Gas analysis implications of the new Non-Road Mobile Machinery (NRMM) Regulation

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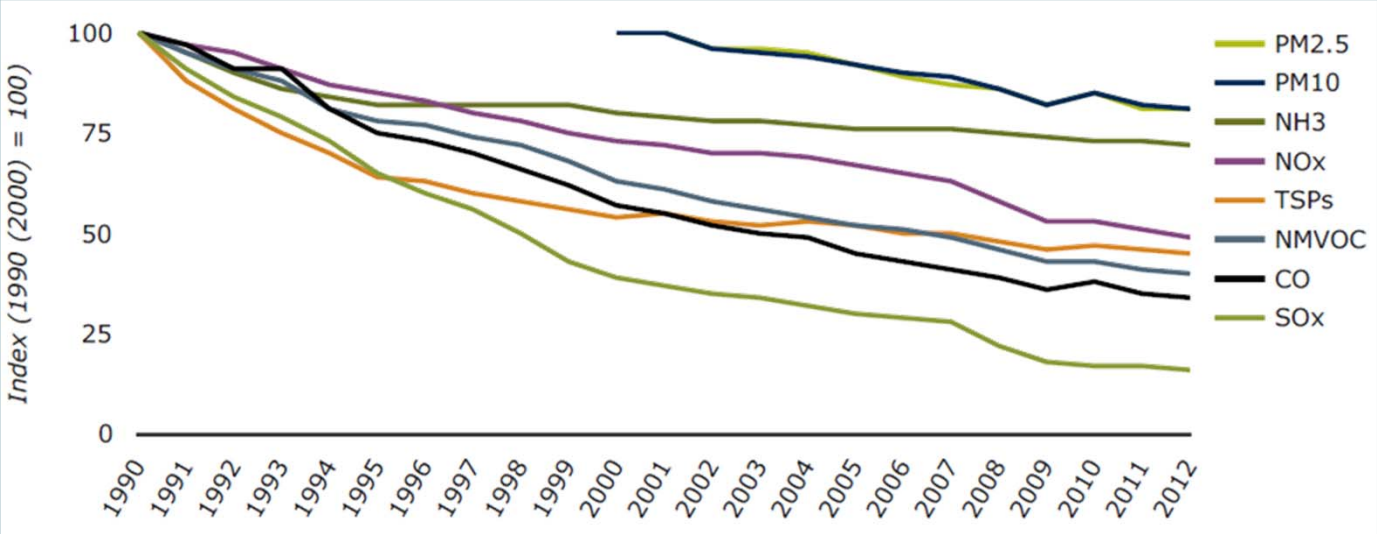
CEM 2016

Introduction

EU-28 emission trends for the main air pollutants



Data source: EEA, National emissions reported to the Convention on Long-range Transboundary Air Pollution (LRTAP Convention)

- The main air pollutants have generally declined over the past two decades
- Increase in the fraction of NO_x emitted as NO_2 by diesel vehicles
- NO_x emissions from diesel vehicles under real-world driving conditions (RDE) often exceed the test-cycle limits specified in the Euro emission standards
- **NRMM are responsible of ~15% of NOx and ~5% of PM emissions in the EU**
- In 2012 the WHO classified diesel engine exhaust as carcinogenic to humans

Non-Road Mobile Machinery (NRMM) – Scope

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Engines:

- Small gardening and handheld equipment
- Construction and mining machinery
- Generator sets
- Agricultural and farming machinery
- Railcars
- Locomotives
- Inland waterways vessels

Pollutants:

- Carbon monoxide (CO)
- Hydrocarbons (HC)
- Nitrogen oxides (NOx)
- Particulate matter (PM)

Same species considered in CEM!

