MOVES
Motor Vehicle Emission Simulator

Update of Engine Categories, Emission Rates and Speciation Profiles for Tier-4 Nonroad Compression Ignition Engines

Jaehoon Han and Darrell Sonntag

MOVES Review Work Group

December 6, 2017

Agenda

- Emission Standards
- Compliance Technology
- Scope of Modeling Updates
- Data and Approaches
- Summary
- Q&A

This presentation includes preliminary results from analysis in progress. The actual implementation in future MOVES versions is subject to change.

EPA Nonroad Compression Ignition Exhaust Emission Standards*

kW (HP)	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
<8 (11)					7.5 --- 0.80			7.5 --- 0.40							
≥8 (11) <19 (25)					7.5 --- 0.80			7.5 --- 0.40							
≥19 (25) <37 (50)				7.5 --- 0.60				7.5 --- 0.30					4.7 --- 0.03		
≥37 (50) <56 (75) Opt 1				7.5 --- 0.40				4.7 --- 0.30					4.7 --- 0.03		
Opt 2								4.7 --- 0.40				4.7 --- 0.03			
≥56 (75) <75 (100)				7.5 --- 0.40				4.7 --- 0.40				3.4 0.19 0.02			0.40 0.19 0.02
≥75 (100) <130 (175)			6.6 --- 0.30				4.0 --- 0.30					3.4 0.19 0.02			0.40 0.19 0.02
≥130 (175) <225 (300)			6.6 --- 0.20			4.0 --- 0.20					2.0 0.19 0.02			0.40 0.19 0.02	
≥225 (300) <450 (600)	6.4 --- 0.20														
≥450 (600) <560 (750)		6.4 --- 0.20													
≥560 (750)						6.4 --- 0.20					3.5 0.19 0.10				3.5 0.19 0.04

TIER Color Code
Tier 1
Tier 2
Tier 3
Tier 4 Transitional
Tier 4 Final

Rates [g/kW-hr]
NMHC+NOx --- PM
or
NOx NMHC PM

* EPA NRCI exhaust emission standards at https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100OA05.pdf

Tier-4 Compliance Technology

- After-treatment systems
  - **S**elective **C**atalytic **R**eduction (SCR) for NOx
  - **D**iesel **P**articulate **F**ilter (DPF) for PM
  - **D**iesel **O**xidation **C**atalyst (DOC) for HC/CO/PM, …
- In-cylinder air handling technology
  - **E**xhaust **G**as **R**ecirculation (EGR)
  - Turbo-charging, …
- In-cylinder fuel injection system
  - Injection pressure, rate, timing, …

Emission rates vary depending on technology

MOVES2014a NRCI Modeling

- "Engine technology categories" for NRCI equipment
  - Defined to assign population fractions & emission factors
  - Classification based on EPA emission standards

Base	Tier 0	Tier 1	Tier 2	Tier 3	Tier 3B	Tier 4A	Tier 4B	Tier 4	Tier 4N

  - Not differentiated by control technology
- Population fraction values for Tier-4 model years
  - Estimates based on Tier-4 Transitional (Interim) & Final Standards phase-in schedule
- Emission factor values for Tier-4 model years
  - Estimates based on standards with compliance margin applied

Scope of Tier-4 Updates

- Engine technology categories
  - New Tier-4 definition considering after-treatment types
- Population fractions*
  - Tier-4 data from EPA engine certification database (VERIFY)
  - Consideration of Tier-4 flexibility program (TPEM)
- Emission factors
  - Tier-4 rates from engine certification database (VERIFY)
- Speciation profiles
  - Differentiation based on after-treatment types
  - A topic discussed in 2017 June Workgroup meeting

*Note: Population growth updates are handled in other related projects.

Recommended Engine Tech Categories

- New Tier-4 Definition
  - Now considering after-treatment configurations

Base	Tier 0	Tier 1	Tier 2	Tier 3	Tier 4IA	Tier 4IB	Tier 4IC	Tier 4ID	Tier 4FA	Tier 4FB	Tier 4FC	Tier 4FD

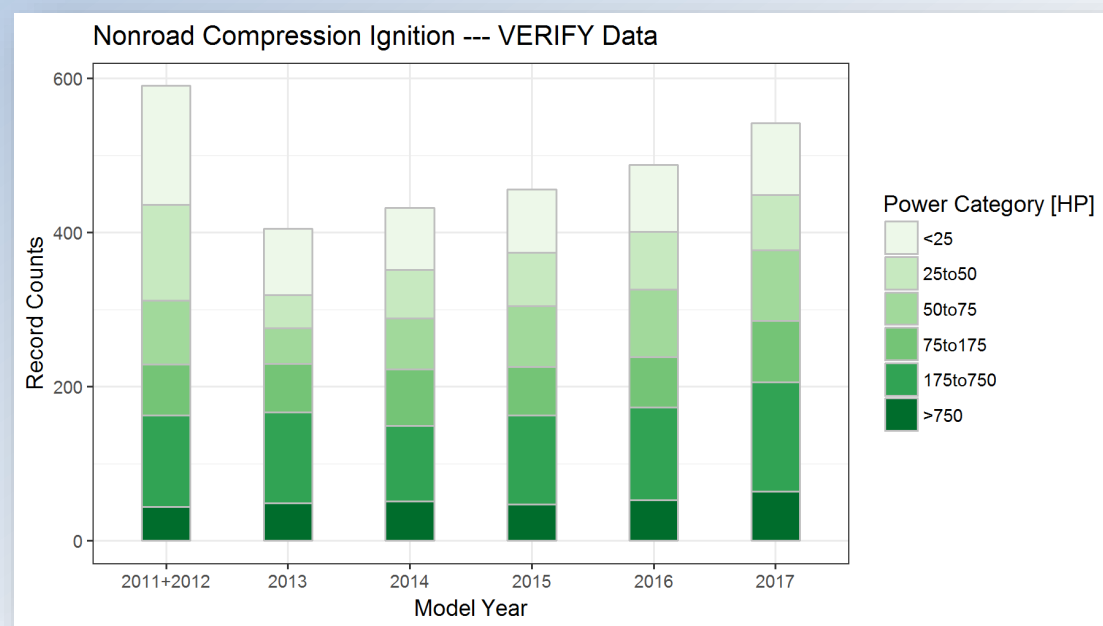
I: Interim (Transitional) **F**: Final

A	No DPF	No SCR
B	No DPF	With SCR
C	With DPF	No SCR
D	With DPF	With SCR

Engine Certification Data

- NRCI compliance data extracted from VERIFY
  - Model years

    from 2011* thru 2017
  - Includes info about:
    - Engine family
    - Power category
    - Applicable certification tier
    - After-treatment device types
    - Emission rates: NOx, PM, NMHC, CO
    - Projected sales volume (CBI)



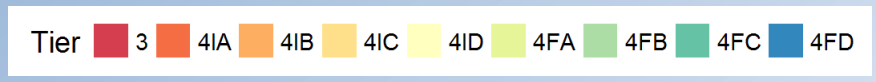
*Partial data for MY 2011

Certified Engine Population Fractions

- The volume-averaged fractions of the engines in each engine tech category are calculated
  - Per power category
  - Per model year group
- "Stationary engines" in certification data set
  - Exemption clause in Tier-4 rules*
  - Certified as "Tier 2" or "Tier 3" instead
  - Excluded from our analysis
    - since MOVES has "mobile engine" population only

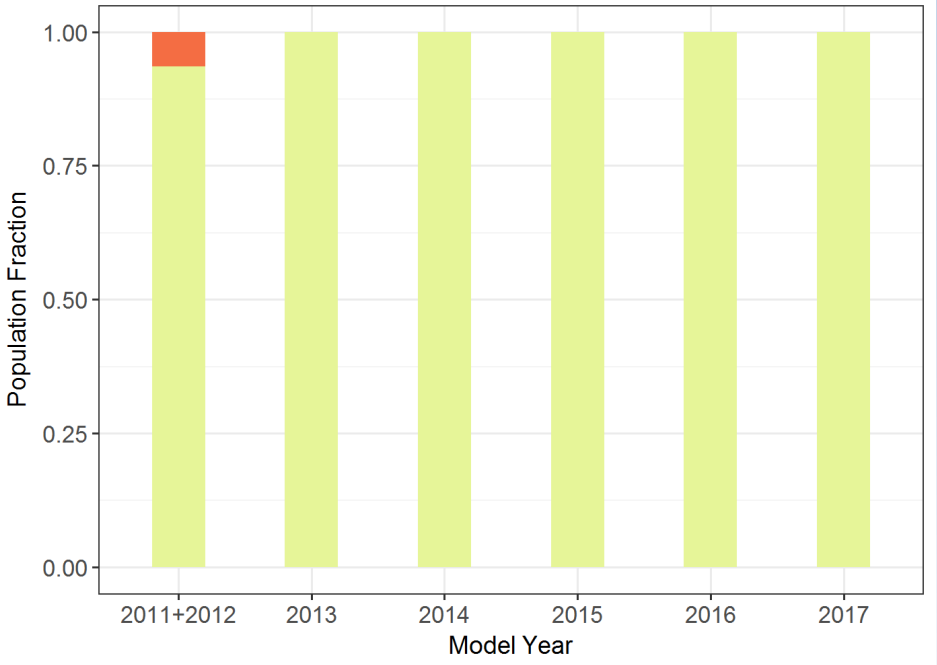
*https://www.epa.gov/regulations-emissions-vehicles-and-engines/regulations-emissions-heavy-equipment-compression

