CALIFORNIA
AIR RESOURCES BOARD

Preliminary Baseline Emissions for Small Off-Road Engines (SORE2020)

Air Quality Planning & Science Division
California Air Resources Board

March 25, 2020

Last Updated: March 30, 2020

Outline

- Purpose
- Timeline
- Major updates
- 2018 Cal State Fullerton Survey
- Development of Emission Factors
- Population Growth Forecast
- Next Steps

Small Off-Road Engines (SORE)

- Small Off-Road Engines (SORE) are spark-ignition engines rated at or below 19 kilowatts (i.e., 25 hp)
- Used in lawn & garden equipment as well as other outdoor power equipment and specialty vehicles
- The majority of these equipment belong to the Lawn & Garden (e.g., lawn mower, leaf blower) and Light Commercial (e.g., compressor, generator) categories

Lawn & Garden

Light Commercial

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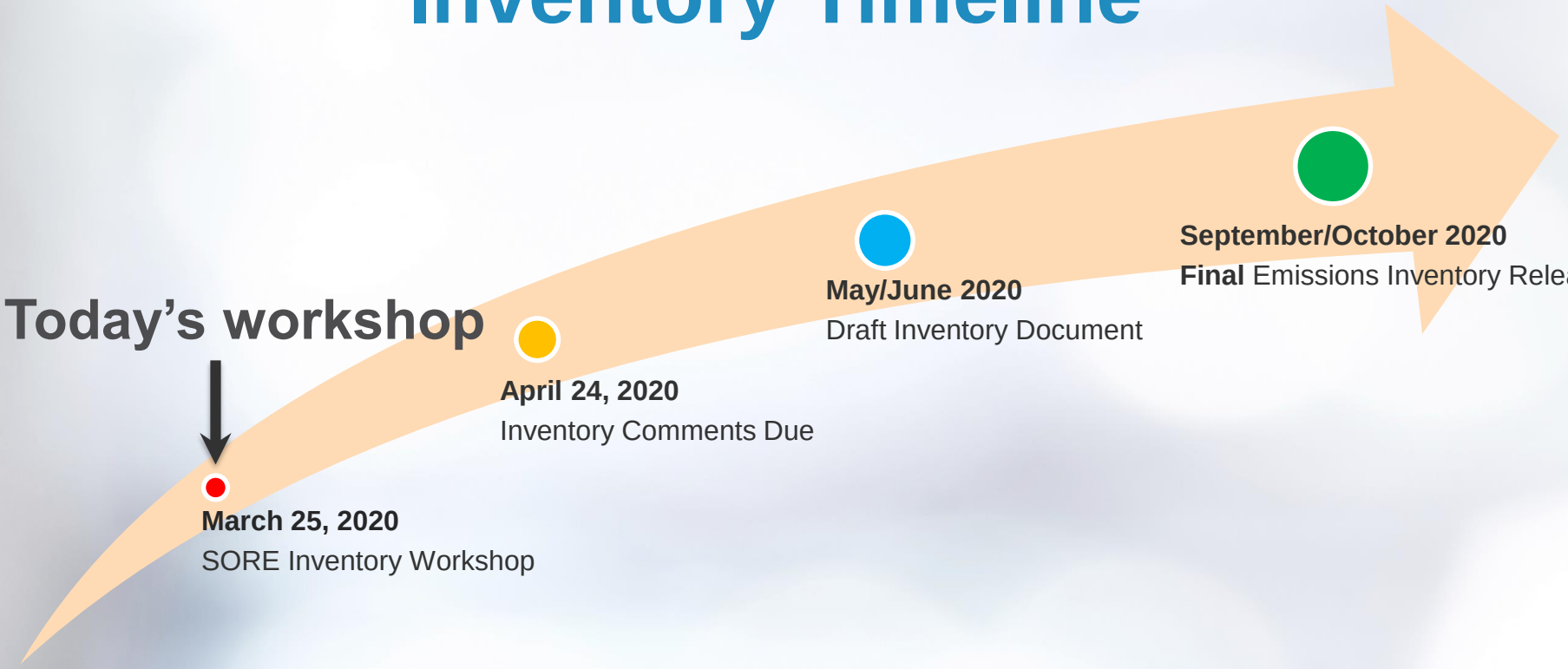
Purpose of Model Update

- Underlying data and growth assumption used in OFFROAD2007 are outdated
- Support the upcoming SORE regulation in 2020
- Availability of new data
  - ✓ 2018 CS Fullerton SORE survey on population and activity
  - ✓ Engine Production Line Testing (PLT) data – annual production of SORE engine
  - ✓ Evap. Reporting Data – Annual production volume of SORE equipment
  - ✓ Emissions Data – Certification data and in-house test data (evap and exhaust)

Inventory Timeline



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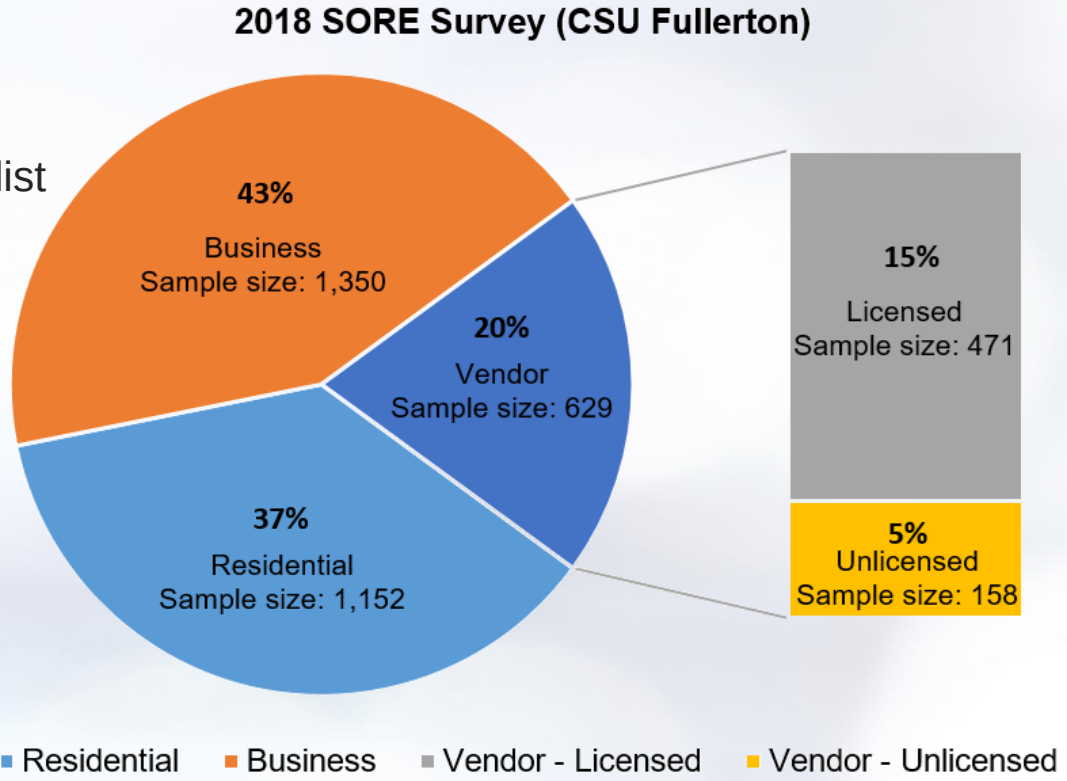
Major Updates

- **Model Structure**
  - ✓ Stand-alone Visual Basic based model for SORE from all off-road sectors
- **Population & Activity**
  - ✓ 2018 Cal State Fullerton survey data, reported engine production volume and reported equipment sales by manufacturers
  - ✓ Future annual growth based on California household growth
  - ✓ L&G equipment operated by landscaping service providers (vendors) - *New*
  - ✓ Electric L&G population - *New*
- **Emission Factors** – Exhaust and evap test data from in-house study combined with certification database

2018 Cal State Fullerton Survey for SORE

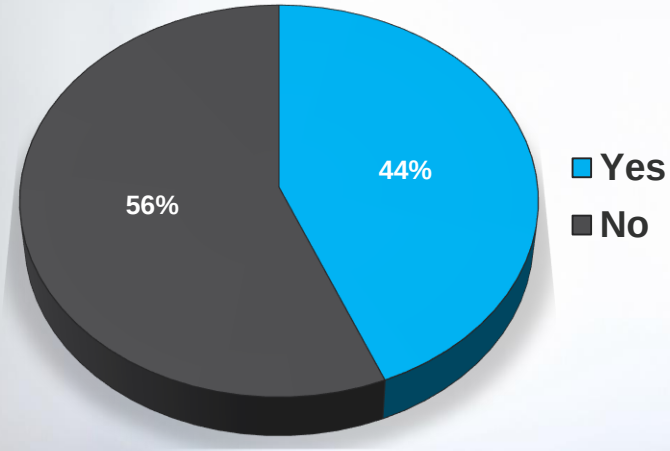
Brief Overview

- Phone data come from Marketing System Group (MSG), Scientific Telephone Samples (STS), and Craigslist
- Each survey consists of about 45 to 50 questions
- **R**esidential survey: 1,152 complete surveys over 13,638 calls (8.4%)
- **B**usiness survey: 1,350 complete surveys over 8,079 calls (16.7%)
- **V**endor: 629 complete surveys over 7,247 calls (8.7%)



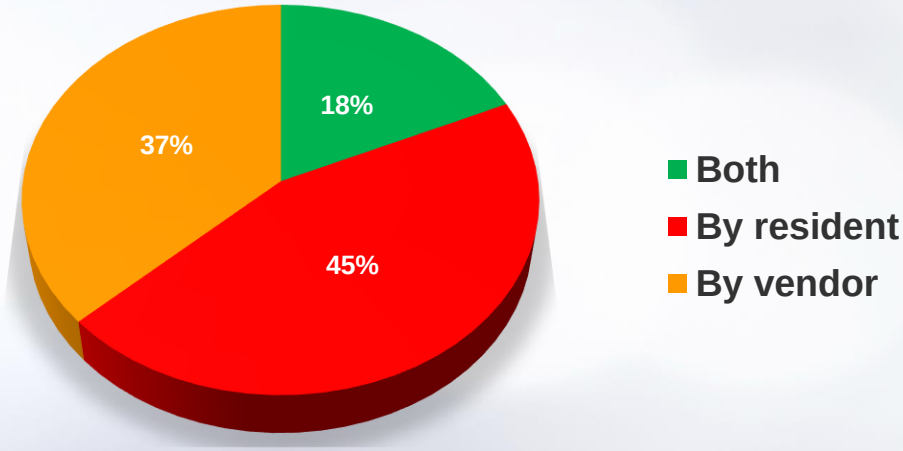
L&G Equipment Ownership (Residents)

% Owned L&G Equipment (Survey [R])



- From the 1,152 responses to the Residential Survey, less than half or approximately 44% indicated that they owned L&G equipment

% Responses from Survey [R]



- From Residential Survey, 37% indicated they use a vendor, 45% do their own yardwork and 18% are a combination of both

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2018 SORE Population

Category		Lawn & Garden	Light Commercial	Total
OFFROAD2007 (Gas)		16,012,486	439,198	**16,451,684**
CS Fullerton Survey	**Gasoline**	9,487,701	3,045,714	**12,533,415**
	Electric	8,373,919	7,352,375	15,726,294
	Total	17,861,620	10,398,089	28,259,709

- Compared to the survey, OFFROAD2007 overestimates L&G equipment population but underestimates the population of Light Commercial equipment
- According to the survey, there are approximately 28.3 million small off-road engines operating in California

