A Geospatial Comparison of the Exposure to Ambient Air Pollution Faced by LA County's Public & Private Facilities for the Elderly

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Abstract: As providers of affordable housing for the elderly work to meet rising demand over the coming decades, it is important that new housing is built in a manner that considers the health of seniors in public housing. This study compared the approximate ambient air pollution burden faced by residents of public and private senior housing in order to determine if there was a statistically significant difference in exposure. The study area was Los Angeles County, which offers a pronounced example of both air pollution exposure and a rapidly-aging low-wealth population. **Methods:** This study aimed to quantitatively observe the approximate air pollution burden faced by these two types of facilities by comparing the location of facilities to census tract-level aggregated air pollution data. A dataset of LA County's publicly-subsidized facilities targeted toward the elderly was downloaded from the National Housing Preservation Database Research Tool. A dataset of private residential care facilities for the elderly was downloaded from the California Department of Social Services website and addresses were geocoded into latitudes and longitudes. Public and private facilities were imported into ArcMap, a geographic information systems program, along with CalEnviroScreen data showing the spatial distribution of air pollution in LA County. Each public and private facility, based on its census tract, was spatially joined to the CalEnviroScreen data so that pollution exposure for each facility could be approximated. A visual analysis was conducted to gather a basic understanding of how the independent and dependent variables were spatially distributed. A kernel density cluster analysis was conducted to better understand if there were clusters of public or private facilities throughout the county. Then, means for pollution-related variables were calculated for the groups of public and private facilities, in order to set up a statistical comparison using two-variable t-tests. T-tests were conducted for all relevant air pollution variables to determine if there were statistically significant differences in exposure between public and private facilities. **Findings:** In general, public facilities faced higher exposure. While ozone was found to be at statistically significantly higher concentrations in the census tracts of the private facilities, particulate matter 2.5 and diesel particulate matter were found to be at statistically significantly higher concentrations in the tracts of public facilities. The census tracts of the average public elder care facility also had statistically significantly higher exposure to toxicity-weighted chemical releases, cleanups, and hazardous and solid waste sites. Asthma, low birth weight, and cardiovascular disease was statistically significantly higher in the census tracts of public facilities.

Introduction

It has been widely demonstrated, through census population projections (Vespa, 2018) and congressional reports (Perl, 2010), that the U.S. is a rapidly-aging country. A new, larger group of seniors is reaching retirement age, and they will not be identical to the U.S.'s current elder population; the new senior citizens will be poorer (Pearson et al. 2019). Because of both the approaching larger senior generation and its decreased financial resources, housing experts and those in the field of senior services have sounded the alarm for decades (A Quiet Crisis in America, 2002) (Housing America's Older Adults, 2018-2019), saying that the U.S. must create more affordable housing for seniors.

If this need is not met, there will be an equity issue beyond the socioeconomic realm; the new generation of poorer elders will also be more racially diverse (Pearson et al. 2019). Furthermore, an analysis of population demographics among the senior residents currently utilizing the Department of Housing and Urban Development (HUD)'s various subsidized housing options shows that racial equity issues *already* exist, as current HUD residents are disproportionately non-white (HUD Assisted Housing Data Portal, 2011-2019). As housing is developed, it is important that it is done in a pragmatic and equitable manner, so as not to create further problems down the line or exacerbate inequality.

Because of both the current demographics of those in affordable senior housing and the expected augmentation of these trends in future years, it is important to examine solutions to the housing insecurity of seniors through lenses of socioeconomic and racial justice. One way to do this is through the comparative framework often used in environmental justice research, which contrasts burdens of environmental injustice between more privileged groups and more marginalized groups. Nearly 30 years of research in the field of environmental justice has shown unequivocally that low-income people of color have a greater exposure to air pollution (Wilson 2010). As low-income people of color make up a disproportionate share of people in affordable elder housing, it is possible that this inequitable exposure trend will also be found there.

To create socially-just new housing, it is necessary to determine if our current private and public housing options for seniors are equitable. While there is some research showing disparities in the health of residents in public housing as opposed to private housing (Northridge et al. 2010; La Mort 2019; Manjarrez, Popkin, and Guernsey 2007) there is a lack of research comparing public and private housing specifically for *elders*, and this paper seeks to begin the process of addressing that research gap.

The aforementioned reports on the so-called "Quiet Crisis" have made many recommendations on how best to house the new generation of low-wealth elders. However, there remains a crucial gap in this field's literature that must be addressed in order to make these decisions: Do seniors in public housing face a greater environmental health burden than their counterparts in private housing?

A logical place to begin this research is with a study comparing the burden of air pollution between elders in subsidized housing and private housing. Instead of directly measuring residents' health, this study worked towards a reasonable approximation of air

pollution burden by analyzing the location of private and public facilities in comparison to aggregated pollutant concentration estimates and aggregated data on sources of pollution (at the census tract level). The research question that was tested was whether, based on location, there is a measurable, statistically significant difference in the exposure to environmentally-transferred pollutants for seniors in publicly-subsidized versus private buildings.

In conclusion, in the coming decades there will be more and more low-income seniors, more of whom are people of color, who will need access to affordable elder housing. As these seniors are vulnerable populations for multiple reasons, and they have already been marginalized by society in other ways, it will be important to know if subsidized housing is, on average, located in areas with higher exposure to toxic air pollutants. In other words, it is important to know if these seniors who have no other option besides to enter subsidized housing are therefore being put at further risk. If that is the case, it will be necessary to enact policies that mitigate these disparities and protect seniors from preventable pollutant exposure.

Area of Study: Los Angeles County

The area of study will be limited to Los Angeles County. The greater LA area is an ideal place of study for a number of reasons. From an elder housing perspective, the area falls in line with national elder housing shortage trends. However, in some ways, LA takes the national problem of housing affordability to the extreme, making it an important "worst case" example. If LA can make meaningful policy changes that address housing affordability for elders, then the U.S. can learn from those hard-won improvements.

Like the U.S., Los Angeles' supply of residential care does not meet its demand (Frochen, Ailshire, and Rodnyansky 2019). Statewide, California has a housing crisis much worse than the nation as a whole — in 2018, the state ranked 49th in housing per capita (McDermid 2018). The price of buying a house in LA was already reaching an all time high prior to the pandemic (Chiland 2018) and, since the pandemic, that trend has, surprisingly, gotten worse, breaking records anew (Khouri 2020).

Housing insecurity is a pressing problem for the LA metro area's senior citizens in particular. Greater LA Homeless Counts have shown large increases in the number of elderly (62 years and over) homeless people in each of the past three years. The proportion of elderly people among the city's homeless increased by 22% in 2018, 8% in 2019, and 20% in 2020 (Greater Los Angeles Homeless Count Results 2018-2020). These statistics emphasize the importance of expanding affordable housing targeted toward the elderly in LA and show that if LA can successfully tackle this issue, other metro areas could learn important lessons.

LA County also represents a good place to study air pollution for the same "worst case" reasoning. The American Lung Association's 2019 State of the Air report showed that the LA metro area was the worst city in the nation for air pollution (State of the Air 2019).

Background

Introduction

This background section covers three overarching topics: 1) the present and future demographics, nationally and locally, of the elderly, as well as their current options and future needs for affordable housing 2) information about two key air pollutants that affect respiratory health and 3) the particular climate, air pollution, and environmental health challenges found in Los Angeles, the area of study.

First, the U.S.' aging population is discussed, with emphasis on projections that show this generation of elders will be poorer and less white than prior generations. Then, this background section describes the affordable housing options for the elderly and their respective characteristics and demographics. A lack of supply of affordable elder housing commensurate to its rising demand is then discussed, followed by the immediate concern of COVID-19 (and the possibility of future pandemic diseases) in the context of elder housing.

The second section of background briefly describes the air pollutants most relevant to this study. For each pollutant, health impacts are described as well as prevalence of the pollutant in the Los Angeles area.

In the third and final background section, Los Angeles' particular climate is discussed, in the context of air pollution. First, studies that describe the unique diffusion of air pollution in Los Angeles are reviewed in order to determine how best to interpret the reach and burden of point source pollution in this particular city. Then, the high-heat and wildfire-prone climate of Southern California and Los Angeles is considered, with particular attention given to how these conditions may create synergistic cumulative impacts when combined with air pollution exposure.

A Growing Population of Middle & Low-Income, Nonwhite Elders

National Aging Overview

It has been well-documented that the U.S. has a rapidly-aging population. The oldest of the "baby boomers," the generation born between 1946 and 1964, are just reaching 75 years old, while the youngest are 55, still a decade away from the traditional American retirement age of 65. According to the US Census Bureau's 2018 estimate, by 2034 there will be 77 million people 65 years and older and only 76.5 million people under the age of 18 (Vespa, 2018). By 2060, the U.S.'s population, if it remains on the same course, will be very similar to the current population of Japan, the world's oldest country (1 in 4 Japanese people are over 65). The Census projects that in 2060, 23.4% of Americans will be 65 or older, while people under 18 will make up only 19.8% of the population (Vespa, 2018). As of 2016, adults over 65 were 15.2% of the population, while children under 18 were 22.8%. This shows that, in just a few decades, the country will have a much higher proportional need for housing options for the elderly.

The huge new generation of U.S. seniors does not share the same demographics as previous ones; they are not as wealthy or as white (Pearson et al. 2019). The Pearson et al.

(2019) study forecasts that in 2029 there will be 14.4 million seniors considered middle-income, many of whom will have special needs, including mobility problems and health care issues. According to the article, middle income seniors are those who are too wealthy to qualify for public programs, but not wealthy enough to cover long-term costs at private senior homes. Specifically, middle income seniors are considered the 41st to the 80th percentile of wealth for their age group: "In 2029, for people ages 75–84, that middle-income definition corresponds to annuitized financial resources of $25,001–$74,298 in 2014 dollars. For those ages 85 and older, middle income is $24,450–$95,051" (Pearson et al. 2019, Pg. 853). Currently, there are 7.9 million middle-income seniors, the study found, so this number will nearly double in a decade. The study's projections also found that there will be demographic differences in the new cohort of middle-income seniors, including more racial diversity: Hispanic elderly will grow from 2.4% to 6.3% and non-Hispanic Black elderly will grow from 5% to 6.7%. Non-Hispanic white elderly will shrink from 90.9% to 83.8%. The study concludes that many changes and innovations will need to be made to both the public and private senior housing sectors to cut costs in order to accommodate more seniors with lower budgets for housing.

It is important to note that even as more low-income seniors of color will enter retirement age over the next few decades, there is already a disproportionate share of low-income people of color in subsidized housing for the elderly. For example, Section 202 Supportive Housing for the Elderly, HUD's only subsidized housing program dedicated exclusively for elderly residents, is already "majority-minority." According to HUD's data portal, 49% of heads of households in Section 202 units are minorities, 47% are non-Hispanic white, 23% are non-Hispanic Black, 15% are Hispanic, 10% are Hispanic white, 9% are Asian/Pacific Islander, 1% are Native American, and 1% are multiple races (Assisted Housing: National and Local, 2011-2019). Unsurprisingly, 98% of Section 202 residents are very low-income, which HUD defines as earning 50% or less of the median family income for the area.

California and Los Angeles County Aging Overview

In California, a similar aging trend is occurring, albeit even more drastic. The state's Department of Finance predicted that between 2018 and 2026, the number of Californians over 65 would rise by 2.1 million (Mason 2018). Meanwhile, the number of people 25-64 was expected to increase by just over 500 thousand and people under 25 would increase by only 2,500. By 2060, the state's cohort of residents 65 and over is projected to be 13.5 million, in comparison to the 5.5 million in the same age bracket now.

Similar to national trends, the new, larger generation of seniors in California will be less white and poorer. According to a report from U.C. Berkeley's Labor Center, California seniors were 41% people of color in 2015, but will be 55% nonwhite by 2035 (Rhee and Ebner 2015). Forty-four percent of Latino seniors, who were expected to rise from 21 to 33% of the statewide senior population between 2015 and 2035, are currently below 200% of the Federal Poverty Line (200% FPL), compared to the 23% of current white seniors with the same income status. The report stated that, in general, seniors of color currently have about half the income of white

seniors in California. The report also noted that the quickest-growing bracket of seniors is the oldest (age 80 and older), which is also the age group with the largest percentage below two times the poverty line, at 36%.

The Labor Center report cited Los Angeles as one of two places, along with the Central Valley, where these demographic changes will have the most drastic effects. The two regions have the highest poverty rates (with 32% of Los Angeles seniors below 200% FPL) and lowest median incomes. Los Angeles also has the highest number of seniors living alone, perhaps showing that senior living in the city could be made more efficient.

It is clear that across the U.S., there is a need for more housing for seniors that is affordable, but California and Los Angeles represent some of the most dire examples of this trend.

Types of Senior Living Facilities

With the population of seniors — in the U.S., California, and Los Angeles — rapidly increasing, diversifying, and getting poorer, it is imperative that more affordable housing for the elderly is created. If this is not done, it will likely drive more elderly people into extreme poverty and homelessness (a trend that has already been observed in Los Angeles) and these people will increasingly be people of color and people who have lived poor throughout their lives.

The introduction of new affordable housing for the elderly can be done either publicly, through the variety of programs that exist or through new programs, or in the private sector. In order to make policy recommendations for elder housing, it is important to understand the landscape of public housing in the U.S., as well as existing types of public and private facilities that are used by the elderly.

Proportion of Elderly People in Public Housing: Nationally, Statewide, and Locally

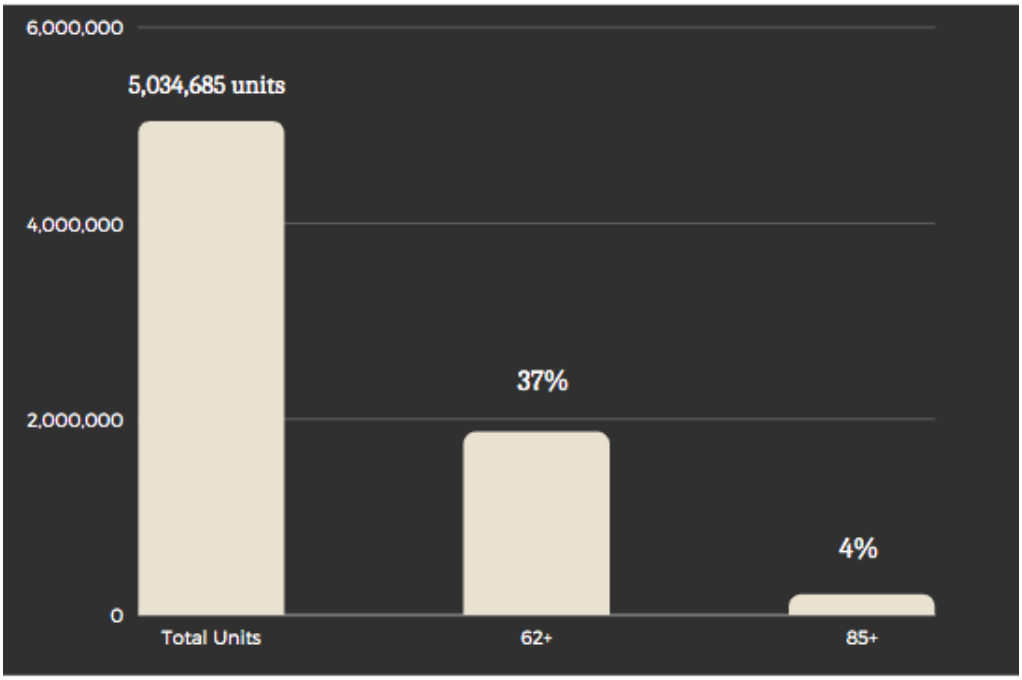
Public housing programs for the elderly are just one part of HUD's affordable housing offerings, which have existed since 1937 (HUD Assisted Housing Data Portal, 2011-2019). HUD defines elderly persons eligible for housing as households with at least one person who is 62 years or older. The best metric on the HUD Data Portal for understanding what percentage of this housing stock is used by elderly people is the percentage of units where the head of household ("head") or spouse is elderly. About a third of subsidized units nationally have an elderly spouse or head. The proportion of affordable housing used by the elderly is higher in California, and higher again in Los Angeles County.

HUD brackets the elderly into two overlapping age groups: 62 and older and 85 and older. As of 2019, HUD offers 5,034,685 subsidized units nationwide across all its programs, and 37% (up from 33% in 2015) have an elderly head or spouse, 4% of whom are over 85 (same as 2015).

In California, 47% (up from 42% in 2015) of 493,534 total units have an elderly head or spouse, 7% of whom are over 85 (up from 6% in 2015).

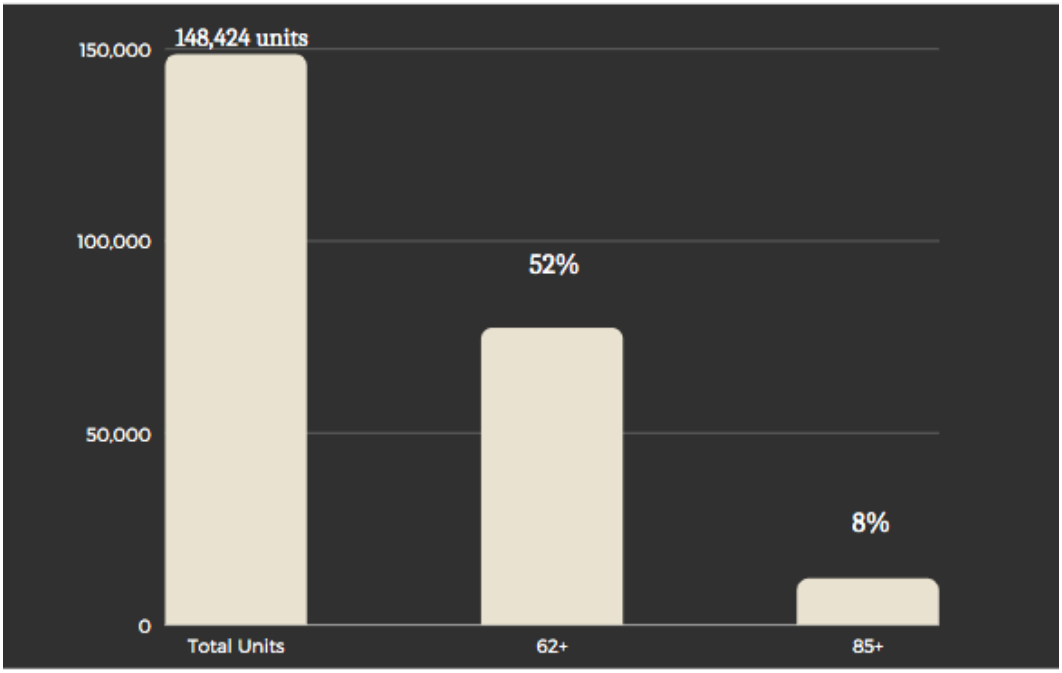
Los Angeles County, which offers a total of 148,424 subsidized units across all programs, has 52% of units where the head or spouse is elderly (up from 46% in 2015), 8% of whom are over 85 (same as 2015).

