Emissions of HFC-134a in Auto Dismantling and Recycling

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ABSTRACT

The United States Environmental Protection Agency (U.S. EPA) has identified the recovery of HFC-134a, a vehicle refrigerant used in 1995 and newer model years, from End of Life Vehicles (ELVs) as a greenhouse gas reduction strategy. This analysis estimates the amount of HFC-134a remaining in the air-conditioning units of California's population of ELVs, defined as vehicles that have been issued a junk title or salvage certificate over their lifetime, to determine if enforcement of federal regulations pertaining to its removal and storage on licensed vehicle dismantler lots in California is warranted. To determine the amount of HFC-134a remaining in ELVs, refrigerant samples, including HFC-134a and its predecessor, R-12, were obtained from 2,002 ELVs on 30 licensed vehicle dismantler lots throughout California from January 2008 through August 2009. Of these sampled vehicles, 1,340, or 67%, were ELVs. Across the sampled ELVs containing HFC-134a, an average of 27% of the vehicles' total refrigerant capacity, or 220 grams of HFC-134a, was recovered. The amount of HFC-134a recovered from sampled ELVs varied widely by vehicle and was not strongly correlated with vehicle or geographic specific characteristics.

In order to extrapolate our sample findings to the entire state, California's ELV population from 2000 through 2008 was estimated using California Department of Motor Vehicle (CA DMV) registration records as well as vehicle Smog Check histories. The mean model year of the ELV population from 2000 through 2008 was significantly different from the sampled ELVs, though both distributions were normal. We then narrowed the scope of the analysis to focus on the time frame 2005 through 2007 to better reflect the distribution of the sample, as well as the forecasted population of ELVs going forward. From 2005 through 2007, there were 1,020,938 ELVs containing HFC-134a, an average of 340,313 a year.

From 2000 through 2008, ELVs were owned by 2,107 unique vehicle dismantler locations in California as well as 487 non-dismantling businesses. In 2007, the most recent year for which reliable data is available, 79% of the ELV population was owned by licensed vehicle dismantlers within California. An additional 20% of the ELV population in California was owned by non-dismantler businesses while 1% was owned by dismantlers operating without a proper license. Any U.S. EPA efforts to improve the recovery of HFC-134 would be successful in regulating 79% of the ELV population. Thus, we estimate that an average of 59,146 kg of HFC-134a remained in the air conditioning units of ELVs at licensed California dismantlers each year from 2005 through 2007.

Each year the portion of ELVs containing HFC-134a grows by an average of 3%. The total amount of HFC-134a remaining in ELVs on vehicle dismantler lots will continue to grow and by 2012 we project that approximately 68,566 kg of HFC-134a will remain in ELVs on licensed dismantler lots in California each year. Thus, the maximum potential benefit to any increased enforcement of U.S. EPA regulations pertaining to the removal and storage of HFC-134a would increase from 59,146 kg of HFC-134a in 2007 to 68,566 kg of HFC-134a in 2012.

EXECUTIVE SUMMARY

Background

Under sections 608 and 609 of the Clean Air Act, the United States Environmental Protection Agency (U.S. EPA) established guidelines for the removal, recovery, and possible recycling of vehicle refrigerant, including HFC-134a, from End of Life Vehicles (ELVs). ELVs are vehicles that have or those vehicles that have reached the end of their drivable lives (US EPA 1). However, there has been no aggressive enforcement of these requirements. In order to improve the recovery rate of HFC-134a, a vehicle refrigerant used in 1995 and newer model years, the California Air Resources Board (CARB) has identified enforcement of these federal requirements as a possible greenhouse gas (GHG) reduction strategy, though little is known about the amount of refrigerant remaining in ELVs.

Methodology

This analysis estimates the amount of HFC-134a remaining in the ELV population of California from 2000 through 2008 as well the population from 2005 through 2007. We estimate the extended time frame from 2000 through 2008 in order to characterize the entire ELV population. We then look at the population from 2005 through 2007 to best estimate the potential benefit of increased regulation on the current and forecasted population of ELVs.

We define an ELV as a vehicle that has been issued a junk title or salvage certificate. Using data from the California Department of Motor Vehicles (CA DMV) and smog check records, vehicles with lapsed registration records were identified and investigated further to determine their CA DMV status. From this group, we estimated the number of ELVs and characterized them by CA DMV classification, smog check results, geographic location, and vehicle specific attributes. In order to quantify the amount of HFC-134a within this ELV population, 2,002 vehicles were sampled at vehicle dismantlers through out the state. The 30 participating vehicle dismantlers were licensed by the state of California and were members of the State of California Auto Dismantlers Association (SCADA).

Results

In order to estimate the population of ELVs, we identified 39,645,818 vehicles with lapsed registration status from 2000 through 2008. Of this total, 8,537,707, or 22%, were classified as ELVs. An additional 60% of vehicles were found to have non-ELV DMV status, and 6% went out of state. For the remaining 12% of vehicles with lapsed registration status, CA DMV has either lost track of the vehicle, no CA DMV records exist for the vehicle, or multiple registration histories exist for VIN. These 4,426,062 vehicles with lapsed registration status were excluded from the analysis due to lack of accurate data, reducing the precision of the analysis.

The 8.537.707 ELVs from 2000 through 2008 were owned by 2,107 different vehicle dismantlers in California as well as 487 non-dismantling and out of state businesses. Vehicle dismantlers operating without proper licenses as required by California Vehicle Code owned 1% of the ELV population from 2000 through 2008, while out of state dismantlers and non-dismantling businesses owned 19%. For the remaining 11% of ELVs, the last owner was a private individual or an entity that we were not able to identify.

In order to best encapsulate the current ELV population, we then focus on the ELV population from 2005 through 2007. This ELV population is comprised of 3,190,430 vehicles. These ELVs were owned by 1,629 vehicle dismantlers in California as well as 210 non-dismantling and out of state businesses. Licensed California dismantlers owned 79% of these ELVs, dismantlers without the proper licenses owned 1%, out of state and non-dismantler businesses owned 15%, and unidentified entities owned the remaining 5% of these vehicles. Data pertaining to vehicle ownership has dramatically improved in recent years, driving the differences in these results from the entire ELV population from 2000 through 2008.

Extrapolating the findings from the ELV population from 2005 through 2007, any regulation targeting recovery of HFC-134a from licensed California vehicle dismantlers will regulate 79% of the California ELV population. From 2005 through 2007, 1,020,938 ELVs were 1995 or newer model year vehicles, an average of 340,313 a year. As time passes the portion of ELVs containing HFC-134a continues to increase. From 2000 through 2008, the ELV population containing HFC-134a increased an average of 3% each year. From January of 2000 through December of 2008, the average percentage of ELVs containing HFC-134a increased from 9% to 44% of the total population. Thus. the population of ELVs containing HFC-134a and the potential benefit from increased enforcement of U.S. EPA regulations will continue to grow.

Across the sample of 2,002 vehicles, 1,966 vehicles had air conditioning systems utilizing HFC-134a. For these vehicles, the recovered HFC-134a varied widely with an average of 27% of the total HFC-134a capacity recovered. Thirty-six sampled vehicles contained the precursor to HFC-134a, R-12 that was phased out in 1994 model year vehicles. An average of 10% of refrigerant capacity was recovered from these vehicles, again with great variation by vehicle. Focusing the analysis on ELVs containing HFC-134a narrows the sample to 1,365 vehicles or 68% of the total. Vehicles containing HFC-134a and classified as an ELV had an average of 26% of their total refrigerant capacity recovered, however the recovered amounts varied widely and were not strongly correlated with vehicle or geographic specific characteristics. These vehicles had an average HFC-134a capacity of 853 grams and 220 grams were recovered on average. Pursuant to CARB's goal of improving HFC-134a recovery, extrapolating the sample findings to the ELV population, a maximum of 26% of total HFC-134a capacity or an average of 220 grams per vehicle could be recovered from ELVs on licensed dismantler lots in California.

Conclusions

From 2005 through 2007, an average of 340,313 ELVs containing HFC-134a were on vehicle dismantler lots in California each year. Across our sample of 1,966 ELVs containing HFC-134a, 26% of refrigerant capacity, or 220 grams, was recovered. Extrapolating the mean capacity and amount recovered from the sample to this population, we find that each year the ELV population contained 74,869 kg of HFC-134a. Licensed vehicle dismantlers in California owned 79% of the ELV population in 2007. Thus, on average there was 59,146 kg of HFC-134a remaining on in ELVs on licensed dismantler lots in California from 2005 through 2007. Based on this information, the maximum benefit of CARB increasing efforts to support U.S. EPA's regulation overseeing the removal and storage of HFC-134a from licensed California vehicle dismantlers was 59,146 kg a year in from 2005 through 2007.

The percentage of ELVs containing HFC-134a continues to grow approximately 3% a year. Thus, the maximum potential benefit to any increased enforcement of U.S. EPA regulations guiding the removal and storage of HFC-134a will increase. We project that by 2012 there will be 68,566 kg of HFC-134a in ELVs on licensed vehicle dismantler lots in California each year.

1. INTRODUCTION

Under sections 608 and 609 of the Clean Air Act, the United States Environmental Protection Agency (U.S. EPA) established guidelines for the removal, recovery, and possible recycling of vehicle refrigerant from End of Life Vehicles (ELVs), or those vehicles that have reached the end of their drivable lives (US EPA 1). However, U.S. EPA does not aggressively enforce these requirements. Improving the recovery rate of HFC-134a, the mandatory vehicle refrigerant for all 1995 and newer model year vehicles, from ELVs has been identified by the California Air Resources Board (CARB) as a possible greenhouse gas reduction strategy, though little is known about the amount of refrigerant remaining in this vehicle population. This analysis estimates the maximum amount of HFC-134a remaining in California's ELVs in order to determine if enforcement of the federal regulations pertaining to its removal and recovery is warranted.

Much of the literature regarding the emission of HFC-134a from vehicles focuses on leakage that occurs throughout a vehicle's lifetime. In 2001, Winfried Schwarz analyzed the HFC-134a levels of 641 passenger cars in Germany. These vehicles were tested at working body shops and had an average age of 34 months. The analysis found that an average of 62.5% of refrigerant capacity had been lost by the time of testing (Schwarz 2001). In 2003, 276 vehicles were sampled throughout the European Union and found to have an annual leakage rate of 52.4 grams of HFC-134a a year, or 6.9% of total capacity. (Schwarz et al 2003). Relying mainly on survey data collected from vehicle owners and dismantlers staff at the California Air Resources Board (CARB) estimated an annual HFC-134a loss of 85 grams across 966 vehicles (Vincent 2004). Changing their focus to the amount of HFC-134a remaining in ELVs, CARB summarized data from five separate studies (including Schwarz 2003) to conclude that an average of 17% of total HFC-134a capacity remained in vehicles at dismantling yards (CARB 2004). The authors, however, acknowledge that the data largely relied on retrospective estimation by survey participants rather than collected data.

The literature discussing the population of ELVs and auto dismantlers has also relied manly on anecdotal evidence and information collected in surveys. In an analysis of ways to reduce non-point water pollution from auto dismantlers, Arbitman and Gerel report that 700,000 ELVs are handled by licensed vehicle dismantlers each year in California (Arbitman and Gerel 2003). Relying on survey data collected from licensed auto dismantlers, the analysis also estimates that the approximately 1,500 licensed dismantlers in California account for only one-third of all ELVs recycled in the state (Arbitman and Gerel 2003).

The focus of the following analysis represents a unique nexus of the literature by combing empiric sampling of HFC-134a from ELVs with the estimation of the ELV population within California. Combining this data allows us to extrapolate the amount of HFC-134a recovered from sampled vehicles to the entire population of California ELVs.

2. METHODS AND MATERIALS

The analysis is designed to estimate the amount of HFC-134a remaining in California's End of Life Vehicle (ELV) population. We first estimated the ELV population in California from 2000 through 2008 and identified the vehicle dismantlers and other entities that handled these vehicles. We then sampled the refrigerant levels of 2,035 vehicles on licensed dismantler lots throughout California and extrapolated the sample findings to the entire ELV population and estimated the average amount of HFC-134a remaining in ELVs on vehicle dismantler lots in California. The following section details the methodology and equipment used in the analysis.

2.1 End of Life Vehicle Population in California

This analysis begins with the estimation of the ELV population within California from January 1, 2000 through December 31, 2008. This nine-year time frame allows for the detailed characterization of the ELV population. We then narrow the time frame of analysis to focus on the ELV population from January 1, 2005 through December 31, 2007. This three-year period represents the most recent time frame for which complete information pertaining to California's ELVs was available and reflects the current fleet of ELVs as well as the demographics of the ELV population in the future. Both time frames will be discussed in sections of the analysis and contribute to our understanding of the entire ELV population and its movement over time.

We define an ELV as a vehicle that has been issued a junk title or salvage certificate by the California Department of Motor Vehicles (CA DMV). A junk title vehicle is defined as:

> One which has been dismantled because it is wrecked, abandoned, or a low value vehicle that was impounded and acquired from an enforcement agency and is no longer operable. (CA DMV 1)

A salvage certificate vehicle is defined as:

> A vehicle that has been wrecked, destroyed, or damaged to such an extent that the insurance company considers it uneconomical to make repairs to the vehicle and the vehicle is not repaired by or for the person who owned the vehicle when the damage occurred. (CA DMV 1)

No statistics were directly available as to the number of junk titles and salvage certificates issued in California. Given this limitation, we used available CA DMV registration data to obtain information about ELVs using a two-step process. We first looked at annual CA DMV registration records from 2000 through 2008 and identified the cross section of vehicles whose registration status had lapsed from one year to the next. California law requires vehicle owners to annually report the operational status of

any active vehicle as either current or planned non-operational (PNO).[1] A vehicle can only legally be driven with current registration, while a vehicle can be registered PNO if "the vehicle will not be driven, towed, stored, or parked on public roads or highways for the entire registration year" (CA DMV 2). Thus, the vehicles whose registration status changed from current or PNO to another designation represented vehicles that could not legally be driven and could have been issued a junk title or salvage certificate and classified as an ELV. Additional CA DMV registration information was required to determine the status of these lapsed vehicles.

From 2000 through 2008, 39,645,818 vehicles had a change in registration status. These vehicles represented the potential population of ELVs and their unique Vehicle Identification Numbers (VINs) were submitted to CA DMV a second time to obtain their registration histories. These 39,645,818 VINs were submitted to CA DMV in nightly batches of 250,000. This was an iterative process continually refined over the two-years it took to submit the VINs. Table 1 outlines some basic statistics and anomalies of the CA DMV query results. The CA DMV did not recognize 5.6% of the submitted VINs. These vehicles were not in the CA DMV database despite the fact that we had culled these VINs from CA DMV registration records and at one point they had been actively registered in California. In order to reduce the amount of data they store, CA DMV overwrites the registration information of some vehicles every few years, effectively purging the registration records of millions of vehicles.[2] The lack of data on such a large number of vehicles is alarming and unfortunately we were unable to find alternative sources for their registration histories. An additional 0.8% of the submitted VINs had information that was not usable as one VIN was associated with more than one vehicle,. Prior to 1982, vehicles did not have unique VINs and thus the CA DMV histories of these older model years move across multiple vehicles with concurrent registration rendering the registration information useless. These VINs have been excluded from the analysis. Thus, a total of 2,521,503 VINs, 6.4% of all lapsed VINs, were excluded from the analysis due to lack of reliable CA DMV registration information. Of all vehicles with lapsed registration, 37,124,315 VINs had usable CA DMV query results.

Table 1: CA DMV Query Statistics

VINs Submitted	39,645,818
Multiple Vehicles for One VIN	318,322
No Information on VIN	2,203,181

The information contained in the CA DMV query results contained the last known registration action and owner for each submitted VIN. For a portion of the submitted vehicles, detailed registration histories including transfers of title, smog check due dates,

[1] In addition to the two active registration statuses, there are over 60 non-active registration statuses.

[2] This practice has been confirmed by several CA DMV workers who say it occurs as a means to reduce data storage costs.

and yearly registration status were also available. It is not known why registration histories were not accessible for all the submitted vehicles registered in California. Table 2 shows the layout of the registration information for one VIN submitted to the CA DMV query on August 8, 2009. This information, as well as that in subsequent tables, has been altered to maintain owner confidentiality.

Table 2: Raw Data Returned from CA DMV Query

5XXI926U62161081909V 1FALP62WXSH141XX	1
5XXI926 091110 95 FORD 1FALP62WXSH141XX OAKLAND 94621 01	2
5XXI926 PICK N PULL AUTO DISM INC 8451 SAN LEANDRO ST	3
5XXI926 01 090728 JUNK	5
5XXI926 31 041210 UPDATED SUBPLATE/REREG RECORD	5
5XXI926 071609 070809 JOE SMITH	7
5XXI926 1234 56TH ST APT D EMERYVILLE	8

The first line of the query result shows the vehicle license plate followed by the VIN. The second line details the model year and the make of the vehicle. Line three gives the last known owner of this vehicle, in this case, Pick N Pull Auto Dismantler. The next two lines show the CA DMV history available for this vehicle. There are two CA DMV actions for this vehicle, code 31, or re-registration, on December 10, 2004 and code 01, the issuance of a junk title, on July 28, 2009. For approximately 35% of all VINs submitted the CA DMV a second time, there is also information on the vehicle's previous owner as shown here on lines seven and eight. Joe Smith of Emeryville was the vehicle's prior owner and the transfer of title occurred on July 16, 2009. These records were very challenging to decipher, but from the immense amount of information we have found seven possible outcomes for a vehicle that once had current or PNO registration status:

1. The vehicle has current registration status in California
2. The vehicle has lapsed registration and one of 60 non-active registration actions is recorded as its last known status
3. The vehicle has gone out of state
4. The vehicle has PNO status and is not being driven
5. The vehicle has unclaimed registration and all mail sent to the owner's last known address is returned
6. The vehicle is issued a junk title
7. The vehicle is issued a salvage certificate.

Table 3 presents an example of a vehicle that has lapsed registration and a non-active last known registration action. This vehicle was registered PNO on November 12, 2006 and there are no further registration updates, even though the vehicle should have been re-registered in 2007. The last known action for this VIN took place on July 28, 2009 when this vehicle was issued a special license plate. We might infer from this last action that the vehicle has been re-registered in some capacity, but the vehicle's California registration history does not reflect that. For these vehicles, it appears that the CA DMV

registration information may be incomplete or incorrect but no outside source was available to confirm the information.

Table 3. CA DMV Registration History of a Vehicle with Lapsed Registration

4GKPXXXU62161071409V	1B3EJ46X6YN10XXXX				1
4GKPXXX 060826 00 DODGE	1B3EJ46X6YN10XXXX	AMERICAN CYN	94508 28		2
3XXB942	JANE DOE	1234 MAIN ST APT 2E			3
3XXB942 44 090728 SPECIAL LICENSE PLATES					5
3XXB942 69 061112 PNO-REGISTRATION DEFERRED					5

The goal of the analysis, and thus the CA DMV query, was to identify the ELV population or those vehicles described by the final two groups of possible outcomes for vehicles that had been currently registered according to the CA DMV. It is informative, however, to look at the final status and actions of all vehicles with lapsed registration, or those identified as potentially part of the ELV population, as these seven groupings are not mutually exclusive. The name ELV is a bit of a misnomer, as with few exceptions, vehicles that have been issued a junk title or salvage certificate can be 'revived' and re-registered with a few CA DMV stipulations. Table 4 offers more details about the VINs for which CA DMV registration histories were found.

Table 4: CA DMV History of VINs with Lapsed Registration Status, 2000-2008

VINs with Lapsed Registration Status	39,645,818
VINs with Lapsed Status and CA DMV Registration Histories	37,124,315
Issued a Junk Title	6,840,690
Issued a Salvage Certificate	2,389,496
Registered Out of State	2,415,887
Planned Non-Operational	3,566,159
Unclaimed Registration	1,904,559
Junked Multiple Times	235,261
Junked and PNO	755,814
Junked and Registered Out of State	40,372
Junked and Salvage Certificate	457,218
Current and Paid Registration	12,553,285
Non-Active Registration Status	7,689,500

Our population of ELVs consists of the 8,537,707 vehicles in the state of California that had a lapse in registration status and were either issued a junk title or salvage certificate from January 1, 2000 through December 31, 2008. These 8,537,707 vehicles were issued a total of 9,230,186 junk titles or salvage certificates during this time period, as 692,479 vehicles were issued multiple junk titles or salvage certificates. This analysis will focus on the number of vehicles in the ELV population and not the total number of junk title or salvage certificates. In the results section of the analysis we will also discuss the ELV population from 2005 through 2007 to better characterize the current ELV population well as looking more closely at the ELVs for the 2007 calendar year.

2.2 End of Life Vehicle Population Accuracy

ELVs accounted for 22% of the total number of vehicles with lapsed registration status from 2000 through 2008. Six percent of all vehicles with lapsed registration had no CA DMV records despite at one point having current or PNO registration status in the state. These VINs could be incorrect or this could highlight missing information in the CA DMV records.[3] Despite having a lapse in registration status, an additional 32% of all VINs were found to have current registration as their final CA DMV status. These vehicles had a gap in their registration status at some point between 2000 and 2008 but had current registration at the time of the CA DMV query and had paid all registration fees through 2008. An additional 6% of all VINs with lapsed registered were registered out of state while 9% had the final registration status of PNO. Five percent of vehicles with lapsed registration had unclaimed registration. While these vehicles were in the CA DMV database they had no registration actions and any CA DMV correspondence sent to the owner's address was returned. A status of unclaimed registration is likely the result of errors within the CA DMV registration records pertaining either to the VIN or the vehicle's owner.

The remaining 19.4% of vehicles with a lapse in registration had one of the nearly 60 non-active CA DMV registration actions as a final status. For many of these VINs, including the vehicle highlighted in Table 3, the CA DMV registration history is incomplete and appears to be missing key registration actions. Table 5 outlines another example of a vehicle with lapsed registration, a 1999 model year Dodge.

Table 5: CA DMV History of a 1999 Dodge with Lapsed Registration

5XXX816U62161081909V 1B3ES47C8XD1394XX	1
5XXX816 090914 99 DODG 1B3ES47C8XD1394XX SANTA ROSA 95407 49	2
5XXX816 080825 JOE SMITH 1234 SANTA ROSA AVE A1	3
5XXX816 01 040830 JUNK	5
5XXX816 46 070801 SMOG DUE 08/01/09	5
5XXX816 50 070911 TRANSACTION IN PROGRESS	5

[3] VINs for which no current information was available were resubmitted to the CA DMV query over the two-year period of VIN submissions to allow for lags in status updates and to ensure that the registration information was up to date.

The CA DMV has no information pertaining to this vehicle prior to 2004 or after 2007. Nor is there any indication of the vehicle being re-registered after receiving a junk title on August 30, 2004, prior to receiving a smog check on August 1, 2007. The smog check is the only indication that this vehicle has rejoined the population of registered vehicles. This VIN was submitted to the CA DMV query on April 12, 2008 and again on August 9, 2009, but no additional information was available. The lack of complete information on such a large portion of the vehicles with lapsed registration decreases the precision of the analysis as we may be missing vehicles that were issued junk titles or salvage certificates during undocumented, or overwritten, portions of their registration records.[4] This is unfortunate, but is unavoidable given the available CA DMV data.

2.3 Vehicle Dismantlers

Along with estimating the ELV population, we must also identify the businesses and individuals that handle the dismantling and storage of these vehicles. A vehicle dismantler is defined by section 220 the California Vehicle Code as any person who:

> (a) is engaged in the business of buying, selling, or dealing in vehicles of a type required to be registered under this code, including nonrepairable vehicles, for the purpose of dismantling the vehicles, who buys or sells the integral parts and component materials thereof, in whole or in part, or deals in used motor vehicle parts. This section does not apply to the occasional and incidental dismantling of vehicles by dealers who have secured dealers plates from the department for the current year whose principal business is buying and selling new and used vehicles, or by owners who desire to dismantle not more than three personal vehicles within any 12-month period.
>
> (b) Notwithstanding the provisions of subdivision (a), keeps or maintains on real property owned by him, or under his possession or control two ore more unregistered motor vehicles no longer intended for, or in condition for, legal use on the highways, whether for the purpose of resale of used parts, for the purpose of reclaiming for use some or all of the materials, whether metal, glass, fabric, or otherwise, or to dispose of them, for any other purpose. (CA DMV 3)

In California, a junk title vehicle can be re-registered only with a junk receipt issued directly from the CA DMV to the vehicle owner or a Bill of Sale from a licensed vehicle dismantler (CA DMV 5). Thus, if a junk title vehicle changes hands, it is required to go through a licensed dismantler. A junk title vehicle fits the description of a vehicle "required to be registered" under Section 220 of the California Vehicle Code (CA DMV 3). Salvage certificate vehicles, are by definition, "nonrepairable vehicles" and also are "required to be registered" under Section 220 of the California Vehicle Code (CA DMV

[4] The overwriting of CA DMV registration records also may result in the deletion of specific actions within vehicle records as well as the deletion of entire vehicles from the database.

3). Thus, any person or business owning more than three ELVs, as outlined in the Vehicle Code is required to be a licensed vehicle dismantler.[5]

In order to identify vehicle dismantlers in California, we returned to the results from the CA DMV query, as shown in Tables 2, 3, and 5. On line three, the queries contained the last known owner for each vehicle with lapsed registration and a CA DMV registration history. When available, we also looked at the vehicle's previous owner as listed on lines seven and eight. While 39,645,818 vehicles had lapsed registration status from 2000 through 2008, we now focus on the ELV population. Accordingly, we restrict the analysis to those businesses and individuals that owned at least one vehicle that was issued a junk title or salvage certificate from 2000 through 2008. We instituted this restriction due to the immense volume of data that resulted from looking at the individual owners of the nearly 40 million vehicles with lapsed registration. This restriction may cause the exclusion of vehicle dismantlers that obtain vehicles through other means, including vehicle auctions and pools. By focusing on the vehicles that obtain junk titles and salvage certificates from CA DMV, we are also excluding or undercounting entities that handle vehicles without proper CA DMV documentation. These businesses are an important part of the vehicle dismantler industry but no data is available as to their numbers or the quantity of vehicles they handle. While these oversights are unfortunate, given our narrow definition of an ELV and lack of data, they are acceptable.

The CA DMV query produced 161,682 unique address and name combination for businesses and individuals that owned at least one ELV from 2000 through 2008. Given the large physical requirements of a vehicle dismantling operation, we used dismantler location as our defining unit of measure. Thus, a dismantler may have changed ownership or name over the nine-year period of analysis but it if retained the same physical address, it was indexed as one dismantler.[6] As a corollary, two dismantlers with the same name yet different physical addresses were indexed as two distinct dismantlers.

The CA DMV query results were sorted first by the last owner's address and then by the last owner's name. Unique addresses were grouped together and assigned a location code. Table 6 shows how two addresses were matched and given the same location code, while two other addresses were determined to require two separate location codes.

Table 6: Matching Dismantler Addresses from the DMV Query

123 EAST FIRST STREET	SACRAMENTO
123 1ST E	SAC
324 W WASHINGTON	SACRAMENTO
324 E WASHINGTON SUITE 12	WSAC

[5] As defined in Section 220 (b), owning more than two PNO vehicles also requires a dismantling license, but this falls outside the scope of the analysis.

[6] This methodology is supported by the data in which many dismantlers have more than one name to signify different sections of their business though they have the same owner and physical location.

After compiling the index of unique location codes, we identified and grouped vehicle dismantlers by name. While some locations were easily identified as a dismantler, for example, Pick Your Part Vehicle Dismantling, others required additional research to determine the nature of their business. For example, the nature of Route 12 Automotive Parts' business was not readily apparent. Given that the analysis comprises nine years, many different names also exist at the same physical address. Table 7 outlines two scenarios, one in which different names existed at the same address and a second in which three dismantlers with the same name were given unique location codes.

Table 7: Matching Dismantler Names to Location Codes

DISMANTLING	789 CRANDALL	LOS ANGELES
HARROLDS DISM	789 CRANDAL	LA
ZIPPY CAR DISM	982 E MAIN ST	FRESNO
ZIPPY CAR DISM	1127 W MAIN STREET	CLOVIS
ZIPPY CAR DISMANTLING	832 CLYDE AVE	FRESNO

The 161,682 unique owner address and name combinations were condensed down to 2,107 unique locations identified as vehicle dismantlers within California as well as 487 out of state or non-dismantler businesses. These dismantlers and non-dismantler businesses will be discussed in further detail in the Results section of the analysis.

2.4 Vehicle Sampling

The Foundation for California Community Colleges (FCCC) partnered with the State of California Auto Dismantlers Association (SCADA) to facilitate the sampling of HFC-134a from vehicles on dismantler lots throughout California. The sampling was conducted by three FCCC Smog Check Referees, all trained in refrigerant handling and safety procedures as outlined in the Federal regulations pursuant to Section 609 of the Clean Air Act (U.S. EPA 1). The Smog Check Referees placed calls to participating SCADA vehicle dismantlers to arrange appointments to sample and collect HFC-134a from vehicles. Dismantler participation was voluntary and no compensation was provided.

From January 14 to January 19 2008, two FCCC Smog Check Referees conducted an initial round of sampling and refrigerant collection on 161 vehicles on a dismantler lot in Antelope, California. This initial sample was intended to facilitate the stratification of later sampling to accurately reflect the entire ELV population as determined from CA DMV registration information. The initial sample of 161 vehicles was completed using two Robinair Cool-Tech 34134Z refrigerant recovery machines.

The Robinair Cool-Tech 34134Z recovery units were compliant with SAE standard J2210, the standard for automotive refrigerant recovery and recycling at the time of the initial sampling. SAE J2210 required a refrigerant recovery rate of 80% and a recovery

accuracy of +/- 28.34 grams (Sciance 2006). The Robinair 34134Z met or exceeded the requirements of SAE J2210, and had a 14 kg refrigerant capacity with a recovery rate of 0.2 kg/minute (Robinair 1).[7] These units had the capability to recover HFC-134a as well as its predecessor, R-12, which was used in pre-1995 model year vehicles. Each Robinair 34134Z was powered by a Honda EU 2000I generator.

This equipment was transported from its storage in Sacramento to the dismantler location using a rental van with a lift as each recovery machine weighed 80 kg and the generators weighed 22 kg each. The two FCCC Smog Check Referees entered the dismantler lot and identified vehicles with enough spatial clearance to allow for sampling and refrigerant collection. In order to be sampled, a vehicle was required to have an operational front hood and a visible Vehicle Identification Number (VIN). Once a vehicle was identified for sampling and collection, the Referee propped the hood open and connected the recovery machine. The sampling took an average of 30 minutes per vehicle, and an average of 30 vehicles were sampled each day. Once a vehicle's refrigerant was sampled, the refrigerant was returned to the vehicle and the vehicle was marked for refrigerant collection. As the amount of refrigerant was sampled, the Referees recorded the following vehicle specific information:

1. VIN
2. License plate number (if available)
3. Vehicle model year
4. Vehicle make
5. Vehicle model
6. Vehicle type (car, minivan, pick up truck, station wagon, SUV, or van)
7. Vehicle engine size
8. Mileage (if available)
9. Vehicle color
10. Refrigerant type
11. Amount of refrigerant recovered
12. Vehicle refrigerant capacity
13. If the vehicle had an air conditioning system
14. If the vehicle had rear air conditioning units
15. If the vehicle was at the dismantler due to a collision
16. If the vehicle was at the dismantler due to a front end collision

At the end of each day of sampling, the refrigerant was collected from each sampled vehicle. The recovery of the refrigerant took approximately 30 minutes each day and once the refrigerant was collected it was placed into U.S. EPA approved storage bottles. When the 20 refrigerant storage bottles were filled, the refrigerant was reclaimed by Newcomb Mechanical Incorporated in Foster City, California, a U.S. EPA sanctioned refrigerant handling and disposal service.

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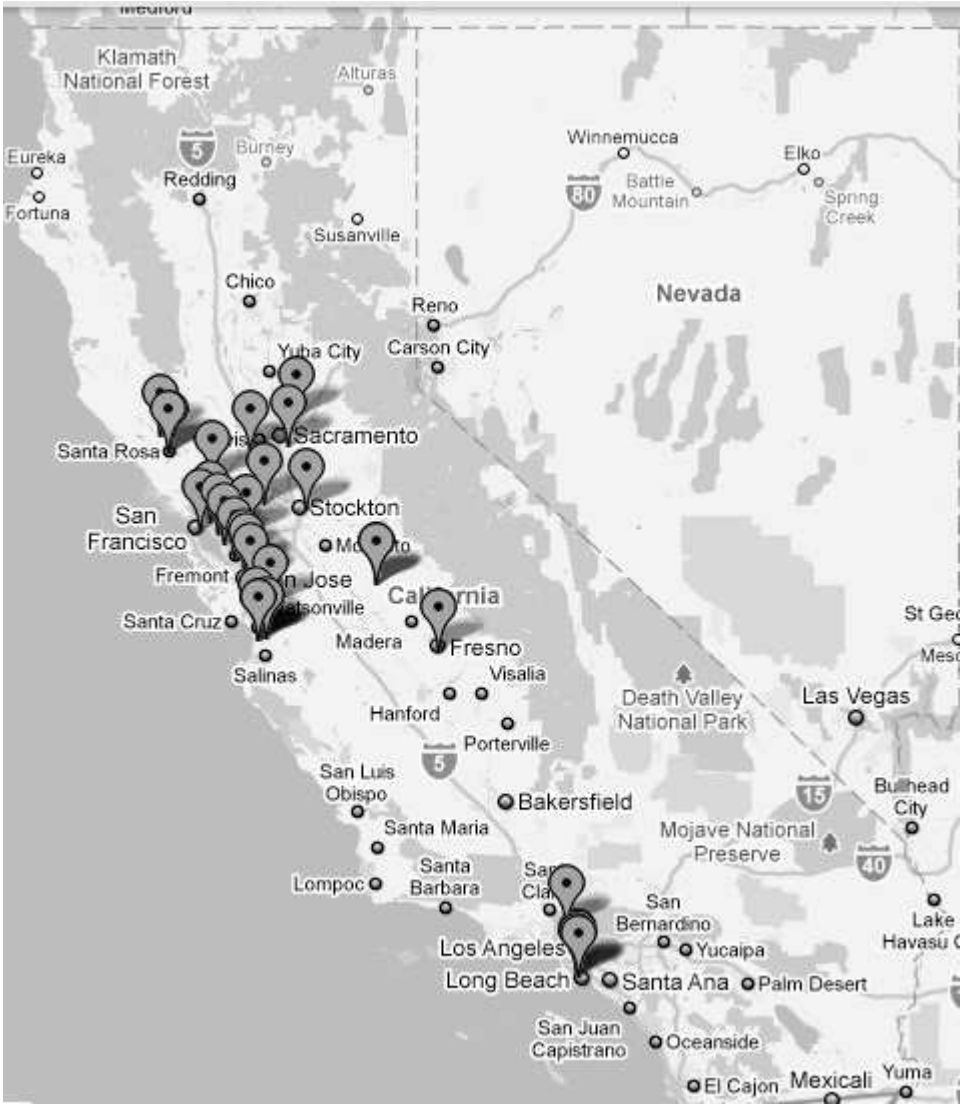
[7] Full specifications of the Robinair Cool-Tech 34134Z are available at http://www.setonresourcecenter.com/cfr/40CFR/P82_047.HTM

The second round of vehicle sampling and collection began February 2, 2009 and was conducted by one FCCC Smog Check Referee based out of San Leandro, California. Prior to the second sampling, a new SAE standard for automotive refrigerant recovery, recycling, and recharge, SAE J2788, came into effect. It required a 95% recovery rate and a recovery accuracy of +/- 14.17 grams (Sciance 2006). As the Robinair Cool-Tech 34134Z was no longer compliant with the new standard, a new refrigerant recovery device was purchased, the Robinair 34788. Like the Robinair Cool-Tech 34134Z, The Robinair 34788 had a refrigerant capacity of 14 kg and a recovery rate of 0.2 kg/minute (Robinair 2), and was powered by a Honda EU 2000I generator.[8] However, the new Robinair 34788 did not have the capacity to sample and collect R-12, and thus the second round of sampling focused on those vehicles containing HFC-134a.

The second round of sampling took place from February 2, 2009 to August 27, 2009. During this time frame an additional 1,874 vehicles were sampled. The FCCC Referee worked alone and visited 29 dismantler locations through out the state. Given the geographic diversity of California's vehicle fleet, the second round of sampling aimed to sample and recover refrigerant across the entire state. However, due to limited travel funds and the logistical difficulty of moving the sampling equipment, only two of the twenty-nine vehicle dismantlers visited by this FCCC Referee were located in Southern California. The other sampling locations were all within driving distance of San Leandro. Figure 1 presents the geographic locations of all 30 sampled dismantlers.

[8] Full Specifications for the Robinair 34788 are available for download at http://cache01.voyageurweb.com/otctools.com/newcatalog/products/539602%20E.pdf

Figure 1: Map of 30 Sampling Locations



The FCCC Referee contacted SCADA vehicle dismantlers by phone and then drove a rental van with a lift to the dismantler lots for sampling, often only getting same day approval to enter the lot. The Referee entered the dismantler lot with no prior knowledge as to the layout of the lot, nor the potential vehicles to be sampled. Thus the amount of vehicles sampled varied greatly depending on the lot's inventory of vehicles containing HFC-134a and access to those vehicles. During this second round of sampling, an average of 20 vehicles containing HFC-134a were sampled per day. On May 7, the Robinair 34788 required a compressor repair. The machine was down for four weeks and during that period, the Robinair Cool-Tech 34134Z was used to sample vehicles, however

only vehicles containing HFC-134a were sampled.[9] The sampling protocol and information recorded remained consistent through the two separate rounds of sampling. During the second sampling round, the majority of the HFC-134a was also handled by Newcomb Mechanical Incorporated in Foster City, California. However, several vehicle dismantlers requested that any HFC-134a recovered be placed into their own storage tanks. These dismantlers had secondary uses for the HFC-134a recovered from the vehicles on their lots.[10]

Through out the two sampling periods, several vehicles were sampled that had participated in the Federal car allowance rebate system (CARS), formerly referred to as the "Cash for Clunkers" program. Through this program, older vehicles with low fuel economy were traded in for cash vouchers to be used towards the purchase of a new, fuel-efficient vehicle. These older vehicles were sold to vehicle dismantlers who were required to destroy the engine and transmission of these vehicles to ensure that they remained off the road.

