

The USEPA MOVES Model: A Midcourse Review

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Outline of Topics

1. Background
2. Model History/Evolution
3. Current Uncertainties in Data/Methods
4. Inventory Results
5. Final Remarks

Background

- Synthesis of observations built from:
 - ❖ CRC E-101 – Review of MOVES2014
 - ❖ CRC E-116 – Development of MOVES Evaporative Input
 - ❖ Various US and Canadian MOVES Projects
- External review; views are those of the participants:
 - ❖ Jeremy G. Heiken – On-road model review and development since 1989
 - ❖ CRC Projects completed in collaboration with Sierra Research (Jim Lyons, Tom Carlson, Mark Hixson & Dennis McClement)

EPA On-Road Model History

- MOBILE Model (1978 to 2004)
 - ❖ MOBILE1 released in 1978
 - ❖ MOBILE6.2 released in 2004
- MOVES Model
 - ❖ Concept release 2004 (energy calculations)
 - ❖ Draft release 2009 (criteria pollutants)
 - ❖ MOVES2010 (December 2009)
 - ❖ MOVES2014 (July 2014)

History Matters

- The development path has impacted the form and function of the on-road models
- Successive versions of MOBILE built off each other
- MOVES is the first wholesale model revision
 - ❖ New concepts
 - ❖ Data & Method
 - ❖ Platform
- MOVES has “evolved” through successive releases

MOVES Development

- Vision
 - ❖ New modeling approach to complement the anticipated watershed of instrumented vehicle data
 - ❖ Locally collected emissions/activity collection
- Original Concept (2004)
 - ❖ Transcend scales (microscale, macroscale, regional)
 - ❖ Advanced vehicle technologies
 - ❖ Fuel choice evaluations (full fuel lifecycle)
 - ❖ Instrumented vehicle emissions based
 - Light & heavy-duty

Evolutionary Causes

- Priorities change with regulatory actions
- Adding features while maintaining model performance
- Need for agency consistency with other modeling tools (e.g., fuel economy/GHG modeling)

Evolution of Original Concepts

MOVES Achievement of Concept Element by Version			
Element	Draft 2004	2010	2014
Transcend Scales	Yes	Yes	Yes
Fuel Choice, Lifecycle Modeling	Yes	No	No
Advanced Technology Vehicles	Yes	Partial	No
HD Instrumented Vehicle Emission Data	Yes	Yes	Yes
LD Instrumented Vehicle Emissions Data	Yes	No	No

Notable Achievements beyond Concept

- Modal method for evaporative emissions
- Improved method for light-duty exhaust deterioration
- Incorporation of comprehensive light-duty PM test program
- Data and regulatory updates
- Improved fuel parameter modeling
- Updated chemical and photochemical model speciation
- Incorporation of non-road sources

Example Area of Uncertainty

- Light-duty (LD) gasoline exhaust underlying data record is fragmented supporting THC, NOx and CO emissions calculations. 3 primary components (with distinct sources):
 - ❖ Low-power running exhaust
 - ❖ High-power running exhaust
 - ❖ Start exhaust

LD Gasoline Exhaust is Significant

LD Gasoline Exhaust Share of Total On-Road Inventory

CRC E-101 3-City Average

Pollutant	2011 (Annual)	2022 (Annual)
THC	51%	41%
CO	86%	87%
NOX	48%	44%
PM2.5	17%	46%