Certified Engine Population Fractions

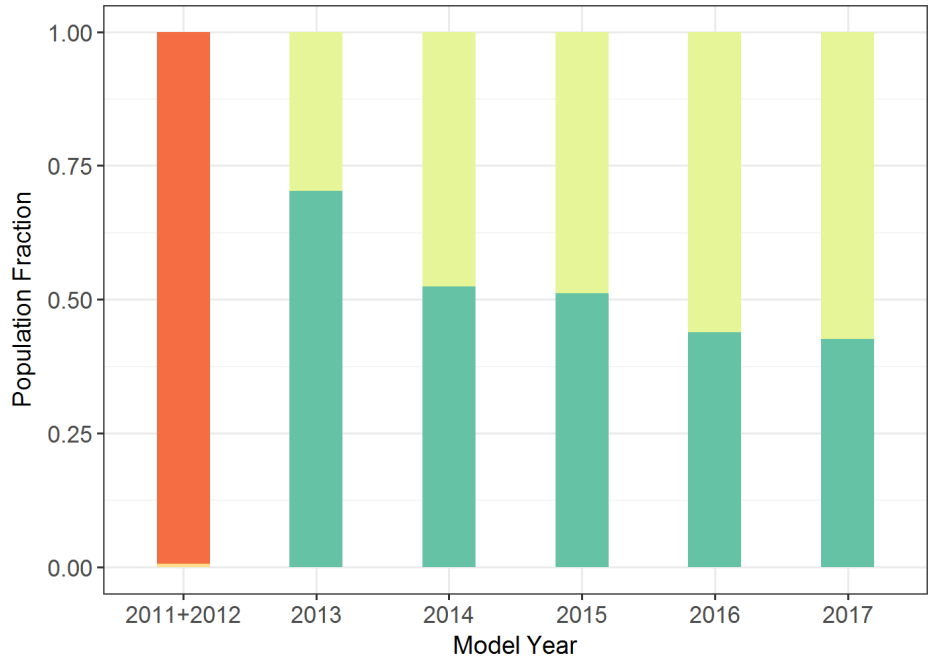


A	No DPF	No SCR
B	No DPF	With SCR
C	With DPF	NO SCR
D	With DPF	With SCR

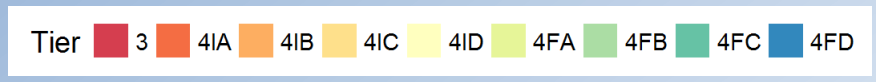
HP <=25



HP 25 to 50

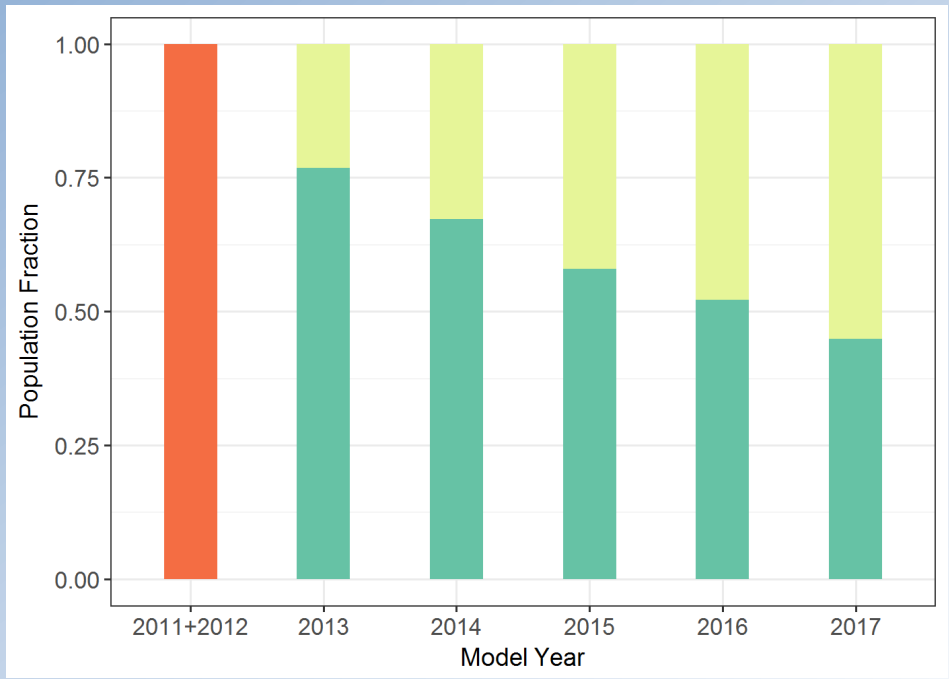


Certified Engine Population Fractions

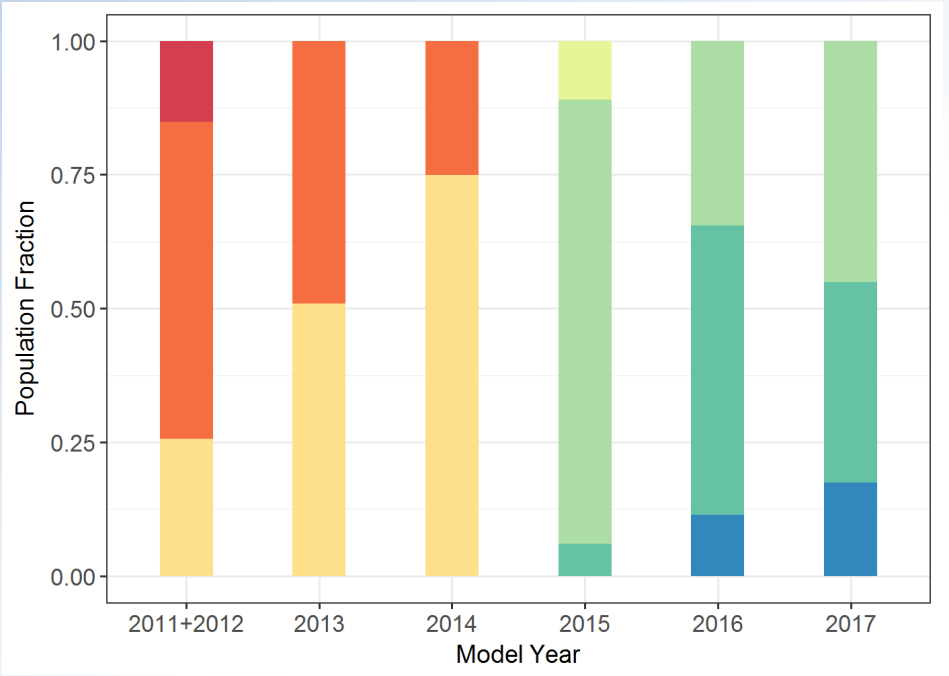


A	No DPF	No SCR
B	No DPF	With SCR
C	With DPF	NO SCR
D	With DPF	With SCR

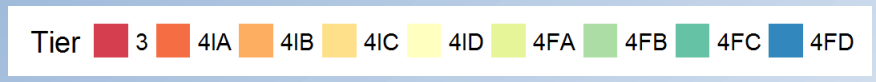
HP 50 to 75



HP 75 to 100

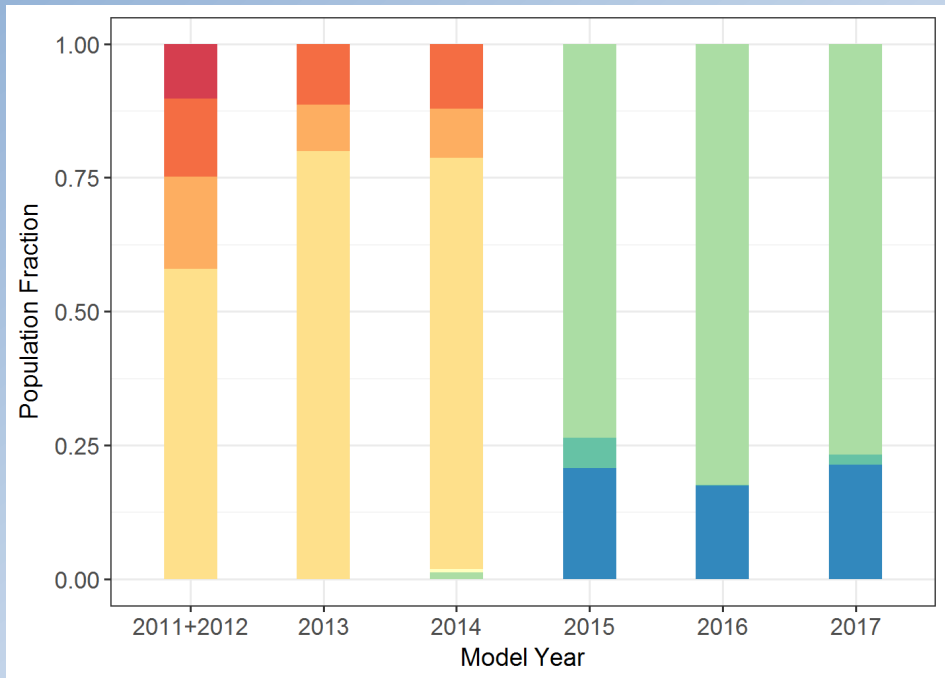


Certified Engine Population Fractions

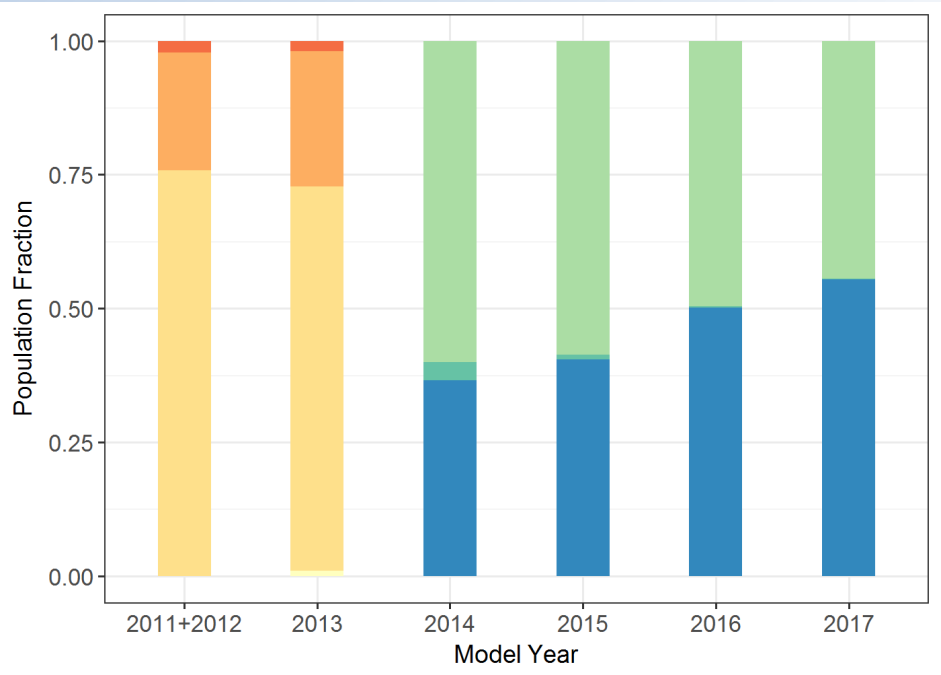


A	No DPF	No SCR
B	No DPF	With SCR
C	With DPF	NO SCR
D	With DPF	With SCR

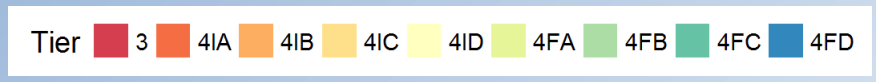
HP 100 to 175



HP 175 to 300



Certified Engine Population Fractions



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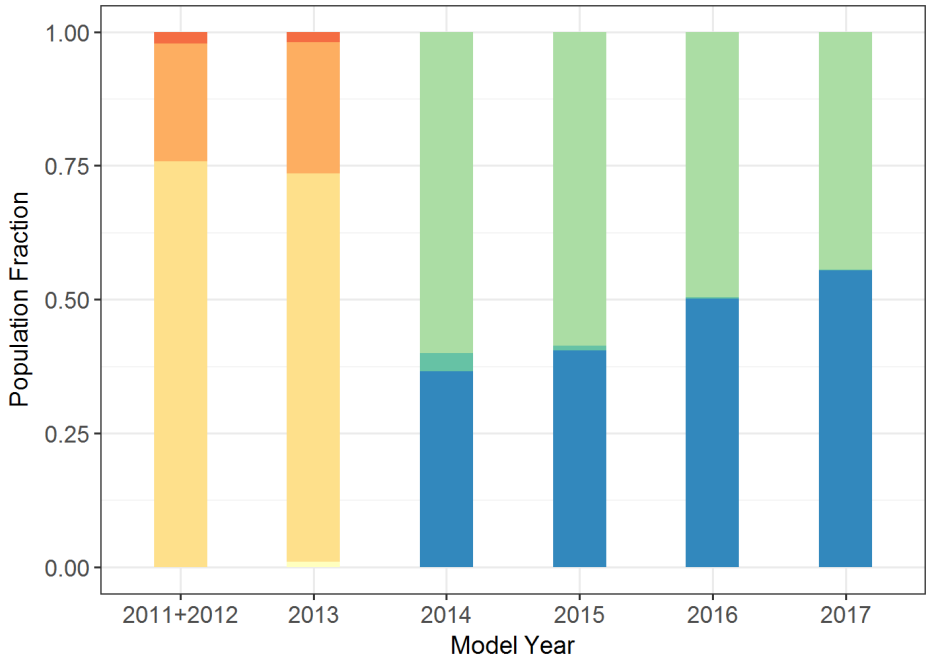
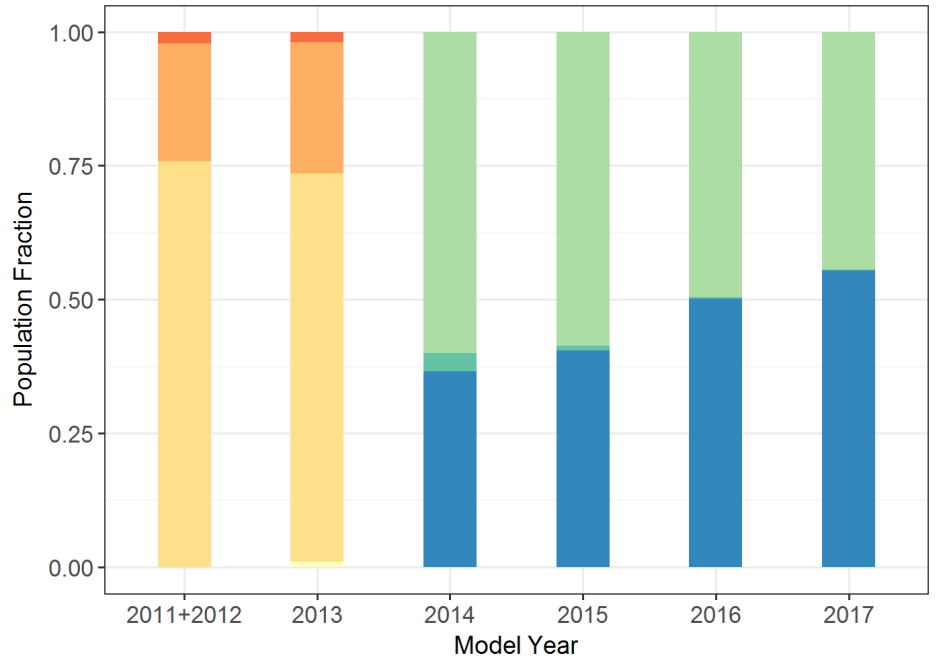
B	No DPF	With SCR
C	With DPF	NO SCR
D	With DPF	With SCR

