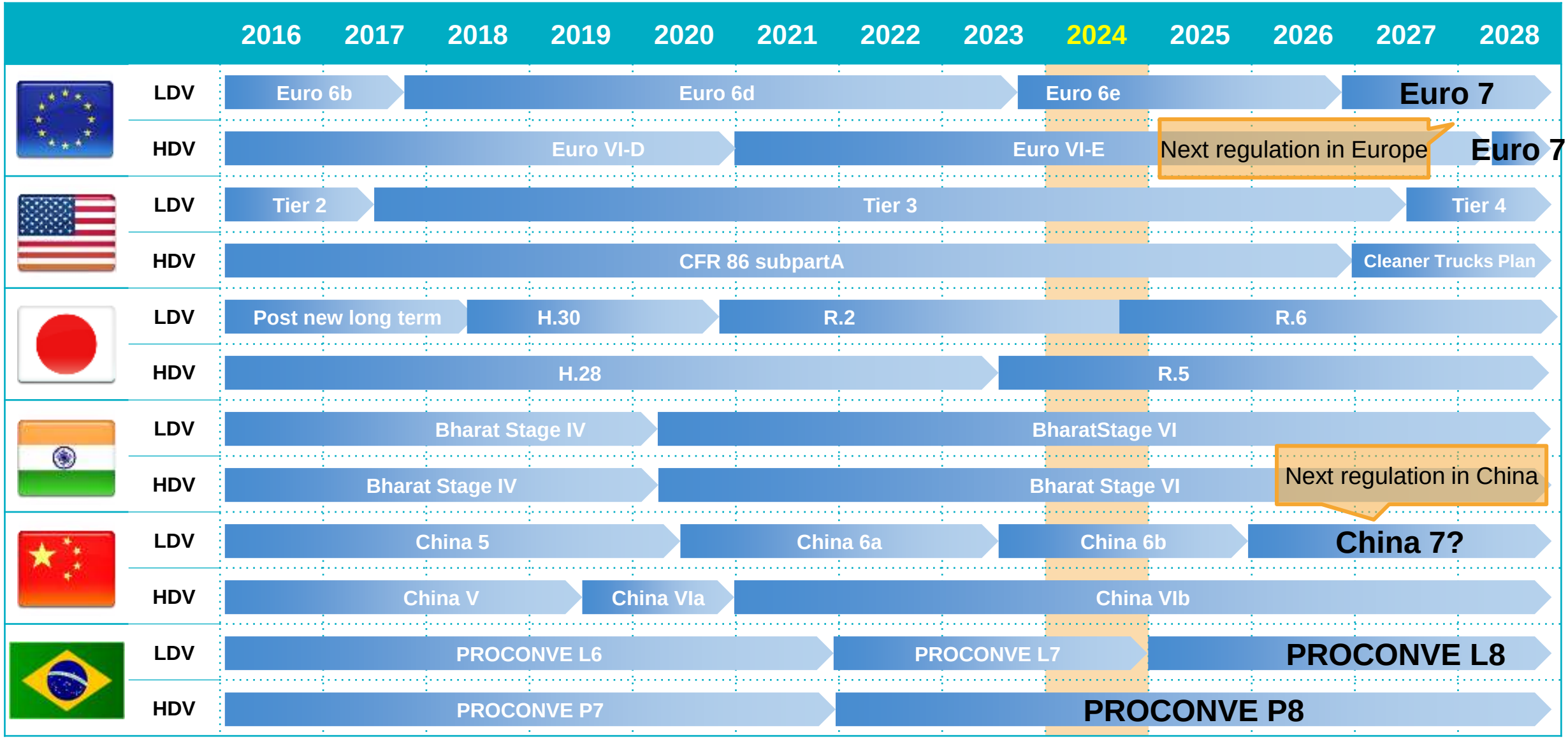
October 22, 2024

Agenda

1	Technical challenges in future regulatory requirements
2	Key technology – “IRLAM”
3	Overview of “VERIDRIVE”
4	Performance
5	Conclusions

Regulatory roadmap worldwide (as of July 2024)



Euro 7 emission limits : provisional agreement on the trilogue

M1, N1 vehicles

		Mass in running order (MRO) (kg)	Mass of carbon monoxide (CO)		Mass of total hydrocarbons (THC)		Mass of nonmethane hydrocarbons (NMHC)		Mass of oxides of nitrogen (NOx)		Combined mass of total hydrocarbons and oxides of nitrogen (THC + NOx)		Mass of particulate matter (PM)		Number of particles (PN_{10})	
			L_1 (mg/km)		L_2 (mg/km)		L_3 (mg/km)		L_4 (mg/km)		$L_2 + L_4$ (mg/km)		L_5 (mg/km)		L_6 (#/km)	
Category	Class		PI	CI	PI	CI	PI	CI	PI	CI	PI	CI	PI	CI	PI	CI
M_1	-		1000	500	100	-	68	-	60	80	-	170	4.5	4.5	$6x10^{11}$	$6x10^{11}$
N_1	I	MRO ≤ 1280	1000	500	100	-	68	-	60	80	-	170	4.5	4.5	$6x10^{11}$	$6x10^{11}$
	II	1280 < MRO ≤ 1735	1810	630	130	-	90	-	75	105	-	195	4.5	4.5	$6x10^{11}$	$6x10^{11}$
	III	1735 < MRO	2270	740	160	-	108	-	82	125	-	215	4.5	4.5	$6x10^{11}$	$6x10^{11}$

- Same limits and test condition as Euro 6 except for PN for passenger cars.
- PN will be **PN10 instead of PN23**
- PN and PM will apply not only DI-PI but also **all PI vehicles**.
- N1 category is divided into three based on Mass in running order.

Source) https://data.consilium.europa.eu/doc/document/ST-16960-2023-REV-1/en/pdf

Euro 7 emission limits : provisional agreement on the trilogue

M2, M3, N2 and N3 vehicles

Source) https://data.consilium.europa.eu/doc/document/ST-16960-2023-REV-1/en/pdf

Pollutant emissions	*WHSC (CI) and WHTC (CI and PI)*	**REAL Driving Emissions (RDE)**
	per kWh	*per kWh*
NO_x in mg	***200***	***260***
PM in mg	***8***	-
PN_{10} in #	$6x10^{11}$	9×10^{11}
CO in mg	***1500***	***1950***
NMOG in mg	80	*105*
NH_3 in mg	*60*	*85*
CH_4 in mg	*500*	*650*
N_2O in mg	*200*	*260*

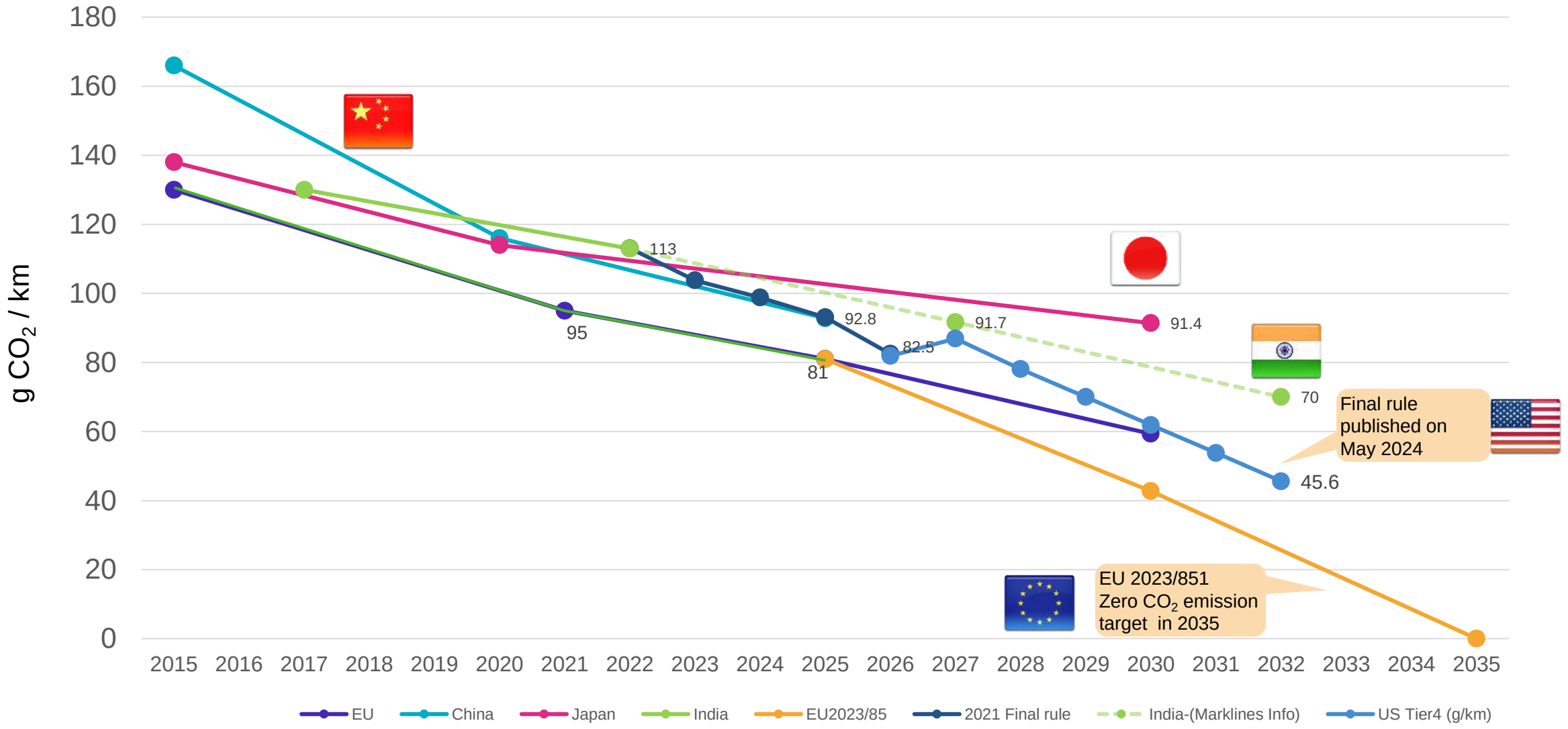
New measurement methodology with reliable performance for additional pollutants (NH_3, N_2O, HCHO)

