

# Tier 4 Emissions Regulations for Electric Power





# Notice

- The following material represents an overview of regulatory requirements related to engine emissions for Electric Power applications
- The material is intended for general informational purposes only
- The information is NOT COMPREHENSIVE and DOES NOT address specific manufacturers' circumstances
- There is no substitute for reading and understanding the rules; companies are strongly encouraged to investigate and apply the regulations accordingly
- Regulations may change, and these materials may not be updated to reflect the latest regulatory revisions
- Companies relying on this information do so at their own risk and assume any liability for so doing
- The information IS NOT intended to be and should not be construed as legal advice or as a substitute for competent legal advice
- Please consult your legal advisor if you have questions or need assistance



# Presentation Objectives

Level-set to bring audience to a minimum common level of knowledge & allow them to:

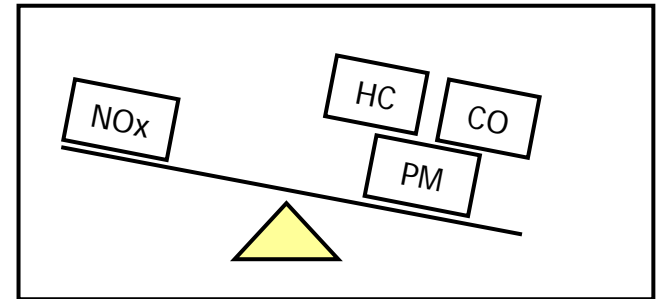
- Retrace the evolution of emissions regulations from Tier 1 to the upcoming Tier 4 regulations facing the industry.
- Understand the timeline for emissions regulations and how their effective dates & regulated limits vary by engine application and power output.
- Explain the difference between Tier 4 Interim and Tier 4 Final emission standards.
- Understand the difference between non-road & stationary regulations.
- Understand how emissions regulations for electric power can vary inside the U.S. and throughout the world



# Air Quality Basics

## ■ Emissions Regulated by EPA Standards

- Carbon Monoxide (CO)
- Hydrocarbons (HC)
- Particulate Matter (PM)
- Oxides of Nitrogen (NO<sub>x</sub>)



## ■ Emphasis is on NO<sub>x</sub> and PM

## ■ NO<sub>x</sub> and PM act as tradeoffs during combustion

- HC and CO can also increase due to in-cylinder NO<sub>x</sub> reduction

## ■ During combustion, the sulfur in fuel converts to SO<sub>2</sub>



# EPA Non-Road Regulations

- 1990 – Congress & President Bush sign the Clean Air Act Amendments
  - United States Environmental Protection Agency (EPA) to regulate exhaust emissions from new non-road engines
    - Reduce ozone by controlling NOx and HC
    - Reduce acid rain by controlling NOx and sulfur dioxide
    - Improve air quality
- Tier 1 regulations implemented in 1996
- Tier 2 phased-in 2000 – 2003
- Tier 3 phased-in 2005 – 2008
- Tier 4 is the next step .....



## EPA Nonroad Emissions Limits and Timing

kW	NO <sub>x</sub> , HC CO, PM g/kW-hr <i>OR</i>										NO <sub>x</sub> +HC CO, PM g/kW-hr											
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	
<8																						
≥8 <19																						
≥19 <37																						
≥37 <56																						
≥56 <75																						
≥75 <130																						
≥130 <225																						
≥225 <450																						
≥450 <560																						
>560 Non Genset																						
>560 ≤900 Genset																						
>900 Genset																						



# EPA Non-Road Regulations

- This is what the majority of industry is thinking about when it talks about “EPA” or “Tier 4” regulations
- Applies to non-road mobile machinery
  - includes gensets e.g. rental units
- Includes a “flexibility program” for equipment OEMs
- Other countries such as the EU & Japan also regulate non-road mobile machinery to similar levels

BUT

- Engines in stationary applications are regulated separately



# EPA Stationary Regulations

- Introduced much later than non-road regulations
- In 2006 EPA began to regulate engines in stationary applications
- Known as New Source Performance Standards (NSPS)
- No “flexibility program” for OEMs in NSPS
- From April 2006 Tier 1 standards were mandated
  - No factory certification required





