MOVES4 vs. MOVES5: Comparing Emissions Inventory Trends and Transportation Conformity Implications

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Purpose and Key Questions

- How do Texas emissions estimates differ between MOVES4 and MOVES5?
- How much of the difference comes from activity assumptions versus emission rates?
- What should inventory users consider when interpreting these results?

Texas Trends Emissions Inventory History

Inventory	Delivery / presentation
MOVES3 Trends	January 2023
MOVES5 Trends	January 2026
MOVES4 Trends with MOVES5 comparison	Current TxDOT–TTI IAC study

TTI typically prepares and develops a Trend Emissions Inventory for each MOVES release within 6-7 months after its release.

MOVES5 was already scheduled for release before a MOVES4 Trend Emissions Inventory could be developed.

Texas Trends EI Coverage and Intended Use

Item	Coverage
Geography	All 254 Texas counties
Analysis years	1990 and 1999–2060 (63 years)
Reporting periods	Annual and summer weekday
Pollutants	Criteria pollutants, precursors, and air toxics
Purpose	Consistent county and year comparisons

Key Updates in MOVES5 Relevant to This Comparison

- Revised emission rates and vehicle-technology assumptions.
- Expanded age detail through age 40+, compared with age 30+ in MOVES4.
- Updated brake wear, fuels, fleet distributions, and default activity assumptions.
- The comparison reflects the model versions and input vintage used in this study.

Comparison Design: Fixed and Changing Inputs

Held consistent	Changes between modeled cases
Local input vintage	MOVES4 versus MOVES5 emission rates
2023 registration and HPMS VMT	Model-dependent VMT and fuel mix
2014–2023 ATR data	Activity allocation by vehicle / fuel category
County-group framework	Age-bin treatment and model defaults

Emission Rate Development

TTI conducted 2,749 MOVES4 Inventory mode runs across 63 years and 36–46 county groups.

Custom Python scripts calculated emission rates by combining emission processes and activity.

For each year, all counties in a group share the representative county's emission rate.

Emissions Process	Activity	Emission Rates
Running Exhaust	VMT	mass/mile (mass/mi)
Crankcase Running Exhaust	VMT	mass/mi
Brake Wear	VMT	mass/mi
Tire Wear	VMT	mass/mi
Start Exhaust	Starts	mass/start
Crankcase Start Exhaust	Starts	mass/start
Extended Idle Exhaust	SHEI	mass/hour
Crankcase Extended Idle Exhaust	SHEI	mass/hour
Auxiliary Power Exhaust	APU Hours	mass/hour
Running exhaust (1) – Road Type 1 off-network	Off Network Idling (ONI) Hours, SHP	mass/hour
Evaporative Permeation Evaporative Fuel Vapor Venting Evaporative Fuel Leaks	VMT, SHP	mass/mi, mass/hour

Activity and Emission Calculation

Emissions = Activity X Emission Rate

Activity utilized in this emissions inventory was developed from the same local inputs from the MOVES5 Trends Emissions Inventory

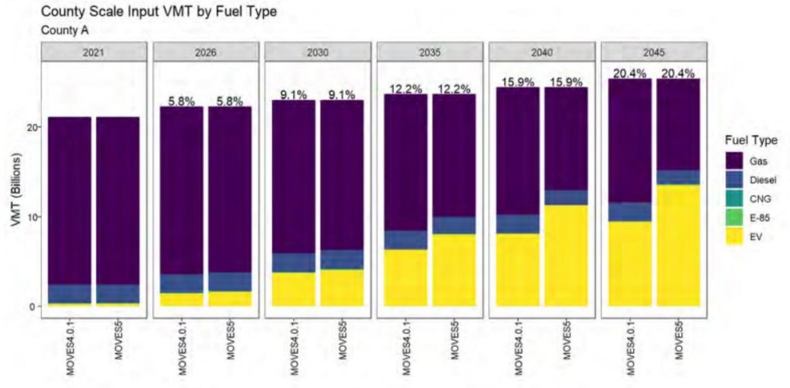
For age distribution, all age 31-40+ fractions were summed to 30+.

Table 11. Data Sources and Aggregations for SUT Age Distributions and Fuel/Engine Fractions.

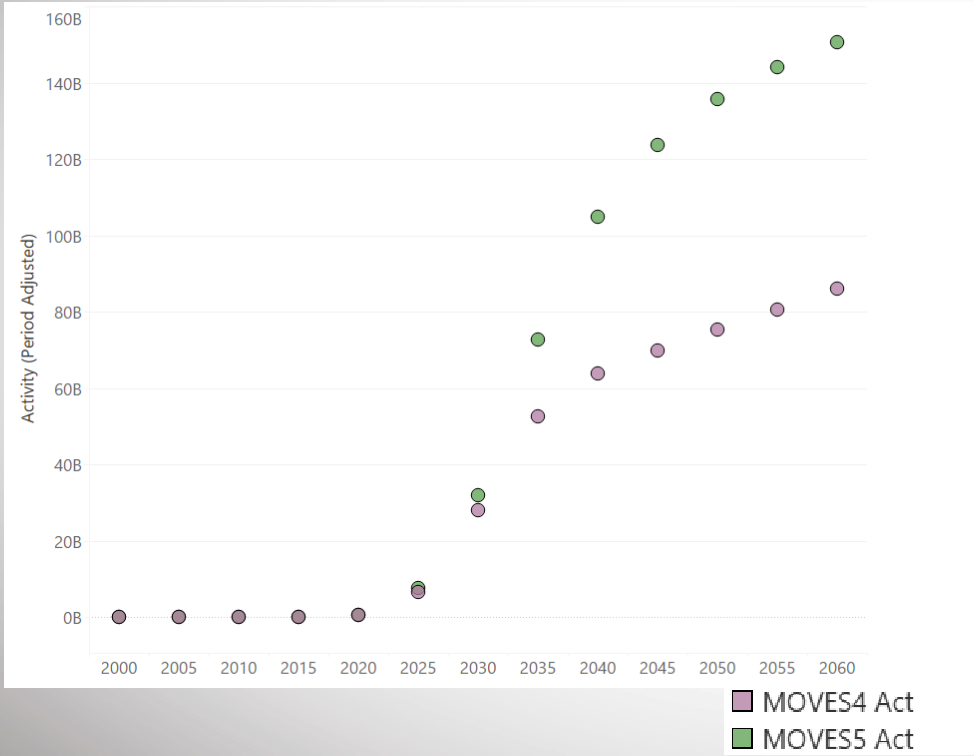
SUT Name	SUT ID	Geographic Aggregation for Age Distributions[1]	Geographic Aggregation for Fuel/Engine Fractions[2]
Motorcycle	11	TxDOT District	NA – 100% gasoline, no Fuel/Engine Fractions
Passenger Car	21	TxDOT District	MOVES default[1] with district-level local EV adjustment[4]
Passenger Truck	31	TxDOT District	MOVES default[1] with district-level local EV adjustment[4]
Light Commercial Truck	32	TxDOT District	MOVES default[1] with district-level local EV adjustment[4]
Single-Unit Short-Haul Truck	52	TxDOT District	Texas Statewide
Single-Unit Long-Haul Truck	53	Texas Statewide	MOVES default[3]
Refuse Truck	51	TxDOT District	Texas Statewide
Motor Home	54	MOVES default[3]	MOVES default[3]
Other Buses	41	MOVES default[3]	MOVES default[3]
Transit Bus[2]	42	MOVES default[3]	MOVES default[3]
School Bus	43	MOVES default[3]	MOVES default[3]
Combination Short-Haul Truck	61	TxDOT District	Texas Statewide
Combination Long-Haul Truck	62	Texas Statewide	MOVES default[3]

[1] Where county and region aggregations are typically used for individual counties in the metropolitan regions, TxDOT district aggregations were used for the county group modeling.

[2] MOVES fuel engine fraction defaults (for gasoline, diesel, E85 capability) were used for light-duty SUTs (with E85 use set to zero in the fuelusagefraction table). MOVES default fuel engine fractions were taken from the movesdb20241112 sample vehicle population table.



Difference in EV VMT in MOVES4 and MOVES5



As reported in the MOVES5 Overview, EV fractions in MOVES5 was substantially higher than MOVES4.

With the has total VMT (i.e., gasoline + diesel + electricity), the MOVES5 activity shows higher EV VMT compared to MOVES4.

In turn, this lowers gasoline and diesel VMT as their fraction from total VMT decreased.

Statewide Changes in VMT by Fuel Type

2060 VMT	MOVES4-based VMT	MOVES5-based VMT
Gasoline	≈285 billion miles	≈229 billion miles
Diesel	≈33 billion miles	≈25 billion miles

With A larger future EV share under MOVES5-based assumptions, a lower combustion-vehicle share changes emissions even when rates stay fixed.

Three Scenarios for Understanding Differences

Scenario	Emission rates	Activity assumptions
S1: MOVES4 baseline	MOVES4	MOVES4-based
S2: Common-activity case	MOVES4	MOVES5-based
S3: MOVES5 baseline	MOVES5	MOVES5-based

S2 – S1: activity effect under MOVES4 rates
S3 – S2: rates effect with MOVES5 activity
S3 – S1: total difference

This is a sequential attribution using the selected reference scenarios.

