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Rebuilding Silicon Valley - An Assessment of the Silicon Valley Corporate Campus and the Potential for Suburban Sustainability

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Rebuilding Silicon Valley: An Assessment of the Silicon Valley Corporate Campus and the Potential for Suburban Sustainability

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Abstract

Silicon Valley is the San Francisco Bay Area's economic powerhouse and is herald for its innovation and success. However, Silicon Valley's urban design is unsustainable and characterized by remote and large corporate campuses that contribute to job sprawl and heavy traffic congestion. Many of the buildings are also not performing at an efficient level and are due for deep overhauls to cut back energy consumption and costs. The inevitable effects of climate change continue to loom large over the world, heightening the importance for the built environment to be reformed into an environment that can mitigate and adapt to climate change impacts. The standard template of the corporate campus is the antithesis of sustainability, and thus contributes to a region that is developing inefficiently and increasing the built environment's carbon footprint. In this paper, current corporate campuses are evaluated to gauge their sustainability and to develop recommendations for improvement. The core issues found within the corporate campus model are locational and transportation issues, campus layout, and building design. It is suggested that campuses be redesigned to be more accessible by transit other than vehicles, be proximate to services and amenities, be pedestrian and bicyclist friendly, and have highly efficient building design. While the issues with the corporate campus are understood, many are still being developed inefficiently due to resistance within the company and local governments. Further research is required to determine how companies can best be encouraged to relocate or reform their corporate campuses and how local governments can be pushed to update policy and support Silicon Valley's shift towards a more sustainable urban form.

Introduction

Silicon Valley is the mitochondria of the Bay Area's economy and a hub for the most innovative companies in the nation. Silicon Valley's innovative backbone has led to some of the United States' most elaborate and creative new developments, but now, with pressures from climate change, steep land costs affordable only to region's most successful companies and the minimal availability of undeveloped land, reforming the existing corporate campuses has become a necessity (Arieff and Warbug, 2016). Despite Silicon Valley being inhabited by some of the worlds brightest, most advanced, and creative thinkers, regional growth has been marked by unsustainable suburban development that has been characterized by the isolated, auto-dependent, low-slung, suburban corporate campus - the primary form of real estate for Silicon Valley employers (SPUR, 2017). The perception of Silicon Valley employers is that they are on the forefront of sustainability practices, with most supporting sustainability programs and initiatives (Sanquiche, 2017). However, many have situated themselves into workplaces that don't match the innovation occurring within (SPUR, 2017).

In the United States, the built environment accounts for up to 50% of global carbon dioxide (CO_2) emissions with the construction sector being responsible for a large portion of the environmental impact caused by human activity (Khasreen et al., 2009). In 2014, buildings were responsible for 12% of total U.S. greenhouse gas emissions (U.S. EPA, 2017), and in the year prior, 968 million metric tons of CO_2 were emitted due to the consumption of fossil fuels to supply energy to commercial buildings (U.S. EIA, 2015). Commercial buildings alone account for 18% of the United States' energy consumption and are responsible for 49%-65% of total building energy consumption during the non-working hours of both weekdays and weekends (Kim and Srebric, 2016). Buildings are also heavy users of other natural resources other than energy; water use in the building sector was estimated to be 39.6 billion gallons per day in 2005 with water usage in the commercial sector growing twice as fast as the U.S. population growth between 1985 and 2005 (U.S. DOE, 2011) and commercial buildings are responsible for about 45% of the 150 million tons of waste in the United States (EPA, 2016). In the same way, transportation is responsible for a large portion of the greenhouse gas emissions that contribute to climate change. In 2015, the transportation industry alone was responsible for 27% of United States greenhouse gas emissions (EPA, 2015) and has also contributed to the emission of certain criteria pollutants, such as Carbon monoxide (CO), Nitrous oxide (NOx), PM-10, and PM-2.5 (Wilson and Navaro, 2007). With this in mind, it is crucial that the region reforms its sprawled suburban commercial growth into accessible and dense urban-like centers that lessen the built environment's impact on climate change.

While commercial growth in the city of San Francisco is booming, many Silicon Valley companies are still choosing to establish themselves out of urban centers as their work environments rely on campus settings that provide advanced security and large continuous floorplates that enhance corporate culture and encourage collaboration (Terplan and Grant, 2012). However, urban amenities, such as pedestrian and bike paths, access to public transportation, proximity to retail, community facilities, and public open spaces are highly desired by many of the region's young and creative workforce, prompting some companies, like Google and Facebook, to redesign their current campuses to create more sustainable urban-like settings (Terplan and Grant, 2012). These companies are on the forefront of achieving a sustainable corporate campus and represent the exception not the norm. A more sustainable corporate campus opens the opportunity to lessen the region's environmental footprint, strengthen company culture, increase employee happiness, reap cost benefits, and showcase a company as an innovative, sustainable leader. The current template of the corporate campus contributes to higher air pollution, water pollution, and heat impacts than urban workplaces due to their auto dependency, large surface areas, and high usage of pavement (SPUR, 2017). As the inevitable effects of climate change continue to take form, the need for companies to redesign their campuses into more environmentally sustainable workplaces is rising.

This paper will explore the current state of the Silicon Valley corporate campus and the decisions that drive employers to develop them. A comprehensive review on the corporate campus model's urban and building design will be conducted to determine its potential for sustainability. Current and future campuses will be evaluated to establish common themes, successes, and failures among developments and be used to understand the feasibility of suburban sustainability and region wide reform. This paper will present recommendations for developing the suburban corporate campus into more efficient workplaces by addressing core issues, such as location, transportation, and campus form.

The Evolution of the Suburban Workplace

Silicon Valley Corporate Campuses, and their current challenges, are an outgrowth of the suburban mindset in the United States that took root after the completion of World War II in 1945. Urban growth in the United States at the time was characterized by low-density, decentralized suburban development (Goetz, 2011) and by 1950, the suburban growth had expanded ten times the rate of central urban growth (Hoffman and Felkner, 2002). Facilitated by factors, such as population growth, automobile demand, and improved transportation infrastructure, suburbanization became the standard form of development. This was emphasized when the baby-boom period hit the United States and increased the need for housing. During this time, suburban development became a business and the suburbs were marketed as the ideal location to raise a family. Moving to the suburbs allowed for families to have larger and cheaper homes and seclude themselves from the city's higher crime rates. In time, the home had become a reflection of success, with the suburban home being marked with high accomplishment (Hoffman and Felkner, 2002).

As the demand for suburban housing development increased, urban commercial decentralization quickly followed suit with manufacturing, hospitals, schools, and retail stores moving out of cities to join the new-wave of suburban communities. The last of commercial land uses to develop in the suburbs was the business workplace (Mozingo, 2011). Suburban areas began to attract employers as they allowed for them to capitalize on cheaper land prices, access a more educated workforce, contract with fewer unions (Grant, 2016). Following the country's economic rise after World War II, competition with in the labor market increased and required corporations to build workplaces that attracted qualified employees, who were in search of attractive open settings, access to parking, and employment near their suburban homes (Britton and Hargis, 2015). Corporations, such as AT&T Bell Laboratories, General Motors, General Foods, and General Life Insurance Company were the first to spearhead the corporate move into suburbia and contributed to the mold of commercial suburban form commonly seen today (Mozingo, 2011).

Distinguished by the site layout of buildings, parking infrastructure, roadways, and green spaces, the corporate campus and the business office park became the framework for commercial development (Grant, 2016). First developed in the 1940s with inspiration from the university campus, the corporate campus contained a site plan that contained large parking areas, laboratory facilities, and office space situated around a central greenspace. The purpose of the corporate campus was to stimulate corporate research, facilitate collaboration between peers, and is commonly used by technology and engineering based corporations. This commercial landscape was typified by AT&T Bell Laboratories who built the first corporate research campus in 1942. The campus, which was built in Murray Hill, New Jersey, contained multiple lab buildings and lounge areas for suited for socializing and collaboration within a parklike setting (Grant, 2016), a structure not unlike the Silicon Valley campuses of today.

Shortly thereafter, the business office park was developed to provide multi-business alternative to the corporate campus for smaller companies unable to inhabit an entire campus on their own. Tenants of these communities tended to be lower-level corporate management and start-up companies who were attracted to the flexibility and lower-cost of the office park (Mozingo, 2011). As individual corporations increasingly developed new suburban workspace, the corporate campus and office park became a symbol of corporate class and power, inserting these landscape types as standard forms of development (Mozingo, 2011).

The Birth of Silicon Valley

The foundation for what we now know as Silicon Valley was laid during World War II when Stanford University's Engineering Laboratory received federal funding for electronics research and development. Shortly thereafter, Stanford University, located near Palo Alto in Stanford, CA, became a home for proto-firms to innovate and collaborate on their ideas before eventually breaking off into their own independent firms. Through these means, companies such as Hewlett-Packard, Cisco, Google, and Yahoo were born (Saxenian, 1991). The high proximity of technology companies within Silicon Valley exploded further when Fairchild Semiconductor, a developer and manufacturer of silicon transistors, was created in 1957. Founded by eight engineers who left their difficult boss and inventor of the transistor, William Shockley, Fairchild Semiconductor laid the framework for Silicon Valley's entrepreneurial culture and supported the benefits of leaving established enterprises to start new ventures (Grant, 2016). Numerous Fairchild Semiconductor employees left to develop over 30 companies within the corporation's first 12 years, including Intel and Advanced Micro Devices (Grant, 2016).

By the 1960's, Silicon Valley was recognized for its high-tech entrepreneurship, with a new firm entering the area's electronics industry every two weeks. Unique in its large number of successful, high-growth companies, Silicon Valley became the birthplace of the start-up culture as large academic research groups and existing firms continued to foster up and coming technology champions (Etzkowitz, 2013).

In the 1980's local firms, such as Apple Computers, Hewlett-Packard, and Intel had grown very large, increasing their need for expansive and collaborative workplaces. As more employers began to settle in the Bay Area's suburban communities, the commercial landscape of the Silicon Valley corporate campus was born (Grant, 2016). By the 1990's, Silicon Valley's more recognizable companies began to invest in expansive corporate campuses in the suburbs, close to the homes of many of their early employees. Sun Microsystems built an 11-building, 1 million square foot Menlo Park campus, now inhabited by Facebook's East Campus, and Silicon Graphics opened their Mountain View campus that is the present-day Google headquarters (Grant, 2016). The region evolved alongside the developmental postwar mindset that popularized the suburb. The cheap, expansive land plots and advancements in road and highway infrastructure paved the way for early Silicon Valley decision makers to develop their corporate campuses in remote suburban locations (SPUR, 2017). Now, Silicon Valley is characterized by large technology campuses that are not all as innovative as their tenants or the area they call home.