# EPA Stationary Regulations

- From Jan 2007 NSPS harmonized regulatory limits & timing with EPA's non-road regulations
- 2007-2010
  - engines  $\leq 3000$  bhp &  $< 10$  litre / cylinder must be certified to the non-road Tier limits for their specific model year & power output
  - engines  $> 3000$  bhp but  $< 10$  litre / cylinder must be certified to non-road Tier 1 limits for their specific maximum engine power
  - engines  $\geq 10$  litre / cylinder &  $< 30$  litre / cylinder must be certified to Marine Tier 2 limits for their specific displacement & maximum engine power
- 2010+
  - Alignment with non-road regulations continues for non-emergency engines



## EPA Stationary Diesel Genset Emissions Limits and Timing (engines <10 litres per cylinder)

bkW	NOx, HC CO, PM g/kW-hr										OR							NOx+HC CO, PM g/kW-hr				
	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	
<8											10.5 8.0, 1.0	7.5 8.0, 0.80	7.5 8.0, 0.40 <sup>2</sup>		7.5 8.0, 0.60 <sup>3</sup>							
≥8 <19											9.5 6.6, 0.80	7.5 6.6, 0.80	7.5 6.6, 0.40									
≥19 <37											9.5 5.5, 0.80	7.5 5.5, 0.60	7.5 5.5, 0.30					4.7 5.5, 0.03				
≥37 <56											9.2, --- ---, ---	7.5 5.0, 0.40	Option #1 4.7 5.0, 0.30	4.7				Option #1 4.7 5.0, 0.03				
													Option #2 4.7 5.0, 0.40	4.7				Option #2 4.7 5.0, 0.03				
≥56 <75													4.7 5.0, 0.40					3.4 <sup>1</sup> , 0.19 5.0, 0.02		0.40, 0.19 5.0, 0.02		
≥75 <130												4.0 5.0, 0.30						3.4 <sup>1</sup> , 0.19 5.0, 0.02		0.40, 0.19 5.0, 0.02		
≥130 <225											9.2, 1.3 11.4, 0.54	4.0 3.5, 0.20				2.0 <sup>1</sup> , 0.19 3.5, 0.02			0.40, 0.19 3.5, 0.02			
≥225 <450											9.2, 1.3 11.4, 0.54	4.0 3.5, 0.20				2.0 <sup>1</sup> , 0.19 3.5, 0.02			0.40, 0.19 3.5, 0.02			
≥450 ≤560											9.2, 1.3 11.4, 0.54	>300 hp <750 hp per CD				2.0 <sup>1</sup> , 0.19 3.5, 0.02			0.40, 0.19 3.5, 0.02			
>560 ≤900											9.2, 1.3 11.4, 0.54	6.4 3.5, 0.20				3.5, 0.40 3.5, 0.10				0.67, 0.19 3.5, 0.03		
																		0.67, 0.40 3.5, 0.10			0.67, 0.19 3.5, 0.03	
>900 ≤2237											9.2, 1.3 11.4, 0.54									0.67, 0.19 3.5, 0.03		
>2237											9.2, 1.3 11.4, 0.54									0.67, 0.19 3.5, 0.03		
Fuel Sulfur	5000 ppm											500 ppm					15 ppm					
	Tier 1			Tier 2			Tier 3			Tier 4 Interim					Tier 4 Final							



# What changes with Tier 4?

- Tier 4 calls for such dramatic reductions in emissions that introduction is divided into two phases
  - Interim – focuses primarily on PM reduction for engines  $\leq 900$  bkW
    - Commenced in 2008 for engines  $< 56$  bkW
    - Main impact is in 2011 /12 for engines  $\geq 56$  bkW
    - Up to 90 % PM reduction & up to 50% NOx reduction vs Tier 3
    - 90% NOx reduction for gensets  $> 900$  bkW
  - Final – focuses primarily on NOx reduction
    - Does not affect engines  $< 19$  bkW
    - 2013 introduction for engines  $\geq 19 < 56$  bkW
    - Main impact is in 2014 / 15 for engines  $\geq 56$  bkW
    - Up to 80% NOx reduction & further PM reductions (gensets  $\geq 56$  bkW  $\leq 560$ )
    - 70% further PM reduction for gensets  $> 900$  bkW



