

## **OFFROAD Modeling Change Technical Memo**

**SUBJECT:** Change in Population and Activity Factors for Lawn and Garden Equipment

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### **Background**

Lawnmowers, edgers, trimmers, leaf blowers, and chainsaws all fall into the Lawn and Garden equipment category of the OFFROAD model. These equipment types primarily use small off-road engines (SORE) which are less than 25 horsepower (hp).

Under a grant from the United States Environmental Protection Agency (U.S. EPA), staff of the Air Resources Board (ARB or Board) conducted a survey of California households to determine the population and usage of lawn and garden equipment. Over 15,000 surveys were sent to randomly selected households. A subset of survey respondents also agreed to install instrumentation capable of electronically recording the date, time, and duration of usage on their lawn and garden equipment.

An analysis of the survey responses were compared to the current estimates used in the OFFROAD model for lawn and garden equipment. The results suggest that the OFFROAD model may understate both the current population and usage of several equipment types within the lawn and garden category. The current estimates are based on information provided by Booz-Allen Hamilton (BAH) as outlined in their report entitled "Off-Road Mobile Equipment Emission Inventory Estimate". Staff is proposing to use the survey results to update the population and activity estimates within the OFFROAD model.

The proposed changes would increase the current gasoline powered lawn and garden equipment emissions inventory by 76 tons per day (tpd) for exhaust hydrocarbons (HC), 18 tpd for evaporative emissions, 552 tpd for carbon monoxide (CO), 3.6 tpd for oxides of nitrogen (NOx), and 2.4 tpd for particulate matter (PM), statewide in calendar year 2000. By 2010, the proposed changes would result in an inventory which is 32 tpd higher for exhaust HC, 21 tpd higher for evaporative emissions, 375 tpd higher for CO, 5.6 tpd higher for NOx, and 0.8 tpd higher for PM, statewide (See Table 1).

**Table 1. Effect of Proposed Population and Activity Changes on Lawn and Garden Equipment Inventory (Statewide Annual Average Tons per Day)**

	HCex	Hcev	HCtotal	CO	NOx	PM
<b>Year 2000</b>						
<b>Baseline</b>	46.96	14.99	61.95	346.18	2.15	0.91
<b>New Pop/Act</b>	123.19	33.39	156.58	898.47	5.75	3.34
<b>Δ Tons</b>	76.23	18.40	94.63	552.29	3.60	2.43
<b>% Diff.</b>	162%	123%	153%	160%	167%	267%
<b>Year 2010</b>						
<b>Baseline</b>	25.72	17.17	42.89	252.86	3.28	0.20
<b>New Pop/Act</b>	58.04	38.25	96.29	627.67	8.89	0.98
<b>Δ Tons</b>	32.32	21.08	53.40	374.81	5.61	0.78
<b>% Diff.</b>	126%	123%	125%	148%	171%	390%

Where ex = exhaust and ev = evaporative emissions

### **Methodology**

In the OFFROAD model, the emission rates of lawn and garden equipment are calculated for handheld (small equipment like chainsaws), non-handheld (larger equipment like lawn mowers), pre-empted and non-preempted (equipment that is or is not subject to ARB regulation), commercial (professional), and residential (non-professional) usage.

The population and activity estimates currently used by the OFFROAD model were last presented to, and approved by the Board in 1998. A more detailed discussion to the development of these estimates can be found in ARB Mail-out #98-04 (<http://www.arb.ca.gov/msei/off-road/pubs.htm>).

Population and activity affect both the exhaust and evaporative emissions inventory estimates. The magnitude of exhaust emissions is directly affected by usage and is therefore more sensitive to changes in activity. With the exception of running losses, the evaporative emissions inventory is calculated for equipment which is not being used. Therefore, population plays a greater role than activity in estimating these emissions.

## Population

Table 2 lists the equipment types and the current estimates of population and activity for residential, gasoline-powered, lawn and garden equipment.