United States: Proportion of HUD-Subsidized Units Where the Head of Household or Spouse is Elderly

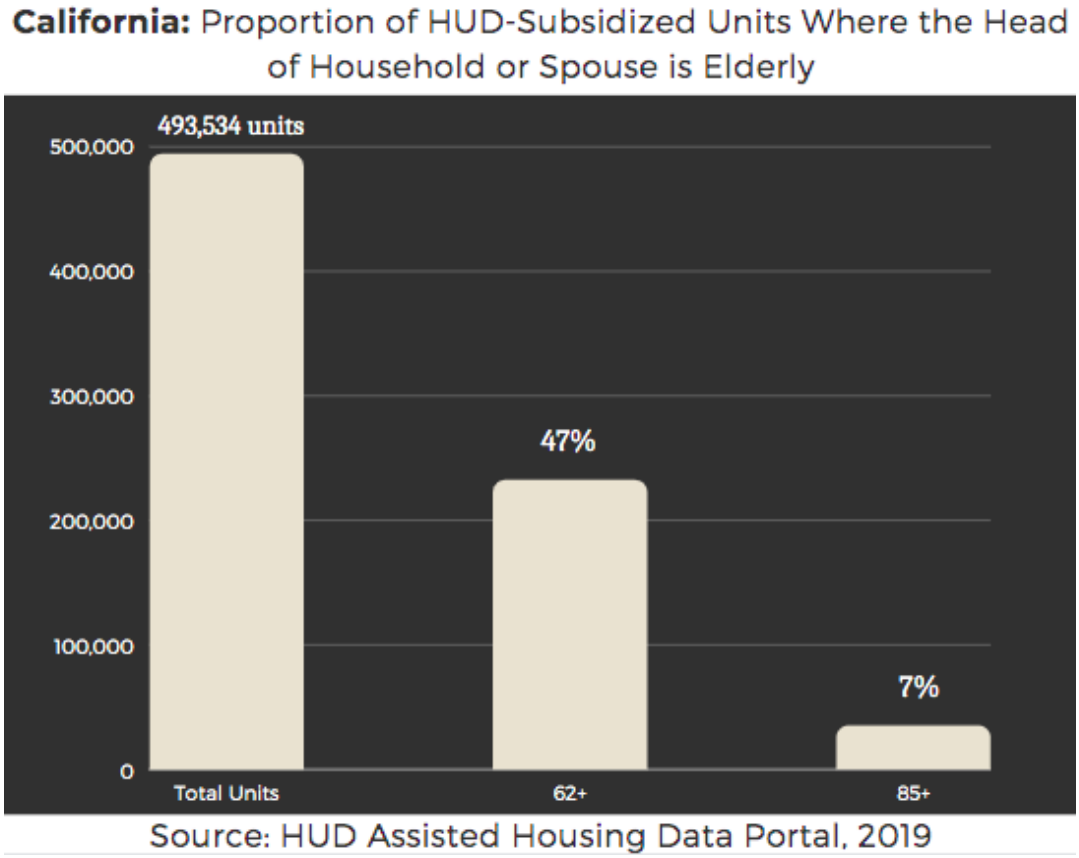


Source: HUD Assisted Housing Data Portal, 2019

LA County: Proportion of HUD-Subsidized Units Where the Head of Household or Spouse is Elderly



Source: HUD Assisted Housing Data Portal, 2019



These data show that elderly people use a large portion of public housing nationally, an even larger portion in California, and an again larger portion in Los Angeles County. This reinforces the assertion that Los Angeles is a more drastic example of a larger aging phenomenon statewide and nationally. These current figures, when compared with a year as recently as 2015, also reify projections that the nation is growing older and poorer and show that this manifests in a growing usage of affordable housing by the elderly. This may be due simply to the fact that people in affordable housing have stayed there, aging into an elderly categorization. However, the fact remains that this demonstrates an aging low-income population.

Types of Publicly-Assisted Housing for the Elderly

HUD offers a number of programs that assist low-income renters with housing costs, mostly by providing subsidies to help people pay for privately-owned housing. In addition to Section 202, the program exclusively for senior citizens, there are a number of other programs for which elders are also eligible. Section 202 is what is considered a project-based program, which means that it has specific buildings designated for public housing. Project-based housing targeted toward senior tenants is the only type of housing that this study will examine; even though housing voucher programs provide about half of the country's public housing (HUD Assisted Housing Data Portal 2019), it is much less feasible to measure the pollution exposure of these units using the methods of this study. Aside from Section 202, some other project-based

programs that serve high proportions of elderly residents are Project-Based Section 8 Housing and HUD Public Housing, which each have projects dedicated to elderly households.

Section 202 Supportive Housing for the Elderly

Section 202 facilities are publicly-subsidized buildings "open to very low-income households which include at least one person 62 years of age or older" (HUD Programs 2020), who pay no more than 30% of their adjusted income to private providers of Section 202 project housing. HUD subsidizes the remaining 70%, or more, of the cost. Established in the Housing Act of 1959, it is the only program that exclusively serves elderly people.

Nationally, 17% of Section 202 units have a head or spouse who is 85 years or older (HUD Assisted Housing Data Portal, 2019). In California, 21% of Section 202 heads or spouses are 85 years and older, and in Los Angeles County, the figure is again higher, at 25%. This shows that Los Angeles County and California have older users of Section 202, again emphasizing the point that this study will be conducted in an area that takes national aging trends to the extreme.

With data showing that the oldest group of seniors in California are often the most financially insecure (Rhee and Ebner 2015), this raises the question of whether Section 202 residents in California and Los Angeles residents may not only be *older* than their Section 202 counterparts nationwide, but may also be *poorer*. When looking at household income, Section 202 residents nationally make an average of 25% of their area median income (AMI). In California, Section 202 residents make, on average, 21% of AMI and for residents in LA, the figure is 18% (HUD Assisted Housing Data Portal, 2019). This shows that residents of Section 202 in LA are *poorer*, *older*, and *less white* than in California, and residents in California are, in turn, *poorer*, *older* and *less white* than residents nationally, reiterating that LA is an extreme example of national trend. Overall, the household incomes in Section 202 show that residents are not low-income or very low-income, but extremely low-income. HUD defines low-income as 80% of AMI and very low-income as 50% (LA Almanac, 2020). The Fiscal Year 2014 Consolidated Appropriations Act (Smith 2014, Sec. 238) changed the definition of extremely low-income, which HUD defined in 2010 as 30% of AMI, to a more opaque definition, yet it is very apparent that the average Section 202 resident, especially in LA and California, is extremely low-income, often earning 25% AMI — less than half as much as a federally-defined very low-income person would.

Section 202 residents are not only extremely low-income, but also disproportionately people of color. As cited previously, nationally, Section 202 units are 49% minority, meaning that in 49% of units, the head of household is Black, Native American, Asian or Pacific Islander, or Hispanic. In California, Section 202 is even more disproportionately used by people of color, at 66% minority, and in Los Angeles County, 71% of Section 202 head-of-households are minorities.

Section 202 housing is disproportionately used by extremely low-income people of color, a trend that will likely become more pronounced as demographics change. If my research finds there is a higher pollution exposure in Section 202 and other subsidized housing than in private

senior housing, this represents an equity issue in regards to both race and class and should be remedied with appropriate policy.

Project-Based Section 8 Housing

Project Based Section 8 (PBS8) housing is another HUD program that provides subsidies to help low-income households rent designated PBS8 units, which are privately owned and managed. When a resident leaves the unit or home, the subsidy remains there and the resident no longer has PBS8 rental assistance. In most units, PBS8 recipients pay 30% of their household adjusted gross income in rent. There are many types of housing available, including apartments, single-family homes, and townhomes (HousingLink, 2020).

Nationally, there is a large proportion of older residents in PBS8 — 50% (up from 48% in 2015) of PBS8 units have a head of household or spouse who is elderly (62 years and over) and 7% of units have a head of household or spouse 85 years or older (HUD Assisted Housing Data Portal, 2019). In California, 68% of Project-Based PBS8 units (up from 64% in 2015) have an elderly head of household or spouse, and in LA county, that figure is even higher, at 72% (up from 69% in 2015). This shows that, in LA County and California, Project Based PBS8 is much more likely to be used by elderly residents than elsewhere in the country, and that — everywhere in the U.S. and especially in LA and California — the number of elderly users of PBS8 is rising.

PBS8 residents are also disproportionately people of color. Nationwide, 56% of heads of households are minorities. In California, this figure is 70%, and in LA County, it is 78%.

Like Section 202 residents, PBS8 residents are often extremely low-income. Nationally, PBS8 residents (about half of whom are elderly) earn 22% of AMI. In California, residents of PBS8 (68% of whom are elderly) earn, on average, 20% of AMI and in LA County, the average earnings of residents (72% of whom are elderly) are 19% of AMI. If my research finds a higher pollution exposure in the elder-targeted PBS8 housing than in private senior housing, this, again, represents an equity issue in regards to both race and class.

HUD Public Housing

HUD Public Housing is the agency's only program where government officials are the landlords. As of 2019, HUD offers 987,133 units in the HUD-funded Public Housing program, managed by 3,300 state and local housing agencies.

Nationally, in HUD Public Housing, 34% of households have an elderly person as head of household or spouse. The statistic for LA County is the same, while in California only 31% of households have a head or spouse over 62 (HUD Assisted Housing Data Portal, 2019).

Nationally, 71% of Public Housing head of households are minorities, while in California that figure is 87% and in Los Angeles County it is 93%. These data show that California and LA have a very high proportion of people of color in Public Housing.

The average public housing resident is extremely low-income, but makes about the same percentage of median income nationally (25% of AMI), statewide (26%), and in LA County (24%).

The demographic makeup of Public Housing residents is relatively similar nationally to California and Los Angeles. About a third of residents are elderly and residents make about a quarter of median income. However, Los Angeles and California have much higher proportions of residents of color in Public Housing. If there is a higher pollution exposure in Public Housing, that again represents an equity issue.

Low-Income Housing Tax Credits (LIHTC)

The Low-Income Housing Tax Credit Program (LIHTC) is currently the program providing the most low-income housing. It gives $8 billion each year to state and local agencies and deputizes them to give tax credits to developers to acquire, renovate, or build housing for the purpose of making it affordable housing. Since 1987, there have been 48,672 projects and 3.23 million units placed on the market through LIHTC (Housing and Urban Development, n.d.). Even though the program is not intended specifically to build housing for seniors, as of 2002, each year 13,200 units of senior housing were being created with LIHTC tax credits (Commission on Affordable Housing and Health Facility Needs for Seniors in the 21st Century, 2002).

According to HUD's LIHTC-specific data portal, there are 4,165 LIHTC buildings in California, and 880 (just over 21%) of them are targeted specifically to the elderly (LIHTC Database 2020). In LA County, there are 968 LIHTC buildings and 215 (just over 22%) are dedicated to the elderly. There are 7,423 LIHTC buildings targeted toward the elderly nationwide, meaning about 15% of LIHTC's total stock is elderly-only. The LIHTC-specific database does not have information on the race or income status of tenants. In 2017, 30% of LIHTC residents using more than 30% of their income for housing were elderly (Gudzinas 2017).

U.S. Not on Track to Meet Needs for Affordable Elder Housing

At the start of the century, the Bipartisan Housing Commission (which was created in 1999 and, in 2002, published *A Quiet Crisis in America*) estimated that the aging of the population will result in the need for an additional 730,000 units of affordable elderly housing to be created by 2020 (Perl, 2010). HUD does not have data for the years 2001-2004, but in 2000, there were a total of 4,881,081 units across all of HUD's programs, of which 31% had a head of household or spouse 62 years and older. In 2019 there were 5,034,685 total HUD-subsidized households nationwide, 37% of which had an elderly head or spouse. These data show that HUD increased its *total* supply of subsidized housing by 153,604 units in 19 years. This total increase does not come close to the 730,000 units in *elder-specific* affordable housing called for by the commission. Furthermore, seniors are only taking up a slightly larger percentage of the total subsidized housing stock.

It is difficult to quantify exactly how much elder-specific subsidized housing has been built in the past 20 years because of missing data on HUD's data portal. However, the most recent year for which HUD has data on available units of Section 202, the only

exclusively-elderly program, is 2014. In that year, there were 122,040 Section 202 units. As of 2019, that number had risen only to 125,761. Despite the 2002 report's warnings, it seems the HUD has not significantly increased its amount of affordable elder housing to meet growing demand. This may be simply due to a lack of funding. According to HUD Exchange, Congress had not provided funding for any additional Section 202 units since fiscal year 2012 (HUD Exchange 2020).

Current Concerns About COVID-19 and Global Pandemics

A final concern considering the growing elderly population is their susceptibility to, and increased risk of death from, communicable diseases such as COVID-19. Experts assert pandemics will continue to be a problem for our globalized society, especially as the melting of the ice caps start to release ancient diseases (Resnick 2017). COVID has been shown to be associated with cardiovascular and respiratory disease, so the presence of respiratory-affecting pollutants may increase risk of serious outcomes from COVID (Comunian, Dongo, Milani & Palestini, 2020). Although one percent of the nation's population lives in long-term care facilities, as of March 4th, they accounted for 34% of US COVID deaths. In California, 24% of deaths are from long-term care facilities (The Long Term Care COVID Tracker). Concerns of rapid spread of disease among the elderly are important to consider when proposing solutions to the growing demand for affordable senior housing.

Air Pollutants

In order to properly approximate and compare point pollution exposure between residents of private and public senior housing, it is important to understand which air pollutants have the greatest adverse health impacts on the elderly. Because there is also a high proportion of people of color in affordable elder housing, and because the proportion of elders of color will continue to increase, it is also important to understand air pollution's effects on people of color.

National Ambient Air Quality Standards and Criteria Pollutants

The EPA was tasked by the Clean Air Act with setting regulations for six harmful "criteria pollutants": particulate matter, ground-level ozone, lead, carbon monoxide, sulfur dioxide, and nitrogen dioxide. These regulations are called the National Ambient Air Quality Standards (NAAQS), and are periodically reviewed and updated.

For air pollution data, this study used data from CalEnviroScreen 3.0, a statewide pollution data source that shows how a number of pollution-related variables vary from one census tract in California to another (census tracts are geographic areas used in the census).

CalEnviroScreen 3.0 offers a number of variables related to sources of pollution, such as the number of hazardous waste sites in a given census tract, but offers fewer variables that show concentrations of pollutants in a census tract. It does show concentrations for particulate matter (including diesel particulate matter) and ozone, two key pollutants, which this study examines in relation to public and private facilities.

Particulate Matter

Particular matter are very small particles that can exacerbate respiratory and cardiovascular diseases and act like a gas if small enough, entering the lungs. According to the EPA, PM2.5 is less than 2.5 micrometers in diameter, and it therefore poses the greatest risk to health. One source of particulate matter is vehicle emissions. The particulate matter from these emissions is often divided into two categories: primary combustion particles and near-tailpipe ultra-fine particles (UFPs). Primary combustion particles are mostly carbonaceous materials formed in the engine or tailpipe and are between 30 to 500 nanometers in size. They can also contain metallic ash, hydrocarbons, and sulfur compounds (Knibbs, Cole-Hunter & Morawska). Near-tailpipe UFPs are less than 30 nanometers in size, consist mostly of hydrocarbons and hydrated sulfuric acid, and are found near busy highways, especially ones with many large diesel-powered vehicles, like trucks. The distance of facilities from large freeways could play an important role in how much exposure facility residents have to particulate matter.

Because of high automobile usage, LA is one of the worst cities for particulate matter air pollution (State of the Air 2019). Particulate matter will be one of the key pollutants researched in this study, as it has been asserted in research (Simoni et al. 2015) — which will be reviewed in the literature review section "Effects of Exposure to Airborne Toxins in Elderly Populations" — as a pollutant to which seniors are highly vulnerable.

Diesel Particulate Matter

One type of particulate matter comes from diesel exhaust, emitted by diesel-powered automobiles. Diesel particulate matter is composed of tiny particles which include carbon, sulfates, metals, silicates, and ash (Occupational Safety and Health Administration n.d.). Diesel exhaust also contains nitrogen oxides (Perez et al. 2019). According to a study by UCLA's Institute of the Environment and Sustainability (Perez et al. 2019), diesel cargo trucks that enter and exit the Port of Los Angeles emit 400,000 tons of air pollutants annually, including particulate matter. Long-term exposure to diesel particulate matter can cause respiratory and cardiovascular diseases as well as lung cancer (Occupational Safety and Health Administration n.d.).

Ground-Level Ozone

Ground-level ozone is the second pollutant on which this study will focus. Ozone is created when sunlight hits sulfur oxides (which come from sources like motor vehicles and power plants). Exposure to the pollutant can cause serious lung damage, which can lead to chronic respiratory diseases like asthma (US EPA 2014). Ground-level ozone is caused primarily by vehicular pollution, and because of the high volume of traffic in LA, sun-heavy weather conditions, and the mountains that surround LA (Neuman et al. 2012), the greater Los Angeles area has consistently had some of the nation's highest ozone levels.

In September 2020, Downtown Los Angeles had its worst smog in 26 years, which was due to increased levels of ozone during a record-breaking heat wave (Barboza 2020). During a

prolonged spike over a very high-temperature weekend, ozone concentration reached a high of 185 parts per billion September 6, far higher than the federal regulatory limit of 70 parts per billion. As temperatures rise because of climate change, high concentrations of ozone may continue to be a threat to public health, especially in hot regions like Southern California.

Further Information on CalEnviroScreen Variables Used in This Study

This study uses certain CalEnviroScreen variables to approximate the pollution burden faced by public and private facilities. Listed below are CalEnviroScreen's methodologies for calculating these variables for each census tract, the units in which the variables are reported, if applicable, and the original data source.

CI Score (CalEnviroScreen Score)
Methodology: Pollution Burden Score multiplied by Population Characteristics Score.
Data Sources: All other sources. (CalEnviroScreen3.0, 14).

Ozone
Units: parts per million (ppm). Methodology: Daily maximum 8-hour ozone concentration, using the mean of summer months (May-October) averaged over three years (2012 to 2014).
Data Source: Air Monitoring Network, California Air Resources Board. (CalEnviroScreen3.0, 22).

Particulate Matter
Units: Micrograms per cubic meter of air (µg/m3). Methodology: Annual mean PM 2.5 concentrations (average of quarterly means).
Data Source: Air Monitoring Network, California Air Resources Board. (CalEnviroScreen3.0, 26).

Diesel Particulate Matter
Units: Kilograms per day (kg/day). Methodology: Spatial distribution of gridded diesel PM emissions from on-road and non-road sources for a 2012 summer day in July.
Data Source: California Air Resources Board. (CalEnviroScreen3.0, 32).

RSEI Haz (Toxic Releases from Facilities)
Units: N/A — Numeric Risk Screening Environmental Indicators (RSEI) scores must be compared to other RSEI scores to generate meaning. Methodology: Toxicity-weighted concentrations of modeled chemical releases to air from facility emissions and off-site incineration.
Data Sources: RSEI; US Environmental Protection Agency; Toxic Release Inventory. (CalEnviroScreen3.0, 53).