Note: Utility carts/vehicles were not included

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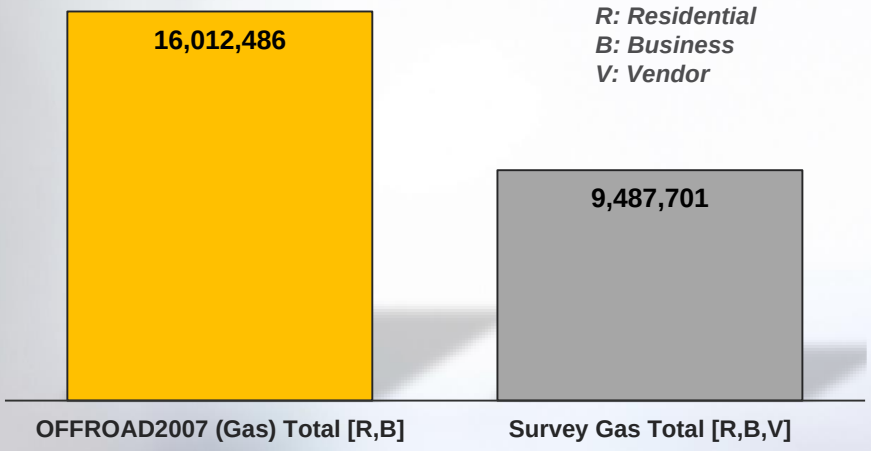
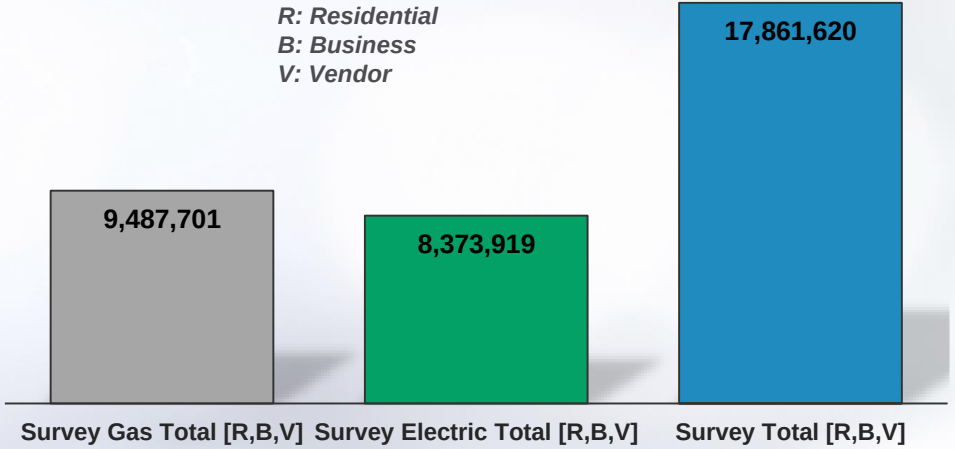
L&G Equipment Population

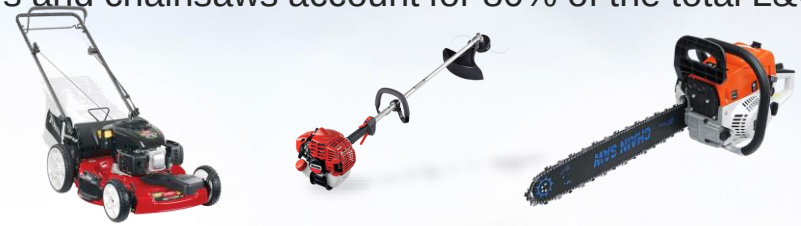
OFFROAD2007 vs Survey



Survey Population by Fuel Type



- Lawn mowers, trimmers and chainsaws account for 80% of the total L&G Population:



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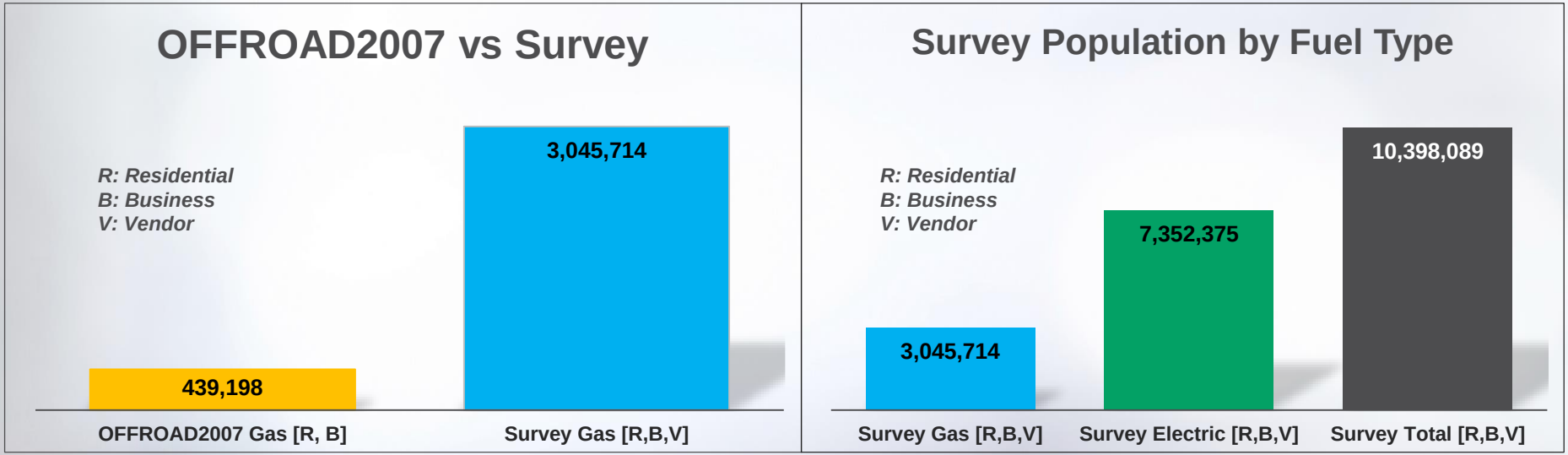
Light Commercial Equipment Population

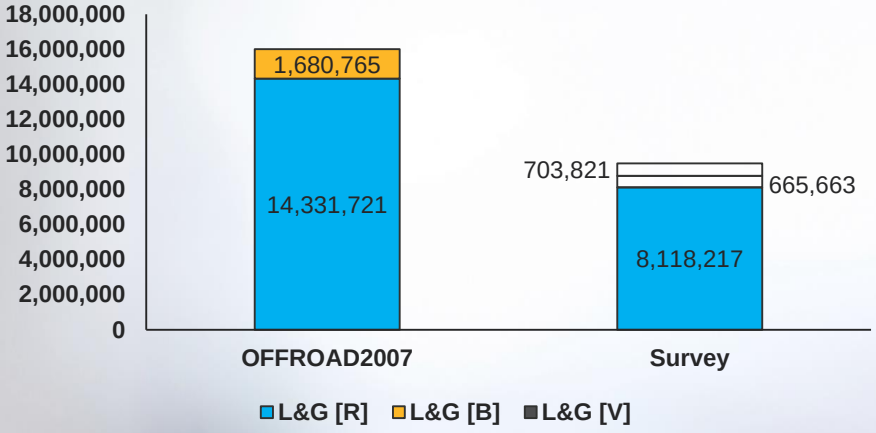


- Generators, compressors and pressure washers account for 88% of the total Light Commercial Population:

L&G Population (Residential vs. Business)

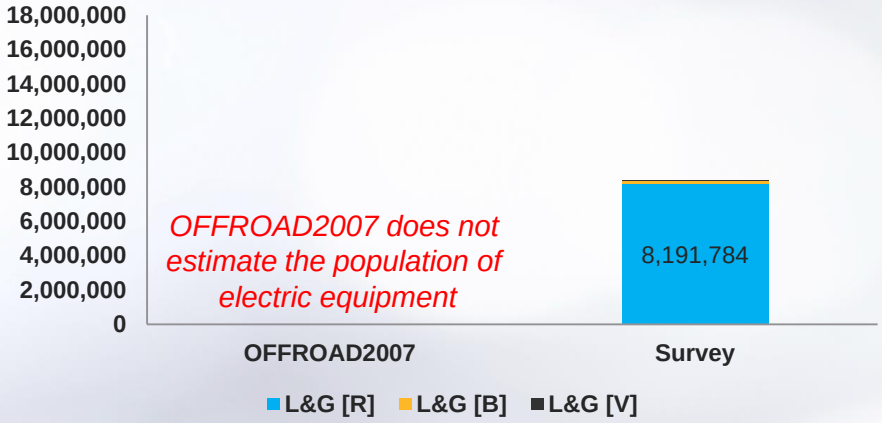
Gasoline

L&G [R] [B] - 2018 Population



Electric

L&G [R] [B] - 2018 Population)



- From the survey, the majority of the “electric” L&G equipment is used in the residential sector and the majority consists of leaf blowers and trimmers
- Nearly 3:1 homeowners purchased electric leaf blowers over gasoline, while that same percentage bought gasoline lawn mowers over electric

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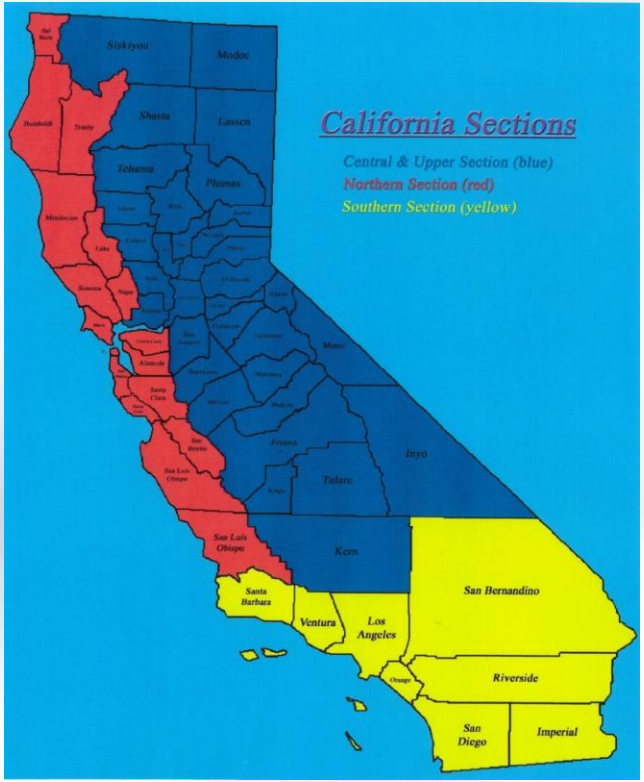
Equipment Population Scaling

- The 2018 CSUF survey scaled up the population of equipment using statewide household information
- Staff assesses that a revised weighting method should be utilized to take into account geographical areas separated by northern, central/upper and southern regions of the state
- Survey results from each region are used to scale up the SORE population in that region. It helps to characterize the SORE equipment more relevantly to such region



