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GEOG 2134 Section 10

Effects of Parking Garages on Energy Efficiency

When examining the environmental effects and efficiency of suburban sprawl, there are a number of issues in its large-scale development that point to poor design and sizeable social cost. Among the greatest costs imposed on the environment and energy structure as a result of suburban sprawl is parking infrastructure. Often built in excess of demand, incentivizing regular commuting, and setting prices too low to offset cost, parking garages are a massive complication to efficient land use and energy efficiency.[1] Many cities have recognized this issue within the last decade and have attempted to reduce parking energy usage in addition to redesigning the way public parking is provided. As reducing parking infrastructure and mass auto commute is unlikely to occur in the near future, it is important to analyze the best ways in which existing parking structures can reduce or eliminate the effect they have on their environment. By examining case studies from Phoenix, Los Angeles, and Austin, a number of different strategies can be developed to minimize parking garages' impacts.

First, it is important to determine the elements of parking garages that place such a cost on the communities they exist in. To break it down, a parking garage can have a negative environmental impact in construction, energy use, heat creation, land use, and incentivization of auto commuting.[2] From the stage of construction, parking infrastructure (garages and lots alike) depend on asphalt and concrete production that account for 8% of global emissions.[3] A study

[1](https://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=ENV/WKP(2019)4&docLanguage=En, 3)
[2] (https://iopscience.iop.org/article/10.1088/1748-9326/5/3/034001)
[3] (https://psci.princeton.edu/tips/2020/11/3/cement-and-concrete-the-environmental-impact)

done by the Department of Civil Engineering at UC Berkeley evaluated the increase in emissions caused by parking infrastructure construction and maintenance based on the average life-cycle of SUVs and sedans, and found a 27% increase in greenhouse gas emissions from parking infrastructure construction alone.[4] This rate is further encouraged by suburban sprawl as parking infrastructure accounts for more than 5% of land use in sprawled areas as opposed to urban centers that may be more likely to use on-street parking or take advantage of public transportation.[5] Once constructed, concrete and asphalt pavement "emit 15% and 37% more sensible heat compared to the bare ground, respectively," ultimately raising metro temperatures and potentially affecting local climate.[6] Furthermore, heat centers generate greater energy costs for cooling and place a strain on the energy grid.[7] This radiative heat effect is then augmented by cities in hotter climates, even as one moves out to the urban fringe.

In addition to producing a great amount of heat, parking garages and facilities take up a mass amount of space. Sprawl and construction of parking garages are inexorably linked in that road network expansion creates greater parking demand and creation of parking opportunities allows for easier travel. Therefore it is unsurprising that parking facilities are most prevalent and spacious in the outskirts of urban areas, where land cost also tends to be lower.[8] While statistics vary between cities, parking minimums and direct/indirect subsidies lead to creation of excess parking and land use, generating nearly 3 to 4 times the amount of spaces needed for each automobile in a metro area.[9] Excess parking then places a greater burden on taxpayers in maintenance, energy, and environmental impact. Design tactics for parking garages cause "A variety of pollutants [to] enter streams from parking areas, including heavy metals (e.g.,

[4](https://iopscience.iop.org/article/10.1088/1748-9326/5/3/034001/pdf, 6)
[5] (https://www.vtpi.org/landuse.pdf, 14)
[6] (https://www.tandfonline.com/doi/abs/10.1080/23789689.2020.1773013?journalCode=tsri20)
[7] (https://iopscience.iop.org/article/10.1088/1748-9326/5/3/034001/pdf, 2)
[8] (https://www.vtpi.org/landuse.pdf, 14)
[9] (https://iopscience.iop.org/article/10.1088/1748-9326/5/3/034001/pdf, 2)

cadmium, zinc), oils and fuels, and radiator fluid."[10] The prevalence of parking facilities in suburban areas has a sizeable impact on runoff patterns and biodiversity loss in that community.[11]