3 Components to LD Gasoline Exhaust

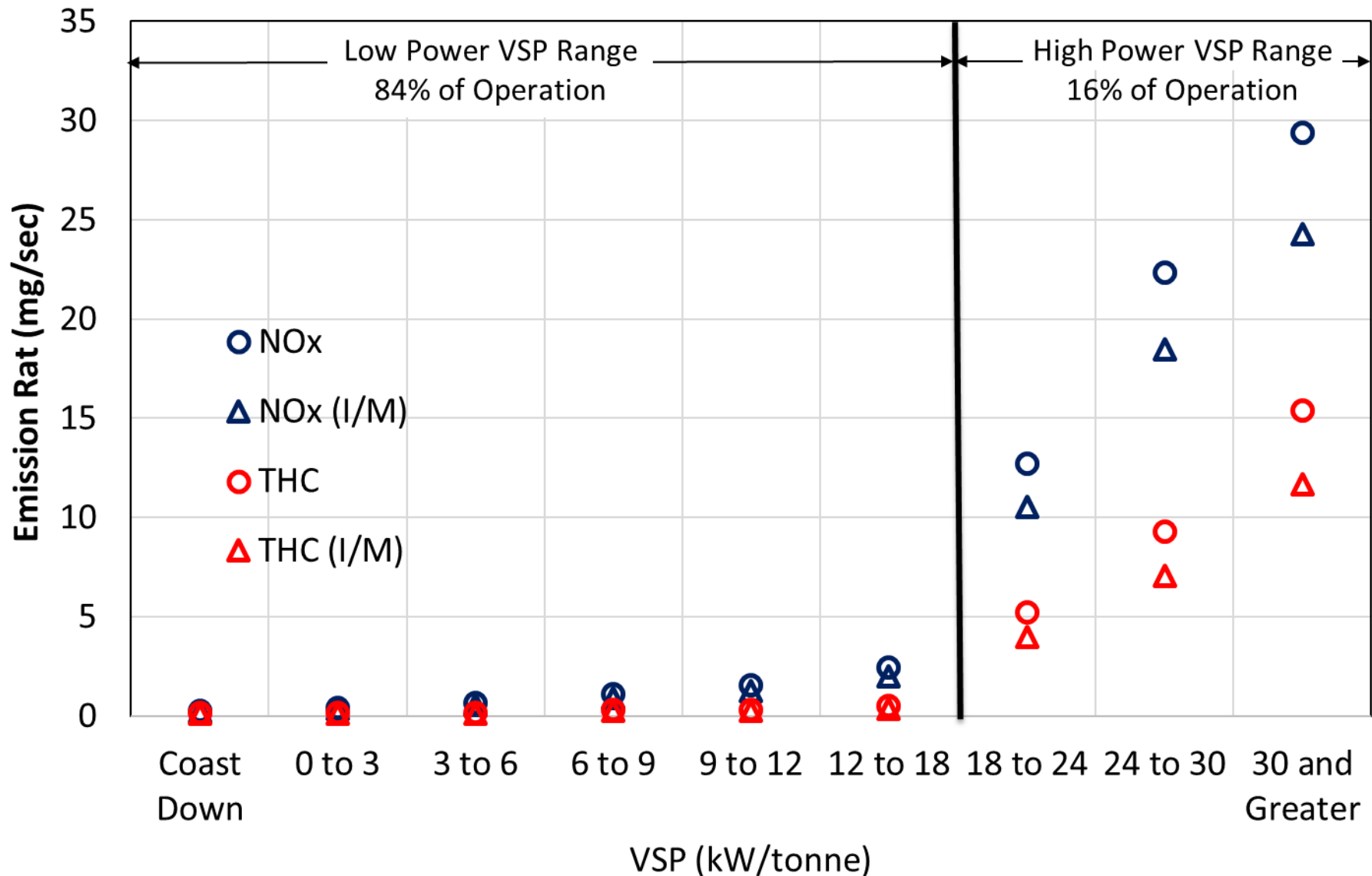
- Running Exhaust (Low Power)
 - ❖ AZ I/M data (Tier 0 & Tier 1) – 1 Hz resolution
 - ❖ FTP75 cycle data (NLEV & Tier 2)
- Running Exhaust (High Power)
 - ❖ EPA US06/MEC lab data (Tier 0 & Tier 1) - 1 Hz resolution
 - ❖ IUVP US06 cycle data (NLEV & Tier 2)
- Start Exhaust
 - ❖ EPA MSOD (Tier 0)
 - ❖ IUVP (NLEV & Tier 2)