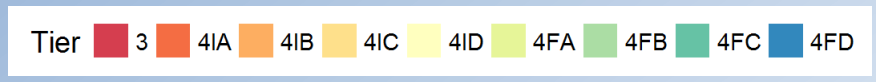
HP 300 to 600



HP 600 to 750

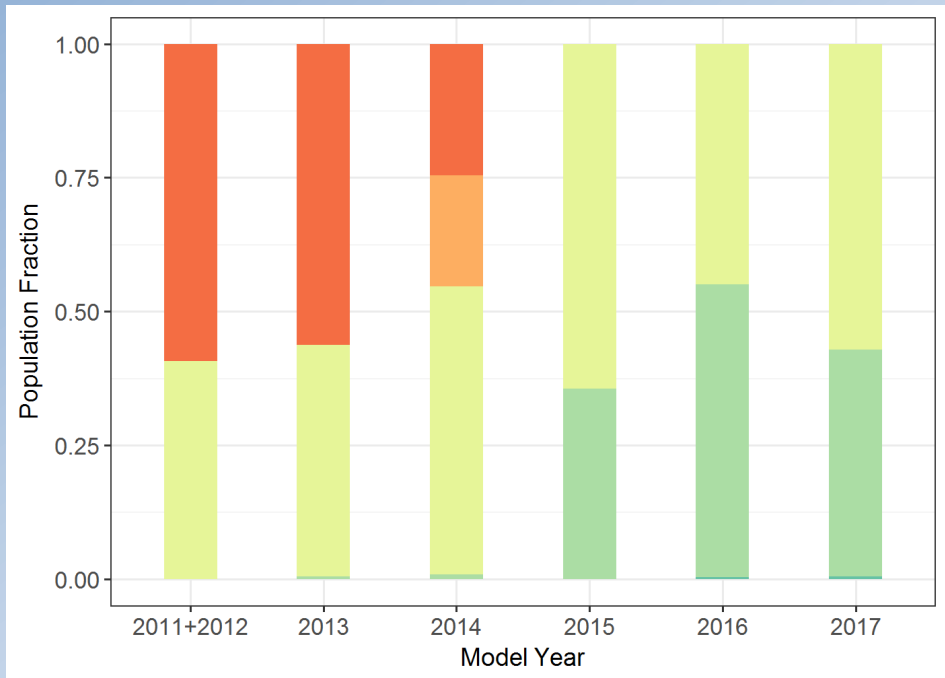


Certified Engine Population Fractions

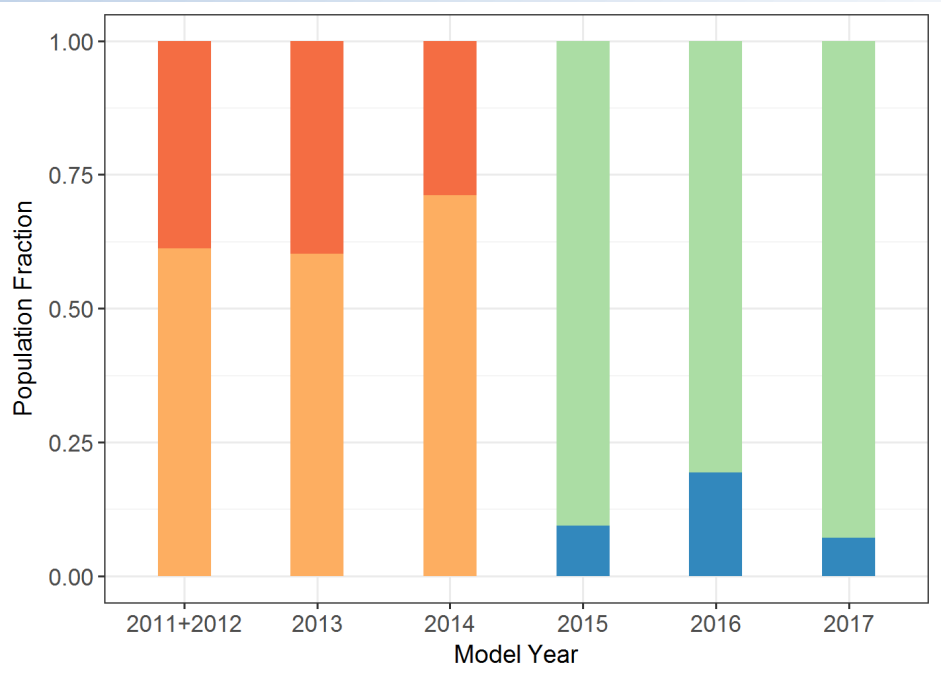


A	No DPF	No SCR
B	No DPF	With SCR
C	With DPF	NO SCR
D	With DPF	With SCR

HP >750 - non generator

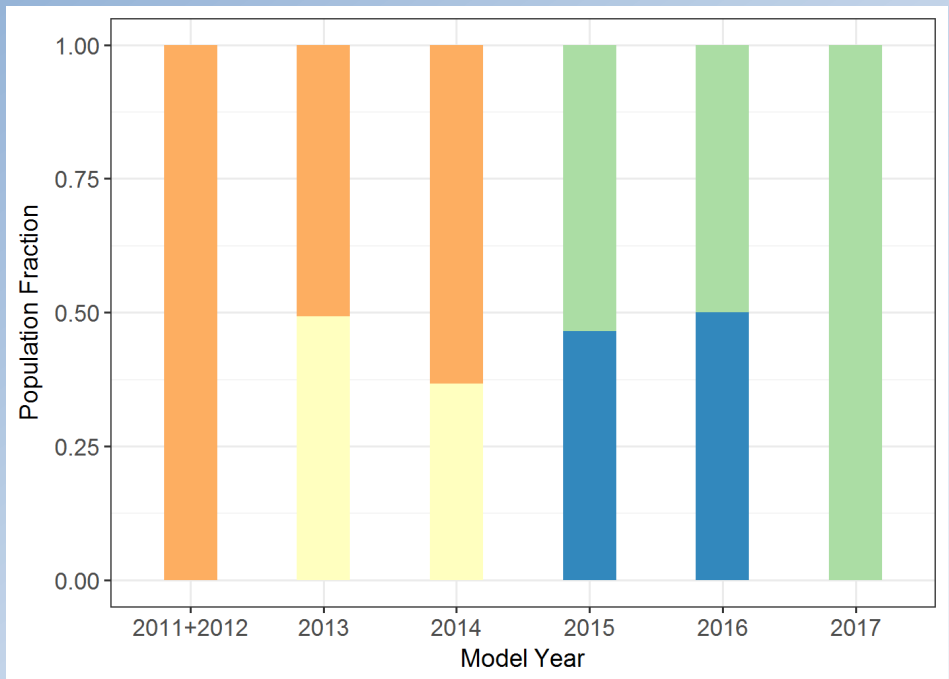


HP 750 to 1200 - generator



Certified Engine Population Fractions

A	No DPF	No SCR
B	No DPF	With SCR
C	With DPF	NO SCR
D	With DPF	With SCR



TPEM Exemption

- **T**ransition **P**rogram for **E**quipment **M**anufacturers* (a.k.a. “flexibility program”)
  - Temporary exemption that allows equipment manufacturers to delay installing Tier-4 compliant engines in their products for up to 7 years

TPEM Category kW (HP)	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
<19 (25)														
≥19 (25) <56 (75)														
≥56 (75) <130 (175)														
≥130 (175) <560 (750)														
≥560 (750)														

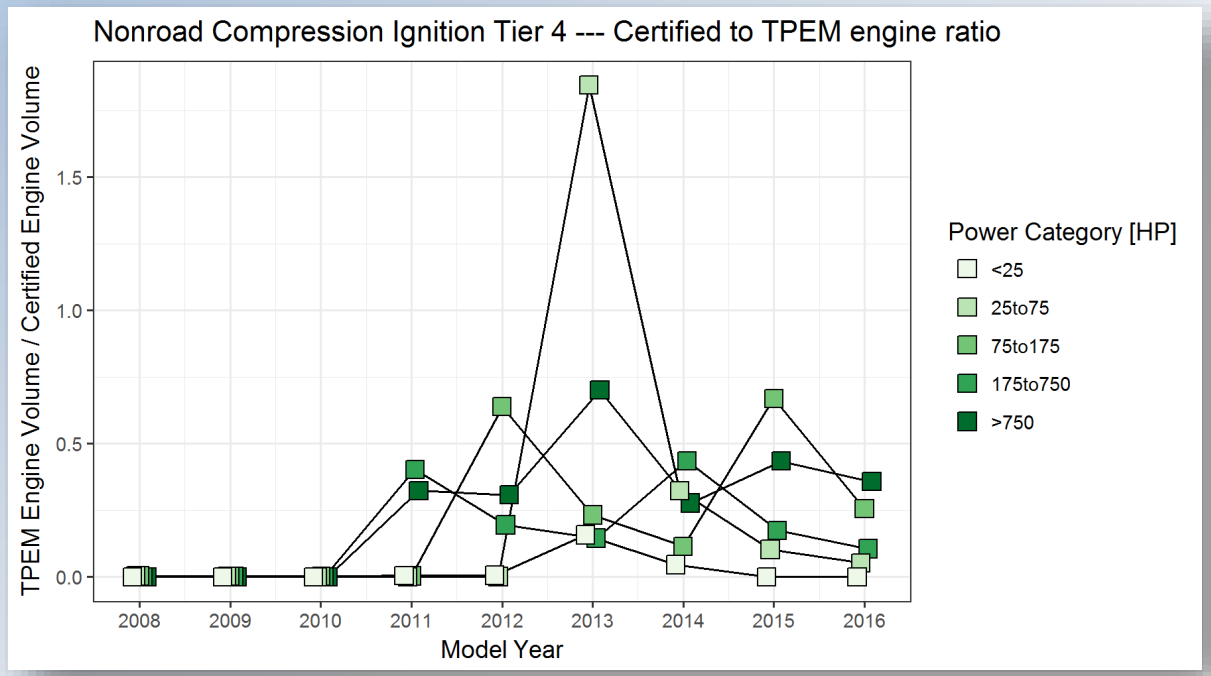
TPEM Color Code
Tier 4 Regular TPEM available
Tier 4 Delayed TPEM available

  - Participation is voluntary

* https://www.epa.gov/vehicle-and-engine-certification/transition-program-equipment-manufacturers-tpem

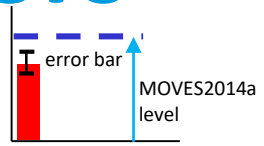
Certified vs. TPEM Engine Volumes

- The volume ratio of Tier-4 certified engines to the TPEM engines needs to be accounted for in the total population fraction calculation
- Analysis is in progress using limited data available based on yearly reports from manufacturers to EPA (separate DB from VERIFY)



Recommended Emission Factors
HP <11

A	No DPF	No SCR
B	No DPF	With SCR
C	With DPF	NO SCR
D	With DPF	With SCR



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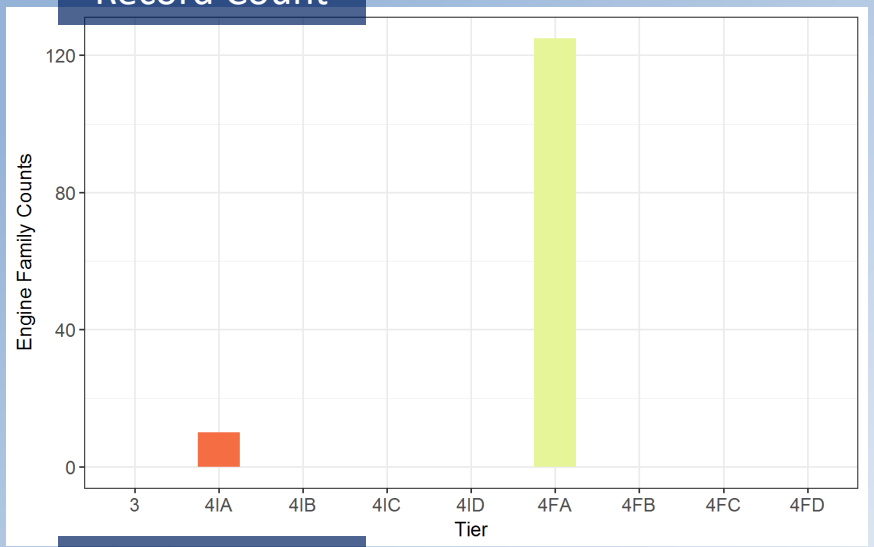

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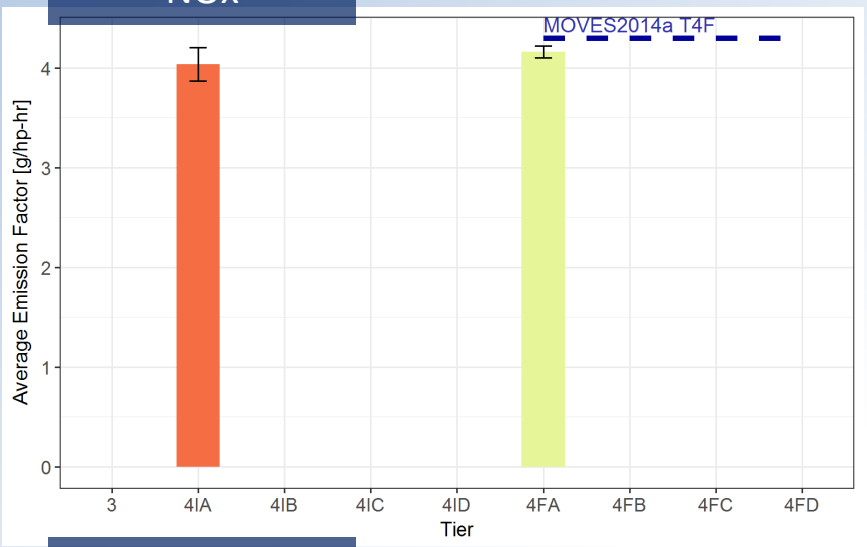

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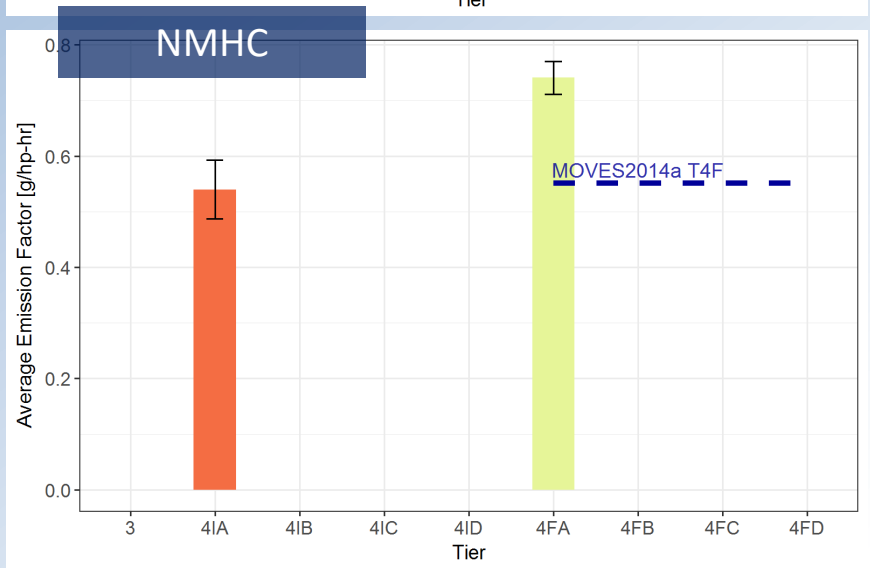

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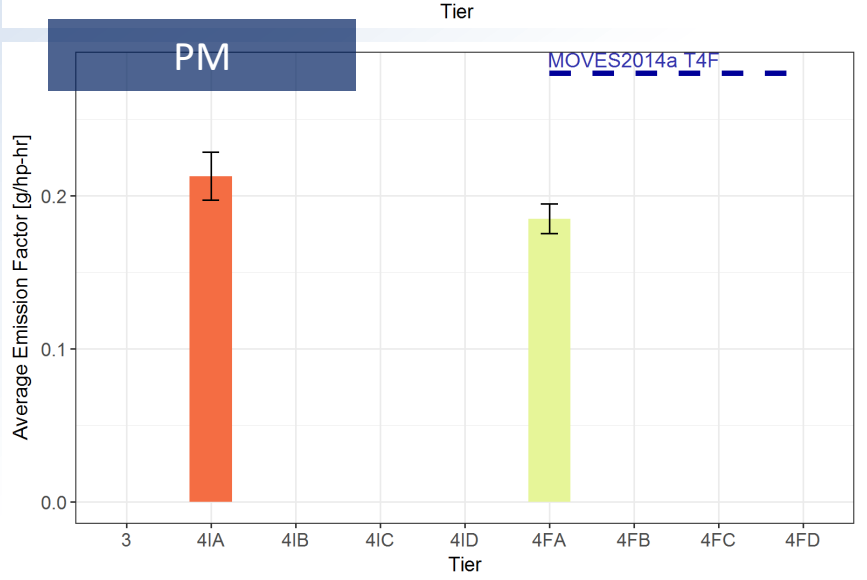
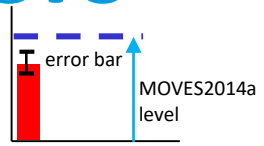


Recommended Emission Factors
HP 11 to 25

A	No DPF	No SCR
B	No DPF	With SCR
C	With DPF	NO SCR
D	With DPF	With SCR



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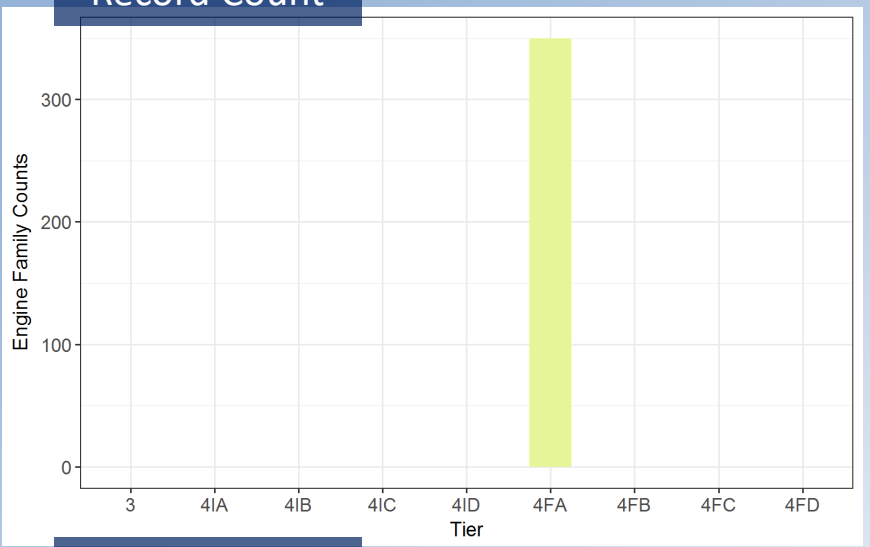

