



# Locomotive Inventory Update: Line Haul Activity



Air Resources Board  
Air Quality Planning and Science  
November 7, 2014



# Locomotives

- The California locomotive inventory represents:
  - Line haul activity
  - Switcher activity
  - Passenger activity
  - Metrolink activity
- Line haul  $\text{NO}_x$  emissions represent > 80% of statewide locomotive emissions (> 67% in SC)
- This inventory update is for Class I line-haul locomotives only

# Industry Structure

- Two Class I rail lines in California
  - BNSF (Berkshire Hathaway)
  - Union Pacific
- Multiple class III rail lines
- No public reporting of activity data
  - Surface Transportation Board
  - FHWA's Freight Analysis Framework

# How Locomotives Work

- Locomotives have diesel-electric engines
  - Engine powers direct current electricity generator
  - Electricity routed to traction motors that move the train
- The diesel engine operates at set output levels, called notches
- Higher notch settings generate more power, use more fuel, and generate more emissions
- Newer locomotives are manufactured to cleaner emissions levels, called tiers

# Estimating Locomotive Emissions

- Base year inventory estimated from:
  - The population of line-haul locomotives
  - How much they operate
  - How much fuel they burn
  - Emission rates (based on age/tier and fuel type)
- Future emissions estimated from:
  - Projections about future locomotive activity
  - Improved fuel efficiency of operations
  - How quickly locomotives are retired / sold

# Confidentiality

- Activity data provided by UP and BNSF considered business confidential
- Data provided at subdivision level, but many regions have only one operator
- Inventory released in aggregate (i.e. activity data released at air basin level, emissions at county, etc.)

# Inventory Scope

- Inventory categories
  - Premium
  - Bulk/Manifest
  - Other
  - Foreign
- Categories disaggregated according to similar duty cycle and growth parameters
- Rail line data submission for the 2011 calendar year

# Detailed Activity Data Example\*

<b>Subdivision:</b>	Roseville Sub																
<b>Descriptor:</b>	EB, Roseville to Sparks MP 91.6 to 226.4 134.8 miles timetable distance																
								<b>Duty Cycle</b>									
Train Category	No. of Trains	Avg No of Locos	Calc No. of Locomotives	Avg Miles	Annual Gross Tons (MM)	Avg Time (min)	Sample Size	DB	I	N1	N2	N3	N4	N5	N6	N7	N8
UPRR Premium	200	4.0	800	136	NA	360	100	5.0%	10.0%	4.0%	4.0%	5.0%	7.0%	10.0%	10.0%	15.0%	30.0%
UPRR Manifest/Bulk	400	3.0	1,200	136	NA	420	100	7.0%	8.0%	8.0%	6.0%	6.0%	10.0%	14.0%	18.0%	6.0%	17.0%
UPRR Other	100	2.0	200	136	NA	420	100	10.0%	12.0%	5.0%	4.0%	4.0%	8.0%	10.0%	14.0%	7.0%	26.0%
Total						10											

								<b>Fleet Mix</b>									
Train Category	No. of Trains	Avg No of Locos	Calc No. of Locomotives	Avg Miles	Annual Gross Tons (MM)	Avg Time (min)	Sample Size	Tier N	Tier 0	Tier 0+	Tier 1	Tier 1+	Tier 2	Tier 2+	Tier 3	Tier 3+	Tier 4
UPRR Premium	200	4.0	800	136	NA	360	100	1.0%	10.0%	16.0%	20.0%	4.0%	49.0%	0.0%	0.0%	0.0%	0.0%
UPRR Manifest/Bulk	400	3.0	1,200	136	NA	420	100	2.0%	20.0%	6.0%	18.0%	4.0%	50.0%	0.0%	0.0%	0.0%	0.0%
UPRR Other	100	2.0	200	136	NA	420	100	12.0%	20.0%	25.0%	10.0%	2.0%	31.0%	0.0%	0.0%	0.0%	0.0%
Total						10											

\*Note: Subdivision-level activity data have been fictionalized



# Comprehensive Activity Data Example\*

Subdivision	Segment	Track Type	County Beg MP	County End MP	Miles of Track	MGT Incr MP	MGT Decr MP	Annual Avg MGT	Total MGTM	Avg Daily Trains
ALAMEDA CORRIDOR	6621-0	NO 1	0	18.17	18.17	10	5	15	272.55	5
ALAMEDA CORRIDOR	6621-0	NO 2	0	16.85	16.85	10	5	15	252.75	5
ALAMEDA CORRIDOR	6621-0	NO 3	0	16.72	16.72	10	5	15	250.80	5
ALAMEDA CORRIDOR	6621-0	NO 2	16.85	18.18	1.33	10	5	15	19.95	5
ALAMEDA CORRIDOR	6621-0	NO 3	16.85	18.18	1.33	10	5	15	19.95	5
ALHAMBRA SUB	6680-0	NO 1	482.6	488.27	5.67	5	8	13	73.71	5
ALHAMBRA SUB	6680-0	NO 2	482.6	488.27	5.67	5	8	13	73.71	5
ALHAMBRA SUB	6680-0	SIMN	488.27	503.92	15.65	5	8	13	203.45	10
ALHAMBRA SUB	6684-0	SIMN	503.92	515.39	11.47	5	8	13	149.11	14
ALHAMBRA SUB	6686-0	SIMN	515.39	516.17	0.78	5	8	13	10.14	34
ALHAMBRA SUB	6686-0	SIMN	516.17	532.37	16.20	5	8	13	210.60	34
ALHAMBRA SUB	6686-0	NO 1	532.37	538.5	6.13	5	8	13	79.69	17
ALHAMBRA SUB	6686-0	NO 2	532.37	538.5	6.13	5	8	13	79.69	17
CAJON (BNSF)	6035-3	NO 1	0	39.1	39.10	20	0	20	782.00	20
CAJON (BNSF)	6035-3	NO 2	0	39.1	39.10	0	14	14	547.40	20
CAJON (BNSF)	6035-3	NO 1	39.1	62.29	23.19	20	0	20	463.80	20
CAJON (BNSF)	6035-3	NO 2	39.1	52.86	13.76	0	14	14	192.64	20
CAJON (BNSF)	6035-3	NO 2	52.86	62.29	9.43	20	16	36	339.48	20
CAJON (BNSF)	6035-3	NO 3	52.86	62.29	9.43	0	3	3	28.29	14
CAJON (BNSF)	6035-1	NO 1	62.29	81.32	19.03	20	0	20	380.60	20
CAJON (BNSF)	6035-1	NO 2	62.29	81.32	19.03	5	3	8	152.24	20
CAJON (BNSF)	6035-1	NO 3	62.29	81.32	19.03	0	16	16	304.48	14

\*Note: Subdivision-level activity data have been fictionalized

# Base Year Fuel Consumption

- 2011 fuel burn estimated in three ways
  - Fuel burn rates (gal/hr) of locomotives estimated directly from duty cycle data provided by rail lines, then multiplied by reported locomotive activity  
(74% UP; 23% BNSF)
  - Productivity (GTM/gal) modeled from grade of subdivisions, scaled to reported level of activity  
(26% UP; 69% BNSF)
  - Fuel burn rate estimated from subdivision grades, scaled by estimated locomotive activity  
(8% BNSF)
- 2011 CA fuel burn ~ 210 million gallons

# California Network



# Spatial Allocation of Base Year Fuel

- Activity reported by subdivision
- Fuel consumption allocated to counties from subdivision according to two methods:
  - Straight allocation (constant productivity regardless of location within subdivision)
  - Refined allocation (varying productivity based on location/grade within subdivision)