3 Components to LD Gasoline Exhaust

- Running (Low Power)
 - ❖ AZ I/M data – robust random sample, best quantification of deterioration
- Running (High Power)
 - ❖ Results are normalized/scaled to low power rates (AZ I/M)
 - ❖ Deterioration rate not explicit (implicitly equal to low-power running exhaust)
- Start Exhaust
 - ❖ Tier 0 rates are not age specific (no deterioration)
 - ❖ NLEV & Tier 2 rate deterioration scaled to low-power running exhaust including a MOBILE model adjustment

LDT Emission Rates by VSP Bin

Model Year 2016, 25 - 50 mph

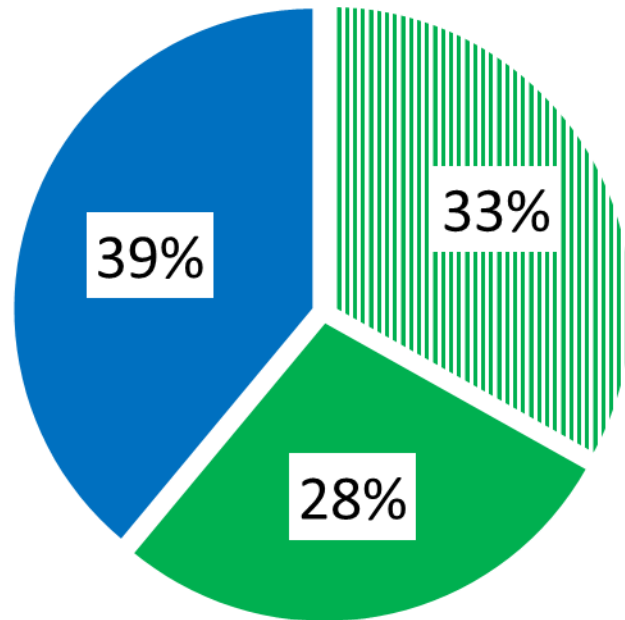


Service Life Exhaust Emissions

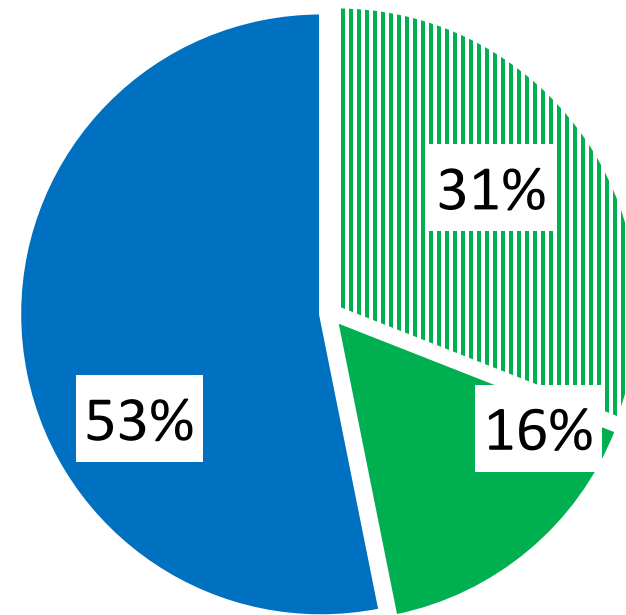
- Total exhaust emissions per vehicle over its lifetime
 - ❖ 2016MY vehicle examined from 2016 through 2046
- National average in-use conditions (Ambient, fuels, I/M)
- Quantification of the relative contributions by exhaust component
 - ❖ Low-power running exhaust
 - ❖ High-power running exhaust
 - ❖ Start exhaust

