

EUROPEAN STAGE V NON-ROAD EMISSION STANDARDS

ICCT **POLICY UPDATES**
SUMMARIZE
REGULATORY
AND OTHER
DEVELOPMENTS
RELATED TO CLEAN
TRANSPORTATION
WORLDWIDE.

The European Commission has proposed the world's toughest emission standards for non-road mobile machinery (NRMM)¹, such as construction equipment, railroad engines, inland waterway vessels, and off-road recreational vehicles. The Stage V standards, adopted by the EU Parliament in July 2016 and published in the Official Journal of the EU as Regulation (EU) 2016/1628 in September, will tighten restrictions on non-road engines and equipment and set stricter limits on emissions of particulate matter (PM). These changes, along with newly proposed particle number (PN) limits are expected to force manufacturers to equip non-road engines of between 19 kW and 560 kW with diesel particulate filters.

The Stage V emission standards will phase in as early as 2018 for approval of new engine types, and in 2019 for all sales. The rules would replace an existing, multi-layered legal framework in Europe with one overarching regulation. The commission laid out a split-level approach, putting forth legislation in two steps. The first focuses on fundamental provisions, and the second, on developing technical specifications of implementation.

BACKGROUND

The EU has adopted a series of seven directives over the past two decades to address emissions from non-road engines. Current EU regulation of emissions from these engines consists of various annexes that have been amended eight times since adoption in 1997. These directives left it up to individual EU member states to modify laws to achieve the intended outcomes, which resulted in 28 national laws currently in effect.²

¹ European Commission, "Cutting emissions and cutting red tape: a new regulation for off-road engines" (2014). http://europa.eu/rapid/press-release_IP-14-1044_en.htm

European Commission, "Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on requirements relating to emission limits and type-approval for internal combustion engines for non-road mobile machinery" (2014). http://europa.eu/rapid/press-release_IP-14-1044_en.htm

² The previous non-road emission standards (Stage I, II, IIIA, IIIB, and IV) are addressed in "Directives". These standards only set targets for member states to achieve, without specifying methodology. Directives can be adopted through various implementation measures that are preferred by individual member states.

Table 1 summarizes the previous regulation progress on non-road emission control and the corresponding directives.³

Table 1. EU NRMM emission regulation progress

Directive	When Adopted	Progress
97/68/EC	December 1997	Established Stage I and Stage II emission standards setting exhaust emission limits for diesel-fueled engines with a horsepower rating between 37 and 560 kW.
2002/88/EC	December 2002	Extended the scope of the previous directive to apply Stage I and Stage II emission standards to gasoline engines up to 18 kW.
2014/26/EC	April 2004	Incorporated Stage IIIA, IIIB, and IV emission standards. This directive also extended the scope of regulated diesel engines to those rated beyond 19 kW, and added railway and inland maritime engines.
2006/105/EC	November 2006	Introduced modifications to Directive 97/68/EC regarding concerns on the approval certificate numbering system.
2010/26/EU	March 2010	Modified type approval requirements for Stage IIIB and IV emission standards.
2011/88/EU	November 2011	Revised the flexibility percentage for Stage IIIB engines.
2012/46/EU	December 2012	Updated directive 97/68/EC to reflect technical progress on emission measures.

In addition to the 28 national laws, regional amendments set supplementary requirements on the engines sold and used in targeted areas, reflecting more stringent requirements than European law. Germany,⁴ Austria,⁵ and the Netherlands⁶ have adopted national laws requiring mandatory diesel particulate filters on construction equipment.

They are following Switzerland's approach, even though Switzerland is not part of the EU. Switzerland has required filters on underground construction equipment since 2000, based on a Swiss National Accident Insurance Fund workplace emission directive.^{7,8} Since 2002, the requirement has been extended to include general construction equipment.⁹ Amendments to the Swiss Ordinance on Pollution Control in 2008 required all new (>18 kW) and existing (>37 kW) construction equipment