- PN10, **NMOG, NH_3, CH_4, N_2O** as additional pollutants
- **HCHO** will be reviewed by the end of 2027
- **NMOG** might be calculated by **THC - CH_4 + HCHO** (TBD)

Change in operating conditions

- Temperature/humidity
- Altitude
- Shock/Vibration
- Downsizing

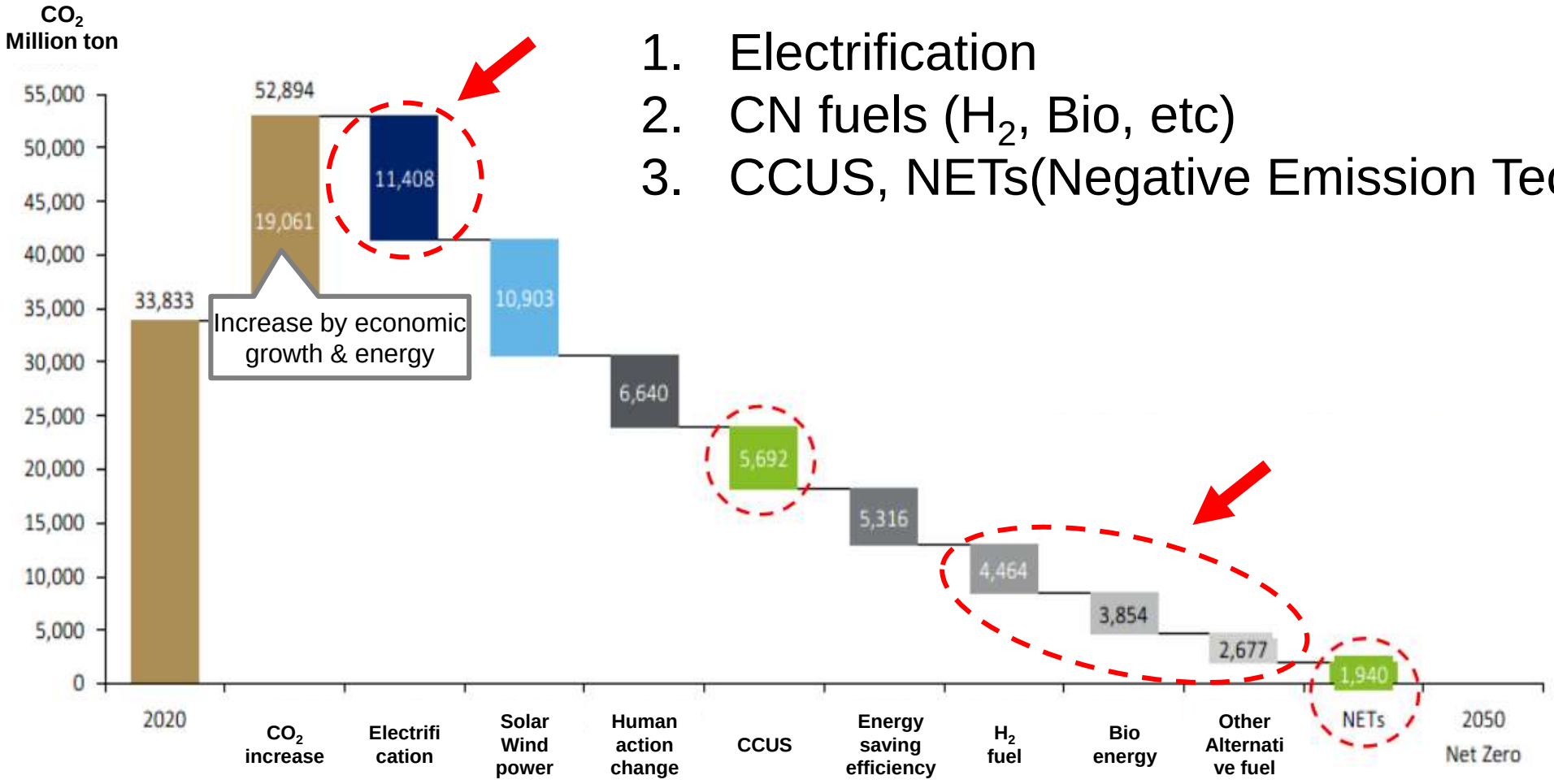
Time line of LDV CO_2 emission standard



Tightening emissions regulations worldwide

Toward carbon neutrality

Estimation of Carbon reduction



1. Electrification
2. CN fuels (H_2, Bio, etc)
3. CCUS, NETs(Negative Emission Technology)

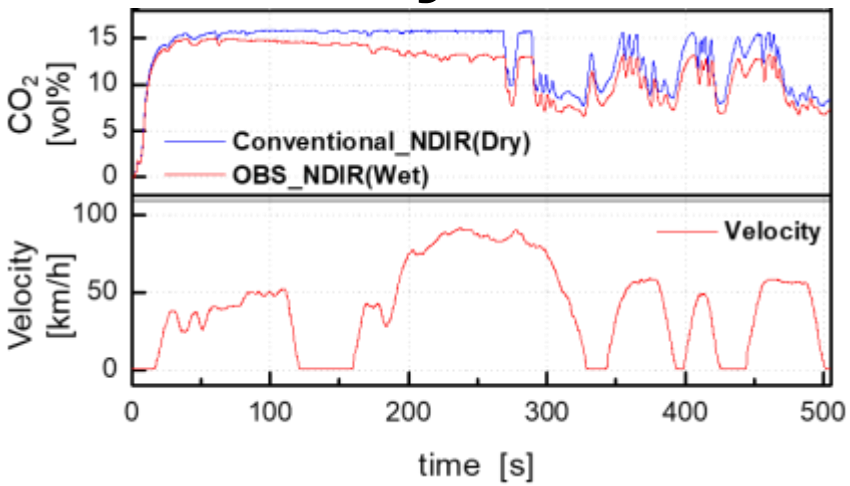
Source: https://www.nedo.go.jp/content/100965445.pdf, https://www.myclimate.org/en/information/faq/faq-detail/what-are-negative-emissions/

Technical challenges in carbon neutral fuels

CN fuel usually emits high concentration of moisture

➔ H_2-ICE theoretically up to 35%

- **Water condensation on tailpipe and sample line**
- **Difficulty in dry-to-wet correction after gas cooling**
- **Water interference to non-dispersive infrared analyzers**
- **Water quenching in chemiluminescence analyzers**



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2	**Key technology – “IRLAM”**
3	Overview of “VERIDRIVE”
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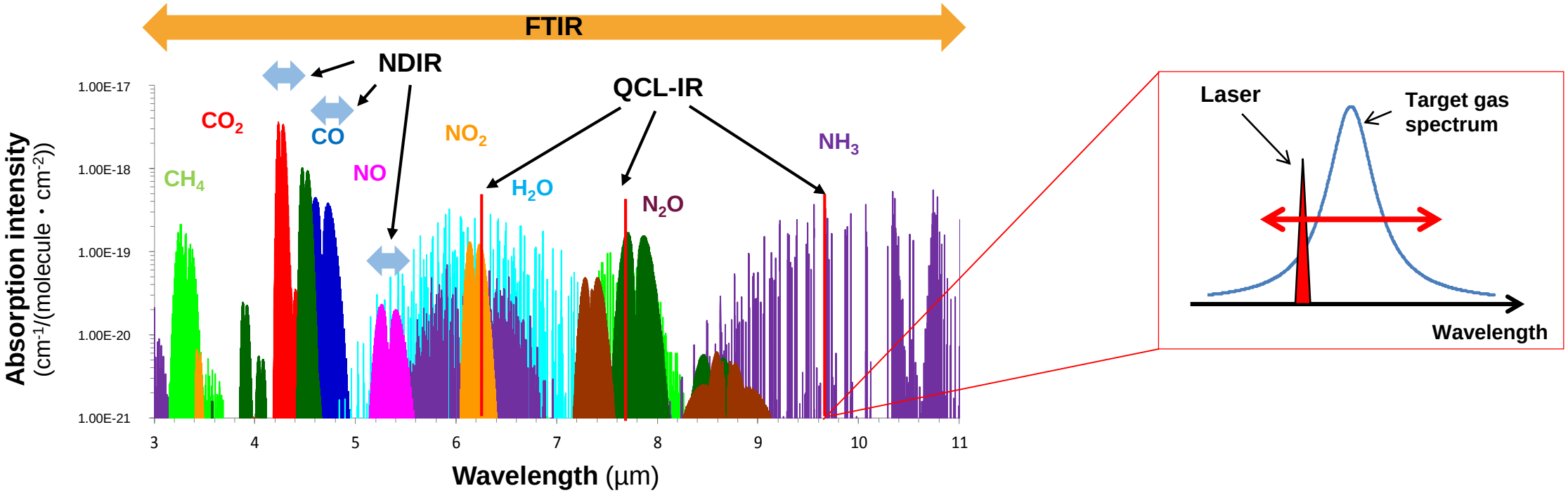
Mid-infrared absorption spectroscopy for gas analysis