Service Life NOx Exhaust, Tier 2 Bin 5 Vehicle

Light-Duty Truck
25,144 grams/vehicle



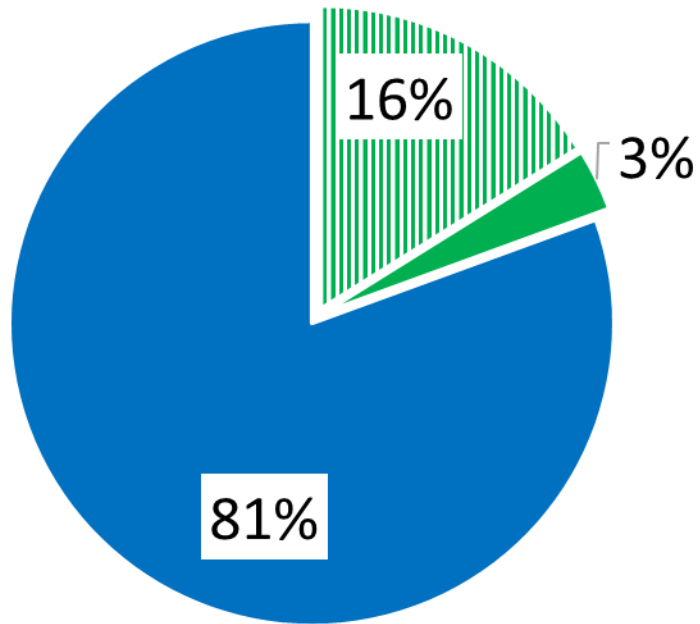
Passenger Car
19,265 grams/vehicle



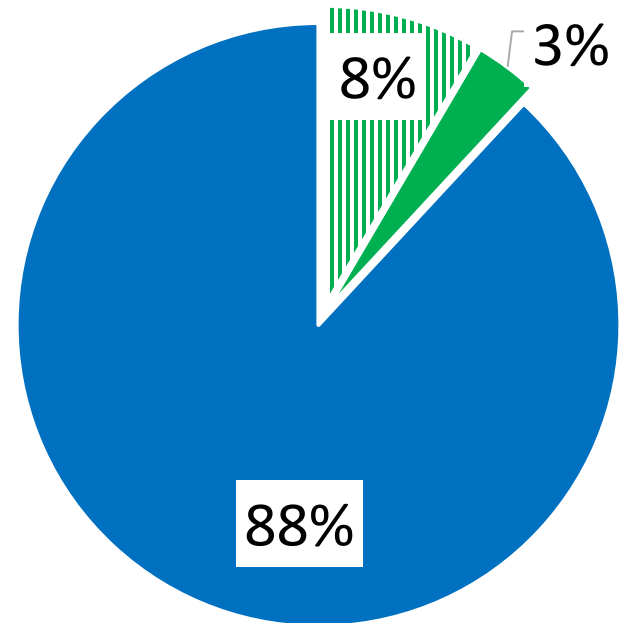
Running (High Power) Running (Low Power) Start

Service Life THC Exhaust, Tier 2 Bin 5 Vehicle

Light-Duty Truck
19,143 grams/vehicle



Passenger Car
18,345 grams/vehicle



Running (High Power) Running (Low Power) Start

LD Gasoline Exhaust Summary

- While the LD gasoline exhaust data used in MOVES represents the best available – the underlying test record is fragmented and not ideally suited for approach.
- Low-power running exhaust gets priority focus but is the smallest contributor.
 - ❖ MOVES validation efforts focus on the low-power running exhaust component (RSD, I/M data)
- Future focus needs to be on the full power range of running exhaust and start exhaust.
 - ❖ Current uncertainty in deterioration for high-power running exhaust and start exhaust and I/M effects.