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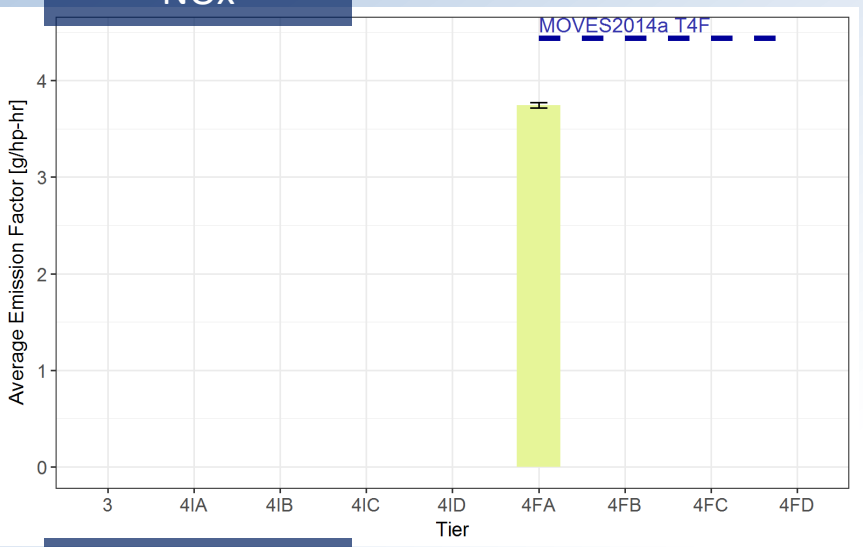

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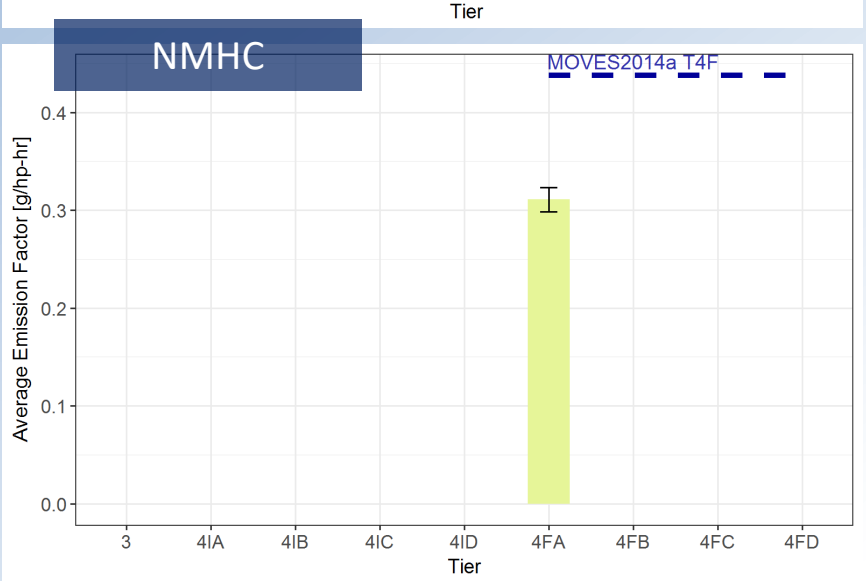

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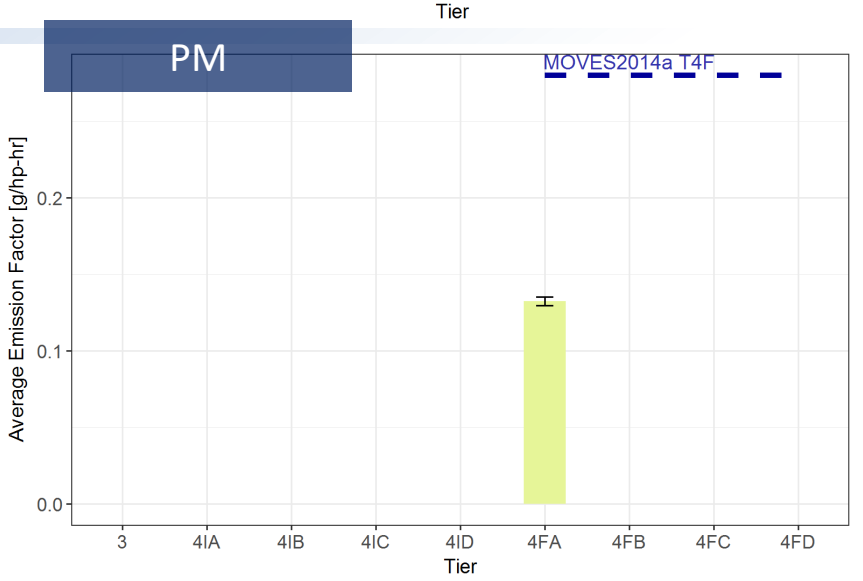
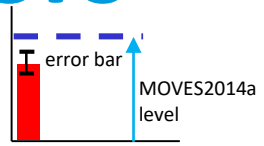


Recommended Emission Factors
HP 25 to 50

A	No DPF	No SCR
B	No DPF	With SCR
C	With DPF	NO SCR
D	With DPF	With SCR



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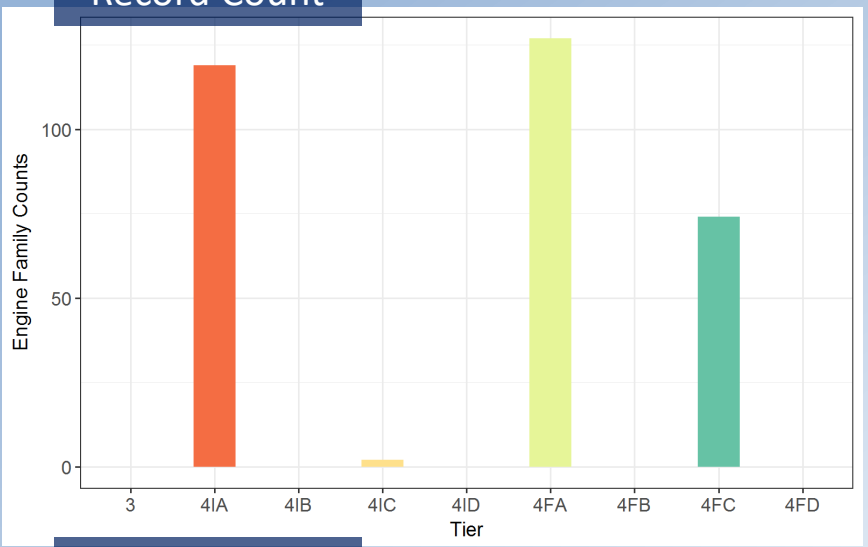

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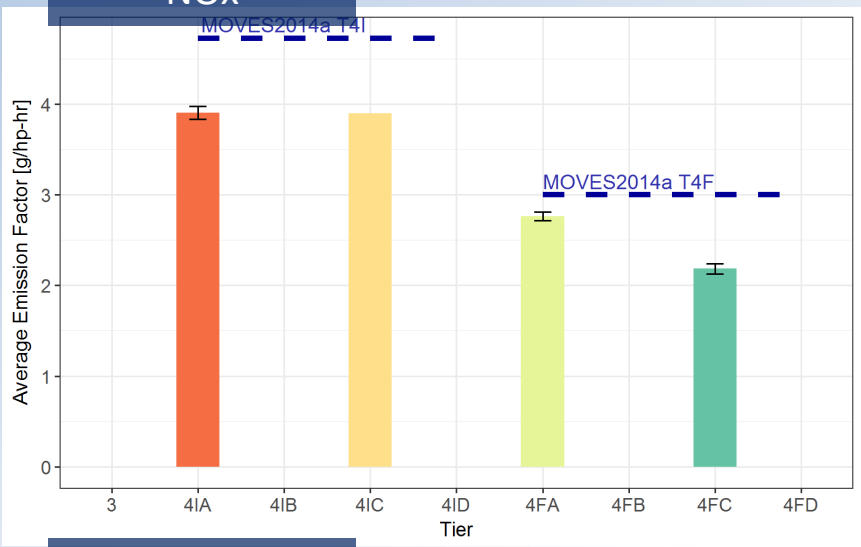

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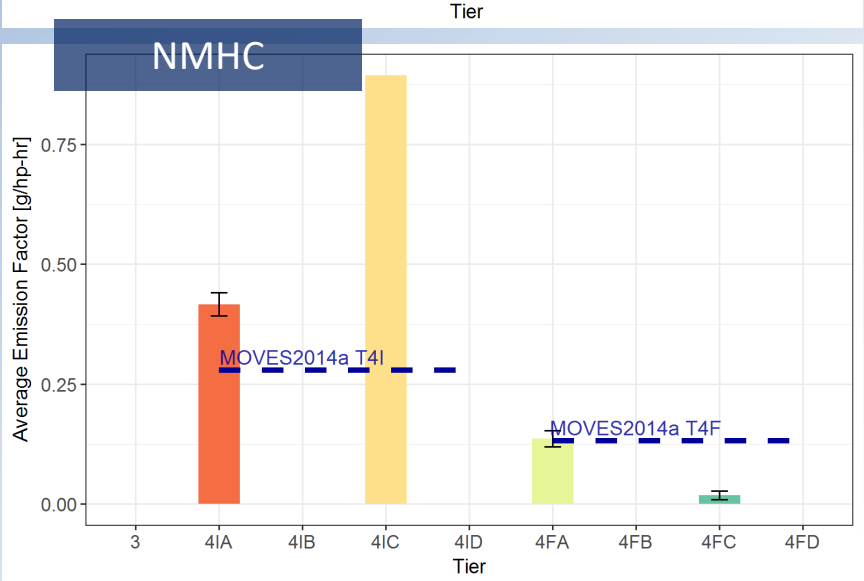

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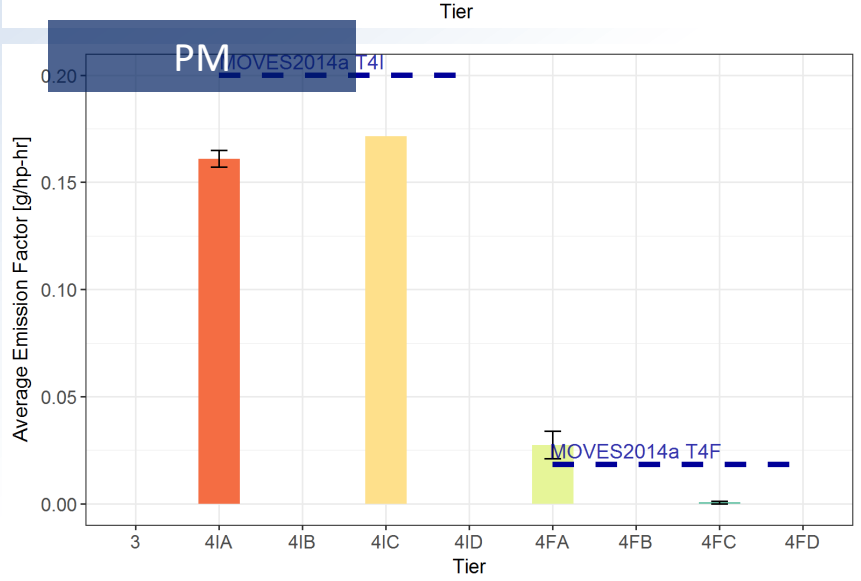
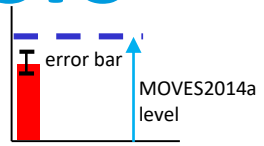


Recommended Emission Factors
HP 50 to 75

A	No DPF	No SCR
B	No DPF	With SCR
C	With DPF	NO SCR
D	With DPF	With SCR



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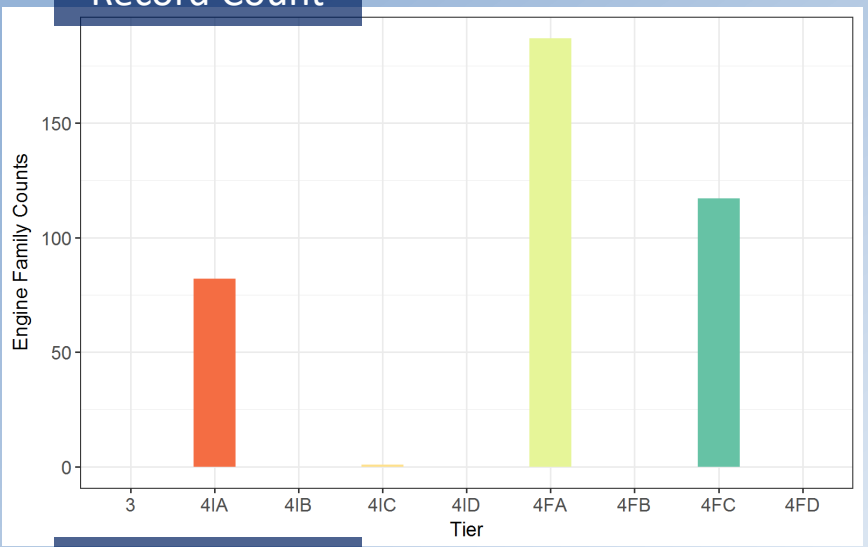