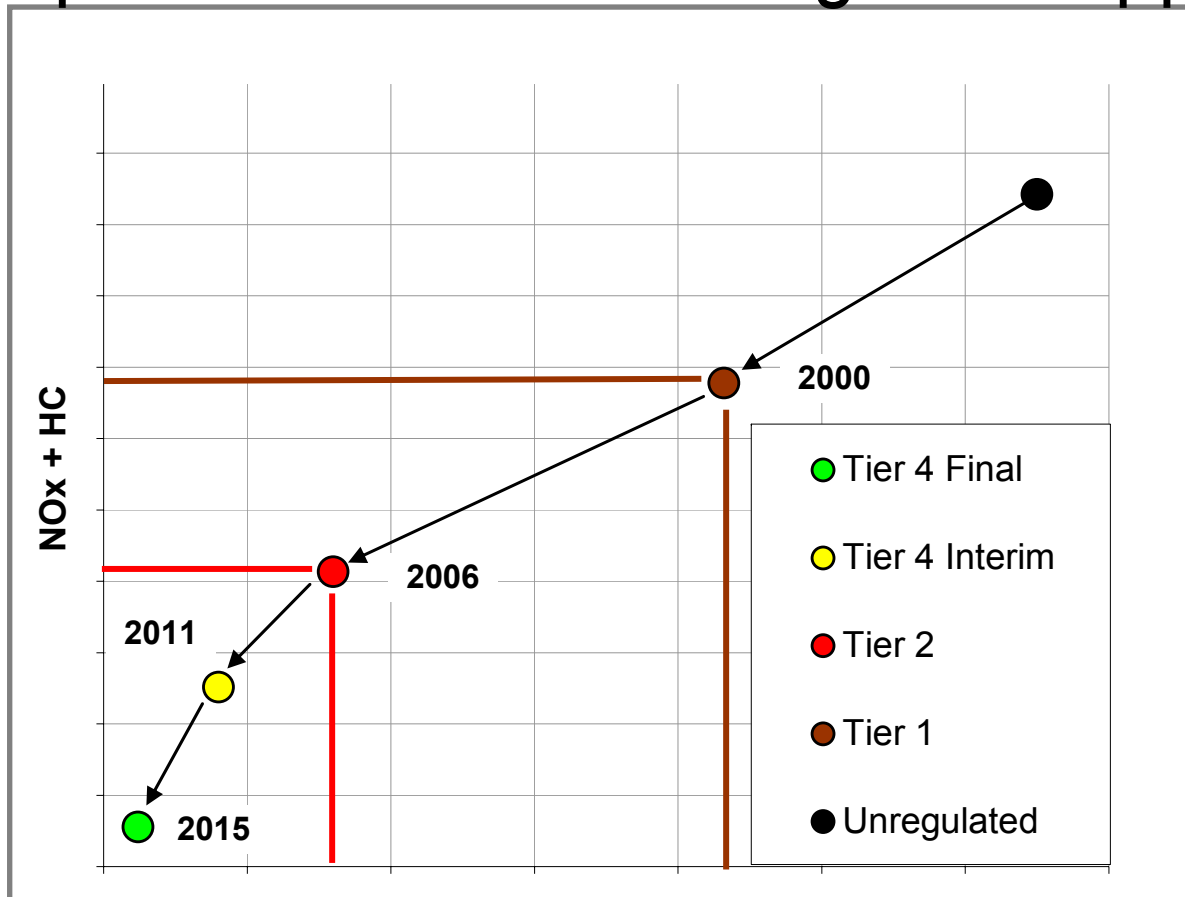
# What changes with Tier 4?