# Air Basin Allocation - Sample

Company	SubName	Direction	Air Basin	Share
BNSF	Cajon	E	Mojave Desert	60%
BNSF	Cajon	E	South Coast	40%
BNSF	Cajon	W	Mojave Desert	86%
BNSF	Cajon	W	South Coast	14%
BNSF	Needles	E	Mojave Desert	100%
BNSF	Needles	W	Mojave Desert	100%
BNSF	San Bernardino	E	South Coast	100%
BNSF	San Bernardino	W	South Coast	100%
BNSF	Stockton	E	Bay Area	30%
BNSF	Stockton	E	San Joaquin Valley	70%
BNSF	Stockton	W	Bay Area	28%
BNSF	Stockton	W	San Joaquin Valley	72%
UP	Fresno North	E	San Joaquin Valley	84%
UP	Fresno North	E	Sacramento Valley	16%
UP	Fresno North	W	San Joaquin Valley	83%
UP	Fresno North	W	Sacramento Valley	17%
UP	Los Angeles	E	South Coast	100%
UP	Los Angeles	W	South Coast	100%
UP	Roseville	E	Mountain Counties	78%
UP	Roseville	E	Sacramento Valley	22%
UP	Roseville	W	Mountain Counties	85%
UP	Roseville	W	Sacramento Valley	15%
UP	Yuma	E	South Coast	31%
UP	Yuma	E	Salton Sea	69%
UP	Yuma	W	South Coast	23%
UP	Yuma	W	Salton Sea	77%

# Estimated Fuel Productivity Factor 2011

Air Basin	Gross Ton- Miles/Gallon
CA (Statewide)	640
Bay Area	731
Mojave Desert	560
South Coast	696
San Joaquin Valley	794
Sacramento Valley	747

# 2011 Fuel Estimates

(million gallons)

Air Basin	Current Inventory	Model Update	Change
CA (Statewide)	222.8	210.0	-6%
Bay Area	15.8	5.2	-67%
Mojave Desert	49.8	89.9	81%
San Joaquin Valley	39.3	25.3	-36%
South Coast	47.5	37.5	-21%
Sacramento Valley	35.0	11.5	-67%

# Comparison to Other Data Sources – Activity and Fuel Consumption

- Corroborative Data
  - Locomotive Counts

Subdivision (UP/BNSF Submission; 2011)	Route (External Train Counts; 2014)	Difference
UP-Cima	Cima	21%
UP-Yuma	Sunset	3%
UP-Mojave	Palmdale	28%
BNSF-Cajon	Transcon	-21%

- Fuel consumption estimated in the South Coast from the MOU data at 39.5 million gallons for 2011, the updated inventory is 41.6 million gallons (both include switchers)



# Comparison to Other Data Sources – Fuel Productivity Factor

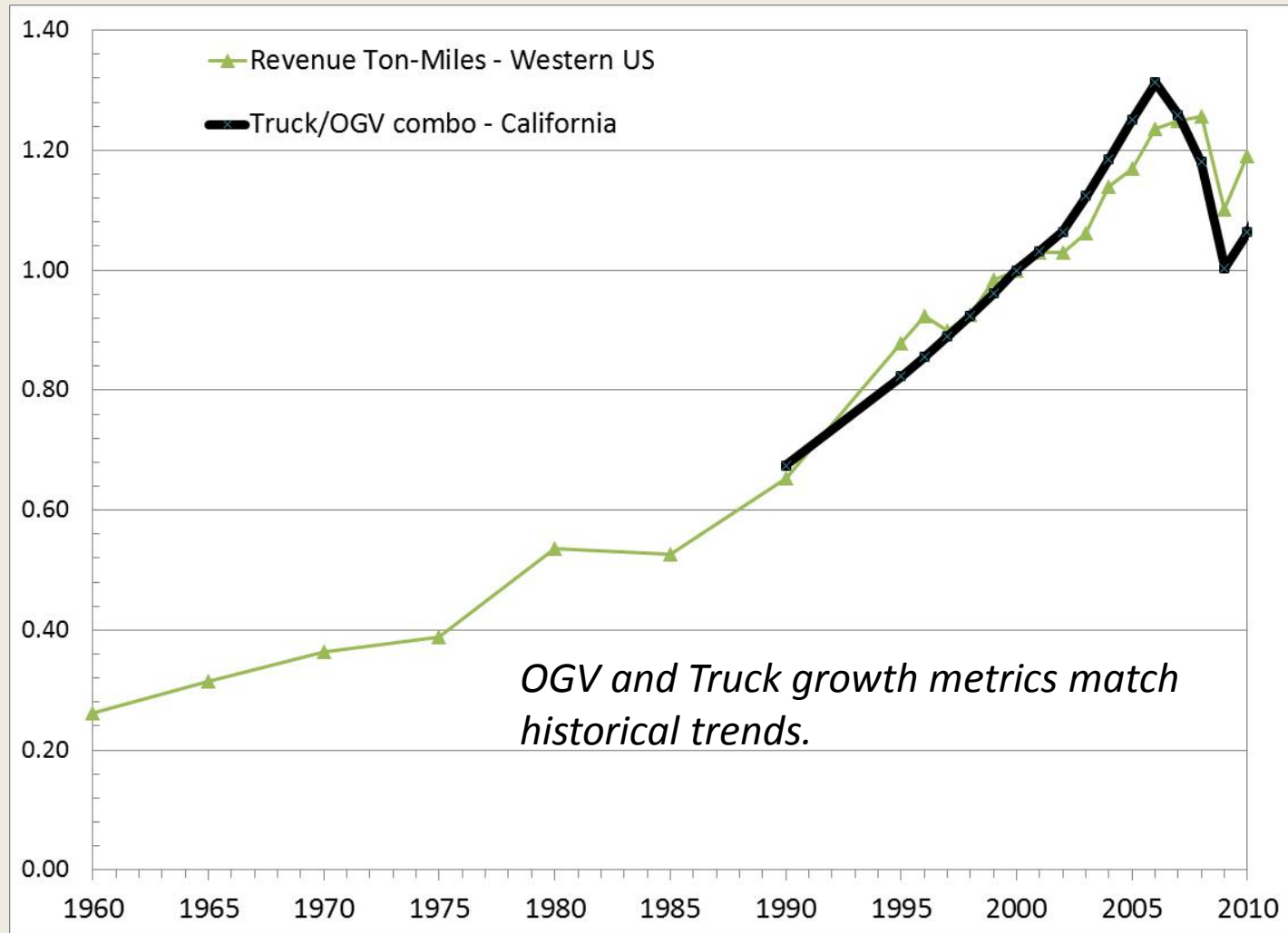
Source	Calendar Year	Revenue Ton-Miles/Gallon	Gross Ton-Miles/Gallon
ARB Inventory Update (CA)	2011	(365)	640
ARB Inventory Update (Bay Area)	2011	(417)	731
ARB Inventory Update (Mojave Desert)	2011	(319)	560
ARB Inventory Update (South Coast)	2011	(397)	696
ARB Inventory Update (San Joaq Val)	2011	(453)	794
ARB Inventory Update (Sac Val)	2011	(426)	747
Association of American Railroads - Press Release	2012	476	(835)
Association of American Railroads - Railroad Facts	2009	480	(842)
CSX - Press Release	2009	468	(821)
Texas Transportation Institute	2004	413	(725)
Federal Railroad Adminsitration (ICF)	2006	422	775
Environment Canada	1998	455	769
North Dakota State	2013	464	809