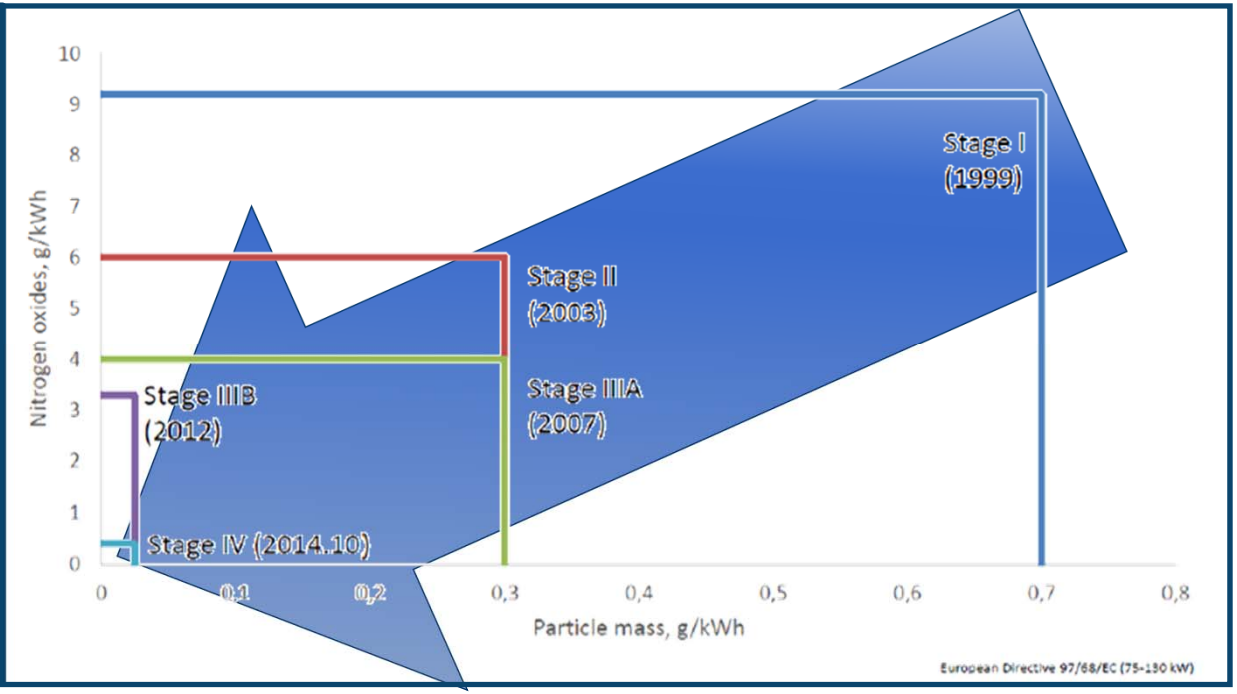



NRMM – The Current Regulatory Framework

- **Directive 97/68/EC**
  - ≦ 5 other Directives
  - ≦ 15 Annexes
  - ≦ 28 National laws

HIGH COMPLEXITY!

- **5 Stages**:
  - Ð I → 1999
  - Ð II → 2003
  - Ð IIIA → 2007
  - Ð IIIB → 2012
  - Ð IV → 2014
  - Ð **V** → **2017 NEW!**



Data source: Advanced Motor Fuel (AMF) Implementation Agreement, Progress Report ExCo 48