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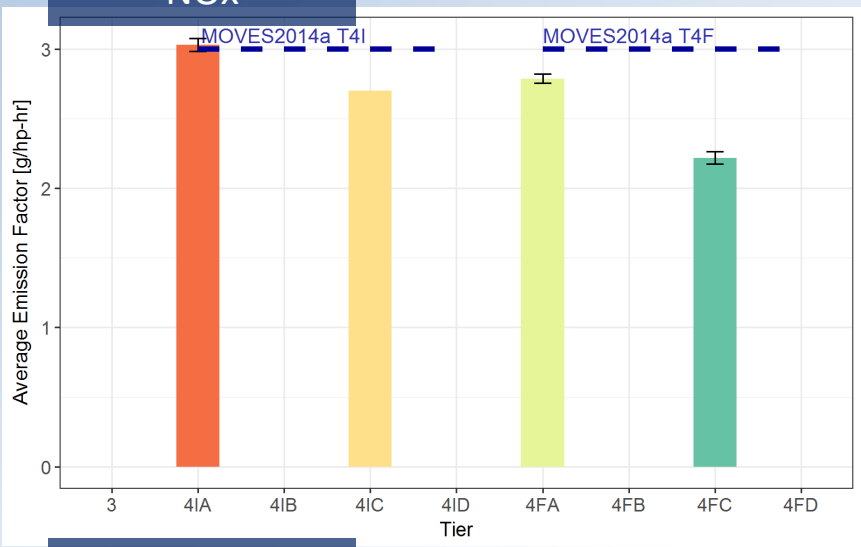

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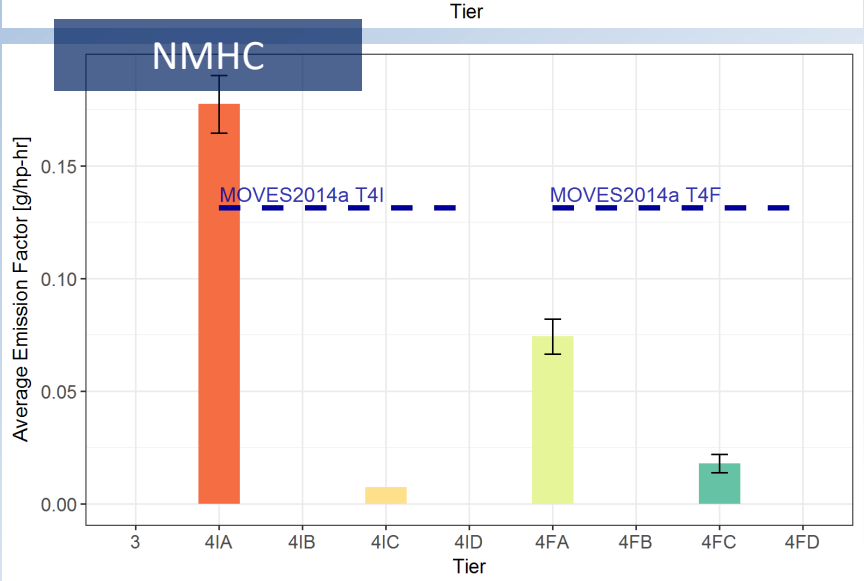

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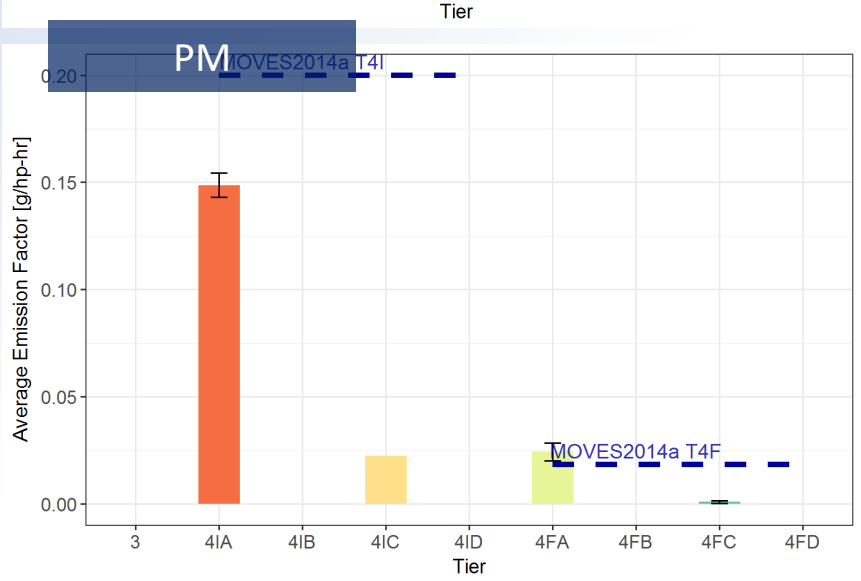
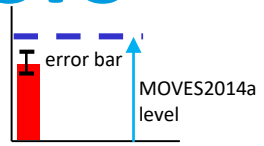


Recommended Emission Factors
HP 75 to 100

A	No DPF	No SCR
B	No DPF	With SCR
C	With DPF	NO SCR
D	With DPF	With SCR



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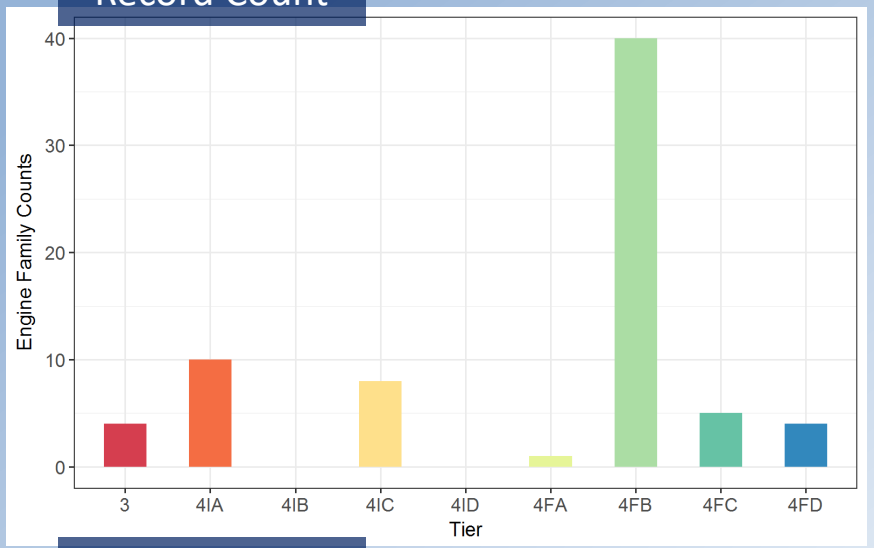

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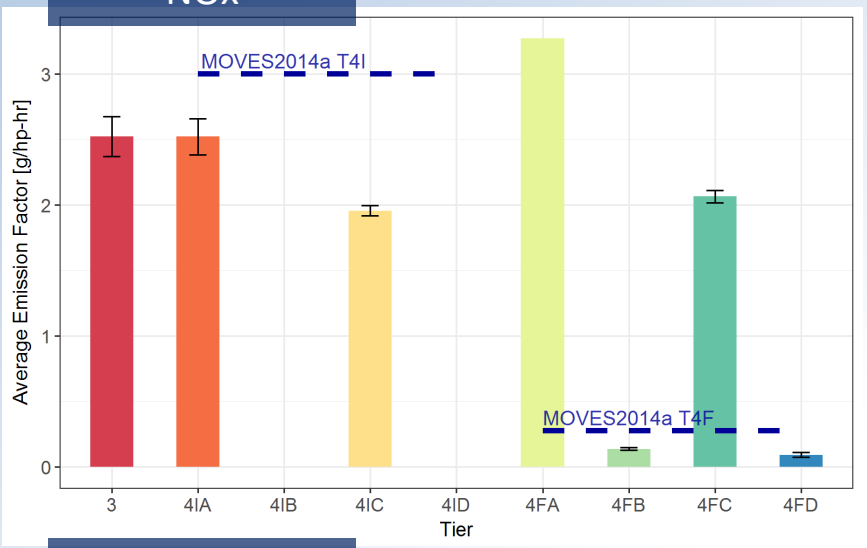

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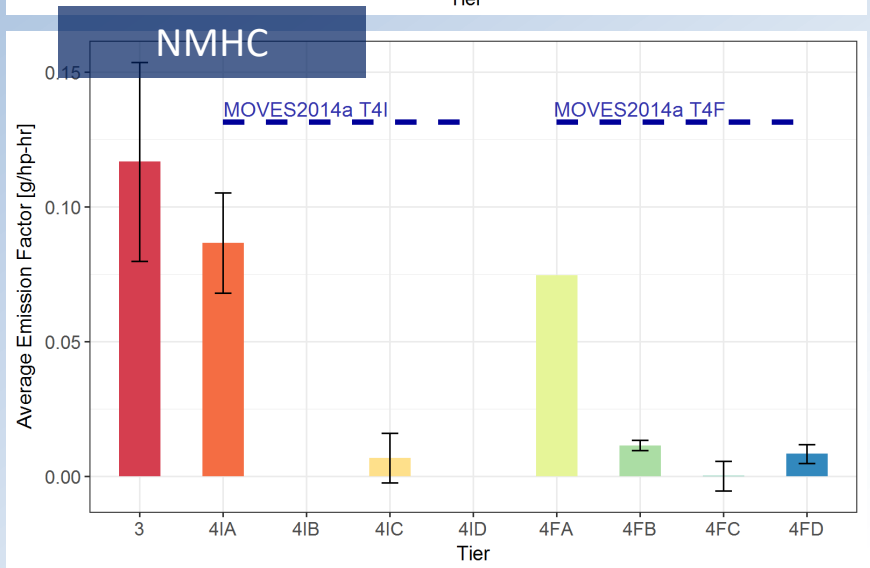

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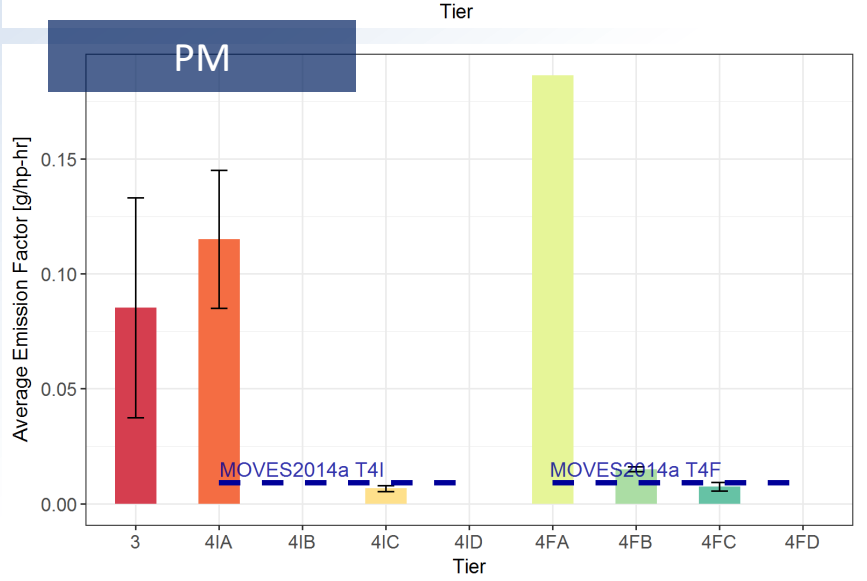
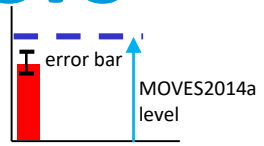
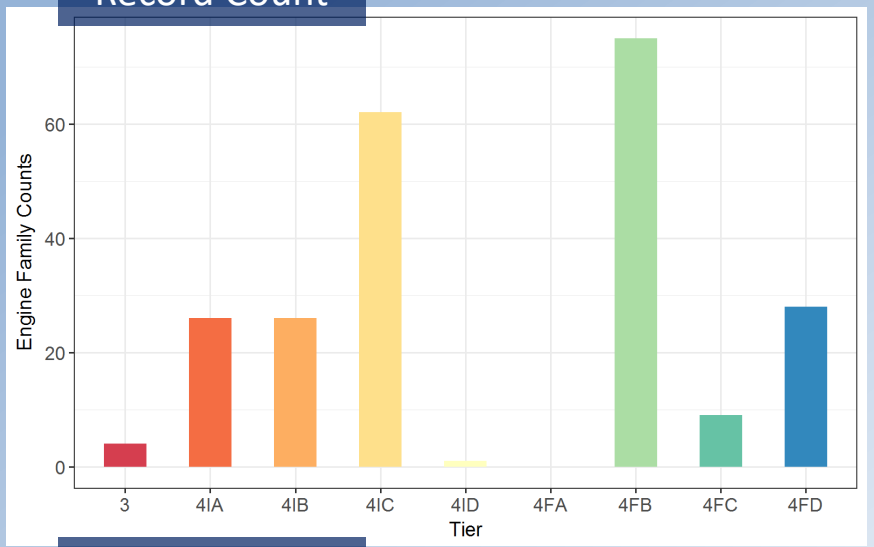


Recommended Emission Factors
HP 100 to 175

A	No DPF	No SCR
B	No DPF	With SCR
C	With DPF	NO SCR
D	With DPF	With SCR



Record Count



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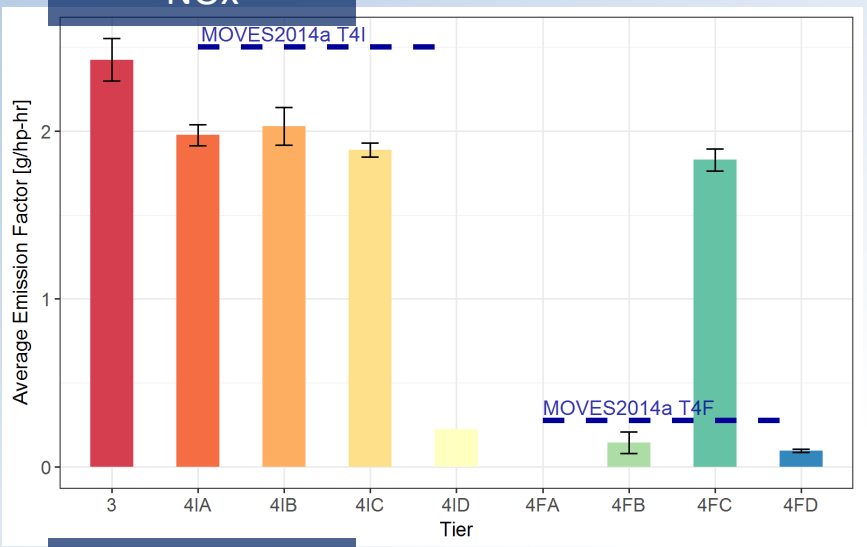