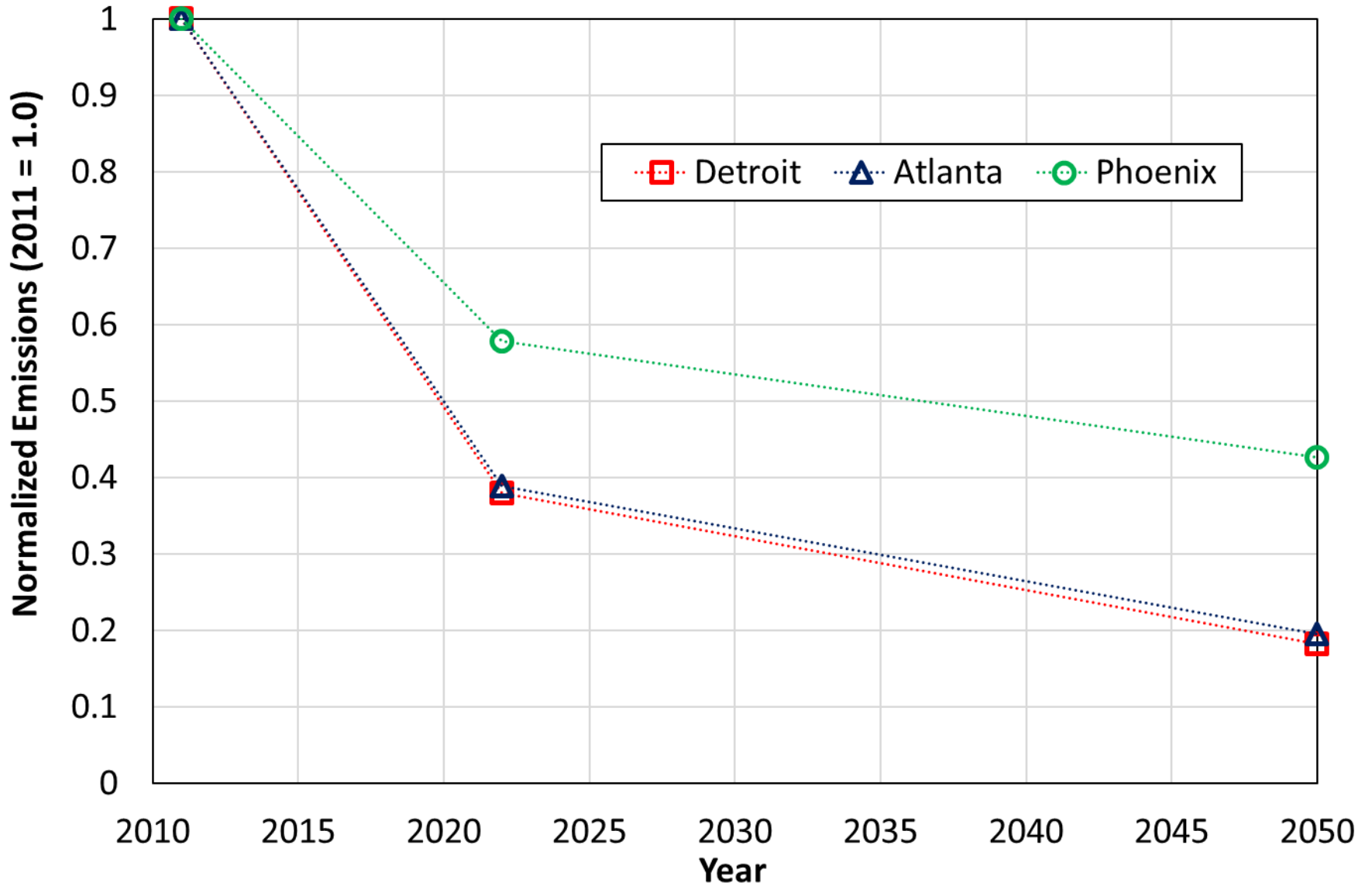
Emission Inventory Results

- CRC E-101 examined 3 locations picked for diversity of input
 - ❖ Maricopa County (Phoenix)
 - ❖ Wayne County (Detroit)
 - ❖ Fulton County (Atlanta)
- Detailed inventory examination using local input (2011 to 2050)
- Sensitivity Analyses
 - ❖ I/M, fuels and modeling variables