**Table 2. Current Residential Gas Lawn and Garden Population and Activity**

<b>Equipment</b>	<b>2000 Population</b>	<b>Activity (hr/yr)</b>
Chainsaws	548,946	7.0
Lawn and Garden Tractors	44,624	56.0
Lawn Mowers	2,378,928	20.0
Leaf Blowers / Vacuums	367,095	10.0
Other Lawn and Garden Equipment	42,398	5.0
Riding Mowers	110,579	38.0
Shredders	7,166	16.5
Snow Blowers	87,896	10.0
Tillers	94,989	18.0
Trimmers/Edgers/Brush Cutters	770,048	10.0
Wood Splitters	46,585	16.5
<b>Total</b>	<b>4,499,254</b>	<b>73,181,202<sup>1</sup></b>

<sup>1</sup>Reflects total hours/year from all equipment.

In May of 2000, the ARB was awarded a grant by the U.S. EPA to determine the population and usage rates of lawn and garden equipment in California. ARB staff approached this task by surveying approximately 1,000 randomly selected households each month from three broad regions of the state, (i.e. Northern, Southern and Central California). A total of 15,700 surveys were mailed in the course of the study. A copy of the residential survey is attached to this memo.

Surveyed participants were asked to provide information regarding their dwellings (house, apartment, condo, etc.), about who provides their yard care services (mow own lawn vs. professional gardening service), and information about each piece of lawn and garden equipment they might own (equipment type, age, fuel type, etc.). A total of 2,169 completed residential surveys, a response rate of about 14%, were received for which each participant was paid \$5.

## Survey Responses

An overwhelming number of respondents, 74 percent, reported living in single family dwellings, 71 percent owned their own homes and 18 percent were renters, the remainder did not specify. Eighty four percent of the respondents said that their home or apartment had a lawn and garden area. Fifty one percent of respondents claimed to do their own gardening.

Table 3 (below) presents the survey results pertaining to the number and types of residential lawn and garden equipment currently in use by fuel type. The resulting analysis suggests that 61 percent of all residential lawn and garden equipment is powered by gasoline, and the remaining 39 percent by electricity. It should be noted that the OFFROAD model does not currently account for electric powered lawn and garden equipment.

**Table 3.  
Residential Lawn and Garden Equipment Population Survey Results**

	<b>Gas</b>	<b>%</b>	<b>Diesel</b>	<b>%</b>	<b>Electric</b>	<b>%</b>	<b>Total</b>
Chainsaws	396	68	0	0	187	32	583
Lawn and Garden Tractors	41	79	10	19	1	2	52
Lawn Mowers	772	85	0	0	133	15	905
Leaf Blowers / Vacuums	173	32	0	0	372	68	545
Other Lawn & Garden Equip.	66	64	0	0	37	36	103
Riding Mowers	87	96	2	2	2	2	91
Shredders	45	76	0	0	14	24	59
Snow Blowers	12	100	0	0	0	0	12
Tillers							
Trimmers/Edgers/Brush Cutters	534	47	0	0	610	53	1,144
Wood Splitters	38	100	0	0	1	0	39
<b>Total</b>	<b>2,164</b>	<b>61%</b>	<b>12</b>	<b>0%</b>	<b>1,357</b>	<b>39%</b>	<b>3,533</b>

By normalizing the equipment population by the number of households represented in the surveys, an estimate can be made regarding the percentage of households with lawn and garden equipment by type and fuel utilized. Finally, by applying these percentages to the 11,502,870 California households as reported by the latest census (<http://quickfacts.census.gov/qdf/states/06000.html>) an estimate of the total lawn and garden equipment population can be derived (see Table 4. below).

The resulting estimate of 11.6 million pieces of residential, gasoline powered lawn and garden equipment (about one piece of equipment per household), can be contrasted to the 4.5 million units (about one piece per every 2.5 households) currently assumed in the OFFROAD model (See Tables 2 and 4).

**Table 4.**  
**Revised Estimates of Residential Lawn and Garden Equipment Populations**  
**(Year 2000)**

	<b>Gas</b>	<b>Diesel</b>	<b>Electric</b>	<b>Total</b>
Chainsaws	2,100,109	0	991,718	3,091,827
Lawn and Garden Tractors	217,436	53,033	5,303	275,772
Lawn Mowers	4,094,152	0	705,340	4,799,492
Leaf Blowers / Vacuums	917,472	0	1,972,830	2,890,302
Other Lawn & Garden Equip.	350,018	0	196,222	546,240
Riding Mowers	461,388	10,607	10,607	482,602
Shredders	238,649	0	74,246	312,895
Snow Blowers	63,640	0	0	63,640
Tillers*	94,989	0	0	94,989
Trimmers/Edgers/Brush Cutters	2,831,965	0	3,235,016	6,066,981
Wood Splitters	201,526	0	5,303	206,829
<b>Total</b>	<b>11,571,344</b>	<b>63,640</b>	<b>7,196,585</b>	<b>18,831,569</b>

\*It should be noted that no survey information regarding tillers was received, therefore, the OFFROAD estimate of the tiller population will be retained.