Dissecting the Corporate Campus Model

Attractive for its strong corporate branding, intended facilitation of collaboration, and the ability to entice and retain employees, the corporate campus has been utilized in some capacity by companies over much of the past century (Becker et al., 2003). These workplace behemoths offer a variety of benefits for large regional based companies, such as security, community centered workplaces, and control over property and operational costs and quality (Grant, 2016). In the earlier years these campuses were a great success, seemingly providing more positives than negatives. They were easily accessed by vehicles, contained ample free parking, were located close to employee homes, and provided a wide range of perks to their employees, such as cafeterias and on-site gyms (SPUR, 2017). In short, the standard corporate campus model served its purpose by creating competitive and interesting environments that spurred innovation, protected intellectual property, and attracted talent in the workforce (SPUR, 2017).

However, the drawbacks of building a corporate campus tend to be overlooked when investing the time and money to develop them. Over the past decade, Silicon Valley has seen a rapid production of corporate campuses, characterized by a dense, single tenant, multi-building site plan that is surrounded by surface parking, landscape buffers, but that lacks the appeal of urbanism (i.e. walkability, access to amenities, diversity, etc.) that many employees desire (Grant, 2016). While companies such as Google, Samsung, and Facebook have made a conscious effort to build energy efficient and sustainable campuses, many of the existing campuses are remote, have inefficient energy performance and poorly planned land use patterns (Grant, 2016). The potential impact of corporate campuses on the environment is a prevalent issue as the Bay Area's population and economy continue to grow. This section presents an overview of the core issues found within the standard template of the Silicon Valley corporate campus.

The Buildings

The corporate campus model contains a multi-building site plan and for established companies, such as at Google and Facebook, supports the power, heating and air conditioning loads, water, and waste usage of nearly 15,000 employees (BASF Corporation, 2010). Occupancy levels and behavior play a considerable role in the energy consumption of a commercial building (Kim and Srebric, 2016) and the immense number of employees within a campus can use the same amount of resources as a small community. The larger technology companies that inhabit Silicon Valley require multiple laboratories, IT rooms, and data centers within their campuses that require extensive cooling energy to maintain and operate. They also have an assortment of jobs on site that require the use of a variety of energy-using equipment throughout the day.

The specific building design on a corporate campus varies dependent on the companies who inhabit them and the location in which they are developed. The range from multi-short-story, conventional modular buildings, such as Cisco's campus in San Jose, to urbanized ten-story high-performance towers, like at Samsung Semiconductor's San Jose headquarters. Some campus buildings are as simple as Facebook's West Campus, which has single, expansive open office floor that is sandwich between a rooftop garden and parking garage (SPUR, 2017). There is not a set prescription for the corporate campus building as there are a variety of factors that determine what is built, and while some companies have chosen to build or retrofit their campuses to have energy efficient and green buildings, there are still many performing at or below conventional levels (SPUR, 2017).

Additionally, these purpose-built corporate campuses are not inherently adaptable or flexible like the companies that tend to inhabit them and don't provide the growth and exit strategy they desire. Once vacated, it is difficult for developers to re-work these large fixed structures into workplaces suitable for other uses as they were originally designed to establish brand identity, causing many leftover campuses to be used inefficiently and ill-suited to the need of their tenants (Grant, 2016). Apple's newest 2.8 million square feet campus, Apple Park, commonly known as the "spaceship" (Figure 1) is the most expensive commercial office building in history and was designed specifically to meet Apples' current corporate requirements (SPUR, 2017) and at the end of construction will be a fixed megastructure best suited only for a particular type of company making it difficult to reform if it is abandoned (SPUR, 2017).

Figure 1: Apple Park "Spaceship", Cupertino, CA Source: MacWorld, IDG UK

For tenants these inflexible, large corporate campuses can also have negative economic impacts as inefficient buildings cost more to maintain and operate. Tenants are more likely to spend more on power bills due to the lack of energy savings that are found in more efficient buildings (World Green Building Council, 2013). The design and performance of the buildings that make up a corporate campus contribute greatly to their overall impact on the environment and should be a key focus point in developing more sustainable corporate campuses.

Location, Transportation, and Connectivity

Beyond the building envelope and operation systems, the current model of the Silicon Valley corporate campus also contributes to major traffic congestion and longer commutes time (Wey, et al., 2016). Although originally the workforce resided primarily in the suburban neighborhoods in towns surrounding the campuses, this is no longer entirely true. Many Silicon Valley employees are now commuting from their homes in an urban center or another suburban area than where they work (Terplan, 2009). The proximity to housing plays a critical role on corporate campus sustainability. However, the region currently does not provide enough affordable housing for the amount of people who work in it. From 2011-2016, the Bay Area added 546,000 jobs but did not match this growth by building new housing. In the same time frame only 62,600 housing units were added, causing a lot of competition between residents and driving up housing prices (SPUR, 2017). The housing costs and shortages in the Bay Area has contributed to a region that is too expensive for some to afford, forcing many employees to live far from their workplaces (SPUR, 2017). In addition, corporate campuses tend to be located miles outside of urban centers, causing most to be auto-dependent as they cannot be easily accessible through other means of transportation. The reliance on automobiles has increased the United States' energy consumption and the emission of air pollutants into the environment. *Environmental Building News* (EBN) calculated that the transportation energy intensity used to get employers to and from work accounts for 30% more energy than the average office building itself and when compared to the energy consumption of a more energy efficient building, transportation energy surpasses the building's operation energy by 137% (Wilson and Navaro, 2007).

The expansiveness of Silicon Valley (Figure 2) has allowed for a disorganized development of workplaces across the region and complicates the ability for transit to serve the entire region efficiently. The Silicon Valley corporate campus has exacerbated the human impact on the environment by promoting unsustainable commute patterns and subsequently emitting more greenhouse gasses into the atmosphere through car-dependency. Additionally, peak traffic and congestion causes travelers to spend a large portion of their day sitting in traffic and can cost them as much as $1,000 in wasted fuel and time (Terplan, 2009). This can contribute to an unhappy workforce who would like to spend less time in their cars and less money on fuel and resources. Furthermore, as Silicon Valley's companies continue to grow the need for more space has resulted in the addition of office buildings to some already large campuses. In many cases office space is separated from the services and amenities that many corporate campuses offer and has resulted in the need for some employees to travel through vehicle to access the other buildings on campus. Thus, the redesign of the transportation map used to access Silicon Valley's corporate centers and navigate within them is a critical component to developing a more sustainable workplace and region.

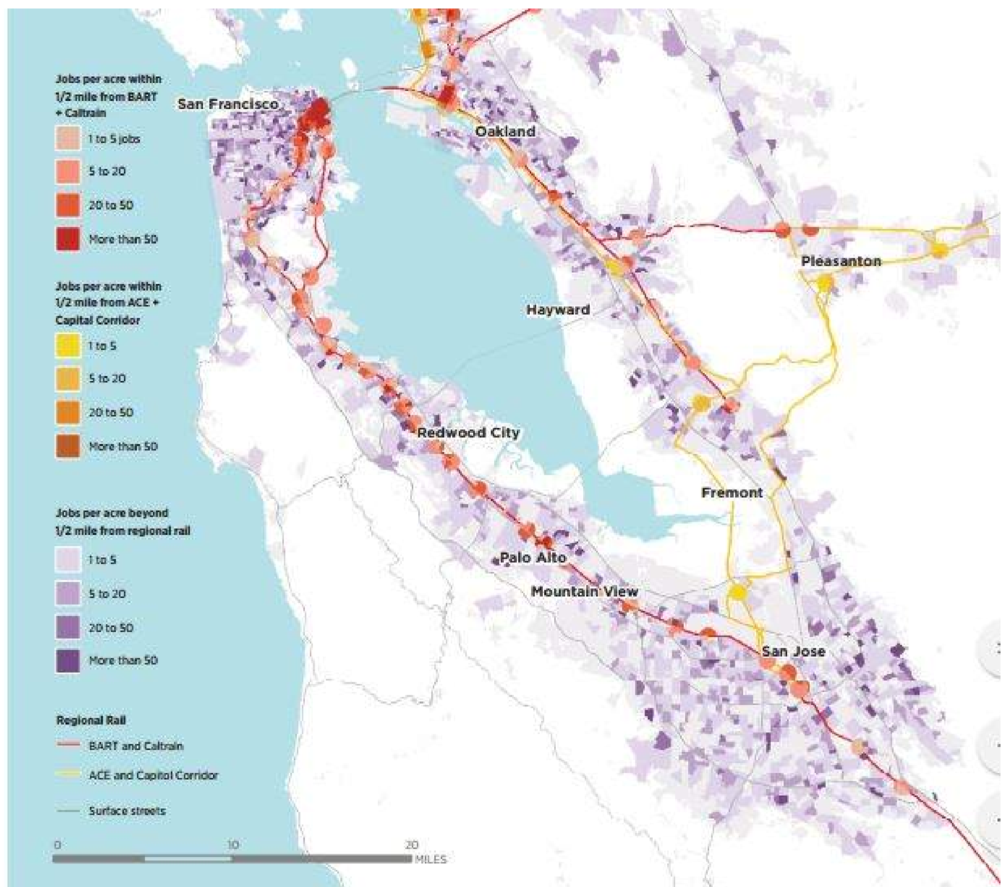

Figure 2: Job Density in 2015 relative to regional transit Source: SPUR, Rethinking the Corporate Campus, 2017

Parking and Pavement Management

The typical corporate campus is surrounded by an expansive asphalt parking lot (Figure 3) that can accommodate more than the number of employees who inhabit it (Cervero, 2006). Poor parking management suggests to employees that single-vehicle commuting is an acceptable form of transportation because, in most cases, driving is more convenient than other forms of transit when ample free parking is available (Wilson and Navaro, 2007). In 2009, the U.S. Environmental Protection Agency (EPA) listed parking as a key hindrance in reaching sustainable communities (Talen, 2012). Parking lots are built out of impervious pavement that cause polluted storm water runoff due to water being unable to permeate the surface. Large areas of pavement also contribute to the urban heat island effect as they absorb high amounts of solar energy, which results in higher surface temperatures and worsened smog conditions (Talen, 2012).

Figure 3: Bell Labs, Murray Hill, NJ Source: SPUR, Rethinking the Corporate Campus, 2017

The corporate campus parking lot consumes a large surface area and is only used for a portion of the day. This results in a large and unusable dead space in the evenings that provide no other benefits to the environment or community. Parking lots can also seem unsafe, take a long amount of time to cross, and make the surrounding environment, natural and built, less interesting (Wilson and Navaro, 2007).

Addressing the parking problem is critical for improving traffic congestion, encouraging employees to use other means of transportation, and protecting the environment. Using better parking management in site design will also make the corporate campus more appealing to tenants and visitors as the majority of surface space will not be covered by asphalt.

