Assessing the Potential for Telecommuting at UC Berkeley

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EXECUTIVE SUMMARY

Telecommuting is the practice by which employees work from home or a designated location outside of the office with the assistance of telecommuting technologies (i.e. the internet, phone, etc.). Telecommuting allows employees greater flexibility in working hours as well as their home life. UC Berkeley's motivations for its staff to telecommute are to reduce emissions associated with elimination of commutes. Additional emission cuts are possible through reduction of office energy on campus. However, telecommuting increases home energy use and may induce other forms of energy consumption, like driving to lunch. Past studies on telecommuting mainly focused on the social impacts that result from working at home. There remains a need to assess the environmental impacts of formalized telecommuting programs. In this case study, we considered the environmental impacts of telecommuting programs for staff employees at UC Berkeley.

At UC Berkeley, 21.5% of greenhouse gas emissions are related to transportation while 78.5% of emissions result from building use. For the campus to meet its goal of climate neutrality (net zero emissions), transportation and building related emissions need to be minimized . This report aims to quantify emissions impacts of telecommuting at UC Berkeley by analyzing various scenarios in three main administrative buildings: Sproul Hall, University Hall, and Campus Shared Services offices on Fourth Street.

Three sources of employee-related emissions are considered: consumption at work, during commute to work, and off-site work emissions. Transportation-related emission savings are based on average commute distances and transit mode-splits for UC Berkeley staff. Building energy consumption is related to building characteristics and occupancy; the Office of Sustainability and Space and Capital Resources provide information for these. Building power consumption is obtained through Berkeley's online tool myPower. Home energy increases are assumed to be 10% of the average household energy use for a home in the PG&E service area - a result determined by past research.

We found that telecommuting saves energy and reduces emissions in every scenario we tested. Eliminating staff commutes is the greatest contributor to this energy/emissions savings. Additionally, there are financial benefits for telecommuters who normally drive alone to work. Their savings on fuel costs are substantially more than their increase in home energy costs. The University also realizes financial benefits when significant numbers of employees telecommute, which allows for partial building shutdown.

As UC Berkeley and other organizations continue to explore solutions to reduce their emissions and manage their resources more efficiently, telecommuting will be a viable option both economically and in terms of energy consumption. However there are other costs and benefits that must be weighed before commitment to telecommuting can occur. Furthermore, to determine what these costs are, research specific to the constraints of UC Berkeley is needed to quantify the impacts on campus and workers brought about by telecommuting.

ABSTRACT

Transportation-related activities at UC Berkeley contributed to over one-fifth of total campus greenhouse gas (GHG) emissions in 2009. The University continues to look for opportunities to reach zero net emissions by reducing the environmental impacts of faculty, staff, and student presence on campus. This study considered the emissions impacts of structured telecommuting programs for administrative staff at UC Berkeley. By considering reductions in commute related vehicle-miles traveled (VMT), campus building energy use, and induced residential energy use, we modeled the emissions impacts for a range of possible telecommuting programs. Our assessments suggest telecommuting reduces net GHG emissions associated with staff working for UC Berkeley. Depending on the specifics of the telecommuting program, GHG emissions associated with a campus building can be reduced 0.5% to 26%. The decrease in campus building energy consumption results in minimal monetary savings for the University. Financial and emissions benefits drastically increase for campus-wide programs with high fractions of staff telecommuting. Where these scenarios allow for total or floor-level shutdown of buildings to occur - shutting down buildings is key for realizing substantial building GHG reductions. The most significant GHG emission savings are from eliminating staff driving alone to campus. As such, our study provides initial insight into potential emissions savings for a range of telecommuting programs. The complete set of effects telecommuting has on UC Berkeley can be assessed with further studies geared at examining the total cost such programs have on the campus and staff. However, these studies would be difficult due to the complex nature of staff interactions with UC Berkeley.

INTRODUCTION

Telecommuting

Telecommuting is the practice by which employees work from home or a designated location outside of the office with the assistance of telecommuting technologies. The popularity of telecommuting has increased in recent years largely due to improved network technologies that enable effective telecommuting. A shift towards employers becoming more accommodating to the differing work habits of their employees has also helped to increase the prevalence of telecommuting. Between 1990 and 2009, the number of telecommuters in the United States grew from 4 million to 17.1 million (Lari 2012), an increase from 5.4% to 12.3% of the employed workers. One third of workers in the Bay Area are thought to telecommute, at least partially from home, while across the United States, 24% of employed workers report that they work partially from home each week (Noonan and Glass 2012). As the percentage of workers telecommuting grows, we expect to see increased benefits such as relative reductions in road congestion, office energy use, and GHG emissions from reduced commutes. However, an increase in energy use in the home or at the location where the telecommuting employee chooses to work is expected. The net energy savings are dependent on the energy use of the employer, the energy consumed during commute of the employee, and the habits of the employee while telecommuting.

Environmental implications of telecommuting and transportation

Telecommuting has great potential to reduce VMT and emissions from commuting to and from work. According to the 2009 National Household Travel Survey, over 623 million miles driven were designated as commute travel, making up 28% of the total VMT for that year (Santos et al. 2009). According to the Journal of Infrastructure Systems, 26% of the U.S. energy demand comes from the transportation sector, of which one third can be attributed to commuting (Matthews 2005). Transportation is the one of the few remaining sectors of the economy where energy use is currently increasing and is expected to continue to increase for the foreseeable future. Energy used during commuting results in significant GHG emissions, with passenger vehicles responsible for approximately 35% of all transportation emissions (Figure 1).

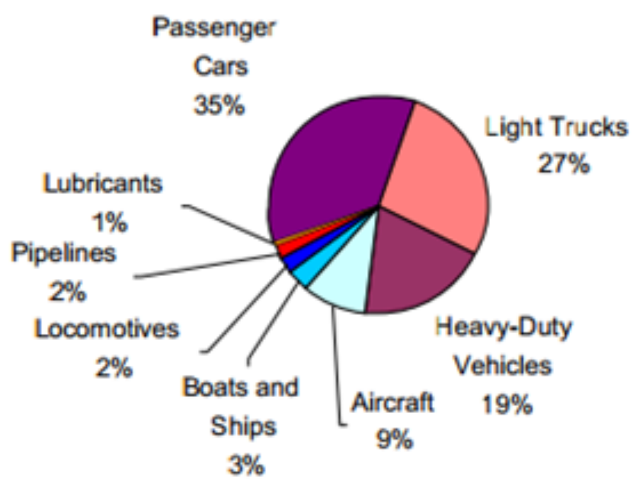


Figure 1. Transportation emissions by source. Passenger vehicles contribute the most emissions due to widespread and frequent use (EPA 2006).

In California, transportation is the largest source of GHG emissions (California Air Resource Board 2013). In 2011, transportation was responsible for 37.6% of carbon dioxide emissions throughout the state, with on-road emissions from passenger vehicles, trucks, and buses making up 92% of these emissions (Matthews and Williams 2005). It is important to note that emissions from transportation depend on VMT as well as time spent stuck in congestion. Widespread telecommuting programs have the potential to alleviate some rush hour congestion if the level of telecommuters is high enough to significantly reduce demand for road space. However there are uncertainties about a telecommuter's driving behavior since they may drive to non-essential work locations throughout the workday or move farther from their offices, creating longer commutes on the days when they do travel to work.

Current telecommuting practices are impacting energy consumption in the United States. According to H. Scott Matthews and Eric Williams, there has been a 0.01-0.4% reduction in energy use in the United States due to telecommuting (2005). The U.S. Department of Transportation found that if 5.2% of the total American workforce telecommuted three to four days each week, U.S. fuel consumption would decrease by roughly 1.1% (Matthews and Williams 2005). These considered not only at transportation-related emissions, but also the effects of decreases in office energy use and increases in home energy use. A full evaluation of the environmental implications of telecommuting must take into account all aspects of avoided and induced energy use.