The dramatic difference in equipment population estimates lead staff to seek a source of information independent of the BAH study and the survey data to either support or refute the current assumptions. Staff analyzed historic nationwide sales data covering several types of lawn and garden equipment and the estimates of their useful lives. This information was made available by the equipment manufacturers and is also posted on their web site (<http://www.opei.org>).

By assuming a constant California sales fraction of ten percent of nationwide production for all lawn and garden equipment, (with the exception of snow blowers where one percent of sales was assumed), and using the model's current assumptions of age distribution and attrition, the resulting population estimates can be compared and contrasted (see Table 5).

**Table 5. Comparison of Residential Lawn and Garden Population Estimates**

<b>Equipment</b>	<b>OFFROAD</b>	<b>Survey Data</b>	<b>Sales Data</b>
Lawn Mowers (Walk Behind)	2,378,928	4,094,152	4,031,199
Lawn Mowers (Riding)	110,579	461,388	937,265
Chainsaws	548,946	2,100,109	1,262,202
Leaf Blowers	367,095	917,472	1,106,605
Trimmer/Edger/Brush Cut	770,048	2,831,965	3,484,871
Snow Blowers	87,896	63,640	40,623
Tractors	44,624	217,436	132,118

Staff proposes to use the results of the survey as the basis for updating the equipment population estimates within the OFFROAD model. Staff's recommendation is based on the fact that these population estimates are more direct in their derivation, and because there is better agreement between equipment manufacturer's sales data and the survey data for most categories of equipment.

### **Growth Rates**

The growth rates used in the OFFROAD model, and the estimates of how the population of lawn and garden equipment will change in the future, is currently based on the change in the number of California households. Staff is not proposing to change the growth rates at this time.

### **Activity**

Activity is expressed in hours per year for lawn and garden equipment. The current estimates of activity used in the OFFROAD model are derived from the BAH study mentioned earlier.

In order to update the estimate of what percent of the total equipment population is in use at any given time, and for how long, a subset of survey respondents were asked to install event loggers on their lawn and garden equipment. Respondents were paid a \$25 incentive for their participation.

In the course of the study, 224 event loggers were installed on various pieces of lawn and garden equipment for approximately two weeks. These event loggers were capable of recording when and how long each piece of equipment was used. Because the equipment monitoring was staggered across several months, an estimate of annual average operation, as well as daily and seasonal variations in usage could be determined.

A summary of the average usage rates derived from the event logger data is displayed in Table 6 below. It is important to note that the proposed activity estimates are not directly comparable to those currently used in OFFROAD in that they do not represent the fleet average. Rather, the event logger data only reflects the average usage of equipment in operation.

For example, only 18 percent of the walk behind lawn mowers were found to be in use at any given time according to the event logger data. Taking this fact into account, the OFFROAD estimate of 20 hours per year can be directly compared to the proposed rate of about 16 hours per year (85.3 hours/year X 0.182 equipment used).

**Table 6. OFFROAD and Event Logger Residential Equipment Activity**

	Fleet Average Hrs/Yr.		Logger/Survey Data	
	Current	Proposed	Hrs/Yr.	% Used
Lawn Mowers(Walk Behind)	20.0	15.5	85.3	18.2
Chainsaws	7.0	4.9	23.5	21.0
Leaf Blowers	10.0	4.8	38.2	12.5
Lawn Mowers (Riding)	38.0	28.2	131.6	21.4
Trimmer/Edger/Brush Cut	10.0	21.5	96.2	22.3
Other	5.0	4.3	29.8	14.3
Tractors	56.0	14.6	136.0	10.7
Snow Blowers	10.0	1.8	10.0	18.2
Shredders	16.5	0.9	16.5	5.6
Wood Splitters	16.5	1.1	16.5	6.7
Tillers	18.0	18.0	18.0	

For riding and walk behind lawn mowers, chainsaws, leaf blowers, trimmers/edgers and brush cutters, other lawn and garden equipment, and tractors, a sufficient amount of event logger data was available to determine the percent of equipment in use at any given time. For other categories of equipment including, snow blowers, shredders, and wood splitters, survey responses were used (See Table 6 above).