*(Estimated using ratio - 0.57)*

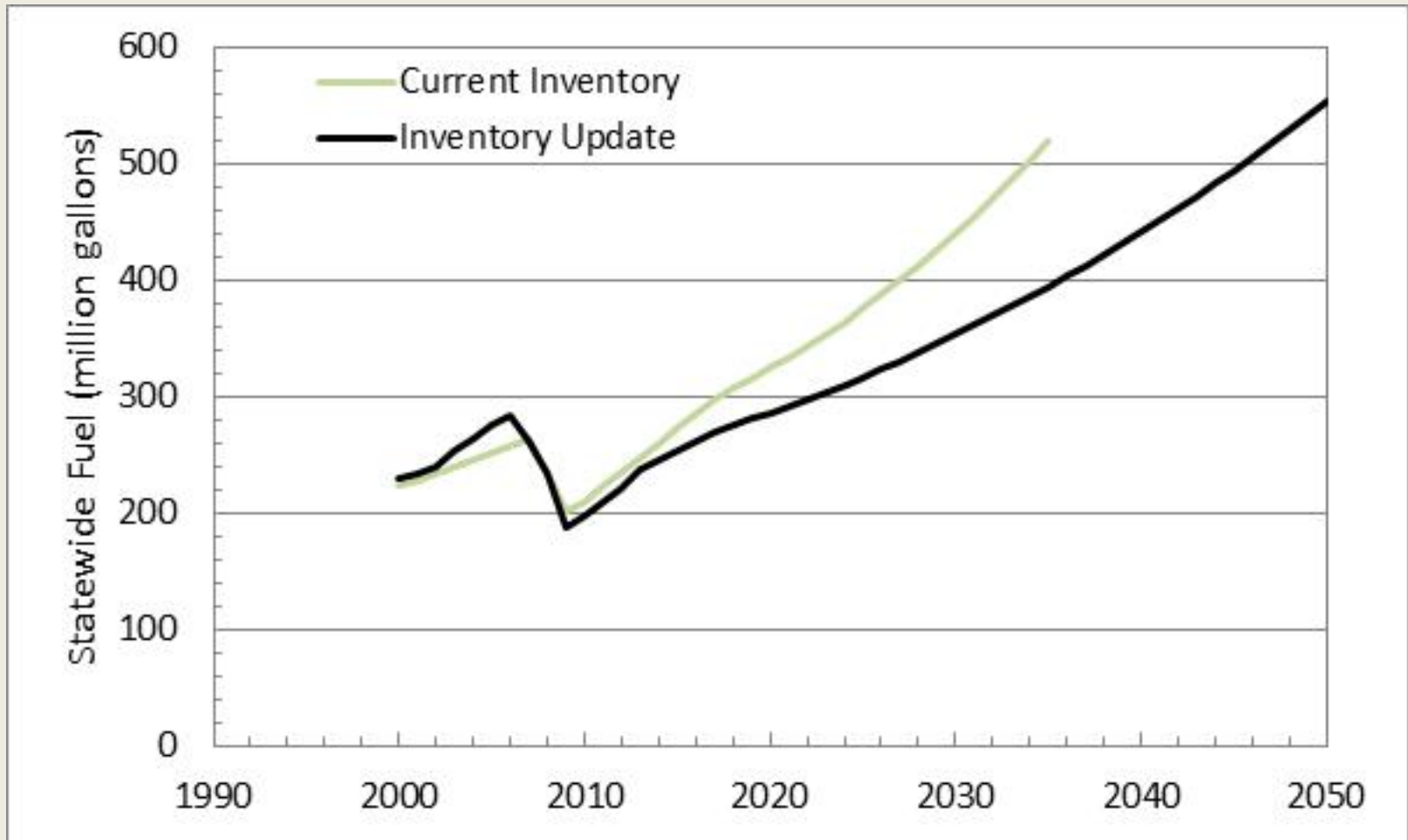
# Projecting Fuel Consumption

- Future fuel consumption projected from 2011
  - Activity grows at rate consistent with other ARB mobile source sectors
    - 3.7% for premium traffic (ocean going vessels)
    - 2.5% for manifest/bulk and other traffic (trucks)
  - Future fuel efficiency (GTM/gallon) projected to increase at 1% annually until 2050
  - Method results consistent with historical revenue ton-miles.