Finally is the energy costs associated with parking garages. As previously stated, the non-reflective materials garages are often built with create the urban heat island effect, driving up cooling costs and grid stress. And, while significant changes have been made in the past decade, many garages are still lit 18 or more hours a day, making no account for occupancy or amount of daylight.[12] Furthermore, typical construction of concrete parking garages require mechanical ventilation as to reduce the sensible heat and account for the enclosed space.[13] The flaw is not only in design but the materials being used, whether it be energy-inefficient lighting or non-perforated materials that allow for practically no ventilation.[14]

With the widespread flaws in parking infrastructure identified, case studies attempting to make improvements and reductions in energy and environmental cost of parking garages can be analyzed. Phoenix has nearly 7.5 million off-street parking spaces (residential and non-residential) with a population of 4 million.[15] And despite the majority of parking availability lies on-street, those spaces are utilized far less than parking structures.[16] Just like any other large metro area, Phoenix faces provision of excess low-return parking structures that produce a great amount of heat and raise energy costs. What makes Phoenix unique is the already abnormally hot climate in which infrastructure must be adapted for the comfort of residents and energy efficiency. The burden is then on the city to reduce inefficient parking heat islands, conserve clean water supply, and reduce the incentive to privately commute. Phoenix's greatest effort in

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[10] (https://link.springer.com/content/pdf/10.1007/s002679900231.pdf, 265)
[11] Ibid.
[12] (https://www.energy.gov/sites/default/files/2014/02/f7/parking_structure_lighting_guide.pdf, 4)
[13] (https://www.nrel.gov/docs/fy13osti/58137.pdf, 1-2)
[14] Ibid. 1
[15] (https://transfersmagazine.org/magazine-article/issue-5/valley-of-the-sun-drenched-parking-space/)
[16] Ibid.

reducing parking infrastructure effects is their inclusion of EV charging stations in off-street facilities.[17] The city government aims to reduce utility and maintenance costs through charging relatively cheap rates for charging, while keeping parking costs low.[18] To incentivize low-income EV drivers to purchase a vehicle, parking at many said facilities would be free.[19] The barriers Phoenix faces with this installation, however, is the markedly high price to retrofit current garages with these stations rather than solely incorporate in new construction projects. Including sufficient charging stations to meet the space-per-dwelling-unit goal would 4 to 6 times more expensive in existing facilities than new.[20] Still, as the city of Phoenix significantly grows in size, it is essential to reduce the desire to spread out and take advantage of current infrastructure that would reduce the need to travel in polluting vehicles.

Most recently, in October of 2021, Phoenix implemented the cool pavement project in which neighborhood roads and one public parking facility in need of maintenance were repaved with a lighter gray and water-based asphalt covering.[21] However, it is unclear if or when this initiative will later include more parking garages or other facilities. At the moment, this project is in its infancy and for the coming years could prioritize roads requiring asphalt repair. Phoenix is among the few cities to begin implementation of such a project, however, and should heavily consider including parking garages in future repairs. According to a study of the pilot program by Arizona State University, cool pavement has been shown to reduce asphalt temperatures by 12 degrees in sun-exposed areas.[22] This could mean significantly reducing the heat and therefore energy cost of uncovered or open-air parking garages. Unlike suggested strategies of

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[17](https://www.phoenix.gov/oepsite/Documents/Business%20and%20Climate%206.16.2021%20Presentation.pdf, 56)
[18] Ibid.43
[19] Ibid.41
[20] Ibid. 56
[21](https://www.phoenix.gov/streetssite/Documents/Phoenix%20Cool%20Pavement%20Exec%20Summary_091420213.pdf, 4)
[22] (https://www.phoenix.gov/streets/coolpavement)

white-topping asphalt and concrete, cool pavement has no demonstrated glare.[23] Furthermore, the covering is made of recycled materials and attempts to reduce the impact of runoff or any soil contamination.[24] Incorporation of this cover on concrete and asphalt parking garages could further limit moisture damage during Phoenix monsoon season as well as reduce damage from regular traffic, lowering maintenance costs and allowing for funding of more energy efficient construction.