Measurement principle	Light source	Gas cell	Features
NDIR (Non-dispersive infrared spectroscopy)	Thermal radiation source + optical filter	Straight tube cell	Low cost small size
FTIR (Fourier transform infrared spectroscopy)	Thermal radiation source + interferometer	Multi-pass cell (White cell)	Multi-component measurement
IRLAM (Infrared laser absorption modulation)	**Quantum cascade laser (QCL)**	**Multi-pass cell (Herriott cell)**	**High sensitivity low interference**

Three pillars of IRLAM technology

HORIBA's original

Patent pending

1. In-house manufactured QCL device

HORIBA's original

Patented※

※US Patent No. : 10551299

2. Compact type Herriott cell

HORIBA's original

Patented※

※Japan Patent No. : 6886507

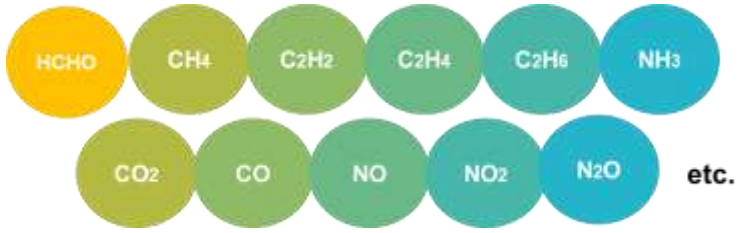
※US Patent No. : 11030423

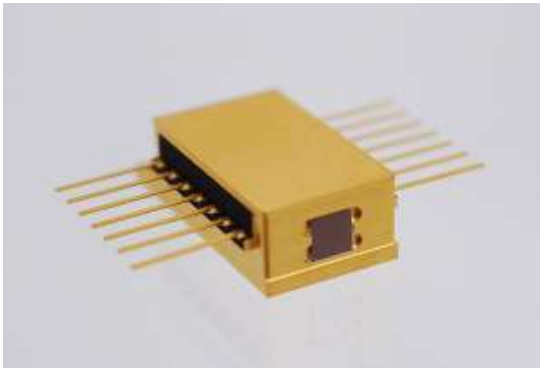
3. Concentration Calculation Algorithm

※IRLAM is a registered trademark or trademark of HORIBA, Ltd. in Japan and other countries.

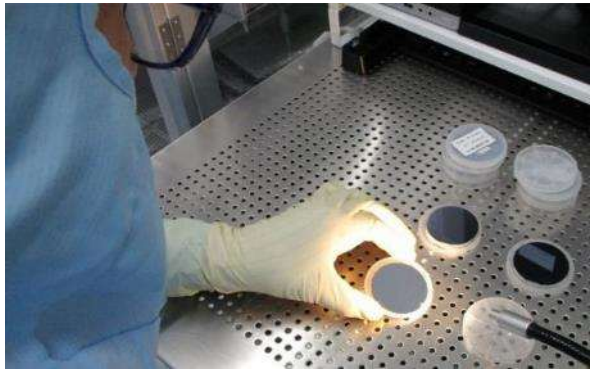
1. In-house manufactured QCL device

- A type of semiconductor laser emitting light with wavelength in the mid-infrared region, where many gas molecules exhibit the strongest absorption.
- The laser chip consists of several hundred layers of semiconductor thin film, and by controlling the material composition and film thickness, the emitting wavelength can be arbitrarily designed.
- HORIBA is capable of designing and manufacturing QCLs from 4 to 10 μm.



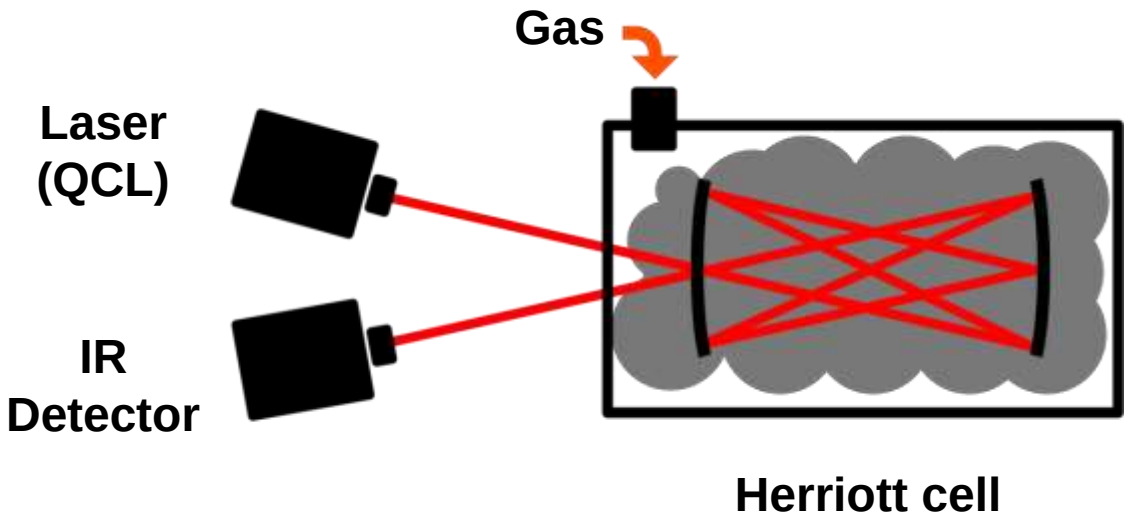


QCL by HORIBA



QCL manufacturing process

2. Compact type Herriott cell



5m optical path length in just 50mL
(New Compact)

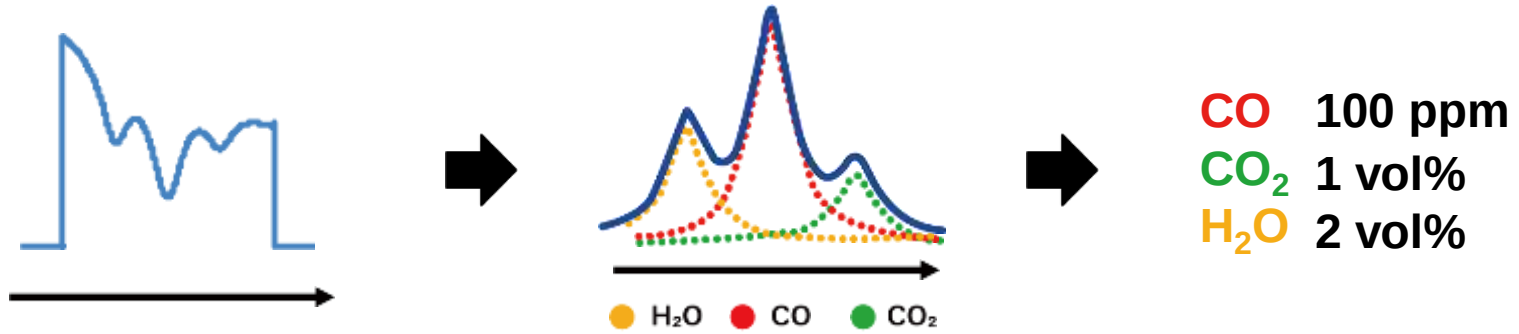
HORIBA's original

80% smaller than conventional product volume

- A pair of well-designed concave mirrors works as a multi-pass cell called “Herriott cell”
- Longer optical path-length brings higher sensitivity in absorption spectroscopy
- HORIBA's original Herriott cell has a long path-length with a small internal volume, which improves the response time of the analyzer.