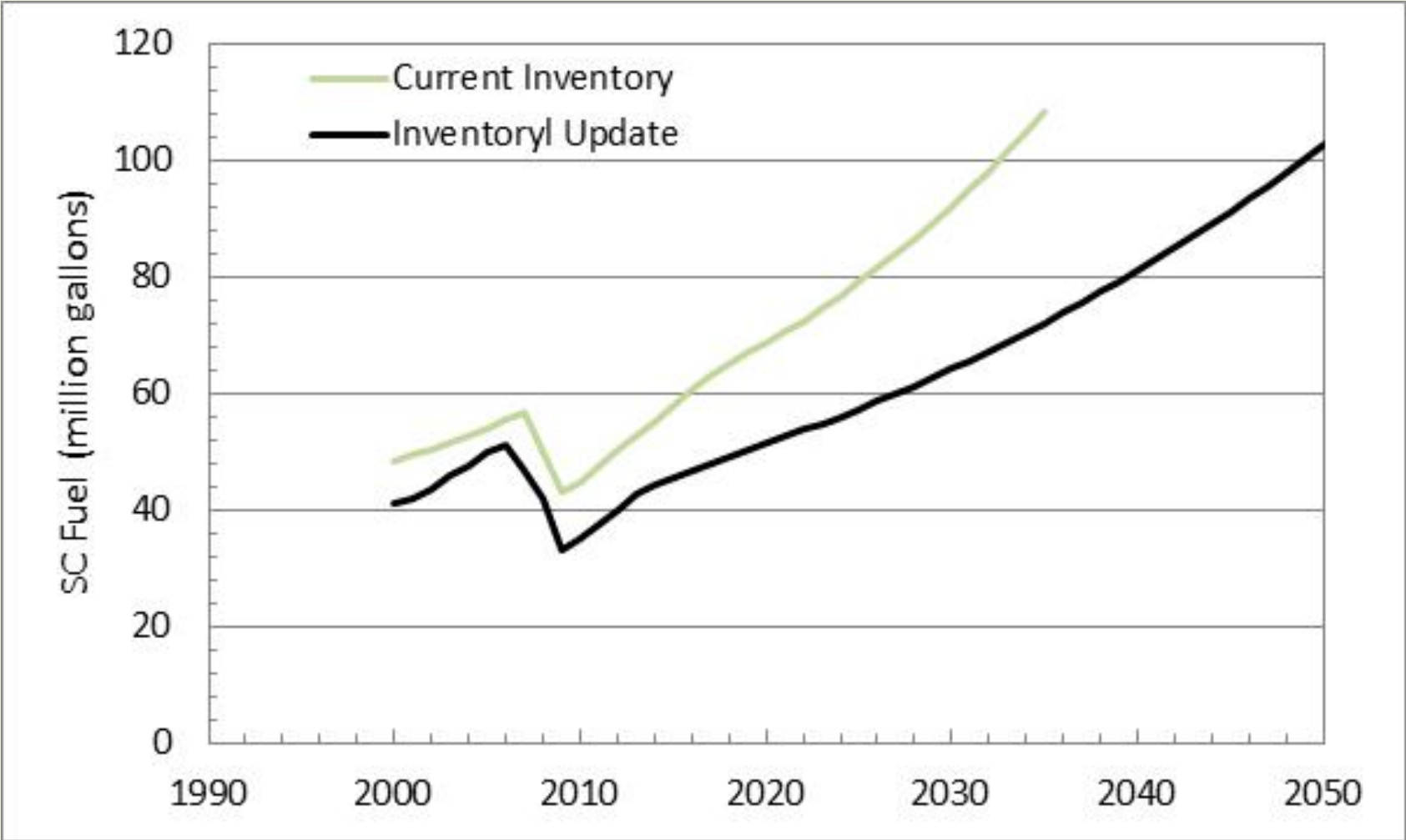
# Historical Growth Comparison



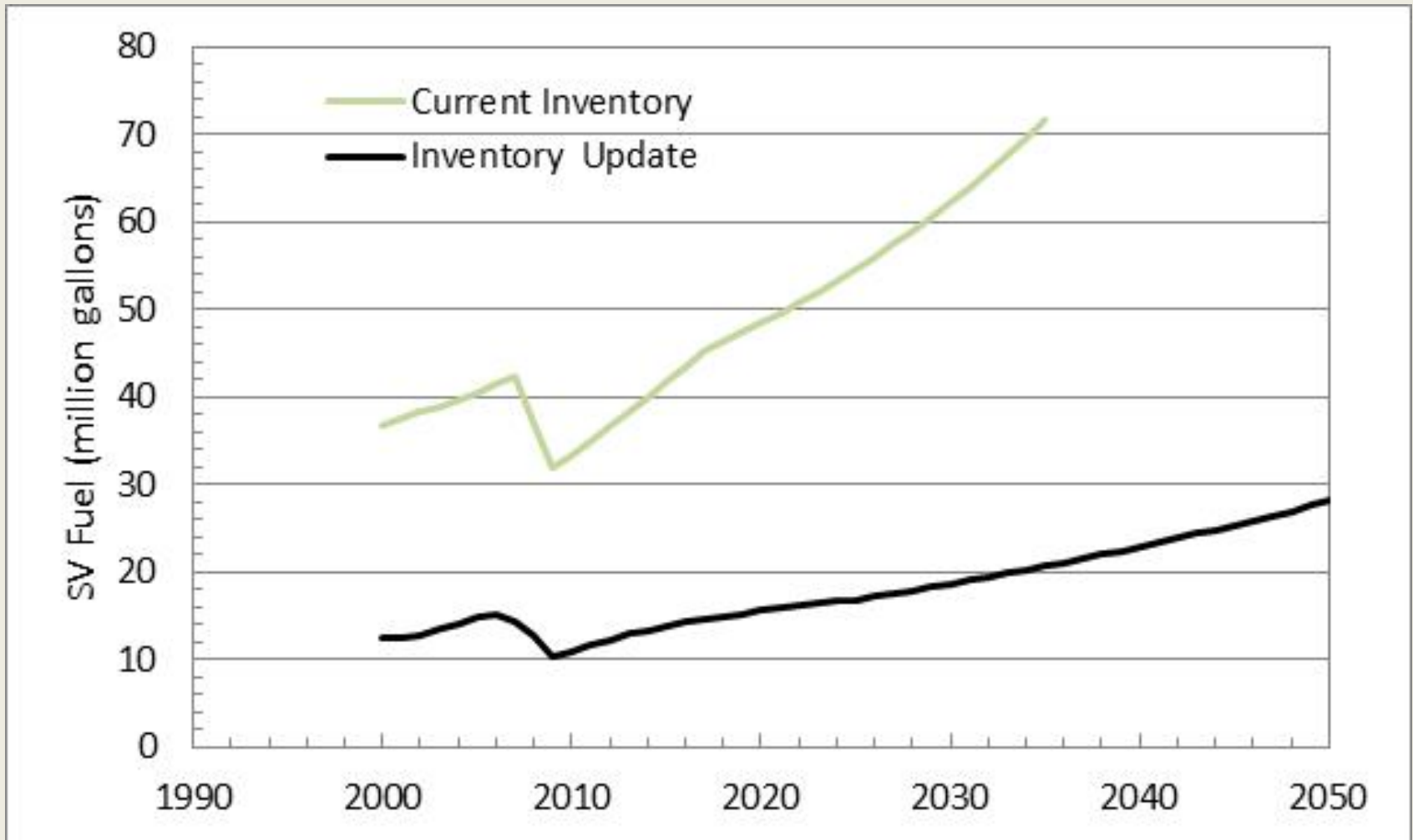
# Comparison of Inventories – CA Fuel



# Comparison of Inventories – SC Fuel



# Comparison of Inventories – SV Fuel



# Emissions Calculation

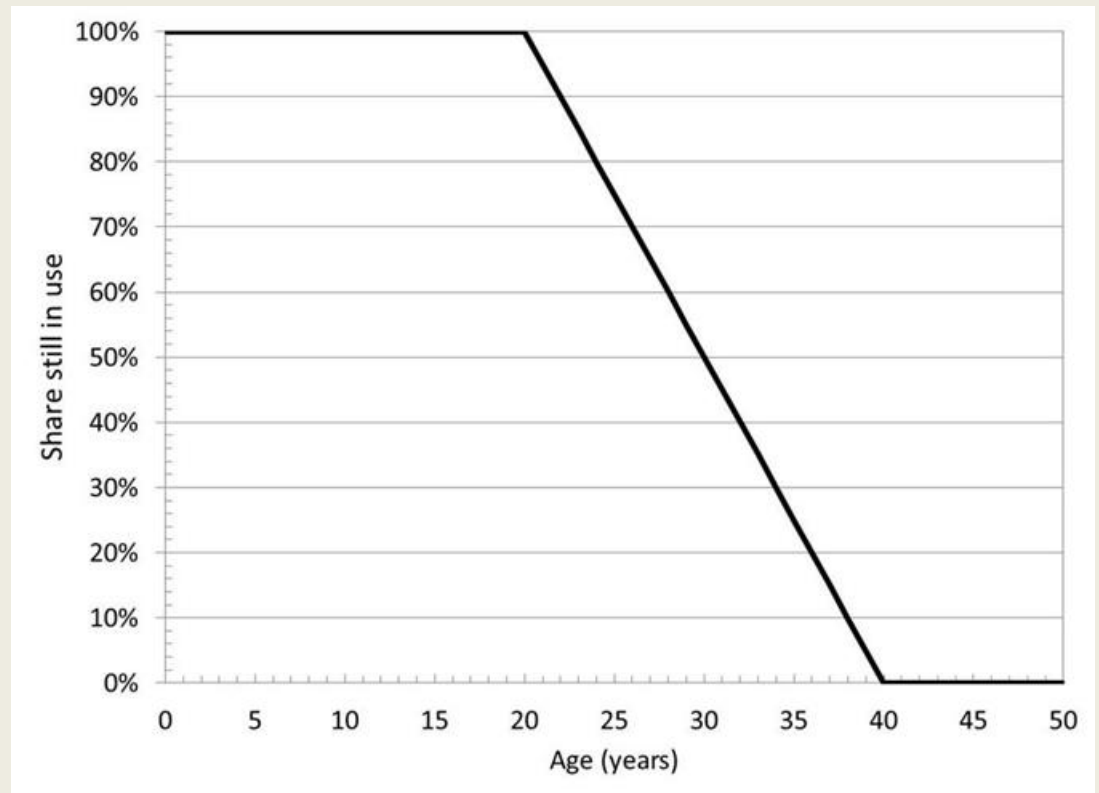
- Past/Future locomotive fleets modeled using AAR population data and USEPA survival curve
- Tier distribution defined by model year (MY) distribution
  - Represents aggregate horsepower; related to MY
  - Reported directly for 2011 (MOU)
  - Tier 4 introduced in 2017
- Emission factors defined by tier distribution
- Emissions adjusted for CARB diesel and sulfur content
  - Sulfur modeled 2007-12 @ 500 ppm; 2012+ @15 ppm

# 2012 Model Year Distribution

MY	# Locos
2012	683
2011	498
2010	256
2009	461
2008	777
2007	911
2006	1122
2005	875
2000-2004	4650
1995-1999	4173
1990-1994	2464
1985-1989	1558
Pre-1985	7054

Source:

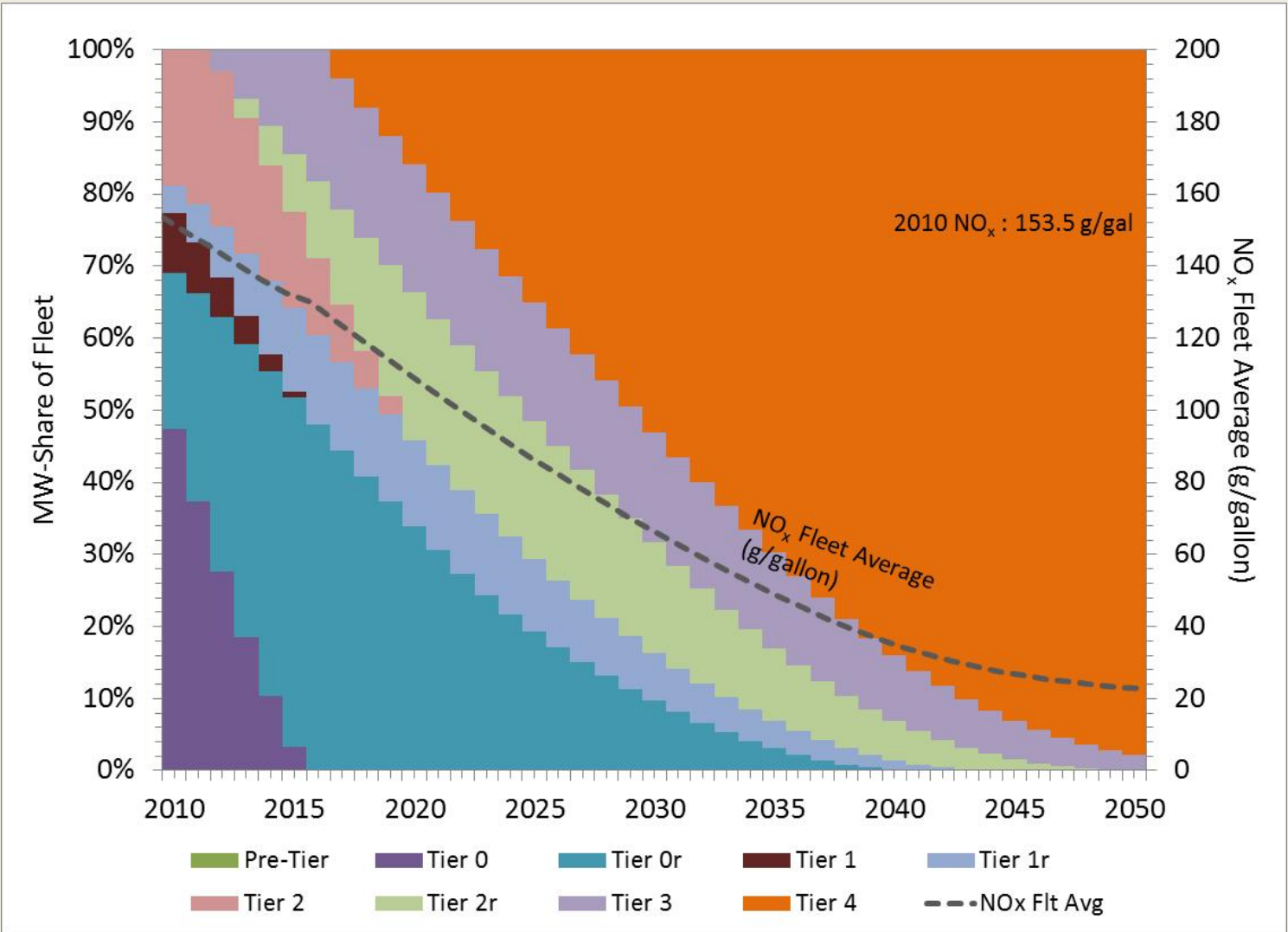
AAR Railroad Facts, 2010-12



Source: USEPA (2008)



# Baseline Tier Distribution by Calendar Year



# Tier Distribution - Observations

- Rail lines manage line haul locomotives differently to meet requirements of MOU
  - South Coast line-haul average not quite Tier 2; switchers cleaner than Tier 2
  - BNSF employs more Tier 2 line-hauls while UP utilizes localized ULEL switchers
  - Spillover stronger for UP than BNSF
  - South Coast NO<sub>x</sub> fleet average constant 2010-13

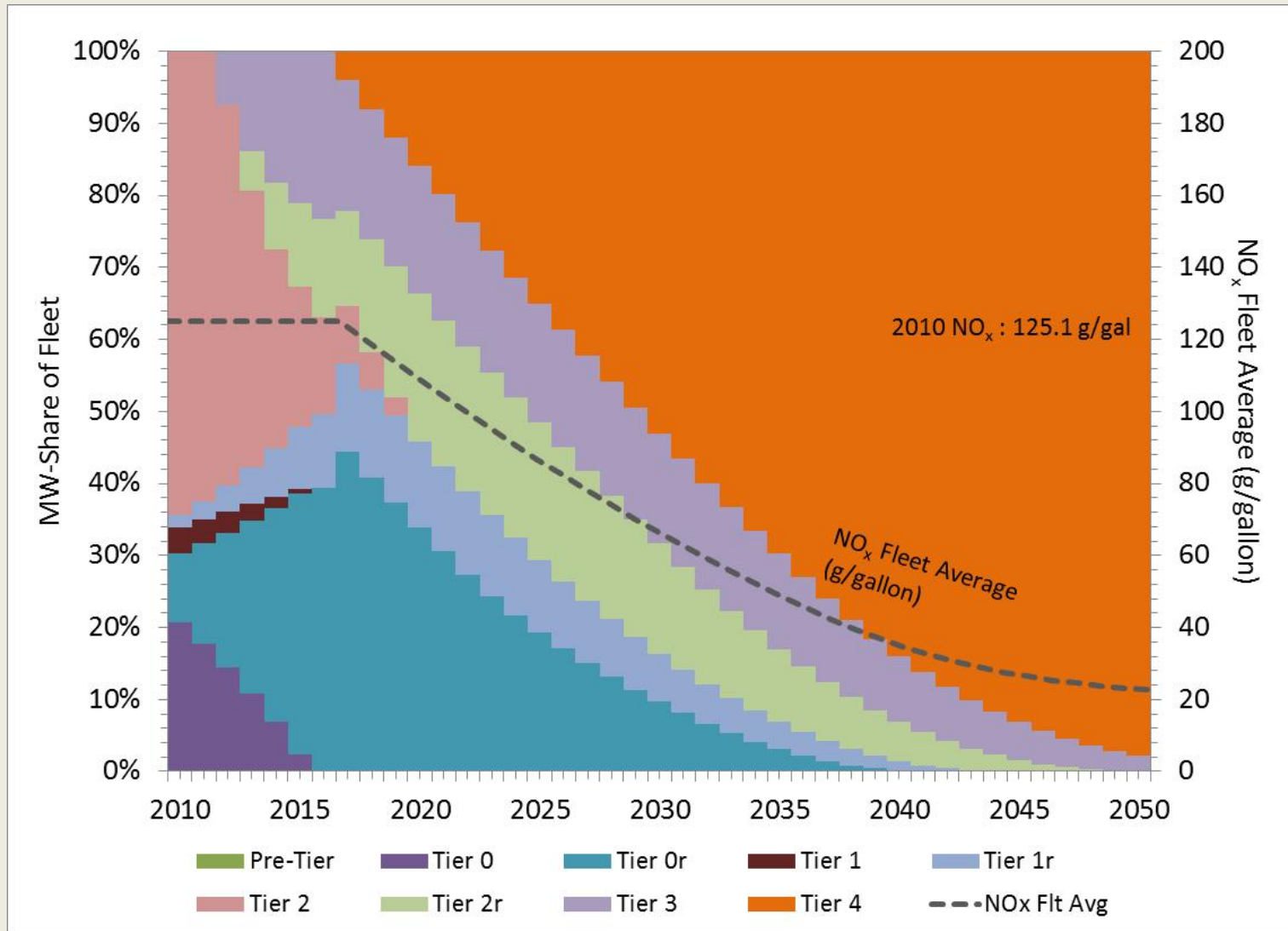
# South Coast Fleet Averages\*

NO <sub>x</sub> EF	UP	BNSF
2010	6.35	5.46
2011	6.21	5.42
2012	6.25	5.38
2013	6.26	5.55