Transportation sustainability at UC Berkeley

The UC Berkeley campus is committed to many aspects of sustainability ranging from reducing energy use to green purchasing practices in accordance with its 2007 Climate Action Plan and the California Global Warming Solutions Act of 2006 (AB 32) to reduce GHG emissions to 1990 levels by 2014. Since the initiation of the Climate Action Plan, the campus has kept inventory of its GHG emissions from various sectors including waste, energy, and transportation. Transportation related emissions, including faculty, staff, and student commute, as well as air travel and the campus vehicle fleet, contribute 21.5% of the campus' emissions (Figure 2).

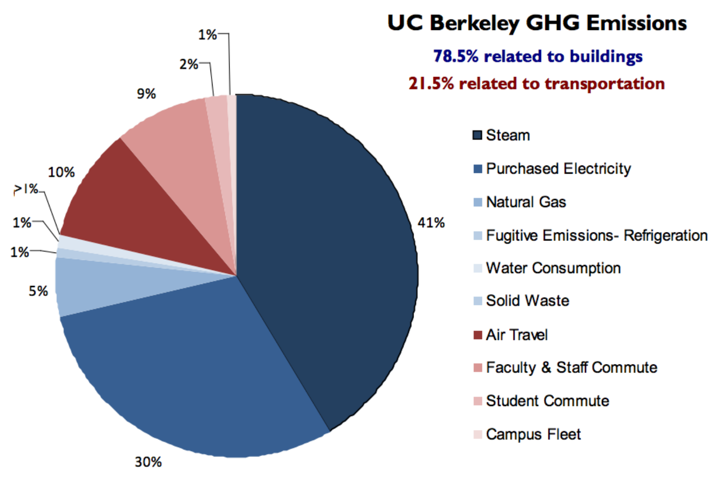


Figure 2. UC Berkeley emissions contributions from various sectors (CalCAP 2009).

The campus has met its goal to reduce fuel use by commuters and the campus fleet to at least 25% below 1990 levels by 2014, and transportation programs such as car-sharing and digital parking space information are being evaluated as other avenues for greater emission reduction.

The University houses over 50,000 faculty, staff, and students and resides at the core of Downtown Berkeley, a public transit hub for services such as AC Transit and Bay Area Rapid Transit (BART). In 2012, Physical and Environmental Planning conducted a transportation survey of the campus population which found that driving alone is the primary mode of transportation for 45% of campus staff, while 23.5% use public transit (Figure 3). In light of this disambiguated transportation mode-split, the campus can begin to consider ways to take advantage of the potential GHG reduction from reducing employee commutes.

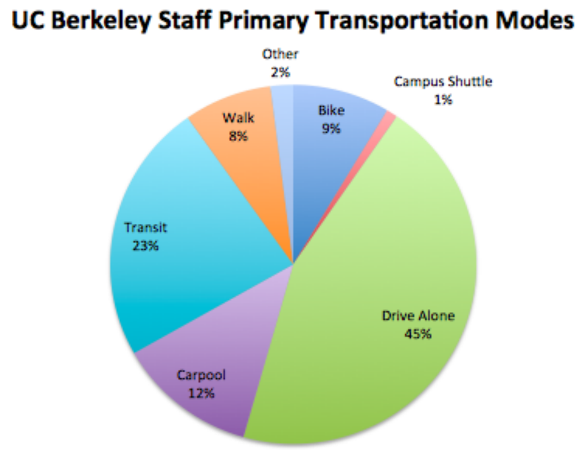


Figure 3. Staff primary transportation at UC Berkeley (2012 UC Berkeley Transportation Survey).

A report by Nelson\Nygard Consulting Inc. addressing the University's parking demand found that over 50% of faculty and staff parking permit holders commute greater than 5 miles (Table 1).

Table 1. Distance to campus for student, faculty/staff parking permit holders (Parking and Transportation 2011).

	Students		Faculty/Staff		Combined	
Distance from center of campus	**#**	**%**	**#**	**%**	**#**	**%**
Less than ¼ mile	173	11%	502	5%	675	5%
Between ¼ to ½ mile	37	2%	274	3%	311	3%
Between ½ to 1 mile	45	3%	560	5%	605	5%
Between 1 and 2 miles	151	10%	1,202	11%	1,353	11%
Between 2 and 5 miles	443	28%	2,596	24%	3,039	25%
More than 5 miles	717	46%	5,619	52%	6,336	51%
Total	**1,566**	**100%**	**10,753**	**100%**	**12,319**	**100%**

Faculty and staff travel from various locations across the San Francisco Bay Area and some cover significant distance on their commute (Figure 4). Implementing structured telecommuting programs in administrative offices at UC Berkeley could help decrease VMT by campus staff and ultimately reduce transportation emissions.

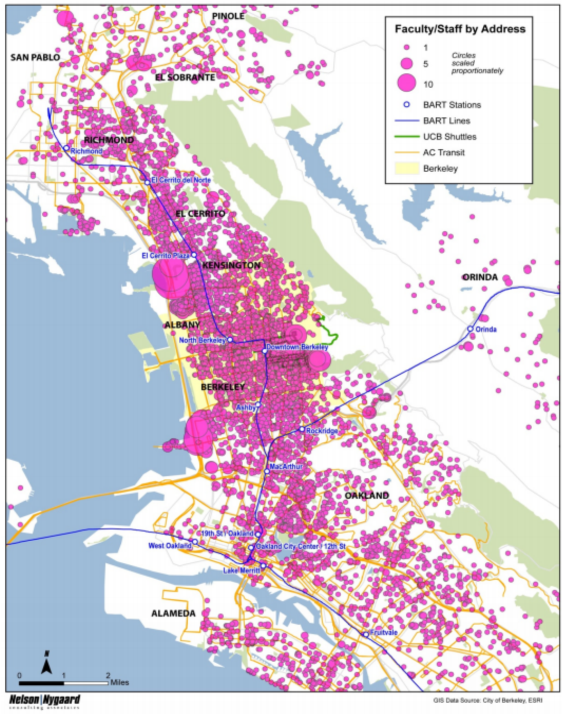


Figure 4. Faculty and staff addresses on the East Bay (Parking and Transportation 2011).

BACKGROUND

Numerous studies have examined the social impacts of telecommuting, such as effects of telecommuting on work life, family life, and long-term effects on relocation. Current research has focused on: management policies on the part of the employer and effective telecommuting on the part of the employee (Nilles 1994), modeling of the effects of telecommuting on change of residential location (Lund and Mokhtarian 1994), the psychological effects that come with increased job and location flexibility (Kossek et al. 2006), and effect on household travel patterns form telecommuting (Mokhtarian et al. 1995).

However, relatively few studies have focused on a quantitative analysis of transportation reductions from telecommuting. The primary focus of many studies has been to determine if there is a reduction in VMT due to telecommuting. Reduced commute-related travel may be compensated for by induced accessory travel (i.e. trips to grocery store, school, lunch, etc). As a result, a telecommuter's total VMT may be greater than if they were to commute and work from an office (Black 2000). However, there are conflicting studies showing a reduction in VMT for an employee telecommuting. Travel diaries of telecommuters have shown reduced commute and overall household trips when compared to an employee who does not telecommute (Niles 1994). In addition, a study in Minneapolis, Minnesota found the majority of employees who telecommuted did not take extra trips during the work day, resulting in a savings of 1.99 trips per day or 27.96 VMT per individual per day (Lari 2012). Another study found that telecommuting reduces about 1% of total household VMT if 6.1 % of total workforce telecommutes an average of 1.2 days a week (Mokhtarian 1998). Although telecommuting may result in a short-term reduction in household VMT, it may not decrease VMT in the long-run due to workers moving to residences further from their place of employment. Therefore, assuming a worker does not telecommute everyday, they will end up commuting longer distances on days they do commute to the work office (Lund and Mokhtarian 1994).

