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University of California Sustainability:

A Multi-Criteria Decision Analysis of Distance Learning

Sarah Thorne

A Thesis in the Field of Sustainability

for the Degree of Master of Liberal Arts in Extension Studies

Harvard University

November 2018

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Abstract

Achieving sustainability in universities is key to achieving a resilient society. Universities educate students, engage local communities, raise awareness about impacts, and encourage the incorporation of sustainability values into society. Faculty research and technology development is solving some of the most critical environmental problems. Recognizing their leadership role, many are now incorporating sustainability goals into their core activities and looking for ways to reduce their own impacts.

The University of California (UC) is a leader in efforts to achieve sustainability, setting an aggressive target of carbon neutrality by 2025 (UCOP, n.d.-a). Achieving this goal will be challenging given expanded enrollments and targets that seek to eliminate emissions from campus commutes and air travel. Given the scale of impacts from campus energy consumption and transportation, distance education initiatives may prove valuable in achieving sustainability.

The primary objective of this study was to develop an expanded analytical framework for evaluating university sustainability programs and policies like distance education and e-learning that reduce environmental degradation (represented by CO_2e emissions) in a cost-effective and socially-beneficial manner. I hypothesized in this test case that the direct effect of 10,000 enrolled UC Santa Cruz students completing their undergraduate degree remotely rather than in expanded traditional brick and mortar buildings will help meet state enrollment growth targets while significantly reducing environmental impacts. This shift will help achieve carbon neutrality goals for the campus without moving boundaries to outsource student and operational impacts.

Further, I proposed that the social and economic benefits from expanded access will outweigh potential negative impacts.

To test this hypothesis, greenhouse gas (GHG) emission models were constructed for a pilot UC campus, Santa Cruz, with existing and proxy foreground data. After calculating the difference between impact categories, it was determined that meeting growth expectations of 10,000 additional students over the next 20 years through expanded distance programs paired with a static but more sustainable campus will be superior to plans to expand the residential and peripheral facilities to educate in a traditional model.

The modeling tool developed to demonstrate that the university should significantly increase the development of high-quality online/distance programs to achieve long-term sustainability can now be applied to other critical sustainability issues like business travel and procurement to demonstrate leadership in identifying net-positive initiatives to achieve true sustainability.

Dedication

This thesis and degree is dedicated first to my boys, Lachlan and William. I hope I modeled how to follow your passions, no matter what others think, work for what you want, and remember that nothing great is achieved alone. I love you to the moon and back.

And, for my wonderful husband, Flint…no words can express the gratitude I feel for the man crazy enough to date and then marry me during this process. Your love has carried me and given me the strength for one last “Hail Mary” pass.

Now back to getting every day started right and dancing the night away like no one is watching.

Acknowledgments

I wish to acknowledge the ongoing support of Dr. Thomas P. Gloria, director of the Sustainability Program at the Harvard University Division of Continuing Education and my thesis director. Thank you for having confidence that I could tackle a LCA thesis after only one class.

And, special thanks to Lacey Klingensmith, advisor for Sustainability and Development Practices.

The guidance, flexibility, and support you both provided kept me moving forward when the original idea did not work as planned and my health failed. I am eternally grateful!

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Definition of Terms

ACUPCC	American College & University Presidents' Climate Commitment
AVR	Average vehicle ridership
BAU	Business as usual – Traditional university model
BEES	Building for Environmental and Economic Sustainability
E-LCA	Environmental life cycle analysis
FTE	Full-time equivalent student (assumes 3 academic quarters per year)
GHG	Greenhouse gas emissions
REC	Renewable Energy Credits
S-LCA	Social life cycle analysis
TRACI	Tool for the Reduction and Assessment of Chemical and other Environmental Impacts
UC	University of California
UCOP	University of California, Office of the President

Chapter I

Introduction

The importance of sustainable universities is well established in the literature (Alshuwaikhat & Abubakar, 2008; Velazquez, Munguia, Platt, & Taddei, 2006). Universities export sustainability values beyond the campus gates to the greater society through alumni, community service, conferences, workshops, courses, and faculty research and development (Alshuwaikhat & Abubakar, 2008). Recognizing their vital role, an increasing number of universities are adopting more sustainable practices, including certified “green” building standards to reduce the impacts from construction, maintenance, and operations (McGraw-Hill Construction, 2013). Waste reduction and recycling programs for students, staff, and faculty have become widespread.