Lastly is the trend throughout Phoenix (though not a government program) to shade parking garages with photovoltaic panels and replace majority of lighting with time sensitive LEDs. Phoenix International Airport has incorporated "5.4 megawatts of solar photovoltaics" on separate parking garage roofs on the property, accounting for half of the energy consumption for each facility.[25] Furthermore, 3,200 LED fixtures were installed in each parking garage with "daylight harvesting and dimming capabilities", ultimately saving "1.4 million kilowatt hours of electricity" each year.[26] Future plans for the airport's garages include variable frequency drives on cooling systems and more widespread photovoltaic installation as the original program completed in 2020.[27] Many local condominium homeowner associations have followed suit under the Energize Phoenix initiative and saved over 15% in energy costs due to more efficient LED lighting and cooling fixtures in their garages.[28] What should be noticed about Phoenix and it's parking efficiency initiatives is that few to none are implemented city-wide. Many of the programs are momentarily limited to small corridors of the city, as Phoenix looks to larger cities like Los Angeles as testing grounds for energy-efficient parking facilities. Furthermore, parking minimums remain in place and the city does not appear to have any plans regarding reducing the

[23] Ibid.
[24] Ibid.
[25] (https://www.skyharbor.com/about/Sustainability/energy)
[26] Ibid.
[27] Ibid.
[28] (https://www.osti.gov/servlets/purl/1158809)

number of garages built in the future. The barrier of homeowner associations and cost of either demolishing or retrofitting garages with efficient technology remains high.

Los Angeles faces many similar challenges to energy efficient parking facilities as Phoenix. As of 2020, parking minimums are of 1 to 2 spaces per resident or (depending on the type of building) one space for every hundred or more square feet.[29] For a city with 4 million residents, this amounts to about "5.5 million residential off-street, 9.6 million non-residential off-street" with statistics having increased in the past decade.[30] As a result, a city facing a housing crisis now finds itself with 14% of its land occupied by parking facilities it is unable to properly maintain.[31] LA's approach to dealing with excess parking facility impact, however, is perhaps less obvious than strategies employed by Phoenix. With many parking garages within the city being possibly a third empty throughout the day, the city's primary solution has been to fill those spaces, thereby reducing the amount of cars on the road looking for a spot. Recent developments have included wireless sensors underneath spaces to alert drivers with an app where a nearby space would be, reducing the drive-around traffic the city is prone to.[32] Prices would then vary based on occupancy daily, raising revenue significantly for city-owned infrastructure repairs and improvements.[33] This strategy is perhaps less effective in reducing emissions as desired, however. While smart parking technology could potentially reduce downtown congestion by 30%, without EV incentives, LA is doing little do encourage decreased travel or travel with zero-emission vehicles.[34] The only city-wide standard for parking garage

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[29](https://www.ladbs.org/docs/default-source/publications/information-bulletins/zoning-code/summary-of-parking-regulations-ib-p-zc2002-011.pdf?sfvrsn=24, 1)
[30](https://www.accessmagazine.org/wp-content/uploads/sites/7/2016/11/access49-web-do-cities-have-too-much-parking.pdf, 3)
[31] Ibid.
[32] (https://statetechmagazine.com/article/2017/02/cities-embrace-smart-parking-make-best-use-space)
[33] Ibid.
[34](https://reader.elsevier.com/reader/sd/pii/S1877042812043042?token=94E0FDEDD6C40FCF83174D889F21BCD4BEDD249B7F171DE0F47B51762D8723C0F496520AF9F6EEB19328AF0E0DAA8279&originRegion=us-east-1&originCreation=20211114180702, 1)

efficiency is in regards to enclosed space ventilation, though not specifically for cooling.[35] The Los Angeles Department of City Planning has proposed eliminating parking minimums as a plan to increase future space for affordable housing developments.[36] Plans regarding repurposing garages into housing units, including EV charging stations, and retrofitting garages with LED and fluorescent lighting have all been suggested to the city council but no concrete program has been created to reduce the impact parking structures have on the metro area.[37]