NRMM – The New Regulatory Framework

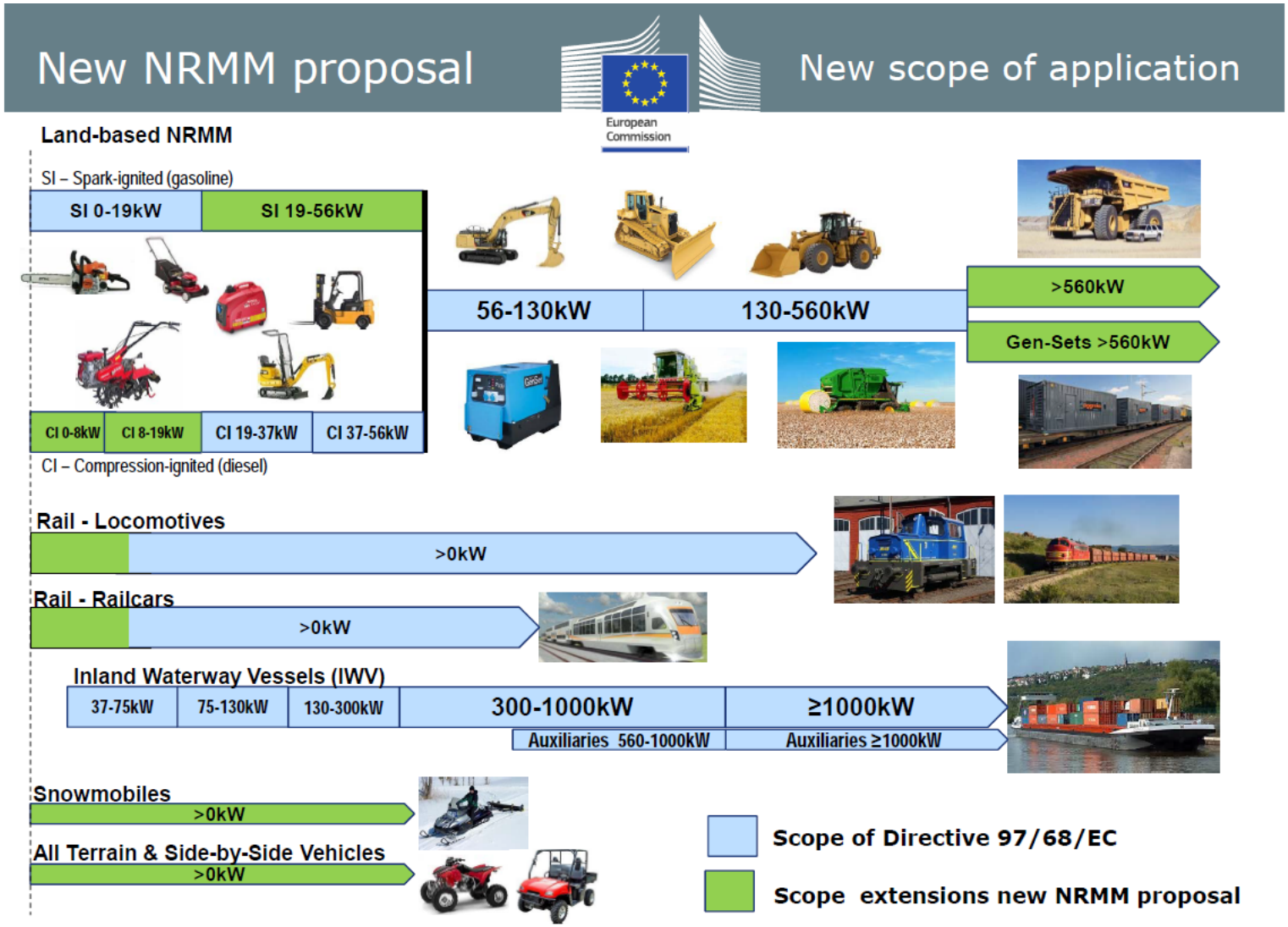
Objectives:

1. **Reduce emissions**
   - Ð Reduce the Emission Limits Values (ELVs) from new engines being brought on the market
   - Ð Phase out polluting equipment

2. **Harmonise across the EU**
   - Ð Cut complexity
   - Ð Cut exemptions

3. **Update requirements to the state of the art of technology**
   - Ð Euro 6 for heavy duty vehicles
   - Ð US Tier 4 final