Some schools have gone much further to adopt aggressive climate neutrality goals. However, it is not possible to completely eliminate emissions in a built-environment so they have turned to renewable energy credits (REC) and other purchased carbon market offsets to achieve these sustainability goals (Carlson, 2008) with questionable returns on their investment (Böhm, 2009). Additionally, achievement of climate neutrality goals has been achieved through the exclusion of core university impact categories such as procurement, business travel, and off-campus student housing from the measured system boundaries.

The University of California is one of the nation’s top ranked public university systems (US News, 2016) and has been a leader in efforts to achieve sustainability through aggressive reduction efforts and renewable energy sourcing. The UC system has set a target of carbon neutrality by 2025 (UCOP, 2014). Achieving this goal will be challenging given the need for expanded infrastructure to accommodate increasing student enrollment (University of California, 2016). Impacts from transportation will also increase with more students traveling to campus by public transportation and private automobile. Many proposals to mitigate GHG emissions have been put forward and implemented. However, one option that could help the university avoid the need for expanded infrastructure and transportation systems has not been fully examined: distance education.

Research Significance and Objectives

The primary objective of this study was to develop a life cycle analysis (LCA) model for evaluating campus-specific and system-wide sustainability initiatives to minimizing environmental impacts. This model can become one component in a multi-criteria decision analysis that integrates social and economic costs with environmental. This framework can then be used to evaluate the option of expanded distance education programs to determine if they can reduce the footprint of the university.

Background

The University of California is a founding signatory of the American College & University Presidents' Climate Commitment (ACUPCC) (Second Nature, 2017). By agreeing to participate in the ACUPCC Carbon Initiative, the UC system needs to reduce GHG emissions to 1990 levels by 2020 and achieve carbon neutrality by 2025 (UCOP, n.d.-a). This equates to a reduction of 360,000 metric tons CO_2e by 2020 and 1.2 million metric tons by 2025 (UCOP, 2014). To achieve these ambitious goals, UC President

Janet Napolitano convened a Leadership Council, comprised of experts from each campus as well as business and non-profit advisors to review efforts and ensure 2025 neutrality goals are achieved.

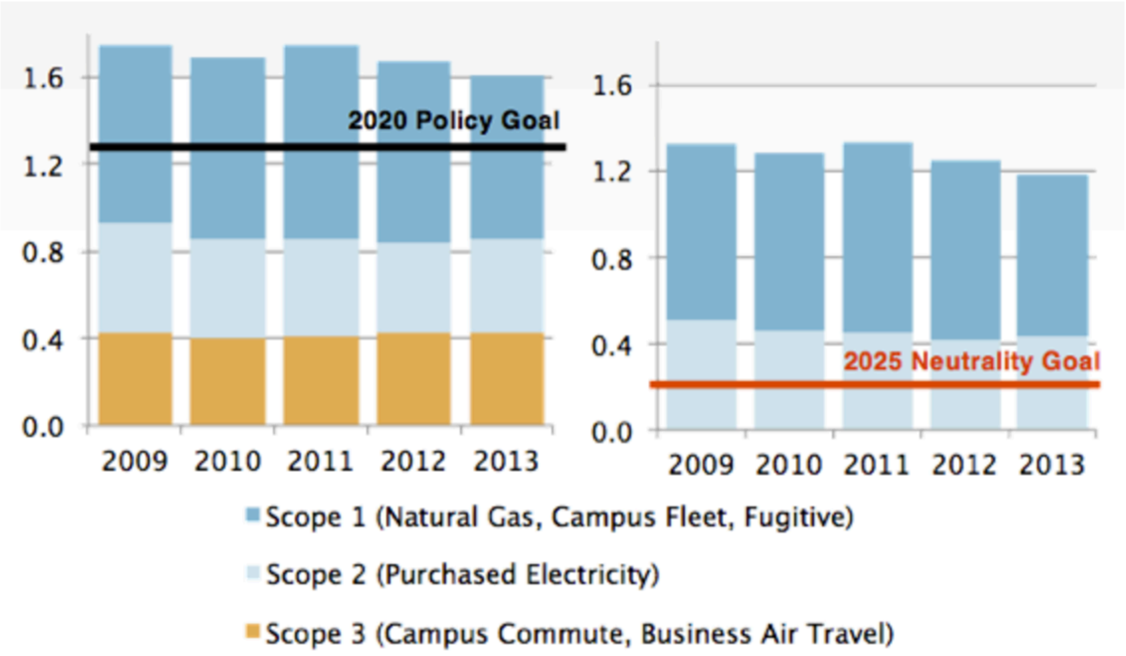


Figure 1. UC greenhouse gas emissions (UCOP, 2014).