Where there seems to be unique initiative in LA county is in Santa Monica. In 2017, Santa Monica was the first city in the region to eliminate parking minimums.[38] And while new developments continue to provide parking beyond peak demand, the city has successfully created zero net energy parking facilities. In 2012, the Civic Center parking structure was constructed out of majority recycled steel and "Concrete [that] contains locally mined aggregate, and recycled fly ash".[39] The LEED certified building has 14 EV charging stations and photovoltaic panels covering the top level that generate all necessary energy for the facility while providing shade for the structure.[40] Water waste and runoff is filtered on site and reclaimed water lines reduce potable water use for nearby landscaping.[41] Lastly, the building uses natural light and open air to ventilate and light the building during lower occupancy or daytime hours.[42] Each of these strategies could be implemented county wide and ultimately reduce future management costs. However, the possibility of the city retrofitting garages with similar technology is unlikely

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[35](https://www.energy.ca.gov/sites/default/files/2021-01/2019_CEC-Enclosed%20Parking%20Garages-ADA.pdf, 1)
[36] (https://www.latimes.com/opinion/story/2020-02-05/los-angeles-parking-too-much-housing-for-cars)
[37](https://www.accessmagazine.org/wp-content/uploads/sites/7/2016/11/access49-web-do-cities-have-too-much-parking.pdf, 6)
[38] (https://www.latimes.com/opinion/story/2020-02-05/los-angeles-parking-too-much-housing-for-cars)
[39](https://www.smgov.net/departments/ose/categories/green_building/civic_center_parking_structure.aspx)
[40] Ibid.
[41] Ibid.
[42] Ibid.

(and as demonstrated with Phoenix) far more expensive than developing new parking. It is therefore up to the LA city council and county to follow Santa Monica's example in future efforts to reduce waste and energy expenditure of the parking garages that cover more than a sixth of their land. Again, reduction of future parking seems to only be successfully done by reducing parking minimums or creating parking maximums. Therefore, in addition to such a policy, it is essential that the city considers changing current parking facilities to reduce their heat generation and cost to the grid.

Austin is the smallest city of the three examined and still faces the issue of excess parking and energy inefficient facilities. In downtown, 70-80% of garage space is left empty throughout the day, with little decrease during peak demand.[43] Yet, the space garages occupy throughout the city has not changed in response to this demand. What makes Austin unique in this struggle is that a fourth of these off-street spaces are restricted to the general public, requiring just as much maintenance but bringing nothing in revenue.[44] The city of Austin has placed precedence on lowering parking costs and making garages in high-traffic areas more accessible.[45] Their reasoning mimics that of LA's smart parking program: Reduce congestion produced from circling, and maximize the infrastructure available through private-public partnerships rather than encourage new construction. This is accompanied by a widespread EV charging station initiative though these are primarily located on-street near major transit routes.[46] Therefore, rather than incur the cost of retrofitting or designing new garages, Austin will make parking facilities more accessible while incentivizing EV use. Again this is not an unreasonable strategy in shortening commutes and reducing pollution but it ignores the bigger picture of the harm large

[43] (http://www.austintexas.gov/edims/document.cfm?id=280607, 15)
[44] Ibid. 16
[45] Ibid.31
[46] (https://austinenergy.com/ae/green-power/plug-in-austin)

parking facilities have. In 2019, Austin's central business district voted to eliminate parking minimums and place codes on garage height, thereby disincentivizing new construction and encouraging more underground garages.[47] The elimination of parking minimums in parts of large cities across Texas is common, and outpaces any similar action in the other two states discussed.[48]