Statewide Total Differences (Ton/Year)

MOVES4 Trends (S1)

Year	CO	NO_X	VOC	CO_2	PM_{10}	$PM_{2.5}$
1990	8,898,069	899,939	502,501	113,123,652	44,948	36,294
2000	5,442,890	1,046,407	407,577	128,441,935	35,682	26,203
2010	2,114,561	481,808	163,225	137,283,685	23,017	14,164
2020	1,115,924	158,627	62,411	136,115,199	13,530	4,818
2030	724,689	66,456	41,020	129,108,535	13,496	2,983
2040	455,759	35,982	32,407	120,558,598	14,047	2,646
2050	418,185	33,414	30,219	124,828,847	15,026	2,766
2060	434,338	34,800	31,548	132,262,986	15,987	2,933

MOVES5 Trends (S3)

Year	CO	NO_X	VOC	CO_2	PM_{10}	$PM_{2.5}$
1990	9,491,497	1,010,221	525,759	123,386,731	51,678	41,550
2000	5,877,875	1,159,026	429,805	139,217,364	40,775	29,710
2010	2,250,899	531,864	171,282	147,547,110	26,129	15,849
2020	1,201,665	173,858	64,570	146,520,778	12,603	5,674
2030	775,853	74,574	42,516	133,334,040	9,976	3,635
2040	439,677	34,165	30,135	89,045,033	8,433	2,589
2050	368,543	27,277	25,716	78,635,434	8,318	2,311
2060	376,021	27,506	25,528	81,063,963	8,672	2,355

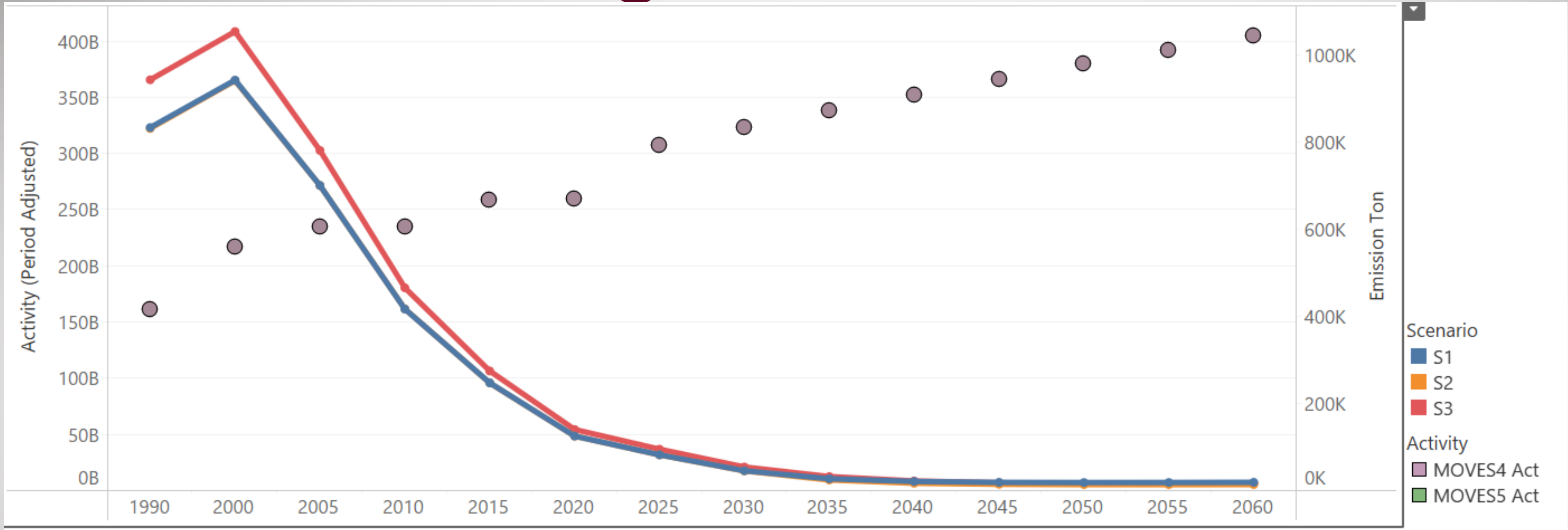
- Overall, MOVES5 values are higher compared to MOVES4 (as shown as highlighted in red) before 2040, but generally lower than MOVES4 after 2040.
- This matches the MOVES5 Overview's observation where national emissions are higher in MOVES5 until about 2040.

Statewide Inventory Comparison

Percent change: (S3 − S1) / S1 × 100

Year	CO	NO_x	VOC	CO_2	PM_{10}	$PM_{2.5}$
2020	+7.7%	+9.6%	+3.5%	+7.6%	-6.9%	+17.8%
2030	+7.1%	+12.2%	+3.6%	+3.3%	-26.1%	+21.9%
2040	-3.5%	-5.0%	-7.0%	-26.1%	-40.0%	-2.2%
2060	-13.4%	-21.0%	-19.1%	-38.7%	-45.8%	-19.7%

NOx Running Exhaust & VMT



Emissions (Tons/year)

Pollutant = NOx; County = All; Process Type = Running Exhaust; Activity Type = VMT

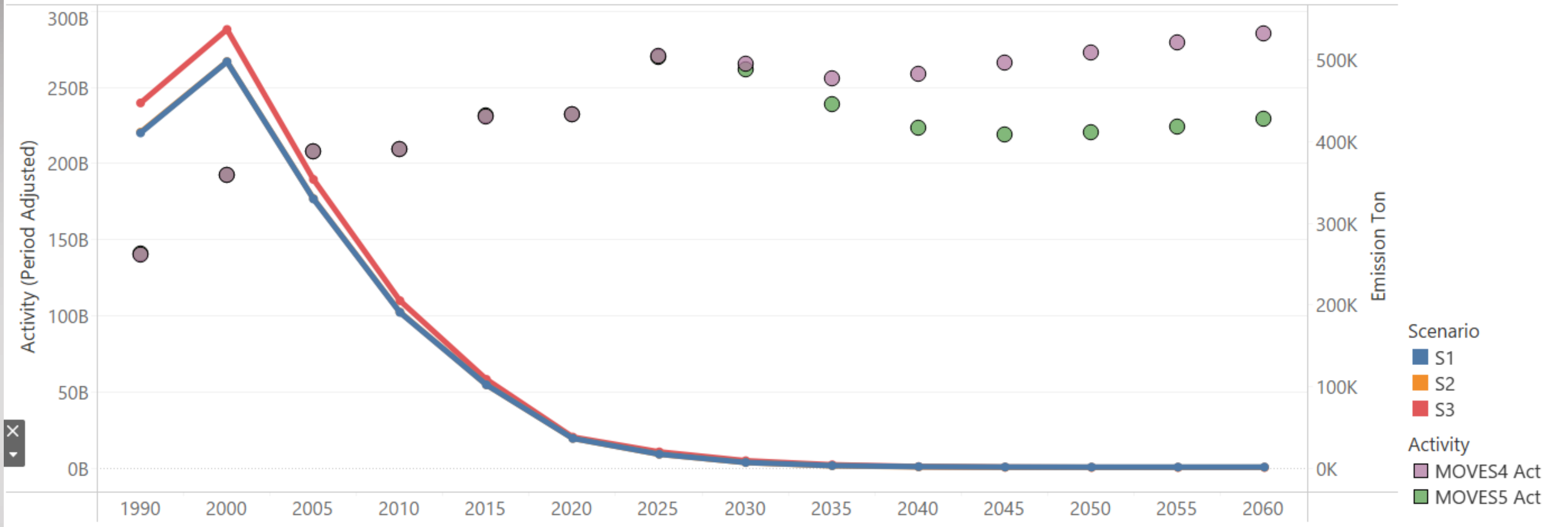
Scenario	MOVES	1990	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
S1	MOVES4	834,042	943,040	701,106	417,144	247,577	125,406	82,238	45,676	27,213	21,035	18,958	18,597	18,738	19,140
S2	MOVES4 (MOVES5 VMTm..	832,004	941,797	700,967	417,434	247,240	125,229	82,032	45,219	24,479	17,009	14,538	13,877	13,812	14,010
S3	MOVES5	943,777	1,054,635	781,530	465,965	274,881	140,382	95,160	54,256	32,321	22,126	18,118	16,944	16,741	16,958

S2 - S1:
Larger impact from activity

S3 – S2:
Larger impact from rate change

Larger S2 – S1 difference compared to S3 – S2 indicate VMT mix has larger impact than change in emission rate.

NOx Running Exhaust & VMT (Gasoline)



Emissions (Tons/year)

Pollutant = NOx; County = All; Process Type = Running Exhaust; Activity Type = VMT

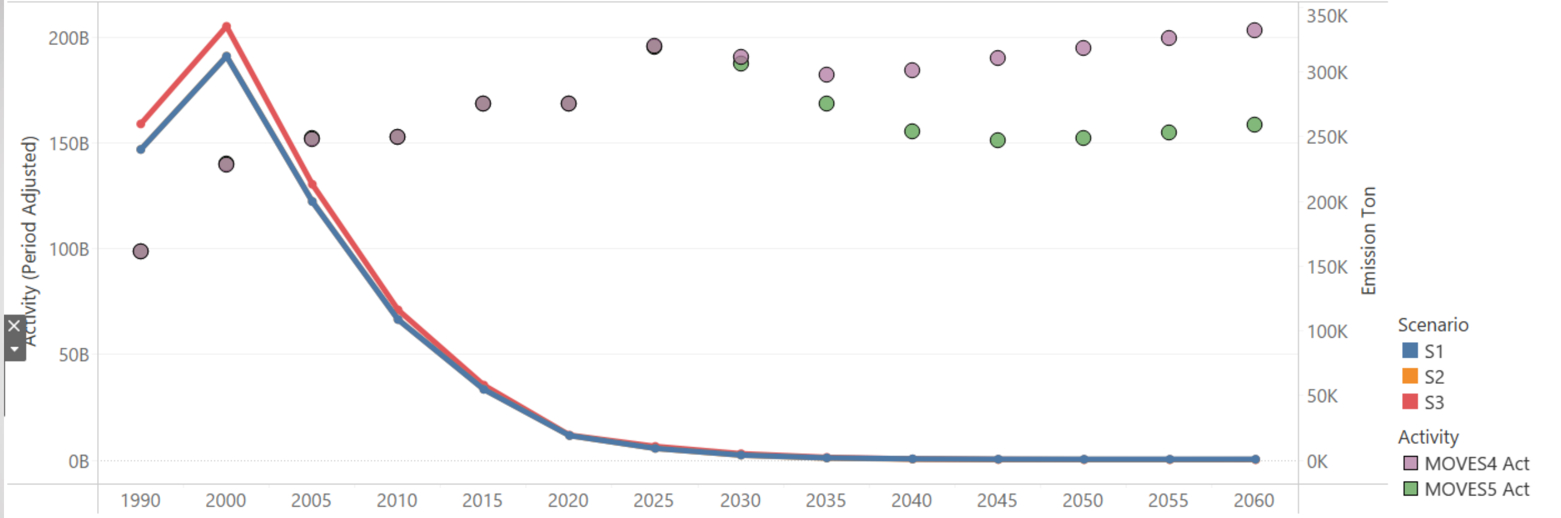
Scenario	MOVES	1990	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
S1	MOVES4	410,873	498,008	330,035	191,111	102,478	36,798	17,464	7,330	3,469	2,214	1,763	1,639	1,636	1,687
S2	MOVES4 (MOVES5 VMTm..	411,710	498,199	330,336	191,489	102,473	36,774	17,374	7,230	3,264	1,968	1,524	1,402	1,396	1,442
S3	MOVES5	447,574	537,561	353,902	205,480	109,146	38,390	20,290	9,471	4,505	2,319	1,517	1,295	1,266	1,282

S2 - S1:
Larger impact from activity

S3 – S2:
Larger impact from rate change

S2 – S1 difference about the same as S3 – S2; indicating VMT mix changes and emission rate updates to be roughly equivalent in contribution.