While these studies provide insight into the implications of telecommuting on commute reduction, there has been little research done on the effects of telecommuting on office building and residential energy consumption. Mokhtarian et al. found decreases in office energy use are small because heating, air conditioning, and at times lights are operating even if a single employee does not come to the office (1995). This implies that a telecommuting employee may increase their use of certain resources. For example, an employee working from home may run his home air conditioner while air conditioning at his office is running as well. It has also been noted that telecommuting is only beneficial for reducing office energy use when the office space is shared with other employees while an employee is telecommuting, or if the office space is eliminated (Kitou & Horvath 2003). There is a knowledge gap when it comes to understanding the effects that telecommuting has on office and residential energy use, especially in the context of a large university. Our research aims to gather a deeper understanding of the role telecommuting has on net reductions in carbon emissions of an employer. We will focus specifically on the potential for telecommuting to reduce net carbon emissions at the University of California, Berkeley.

Problem statement

UC Berkeley has met its GHG emissions to 1990 levels by 2014 and is exploring new options to reach zero net emissions. This study investigates whether telecommuting is a viable option to reduce campus GHG emissions and help the University meet its emissions goals by lessening staff commutes and building energy use. We also examine the potential economic benefits of telecommuting.

METHODS

In this study, we calculated the impacts of a telecommuting program in three administrative buildings: University Hall, Sproul Hall, and Campus Shared Services on Fourth Street. We considered three major sources of employee related emissions to be transportation, office building and residential energy use. A system quantifying energy consumption and emissions from these three aspects of UC Berkeley employees is developed. We considered the cases when 10%, 50, 75%, or 100% of the building employees telecommute for either 1, 3, or 5 days a week. Since the roles of faculty and students are (at this point in time) inflexible, requiring a physical presence on campus - only campus staff are considered eligible to telecommute.

Transportation energy savings from telecommuting

When workers telecommute, their carbon emissions decrease through elimination of their physical commutes. To determine this energy and emissions savings, we estimated the average energy an employee consumes commuting to work. We only considered the 45% of staff employees who drive alone to work because driving alone is the dominate source of commute related emissions. We assumed the energy savings from other transit modes such as walking, bicycle, and public transit, to be minimal. Our estimation of the average staff employee commute distance was 11.5 miles for a one way trip to campus (meaning the daily driving distance for one staff member was 23 miles). This is the weighted average of distance all staff employees live from campus as provided by the Physical and Environmental Planning office.

Reductions in fuel consumption and emissions are based on 45% of telecommuters not driving 23 VMT per day. Assuming an average fuel economy of 24.8 miles per gallon, and the energy content of gasoline to be 121.3 MJ/gallon (Davis et al. 2012), it then takes 31.25 kWh for every staff commute. The California Air Resources Board estimates the GHG emissions factor for vehicles in the San Francisco Bay Area air basin to be 340 g CO_2e per mile (2013). Our estimation of energy consumption and GHG emissions from staff commutes are just the product of these use/emission factors with the total staff VMT.

It is important to note that the staff commute distance to campus is a simplified measure of a commute impact on emissions. This distance significantly impacts the emissions and energy use associated with an employee. We address the consequences of this simplification in the Limitations section of this report.

Campus building energy use

UC Berkeley's Office of Space and Capital Resources defines three types of core campus buildings - academic, research, and administrative. In our assessment of the impacts from telecommuting programs, we focused on administrative buildings where staff predominantly work. Building energy use depends on a variety of factors including building size, age and function. The number of employees occupying each building is assumed to be equal to the number of possible work spaces in a building. The

Office of Space and Capital Resources provided the relevant building occupancy and function data. The three buildings we consider for this study are Sproul Hall, University Hall, and the Campus Shared Services Center. The combined staff population of these buildings house approximately 16% of the 12,000 staff employees of UC Berkeley - this provides a sufficient sample from which we begin our assessment of telecommuting impacts on campus related emissions.

Campus building energy use throughout time is recorded on UC Berkeley's myPower tool. In this study we used the average work day energy consumption provided by myPower for our studied buildings.

The amount of building energy saved per employee telecommuting depends on the fraction of all staff in a building who are telecommuting. If the entire building or large zones of it are void of employees, there is the possibility of significant energy savings by reducing demand for lighting and heating, along with ventilation and air conditioning (HVAC). In telecommuting programs where there are both workers in the office and at home, the energy overhead of operating a building is realized, marginalizing building energy use savings. However, through a coordinated telework program it is possible to reduce the number of employees in a building so that sections of the can be "shutdown." Building shutdown reduces overhead building energy use and leads to notable building energy and emission savings.

Administrative buildings were examined in terms of plug load and baseline energy use. The goal is to differentiate between essential power consumption (energy used regardless of any one person being present - power being used to supply HVAC) and nonessential energy use that depends on workers being present (computers, fans, lights, personal heaters). For our purposes, we considered plug loads nonessential energy use, while baseline power to be essential energy use.

The percentage of building energy usage dedicated to lighting, office equipment, and HVAC was reported by the the California Commercial End-Use Survey, see Table 2.

Table 2. Electricity end use breakdown of office buildings in PG&E Climate Zone 3 (Itron 2006).

End Use	End-use Distribution %
HVAC	36
Interior Lighting	28
Office Equipment	16

We computed both average essential and nonessential energy use per occupant for administrative buildings throughout UC Berkeley. The nonessential energy use per occupant per day is the potential energy that is saved by one telecommuting employee. The number of employees who telecommute depends on the nature of their jobs and whether or not their physical presence in the office is required. To account for the uncertainty in the amount of workers who will telecommute, we constructed various building energy use scenarios. These are contingent on the fraction of staff telecommuting and the number of days per week they telecommute. We consider all these situations to be highly structured work at home programs. Table 3 shows the six different scenarios we reviewed in this study. Where we define lighting and office equipment are nonessential energy uses, and HVAC as essential.

Table 3. Campus building energy savings scenarios.

Telecommuting Scenario	
Days Per Week	**Intended Savings**
1	0% building savings
	Save lighting + office equipment
3	0% building savings
	Lighting + Office equipment + HVAC savings
5	Save lighting + Office equipment
	Lighting + Office equipment + HVAC savings

Residential energy use

The Pacific Gas and Electric (PG&E) utility is the major service provider of gas and electric power for the geographical region surrounding UC Berkeley. We assumed all staff homes fall into the domain of PG&E and therefore we used data from PG&E as the basis for calculations on household energy consumption. We presume a UC Berkeley staff employee has home energy usage patterns equivalent to those of an average PG&E residential user. Average household energy consumption of PG&E users is reported in Table 4. PG&E's E-1 Residential Rate Schedule was used for any calculations pertaining to home energy expenditures, see Table 6 for the utility rates we used.

Table 4. Average monthly energy use of a PG&E residential customer (PG&E's ClimateSmart program 2012).

	PG&E Monthly Household Energy Use
Electricity	540 kWh
Natural Gas	45 therms

We expect household energy consumption to increase from the additional demand created by a person occupying a house when working. Demands for heating, air conditioning, appliance electrical use, and plug loads from computing and telework technologies, all increase when someone works from home. Roth et al. showed telecommuting is responsible for 10% increase in total household energy demand (gas and electricity)(2008). Our estimate of the induced increase in home energy consumptions are based on Roth's findings - the energy cost for a worker to telecommute is 10% the average PG&E users daily energy consumption.

Emissions impact of telecommuting

Energy consumptions are converted to GHG emission amounts using emissions factors corresponding to the source of the energy (Table 5). Net energy/emissions savings from a telecommuting scenario are the sum of the three sources of work related emissions (household, commute, UC Berkeley building) over all employees in a building. The base rate emissions of the building when no employees telecommute are compared to emission outputs with a varying number of working days telecommuted (the different scenarios from Table 3). As the number of employees present in campus buildings decreases, the savings from reducing overhead building operation energy increases.

Table 5. Emissions factors from different fuel types - Emissions factors for electricity and natural gas are specifically for PG&E customers (PG&E April 2013). Gasoline emissions factors are for pump-to-wheels tailpipe emissions (Cal Air Resource Board 2013).