Services and Amenities

The standard template for the corporate campus often provides employees with amenities, such as cafeterias and wellness centers or gymnasiums (Mozingo, 2011). However, these can be limiting and provide employees with minimal options for food and service (Mozingo, 2011). When a campus is in a suburban area rather than an urban area, employees are not able to walk to nearby restaurants, service centers, or retail stores. This requires them to return to their vehicles to complete errands in the surrounding suburban area due to the lack of on-site consumer services and inadequate pedestrian pathways (Cervero, 2006).

The access to amenities and support services has been a core selling point for the future workforce as many other companies are able to provide similar salaries and benefits (Arieff and Warburg, 2016) to their employees. As the technology industry becomes more competitive, many have already begun to add extensive amenities and services to their campuses to create workplace settings that bring their employees closer to the services they desire and lessen the need to use vehicles to reach them. While some campuses are amenity-rich, the type and amount of amenities and services provided is not uniform across the region. Additionally, many campus amenities are not open to the public, making them less useful to the community and segregates the corporate campus from the surrounding region (SPUR, 2017).

Reforming the Corporate Campus

As a more economically developed country, much of the United States' built environment has already been formed, heightening the need to optimize the country's existing buildings. Existing buildings represent 85-90% of the entire building stock in the United States and typically have inefficient building systems and infrastructure (Abaza, 2015). This vast stock of buildings, many developed decades ago when sustainability was not considered, need to be retrofitted to effectively diminish the built environment's carbon footprint (Miller and Buys, 2008).

The United States government has placed emphasis on the importance of green retrofitting in recent years by establishing policies that address the environmental and energy concerns amplified by the built environment. For example, the Energy Policy Act of 2005 created the 179D Commercial Buildings Energy Efficiency tax deduction that enables buildings owners to claim a tax deduction of $1.80 per square foot when they install operational or building envelope systems that reduce the building's total energy and power cost by 50% or more compared to meeting minimum building requirements set by the ASHRAE Standard 90.1-2001 or 90.1-2007 (DOE, 2016). Additionally, to combat their own energy usage, the United States federal government is required by Executive Order 13693 to reduce agency building energy usage by 2.5 percent annually through 2025 (U.S. EPA, 2015).

Over 77.9 billion square feet of the U.S. built environment is commercial building space; however, the amount of retrofit activity in this sector remains low due to a variety of reasons including the uncertainty in the success and cost-effectiveness, lack of general knowledge on retrofit projects, and insufficient incentives (Bernstein, 2011). Green retrofitting existing buildings is thought to be more difficult than developing a new green building from the ground up as retrofitting projects require the participation and cooperation of a variety of stakeholders, such as owners, managers, tenants, contractors, and engineers, and the design can be limited by the building's current shell. Ultimately, the environmental consciousness of stakeholders alone is not enough to incentivize them to retrofit without also presenting proven cost benefits and consumer demand (Miller and Buys, 2008), but while the task can seem daunting, it has been proven that through integrative design and collaboration, retrofits can result in high energy and cost savings, and have rising market potential and demand (Nock and Wheelock, 2010).

The redesign of an existing corporate campus would require a complete overhaul to the campus buildings and site plan best completed through a deep retrofit. Deep retrofit projects use an integrated whole-building design process to achieve larger energy, water, and waste savings than what can be achieved through other methods of retrofitting, such as retro-commissioning and standard retrofits. Through the integrated design process all building systems are viewed and evaluated as one overall system and can involve the concurrent retrofit of multiple systems including the building envelope, mechanical systems, and lighting systems. (Moser et al., 2012).

However, as it is inevitable that some companies will build new campuses throughout the region, it is important to discuss how new developments can also be designed sustainably. The integrated design approach can be used on both new development and retrofit projects and includes the collaboration of architects, contractors, engineers, and consultants who use their individual expertise to design building systems that will meet the owner's needs and save energy and resources (Energy Design Resources, 2002). As the issues with the corporate campus extend beyond the buildings themselves, it is imperative that the design team uses a whole campus systems view to design campuses that incorporate urban and building design to optimize energy savings, sustainability, cost-effectiveness, and meets the owner's specific goals. Changing the corporate campus model requires focus on four key areas: location, transportation, campus layout, and building design. The following sections, methods for improving these areas will be explored. Examples from current corporate campuses will be used to support the feasibility of implementing sustainable changes to the corporate campus.

Location and Transportation

Silicon Valley's booming economy has added 640,000 jobs between 2010 and 2015 with 36% of job growth being in the knowledge and technology sector (SPUR, 2017). Despite new job growth being led by the most innovative companies in Silicon Valley, the region is still growing unsustainability with only 28% of the Bay Area's new office development occurring near transit and when San Francisco is not considered this percentage decreases to 9% (SPUR, 2017). The chosen location of a corporate campus can be a driving force behind the campus' ability to reach sustainability. Location can have an influence on commute, building form, and employee happiness and well-being. It should be the first and most important consideration for building owners in both new development and campus retrofit projects.

Ideally, the corporate campus should be located in an accessible area that contains multiple transportation options and is near basic amenities and services. As location has a heavy influence on commute patterns, campuses located in areas that are well-served by transit will contribute to reducing single-occupancy vehicle commuting and subsequently contribute to the reduction of energy consumption and greenhouse gas emissions from transportation energy (SPUR, 2017., Wilson and Navarro, 2007). It is important for companies to plan their campus around access to public transportation to decrease car-dependency as shown by Juniper Networks, who strategically developed their new campus near regional transportation hubs in Sunnyvale to encourage the use of public transit (Todd and Silkwood n.d), Box who is stationed in two seven-story towers above the Redwood City CalTrain Station, and Samsung who's headquarters is adjacent to a light rail station in San Jose (SPUR, 2017). The selected location of a corporate campus can have several locational related impacts on the environment, corporate overhead, and employee recruitment and retention. After Los Angeles, the San Francisco Bay

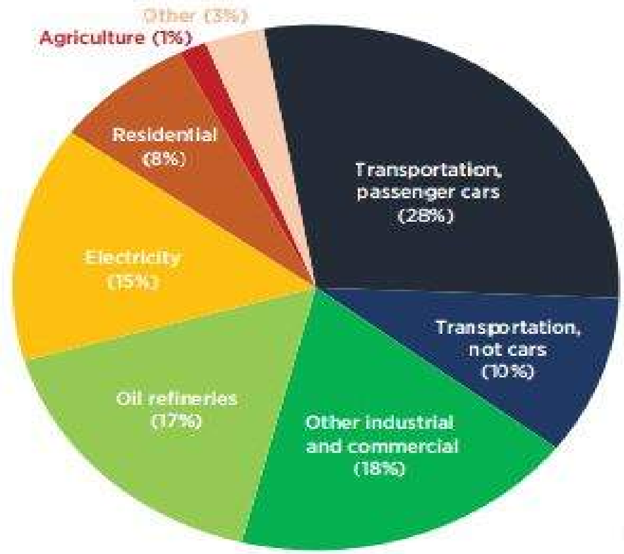

Figure 4: Sources of Greenhouses in the Bay Area Source: SPUR, Rethinking the Corporate Campus, 2017.

Area has the highest total delay and commuter stress of any other United States' metropolitan area (SPUR, 2017). Commuters in the Bay Area are spending 57% more time in their cars during peak rush hours than they would be if traveling during off-peak and it is estimated that cars account for 28% of greenhouse gas emissions in the Bay Area (Figure 4); therefore, the development of corporate campuses in car-dependent locations is increasing the region's contribution to climate change (SPUR, 2017). As the competition for talent in Silicon Valley grows, companies are forced to find ways to make their remote campuses more accessible and appealing. In some cases, the lack of access to public transportation has led companies to expend costs on improving transportation services for their employees. By locating a campus near transit centers from the start of development, companies will be able to better maintain their environmental impact, reduce excess cost on transportation programs, and improve employee satisfaction in their commutes.

The current sprawl found in Silicon Valley is a unique challenge because unlike most suburban areas, many employees live in the Bay Area's central cities and commute into the suburbs for work. As of 2015, only 21% of jobs and 9% of new office development in the Bay-Area are within a half-mile of public transportation (SPUR, 2017) forcing many employees to commute by car. While expansions are planned for the Bay Area Rapt Transit (BART) and Caltrain systems, improvements are not being made at a pace that can meet demand and forces Silicon Valley companies to become more creative in addressing the congestion and transportation problem their employees face daily. For some companies, new development is not an option as they may already have well established campuses or cannot afford the cost of a ground-up project making their locational and transportation problems harder, but not impossible, to address. Companies can create shuttle programs, as used at Facebook and Google's respective campuses, to create a more efficient mode of transporting employees to work. Comfortable and energy efficient shuttles, such as natural gas fueled and hybrid biodiesel shuttles can be used to transport employees to and from city centers (long-haul shuttles) and public transit stops (last-mile shuttles), and reduce single occupancy single commuting. This will help relieve traffic congestion, lessen commuter stress, and decrease transportation energy intensity (Wilson and Navaro, 2007, SPUR 2017).

Providing services and incentives that encourage the use of cleaner methods of transportation, such as bicycling, is another option. Bicycle accessibility is crucial to achieve transit-oriented development. While some employees may have a commute that is too long to travel by bike, it is important for campuses consider bicyclists in their design. The addition of designated bicycle lanes, paths, and trails that connect the campus with its surroundings can encourage bicyclist to use their bikes more often. Oracle's Redwood Shores campus is surrounded by the Bay Trail, which directly connects to the O'Neill Slough 101 pedestrian overpass to allow employees and visitors ease of access from the Belmont CalTrain station to the campus (Oracle Corporation, 2014) and Facebook partnered with the City of Menlo Park to improve bicycle routes and make their campuses more accessible by bike (Atkins, 2012). Additionally, Facebook's campus expansion that is slated to be completed in 2020 will add a new pedestrian and bicycle bridge over the Bayfront Expressive that improves transportation connections between the city's popular Belle Haven neighborhood to the campus (City of Menlo Park, 2016). While bicyclists need to have safe and accessible paths they will also need to feel comfortable throughout their work day following a ride into campus. Depending on factors, such as the weather and travel distance, bicycling can cause employees to get dirty and sweaty; therefore, providing secure bike storage and changing facilities is a necessity to make cycling a practical commuting option (Wilson and Navaro, 2007). Juniper Networks followed this by installing bike storage with shower facilities to allow employees the ease of security and washing up after their ride (Todd and Silkwood n.d.).

Using transportation demand management and developing a campus specific program is another solution to reduce single vehicle driving. Transportation demand management removes driving incentives, such as ample and free parking, and replaces them with incentives that promote other modes of transportation. Facebook initiated a transportation demand management program at their campus to combat single occupancy vehicle driving and support alternative commutes. A daily trip cap was created for employees and visitor travel to incentivize people to access the campus in a different manner (Atkins, 2012).