The FCCC Referees were able to identify these CARS vehicles and reported to have sampled a handful of these vehicles on several different dismantler lots. However, these vehicles were not recorded as being part of the CARS program and are not discernable for the rest of the sample. These vehicles may represent a unique sub sample but only constitute a small percentage of the total sample and thus should not bias the sampling results.

2.5 Sampling Accuracy

While 2,035 vehicles were sampled from 30 licensed vehicle dismantler locations, 33 vehicles were sampled more than once. One vehicle was sampled twice in the initial sample of 161 vehicles while the remaining 32 double samples occurred in the second sampling period. The double samples have been excluded from the analysis and our corrected sample consists of 2,002 unique vehicles. The majority, or 23, of the doubled samples occurred in the Bay Area Air Quality Management District (AQMD) where the doubles were often sampled on different testing days.[11] Plausible explanations for the double sampling include Referees not clearly marking sampled vehicles or Referees not acknowledging another Referee's marked vehicles in times of concurrent sampling.

The VIN of each sampled vehicle was recorded by the FCCC Referee conducting the sampling in order to link the sampled vehicles to their CA DMV registration history. We were able to identify 48 VINs that were recorded incorrectly out of the 2,002 unique samples. The incorrect VINs were identified using the check digit. The 9th digit of the

[9] The vehicles sampled in the second round using the Robinair Cool-Tech 34134Z were not identified by the FCCC Referee nor was the exact dates it was used recorded. Thus we were not able to compare the measurements of the two different sampling and recovery machines in the field.

[10] While secondary markets for HFC-134a are a much discussed topic, no additional information was provided by these dismantler locations as to how they use or dispose of the refrigerant.

[11] These doubles provided a check of data accuracy. For all sets of doubled samples, the information was identical.

17 digit VIN (for all 1982 and newer model years) represents the remainder to an algorithm unique to that specific VIN. If the 9th digit of the VIN does not correspond to the remainder of the algorithm, then the VIN cannot be correct. Using other vehicle specific characteristics recorded by the FCCC Referees, we were able to correct these VINs.[12]

Additional errors were corrected in regards to the refrigerant capacity of sampled vehicles. The FCCC Referees were required to look up the refrigerant capacity of each vehicle based on its manufacturer, make, and model year. For 12 of the sampled vehicles, the refrigerant capacity was left blank and the author looked up the correct values.

For 25 of the 2,002 unique sampled vehicles, the amount of recovered refrigerant exceeded the vehicle's refrigerant capacity. For each of these vehicles, the capacity was checked and found to be accurate based on the recorded vehicle specifications. While it is likely that errors exist in these 25 cases, it could be at a variety of levels and thus these figures have not been corrected.[13] This subset of the sample will be discussed at further length in the Results section of the analysis.

While other vehicle specific information may have been recorded incorrectly, it was not easily identifiable. Thus, apart from the removal of vehicles sampled more than once, 48 VIN corrections, and 12 refrigerant capacity corrections, the analysis relies on the original data and information as recorded by the three FCCC Smog Check Referees.

[12] The number of VIN errors, 48, is a lower bounds and is based on the number of VINs that were corrected. There could be additional incorrect VINs for which we could not easily identify the correct VIN or in rare instances when VIN errors offset the algorithm and the check digit is correct.

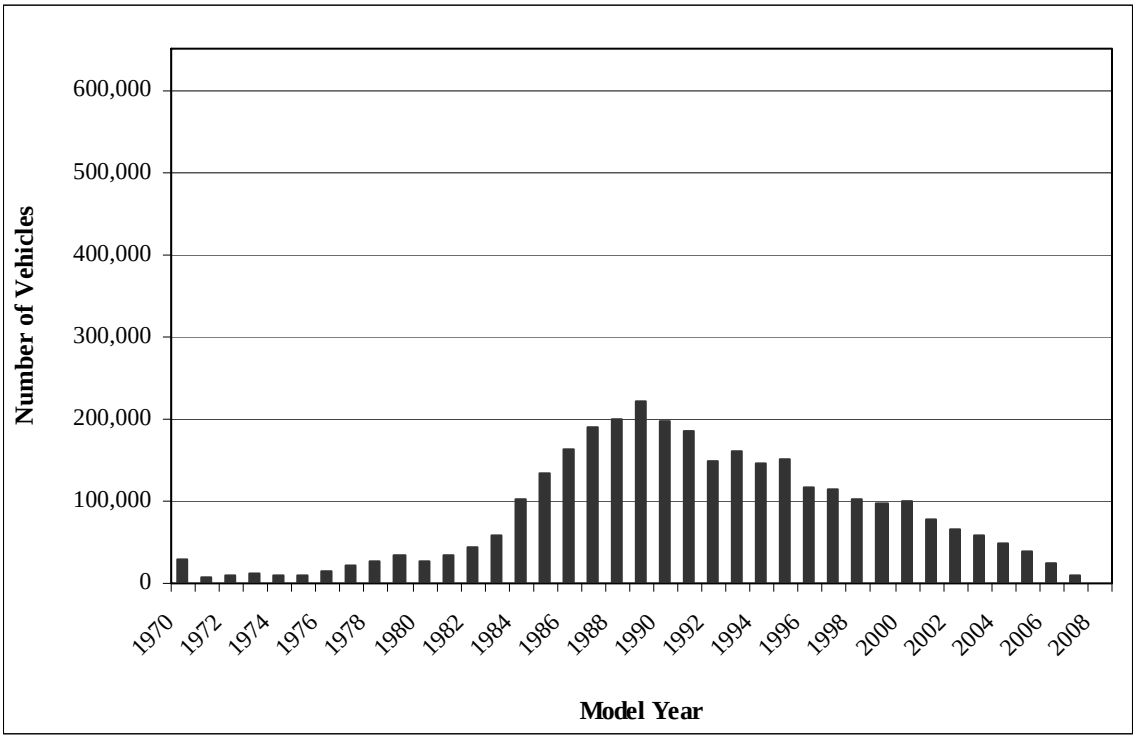
[13] Possible errors include the incorrect recording of vehicle specifications used to find refrigerant capacity, HFC-134a recovery accuracy, and incorrect recharging of refrigerant in these vehicles.

3. RESULTS

3.1 End of Life Vehicle Population

The ELV population of California from 2005 through 2007 consisted of 3,190,430 vehicles that were either issued a junk title or salvage certificate. Figure 2 shows the model year distribution for this truncated time period. Due to the relatively small number of pre-1970 model year vehicles, in this and all subsequent figures, the 1970 model year represents 1970 and older vehicles.

Figure 2: Distribution of the ELV Population by Model Year, 2005 – 2007

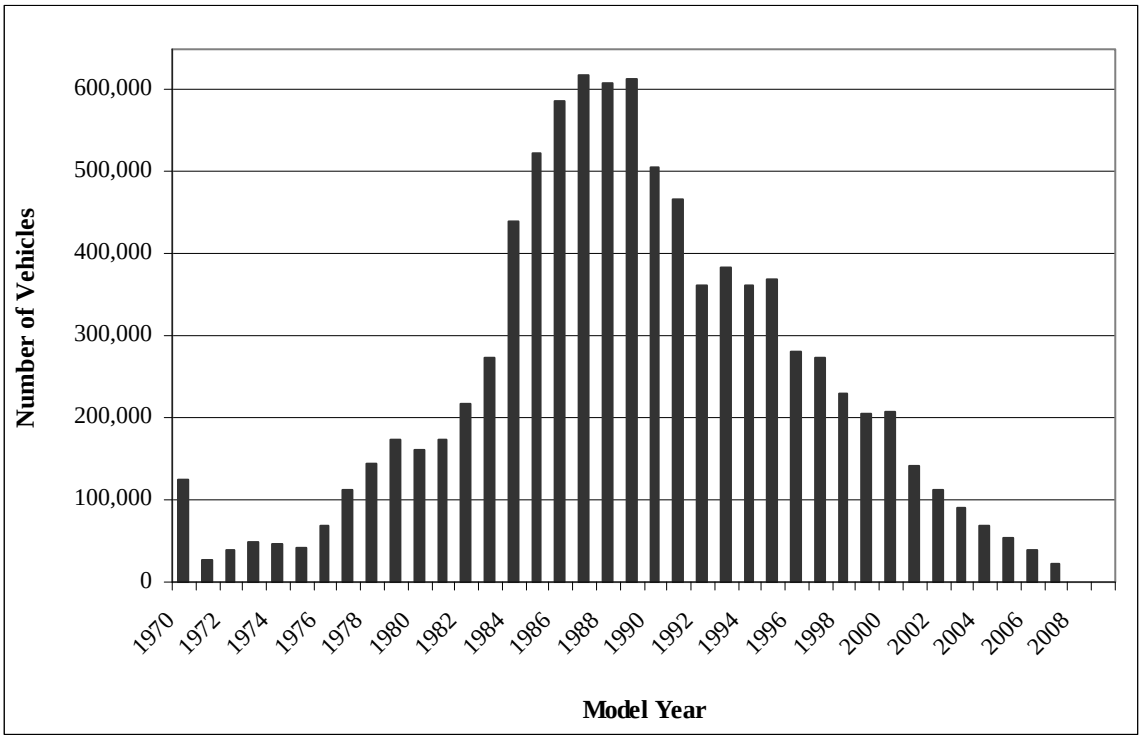


In describing the distribution, we measured the mean, or average, and the standard deviation of the ELVs. Standard deviation is a measure of variability from the mean, and the larger the standard deviation, the more each data point varies from the mean. For the ELV population from 2005 through 2007, the mean model year is 1991 and the standard deviation is 7. The distribution of ELVs from 2005 though 2007 is normally distributed, as more than 68% of all vehicles lie within one standard deviation of the mean. Thirty-two percent of the ELVs from 2005 through 2007 are 1995 and newer model years and thus contain HFC-134a. A very small percentage of vehicles had recorded model years

that were not plausible given the time frame of analysis. These vehicles have been excluded from Figure 2 and all subsequent figures.[14]

Extending our time frame to 2000 through 2008, 8,537,707 vehicles were issued a junk title or salvage certificate in California and classified as an ELV. Figure 3 shows this model year distribution of this population of ELVs.

Figure 3: Distribution of the ELV Population by Model Year, 2000 – 2008

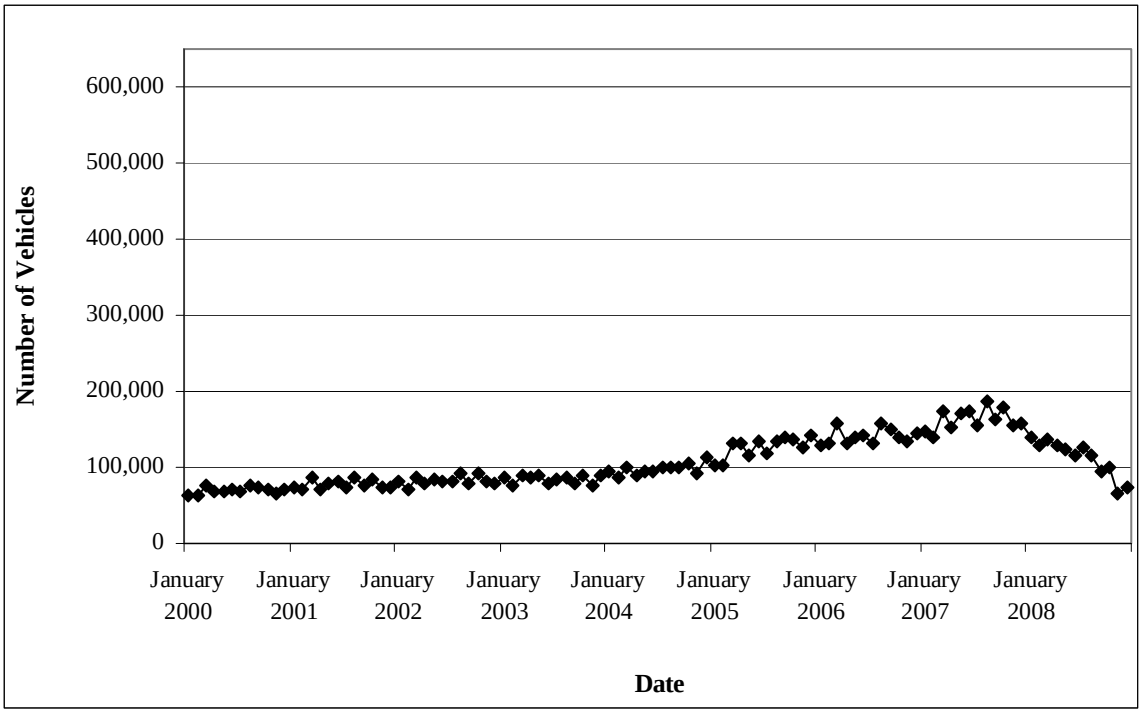


The ELV population from 2000 through 2008 is distributed normally with a mean model year of 1989 and a standard deviation of 7. Twenty-five percent of this population is a 1995 or newer model year containing HFC-134a. Comparing the ELV population from 2000 through 2008 to the truncated period 2005 through 2007, the distribution and basic statistics are not significantly different. Figure 4 looks at the number of ELVs reported each month by the CA DMV from 2000 through 2008. The monthly number of ELVs varied from a 64,617 in November of 2008 to 187,865 in August of 2007 with an average of 105,926 ELVs across the nine-year period. From 2005 through 2007, the mean number of ELVs per month was 143,328. Thus, while the model year distribution has not

[14] Vehicles with a recorded model year of 2010 were not being sold until 2009 and thus are outside the time frame of the analysis. Thus, 2010 model years must be errors. Given the large dataset we were not able to correct each of these model years and they have been excluded from the figures.

varied over the nine years, the number of ELVs reported per month has risen in recent years.[15]

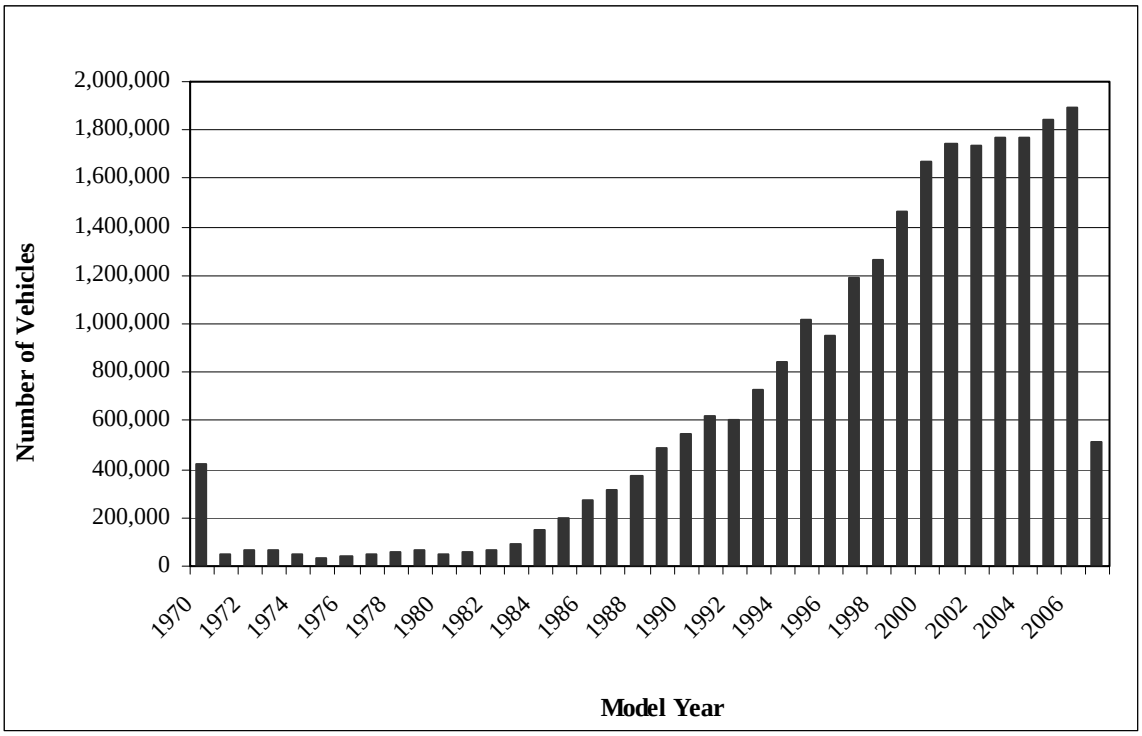
Figure 4: Monthly Time Series of ELVs, 2000 – 2008



To put these numbers in perspective, we compared the ELV populations to the number of vehicles with current registration in California. It has been estimated that approximately 30 million vehicles have current registration status in California each year (Arbitman and Gerel 2003). As registration status is fluid, this figure constantly changes and each day there is a different number of vehicles with current registration. Figure 5 shows the breakdown by model year of the 25,121,632 vehicles with current registration status on April 1, 2007. This date represents a typical cross section of vehicles with current registration for the years 2000 through 2008. While using a different date will alter the numbers slightly, the distribution of model years is not altered and using April 1, 2007 as opposed to any other date did not introduce additional error to the analysis.

[15] The low number of ELV in late 2008 could result from delays in CA DMV reporting. However, these numbers are based on CA DMV records updated through March 1, 2010 so there has been a significant lag between the months in question and the data inquiry.

Figure 5: Population of Vehicles with Current Registration Status on April 1, 2007

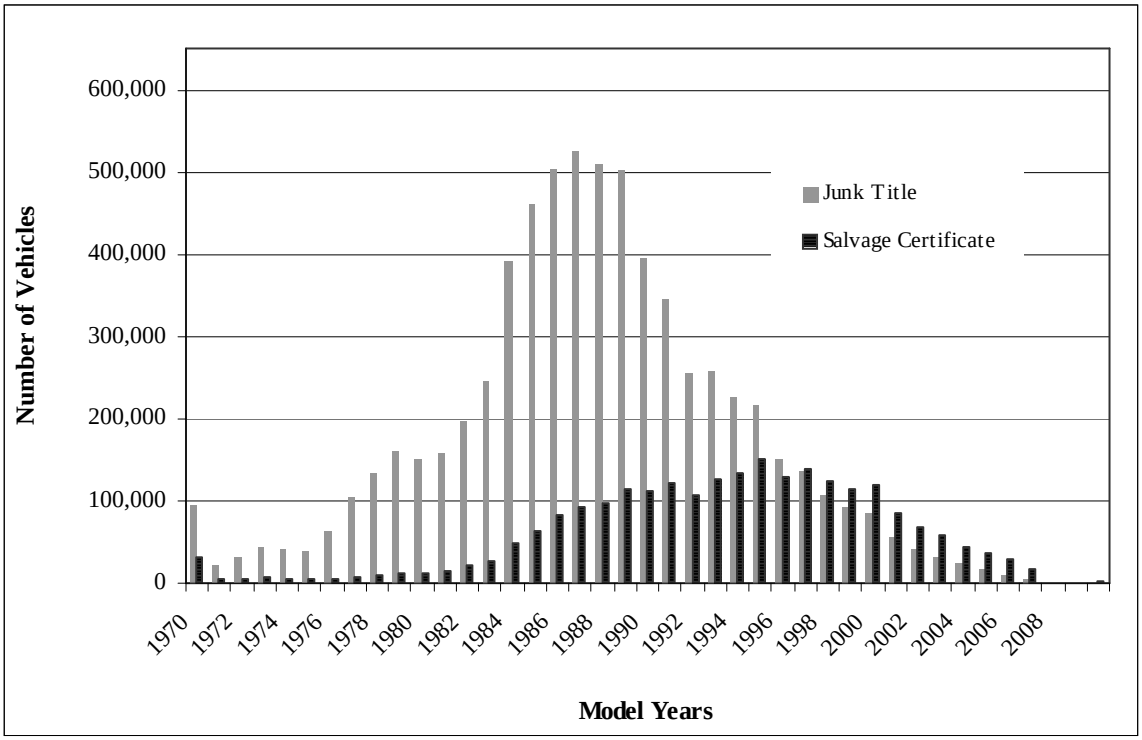


Vehicles with current registration on April 1, 2007 had a model year mean of 1998 and a standard deviation of 7. Model years containing HFC-134a account for 75% of the vehicles with current registration as of April 1, 2007. The distribution is not normally distributed and is heavily skewed towards newer model years. Thus, while the ELV populations from 2000 through 2008 and 2005 through 2007 are similar, they do not resemble the population of vehicles with current registration.

The ELV population is comprised of vehicles that have either been issued a junk title or salvage certificate. Within the ELV population from 2000 through 2008, 457,218 vehicles, 5% of the total population, had been issued both a junk title and a salvage certificate. Figure 6 shows the breakdown of the ELV population into these two groups. For the 5% of vehicles with both a junk title and a salvage certificate, we count only the last action in order to avoid double counting.

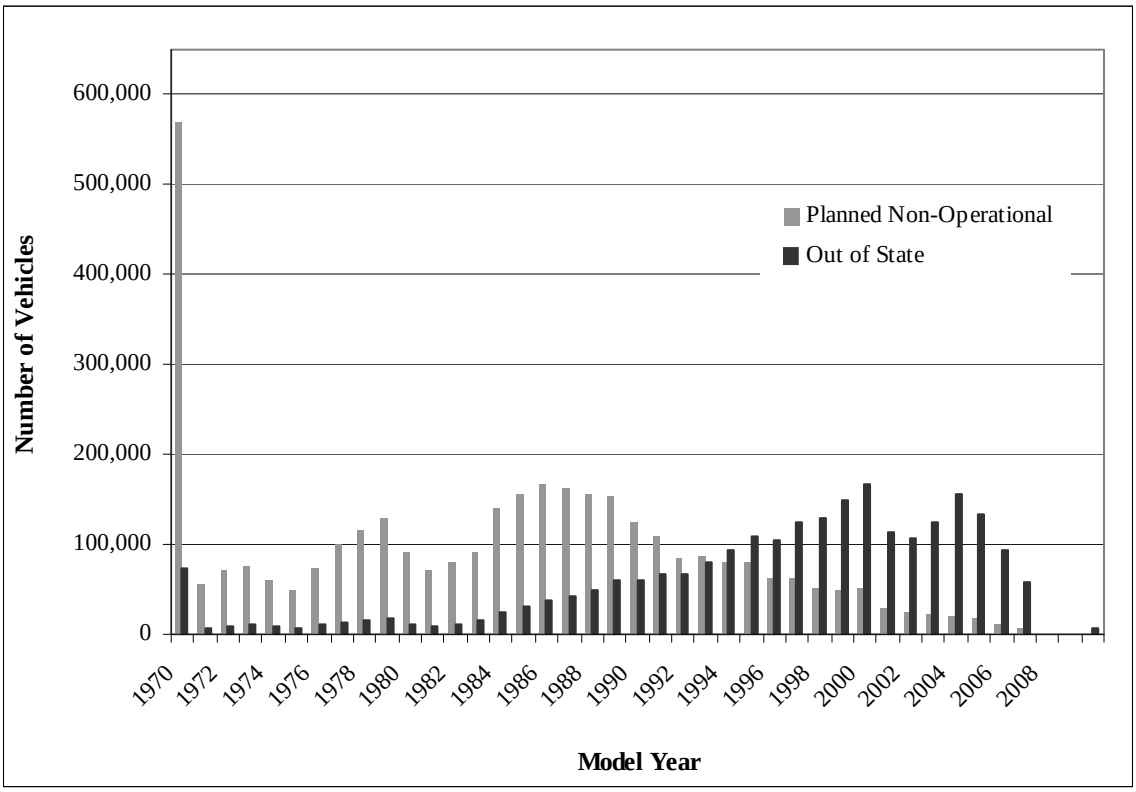
Junk title vehicles have a mean of 1988, while salvage certificate vehicles have a mean of 1993. Each of these distributions is normal and has a standard deviation of 7. Only 14% of junk title vehicles are 1995 and newer model year, compared to 47% of vehicles with a salvage certificate. Thus, a higher percentage of salvage certificate vehicles contain HFC-134a. While the distributions of these grouping are similar, the mean model year of vehicles with junk titles and salvage certificates are significantly different.

Figure 6: Model Year Distribution of Junk Title and Salvage Certificate Vehicles, 2000 – 2008



Given that ELVs comprise only 23% of the vehicles with lapsed registration and CA DMV records from 2000 through 2008, we expanded our analysis to include two additional terminal CA DMV statuses; Planned Non-Operational (PNO) and out of state vehicles. Figure 7 outlines the model year distribution of all these two categories.

Figure 7: Distribution of PNO and Out of State Vehicles by Model Year, 2000 – 2008

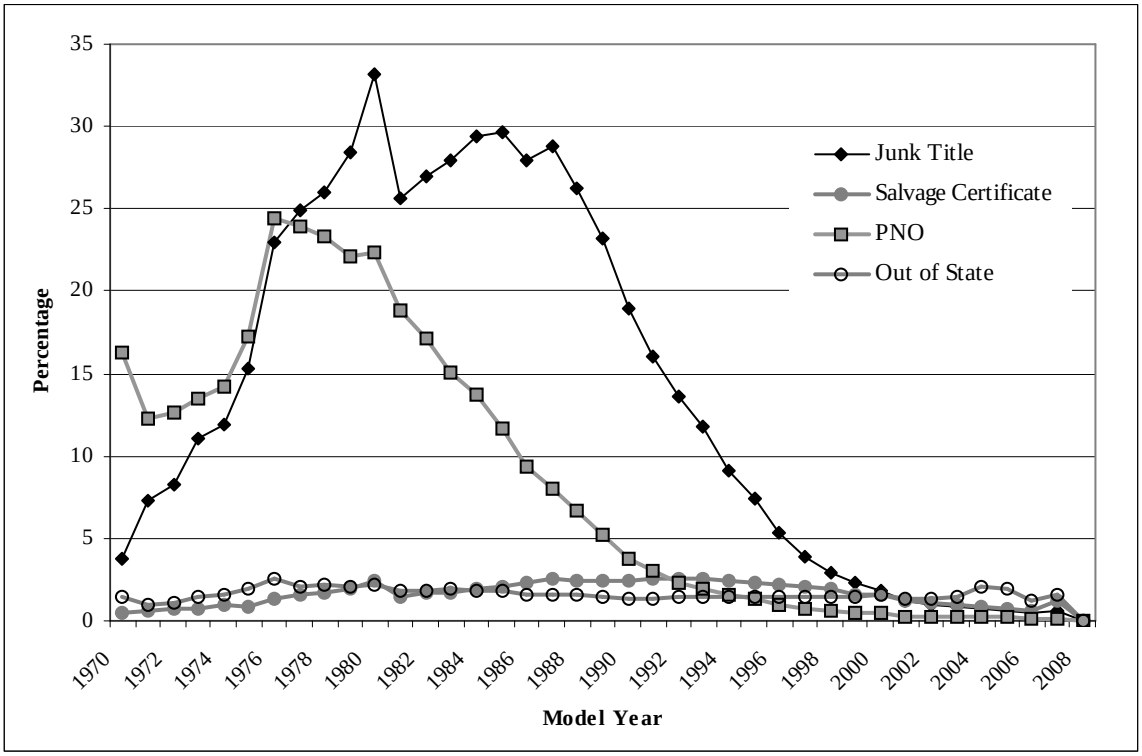


PNO vehicles have a mean model year of 1984 with a standard deviation of 10. Only 15% of the PNO population was a 1995 or newer model year while 16% were 1970 or older. The population of out of state vehicles was very different, with a mean model year of 1996 and a standard deviation of 9. Sixty-five percent of vehicles that went out of state were 1995 or newer model years. Both out of state and PNO vehicles are normally distributed, but the model year means are significantly different. Out of state vehicles are much newer than PNO vehicles and most closely reflect the population of vehicles with current registration status. These statistics confirm a priori expectations that age is a large factor in the decision to retire a vehicle or take it on a large-scale move. The out of state vehicle population most closely resembles salvage certificate vehicles and these classifications have statistically similar model year means. Junk title vehicles have a mean model year similar to that of the population of PNO vehicles, they are 1988 and 1984 respectively.

We next compare the distribution of junk title, salvage certificate, PNO, and out of state vehicles to that of vehicles with current California registration. To this end, we use the number of vehicles reported by the CA DMV in each vehicle category during the 2007 calendar year. We then calculate each category of vehicles as a percentage of all vehicles with current registration as of April 1, 2007. Comparing the annual counts to a representative date of current registration may alter the percentages slightly, but we are interested in the relative change between model years and not the overall magnitude of

the percentages. Figure 8 shows the four vehicle categories as a percentage of vehicles with current registration in 2007.

Figure 8: Vehicle Categories as a Percentage of Vehicles with Current Registration, 2007



The percentage of vehicles with junk titles is distributed normally around the 1990 model year. The distribution of the percentage of salvage certificate vehicles remains fairly constant over all model years and is centered around 1996.[16] Again, these two populations are very distinct despite being joined under the definition of an ELV. PNO vehicle as a percentage of currently registered vehicles are heavily skewed towards older model years with a center of 1985. The percentage of out of state vehicles is constant across all model years with a center of 1988.

The percentage of currently registered vehicles that go out of state closely reflects the percentage of salvage certificate vehicles. Both categories combined account for roughly 3% of vehicles with current registration as of April 1, 2007 across all model years. For example, if one hundred 1990 model year vehicles had current registration as of April 1, 2007, there are additional three 2000 model year vehicles that have either gone out of state or received a salvage certificate during 2007. The percentage of junk title vehicles most closely mimicked the distribution of the percentage of PNO vehicles as both have a similar peak and tail off dramatically during newer model years. In 2007, PNO and junk

[16] The distribution fails the Empiric Test of Normalcy with 64% of all observations within one standard deviation of the mean when the requirement is 68%.

title vehicles ranged from 0.6% of 2006 model year vehicles to 55% of 1980 model year vehicles with current registration on April 1, 2007. Thus, for every one hundred 1980 model year vehicles with current registration on April 1, 2007, there were an additional fifty-five 1980 model year vehicles that were either PNO or received a junk title during 2007. The percentage of vehicles issued a junk title dominated the percentage of salvage certificates issued until the 2002 model year. For 2002 and newer model years, the percentage of vehicles issued a salvage certificate was greater than the percentage of vehicles issued a junk title as a percentage of vehicles with current registration in 2007. Thus, while junk title and salvage certificate vehicles are categorized together as ELVs, they are very different populations of vehicles and deserve additional, and independent analysis.

3.2 Vehicle Dismantlers

We have identified 2,107 unique locations as vehicle dismantlers within California. Each of these locations owned at least one ELV from 2000 through 2008 as identified using CA DMV registration histories. An additional 487 location codes represented insurance companies, vehicle auctions, out of state businesses, fleet vehicles, and taxi services that do not fit without our scope of vehicle dismantlers in California. These non-dismantler businesses were categorized by name and through extensive web searches regarding the nature of their business. Table 8 shows the breakdown of the final owners for the population of 8,537,707 ELVs in California from 2000 through 2008.

Table 8: Last Known Owner of ELVs by Category

Category	Number of ELVs	Number of Businesses
California Dismantler	5,949,956	2,107
Out of State Business	111,513	33
Vehicle Auction	550,637	87
Insurance Company	883,898	59
Fleet Vehicles	99,127	26
Taxi Services	2,650	41
Private Individual and Unidentified Entities	939,926	241

Vehicle dismantlers within California have been identified as the final owner of 70% of the ELV population from 2000 through 2008. Businesses with an out of state address, including vehicle dismantlers, were the final owners of an additional 1% of ELVs. Vehicle auctions owned 6% of ELVs, and insurance companies were the final owner of 10% of the ELV population. Fleet vehicles consisting of rental car agencies, local municipalities, and delivery services were the final owner of 1% of ELVs while taxi services owned an additional fraction of a percent. For 11% of the ELV population, the final owner was not identified as a dismantler or the final owner did not fit in another category. Many of these owners were private individuals at residential addresses or

businesses listing an invalid address. Uncovering the final owners of the ELVs was a cyclical process. As we refined our techniques and uncovered additional vehicles with lapsed registration, we continued to submit new VINs to the CA DMV query, refining these statistics.[17] The 241 unknown entities and private individuals reduce the precision of the analysis as we are not able to determine their license status or specific geographic location. Further research is warranted in determining the identity of these businesses and individuals.

3.3 Licensed Vehicle Dismantlers

While we have identified 2,107 unique dismantler locations in California, not all of these locations are licensed by the state. Licensed vehicle dismantlers are regulated by Section 220 of the California Vehicle Code and are issued biennial licenses. These licenses require the dismantler to be in possession of a business license, resale permit, zoning verification, receive a background check, and pay $224 in fees (CA DMV 4).

In order to differentiate the licensed dismantlers from those without a license, we compared the 2,107 unique dismantler locations to CA DMV dismantler license records provided by the State of California Auto Dismantlers Association (SCADA). SCADA provided the list of licensed vehicle dismantlers from 2002 – 2004 and 2006 – 2009. The records for 2000 and 2001 were unavailable and the records for 2005 were corrupted and unreadable. Attempts to obtain dismantler license information directly from CA DMV were unsuccessful.

During this time period (2002-2004, 2006-2009), 2,241 vehicle dismantling licenses were issued in the state of California. These licenses corresponded to 1,396 unique dismantler locations that owned an ELV from 2000 through 2008.[18] The remaining 711 location codes were the physical addresses of dismantlers that were not licensed by the state of California. Table 9 compares the number of vehicles owned by all unlicensed and licensed dismantler locations in California. Given the small relative size of some dismantler locations, Table 9 presents both the mean, or average, number of junk title and salvage certificates issued to dismantlers from 2005 through 2007 as well as presenting the mean number of ELVs from the extended time frame, 2000 through 2008.

[17] The percentage of final owners that was unidentified was reduced to 11% of the ELV population, down from 18% in preliminary drafts of this analysis.

[18] There are 36 dismantler location codes that have both a licensed and unlicensed dismantler. For all these cases the licensed dismantler superseded the unlicensed and they are categorized as licensed location codes and are counted in the 2,107 statistic.

Table 9: Breakdown of ELVs Owned by Licensed and Unlicensed Dismantlers, 2000 – 2008

	1,396 Licensed Dismantler Locations	711 Unlicensed Dismantler Locations
Total Junk Titles 2005-2007	2,106,764	24,225
Mean Junk Titles 2005-2007	1,509	34
Total Salvage Certificates 2005-2007	50,423	6,645
Mean Salvage Certificates 2005-2007	36	9
Total ELVs 2000-2008	5,839,112	110,844
Mean ELVs 2000-2008	4,182	156

Throughout both time periods, licensed dismantler locations owned significantly more ELVs than their unlicensed counterparts. Both licensed and unlicensed dismantlers owned a much larger proportion of junk title vehicles than salvage certificate vehicles. From 2000 through 2008, licensed dismantler locations on average owned 26 times more ELVs than unlicensed dismantlers. While Table 9 looks at all dismantler locations, only dismantlers owning three or more ELVs annually are required to be licensed. Table 10 breaks down all licensed and unlicensed dismantler locations by volume to identify the dismantlers that were in violation of section 220 of the California Vehicle Code regulating vehicle dismantlers.

For both licensed and unlicensed dismantlers the larger volume locations, those requiring a dismantling license, owned 99% of all ELVs owned by California dismantlers. California dismantlers requiring licenses owned 69% of the entire ELV population from 2000 through 2008. Of the 2,107 dismantler locations in California, 203 appeared to be operating in violation of Section 220 of the California Vehicle Code by owning three or more 'nonrepairable' vehicles annually (CA DMV 3). While our CA DMV vehicle dismantler registration records are incomplete, all 203 of these locations owned ELVs in years for which we can verify they were not in possession of a valid dismantling license.

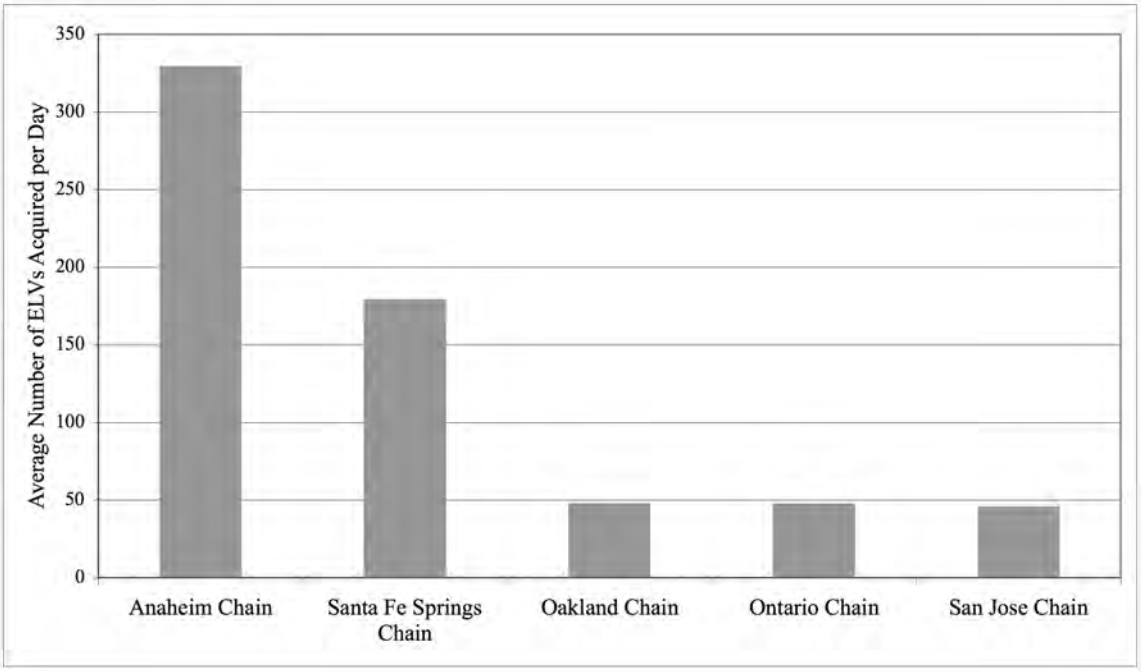
Table 10: ELV Volume Owned by Dismantlers of Varying Sizes, 2000 – 2008

	LICENSED DISMANTLER LOCATIONS		UNLICENSED DISMANTLER LOCATIONS	
	License Required 1,127 locations	No License Required 269 locations	License Required 203 locations	No License Required 508 locations
Total Junk Titles 2005-2007	2,106,111	653	23,083	1,142
Mean Junk Titles 2005-2007	1,869	2	114	2
Total Salvage Certificates 2005-2007	50,310	113	6,487	158
Mean Salvage Certificates 2005-2007	45	0	32	0
Total ELVs 2000-2008	5,766,084	51,126	111,048	21,698
Mean ELVs 2000-2008	5,116	190	547	43

The 2,107 California dismantler locations owned an average of 2,824 ELVs from 2000 through 2008, or 314 ELVs per year. The mean number of ELVs owned per year is significantly different than the median, which is 30 ELVs per year. The difference between the mean and median highlights the extremity of the California dismantler population. A few high volume dismantlers owned the vast majority of ELVs. While the average California dismantler owned 314 ELVs a year, 11 locations owned an average of more than 10,000 a year from 2000 through 2008. These 11 dismantler locations owned an average of 48% of all ELVs from 2000 through 2008.