- 3 European Commission—GROWTH, Internal Market, Industry, Entrepreneurship and SMEs. "Directives on emission from non-road mobile machinery." https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=0ahUKEwiW6Y_U45HLAhUX3GMKHVGLCWIQFggmMAE&url=http%3A%2F%2Fec.europa.eu%2FdocsRoom%2Fdocuments%2F11209%2Fat%2Ftranslations%2Fen%2Frenditions%2Fnative&usq=AFQjCNEdfglxq6BPcDuRdUvKsb60v5lVzg&sig=2=tDLfimt06RwtqD-DGhfLSg
- 4 Federal Institute for Occupational Safety and Health (BAuA). "Technische Regel für Gefahrstoffe 554" (2008). <http://www.baua.de/de/Themen-von-A-Z/Gefahrstoffe/TRGS/TRGS-554.html>
- 5 The Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management. "Verordnung über die Verwendung von mobilen technischen Einrichtungen, Maschinen und Geräten" (2015). <https://www.bmlfuw.gv.at/umwelt/luft-laerm-verkehr/luft/richtlinien/offroad-vo.html>
- 6 The Inspectorate SZW. <http://www.inspectieszw.nl>
- 7 Suva Mitteilung AS456. "Information zur Einführung des Partikelfilter-Obligatoriums für dieselmotorbetriebene Fahrzeuge und Maschinen im Untertagebau" (2001). AS 456.d - 05.01. https://www.dieselnet.com/tech/text/ch_suva_as456.pdf
- 8 This requirement lists two exceptions: 1) Equipment of below 50 kW, operated for less than 2 hours per shift; 2) Equipment which is not used in regular transport work and which is operated less than 1 hour per day.
- 9 Herausgegeben vom Bundesamt für Umwelt, Wald und Landschaft BUWAL. "Luftreinhaltung auf Baustellen -- Baurichtlinie Luft" (2002). https://www.dieselnet.com/tech/text/ch_vu-5024-d.pdf

to meet a solid PN emission limit of 1×10^{12} /kWh over a non-road steady cycle and non-road transient cycle, or to install particulate filters that conform to the directive's requirements.¹⁰ This additional layer of stringency in a handful of countries has added to the overall complexity of the European approach to NRMM.

The newly proposed Stage V emission standards will replace the existing multi-layered legal framework with one regulation for the whole of the EU. The planned two-step adoption will ensure that the European Council and the European Parliament focus on the regulation's essential elements, leaving technical and administrative details to be developed later.

The European Commission, led by the Directorate-General for Internal Market, Industry, Entrepreneurship, and SMEs (DG-ENTR), is developing supplementing legislation to address the technical and administrative aspects – delegated acts and implementing acts. The delegated acts will include (1) detailed technical requirements for test cycles, measurement procedures, exceptions, and provisions for type-approval procedures and (2) details of in-service monitoring requirements. The implementing act will describe administrative procedures, including templates, formats, number methods, and provisions for an EU-wide data platform.¹¹ Various stakeholder working groups, including participants such as the European Commission, member states, industry and some non-government organizations, have collaborated on developing these regulatory details and are aiming to finalize the acts by early 2017.

KEY IMPROVEMENTS

EXTENDED SCOPE

*"Extend the scope, with a view to improving market harmonization (EU and international) and minimizing the risk of market distortions."*¹²

The proposed regulation includes a wider range of engine types and sizes. The proposal covers previously unregulated engines, including rail, snowmobiles, and engines below 19 kW or over 560 kW. These actions broaden the authority of member states to regulate their internal and external markets for these engines. Engine categories included in the Stage V proposal are listed in Table 2 below:

¹⁰ The federal Council, The portal of the Swiss government. "Ordinance on Air Pollution Control (OAPC)" (2010). <https://www.admin.ch/opc/en/classified-compilation/19850321/index.html>

¹¹ Troppmann, P., Escobar, L., Perujo, A. "Non-Road Mobile Machinery – Revision of Directive 97/68/EC" (2014). GEME Meeting.

¹² European Commission. "Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on requirements relating to emission limits and type-approval for internal combustion engines for non-road mobile machinery" (2014). <http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52014PC0581>

Table 2. Engine categories regulated in the Stage V proposed emission standard

Engine Type	Equipment Category	Explanation
1. NRE	Other non-road mobile machinery	(a) Engines for non-road mobile machinery intended and suited to move, or to be moved by road, and are not included in any other category set out in points (2) to (10). (b) Engines with a reference power of less than 560 kW used in place of engines of categories IWP, RLL or RLR.
2. NRG	Generating sets	Engines greater than 560 kW exclusively used in generating sets.
3. NRSh	Equipment with SI engines	Spark-ignition (SI) engines less than 19 kW exclusively used in hand-held machinery.
4. NRS		SI engines less than 56 kW and not included in category NRSh.
5. IWP	Inland waterway vessels	Engines greater than or equal to 37 kW exclusively used in inland waterway vessels, for their propulsion or intended for their propulsion.
6. IWA		Engines greater than 560 kW exclusively used in inland waterway vessels, for auxiliary purpose or intended for auxiliary purpose.
7. RLL	Railway	Engines exclusively used in locomotives, for their propulsion or intended for their propulsion.
8. RLR		Engines exclusively used in rail cars, for their propulsion or intended for their propulsion.
9. SMB	Snowmobiles	SI engines exclusively used in snowmobiles.
10. ATS	ATVs and SbS	SI engines exclusively used in all terrain and side-by-side vehicles (ATVs and SbS).