It is not realistic to assume that all employees will chose or be able to use alternative modes of transportation. Therefore companies should work to promote fuel-efficient vehicles and prioritize their use over standard vehicles. Providing incentives to fuel-efficient vehicle drivers can motivate them to choose more energy-efficient vehicles. Google has the largest corporate electric vehicle charging infrastructure in the United States that offers free charging to employees who use electric vehicles (Google, 2016). Similarly, Juniper Networks saved a considerable space in their parking lot for preferred electric-vehicle parking complete with charging stations (Todd and Silkwood n.d.).

Aggressive transportation programs are proven to be successful in the corporate campus setting. Google has achieved a rate of only 46.3% of employees who commute alone by car through their long-haul and last-mile shuttle services, providing carpool programs and incentives, and have campus car sharing (SPUR, 2017). Ultimately, to reduce single-occupancy travel companies will have to encourage employees to use alternative transportation modes by making them easier, cheaper, and more pleasant to use.

Location and Accessibility to Services and Amenities

The proximity of a campus to basic services and amenities is critical factor to consider when choosing a location for a corporate campus. Integrating services and amenities to create a mixed-use workplace is important to create a campus that is sustainable and competitive. Many employees who drive long commutes to reach their remote suburban campus are left with no choice but to drive considerable distances from work to get food and complete errands (SPUR, 2017). Therefore, campuses that are not in an amenity rich area should focus on bringing services and amenities to their campus to reduce the need for employees to leave the campus and drive to access services. People need to be able to accomplish multiple things in a day to satisfy their needs and with the amount of time spent commuting and working at a suburban campus, employees should easily be connected to a variety of amenities that would commonly be found at urban workplace centers (SPUR, 2017). Established corporate campuses have begun to create amenity rich settings. Facebook notably retrofitted their campus to incorporate a mix of retail and commercial services to their employees by designing a “Main Street” within the campus that built on the urban experience wanted by their employees. Facebook’s Main Street (Figure 5) is compact, walkable, and centered on a courtyard that features streets and alleys, retail, food, and service centers, such as doctors' offices, hair salons, and bicycle repair shops (Crescimano, 2012).

Figure 5: Facebook Main Street, Menlo Park, CA Source: SFGATE Photo: Leah Millis/The Chronicle

The access to affordable and nearby housing is another vital component of creating a sustainable workplace. The proximity of employee housing to job centers plays a significant role on commute and employee lifestyle. The notoriously limited and expensive housing in the Bay Area has made it difficult for employees to live nearby prompting some companies to consider the addition of housing to their list of amenities (SPUR, 2017). On-site or near-site housing units allows for employees to cut commute times, decrease regional congestion and greenhouse gas emissions, and accomplish more in the day as they don't have to travel long distances home at the end of the work day (SPUR, 2017). While adding housing to a campus is a developing concept, there has been movement in Silicon Valley with companies like Facebook and Google proposing the addition of housing units to their respective campuses (SPUR, 2017). Large companies who have offices in multiple locations or employees traveling from around the world can also find benefits from building hotels on their campus. Juniper Networks' 300-room hotel allows remote employees to travel to Sunnyvale and stay on campus, removing the need to commute long distances from an off-site hotel for work (RMW, n.d.). Facebook's campus expansion will also include a hotel, providing 200 limited service rooms to employees and guests (City of Menlo Park, 2016). Additionally, companies should consider allowing public access to services and amenities to increase the usability of their campus. Google's pending Charleston East Campus will be encompassed by a green loop that contains indoor and outdoor public spaces and public access to amenities that include a public park and plaza, retail and food shops, and a sculpture garden (City of Mountain View, 2017b). The creation of campuses that mimic the dense and walkable urban environment that many of the young and environmentally conscious talent desire (Smith and Brower, 2012) is a critical component in attracting workers who would not otherwise be willing to spend a large amount of their time commuting to work. There is no limit to the number of amenities and services that campuses can provide to diversify and improve the usefulness of their campus. A multi-purpose built environment is the most sustainable form, thus the corporate campus model should be designed to accommodate mixed-uses for both the employees and public.

For the corporate campus to be sustainable they should be located in accessible, high-performance locations that provide a mix of workplace, housing, and commercial services. However, as much of the current building stock in urban centers is expensive and occupied (SPUR, 2017) it is imperative that companies who are located in suburban areas work to build campuses that can competed with dense, mixed-use, and transit-oriented locations. Creating workplaces that are easy to access, beautiful to look at, and contain services and amenities can improve employee happiness and strengthen company culture. Employees will be more likely to want attend and spend time at work if they come to a campus that offers more than workspace and caters to their lifestyle (SPUR, 2017). The focus on collaboration within the innovation and technology sector suggests that companies would like their employees to feel comfortable and close to another. This concept can be strengthened by creation of a “campus community” that is complete with amenities and activity options rather than a single-purpose workplace (SPUR, 2017).

Campus Layout and Building Design

The built environment plays a significant role on the environment and the way people behave and interact with it (SPUR, 2017). The standard template for the Silicon Valley corporate campus consists of multiple large, low-rise buildings with a layout designed to accommodate driving and parking (Arieff and Warburg, 2016). The campus layout and building design is a fundamental component gauging the sustainability of the corporate campus. The following section will explore these components and discuss how they can be improved.

Connectivity

As the campus model is multi-building and can be expansive, strategic site design and connectivity is crucial so that employees can easily access other site buildings and spaces. When designing a new development, campus buildings should be placed near public streets and have clear pedestrian entrances that are accessible from sidewalks and be connected with walkable and connected pathways throughout the campus site to encourage walking, cycling, and use of public transit. Additionally, buildings should be placed close together to support an active and walkable workplace and if they are not companies should address site connectivity issues by creating on-site transportation programs such as free bikes or scooters that can be made available for employee use if walking distance is too far. This will prevent employees from needing to drive across campus to reach the appropriate building. An example is Google, who recently implemented a “G-Bike” program that allows employees to rent a bike for leisure or for transport between campus buildings and has lessened the amount of employees driving between campus buildings (Google, 2016). As campuses expand beyond their original layout, companies should build in between current buildings and create accessible pathways to connect new buildings to existing ones. This can be shown by Google who is in the process of adding a new building to their Mountain View Campus. The pending Charleston East Campus will be encompassed by a green loop that connects to Charleston Park and serve as a walkable pathway to the nearby Googleplex campus giving employees and visitors the option to walk across campuses rather than drive (City of Mountain View, 2017b).

Parking and Pavement Management

The corporate campus is design around driving and subsequently parking, hindering the ability for pedestrians and cyclists to safely commute to work (SPUR, 2017). Therefore, it is important that in the design of a campus the emphasis on parking should be diminished to promote a safer and more sustainable environment. Corporate campuses are notoriously surrounded by massive parking lots that provide free parking to employees and visitors. While parking is an understandable requirement, companies should look to design parking lots and garages that use minimal surface area and incorporate environmentally friendly materials. Parking lots should be designed or replaced with permeable pavement that allows stormwater to drain though pavement. This adjustment will help reduce stormwater runoff pollution and recharge groundwater supplies (Borst, 2016). Green infrastructure should also be integrated into parking lots and structures to absorb excess water runoff and absorb solar energy – mitigating urban heat island effects (U.S. EPA, 2016). Juniper Networks' spruced up their parking areas at their new campus by installing green roofs, adding trees around the parking and hardscape areas, and the installing a vegetated wall made from recycled plastic and a drought-tolerant grass-like species on one of the parking garage walls (Todd and Silkwood, n.d.). This design provided Juniper Networks with parking areas that have environmental benefits and are aesthetically appealing.

Parking lots take up a lot of surface area and destroy large plots of land by covering them with asphalt. Not only is this problematic for the environment, but also for campus accessibility and design as it inconveniences employees and forces them to walk further to reach their destination (Wilson and Navaro, 2007). New developments should consider building parking garages under the building to avoid the usage of additional land (Brueckner and Franco, 2016). Facebook's built underground parking just beneath the office space of their MPK 20 campus to reduce the heat island created from exposed asphalt (Facebook, 2016) and Apple is building an underground parking garage at their new Apple Park campus that will provide 11,000 spaces (Apple Inc., 2017). The investment in underground parking will allow companies to use land that would otherwise be wasted in a manner that will benefit the environment, occupants, and beautify the campus. If underground parking is not an option, strategically placed garages and parking lots should be designed and should never serve as a buffer between the campus and public streets (SPUR, 2017). Additionally, parking infrastructure can be resource intensive as they require ample lighting to create a safe environment. To address this, companies should use only energy-efficient lighting systems and controls, as well as, incorporate daylighting technology like the aforementioned "smart control" lighting upgrade to the parking structures at Oracle's campus.

The Buildings

Silicon Valley companies have the most control over their buildings with most being involved in the design and development of them from the ground up. Rating systems and certification programs, such as the Leadership in Energy and Environmental Design (LEED) and Zero Energy Building certification, have made it easier for design teams to set and achieve sustainable building goals in their projects. However, even with an available framework, a building is a complex system and requires the contribution of experienced design team members to create a building that is sustainable and functions efficiently. Using the Whole Building Design approach, which is the understanding of how building systems and subsystems interact and affect another, is imperative to reach peak energy savings (Graham, 2016). In this section, multiple building systems will be examined, including the building envelope, the heating, ventilation, and air conditioning systems (HVAC), lighting systems, and water usage.

Building Envelope

The building envelope is the skin and bones of a building and serves to protect the interior of the building from outside weather and pollutions, as well as, control the flow of heat, moisture, and air (BASF Corporation, 2010). The building envelope consists of the foundation, the roof, the walls, and the fenestration. All these features play a critical role in the overall performance of a building with 20-60% of all energy used being affected by the building envelope construction (Perez et al., 2017). This fact makes incorporating highly efficient, green envelopes into the corporate campus building design a necessity for Silicon Valley as we look toward reducing energy consumption and the built environment's impact on climate change.

The following sections discuss key building envelope features and possible improvements to increase their efficiency.