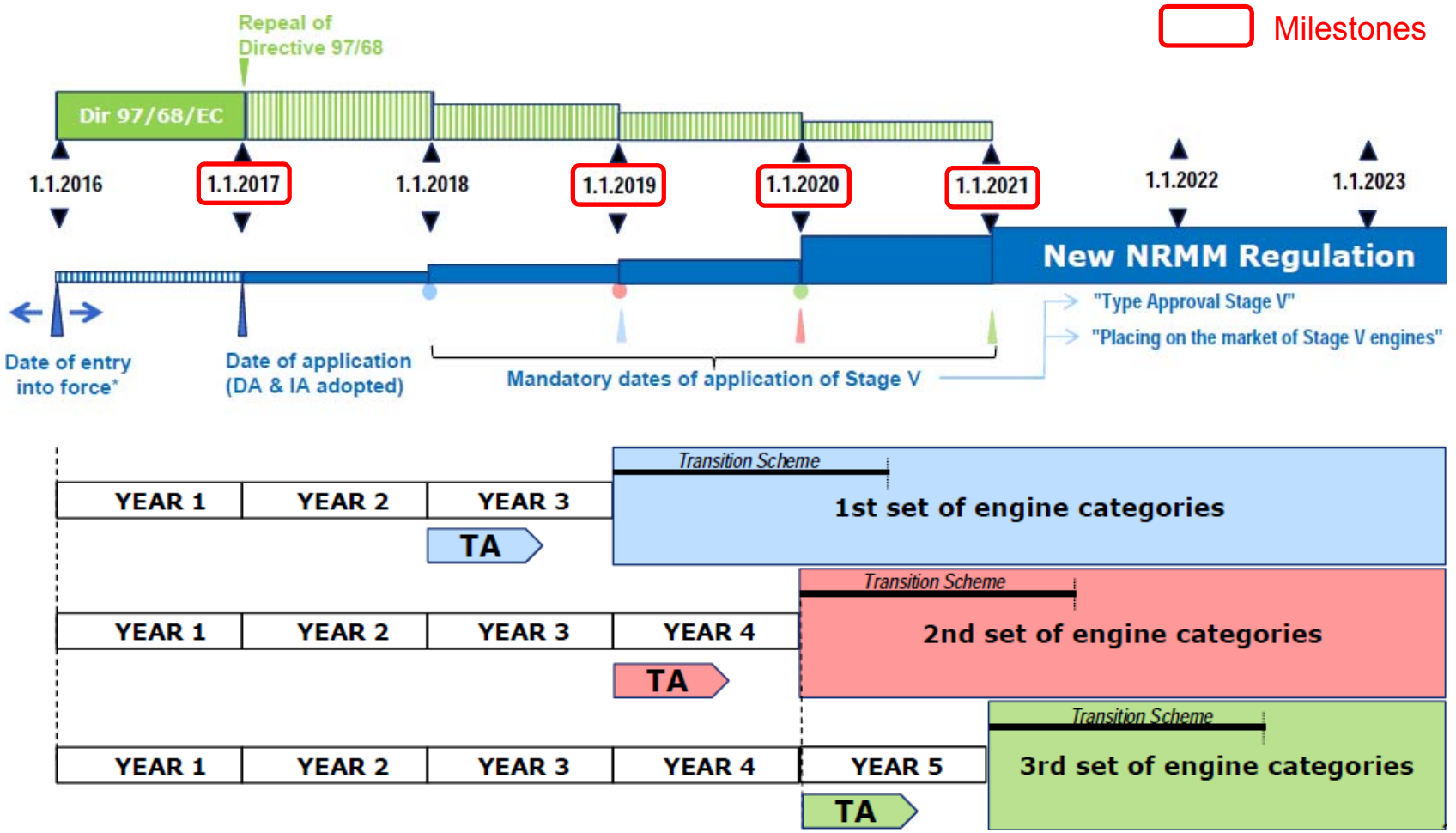
NRMM – The New Regulatory Framework



Data source: Commission proposal for a new Regulation for engines in NRMM, Dr-Ing. P.Troppmann, 11th Integer Emission Forum 2015 Brussels

NRMM – The New Regulatory Framework

Timeline:



Data source: Commission proposal for a new Regulation for engines in NRMM, Dr-Ing. P.Troppmann, 11th Integer Emission Forum 2015 Brussels

NRMM – The New Regulatory Framework

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Proposed Stage V emission standards for non-road engines

Ignition	Net Power	Date	CO	HC	NOx	PM	PN
	kW		g/kWh				1/kWh
CI	P < 8	2019	8.00	7.50		0.40	-
CI	8 ≤ P < 19	2019	6.60	7.50		0.40	-
CI	19 ≤ P < 37	2019	5.00	7.50		0.015	1×10^{12}
CI	37 ≤ P < 56	2019	5.00	7.50		0.015	1×10^{12}
All	56 ≤ P < 130	2020	5.00	0.19	0.40	0.015	1×10^{12}
All	130 ≤ P ≤ 560	2019	3.50	0.19	0.40	0.015	1×10^{12}
All	P > 560	2019	3.50	0.19	3.50	0.045	-