NOx Running Exhaust & VMT (PC-Gasoline)



Emissions (Tons/year)

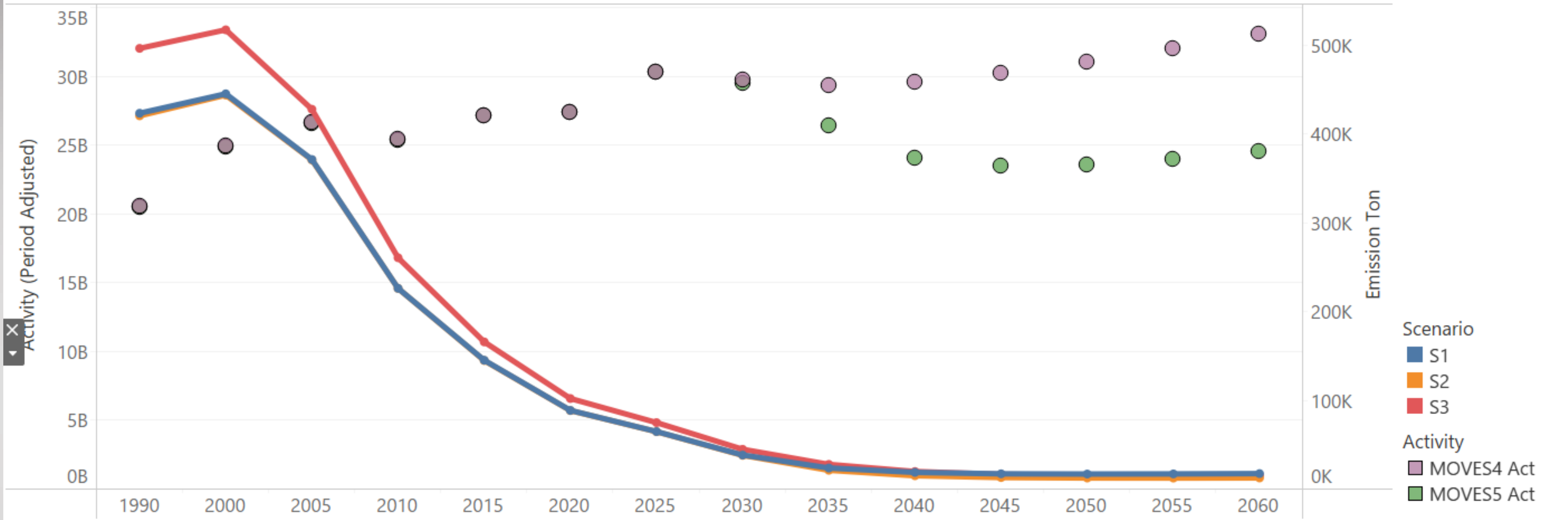
Pollutant = NOx; County = All; Process Type = Running Exhaust; Activity Type = VMT

Scenario	MOVES	1990	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
S1	MOVES4	240,219	312,249	200,005	108,812	54,857	19,156	9,274	4,090	1,883	1,157	906	841	839	867
S2	MOVES4 (MOVES5 VMTm..	240,260	312,335	200,073	108,856	54,886	19,160	9,241	4,024	1,745	978	724	658	654	678
S3	MOVES5	259,964	335,388	213,333	116,273	58,108	19,497	10,765	5,139	2,299	1,090	665	554	538	545

S2 - S1:
Larger impact from activity

S3 – S2:
Larger impact from rate change

NOx Running Exhaust & VMT (Diesel)



Emissions (Tons/year)

Pollutant = NOx; County = All; Process Type = Running Exhaust; Activity Type = VMT

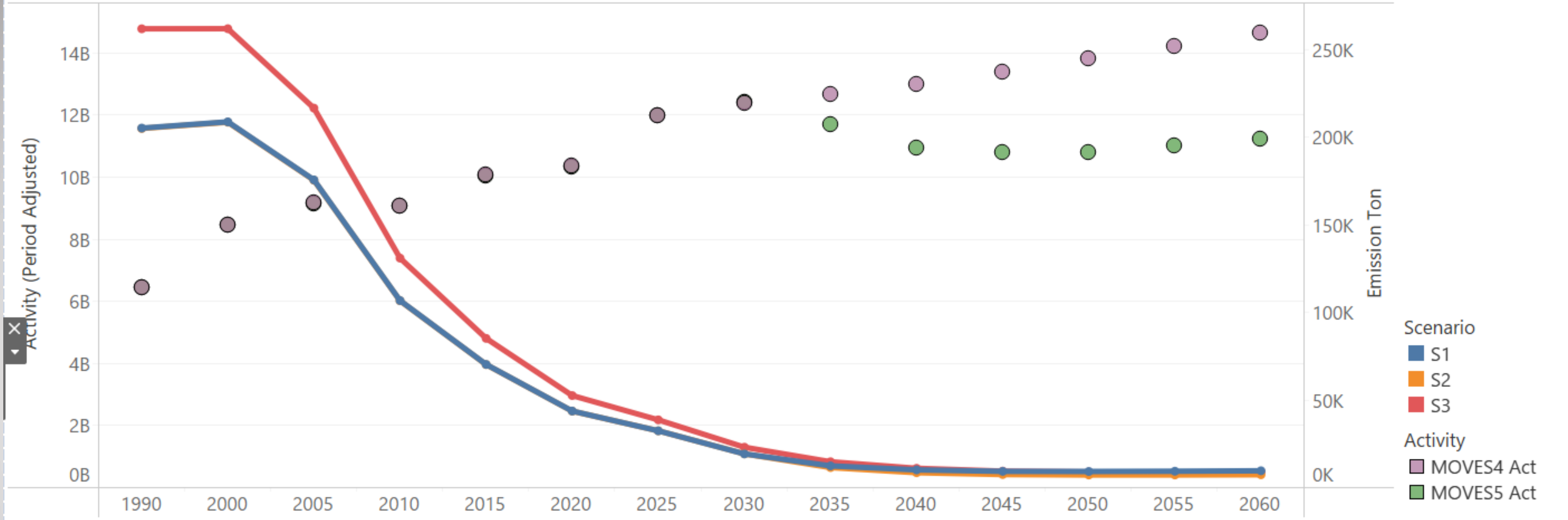
Scenario	MOVES	1990	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
S1	MOVES4	423,169	445,032	371,070	226,033	145,098	88,609	64,774	38,346	23,743	18,821	17,195	16,958	17,102	17,453
S2	MOVES4 (MOVES5 VMTm..	420,294	443,597	370,630	225,945	144,767	88,455	64,658	37,990	21,215	15,041	13,014	12,475	12,416	12,568
S3	MOVES5	496,204	517,074	427,628	260,486	165,735	101,992	74,870	44,786	27,816	19,807	16,601	15,649	15,475	15,676

S2 - S1:
Larger impact from activity

S3 – S2:
Larger impact from rate change

Larger S2 – S1 difference compared to S3 – S2 indicate VMT mix has larger impact than change in emission rate.

NOx Running Exhaust & VMT (CLhT-Diesel)



Emissions (Tons/year)

Pollutant = NOx; County = All; Process Type = Running Exhaust; Activity Type = VMT

Scenario	MOVES	1990	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
S1	MOVES4	205,088	208,652	175,539	106,714	70,279	43,687	32,413	19,243	12,415	10,130	9,292	9,225	9,362	9,614
S2	MOVES4 (MOVES5 VMTm..	204,892	208,444	175,366	106,606	70,208	43,642	32,414	19,279	11,454	8,523	7,481	7,223	7,236	7,367
S3	MOVES5	261,735	261,781	216,483	130,926	85,147	52,529	38,654	23,059	14,770	11,014	9,408	8,928	8,873	9,023

S2 - S1:
Larger impact from activity

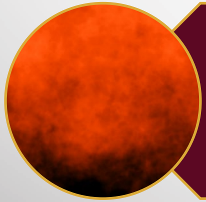
S3 – S2:
Larger impact from rate change

Larger S2 – S1 difference compared to S3 – S2 indicate VMT mix has larger impact than change in emission rate.

NOx Running Emission - Summary

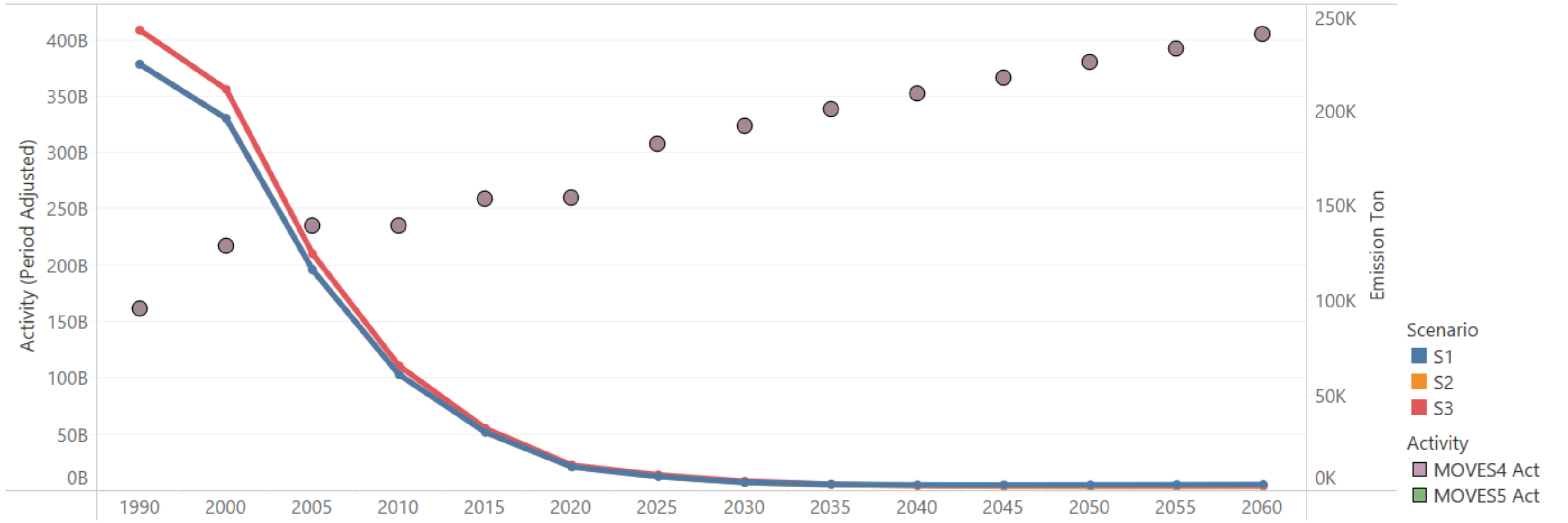
NOx emissions were dominated by diesel vehicles.