Fuel Type	**Emissions Factor**
Electricity	238 gCO_2e per kWh
Natural Gas	208 g CO_2e per kWh
Gasoline	340 g CO_2e per mile

Cost savings resulting from telecommuting are figured using the University energy rate it pays PG&E. These rates are provided by the Office of Sustainability, see Table 6. Any formal telecommuting program at UC Berkeley must contribute to campus emission reduction goals. In addition, a program must be economically viable to both the University and the staff using the telecommuting program. Monetary cost and savings are found by simple multiplication of energy savings/expenditures by the appropriate rate for that energy.

Table 6. PG&E service area electricity and gas rates. Flat rate for residential customers on the E-1 rate schedule with baseline energy demand. The natural gas rates are the Total Residential non-CARE rate schedule, averaged for 2011 and 2012. (pge.com). Electricity rates at UC Berkeley vary for main campus and off-campus buildings and are averaged for differences in time-of-use and seasonal variation (blended). The University off-campus rate was applied for the 4th Street offices.

PG&E E-1 Residential Rate Schedule	
Electricity	\$0.13230 (baseline) per kWh
Natural Gas	\$0.98077 (baseline) per therm
UC Berkeley Energy Rates	
Electricity - Main Campus (blended)	\$0.106 per kWh
Electricity - Off-Campus (blended)	\$0.15 per kWh

RESULTS

The telecommuting scenarios we examined resulted in net positive energy savings. The net energy and emissions savings for University Hall are shown in Table 10. Net energy savings are mainly due to transportation savings being greater than induced residential energy usage. An employee telecommuting one day per week saves approximately 400 kg of CO2e per year from eliminating their commute. With all employees of University Hall telecommuting one day per week, the resulting transportation related GHG emissions savings are 188,000 kg of CO2e annually (Table 7). A one-day per week telecommuting program with 100% of University Hall employees telecommuting resulted in net energy savings of about 5% and net GHG reductions of 136 metric tons CO2e (Table 10). Additionally, an employee telecommuting one day per week can save \$170.00 annually. Table 11 shows potential monetary savings for both workers and the University for our different telecommuting scenarios. The University can save approximately $8,400 annually by implementing a one day per week telecommuting program in one building. The results for Sproul Hall and the Fourth Street offices are displayed in the Appendix (Tables 12-22).

Table 7. Transportation savings from telecommuting by employees in University Hall.

Days per week	Intended Savings	% Employees Telecommuting	Transport Savings in a year (kWh)	Transport Emissions Savings in a year (gCO2e)	Transport Emissions Savings in a year per telecommuter who drives (gCO2e)
1	0% building savings	10%	167,494	18,794,996	389,614
		50%	837,470	93,974,981	
		75%	1,256,205	140,962,471	
		100%	1,674,940	187,949,962	
	Save lighting + office equipment	10%	167,494	18,794,996	
		50%	837,470	93,974,981	
		75%	1,256,205	140,962,471	
		100%	1,674,940	187,949,962	
3	0% building savings	10%	502,482	56,384,989	1,168,843
		50%	2,512,410	281,924,943	
		75%	3,768,615	422,887,414	
		100%	5,024,820	563,849,886	
	Lighting + Office equipment + HVAC savings	10%	502,482	56,384,989	
		50%	2,512,410	281,924,943	
		75%	3,768,615	422,887,414	
		100%	5,024,820	563,849,886	
5	Save lighting + Office equipment	10%	837,470	93,974,981	1,948,072
		50%	4,187,350	469,874,905	
		75%	6,281,025	704,812,357	
		100%	8,374,700	939,749,809	
	Lighting + Office equipment + HVAC savings	10%	837,470	93,974,981	
		50%	4,187,350	469,874,905	
		75%	6,281,025	704,812,357	
		100%	8,374,700	939,749,809	

Table 8. Building energy savings from telecommuting by employees in University Hall.

Days per week	Intended Savings	% Employees Telecommuting	Building Savings in a year (kWh)	Building Emissions Savings in a year (gCO2e)	Building Emissions Savings in a year per telecommuter (gCO2e)
1	0% building savings	10%	0	0	0
		50%	0	0	
		75%	0	0	
		100%	0	0	
	Save lighting + office equipment	10%	7,954	1,890,685	17,637
		50%	39,770	9,453,424	
		75%	59,656	14,180,136	
		100%	79,541	18,906,848	
3	0% building savings	10%	0	0	0
		50%	0	0	
		75%	0	0	
		100%	0	0	
	Lighting + Office equipment + HVAC savings	10%	43,203	10,269,268	95,795
		50%	216,013	51,346,338	
		75%	324,020	77,019,506	
		100%	432,026	102,692,675	
5	Save lighting + Office equipment	10%	39,770	9,453,424	88,185
		50%	198,852	47,267,120	
		75%	298,278	70,900,681	
		100%	397,704	94,534,241	
	Lighting + Office equipment + HVAC savings	10%	72,004	17,115,446	159,659
		50%	360,022	85,577,229	
		75%	540,033	128,365,844	
		100%	720,044	171,154,459	

Table 9. Residential energy increase from telecommuting by employees in University Hall.

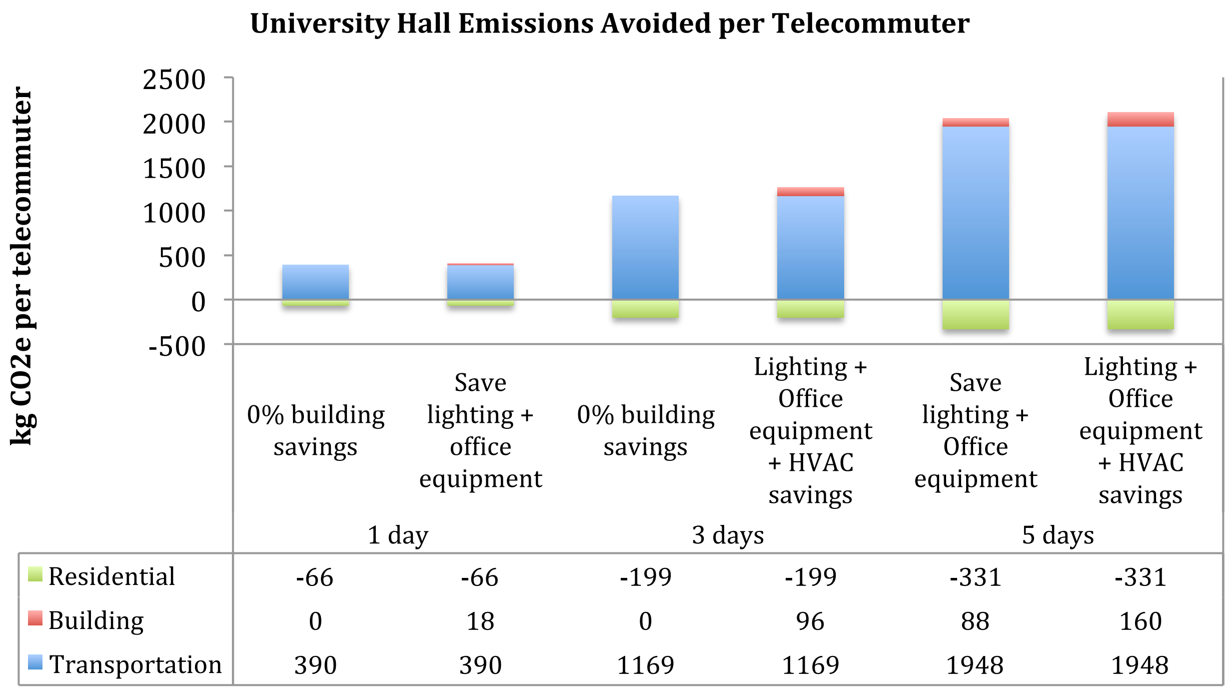
Days per week	Intended Savings	% Employees Telecommuting	Residential Total Energy Increase (kWh/year)	Residential Emissions Increase (gCO2e)	Residential Emissions Increase per telecommuter (gCO2e)
1	0% building savings	10%	32,750	7,099,337	66,225
		50%	163,752	35,496,684	
		75%	245,628	53,245,026	
		100%	327,503	70,993,367	
	Save lighting + office equipment	10%	32,750	7,099,337	
		50%	163,752	35,496,684	
		75%	245,628	53,245,026	
		100%	327,503	70,993,367	
3	0% building savings	10%	98,251	21,298,010	198,675
		50%	491,255	106,490,051	
		75%	736,883	159,735,077	
		100%	982,510	212,980,102	
	Lighting + Office equipment + HVAC savings	10%	98,251	21,298,010	
		50%	491,255	106,490,051	
		75%	736,883	159,735,077	
		100%	982,510	212,980,102	
5	Save lighting + Office equipment	10%	163,752	35,496,684	331,126
		50%	818,758	177,483,419	
		75%	1,228,138	266,225,128	
		100%	1,637,517	354,966,837	
	Lighting + Office equipment + HVAC savings	10%	163,752	35,496,684	
		50%	818,758	177,483,419	
		75%	1,228,138	266,225,128	
		100%	1,637,517	354,966,837	