Particulate Number
NEW ELV

NEW IN SCOPE

ELVs REDUCTION

NEW IN SCOPE

Proposed Stage V emission standards for generator set engine above 560 kWh

Ignition	Net Power	Date	CO	HC	NOx	PM	PN
	kW		g/kWh				1/kWh
All	P > 560	2019	3.50	0.19	0.67	0.035	-

NEW IN SCOPE

CI: Compression-Ignited engine (diesel)
All: CI and Spark-Ignited engine (gasoline)

NRMM – The New Regulatory Framework

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Proposed Stage V emission standards for inland waterways vessels

Category	Net Power	Date	CO	HC	NOx	PM	PN
	kW		g/kWh				1/kWh
Propulsion engines	37 ≤ P < 75	2019	5.00	4.70		0.30	-
	75 ≤ P < 130	2019	5.00	5.40		0.14	-
	130 ≤ P < 300	2019	3.50	1.00	2.10	0.11	-
	300 ≤ P < 1000	2020	3.50	0.19	1.20	0.02	1×10^{12}
	P ≥ 1000	2021	3.50	0.19	0.40	0.01	1×10^{12}
Auxiliary engines	560 ≤ P < 1000	2020	3.50	0.19	1.20	0.02	1×10^{12}
	P ≥ 1000	2021	3.50	0.19	0.40	0.01	1×10^{12}

Particulate Number NEW ELV

ELVs REDUCTION

Proposed Stage V emission standards for rail traction engines

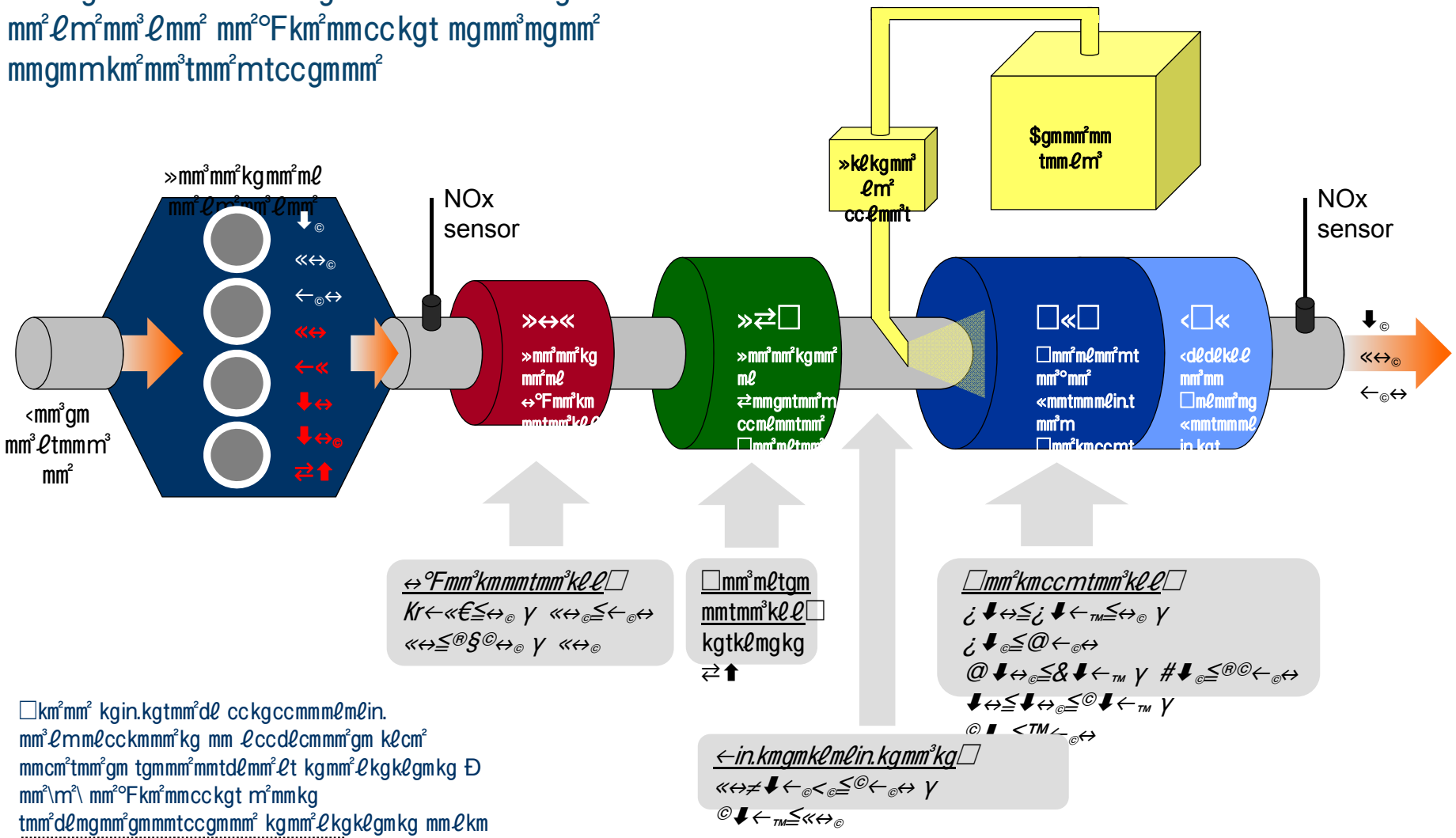
Category	Net Power	Date	CO	HC	NOx	PM	PN
	kW		g/kWh				1/kWh
Locomotives	P > 0	2021	3.50	4.00		0.025	-
Railcars	P > 0	2021	3.50	0.19	2.00	0.015	1×10^{12}