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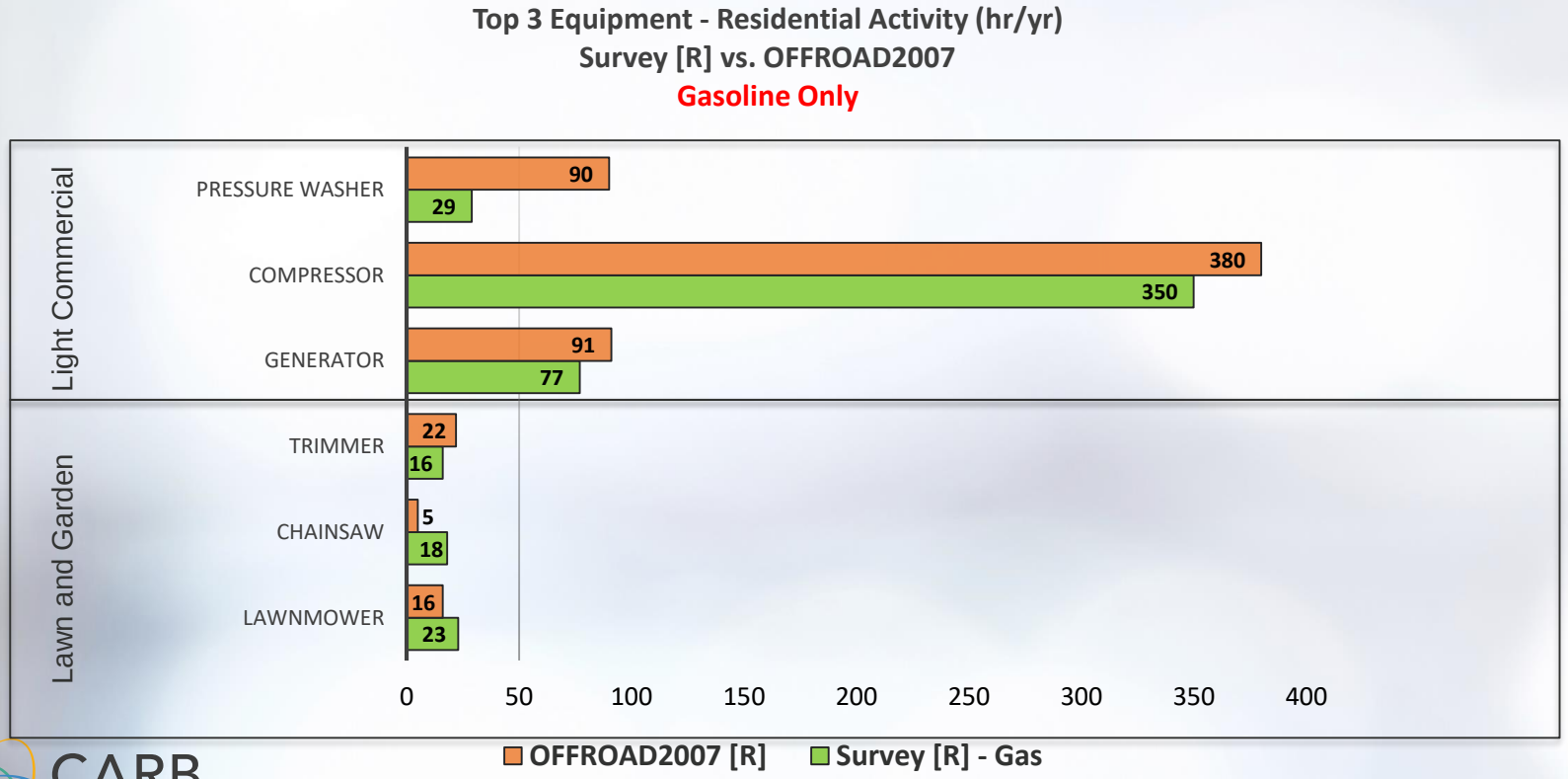
OFFROAD2007 vs. 2018 CSUF Survey Activity (hr/yr)

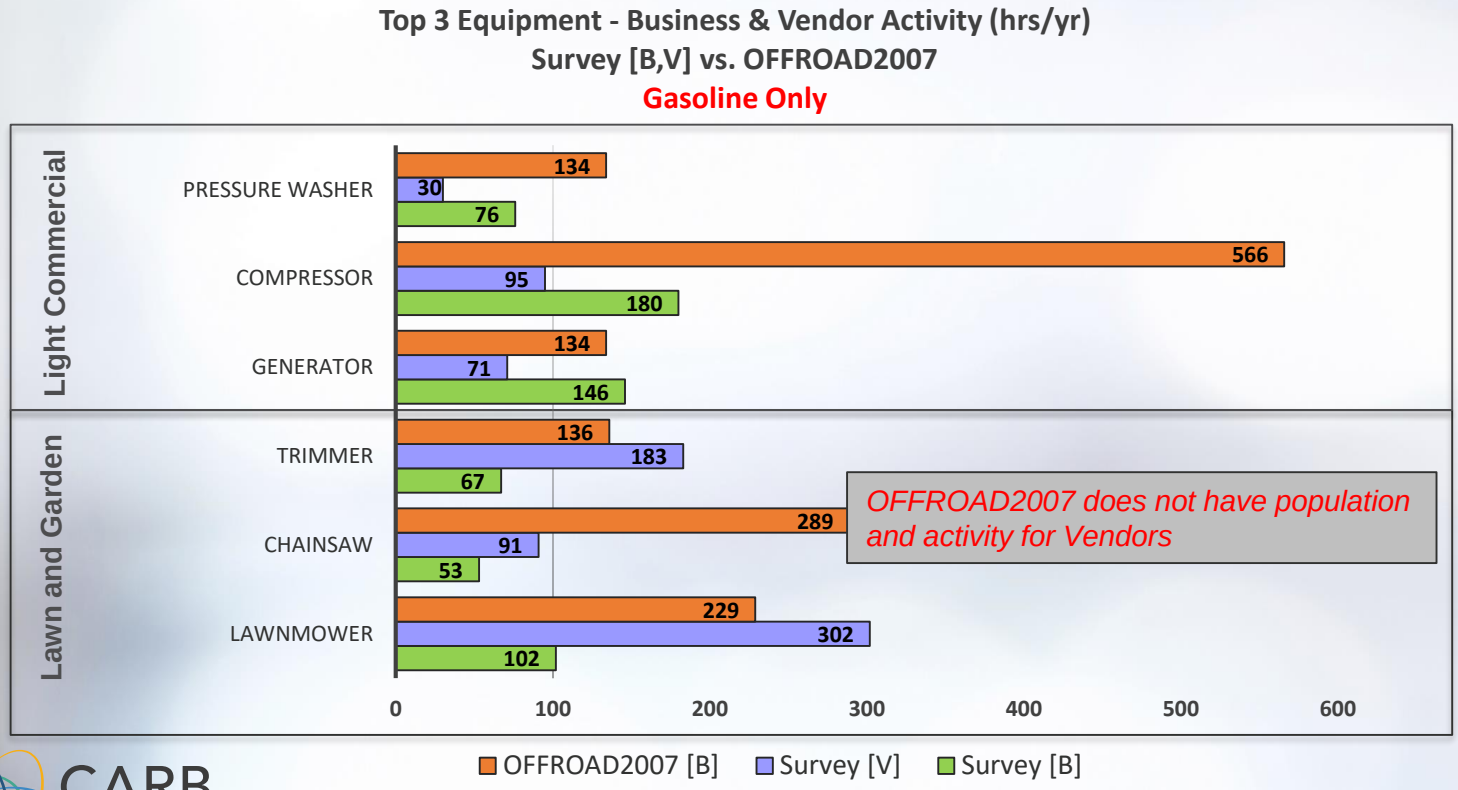
		OFFROAD2007 (hr/yr)		Survey (hr/yr) -- Gas			Survey (hr/yr) Electric		
		Residential	Business	Residential	Business	Vendor	Residential	Business	Vendor
Lawn & Garden	lawn mower	16	229	23	102	302	17	63	42
	Chainsaw	5	289	18	53	91	21	3	17
	Trimmer	22	136	16	67	182	8	9	35
	Blower	5	196	15	151	280	14	18	118
	Other L&G	4	69	43	60	84	7	9	13
	Riding lawn mower	29	271	152	--	330	57	--	--
Light Commercial	Generator	91	134	77	146	71	100	166	13
	Pump	174	258	9	168	159	844	872	110
	Compressor	380	566	350	180	95	61	180	88
	Welder	208	208	178	115	19	31	329	65
	Pressure Washer	90	134	29	76	30	8	311	22

- From the survey, residential activity for most L&G increased but for Light Commercial, the residential activity decreased
- For the business sector, activity for L&G decreased, but increased for Light Commercial as compared to OFFROAD2007

Residential Activity for Top 3 (Lawn and Garden & Light Commercial)



Business & Vendor Activity for Top 3 (Lawn and Garden & Light Commercial)



Median Life (years)
OFFROAD2007 vs. Survey

		Median Life (years)							
		OFFROAD2007		Survey -- Gas			Survey Electric		
		Residential	Business	Residential	Business	Vendor	Residential	Business	Vendor
L&G	Lawn mower	16	1	6	5	3	5	7	3
	Chainsaw	16	1	6	3	3	5	3	1
	Trimmer	7	2	5	3	2	5	5	2
	Blower	16	2	5	3	2	5	3	2
	Other L&G	16	3	10	3	6	8	8	3
	Riding lawn mower	9	1	8	--	5	8	--	--
Light Commercial	Generator	16	10	7	5	4	8	5	3
	Pump	13	5	6	8	3	5	5	3
	Compressor	4	3	3	3	3	8	4	3
	Welder	16	11	10	5	4	8	5	5
	Pressure Washer	15	10	5	3	3	5	3	2

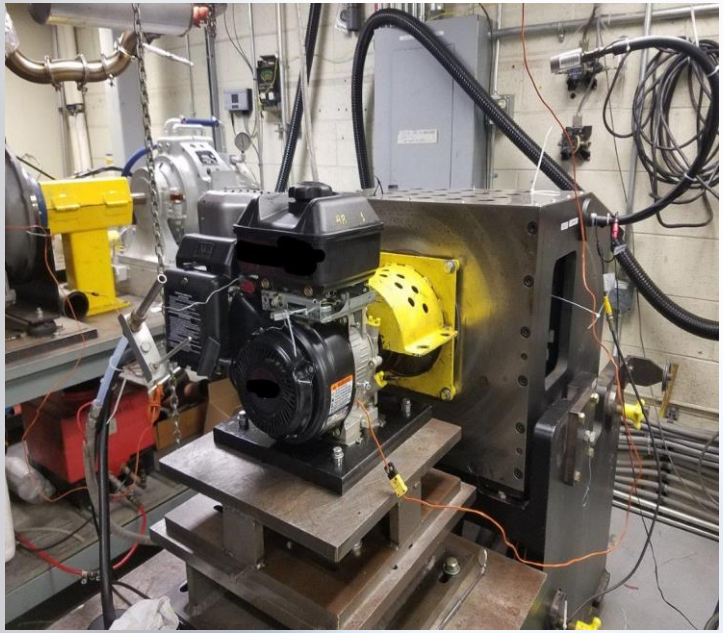
- The median life is the age of the equipment corresponding to 50% of the population
- For the residential sector, the median life from the survey mostly decreased as compared to OFFROAD2007
- The median life for the equipment in the business and vendor sectors were consistent with each other from the survey

Development of Emission Factors

Exhaust and evaporative
running loss
(Operating)