MOVES2014 Modeling – CRC E-101

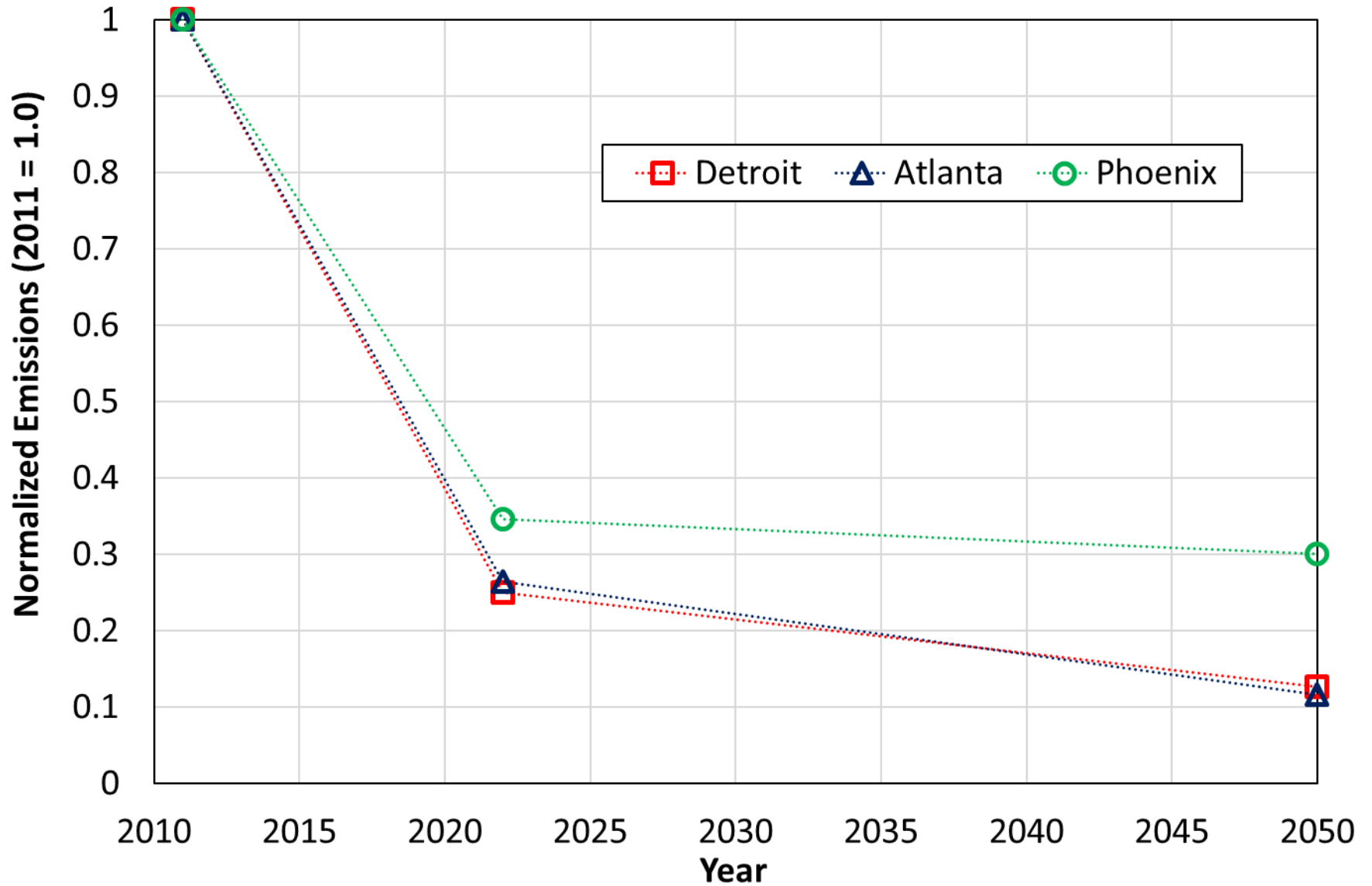
Parameter	Fulton County (GA)	Maricopa County (AZ)	Wayne County (MI)
Metropolitan Statistical Area	Atlanta-Sandy Springs-Roswell	Phoenix-Mesa-Glendale	Detroit-Warren-Livonia
Human Population (2011)	949,599	3,880,244	1,802,096
County Population Rank within State (2011)	1	1	1
Area (mi ²)	534	9,224	673
Mean Temperature:			
July Min/Max (°F)	71/91	80/105	69/89
January Min/Max (°F)	29/48	40/67	15/29
Vehicle Population (2011)	807,939	2,787,358	1,214,732
Vehicle Miles Traveled (2011, Annual)	12,221,921,568	32,442,909,320	16,694,871,362
Forecasted Growth in On-Road Activity	Moderate	High	Low
Vehicle Class VMT Splits (2011)	Greater light-duty proportion (than the national average)	National-average light and heavy-duty proportion; motorcycle usage twice the national average	National-average light and heavy-duty proportion
Average Age, Light-Duty Vehicle (2011, Years)	8.4	8.6	7.8
Rural Interstate Roadways	No	Yes	No
I/M Program	Yes	Yes	No
Gasoline Program	Conventional gasoline with local summer season RVP limit	Reformulated gasoline with local winter season RVP limit	Conventional gasoline with local summer season RVP limit