- Regulated levels are so low that other technology solutions are needed, including the use of aftertreatment devices
- Significant engine development required
  - NO<sub>x</sub> : PM ratio is critical to optimizing aftertreatment cost / size / performance



# EPA Non-Road Regulatory Impact

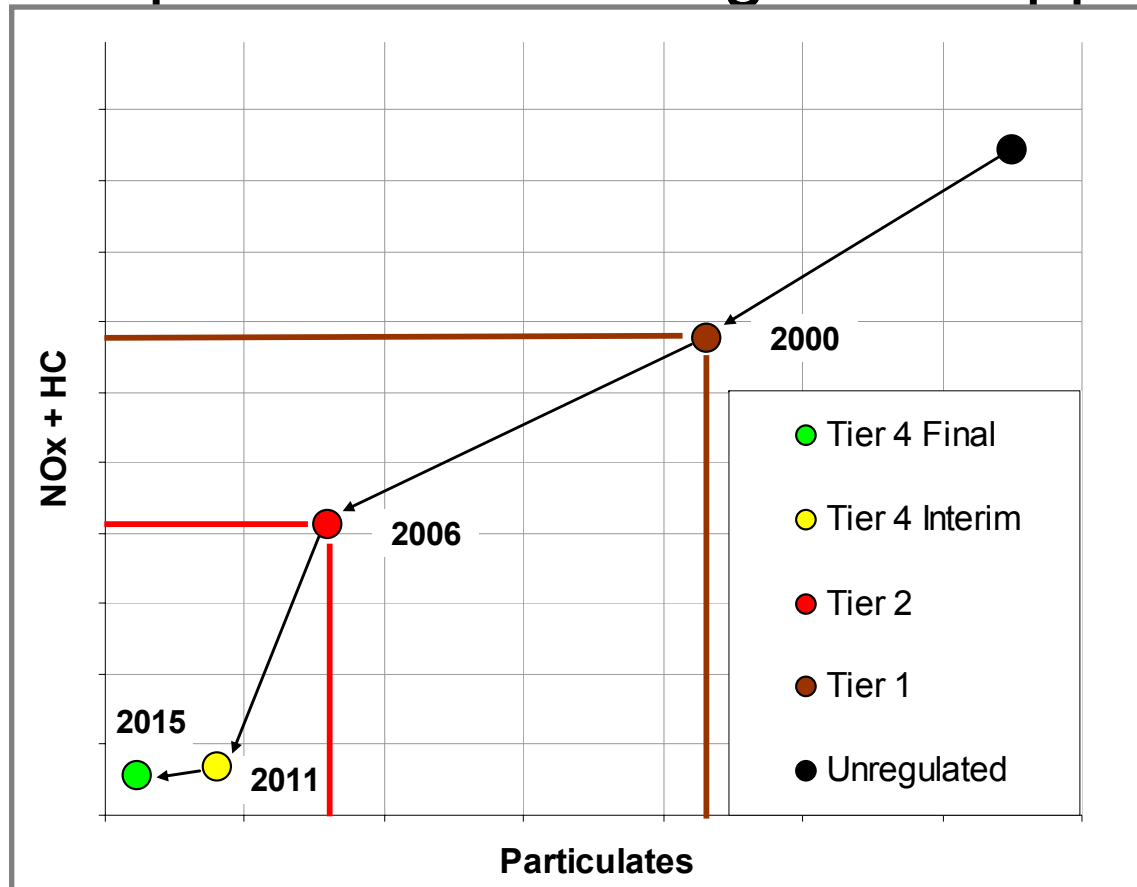
Example -  $>560$  bkW  $\leq 900$  genset applications





# EPA Non-Road Regulatory Impact

Example - >900 bkW genset applications





# What changes with Tier 4?

- Emissions standards vary based on the power category
  - optimum technology varies by power category
- Reliant on introduction of ULSD (<15 ppm)
  - High sulfur content in fuel is incompatible with aftertreatment devices – specifically catalysts
  - Gensets using Tier 4 aftertreatment cannot be sold / operated in territories where ULSD is unavailable
- Engine & aftertreatment must be certified as a complete system



# What changes with Tier 4?

- Delegated Final Assembly

## General Rule:

Engines must be in their certified configurations when introduced into US commerce (i.e., shipped from engine manufacturers' factory), meaning that the engine and aftertreatment must be assembled prior to shipment or shipped together.