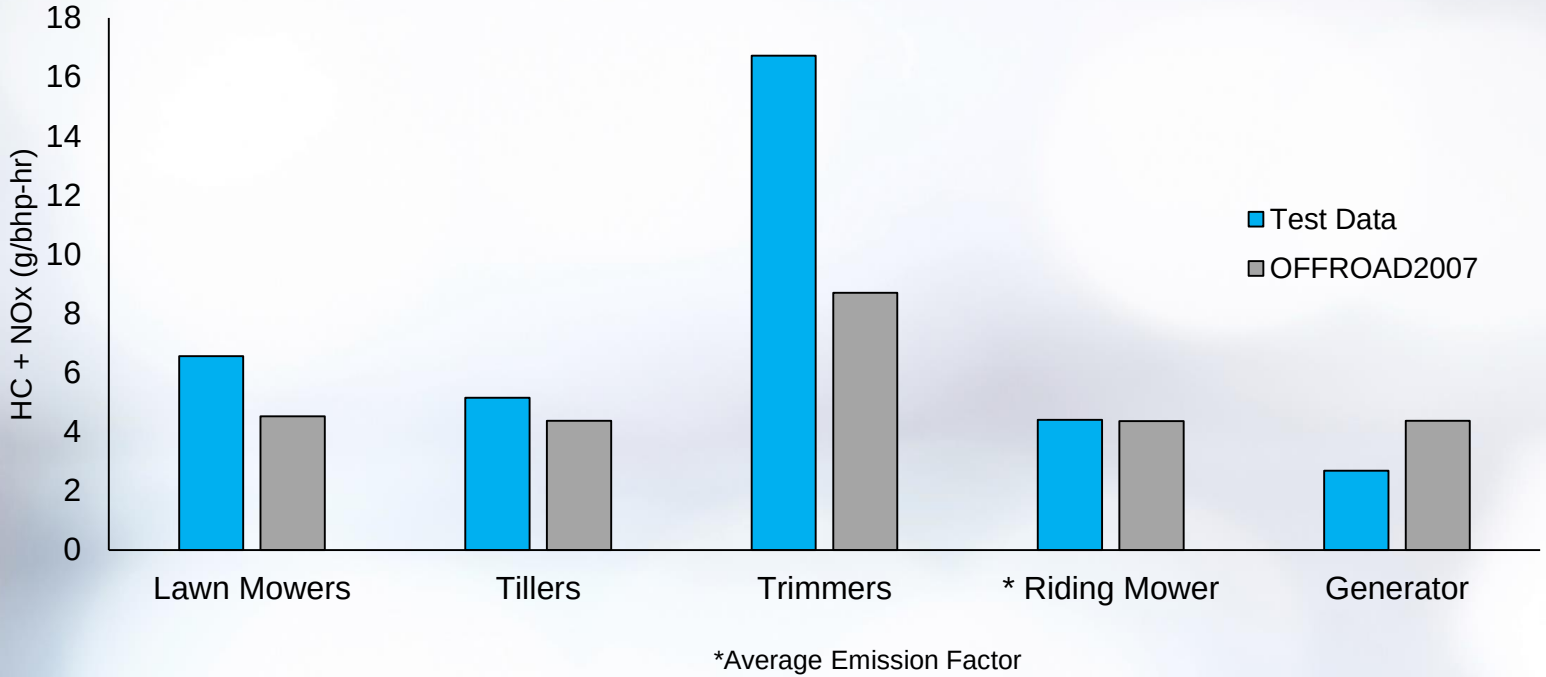
Evaporative
(After operation and
during storage)

In-Use and Certification Exhaust Emission Data



- In-House Baseline Testing
  - SORE engine test cycle
  - Four-stroke engines
  - Lawn mower, trimmer, leaf blower, riding mower, tiller, generator
- SORE Engine Certification Database
  - Calendar year 2001 to 2018
  - Cover multiple engine families and horsepower groups

In-House Testing vs. OFFROAD2007
(HC+NOx Exhaust Emission Factors)



*Average Emission Factor

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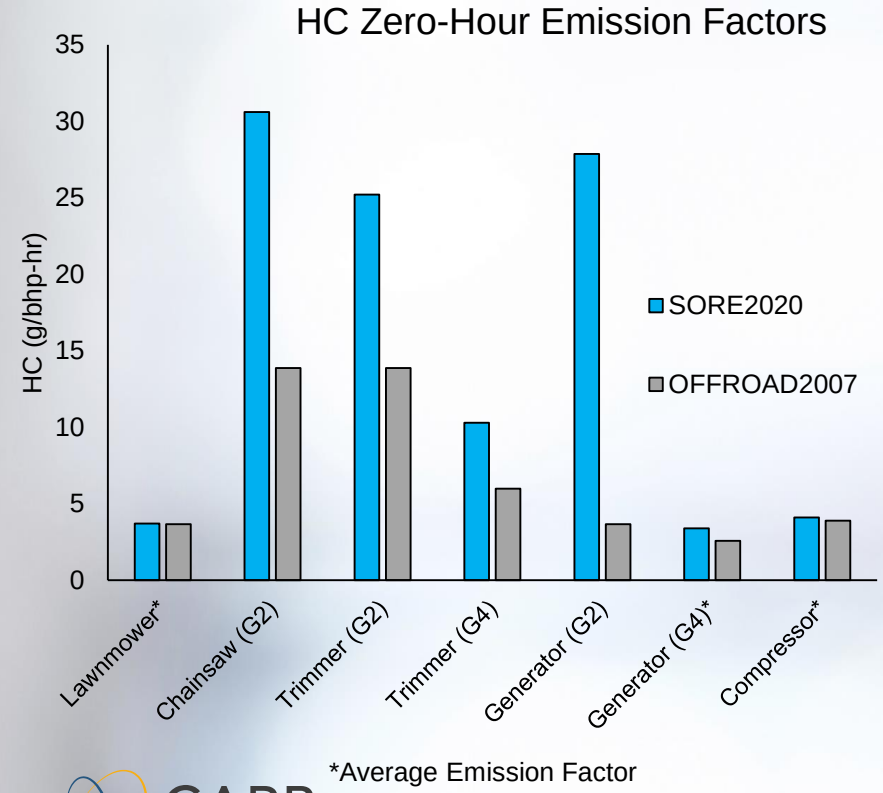
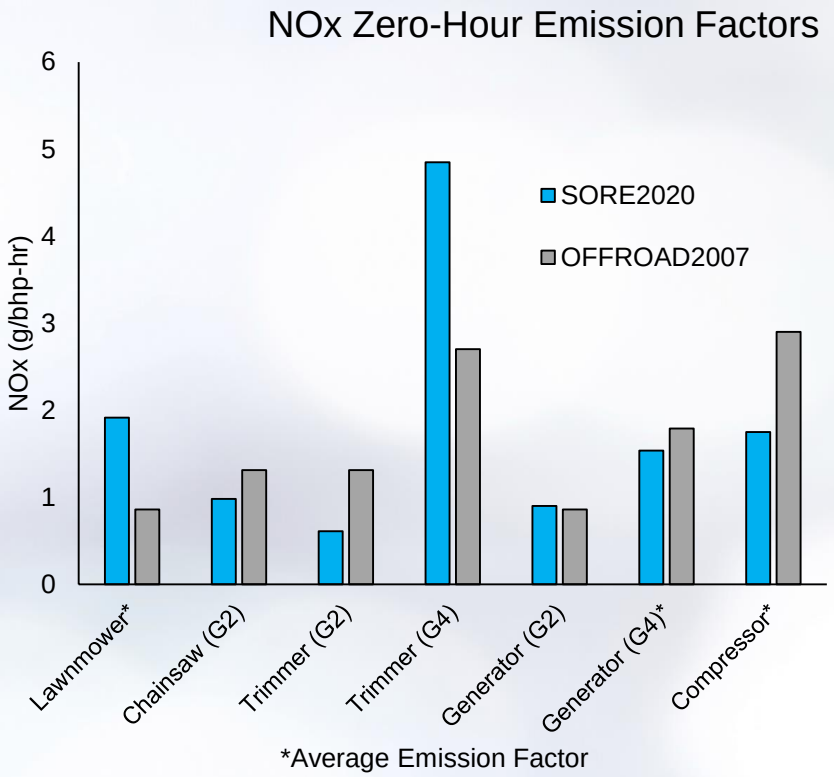
2018 Certification Data

Category	Equipment	Tech Type	HP Bin	2018 Certification Data	
				HC (g/hp-hr)	NOx (g/hp-hr)
Lawn & Garden	Chainsaws	G2-Carb	2	30.61	0.98
	Lawn Mowers	G4-Carb	5	4.47	1.89
			15	3.49	1.34
	Leaf Blowers/Vacuums	G2-Carb	2	29.46	0.54
		G4-Carb	5	16.38	1.21
			15	2.67	2.51
			25	2.42	3.01
		G4-FI	15	1.34	3.39
Light Commercial	Air Compressors Preempt	G4-CARB	5	5.44	1.77
			15	2.77	1.73
	Generator Sets	G2-CARB	2	27.86	0.90
		G4-CARB	5	5.63	1.48
			15	2.89	1.98
			25	3.39	1.42
		G4-FI	15	1.07	2.13
	Pressure Washers	G4-CARB	5	4.58	1.85
			15	2.76	1.72

Proposed Exhaust Emission Factors





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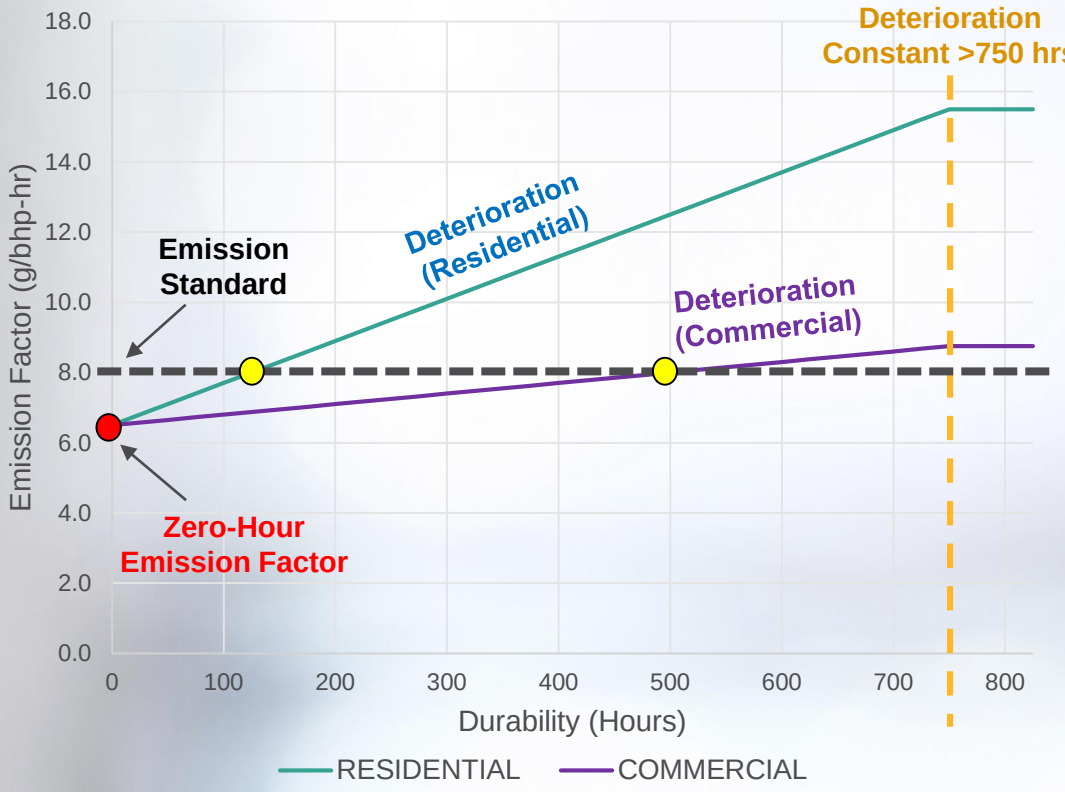
Deterioration Factor (Exhaust)



- Exhaust emission factors are derived by:
  - ✓ Initially setting the Zero-Hour emission factor at a level below the emissions standard
  - ✓ Over time, it would deteriorate or the emissions would become equal to the standard at the set durability hour
- Lawn Mower Durability
  - ✓ Residential (125 hours)
  - ✓ Commercial/vendor (500 hours)
- Emission factor is capped at 750 hours