The five highest volume California dismantler locations owned an average of 47,530 ELVs per year, acquiring on average 651 new ELVs per day. As a comparison, the five lowest volume dismantler locations (that still required a vehicle dismantler license) owned an average of 4 ELVs per year. In fact, 590 dismantler locations owned an average of 4 or fewer ELVs per year. Figure 9 details the number of ELVs acquired per day by the five highest volume dismantler locations. The largest California dismantler was located in Anaheim and was part of a large chain of dismantlers. This dismantler acquired an average of 330 ELVs per day from 2000 through 2008. During this time frame, the dismantler owned 1,083,599 ELVs, more than the next four highest volume dismantler locations combined. The five highest volume dismantler locations were all franchised locations of different chains of dismantlers. All five high volume locations were licensed and did not change ownership from 2000 through 2008. This small number of high volume dismantler locations dominated the industry.

Figure 9: ELVs per Day for the Five Highest Volume Dismantler Locations



3.4 Vehicle Dismantlers by Air District

We next organized the ELV population geographically to analyze the distribution and movement of ELVs through out the state. We categorized the 2,107 licensed and unlicensed dismantler locations by the 35 Air Quality Management Districts (AQMD) and Air Pollution Control Districts (APCD) throughout California. Table 11 outlines the Air Districts and their ELV populations.

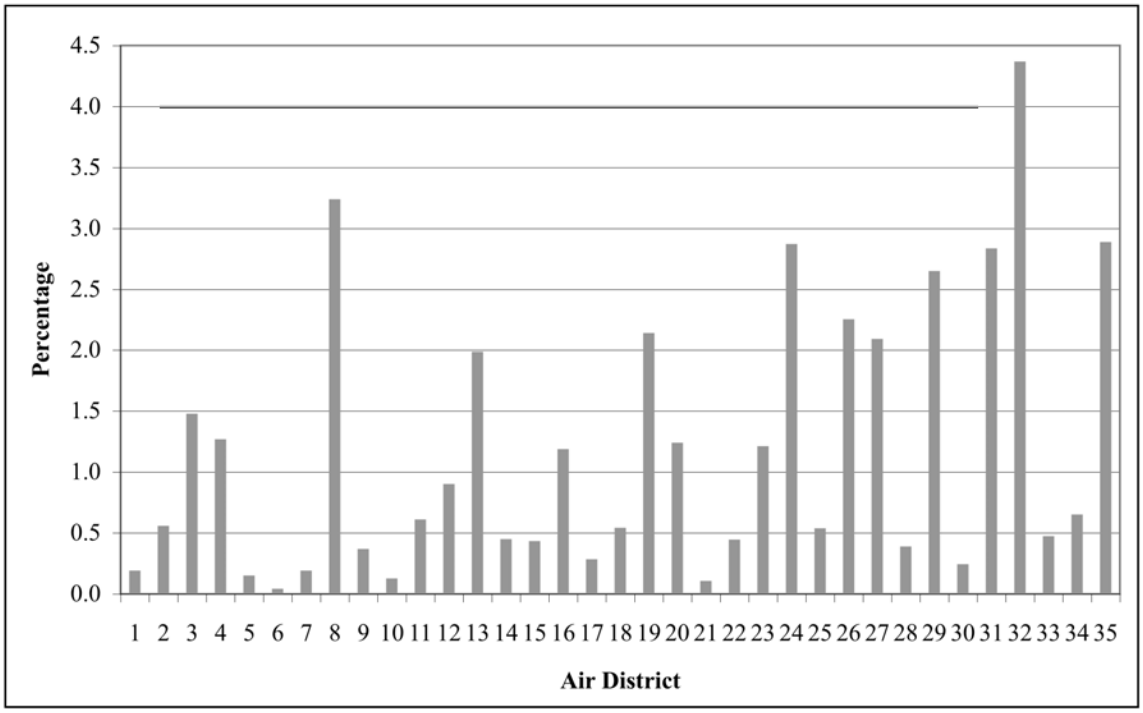
Table 11: ELVs by Air District

Number	Air District	ELVs 2000-2008	Junk Titles 2005-2007	Salvage Certificates 2005-2007
1	Amador County	961	408	3
2	Antelope Valley	24,055	10,618	143
3	Bay Area	812,644	240,129	5,139
4	Butte County	27,414	11,031	406
5	Calaveras County	1,017	498	5
6	Colusa County	120	16	0
7	El Dorado County	3,906	1,221	7
8	Feather River	50,244	20,301	3,654
9	Glenn County	1,285	494	11
10	Great Basin Unified	550	333	5
11	Imperial County	8,743	2,427	1,201
12	Kern County	13,032	4,941	95
13	Lake County	15,995	6,319	34
14	Lassen County	1,673	668	13
15	Mariposa County	1,095	349	7
16	Mendocino County	12,447	5,764	15
17	Modoc County	367	186	3
18	Mojave Desert	29,283	12,030	77
19	Monterey Bay Unified	132,220	46,119	600
20	North Coast Unified	22,523	9,349	101
21	Northern Sonoma County	668	287	1
22	Northern Sierra	6,723	2,211	11
23	Placer County	40,645	7,812	300
24	Sacramento Metropolitan	351,296	138,918	5,903
25	San Diego County	128,925	35,412	7,792
26	San Joaquin Valley Unified	647,601	253,053	4,630
27	San Luis Obispo County	54,588	21,476	90
28	Santa Barbara County	13,409	4,613	60
29	Shasta County	57,316	24,084	589
30	Siskiyou County	1,562	335	6
31	South Coast	3,342,225	1,207,612	22,748
32	Tehama County	27,123	15,297	557
33	Tuolumne County	3,394	1,076	28
34	Ventura County	45,215	15,753	145
35	Yolo/Solano County	69,692	29,845	2,689

To normalize the variation in population and number of registered vehicles across Air Districts, we annualized the junk title and salvage certificate vehicles from 2005 through 2007. Junk title and salvage certificate vehicles was then calculated as a percentage of

vehicles with current registration by Air District.[19] For this calculation we used the 32,623,268 vehicles with current registration as of November 7, 2005. This date represents an average slice of the CA DMV registration records from 2005 through 2007. Figure 10 presents the annualized ELV population as a percentage of vehicles with current registration by the 35 Air Districts, which have been arranged in alphabetical order and are represented by a numeric code that is detailed in the Appendix.

Figure 10: ELVs as a Percentage of Vehicles with Current Registration by Air District



Even normalizing for vehicle population, there was a large discrepancy in the percentage of junk title and salvage certificate vehicle among Air Districts. Figure 11 presents the five Air Districts with the highest percentage of junk title vehicles. There were 211 dismantler locations within these five Northern California Air Districts and 117 of the dismantlers were licensed. Tehama County APCD had the largest percentage of junk titles with 7.4%. There are 10 dismantler locations in Tehama County APCD, all of which were licensed. The high percentage of junk title vehicles is likely the result of dismantlers pulling ELVs into the Air District rather than an anomaly of the population of vehicles with current registration.

[19] We did not impose the condition that the ELVs owned in a specific Air District must have had current registration status in that Air District. Thus, we may be picking up on vehicles that travel in order to be issued a junk title or salvage certificate. These calculations are presented as a representation of the ELV volume compared to the size of an Air District's fleet and should not be used for magnitude calculations.

Figure 11: Highest Percentage of Junk Title Vehicles by Air District

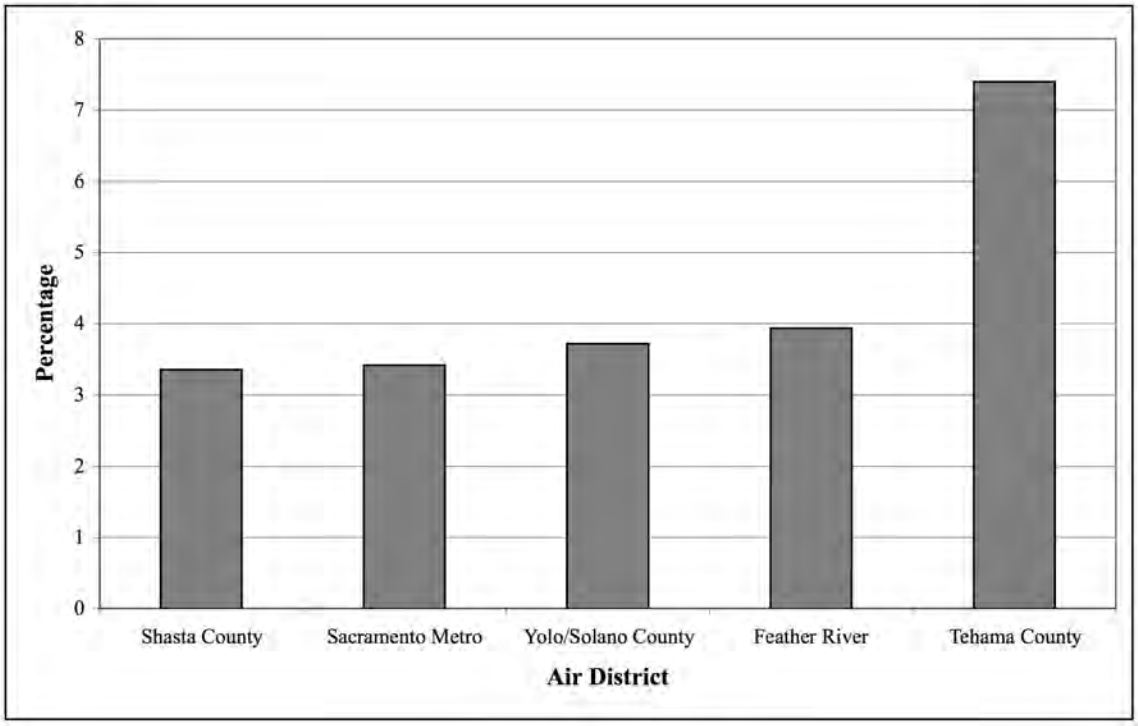


Figure 12 outlines the five Air Districts with the lowest percentage of junk title vehicles. Colusa County APCD had the lowest percentage representing 0.02% of its vehicles with current registration. There were only two dismantler locations in the Colusa County APCD and neither had the capacity, or franchised connections, to pull vehicles in to the Air District from other parts of the state. The five Air Districts with the lowest percentage of junk title vehicles contained only 15 dismantler locations, 13 of which were licensed. All five of these Air Districts were located in Northern California.

Figure 12: Lowest Percentage of Junk Title Vehicles by Air District

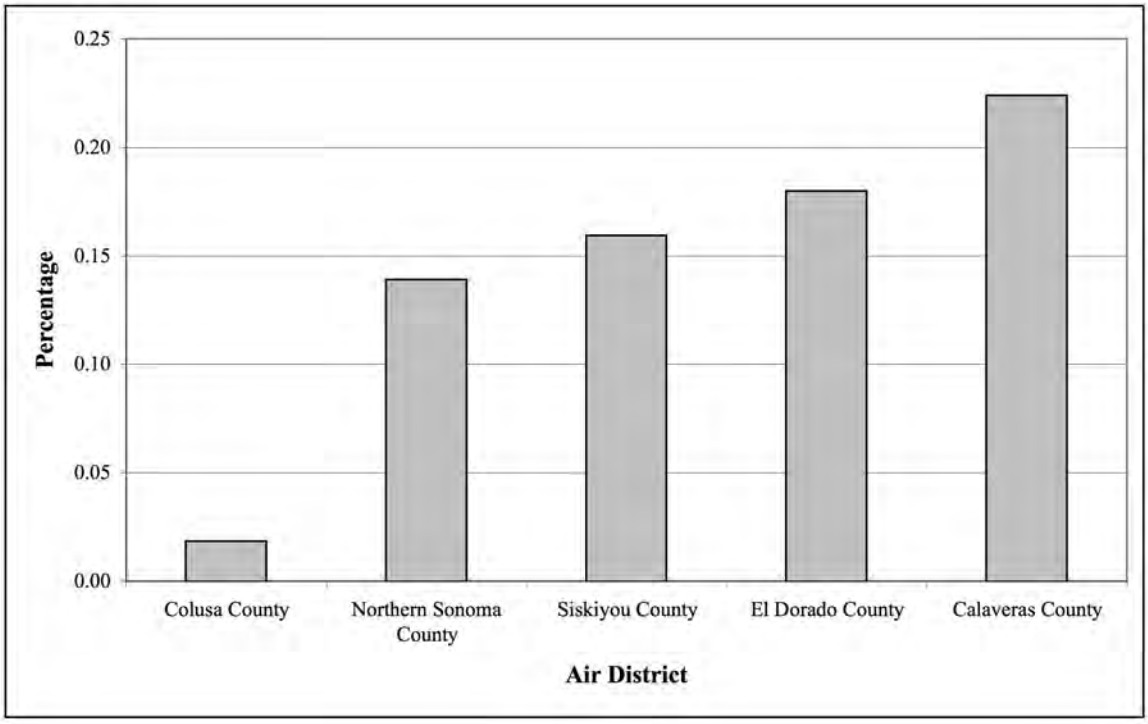
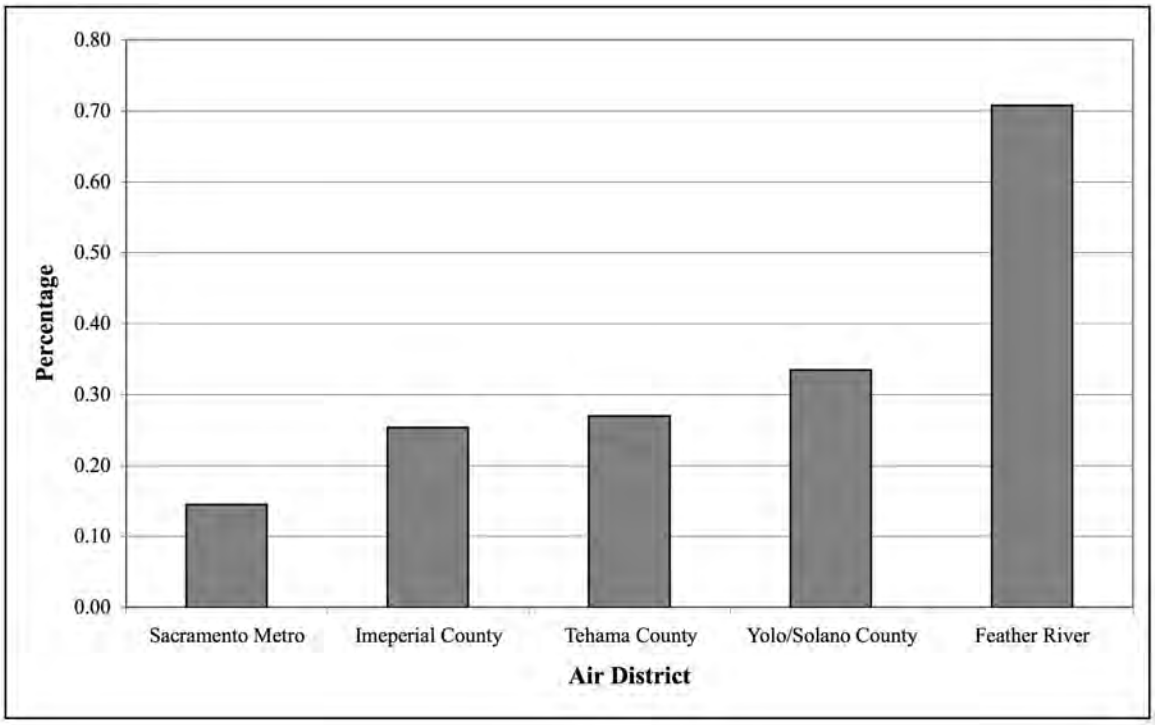


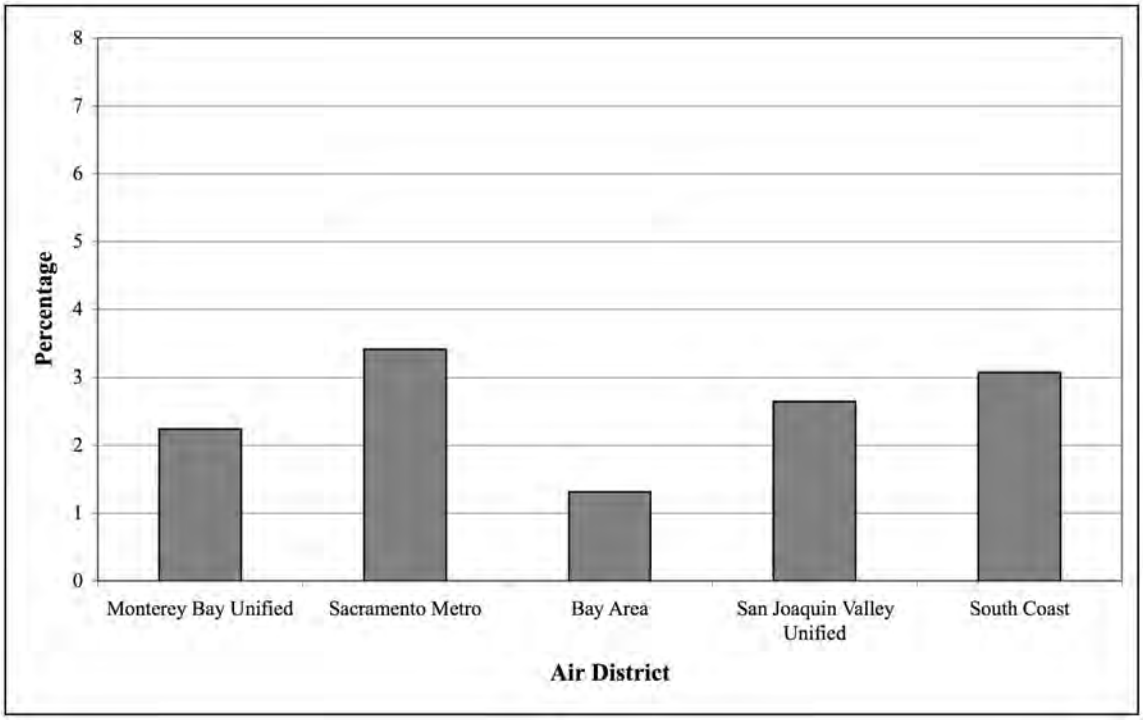
Figure 13 presents the Air Districts with the highest percentage of salvage certificate vehicles, the other component of ELVs. Four of the five Air Districts are the same as those with the highest percentage of junk title vehicles. Feather River AQMD had the largest percentage of salvage certificate vehicles with 0.71% of vehicles with current registration status. Imperial County APCD had the second largest percentage of salvage certificate vehicles and contained 43 dismantler locations, only 9 of which were licensed. Imperial County APCD is on the Mexican border, which makes it difficult to decipher legitimate dismantler locations from those that might actually be in Mexico. Calexico, in particular, was an extremely difficult geographic area in which to decipher legitimate dismantling operations.

Figure 13: Highest Percentage of Salvage Certificate Vehicles by Air District



There are an additional 10 Air Districts that did not contain one salvage certificate vehicle from 2005 through 2007. It is likely that many salvage certificate vehicles traveled through insurance companies rather than licensed vehicle dismantlers. Thus our methodology and analysis is likely vastly underestimating this portion of the ELV population. With the exception of the Sacramento Metro AQMD, Air Districts with the highest percentages of junk title and salvage certificate vehicles tend to be small both geographically and according to total ELV volume. We next analyze the five Air Districts with the highest ELV volumes. Figure 14 presents junk title vehicles as a percentage of vehicles with current registration for the five Air Districts with the highest volume of junk title vehicles from 2005 through 2007.

Figure 14: Junk Title Vehicles as a Percentage of Currently Registered Vehicles for the Air Districts with the Highest Volume of Junk Title Vehicles, 2005 – 2007



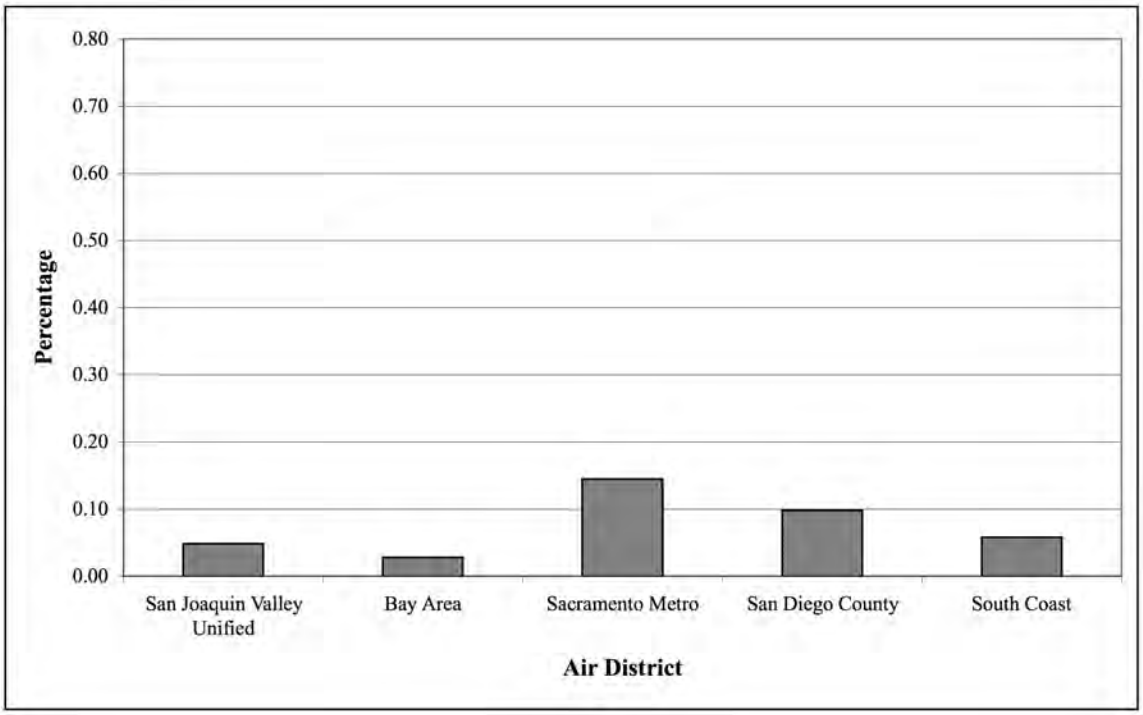
These Air Districts had a range of 15,373 to 402,537 junk title vehicles a year, with an average of 125,722. South Coast AQMD had the highest volume of junk titles, which equaled 3% of its currently registered fleet, compared to the high of 7.4% for Tehama County APCD. The percentage of junk titles was not constant across the highest volume Air Districts, and neither was the make up of their dismantler population. Table 12 outlines the dismantler location of the five highest volume junk title Air Districts.

Table 12: Five Highest Volume Junk Title Air Districts, 2005 – 2007

	Monterey Bay Unified	Sacramento Metro	Bay Area	San Joaquin Valley	South Coast
Dismantler Locations	27	121	260	269	858
Percent Licensed	67%	80%	58%	64%	70%
Mean Junk Titles	170,811	114,808	92,357	94,072	140,747
Mean Salvage Certificates	2,222	4,879	1,977	1,721	2,651

Figure 15 details salvage certificate vehicles as a percentage of vehicles with current registration for the Air Districts with the highest volume of salvage certificates from 2005 through 2007.

Figure 15: Salvage Certificate Vehicles as a Percentage of Registered Vehicles for the Air Districts with the Highest Volume of Salvage Certificate Vehicles, 2005 – 2007



While the number of dismantler locations varies between Air Districts with similar ELV volume, model year distributions do not. Figures 16 and 17 break down the model year distributions of vehicles with current registration status as of November 7, 2005 for the five highest and lowest volume Air Districts. While the magnitudes vary among Air Districts, the model year distributions are similar. Figure 16 shows that the model year distributions for the highest volume Air Districts are skewed towards newer vehicles, with 1970 and older model years comprising only an average of 2% of the currently registered vehicles within these Air Districts.

Figure 16: Vehicles with Current Registration as of November 7, 2005 by Model Year for the Five Air Districts with the Highest Volume of End of Life Vehicles

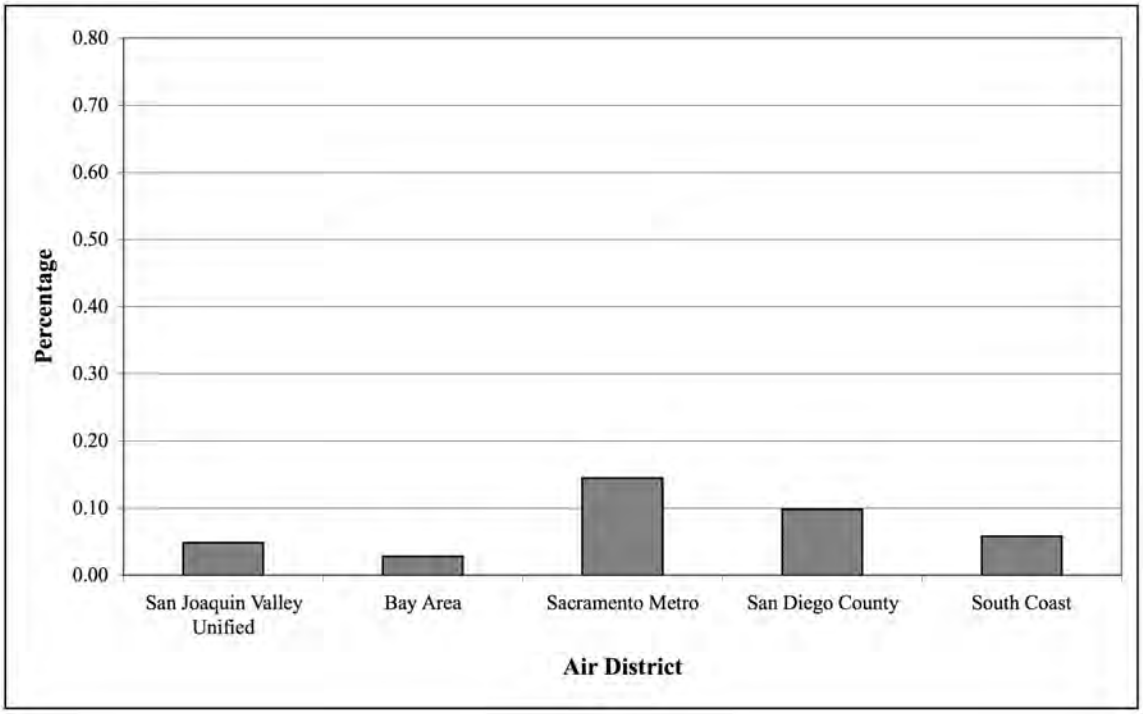
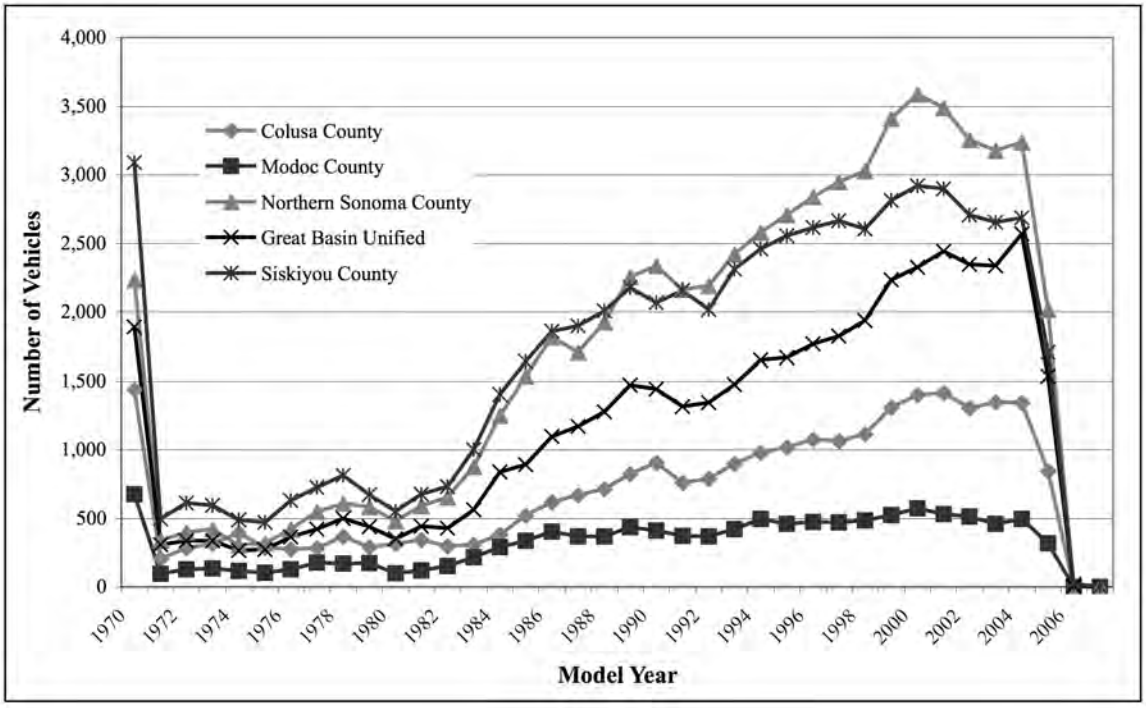


Figure 17: Vehicles With Current Registration Status as of November 7, 2005 by Model Year for the Five Air Districts with the Lowest Volume of End of Life Vehicles



The model year distributions for the five lowest volume Air Districts show more variance than those of the high volume Air Districts due to the low number of total vehicles. Thus, the distribution is not as smooth as that of the high volume Air Districts. The 1970 and older model years comprise 5% of the vehicles with current registration in these Air Districts, double that of the high volume Air Districts. The distribution of vehicles with current registration does not offer insight as to the difference between high and low volume Air Districts.

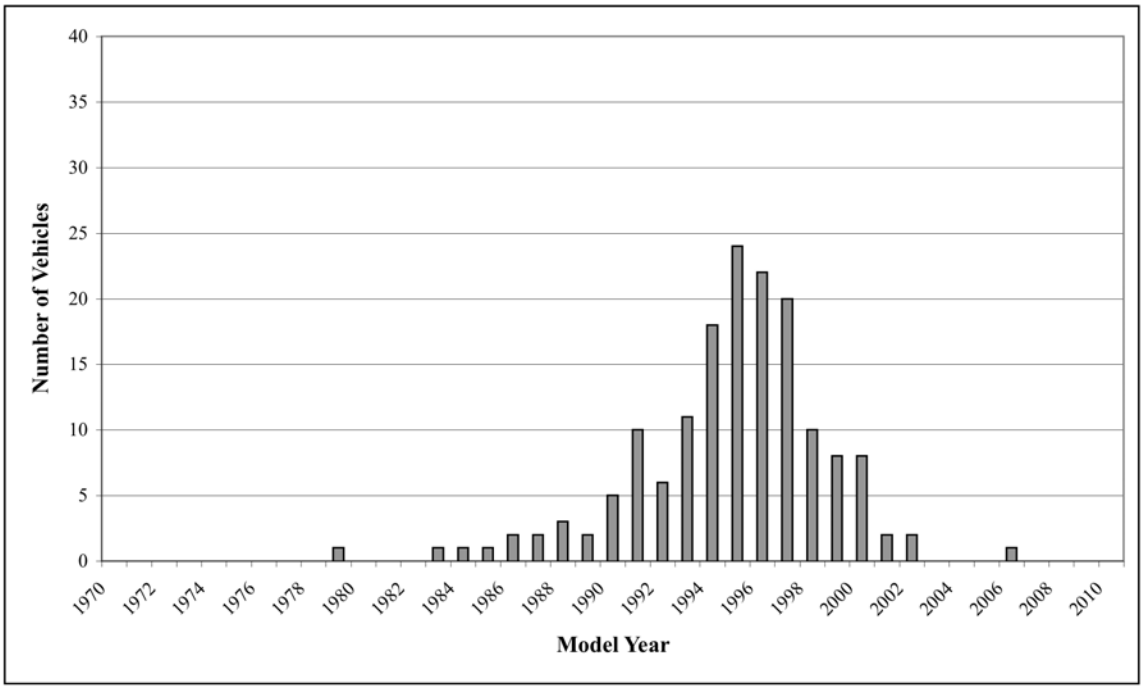
There does not appear to be a strong connection between the vehicles actively registered in a geographic area and End of Life Vehicles. A low number of large volume dismantlers dominated the industry and were often franchises of large chains of dismantlers. Looking within the ELV population, the number of salvage certificate vehicles is low relative to the number of junk certificate vehicles. It does however appear that the high volume dismantlers do seem to own both a high volume of both junk title and salvage certificate vehicles and we did not find a specific geographic region, or a specific dismantler location that appeared to specialize in either of these vehicle classifications. As insurance companies and vehicle auctions are outside the scope of this analysis, we may be missing a large portion of the salvage certificate population.

3.5 Vehicle Sampling

3.5.1 Initial Sampling

An initial sampling of 160 unique vehicles took place from January 14, 2008 through January 19, 2008. The vehicles were sampled at a licensed dismantler in Antelope, California which is in the Sacramento Metro AQMD. Figure 18 details the model year distribution for the 160 unique VINs comprising the initial sample.

Figure 18: Model Year Distribution for Initial 160 Sampled Vehicles



The model years of the initial sample ranged from 1979 to 2006 with a mean of 1995 and a standard deviation of 4. Sixty-one percent of the initial sample were 1995 or newer vehicles. These statistics vary greatly from the ELV population from 2000 through 2008, which had a model year mean of 1989 and a standard deviation of 7. Only 25% of the ELV population from 2000 through 2008 were 1995 and newer model years, while 32% of the ELV population from 2005 through 2007 were 1995 and newer model years. Figure 19 outlines the vehicle makes for the 160 vehicles in the initial sample. Ford was the dominant manufacturer comprising 24% of the sample. The three highest volume makes, Ford, Chevrolet, and Honda accounted for 47% of the sample.