3. Concentration calculation algorithm

- **Conventional conc. calculation algorithm for QCL**

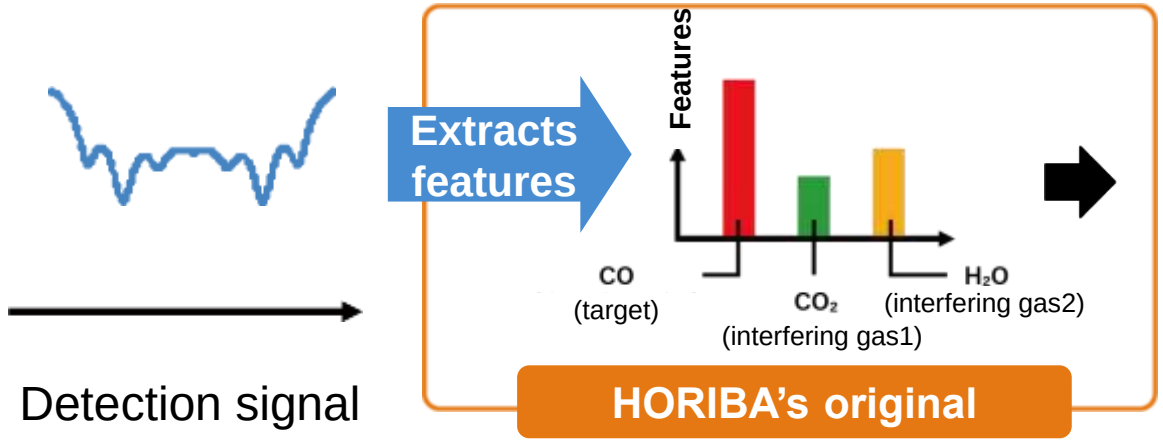


Detection signal　　Calculation　　Result

CO 100 ppm
CO_2 1 vol%
H_2O 2 vol%

The calculation, which use spectral fitting, takes time so requires high performance computer.

- **New conc. calculation algorithm for IRLAM**



Detection signal　　Result

CO 100 ppm
CO_2 1 vol%
H_2O 2 vol%

Feature-based approach can use only a few numerical values, thus significantly reducing the amount of calculations.

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3	**Overview of “VERIDRIVE”**
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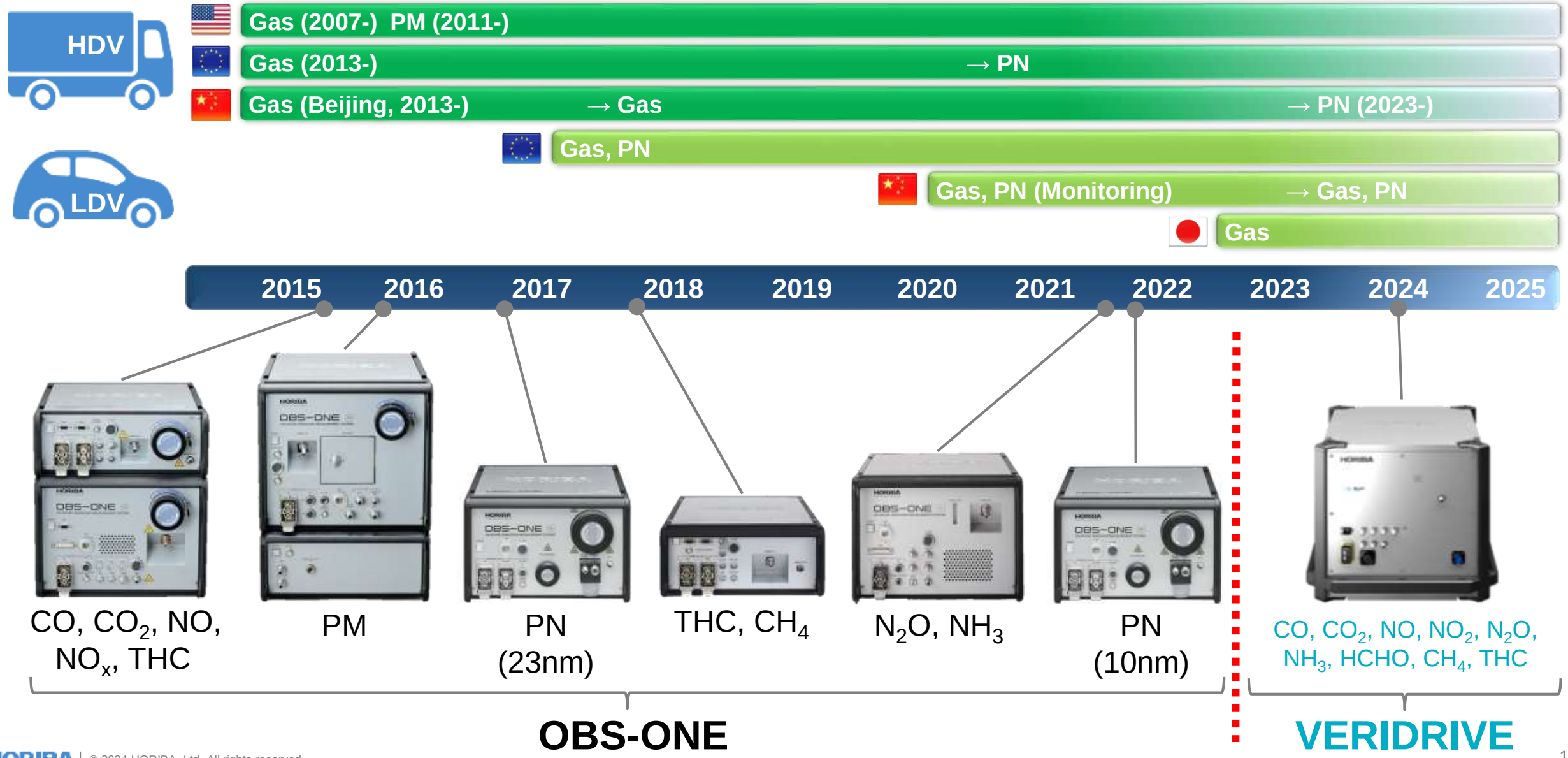
HORIBA PEMS toward Real Driving Emissions



VERIDRIVE basic specification

Measurement principle	Quantum cascade laser infrared spectroscopy (QCL-IR) Flame ionization detection (FID)	
Components and Range	**CO**	0 - 8000 ppm, 0 - 12vol%
	CO_2	0 - 20vol%
	NO	0 - 2000ppm
	NO_2	0 - 800ppm
	N_2O	0 - 1000ppm
	NH_3	0 - 1500ppm
	HCHO	0 – 50ppm
	CH_4	0 - 2000ppm, 0 - 10000ppm
	THC	0 - 10000ppm
Sample line temperature	190℃ (**wet measurement for all components**)	
Sample gas flow rate	Approx. 3.3 L/min (20°C, 1 atm)	
External dimensions	481 (W) x 631 (D) x 385 (H) mm	
Usage environment	Temperature: -10 to 45°C Humidity: 80%RH or less Altitude: 0 to 3000 m above sea level	

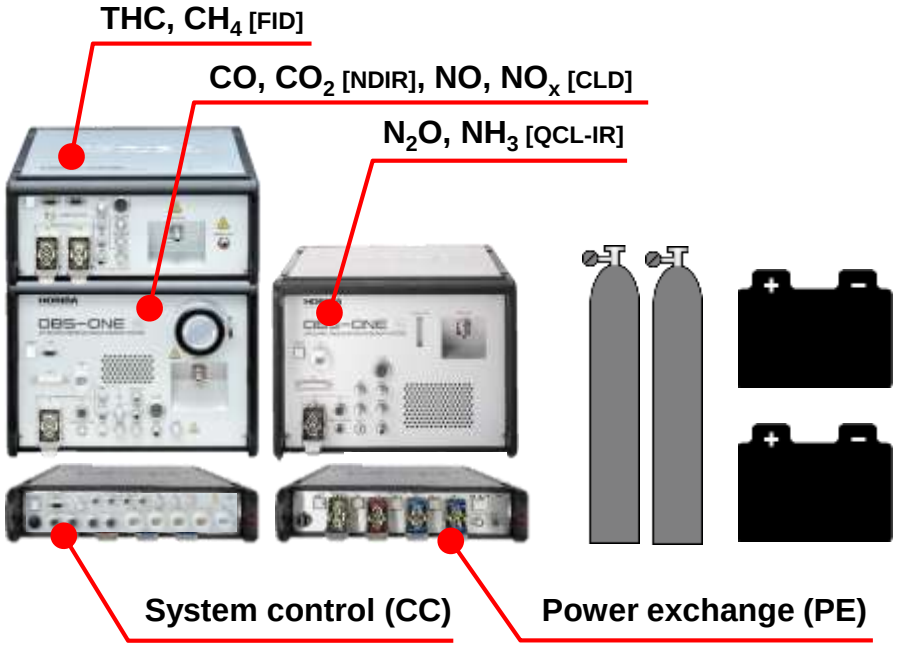
New Compact at a glance

■ Customer value

- ✓ Wide range of applications such as **not only Real world but also Laboratory measurement**.
- ✓ **Reducing power consumption by 80%** and **volume by 86%** compared to MEXA-ONE with OVN.
- ✓ **No need** for consumables such as **NOx converters**
- ✓ **No liquid nitrogen** is used, reducing running costs
- ✓ **50 % reduction** in number of cables, eliminating complications in installation
- ✓ Expanded software functions & Improved testing efficiency
- ✓ Failure reduction in PEMS Validation with IRLAM & Cross Pitot tube
- ✓ Trusted experience and expertise in RDE testing by MIRA
- ✓ **Total solution package for Euro 7 / China 7** regulatory components
- ✓ New Compact will be **capable of testing for Alternative fuel / H_2 engine** toward decarbonization

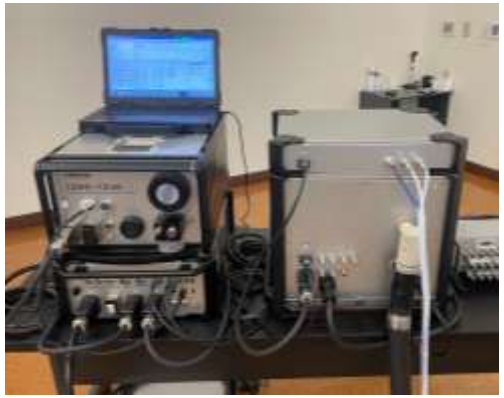
Movable and Compact system

Conventional system



VERIDRIVE (New)

CO Low / High, CO_2, NO, NO_2, NH_3, N_2O, HCHO, CH_4 Low / High [QCL-IR], THC [FID]



Reduce number of pipes & cables by 50%

Saving running cost

Approx. 40% less power consumption compared to OBS-ONE series

Approx. 80% less power consumption compared to MEXA-ONE series

No liquid nitrogen and purge gas are required

Long term stability

to keep within ± 2% of variation for 185 days.