Roofs

The roof of a building is a vital component as it is the most susceptible to solar radiation and weather events (Sadineni et al., 2011). The roof has a large influence on the thermal performance of building. The solar reflectivity – the percentage of reflected solar energy – of an average roof ranges from 0.05 to 0.25 as they tend to be made of materials that absorb high amounts of solar heat, such as wood, asphalt, metal, or cement (Sadineni et al., 2011). Additionally, the thermal emittance – the rate of which a roof surface cools itself – of a standard roof is relatively high, causing it to readily release the majority of the solar heat it absorbs (U.S. EPA, 2008). Standard roofs increase the solar heat gain within the interior of the buildings, which can increase the load of building air-conditioning systems that must balance the overall temperature of the interior space to keep occupants comfortable. This also affects the energy usage of a building (Pisello, 2017). Additionally, standard roofs negatively affect the environment by contributing to the urban heat island effect from the high absorption of solar energy and provide no additional benefits to the building beyond structural protection. Innovative roof designs that reduce solar absorption and save energy have become more prominent within construction as the benefits become more understood. High-performance roofs are classified by the type of construction and benefits. The section below will explore the different type of roof designs that can be incorporated into the Silicon Valley corporate campus.

Cool Roofs

Popular for their combination of low solar absorption, high thermal emissivity, and simple installation procedures, cool roofs installations have become more common in warm and hot climates across the United States (Testa and Krarti, 2017) and can be seen on the tops of Apple's Maiden Data Center in North Carolina and IBM's San Jose Data Facility. These highly solar-reflective roofs can reach a solar reflectance level of more than sixty percent (Sadineni et al., 2011) and only absorb about thirty-five percent or less of heat energy into the building (U.S. EPA, 2008). Combined with a high thermal emittance, cool roofs reflect and emit most the sun's energy and tend to level within 10 to 20 degrees of the outside temperature (U.S. EPA, 2008).

Cool roofs are typically installed by placing a single ply or liquid white material over the roof's surface. There are a variety of materials that can be used for cool roofs, such as acrylic coatings, paint, shingles, tiles, and polyurethane; however, the application of white acrylic coatings and paint have proven to be the most effective in thermal performance (Pisello, 2017). White cool roof coatings can be applied to a range of surfaces, including asphalt, metal, and gravel, giving building owners the flexibility of converting their existing roofs into a cool roof without replacing the roof entirely (U.S. EPA, 2008). Additionally, cool roofs increase the life cycle and durability of a roof top by protecting it from the sun damage (Pisello, 2017).

Cool roofs provide multiple benefits, including urban heat island mitigation, reduced cooling loads and peak electricity demand, increased energy savings, reduced greenhouse gas emissions, and improved occupant comfort (U.S. EPA, 2008) Economically, cool roofs can provide investors with an average yearly savings of approximately 50 cents per square foot from energy savings found from the usage reduction of cooling equipment, as well as, save labor and maintenance costs due the increased lifecycle (U.S. EPA, 2008).

Cool roofs are a cost-efficient option that contains similar installation and maintenance procedures as traditional roofs (William et al., 2016). They are highly effective in reducing roof and building temperatures in hot and dry climates like Silicon Valley.

Green Roofs

The installation of a vegetated roof, commonly known as a green roof, is another sustainable alternative to the standard roof. Green roofs incorporate vegetation layers into the roof structure and help replace the vegetated and wildlife habitat that was destroyed during the construction of the building (BASF Corporation, 2010). Like cool roofs, green roofs help reduce roof top temperatures through increased solar reflectivity and can improve a building's thermal protection (William et al., 2016). Green roofs provide a shaded surface that uses vegetation to decrease heat temperatures through evapotranspiration, and unlike traditional roofs, the rooftop of green roof can be cooler than the surrounding air temperatures (U.S. EPA, 2008). Green roofs can be installed on a wide range of building roof types and give building owners the ability to be creative in designing a roof provides environmental, economic, and social benefits.

Green roofs can be categorized into two types: extensive and intensive. Extensive green roofs have a thin substrate layer (Sadineni et al., 2011) and are typically built from low maintenance plants, such as succulents and herbs (BASF Corporation, 2010). Extensive green roofs are commonly used in building retrofits as they can be installed on existing rooftops without the need to modify the roof structure (Sadineni et al., 2011). Extensive roofs are also excellent choices for areas that experience drought as they are constructed from plants that adapt well to extreme weather events (U.S. EPA, 2008).

Intensive green roofs have a thick substrate layer that can support a wide range of plants, including deep rooted species like shrubs and trees (Sadineni et al., 2011). Intensive green roofs function similarly to a garden or park and can be used by building owners as gathering space for building occupants and the public (U.S. EPA, 2008). Unlike extensive green roofs, intensive green roofs require intensive planning and require a roof's structure to be modified so that it can support the weight of a growth medium and accommodate public use (U.S. EPA, 2008).

Green Roofs provide a variety of benefits to the environment, building owners, and occupants. Similar to cool roofs, they help mitigate the urban heat island affect by reflecting high amounts of solar energy and help reduce the formation of ground-level ozone by keeping air temperatures low (U.S. EPA, 2008). Green roofs also provide a natural insulation to buildings that lessen building temperature fluctuations and in turn reduce the cooling and heating loads in the summer and winter (William et al., 2016). The reduced energy usage for heating and air condition equipment allows for building owners to gather savings in their energy bills and over its lifetime can save a building owner about $200,000 (U.S. EPA, 2008). Additionally, the vegetation on green roofs can improve air quality as plants act as natural carbon sequestration and storage, diminishing greenhouse gas emissions and air pollution (U.S. EPA, 2008).

Green roofs provide additional benefits to the environment by improving stormwater management and water quality. Unlike cool roofs, the vegetated structure of a green roof will absorb water from rain events that would otherwise be stormwater runoff. Depending on factors, such as the depth of the growing medium and the intensity of a rain event, green roofs can absorb between 50 and 100 percent of rainwater and with the careful selection of plant species can act as a water filter and improve the quality of stormwater runoff (U.S. EPA, 2008). Moreover, green roofs can provide a social benefit to building owners and occupants by creating a useable public space and beautifying the rooftop.

These benefits have already led some Silicon Valley companies to incorporate green roofs into their corporate campuses. In 2015, Facebook installed a nine-acre rooftop garden complete with a walking loop on their 440,000 square-foot LEED Gold West Campus (MPK 20) in Menlo Park (Figure 6). The roof is often used for walking and outdoor meetings providing employees with the benefit to spend time outdoors. It was carefully designed with a team of environmental organizations, including the Sierra Club and the Santa Clara Valley Audubon Society, to ensure that the appropriate species were selected to receive the highest environmental benefits (Facebook, Inc., 2016).

Figure 6: Facebook MPK20 Menlo Park, CA Source: Forbes Life, 2015

Juniper Networks took a different approach to the green roof by installing 9,000 square-feet of green roof space along the lower areas of their LEED Platinum Sunnyvale campus' central courtyard to reduce solar absorption around large surface areas of pavement (Build Group, Inc., 2013). Despite the higher initial investment in cost and planning, green roofs are placed among the most popular and efficient sustainable roof structures due to the wide range of benefits provided to both the environment and building owner.

Photovoltaic Roofs

The sun's energy is the world's most abounding renewable resource and photovoltaic (PV) technology is one of the more efficient means of using solar power (Tripathy et al., 2016). PV technology, which has significantly progressed over the past decade, is used to convert solar energy into electricity with creating pollutants (Lukac et al., 2016) and has been incorporated into the power systems of many countries (Sadineni et al.,2011). PV technology can be integrated into the building envelope through building integrated photovoltaic (BIPV) and serves as an onsite renewable energy source. The rooftop of a building is an ideal place to install a PV system as the roof receives the highest solar irradiance and is often unused - preventing the need to take up ground space for installation (Tripathy et al., 2016). PV arrays are made from crystalline silicon solar cell or thin-film solar cell roof tiles and are installed directly on the roof's surface, replacing other traditional roofing materials (Sadineni et al., 2011). Rooftop PV systems allow building owners to supply a portion, if not all, of their own onsite clean energy, which reduces the building's energy consumption while simultaneously providing electricity at a lower cost. The usage of renewable clean energy through a rooftop PV system helps reduce a building's contribution to climate change by diminishing greenhouse gas emissions, provides weather and thermal protection, and can be aesthetically designed (Tripathy et al., 2016).

The power generated through PV technology is dependent on solar irradiance and outside ambient temperatures (Hossain, 2016) making the warm and sunny climate of Silicon Valley an ideal location for installation. PV performance can vary based on system size, which determines the amount of power output at peak performance, and array design. Due to the advanced balancing of multiple systems - i.e. PV technology, building envelope design, and building power systems – PV arrays should be installed in close coordination with PV technology experts, engineers, and contractors (Tripathy et al., 2016).

To use clean energy, cut down on energy consumption, and save on energy bills, Silicon Valley's more environmentally conscious companies have already invested in high-performance rooftop PV systems at their corporate campuses. Juniper Network's rooftop PV array contributes to the 1.4 MW of the campus' onsite produced power (Todd and Silkwood n.d.) and Google's LEED Platinum "Googleplex" Campus in Mountain View includes a 1.9 MW rooftop solar installation that generates 1.3 million kilowatt hours (kWh) of electricity to generate their power (Google, Inc. 2016). Facebook's campus rooftops flaunt a 1.2-megawatt rooftop photovoltaic array and 2.2- megawatt solar carport system (Facebook, Inc., 2016) and Apple's new Cupertino headquarter campus, Apple Park, will boast a 17 MW rooftop solar installation that generates 75% of the campus' energy and places Apple's campus as the top corporate solar installation in the United States (Apple, Inc., 2017). The success of PV systems across the region builds the business case for companies whose corporate campus buildings need to be upgraded and showcase the possibility for rooftops to support sustainability.

Walls and Fenestration

Like roofs, walls and fenestration – the arrangement of windows and doors - play an important role in the insulation, thermal comfort, and efficiency of a building (BASF Corporation, 2010). Successful modifications to rooftops have inspired the development of similar designs for building walls and fenestration (Tripathy et al., 2016), integrating green infrastructure and photovoltaic/solar systems into vertical walls and building facades.

Vertical greenery systems (VGS) have complemented high-performing roof systems by providing similar benefits as green infrastructure. Like green roofs, VGS can be distinguished between extensive and intensive structures. An extensive VGS, or green façade, requires minimal investment, maintenance, and modification to building structure. Green facades are mostly made from climbing plants, such as vines and ivy, which grow vertically on a building's façade and can be installed by attaching plants directly to a wall or a discreet support structure (Yin et al., 2017). An intensive VGS, or green/living wall, contains soil substrate, has a built-in irrigation system, and can support a variety of plant species that grow in a uniform manner across the wall surface (Giordano et al., 2017). As seen in extensive green roofs, green wall systems require a higher initial investment and continuous maintenance, but with an experienced design team these walls can provide high energy savings by lowering the heat and cooling load of a building, especially when paired with other energy-efficient building upgrades (Riley, 2016, Perini et al., 2017). Even though green wall systems are not as common as their roof counterpart they are gaining popularity and have been integrated on corporate structures across the globe. In 2009, Citigroup installed an expansive vertical green wall that is irrigated with recycled water at their Frankfurt, Germany data center and in 2012, Amazon added living wall to their campus building in Seattle, Washington. Green walls have also made their way to Silicon Valley with the most notable example being Juniper Networks, who incorporated a 2,300 square-foot green wall into their campus parking garage to improve air quality and reduce the campus' carbon footprint (Figure 7).