Traffic (Traffic density)
Units/Methodology: Vehicle-kilometers per hour per road length within 150 meters of the census tract boundary.
Data Sources: California Environmental Health Tracking Program, California Department of Public Health; US Department of Transportation; US Customs and Border Protection. (CalEnviroScreen3.0, 59).

Cleanups (Cleanup sites)
Units/Methodology: Sum of weighted EnviroStor cleanup sites within each census tract.
Data Sources: EnviroStor Cleanup Sites Database, Department of Toxic Substances Control; US Environmental Protection Agency, Region 9 Superfund sites. (CalEnviroScreen3.0, 66).

Haz Waste (Hazardous Waste Generators and Facilities)
Units/Methodology: Sum of weighted permitted hazardous waste facilities and hazardous waste generators within each census tract.
Data Source: EnviroStor Hazardous Waste Facilities Database and Hazardous Waste Tracking System, Department of Toxic Substances Control. (CalEnviroScreen3.0, 82).

Solid Waste (Solid Waste Sites and Facilities)
Units/Methodology: Sum of weighted solid waste sites and facilities within each census tract, as of December 2016.
Data Sources: Solid Waste Information System and Closed, Illegal, and Abandoned Disposal Sites Program, California Department of Resources Recycling and Recovery, CalRecycle; Hazardous Waste Tracking System, Department of Toxic Substances Control. (CalEnviroScreen3.0, 94).

Pollution (Pollution Burden Score)
Units/Methodology: "Pollution Burden scores for each census tract are derived from the average percentiles of the seven Exposures indicators (ozone and PM2.5 concentrations, diesel PM emissions, drinking water contaminants, pesticide use, toxic releases from facilities, and traffic density) and the five Environmental Effects indicators (cleanup sites, impaired water bodies, groundwater threats, hazardous waste facilities and generators, and solid waste sites and facilities). Indicators from the Environmental Effects component were given half the weight of the indicators from the Exposures component. The calculated average pollution [burden] score (average of the indicators) was divided by 10 and rounded to one decimal place for a Pollution Burden score ranging from 0.1 -10."
Data Sources: All other sources. (CalEnviroScreen3.0, 103).

Asthma
Units/Methodology: Spatially modeled, age-adjusted rate of emergency department visits for asthma per 10,000, averaged over 2011-2013.

Data Sources: California Office of Statewide Health Planning and Development; California Environmental Health Tracking Program, California Department of Public Health. (CalEnviroScreen3.0, 106).

Low Birth Weight
Units/Methodology: Percent low birth weight, averaged over 2006-2012.
Data Source: California Department of Public Health. (CalEnviroScreen3.0, 116).

Cardiovascular Disease
Units/Methodology: Spatially modeled, age-adjusted rate of emergency department visits for acute myocardial infarction (heart attack) per 10,000, averaged over 2011-2013.
Data Sources: California Office of Statewide Health Planning and Development; California Environmental Health Tracking Program; Environmental Health Investigations Branch, California Department of Public Health. (CalEnviroScreen3.0, 111).

Source: Update to the California Communities Environmental Health Screening Tool (CalEnviroScreen 3.0).

Air Pollution in Los Angeles & Cumulative Health Risks of Heat & Wildfires

Another important background area is how air pollution functions in Los Angeles. Aside from the well-known information that LA has higher air pollution than most other areas in the country because of high local usage of automobiles, it is important to know how air pollution travels in LA and what the effects are of the cumulative threats of heat, wildfires, and pollution.

Air Pollution in Los Angeles

LA has long been well-known for its air pollution, and recent reports have shown that air quality in the city is still among the worst in the nation. According to the American Lung Health Association's 2019 State of the Air report, the LA metro area is first in the nation for ozone pollution, fourth nationally for year-round particle pollution, and sixth in the nation for short-term particle pollution (State of the Air 2019). This makes LA an important place to study air pollution's potentially differing burdens on elderly residents of public and private housing, because the health effects of air pollution in LA County may be more significant than in other areas.

Air pollutants in LA tend to concentrate around the city's freeway networks (Neuman et al. 2012), but because of the unique geography and conditions of LA, they also may be able to travel farther distances than in other cities. A study in Environmental Research used land use regression to determine distances that certain air pollutants travel in LA (Su et al. 2009). Specifically, it studied concentrations of Nitric Oxide (NO), Nitrogen Oxide (NOx), and Nitrogen Dioxide (NO2). The researchers selected 201 sampling sites across LA, using an algorithm to ensure maximum variability in pollutant concentrations and population

characteristics. They used three sources of data for roadway configuration and traffic volume data to estimate vehicle miles traveled (VMT). They used models to incorporate factors such as the slopes of truck routes and used satellite imagery to derive soil brightness and vegetation greenness in order to predict NOx concentrations. They also created a model called A Distance Decay Regression Selection Strategy (ADDRESS) to select the best buffer distances for their potential predictor models. According to the study, "Final regression models explained 81%, 86% and 85% of the variance in measured NO, NO2 and NOx concentrations, respectively. Cross-validation analyses suggested a prediction accuracy of 87–91%." The study found, unsurprisingly, that closer distance to truck routes resulted in higher concentrations of the pollutants. Industrial and commercial land use was also associated with higher concentrations. The study concluded that distances of influence for highways and major roads could be over 10 kilometers. While the traditional buffer distance used to approximate the radius of air pollution's impact is only 500 feet (this is the proximity deemed most dangerous) this shows that pollutants can have much larger areas of influence. A key finding was that the range of influence is greater in megacities like LA than smaller urban areas, likely because of existing concentrations of pollutants. The authors recommended that larger zones of influence be used in megacities like LA while studying the effects of air pollution.

Health Complications from Heat and Wildfires in Los Angeles

Rising temperatures from climate change can also exacerbate the effects of air pollution, especially for seniors (Simoni et al. 2015). LA County experienced a new record high temperature September 6, 2020 as the Woodland Hills neighborhood in the San Fernando Valley recorded a temperature of 121 degrees (Fuhrman and Pereira 2020).

A study on trends in heat waves across Southern California found that this heat wave was in line with general warming patterns in the area that have a high probability of increasing in duration, intensity, and frequency (Hulley, Dousset, and Kahn 2020). The study found that inland urban areas are currently, and will continue to be, the most affected. In urban regions, the study found that heat waves are starting earlier and ending later in the year. The study states that these changes exacerbate public health risks and are causing worsened wildfires due to more dried-out fire fuels.

Increasing frequency of heat waves will likely have the effect of worsening ozone concentrations. It could also increase danger for elder populations; high heat and air pollution can have synergistic effects, especially for the elderly, for whom high heat can increase risk of mortality from air pollution exposure (Simoni et al. 2015). High heat also increases risk of wildfires, which, in turn, increase PM2.5 concentrations (Liu et al. 2017). The Liu et al. study attempted to differentiate the effects of wildfire-caused particulate matter and particulate matter from other sources and found that wildfire-specific PM2.5 was associated with even stronger respiratory health conditions than particulate matter from other sources.

Conclusion to Background

As climate change continues to raise temperatures, it is possible that elders will have stronger reactions to air pollution. This represents a potential negative feedback loop: wildfire-specific particulate matter may couple with existing air pollution and heat-heightened ozone concentrations to create harmful synergistic reactions for elders. LA is a highly-important place to study how seniors are affected by air pollution because of both these heightened risk factors for health and the particularly concerning socioeconomic conditions for seniors in the area.

Literature Review

It is clear that there is a need for more affordable housing for the elderly, but there is very little research on the topic of potential air pollution exposure disparities between *public and private* elder housing. There is a study on the air pollution exposure of elder care facilities, in general, in LA, yet it does not compare public and private elder housing. In order to be best prepared to answer my research question, it is imperative to understand several sub-questions:

- What are the adverse health outcomes associated with exposure to air pollution for elders and people of color, who represent a disproportionate share of affordable elder housing residents?
- Where are elder care facilities, in general, located in Los Angeles and what are the characteristics of those facilities?
- Does existing research show that elder care facilities in general are at risk of air pollution?
- And finally, are there any other differences that have been observed between public and private elder care facilities, or at the very least, public and private housing in general?

This literature review will summarize the results of studies that attempt to answer these questions.

Effects of Pollutant Exposure on Seniors and People of Color

Effects of Exposure to Airborne Toxins in Elderly Populations

How are elders affected by air pollution, as opposed to other populations? A population-level study published in the *New England Journal of Medicine* observed the effects of ozone and particulate matter on all recipients of Medicare benefits over a period of 12 years, 2000 to 2012 (Di et al. 2017). To determine exposure to PM2.5 and ozone, the researchers used zip code-level estimates of exposure based on monitored levels from the EPA's Air Quality System. They also used a system of "satellite-based measurements, simulation outputs from a chemical transport model, land-use terms, meteorologic data, and other data" (Di et al. 2017, 2514). to predict exposure to the two pollutants in unmonitored areas. The study found significant evidence of negative health outcomes from exposure to the two pollutants in the entire Medicare population, even at concentrations below national EPA standards. Other important findings were that men, Black, Asian and Hispanic people, and recipients of Medicaid (lower-income people) had higher estimated risk of death in association with PM exposure, and that risk of death associated with ozone exposure was higher in white Medicaid recipients. Risk estimates associated with PM were three times higher for Black people than the rest of the population. The risk of death associated with PM was higher than ozone, and there was a small but significant interaction between the two types of exposure. The study of over 61 million older people (most Medicare recipients are over 65, but some are younger) ultimately found that Black

men and Medicaid recipients were the most at-risk groups following exposure to ozone and PM. These findings are significant for my study because low-income elders of color are a disproportionate portion of the population in public housing for the elderly.

A literature review-style study in the *Journal of Thoracic Disease* found that increased exposure of elderly people to outdoor pollution is associated with increased mortality and hospital and emergency room visits (Simoni et al. 2015). The study found that current researchers are inconclusive on which pollutants are the most harmful to the elderly, but that research has shown that older populations are more susceptible to particulate matter than other pollutants and that long-term ambient air pollution has harmful effects on lung health. The study concludes by calling for more research specifically on older populations and air pollution, but states that most studies find older populations are more at risk. Finally, the study notes that increased exposure to high heat can exacerbate elder mortality associated with exposure to air pollution, an important finding for my study based in Los Angeles County. The finding that seniors are particularly at risk from particulate matter is also a very important finding for this study and will help guide its methodology.

Cumulative Effects of Exposure to Air Pollution on People of Color

As research has demonstrated throughout the pandemic (Bui et al. 2020) (Karaca-Mandic, Georgiou, and Sen 2021) people of color are at higher risk for respiratory and cardiovascular diseases like COVID, and at higher risk of death from these diseases, because of a number of factors that accompany systemic racism. A study by the American Thoracic Society's Health Equality Subcommittee set out with the goal of defining health equality and how it could be attained in the U.S. (Celedón et al. 2014). To do so, the study reviewed literature on how the U.S. displays health inequality — how low-income people of color and particularly Black Americans suffer worse health outcomes than white Americans and higher-income people. The study found differences in life expectancy due to socioeconomic status and race, health disparities in most major respiratory diseases, and higher risk of lung cancer mortality in Black Americans. In other words, low-income people of color, and specifically low-income Black people, are categorically at higher risk for many chronic conditions, and especially respiratory ones, including asthma and COPD, which is explained by the authors as a result of socioeconomic and racial differences in pollution exposure, cigarette use, and occupancy in hazardous jobs.

These findings are key, because lower income people of color are already at higher risk of conditions that can then be exacerbated by further exposure to air pollutants. If inhabitants of subsidized housing face a higher air pollution burden than those of non-subsidized housing, then the disproportionately low-income and nonwhite seniors in subsidized elder care facilities are put at further risk, exacerbating health inequalities that already exist before old age.

Location and Characteristics of Elder Care Facilities in Los Angeles

It is important to review any literature that provides information on where senior housing is in Los Angeles. A study in *Local Environment* found that there are clusters of large facilities in a few very central areas close to Hollywood and Downtown LA and clusters of smaller facilities in the Panorama City/Sun Valley area of the San Fernando Valley (Frochen, Ailshire, and Rodnyansky 2019). The latter study also found that many of the facilities in the San Fernando Valley area had fewer than 6 beds. Overall this study finds that there is not enough supply for the need for residential care (approximated by the percentage of older women in each LA census tract).

A 2016 study in *Environmental Science Policy* set out to spatially examine the location of elder care facilities in Los Angeles and determine their exposure to vehicular air pollution, a project that is very similar to my own (Woodward and Levine 2016). However, this study only researched vehicular pollution from large roadways and highways and did not stratify facilities by subsidized and private status. The study researched the distance of 858 facilities from major roadways, defined as roadways with traffic volume of over 100,000 cars per day. Road points were only kept in the study if they were within 500 feet of a facility, which seems to be a limitation of this study — other studies have found that certain vehicular pollutants can travel farther than 500 feet. Of the 858 facilities, the researchers found that 54 were near a major roadway. The study recommends that, echoing the standards set for schools, new elder care facilities should not be placed within 500 feet of a major roadway. Thus, there is a gap in the literature in terms of researching how point pollution from toxin-emitting facilities affect elder care homes and in the particular burdens of private and public elder care facilities.

Observed Differences in Resident Health Between Public and Private Housing

There seems to be little relevant research comparing health in public and private *senior* housing. There is more literature available on observed health differences between public and private housing in general.

A study that compared blood lead levels of children in public and private housing in New York City between 2003 and 2017 offers some insight, but has many limitations (Chiofalo et al. 2019). The study found that 0.25% of children in public housing had blood lead levels above 5 micrograms per deciliter, compared with 2.76% of children in private housing. There are multiple limitations to using this as a reference for the work that I am doing. First, although lead can also be an airborne pollutant, the study acknowledges that the most common sources of lead exposure are paint, water and soil (and formerly gasoline, before the EPA banned the sale of leaded fuel in 1996). In other words, this study likely does not accurately reflect air quality differences in public versus private housing, but it does show a key health difference. Second, it is important to note that the researchers were from the New York City Housing Authority, creating possible bias. Nonetheless, this study does show that children in New York were less at risk of high lead levels in public housing than in private housing, which is a relevant finding for my work, and goes against my initial hypothesis that, generally, environmental health would be

better in private facilities than public ones. One possible explanation in the study is that "the Residential Lead-Based Paint Hazard Reduction Act of 1992 (Title X) took a proactive and preventive approach against lead poisoning in public housing by mandating completion of risk assessments by 2002 for all public housing units built before 1978." Meanwhile, it was not until 2016, that "the HPD [New York City Department of Housing Preservation and Development] inspected nearly 26,000 privately owned buildings, issued approximately 12,000 lead violations, and corrected 826 violations..." (Chiofalo et al. 2019, 907). This delayed enforcement may be responsible for the differences in lead levels.

Another study in New York observed the differences between systems that public and private tenants must use to receive inspection and remediation of housing issues (La Mort 2019). They found that the public housing system in New York made it much more difficult for tenants to get problems fixed, leading to worse conditions and worse health outcomes in public housing. This is in line with my hypothesis.

A study of asthma incidence in New York public and private housing found that children in public housing had the highest incidence of asthma, at 21.8%, and that residents of all types of private housing had lower rates of asthma (Northridge et al. 2010). The highest incidence rate in private housing was walk-up apartments, with 13.1%. This association remained after adjusting for community-level demographic and economic factors. The study found a high correlation between cockroaches, rats, and water leaks and higher asthma, showing that, again, ambient air quality might not be the primary factor causing the difference here. However, the significant difference in asthma rates, consistent with my hypothesis, is useful for my study.

The Hope VI Panel Study surveyed the health of residents from five public housing developments in 2001, 2003, and 2005 and found "a picture of a population in shockingly poor health, a situation that seems to be worsening rapidly over time as residents grow older" (Manjarrez, Popkin, and Guernsey 2007). They found that, overall, public housing residents were in extremely poor health and suffered from high rates of chronic illness and much higher rates of death than national averages. The study's findings are in line with other research and my hypothesis, which is that health in public housing is worse. However, it does not discuss whether these findings are due to air quality.

Hypothesis:

The hypothesis of this researcher, following a review of literature examining differences between public and private housing, is that public elder care facilities will have a higher exposure to air pollution than private facilities. This is based on the assumption that costs must be cut to provide housing below market rate and that locating facilities in undesirable locations (based on proximity to freeways or polluting facilities) is one way to cut costs.

Methods:

In order to compare the air pollution exposure of elderly residents in private and public housing, this study was first tasked with sourcing spatial data for public and private elder housing/residential care facilities, before analyzing these two stratified datasets using aggregated pollution data from CalEnviroScreen3.0.

Collecting Public and Private Elder Housing and CalEnviroScreen Datasets:

This study collected locational facility data for both private and public elder housing in LA County. Locational data for subsidized housing facilities in the state of California were collected from the National Housing Preservation Database Research Tool (NHPD 2020), which included all types of project-based facilities for the elderly. This dataset included variables for program type, latitude and longitude, and a "target tenant" variable. After restricting the NHPD dataset to facilities whose target tenant was "elderly" or "elderly and disabled" the dataset was ready for use as the list of public elder housing.

Private facility data were collected from the California Department of Social Services' data portal, in a dataset that included residential care facilities for the elderly, as well as addresses for each facility, which were geocoded into coordinates using an online geocoding service called BatchGeo, which uses Google Earth's geocoding system. Before geo-coding, to ensure mutual exclusivity, the two datasets were cross-listed using Microsoft Excel's VLOOKUP function. After a number of combinations of addresses were tested, the datasets were found to be mutually exclusive, creating the possibility of doing geospatial analysis in ArcGIS with stratified public and private facilities for the elderly.

The CalEnviroScreen 3.0 Results Shapefile data was downloaded from the California Office of Environmental Health Hazard Assessment website.

Analysis of Data

The points of the public and geocoded private facilities were imported into ArcMap and given contrasting colors. They were overlaid on top of the CalEnviroScreen shapefile, which divides California into its census tracts. The CalEnviroScreen census tracts were intersected with a shapefile boundary of LA County to reduce the scope of the CalEnviroScreen data to the census tracts in the county. With the facilities overlaid on a shapefile of LA county, visual and empirical analyses were conducted.

A kernel density analysis was conducted for both public and private facilities to visualize the spatial distribution of both types of facilities and determine if there were any significant clustering patterns of public or private facilities.

Choropleth maps were made for the key CalEnviroScreen pollution-related variables, categorizing the data for each variable into 10 classes of Jenks Natural Breaks, so that the highest and lowest values for each variable (i.e. PM concentration or number of hazardous waste sites in the census tract) could be visualized in scales of red (high pollution exposure) to green (low pollution exposure). The public and private facility points were individually placed over these

choropleth maps to create a visual sense of where facilities were in relation to the highest and lowest pollution exposure at the census tract level.