Table 10. Energy and emissions savings from telecommuting by employees in University Hall.

Days per week	Intended Savings	% employees telecommuting	Net Savings in a year (kWh)	Net Emissions Avoided in a year (metric tons CO2e)	Net Emissions Avoided in a year per telecommuter (kg CO2e)	% Energy savings relative to baseline
1	0% building savings	10%	134,744	11.70	109.10	0.47%
		50%	673,718	58.48		2.36%
		75%	1,010,577	87.72		3.54%
		100%	1,347,437	116.96		4.71%
	Save lighting + office equipment	10%	142,698	13.59	126.74	0.50%
		50%	713,489	67.93		2.50%
		75%	1,070,233	101.90		3.74%
		100%	1,426,977	135.86		4.99%
3	0% building savings	10%	404,231	35.09	327.30	1.41%
		50%	2,021,155	175.43		7.07%
		75%	3,031,732	263.15		10.61%
		100%	4,042,310	350.87		14.14%
	Lighting + Office equipment + HVAC savings	10%	447,434	45.36	423.10	1.57%
		50%	2,237,168	226.78		7.83%
		75%	3,355,752	340.17		11.74%
		100%	4,474,336	453.56		15.65%
5	Save lighting + Office equipment	10%	713,489	67.93	633.69	2.50%
		50%	3,567,444	339.66		12.48%
		75%	5,351,165	509.49		18.72%
		100%	7,134,887	679.32		24.96%
	Lighting + Office equipment + HVAC savings	10%	745,723	75.59	705.17	2.61%
		50%	3,728,614	377.97		13.04%
		75%	5,592,920	566.95		19.57%
		100%	7,457,227	755.94		26.09%

Table 11. University and telecommuter cost savings by employees in University Hall.

Days per week	Intended Savings	% employees telecommuting	University Annual Savings ($)	Annual Residential Expenditures (per telecommuter)	Annual Driving Savings (per telecommuter driver)
1	0% building savings	10%	$0.00	$19.00	$172.41
		50%	$0.00		
		75%	$0.00		
		100%	$0.00		
	Save lighting + office equipment	10%	$843.13		
		50%	$4,215.66		
		75%	$6,323.49		
		100%	$8,431.32		
3	0% building savings	10%	$0.00	$57.00	$517.22
		50%	$0.00		
		75%	$0.00		
		100%	$0.00		
	Lighting + Office equipment + HVAC savings	10%	$4,579.48		
		50%	$22,897.40		
		75%	$34,346.10		
		100%	$45,794.80		
5	Save lighting + Office equipment	10%	$4,215.66	$94.99	$862.04
		50%	$21,078.31		
		75%	$31,617.47		
		100%	$42,156.62		
	Lighting + Office equipment + HVAC savings	10%	$7,632.47		
		50%	$38,162.33		
		75%	$57,243.50		
		100%	$76,324.66		



	1 day: 0% building savings	1 day: Save lighting + office equipment	3 days: 0% building savings	3 days: Lighting + Office equipment + HVAC savings	5 days: Save lighting + Office equipment	5 days: Lighting + Office equipment + HVAC savings
Residential	-66	-66	-199	-199	-331	-331
Building	0	18	0	96	88	160
Transportation	390	390	1169	1169	1948	1948

Figure 5. Net emissions avoided per telecommuter. The net emissions avoided are all positive, due to the large decreases in transportation-related emissions.

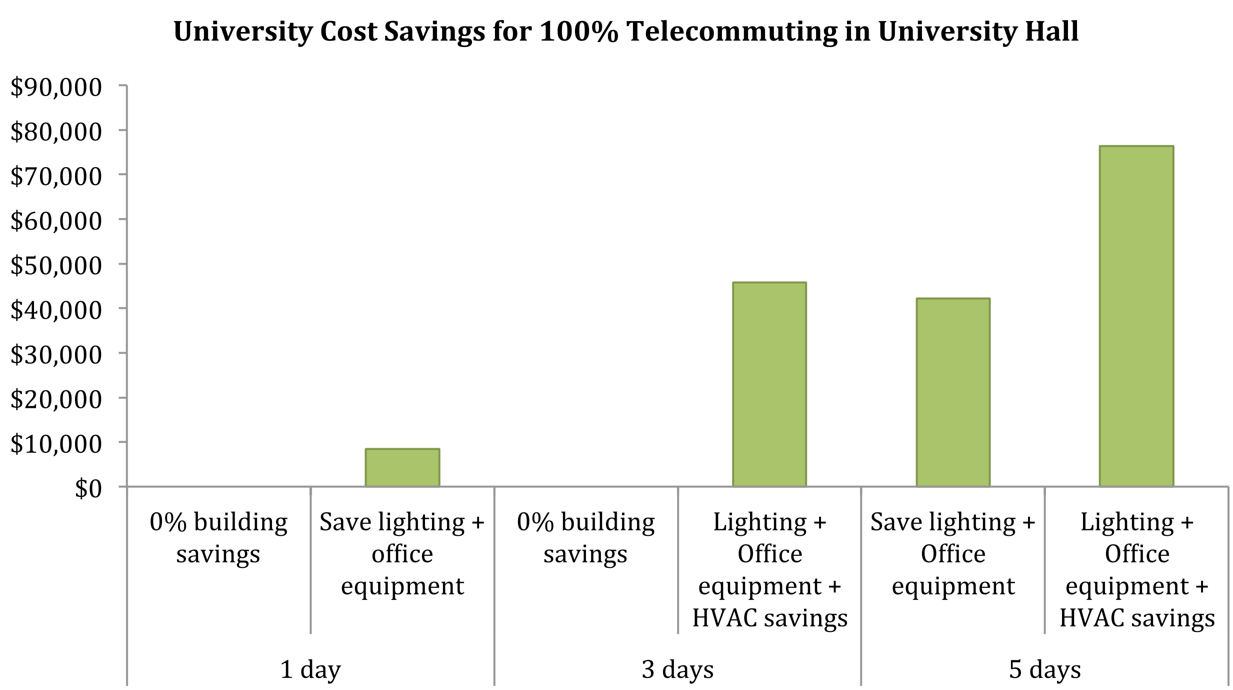


Figure 6. Total cost savings for scenario in which all employees are telecommuting. The greatest cost savings occur for a situation in which the building lighting, office equipment, and HVAC is turned off.

DISCUSSION

System energy reductions and cost savings

In our models of telecommuting for staff at UC Berkeley, we found that energy savings due to transportation reduction were significant compared to campus building energy savings and residential energy increases. This resulted in net energy savings in each scenario we examined. A telecommuter's cost savings from commute elimination are nine times their increase in expenditures on home energy - they save money.