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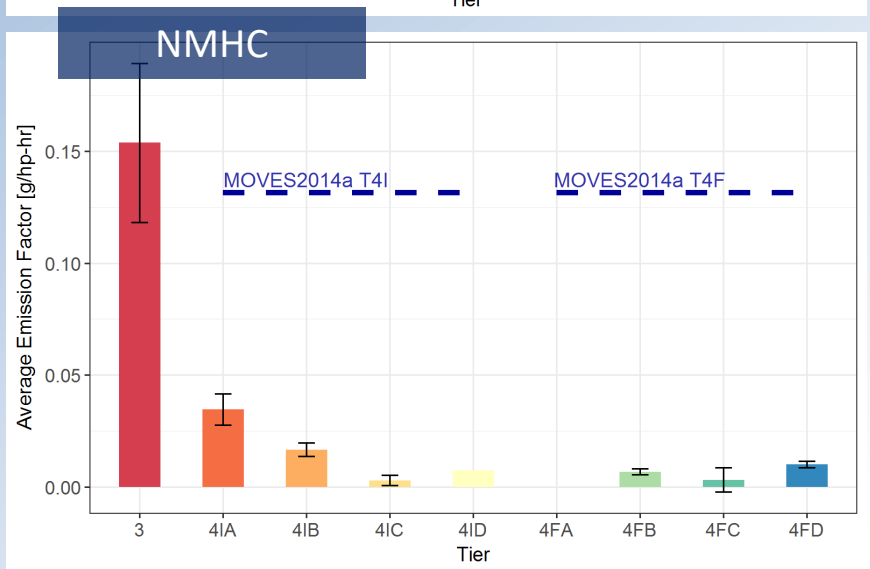

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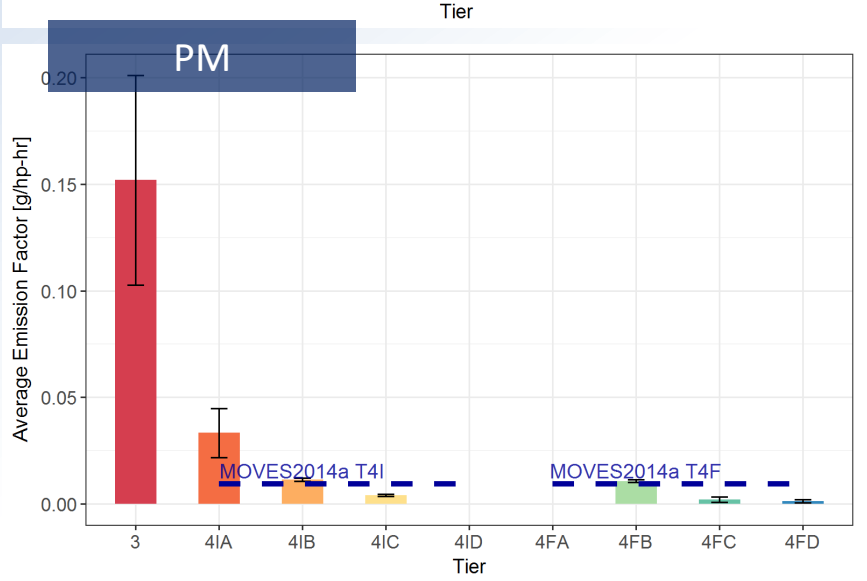
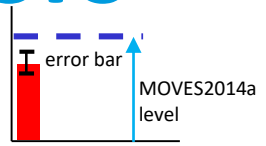


Recommended Emission Factors

HP 175 to 300

A	No DPF	No SCR
B	No DPF	With SCR
C	With DPF	NO SCR
D	With DPF	With SCR



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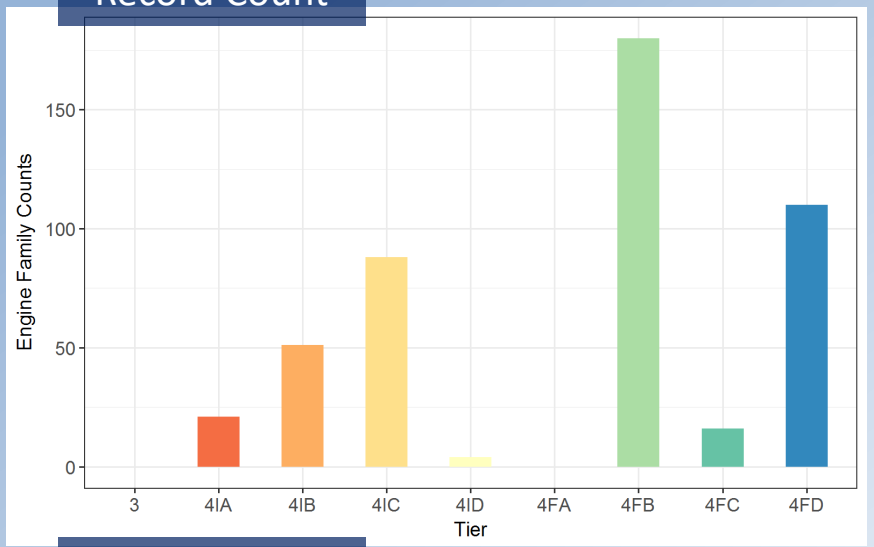

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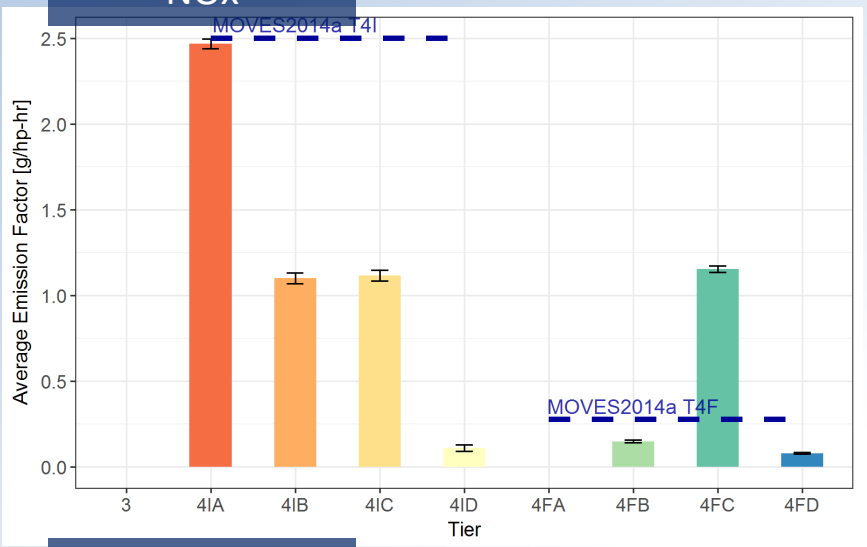

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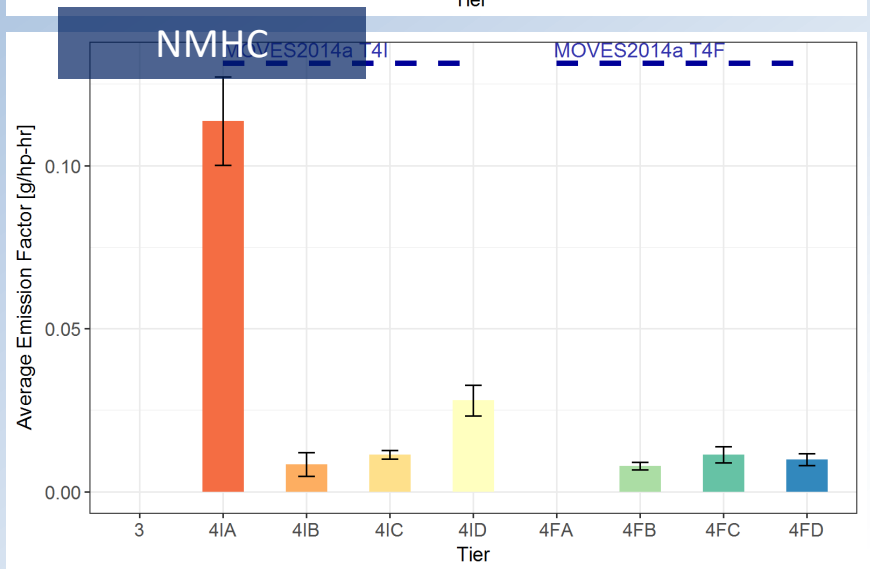
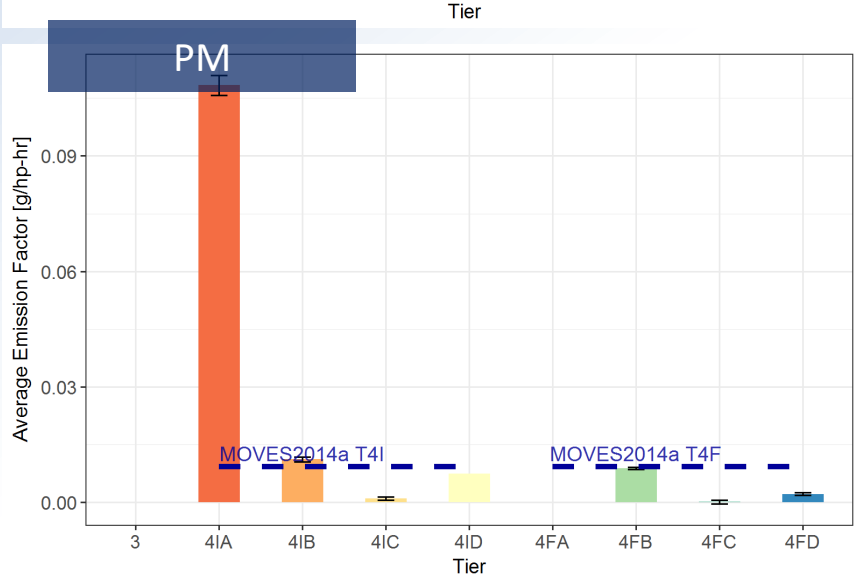


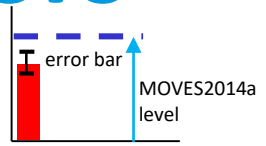
PM



Recommended Emission Factors

HP 300 to 600

A	No DPF	No SCR
B	No DPF	With SCR
C	With DPF	NO SCR
D	With DPF	With SCR



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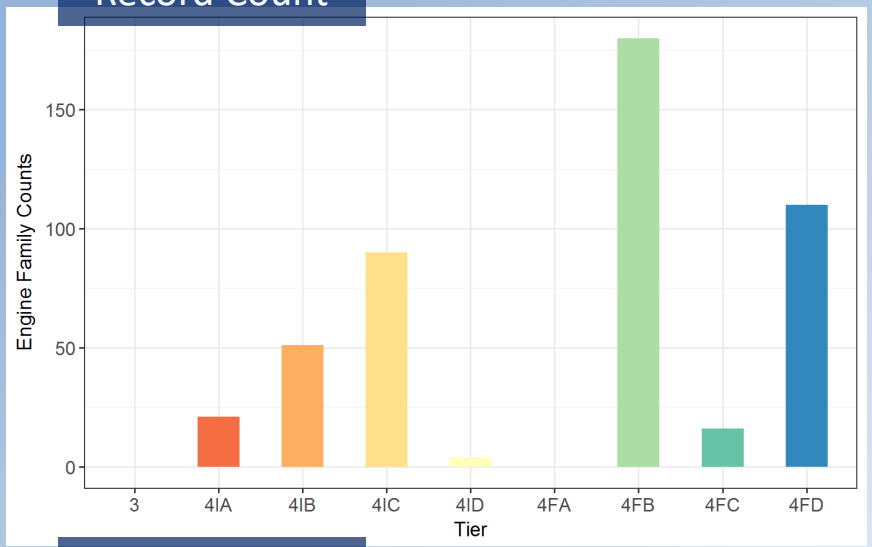

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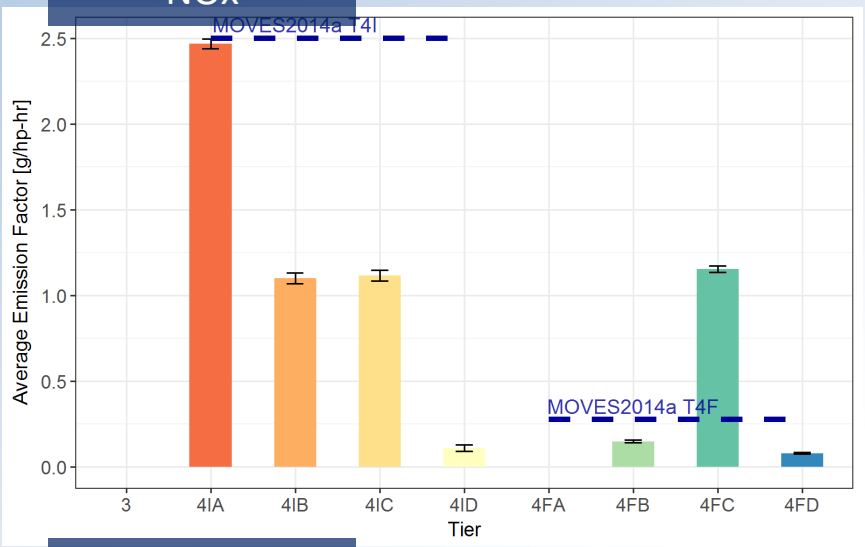

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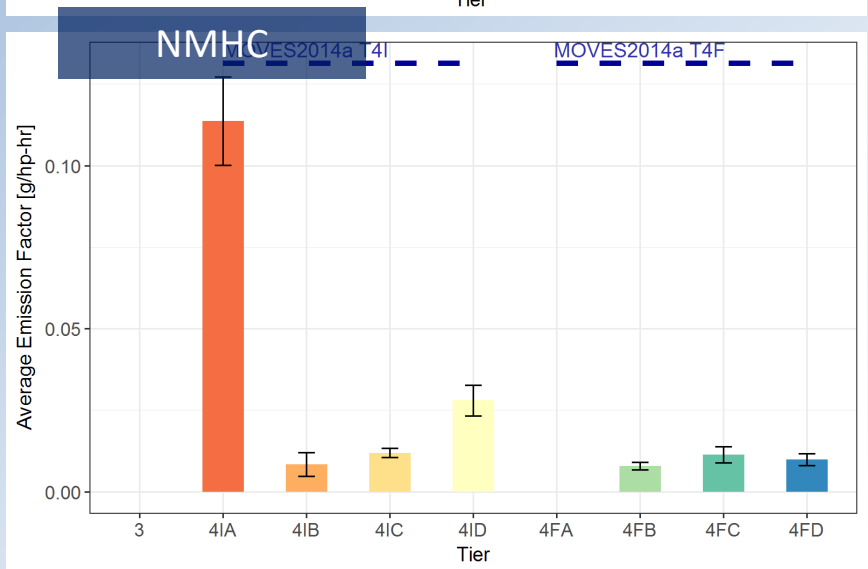