Where insufficient information was available to suggest a change in the estimate of annual hours of operation (i.e. snow blowers, shredders, tillers and wood splitters), the current assumption of hours per year operation was retained. Because no additional information was available for tillers, the annual use hours will be assumed to apply to 100% of the tillers. The proposed changes to the equipment population and activity estimates are summarized in Table 7 below.

**Table 7. Proposed Residential Gasoline Lawn and Garden Population and Activity Estimates – Calendar Year 2000**

Equipment	Population	Hrs/Yr	Total Hrs/Yr
Chainsaws	2,100,109	4.9	10,290,534
Lawn and Garden Tractors	217,436	14.6	3,174,566
Lawn Mowers	4,094,152	15.5	63,459,356
Leaf Blowers / Vacuums	917,472	4.8	4,403,866
Other Lawn & Garden Equip.	350,018	4.3	1,505,077
Riding Mowers	461,388	28.2	13,011,142
Shredders	238,649	0.9	214,784
Snow Blowers	63,640	1.8	114,552
Tillers	94,989	18.0	1,709,802
Trimmers/Edgers/Brush Cutters	2,831,965	21.5	60,887,248
Wood Splitters	201,526	1.1	221,679
<b>Total</b>	<b>11,571,344</b>		<b>158,992,606</b>

## **Commercial Equipment**

Professional gardeners and a number of institutions, including universities, businesses, and golf courses, were also sent surveys. Unfortunately, few responses were received. Staff proposes to maintain the same assumption of population fraction of residential and commercial equipment currently used in OFFROAD. Therefore, the population of commercial equipment will change in proportion to the change in the residential equipment population.

Staff is not proposing to change the hour per year activity assumption for commercial equipment in the OFFROAD model at this time. However, based on the limited survey and event logger information received, it will no longer be assumed that this equipment is operated on weekends (See Table 8).

**Table 8. Commercial Gasoline Lawn and Garden Population and Activity Estimates – Calendar Year 2000**

<b>Equipment</b>	<b>Current Population</b>	<b>Proposed</b>		
		<b>Population</b>	<b>Hrs/Yr</b>	<b>Total Hrs/Yr</b>
Chainsaws	47,734	182,618	405	73,960,290
Lawn and Garden Tractors	1,380	6,725	180	1,210,500
Lawn Mowers	135,009	233,217	320	74,629,440
Leaf Blowers / Vacuums	41,498	104,065	275	28,617,875
Other Lawn & Garden Equip.	53,962	445,478	96	42,765,888
Riding Mowers	3,420	14,269	380	5,422,220
Shredders	4,081	135,812	190	25,804,280
Snow Blowers	9,766	7,072	60	424,320
Tillers	44,701	44,701	72	3,218,472
Trimmers/Edgers/Brush Cutters	93,138	346,127	170	58,841,590
Wood Splitters	26,204	113,358	190	21,538,020
<b>Total</b>	<b>460,893</b>	<b>1,633,442</b>		<b>336,432,895</b>

## **Effect on Emissions**

The effect that these changes would have on the overall emissions inventory for lawn and garden equipment (residential and commercial) is displayed in Table 9 for exhaust emission in calendar years 2000 and 2010 and for evaporative emissions in Table 10. Tables 11 and 12 present this same information for several areas of the state.

The exhaust emission rates used in Table 9 are those currently used in the OFFROAD model. The evaporative emission rates used in Table 10 are proposed for inclusion in OFFROAD as outlined in the Technical Memorandum entitled "Addition of Evaporative Emissions for Small Off-Road Engines."