As seen in Table 10, the rate at which energy savings per percent of employees telecommuting increases with a rise in the number of telecommuting days per week. As weekly telecommuting days increase, more building energy saving adjustments are possible. Our results show that energy and economic benefits to the University substantially increase if buildings are able to reduce the essential energy use. Enough employees need to telecommute for partial building shutdown to be practical. This building shutdown can be facilitated through coordination of teleworkers office spaces being confined to parts of the building that only host other teleworkers.

According to the 2012 Campus Sustainability Report, the UC Berkeley campus emitted 182,000 metric tons of CO_2e in 2011. The net energy savings from building and transportation at University Hall result in 0.11% of 2011 total campus emissions (one-day lighting and office equipment savings) (Table 10). Our results show GHG emissions savings per building range from 0.47-31% depending on the extent of the number of workers telecommuting and the specifics of the building. This implies a widely implemented telecommuting program can cut a lot of campus total emissions.

Limitations

There are two main sources of limitations in our study, those stemming from lack of data relating to UC Berkeley employee traits, and limitations due to incomplete understanding of telecommuting effects. First we discuss uncertainties that are the result of poor understanding of telecommuting itself.

We did not consider in this study many forms of induced energy consumption that may result with telecommuting. For example, the additional car trips a teleworker may take throughout the day (perhaps a drive to buy lunch, this is the "rebound effect") are an energy expenditure we did not bother to calculate. This would require research aimed at understanding the non-work related driving behavior of UC Berkeley telecommuters. Other savings and cost are not consider as well - the reduction in mileage an employee saves on his car by not driving is neglected. This may or may not save substantial GHG emissions in the long run by reducing the demand for automobiles. Again, we do not bother to speculate because we do not know enough about the driving habits of the employees to do so. There are other long-term impacts of telecommuting we ignored - the possibility people to relocate further from the university changing their energy use patterns. Generally, we do not consider cost due to changes in social behavior that resulted from people staying at home to work.

Moreover, social, economic, and technological changes that occur independently of telecommuting may also influence the effectiveness of telecommuting programs to reduce GHG emissions. For example, the benefits from reducing the driving commute may change in the coming years as vehicle technologies improve and fuel prices vary. If battery electric vehicles are considered instead of internal combustion engine vehicles, there may be fewer emissions avoided, but cost savings may still be significant.

Other limitations are the result of poor or nonexistent data about UC Berkeley and its employees. Most notably, we do not know the scope to which telecommuting is feasible at UC Berkeley (how many people can practically work from home is unknown). Additionally, our building shut down estimations are rough - we do not know how much a buildings energy demand is reduced when workers are removed. We based our results off of crude assumptions about office building dynamics. Similarly our assumption that the VMT a staff member drives daily is equal to the distance they live from campus is an optimal case. To compensate for our lack of knowledge of how buildings work and employees drive, we constructed a wide range of possible telecommuting situations. How accurately these results match what would actually happen given the implementation of a telecommuting program is hard to say. Though understanding the constraints of our study will help to interpret our results.

Our estimation of residential energy use increases are based on a national study and may not be indicative of energy demand increases for UC Berkeley employees. Once more, data specific to the case of UC Berkeley would increase the resolution of our results.

Eventually, carpools as well as individuals will not have to drive as the number of telecommuters in a building increases. Our results only examined decreases in energy use and emissions resulting from employees who drive alone to campus. This underestimates the true energy/emissions savings as it leaves out the effects of reduced driving from carpools. Finally, we assumed that campus building HVAC energy comes primarily from electricity rather than steam or natural gas. This could lead to an underestimation of the percent energy savings that we calculated.

Further study of which employees can actually telecommute need to be done before our conclusions can become more focused. In the example of Sproul Hall, employees of the UC Berkeley police department and student services are essential to University operations, so our best-case telecommuting scenario would not be possible. Telecommuting at the University is difficult on a logistical level because administrative offices are often dispersed among buildings that have multiple uses.

By consolidating workers likely to telecommute in specific buildings, more building energy savings could result from partial building shutdowns on telecommuting days. Without a structured telecommuting program with coordinated telecommuting schedules, costs and emissions from building energy use would not decrease significantly. Many Human Resources staff have already been consolidated at Campus Shared Services, but further opportunities for staff consolidation should be considered for telecommuting to be effective.

CONCLUSION

UC Berkeley is considering telecommuting as a means to reduce carbon emissions and save money, while conserving space - a valuable campus resource. Our study shows telecommuting can reduce GHG emissions as well as contribute minor monetary savings to the University. Reducing the daily on-campus population would also be a consequence of a telecommuting regimen. However, the implications of telecommuting are complex and reach far beyond the benefits of carbon emissions and improved finances. Substantially reducing the amount of staff working on campus will alter the dynamic of UC Berkeley. Before a telecommuting program is seriously considered as a way to reduce emissions, there are other costs and benefits to consider.

Our study is an initial step in assessing the feasibility of telecommuting at UC Berkeley. The University administration needs to decide what aspects of its campus it values (other than reducing emissions and saving money), and how telecommuting affects these values. A more detailed feasibility assessment is a logical next step before the scope of an official university telecommuting program can be determined. Issues that need greater examination are assessment of the impacts a program has on the Berkeley campus and the employees being asked to work off-site. Specific issues that need greater resolution are - who pays for the necessary equipment to telecommute and what is this cost? Do workers actually want to work from home? How will telecommuting alter worker productivity and the overall efficiency in which staff functions are performed at the University? Are there alternatives that help the University meet its GHG reduction goals without impacting university functions as much as telecommuting?

Surveying university employees to deduce campus wide attitudes towards telecommuting would help in assessing the usefulness of telecommuting at Berkeley. Does implementing a telecommuting program (with emissions reduction as the stated goal) make sense if the idea is not popular among the members who compose the university? Assessing the impact of telecommuting on workplace dynamic, employee mental health, employee productivity, and other traits less tangible than GHG emissions are difficult to measure and quantify. Perhaps a small pilot program could be used to address concerns about the impacts of a large-scale university telecommuting program. Such a program could be used to perform a high-level cost benefit analysis of telecommuting at UC Berkeley.

Beyond staff workers telecommuting, there is potential for students and staff to perform a fraction their duties off-site. We did not examine this possibility because, at this time, the University is not considering removing student and faculty from campus. The work and commute patterns of faculty and students are also more difficult to quantify than those of staff. The number of faculty working at UC Berkeley is also an order of magnitude less than staff employees (there are approximately 1,500 faculty and 12,000 staff) - lessening the potential impact from faculty telecommuting. Though, in the future, if the University is looking to cut emissions even further, they may want to consider a coordinated faculty telecommute program.

The concept of students taking courses off-campus is gaining traction. Large internet-based university level classes, by companies like Coursera, are currently demonstrating the effectiveness of such concepts. For large state run public universities like UC Berkeley, there may be potential to reduce the daily influx of students on campus by having students work from home. This might be particularly appealing to students looking to save money many of whom have family homes in the general vicinity of the University (San Francisco Bay Area). Online courses can also be used to reduce demand for campus building use, including dorm space. Online courses could also be highly profitable for the University, but that is a topic for another paper.

However, talk of having staff, students, and faculty telecommute must be done under the assumption that such drastic implementation of telecommuting programs will alter the landscape of UC Berkeley. The University needs to reconcile their ambitions for telecommuting and the resulting GHG emissions savings with their vision for UC Berkeley's future. Displacing large fractions of UC Berkeley's members runs the risk of ending what we currently consider UC Berkeley.