## Exception:

EPA regulations provide the Delegated Final Assembly (DFA) exemption, which allows engine manufacturers to ship the engine and aftertreatment separately.

Note:- CARB has not updated its DFA exemption regulation & is thus not in complete harmony with the current EPA regulation.





# What changes with Tier 4?

## ■ Delegated Final Assembly

To take advantage of the DFA exemption, EPA regulations require engine manufacturers to take certain steps to ensure that proper engine and aftertreatment pairing takes place, including:

- Supplying equipment manufacturer with robust A&I guidelines
- Entering into DFA contract with dealers/distributors and OEMs
- Collecting data from dealer/distributor or OEM that provides evidence of proper pairing of engines and aftertreatment
- Collecting annual affidavits, whereby dealer/distributor or OEM attests to validity of pairing data
- Performing DFA audits required by EPA regulations

Note: To ensure that proper engine and aftertreatment pairing takes place, Caterpillar will require dealers to conduct installation audits of key emissions-related parameters



# What changes with Tier 4?

- Emissions Useful Life

- Defines the emissions compliance period for the engine, not the actual service life
- The EPA certification process includes demonstration of aftertreatment deterioration factors to ensure this compliance period is met in-service

Emissions Useful Life	
$P < 19 \text{ kW}$	5 yr / 3000 hr
$P < 37 \text{ kW}$ (constant speed rated >3000 rpm)	5 yr / 3000 hr
$19 \text{ kW} \leq P < 37 \text{ kW}$	7 yr / 5000 hr
$P \geq 37 \text{ kW}$	10 yr / 8000 hr



# What changes with Tier 4?

- Emissions Warranty Period
  - May not be shorter than any published warranty offered without charge for the engine
  - Covers all components whose failure would increase an engine's emissions
  - Does NOT cover components whose failure would NOT increase an engine's emissions.

Emissions Warranty Period	
$P < 19 \text{ kW}$	2 yr / 1500 hr
$P < 37 \text{ kW}$ (constant speed rated >3000 rpm)	2 yr / 1500 hr
$19 \text{ kW} \leq P < 37 \text{ kW}$	5 yr / 3000 hr
$P \geq 37 \text{ kW}$	5 yr / 3000 hr



# What changes with Tier 4?

- Critical Emission-Related Maintenance

- May not be scheduled more frequently than the following

- EGR filters and coolers, PCV valves, crankcase vent filters, and cleaning of fuel injector tips – **1500 hours**
- Fuel injectors; turbochargers; catalytic converters; electronic control units; PM traps, trap oxidizers, and related components; EGR systems (excluding filters and coolers); other emission reducing devices and associated sensors and actuators – **3000 hours (<130 kW) or 4500 hours (≥130 kW)**
- Maintenance on PM traps, trap oxidizers, and related components is limited to cleaning and repair only



# What changes with Tier 4?

- Affects mobile diesel generator sets in U.S. & Canada
- Affects stationary diesel generator sets in U.S.
- Stationary engines  $\geq 10$  liter / cylinder &  $< 30$  liter / cylinder must be certified to Marine Tier 2 limits defined in 40 CFR 94 Subpart C.
- Stationary Emergency engines do not need to meet Tier 4 emission standards.
  - Instead can meet alternative emission standards set forth in 40 C.F.R. Part 60, Subpart IIII.