Figure 7: Juniper Networks, Sunnyvale, CA Source: RMW Architecture & Interiors

The green wall is supported by recycled plastic and is constructed of drought-tolerant species that can survive Silicon Valley's warm and dry climate, require minimal watering, and absorb/convert carbon dioxide to oxygen (Todd and Silkwood, n.d.). The addition of a VGS to a building envelope is an sustainable option that will help regulate ambient air temperatures, provide natural insulation, regulate heat gain/loss within a building, and improve air quality though the reduction of greenhouse gas emissions (Jayasooriya et al., 2017, Perini et al., 2017).

Vertical photovoltaic and solar systems have also made headway as the PV panel application can also be used on building walls and facades (Zahedi, 2006). Buildings that pair vertical and rooftop PV systems can gain substantial energy savings and power output through increased PV capacity. However, vertical PV systems are not as efficient on their own due to the shadowing and lower solar irradiance walls receive compared to rooftops and should be used as a complement rather than sole source of onsite energy production (Hwang et al., 2012).

The selection and design of building fenestration is a crucial component to developing an efficient building envelope. Windows are responsible for a large amount of heat gain and loss from a building - impacting the building's heating and cooling load - and can contribute to mold and mildew problems by allowing moisture in to the interior (BASF Corporation, 2010). It is important for buildings to contain high-performance windows that give thermal protection and insulation, as well as, can survive wind stress and impact. Additionally, installing glazing film, tints, or coatings on to new or existing windows can improve thermal performance and provide weatherproofing benefits (BASF Corporation, 2010). Fenestration can also be strategically designed to use daylight rather than electrical lighting for interior building space. Techniques such, as façade shading devices or automated window shades can be incorporated to balance daylight with electrical lighting transmission (Konis, 2012).

When planning for sustainable building upgrades or designing a new development, the building envelope cannot be overlooked. Creating a strong and sustainable envelope is key to creating a highly efficient building as the remaining building systems will not performing at their highest without proper support from the building's exterior components.

HVAC

Heating, ventilation, and air conditioning systems are responsible for regulating interior building temperatures, humidity levels, and air quality to keep occupants comfortable and safe. These important systems account for 39% of total energy usage in U.S. commercial buildings (Graham, 2016) and their efficiency levels have a high contribution to the overall performance of a building (BASF Corporation, 2010). The National Institute of Building Sciences has developed fundamental guidelines for creating an energy and resource efficient HVAC design with the first being the importance of considering all building systems concurrently. There are many factors that contribute to the load requirement of HVAC systems, e.g. the building envelope, lighting systems, efficiency of office equipment etc.; therefore, the selection of HVAC equipment should factor in the interactions between the HVAC and other building systems. High-performing HVAC equipment should be paired with an energy-efficient building envelope and lighting systems to ensure that help balance the load (Graham, 2016). This can be done by installing energy management control systems or by using alternative fuel sources for heating and cooling

(Graham, 2016). Oracle Corporation used energy management controls by installing lighting control sensors at their Redwood Shores headquarter campus that work with the HVAC and VAV systems to manage HVAC operations based on the occupancy of a space to reduce unneeded peak demand charges and energy consumption (Oracle Corporation, 2014). To minimize the load on their HVAC equipment, Juniper Network's turned to alternative fuel sources, including Bloom Energy fuel cells and Cogenra solar thermal system that use renewable energy to supply heat (Todd and Silkwood, n.d.).

The proper selection of HVAC system size is also imperative to performance. The size of most HVAC systems is designed to meet full-load conditions that only happen 1% to 2.5% of the time, leading most to be oversized and inefficient. For the highest efficiency, HVAC systems should be sized at a reasonable safety baseline and should be based on part-load performance (Graham, 2016). An increase in load demand can be caused from changes in building use, the implementation of different technology, or the addition of more occupants. However, HVAC systems should be designed to easily accommodate growth but not be initially sized for it as having excess capacity will cause energy and resources to be wasted unnecessarily. Additionally, the commissioning and maintenance of a HVAC system is a crucial step in ensuring the system is operating effectively as individual components may fail and affect the efficiency of the entire system (Graham, 2016).

Many of the high-tech companies in Silicon Valley require large IT and data centers that are notoriously resource intensive due to their heavy cooling load requirements. While balancing the requirements of IT equipment and energy consumption can seem difficult, leaders in Silicon Valley have found strategic solutions. Oracle focused on creating chiller less designs for their data centers and IT equipment labs and installed sub meters to monitor individual labs and large equipment to control excess cooling (Oracle Corporation, 2014). While designing their new ground up campus, Juniper networks sought to achieve efficient cooling in their labs from outside air. This was achieved through architectural building design which included vertical fins that set the mechanical louvers at the lab floors (Todd and Silkwood, n.d.).

Additionally, there is research that supports the correlation between efficient buildings and tenant health and productivity (Kats et al., 2003). In corporate settings where productivity is vital for success caring for the well-being of employees is critical. Properly designed sustainable buildings contain better indoor air quality and thermal comfort that decrease the risks of Sick

Building Syndrome (SBS), defined by the U.S. EPA as "situations in which building occupants experience health and comfort effects that appear to be linked to time spent in the building and which lessen after leaving the building" (World Green Building Council, 2013). SBS is commonly associated with poor building ventilation levels and indoor air quality leaving occupants with symptoms such as, headaches, eye, nose, or throat irritation, and fatigue (World Green Building Council, 2013). Healthier workplaces that provide clean and ventilated air are estimated to provide companies within the United States with $10 to $30 billion worth of savings and productivity gains from reduced Sick Building Syndrome symptoms (World Green Building Council, 2003).

The efficiency of the HVAC system is vital to reach sustainability within a corporate campus. However, the selection of energy-efficient equipment alone will not achieve the greatest results. It is imperative when designing HVAC systems to take the other building systems into account. This is where the greatest opportunity for energy savings will be found.

Lighting Systems

Over the past few decades there has been an increase in electricity consumption in commercial buildings due to advances in technology, including the computer, servers, printers, and phones. Now, electricity accounts for nearly 61% of total commercial energy consumption (U.S. EIA, 2012) and in most cases, is used to power entire building systems, including the HVAC systems and hot water supply (Balaban and Oliveira, 2016). While there are many users of electricity within buildings, lighting systems are the largest end user of electrical energy (Konis, 2012), accounting for approximately 37% of energy usage in commercial buildings (McGraw Hill Construction, 2009) which also makes them a prime target to find potential energy savings.

There are a variety of ways to improve the efficiency of lighting systems, including the replacement of inefficient light fixtures, the installation of occupancy sensors, adding individual lighting controls, and incorporating daylighting – the use of daylight to reduce electrical lighting (Megri, 2015). The simple replacement of lighting fixtures with LED lighting has the potential to cut lighting energy consumption in half (U.S. DOE, 2017). Investing in LED lighting provides building owners with benefits, such as low investment and quick payback, long life cycles and low upkeep, and the ability to integrate them into sensor and control systems. LED lighting save energy by emitting light in specific directions, only providing light where it is intended and removing the potential of wasting light energy. Additionally, the integration of LED lighting into sensor and control systems increases energy savings by pairing them with occupancy or daylighting sensors (U.S. DOE, 2017). LED lighting is quickly becoming the new standard in commercial buildings with many building owners and companies revamping their lighting systems to accommodate LED technology. Oracle Corporation transitioned all the interior lighting and exterior accent lighting at their Redwood Shores headquarter campus to LED fixtures and incorporated them into occupancy and daylighting control systems to reduce lighting demand. These interior and exterior lighting upgrades are projected to save Oracle 81.4% kWh per year and are expected to give a 42% annual return on investment with a simple payback period of just 2.4 years (Oracle Corporation, 2014). Oracle also installed "smart" lighting controls into all campus parking garages that included occupancy sensors to reduce lighting by 70% when space was not occupied and daylight harvesting to dim lighting based on the natural light, resulting in an 89% reduction in electricity and saved Oracle $148,155 annually in electricity bills (Denise, 2015). Further south at Juniper Networks' Sunnyvale campus, PG&E was consulted to help design the most efficient lighting systems for their campus. Daylight-sensing controls were installed to optimize the harvesting of sunlight and occupancy sensors were placed throughout (PG&E, 2013). Juniper Networks' campus was projected to save approximately 1 million kilowatt-hours (kWh) within the first year with an estimated savings of $121,295 in their annual electric bill (PG&E, 2013).

Water Usage

Water consumption in commercial office buildings accounts for nearly 9 percent of total water consumption in commercial facilities in the United States (U.S. EPA, 2012) and on average, office buildings use 15,000 gallons of water per thousand square feet per day (U.S. EIA, 2015). Water is a limited resource and being in a drought-prone region heightens the importance for Silicon Valley corporate campuses to reduce water consumption and find sustainable means of using and recycling water. Water is required for many building systems, including plumbing fixtures in restrooms and cafeterias, heating and cooling equipment, and site landscaping. Thus, the integration of highly efficient plumbing fixtures, HVAC equipment, and smart landscaping design is critical to reducing water usage.

Corporate leaders in Silicon Valley have made conscious efforts to reduce water consumption in their large campus settings. Oracle, who has seen a 16% reduction in water use per employee at their Redwood Shores headquarters, introduced several equipment upgrades to address water consumption, such as water efficient shower and restroom fixtures, upgraded dishwashing equipment in cafes, dual-flush valves that conserve water, domestic hot water upgrades, modified boiler systems that reduce operation times, and the implementation of a xeriscape around the grounds that uses plants that are less water-dependent and are irrigated with recycled water (Oracle Corporation, 2014).

The Googleplex in Mountain View contains solar water heaters that supply 3.8 million liters of hot water per year as well as high-efficiency indoor water fixtures. Additionally, the campus uses recycled municipal water for landscape irrigation systems and is landscaped with drought-tolerant plants (Google, Inc., 2016). Pending approval by the city of Mountain View, Google has plans to add a 595,000 square foot office building, named the Charleston East Campus, next to the Googleplex. The building is designed to reach LEED platinum certification and will contain its own utility plant, have on-site water, treatment, storage, and collection, will use reclaimed water and have highly efficient plumbing fixtures and equipment.

Adaptability

The idea of mitigating the built environments impact on climate change is commonly discussed; however, adapting the built environment to potential climate change impacts we cannot mitigate is equally necessary (Ward and Wilson, 2009). In all, buildings must be able to adapt to environmental, economic, and social changes to be considered sustainable (Manewa et al., 2015). As climate change effects continue to take form it is imperative that the built environment is able to adapt, and when you consider that the ability to be flexible and adjust to growth is an important virtue in Silicon Valley (SPUR, 2017), adaptability should be a requirement for corporate campus design.