**This data is obtained by using OBS-ONE-XL which uses IRLAM technology too.*

X in 1 package for exhaust emission regulation

Euro 7 (2024/1257) ✓: Reporting, : Measurement

* CO, THC: PEMS margins have not been specified yet.
** HCHO: to be reviewed by Dec 2027.

Regulation	Vehicle	CO_2	CO	NO_x	THC	CH_4	NMHC	NH_3	N_2O	HCHO	NMOG	PN_{23}	PN_{10}	PM	Exhaust flow (Pitot)	Post Processing
Euro 6e	LDV		*	✓	*							✓				
Euro 7	**LDV**		*	✓	*								✓			
	HDV		✓	✓		✓		✓	✓	**	✓		✓			

VERIDRIVE

PN10

Tailpipe attachment

Regulatory compliance

Testing

HORIBA can offer all solutions tailored to your regulatory compliance needs

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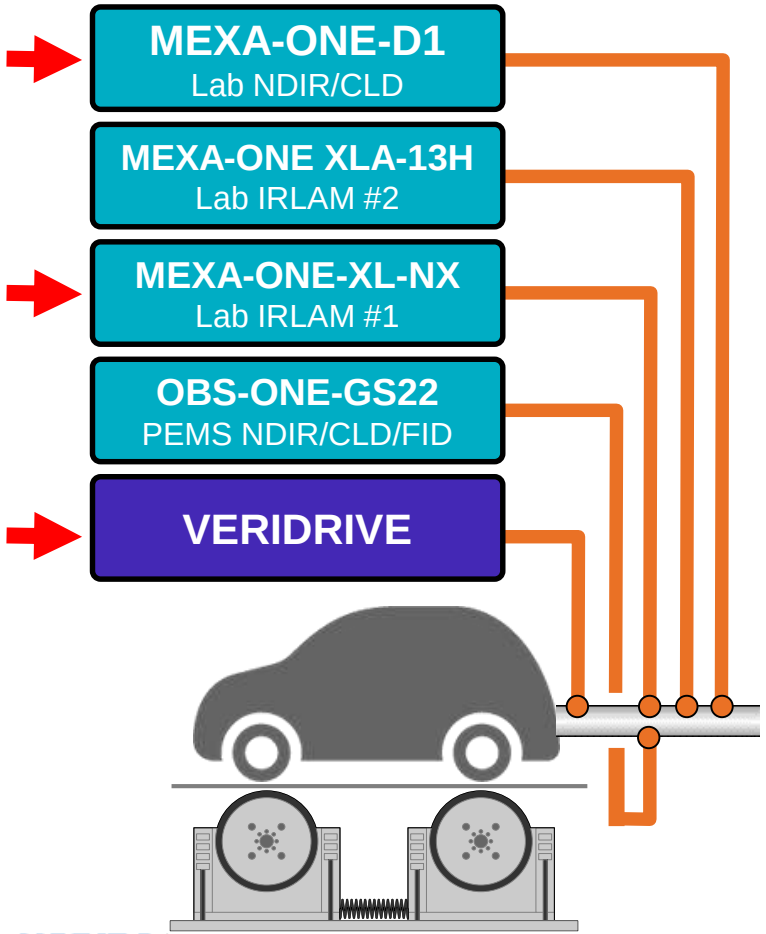
Good agreement with laboratory analyzers, improving development efficiency