Particulate Number NEW ELV

ELVs REDUCTION

After Treatment Methods

□in.mgmm³mmmmℓ mℓmmgmm²mm² »mm³mm²kgmm²mℓ mm²ℓm²mm³ℓmm² mm²°Fkm²mmcckgt mgmm³mgmm² mmgmmkm²mm³tmm²mtccgmmm²



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Analytical Systems

NOx

Chemioluminesence Spectroscopy (CLD)

Chemiluminescence uses quantitative measurements of the optical emission from excited chemical species to determine analyte concentration. The most widely used of these methods is for the determination of nitrogen monoxide. The instrumentation for chemiluminescence measurements is simple and can consist of only a suitable reaction vessel and a photomultiplier tube

CO

Non-Dispersive Infrared Spectroscopy (NDIR)

Non dispersive infrared spectroscopy (NDIR) is often used to detect gas & measure the concentration of carbon oxides (e.g. carbon monoxide, carbon dioxide). An infra-red beam passes through the sampling chamber and each gas component in the sample absorbs some particular frequency infrared. In parallel a reference gas, typically nitrogen, is used in another chamber. By measuring the amount of absorbed infrared at the necessary frequency, the concentration of the gas component can be determined

HC

Flame Ionisation Detector (FID)

A Flame ionization detector (FID) consists of a hydrogen/air flame and a collector plate. The effluent from the gas chromatography column passes through the flame, which breaks down organic molecules and produces ions. The ions are collected on a biased electrode and produce an electrical signal. Flame ionization detectors are used for detecting hydrocarbons (HC)

Same instrumentations used in CEM!

Analytical Systems – Pure Gases and Mixtures

Definitions

Calibration gas:
A gas or gas mixture of accurately known composition used as a comparative standard in analytical instrumentation

Span gas:
A calibration gas containing a given amount of impurity generally used with a zero gas

Zero gas:
A gas which has a total hydrocarbon content below the minimum detection range of an analyser, and used as a reference point to "zero" the analyser

Example of gases needed for a FID analyser

Zero gas:
Purified synthetic air or purified nitrogen

«kℓℓkgtmm³t ccm㎡ℓt	⇄ccgmm³cm² m³m²km ⬇©	⇄ccgmm³cm²m³m²km kgin.ℓtk㎡m²tm³m mmm³gm
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Requested amount of methane (CH_4) or Propane (C_3H_8) – ppm level – in purified synthetic air or purified nitrogen

FID Fuel gas:
39%-41% hydrogen (H_2) in helium (He)
Hydrocarbons (THC) ≤ 0.05 ppm

FID burner air:
Purified synthetic air (as above)

Analytical Systems – Packaged and equipment

Package

Calibration gases need to be available in the most appropriate package, for example:

- Laboratory test → **10 litres cylinder**
- Portable Emission Measurement System (PEMS) → **1 litre portable cylinder**