To continue with a statistical analysis of means, the public and private facilities were then attached to the CalEnviroScreen data using a spatial join. This allowed for each facility to not only be attached to its respective census tract but also to be attached to all the key pollution variables that CalEnviroScreen calculated for that census tract. Each facility now had a value for each relevant CalEnviroScreen pollution variable — an approximation based on the aggregated value for the census tract in which the facility was located. This spatial join allowed for a comparison of mean levels of pollution indicators and pollutant concentrations between the public and private facilities.

Next, t-tests were run in Microsoft Excel for each of the pollutant-related variables to determine if potential differences in the means between the public and private facilities were statistically significant.

Possible Limitations of Study Design & Accompanying Literature Review

Before detailing findings, it is important to recognize that the theoretical design and methods of this study present some limitations, which should be considered when interpreting its eventual findings. First, the study population, elders in project-based housing, are a group of people who likely spend less time outdoors than the average person. Second, aggregated pollution data is the primary method of determining pollution exposure, which has limitations.

Likelihood of Seniors in Facilities to be Affected by Outdoor Air Pollution

Access to the Outdoors for Elders in Homes

There is an important limitation for this study, which is that it studies outdoor air pollution's effects on a population that spends a large amount of time indoors. Although polluted air can travel inside when windows are open, it is important to know how much time seniors spend outside. A study in the *Journal of Housing for the Elderly* gathered information about 1,988 residents in 131 nursing units in 40 randomly-selected nursing homes in 5 states (California, Florida, New Jersey, Minnesota, and New York) and their habits of participating in outside activities. 55.7% of the units did not have amenities for seniors to go outside. Further, the study found that of the residents who were able to go outdoors, 32% did so less than once a month, and only 22% did so daily. This does raise important questions about the validity of my study. Still, the combined exposure that can happen if residents leave their windows open and the reduced, yet still significant, amount of time that residents spend outdoors shows that this is still an important topic to research. Furthermore, nursing homes and supportive residential care are the most limited-mobility types of elder housing — a good deal of the buildings that will be examined in this study allow seniors to live independently and, outside of the current social distancing necessitated by the pandemic, go outside according to their will.

How Does Outdoor Air Quality Affect Indoor Air Quality?

As many of the subjects of interest in this study spend a significant amount of time indoors, it is important to know whether outdoor air pollution can affect indoor air pollution. A study published in the *International Journal of Environmental Research and Public Health* sampled concentrations of PM2.5, black carbon, carbon monoxide, and nitrogen dioxide in low-income homes in Denver, Colorado during wildfire season (Shrestha et al. 2019). As one would expect, pollutant concentration was higher outdoors than indoors for all pollutants except for carbon monoxide. However, the study found that wildfires elevated indoor pollutant levels more than they elevated outdoor pollutant levels — "long-range wildfire plumes elevated median indoor PM2.5 concentrations by up to 4.6 times higher than outdoors" (Shrestha et al. 2019, 1). The study also observed that in homes closer to roadways, black carbon, carbon monoxide, and nitrogen dioxide levels were higher, and that some homes with mechanical ventilation systems had higher pollutant levels. It also found that "homes with windows open for more than 12 hours a day during sampling had indoor BC 2.4 times higher than homes with windows closed" (Shrestha et al. 2019, 1). The Shrestha et al. study shows that this paper on how outdoor air quality affects elders who live inside is still relevant, with the reasonable assumption that the most mobility-restricted elders have their windows open at least some of the time to air out their rooms.

A review article in *Frontiers in Environmental Science* noted a number of studies that found that outdoor air quality and pollution affected indoor air quality (Leung 2015). A study in Birmingham, England studied the chemical composition of indoor air pollution and found that the particulate matter found inside buildings had originally come from the outdoors (Jones, et al. 2000). Other studies reviewed by Leung (2015) found that diesel exhaust, a large contributor of particulate matter, can travel inside through mechanical ventilation, and that ambient air was important in determining indoor air pollution in urban areas in Korea. In conclusion, while seniors may not go outside, they still may be vulnerable to pollution, meaning that this limitation may be less important than on first inspection.

Limitations of Census Tract Analysis

Another important limitation is found in the methods of this study — the fact that aggregated pollution data is the primary method of analysis may be a large limitation in the validity of this study. A study in the *International Journal of Health Geographics* argues that census level aggregated data is insufficient as a method of spatial analysis (Zandbergen and Chakraborty 2006). The study argues that measuring discrete distances is a better method. Because of limited resources in this study, aggregated pollution data was determined to be sufficient. However, further research on this topic should be conducted using more rigorous methods of point pollution analysis.

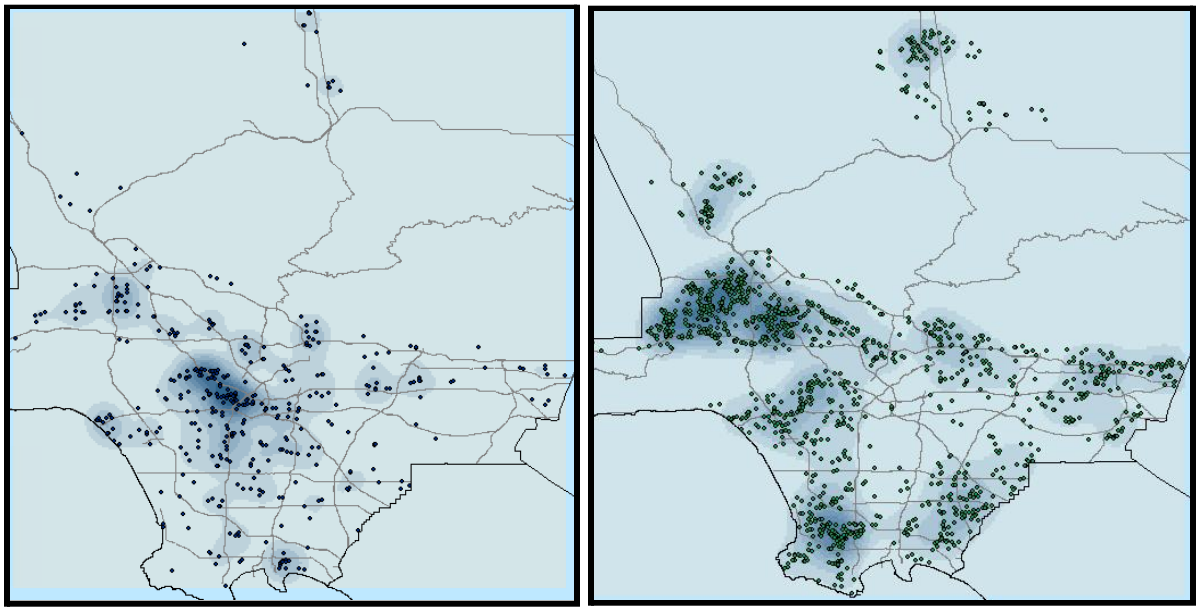
Findings

At the outset of exploring this study's findings, it was useful to determine, at a basic level, where the public and private facilities for the elderly in Los Angeles County were spatially located.

Kernel Density Cluster Analysis

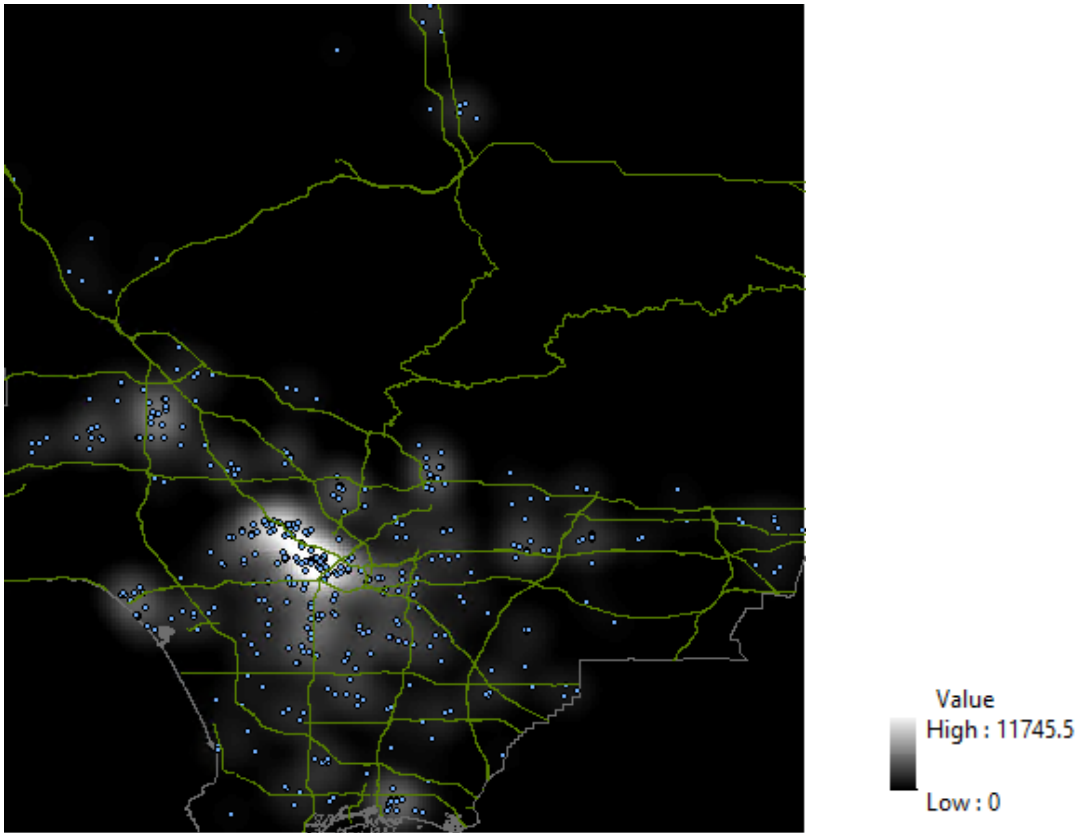
In particular, it was important to understand if both types of facilities are generally randomly distributed or if public and/or private facilities are clustered together in certain areas of the county. To determine if there was clustering, ArcMap's kernel density tool was used to analyze the public and private facilities. Light and dark kernel density maps are provided, with the most clustered areas shown in dark blue in the lighter map, and the most clustered areas shown in bright white in the dark map.

Figure 1A: Clustering (Kernel Density) of Public and Private Facilities for the Elderly

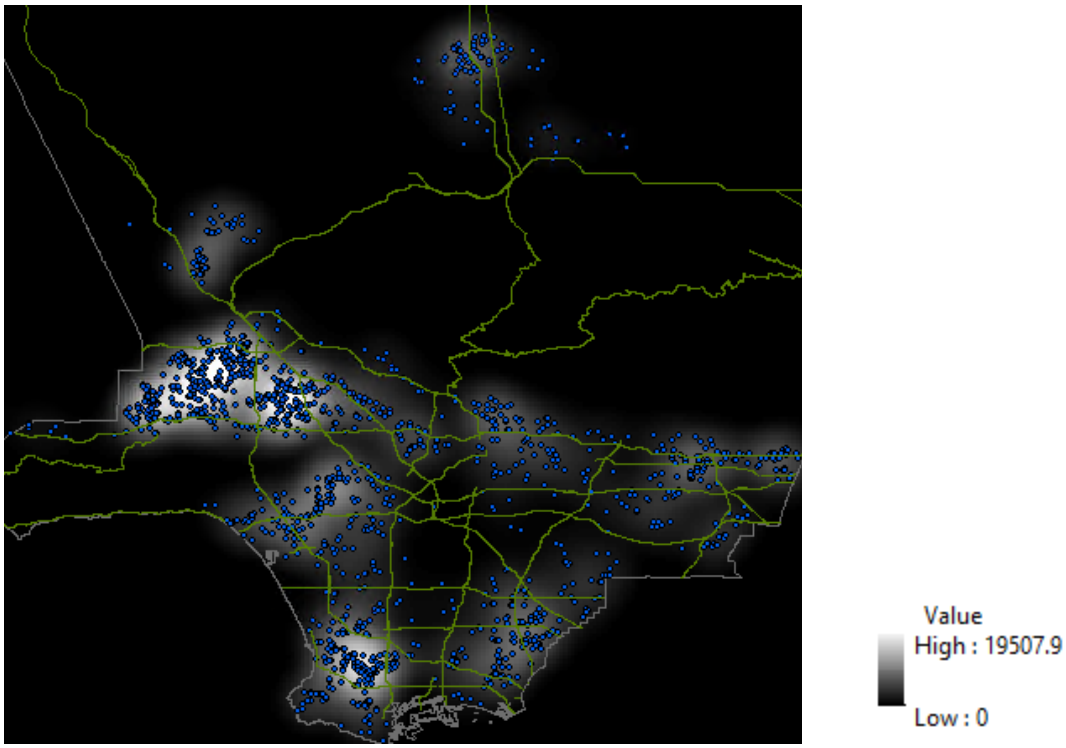


Public Housing Facilities for the Elderly (Source: NHPD) | **Private Residential Care Facilities** (Source: CDSS)

Figure 1B: Kernel Density of LA County's Public and Private Elder Care Facilities (Dark)



Kernel Density of Public Facilities (Source: NHPD)

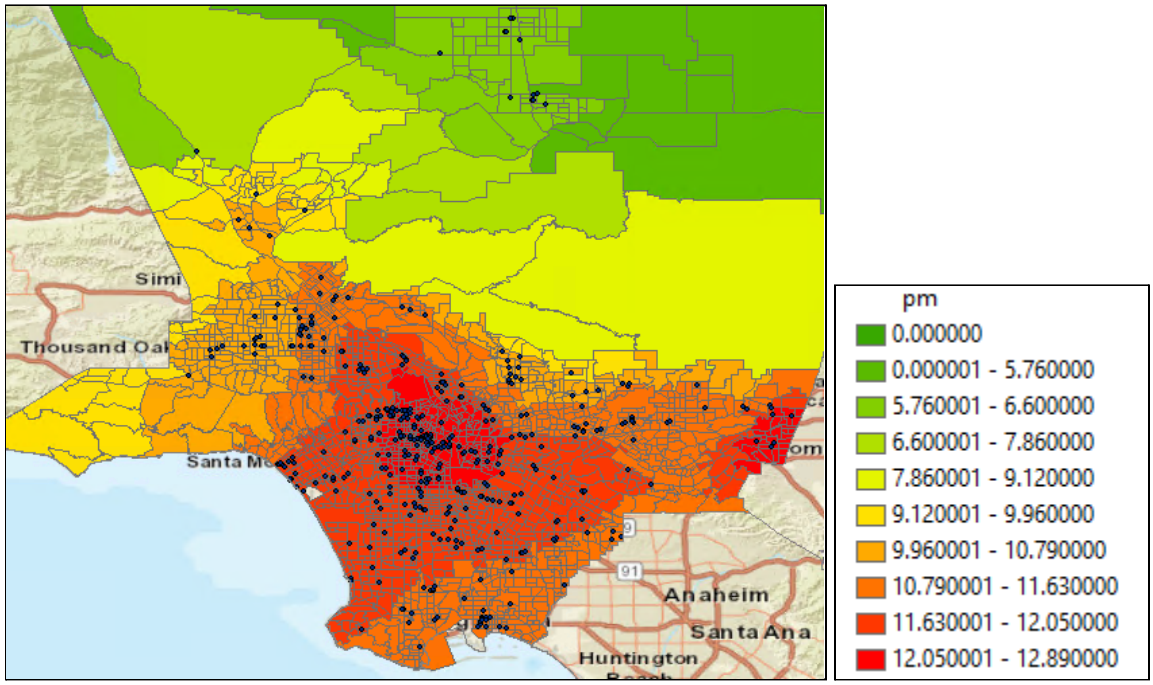


Kernel Density of Private Facilities (Source: CDSS)

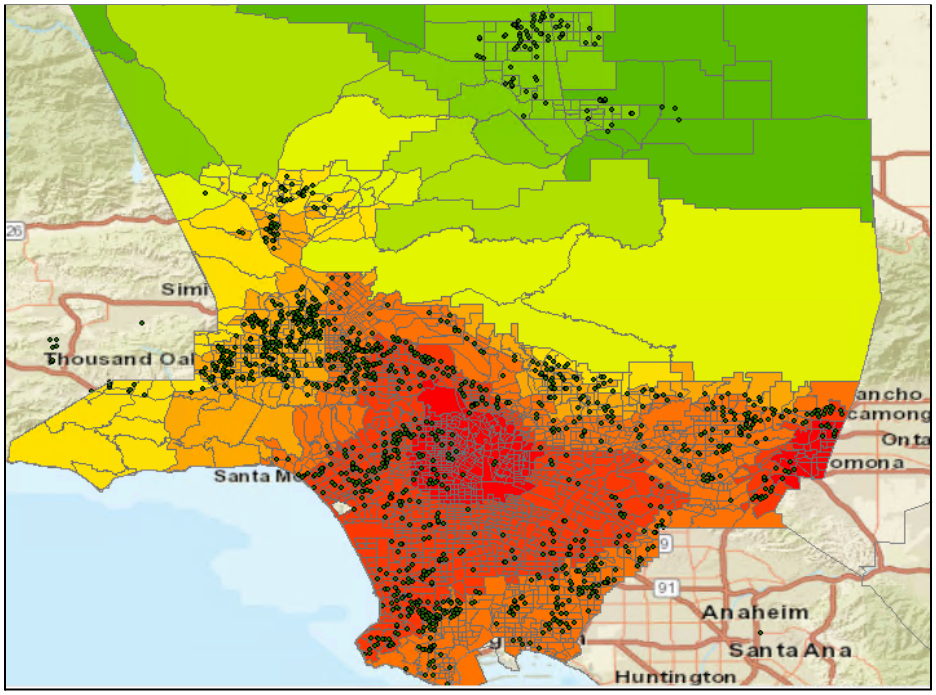
Visualizing Public & Private Facilities in Comparison to Distribution of Pollutants

A key next step was exploring, visually at first, the relationship between the location of public and private facilities and the distribution of various pollutants throughout the county. In the following maps, pollutant concentration was visualized by dividing CalEnviroScreen data into 10 ordinal classes, using the Jenks Natural Breaks classification, with highest concentrations in red.