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SORE2020 Load Factors

Category	Equipment	Load Factor
Lawn and Garden	Chainsaws	0.5
	Lawn Mowers	0.36
	Leaf Blowers/Vacuums	0.5
	Trimmers/Edgers/Brush Cutters	0.36 – 0.5
Light Commercial	Air Compressors	0.56
	Generator Sets	0.68
	Pressure Washers	0.85
	Pumps	0.69
	Welders	0.51

- The load factors in the SORE2020 Model were carried over from OFFROAD2007

Average Horsepower

Category	Equipment	Average Horsepower							
		2018 Cert Data (Weighted)				OFFROAD2007			
		G2 0-2hp	G4 0-5hp	G4 5-15hp	G4 15-25hp	G2 0-2hp	G4 0-5hp	G4 5-15hp	G4 15-25hp
Lawn and Garden	Chainsaw	2.0	-	-	-	1	-	-	-
	Leafblower	1.0	1.2	9.3	24.8	1	2	-	-
	Trimmer	1.0	1.2	-	-	0.9	1	-	-
	Lawnmower	-	4.6	-	17	-	4	-	-
Light Commercial	Compressor	-	3.6	10.7	-	-	5	7	17
	Generator	2.0	3.5	8.0	20.8	1	4	9	19
	Pressure Washer	-	4.4	10.7	-	-	5	7	18
	Pump	1.4	3.7	9.4	-	1	3	8	17

SORE Evaporative Testing

- Diurnal (65 to 105 F)
- Hot soak at 95 F
- In-house Test Studies
  - ✓ Compliance and validation studies
  - ✓ E10 baseline testing

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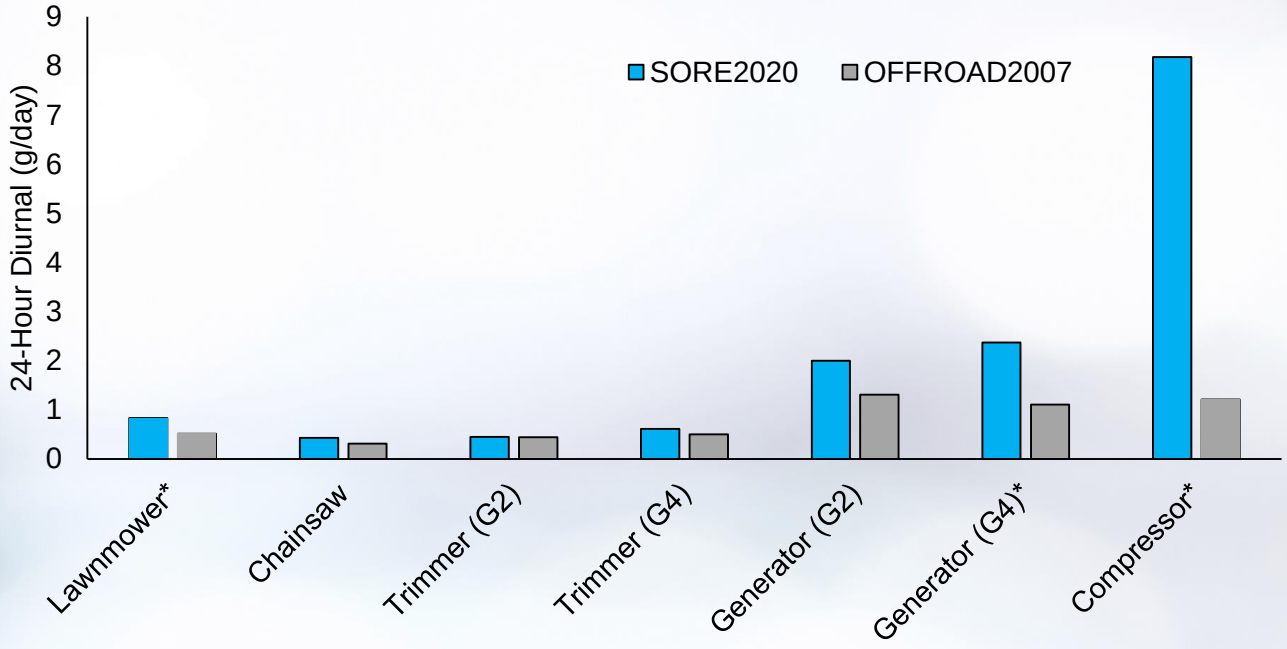
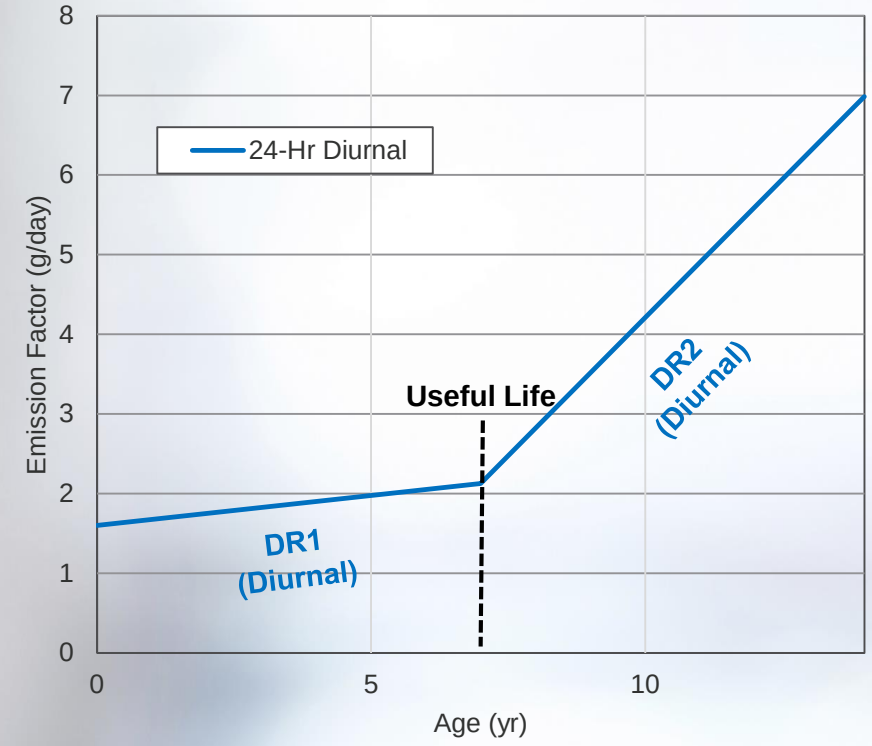
Proposed Evaporative Emission Factors
(24-Hour Diurnal Emission Factors)



*Average Emission Factor

Deterioration Factor (Evap) for Lawn Mowers



- Due to lack of available data, SORE2020 does not explicitly account for liquid leakers
- SORE2020 Model utilizes the same deterioration factors from OFFROAD2007
- Previous in-use 24-hour diurnal emission data suggested aged equipment have much higher 24-hr diurnal emissions
- Assumption was made that emissions deteriorate faster once equipment passes their useful life
- Led to development of two deterioration factors for lawnmower evaporative emission
  - ✓ DR1 - From age 0 to useful life
  - ✓ DR2 - From useful life to 2x useful life

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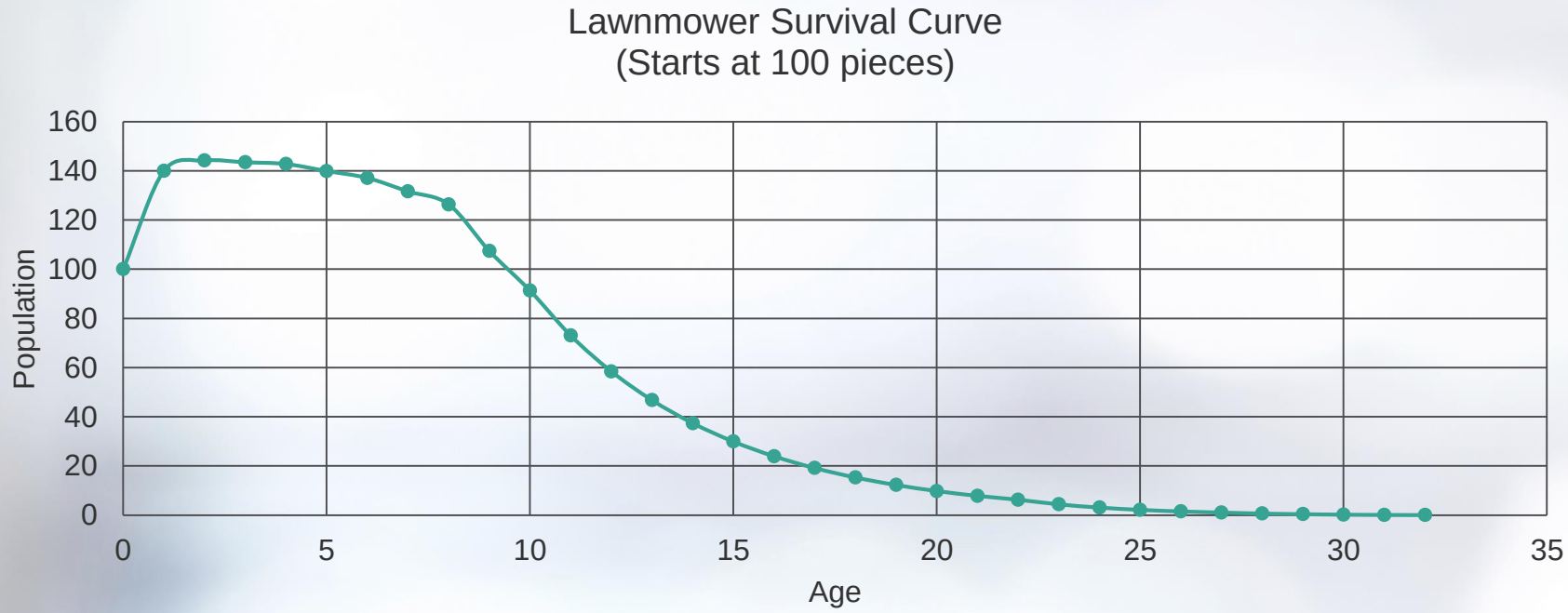
Population and Growth Forecast

Summary of Population Calculation & Forecasting

- Survey data from 2001, 2012, and 2018 (base year)
- Data available:
  - ✓ Fleet gasoline and electric population from 2001, 2012, and 2018
  - ✓ Age distribution from 2001 and 2018 for certain equipment
- Use age distribution to estimate survival curve, where possible
- Fit survival curve until fleet populations match 2001, 2012 and 2018 numbers
- Cross check new equipment sales against 2018 SORE Evap Production Volume Reports
- Check against annual shipment data provided by Outdoor Power Equipment Institute (OPEI)
- Use California household growth as a surrogate for future annual growth