# What changes with Tier 4?

- Different emissions standards for EP above 560 kW

EPA Nonroad Emissions Limits and Timing >560 kW											
NO <sub>x</sub> , HC CO, PM g/kW-hr											
kW	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
>560 Non Genset						3.5, 0.40 3.5, 0.10				3.5, 0.19 3.5, 0.04	
>560 ≤900 Genset	6.4 3.5, 0.20									0.67, 0.19 3.5, 0.03	
>900 Genset						0.67, 0.40 3.5, 0.10					
	Tier 2				Tier 4i			Tier 4f			

- >900 kW - NO<sub>x</sub> limits are very severe at Interim  
- followed by significant PM reduction at Final
- >560 kW ≤900 - same limits as Industrial at Interim  
- same severe limits as >900 kW at Final



# Tier 4 – Stationary Emergency Definition

- Engines in installations which meet the definition of “emergency” will not have to meet Tier 4 emissions standards
- Must be certified to prior tier requirements
  - <37 bkW to Tier 4 Interim 2008 standard  
per table 2 in 40 CFR Part 60 Subpart III
  - ≥37 bkW to Tiers 2 or 3 depending on power band  
per 40 CFR 89.112
- Emergency standby engines >3000 bhp (<10 liters / cylinder) will be required to be certified to Tier 2 emissions standards beginning in Jan 2011



# Tier 4 – Stationary Emergency Definition

- “Emergency” effectively means no running except when normal source power fails
- No limit to actual emergency running time
- Maintenance & testing limited to 100 hours per year
  - Unless local codes mandate other limits
- Operator must record use & reference to hours meter

Note: EPA is currently reviewing the allowances for non-emergency running of stationary emergency CI engines. The definition above may change during 2011 as a result.





# Tier 4 for Electric Power

- Tier 4 certified generator sets will be required for the following applications:
  - Non-emergency standby units
  - Prime Power applications
  - Load management / peak shaving
  - Electric Power Rental units
  - Storm Avoidance
  
- In addition, there are potential state and local regulations that may drive the use of Tier 4 generator sets in 2011 and beyond.



# Tier 4 for Electric Power

- Other Territories
- California
- Local Regulations



# Other Territories

- There is no widespread regulation to Tier 4 levels outside of N. America
- There is a wide variety of different national & regional regulations effecting mobile & stationary EP applications around the world
- Although these regulations are often not exactly alignment to the EPA emission tiers, the technologies required to comply are often similar.

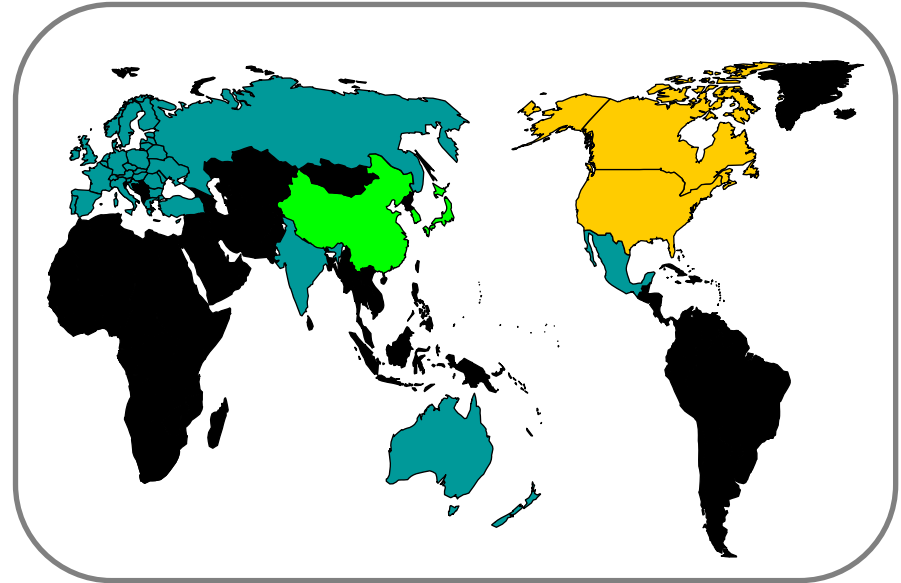
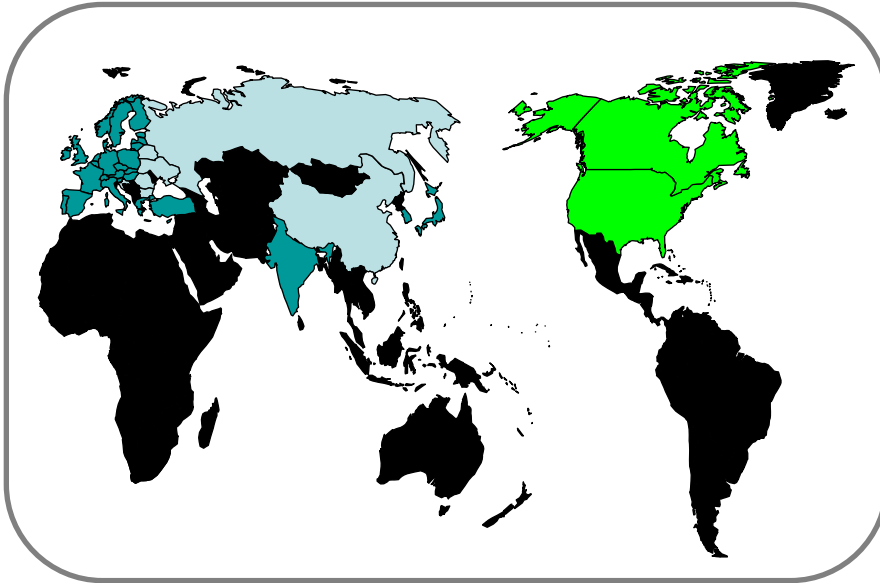