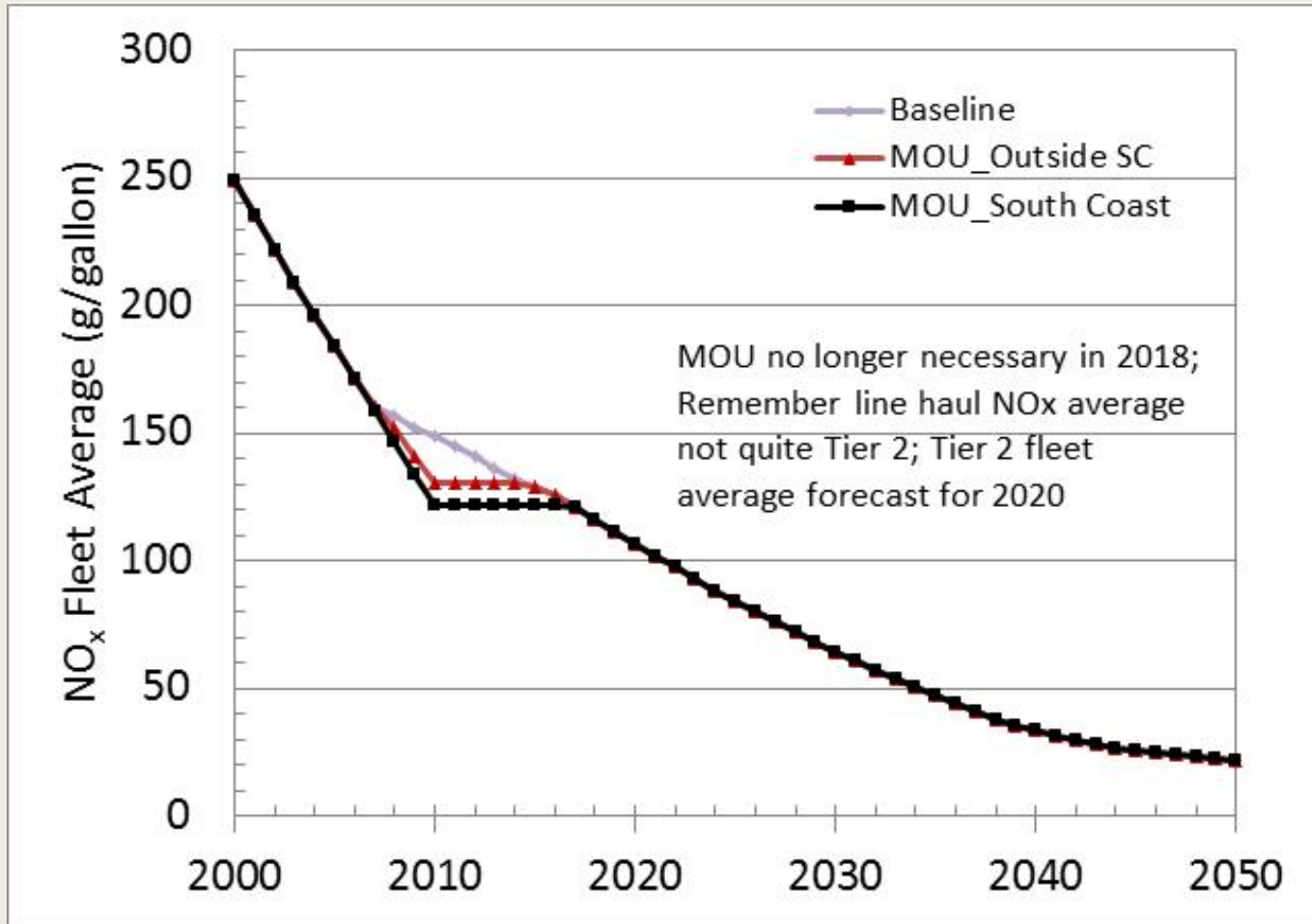
*\*g/hp-hr*

Note that the fleet averages published on the ARB website use USEPA certification values rather than USEPA emission factors and incorporate various adjustment factors, e.g. early adoption credits.

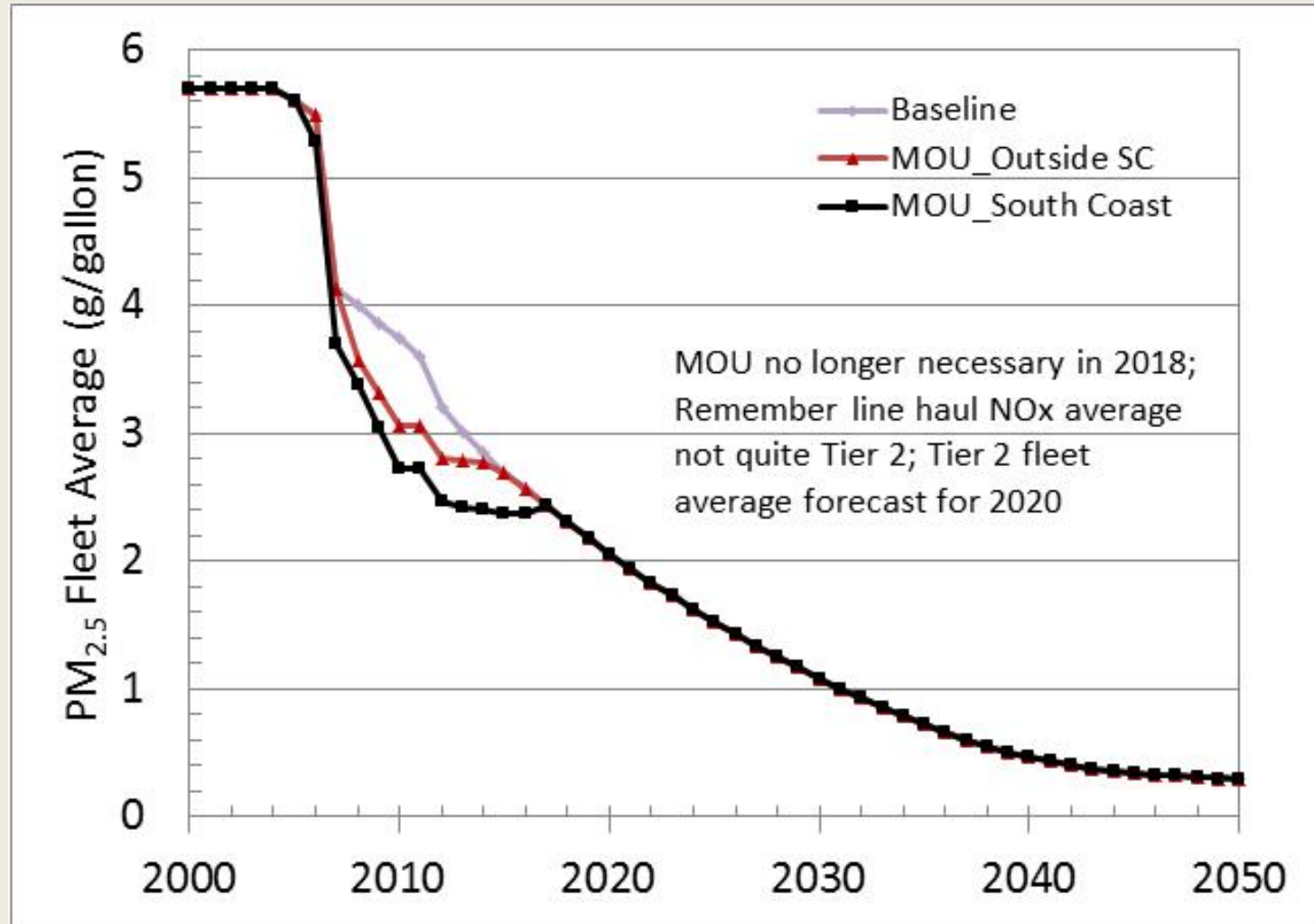
# SC Tier Distribution (w/MOU) by Calendar Year