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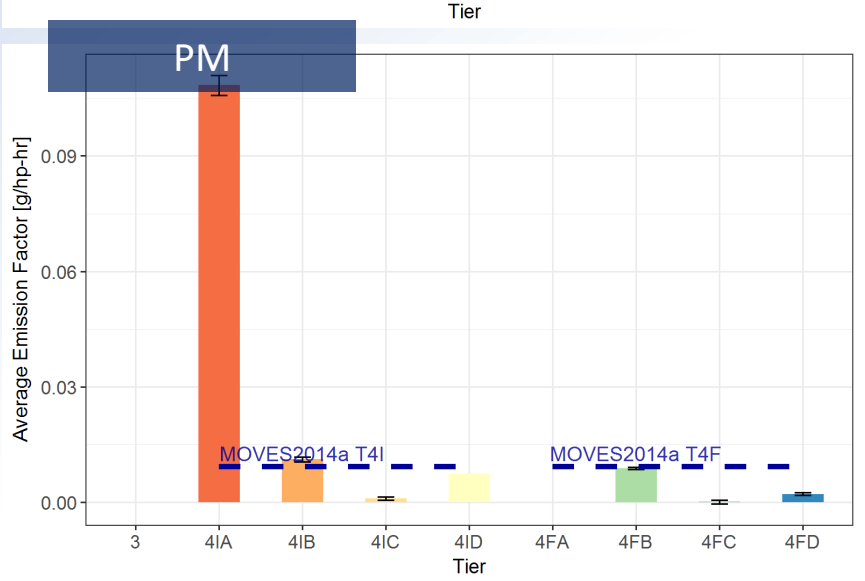
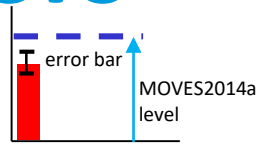


Recommended Emission Factors

HP 600 to 750

A	No DPF	No SCR
B	No DPF	With SCR
C	With DPF	NO SCR
D	With DPF	With SCR



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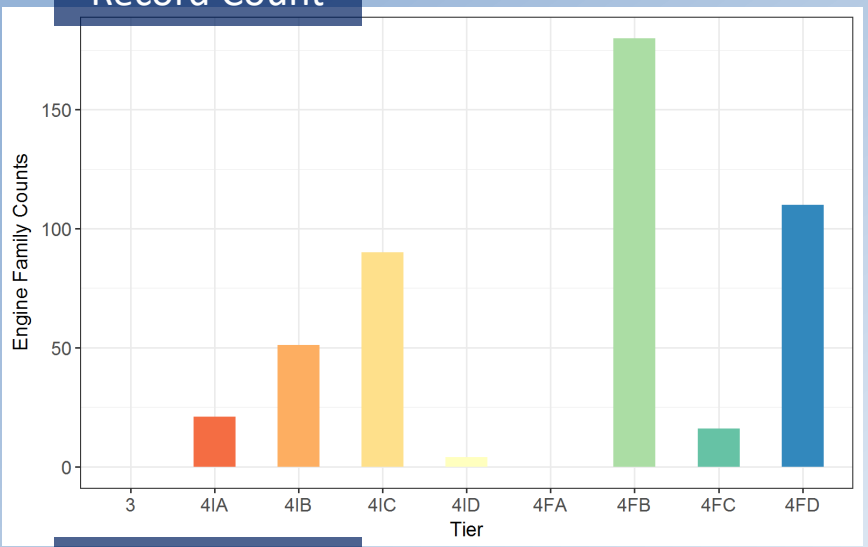

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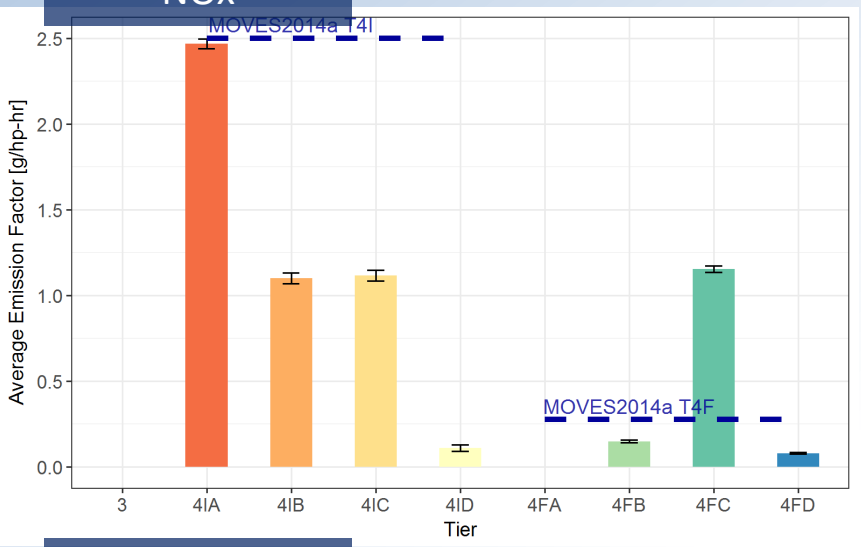

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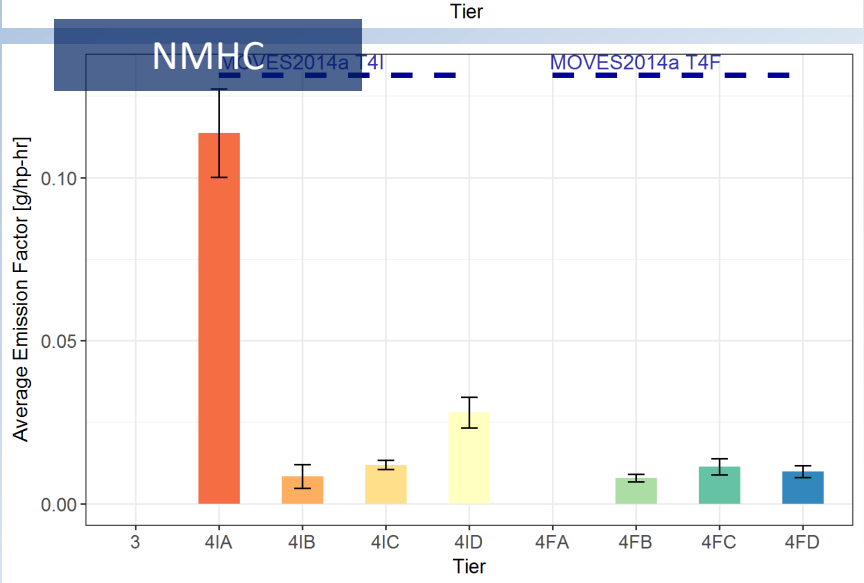
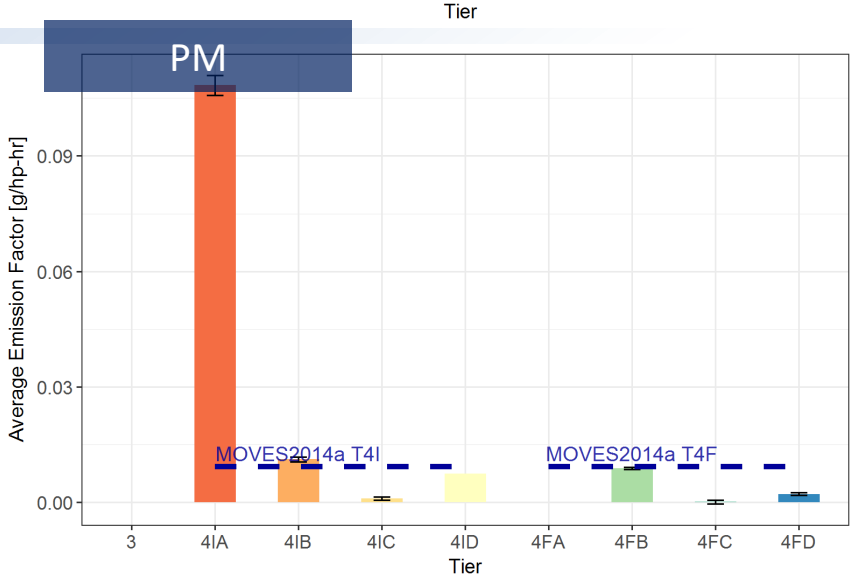


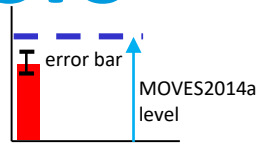
PM



Recommended Emission Factors

HP >750 – non generator

A	No DPF	No SCR
B	No DPF	With SCR
C	With DPF	NO SCR
D	With DPF	With SCR



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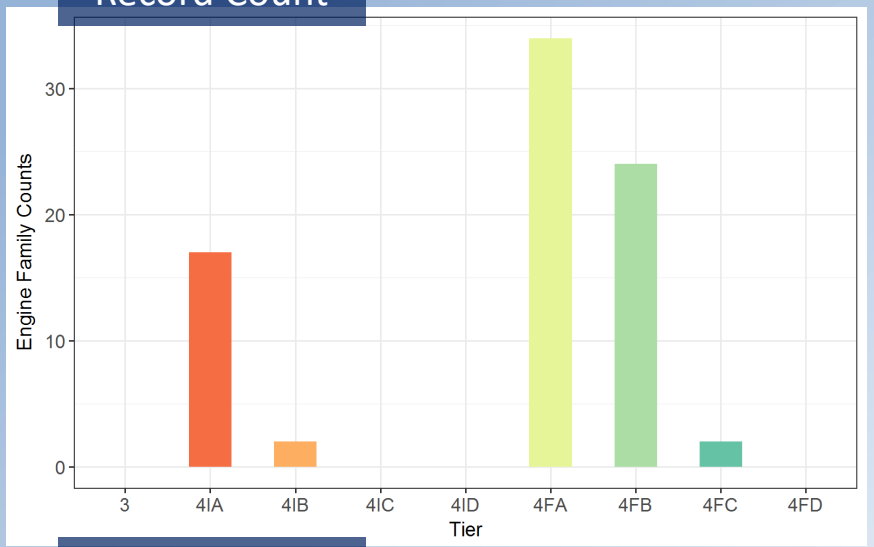

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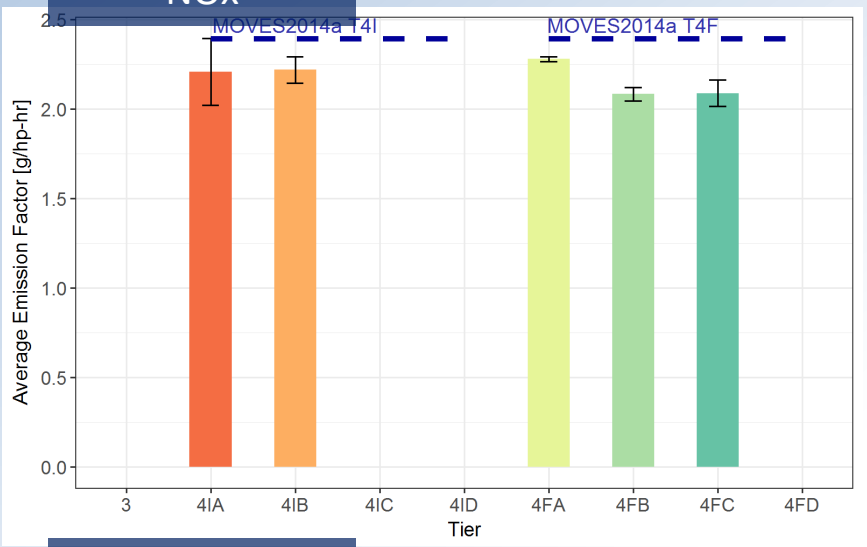
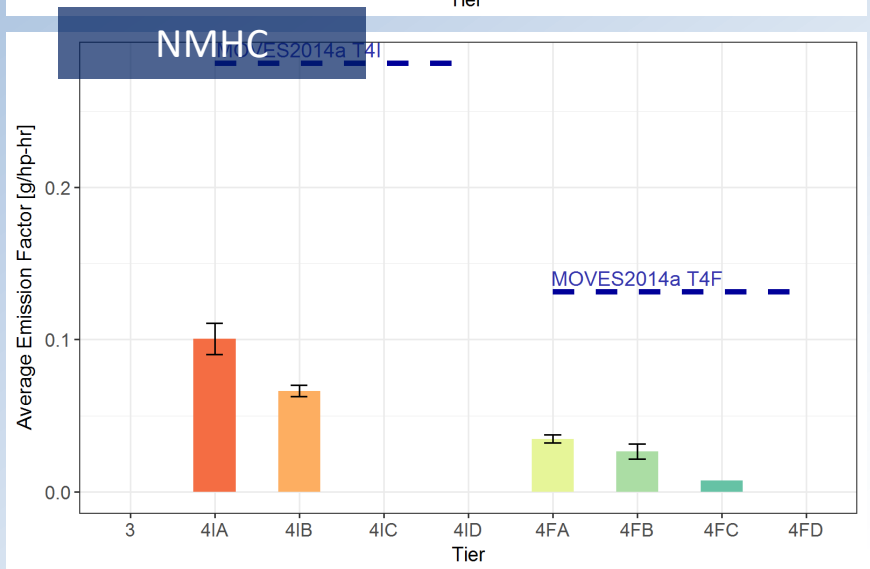
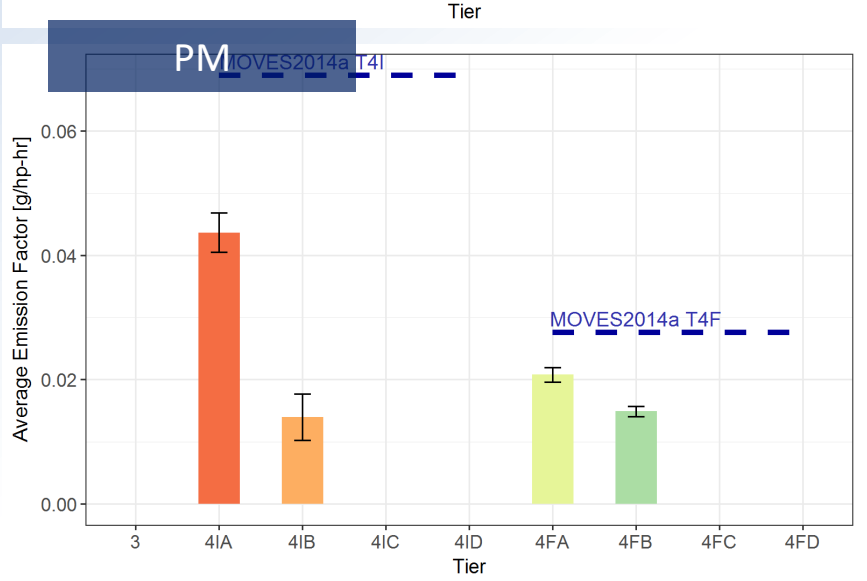