Fig. 2A: Particulate Matter (Census Tract Level) & Facilities

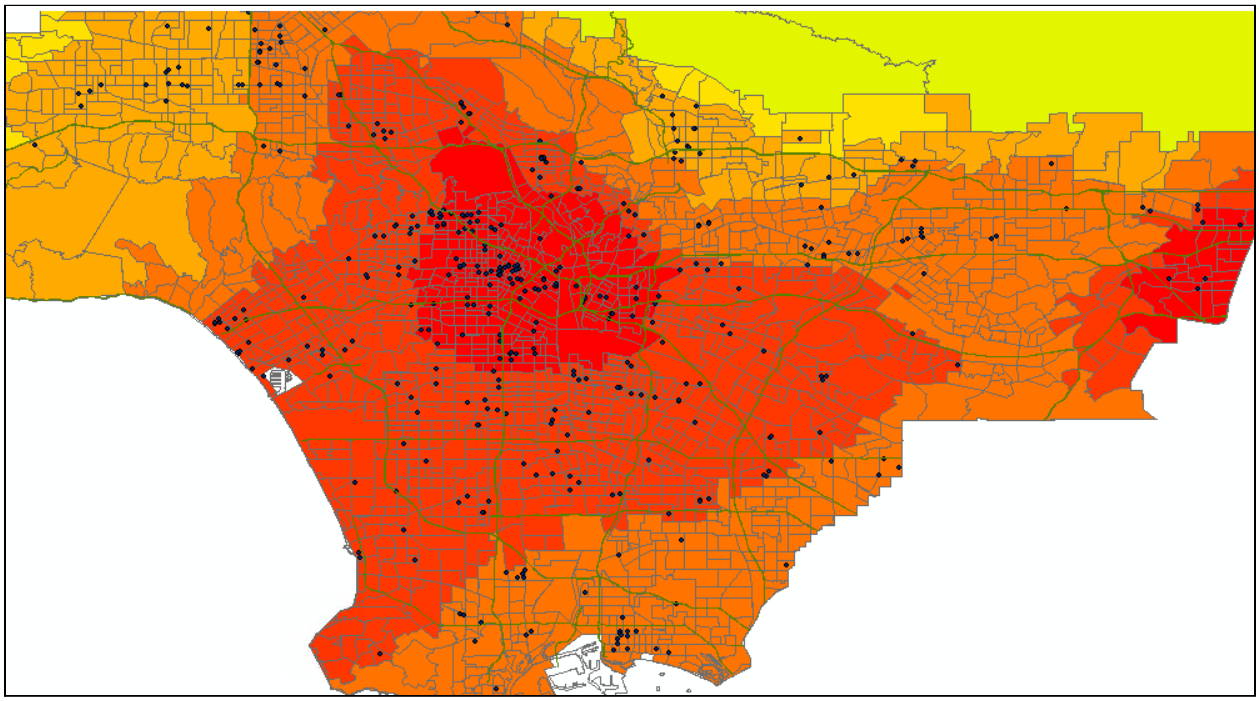


Above: Public Facilities (Sources: NHPD, CalEnviroScreen 3.0) PM in µg/m3

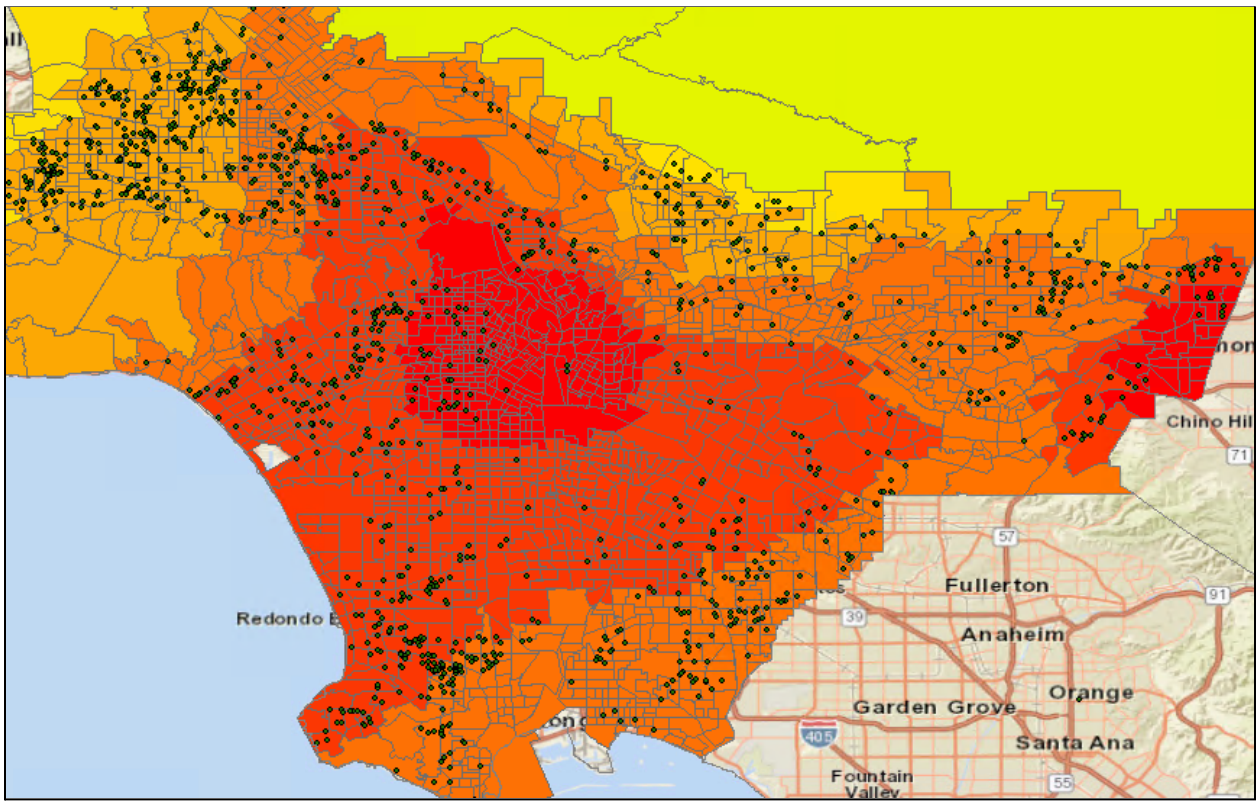


Above: Private Facilities (Sources: CDSS, CalEnviroScreen 3.0)

Fig. 2B: Particulate Matter & Facilities — Closeups of Greater Los Angeles Area

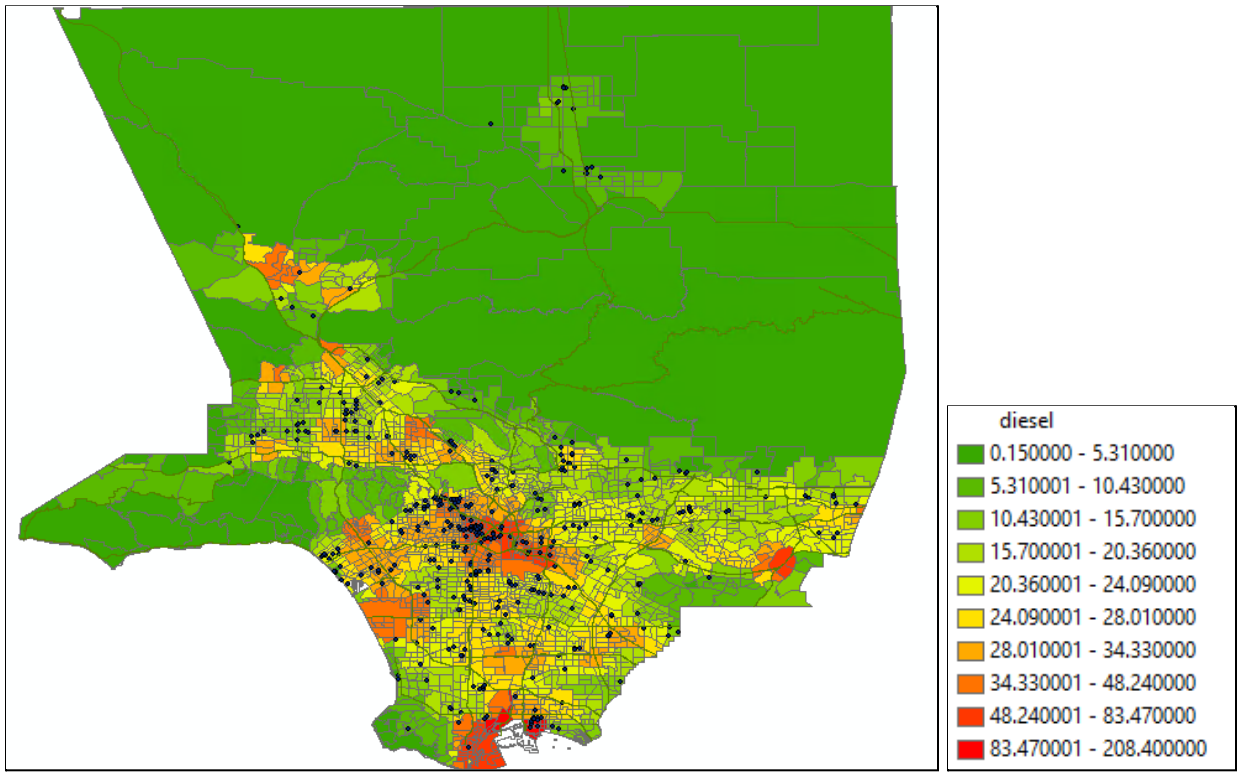


Above: Public Facilities (Sources: NHPD, CalEnviroScreen 3.0)

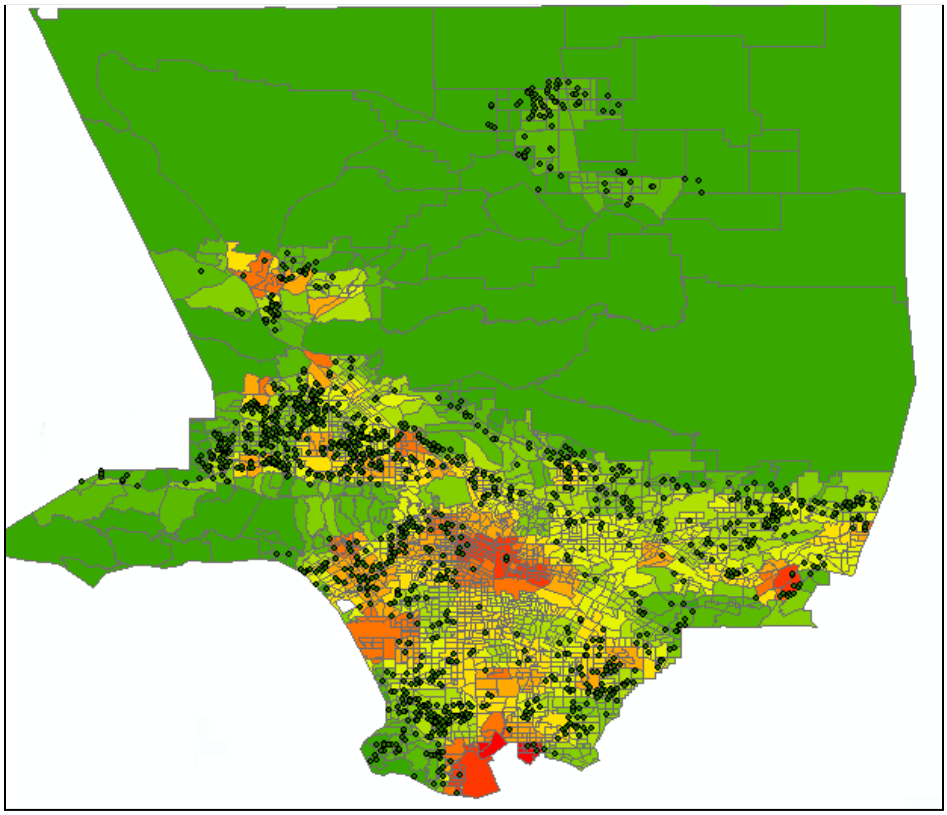


Above: Private Facilities (Sources: CDSS, CalEnviroScreen 3.0)

Fig. 3A: Facilities & Diesel PM Pollution

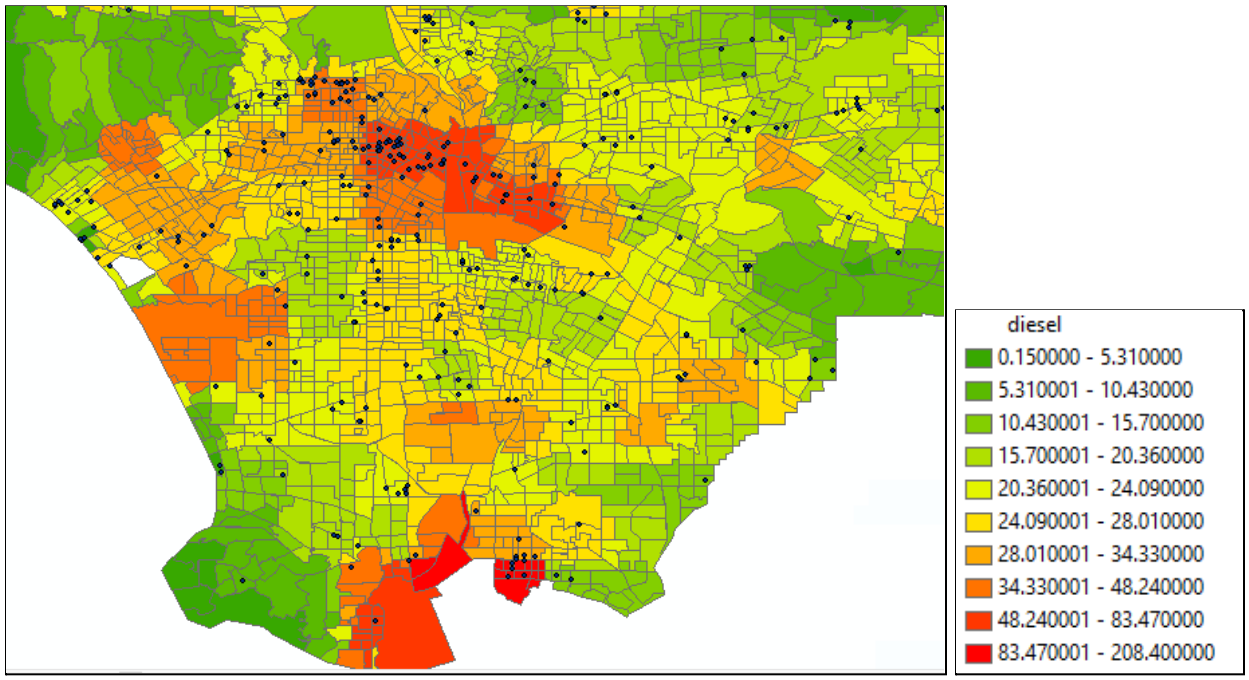


Above: Public Facilities (Sources: NHPD, CalEnviroScreen 3.0)

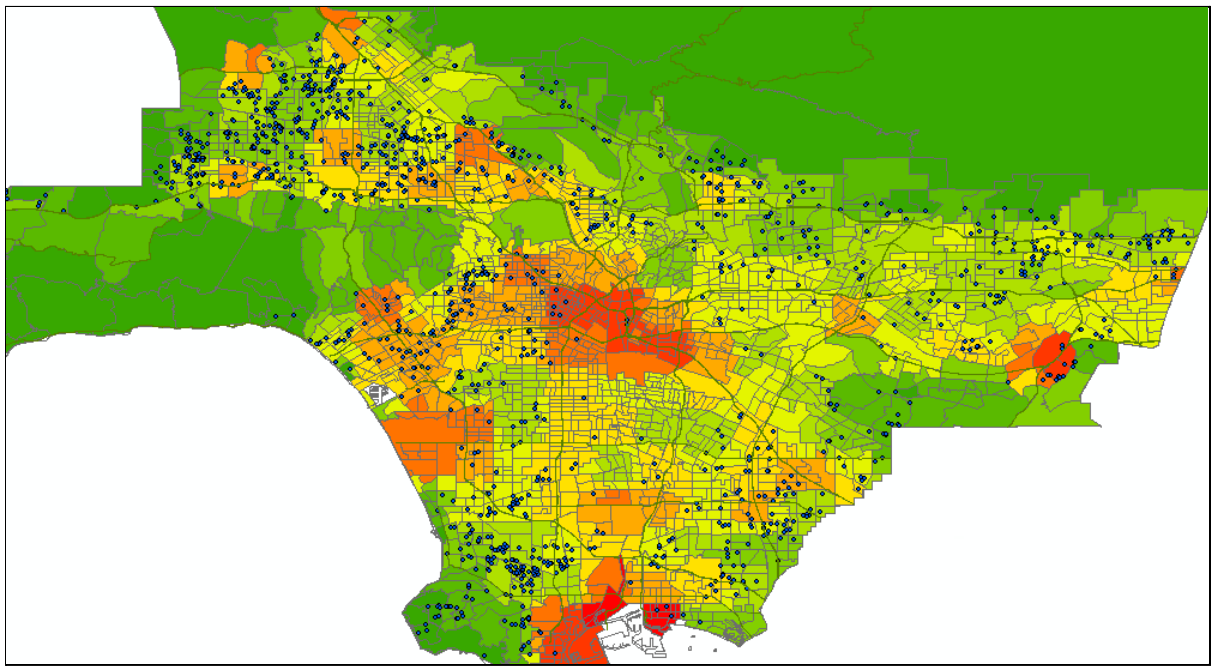


Above: Private Facilities (Sources: CDSS, CalEnviroScreen 3.0)

Fig. 3B: Diesel PM & Facilities — Closeups of Greater Los Angeles Area

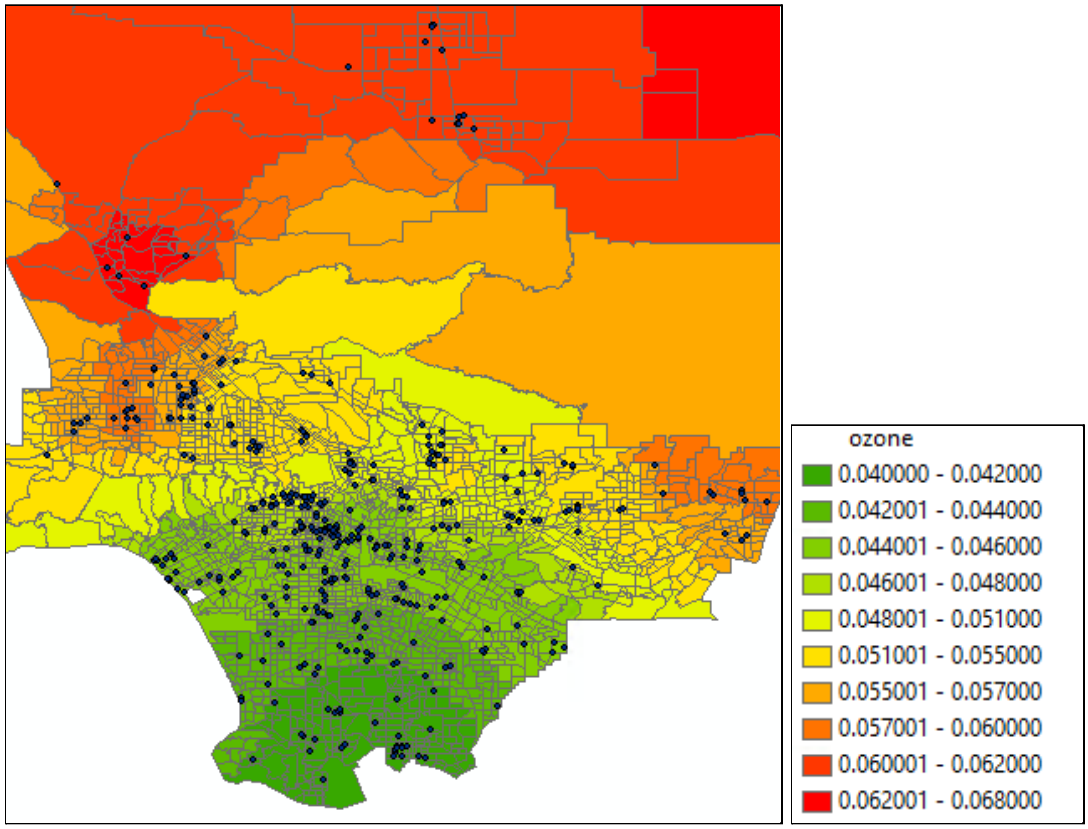


Above: Public Facilities (Sources: NHPD, CalEnviroScreen 3.0)