Emission from diesel vehicles (mostly heavy-duty) were more dependent on VMT mix as the variation in emission rate between vehicle types are much larger than gasoline vehicles (mostly light-duty).



Thus, VMT mix plays a much more significant part in altering NOx running emissions compared to updated emission rates.

VOC Running Exhaust & VMT



Emissions (Tons/year)

Pollutant = VOC; County = All; Process Type = Running Exhaust; Activity Type = VMT

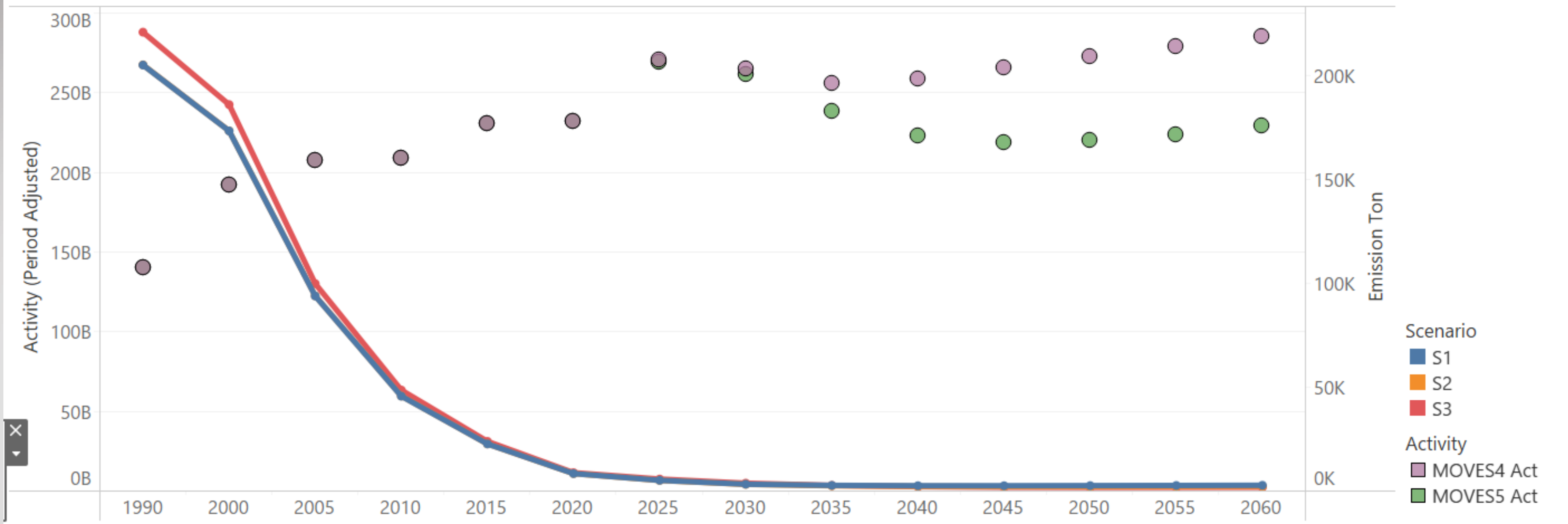
Scenario	MOVES	1990	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
S1	MOVES4	224,162	195,669	116,080	61,003	30,697	12,489	7,403	4,332	3,305	3,019	2,987	3,045	3,129	3,228
S2	MOVES4 (MOVES5 VMTm..	224,194	195,692	116,100	61,028	30,656	12,468	7,353	4,262	3,075	2,621	2,494	2,500	2,557	2,640
S3	MOVES5	242,161	211,003	124,533	65,633	32,750	13,408	8,271	4,968	3,365	2,581	2,265	2,181	2,200	2,251

S2 - S1:
Larger impact from activity

S3 – S2:
Larger impact from rate change

S2 – S1 difference about the same as S3 – S2; indicating VMT mix changes and emission rate updates to be roughly equivalent in contribution.

VOC Running Exhaust & VMT (Gasoline)



Emissions (Tons/year)

Pollutant = VOC; County = All; Process Type = Running Exhaust; Activity Type = VMT

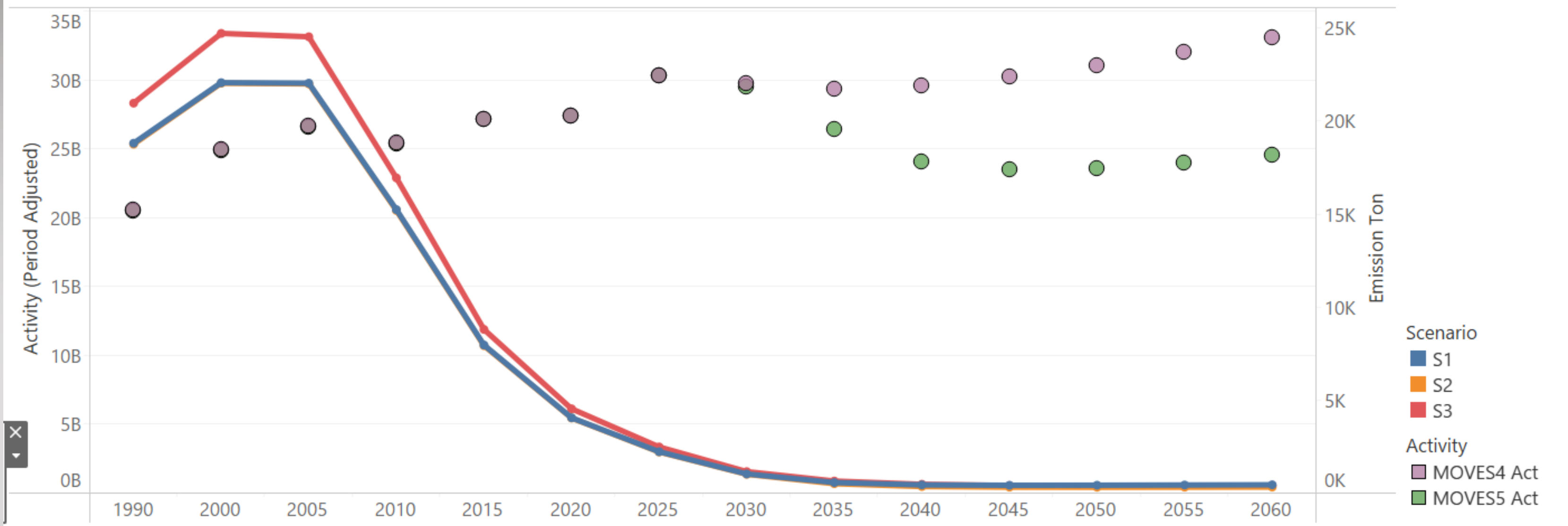
Scenario	MOVES	1990	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
S1	MOVES4	205,356	173,609	94,046	45,766	22,737	8,441	5,177	3,302	2,738	2,579	2,567	2,621	2,695	2,782
S2	MOVES4 (MOVES5 VMTm..	205,441	173,662	94,105	45,835	22,732	8,432	5,145	3,251	2,570	2,269	2,175	2,187	2,239	2,316
S3	MOVES5	221,203	186,295	100,007	48,691	23,953	8,876	5,790	3,814	2,718	2,107	1,859	1,788	1,802	1,845

S2 - S1:
Larger impact from activity

S3 – S2:
Larger impact from rate change

S2 – S1 difference about the same as S3 – S2; indicating VMT mix changes and emission rate updates to be roughly equivalent in contribution.

VOC Running Exhaust & VMT (Diesel)



Emissions (Tons/year)

Pollutant = VOC; County = All; Process Type = Running Exhaust; Activity Type = VMT

Scenario	MOVES	1990	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
S1	MOVES4	18,806	22,060	22,034	15,237	7,959	4,049	2,226	1,030	567	441	420	424	435	446
S2	MOVES4 (MOVES5 VMTm..	18,753	22,031	21,995	15,193	7,924	4,035	2,208	1,011	506	352	318	314	318	324
S3	MOVES5	20,958	24,708	24,526	16,942	8,797	4,532	2,481	1,154	647	474	405	393	398	406

S2 - S1:
Larger impact from activity

S3 – S2:
Larger impact from rate change

Larger S2 – S1 difference compared to S3 – S2 indicate VMT mix has larger impact than change in emission rate.

VOC Running Emission - Summary

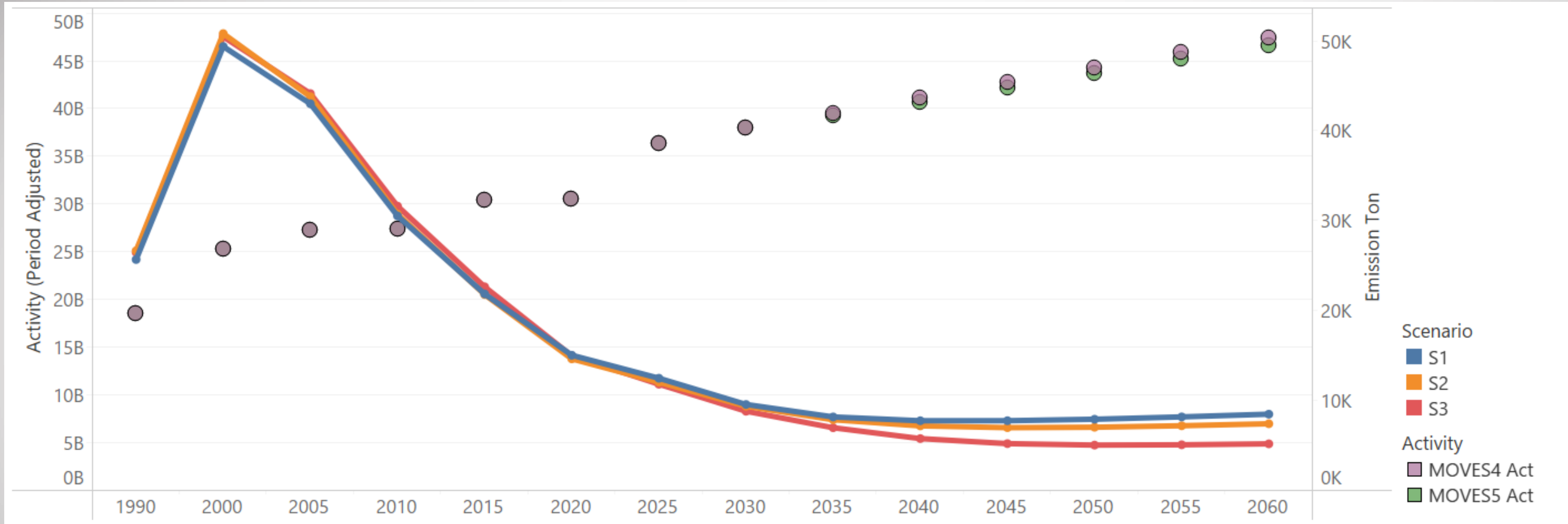
For gasoline vehicles, changes in running VOC emissions were driven roughly equally by changes in emission rates (due to regulations and fleet-average improvements) and by updates to VMT mix.