What stands out in Austin's parking infrastructure is a garage that made headlines in 2014 for being built with the intention of preserving the surrounding ecosystem. The garage is open air, shaded by vines covering steel screens and a "planted green roof" over the top level for local wildlife.[49] The openness of the garage allows for natural lighting for a large portion of the day, regardless of occupancy throughout the day. Lastly, the structure contains a water detention pond on the roof where "water collected from the roof enters a cistern...and is used to irrigate the roof and surrounding landscaping."[50] Unlike the previous structures examined (in either LA or Phoenix) this focuses on reducing land-use impact and water conservation though it is unclear as to whether the facility uses cool pavement or efficient lighting. Furthermore, it faces the issue of still providing incentive for sprawl and auto commute, with low prices that do not allow for sustainable maintenance.

Also among Austin's sustainable parking examples is the Parking Spot-owned garages and lots at Austin International Airport. The company used Austin as a testing ground in 2017 for their canopy covered parking that has earned LEED designation and features 100% LED lighting.[51] Not seen in previous examples, this facility uses "old spoil piles and concrete slabs" to

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[47] (https://www.austinmonitor.com/stories/2019/02/2019-could-be-the-year-to-end-city-parking-minimums/)
[48](https://www.strongtowns.org/journal/2018/11/23/a-map-of-cities-that-got-rid-of-parking-minimums-updated?rq=parking)
[49] (https://john-blood.squarespace.com/t3-parking-structure)
[50] Ibid.
[51] (https://www.theparkingspot.com/blog/new-austin-location)

minimize transportation or production related pollution.[52] The runoff of these materials is then managed with onsite filtration.[53] The facility is additionally covered in reflective, cooling coating that reduces the heat island effect.[54] Austin's local government followed suit in 2021 and covered remaining parking garages at the airport with 6,642 solar panels, "and will generate enough solar energy to power up to 160 homes per year" in addition to providing power to nearby airport facilities.[55] As Parking Spot has facilities at 21 different airports around the US, it is possible that this design could be expanded nationally, regardless of local action.

When looking at the three cities examined, a few common themes are present. Local governments are hesitant to eliminate parking minimums on a widespread scale for fear that suburban or high traffic urban center areas will not have proper parking access. As a result, every city is left with a burdensome overabundance of parking spaces that they do not generate nearly enough revenue to maintain. Rising temperatures and poor material usage increase the harm these garages have on their surrounding environments, especially in these cities with warmer climates. Construction and sprawl cannot stop, however, until better public transportation options are provided or parking minimums are eliminated. Second, demolition of barely used parking infrastructure is practically unheard of in each of these cities. Small scale projects through specialty architects or neighborhood initiatives are the most likely to take control of parking garage renewal and efficiency at the moment, while local government initiatives are more likely to focus on pricing and minimum regulation. The focus on efficiency will then be placed on new construction, though strategies that do not have the same cost as retrofitting garages with EV charging exist. Phoenix and Austin's example of including greenspaces and covering pavement

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[52] Ibid.
[53] Ibid.
[54] Ibid.
[55](https://austintexas.gov/news/austin-bergstrom-international-airport-and-austin-energy-unveil-large-community-solar-project-atop-parking-garage)

with cooling coating are options regardless of when the garage was built and can significantly reduce the heat (and therefore energy cost) of the facility. LED or fluorescent lighting can replace current lighting with sensitivity to both occupancy and time of day. Concerns with ventilation and water usage would be focused on new construction. Recycled materials and onsite water filtration can all reduce the polluting effects of garages and help with water conservation efforts. EV charging can be implemented in new construction as well as on on-street parking as a more indirect means of discouraging regular pollutive commute.

Programs suggested to local councils such as garage repurposing for housing crises, adaptation for shared autonomous vehicles, or narrowing future construction to exclusively underground structures seem far down the line and highly unlikely. It is therefore crucial to look to these three cities' efforts towards sustainable parking as examples in reducing the many ramifications parking garage construction has on the environment and energy consumption.