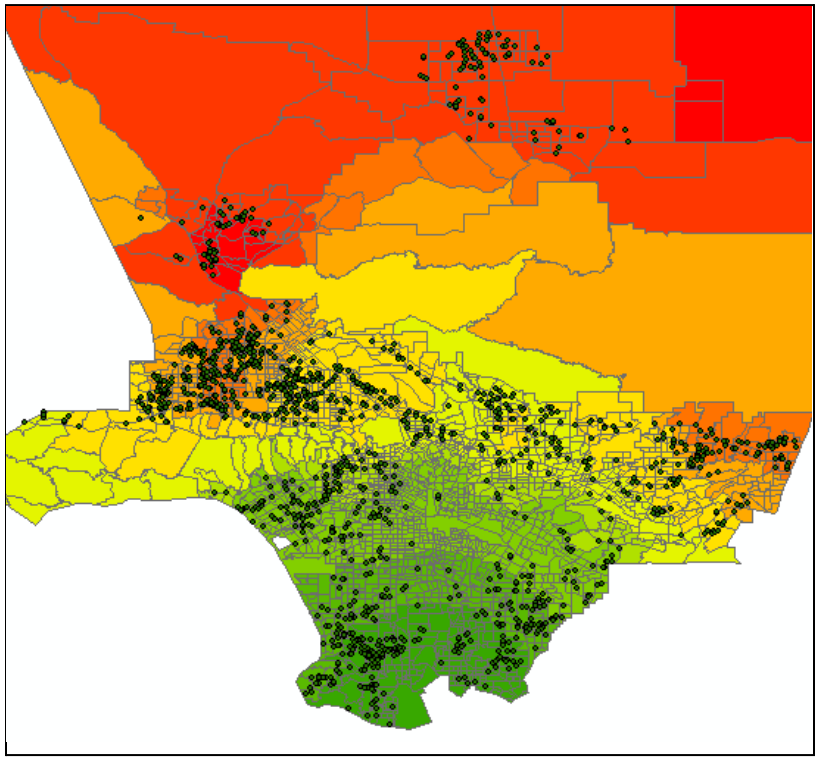


Above: Private Facilities (Sources: CDSS, CalEnviroScreen 3.0)

Fig. 4: Facilities & Ozone at Census Tract Level - Jenks Natural Breaks, 10 Intervals



Above: Public Facilities (Sources: NHPD, CalEnviroScreen 3.0)



Above: Private Facilities (Sources: CDSS, CalEnviroScreen 3.0)

Revisiting the Research Question

The research objective of this study was to determine whether or not there is a statistically significant difference in pollution exposure between public and private senior housing. To fully answer this question, it was necessary to use statistical tools to observe 1) if differences between the two groups exist in the first place and 2) whether that difference is big enough that we can statistically prove that the difference is not simply due to random chance.

At the outset of the process of analyzing findings, there were still two groupings of NHPD-sourced facilities that could be used as the sample of public senior housing facilities: a grouping of facilities whose target tenant was listed only as elderly, and another grouping that also included 177 facilities whose target tenant was listed as "elderly and disabled." To answer the research question, it was first necessary to see if there was any statistically significant difference between the "elderly only" sample and the sample that included both "elderly" and "elderly and disabled" facilities.

Are "Elderly" and "Elderly and Disabled" Statistically Identical?

To determine if these two samples of elderly facilities were statistically significantly different, means for three CalEnviroScreen variables were tested — pollution percentile, particulate matter percentile and ozone percentile. The means were first tested for equal variances through Excel's F-Test for Two Sample Variances tool, and all three variables were found to have equal variances between the two groupings. A Two Sample T-Test was then conducted for each of the variables. For each variable, the p-values were well higher than the significance level of .05, meaning that the means between the two groupings were not statistically significant.

Table A: Equal Variances T-Test for Pollution Score Percentile

	Mean	Variance	T-Stat (Both)	Degrees of Freedom	Two-Tailed P-Value
Elderly Only	72.59	450.33	-0.04	651	0.97
Elderly and Disabled	72.53	450.2	Reject Null Hypothesis Based on High P-Value: **Y**		

The results of an Excel Equal Variances T-Test showing that the Pollution Score variable was not statistically significantly different between the "elderly only" grouping and the grouping that also contained "elderly and disabled"-targeted facilities.

Because the grouping that included facilities targeted towards "elderly and disabled" tenants was not statistically significantly different from the "elderly only" grouping, ***the larger "elderly and disabled" grouping was used as the public facility sample for all further t-tests comparing public and private facilities***. The larger sample size in this grouping enables stronger conclusions when compared to the private facilities.

What Variables Were Tested

The variables whose means are listed in the following tables were selected out of all CalEnviroScreen variables as they are the variables most pertinent to air pollution. Please see the "CalEnviroScreen 3.0" section of Background for definitions of each variable.

CalEnviroScreen Means Comparison: Pollutant Concentrations

Some of the CalEnviroScreen variables measure the prevalence of certain types of pollutants in a given census tract.

These variables include Ozone (in parts per million, the mean of the daily maximum 8-hour ozone concentration in May–October), PM (Annual mean Particulate Matter 2.5 concentrations, in micrograms per cubic meter of air — µg/m3) and Diesel (spatial distribution of gridded concentrations of Diesel PM emissions, in kilograms per day, from on-road and non-road sources). Ozone and PM were measured over three years, from 2012 to 2014, while diesel particulate matter was estimated using models for a July weekday in 2012.

Mean diesel, ozone, and PM exposure for public and private facilities were calculated by averaging the concentrations of each pollutant across all census tracts of each type of facility. When multiple (N) public and private facilities were in the same census tract, the concentration for that tract registers N many times in the mean calculation. In the table below (Figure A), the mean concentrations for all public and all private facilities in LA County are shown, along with the mean concentration of each pollutant across all census tracts in LA County.

Figure A: Pollutant Concentration Means At Census Tract Level

Facility Type	N	Ozone (ppm)	PM2.5 (µg/m3)	Diesel PM (kg/day)
Public	415	0.049	**11.72**	**29.32**
Private	1581	**0.052**	10.98	19.51
LA County Mean	N/A	0.049	11.51	24.37

Cells shown in red indicate a public/private mean that is statistically significantly higher than its public/private counterpart (LA County Means were not included in t-tests for statistical significance). For example, the mean PM concentration of 11.72 µg/m3 in the census tracts of private facilities is statistically significantly higher than the mean PM concentration of 10.98 µg/m3 in the census tracts of private facilities. (Sources: CalEnviroScreen 3.0, NHPD, CDSS).

CalEnviroScreen Means Comparison: Aggregated Data/Toxic Sites

Another set of CalEnviroScreen pollution-related variables uses aggregated toxic release data and/or summarizes the burden of toxic sites, toxic cleanups, and traffic pollution. For full descriptions of how each CalEnviroScreen variable is measured, see the "CalEnviroScreen 3.0" section in Background. Statistically significantly higher means are shown in red.

Figure B: Aggregated Pollution Data Means At Census Tract Level

Facility Type	N	RSEI Haz (Toxic Emissions Score)	Traffic Density (km/hr/Rd.L)	Pollution Score
Public	415	5007.25	1330.27	51.85
Private	1581	3929.78	1249.78	47.17
LA County Mean	N/A	5060.69	1288.6	50.28

Cells shown in red indicate a public/private mean that is statistically significantly higher than its public/private counterpart (LA County Means were not included in t-tests for statistical significance). (Sources: CalEnviroScreen 3.0, NHPD, CDSS).

Figure C: Mean Number of Toxic Sites at Census Tract Level

Facility Type	N	Cleanups (Sum)	Haz Waste (Sum)	Solid Waste (Sum)
Public	415	9.55	0.57	2.26
Private	1581	5.99	0.41	1.63
LA County Mean	N/A	9.73	0.64	2.32

Cells shown in red indicate a public/private mean that is statistically significantly higher than its public/private counterpart (LA County Means were not included in t-tests for statistical significance). (Sources: CalEnviroScreen 3.0, NHPD, CDSS).

CalEnviroScreen Means Comparison: Health Indicators of Air Pollution

The final grouping of relevant CalEnviroScreen variables measures shows, for each census tract, three air pollution-associated risk factors/pollution exposure health outcomes — asthma, low birth weight, and cardiovascular disease. Asthma is calculated by age-adjusted emergency room visits for asthma per 10,000 people, cardiovascular disease is measured by age-adjusted emergency room visits for acute myocardial infarction (heart attack), and low birth weight is calculated by the percentage of low birth weight infants between 2006 and 2012. In the table below, public and private facility means are compared, and statistically significantly higher means are shown in red.

Figure D: Air Pollution-Related Risk Factors at Census Tract Level

Facility Type	N	Asthma (ER Visits per 10k)	Low Birth Weight (%)	CVD (ER Visits Per 10k)
Public	415	56.9	5.55	8.4
Private	1581	46.22	5.11	8.1
LA County Mean	N/A	51.6	5.2	8.29

CVD (Cardiovascular Disease) = ER visits for heart attack per 10k population. Cells shown in red indicate a public/private mean that is statistically significantly higher than its public/private counterpart (the LA County Means were not included in t-tests for statistical significance). (Sources: CalEnviroScreen 3.0, NHPD, CDSS).

A full inventory of f-tests for variance and t-tests for statistical significance can be found in Index A.

Discussion

Overview

The data and maps showed that there were clear differences between public and private elder care facilities in LA County, both in terms of general location and in terms of exposure to pollution based on that location. Further, t-tests comparing the means of pollution-related CalEnviroScreen variables showed that, on average, public elder care facilities are in census tracts that bear a statistically significantly higher air pollution burden than the census tracts of private facilities. For almost all pollutants and pollution indicators measured by CalEnviroScreen, public facilities are more likely to be at risk of high pollution than private facilities. A notable exception is ozone — the average private residential care facility has a statistically significantly higher exposure to ozone at the census tract level than the average public facility. Particularly large gaps between the two facility types (in the direction of higher exposure at public facilities) were observed in exposure to diesel particulate matter, hazardous waste facilities, solid waste sites and areas where presence of toxins has necessitated cleanups.

Clustering of Facilities

When observing the kernel density maps in Fig. 1, there were clear patterns in terms of where public and private facilities are clustered in LA County. Clusters of the two types of facilities mostly are isolated from each other.

Clusters of Public Facilities

Public facilities are slightly less clustered than private facilities, which may be due to their smaller sample size. The kernel density map of public facilities for the elderly showed that the highest concentration of subsidized facilities for the elderly is along the 101 Freeway, especially across Hollywood and farther Southeast along the freeway, near its confluence with Interstate 10. There are also smaller clusters throughout the county, including in areas near Santa Monica, Van Nuys/Panorama City, Long Beach, and Altadena. Nonetheless, the largest number of public facilities is in Central LA, along the 101, and in South LA, on both sides of the 110.

Clusters of Private Facilities

Private facilities showed a stronger clustering effect than public facilities. The two largest clusters are both in the San Fernando Valley, in one very large cluster (which is actually a combination of several smaller clusters) west of the 405 Freeway, and another large cluster east of the same freeway. The next largest cluster is in the Torrance/Carson area. In some areas where there are very few public facilities, private facilities are present in droves. For example, while there are few public facilities in the Pico-Robertson/La Cienega Heights area, there are a great number of private ones. Similarly, there are few public facilities in Burbank along the north side of Interstate-5, while there is a string of private facilities in the same area.

Clustering Conclusions

Because there are so many more private facilities than public ones, it was difficult to distinguish exactly how the patterns of the types of facilities interplay. However, some broad trends were apparent, including that public facilities are highly-clustered in Hollywood and Central and Downtown LA, and that private facilities are highly-clustered in the San Fernando Valley and in the southeastern corner of the county.

Visual Analysis of Spatial Relationship Between Pollutants & Facilities

In the study area of Los Angeles County, pollutant concentrations and other indicators of pollution were divided into 10 classes using the Jenks Natural Breaks classification system. By using a red to green color gradient, with red symbolizing the highest burden of pollution, it was possible to visualize the areas with the highest and lowest exposure. By using maps that indicate pollution burden of various types as base maps and overlaying the locations of private and public facilities in separate maps, it was possible to create a side-by-side comparison. This allowed for a visual showcase of how each relevant pollutant or pollution indicator interacts spatially with public and private facilities.

Particulate Matter 2.5

Figure 2A in the Findings section shows particulate matter across LA County, with the first map showing overlaid public facilities and the second showing overlaid private facilities. In these maps, there is a clear distinction between the Los Angeles Basin, below the San Gabriel mountain range — which has high concentrations of particulate matter 2.5 — and the Northern parts of Los Angeles County, which have much lower concentrations. A closer inspection of these maps (Fig. 2B) shows that, while PM is high across the basin, there are only two areas where its concentration is above 12 μg/m3 — a large area that covers a wide swath of Central LA, Hollywood and South LA, and an area in the easternmost portion of the county, near Pomona. The Central LA area where PM is highest followed a similar spatial pattern to the clustering of public facilities.

Diesel Particulate Matter

Whereas the map of general particulate matter shows that the whole LA basin has a high burden, the map of diesel particulate matter emissions (Fig. 3) shows smaller pockets of highly-polluted areas. The general areas with the highest diesel concentrations are Long Beach and San Pedro and Hollywood and Downtown LA. Aside from the aforementioned small cluster of public facilities in Long Beach, there is a general dearth of facilities in the Long Beach and San Pedro areas. However, in the Hollywood area, one of the biggest clusters of public facilities lines up with one of the areas where diesel pollution is at its highest.

Ozone

Ozone concentrations across LA County (Fig. 4) follow an almost-inverse relationship with particulate matter concentrations, and that of most other pollutants. While most pollutants concentrate in the LA Basin, as opposed to the northern regions of the county, ozone is at its highest concentrations across the Northern parts of the county. Following northern LA County, the second highest concentrations of ozone can be found in the San Fernando Valley and on the eastern border of the county, near Pomona. Private facilities are more spread out across the county, including in its north, east, and in a large cluster in the San Fernando Valley. This indicates that private facilities face a higher burden of ozone exposure than public facilities.

Asthma and Facilities

A final set of maps in Index B shows the areas of the county where asthma emergency room visits are highest, in comparison with public and private elder care facilities. The areas with the highest asthma burden were in South Central, South LA, East LA (South of Downtown), and in Compton and Lakewood. Overall, these areas have fewer elder care facilities than other parts of the county. However, the proportion of public facilities located in this area is higher than the proportion of private facilities in the same area.

Means and Statistical Differences

Visual maps comparing facilities for the elderly and pollution concentrations are useful in gaining a basic understanding of how the independent and dependent variables are spatially distributed, but they are unable to statistically prove whether exposure to pollution differs between public and private senior facilities. To statistically answer the research question, this study tied the census tract-level CalEnviroScreen pollution exposure data to the census tracts of each public and private facility. Each facility, based on its census tract, was joined to the CalEnviroScreen data so that pollution exposure for each facility could be approximated.

Means for pollution-related variables were then calculated for the groups of public and private facilities, in order to set up a statistical comparison using two-variable t-tests.

Relevant variables to analyze were chosen based on their relation to air pollution. These variables can be divided into three categories: pollutant concentrations, aggregated pollution data & summed toxic sites, and health indicators of air pollution.

Pollutant Concentrations

On average, ozone was found to be at statistically significantly higher concentrations in the census tracts of the private facilities, while particulate matter 2.5 and diesel particulate matter were found to be statistically significantly higher concentrations in the tracts of public facilities.

The average ozone concentration in the tracts of private facilities was approximately .0524 parts per million (ppm), while the concentration in the tracts of public facilities was .0493 ppm. Both of these concentrations are at very high levels, considering that the Occupational Safety and Health Administration's Permissible Exposure Limit for ozone is .01 ppm, and the

U.S. EPA regulation is set at .07 ppm. This high average level of exposure in the census tracts where senior facilities are located raises the question of whether more measures should be taken to mitigate exposure to outdoor air pollution in these facilities. Ozone exposure is especially dangerous to people over the age of 65, so action should be taken to protect the health of Southern California seniors.

The average particulate matter concentration in the census tracts of private facilities was 10.98 µg/m3, while the average concentration in the tracts of public facilities was 11.72 µg/m3, a statistically significant difference. The World Health Organization (WHO) has chosen an annual average concentration of 10 µg/m3 as the long-term guideline for PM2.5. According to a WHO report, "this represents the lower end of the range over which significant effects on survival were observed in the American Cancer Society's (ACS) study (Pope et al., 2002)" (World Health Organization 2006, 10). According to this guideline, both the private and public concentrations observed in this study are too high and should be mitigated.

The average diesel particulate matter concentration in the census tracts of private facilities was 19.51 kg/day while in public facilities the average was 29.32 kg/day. This high pollution burden on both types of facilities, and particularly public facilities, indicates that mitigation efforts should be undertaken to protect senior residents from harmful diesel pollution.

Aggregated Pollution Data & Summed Toxic Sites

The average toxicity-weighted concentration of chemical releases from industrial facilities was 3929.78 in the census tracts of private facilities for the elderly, while the average concentration in the tracts of the public facilities was 5007.245, a statistically significant difference.

The average traffic density was 1249.779 vehicle km/hour in the census tracts of private facilities for the elderly, while the average concentration in the tracts of the public facilities was 1330.271 vehicle km/hour. Using a one-tailed t-test, this difference was significant, but using a two-tailed t-test, it was not.

The average number of toxic cleanup sites was 5.99 in the census tracts of private facilities for the elderly, while the average in the census tracts of public facilities was 9.55 sites, a statistically significant difference.

The average number of hazardous waste facilities and generators in the census tracts of private facilities was .41, compared to .58 in the tracts of public facilities, a statistically significant difference.

The average number of solid waste sites in the tracts of private facilities was 1.63, compared to 2.26 in the tracts of public facilities, a statistically significant difference.

The statistically higher burden of polluting facilities and toxic releases on public facilities, again, raises the question of whether policy changes need to be made to protect seniors in public facilities.

Health Indicators of Air Pollution

On average, emergency room visits for asthma and heart attack, as well as percentages of children born underweight, were statistically significantly higher in the census tracts of public facilities than in the tracts of private facilities. These health indicators not only show sensitive populations, but show that air pollution in these tracts can lead to dangerous outcomes. As seniors in public housing may face a higher burden of air pollution, it is important that these dangers are mitigated, so as to avoid health emergencies.