Figure 19: Vehicle Make of Initial 160 Sampled Vehicles

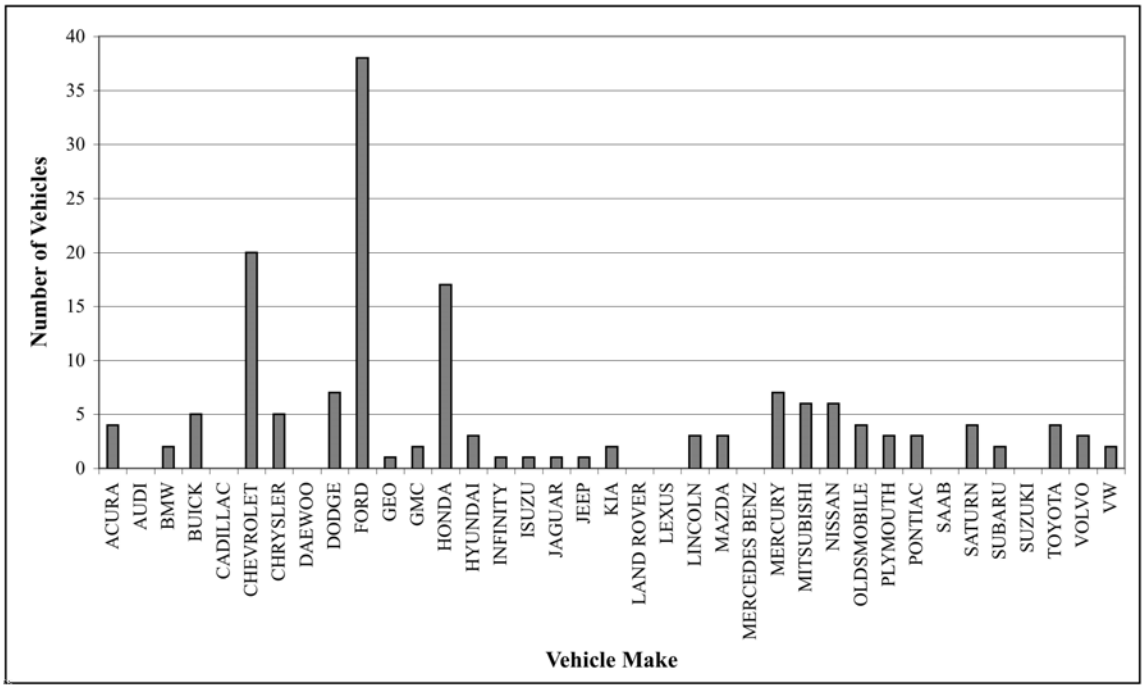
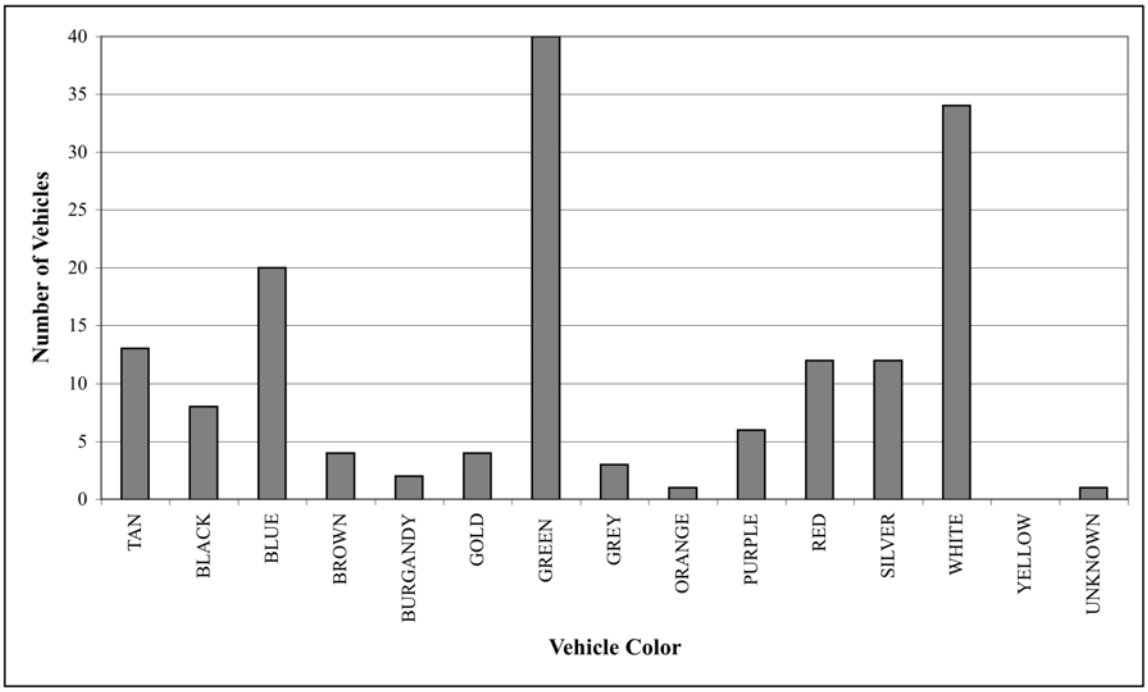


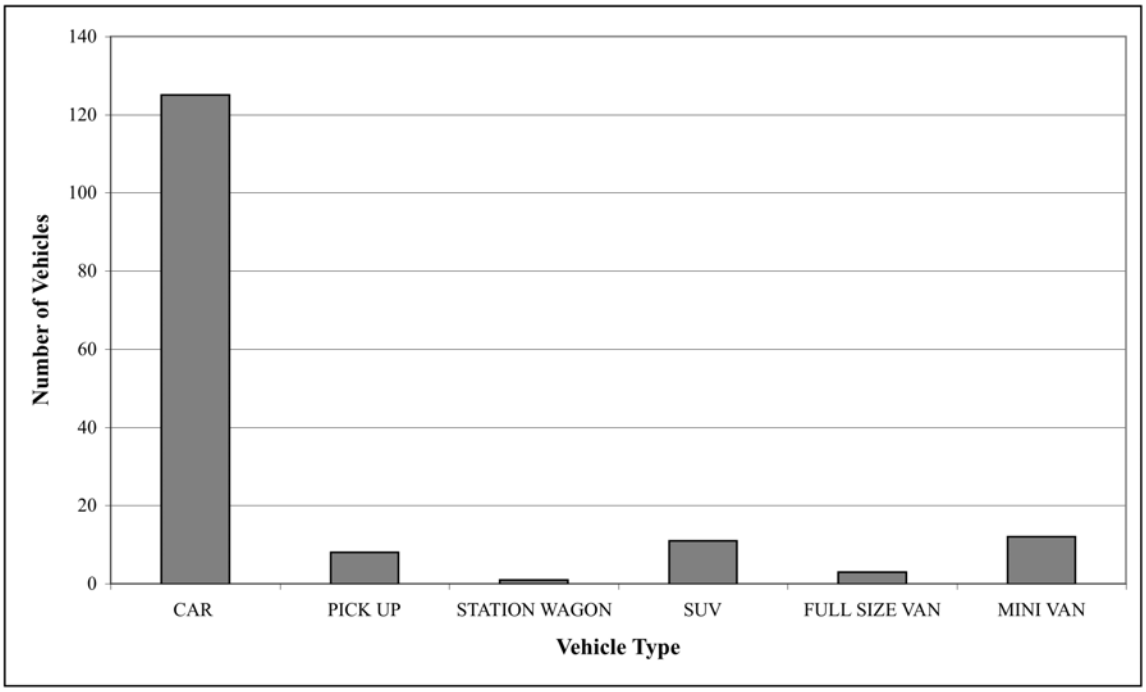
Figure 20 details the vehicle color for the initial sample of vehicles. Green vehicles comprised 25% of the sample with 40 vehicles, while white vehicles made up an additional 21%.

Figure 20: Vehicle Color of Initial 160 Sampled Vehicles



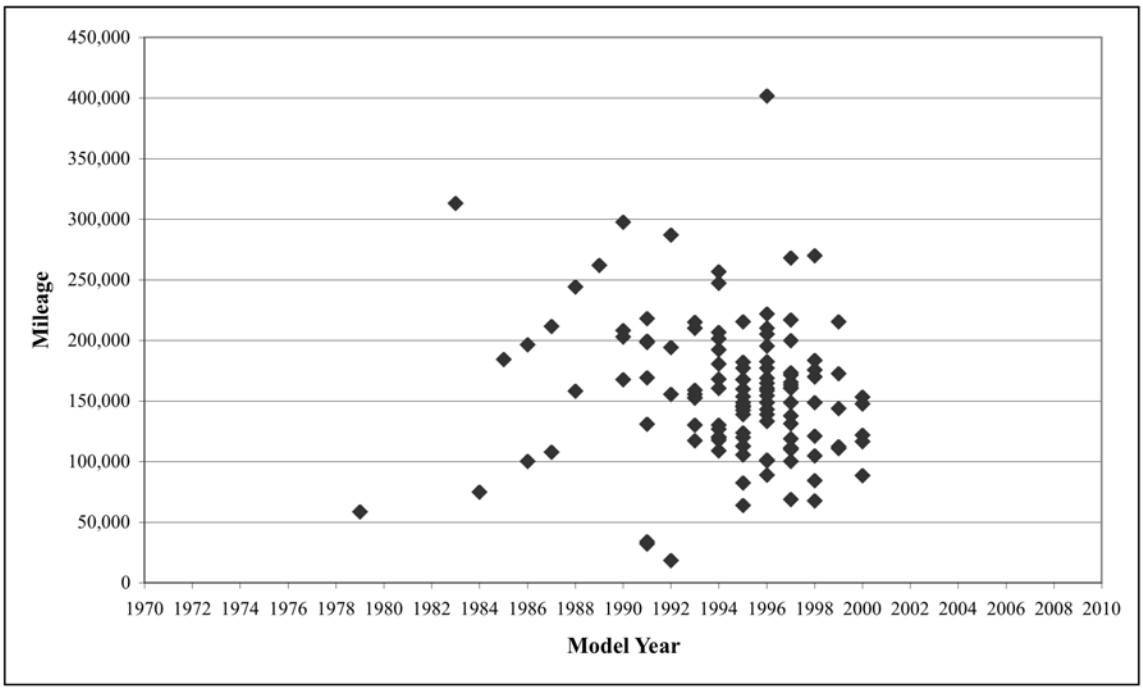
Of the 160 vehicles in the initial sample, 125 were passenger cars. Figure 21 outlines the vehicle type of the initial sample.

Figure 21: Vehicle Type of Initial 160 Sampled Vehicles



When possible, the mileage of each sampled vehicle was also recorded. Out of the initial sample, mileage was recorded for 123 vehicles. The other 37 vehicles either had digital odometers that are only visible when the car is in operation or had extensive front end damage which obscured the odometer. The mileage of the 123 vehicles varied from 18,682, on a 1992 model year, to 403,034, a 1996 model year. The mileage varied widely with a mean of 158,151 miles and a standard deviation of 57,878 miles. As highlighted in Figure 22 there is no correlation between mileage and model year for the initial sample. While this is counter-intuitive as older vehicles are assumed to have higher mileage, we have no data regarding the date the vehicles entered the dismantler. Thus, a 1981 vehicle might have entered the lot in 1988 and thus have a much lower mileage than assumed a priori.

Figure 22: Mileage by Model Year of Initial 160 Sampled Vehicles



Of the initial sample, 78 were at the dismantler due to a collision, 48 of which were front end collisions.[20] The mean model year of these collision vehicles was 1996 with a standard deviation of 3. CA DMV records were found for 135 of the initial 160 sampled vehicles, which are outlined in Table 13. Seventy-five percent of the initial sample was issued a junk title as their final CA DMV action. One vehicle was issued a salvage certificate and another was registered PNO. Three vehicles had unclaimed registration, meaning that CA DMV has lost track of these vehicles and the remaining ten vehicles had other non-ELV registration statuses. Looking at the entire CA DMV registration

[20] These statistics rely on the observations of the FCCC Referees rather than data provided by either the dismantler or found in the CA DMV records.

histories for the initial sample, 123 of the 160 vehicles had ever been junked or salvaged. Thus, 77% of the initial sample of vehicles was classified as an ELV.

Table 13: Final CA DMV Status of Initial 160 Sampled Vehicles

VINs Associated with CA DMV Records	135
Issued a Junk Title	120
Issued a Salvage Certificate	1
Planned Non-Operational	1
Unclaimed Registration	3
Other Registration Status	10

In the initial 160 sampled vehicles, 36 contained R-12. This 23% of the sample had a mean model year of 1990 and a standard deviation of 3. Twenty-five of the vehicles containing R-12 were passenger cars. The mean mileage of vehicles containing R-12 was 165,277 miles across the 28 vehicles with recorded odometer readings. Thus on average, these vehicles were older and had higher mileage than the rest of the initial sample.

The percentage of recovered refrigerant varies greatly for vehicles containing R-12 as well as HFC-134a as shown in Figure 23. No refrigerant was remaining in 48 of the initial 160 sampled vehicles. The mean recovered refrigerant for HFC-134a vehicles was 31% with a standard deviation of 30%. For vehicles containing R-12, the mean was 9.5% of total capacity with a standard deviation of 27%. The 29 R-12 vehicles with no refrigerant had a model year average of 1989, while the 19 HFC-134a vehicles with no refrigerant had a mean model year of 1997. We also looked at the correlation, or the statistical relationship, between variables. There is a slight positive correlation between model year and the percentage of recovered refrigerant.[21] Thus, for the initial sample of 160 vehicles the percentage of recovered refrigerant and model years are related.

[21] The correlation coefficient, which measures how strongly two variables are linearly related from zero to one, is 0.28 for model year and percentage of refrigerant recovered. This value is low but does signify a relationship between the two variables.

Figure 23: Percentage of Refrigerant Remaining in Initial 160 Sampled Vehicles

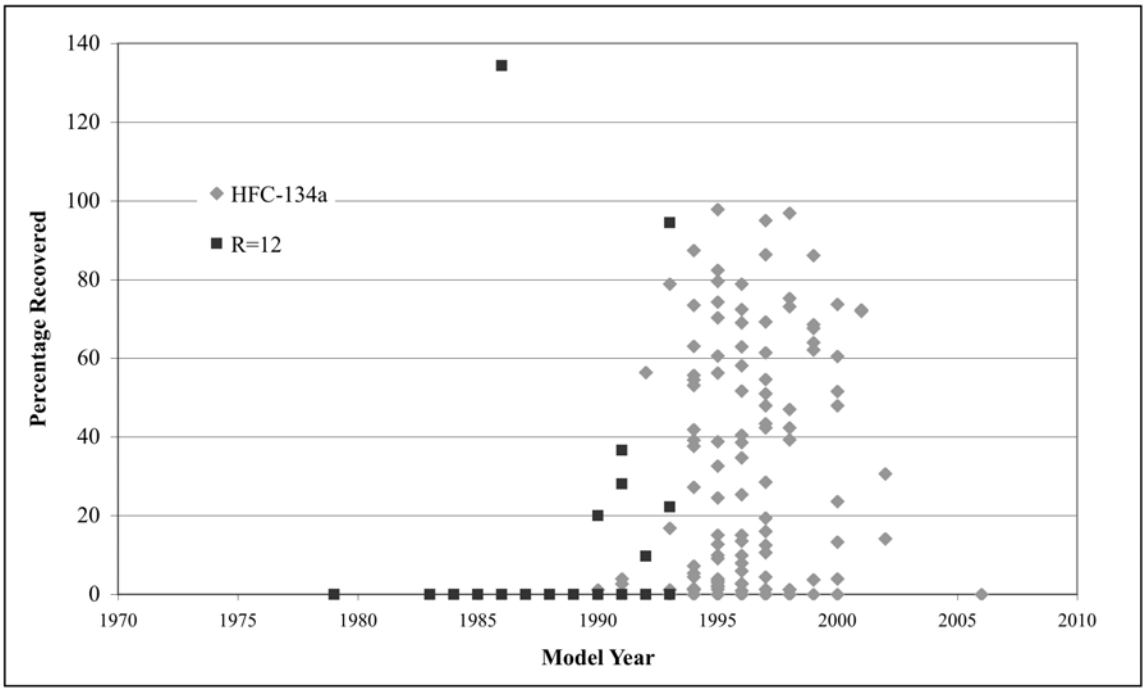


Figure 24 presents the percentage of refrigerant recovered from the initial sample by vehicle make. Each of the 36 vehicle makes was alphabetized and assigned a numeric code. Please see the Appendix for detailed information. The percentage recovered varies greatly within and across vehicle makes for both HFC-134a and R-12. There is no correlation between the percentage of refrigerant recovered and the vehicle make.

Figure 24: Percentage Refrigerant Recovered by Vehicle Make of Initial 160 Sampled Vehicles

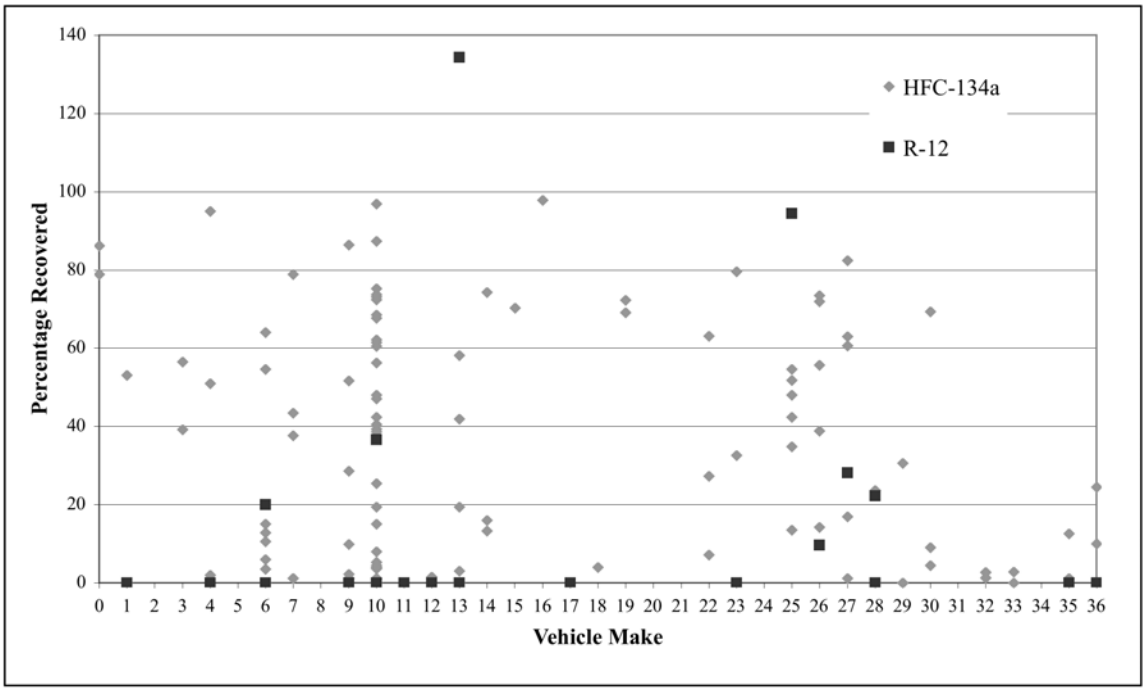


Figure 25 presents the percentage of recovered refrigerant by vehicle color. Vehicle color has been alphabetized and is represented by a number, the definition of which is available in the Appendix. There is no correlation between vehicle color and the percentage of refrigerant recovered from sampled vehicles. The percentage of refrigerant recovered varies greatly across vehicle color as well as within vehicle color for both HFC-134a and R-12 vehicles.

Figure 25: Percentage Refrigerant Recovered by Vehicle Color of Initial 160 Sampled Vehicles

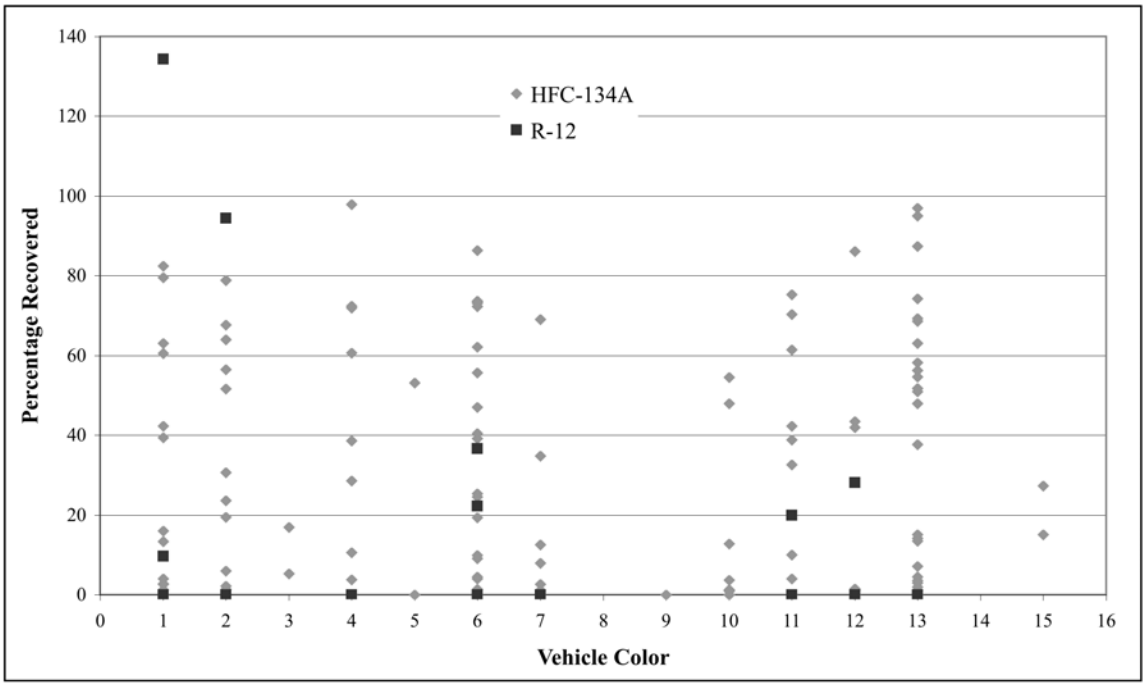


Figure 26 presents the percentage of refrigerant recovered by vehicle type. The vehicle types have been alphabetized and assigned a numeric code, which is explained in the Appendix. The lack of correlation between variable type and recovered refrigerant is evident as the percentage recovered varies greatly for each vehicle type.

Figure 26: Percentage Refrigerant Recovered by Vehicle Type of Initial 160 Sampled Vehicles

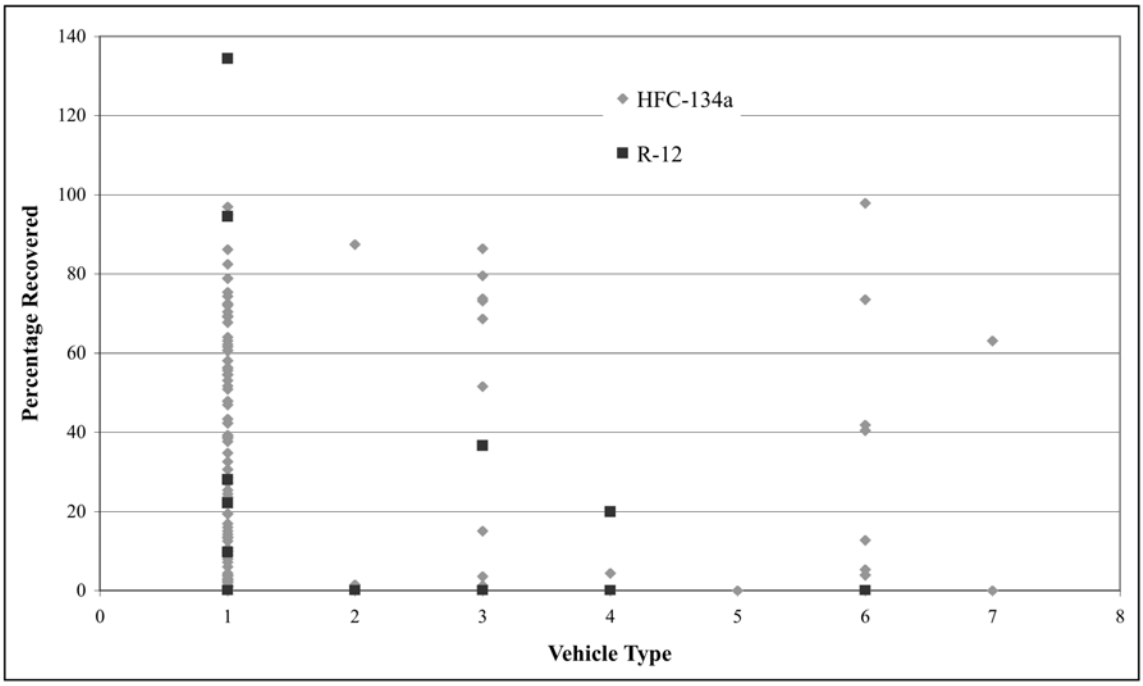


Figure 27 presents the percentage of recovered refrigerant as a function of recorded vehicle mileage. Again, the percentage of refrigerant recovered varies greatly for vehicles of the same mileage. There is a very slight negative correlation between the variables. As mileage increases, the percentage of refrigerant recovered decreases slightly. But the relationship between the variables is not significant and mileage is not an accurate predictor of recovered refrigerant.

Figure 27: Recovered Refrigerant and Mileage of Initial 160 Sampled Vehicles

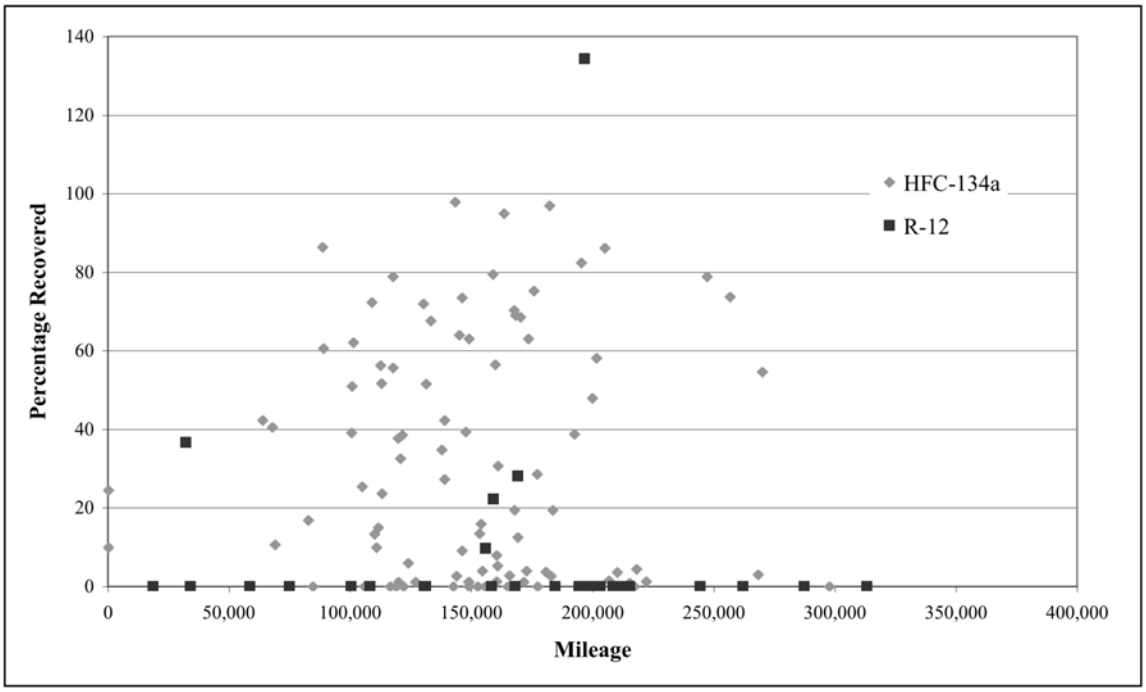
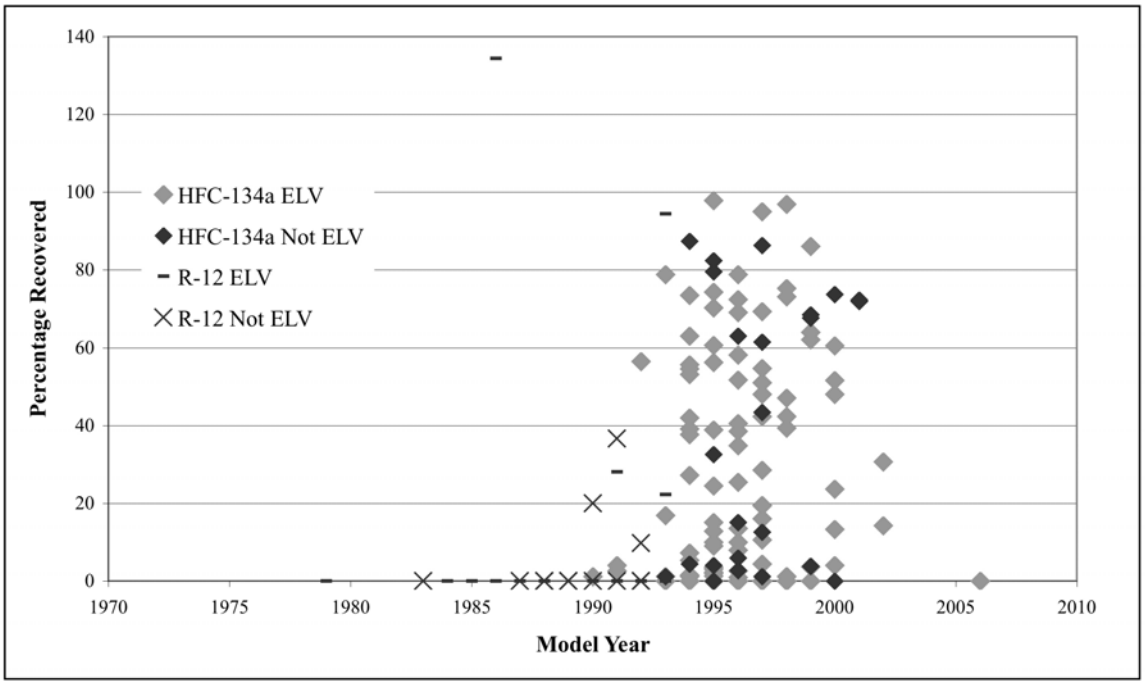


Figure 28 breaks down the sampled vehicles into ELVs and those with other CA DMV classifications and presents them by model year. The percentage of refrigerant recovered from both HFC-134a and R-12 vehicles is not dependent on their classification as an ELV. While there were fewer sampled vehicles that were ELVs, the percentage of refrigerant recovered from these vehicles varies just as much as those that were issued a junk title or salvage certificate.

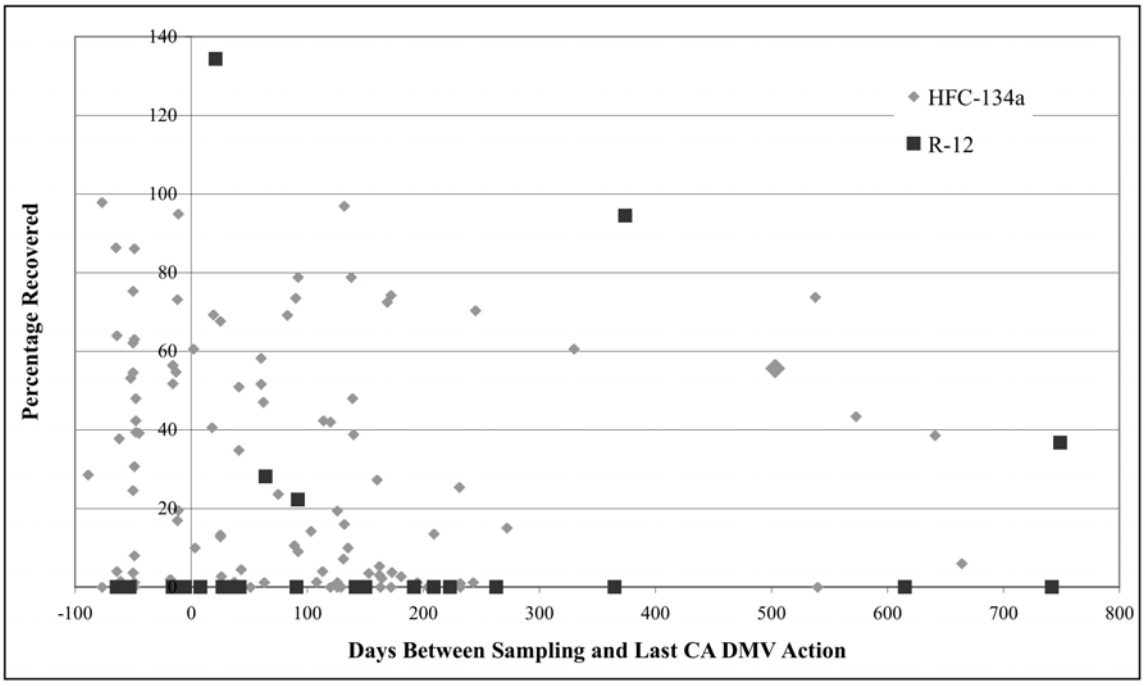
Figure 28: Recovered Refrigerant by Model Year and CA DMV Status of Initial 160 Sampled Vehicles



As we do not have data as to the exact date each sampled vehicle arrived on the lot, we have approximated this data using the date of the vehicle's last CA DMV action. The dismantler at which the sampling occurred was listed as the final owner for 140 of the 160 sampled vehicles. Figure 28 presents the percentage of recovered refrigerant and the number of days between the sampling and the last CA DMV action. For 43 of the sampled vehicles, the date of the last CA DMV action was after the date upon which the sampling occurred. For each of these vehicles, the last known owner was the sampling location and thus this negative elapsed time might be the result of delays within the CA DMV.

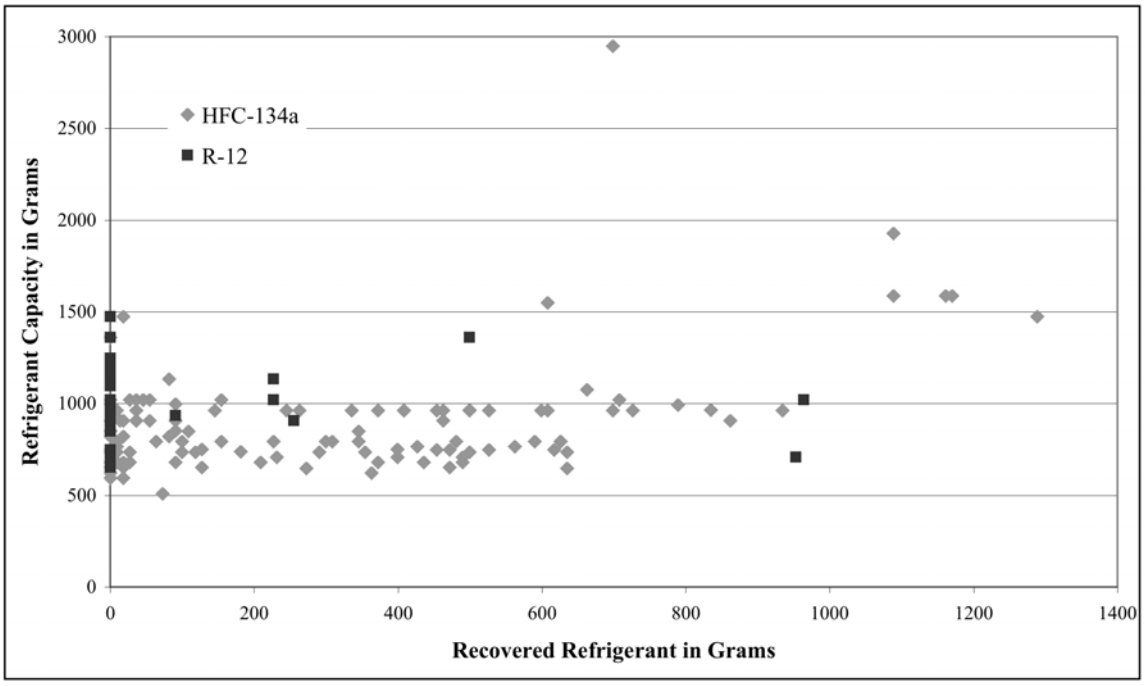
While there is no correlation between the percentage of refrigerant recovered and the length of time the vehicle spent on the dismantler lot, there is a slight downward trend in Figure 29. Thus, on average as the length of time between the final CA DMV action and testing increased, the smaller the percentage of refrigerant recovered. These variables are not significantly related and the length of time a vehicle has been on the dismantler lot is does not explain the percentage of refrigerant recovered.

Figure 29: Percentage Refrigerant Recovered and Days Between Last CA DMV Action and Sampling of Initial 160 Sampled Vehicles



Looking at the amount of refrigerant recovered, Figure 30 plots vehicle refrigerant capacity and the recovered refrigerant in grams for both HFC-134a and R-12. Vehicles containing R-12 had a capacity from 652 grams to 1,474 grams, with an average of 1,003 grams and a standard deviation of 220 grams. On average, 89 grams of R-12 were recovered across the 36 vehicles. HFC-134a vehicles had a capacity range from 510 grams to 2,948 grams. The average HFC-134a capacity was 886 grams with a standard deviation of 294 grams. On average 286 grams of HFC-134a was recovered with a standard deviation of 309. The values of HFC-134a recovered ranged from 0 grams to 1,288 grams.

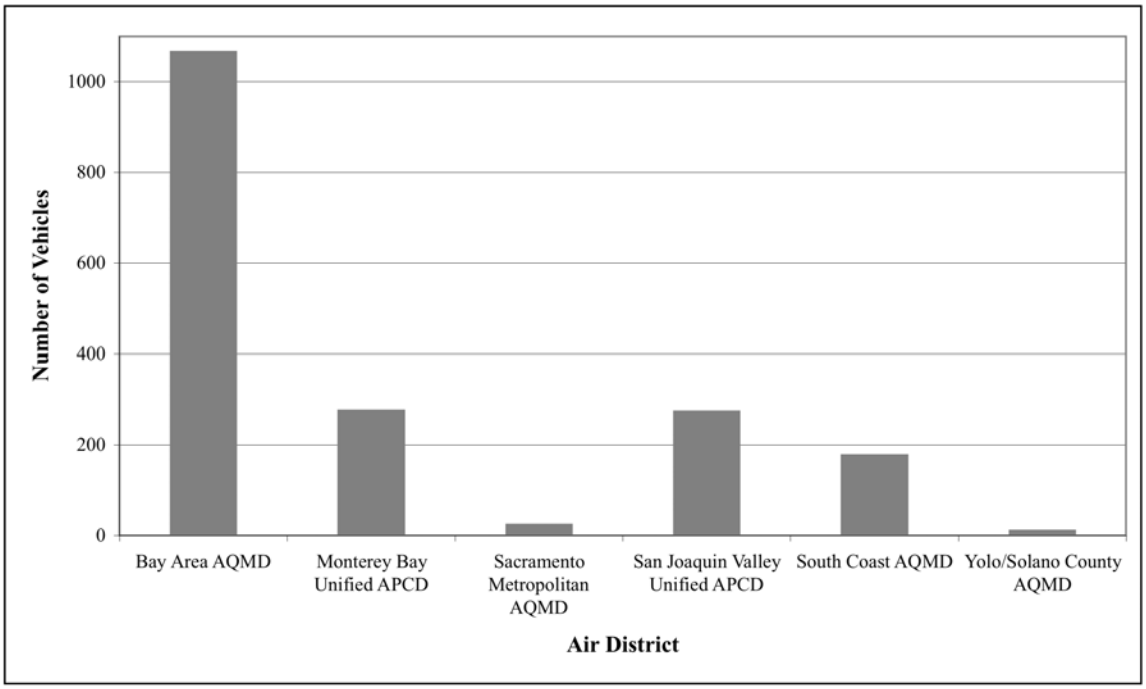
Figure 30: Refrigerant Capacity and Recovered Refrigerant of Initial 160 Sampled Vehicles



3.5.2 Sampling Round Two

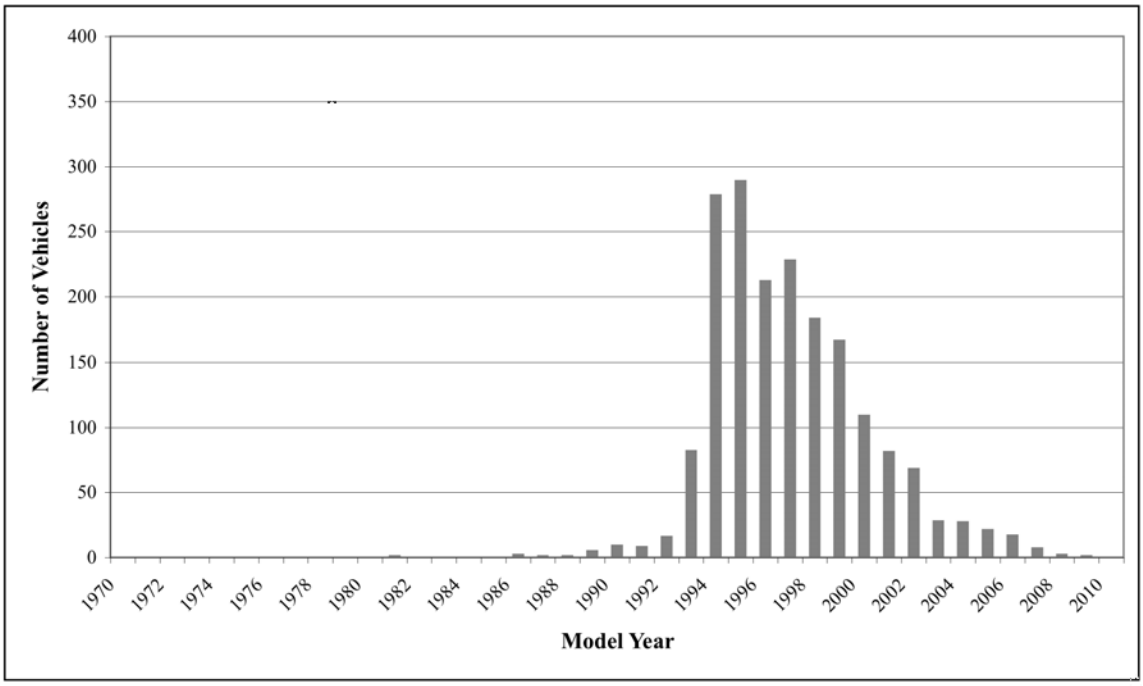
In the second round of sampling, 1,842 unique vehicles were sampled from 29 different licensed dismantlers throughout California. Figure 31 presents the Air District breakdown of the vehicle dismantler locations in the second round of sampling.