Linde ECOCYL® is an example of small refillable cylinder equipped with integrated regulator and flow meter

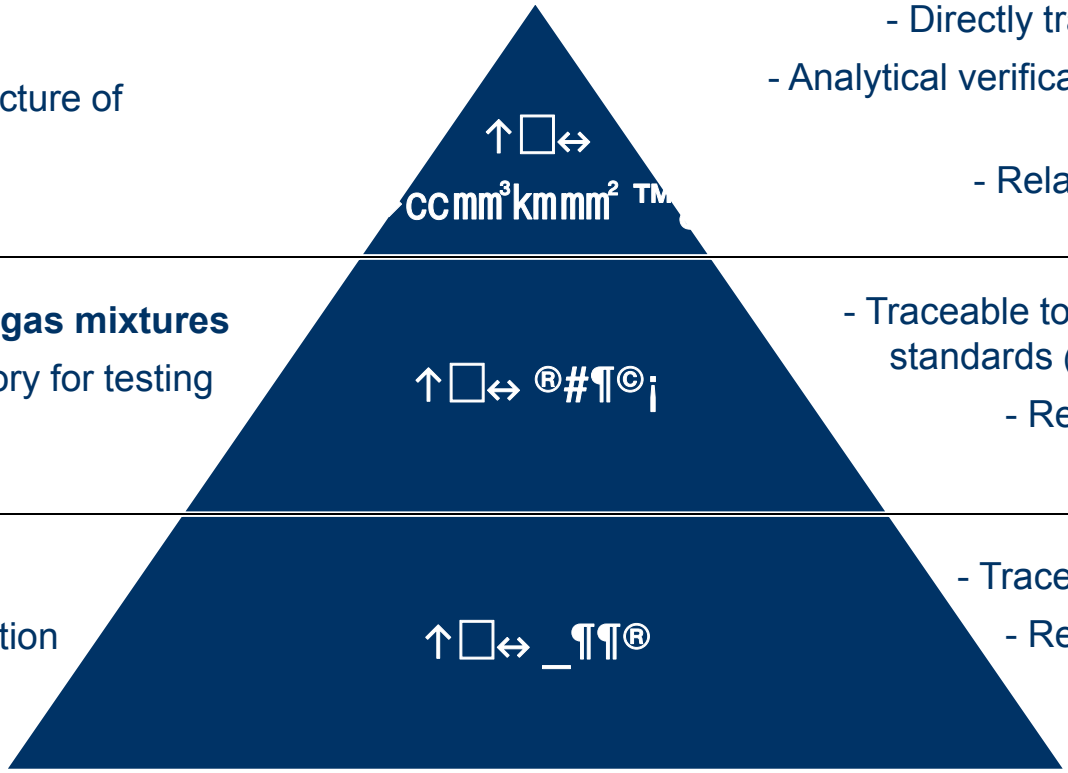
Equipment

Equipment to supply the gas at the point of use needs to be suitable for gases where the demand on purity is high

Linde REDLINE® range is an example of specialty equipment – i.e. pressure regulators and gas panels – suitable for high purity gases