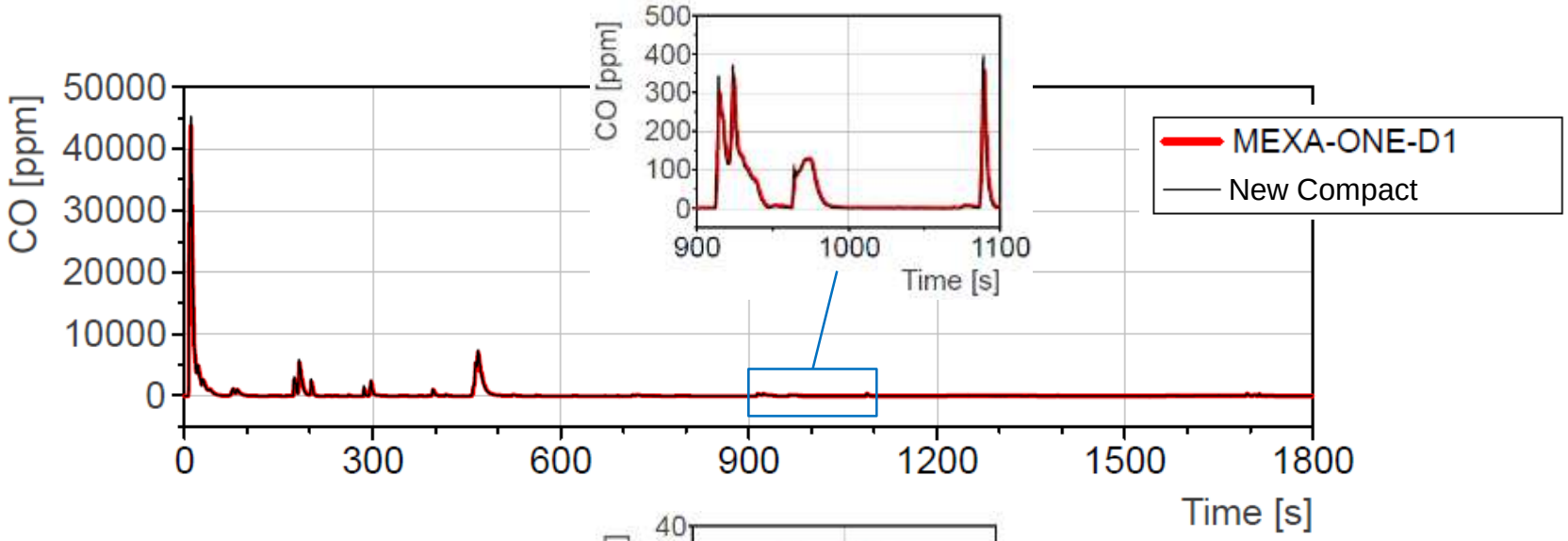
Testing vehicle

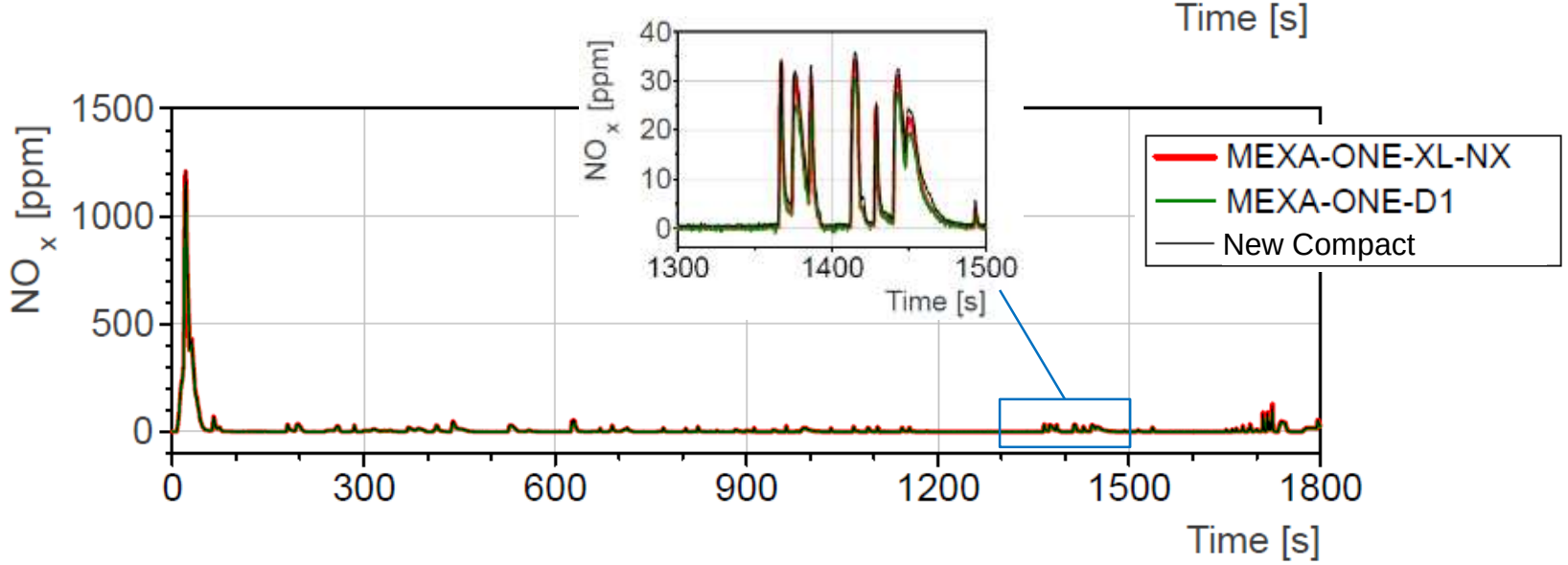
1.6 L / Gasoline / Direct Injection

Testing cycle

WLTC / 23 ℃ / Cold Start







High correlation with NDIR / CLD

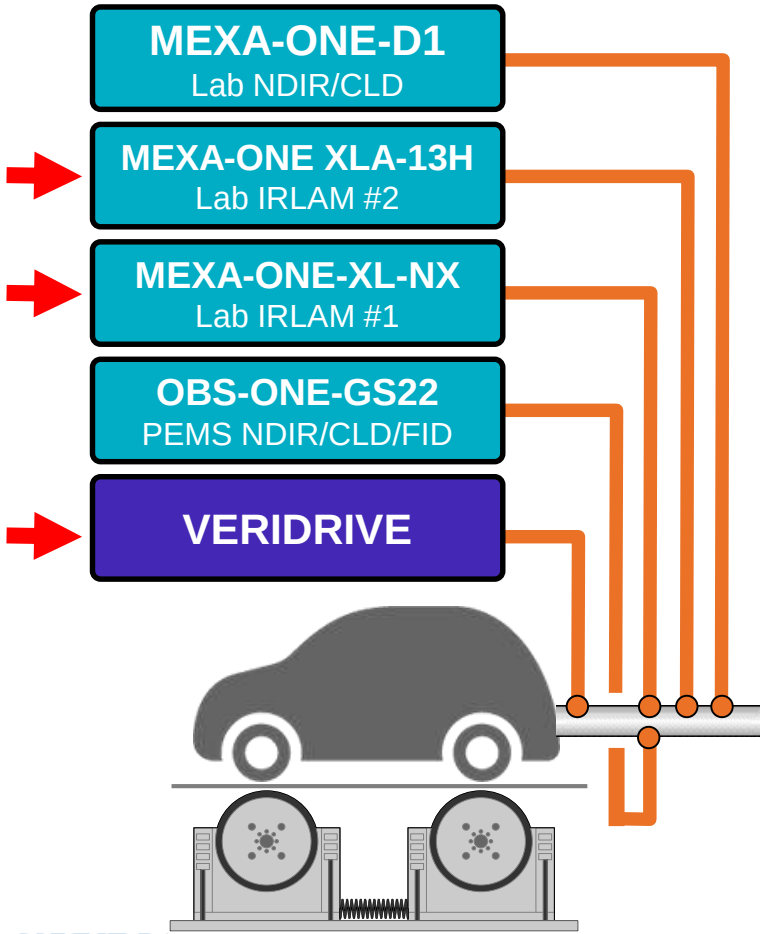
Good agreement with laboratory analyzers, improving development efficiency