Example of Survival Curve



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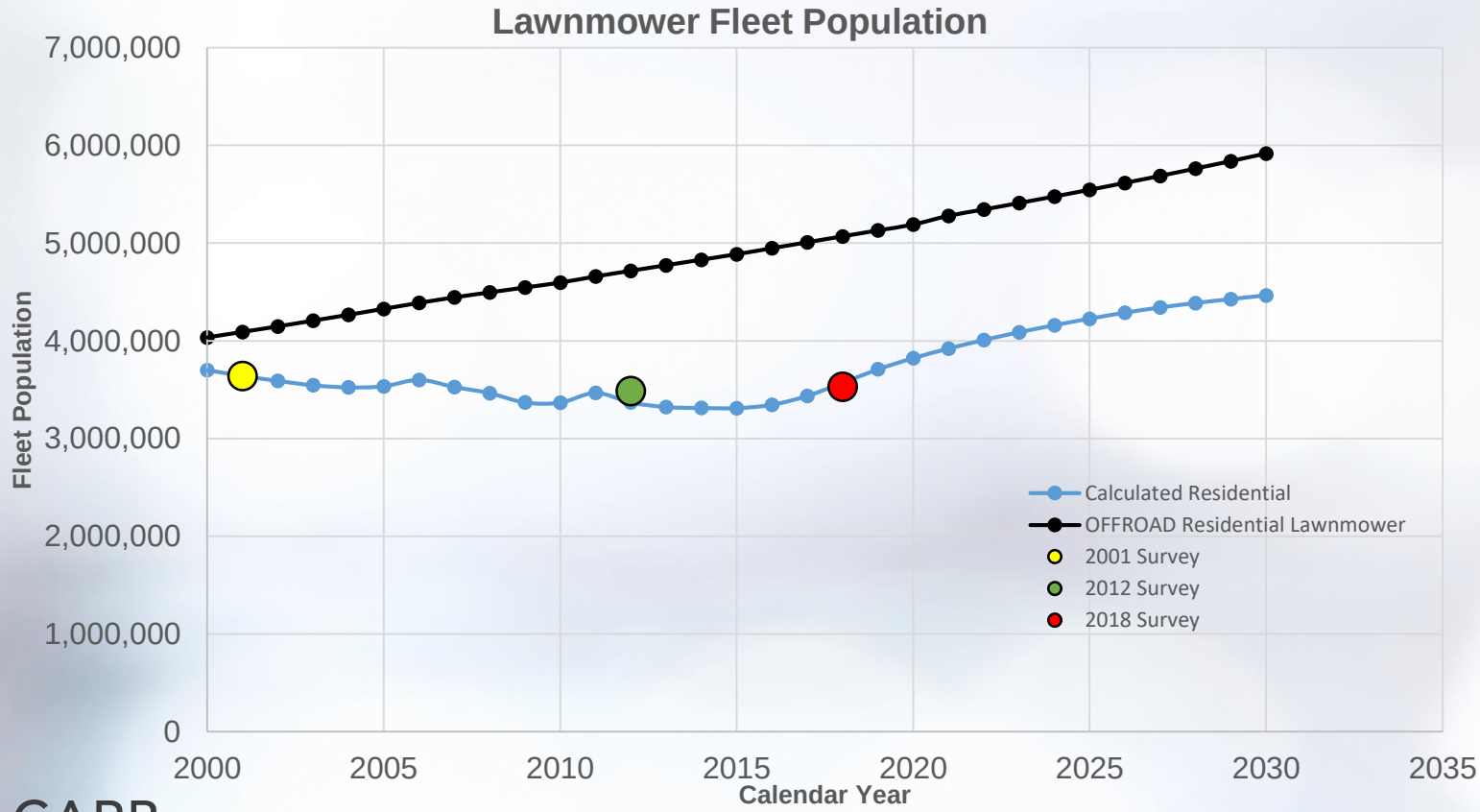
Example of Population Estimate



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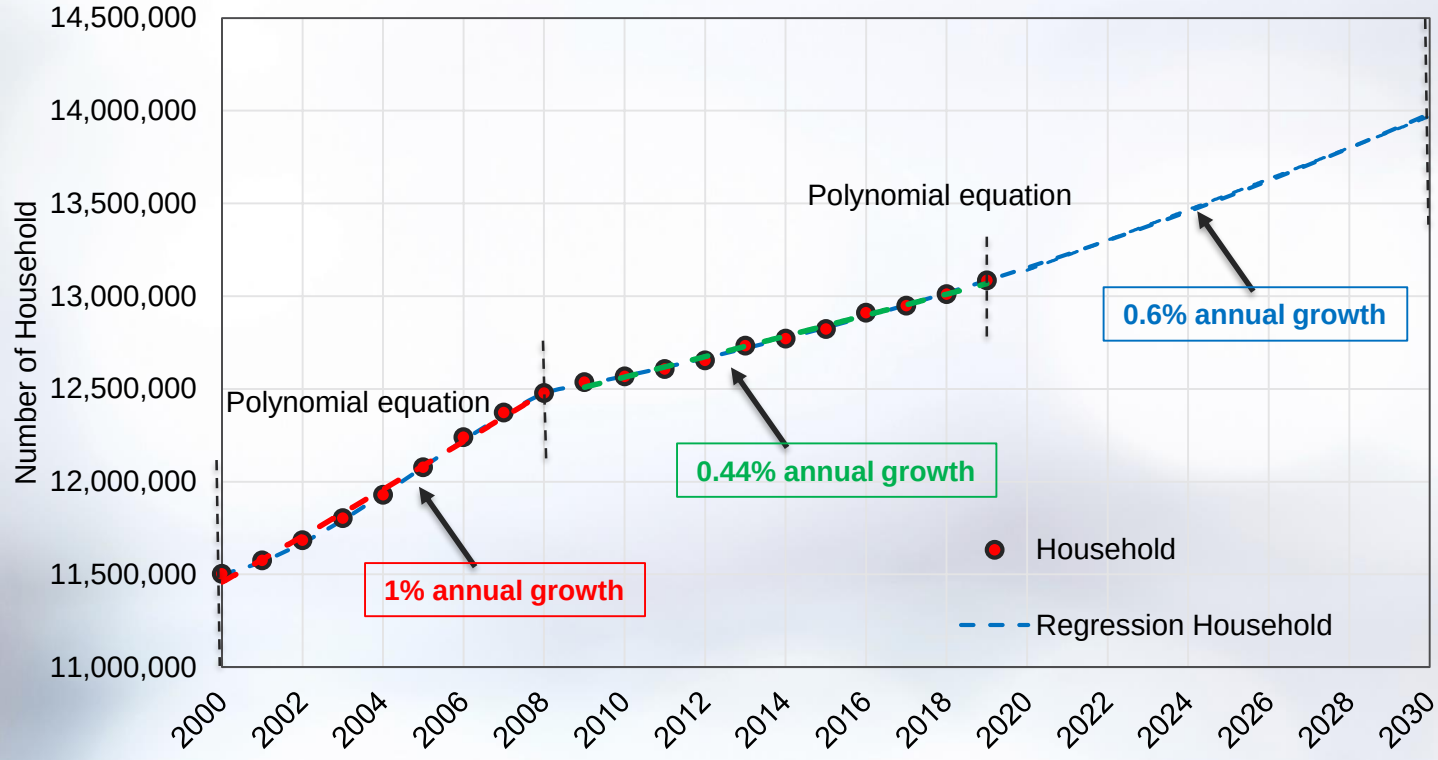
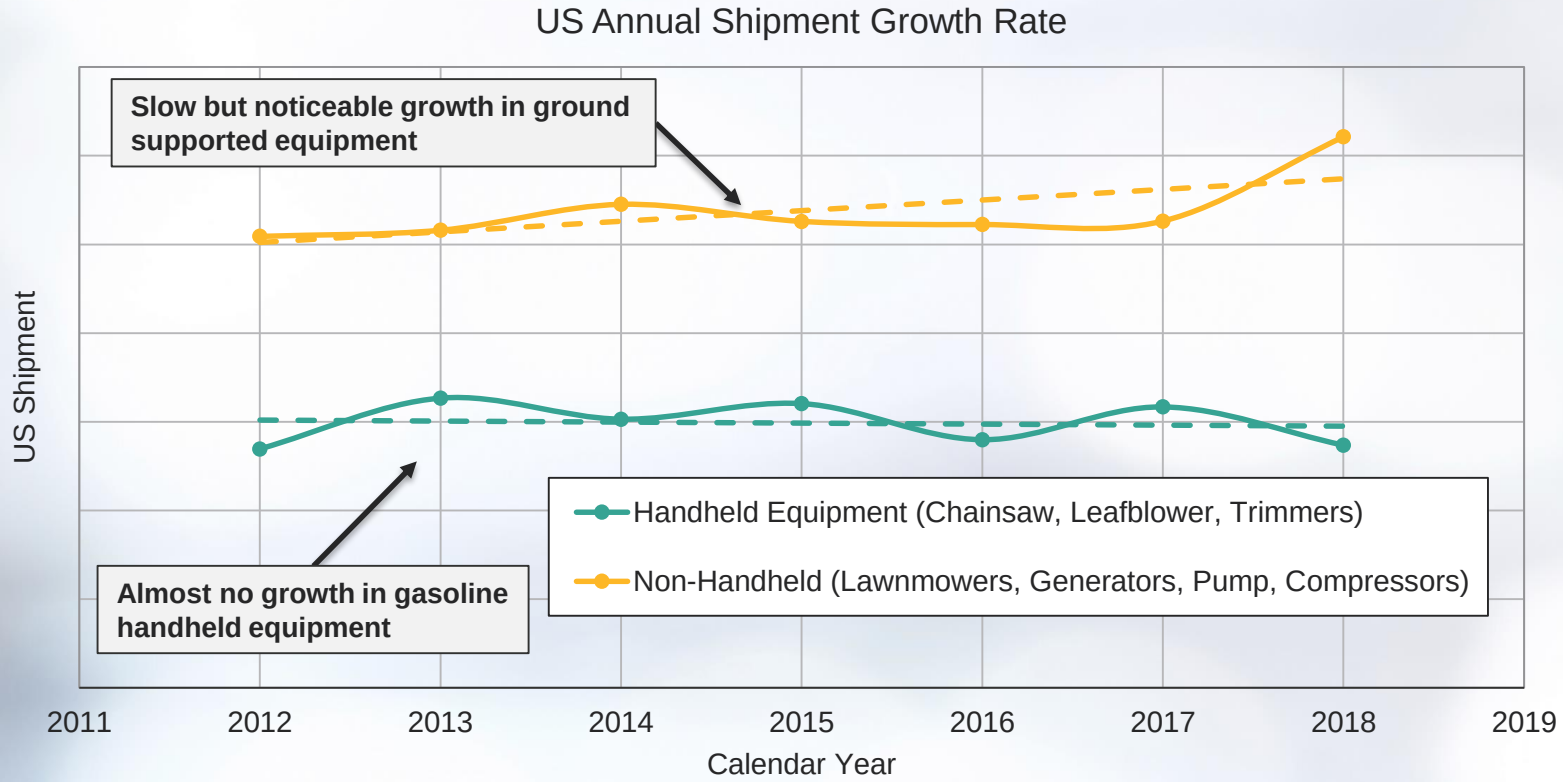
California Household Annual Growth Rates



Data Source: Dept. of Finance

Historical Growth Rates (Gasoline SORE)



This chart is only to illustrate relative growth in handheld vs. non-handheld equipment. Therefore, the absolute numbers are masked

Gas & Electric Compound Annual Growth Rate (CY2019+)

Preliminary Assumptions

Equipment		Gas 2018 New Sales*	Electric 2018 New Sales*	Gas Growth	Electric Growth	Weighted Composite Growth
Lawn & Garden	Lawn mower	399,000	140,000	0.5%	1.0%	0.6%
	Chainsaw (HH)	230,000	178,000	0.0%	1.4%	0.6%
	Leaf blower (HH)	198,000	519,000	0.0%	0.8%	0.6%
	Trimmer (HH)	393,000	461,000	0.0%	1.1%	0.6%
Light Commercial	Pump	15,000	233,000	0.0%	0.7%	0.6%
	Compressor	29,000	400,000	0.0%	0.7%	0.6%
	Generator	197,000	38,000	0.7%	0.0%	0.6%
	Pressure Washer	112,000	200,000	0.5%	0.7%	0.6%

*Estimated from 2018 SORE Survey from CS Fullerton

- Targeted future growth rate of 0.6% based on CA Household growth
  - ✓ Composite growth rate formula = gas new sales x gas growth + electric new sales x electric growth)