Alternatives to widespread telecommuting exist and may make sense if UC Berkeley's main goal is to reduce GHG emissions while minimizing the impact to the current campus environment. Our results show the greatest source of emissions savings is from reducing transportation-related emissions. Therefore, rather than using telecommuting to cut emissions, the University could focus on improving the efficiency in which staff commute to campus. This can be done by promoting carpooling, public transportation, or other low emissions means of getting to work. If possible, providing incentives for workers to live close to campus would help lower commute distances. Reducing average VMT of employee commutes results in notable GHG emissions savings. This can be done by lowering staff driving distances, as well as lowering staff demand for driving to campus (e.g. if workers live close to campus they may be more inclined to walk, bike or take the bus to work). Moreover, improvements to campus transportation systems can also be taken advantage of by students and faculty - further increasing emissions savings. A final benefit worth mentioning - reducing the amount of commutes by automobiles to campus will also help the University obtain its goal of decreasing the demand for on-campus parking spaces.

Our report shows that formalized telecommuting programs at UC Berkeley can significantly reduce GHG emissions. However, the exact extent to which emissions can be cut is hard to define because the breadth and nature of a possible telecommuting program cannot be determined at this time. UC Berkeley needs to conduct research on the impacts of telecommuting with the specific needs of the campus in mind. Once the dynamics of the University are quantified and considered, then the broad impacts of telecommuting can be discussed and evaluated. After these further studies UC Berkeley can evaluate the costs and benefits that telecommuting bring to campus. Only then can UC Berkeley determine at what scale (if any) to implement a structured telecommuting program.

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APPENDIX

Table 12. Energy consumption of administrative buildings on campus. From mypower.berkeley.edu.

Name	Square footage	Energy Consumption (kWh/weekday)	kWh/square foot (each building)
Energy Institute at Haas	7,899	58	0.007
Warren Hall	69,354	25,585	0.369
Alumni House	15,590	302	0.019
Anthony Hall	2,010	35	0.017
Birge Hall	97,032	8,558	0.088
Blum Hall	26,266	357	0.014
Durant Hall	22,038	645	0.029
Dwinelle Annex	8,787	56	0.006
McLaughlin Hall	531,607	938	0.002
O'Brien Hall	41,822	1,486	0.036
South Hall	30,401	419	0.014
Sproul Hall	111,198	2,797	0.025
Stephens Hall	59,548	1,236	0.021
University Hall	152,987	3,632	0.024
TOTAL	1,176,539	46,104	
kWh/square foot (all buildings)	0.039		

Table 13. Transportation savings from telecommuting by employees in Sproul Hall.

Days per week	Intended Savings	% employees telecommuting	Transport Savings in a year (kWh)	Transport Emissions Savings in a year (gCO2e)	Transport Emissions Savings in a year per telecommuter who drives (gCO2e)
1	0% building savings	10%	86,716	9,730,618	389,614
		50%	433,578	48,653,092	
		75%	650,367	72,979,638	
		100%	867,156	97,306,184	
	Save lighting + office equipment	10%	86,716	9,730,618	
		50%	433,578	48,653,092	
		75%	650,367	72,979,638	
		100%	867,156	97,306,184	
3	0% building savings	10%	260,147	29,191,855	1,168,843
		50%	1,300,735	145,959,275	
		75%	1,951,102	218,938,913	
		100%	2,601,469	291,918,551	
	Lighting + Office equipment + HVAC savings	10%	260,147	29,191,855	
		50%	1,300,735	145,959,275	
		75%	1,951,102	218,938,913	
		100%	2,601,469	291,918,551	
5	Save lighting + Office equipment	10%	433,578	48,653,092	1,948,072
		50%	2,167,891	243,265,459	
		75%	3,251,837	364,898,189	
		100%	4,335,782	486,530,918	
	Lighting + Office equipment + HVAC savings	10%	433,578	48,653,092	
		50%	2,167,891	243,265,459	
		75%	3,251,837	364,898,189	
		100%	4,335,782	486,530,918	

Table 14. Building energy savings from telecommuting by employees in Sproul Hall.

Days per week	Intended Savings	% employees telecommuting	Building Savings in a year (kWh)	Building Emissions Savings in a year (gCO2e)	Building Emissions Savings in a year per telecommuter (gCO2e)
1	0% building savings	10%	-	-	-
		50%	-	-	
		75%	-	-	
		100%	-	-	
	Save lighting + office equipment	10%	6,125	1,456,015	26,234
		50%	30,627	7,280,074	
		75%	45,941	10,920,110	
		100%	61,254	14,560,147	
3	0% building savings	10%	-	-	-
		50%	-	-	
		75%	-	-	
		100%	-	-	
	Lighting + Office equipment + HVAC savings	10%	33,270	7,908,354	142,493
		50%	166,352	39,541,769	
		75%	249,527	59,312,654	
		100%	332,703	79,083,539	
5	Save lighting + Office equipment	10%	30,627	7,280,074	131,172
		50%	153,136	36,400,368	
		75%	229,704	54,600,552	
		100%	306,272	72,800,736	
	Lighting + Office equipment + HVAC savings	10%	55,451	13,180,590	237,488
		50%	277,253	65,902,949	
		75%	415,879	98,854,423	
		100%	554,505	131,805,898	

Table 15. Residential energy increase from telecommuting by employees in Sproul Hall.

Days per week	Intended Savings	% employees telecommuting	Residential Total Energy Increase (kWh/year)	Residential Emissions Increase (gCO2e)	Residential Emissions Increase per telecommuter (gCO2e)
1	0% building savings	10%	16,956	3,675,496	66,225
		50%	84,778	18,377,481	
		75%	127,167	27,566,221	
		100%	169,556	36,754,962	
	Save lighting + office equipment	10%	16,956	3,675,496	
		50%	84,778	18,377,481	
		75%	127,167	27,566,221	
		100%	169,556	36,754,962	
3	0% building savings	10%	50,867	11,026,489	198,675
		50%	254,334	55,132,443	
		75%	381,502	82,698,664	
		100%	508,669	110,264,885	
	Lighting + Office equipment + HVAC savings	10%	50,867	11,026,489	
		50%	254,334	55,132,443	
		75%	381,502	82,698,664	
		100%	508,669	110,264,885	
5	Save lighting + Office equipment	10%	84,778	18,377,481	331,126
		50%	423,891	91,887,404	
		75%	635,836	137,831,106	
		100%	847,782	183,774,808	
	Lighting + Office equipment + HVAC savings	10%	84,778	18,377,481	
		50%	423,891	91,887,404	
		75%	635,836	137,831,106	
		100%	847,782	183,774,808	

Table 16. Energy and emissions savings from telecommuting by employees in Sproul Hall.

Days per week	Intended Savings	% employees telecommuting	Net Savings in a year (kWh)	Net Emissions Avoided in a year (metric tons CO2e)	Net Emissions Avoided in a year per telecommuter (kg CO2e)	% Energy savings relative to baseline
1	0% building savings	10%	69,760	6.06	109.10	0.46%
		50%	348,800	30.28		2.32%
		75%	523,200	45.41		3.48%
		100%	697,600	60.55		4.64%
	Save lighting + office equipment	10%	75,885	7.51	135.34	0.50%
		50%	379,427	37.56		2.52%
		75%	569,141	56.33		3.79%
		100%	758,854	75.11		5.05%
3	0% building savings	10%	209,280	18.17	327.30	1.39%
		50%	1,046,400	90.83		6.96%
		75%	1,569,600	136.24		10.44%
		100%	2,092,800	181.65		13.93%
	Lighting + Office equipment + HVAC savings	10%	242,550	26.07	469.80	1.61%
		50%	1,212,752	130.37		8.07%
		75%	1,819,128	195.55		12.10%
		100%	2,425,503	260.74		16.14%
5	Save lighting + Office equipment	10%	379,427	37.56	676.68	2.52%
		50%	1,897,136	187.78		12.62%
		75%	2,845,704	281.67		18.94%
		100%	3,794,272	375.56		25.25%
	Lighting + Office equipment + HVAC savings	10%	404,251	43.46	782.99	2.69%
		50%	2,021,253	217.28		13.45%
		75%	3,031,879	325.92		20.17%
		100%	4,042,506	434.56		26.90%

Table 17. University and telecommuter cost savings by employees in Sproul Hall.