EMISSION LIMITS

“Introduce new emission limits reflecting technological progress and EU policies in the on-road sector, with a view to achieving EU air quality targets.”¹³

The proposal introduces more stringent PM emission limits, as well as new PN emission requirements for engines between 19 kW and 560 kW. Table 3 presents the proposed Stage V emission limits for non-road engines, based on the engine categories used in Table 1. The PM limit of the Stage V standard is 97 percent lower than that of the Stage I standard, and the hydrocarbon (HC) + nitrogen oxides (NOx) limit is 94 percent lower, as shown in Figure 1. Using diesel NRE engines between 130 kW and 560 kW as an example, the PM limit is lowered to 0.015 gram per kilowatt-hour (g/kWh), a 40 percent reduction from the previous Stage IV emission limit (0.025 g/kWh).

Additionally, a PN limit of 1×10^{12} /kWh is introduced. This, combined with stricter PM limits, will ensure that the best available control technology for particle emissions from diesel engines – the diesel particulate filter – will be used broadly in non-road applications.

¹³ European Commission. “Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on requirements relating to emission limits and type-approval for internal combustion engines for non-road mobile machinery” (2014). <http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52014PC0581>

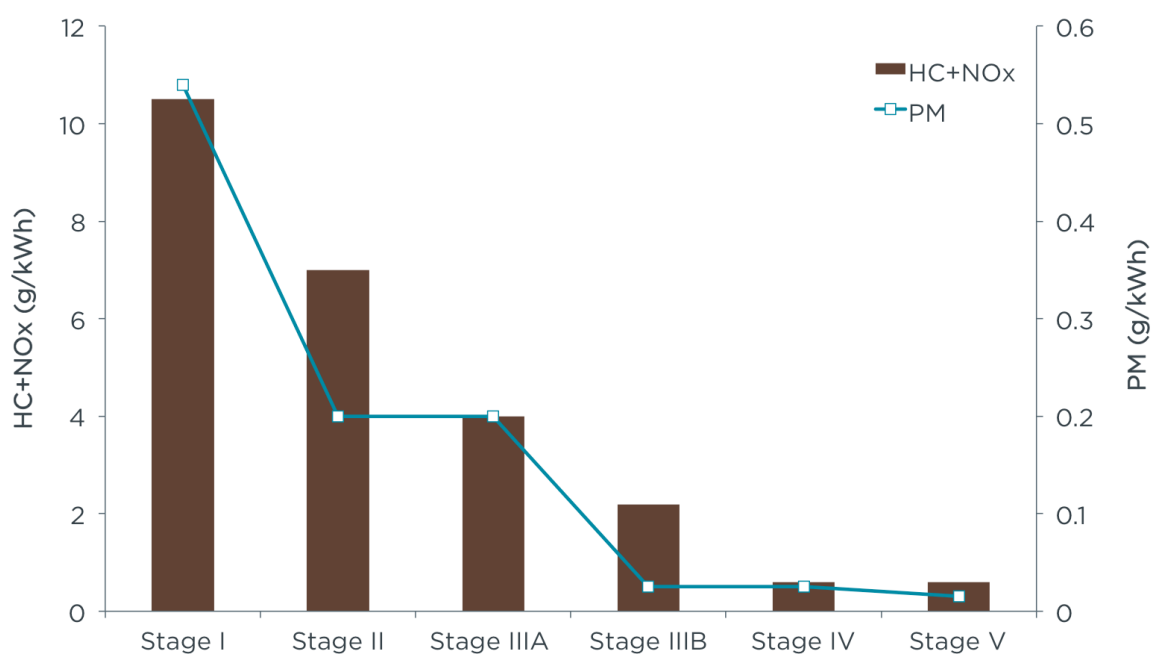


Figure 1. Emission limits from Stage I to Stage V for HC + NOx and PM

Table 3. Stage V emission limits by engine category

Engine Category	Equipment Type	Power Range (KW)	Engine Type	CO (G/KWH)	HC (G/KWH)	NOx (G/KWH)	PM (G/KWH)	PN (#/KWH)	A [#]
NRE-v-1 NRE-c-1	Other non-road mobile machinery	0<P<8	CI	8.00	HC + NOx ≤ 7.50		0.40	-	1.1
NRE-v-2 NRE-c-2		8≤P<19	CI	6.60	HC + NOx ≤ 7.50		0.4	-	1.1
NRE-v-3 NRE-c-3		19≤P<37	CI	5.00	HC + NOx ≤ 4.70		0.015	1×10 ¹²	1.1
NRE-v-4 NRE-c-4		37≤P<56	CI	5.00	HC + NOx ≤ 4.70		0.015	1×10 ¹²	1.1
NRE-v-5 NRE-c-5		56≤P<130	All	5.00	0.19	0.40	0.015	1×10 ¹²	1.1
NRE-v-6 NRE-c-6		130≤P≤560	All	3.50	0.19	0.40	0.015	1×10 ¹²	1.1
NRE-v-7 NRE-c-7		P>560	All	3.50	0.19	3.50	0.045	-	6.0