Figure 31: Air Districts of Twenty-Nine Round Two Sampling Locations



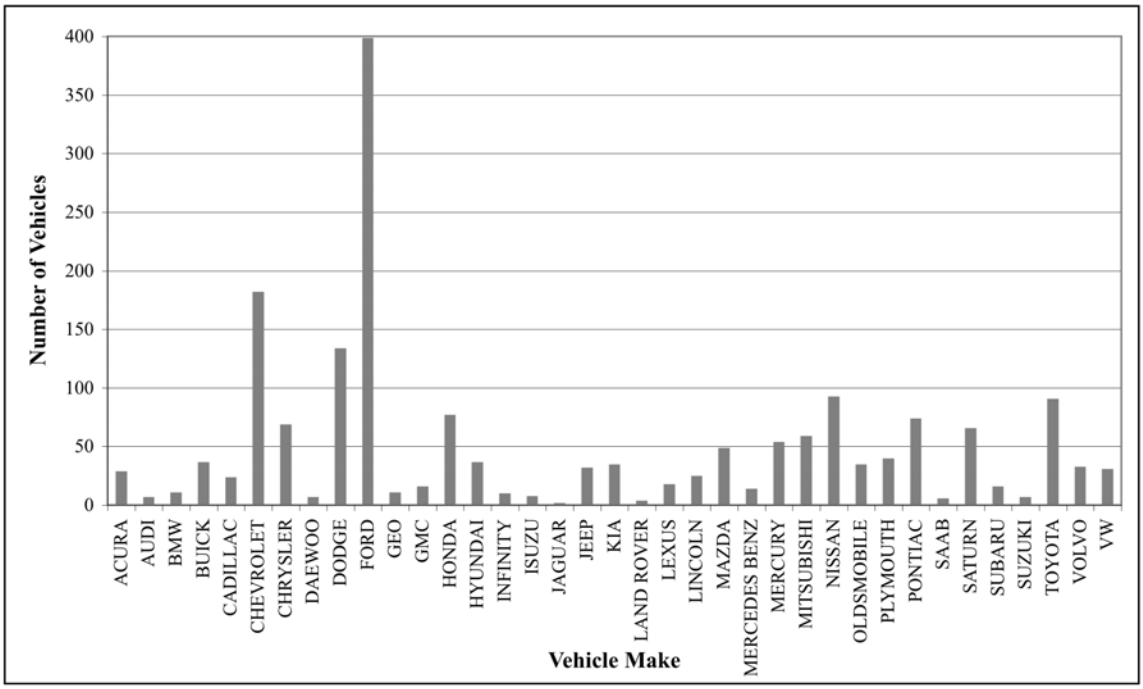
Fifty-eight percent of the vehicles were sampled in the Bay Area AQMD at 16 different vehicle dismantlers. An additional 15% of vehicles were sampled at five dismantlers in the Monterey Bay Unified APCD, 15 % were sampled at four locations in the San Joaquin Valley APCD, 10% of vehicles were sampled at two sites in the South Coast AQMD, 13 vehicles were sampled at one location in the Yolo/Solano County APCD, and a final 0.7% of vehicles were sampled at one dismantler in the Sacramento Metro AQMD. Thus, the efforts at geographic stratification were quite limited. Figure 32 shows the model year distribution of the 1,842 vehicles in the second round of sampling.

Figure 32: Model Year Distribution of 1,842 Round Two Vehicles



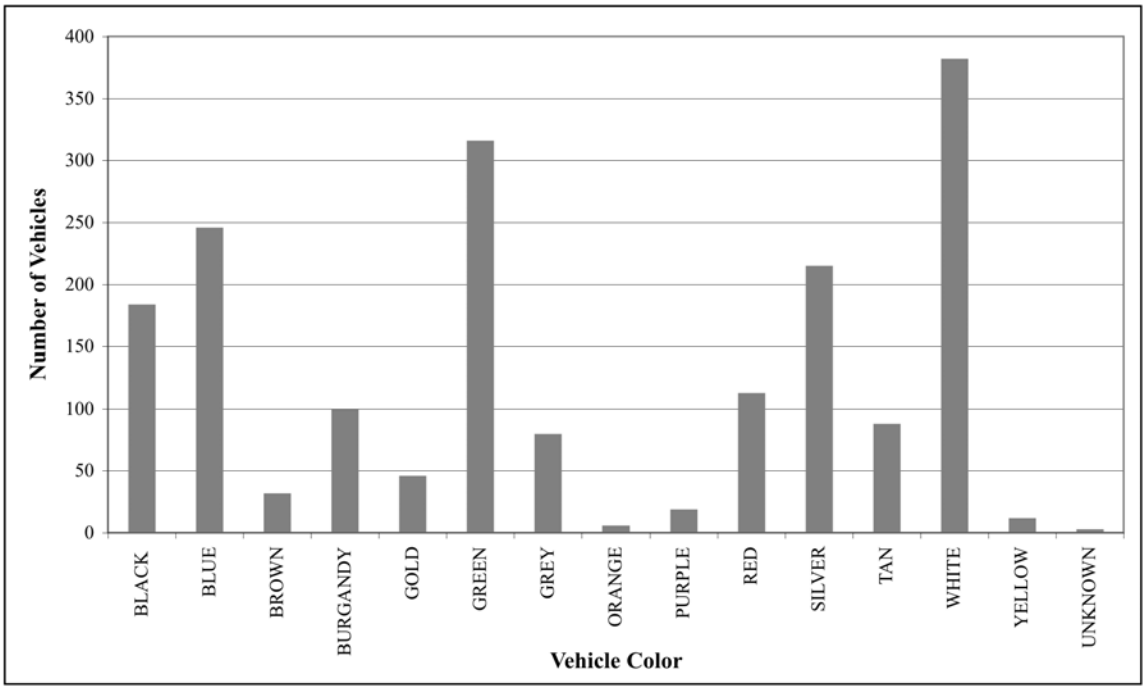
The model years ranged from 1981 to 2009 with a mean of 1997 and a standard deviation of 3. This is significantly different from the model year distribution of the ELV population, which had a mean of 1995 and a standard deviation of 4. Figure 33 shows the vehicle makes for the 1,842 sampled vehicles. Ford is again the most sampled vehicle make, accounting for 22% of the vehicles. The highest volume makes, Ford, Chevrolet, and Dodge comprise 39% of the sample.

Figure 33: Vehicle Make for 1,842 Round Two Vehicles



The body colors of the sampled vehicles are detailed in Figure 34. Twenty percent of the sampled vehicles were white and an additional 17% were green. The body color was not known for three vehicles that were in very poor condition.

Figure 34: Vehicle Color for 1,842 Round Two Vehicles



The vast majority of vehicles sampled were passenger cars. Table 14 presents the vehicle types for the vehicles in the second round of sampling.

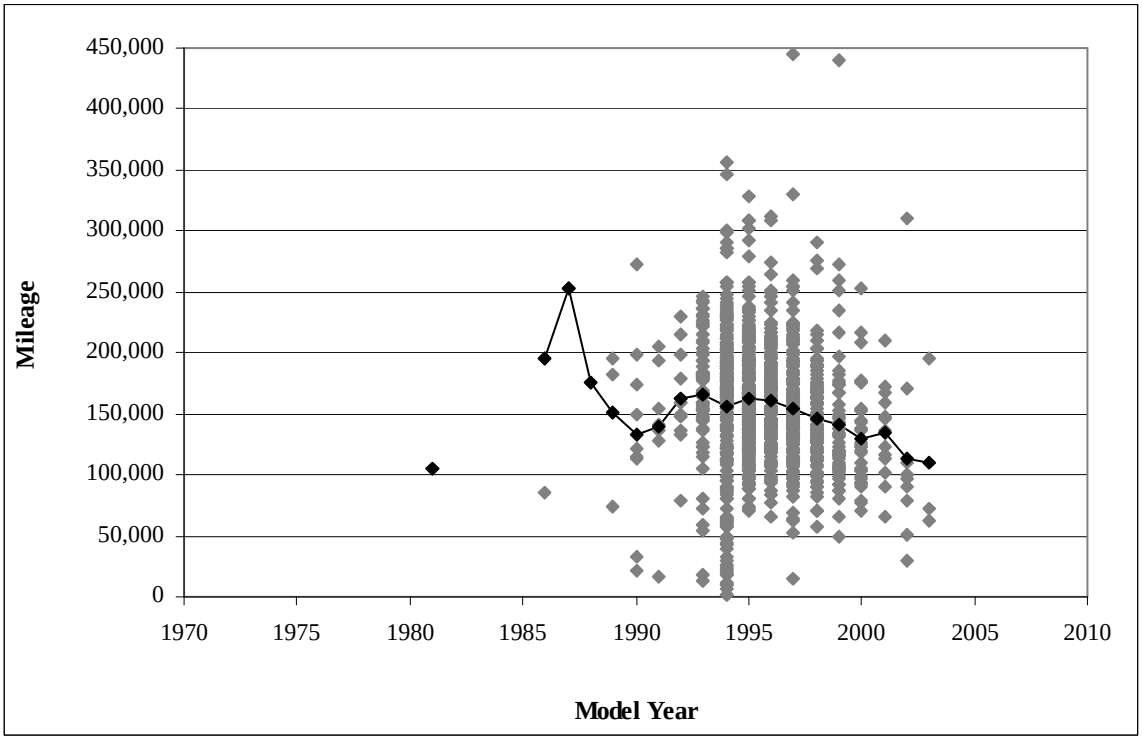
Table 14: Vehicle Type for 1,842 Round Two Vehicles

Vehicle Type	Number of Vehicles	% of Sample
Passenger Car	1302	70.7%
Full Size Van	31	1.7%
Mini Van	193	10.5%
Pick Up Truck	93	5.0%
Station Wagon	54	2.9%
Sports Utility Vehicle	169	9.2%

Mileage was recorded for 1,086 or 59%, of the vehicles sampled in the second round. The mileage ranged from 1,489, for a 1993 model year, to 455,380, for a 1997 model year vehicle. The mean mileage was 154,715 with a standard deviation of 53,216. As shown in Figure 35, the mileage varies greatly by model year and there is a slight downward trend, as newer model years tend to have lower mileage. The mean mileage for each model year is shown in black while each gray point represents one sampled vehicle. There is no statistical correlation between the mileage and model year of the vehicles sampled in the second round and variation in mean mileage by model year is driven by the wide variation of reported mileage within each model year. The 756

vehicles for which no mileage was recorded had a model year range from 1989 to 2009 with a mean of 1999 and a standard deviation of 3 years.

Figure 35: Mileage by Model Year for 1,842 Round Two Vehicles



CA DMV records were found for 1,642 of the 1,842 sampled vehicles. Table 15 outlines the final CA DMV status for each of these 1,642 vehicles.

Table 15: Final CA DMV Status for 1,842 Round Two Vehicles

VINs Associated with CA DMV Records	1,642
Issued a Junk Title	1,180
Issued a Salvage Certificate	23
Planned Non-Operational	16
Unclaimed Registration	23
Other Registration Status	400

In the second round of sampling, 64% of vehicles were issued a junk title as their final DMV action. An additional 1% of vehicles were issued a salvage certificate while no registration information was available for 11% of the sample. Looking at each vehicle's entire CA DMV history, 1,242 vehicles had either been issued a salvage certificate or a

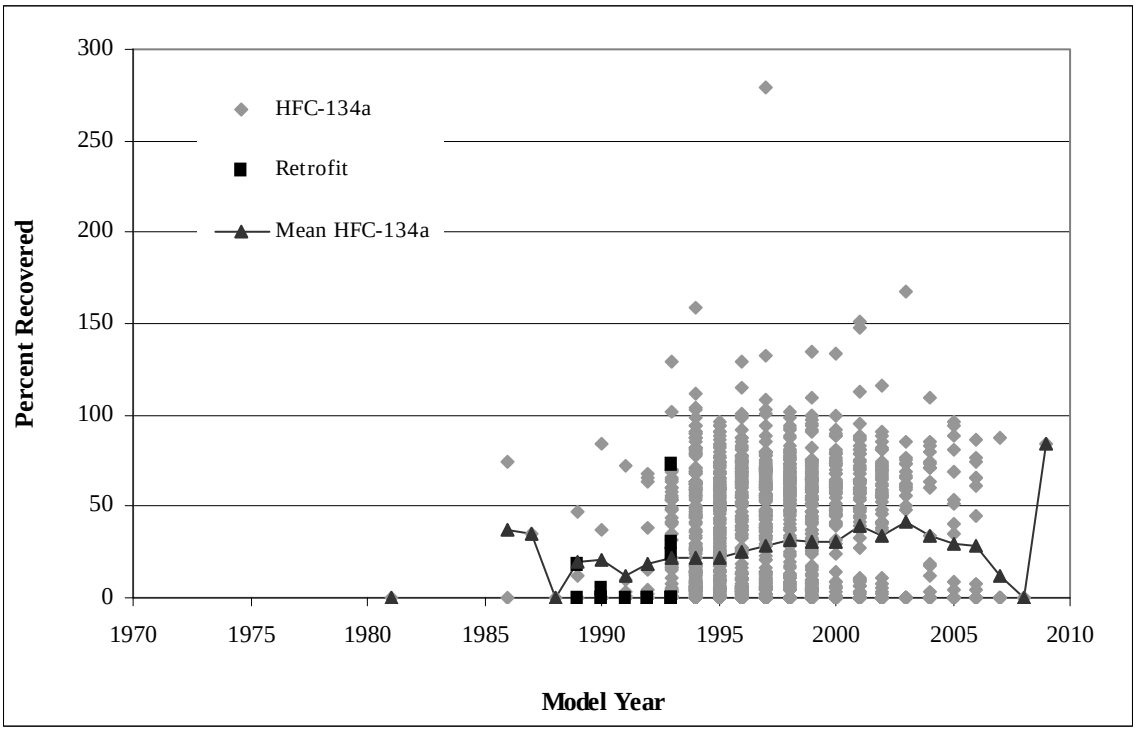
junk title and were classified as an ELV. These vehicles had a model year range from 1981 to 2009 with a mean of 1997 and a standard deviation of 3 years. Vehicles that either had no registration history or had never been issued a salvage certificate or junk title had a model year range from 1986 to 2007 with the same mean of 1997 and standard deviation of 3 years.

Fifteen of the 1,842 vehicles were older model year vehicles that had been retrofitted from R-12 to HFC-134a. The model years of these retrofit vehicles ranged from 1989 to 1993. Figure 36 presents the HFC-134a recovered from all 1,842 vehicles in the second round of sampling. The retrofit vehicles are separated from the sample in black and had a mean of 10% of HFC-134a capacity remaining with a standard deviation of 20%. The percentage of refrigerant recovered from retrofit vehicles ranged from 0% to 73% of vehicle capacity. Given the small number of retrofit vehicles in the rest of the analysis we will analyze all 1,842 round two vehicles together. The 1,827 vehicles that contained HFC-134a and were not retrofitted had a model year range from 1981 to 2009 with a mean of 1997 and a standard deviation of 3. The mean percentage of recovered HFC-134a for each model is dark grey. These vehicles had an average of 27% of HFC-134a capacity recovered with a standard deviation of 32%. Thus, the remaining refrigerant varied widely across the sample with a range from 0% to 280% of vehicle refrigerant capacity.

There were 24 vehicles in the second round of sampling with recovered HFC-134a over 100% of capacity. There were also 762 sampled vehicles that had no HFC-134a remaining in the system. These vehicles had a mean of 1997 with a range from 1981 to 2008 and a standard deviation of 3 years. There was a very slight positive correlation between model year and the percentage of refrigerant recovered from all vehicles in the second round of sampling.[22] Thus, as model year increases, or as vehicles decrease in age, the percentage of recovered refrigerant tends to increase. While these variables are related, model year alone cannot be used to predict the percentage of refrigerant remaining in sampled vehicles.

[22] The correlation coefficient for model year and percentage of refrigerant recovered was 0.14 for vehicles in the second round of sampling.

Figure 36: Recovered Refrigerant of 1,842 Round Two Vehicles



In the second round of sampling 832 vehicles were at the dismantler due to a collision, according to the FCCC Referees. Of these vehicles, 490 had a front-end collision while 344 were not front-end collisions. An additional 663 vehicles had no information regarding their collision status. Table 16 presents the model year calculations for the 1,842 Round 2 vehicles with different collision statuses.

Table 16: Model Year Calculations by Collision Status for 1,842 Round Two Vehicles

Category	Number	Mean	Standard Deviation	Minimum	Maximum
No Collision	663	1996	2	1986	2004
Front End Collision	490	1998	3	1990	2007
Non-Front End Collision	344	1997	3	1987	2005
No Information	345	1998	4	1981	2009

The model year mean and standard deviation across all sampled vehicles are similar regardless of collision status. Table 17 presents the mean percentage of recovered HFC-134a for Round 2 vehicles according to collision status. The mean percentage of

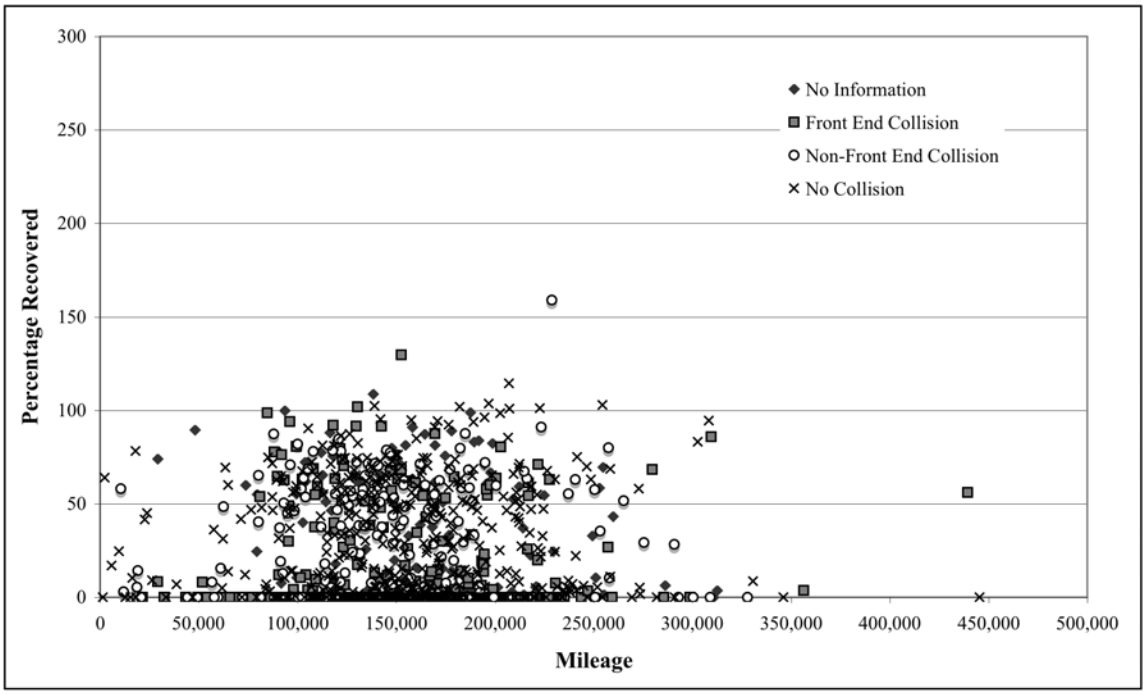
refrigerant is not significantly different across the sample and for each collision status, the standard deviation is greater than the mean percentage of recovered refrigerant. These calculations are unstable, as shown by the very divergent minimum and maximum percentages of recovered refrigerant. Thus, it does not appear from the 1,842 sampled vehicles, that collision status affects the percentage of refrigerant remaining in ELVs.

Table 17: Recovered Refrigerant by Collision Status for 1,842 Round Two Vehicles

Category	Number	Mean	Standard Deviation	Minimum	Maximum
No Collision	663	29%	31%	0%	132%
Front End Collision	490	21%	31%	0%	134%
Non-Front End Collision	344	28%	31%	0%	159%
No Information	345	31%	38%	0%	280%

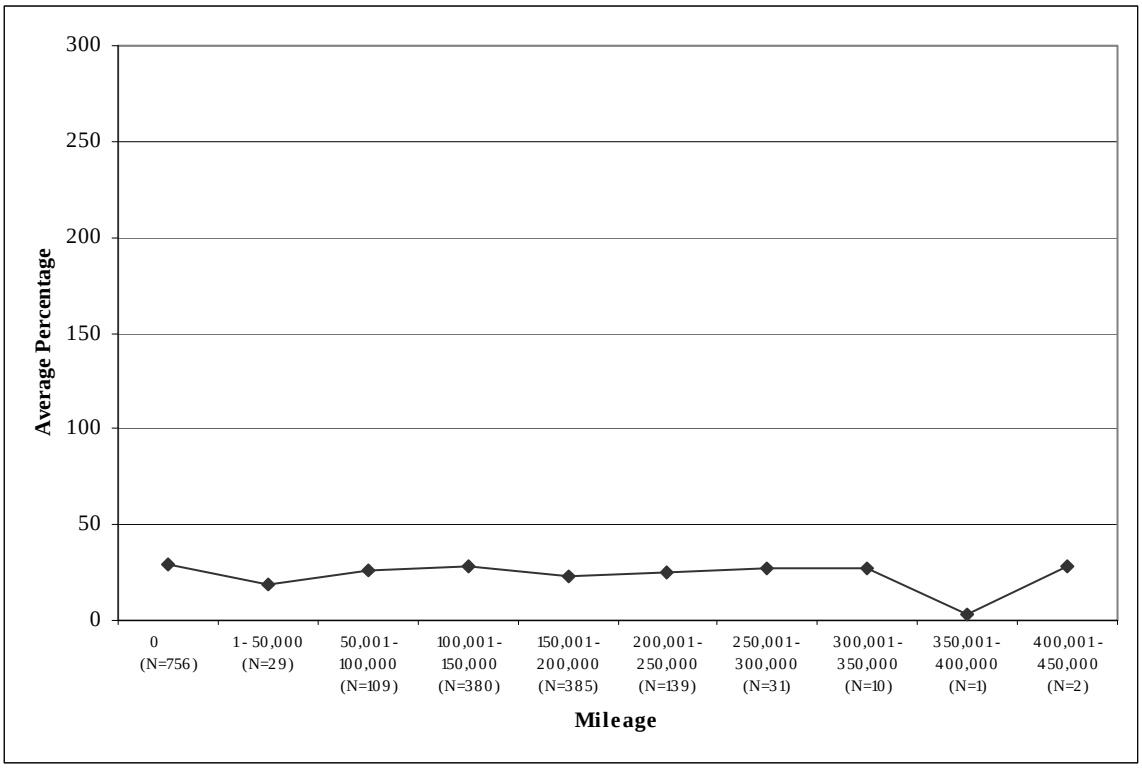
Figure 37 looks at the recovered refrigerant by collision status for the 1,086 sampled vehicles with recorded mileage. The recovered refrigerant and mileage vary greatly by vehicles with and without evidence of a collision.

Figure 37: Recovered Refrigerant and Mileage for 1,842 Round Two Vehicles



There is no correlation between the percentage of HFC-134a and mileage for any vehicle, regardless of its collision status.[23] The mean mileage varies from 151,839 miles for vehicles with evidence of a front-end collision to 155,765 for vehicles with no collision information. Thus, the mileage is very similar for all groups of vehicles. Partitioning the mileage of sampled vehicles into grouping of 49,999 miles, Figure 38 shows that the average percentage of recovered refrigerant does not vary significantly with vehicle mileage. Figure 38 presents the average percentage of recovered refrigerant for all 1,842 sampled vehicles across all collision statuses. The number of vehicles within each mileage partition is given in parenthesis along the horizontal axis and the first grouping labeled 0 represents all vehicles for which no mileage was recorded. The average percentage of recovered refrigerant varies from 4% for vehicles with 350,001 to 400,000 recorded miles to 30% for vehicles with no mileage information.

Figure 38: Average Recovered Refrigerant Across Mileage Partitions for 1,842 Round Two Vehicles



While these averages are significantly different, the results are driven by the wide variation of recovered refrigerant within each mileage grouping as shown by the difference between the mean and median values. Table 18 presents the mean, median,

[23] The correlation coefficient varies from 0.045 to 0.048 for vehicles of different collision statuses. Thus, these variables are not related and collision status is not a good indicator of the percentage of refrigerant remaining in sampled vehicles.

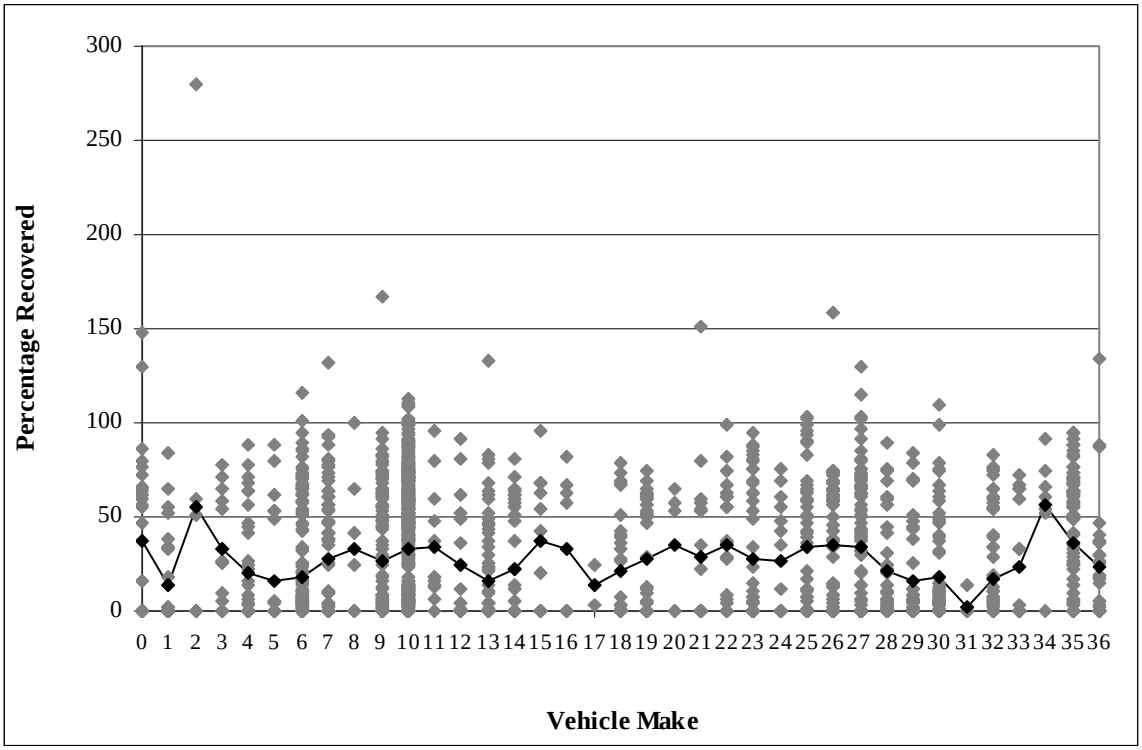
minimum, and maximum values of recovered refrigerant for each mileage grouping and shows that the mean is driven by outliers rather than a natural consensus of the data.

Table 18: Statistics Pertaining to Recovered Refrigerant Across Mileage Partitions for 1,842 Round Two Sampled Vehicles

Category	Number	Mean	Median	Minimum	Maximum
0 - No Mileage Information	756	30%	8%	0%	280%
1 - 50,000 Miles	29	19%	5%	0%	78%
50,001 - 100,000 Miles	109	26%	6%	0%	99%
100,001 - 150,000 Miles	380	28%	12%	0%	109%
150,001 - 200,000 Miles	385	23%	12%	0%	102%
200,001 - 250,000 Miles	139	25%	6%	0%	159%
250,001 - 300,000 Miles	31	27%	6%	0%	103%
300,001 - 350,000 Miles	10	28%	11%	0%	95%
350,001 - 400,000 Miles	1	4%	2%	4%	4%
400,001 - 450,000 Miles	2	28%	28%	0%	56%

Figure 39 presents the percentage of recovered HFC-134a and the vehicle make for all 1,842 sampled vehicles. As described in Section 3.5.1, the 37 vehicle manufacturers have been alphabetized and assigned a numeric code, which is detailed in the Appendix.

Figure 39: Percentage of Recovered HFC-134a and Vehicle Make for 1,842 Round Two Vehicles



For each vehicle make there is a wide distribution of recovered HFC-134a and there is no correlation between any vehicle make and the percentage of recovered refrigerant. In Figure 38, the mean percentage of recovered refrigerant for each vehicle make is shown in black. The average percentage of recovered HFC-134a varies from 2% for Saabs to 57% across Suzukis. Again, while these means are significantly different, they are driven by wide variation in recovered refrigerant within vehicle makes.

Figure 40 presents the percentage of recorded refrigerant by vehicle body color. The 15 vehicle colors have been alphabetized and given a numeric code that is detailed in the Appendix. The mean percentage of HFC-134a for each vehicle color is shown in black. The mean percentage of recovered refrigerant is not significantly different across vehicle colors. Vehicle color is not correlated with the percentage of recovered HFC-134a.

Figure 40: Percentage of Recovered HFC-134a and Vehicle Color for 1,842 Round Two Vehicles

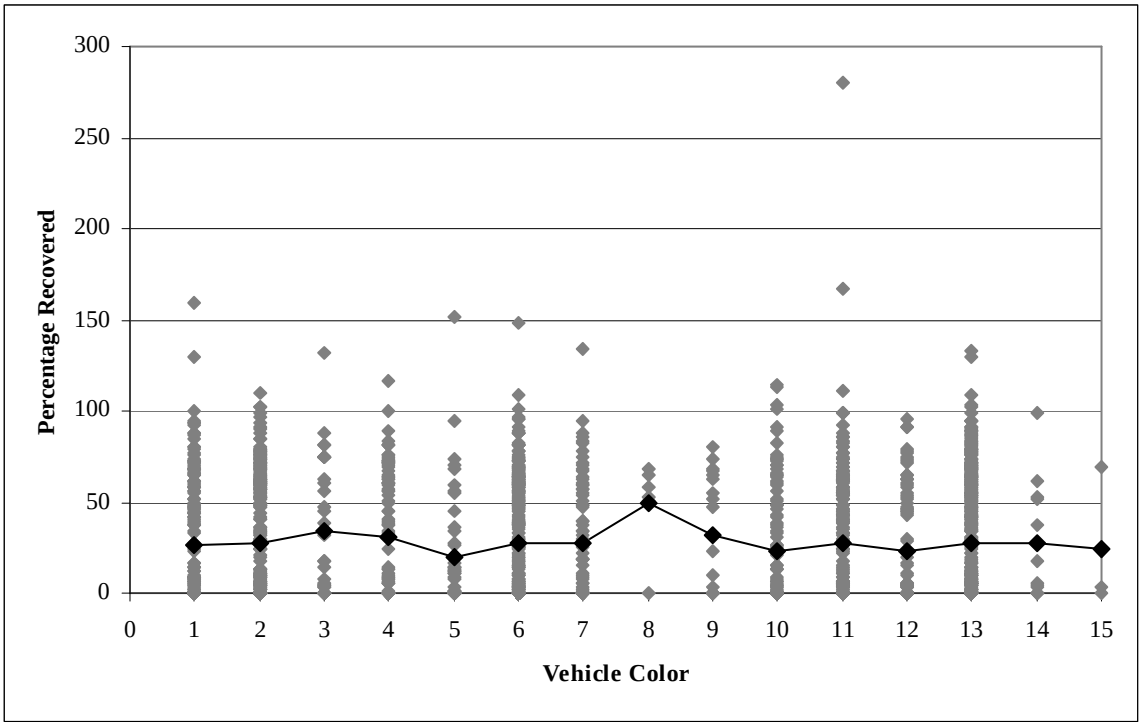


Figure 41 outlines the percentage of HFC-134a recovered by vehicle type. The six vehicle types have been assigned a numeric code, which is detailed in the Appendix. The mean percentage of recovered HFC-134a is shown in black. There was no correlation between any vehicle type and the percentage of recovered HFC-134a nor were the mean values across vehicle types significantly different. Table 19 presents statistics pertaining to the percentage of refrigerant recovered by vehicle type.

Figure 41: Percentage of Recovered HFC-134a and Vehicle Type for 1,842 Round Two Vehicles

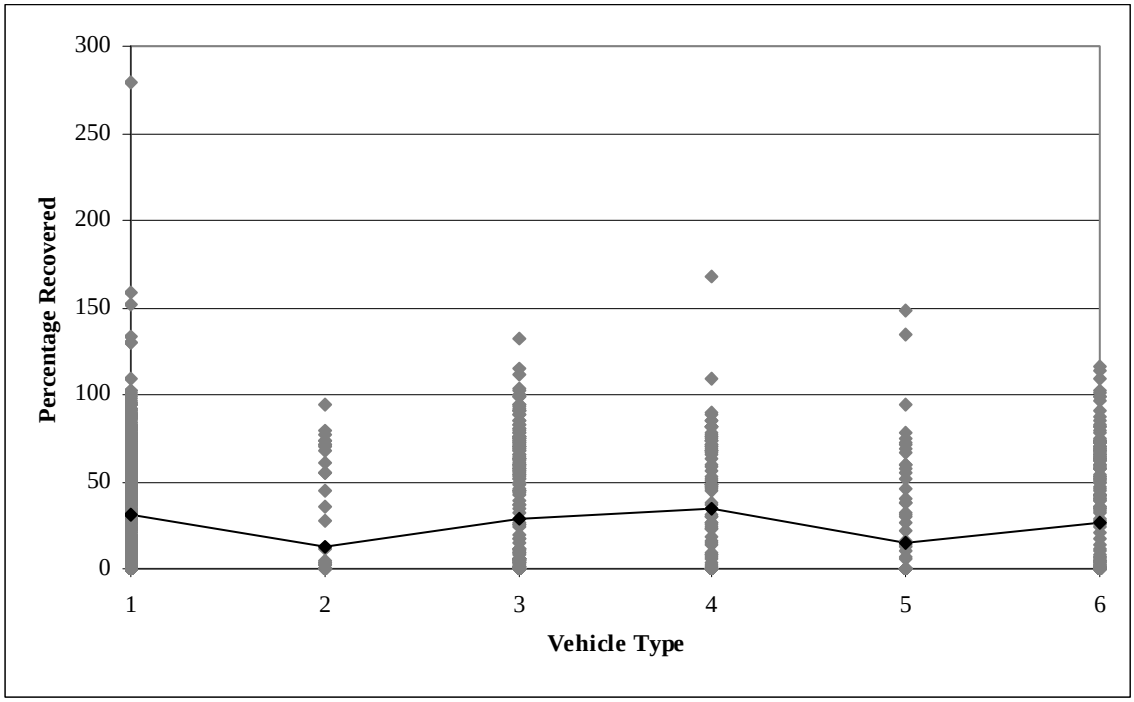


Table 19: Statistics Pertaining to Recovered Refrigerant Across Vehicle Types for 1,842 Round Two Vehicles

Vehicle Type	Number	Mean	Standard Deviation	Minimum	Maximum
Passenger Car - 1	1302	25%	31%	0%	280%
Full Size Van - 2	31	32%	34%	0%	94%
Mini Van - 3	193	32%	36%	0%	132%
Pick Up Truck - 4	93	37%	35%	0%	167%
Station Wagon - 5	54	27%	36%	0%	148%
Sports Utility Vehicle - 6	169	32%	34%	0%	116%

Figure 42 and Table 20 details the percentage of HFC-134a recovered by final CA DMV status. For five of the six CA DMV final status categories, the standard deviation is greater than the mean percentage of refrigerant recovered. This shows the wide range of refrigerant that was recovered within and across CA DMV categories and the instability of these values. There is no correlation between recovered refrigerant and the sampled vehicles final CA DMV status.