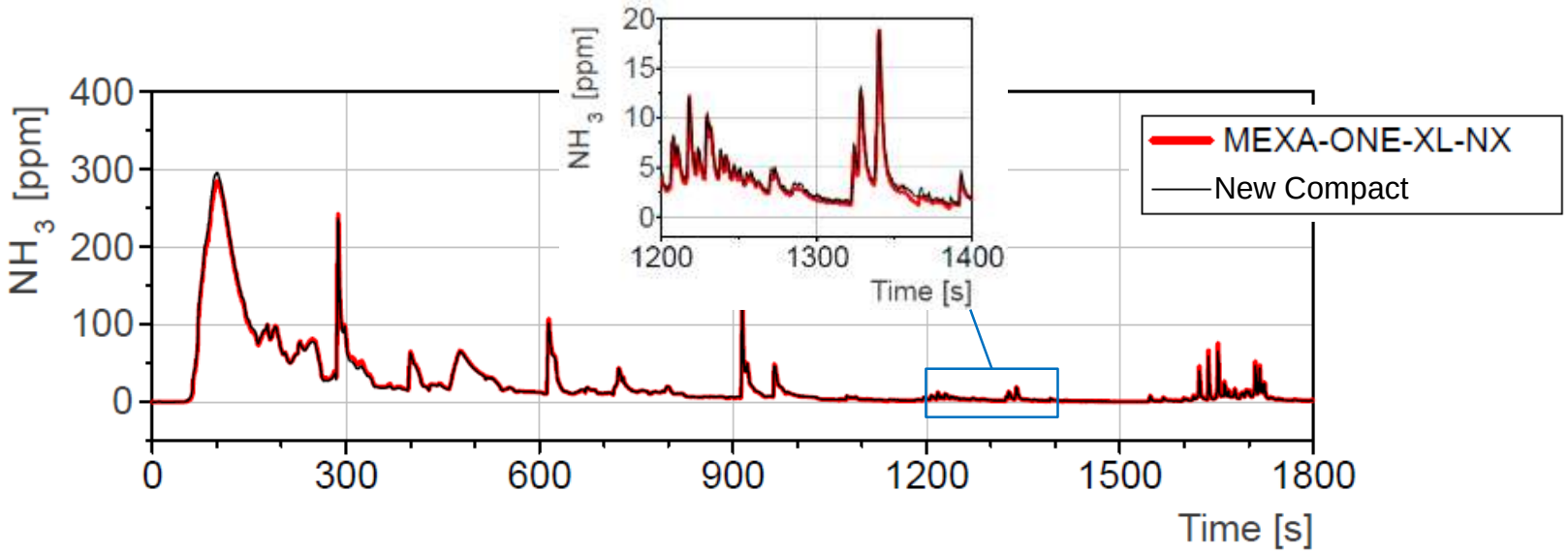
Testing vehicle

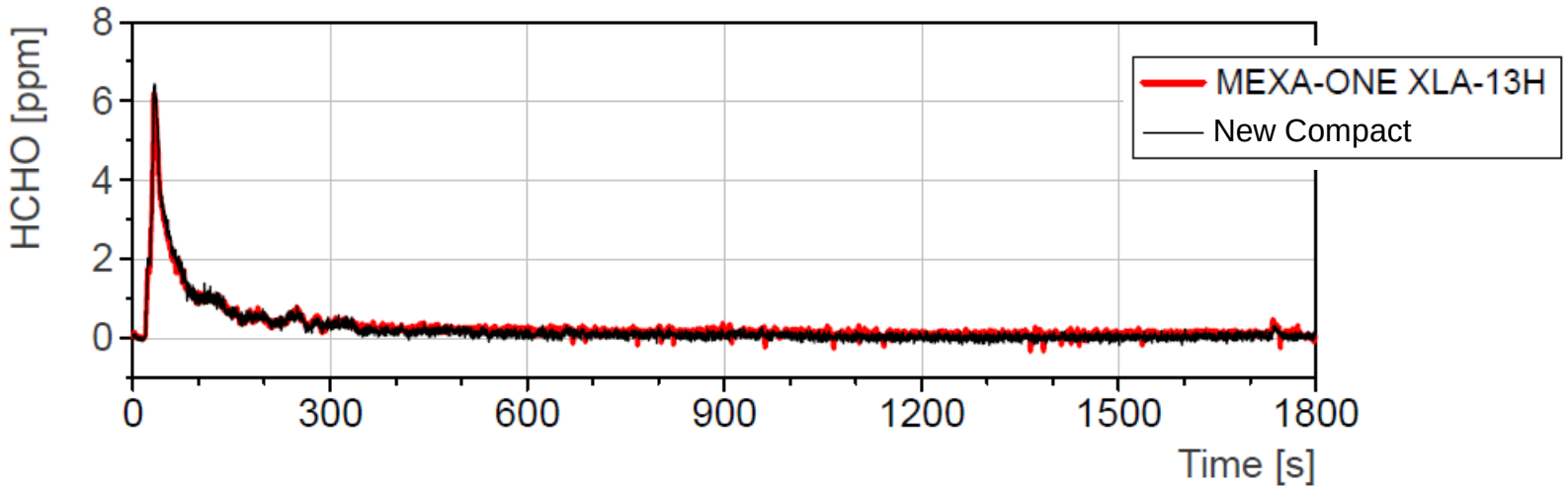
1.6 L / Gasoline / Direct Injection

Testing cycle

WLTC / 23 ℃ / Cold Start



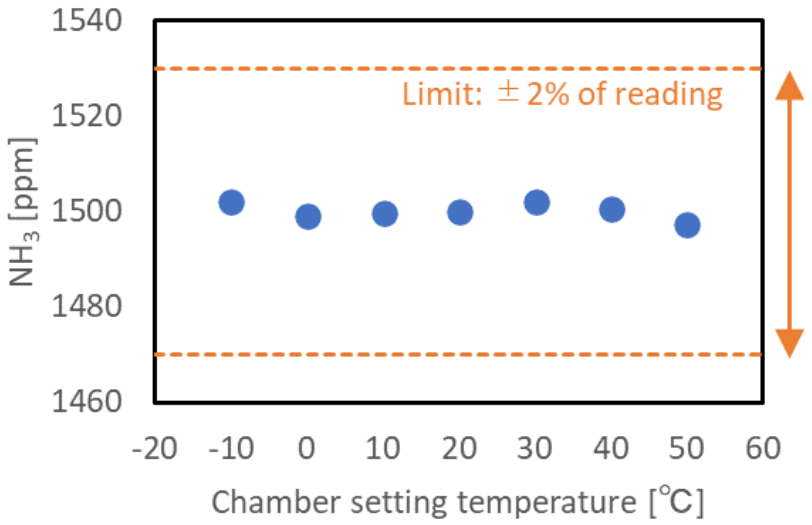




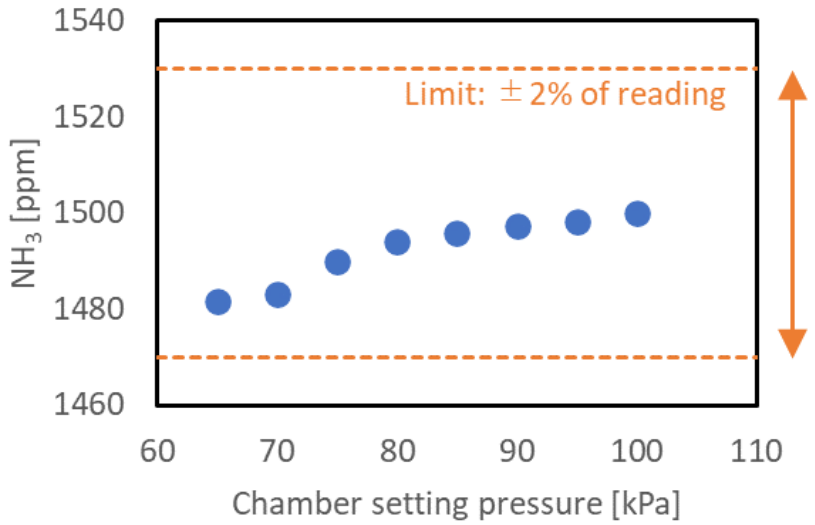
High correlation with laboratory analyzers with IRLAM

Improved robustness and flow accuracy

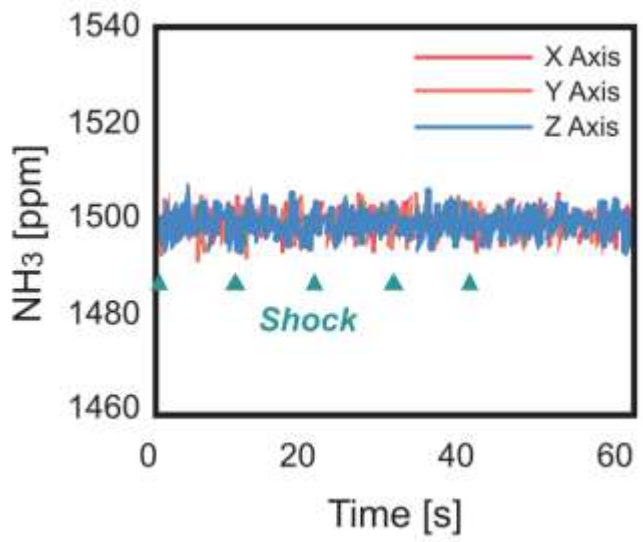
NH_3 Span 1500ppm



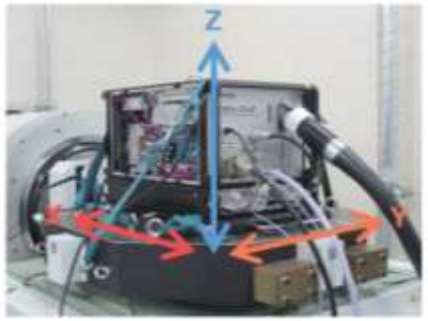
Ambient pressure 100 ～ 70 kPa
（Altitude 0 ～ 3000 m equivalent）



5G shocks



Highly robust against temperature, pressure and shock

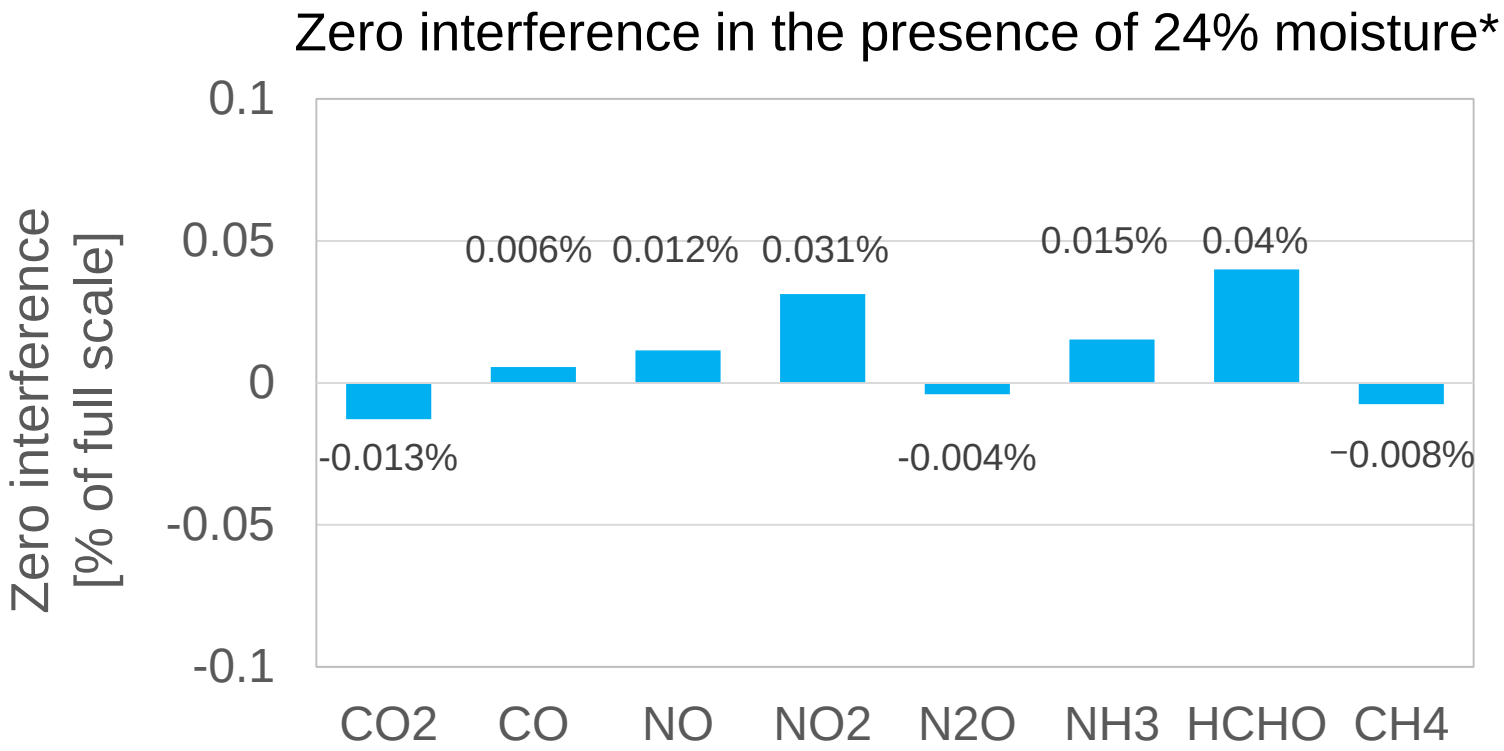


**This data is obtained by using OBS-ONE-XL which uses IRLAM technology too.*

Capable with the measurement of carbon neutral fuels

Carbon neutral fuel includes high moisture concentration.