**Table 9. Effect of Proposed Population and Activity Changes  
on Lawn and Garden Equipment Inventory  
(Statewide Annual Average Tons per Day - Exhaust)<sup>1</sup>**

	Population	HC	CO	NOx	PM
<b>Year 2000</b>					
<b>Baseline</b>	4,960,147	46.96	346.18	2.15	0.91
<b>New Pop</b>	13,204,786	172.66	1231.87	8.04	4.51
<b>New Act/Pop</b>	13,204,786	123.19	898.47	5.75	3.34
<b>Δ Tons</b>		76.23	552.29	3.60	2.43
<b>% Diff.</b>	<b>166%</b>	<b>162%</b>	<b>160%</b>	<b>167%</b>	<b>267%</b>
<b>Year 2010</b>					
<b>Baseline</b>	5,682,541	25.72	252.86	3.28	0.20
<b>New Pop</b>	15,127,928	89.70	<b>864.64</b>	12.49	1.36
<b>New Act/Pop</b>	15,127,928	58.04	627.67	8.89	0.98
<b>Δ Tons</b>		32.32	374.81	5.61	0.78
<b>% Diff.</b>	<b>166%</b>	<b>126%</b>	<b>148%</b>	<b>171%</b>	<b>390%</b>

<sup>1</sup>The Δ Tons compares the baseline and the revisions to both population and activity. Rest is resting losses and Run is running losses.

**Table 10. Effect of Proposed Population and Activity Changes  
on Lawn and Garden Equipment Inventory  
(Statewide Annual Average Tons per Day - Evap.)**

	Population	Diurnal	Rest	Hot Soak	Run
<b>Year 2000</b>					
<b>Baseline</b>	4,960,147	4.93	4.65	1.16	4.25
<b>New Pop</b>	13,204,786	11.89	11.21	2.99	10.31
<b>New Act/Pop</b>	13,204,786	11.89	11.21	2.99	7.30
<b>Δ Tons</b>		6.96	6.56	1.83	3.02
<b>% Diff.</b>	<b>166%</b>	<b>141%</b>	<b>141%</b>	<b>158%</b>	<b>71%</b>
<b>Year 2010</b>					
<b>Baseline</b>	5,682,541	5.65	5.33	1.32	4.87
<b>New Pop</b>	15,127,928	13.62	12.84	3.42	11.82
<b>New Act/Pop</b>	15,127,928	13.62	12.84	3.42	8.37
<b>Δ Tons</b>		7.97	7.51	2.10	3.50
<b>% Diff.</b>	<b>166%</b>	<b>141%</b>	<b>141%</b>	<b>159%</b>	<b>72%</b>

<sup>1</sup>The Δ Tons compares the baseline and the revisions to both population and activity. Rest is resting losses and Run is running losses.

**Table 11. Baseline and Proposed Emissions Inventory for Various Areas of the State (2000 Annual Average - Tons per Day)**

Area	HCex	HCev	Hctotal	CO	NOx	PM
<b>Baseline</b>						
<b>Santa Barbara Co</b>	0.55	0.16	0.71	4.03	0.03	0.01
<b>South Coast AB</b>	20.65	6.72	27.37	151.41	0.94	0.40
<b>San Francisco AB</b>	9.06	2.73	11.79	66.56	0.42	0.18
<b>San Joaquin AB</b>	3.47	1.12	4.59	25.72	0.16	0.07
<b>Sacramento AB</b>	3.10	0.98	4.08	23.00	0.14	0.06
<b>New Population and Activity Estimates</b>						
<b>Santa Barbara Co</b>	1.44	0.34	1.78	10.51	0.07	0.04
<b>South Coast AB</b>	54.18	14.15	68.33	394.28	2.52	1.47
<b>San Francisco AB</b>	23.86	5.67	29.53	173.66	1.11	0.65
<b>San Joaquin AB</b>	9.13	2.35	11.48	66.80	0.43	0.25
<b>Sacramento AB</b>	8.13	2.04	10.17	59.47	0.38	0.22

**Table 12. Baseline and Proposed Emissions Inventory for Various Areas of the State (2010 Annual Average - Tons per Day)**

Area	HCex	HCev	HCtotal	CO	NOx	PM
<b>Baseline</b>						
<b>Santa Barbara Co</b>	0.29	0.19	0.48	2.81	0.04	0.00
<b>South Coast AB</b>	11.02	7.70	18.72	107.82	1.40	0.09
<b>San Francisco AB</b>	4.69	3.12	7.81	45.84	0.59	0.04
<b>San Joaquin AB</b>	2.08	1.29	3.37	20.46	0.26	0.02
<b>Sacramento AB</b>	1.78	1.12	2.90	17.63	0.23	0.01
<b>New Population and Activity Estimates</b>						
<b>Santa Barbara Co</b>	0.65	0.39	1.04	7.00	0.10	0.01
<b>South Coast AB</b>	24.90	16.21	41.11	268.95	3.81	0.43
<b>San Francisco AB</b>	10.60	6.50	17.10	114.33	1.62	0.18
<b>San Joaquin AB</b>	4.69	2.70	7.39	50.69	0.72	0.08
<b>Sacramento AB</b>	4.02	2.34	6.36	43.54	0.62	0.07

## **Modeling Change**

The OFFROAD model will be modified to accept the population and activity changes displayed in Tables 7 and 8.