# Anticipated Technology Levels

## Mobile EP Applications

2011

2016



- No regulations
- Tier 2 & equivalent
- Tier 3 & equivalent
- Tier 4 Interim & equivalent
- Tier 4 Final & equivalent

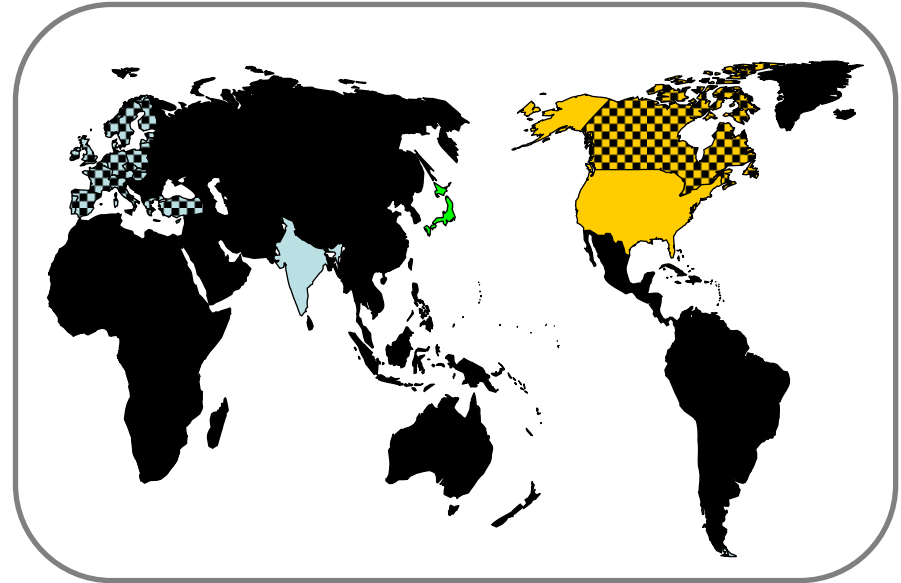
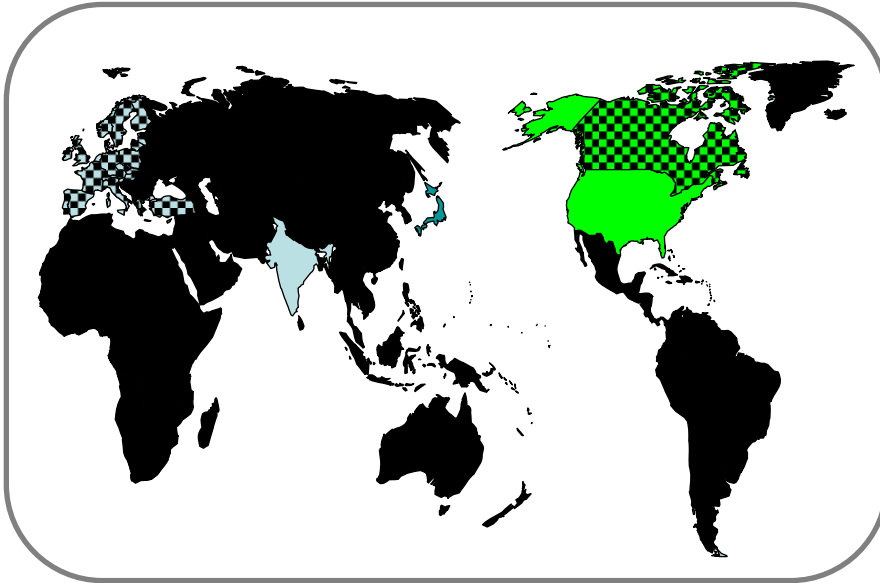