Diesel VOC emissions changes were driven more by changes in VMT mix than by emission rate changes.

In contrast to NOx, VOC emissions are dominated by gasoline, primarily light-duty vehicles.

- As a result, the impact of emission rate updates on VOC trends is approximately equal to the impact of changes in VMT mix.

NOx Start Exhaust & Start Activity



Emissions (Tons/year)

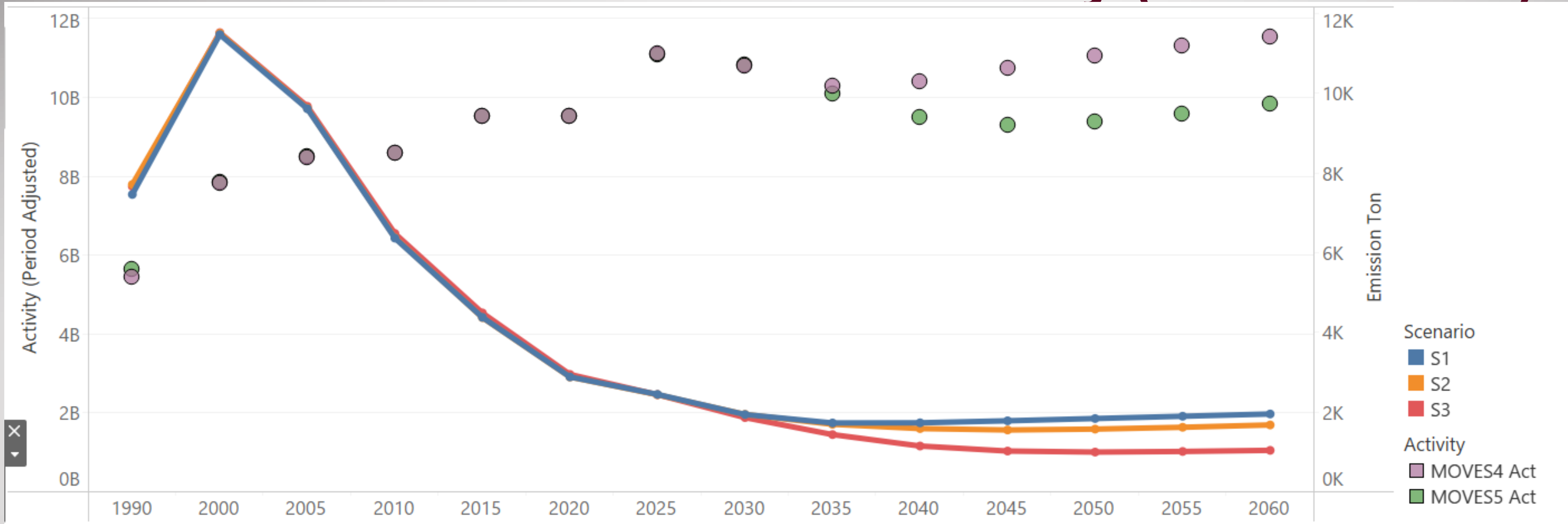
Pollutant = NOx; County = All; Process Type = Start Exhaust; Activity Type = Starts

Scenario	MOVES	1990	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
S1	MOVES4	25,684	49,377	43,010	30,532	21,859	15,040	12,481	9,561	8,177	7,753	7,757	7,919	8,181	8,483
S2	MOVES4 (MOVES5 VMTm..	26,658	50,810	43,802	30,742	21,791	14,637	12,034	9,369	7,866	7,182	6,985	7,031	7,196	7,419
S3	MOVES5	26,474	50,465	44,138	31,624	22,647	14,976	11,817	8,811	6,974	5,768	5,207	5,043	5,079	5,183

S2 - S1:
Larger impact from activity

S3 – S2:
Larger impact from rate change

NOx Start Exhaust & Start Activity (PC-Gasoline)



Emissions (Tons/year)

Pollutant = NOx; County = All; Process Type = Start Exhaust; Activity Type = Starts

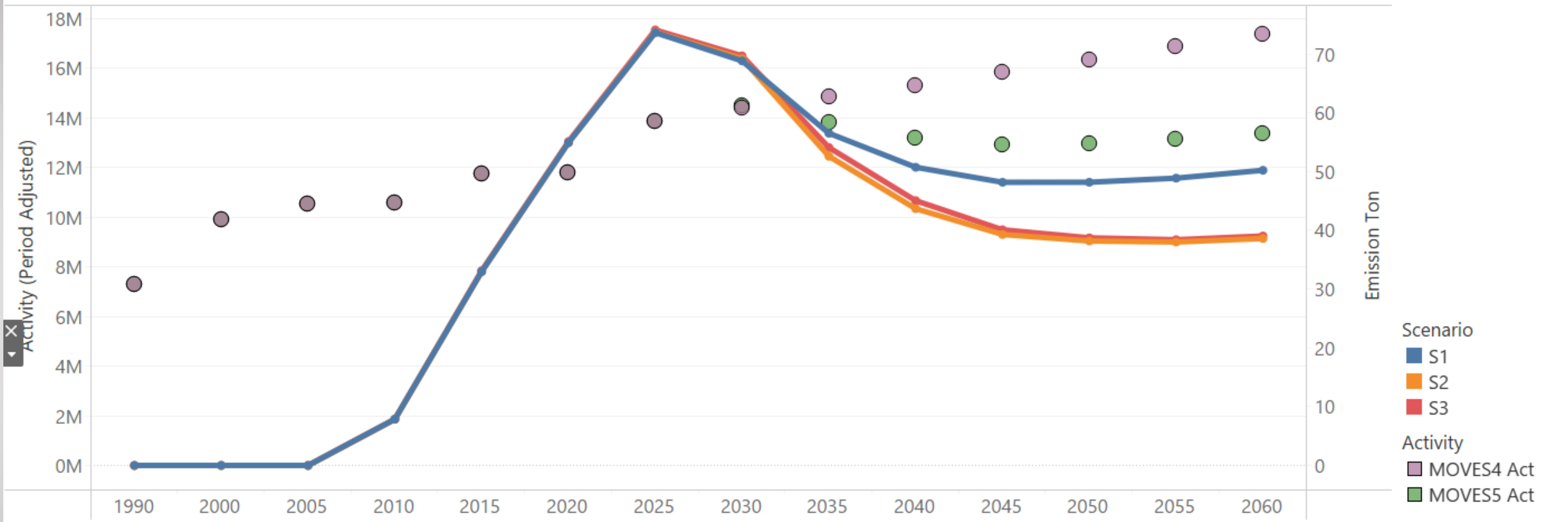
Scenario	MOVES	1990	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
S1	MOVES4	7,461	11,473	9,611	6,366	4,378	2,883	2,444	1,939	1,727	1,731	1,782	1,839	1,896	1,953
S2	MOVES4 (MOVES5 VMTm..	7,710	11,505	9,624	6,380	4,372	2,880	2,437	1,942	1,694	1,586	1,552	1,573	1,619	1,678
S3	MOVES5	7,662	11,520	9,673	6,482	4,488	2,945	2,438	1,862	1,436	1,149	1,023	997	1,012	1,040

S2 - S1:
Larger impact from activity

S3 – S2:
Larger impact from rate change

"Updated rates for LD start emissions to account for new emission standards. The lower rates phase-in beginning in MY 2027." (EPA, 2024)

NOx Start Exhaust & Start Activity (CLhT-Diesel)



Emissions (Tons/year)

Pollutant = NOx; County = All; Process Type = Start Exhaust; Activity Type = Starts

Scenario	MOVES	1990	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
S1	MOVES4	0.00	0.00	0.00	7.87	32.98	54.91	73.63	68.83	56.52	50.73	48.17	48.18	48.88	50.22
S2	MOVES4 (MOVES5 VMTm..	0.00	0.00	0.00	7.87	32.98	54.91	73.71	69.21	52.59	43.68	39.30	38.19	38.01	38.61
S3	MOVES5	0.00	0.00	0.00	7.87	33.13	55.11	74.10	69.68	54.09	45.05	40.09	38.72	38.40	39.04