NMHC



PM

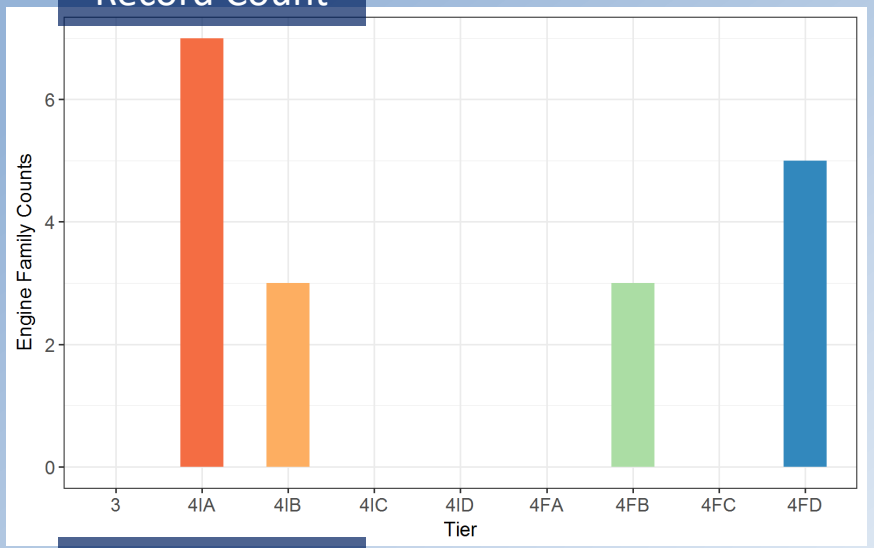


Recommended Emission Factors

HP 750 to 1200 - generator

A	No DPF	No SCR
B	No DPF	With SCR
C	With DPF	NO SCR
D	With DPF	With SCR

Record Count



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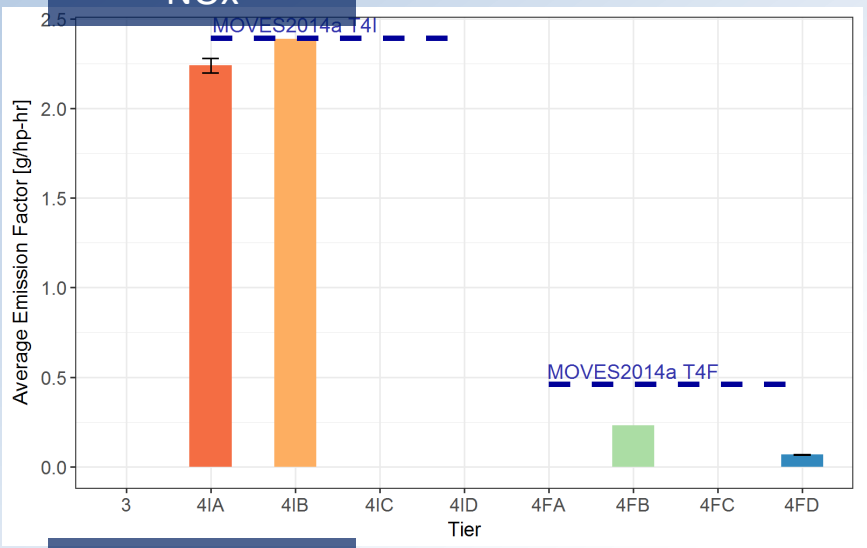

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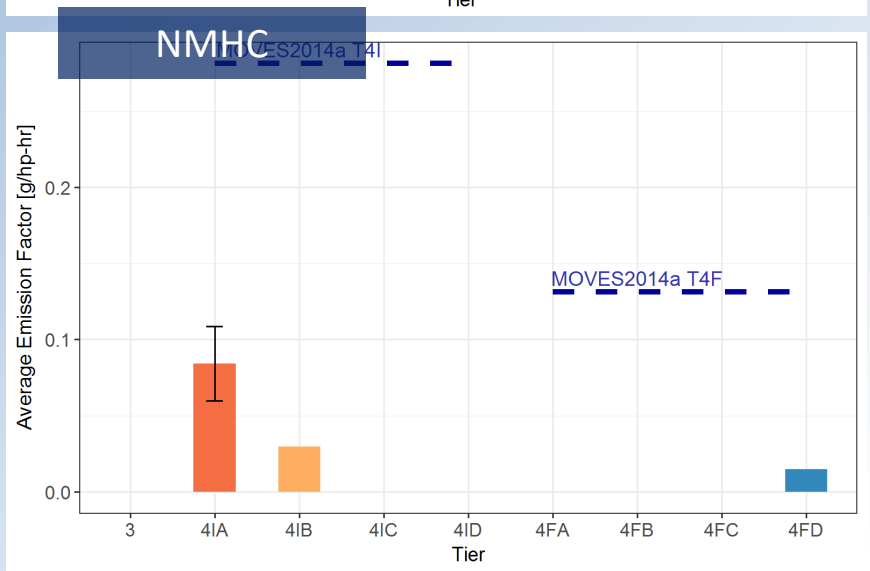

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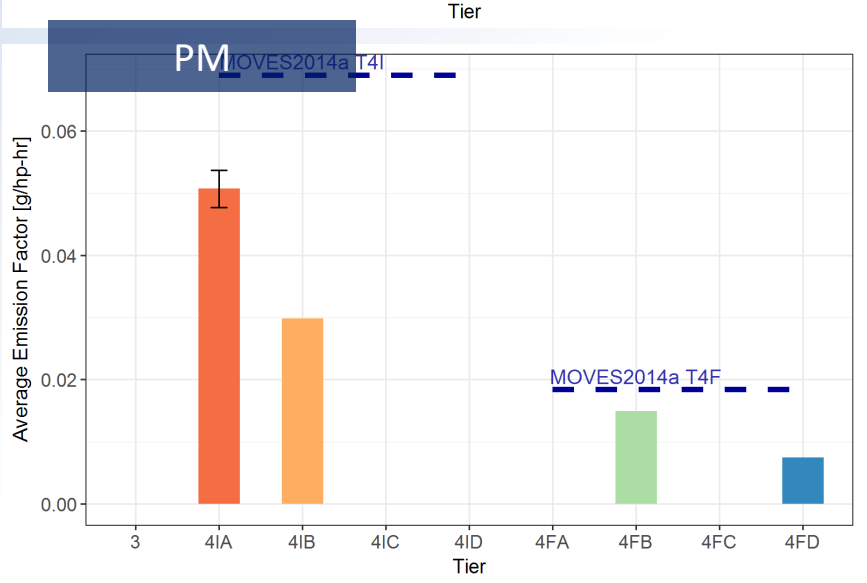
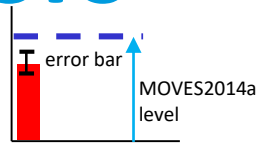


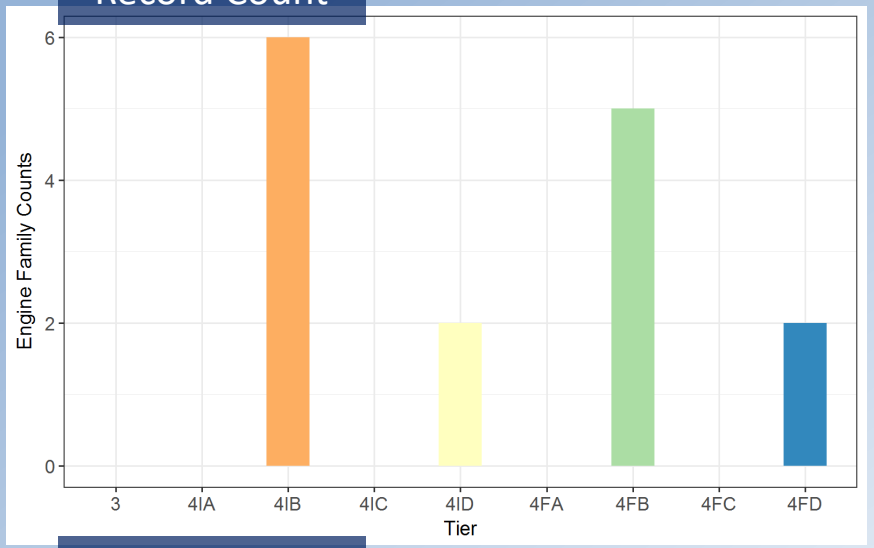
Recommended Emission Factors

HP >1200 - generator

A	No DPF	No SCR
B	No DPF	With SCR
C	With DPF	NO SCR
D	With DPF	With SCR



Record Count



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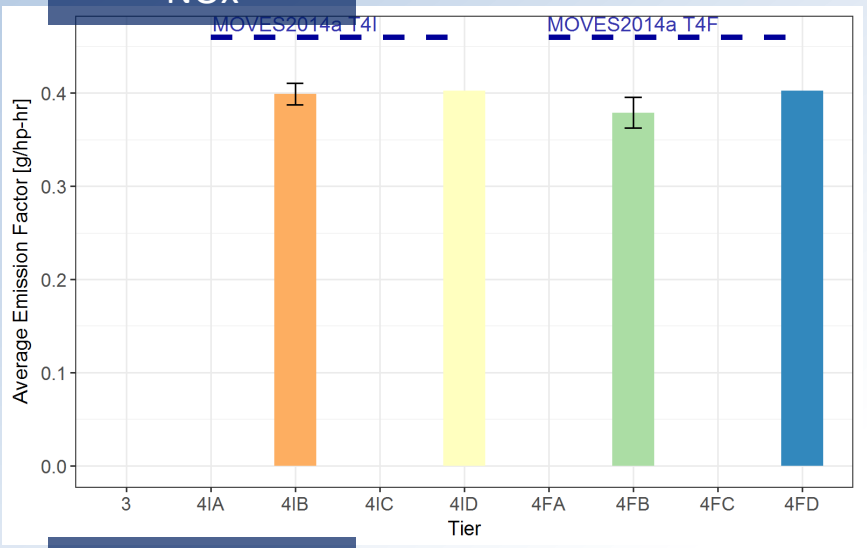

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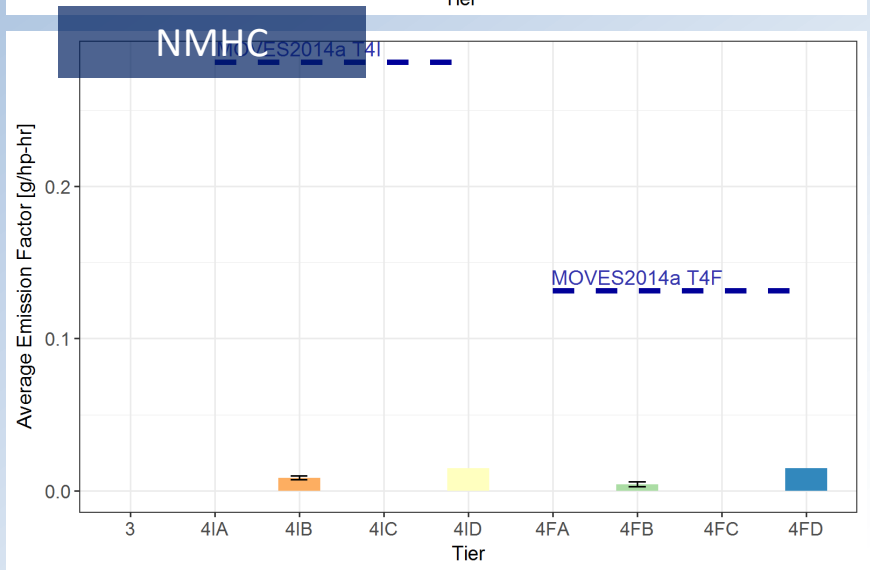

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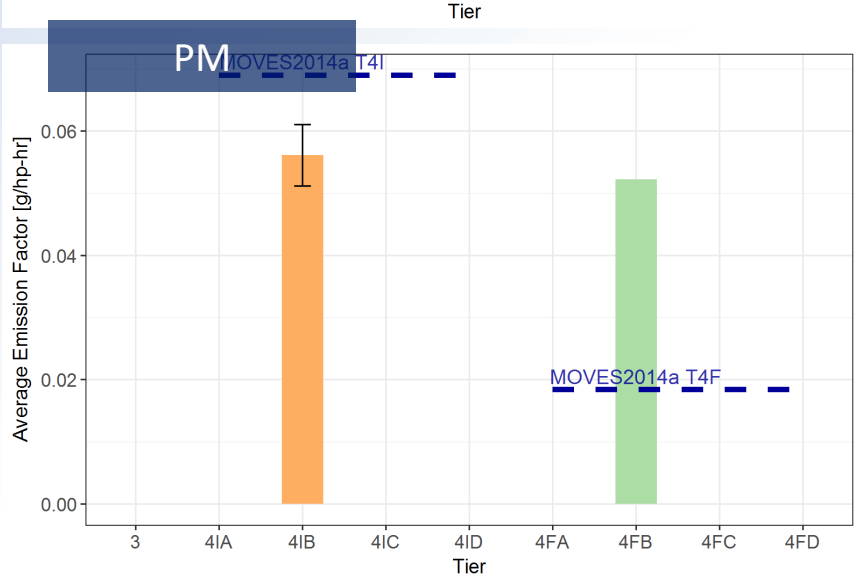

Recommended Speciation/Toxic Update

- Distinguish Tier-4 engines equipped with different after-treatment technology

Engine Tech Category			Profile for TOG speciation	Toxic Fraction of VOC	PAH emissions factors (as faction of PM2.5)	Metal emission factors*
A	No DPF	No SCR	Tier 2 nonroad diesel engine	←	Same way as Tiers 2 & 3 using nonroad CI test program data	Same way as pre-Tier 4 using onroad data
B	No DPF	With SCR				
C	With DPF	NO SCR	ACES Phase 1 onroad data	←	←	←
D	With DPF	With SCR	ACES Phase 2 onroad data	←	←	←

* For Manganese and Nickel; Pollutant specific approaches for other metals

Summary

- We are proposing updating the Tier 4 nonroad diesel engine classification, population split, emission rates based primarily on EPA certification data sets.
- The effect of different after-treatment configurations will be accounted for in order to enhance modeling detail.
- It will also allow different speciation by after-treatment configurations.

QUESTIONS?