Silicon Valley in particular is prone is drought, water shortages, increased temperatures, and sea-level rise. The building improvements that have been previously discussed are the first steps to adapting buildings to climate change. To address drought and water shortages buildings must specify water-efficient fixtures and appliances, incorporate water-recycling, design plumbing in buildings to be able to accommodate graywater usage, and be landscaped with only native, drought-tolerant, and climate appropriate vegetation species (Ward and Wilson, 2009). Increased temperatures should be accounted through efficient cooling and ventilation systems, as well as, building design and landscaping that mitigates urban heat island and minimizes the building cooling load (Ward and Wilson, 2009). New campuses should not be developed in flood zones or on wetlands in response to sea-level rise, but for campuses that are already located on shorelines, natural stormwater management systems should be restored back into the ecological landscape to provide a buffer. Specialized building components, such as flood vents and breakaway wall panels, should also be installed to protect buildings from potential flood damage (Ward and Wilson, 2009). Additionally, the materials chosen in the buildings should be durable, flood-resistant, contain low embodied, operational carbon, and toxic chemicals, and have longer life-cycles (Manewa et al., 2016, Ross et al., 2016). These adaptive measures are feasible improvements that should be accounted for now. Fortunately, these measures also help mitigate climate change and help protect building owners in the face of disaster.

Buildings should also be designed to provide flexibility in office layout so that redesign is quicker, cheaper, and requires less demolition and subsequent waste. Open plan layouts that are not obstructed by structural, mechanical, or other features allow for reuse that has minimal to no impact on the existing building (Ross et al., 2016) making it easy for building owners to reformat their office layout to account growth or other corporate changes. Building design should be adaptable to both the physical change of space, the change of use, and have equipment and furnishings that are adjustable based on occupant needs (Schmidt et al., 2010). As innovation and the economy continue to grow in Silicon Valley, the corporate campus must be developed so that it can be repurposed based on social and economic needs, as well as, being adaptable to inevitable climatic changes.

Obstacles and Resistance

There are facts to support the unsustainability found within the traditional corporate campus model, but yet implementing region wide reform into a more sustainable urban form has been passive and slow. There are many parties who are responsible for shifting Silicon Valley away from the developing the problematic suburban campus. This includes the companies who own them, the local governments of the cities they reside in, and the state and transit authorities who develop regional transportation. The following sections will discuss each party’s role and explore reasons for resistance.

Corporate Culture and Resistance

There are many know improvements that companies can make to shift the corporate campus towards sustainability; however, many companies are still choosing to develop in remote suburban areas, are comfortable with their current campus design, and aren't motivated to invest in a sustainable campus (SPUR, 2017). Technology companies are competitive and protecting their intellectual property is a core driver behind the standard corporate campus design as companies see the low-slung, remote suburban campus as more secure. For this reason it is common to see corporate campuses placed far away from streets and public spaces a design that worsens the accessibility to and from the campus (SPUR, 2017). Moreover, expansive, low-slung, and flexible floorplates are favored among many of the Silicon Valley technology companies as horizontal circulation facilitates collaboration and allows for the spontaneous configuration of large teams. Security and floorplate flexibility are core drivers behind the apprehension some companies feel about moving into urban centers as they feel they can't support their culture or needs (Britton and Hargis, 2015, SPUR, 2017). For this reason, companies tend to develop large buildings that are built away from public areas and do not support pedestrian lifestyle, transit use, or the community (SPUR, 2017).

Additionally, many Silicon Valley companies that have high-growth and success hold large amounts of irreplaceable real estate and already have well-established corporate campuses (SPUR, 2017). This gives companies little incentive to invest in new developments that are in better locations and doesn't encourage them to retrofit as reworking existing campuses requires extensive planning and disrupts the existing workspace during construction (SPUR, 2017). Without motivation from the companies who own and build corporate campuses to make a difference, Silicon Valley is in danger of growing in the same unsustainable patterns. The movement towards a more sustainable Silicon Valley starts with the companies who inhabit it and without their support the resistance is stronger.

Jurisdictions and Zoning Code

To complicate it further, Silicon Valley is made up of multiple cities and jurisdictions that have different policies and standards for growth. This makes it difficult to prescribe the same framework to each campus as they all have their own local obstacles to hurdle. Each city has its own zoning codes, building restrictions, and overall goals for development. Zoning districts and land use designations of specific land parcels range from residential to industrial and commercial, and have strict development guidelines that vary from city to city. Suburban zoning codes were originally created to allow for commercial use in suburbs while protecting the suburban character (SPUR, 2017).

Land use parcels in the Bay Area have historically consists of the designation of large areas as "commercial" areas that have ordinances on parking lot sizes, building sizes, and distance between developments (SPUR, 2017). Suburban commercial zoning laws typically set height restrictions on buildings and create strict parking ratios that require 2.5 to 3 parking spots per every 1,000 sf that enable unsustainable suburban growth (SPUR, 2017). Mountain View, for example, sets a 2 story maximum for developments located in Commercial Office Zones and set a minimum 10 foot wide landscape buffer between the street and building frontage (City of Mountain View, 2017a). Zoning codes also set strict guidelines on mixed land uses that will not allow for residential units to be built in commercial zones. While there has been modest growth in the housing market, many units are still built far from job centers as many of the cities that are adding the most jobs are also the most resistant to adding more housing (SPUR, 2017). This creates setbacks for some companies who seek to add housing near their campuses for employees For instance, Menlo Park approved Facebook's plan to incorporate housing units in their campus; whereas, Mountain View has pushed back on allowing Google to generate new housing at theirs (SPUR, 2017), muddling some of Google's plans that would improve their workplace. These differences in local policies hinder the ability for the region to improve in a uniform manner. Companies must work within the allowances of their jurisdictions and are limited in the improvements they are legally allowed to make.

Transit Authority

As the hottest issue affecting the Silicon Valley corporate campus is the inefficient regional transportation, it is imperative that public transit is improved region wide so that it is a competitive transportation option that serves every area in Silicon Valley. The best way to address the transportation issue affecting Silicon Valley is to improve transportation infrastructure; however, improvements to infrastructure are expensive, slow, and rely on state agencies and transportation authorities to implement these improvements (SPUR, 2017). Poor regional transit minimizes the locations companies are able to build in if they are looking to be in areas that are well-served by public transit and the urban areas that are known to have more efficient public transit are notoriously more difficult to develop in, have minimal available land due to the existing building stock, and require a larger financial investment (SPUR, 2017). Furthermore, poor regional transit restricts the improvement of campuses that are already established in remote locations as it can be difficult to provide transportation services that are more convenient than a car.

Reaching the sustainable corporate campus requires the support and collaboration between many parties. The individual companies, cities, and public agencies must all have the motivation to improve in order to reach maximum sustainability. However, coordinating groups who have separate goals and measure success differently can be complicated due to the amount of compromise required. At times, facing these obstacles can seemingly outweigh the benefits and disincentivize companies from attempting the challenge of building a sustainable campus.

Progressing Policy and Transit toward Sustainability

As discussed in the previous section, companies rely on policy and transit to support their initiatives. While companies are able to make design decisions and set goals for their campus, policy is the overarching principle behind what is achievable. Urban, transit-rich areas are often the most difficult to develop in due to minimal available land space, restrictive zoning codes, and high cost (SPUR, 2017). This has caused job growth to continue to grow in remote suburban locations (SPUR, 2017). Therefore, improve regional sustainability, the separate jurisdictions in Silicon Valley will be need to engage in collaborative and aggressive policy planning that allows for regional reform and supports companies in the redesign of their campuses.

Zoning policies across Silicon Valley must be updated to allow dense commercial growth in locations that have access to transit and have mixed land uses (SPUR, 2017). The separate cities in Silicon Valley must partner to create infill-oriented development plans that consist of the addition of commercial services and amenities, residential buildings, and job centers to areas that are well-served by regional transit. It is imperative that the region creates more high-performing, transit-rich, sustainable locations rather than just relocate to one; however, this relies on local government and politics to commit to sustainable reform. Moreover, zoning ordinances must lessen parking lot mandates to reduce single-rider vehicle commuting. The requirement to provide a minimum number of parking spaces should be removed from zoning code allowing campuses to limit the number of parking spaces they provide.

The region must also make a commitment to improving regional transit services, including the connection of BART to Silicon Valley hubs and the completion of CalTrain through San Francisco. New BART and CalTrain stations should be integrated into walkable areas of dense, mixed-use growth. Additionally, expansive bus and shuttle networks must be developed to support the transportation to and from areas that are unable to support rapid rail transit. As the development of new infrastructure requires a long amount of time to complete, short-term improvements must be incorporated to implement faster change. A public regional express shuttle program can be created to transport employees whose company does not provide private transportation to and from job centers. Additionally, public shuttle routes that transfer employees the last few miles of their commute from rapid transit stations can be integrated with the rapid transit system schedule to incentivize the use of public transportation. Road infrastructure should be improved to include safe lanes for bicyclists and pedestrians and incorporate dedicated lanes for express regional shuttles to allow high-occupancy vehicles the ability to bypass congestion (SPUR, 2017). In short, the collaboration between regional governments is imperative to create policy that supports the development of high-performance communities. The jurisdictions in Silicon Valley must act as one to improve the region's development and transportation problem. With the support of the region, the Silicon Valley corporate campus will be able to be reformed into sustainable job centers that have access to transit, are pedestrian friendly, and provide mixed-uses, including public open space, services, and amenities.

Discussion

It is clear that the traditional model of the Silicon Valley corporate campus is unsustainable as it supports a built environment that is auto-dependent, resource-intensive, and covers a lot of land area (Arieff and Warbug, 2016). While these isolated megastructures once fit with the suburban mindset of the 20th century, they no longer support the innovative and forward thinking of the region today. The environmental footprint of Silicon Valley continues to loom large as the area's quick job growth supports the need for more commercial development. However, the region's economic success does not have to lead to inefficient and unsustainable workplaces. The strategic development and reform of corporate campuses that are dense, walkable, have mixed-uses, and are accessible by public transit is not only possible, but is also a necessity as the effects of climate change continue to take form.