# Anticipated Technology Levels

## Stationary EP Applications

2011

2016



- No regulations
- Tier 2 & equivalent
- Tier 3 & equivalent
- Tier 4 Interim & equivalent
- Tier 4 Final & equivalent



# California

- The US Clean Air Act prohibits individual states from setting their own emissions standards with the exception of any state that had emissions standards prior to March 30, 1966.
- Severe air quality issues prompted California to enact emissions standards before the federal government passed the Clean Air Act and thus California is the only US state that meets this criterion.
- EPA must approve California's "waiver" request for each new California emissions standard before the standard may be implemented.
- EPA will not permit a California emissions standard that is less stringent than EPA's own standards.



# California

- ATCM For Stationary Engines (Airborne Toxic Control Measures)
  - uses g/bhp-hr limits – beware conversion
  - more restrictive than EPA regulations
  - local districts may adopt even tighter limits
  - focused on PM reduction
  - applies to stationary engines >50 bhp
  - more closely defines “emergency” operation
  - **no alternative standards for stationary emergency gensets**
  
- ATCM For Portable Engines
  - aligns with EPA Non-Road emissions standards
  - drives reduced fleet averages



# California

- **ATCM For Stationary Engines**

- Enforces PM limits of 0.15 g/bhp-hr (0.2 g/bkW-hr) or EPA Non-Road limit – whichever is lowest
- Emergency engines effectively align with EPA Non-Road non-exemption limits
- Only allows 50 hours non-emergency operating & maintenance unless PM  $\leq 0.01$  g/bhp-hr (0.0134 g/bkW-hr)
- Allows for compliance demonstrations other than certification by the manufacturer. However, local air boards may insist on factory certification to simplify the compliance verification process.
- **Non-emergency** engines must meet PM  $\leq 0.01$  g/bhp-hr (0.0134 g/bkW-hr) – **half of the Tier 4 Final limits**





# Local Regulations

- Generally, EPA emission standards must be met before an engine can legally be sold in the US.
- However, once a standard is implemented by California, other states may at their own choosing and without applying for waiver, adopt California's emissions standards.
- States may individually create regulations that control the use of used engines. This is often referred to as an “in-use” regulation instead of an emissions standard.
- In-use regulations generally provide requirements or incentives to use cleaner engines.
- In-use regulations do not govern the sale of the new, EPA certified products.

# Summary





# Tier 4 Regulations Summary

- EPA is the starting point
- Understanding local requirements is vital (i.e. California and non-attainment areas)
- Understanding if an installation falls within the EPA definition of “emergency” is important
- Minimum requirement will be a factory certified solution
  - Tier 2 or 3 engine for emergency
  - Tier 4 engine / aftertreatment for non-emergency