Reduction Scopes

Specific policies, initiatives, and technology are grouped into three scopes with individual reduction targets and timelines for each (Figure 1). Scope 1 emissions include campus use of fuels for heating and campus fleet vehicles. Scope 2 covers emissions from purchased electricity for campus-owned buildings. The wholesale procurement of renewable energy, natural gas, and biogas in addition to installation of renewable energy sources such as solar panels at campus sites has already begun to reduce greenhouse gas emissions in these first two scopes. Scope 3 includes the emissions from campus commutes and business air travel.

The UC target for Scope 3 is the nearly complete elimination of these emissions, a somewhat unrealistic short-term goal given the needs of research faculty to attend and host meetings, symposia, and conferences or complete field research to stay relevant in their fields. With rising costs of living across the state, it is also likely that students, staff, and faculty will continue to commute from more affordable neighborhoods. Moving these high-impact categories outside of the system boundaries to achieve goals is deceptive. To accurately and honestly achieve Scope 3 reductions, the university will need to provide sustainable alternatives to vehicle commute and air travel, especially the development of web conferencing and digital tools for teaching, research, and community engagement. The UC Office of the President could lead the way by reducing or even eliminating in-person meetings in Oakland which require significant travel for most of the system campuses. Expanded distance education options for student may also help in this area. By educating in place, transportation impacts are eliminated and energy use for digital participation may be less than the amount consumed to power traditional university facilities.

Impacts from Projected Enrollment Increases

Adding to the challenges of achieving the stated sustainability goals is the continued growth of the California population (PPIC, 2016), improved high school graduation rates, and increasing demand for higher education (CDE, 2017). Over the next three years the UC system expects to increase enrollment by an additional 10,000 students with 14,000 beds (UCOP, n.d.-b) added to ensure affordable housing options for all students. Many campuses have already reached their geographic limits and cannot easily add infrastructure. Other campuses would need to expand into currently undeveloped natural reserves, removing trees and vegetation that provide carbon sequestration and other valuable environmental services. And, the construction, maintenance, operation, and disposal impacts will increase the environmental footprint, even if LEED certified. Distance education options might allow some of these additional students to remain at home while still receiving an invaluable education.

Triple Bottom Line Metric

As noted by Seagal, et al in "Inspiration to Operation – Securing Net Benefits vs. Zero Outcome," a MCDA process is not solely focused on decision making but rather providing "the necessary information for effective and transparent communication of potential points of conflict or compromise" (Seager, Gisladottir, Mancillas, Roege, & Linkov, 2017) While environmental, social, and economic impact reductions are all important goals, compartmentalizing or focusing on only one or even two of the metrics can leave an organization vulnerable and prevent achievement of long-term sustainability goals.

Environmental impacts are the primary focus of this study. After the Kyoto Protocol was adopted, signatories agreed to reduce GHG by at least 18% below 1990 levels no later than 2020 (United Nations, 2014). Carbon dioxide (CO2), Methane (CH4), Nitrous Oxide (N2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), and Sulphur Hexafluoride (SF6) were specifically identified as the primary contributors to climate change and the most important to reduce. The GHG Protocol was amended in May 2013 to include a seventh critical GHG, Nitrogen Trifluoride (NF3) (United

Nations, 2014). These COP targets form the foundation of current UC sustainability efforts and their exclusive focus on GHG emissions.

While it is certainly critical to reduce GHG to avert a climate catastrophe, this focus on a single eco-indicator leaves the “appearance that something substantive is being done” and “it lulls people into feeling that the environment has been, and is adequately, considered” (Onisto, 1999). While this proposed environmental impact model will focus on a single eco-indicator, it is important to eventually expand to a full spectrum of environmental impact characterizations. For example, water impacts may become more significant as droughts intensify and temperatures rise in California. If one option has lower GHG emissions but utilizes or contaminates significant quantities of water, it may not be the best path forward. The weighting of each impact relative to the others can be negotiated as circumstances change to effectively compare alternatives.