- **Gasoline Growth Rates assumptions** (*electric growth is back-calculated*):
  - ✓ 0.5% for lawn mower and pressure washer,
  - ✓ 0.7% for generators
  - ✓ 0% for the rest

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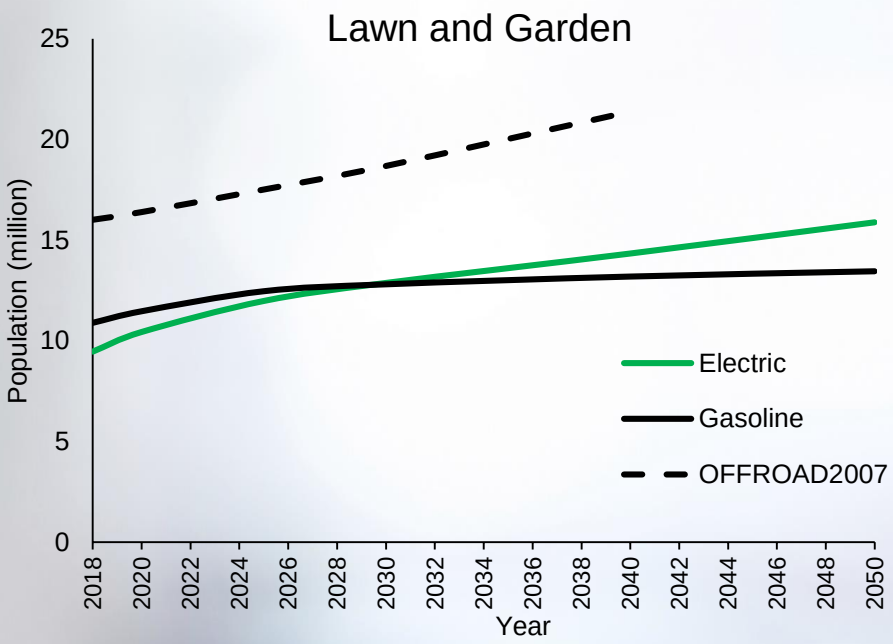
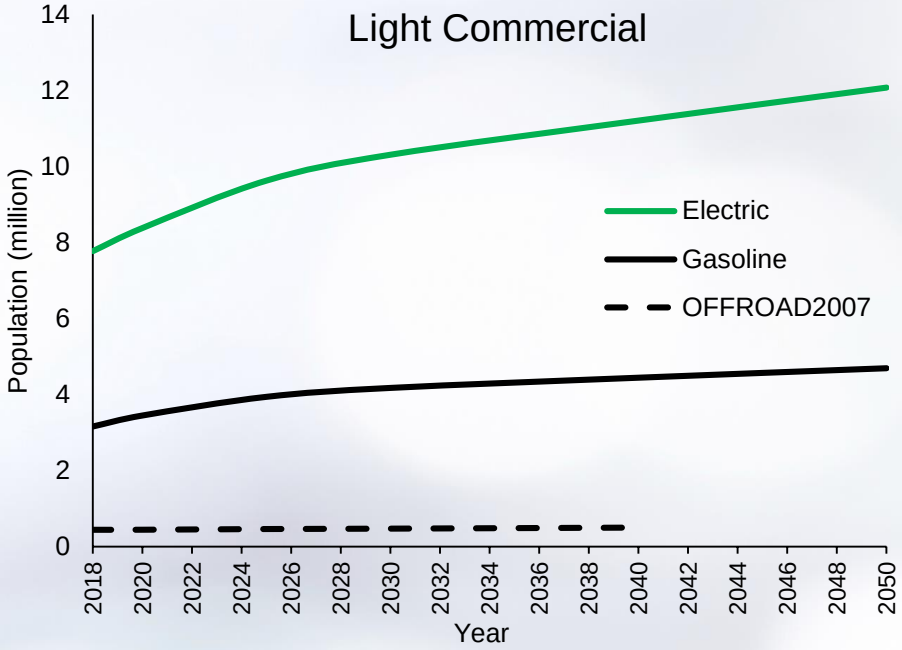
Preliminary Results

Baseline Population* – SORE2020





It is estimated that due to the **<u>baseline growth (i.e., organic growth)</u>** of the electric lawn and garden equipment, their population will surpass the gasoline equipment in 2030.

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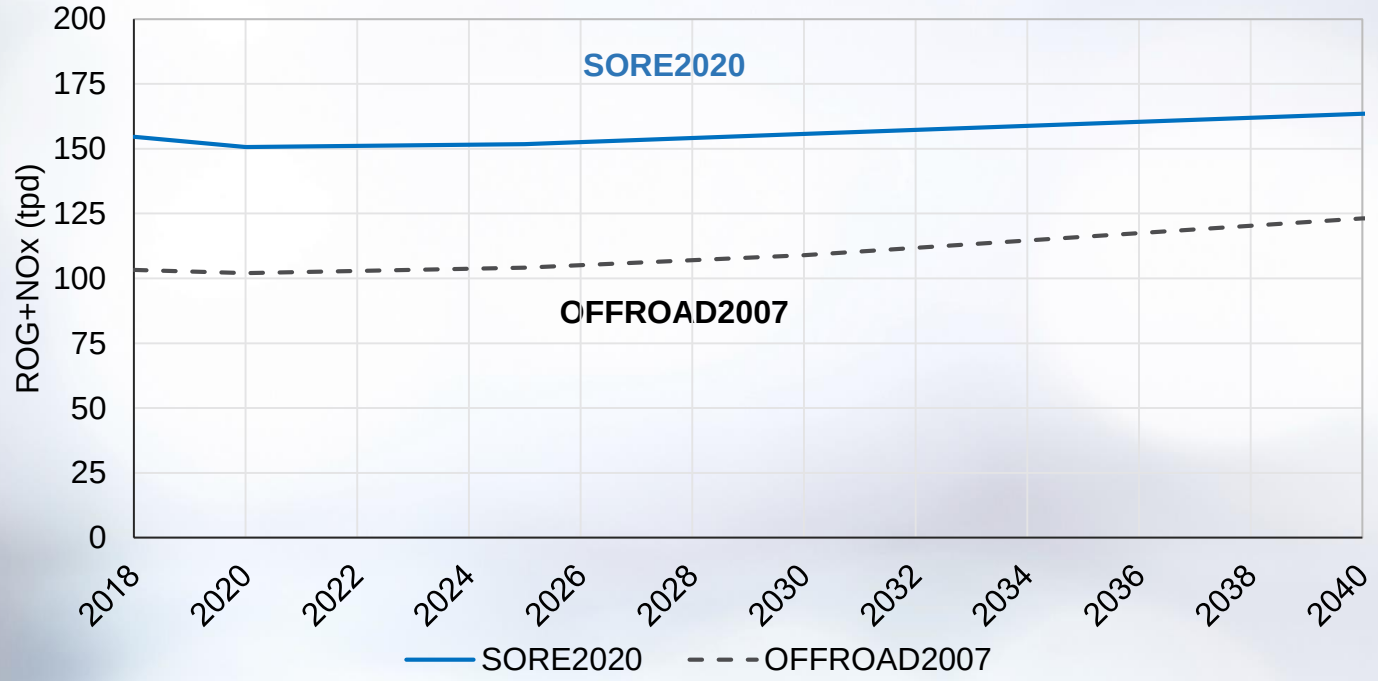
*Please note that staff utilized a regional scaling method which is why the population of equipment reported in the 2018 CSUF survey are slightly different from the ones used in the model.

Statewide Summer ROG+NOx Baseline Emissions

(Lawn & Garden + Light Commercial)

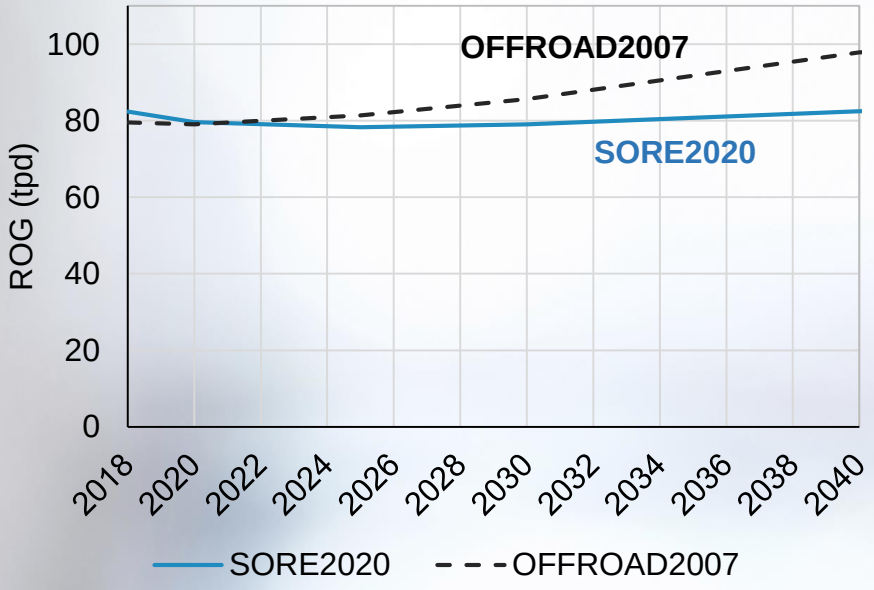


- From 2018 to 2040, the SORE2020 ROG+NOx baseline emissions increases by 5.8% (blue) as compared to a 19% increase in OFFROAD2007 (dotted line)

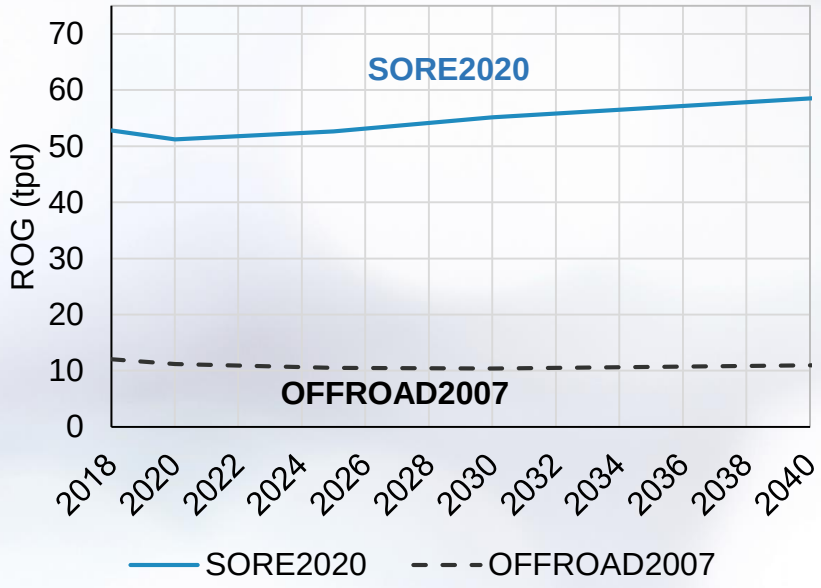
*Note: This chart includes only L&G + Light Commercial

ROG Baseline Emission (Statewide Summer)