NRG-v-1 NRG-c-1	Generating sets	P>560	All	3.50	0.19	0.67	0.035	-	6.0

NRSh-v-1a	Equipment with SI engines	0<P<19	SI	805	HC + NOx ≤ 50		-	-	-
NRSh-v-1b		0<P<19	SI	603	HC + NOx ≤ 72		-	-	-
NRS-vr-1a NRS-vi-1a		0<P<19	SI	610	HC + NOx ≤ 10		-	-	-
NRS-vr-1b NRS-vi-1b		0<P<19	SI	610	HC + NOx ≤ 8.00		-	-	-
NRS-v-2a		19<P<30	SI	610	HC + NOx ≤ 8.00		-	-	-
NRS-v-2b NRS-v-3		19≤P≤56	SI	4.40*	HC + NOx ≤ 2.70*		-	-	-
IWP-v-1 IWP-c-1	Inland waterway vessels	37≤P<75	All	5.00	HC + NOx ≤ 4.70		0.30	-	6.0
IWP-v-2 IWP-c-2		75≤P<130	All	5.00	HC + NOx ≤ 4.70		0.14	-	6.0
IWP-v-3 IWP-c-3		130≤P≤300	All	3.50	1.00	2.10	0.11	-	6.0
IWP-v-4 IWP-c-4		300≤P≤1000	All	3.50	0.19	1.20	0.22	1×10 ¹²	6.0
IWP-v-5 IWP-c-4		P>1000	All	3.50	0.19	0.40	0.01	1×10 ¹²	6.0
IWA-v-1 IWA-c-a		560≤P<1000	All	3.50	0.19	1.20	0.02	1×10 ¹²	6.0
IWA-v-2 IWA-c-2		P≥1000	All	3.50	0.19	0.40	0.01	1×10 ¹²	6.0
RLL-c-1 RLL-v-1	Railway	P>0	All	3.50	HC + NOx ≤ 4.00		0.025	-	6.0
RRL-c-1 RRL-v-1		P>0	All	3.50	0.19	2.00	0.015	1×10 ¹²	6.0
SMB-v-1	Snowmobiles	P>0	SI	275	75	-	-	-	-
ATS-v-1	AVs and SbS	P>0	SI	400	HC + NOx ≤ 8.00		-	-	-

#	Where an “A” factor is defined, the HC emission limits for fully and partially gaseous fueled engines will be calculated with the following formula: $HC = 0.19 + (1.5 \times A \times GER)$, where the gas energy ratio (GER) is the average gas energy ratio over the appropriate cycle. The average GER is determined by the hot-start transient test cycle in both the non-road steady cycle (NRSC) and the transient cycle (NRTC). If the calculated HC limits exceed the value of $0.19 + A$, the limits should be set to $0.19 + A$.
*	Alternatively, any combination of values satisfying the equation $(HC+NOx) \cdot CO^{0.784} \leq 8.57$, as well as the following conditions: $CO \leq 20.6g/kWh$ and $(HC+NOx) \leq 2.7g/kWh$
CI	Compression-ignition engines (also known as diesel engines)
SI	Spark-ignition engines (also known as internal combustion engines, or petrol engines)

IN-USE ENFORCEMENT

“Introduce measures for simplifying administrative procedures and improving enforcement, including conditions for better market surveillance.”¹⁴