S2 - S1:
Larger impact from activity

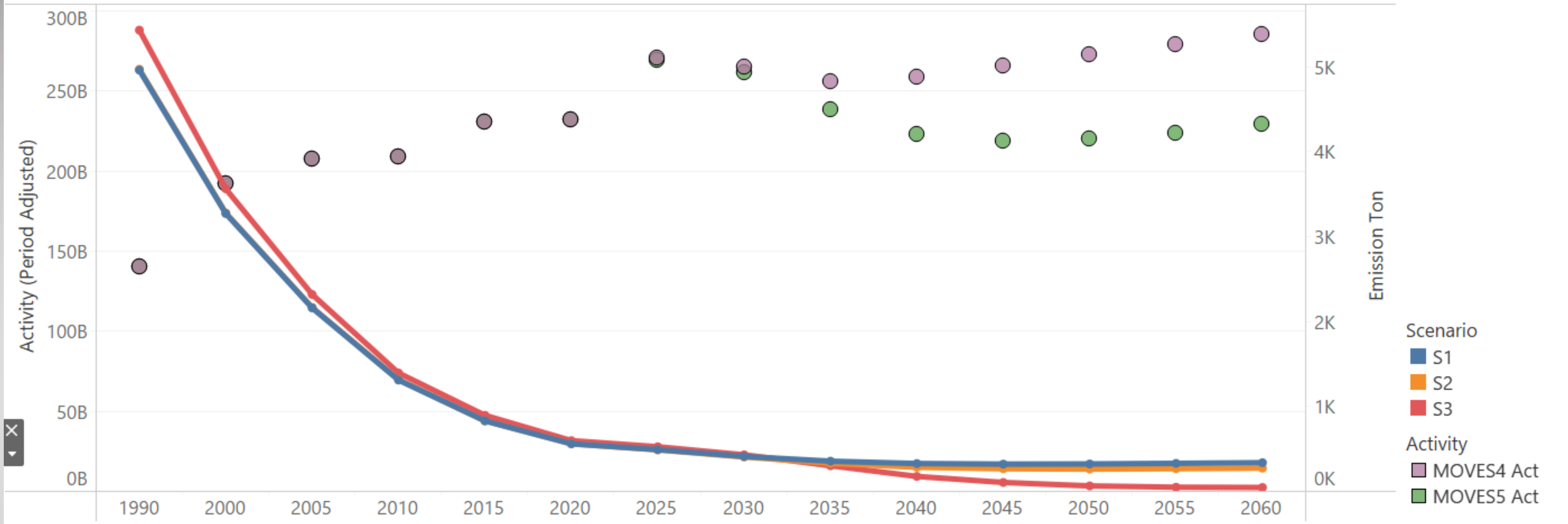
S3 – S2:
Larger impact from rate change

NOx Start Emissions - Summary

The lower LD start NOx emissions in MOVES5 are directly attributable to **reduced LD emission rates** resulting from newer emission standards.

HD start NOx emissions appear to be driven primarily by **changes in activity**, which is consistent with the fact that no updates to HD start emission rates were reported in the MOVES5 Overview.

$PM_{2.5}$ Running Exhaust (Gasoline)



Emissions (Tons/year)

Pollutant = PM2.5-Exhaust; County = All; Process Type = Running Exhaust; Activity Type = VMT

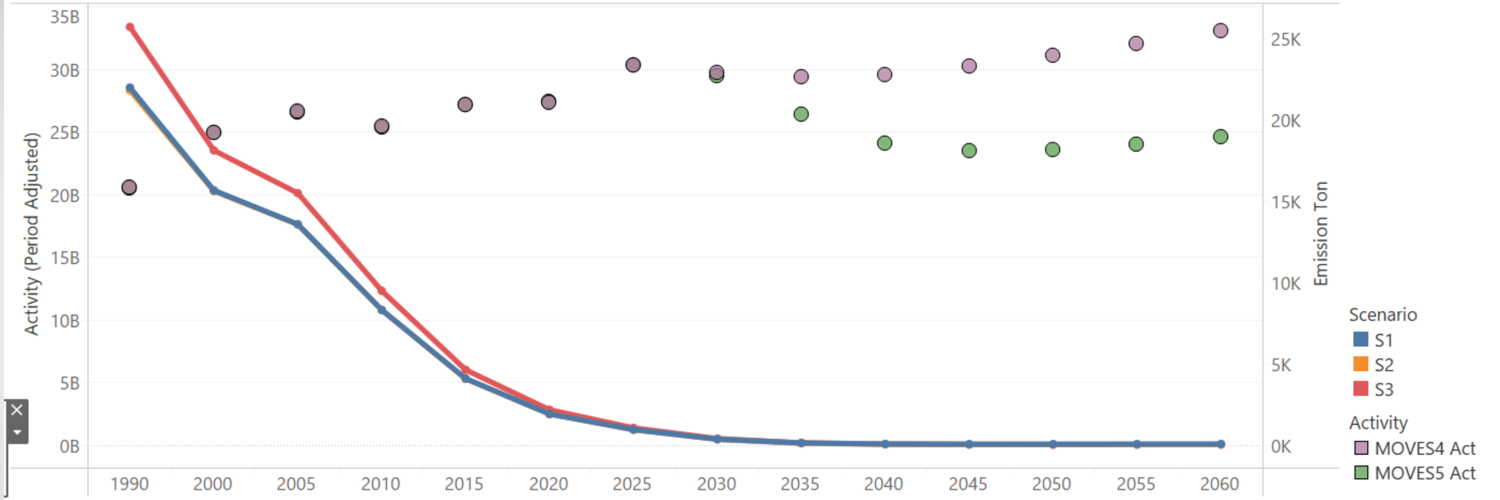
Scenario	MOVES	1990	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
S1	MOVES4	4,963	3,274	2,162	1,312	832	561	493	412	356	329	322	324	331	338
S2	MOVES4 (MOVES5 VMTm..	4,973	3,280	2,167	1,316	830	561	490	406	332	285	267	263	268	274
S3	MOVES5	5,434	3,565	2,320	1,395	897	598	526	431	302	177	106	65	50	46

S2 - S1:
Larger impact from activity

S3 – S2:
Larger impact from rate change

“Updated LD exhaust PM rates that account for new PM standards. The lower PM rates for gasoline vehicles phase-in beginning in MY 2027” (EPA, 2024)

$PM_{2.5}$ Running Exhaust (Diesel)



Emissions (Tons/year)

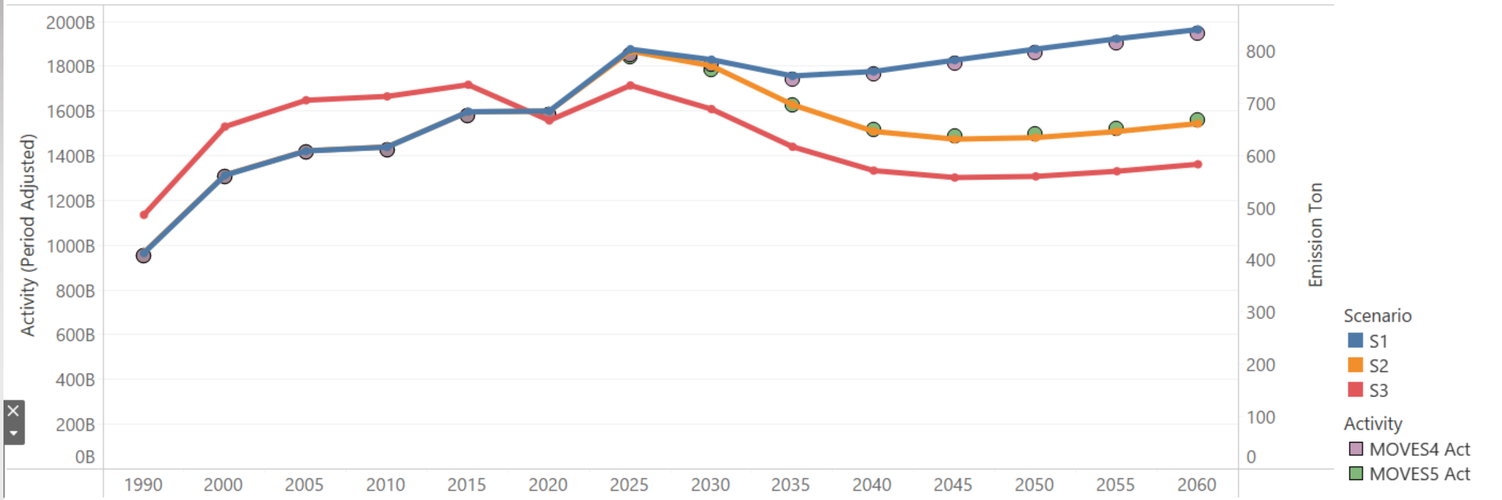
Pollutant = PM2.5-Exhaust; County = All; Process Type = Running Exhaust; Activity Type = VMT

Scenario	MOVES	1990	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
S1	MOVES4	22,019	15,697	13,613	8,347	4,124	1,948	989	397	167	107	96	97	101	105
S2	MOVES4 (MOVES5 VMTm..	21,850	15,649	13,595	8,338	4,111	1,942	983	392	149	84	72	70	72	74
S3	MOVES5	25,745	18,153	15,525	9,523	4,662	2,207	1,094	435	172	101	73	66	67	69

S2 - S1:
Larger impact from activity

S3 – S2:
Larger impact from rate change

Non-exhaust $PM_{2.5}$: Brakewear (Gasoline)



Emissions (Tons/year)

Pollutant = PM2.5-Brake; County = All; Process Type = All; Activity Type = VMT

Scenario	MOVES	1990	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
S1	MOVES4	413.0	561.9	608.2	615.7	683.2	684.6	802.8	782.9	751.7	760.2	781.9	803.1	822.8	840.5
S2	MOVES4 (MOVES5 VMTm..	413.9	562.4	608.5	616.1	683.0	684.4	799.3	771.0	696.7	645.7	630.8	633.8	645.4	660.7
S3	MOVES5	486.1	654.8	705.2	712.6	734.9	666.6	733.6	688.3	616.3	570.7	557.4	559.6	569.5	582.8

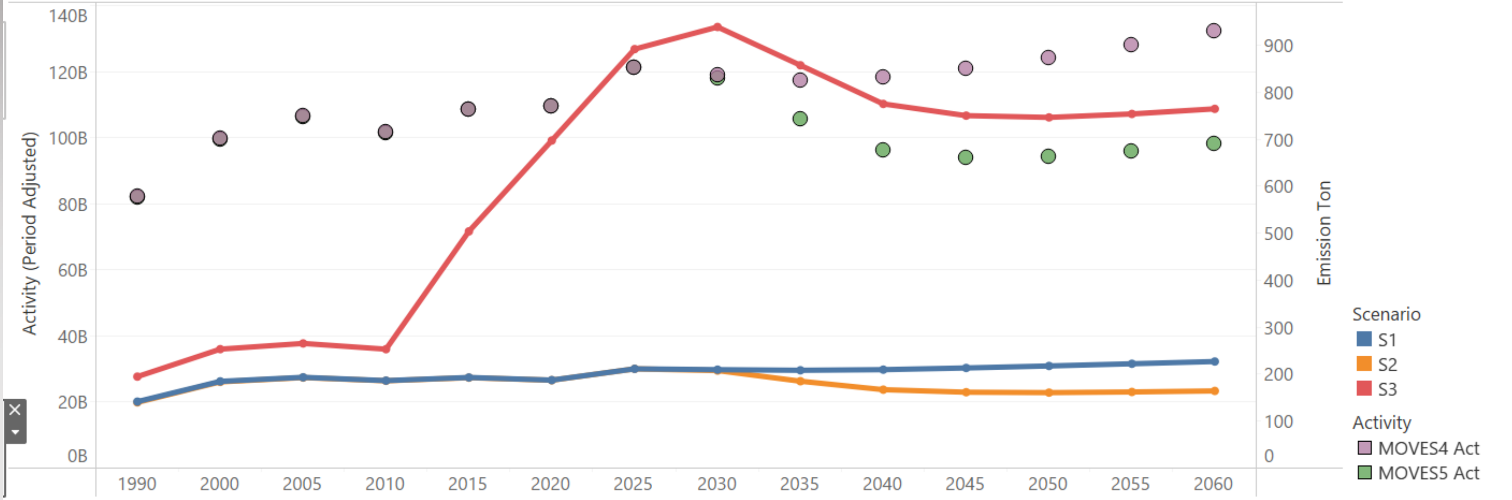
S2 - S1:
Larger impact from activity

S3 – S2:
Larger impact from rate change

Updated LD and HD brake wear emission rates for MY 2011 and later based on new test data. In general, the new $PM_{2.5}$ brake wear rates are lower for light- and medium-duty vehicles, light-heavy-duty vehicles, and urban buses.