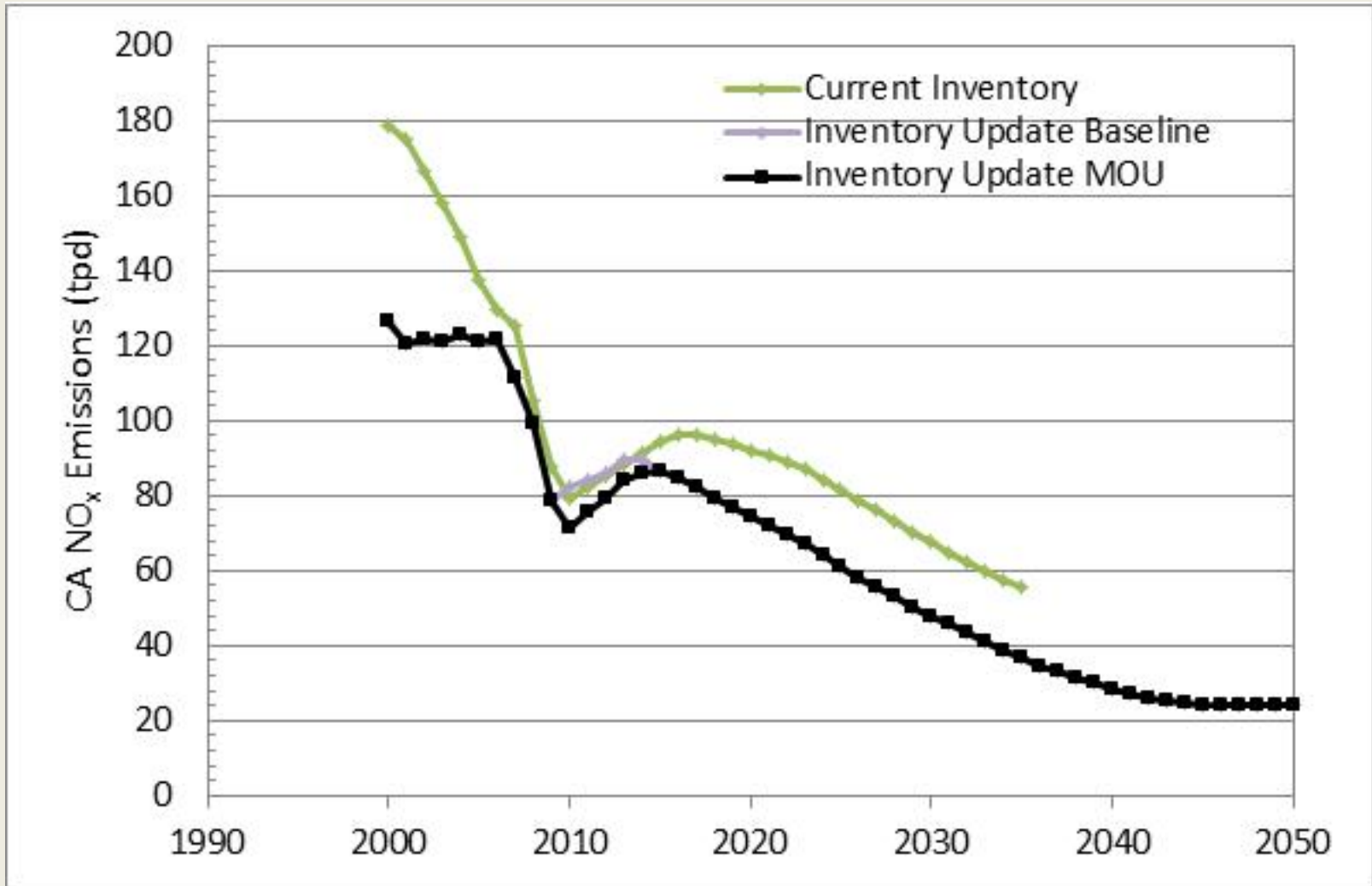
# MOU Impact on NO<sub>x</sub> Fleet Average



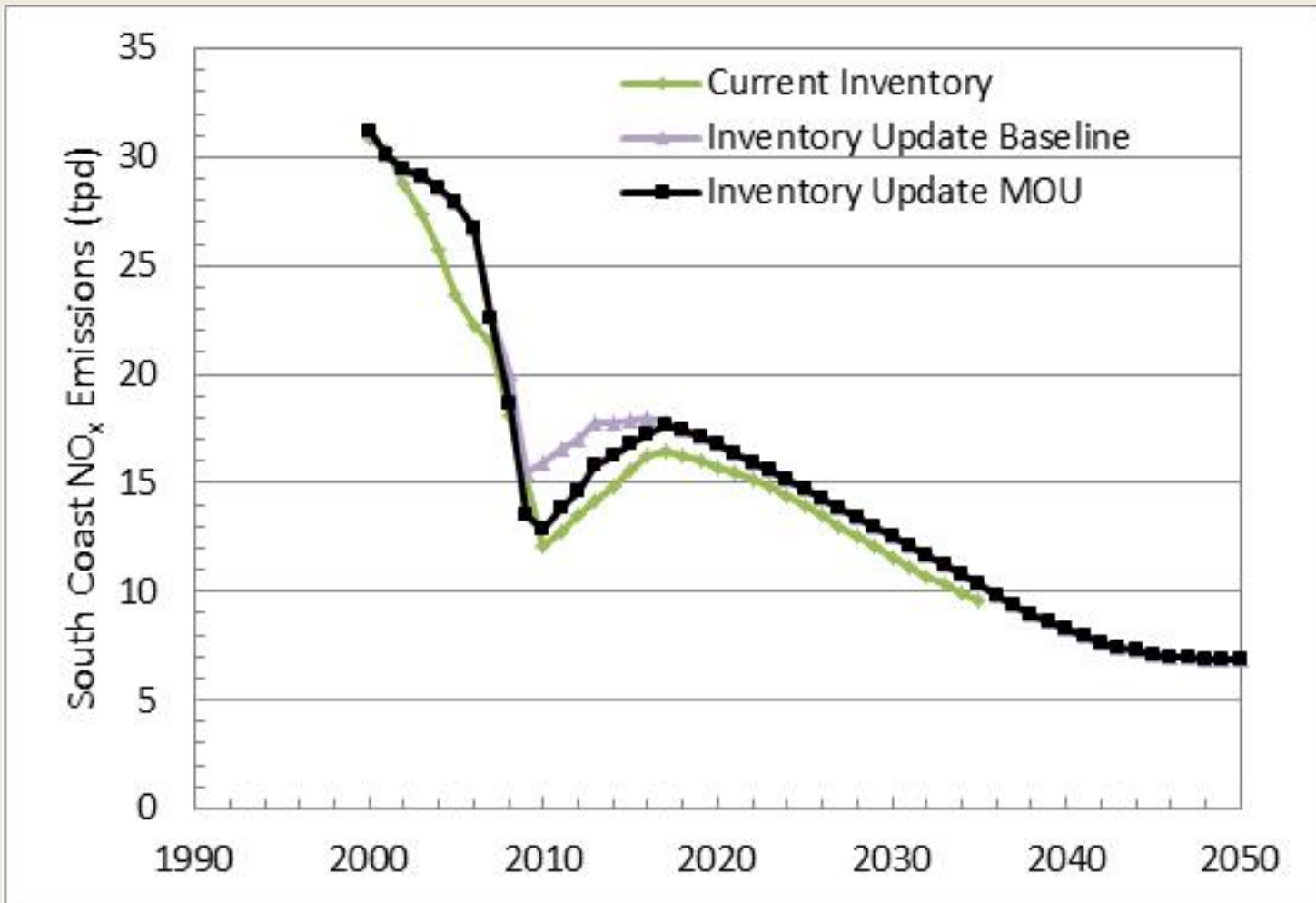
# MOU Impact on PM<sub>2.5</sub> Fleet Average