etc.) E100: H_2O Approx. 18.4% at stoichiometric combustion

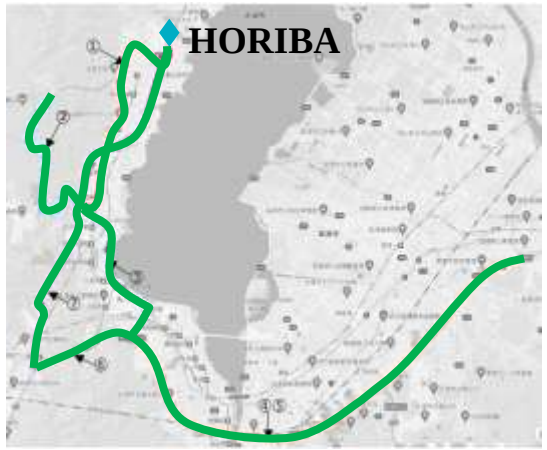


**For applications with higher moisture concentrations, please contact us.*

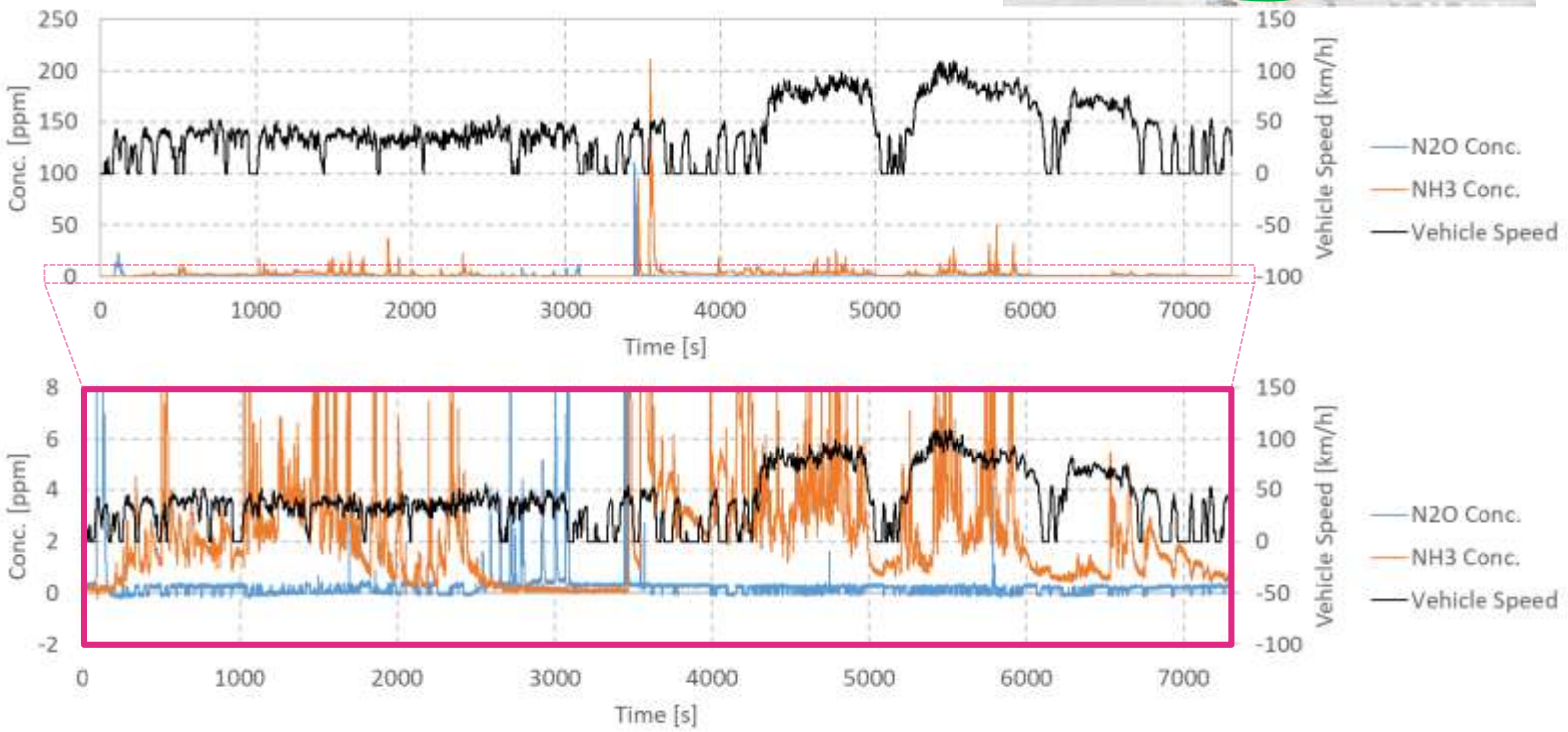
Compatible with high moisture exhaust gases when burning carbon neutral fuel

RDE Test

- Hybrid Electric Vehicle
- Engine displacement: 1.8 L



Route
- 94 km / 116 minutes
- Including hill climbing



Drift check

N2O

	Pre Test [ppm]	Post Test [ppm]	Drift [ppm]	Drift [%]
Zero	0.0	-0.1	-0.1	-
Span	978.8	977.2	-1.5	-0.2%

NH3

	Pre Test [ppm]	Post Test [ppm]	Drift [ppm]	Drift [%]
Zero	0.2	-0.3	-0.5	-
Span	1424.3	1420.8	-3.5	-0.2%

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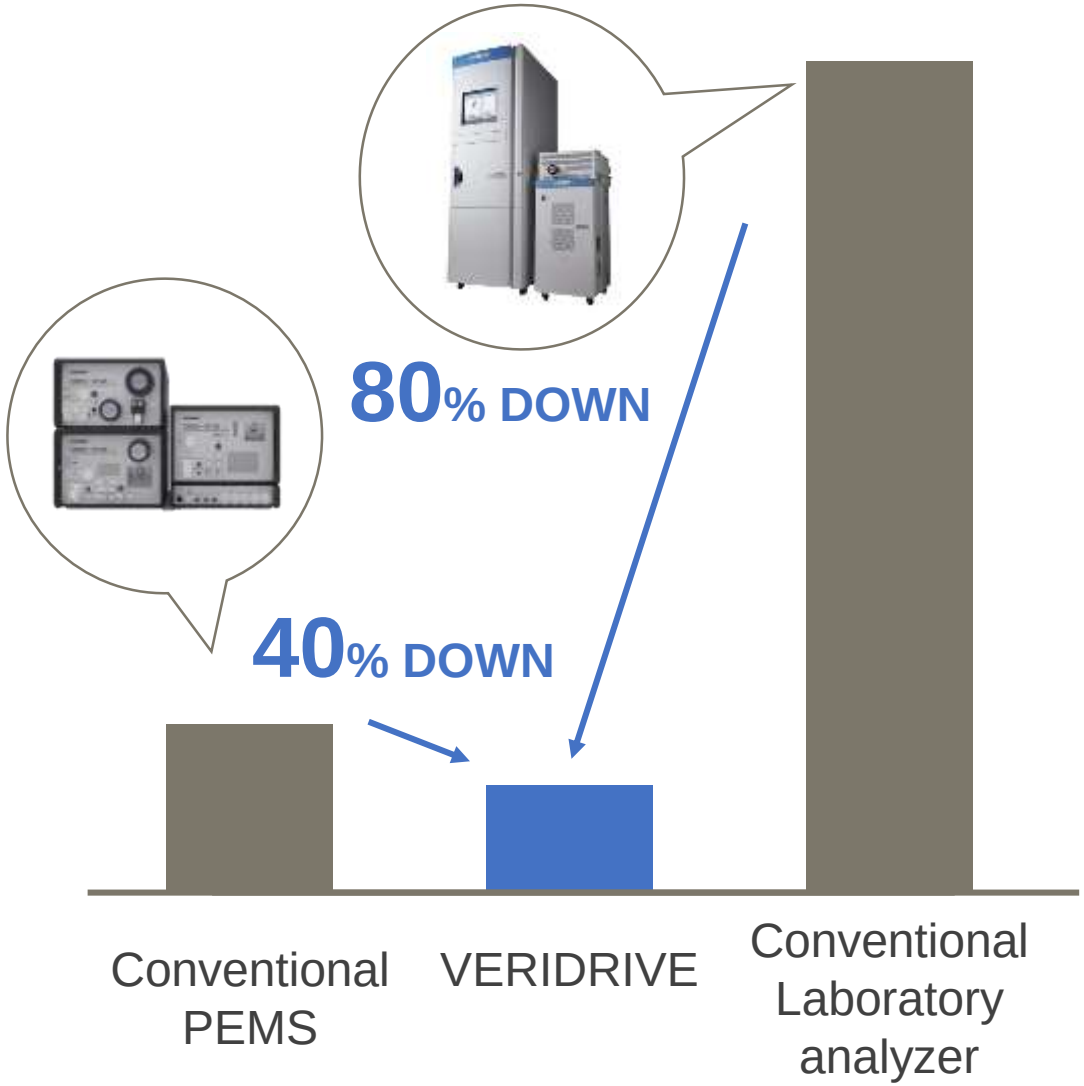
Conclusions

- **IRLAM technology is a new analytical methodology to precisely determine concentration of a specific gas specie by suppressing interference by other gas species by means of high-resolution spectral analysis using a modulated quantum cascade laser**
- **VERIDRIVE is capable to handle engine exhaust with a high-water content emitted by carbon neutral fuel combustion by applying heated sampling and robust IRLAM technology**

IRLAM Technology

Toward developing the next generation of mobility



Support for expanding applications

Greenhouse Gases

- CO_2
- CH_4
- N_2O

Outline of EU-ETS

source: seminar_001.pdf (classnk.or.jp)

Energy saving product and support for next generation of mobility

Omoshiro-okashiku

Joy and Fun

Terima kasih

நன்றி

Gracias

谢谢

Danke

Σας ευχαριστώ πάρα πολύ

Tack ska du ha

धन्यवाद

THANK YOU

شُكْرًا

Grazie

ขอบคุณครับ

Obrigado

Большое спасибо

ありがとうございました

Cảm ơn

Merci

감사합니다

Dziękuję