Account for light-duty vehicle mass by fuel type.

Non-exhaust $PM_{2.5}$: Brakewear (Diesel)



Emissions (Tons/year)

Pollutant = PM2.5-Brake; County = All; Process Type = All; Activity Type = VMT

Scenario	MOVES	1990	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
S1	MOVES4	141.5	184.6	193.2	186.2	192.9	187.3	211.3	209.5	208.2	209.6	213.2	217.4	222.1	226.9
S2	MOVES4 (MOVES5 VMTm..	139.9	183.6	192.7	185.9	192.5	187.1	211.2	207.6	185.0	166.9	161.5	160.7	162.1	164.2
S3	MOVES5	194.7	253.2	265.4	253.1	503.9	697.2	891.8	938.9	857.4	775.1	750.2	746.5	753.8	764.7

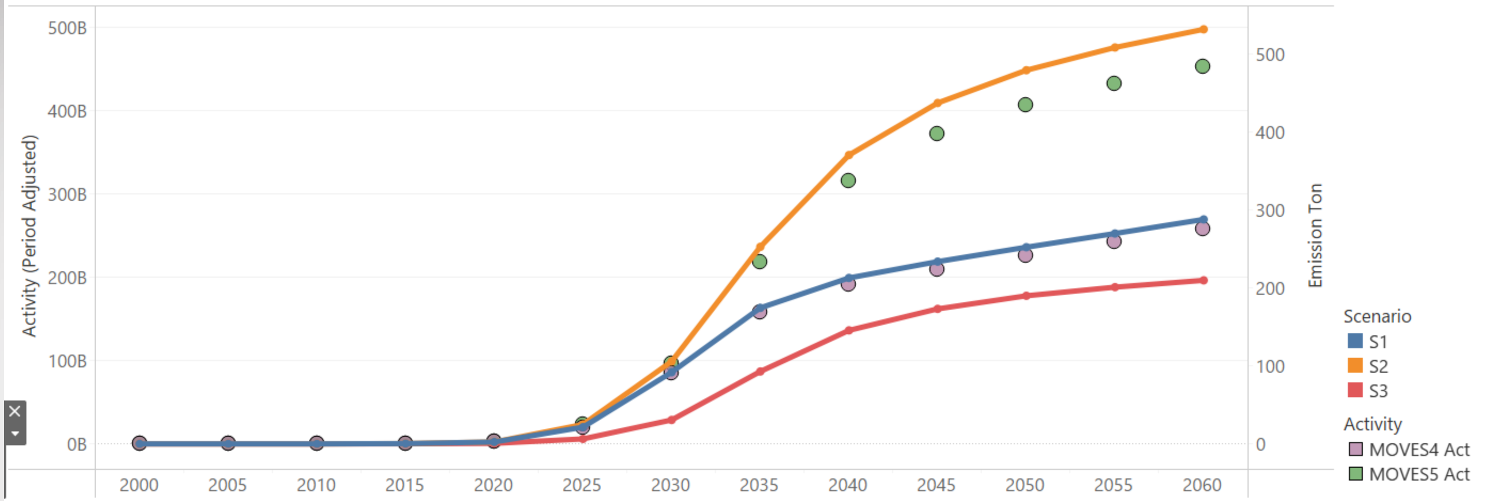
S2 - S1:
Larger impact from activity

S3 – S2:
Larger impact from rate change

Updated LD and HD brake wear emission rates for MY 2011 and later based on new test data. In general, the new $PM_{2.5}$ brake wear rates are higher for other heavy-vehicle classes, most notably for heavy-heavy-duty vehicles.

Account for light-duty vehicle mass by fuel type.

Non-exhaust $PM_{2.5}$: Brakewear (EV)



Emissions (Tons/year)

Pollutant = PM2.5-Brake; County = All; Process Type = All; Activity Type = VMT

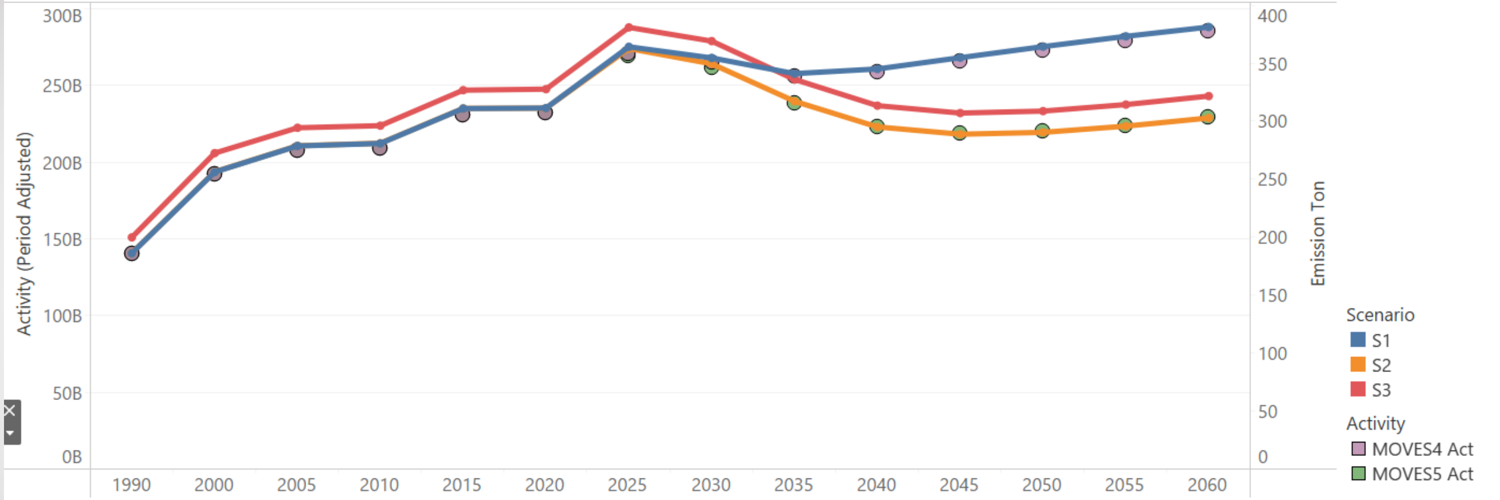
Scenario	MOVES	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
S1	MOVES4	0.0	0.0	0.0	0.3	2.4	21.4	91.8	174.3	212.7	233.6	252.0	269.6	287.6
S2	MOVES4 (MOVES5 VMTm..	0.0	0.0	0.0	0.3	2.4	24.8	105.6	252.5	370.1	436.8	478.8	508.0	531.2
S3	MOVES5	0.0	0.0	0.0	0.1	0.6	6.3	30.6	92.8	145.5	173.0	189.7	200.8	209.6

S2 - S1:
Larger impact from activity

S3 – S2:
Larger impact from rate change

*"In MOVES5, brake wear emission rates for EVs are **lower** than for internal combustion engine vehicles after accounting for both increased vehicle mass and regenerative braking"* (EPA, 2024).

Non-exhaust $PM_{2.5}$: Tirewear (Gasoline)



Emissions (Tons/year)

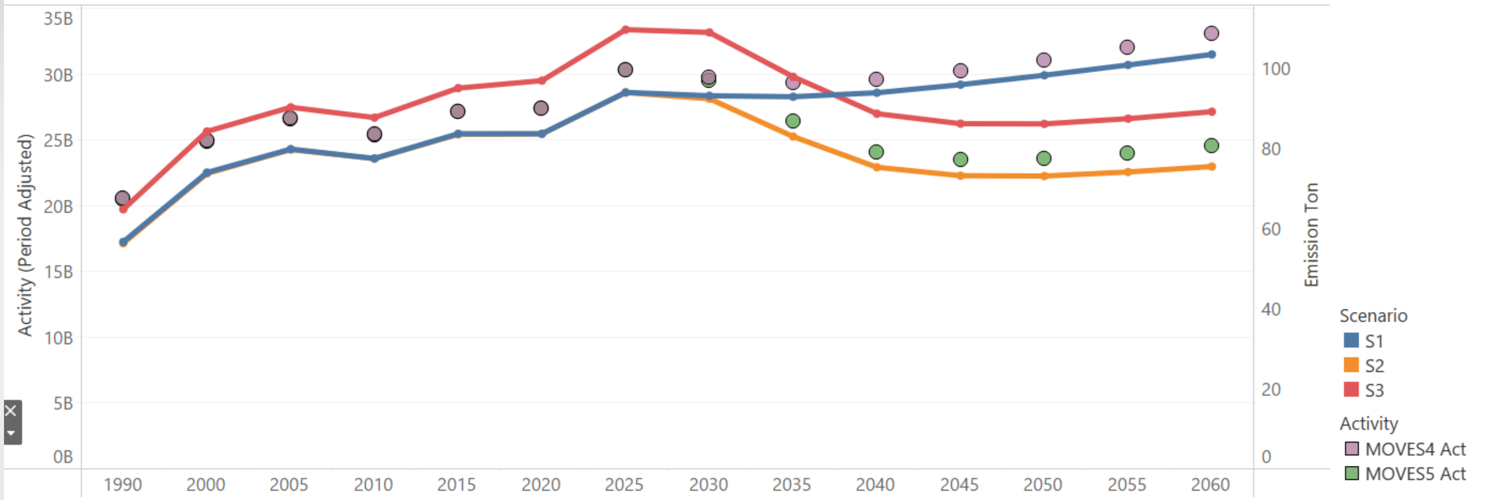
Pollutant = PM2.5-Tire; County = All; Process Type = Tirewear; Activity Type = VMT