## **Survey Results**

	<b>Residential</b>	<b>Commercial</b>	<b>Institutional</b>
Surveys Sent	15,700	705	713
Completed Surveys	2,169	39	103
Event Logger Participants	316	2	1
Completed Event Loggers	224	1	1

### **How Surveys Were Received:**

Email = 76 Fax = 14 Mail = 2079

### **Rent or Own Property?**

Own = 1539 Rent = 401 Unspecified = 229

### **Does Property Have Lawn and Garden Area?**

Yes = 1816 No = 353

### **Residence Type?**

House = 1598 Apartment = 343 Commercial = 9 Other = 3 Unspecified = 216

### **Who Does Lawn and Garden Maintenance?**

Condo/Home Association = 104  
Gardening Service Does Everything = 331  
Gardening Service Does Lawn Only = 135  
I or Others Living at the Property = 1107  
Landlord Does Everything = 168  
Unspecified = 324

### Event Logger Summary

Equipment	# of Loggers	Avg. Usage (mins)	% of Pop Used
Lawn Mower	176	14:01	17.4
Chainsaw	2	3:52	21.0
Leaf Blower	3	6:17	12.5
Riding Mower	6	21:38	21.4
Trimmer	7	15:49	18.0
Tractor	3	22:21	9.6
Other	5	4:54	14.3

### Raw Responses – Pieces of Equipment by Fuel Type

Equipment	Gas	Diesel	Elec	Total	% Gas	%Diesel	% Elec
Chainsaws	396	0	187	583	67.9%	0.0%	32.1%
Riding Mowers	87	2	2	91	95.6%	2.2%	2.2%
Lawn Mowers	772	0	133	905	85.3%	0.0%	14.7%
Leaf Blowers	173	0	372	545	31.7%	0.0%	68.3%
Shredders	45	0	14	59	76.3%	0.0%	23.7%
Snow Blowers	12	0	0	12	100.0%	0.0%	0.0%
Trimmers/Edgers	534	0	610	1144	46.7%	0.0%	53.3%
Tractors	41	10	1	52	78.8%	19.2%	1.9%
Wood Splitters	38	0	1	39	97.0%	0.0%	3.0%
Others	66	0	37	103	64.1%	0.0%	35.9%
<b>Totals</b>	<b>2,164</b>	<b>12</b>	<b>1,357</b>	<b>3,533</b>	<b>61.0%</b>	<b>0.6%</b>	<b>38.4%</b>

### Percent of households with Equipment (Based on 2169 Surveys)

% of Households with Equipment				New Population Estimates*		
Equipment	%Gas	% Diesel	% Elec	Gas	Diesel	Electric
Chainsaws	18.3%	0.0%	8.6%	2,100,109		991,718
Riding Mowers	4.0%	0.1%	0.1%	461,388	10,607	10,607
Lawn Mowers	35.6%	0.0%	6.1%	4,094,152		705,340
Leaf Blowers	8.0%	0.0%	17.2%	917,472		1,972,830
Shredders	2.1%	0.0%	0.6%	238,649		74,246
Snow Blowers	0.6%	0.0%	0.0%	63,640		
Trimmers	24.6%	0.0%	28.1%	2,831,965		3,235,016
Tractors	1.9%	0.5%	0.0%	217,436	53,033	5,303
Wood Splitters	1.8%	0.0%	0.0%	201,526		5,303
Others	3.0%	0.0%	1.7%	350,018		196,222
<b>Totals</b>	<b>99.4%</b>	<b>1.0%</b>	<b>62.6%</b>	<b>11,476,355</b>	<b>63,640</b>	<b>7,196,585</b>

\*based on 11,502,870 California households – (US Census – 2000); does not include tillers (94,989)