Conclusion

The data show that, aside from ozone exposure, exposure to air pollution at the census tract level poses a higher risk to public facilities than private facilities. It is imperative that these differences are not only recognized and researched but are mitigated through policy and regulations.

Policy Proposals

This study's findings and discussion sections show that both public and private elder care facilities in Los Angeles have high exposure to harmful air pollution, and, further, that public facilities have statistically significantly higher exposure to a number of specific pollutants and sources of pollution. These findings show that action must be taken to protect the health of seniors in communal living facilities from air pollution, with special attention to public facilities, which bear a higher burden of pollution.

Elderly people are among the most vulnerable populations to adverse health outcomes associated with air pollution exposure, making it even more important that their exposure to air pollution is mitigated. Furthermore, demand and usage of elder care facilities will continue to rise rapidly as the country's population ages. It is likely that a large quantity of new elder care facilities will be built so that housing supply for this age group meets rising demand — in this building process, it is necessary that senior health is prioritized. Protecting the health of seniors should not come at the cost of failing to build new housing for this age group and, vice versa, building new housing for seniors should not mean that more seniors are condemned to living in areas with high pollution exposure. These two important objectives can both be accomplished as long as this issue is treated as a priority and adequate funding is earmarked for new senior housing.

There are many moral and philosophical reasons for protecting a nation's elderly; there are also financial and economic reasons. Literature shows a direct link between increased exposure to ambient air pollution and hospital visits for life-threatening cardiovascular and respiratory conditions among America's elderly, and particularly residents of facilities for the elderly. If basic proactive steps are taken to mitigate air pollution exposure in these vulnerable populations, the nation could spare itself from the costly societal burden of unnecessary emergency room visits. Furthermore, due to the higher exposure this study observes in public facilities, where most residents have very low wealth and income, proactive measures to limit air pollution exposure in these facilities could eliminate many emergency room visits by uninsured people, which puts healthcare professionals in ethically-challenging positions and creates a financial strain on society.

Finally, there is a high proportion of people of color in public facilities for the elderly. This means that, by failing to address higher air pollution exposure in these facilities, HUD would be exacerbating an equity issue (especially when considering that people of color, on average, have more serious health outcomes related to pollution exposure). HUD may also be exposing itself to legal liability by failing to guarantee equal protection for its residents.

Action must be taken to mitigate this at-risk population's air pollution burden in *both* public and private facilities. However, because public facilities face higher exposure, and because federal and local governments have more control over these facilities, mitigation in public facilities should be prioritized and acted upon immediately. Nonetheless, the concerning level of pollution exposure to private facilities, which hold a far greater number of LA County seniors overall, should also be addressed as quickly as possible.

Priorities of Policy Proposals

In crafting policy responses to the concerning findings of this paper, certain objectives will be prioritized. The first priority is to ensure that — in accordance with the 14th Amendment of the US Constitution and the Civil Rights Act of 1964 (Cornell Law n.d.) — all people within the jurisdiction of the U.S. are afforded equal protection by the law. The finding that, in LA County, elders in public housing have higher exposure to health-threatening air pollution than elders in private housing shows a likely breach of these protections. As HUD builds more housing for the elderly, it is necessary that it rectifies these disparities.

A secondary priority is for HUD to introduce more housing for the low-income elderly, in order to house a huge new generation of poorer seniors. This paper has shown that in each of the past three years, the proportion of elderly people among LA County's homeless population has risen (Greater Los Angeles Homeless Count Results 2018-2020). If HUD requires that affordable housing builders locate their new senior properties in areas with lower pollution, but does not provide adequate funding to offset the higher price of these lower-exposure lots, the supply of new affordable housing will dry up, exacerbating the area's housing crisis. It is crucial that HUD *simultaneously* address these two problems. As new public housing for seniors is built, an injection of new funding could ensure that this housing is located in healthier places. If seniors are housed *and* healthy, this would save countless dollars down the line related to healthcare and homeless services costs.

Immediately addressing pollution exposure health disparities and the increasing need for senior housing are the main priorities of this paper's policy proposals. However, moving vulnerable populations away from pollution does not solve the root problem — in effect, these are "band-aid" solutions to the underlying problem of air pollution. A final priority for this section will be to make recommendations on how to reduce air pollution exposure *at its source,* moving beyond temporary solutions to permanent ones.

Addressing Pollution in Public Facilities As a Priority

This study shows that, aside from ozone exposure, public facilities for the elderly in LA County face a disproportionate level of air pollution at the census tract level. As the nation continues to grow older, and the new generations that reach elderly age continue to be poorer, it is crucial that elders whose low wealth necessitates them living in public housing are not being sentenced to a life of health complications from ambient air pollution.

In addition to the obvious equity issue — that poorer seniors who are unable to pay for market rate housing or long term care are at higher risk of pollution exposure — there is a secondary equity issue. Seniors in public housing are disproportionately nonwhite, and people of color are, on average, at higher risk for adverse health outcomes associated with air pollution exposure. Seniors are already among the most vulnerable to air pollution, but seniors in public housing, based on demographics, are an even more vulnerable group.

It is necessary that local and federal governments take action to curb this inequity and protect low-income seniors from outsize exposure to air pollution.

Protecting Seniors Through Zoning

As mentioned previously, it is essential that, as the nation builds more affordable housing for the elderly, it locates this housing in areas with lower exposure. This necessitates a simple change in zoning policy.

This paper recommends that California state legislators introduce a bill that prohibits public housing facilities targeted toward the elderly from being built within 500 feet of a freeway or a quarter mile of hazardous, pollutant-emitting facilities. This would follow the precedent of similar regulations in a law enacted by the state in 2003, Senate Bill No. 352 (Escutia 2003). That bill prevented new schools from being built within 500 of freeways and updated prior law requiring consulting to prevent schools from being located near hazardous facilities.

While SB 352 provides good inspiration for a law protecting seniors from air pollution, it has notable shortcomings that must be avoided in this new piece of legislation. First, the 2003 law does not explicitly bar schools from being close to hazardous facilities, like it does for freeways. Legislation protecting seniors from pollution should impose the 500-foot buffer on all types of pollution, from hazardous waste facilities to pollutant-emitting factories. Another crippling shortcoming in the 2003 law is a loophole that allows schools to be built within close range of freeways when certain other conditions are met (Larrubia 2007). In 2007, four years after the law, five new schools were still being built within 500 feet of a freeway. Even though there are over a thousand schools in the Los Angeles Unified School District (LAUSD, n.d.), it is striking that a law intended to prevent schools from being located near freeways failed to achieve its stated goal. This study recommends that a law preventing construction of senior housing near freeways and hazardous facilities has no limitations, caveats, or loopholes.

Restrictive zoning laws should be applied first to public facilities in California and LA County. However, if further research shows that similar disparities between public and private senior facilities exist elsewhere in the country, this paper recommends that these laws be adopted more broadly across the nation.

This study found that private residential care facilities in LA County also faced high pollution exposure. It is tempting to recommend that laws restricting future zoning of elder housing be applied to private facilities, but restrictions like this could make private senior housing even more expensive than it already is. Current costs are about $48,000 per year in assisted living facilities and can be up to $100,000 per year in nursing homes, according to the 2018 Genworth Cost of Care Survey (Where You Live Matters 2021). This study recommends that, for now, lawmakers regulate public senior housing and leave the market to make adjustments to the private sector.

Offsetting Costs and Limitations

If zoning regulations are changed, but no further funding is provided to offset the costs of compliance, it is likely that non-governmental providers of affordable housing will be unable to continue to provide new senior housing. This outcome must be avoided at all costs, as literature reviewed in this study has observed and predicted a skyrocketing need for affordable senior

housing.* It is necessary that the costs of finding new housing in less-polluted areas is thoroughly researched prior to the implementation of zoning regulations, so that HUD can provide developers with enough funding to offset the higher cost of this pricier land.

If HUD seeks to truly prioritize the health of seniors, which would avoid future financial strains on healthcare systems and taxpayers, it could ideally go as far as incentivizing the building of public senior housing in less polluted areas. Developers could be rewarded through tax incentives for housing built in lower-pollution areas.

Zoning restrictions for future facilities would not protect existing elder care facilities from pollution. While the omission of protections for current facilities is unfortunate, it is simply unrealistic to require that all existing facilities relocate. During relocation, there would be nowhere for senior residents to live, and it is difficult to even comprehend the costs this process would incur.

**Please see the Senior Housing Policy Index for policy recommendations related to increasing affordable senior housing.*

Protecting Existing and Future Facilities

Because zoning restrictions for future siting do not protect existing facilities, it is necessary to explore options that would protect all senior housing locations from pollutants. These solutions could take the form of either removing the polluted air from facilities or trying to capture or mitigate pollution before it reaches the facilities.

Removing Pollution from Within Facilities: Mechanical Filtration

There is precedent for regulations requiring air filtration, specifically in hospitals. In a hospital, especially in operating rooms, it is essential that air is properly filtered to avoid infections that can occur from air contaminants entering a patients' body during surgery. Air filtration is measured in air changes per hour, the number of times air is replaced in a room over an hour. State building codes have different requirements, but the minimum is between 15 or 20 air changes per hour in operating rooms and 6 air changes per hour in patient rooms (Gormley and Wagner 2018). However, most hospitals use 20 to 25 air changes per hour, and some use up to 40.

In an ideal situation, air filtration would be used to protect seniors from air pollution. However, air filtration may be too expensive to be a viable long-term option. Cost of implementation depends on the size of a facility, but one study, observing a number of hospital sites (Gormley and Wagner 2018) found that "an additional five ACH costs approximately $5,000 to $10,000 per year" per operating room and also that one hospital reduced its air changes per hour by 5 and saved a million dollars in a year. Another study examining filtration as a means of preventing communicable diseases found that the cost of increasing filtration by eight air changes per hour was $8,000 annually for a 70 square-foot laboratory. Based on this high cost, it is highly unlikely that public facilities, or even private residential care facilities, could

afford the prices it would take to have hospital-level filtration (even at the patient room level of 6 air changes per hour). The seemingly-convenient solution of improving filtration in facilities and apartments for elders is therefore untenable, due to its high cost. There are also questions regarding the effectiveness of mechanical filtration in even removing pollutants (Gormley et al. 2017). This study does not recommend air filtration methods as a solution.

Protecting Existing Facilities Through Vegetation

Mitigating or eliminating pollutants on their airborne route from their source to public and private senior facilities may be a more effective, realistic, and cost-efficient solution. Vegetation can be used to form a barrier around pollutant sources, reducing pollutant exposure.

Mandatory Barrier Walls with Vegetation

A study examining the effectiveness of vegetation on highway barriers found that vegetation does act as an effective barrier, resulting in lower downwind pollution concentrations (Ranasinghe et al. 2019). A UK study that observed different types of vegetation barriers and their effect on pollution summarized other studies in concluding that, while vegetation barriers do not quite *remove* pollutants from the air, they can be successful in reducing exposure through "local-scale manipulation of pollutant concentrations and air flows" (Barwise and Kumar 2020). The latter study also found that effectiveness of exposure reduction can vary by vegetation type. The authors found that plants with leaves that were small in size and more complex were better at reducing exposure, and that for ultrafine (sub-micrometer) particles, leaves with ridges, grooves, and trichomes were most effective.

This study recommends that for all freeways in LA County and nationwide, city planners ensure that there are barrier walls and incorporate vegetation onto the barriers. For facilities that are located nearby facilities that house the elderly, this is especially important. When possible, care should be taken to use specific plants that best suit the particular context of the site — the Barwise and Kumar study, although observing plants in the UK, can be used as a general guide to identify best options. Further research should be conducted to determine what plants work best as barriers in the Southern California environment.

Vegetation barriers could also be used nearby other point sources of pollution, like hazardous facilities. This study recommends that more research be conducted on if and how green barriers could be effectively used near toxic facilities.

Removing Pollutants with Trees and Shrubs

There is significant literature showing that increasing the amount of trees and shrubs in an urban area can improve air quality. A study in Urban Forestry and Urban Greening researched the effect of urban trees across the 48 contiguous U.S. states (Nowak, Crane, and Stevens 2006). It estimated that annually, urban trees remove 711,000 metric tons of pollutants, including ozone, particulate matter10, nitrous and sulfur dioxides, and carbon monoxide.

The city of Los Angeles is moving in the direction of increased urban forestation. In August 2019, Mayor Eric Garcetti named the first ever City Forest Officer, Rachel Malarich — the stated goal of her position was to plant 90 thousand trees across LA by 2021 (City News Service 2019). According to Malarich, 31 thousand trees had been planted as of July 29, 2020 (Margolis 2020). The process has been slowed by the pandemic, but the goal of 90,000 remains, even if the process of planting continues into 2022.

This study recommends that, in this planting process, areas with high pollution should be focused on. This study also recommends that nearby any facilities for the elderly, many trees should be planted.

Solving the Underlying Problem: Achievable National Policy Measures to Lower Total Pollution Exposure, Protecting Seniors and *All* US Residents

Revising National Ambient Air Quality Standards (NAAQS)

Based on the burden of pollution shown in this study, it is essential that the EPA revise and strengthen its National Ambient Air Quality Standards to lower permissible levels of pollutants. If elderly populations are moved away from a high pollution area, other, slightly-less vulnerable populations will replace them in the cheap, high-exposure area, and these new residents will also suffer from health complications. Instead of shifting pollution from one population to another, based on who will suffer the least, it is necessary that the nation prioritize lowering pollution *at its source*.

This will require large, nationwide actions. However, under a new administration that has shown it will prioritize science and resilience against climate change — including by naming the first-ever national climate adviser, a former EPA chief (Biden Announces Climate Team 2020) — it is a reasonable and necessary one. All other actions that can be taken to protect the health of seniors in long term care facilities do not address the root cause of the problem, which is that national air quality standards are too lenient, setting harmfully high regulatory limits for air pollution.

Restoring A Scientific Review Process for NAAQS

The first action that should be taken to protect the health of all seniors is to reverse the Trump-Appointed EPA's rules that disregard science in setting National Ambient Air Quality Standards, which federally regulate the six criteria pollutants.

In May 2018, the then-EPA Administrator Scott Pruit signed a memorandum called "Back-to-Basics Process for Reviewing National Ambient Air Quality Standards" (Goffman and Bloomer, 2019). This rushed the ongoing process of reviewing standards for ozone and particulate matter, to October and December 2020, respectfully. This led to the standards being reviewed before an administration shift that would vastly change the character and political role of the EPA.

The memorandum, and earlier EPA directives, also changed the scientific process for reviewing NAAQS. The memorandum altered the review process so that potential economic effects of implementation of new standards could be considered during the portion of the review that was previously required to solely consider science and health concerns. This change, which goes against a 2000 ruling by the Supreme Court in Whitman v. American Trucking Associations, which stated that the EPA cannot consider costs when setting NAAQS, means that what was previously an entirely science-based process for determining safe regulations for toxic pollutants is now warped by economic considerations of implementation. In other words, if it is too costly to protect the lives and wellbeing of Americans from pollution, the EPA can decide not to do so.

Other directives changed the review process by disqualifying large swaths of certain types of experts from review panels (anyone who has received a grant from EPA), while making no such exclusion for experts who are associated with or compensated by industries the EPA regulates (Goffman and Bloomer, 2019). These rules are especially concerning when considering that the entire scientific panel charged with helping in the review process, the Clean Air Scientific Advisory Committee, was replaced by the Trump Administration by 2018. The new panel had no epidemiologist, only two university-affiliated scientists, and several industry-affiliated scientists. The EPA also eliminated other panels of scientists, attempted to change the type of studies that could be considered (excluding any studies where base data was not publicly available), and changed the appointment process for officials on panels.

The new administration's EPA must undo these anti-scientific changes. The review process has been compromised — scientific review of health and safety is no longer the priority of a process that is intended to be objective and health-based. The EPA should revert the process to its pre-2016 standards.

Furthermore, the review processes that occurred during the Trump administration should be redone. They were rushed, influenced by economic and political factors that should not have played a role, and conducted by biased and unqualified scientists. Once the correct process is restored, current standards must be reconsidered properly.

Revising NAAQS for Particulate Matter

Particulate matter is a key pollutant that was shown in this study to be highly-present in the census tracts of both public and private facilities, and even higher near public facilities than private facilities.

The nation's leading scientists believe the national standards regulating the pollutant are insufficient. Furthermore, during the most recent process for reviewing PM standards, recommendations by a scientific panel that the standards should be tightened (lowering permissible levels of pollution) were categorically ignored by the EPA.

Climate activists were outraged in response to the Trump Administration EPA's decision, on December 7, 2020 to retain its existing air quality standards for particulate matter. The decision came after an independent panel of scientists, the Independent Particulate Matter

Review Panel, wrote a decision on October 22, 2019 stating that "the current suite of primary fine particle (PM2.5) annual and 24-hour standards are not protective of public health" (Independent Particulate Matter Review Panel, 2019) and concluding that both standards should be revised.

The retained standards for particulate matter 2.5 are annual averages of 12.0 μg/m3 for the primary health-based standard and 15.0 μg/m3 for the secondary welfare-based standard and 24 hour averages of 35 μg/m3.

This study found that the average annual particulate matter concentration in the census tracts of private facilities for seniors in LA county was 10.98 μg/m3, while the average concentration in the tracts of public facilities was 11.72 μg/m3. While both of these averages are below federal standards, the independent panel of experts would argue that these levels are intolerably unsafe. The panel recommended that the annual averages be lowered to a range of 8–10 μg/m3 and that the 24-hour average be lowered to a range of 25-30.

This study recommends that the lowest limit recommended by scientists, 8 μg/m3, should be adopted as the federal limit for PM2.5. It is imperative that federal law stops pollution at its source, by creating standards that bind industry to cleaner practices. Doing so would save society considerable healthcare costs, especially when factoring in the exposure to ultrafine particulate matter faced by elderly populations living in LA. Particulate matter is associated with the deaths of tens of thousands of Americans each year (Goldman 2020), but the EPA has the power and the scientific consensus to change that. It is crucial that it does so.

Revising NAAQS for Ozone

It is also essential that the EPA revisit and revise the nationwide NAAQS limits for ozone. On December 23, 2020, the EPA decided to retain the ozone level as 70 parts per billion (ppb). This standard requires that the 3-year average of the annual fourth-highest daily maximum 8-hour average of ozone is lower than .07 parts per million (ppm).

This study found that, in the census tracts of private residential care facilities, the average 8-hour level was 52.4 ppb, while in the census tracts of public facilities, the average level was 49.3 ppb. These average levels are below the standard recently retained by the EPA, but that standard is too lenient to protect health, even according to a portion of the questionable Clean Air Scientific Advisory Committee that was entirely selected by the Trump administration. A portion of the facilities in this study, both public and private, were located in census tracts where the ozone level was 65 ppb. Setting the limit at 60 ppb, as many scientist recommend, would necessitate mitigation from energy and chemical industries (Waldheim 2014) that would protect the health of at-risk populations across the country, including people in elder facilities, who are particularly vulnerable.