Scenario	MOVES	1990	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
S1	MOVES4	186.0	256.0	278.5	280.7	310.8	311.2	364.0	354.4	340.9	344.9	354.6	364.2	373.0	381.0
S2	MOVES4 (MOVES5 VMTm..	186.2	256.2	278.7	280.9	310.9	311.1	362.5	349.3	317.0	294.9	288.6	290.2	295.6	302.6
S3	MOVES5	199.7	272.3	294.2	296.0	326.6	327.5	380.7	368.9	335.9	313.3	306.9	308.6	314.2	321.5

S2 - S1:
Larger impact from activity

S3 – S2:
Larger impact from rate change

Non-exhaust $PM_{2.5}$: Tirewear (Diesel)



Emissions (Tons/year)

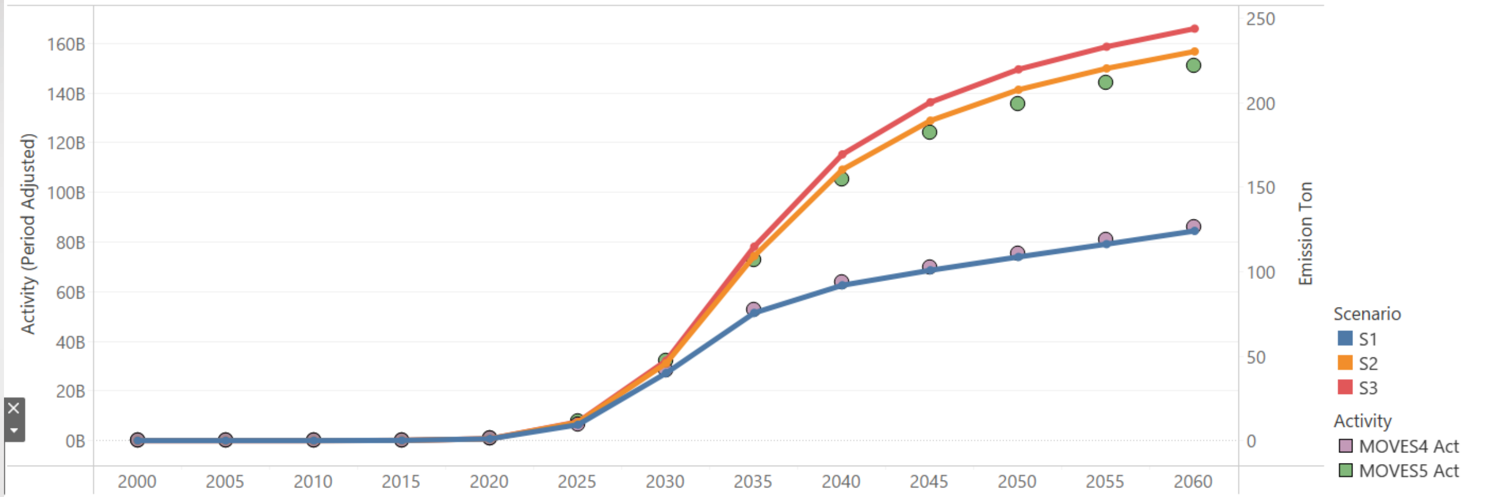
Pollutant = PM2.5-Tire; County = All; Process Type = Tirewear; Activity Type = VMT

Scenario	MOVES	1990	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
S1	MOVES4	56.66	73.97	79.82	77.48	83.65	83.65	93.98	93.13	92.89	93.88	95.90	98.26	100.82	103.44
S2	MOVES4 (MOVES5 VMTm..	56.32	73.73	79.70	77.44	83.54	83.62	93.93	92.39	82.95	75.28	73.18	73.09	74.11	75.47
S3	MOVES5	64.79	84.22	90.26	87.68	95.05	96.90	109.64	108.94	97.88	88.65	86.16	86.11	87.42	89.15

S2 - S1:
Larger impact from activity

S3 – S2:
Larger impact from rate change

Non-exhaust $PM_{2.5}$: Tirewear (EV)



Emissions (Tons/year)

Pollutant = PM2.5-Tire; County = All; Process Type = Tirewear; Activity Type = VMT

Scenario	MOVES	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
S1	MOVES4	0.0	0.0	0.0	0.1	1.1	9.4	40.0	75.6	91.9	100.8	108.7	116.3	124.1
S2	MOVES4 (MOVES5 VMTm..	0.0	0.0	0.0	0.1	1.1	10.8	45.7	109.2	160.3	189.3	207.6	220.2	230.3
S3	MOVES5	0.0	0.0	0.0	0.1	1.1	11.1	47.3	114.8	169.4	200.2	219.7	233.1	243.8

S2 - S1:
Larger impact from activity

S3 – S2:
Larger impact from rate change

$PM_{2.5}$ Emission - Summary

Exhaust $PM_{2.5}$ emissions:

- Gasoline vehicles (primarily LD) show significant reductions in exhaust $PM_{2.5}$ due to updated, lower emission rates.
- Diesel vehicles (primarily HD) show changes in exhaust $PM_{2.5}$ mainly due to changes in activity levels driven by updates to the VMT mix.

Non-exhaust $PM_{2.5}$ emissions

- Brake wear PM is influenced primarily by updates to emission rates.
- Tire wear PM is influenced primarily by changes in activity associated with the updated VMT mix.

In future years, non-exhaust $PM_{2.5}$ emissions are expected to be substantially higher than exhaust $PM_{2.5}$ emissions.

- As a result, PM mitigation strategies should place greater emphasis on non-exhaust sources rather than focusing solely on tailpipe emissions.

Summary of Observation

Overall, the observations are consistent with EPA's MOVES5 Overview:

- MOVES5 emissions is generally higher than MOVES4 until approximately 2040.
- Gasoline and diesel VMT in future years dropped substantially due to higher EV fractions in MOVES5.

Across the three scenarios analyzed:

- Gasoline vehicle emissions (mostly LD) in MOVES5 are affected about equally by updates to emission rates and VMT mix.
- Diesel vehicle emissions (mostly HD) in MOVES5 are influenced more by changes in VMT mix, driven by the updated EV fractions.
- $PM_{2.5}$ emissions were driven by non-exhaust emissions.

Interpretation and Limitations

The results are specific to the MOVES model versions and input data used in this study.

- How emissions are attributed in the three scenarios depends on which emission rates and activity levels are used.

The vehicle examples and emission processes evaluated in this presentation are illustrative and do not represent all components of the full emissions inventory.

County-level results may differ from statewide patterns because fleet composition and activity mixes vary by location.

What These Results Mean for Consultation Partners

Consultation partners can:	Use the comparison results to identify the pollutants, emission processes, and analysis years that are most sensitive to model-version and input changes.
	Carefully review local fleet and fuel assumptions when interpreting differences between MOVES versions.
	Evaluate exhaust and non-exhaust PM emissions separately, as they respond differently to changes in emission rates and activity.
	Apply assumptions and inputs that are appropriate to each specific project's goals, regulatory requirements, and planning context.

Comparison Dashboard

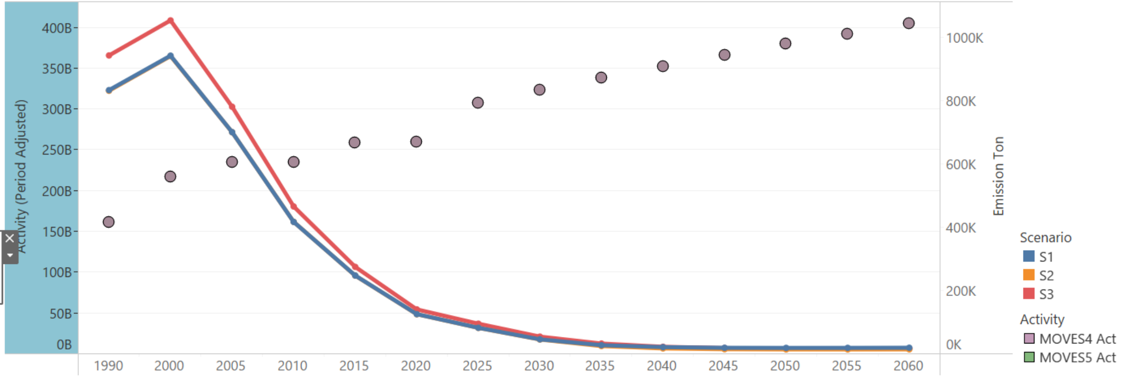
MOVES4 versus MOVES5 Trends Emissions Inventory

This dashboard compares the 1990, 1999-2060 MOVES4 and MOVES5 Trends Emissions Inventory results.
All activities are identical and utilized MOVES5 default values; thus, the MOVES4 results shown are not "true" MOVES4 Emission Inventories.
The MOVES5 Inventories were developed in 2025 under a project sponsored by the Texas Commissions on Environmental Quality (TCEQ) where the MOVES4 Inventories were developed in 2026 under a Task 3.1 of the Texas Department of Transportation (TxDOT)-Texas A&M Transportation Institute (TTI) Interagency Contract.

pollutant: NOx
District Name: (All)
County Name: (All)
roadTypeDesc: (All)
Source Type: (All)
Fuel Type: (All)
Emission Process: Running Exhaust
Activity Type: VMT

Comparison between MOVES4 and MOVES5 Emissions (Tons/year)

(when activity is not specified, the activity number represent an aggregation of all activity, which are in different units, and must not be summed together)



Emissions (Tons/year)

Pollutant = NOx; County = All; Process Type = Running Exhaust; Activity Type = VMT

Scenario	MOVES	1990	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
S1	MOVES4	834,042	943,040	701,106	417,144	247,577	125,406	82,238	45,676	27,213	21,035	18,958	18,597	18,738	19,140
S2	MOVES4 (MOVES5 VMTm..	832,004	941,797	700,967	417,434	247,240	125,229	82,032	45,219	24,479	17,009	14,538	13,877	13,812	14,010
S3	MOVES5	943,777	1,054,635	781,530	465,965	274,881	140,382	95,160	54,256	32,321	22,126	18,118	16,944	16,741	16,958

TTI is currently working on a Dashboard to showcase the results of this study.

It will be available on TX Air Quality Portal when its ready to be shared.

Questions?

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