# Comparison of Inventories – CA NO<sub>x</sub>

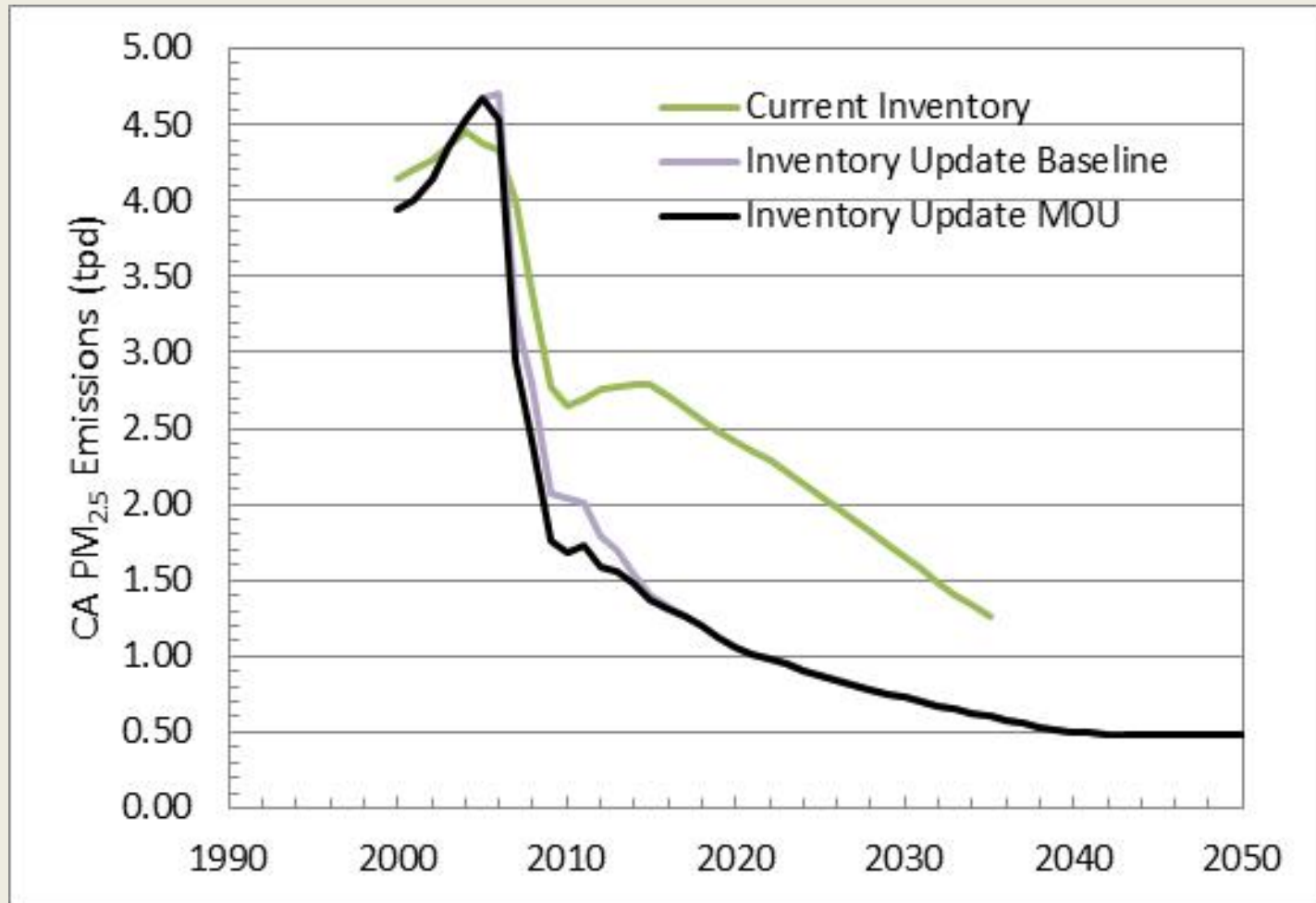


# Comparison of Inventories – SC NO<sub>x</sub>

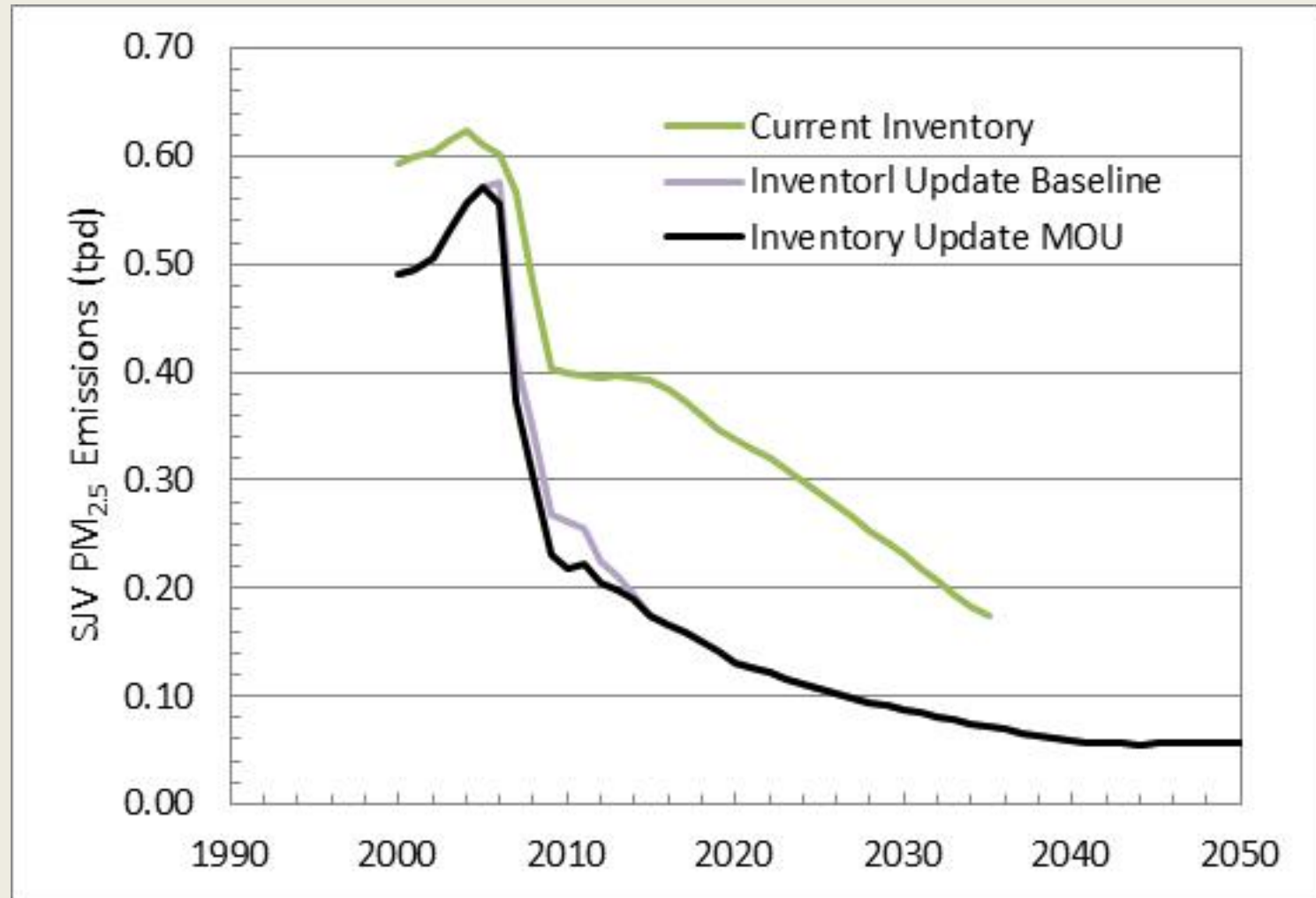




# Comparison of Inventories – CA PM<sub>2.5</sub>



# Comparison of Inventories – SJV PM<sub>2.5</sub>



# Questions/Comments

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