Annual On-Road Inventory (2011 to 2050) THC

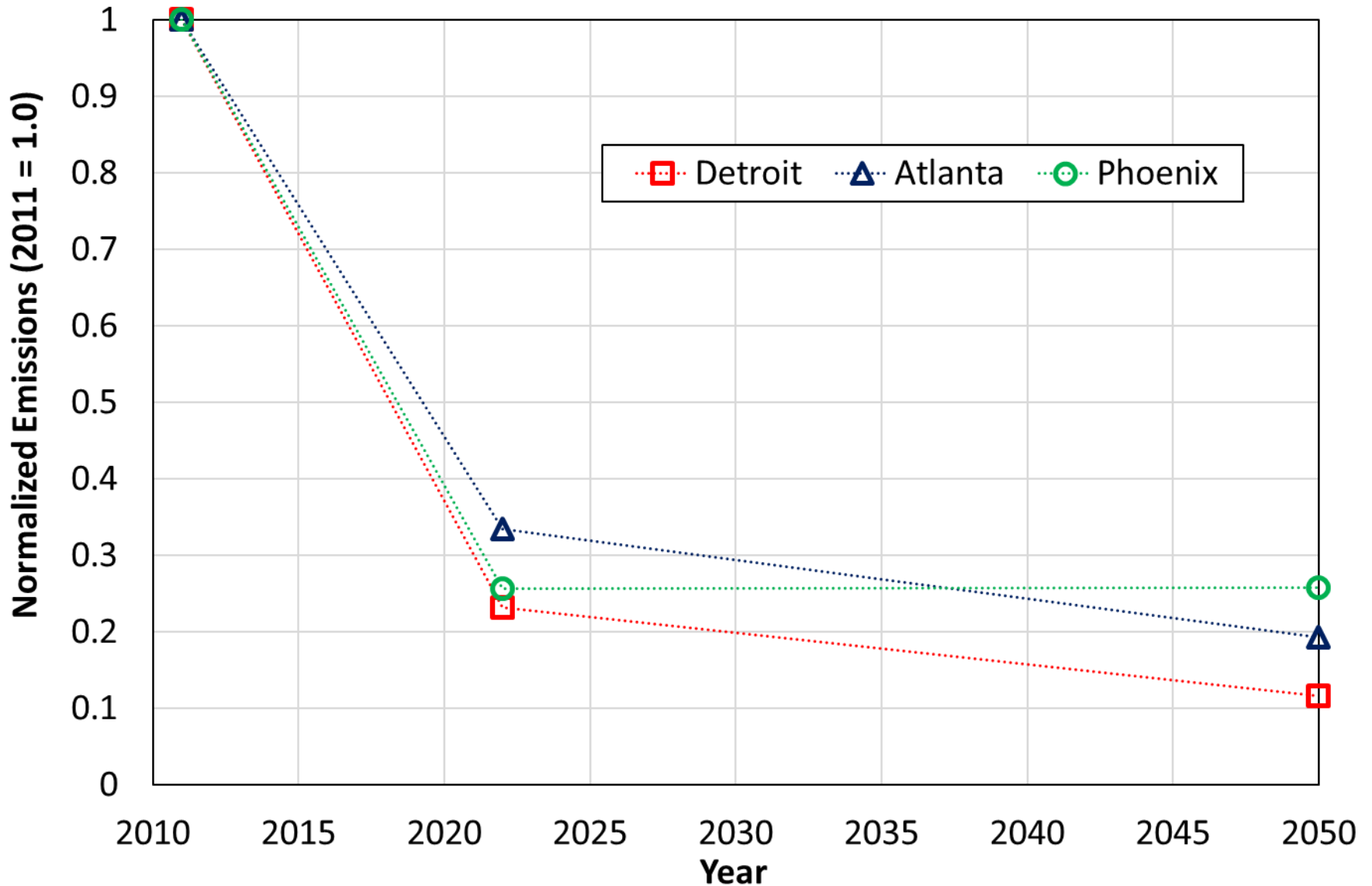


Annual On-Road Inventory (2011 to 2050)

NOx



Annual On-Road Inventory (2011 to 2050) PM2.5 (Excudes Brake/Tire Wear)



Sensitivity Scenarios

Change in Total On-Road Inventory, THC			
Local Program Parameter	Low	High	Mean
Add I/M Program	-18%	-2%	-10%
Increase RVP by 1 PSI	-1%	3%	1%
Add Reformulated Gasoline	-14%	0%	-6%

Change in Total On-Road Inventory, NOx			
Local Program Parameter	Low	High	Mean
Add I/M Program	-12%	-2%	-7%
Increase RVP by 1 PSI	0%	0%	0%
Add Reformulated Gasoline	-10%	0%	-3%

Emission Inventory Findings

- 3 locations selected for variance in underlying inventory assumptions:
 - ❖ Future inventory trends are dominated by the national vehicle and fuel controls.
 - ❖ By 2022, the average declines in THC, NO_x, PM_{2.5}, and CO emissions from 2011 are 55%, 71%, 73% and 43%, respectively.
 - ❖ By 2050 in all but one case, emissions remain below 2022 in spite of another 28 years of growth in on-road activity.

Final Remarks

- The complete model revision (MOVES) is a remarkable achievement
 - ❖ New methods require new data; legacy data is not suitable.
- There will always be uncertainty; models continually require updating. Current examples:
 - ❖ LD Gasoline vehicle exhaust
 - ❖ Variability in SCR/DPF control effectiveness
 - ❖ Trips (i.e., starts) as the primary activity basis
 - ❖ Winter season fuels modeling

Final Remarks (Continued)

- Given that:
 - ❖ National fuel and emissions control programs dominate on-road inventory trends &
 - ❖ Two sectors - LD gasoline and HD diesel - dominate the on-road inventory
- Then:
 - ❖ It is critical that future data collection/analysis be done to replace theoretical effectiveness of LD Tier 2, LD Tier 3 and HD 2007+ MY standards:

Final Remarks (Concluded)

- Further reading/resources:
 - ❖ CRC E-101/E-116 reports
 - ❖ EPA Response Document(s)
 - ❖ EPA's MOVES Model Review Work Group (planned updates for the next version of MOVES)