The proposal includes additional improvements to enforcement through administrative and technical measures. It would simplify the type-approval process by requiring a consistent procedure for all member states and would increase compliance and enforcement by strengthening rules on market surveillance. The proposal recommends adopting portable emission measurement systems (PEMS) to monitor particulate matter as well as ozone precursors (HC and NO_x) over normal duty cycles. The test procedure refers to the provisions adopted in the heavy-duty vehicle Euro VI emission standards, based on a previous pilot study conducted by the Joint Research Centre.¹⁵

An expert group on emissions from NRMM (the GEME group) is finalizing the draft of the in-use testing procedure, which will establish detailed requirements for in-use monitoring that applies to engine manufacturers. It would start with the engine categories NRE-v-5 and NRE-v-6 (56 kW to 560 kW), and may extend to all NRMM engine categories under future amendments. Engine manufacturers will submit their initial plan for in-use monitoring to the type-approval authority within one month of the start of production of an approved engine type or family. Engine manufacturers also need to make sure the selected machines and duty cycles are representative for the entire engine family. The delegated act describing in-use monitoring requirements and procedures is expected to be adopted in early 2017.

In-service testing would be conducted on normal equipment under regular operating conditions with a normal operator of the equipment. In addition, a maintenance record showing that the engine is properly maintained and serviced in accordance with the manufacturers' recommendations would be required as part of monitoring. The proposal also specifies other technical details including ambient conditions, engine coolant temperature, and reference fuel, as well as the PEMS test procedure and reporting format.

TIMELINE

The European Parliament adopted the proposal on 8 July 2016, and the final version of the regulation was published on 14 September 2016¹⁶. The type approval for Stage V new non-road engines will phase in from 1 January 2018, to 1 January 2020, for different engine types. The timeline of market placement for the engines will be one year after the scheduled type approval. According to this timeline, all new non-road engines entering the EU market will be Stage V-certified by 1 January 2021. A detailed implementation plan by engine type can be found in Table 4.

14 European Commission. “Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on requirements relating to emission limits and type-approval for internal combustion engines for non-road mobile machinery” (2014).
<http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52014PC0581>

15 GEME working group. “04.b.3. Draft proposal - In-service monitoring procedure for non-road mobile machinery” (2015). CIRCABC.
https://circabc.europa.eu/d/a/workspace/SpacesStore/2eb73116-46e7-4cc9-92e8-40a0803b9359/4.b.3_ISM_%2056-560kW_PEMS_GEME%202015-11-03.pdf

16 European Parliament and Council. “Regulation (EU) 2016/1628 of the European Parliament and of the Council of 14 September 2016 on requirements related to gaseous and particulate pollution emission limits and type-approval for internal combustion engines for non-road mobile machinery” (2016).
<http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32016R1628>

Table 4. Dates of application for Stage V

Engine Category	Equipment Type	Power Range (KW)	Engine Type	EU Type-Approval of Engines	Placing on the Market of Engines
NRE-v-1 NRE-c-1	Other non-road mobile machinery	0<P<8	CI	1 January 2018	1 January 2019
NRE-v-2 NRE-c-2		8≤P<19	CI		
NRE-v-3 NRE-c-3		19≤P<37	CI		
NRE-v-4 NRE-c-4		37≤P<56	CI		
NRE-v-5 NRE-c-5		56≤P<130	All	1 January 2019	1 January 2020
NRE-v-6 NRE-c-6		130≤P≤560	All	1 January 2018	1 January 2019
NRE-v-7 NRE-c-7		P>560	All		
NRG-v-1 NRG-c-1	Generating sets	P>560	All		
NRSh-v-1a NRSh-v-1b	Equipment with SI engines	0<P<19	SI	1 January 2018	1 January 2018
NRS-vr-1a NRS-vi-1a		0<P<19	SI	1 January 2018	1 January 2019
NRS-vr-1b NRS-vi-1b		0<P<19	SI		
NRS-v-2a		19<P<30	SI		
NRS-v-2b NRS-v-3		19≤P≤56	SI		
IWP-v-1 IWP-c-1	Inland waterway vessels	37≤P<75	All	1 January 2018	1 January 2019
IWP-v-2 IWP-c-2		75≤P<130	All		
IWP-v-3 IWP-c-3		130≤P≤300	All		
IWP-v-4 IWP-c-4		300≤P≤1000	All	1 January 2019	1 January 2020
IWP-v-5 IWP-c-4		P>1000	All	1 January 2020	1 January 2021
IWA-v-1 IWA-c-a		560≤P<1000	All	1 January 2019	1 January 2020
IWA-v-2 IWA-c-2		P≥1000	All	1 January 2020	1 January 2021
RLL-c-1 RLL-v-1	Railway	P>0	All	1 January 2020	1 January 2021
RLR-c-1 RLR-v-1		P>0	All	1 January 2020	1 January 2021
SMB-v-1	Snowmobiles	P>0	SI	1 January 2018	1 January 2019
ATS-v-1	ATVs and SbS	P>0	SI	1 January 2018	1 January 2019