Figure 42: Percentage of Recovered HFC-134a and Model Year for 1,842 Round Two Vehicles Categorized by Final CA DMV Status

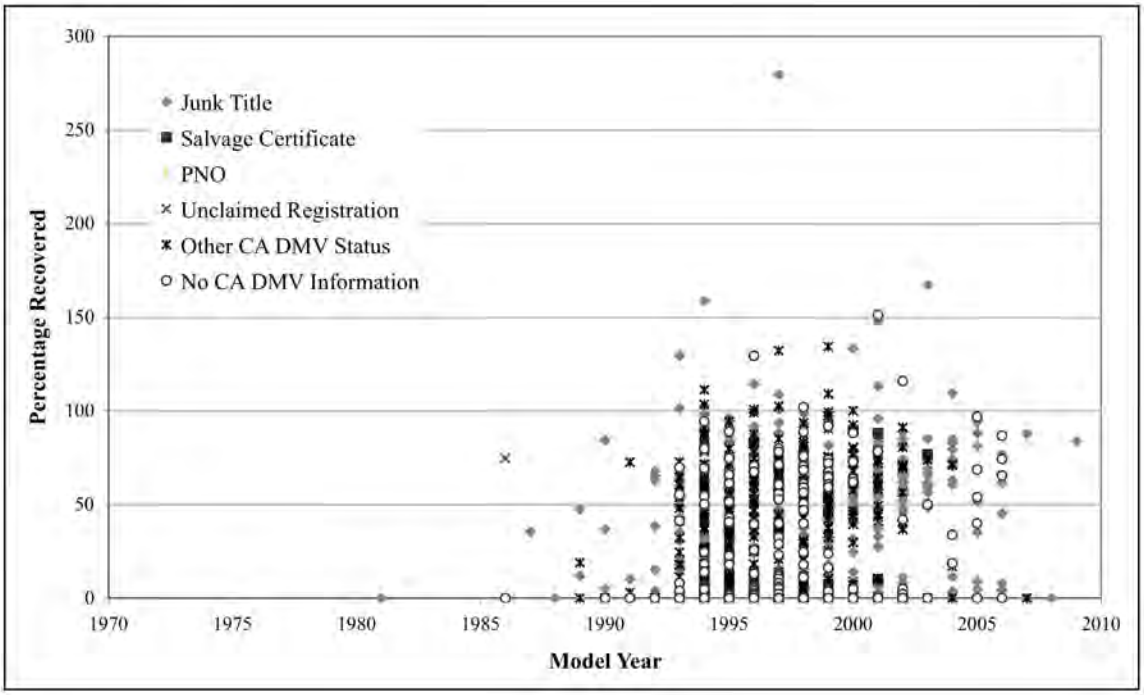


Table 20: Statistics Pertaining to Recovered Refrigerant Across Final CA DMV Status for 1,842 Round Two Vehicles

Vehicle Classification	Number	Mean	Standard Deviation	Minimum	Maximum
Junk Title	1,180	26%	32%	0%	167%
Salvage Certificate	23	30%	33%	0%	109%
PNO	16	27%	31%	0%	77%
Unclaimed Registration	23	34%	33%	0%	81%
Other CA DMV Status	400	31%	32%	0%	280%
No CA DMV Information	200	25%	33%	0%	1515%

Figure 43 presents the percentage of HFC-134a recovered and the number of days between the last CA DMV action and the sampling date. For graphical clarity two outliers have been omitted from the graph but are included in all the calculations. The number of days between the last CA DMV action and the date of sampling ranged from -194 days to 3,364 days with a mean of 154 days and a standard deviation of 316 days. There were 432 sampled vehicles that had a CA DMV action at a later date than the sampling date. For 246 of these vehicles, the sampling location was also the owner listed for the last CA DMV action. For the other vehicles, there may either be errors in

recorded dates within the registration records or the vehicles have been subsequently 'revived' from the dismantler and have a new registration status.

Figure 43: Percentage HFC-134a Recovered and Time Elapsed Between Last CA DMV Status and Sampling for 1,842 Round Two Vehicles

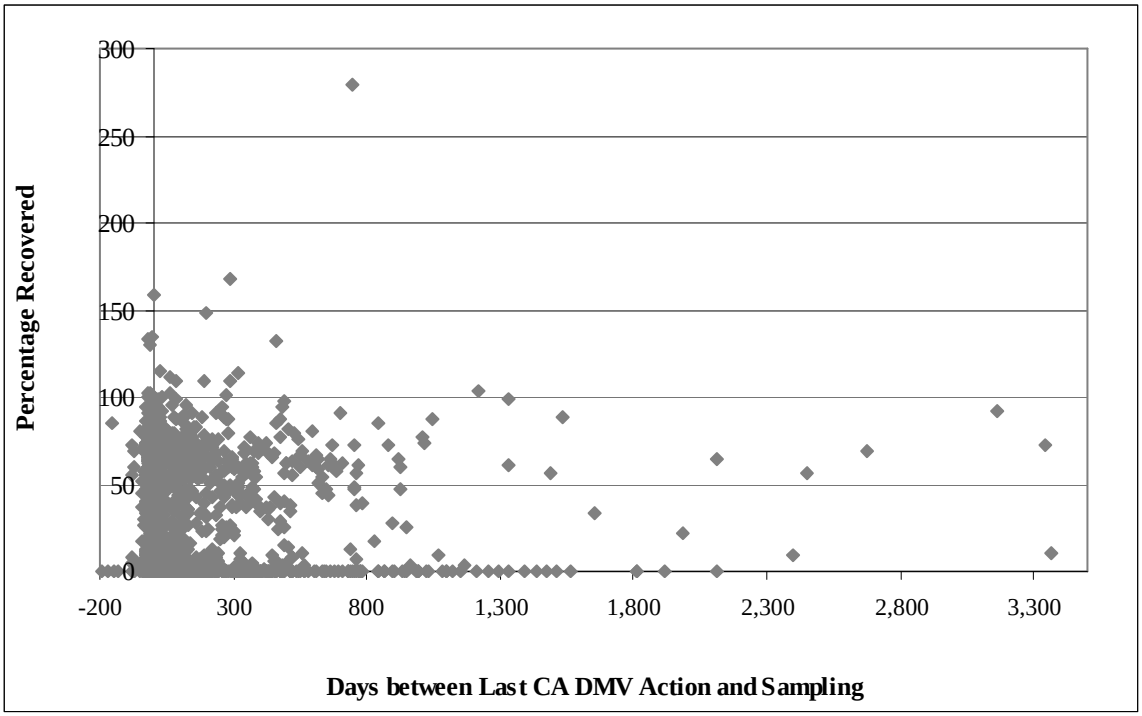
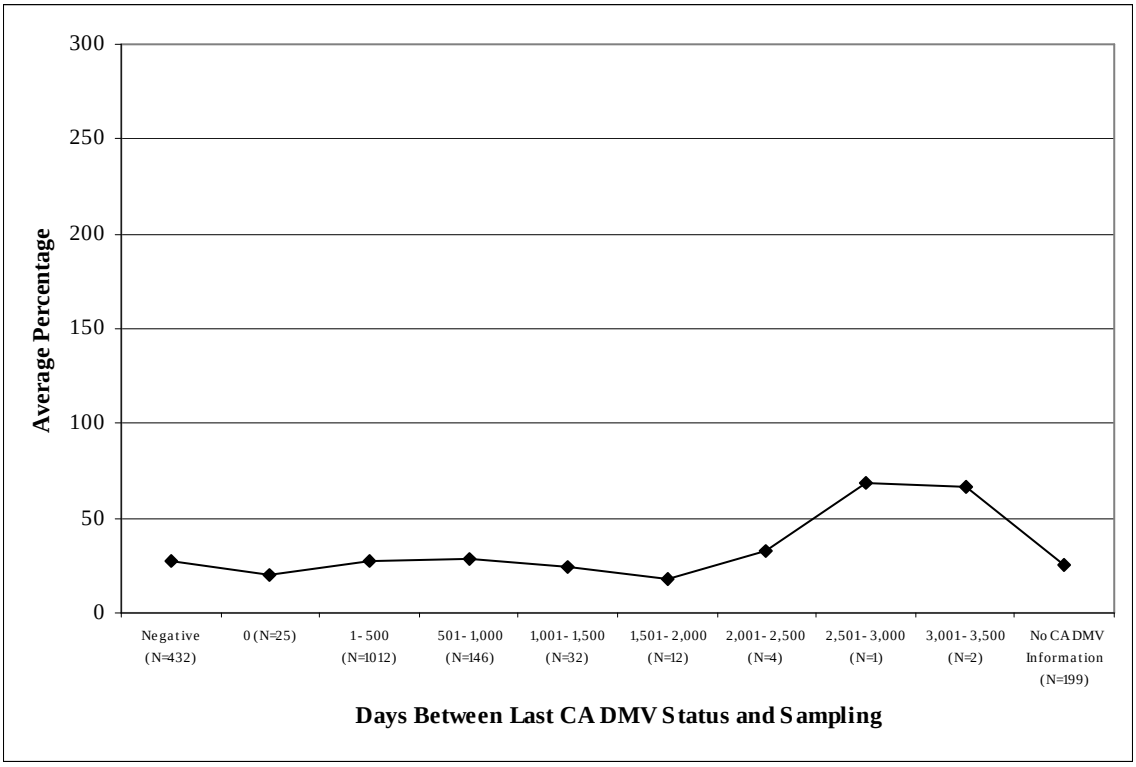


Figure 44 presents the average percentage of refrigerant recovered for vehicles based on the time between their last CA DMV status and sampling. The average percentages are presented in increments of 500 days and the average percentage varied from 18% to 66%. However these means are not significantly different and there is no correlation between the length of time between the last CA DMV action and the sampling and the percentage of HFC-134a recovered from the vehicles.

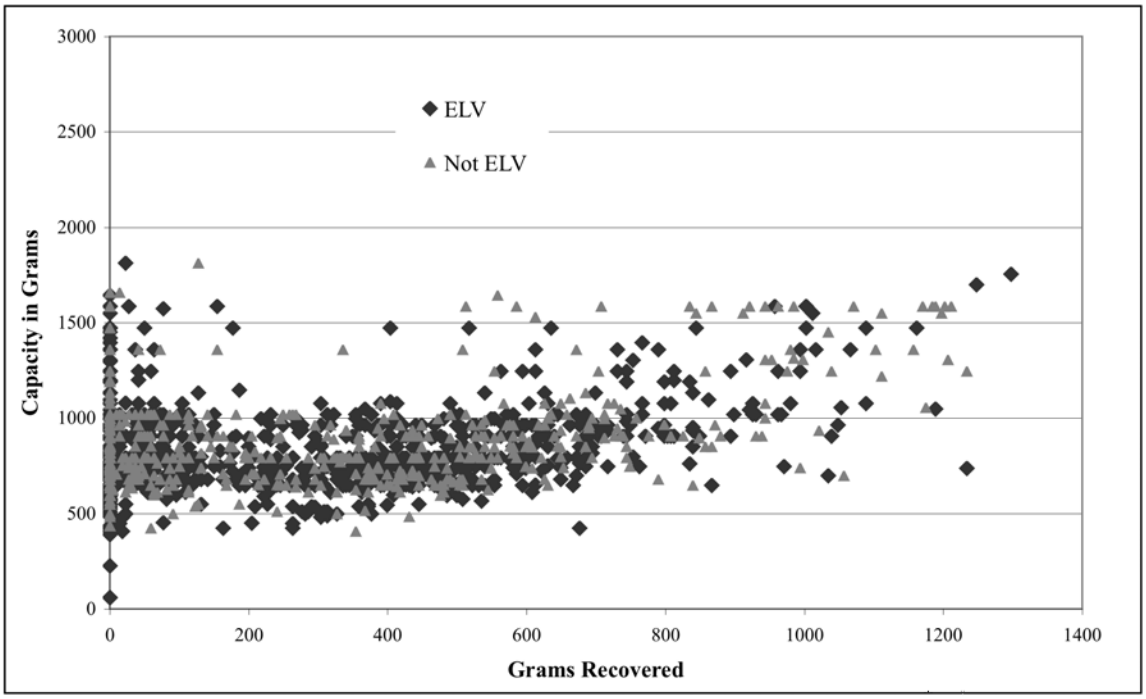
Figure 44: Average HFC-134a Recovered and Time Elapsed Between Last CA DMV Status and Sampling for 1,842 Round Two Vehicles



Looking at the entire CA DMV registration histories of the 1,842 sampled vehicles, 1,242 vehicles were classified as an ELV. The remaining 600 vehicles either had no CA DMV registration history or were never issued a junk title or salvage certificate. Figure 45 plots the amount of HFC-134a recovered and the capacity of vehicles classified as ELVs as well as those that were not. Across all 1,842 vehicles the HFC-134a capacity ranged from 59 grams to 12,700 grams with a mean of 858 grams and a standard deviation of 421 grams. The recovered HFC-134a ranged from 0 grams to 1,914 grams with a mean of 234 grams and a standard deviation of 296 grams. The standard deviation of recovered HFC-134a is larger than the mean, which highlights the instability of these statistics. For vehicles that were classified as an ELV, the mean capacity was 851 grams with a standard deviation of 486 while the mean recovered HFC-134a was 216 grams with a standard deviation of 282. Non-ELVs had a mean capacity of 872 grams with a standard deviation of 231 and a mean recovered HFC-134a of 270 grams with a standard deviation of 320 grams. For clarity in Figure 45, six outliers have been removed from the graph but are included in all calculations. There is a slight positive correlation between grams of refrigerant recovered and the vehicle's refrigerant capacity. Thus, as refrigerant capacity increases the grams of refrigerant recovered tends to increase.[24]

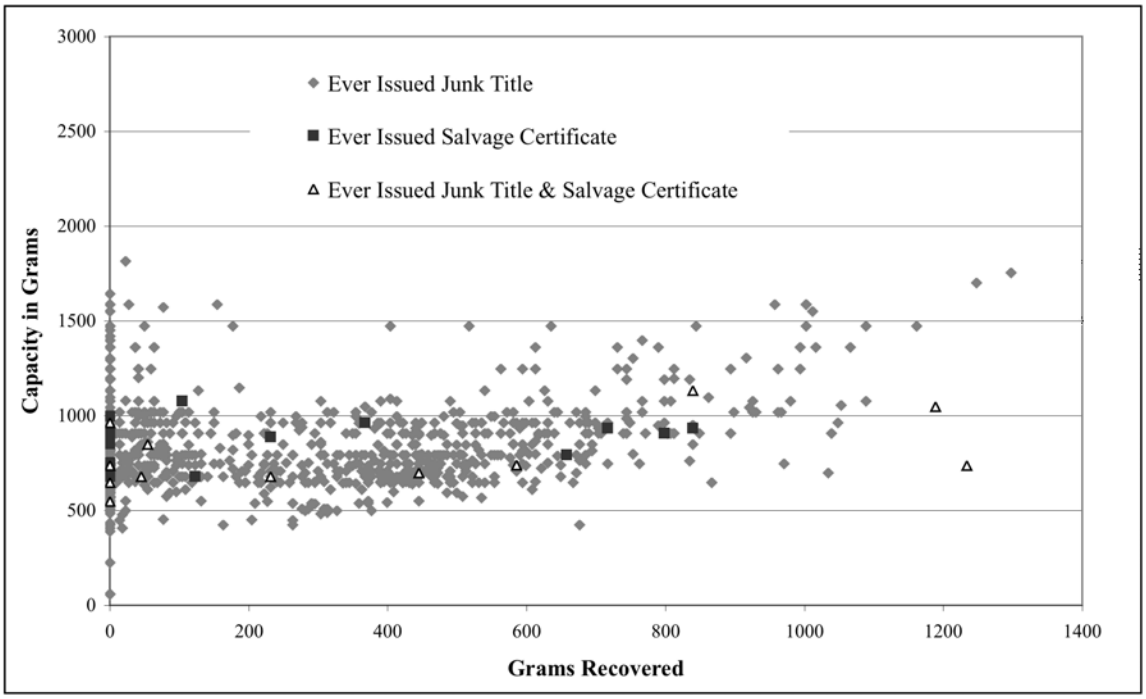
[24] Grams of refrigerant recovered and refrigerant capacity have a correlation coefficient of 0.16.

Figure 45: HFC-134a Capacity and HFC-134a Recovered in Grams for 1,842 Round Two Vehicles



Looking within the ELV classification, 1,215 vehicles were ever only issued a junk title, 15 were only issued a salvage certificate and 12 vehicles were issued both. Figure 46 compares the HFC-134a capacity and grams recovered for each of these classifications. Table 21 also presents the mean capacity and refrigerant recovered by these classifications.

Figure 46: HFC-134a Capacity and HFC-134a Recovered for 1,242 Round Two ELVs



The 12 vehicles that were issued both a junk title and salvage certificate had a mean model year of 1999 with a standard deviation of 3. These vehicles had a high positive correlation between refrigerant capacity and recovered refrigerant.

Table 21: Mean HFC-134a Capacity and Grams Recovered by Vehicle Classification for 1,842 Round Two Vehicles

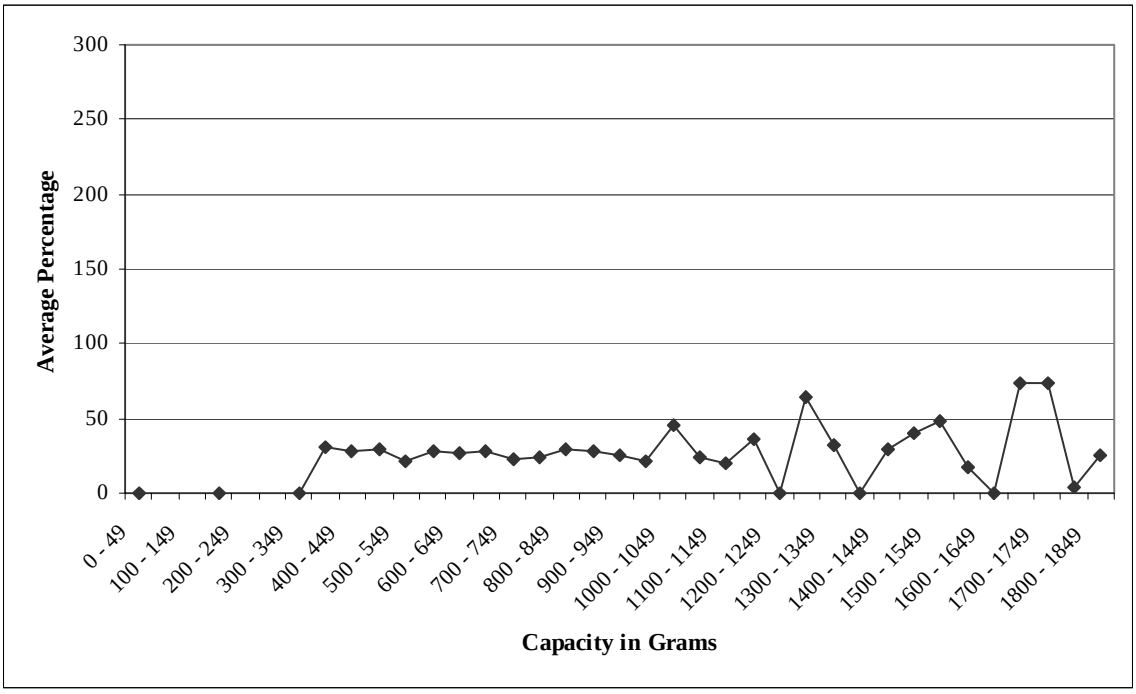
Vehicle Classification	Number	Capacity Mean	Capacity Standard Deviation	Recovered Mean	Recovered Standard Deviation
Ever Issued a Junk Title	1215	851 grams	489 grams	215 grams	282 grams
Ever Issued a Salvage Certificate	15	833 grams	147 grams	313 grams	396 grams
Ever Issued a Junk Title & Salvage Certificate	12	789 grams	175 grams	385 grams	472 grams

Vehicles that were issued a junk title had a mean model year of 1997 with a standard deviation of 3. For these vehicles there was a very small, positive correlation between refrigerant capacity and recovered refrigerant. The 27 salvage certificate vehicles had a mean model year of 1997 with a standard deviation of 3 years. These salvage certificate vehicles had a significant positive correlation between refrigerant capacity and recovered refrigerant. Thus, it appears that there is a stronger correlation between refrigerant capacity and amount recovered for vehicles that had been issued a salvage certificate.

However, these results are likely driven by the small sample size of salvage certificate vehicles. Across all vehicle classifications, the wide range of refrigerant capacity and grams recovered drives the mean statistics.

Figure 47 presents the average percentage of HFC-134a by refrigerant capacity. Refrigerant capacity has been portioned into groups of 49 grams and the mean refrigerant recovered varies from 0% to 73% across the sampled vehicles. The mean values are not significantly different across any amount of refrigerant capacity.

Figure 47: Average Recovered Refrigerant Across Capacity Partitions for 1,842 Round Two Vehicles



3.5.3 All Sampled Vehicles

To look at the sampled vehicles by geographic location we now combine the initial sample of 160 vehicles and the second round of sampling comprising 1,842 vehicles. The 2,002 unique vehicles were sampled at 30 dismantler lots through out California. Figure 48 shows the model year distribution for the entire sample of vehicles. The model year ranges from 1979 to 2009 with a mean of 1997 and a standard deviation of 3 years. There were 1,536 sampled vehicles, 77% of the entire sample, with a 1995 or newer model year.

Figure 48: Model Year Distribution of all 2,002 Sampled Vehicles

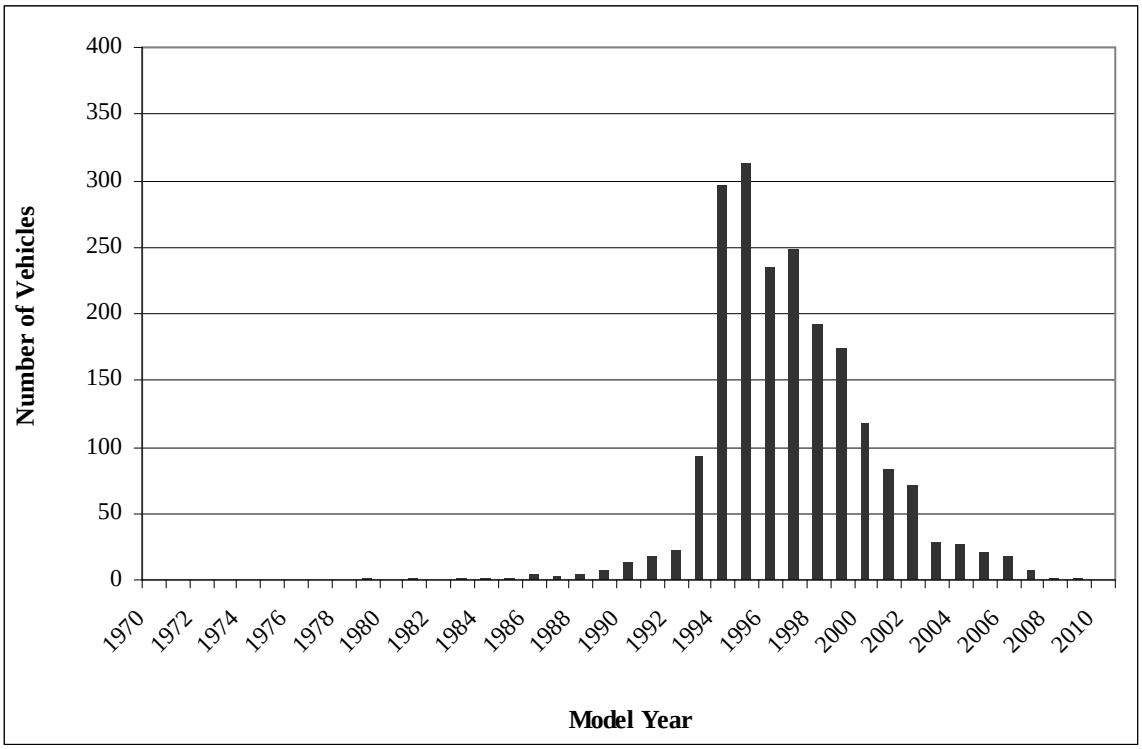
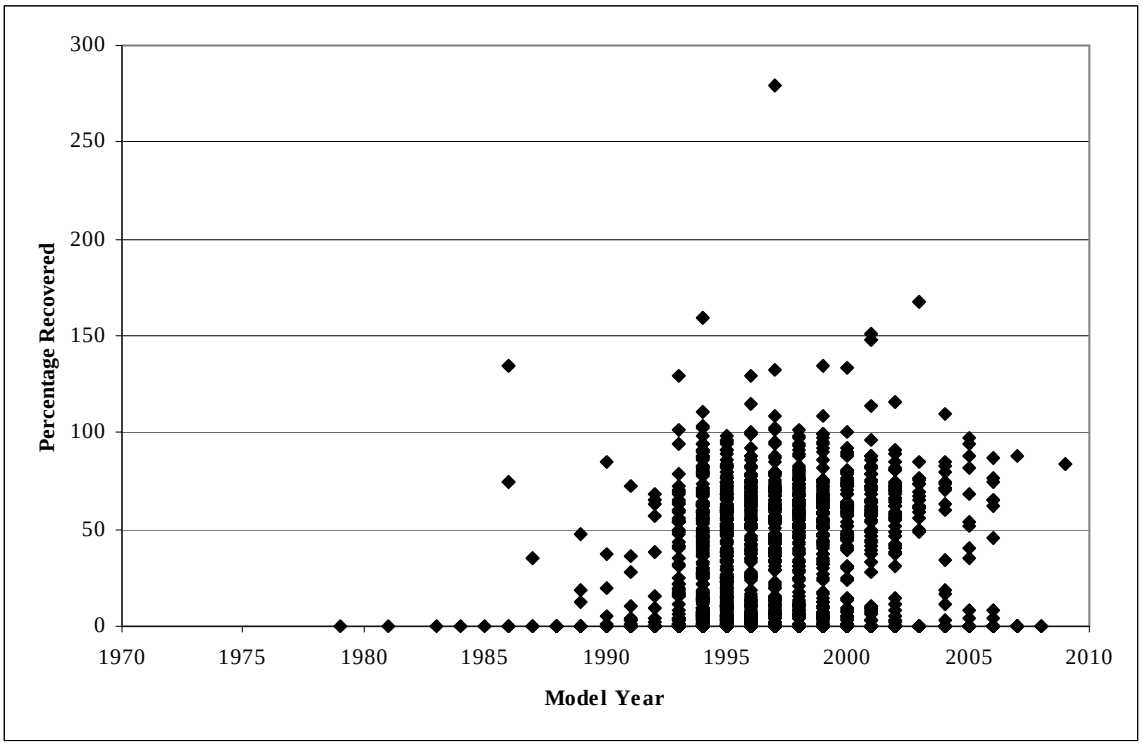


Figure 49 shows the percentage of refrigerant recovered for all sampled vehicles. The recovered refrigerant ranges from 0% to 280% with a mean of 27% and a standard deviation of 3%.

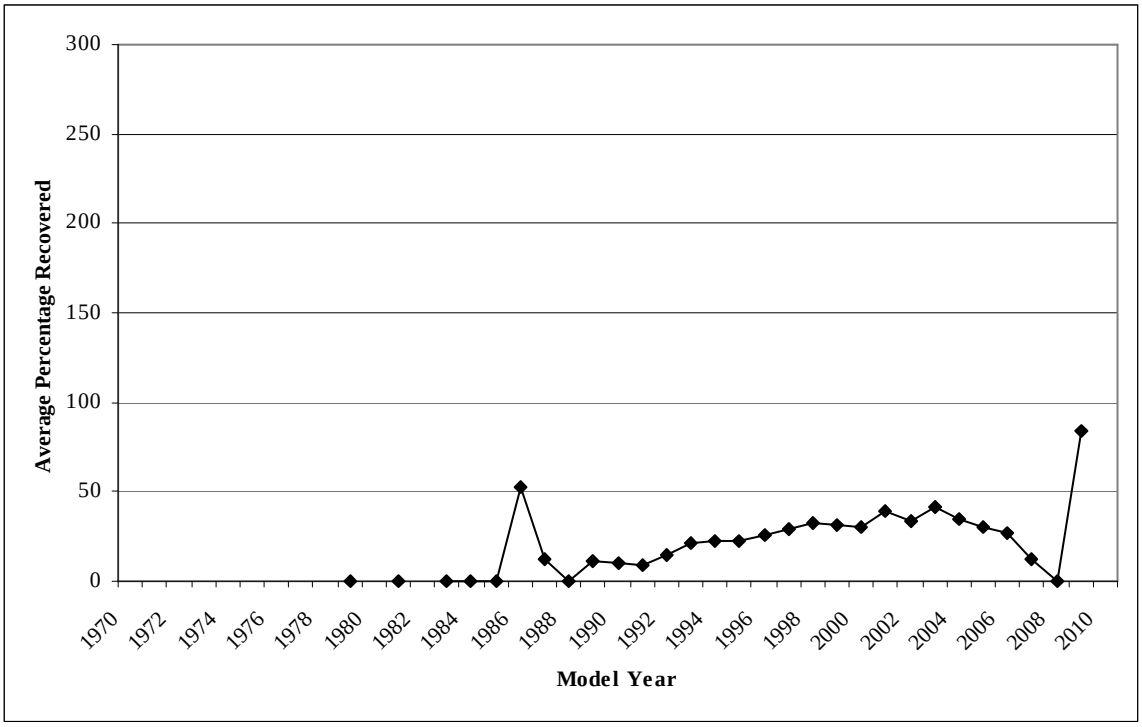
Figure 49: Recovered Refrigerant for 2,002 Sampled Vehicles



There is a positive correlation between the percentage of refrigerant recovered and model year. As model year increases, the percentage of recovered refrigerant tends to increase slightly.[25] While the mean was 27% of refrigerant recovered, the median was only 8%. The difference in these values highlights the variation within these findings. Looking at the same information, Figure 50 presents the average percentage of refrigerant recovered by model year for all sampled vehicles.

[25] The correlation coefficient for model year and percentage of refrigerant recovered is 0.15 across all sampled vehicles.

Figure 50: Average Percentage of Recovered Refrigerant by Model Year for 2,002 Sampled Vehicles

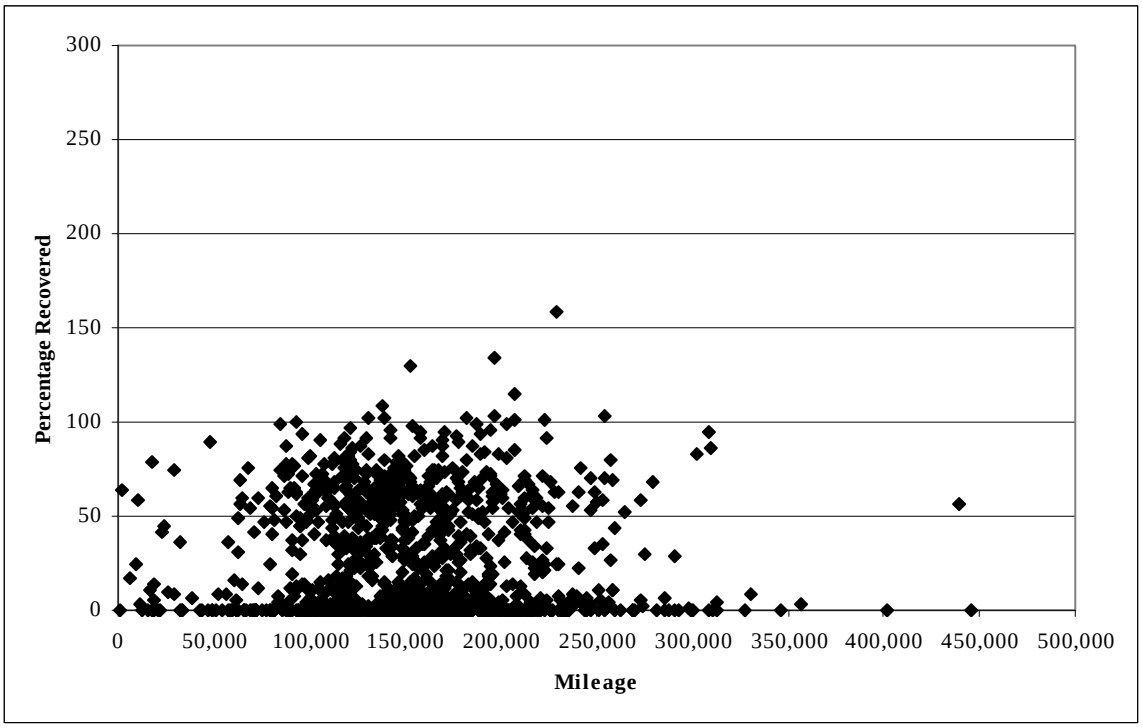


After averaging the percentage of refrigerant recovered by model year, the percentages ranged from 0% to 83% with a mean of 21% and a standard deviation of 19%. Looking at the average percentage of refrigerant recovered, the median is 22%, which is very close to the mean. The correlation between model year and percentage refrigerant recovered is much stronger when computed using averages.[26] However, this result can be misleading as the mean are based on a great range of recovered refrigerant within each model year and do not represent a natural center of the data.

Figure 51 details the mileage recorded at the time of sampling for all 2,002 sampled vehicles. Mileage was recorded for 1,209 or 60%, of all sampled vehicles and ranged from 1,489 to 445,380 miles with a mean of 155,064 miles and a standard deviation of 53,734 miles. There is no correlation between mileage and the percentage of recovered refrigerant, which is surprising as model year is often used as a proxy for mileage. But in this case the two variables do not have the same effect on the percentage of refrigerant that was recovered from sampled vehicles. Differences in the mean percentage of recovered refrigerant by mileage groupings were not significant and corresponded nearly perfectly with Figure 37 in Section 3.5.2.

[26] The correlation coefficient for model year and average percentage of refrigerant recovered is 0.58 across all sampled vehicles.

Figure 51: Mileage and Recovered Refrigerant for 2,002 Sampled Vehicles



Of the 2,002 sampled vehicles, only 287 had a license plate. Table 22 presents the mean model year and percentage of recovered refrigerant for these sampled vehicles.

Table 22: Model Year and Percentage Recovered Refrigerant Statistics by License Plate Classification for 2,002 Sampled Vehicles

Vehicle Classification	Number	Model Year Mean	Model Year Standard Deviation	Percentage Recovered Refrigerant Mean	Percentage Recovered Refrigerant Standard Deviation
License Plate	287	1996	3	38%	35%
No License Plate	1,715	1997	3	25%	31%

The difference in the mean percentage of refrigerant recovered is significant. A vehicle with a license plate was more likely to have a higher percentage of refrigerant remaining than those vehicles without a license plate. Thus, whether the vehicle had a license plate at the time of sampling partially explains the percentage of refrigerant recovered from the vehicle. Figure 52 plots the refrigerant capacity and amount recovered for these two groups within the sample. There is a slight, positive correlation for all vehicles between the refrigerant capacity and the amount of refrigerant recovered.

Figure 52: Amount Recovered and Capacity in Grams by License Plate for 2,002 Sampled Vehicles

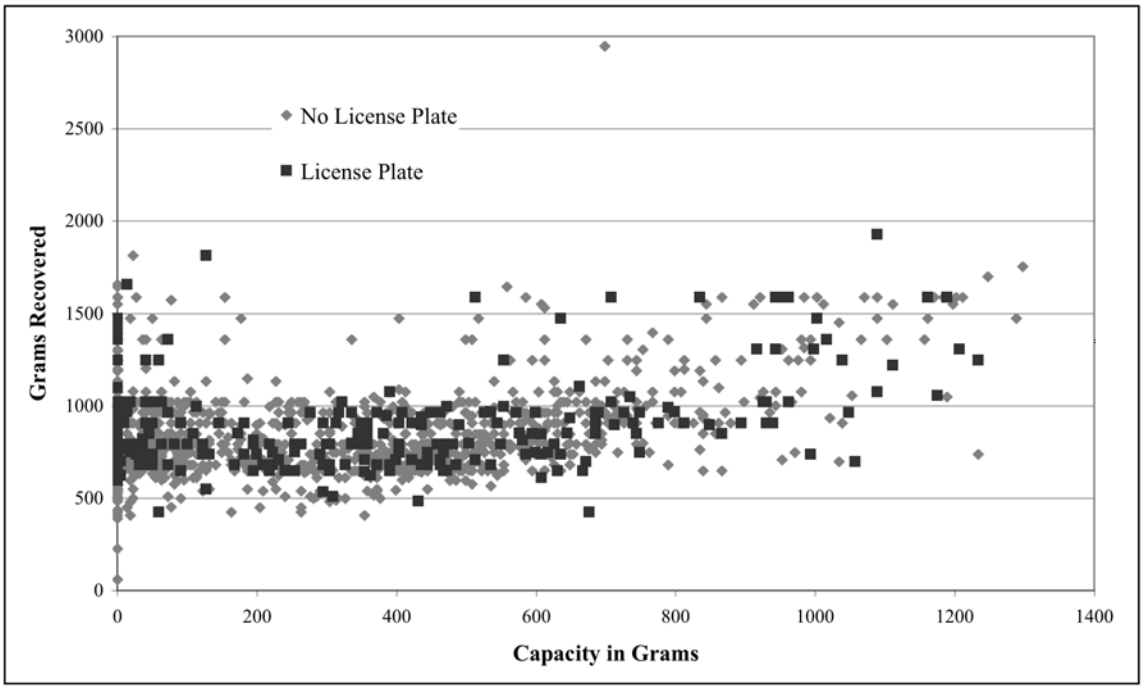
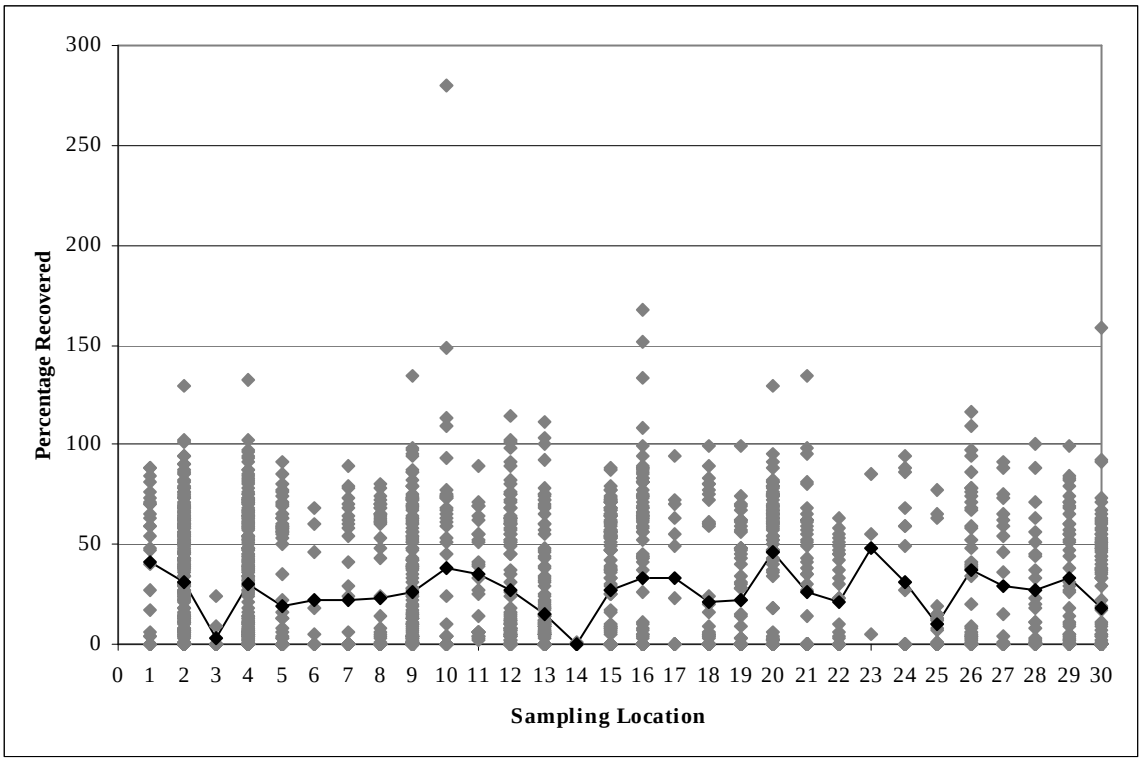


Figure 53 details the percentage of refrigerant recovered from the 2,002 sampled vehicles by sampling location. The vehicles dismantlers have been assigned a numeric code in order to preserve their anonymity.