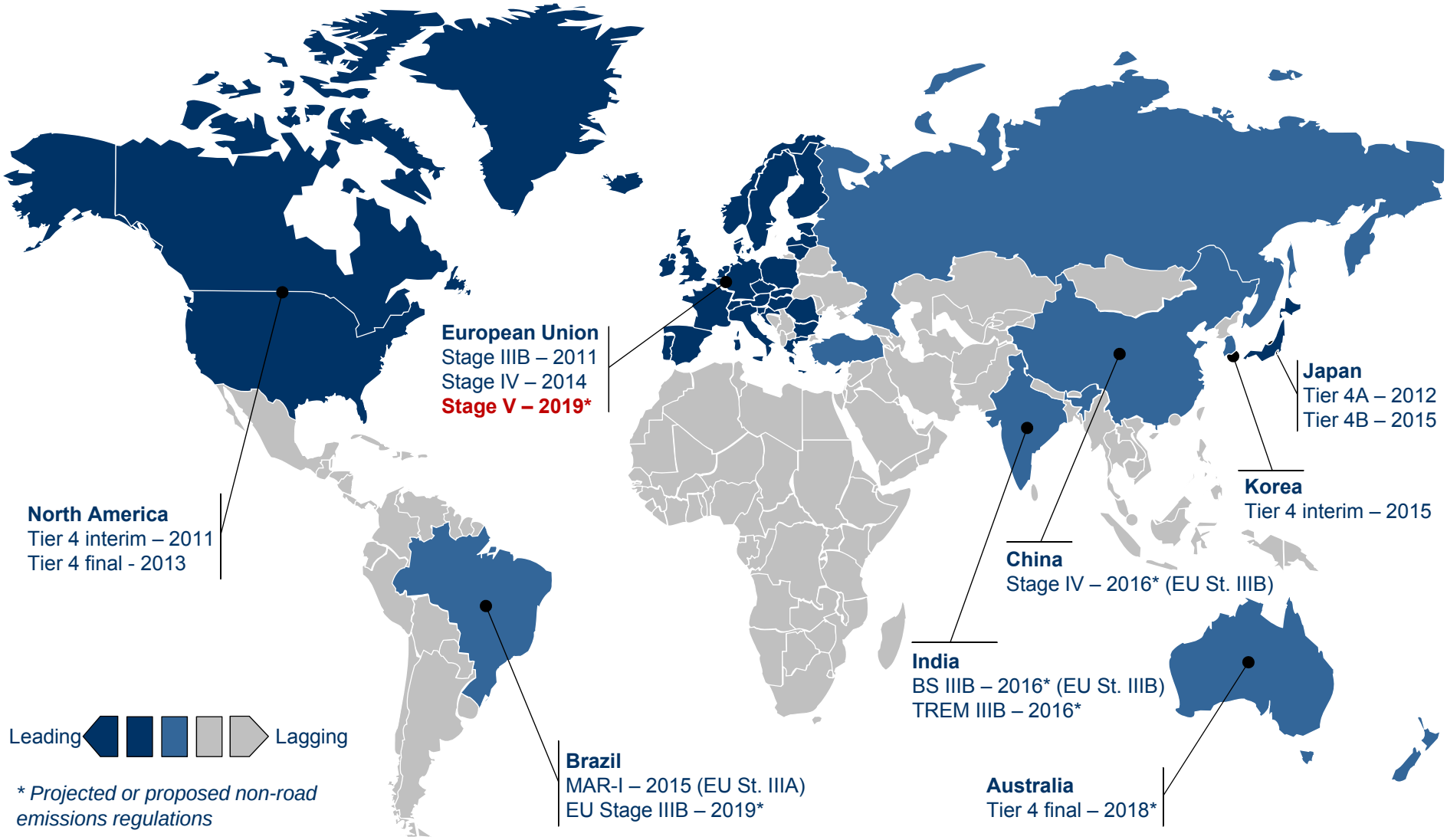
Analytical Systems – Certification

Calibration gas mixtures	Metrological properties
Reference materials Accreditation as manufacture of reference materials	- Directly traceable to SI-units (kg) - Analytical verification using international approved standards - Relative uncertainty ≈ 0,5%
Accredited calibration gas mixtures Accreditation as laboratory for testing and calibration	- Traceable to international approved standards (NIST, BAM, VSL, NPL, …) - Relative uncertainty ≈ 1%
Standard gas mixtures QM – Company certification	- Traceable to plant standards - Relative uncertainty ≥ 2%



Metrological properties of calibration gas mixtures with reference to the relevant ISO standards

↔cm²cm²/□kℓmmkmkg ¢mm²km²mm³mmℓmm²kg Ð →mℓkℓcmmmmℓ ↔°mm²gm°mm³mm²°C



** Projected or proposed non-road emissions regulations*

Summary

- The continued improvement in air pollution levels in the EU is going to impact the NRMM sector within the next 5 years

- The new regulation is set to replace the legal framework currently in place

- Engine manufacturers and OEMs:
  - › have to consider a proper aftertreatment strategy to control engine emissions
  - › must be able – thanks to appropriate analytical methods – to carry out reliable measurements of the controlled pollutants

- That last process includes the use of proper calibration gases, delivered in the most suitable package and supplied to the point of use via distribution equipment that do not compromise the quality level of the gases

Thanks for your attention!

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