The Existing Campus

It may seem that retrofitting the existing corporate campus is nearly impossible, but the actions taken by companies, such as Facebook and Google, to reform their campuses into more sustainable, urban-like job centers prove that it is achievable. Silicon Valley campuses are prime targets for retrofits as most of them are privately owned, with the most landlords or owners also being the tenant. This eliminates the need for approval from some stakeholders, such as property owners/managers and shared building tenants. Additionally, the monetary success of these companies allows for the opportunity of self-funding and removes the challenge of obtaining investors. While initial expenditures may be high, the retrofit of the standard corporate campus model can improve economic sustainability. Sustainable buildings may require higher initial investment costs they will come with the opportunity of increased market value and rapid returns on investment (World Building Council, 2013). There are numerous financial benefits that accompany green buildings, such as energy costs savings and lower operations and maintenance expense. However, to capitalize on the economic benefits of green buildings, construction and design will require the integrated design and collaboration, as well as, a strategic commissioning process once the building is complete (Kats et al., 2003). With proper planning, an experienced design team, and the creation of corporate demand-management and service programs the existing corporate can become more efficient.

The largest challenge for the existing campus is addressing current locational and transportation issues as their owners have no control over improvements in regional transit and have already located in an area not accessible by it. However, in-house transportation services and management practices can be implemented to improve commutes and lessen congestion and greenhouse gas emissions. Long-haul commuter shuttles, as used at Facebook, Google, and Apple's respective campuses, can be used to transport employees who live long distances from work (SPUR, 2017). For employees who are live near public transportation, shuttles that transport riders the last few miles from transit stations to their respective campus can also be used. Additionally, campuses can provide incentives to employees who carpool, use public transportation, have electric-vehicles, or ride their bicycles to work. Secured and convenient bike storage and shower rooms should be provided to encourage bicyclist to ride to work and preferred parking with free charging stations should be provided for drivers who use more efficient vehicles. Companies can also create campus transportation demand management programs that reduce driving through implementing trip caps and charging single-drivers for parking. Transportation demand management programs that include charging for parking have been proven to reduce vehicle trips by 15-30% depending on the availability of public transit (Cambridge Systematics, 2010) and paired with shuttle and incentive programs can reduce single-driver commuting. Moreover, existing campuses that are located on the outskirts of their city and in result are farther away local services and amenities should incorporate them in the campus. Employees' basic needs should be provided to reduce the need to drive off campus to reach them. This should include necessities such as food service, childcare, and gyms. Adding these amenities to a campus will not only reduce car usage, but also improve employee lifestyle and happiness (SPUR, 2017).

Existing campuses that have poor site design and inefficient buildings can be retrofitted to include better campus connections, restoration of ecological landscapes, and highly-efficient buildings. Dedicated pedestrian pathways, streets, and open space should be added to the campus to improve pedestrian circulation and create a safer pedestrian environment. Campuses with a large multi-building site plan should provide free sustainable transit services, such as Google's G-bike program, that allows for employees to easily reach other areas of the campus (Google, Inc, 2016). When new buildings are being added to an existing campus, buildings floorplates should be minimized and be connected to or built in between existing buildings. Existing building systems should be replaced with more efficient, high-performance systems that use less energy, consume fewer resources, and can adapt to climate change impacts (SPUR, 2017). Buildings should be surveyed to determine which systems are underperforming and to develop a phased retrofit plan that addresses the most critical issues first. As each campus has different building forms, a prescriptive building retrofit plan cannot be given; however, all should contain at minimum the most efficient HVAC, lighting, and plumbing system available for that specific building and its occupant's needs. The exterior of buildings that is not otherwise utilizable space should be retrofitted to serve a purpose. This can be completed in a variety of ways, including the addition of PV panels to generate on-site energy (Hwang, et al., 2012) or by adding green roofs and walls to manage stormwater, provide insulation, and reduce heat impacts (Riley, 2017). Campus outdoor spaces should be landscaped to include drought-tolerant, and climate appropriate species, and campuses located on wetland and shoreline habitats should restore native vegetation where possible to increase stormwater management and provide an extra protection barrier against climate change affects, such as sea-level rise, king tides, and storm surges (SPUR, 2017). Additionally, similar to building exteriors, green roofs or PV panels should be installed over large pavement areas and parking lots to give them an environmentally friendly use. Sustainability consultants, engineers, local ecologists, and an experienced design team should be contacted to develop the appropriate retrofit plan for each building and campus.

The New Campus

For companies who have not yet established a campus or are in the market to relocate their existing one, the challenge is easier but equally as important. The Bay Area's economy has continued to produce jobs and success meaning the region will continue to see new developments (SPUR, 2017). Companies that chose to locate in Silicon Valley must follow the framework of companies like Juniper Networks who gathered a team of experts in the beginning stages of design to create a strategic development plan that addressed locational, transportation, and building form concerns (Todd and Silkwood, n.d.). New development should not occur in areas that are not well-served by transit or cannot efficiently be supported by on-site transportation programs. Additionally, companies should choose to locate their campuses closer to downtown or urban centers so off-site amenities and services are accessible, and if they are not the needed amenities and services should be incorporated into the original campus design. Locational and transportation issues should be identified from the start of the project so companies can plan for and implement programs that balance these concerns once the campus is complete.

New campuses should be developed to support the community and public with buildings being oriented towards public streets with dedicated pedestrian entrances and parking that is not visible from the street (SPUR, 2017). These campuses should be as compact and dense as possible, and provide a safe and walkable environment that is open to both employees and the public. To address security concerns, campus should establish clear boundaries between public and private space modeling after urban offices and university campuses (SPUR, 2017). High security can be included in building lobbies but still have spaces such as parks, plazas, and amenities open to the public. By a requirement of the city of Mountain View, Google's campus has accessible public spaces that connect to local parks and trails (City of Mountain View, 2016., SPUR, 2017) this allows for a mixed-use development that serves both the employees and residents. Moreover, it is imperative that the desire for large and open floorplates does not compromise good urban design during the building design phase (SPUR, 2017). Large floorplates disrupt pedestrian environments and don't allow for ease of connections from sidewalks and streets. Building floorplates should be limited and take advantage of vertical growth wherever possible. If companies cannot compromise on floorplate size, the largest campus buildings should be located in the center of the campus away from public streets and sidewalks (SPUR, 2017). Building the first floor level up to allow for open space and pedestrian circulation underneath should also be considered (SPUR, 2017). Similarly, in multi-building site plans, buildings can be built up with the upper levels of adjacent buildings being connected by bridges (SPUR, 2017). Facebook incorporated this design on their campus to allow for the construction of their pedestrian only "Main Street" underneath (Crescimano, 2012). New buildings should be designed to be adaptable with energy efficient building systems, high-performing building envelopes, and should set goals to produce renewable onsite energy, as well as, contain water-recycling and greywater compatible infrastructure.

A new development allows for companies to be more creative and strategic in their design, but in turn removes the excuse for companies to develop unsustainably. Similar, to retrofits, sustainability consultants, engineers, local ecologists, and an experienced design team should be brought together to develop a design plan for a corporate campus that supports company requirements, the community, and reduces the regions carbon footprint.

Alternatives to the Suburban Corporate Campus

The best way to create a workplace that mimics urban centers is to develop them within actual urban areas. Many companies within the knowledge sector have begun to establish themselves in urban centers like San Francisco, Oakland, and San Jose proving that it is possible for companies to establish themselves in structures that aren't corporate campuses. Some companies, such as Airbnb and GitHub, have been able to repurpose old industrial brick-and-timber buildings into unique and open urban workplaces (SPUR, 2017). Others have moved into vertical towers, proving that vertical corporate campuses can provide the security and collaborative floor plans that technology companies require (SPUR, 2017). Salesforce is set to move into the 60-story Salesforce Tower (Figure 8) that is nearing completion in downtown San

Francisco; Slack recently leased 10 floors in San Francisco's SOMA district (Figure 9), and Adobe has a set of towers as their campus in downtown San Jose (SPUR, 2017).

Figure 8: Salesforce Tower, San Francisco, CA Source: SPUR, Rethinking the Corporate Campus, 2017

Figure 9: Slack, San Francisco, CA Source: SPUR, Rethinking the Corporate Campus, 2017

The urban centers in the San Francisco Bay Area are well-served by transit, are proximate to various services and amenities, cover small amounts of surface area, and tend to not contain parking lots or structures (SPUR, 2017). Therefore, the success of an urban vertical corporate campus is mainly dependent on sustainable building design that also serves the needs of its tenant. Vertical environments are able to provide the efficient and effective floorplates that promote the collaboration many owners of suburban corporate campus desire. Stacked office floors should contain a strategic network of paths that connect the floors both vertically and horizontally, such as adding interior and visually appealing stairwells between floors to complement exit stairwells and elevators (Britton and Hargis, 2015). Additionally, dedicated collaborative spaces should be placed throughout the building and set in strategic places in the office that promote the interaction and movement between members (Britton and Hargis, 2015). Floor plans should be contiguous and open with minimal structural obstructions that degraded connectivity across floors, and stairs, elevators, and central areas of each floor should be stacked with activities and amenities to create interest in connection points (Britton and Hargis, 2015). Numerous companies, who rely on security, including Silicon Valley corporate campus owners like Facebook, Apple, and Google, have established and secured offices in urban centers. There are other industries that also require security, such as financial centers and legal offices, who typically establish themselves in urban office buildings (SPUR, 2017). Similarly, to public spaces in the suburban corporate campus, clear security barriers can be established in lobbies and other gateways in buildings. For companies who require the highest level of security, sealed vertical campuses, like Adobe's in San Jose, are possible to develop (SPUR, 2017).

With strategic planning and a good design team, vertical campuses can be designed to integrate both the physical and social attributes of the suburban corporate campus (Britton and Hargis, 2015). Additionally, densifying job centers and encouraging the movement from expansive suburban workplaces to vertical urban ones can reduce the built environment's carbon footprint (Britton and Hargis, 2015), making the vertical corporate campus a sustainable and functional alternative to the suburban corporate campus.

Conclusions

Companies within the region have already begun to notice the need to reform their corporate campuses. However, the idea is still the exception in Silicon Valley. A variety of factors can influence a company's decision to develop unsustainably, including real estate costs, employment rate, local jurisdictional guidelines, and just simple comfortability. Therefore, further research that tackles how employers can be motivated to develop in more sustainable locations is important to start the shift of suburban workplaces in to more urban-like forms.

Additionally, discovering what can encourage local governments to support updates in development guidelines and land usage is necessary for widespread regional reform.

As the Bay Area continues to see increased job and population growth, urban centers will become over extended and roadways more congested, heightening the need to redesign suburban areas into more efficient and dense land forms. The technology companies that have defined the region have brought great economic success to the Bay Area; however, they also risk leaving it with a problematic built environment that is inefficient and unadaptable. It is impossible to predict the future, but it is known for certain that Silicon Valley must be reformed into a more resilient region to prepare for the inevitable challenges ahead. Rethinking the standard model of the corporate campus into a sustainable form is a fundamental step in not only mitigating climate change, but also readying the population for the irreversible negative impacts that have already begun.

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