Figure 53: Percentage Recovered by Sampling Location for 2,002 Sampled Vehicles



Across all sampling locations, the mean percentage of recovered refrigerant was 27% with a standard deviation of 32%. The average percentage of recovered refrigerant for each location is represented in black. The differences in the means between each location are not significant, and there is no correlation between the percentage of recovered refrigerant and the location at which the vehicle was sampled. Table 23 presents the mean number of junk title and salvage certificate owned by the 30 sampling locations from 2005 through 2007 as well as the mean number of ELVs owned from 2000 through 2008. The sampling locations owned, on average, more ELVs than the average licensed dismantler location. However, the sampling locations owned a much smaller volume of ELVs compared to the averages of the 30 highest volume locations.

Table 23: ELV Volume for 30 Sampling Locations

	1,396 Licensed Dismantler Locations	30 Licensed Sampling Locations	30 Highest Volume Locations
Mean Junk Titles 2005-2007	1,509	7,031	47,160
Mean Salvage Certificates 2005-2007	36	89	387
Mean ELVs 2000-2008	4,167	19,561	126,656

The percentage of recovered refrigerant varies greatly across and within each sampling location. Figure 54 plots the percentage of refrigerant recovered by the Air District in which they were sampled. The Air Districts have been alphabetized and assigned a numeric code that is detailed in the Appendix. The mean percentage of recovered refrigerant for each Air District is shown in black.

Figure 54: Percentage Refrigerant Recovered by Sampled Air District for 2,002 Sampled Vehicles

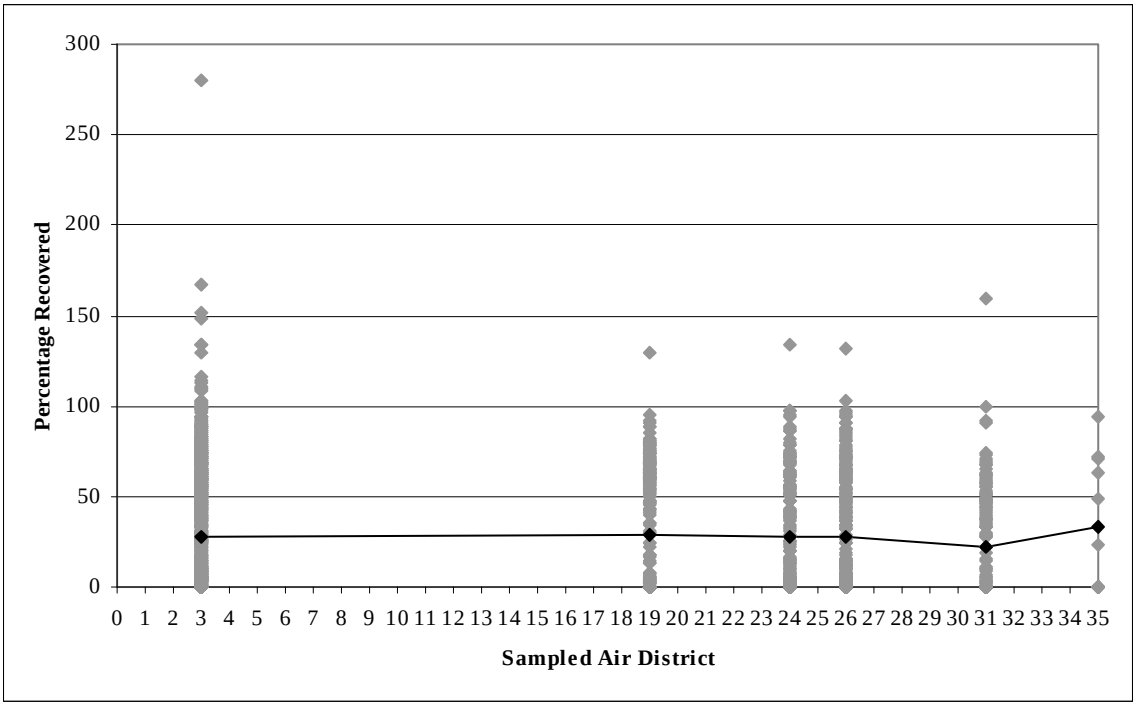


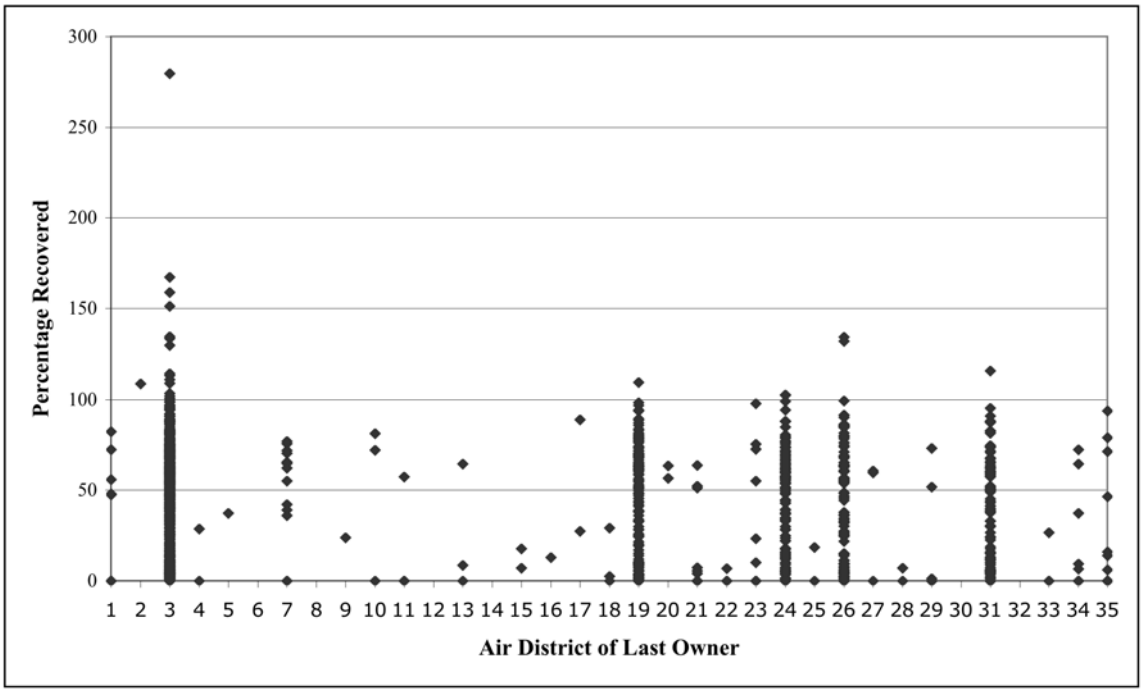
Table 24 presents the model year and percentage of recovered refrigerant statistics for each Air District. While the mean percentage of refrigerant does vary by Air District, the standard deviation for every Air District is larger than the mean. Thus, the differences in the means are not significant. There is also no correlation between the recovered refrigerant and the Air District in which the vehicle was sampled. Figure 50 highlights the sampling imbalance that occurred as high population Air Districts specifically in Southern California were vastly under sampled.

Table 24: Model Year and Percentage Recovered Refrigerant Statistics by Air District for 2,002 Sampled Vehicles

Air District	Number	Percentage Recovered Mean	Percentage Recovered Standard Deviation
Bay Area - 3	853	27%	31%
Monterey Bay - 19	338	26%	31%
San Joaquin Valley - 24	186	19%	29%
Sacramento - 26	275	30%	33%
South Coast - 31	337	31%	36%
Yolo/Solano - 35	13	20%	28%

Figure 55 presents the percentage of recovered refrigerant by the Air District of the last known owner as found in the CA DMV registration records. While more Air Districts are represented, the percentage of refrigerant recovered varies widely within and across the Air Districts.

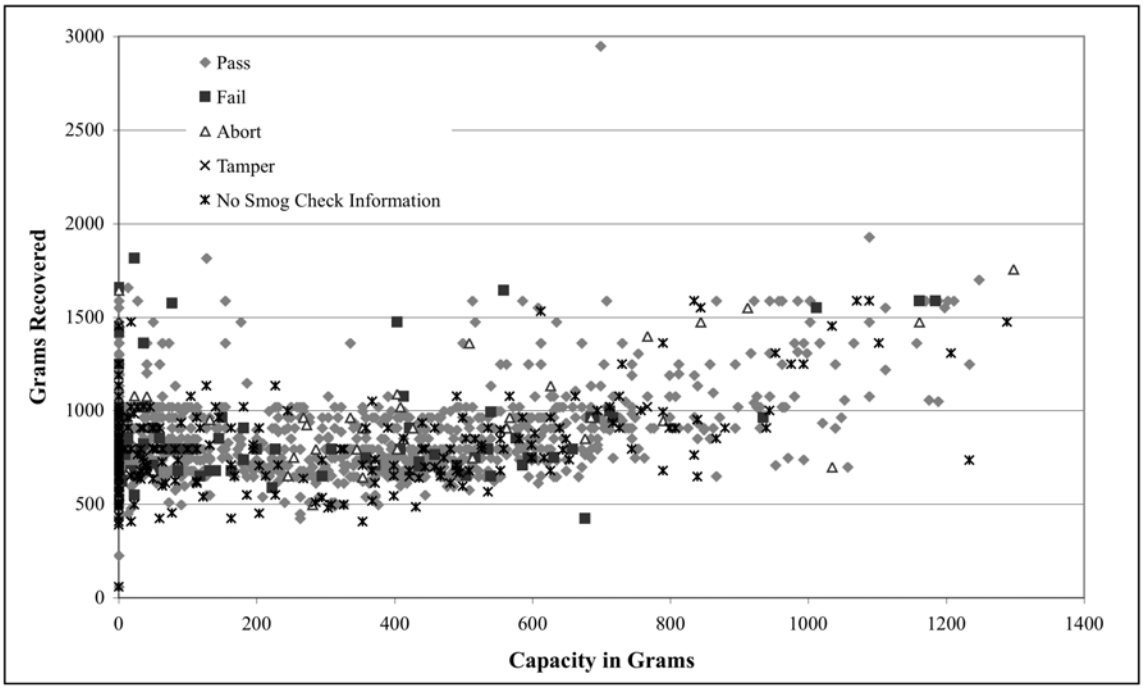
Figure 55: Percentage Refrigerant Recovered by Air District of Last Known Owner for 1,802 Samples with CA DMV Registration Status



There were 1,474 vehicles, or 74% of the sample that according to CA DMV registration records were registered within the same Air District for their entire history. These vehicles had a mean model year of 1996 with a standard deviation of 3. These vehicles had a mean of 26% recovered refrigerant with a standard deviation of 32%. The 530 vehicles that either had no CA DMV registration records or moved through out the state had the same mean model year and standard deviation, but had a mean of 29% refrigerant recovered and a standard deviation of 34%. The location of the last owner was not correlated with the percentage of refrigerant recovered from any vehicle and the difference in the mean percentage of recovered refrigerant between groups was not significant.

Smog check records were obtained for 1,696 of the sampled vehicles. These vehicles had an average of five smog check inspections over their histories with a standard deviation of three. Figure 56 groups the sampled vehicles by their last smog check result and plots their recovered refrigerant and refrigerant capacity.

Figure 56: Recovered and Capacity Refrigerant by Last Smog Check Result for 2,002 Sampled Vehicles



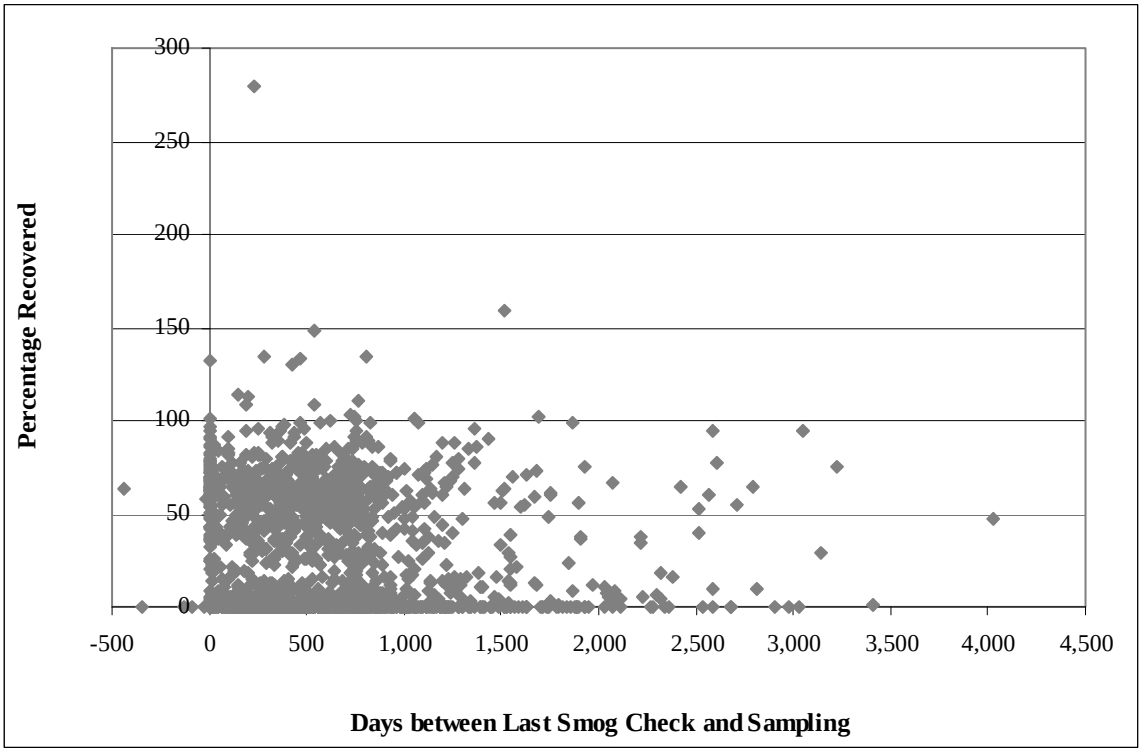
Across the sample of 2,002 vehicles, an average of 234 grams of refrigerant was recovered with a standard deviation of 297 grams. The mean capacity was 862 grams with a standard deviation of 412 grams. For the 1,516 sampled vehicles that passed their final smog check, the mean capacity was 869 grams with a standard deviation of 452 grams and the average amount recovered was 238 grams with a standard deviation of 295 grams. The 111 vehicles that failed their final smog check had a mean capacity of 853 grams and a standard deviation of 261 grams and a mean recovered amount of 206 grams with a standard deviation of 287 grams. The correlation between refrigerant capacity and refrigerant recovered was highest for vehicles that failed their final smog check. Though on average a higher amount of refrigerant was recovered from vehicles that passed their last smog check. Table 25 presents the average recovered refrigerant by final smog check status for each of the sampled vehicles. The standard deviation for each group was larger than the mean highlighting the instability of these results.

Table 25: Model Year Statistics by Final Smog Check Status for 2,002 Sampled Vehicles

Final Smog Check Status	Number	Percentage Recovered Mean	Percentage Recovered Standard Deviation
Abort	64	26%	32%
Fail	111	24%	32%
Pass	1,516	27%	32%
Tamper	4	36%	40%
No Smog Check Info	307	26%	32%

Figure 57 plots the percentage of recovered refrigerant and the number of days between the sampled vehicle's last smog check and the sampling date. Four outliers have been omitted from the graph for clarity but are included in all the statistics. Nineteen of the sampled vehicles have a smog date later than their sampling date. There are also six outliers with a last smog check date in 2012, which are obvious data errors. There is a slight negative correlation between the length of time between the last smog check and the date of sampling. Thus, as the number of days between the last smog check and the sampling increases, on average the percentage of recovered refrigerant decreases. This correlation is not strong however, and there is no significant difference between the mean percentage of recovered refrigerant for different amounts of time between the last smog check and sampling.

Figure 57: Percentage Recovered and Days Between Last Smog Check and Sampling for 1,695 Sampled Vehicles with a Smog Check Record



The smog check records also provide the mileage of the sampled vehicle. The mileage recorded at the last smog check inspection for the 1,695 vehicles with smog check histories. Table 26 compares the mileage recorded at the last smog check of these vehicles to those vehicles for which mileage was recorded at the time of sampling.

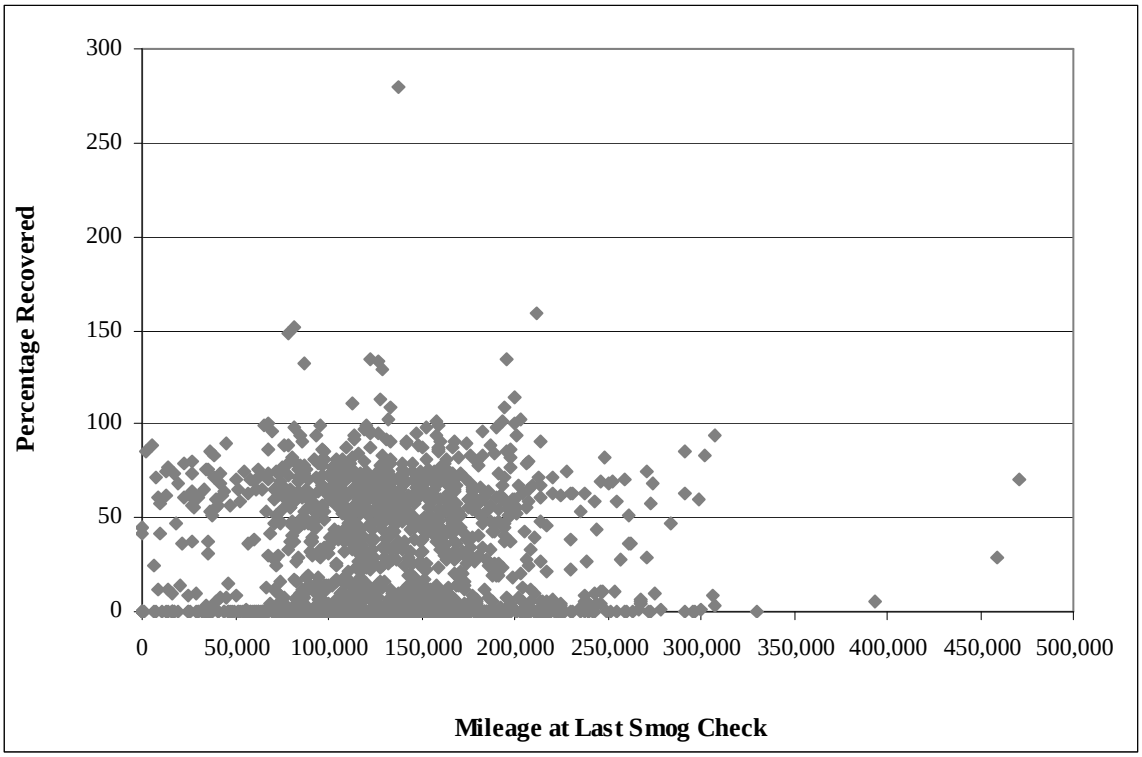
Table 26: Mileage Statistics for Vehicles with Recorded Mileage

Vehicle Classification	Number	Mean	Standard Deviation	Minimum	Maximum
Vehicles with Smog Check Mileage	1,695	136,804	62,877	0	990,010
Vehicles with Mileage at Sampling	1,209	155,064	57,734	1,489	445,380

While the smog check records provide mileage estimates for a larger number of vehicles, they do not appear to be as stable as the mileage recorded at the time of the vehicle sampling. This is apparent in Figure 58 which presents the percentage of refrigerant recovered and the mileage recorded at the time of the vehicle's last smog check inspection. Fifteen outliers have been removed from Figure 58, but it is still extremely scattered. Mileage recorded at the time of the smog check is not correlated with the

percentage of refrigerant recovered from vehicles, nor is mileage or any sort a significant factor in predicting recovered refrigerant.

Figure 58: Percentage Recovered and Mileage Recorded at Last Smog Check Inspection for 1,697 Sampled Vehicles with a Smog Check Record



4. DISCUSSION

4.1 Auto Dismantling and Recycling and ELVs

Initially it was assumed that the population of ELVs would be a good approximation for the vehicle inventory on dismantler lots throughout California, but that was not the case. Within our sample, 1,365 of the 2,002 total vehicles were classified as End of Life Vehicles (ELVs). Thus, ELVs comprised only 68 % of the sampled vehicles. From these results, we know that all dismantled and recycled vehicles are not classified as ELV. As reported in the characterization of the ELV population in Section 3.1, we also found that not all ELVs are dismantled or recycled as they can be re-registered, driven out of state, or disappear from CA DMV records. Thus, our target population and the sampled vehicles do not completely correspond to one another.

This discrepancy between the sampled vehicles and the target population is the result of data limitations. As no data describing the inventory of vehicle dismantlers was available, we estimated the population of ELVs indirectly using CA DMV registration records. While we were able to extract detailed information from the ELV population we analyzed, we failed to account for the 32% of sampled vehicles that were not classified as ELVs but were on vehicle dismantler lots. The path these non-ELVs took before reaching the dismantler is unknown and represents a shortcoming of the analysis. However, the analysis and the findings are robust for the ELV population we estimated and we feel that the overlap between the ELV population and the sampled vehicles is sufficient that the results of the analysis can be extrapolated to similar research questions with confidence. However, further research into the alternative ways that vehicles come to dismantlers such as vehicle auctions and liens is warranted and will strengthen this and subsequent analyses.

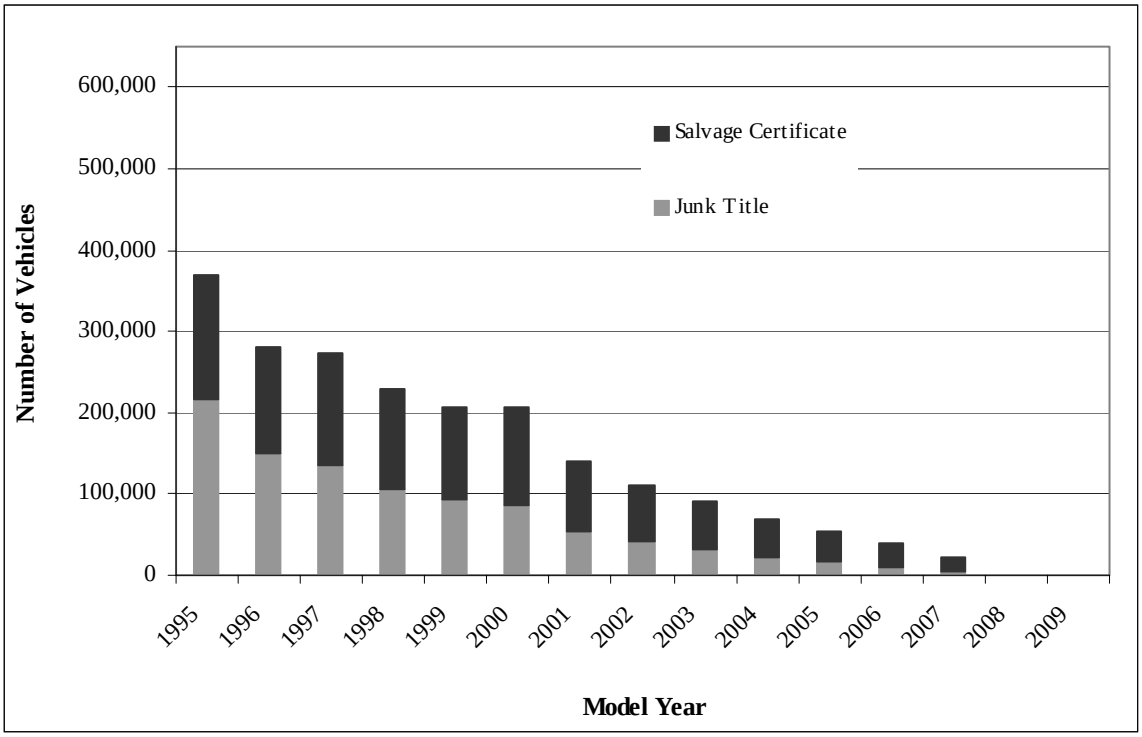
4.2 End of Life Vehicle Population

From 2000 through 2008, 39,645,818 vehicles had a lapse in registration status. Using the CA DMV registration query, 8,537,707 of these vehicles were classified as ELVs. The model year distribution of the ELVs ranged from 1979 to 2009 with a mean model year of 1997. From 2000 through 2008, 75% of the ELV population had a model year of 1994 or older. The use of HFC-134a in vehicle air-conditioning systems became mandatory beginning in 1995 model year vehicles. Thus, we can confirm that only 25% of the ELV population contained HFC-134a. This estimate represents the lower bounds as some older model year vehicles may have been retrofit from R-12 to HFC-134a. Additionally, the phase-in of HFC-134a was not instantaneous, and several manufacturers instituted the use HFC-134a in older model year vehicles. This result varies greatly from sampled vehicles, 77% of which were 1995 and newer model years.

By restricting the ELV population to only vehicles containing HFC-134a, we reduce the population to 2,098,887 vehicles with a mean of 1999 and a standard deviation of 10 years. Focusing on this portion of the ELV population better reflects the 2,002 sampled vehicles, which had a mean model year of 1997 and a standard deviation of 3 years.

Figure 59 shows the model year distribution for the 2,098,887 1995 and newer model year ELVs.

Figure 59: Model Year Distribution for 1995 and Newer Model Year ELVs, 2000 – 2008

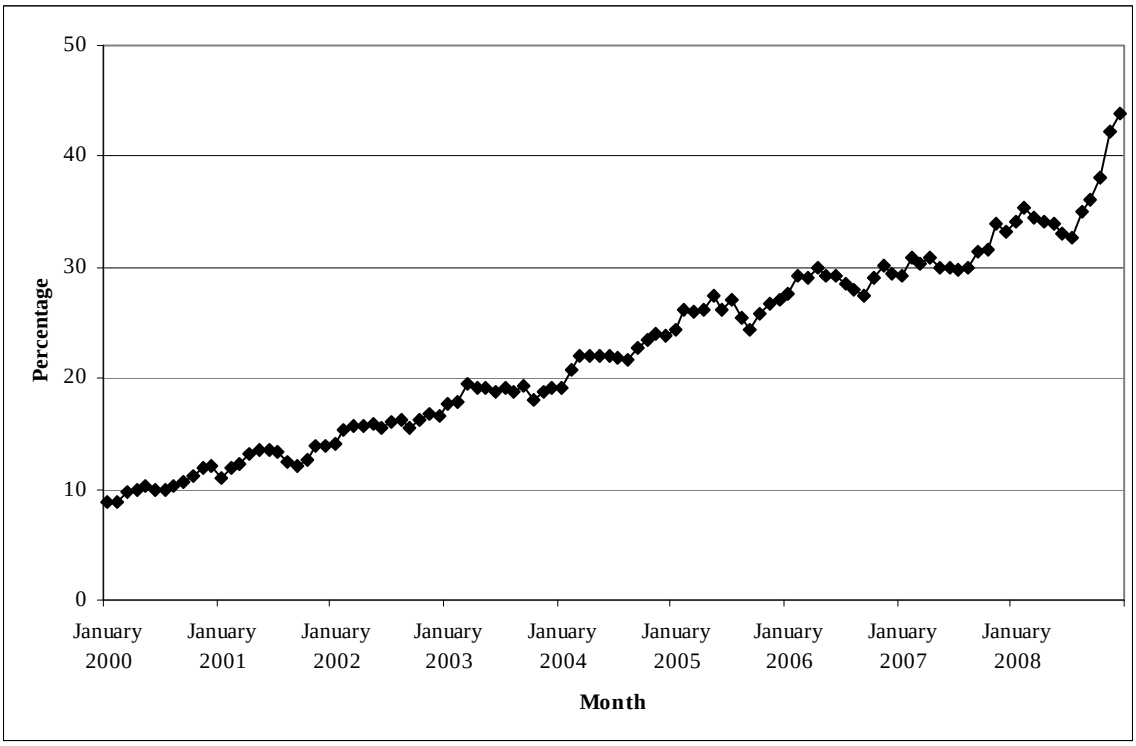


There were 1,340 sampled vehicles that contained HFC-134a and were classified as an ELV. Across these ELVs, 294,776 grams or 295 kg of HFC-134a was recovered. These vehicles had an average refrigerant capacity of 853 grams with an average of 220 grams recovered. Thus, on average 26% of HFC-134a capacity was recovered from each sampled ELV containing HFC-134a. Assuming the sampled vehicles are representative of the ELV population, we can extrapolate these findings to the population of 1995 and newer ELVs. Based on this information, from 2000 through 2008, 461,718 kg of HFC-134a was remaining in ELVs on vehicle dismantler lots in California.[27]

While vehicles containing HFC-134a accounted for only 25% of total ELVs from 2000 through 2008, their numbers have increased steadily throughout the time frame. Figure 60 presents the monthly percentage of ELVs containing HFC-134a from 2000 through 2008.

[27] Based on the magnitude of these numbers, different results can be found using the raw amount of recovered HFC-134a, the average amount recovered, and the average percentage recovered. My calculations are based on the raw amount of HFC-134a recovered from the 1,340 vehicles and extrapolated to the population of 2,098,887 vehicles.

Figure 60: Percentage of 1995 and Newer Model Year ELVs, 2000 – 2008



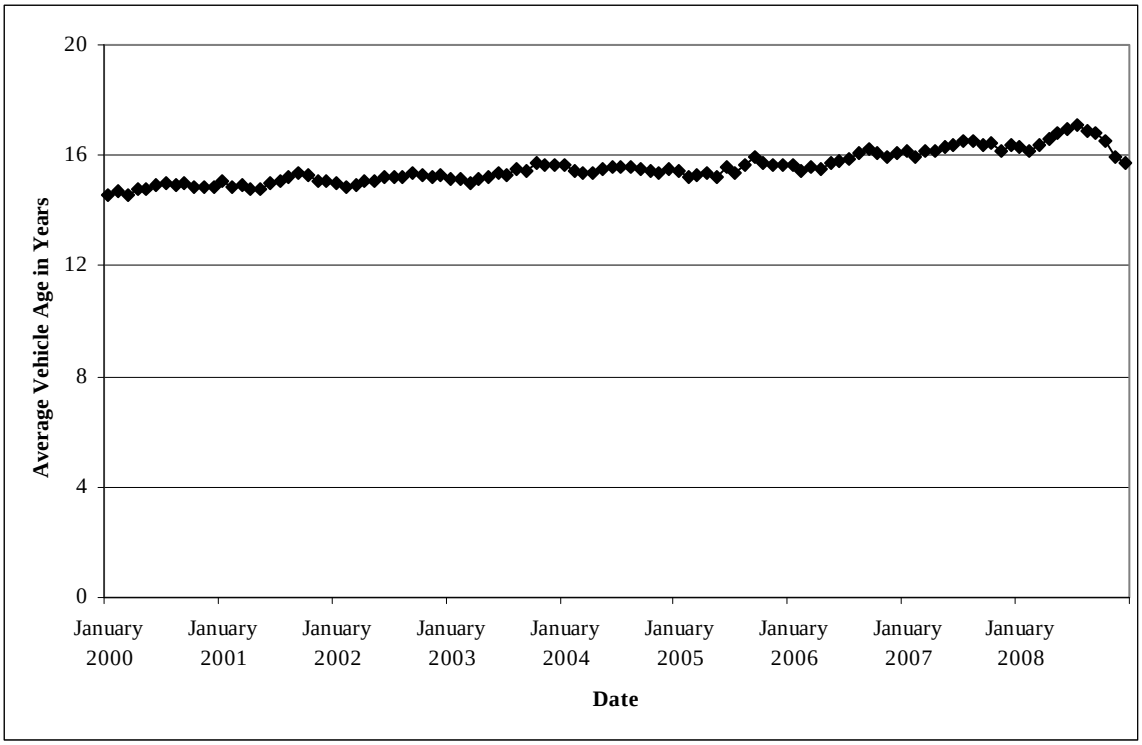
Each year, the percentage of ELVs that are 1995 and newer model years, and thus contain HFC-134a, increases. In January of 2000, only 9% of all ELVs were 1995 and newer model years, but in December of 2008, that figure had climbed to nearly 44%. Not surprisingly, as the 1995 and newer model year vehicles age, a higher proportion become ELVs. On average, the percentage of 1995 and newer ELVs reported to CA DMV increased 0.25% a month, or 3% a year. Extrapolating this forward and including all ELVs from 2000 onwards, ELVs containing HFC-134a will reach 50% of the total population in 2022. Reducing the scope to mimic the nine-year time frame used in the analysis, it will take until 2015 for 50% of all ELVs (2007 through 2015) to contain HFC-134a.[28] Using these calculations, in 2023, 99% of the ELV population will be 1995 and newer model year vehicles. Thus, the impact of HFC-134a in ELVs and subsequent regulation will not fully be realized for many years to come.

Figure 61 looks at the fleet of ELVs by the vehicles' age at the time the vehicle was issued a junk title or salvage certificate by CA DMV. Each year from 2000 through 2008, the average age of ELVs has increased on average by two months. In 2000, the average age of an ELV was 14 years 9 months. In 2008, the average ELV was 16 years,

[28] This is based on a 3% increase of ELVs containing HFC-134a each year based on data from the nine year period, 2007 through 2015.

5 months old. Thus, while the percentage of 1995 and never vehicles is increasing at about 3% per year, the population of ELVs is also increasing in age.[29]

Figure 61: Age of ELV Population, 2000 – 2008



While we are able to estimate the average age of vehicles and forecast the percentage of 1995 and newer model year ELVs into the future, we have no data regarding the length of time that ELVs are physically on dismantler lots. It is entirely possible that ELVs reported in 2000 are still sitting on dismantler lots in California, or they could have been re-registered the following year. Thus, it is difficult to determine the appropriate time frame for the ELV population. On average, there were 117 days between the last CA DMV action and the date of sampling for ELVs containing HFC-134a. The average number of days between the date of sampling and the last date that an ELV with HFC-134a was issued a junk title or salvage certificate was 143 days. Three sampled ELVs containing HFC-134a had been issued their most recent junk title or salvage certificate prior to 2000. Of the 1,340 sampled ELVs containing HFC-134a, 46 were issued their most recent junk title or salvage certificate prior to 2007. Thus, while the majority of sampled ELVs were reported to the CA DMV within the past year, a portion of vehicles have been classified as ELVs for quite some time. Unfortunately, there is no way of knowing how long a vehicle was on the dismantler lot prior to testing, nor how long they remain on the lot after the testing was complete. By analyzing the ELV population from

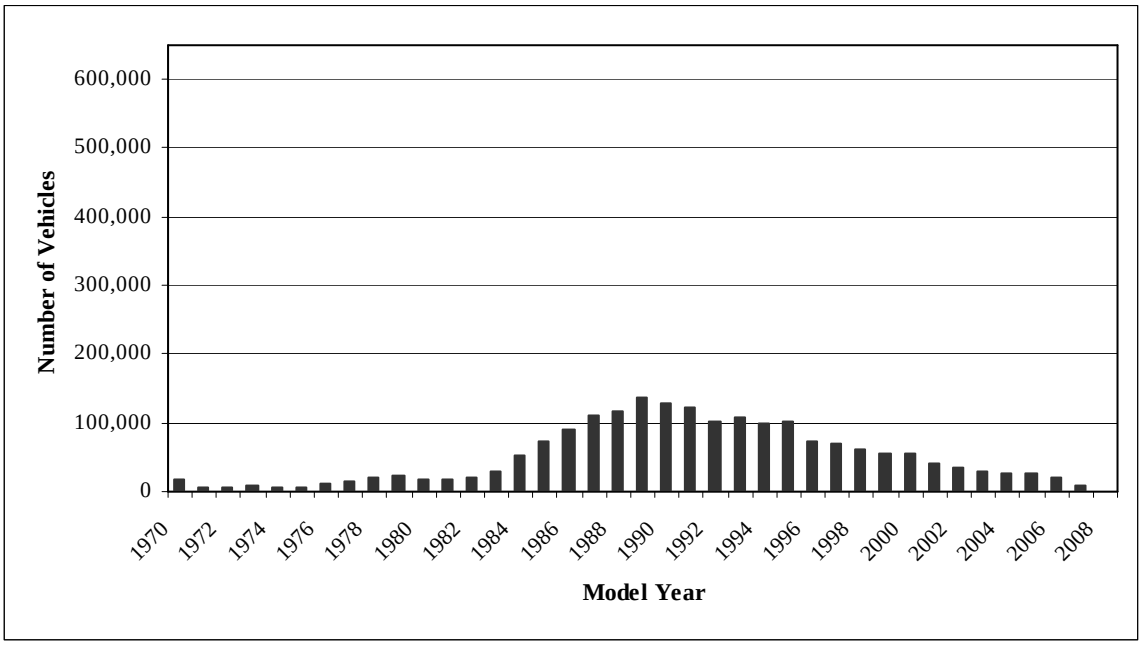
[29] The increasing age of ELVs can be partially traced the economic recession of 2008 and 2009. Historically, in economic downturns, drivers hold on to older vehicles longer, thus increasing the age of driving fleet as well as ELVs.

2000 through 2008, we are maximizing the number of ELVs within the population but run the risk of counting vehicles that have been re-registered since the issuance of a junk title or salvage certificate. While our definition of an ELV does not preclude vehicles that have been re-registered from the analysis, it is informative to look at a recent, narrower time frame to analyze the effects of removing these vehicles from the population.