Days per week	Intended Savings	% employees telecommuting	University Annual Savings ($)	Annual Residential Expenditures (per telecommuter)	Annual Driving Savings (per telecommuter driver)
1	0% building savings	10%	$0.00	$19.00	$172.41
		50%	$0.00		
		75%	$0.00		
		100%	$0.00		
	Save lighting + office equipment	10%	$649.30		
		50%	$3,246.48		
		75%	$4,869.72		
		100%	$6,492.96		
3	0% building savings	10%	$0.00	$57.00	$517.22
		50%	$0.00		
		75%	$0.00		
		100%	$0.00		
	Lighting + Office equipment + HVAC savings	10%	$3,526.65		
		50%	$17,633.27		
		75%	$26,449.90		
		100%	$35,266.53		
5	Save lighting + Office equipment	10%	$3,246.48	$94.99	$862.04
		50%	$16,232.39		
		75%	$24,348.58		
		100%	$32,464.78		
	Lighting + Office equipment + HVAC savings	10%	$5,877.76		
		50%	$29,388.78		
		75%	$44,083.17		
		100%	$58,777.56		

Table 18. Transportation savings from telecommuting by employees in Fourth Street Offices.

Days per week	Intended Savings	% employees telecommuting	Transport Savings in a year (kWh)	Transport Emissions Savings in a year (gCO2e)	Transport Emissions Savings in a year per telecommuter who drives (gCO2e)
1	0% building savings	10%	86,716	9,730,618	389,614
		50%	433,578	48,653,092	
		75%	650,367	72,979,638	
		100%	867,156	97,306,184	
	Save lighting + office equipment	10%	86,716	9,730,618	
		50%	433,578	48,653,092	
		75%	650,367	72,979,638	
		100%	867,156	97,306,184	
3	0% building savings	10%	260,147	29,191,855	1,168,843
		50%	1,300,735	145,959,275	
		75%	1,951,102	218,938,913	
		100%	2,601,469	291,918,551	
	Lighting + Office equipment + HVAC savings	10%	260,147	29,191,855	
		50%	1,300,735	145,959,275	
		75%	1,951,102	218,938,913	
		100%	2,601,469	291,918,551	
5	Save lighting + Office equipment	10%	433,578	48,653,092	1,948,072
		50%	2,167,891	243,265,459	
		75%	3,251,837	364,898,189	
		100%	4,335,782	486,530,918	
	Lighting + Office equipment + HVAC savings	10%	433,578	48,653,092	
		50%	2,167,891	243,265,459	
		75%	3,251,837	364,898,189	
		100%	4,335,782	486,530,918	

Table 19. Building energy savings from telecommuting by employees in Fourth Street Offices.

Days per week	Intended Savings	% employees telecommuting	Building Savings in a year (kWh)	Building Emissions Savings in a year (gCO2e)	Building Emissions Savings in a year per telecommuter (gCO2e)
1	0% building savings	10%	0	0	0
		50%	0	0	
		75%	0	0	
		100%	0	0	
	Save lighting + office equipment	10%	6,125	1,456,015	26,234
		50%	30,627	7,280,074	
		75%	45,941	10,920,110	
		100%	61,254	14,560,147	
3	0% building savings	10%	0	0	0
		50%	0	0	
		75%	0	0	
		100%	0	0	
	Lighting + Office equipment + HVAC savings	10%	33,270	7,908,354	142,493
		50%	166,352	39,541,769	
		75%	249,527	59,312,654	
		100%	332,703	79,083,539	
5	Save lighting + Office equipment	10%	30,627	7,280,074	131,172
		50%	153,136	36,400,368	
		75%	229,704	54,600,552	
		100%	306,272	72,800,736	
	Lighting + Office equipment + HVAC savings	10%	55,451	13,180,590	237,488
		50%	277,253	65,902,949	
		75%	415,879	98,854,423	
		100%	554,505	131,805,898	

Table 20. Residential energy increase from telecommuting by employees in Fourth Street offices.

Days per week	Intended Savings	% employees telecommuting	Residential Total Energy Increase (kWh/year)	Residential Emissions Increase (gCO2e)	Residential Emissions Increase per telecommuter (gCO2e)
1	0% building savings	10%	16,956	3,675,496	66,225
		50%	84,778	18,377,481	
		75%	127,167	27,566,221	
		100%	169,556	36,754,962	
	Save lighting + office equipment	10%	16,956	3,675,496	
		50%	84,778	18,377,481	
		75%	127,167	27,566,221	
		100%	169,556	36,754,962	
3	0% building savings	10%	50,867	11,026,489	198,675
		50%	254,334	55,132,443	
		75%	381,502	82,698,664	
		100%	508,669	110,264,885	
	Lighting + Office equipment + HVAC savings	10%	50,867	11,026,489	
		50%	254,334	55,132,443	
		75%	381,502	82,698,664	
		100%	508,669	110,264,885	
5	Save lighting + Office equipment	10%	84,778	18,377,481	331,126
		50%	423,891	91,887,404	
		75%	635,836	137,831,106	
		100%	847,782	183,774,808	
	Lighting + Office equipment + HVAC savings	10%	84,778	18,377,481	
		50%	423,891	91,887,404	
		75%	635,836	137,831,106	
		100%	847,782	183,774,808	

Table 21. Energy and emissions savings from telecommuting by employees in Fourth Street offices.

Days per week	Intended Savings	% employees telecommuting	Net Savings in a year (kWh)	Net Emissions Avoided in a year (metric tons CO2e)	Net Emissions Avoided in a year per telecommuter (kg CO2e)	% Energy savings relative to baseline
1	0% building savings	10%	69,760	6.06	109.10	0.5%
		50%	348,800	30.28		2.3%
		75%	523,200	45.41		3.5%
		100%	697,600	60.55		4.6%
	Save lighting + office equipment	10%	75,885	7.51	135.34	0.5%
		50%	379,427	37.56		2.5%
		75%	569,141	56.33		3.8%
		100%	758,854	75.11		5.1%
3	0% building savings	10%	209,280	18.17	327.30	1.4%
		50%	1,046,400	90.83		7.0%
		75%	1,569,600	136.24		10.4%
		100%	2,092,800	181.65		13.9%
	Lighting + Office equipment + HVAC savings	10%	242,550	26.07	469.80	1.6%
		50%	1,212,752	130.37		8.1%
		75%	1,819,128	195.55		12.1%
		100%	2,425,503	260.74		16.1%
5	Save lighting + Office equipment	10%	379,427	37.56	676.68	2.5%
		50%	1,897,136	187.78		12.6%
		75%	2,845,704	281.67		18.9%
		100%	3,794,272	375.56		25.3%
	Lighting + Office equipment + HVAC savings	10%	404,251	43.46	782.99	2.7%
		50%	2,021,253	217.28		13.5%
		75%	3,031,879	325.92		20.2%
		100%	4,042,506	434.56		26.9%

Table 22. University and telecommuter cost savings by employees in Fourth Street offices.

Days per week	Intended Savings	% employees telecommuting	University Annual Savings ($)	Annual Residential Expenditures (per telecommuter)	Annual Driving Savings (per telecommuter driver)
1	0% building savings	10%	0	$19.00	$172.41
		50%	0		
		75%	0		
		100%	0		
	Save lighting + office equipment	10%	$649.30		
		50%	$3,246.48		
		75%	$4,869.72		
		100%	$6,492.96		
3	0% building savings	10%	0	$57.00	$517.22
		50%	0		
		75%	0		
		100%	0		
	Lighting + Office equipment + HVAC savings	10%	$3,526.65		
		50%	$17,633.27		
		75%	$26,449.90		
		100%	$35,266.53		
5	Save lighting + Office equipment	10%	$3,246.48	$94.99	$862.04
		50%	$16,232.39		
		75%	$24,348.58		
		100%	$32,464.78		
	Lighting + Office equipment + HVAC savings	10%	$5,877.76		
		50%	$29,388.78		
		75%	$44,083.17		
		100%	$58,777.56		