Lawn & Garden



Light Commercial



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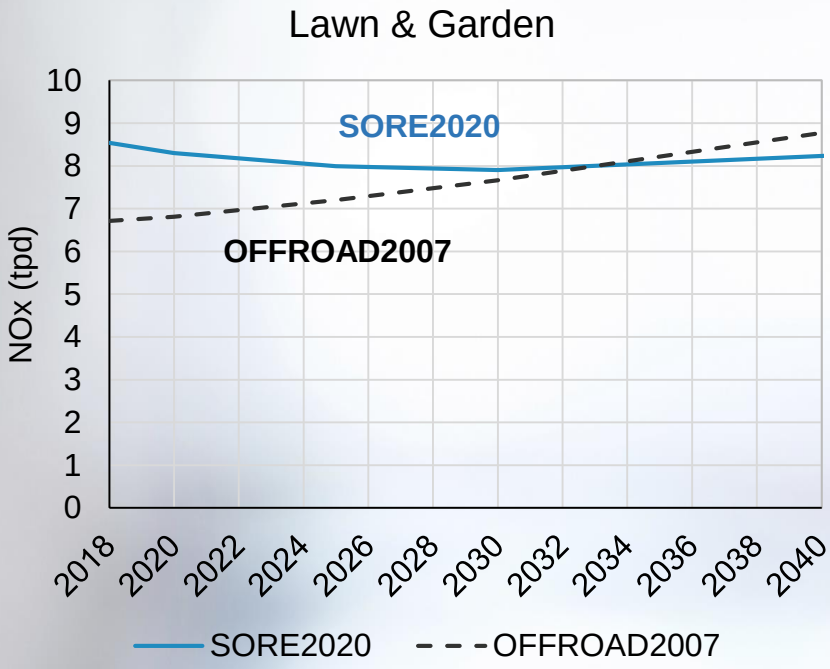
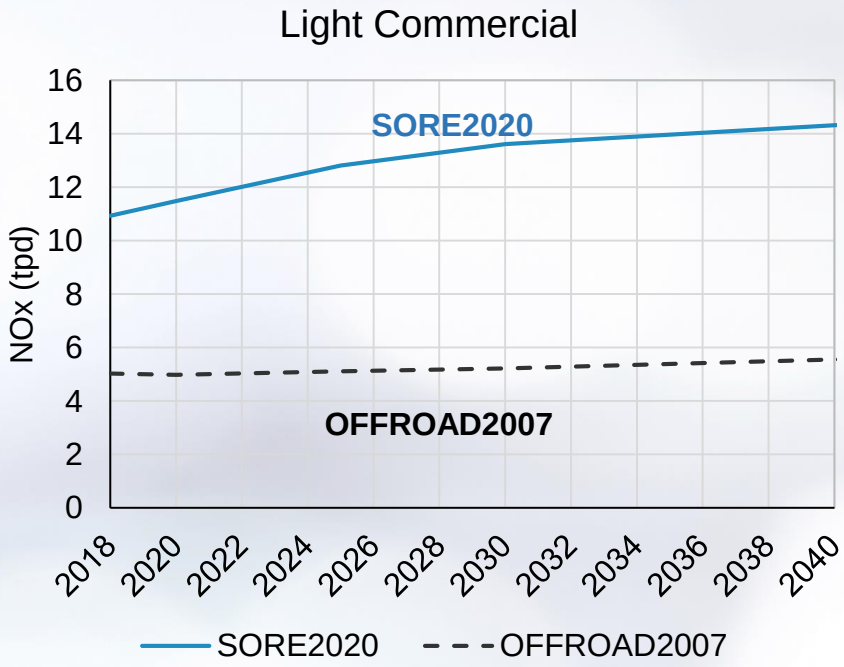
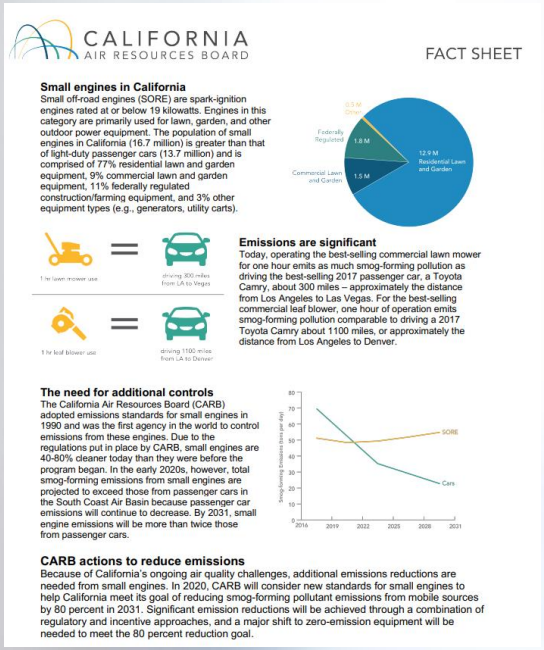
NOx Baseline Emissions (Statewide Summer)





CARB

Comparison of SORE Baseline Emissions (South Coast Air Basin)



CALIFORNIA AIR RESOURCES BOARD

FACT SHEET

Small engines in California

Small off-road engines (SORE) are spark-ignition engines rated at or below 19 kilowatts. Engines in this category are primarily used for lawn, garden, and other outdoor power equipment. The population of small engines in California (16.7 million) is greater than that of light-duty passenger cars (13.7 million) and is comprised of 77% residential lawn and garden equipment, 9% commercial lawn and garden equipment, 11% federally regulated construction/farming equipment, and 3% other equipment types (e.g., generators, utility carts).

Emissions are significant

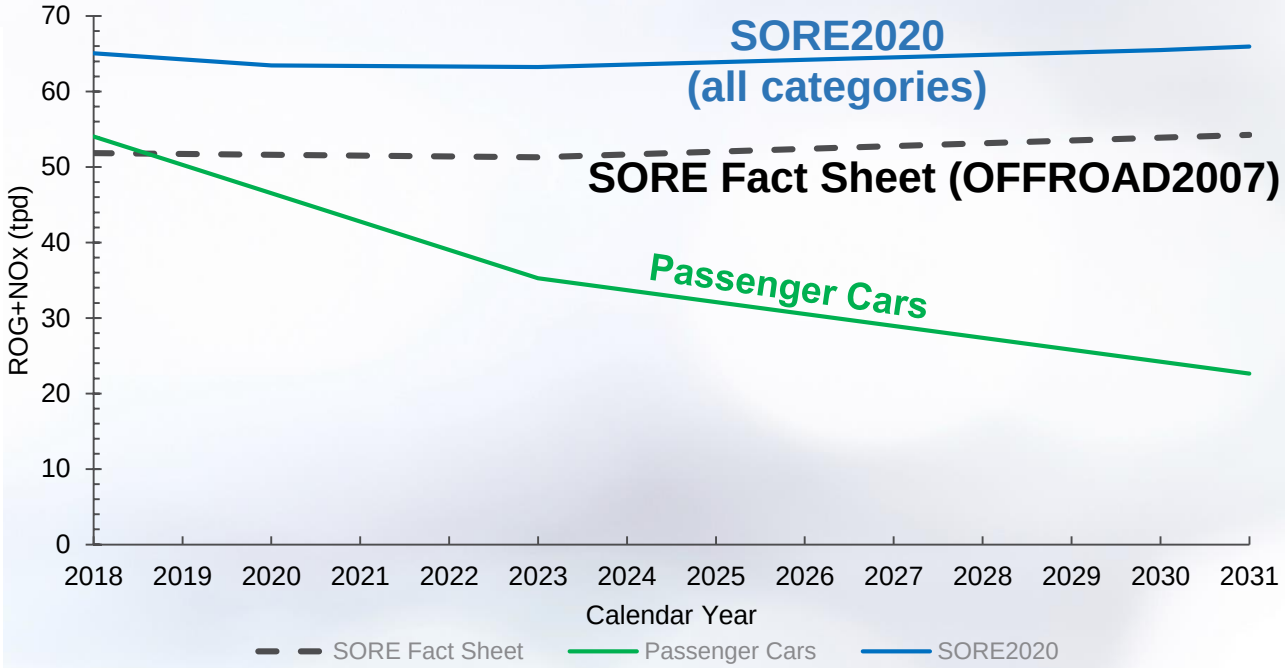
Today, operating the best-selling commercial lawn mower for one hour emits as much smog-forming pollution as driving the best-selling 2017 passenger car, a Toyota Camry, about 300 miles – approximately the distance from Los Angeles to Las Vegas. For the best-selling commercial leaf blower, one hour of operation emits smog-forming pollution comparable to driving a 2017 Toyota Camry about 1100 miles, or approximately the distance from Los Angeles to Denver.

The need for additional controls

The California Air Resources Board (CARB) adopted emissions standards for small engines in 1990 and was the first agency in the world to control emissions from these engines. Due to the regulations put in place by CARB, small engines are 40-80% cleaner today than they were before the program began. In the early 2020s, however, total smog-forming emissions from small engines are projected to exceed those from passenger cars in the South Coast Air Basin because passenger car emissions will continue to decrease. By 2031, small engine emissions will be more than twice those from passenger cars.

CARB actions to reduce emissions

Because of California's ongoing air quality challenges, additional emissions reductions are needed from small engines. In 2020, CARB will consider new standards for small engines to help California meet its goal of reducing smog-forming pollutant emissions from mobile sources by 80 percent in 2031. Significant emission reductions will be achieved through a combination of regulatory and incentive approaches, and a major shift to zero-emission equipment will be needed to meet the 80 percent reduction goal.



- In 2031, OFFROAD2007 model estimated a ROG+NOx emissions of 54 tpd for SORE in South Coast air basin, while the updated SORE2020 Model shows a higher estimate of 66 tpd

CARB

Industry Concerns

Industry Concern #1: Population

- Industry indicated that OFFROAD2007 is overestimating population of gasoline lawn & garden equipment, and underestimating population of gasoline generators (i.e., light commercial)
- After reviewing the 2018 CSUF SORE survey data, staff agree with industry comments that OFFROAD2007 model was overestimating the population of lawn & garden equipment and underestimating the population of light commercial equipment

Category	Lawn & Garden	Light Commercial	Total
OFFROAD2007 (Gas)	16,012,486	439,198	**16,451,684**
SORE2020* (Gas)	10,895,981	3,163,458	**14,059,439**

*Please note that staff utilized a regional scaling method (northern, central/upper and southern portions of the state) to scale survey data to statewide population. This is why the population of equipment reported in the 2018 CSUF survey are slightly different from the ones used in the model.

CARB

Industry Concern #2: Growth Assumptions

- Industry proposed a zero growth for both gasoline ground supported (GS) and gasoline handheld (HH) equipment
- Based on industry inputs and CARB growth analysis, the SORE2020 model assumes zero growth for gasoline HH equipment and between 0.5 – 0.7 percent growth for gasoline GS equipment
- According to 2019 OPEI's spring quarterly nationwide forecast:
  - Consumer lawn mower shipments are forecasted to grow by nearly **5** percent in 2019, with 7.4 million units shipped
  - Commercial lawn mower shipments are forecasted to grow by almost **7.5** percent in 2019, with 330,000 units shipped
  - Handheld power equipment shipments are forecasted to grow by **2.5** percent in 2019, with 25 million units shipped

Source: https://www.opei.org/news-updates/us-outdoor-power-equipment-shipments-to-grow-in-2019/

Industry Concern #3: Emission Factors

- Industry raised concerns that emission factors in the OFFROAD2007 are not representative of current technology and the model assigns unique emission values for different equipment despite similar engine technology
- For the SORE2020 model, staff utilized latest certification data supplemented with in-house exhaust and evaporative emissions test data to develop emission factors for lawn & garden as well as light commercial equipment
- According to staff analysis, OFFROAD2007 has been underestimating HC and NOx emission factors for some of the equipment such as chainsaws and generators

Next Steps

- Incorporate feedback from stakeholders
- Release draft inventory report (May 2020)
- Final inventory staff report (September/October 2020)

Contacts

- Questions, comments and feedback are encouraged and welcome
- To address comments and reflect any changes, please submit comments and any supporting data by **Friday April 24, 2020**

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Demo of SORE2020 Model