4.3 Characterization of ELVs and Dismantlers from January through December 2007

We now focus on the vehicles that were issued a junk title or salvage certificate during 2007.[30] Figure 62 presents the model year distribution of ELVs reported to the CA DMV in 2007. Model years ranged from 1970 to 2008 with a mean of 1991 and a standard deviation of 7 years. For the population of ELVs issued in 2007, 31% were 1995 and newer model years. Thus, 31% of this ELV population contained HFC-134a. Table 27 compares these statistics to the other ELV time frames in the analysis, 2000 through 2008 and 2005 through 2007.

Figure 62: Distribution of ELV Population by Model Year, 2007



[30] Vehicles issued junk titles and salvage certificates in 2008 and 2009 are still being reported to the CA DMV, thus 2007 was the most recent year in which we are confident that the ELV population is accurate.

Table 27: Model Year Statistics for ELV Populations Across Varying Time Frames

ELV Time Frame	Number	Mean	Standard Deviation	1995 and Newer
2007	1,952,338	1991	7	31%
2005 - 2007	3,190,430	1991	7	32%
2000 - 2008	8,537,707	1989	7	25%

Narrowing the time frame of analysis does not significantly alter the model year statistics or the percentage of ELVs that contain HFC-134a.[31] Furthermore, removing vehicles that were issued a junk title or salvage certificate prior to 2007 does not change the distribution of the ELV population. The increasing average age of ELVs has also attributed to the percentage of 1995 and newer vehicles remaining fairly constant across the differing time frames. We believe that based on the stability of the model year distribution that using the largest time frame, 2000 through 2008 is appropriate in describing the ELV population. Using this time frame minimizes the chance that we are undercounting ELVs that have been on vehicle dismantler lots of long periods of time, as highlighted by our sample of vehicles.

However, when looking forward and forecasting the amount of HFC-134a remaining in ELVs, we feel that focusing on a more recent time frame is more suitable. While the distribution of ELVs has not changed, the number of ELVs has increased over time. From 2000 through 2008, an average of 948,634 ELVs were reported each year. Narrowing the time frame from 2005 through 2007, an average of 1,063,477 ELVs were reported to CA DMV each year. In 2007 alone, 1,952,338 ELVs were reported to CA DMV. This growing number of ELVs is due in large part to the greater availability and reliability of CA DMV data in recent years. Thus, while the reported number of ELVs has jumped in recent years, we believe this is in large part due to better data and records, rather than an increase in the number of ELVs. There was a very large jump in reported ELVs between 2006 and 2007. Thus, despite 2007 being the most recent year with reliable ELV population data, we will use the statistics from 2005 through 2007 when forecasting the amount of HFC-134a remaining in the population into the future.[32]

From 2000 through 2008, we identified 2,107 vehicle dismantlers in California that owned at least one ELV. During 2007, 1,629 California vehicle dismantlers owned at least one ELV. Table 28 presents the breakdown of final owners for the population of 1,952,338 ELVs reported to CA DMV in 2007.

[31] Looking at the ELVs reported for 2008, 35% were 1995 and newer model years. For ELVs reported in 2009, 40% were 1995 and newer model years. Again, the ELV population for these years has not been fully reported, and these figures are offered only as rough estimates of the true statistics.

[32] There was a 98% increase in the number of ELVs reported to CA DMV between 2006 and 2007. This is vastly different from the average yearly increase of 11% across the entire time frame.

Table 28: Last Known Owner of ELVs by Category, 2007

Category	Number of ELVs	Number of Businesses
California Dismantler	1,560,735	1,629
Out of State Business	4,824	21
Vehicle Auction	86,803	87
Insurance Company	187,799	56
Fleet Vehicles	9,726	19
Taxi Services	1,850	27
Private Individual and Unidentified Entities	100,600	137

Vehicle dismantlers within California owned 80% of the ELVs in 2007. An additional 10% of ELVs were last owned by insurance companies, 5% by private individuals and unidentified businesses, and 4% by vehicle auctions. The remaining 1% was last owned by other businesses and fleets. From 2000 through 2008, 70% of ELVs were owned by California vehicle dismantlers, as shown in Table 8 in Section 3.2. Thus, we are able to identify a greater percentage of dismantlers focusing on 2007. Table 29 presents the volume of ELVs owned by dismantlers of varying size in 2007.

Table 29: ELV Volume Owned by Dismantlers of Varying Size, 2007

	LICENSED DISMANTLER LOCATIONS		UNLICENSED DISMANTLER LOCATIONS	
	License Required 1,127 locations	No License Required 109 locations	License Required 194 locations	No License Required 113 locations
Total Junk Titles	1,463,295	166	12,751	170
Mean Junk Titles	1,206	1	65	1
Total Salvage Certificates	82,015	29	2,284	25
Mean Salvage Certificates	67	0	11	0
Total ELVs	1,545,310	195	15,035	195
Mean ELVs	1,273	1	77	1

During 2007, 1% of ELVs were owned by a dismantler that was operating outside the California Vehicle Code. Thus, a California dismantler operating legally owned a total of 79% of the entire ELV population during 2007. The 194 illegally operating dismantlers owned an average of 77 ELVs during 2007. Large volume, licensed dismantlers owned

the majority of ELVs in 2007, with an average of 1,273. All legally operating California dismantlers owned an average of 1,145 ELVs during 2007.

From 2000 through 2008, we were unable to identify the final owner of 11% of all ELVs. For the year 2007, this number had dropped to 5%. Greater information pertaining to licensed dismantlers and geographic locations also has increased the precision of the data. We feel that this data will only continue to improve and will use the final owner statistics from the ELV population of 2007 in all subsequent calculations regarding the final owner of ELVs.

4.4 Vehicle Dismantler Accuracy

Vehicle dismantlers in California were the final owner of 70% of the ELV population from 2000 through 2008. We identified 2,107 unique dismantler locations in California, 99% of which were licensed in satisfaction of section 220 of the California Vehicle Code. There were 203 unlicensed dismantlers that owned a total of 111,048, or 1%, of the ELV population from 2000 through 2008. Thus, licensed vehicle dismantlers in California owned 69% of the ELV population from 2000 through 2008. In the year 2007, licensed vehicle dismantlers in California owned 79% of the ELV population. This change is the result of increased data and the ability to better track vehicles and owners over time. There is much discussion in the dismantling industry about the role of these unlicensed and illegally operating dismantlers, as they are not subjected to the same environmental regulations as their licensed counterparts. While these 203 dismantlers in violation of California Vehicle Code owned a small portion of the ELV fleet from 2000 through 2008, their procedures for handling and disposing of vehicle refrigerant are unknown. Their impact on the total volume of ELVs may be low, but their environmental impact could be quite large.

While the final owner of 70% of ELVs from 2000 through 2008 was a California dismantler, an additional 11% of the ELV population was last owned by either a private individual or a business that we could not identify. These 241 unique locations owned a total of 939,926 ELVs from 2000 through 2008. Determining the license status of these unknown locations is vital in order to correctly characterize the vehicle dismantling industry and identify entities operating outside the law. Thus, further analysis, including sampling vehicle refrigerant at unlicensed dismantler locations and identifying all entities that owned ELVs is warranted to improve the analysis. Comparing our findings to the relevant literature, Arbitman and Gerel (2003) reported that licensed dismantlers account for only one-third of all ELVs recycled in the state. While our results do not mimic these findings, the study relied on anecdotal reporting from dismantlers and thus the analysis may have been based on proprietary inventory records for which we have no data.

Another source of concern with regards to illegally operating dismantlers is that our ELV estimates are based only on CA DMV registration records. It can be assumed that many dismantlers operating outside the California Vehicle Code do not follow CA DMV registration protocol for reporting junk title and salvage certificate vehicles. Thus, we may be missing large quantities of vehicles and dismantlers that are moved through other,

non CA DMV channels. Similarly, the CA DMV registrations records themselves also present issues. Out of all VINs that were found to have lapsed registration, the CA DMV had no information on 2,204,181 VINs. An additional 1,904,555 vehicles had unclaimed registration and 318,322 VINs has registration records across multiple vehicles. Thus, we were not able to identify the registration status of 4,426,062 vehicles, 12% of all VINs with lapsed CA DMV registration. Identifying the histories of these missing VINs strengthens the analysis and also will be vital in identifying illegally operating dismantlers.

4.5 Vehicle Sampling

While vehicles were sampled from diverse geographic regions, the density of samples does not reflect the ELV or the population of vehicles with current registration in California. Approximately 40% of vehicles with current California registration status are registered in the South Coast AQMD, yet this Air District represents only 8% of all sampled vehicles. Similarly, the Bay Area AQMD is home to less than 2% of registered vehicles but represents 53% of sampled vehicles. These stratification issues were caused by limited access to dismantler locations as well as travel and time restrictions. This represents a shortcoming of the report, especially given that 74% of all sampled vehicles were registered within the same Air District over their entire registration history.

Table 30 presents the final CA DMV status for the entire sample of 2,002 vehicles. No CA DMV registration records were found for 225 vehicles. This could be the result of an incorrect VIN, missing information within the CA DMV registration records, or the vehicles could have been brought to a dismantler from out of state. Sixty-five percent of all sampled vehicles were issued a junk title as their final CA DMV action. Only 944 of these vehicles had the sampling location listed as their last owner in the CA DMV records. We lack data pertaining to dismantler inventory and vehicle acquisitions and thus have used the CA DMV registration records as a proxy. Given that the 1,300 vehicles that were issued a junk title as their last CA DMV action were sampled on dismantler lots, the sampling location was the owner of all these vehicles. Thus, using CA DMV records is not a perfect approximation for the inventory of vehicle dismantlers. Obtaining data directly from dismantlers would improve the precision of the analysis and would be critical in any extensions of the current research.

An additional 24 vehicles were issued a salvage certificate as their final CA DMV action. Only one of these vehicles had the sampling location listed as the last known owner in the CA DMV records. Again, we are missing data regarding how these vehicles move from private individuals to vehicle dismantlers.

Table 30: Final CA DMV Status for 2,002 Sampled Vehicles

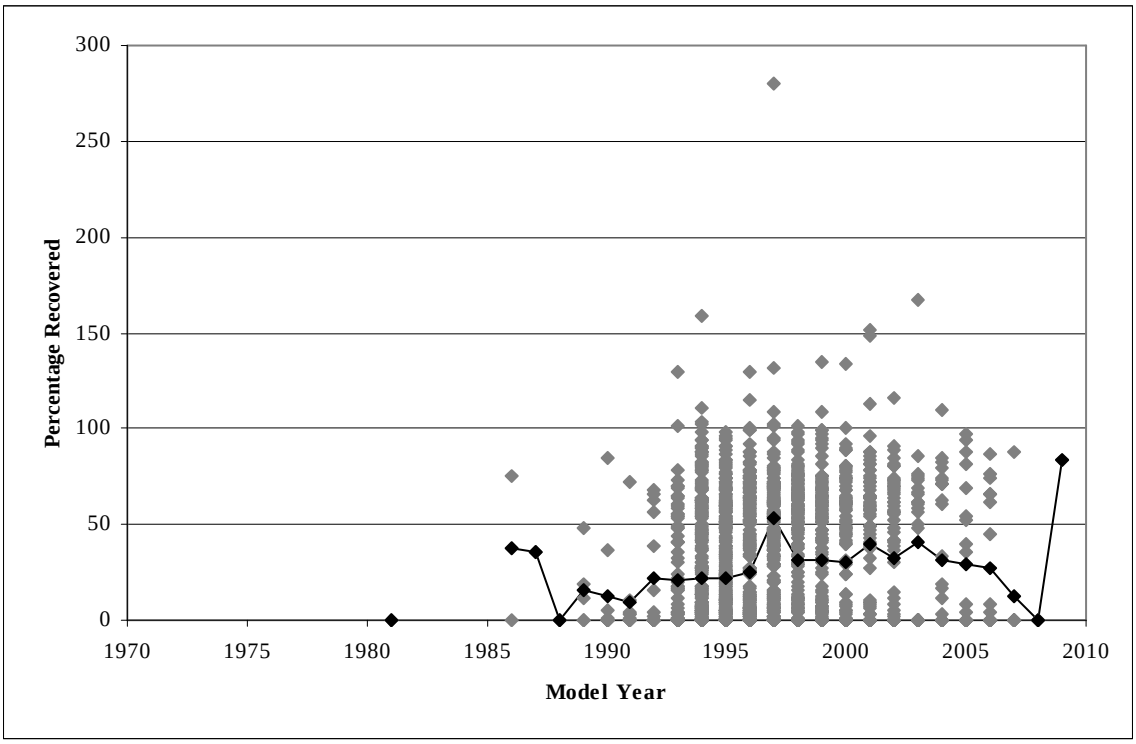
VINs Associated with CA DMV Records	1,777
Issued a Junk Title	1,300
Issued a Salvage Certificate	24
Planned Non-Operational	17
Unclaimed Registration	26
Other Registration Status	410

Looking over the entire CA DMV registration histories only 28 sampled vehicles, or 1% of the entire sample, were ever issued a salvage certificate. The low number of salvage certificate vehicles is likely due to their movement from private individuals to insurance companies, which is outside the scope of the report. Identifying more salvage certificate vehicles and the businesses that dismantle them would greatly improve the precision of any future analysis.

4.6 Recovered Refrigerant

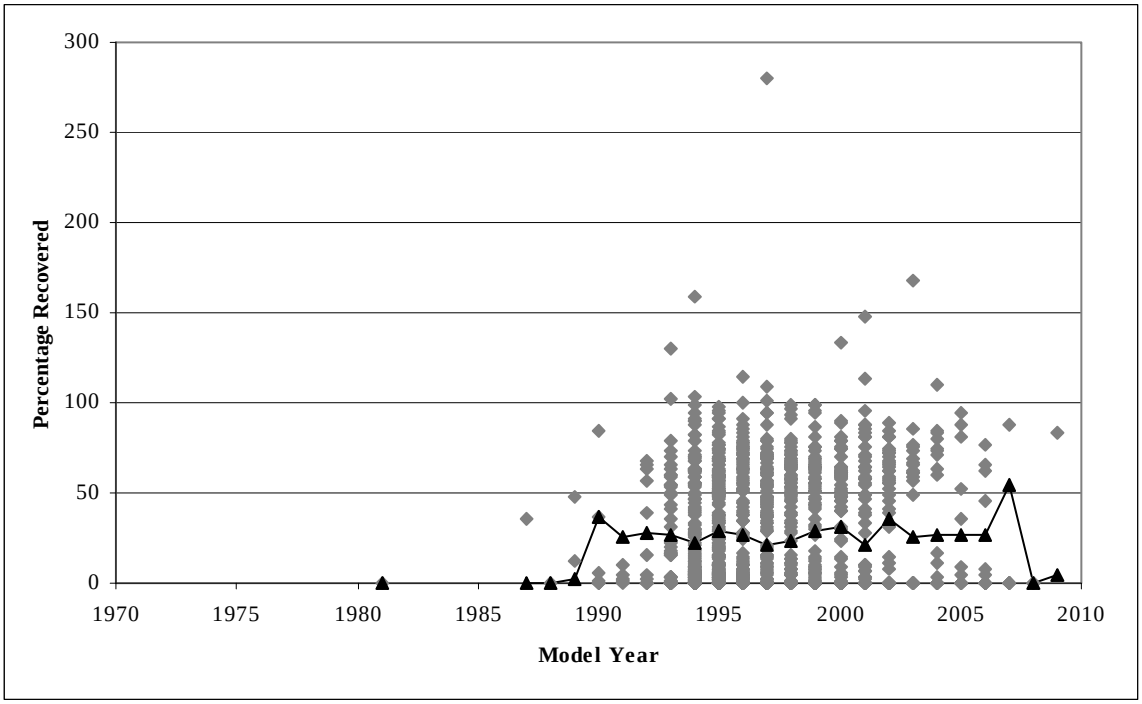
The goal of the analysis is to estimate the amount of HFC-134a remaining in ELVs on vehicle dismantler lots in California. Figure 63 plots the percentage of HFC-134a recovered and model year for the 1,966 sampled vehicles with HFC-134a charged systems. The mean percentage recovered for each model year is shown in black.

Figure 63: Percentage of HFC-134a Recovered from 1,966 Sampled Vehicles



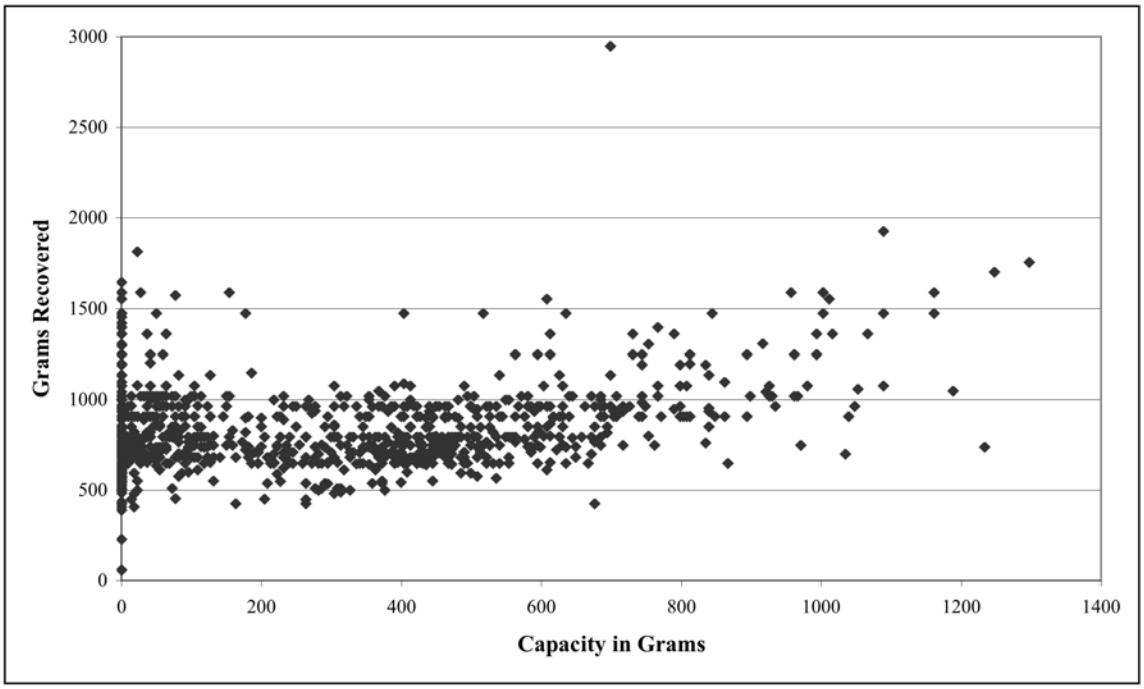
The mean percentage of HFC-134a recovered from all 1,966 vehicles was 27% with a standard deviation of 32%. There is a slight positive correlation between the percentage of refrigerant recovered and vehicle model years across all vehicles containing HFC-134a. While the mean of recovered HFC-134a was 27% across all sampled vehicles, the median was 8%. This highlights the large range of recovered refrigerant within each model year. Figure 64 focuses on only the 1,340 sampled vehicles that contain HFC-134a and were issued either a junk title or salvage certificate and thus classified as an ELV. The mean percentage of HFC-134a recovered by model year is shown in black.

Figure 64: Model Year and Percentage of HFC-134a Recovered from 1,340 Sampled ELVs



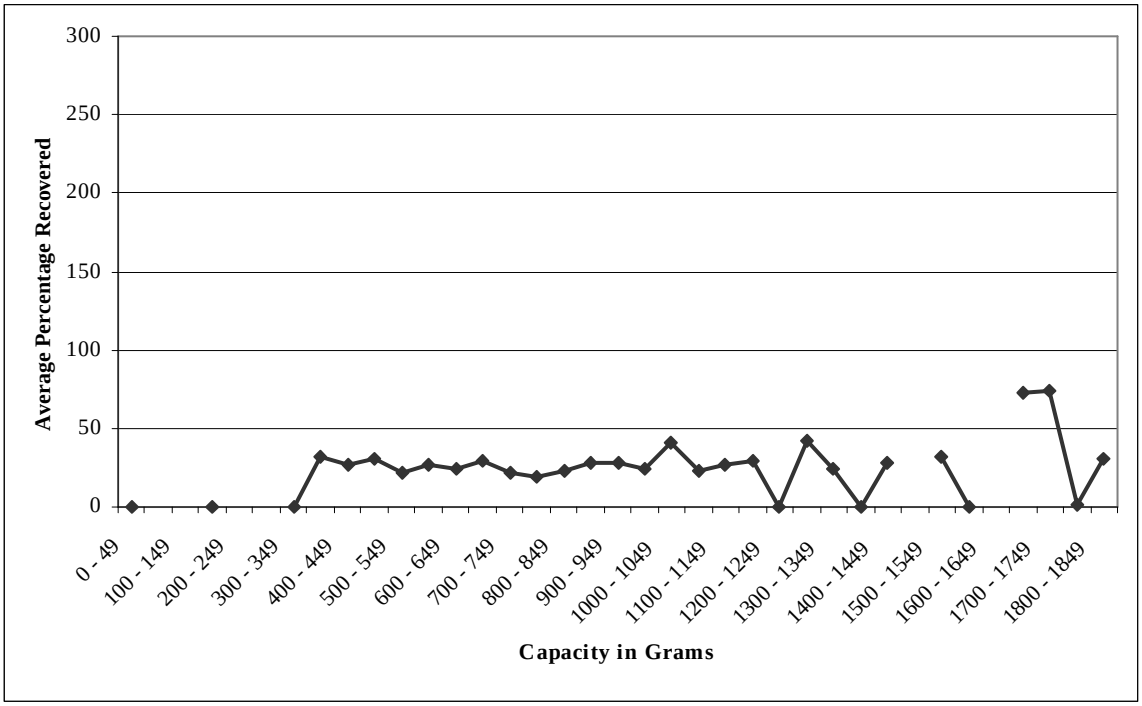
On average, 26% of HFC-134a capacity was recovered from these vehicles with a standard deviation of 32%. These statistics are highly unstable as the standard deviation is greater than the mean. The percentage of HFC-134a recovered also varies greatly within each model year. There is a slight positive correlation between the model year and percentage of refrigerant recovered across all sampled vehicles. The mean percentage of HFC-134a from ELVs is slightly lower than that for all sampled vehicles, but the distributions are stable across the varying population configurations. Figure 65 plots the capacity of HFC-134a and the grams recovered from the 1,340 ELVs. Outliers have been omitted for graphical clarity but all 1,340 ELVs are included in the calculations.

Figure 65: HFC-134a Capacity and Grams Recovered for 1,340 Sampled ELVs



Across the 1,340 HFC-134a ELVs, the mean refrigerant capacity was 852 grams with a standard deviation of 474 grams. The mean recovered HFC-134a was 220 grams with a standard deviation of 283 grams. Figure 66 presents the average recovered HFC-134a for all sampled ELVs. HFC-134a capacity has been portioned into groups of 49 grams and the mean refrigerant recovered varies from 0% to 55% across the sampled vehicles. The mean values are not significantly different across any amount of refrigerant capacity.

Figure 66: Average Recovered HFC-134a Across Capacity Partitions for 1,340 Sampled ELVs



4.7 Amount of HFC-134a Remaining in ELVs

While the amount of HFC-134a recovered from the sampled ELVs varies widely, these statistics represent our best estimate as to the HFC-134a remaining in the ELV population. Comparing our findings to those of relevant literature, CARB (2004) found an average of 17% of HFC-134a capacity remained in vehicles at dismantling yards. This is lower than our figure our 26%, but they relied largely on surveys and anecdotes rather than empiric data. In another analysis, Winifred Schwarz who found that upon testing HFC-134a at vehicle dismantlers, 62.5% of capacity had been lost (Schwarz 2001), meaning 37.5% of refrigerant capacity remained. Our results fall between these two studies and thus, despite the instability of our statistics, our findings are in the realm of those found in the relevant literature. Given our plausible sample findings and the robustness of our ELV population across varying time frames, we are confident that our sample findings can be extrapolated to the entire ELV population.

The population of ELVs from 2000 through 2008 in California containing HFC-134a comprised 2,098,887 vehicles. Extrapolating the sample findings of mean capacity and amount recovered to this population, we find that from 2000 through 2008 the ELV population contained 461,718 kg of HFC-134a, approximately 51,302 kg a year. Licensed vehicle dismantlers in California owned 69% of the ELV population from 2000 through 2008. Thus, from 2000 through 2008, there was 318,585 kg of HFC-134a in ELVs on licensed vehicle dismantler lots in California. An average of 35,398 kg of

HFC-134a was remaining in ELVs on licensed vehicle dismantler lots in California each year from 2000 through 2008.

In determining the benefit of efforts by CARB to support U.S. EPA's regulations governing HFC-134a removal and storage, we focus on the ELV population from 2005 through 2007. This recent time frame best reflects the sampled vehicles as well the ELV population going forward. From 2005 through 2007 there were 1,020,938 1995 and newer model year ELVs. Assuming the sample average of 220 grams of recovered refrigerant was recovered from each vehicle, an average of 74,869 kg of HFC-134a was left in the air-conditioning systems of vehicles on California dismantler lots. Thus, going forward, we propose that the maximum benefit of increased HFC-134a removal and recovery efforts would be 74,869 kg of HFC-134a a year or 0.075 million metric ton CO_2 equivalent ($MMTCO_2$) a year. These benefits will only continue to increase as the proportion of ELVs containing HFC-134a will continue to increase in the future.

We have projected that the percentage of ELVs containing HFC-134a will grow an average of 3% each year. This translates to an increase of 54,203 ELVs containing HFC-134a from 2008 through 2012. Assuming the mean HFC-134a recovered from each ELV remains at 220 grams through 2012, we project that an additional 10,949 kg of HFC-134a will remain in the ELV population. Thus, while approximately 74,869 kg of HFC-134a remained in vehicles on California dismantler lots from 2005 through 2007, by 2012 it will increase to 86,793 kg.

CARB and U.S. EPA only have jurisdiction over licensed vehicle dismantlers in California. Thus the benefits of increased enforcement pertaining to the removal and disposal of HFC-134a will be reduced to only those ELVs that are on licensed vehicle dismantler lots in California. From 2005 through 2007, 79% of all ELVs were owned by licensed vehicle dismantlers in California, up from 69% over the extended time frame 2000 through 2008. Thus, while 74,869 kg of HFC-134a remained on vehicle dismantler lots in California from 2005 through 2007, only 59,146 kg was on licensed vehicle dismantler lots. This reduces the potential benefit of any CARB efforts now and into the future. Assuming that the percentage of ELVs on licensed California dismantler lots remains constant over the next five years, the HFC-134a on licensed dismantler lots will be reduced from 86,793 kg to 68,566 kg. This represents a large decrease in potential benefits of any increased enforcement.

4.8 Correlation of Variables and Outliers

While we have focused on the amount of refrigerant remaining in dismantled vehicles, it is informative to identify the variables that influence this statistic. We have shown graphically and through the correlation coefficient that there is very little correlation between the percentage of refrigerant recovered from sampled vehicles and any geographic, dismantler, or vehicle specific characteristics. Across the entire sample of 2,002 vehicles, the percentage of refrigerant recovered was correlated with two vehicle characteristics; model year and whether the vehicle had a license plate at the time of sampling. Vehicles with license plates tended to have a higher percentage of recovered

refrigerant holding all other variables constant. Similarly, as the model year of a vehicle increases (or the vehicle decreases in age) the percentage of recovered refrigerant tends to increase holding all other vehicle characteristics constant. For both model year and license plate the overall correlation is weak and thus while we can identify the variables are related we cannot assume a dependence between these variables when extrapolating these results to other research questions.

Twenty-five of the 2,002 sampled vehicles had recovered refrigerant over 100% of refrigerant capacity. Their model year ranged from 1986 to 2004 with a mean of 1997 and a standard deviation of 4 years. CA DMV records were found for 21 of these vehicles and 14, or 58%, were ever classified as an ELV. These vehicles represent 13 different makes and 5 different vehicle types. Only one of these vehicles contained R-12 and none had been retrofitted from R-12 to HFC-134a. The vehicle, dismantler and geographic characteristics of these 25 vehicles resemble the sample population as a whole. The mean refrigerant capacity of the 25 outlier vehicles was 816 grams compared to 863 grams for all other sampled vehicles. An average of 1,017 grams of refrigerant was recovered from the 25 outlying vehicles compared to an average of 224 grams for all other sampled vehicles. Thus, while the refrigerant capacity of these 25 outliers is very similar to all sampled vehicles, the amount of recovered refrigerant is not. These abnormally large values could be the result of sampling errors or could be caused by incorrectly charged vehicle air conditioning systems. These vehicles could represent a portion of the ELV population that have been overcharged with vehicle refrigerant.

Given the ambiguous nature of these outliers, we have included them in all calculations and figures. These 25 vehicles represent only 1% of the entire sample and either removing them from the analysis completed or capping their recovered refrigerant at 100% does not alter the analysis or any underlying calculations.

5. SUMMARY AND CONCLUSIONS

The removal, recovery, and possible recycling of HFC-134a, a common vehicle refrigerant, from dismantled vehicles has been identified by the California Air Resources Board (CARB) as a potential greenhouse gas reduction strategy. This analysis quantifies the amount of HFC-134a remaining in dismantled vehicles in California in order to determine whether a sufficient amount of the refrigerant remains in vehicles on dismantler lots to warrant increased enforcement regarding its removal and storage. To that end, refrigerant samples were taken from 2,002 vehicles on 30 dismantler lots throughout California. In order to extrapolate these results to all vehicles dismantled in California, we then estimated the population of End of Life Vehicles (ELVs) or those vehicles that were issued a junk title or salvage certificate.

Using California Department of Motor Vehicle (CA DMV) registration records, we identified vehicles with lapsed registration status from 2000 through 2008. From these vehicles, we identified 8,537,707 that were classified as an ELVs from 2000 through 2008, 2,098,887 of which were 1995 or newer model years containing HFC-134a. This population of vehicles was owned by 2,107 unique vehicle dismantlers in California as well as 487 non-dismantling businesses. Vehicle dismantlers operating in California without the proper licenses owned 1% of the ELV population from 2000 through 2008, while non-dismantling businesses owned 30%.

In order to determine the impact of any CARB effort to increase enforcement of U.S. EPA regulations pertaining to the removal and disposal of HFC-134a, we focus on a more recent time frame that best encapsulates the current ELV population. From 2005 through 2007, there were 3,190,430 ELVs reported to the CA DMV. Of these vehicles, 1,020,938, or 32%, were 1995 and newer model years containing HFC-134a. These vehicles were owned by 1,629 different vehicle dismantlers in California. Licensed California dismantlers owned 79% of the ELVs from 2005 through 2007, dismantlers without the proper licenses owned 1% of these ELVs, and non-dismantling businesses or out of state dismantlers owned the remaining 20%.

Thus, any regulation targeting refrigerant recovery from licensed California vehicle dismantlers would effectively regulate 79% of the California ELV population. Focusing on the portion of ELVs from 2005 through 2007 containing HFC-134a (1995 and newer model years) reduces our population from 3,190,430 vehicles to 1,020,938 or an average of 340,313 a year. Enforcing HFC-134a recovery from licensed California dismantlers will thus potentially regulate 268,847 ELVs a year.

We then estimated the average amount of HFC-134a remaining in ELVs on vehicle dismantler lots in two rounds of sampling. An initial sampling of 160 vehicles was conducted at one location in the Sacramento Metropolitan Air Quality Management District (AQMD) and 1,842 vehicles were later sampled at 29 licensed dismantler locations through out the state. The 30 participating vehicle dismantlers were all licensed by the state of California and were members of the State of California Auto Dismantlers Association (SCADA).

Across the sample of 2,002 vehicles, 1,966 vehicles had air conditioning systems utilizing HFC-134a. For these vehicles, an average of 27% of the total HFC-134a capacity was recovered. An average of 10% of refrigerant was recovered from the 36 vehicles with R-12, the predecessor to HFC-134a, charged air conditioning systems. Of all the sampled vehicles, 1,340 vehicles, or 67%, were classified as an ELV. An additional 11% of the total sample, 222, did not have any CA DMV registration records and 21% of the sample, 415 vehicles, had non-ELV DMV status. Vehicles containing HFC-134a and classified as an ELV had an average of 26% of their total refrigerant capacity recovered. These vehicles had an average HFC-134a capacity of 853 grams and with 220 grams recovered on average.

An average of 340,313 ELVs containing HFC-134a are on vehicle dismantler lots in California each year. Extrapolating the mean capacity and amount recovered from the sample to this population, we find that from each year the ELV population contains 74,869 kg of HFC-134a. Licensed vehicle dismantlers in California owned 79% of the ELV population in 2007. Thus, on average there is 59,146 kg of HFC-134a remaining on in ELVs on licensed dismantler lots in California. Based on this information, the maximum benefit of CARB increasing efforts to support U.S. EPA's regulation overseeing the removal and storage of HFC-134a from licensed California vehicle dismantlers is 59,146 kg a year. This is equivalent to 0.075 $MMTCO_2E$ a year.

6. RECOMMENDATIONS

The robustness of the analysis could be improved by increasing the precision of CA DMV registration records, the identification of vehicle dismantlers, sample stratification, and calibration of sampling instruments. Within the estimation of the ELV population and vehicle dismantlers, further analysis and improved data is needed regarding CA DMV registration histories and the last known owner of ELVs. With the available CA DMV registration information, we were unable to determining the registration status of 4,108,736 VINs that had lapsed CA DMV registration. If even a fraction of these vehicles could be identified and classified as ELVs, this could change the landscape of the ELV population. We were also unable to identify the last owner of 939,926 ELVs, 11% of the total population. Identifying these owners could greatly affect the number of vehicles handled by dismantlers in California as well as dismantlers that may be operating illegally.

In terms of vehicle sampling, additional work regarding the geographic stratification of the sample as well as calibration of the different sampling instruments would improve the analysis. Two refrigerant recovery machines with different recovery effectiveness were used in the sampling and it would strengthen the results to correct for the different sampling errors. This could also lead to a better understanding of the 25 outlying vehicles that had extremely high amounts of recovered refrigerant. Extending the vehicle sampling geographically would strengthen the application of the analysis to locations all over the state. Increased sampling to Air Districts with large vehicle fleets, specifically the South Coast AQMD, would allow the sample to better reflect the overall ELV population and allow for more analysis of the movement of ELVs throughout the state.

Along with improving the existing analysis, steps can be taken to better answer the question of whether increased enforcement of U.S. EPA regulations overseeing the removal and storage of HFC-134a are warranted. The logical next step in the process to answer this question is to conduct a cost benefit analysis determining the cost of the potential maximum amount of HFC-134a that could be removed from ELVs on licensed dismantler lots in California. Until a price per ton can be found it is difficult to determine the appropriateness of any increased enforcement.

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8. GLOSSARY OF TERMS

Air Quality Management District (AQMD): One of 35 air pollution control districts in California.

Air Pollution Control District (APCD): One of 35 air pollution control districts in California.

California Department of Motor Vehicles (CA DMV): State agency that regulates motor vehicle operation and maintains vehicle registration records.

California Air Resources Board (CARB): State agency that protects the public's health and California's environmental assets through the reduction of air pollution.

Car Allowance Rebate System (CARS): A Federal program in which older, low fuel economy vehicles are traded in for a cash voucher to be used in the purchase of a new, fuel efficient vehicles.

End of Life Vehicles (ELVs): Vehicles that have been issued a junk title or salvage certificate.

Foundation for California Community Colleges (FCCC): Assists the California Community Colleges in increasing system resources, efficiency, and effectiveness.

HFC-134a: Refrigerant used in motor vehicle air conditioning systems. Became mandatory beginning with 1995 model year vehicles.

Million metric ton CO_2 equivalent ($MMTCO_2$): Figure used to describe the magnitude of greenhouse gas emissions.

R-12: Refrigerant used in motor vehicle air conditioning systems. The precursor to HFC-134a, its used was phased out after the 1994 model year.

State of California Auto Dismantlers Association (SCADA): Statewide trade organization for licensed vehicle dismantlers in California.

Planned non-operational (PNO): Registration status under which a vehicle can not be driven, towed, stored, or parked on roads or highways for the entire calendar year.

United States Environmental Protection Agency (U.S. EPA): Federal environmental regulatory agency.

Vehicle Identification Number (VIN): Unique vehicle identifier based on vehicle specific characteristics such as model year, manufacturer, and country of origin.

9. APPENDIX

Air District by Numeric Code

Air District	Numeric Code
Amador County	1
Antelope Valley	2
Bay Area	3
Butte County	4
Calaveras County	5
Colusa County	6
El Dorado County	7
Feather River	8
Glenn County	9
Great Basin Unified	10
Imperial County	11
Kern County	12
Lake County	13
Lassen County	14
Mariposa County	15
Mendocino County	16
Modoc County	17
Mojave Desert	18
Monterey Bay Unified	19
North Coast Unified	20
Northern Sonoma County	21
Northern Sierra	22
Placer County	23
Sacramento Metropolitan	24
San Diego County	25
San Joaquin Valley Unified	26
San Luis Obispo County	27
Santa Barbara County	28
Shasta County	29
Siskiyou County	30
South Coast	31
Tehama County	32
Tuolumne County	33
Ventura County	34
Yolo/Solano County	35

Vehicle Manufacturer by Numeric Code

Manufacturer	Numeric Code
Acura	1
Audi	2
BMW	3
Buick	4
Cadillac	5
Chevrolet	6
Chrysler	7
Daewoo	8
Dodge	9
Ford	10
Geo	11
GMC	12
Honda	13
Hyundai	14
Infinity	15
Isuzu	16
Jaguar	17
Jeep	18
Kia	19
Land Rover	20
Lexus	21
Lincoln	22
Mazda	23
Mercedes Benz	24
Mercury	25
Mitsubishi	26
Nissan	27
Oldsmobile	28
Plymouth	29
Pontiac	30
Saab	31
Saturn	32
Subaru	33
Suzuki	34
Toyota	35
Volvo	36
VW	0

Vehicle Body Color by Numeric Code

Color	Numeric Code
Black	1
Blue	2
Brown	3
Burgundy	4
Gold	5
Green	6
Grey	7
Orange	8
Purple	9
Red	10
Silver	11
Tan	12
White	13
Yellow	14
Unknown	15

Vehicle Type by Numeric Code

Vehicle Type	Numeric Code
Passenger Car	1
Full Size Van	2
Mini Van	3
Pick Up Truck	4
Station Wagon	5
SUV	6