According to John Walke, the director of the National Resource Defense Council's Clean Air Program, "Setting the safest recommended standard [60 ppb, from the pre-2015 level of 75 ppb] would have saved almost 6,500 lives and avoided nearly 1.5 million more asthma attacks per year than the smog pollution level the administration has chosen" (Brady 2015).

It is necessary that the EPA work to protect citizens from unneeded deaths by lowering ozone limits to 60. The US EPA can look to the example of the European Union (EU n.d.), where the ozone 8-hour average standard is 120 µg/m3, which when converted to parts per billion using the conversion factor based on the molecular weight of ozone, is 60.

Addressing Nationwide Pollution from Cars

This study also found that traffic pollution was high in the census tracts of both public and private facilities. A specific tailpipe pollutant, diesel particulate matter, was shown by this study to be at high levels in the census tracts of private facilities (average of 19.51 kg/day) and especially high in the tracts of public facilities (29.32 kg/day). Although there are OSHA standards for workplace exposure, there is no federal standard for acceptable environmental levels of diesel-specific particulate matter, even though it is particularly harmful to human health. In 2012, the International Agency for Research on Cancer re-classified diesel from "probably carcinogenic to humans" to "carcinogenic to humans" (Silverman 2018). Diesel alone also makes up a large proportion of all PM2.5 — about 6% of the national ambient PM2.5 inventory, and between 10 and 36% of ambient PM2.5 inventory in urban areas.

The first step that should be taken federally is that the EPA should establish a national environmental limit for diesel PM exposure. LA, partly because of its high volume of diesel truck traffic due to its large ports, has a diesel particulate matter exposure that should be well above the limit that the EPA sets. This study recommends that further research be done to set the correct level — however, the standard would ideally be much lower than the levels identified in this study. Setting standards are a key step towards enforcing reductions of ambient diesel particulate matter and limiting harmful tailpipe emissions more generally. However, in the absence of leadership from the EPA, it is important that states do what they can to address this issue.

Standards for Auto Manufacturers

California has been a leader in requiring auto manufacturers to address fuel efficiency and smog standards. Taking precedent and power from a deal between the California Air Resources Board and automakers, the Biden Administration's EPA is currently drafting auto emissions standards that would adopt the California deal nationally (Joselow 2021). The deal stipulates that automakers must reduce greenhouse gas emissions from their vehicles by 3.7% each year until the deal expires in 2026. This study recommends that the EPA use its bargaining power to require more stringent rules — the Obama-era standards had 5% yearly reductions. It is also crucial that the deal be continued long-term, after 2026.

California's Governor Gavin Newsom, in Executive Order N-79-20 on September 23, 2020, banned the sale of new gas and diesel cars statewide by 2035 (Cahill 2020). The order also requires commercial trucking companies to replace their trucks with zero-emissions vehicles by 2045 "where feasible." These regulations are a step toward a cleaner future of transportation, and more states and localities should adopt similar policies.

Targeting Zero-Emissions Public Transit

Another key method for lowering tailpipe pollutants in urban areas is to electrify buses. Government transit authorities should adopt zero-emissions buses as quickly as possible. LA Metro has committed to replacing all its buses with zero-emissions buses by 2030 — however, due to state funding shortfalls, Metro has delayed its implementation of this commitment, missing a deadline for electrifying an entire bus line and instead launching just one electric bus (Linton 2021). It is essential that the state of California provides LA Metro, one of the largest nationwide transit agencies, with adequate funding for this transition in order to keep its commitment. In the meantime, it is also crucial that other transit agencies work towards zero-emissions buses.

Conclusion

This study first summarized changing nationwide and local demographics that will create key problems for society to address. Los Angeles county represents one of the more extreme examples of a nationwide trend, in which a new, larger generation of seniors is emerging that is increasingly nonwhite and poorer. More affordable housing for seniors will need to be built, especially in high-cost areas for housing like Los Angeles, which continues to see rises in its elderly homeless population. As these new buildings are being cited and built, it is important to recognize that seniors are very vulnerable to adverse health outcomes associated with air pollution exposure, particularly for certain pollutants, like ultrafine particulate matter. To understand whether existing methods for building affordable housing may need to be revised, this study attempted to empirically determine if either public housing for the elderly or private residential care for the elderly had higher exposure to pollution.

This study found disparities in the burden air pollutants inflict on residents of public and private elder housing in Los Angeles County, using GIS spatial analyses at the census tract level. The census tract for each public and private (residential care) facility for the elderly were matched with CalEnviroScreen 3.0's air pollution related data. The means, for the public and private facilities, for each variable (i.e. concentrations of PM or number of hazardous waste sites in the census tract) were compared using statistical t-tests.

Aside from ozone pollution (which was statistically significantly higher in the census tracts of private facilities than public facilities) and traffic volume (no significant difference), public facilities had statistically significantly higher means for all CalEnviroScreen variables tested. This means that, for most pollutants and sources of pollution, public facilities had a higher exposure and/or burden than private facilities, at the census tract level.

Because of these disparities, solutions were recommended with a focus on implementation in or near public facilities for the elderly. For example, vegetational filtration methods were suggested, and these methods would have the largest impact if first implemented near public housing facilities, which faced the highest burden of pollution exposure, for most pollutants and point sources. Additionally, this study recommends that new long term care facilities and apartments targeted towards seniors are located in areas with less pollution burden. Further, this study proposes that local legislation is written and implemented to require buffer distances between these facilities and sources of high pollution, including freeways, toxic release facilities, and hazardous waste facilities. Ideally, as politicians and housing developers work to address the growing "Quiet Crisis" of senior housing in America, they will keep senior health and vulnerability to air pollution at the forefront of siting decisions.

Ultimately, the primary solution that this study recommends is for the EPA to enact lower permissible levels for key pollutants at the federal level. Health risk to seniors related to air pollution can only truly be mitigated if the *sources* of pollution are curtailed and controlled. There are immediate steps that can be taken to tighten regulations on the most harmful pollutant to seniors, particulate matter, and scientific panels that the EPA typically relies on to set these standards have recommended lowering permissible levels. It is incumbent on the EPA of the new

presidential administration to follow the scientists recommendations and strengthen health regulations. This is also a key moment for regulating pollution from transportation sources, and the federal government is in a position to follow California's guidance and adopt strict deals with automakers. If action is not taken to protect the U.S.'s aging and increasingly vulnerable population from air pollution, there will be a significant national repercussions in healthcare costs.

Index A: CalEnviroScreen Means Tests for Statistical Significance

Ozone Exposure Means & Variance			
	Public Facilities	Private Facilities	Stat. Sig. Difference?
Mean	0.049	**0.052**	Y
Variance	2.97E-05	4.70E-05	Y

Ozone Exposure Unequal Variances T-Test		
Degrees of Freedom	794	
T Statistic	9.65	Reject Null Hypothesis?
Two-Tailed P-Value	**6.43E-21**	Y

Ozone F-Test and T-Test. The F-Test shows that the variances are unequal, and the Unequal Variances T-Test shows that we can reject the null hypothesis and say that the private facility mean of .052 ozone ppm is statistically significantly higher than the private facility mean.

Particulate Matter Exposure Means & Variance			
	Public Facilities	Private Facilities	Stat. Sig. Difference?
Mean	**11.72**	10.98	Y
Variance	1.6	2.04	Y

Particulate Matter Exposure Unequal Variances T-Test		
Degrees of Freedom	715	
T Statistic	10.27	Reject Null Hypothesis?
Two-Tailed P-Value	**3.67E-23**	Y

Particulate Matter F-Test and T-Test. The F-Test shows that the variances are unequal, and the Unequal Variances T-Test shows that we can reject the null hypothesis and say that the public facility mean of 11.72 PM µg/m3 is statistically significantly higher than the private facility mean.

Diesel Exposure Means & Variance			
	Public Facilities	Private Facilities	Stat. Sig. Difference?
Mean	**29.32**	19.51	Y
Variance	557.92	122.99	Y

Diesel Exposure Unequal Variances T-Test		
Degrees of Freedom	463	
T Statistic	8.23	Reject Null Hypothesis?
Two-Tailed P-Value	**1.98E-15**	Y

Diesel PM F-Test and T-Test. The F-Test shows that the variances are unequal, and the Unequal Variances T-Test shows that we can reject the null hypothesis and say that the public facility mean of 29.32 kg/day of diesel particulate matter is statistically significantly higher than the private facility mean.

Toxic Releases Means & Variance			
	Public Facilities	Private Facilities	Stat. Sig. Difference?
Mean	**5007.25**	3929.78	Y
Variance	46680135	65781094	Y

Toxic Releases Unequal Variances T-Test		
Degrees of Freedom	750	
T Statistic	2.74	Reject Null Hypothesis?
Two-Tailed P-Value	**0.006**	Y

Toxic Releases (RSEI Haz) F-Test and T-Test. The F-Test shows that the variances are unequal, and the Unequal Variances T-Test shows that we can reject the null hypothesis and say that the public facility mean of a 5007.25 RSEI score is statistically significantly higher than the private facility mean score.

Traffic Volume Means & Variance			
	Public Facilities	Private Facilities	Stat. Sig. Difference?
Mean	1330.27	1249.78	N
Variance	760467.8	628264.2	Y

Traffic Volume Unequal Variances T-Test		
Degrees of Freedom	606	
T Statistic	1.7	Reject Null Hypothesis?
Two-Tailed P-Value	**0.089**	N

Traffic Density F-Test and T-Test. The F-Test shows that the variances are unequal. The Unequal Variances T-Test shows that there is not enough difference between the public and private means to determine that these differences are due to anything more than random chance. We do not reject the null hypothesis — the differences between these means are not statistically significant.

Solid Waste Sites Means & Variance			
	Public Facilities	Private Facilities	Stat. Sig. Difference?
Mean	**2.26**	1.63	Y
Variance	18.57	13.52	Y

Solid Waste Sites Unequal Variances T-Test		
Degrees of Freedom	582	
T Statistic	2.75	Reject Null Hypothesis?
Two-Tailed P-Value	**0.006**	Y

Solid Waste F-Test and T-Test. The F-Test shows that the variances are unequal, and the Unequal Variances T-Test shows that we can reject the null hypothesis and say that the public facility mean of 2.26 waste sites per census tract is statistically significantly higher than the private facility mean.

Hazardous Waste Sites Means & Variance			
	Public Facilities	Private Facilities	Stat. Sig. Difference?
Mean	**0.58**	0.41	Y
Variance	1.95	1.11	Y

Hazardous Waste Sites Unequal Variances T-Test		
Degrees of Freedom	544	
T Statistic	2.2	Reject Null Hypothesis?
Two-Tailed P-Value	**0.028**	Y

Hazardous Waste F-Test and T-Test. The F-Test shows that the variances are unequal, and the Unequal Variances T-Test shows that we can reject the null hypothesis and say that the public facility mean of .58 waste sites per census tract is statistically significantly higher than the private facility mean.

Cleanup Sites Means & Variance			
	Public Facilities	Private Facilities	Stat. Sig. Difference?
Mean	**9.55**	5.99	Y
Variance	164.58	105.33	Y

Cleanup Sites Unequal Variances T-Test		
Degrees of Freedom	561	
T Statistic	5.23	Reject Null Hypothesis?
Two-Tailed P-Value	**2.38E-07**	Y

Cleanup Sites F-Test and T-Test. The F-Test shows that the variances are unequal, and the Unequal Variances T-Test shows that we can reject the null hypothesis and say that the public facility mean of 9.55 waste sites per census tract is statistically significantly higher than the private facility mean.

Index B: Increasing the Supply of Senior Housing:

Increasing the Stock of Affordable Housing for the Elderly

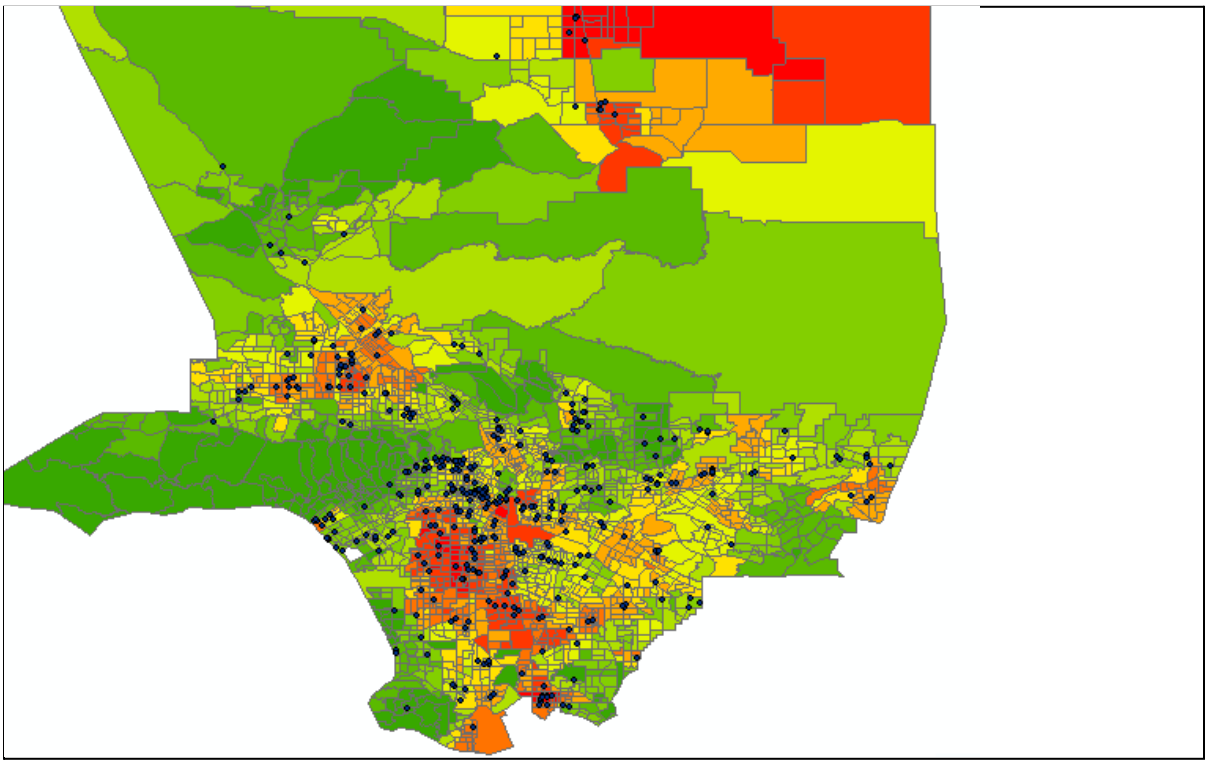
It is extremely important, as the nation ages and the country progressively contains more and more middle- and low-income seniors, that more housing for the elderly, and specifically more affordable housing for the elderly, is built. This study's literature review shows that Section 202, the only subsidized housing program dedicated exclusively to the elderly, is not keeping pace with needs for affordable elder housing. This study recommends that HUD starts significantly expanding Section 202 offerings by building more housing. Alternatively, HUD could continue to build housing with its most momentous program currently, LIHTC, but, in that case, it should add more LIHTC housing that is senior-specific or offers services to seniors. It is also crucial to keep in mind the unique health needs of seniors, and build new senior affordable housing in a way that is conscientious of local pollutant levels. HUD could work with housing providers to consult with, and involve, local air resources boards in making siting decisions.

Creation of a HUD Program that Offers Nursing Homes Services at Affordable Prices

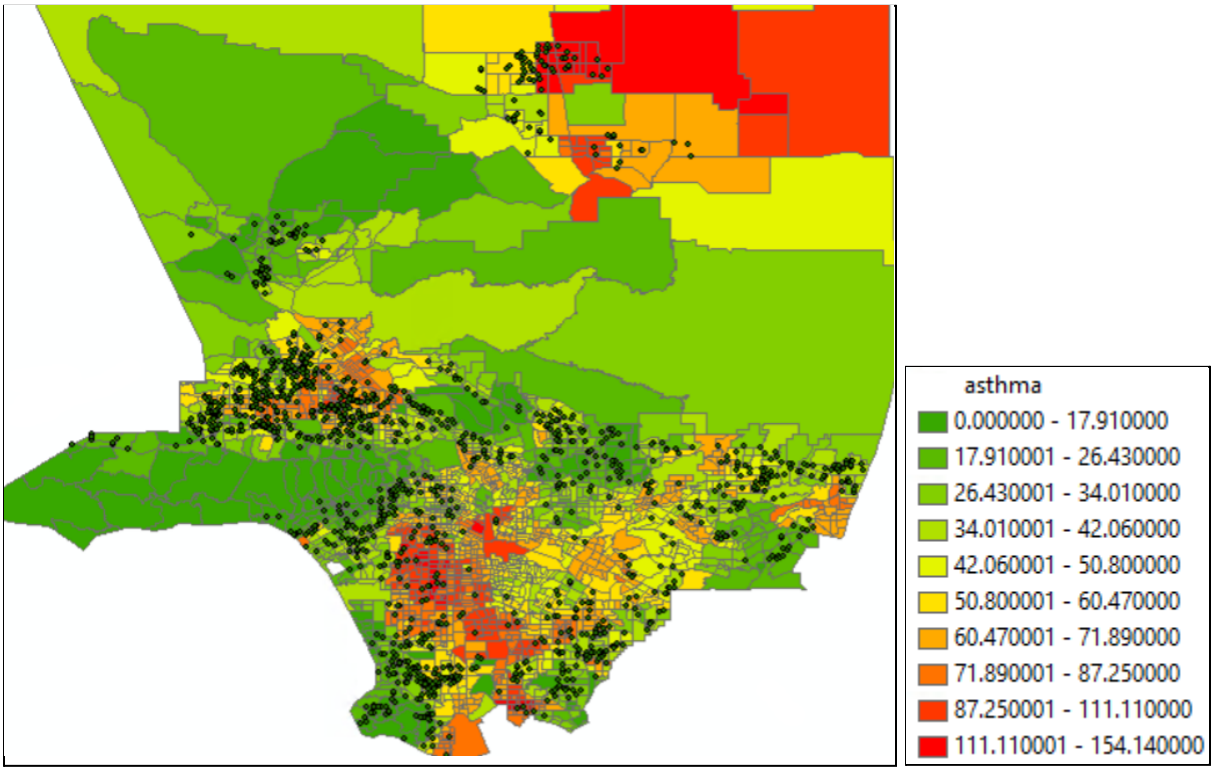
An ideal, but perhaps far-fetched, solution to the increasing need for affordable senior housing that provides services would be for HUD to introduce a program that not only offers affordable apartments, with service coordinators, to low-income seniors, but also offers nursing home and assisted living options in a new program. This would certainly be more costly than Section 202 and other programs that do not offer extensive services, but it would provide relief to a very large, and growing, subset of the low-income senior population who are in need of additional daily assistance (Pearson et al. 2019).

Index C: Asthma Rates and Public and Private Facilities

Fig. A: Asthma and Facilities



Above: Public (Sources: NHPD, CalEnviroScreen 3.0)



Above: Private (Sources: CDSS, CalEnviroScreen 3.0)

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