INTERNATIONAL COMPARISON

The tighter particulate matter limits and the new PN standards would make the Stage V proposal the most stringent set of emission standards for off-road machinery in the world. The new limits aim to require the adoption of diesel particulate filters on non-road engines, based on manufacturers' development strategies for this coming regulation.¹⁷ Figure 2 offers a comparison of the latest PM and NOx emission limits between the EU and the U.S. in units of grams per kilowatt-hour. Both the U.S. Tier 4 Interim and U.S. Tier 4 Final non-road engine standards require lower particulate limits when compared with the EU Stage IIIB and IV standards, respectively.¹⁸ However, the U.S. standards failed to require diesel particulate filters on NRMM. EU Stage V proposes a new low limit of particulate matter – reaching 0.015 g/kWh for engines between 130 kW and 560 kW. This is 25 percent lower than the requirement of the U.S. Tier 4 Final standard. The particulate limits, plus the new PN requirements proposed by the EU, would lead to a high likelihood of diesel particulate filters being used to greatly reduce soot emissions from non-road engines between 19 kW and 560 kW. The proposed Stage V non-road engine standard may be a new best practice for the rest of the world to follow.

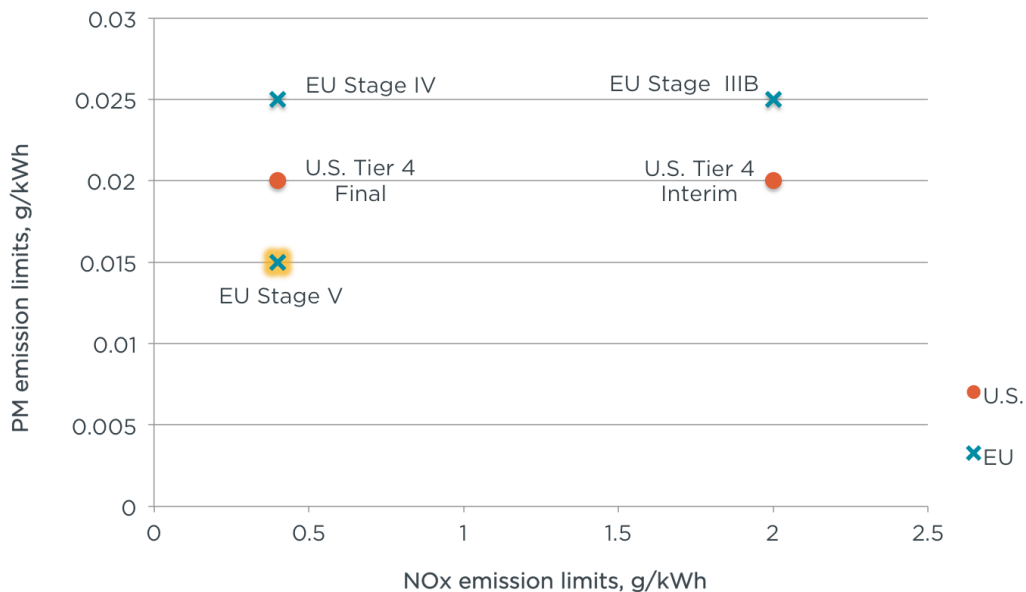


Figure 2. Comparison of PM and NOx emission limits between the U.S. and EU

17 Cottrell, J. "FPT Powertrain Technologies Stage V NRMM. 8th Integer Chicago; DEUTZ. Stage V ready" (2015). <http://deutz-stagev.com/en/>;

& Rolls-Royce power systems AG. "Rolls-Royce to exhibit MTU Stage V engines at bauma 2016" (2016).

http://www.oemoffhighway.com/press_release/12160037/rolls-royce-to-exhibit-mtu-stage-v-engines-at-bauma-2016

18 U.S. standards are at 0.02 g/kWh while EU standards are at 0.025 g/kWh. However, the U.S. only requires reporting to 2 decimal places. Thus, an engine with emissions of 0.0249 g/kWh would be in compliance in the U.S. Functionally the two PM standards are equivalent.