In most businesses, financial costs are the sole metric to evaluate proposed programs, initiatives, and policies. In this MCDA, they remain as one of three pillars for option analyses. The UC system has faced ongoing state funding cuts and is required to justify all expenditures of public monies. However, the economic analysis does not always include a robust life cycle costing. This allows alternatives to be evaluated on both their short term outlay of primary funds, future costs for maintenance and operation, and externalities that have traditionally been omitted. Where construction and management of facilities are outsourced to private vendors, it is important to include these costs to understand the universities full impact. Inclusion of both indirect and direct costs will likely demonstrate the cost-effectiveness of the distance education option.

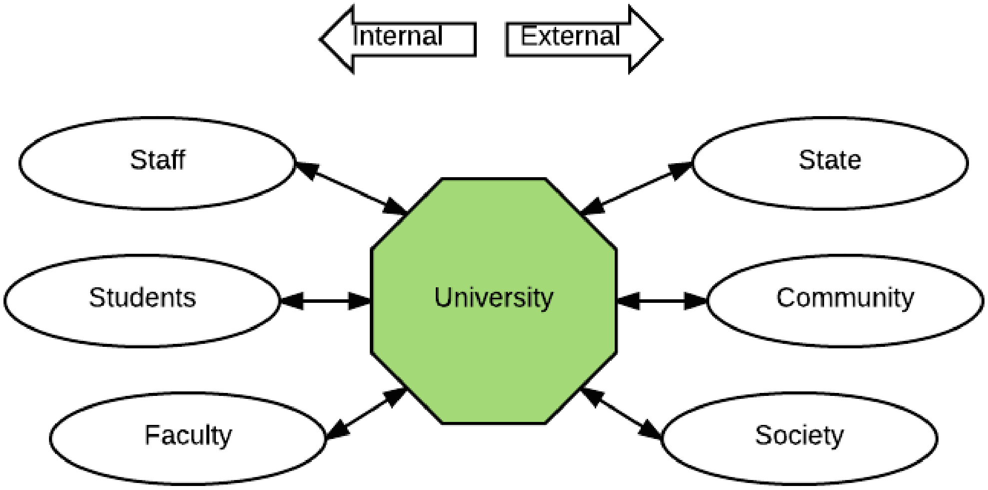


Figure 2. University stakeholders.

Societal impacts are a concern for most decision makers but they are rarely quantified or formally included in the decision-making process. Their inclusion is critical for a robust MCDA. Guided by UNEP-SETAC Life Cycle Initiative standards, LCA practitioners are establishing generally accepted social indicators and collecting data on upstream impacts. The first step is to determine the key stakeholders and the key areas of potential impact that need to be measured qualitatively and quantitatively. Figure 2 proposes the key stakeholders for the UC system. Table 1 (below) provides proposed social impact characterizations for each of these six stakeholder groups.

To fully evaluate distance education initiatives relative to BAU and campus expansion, numeric values would need to be established that reflect the relative importance of each impact. As in the environmental normalization, this process is highly subjective and requires consensus from representatives of each stakeholder group to be useful for decision making. Undertaking this exercise is beyond the scope of this initial study but should be undertaken before a final examination of the options.

Table 1. Social impact characterization.

Stakeholder categories	Subcategories
Staff/Faculty	• Freedom of Association and Collective Bargaining • Feedback Mechanisms • Transparency • Fair Salary • Fair Working Hours • Equal opportunities/Discrimination • Health and Safety
Student	• Health & Safety • Feedback Mechanism • Transparency • Access to resources • Education
Local community	• Access to resources • Safe, healthy, and secure living conditions • Engagement • Local employment
Society	• Public commitment to sustainability • Contribution to economic development • Technology development
State	• Improved social conditions • Educated citizenry • Workforce skills training

Distance Education as Effective Offsets

Beyond the possibility of reducing the environmental footprint of the university, distance education programs may also provide a more effective offset than the REC and other purchased carbon credits currently utilized. The success of carbon markets to help achieve sustainability outcomes has been questioned extensively (Böhm, 2009). REC programs face similar critiques: money is spent on subsidizing projects that do not provide direct renewable energy and may not increase the total mix in the grid or reduce the overall demand for energy, providing little more than an empty marketing claim for the purchaser (Carlson, 2008; Press, 2009). It is imperative the UC system ensure public monies are spent on projects that can demonstrate direct, effective, and measurable sustainability outcomes. It is also preferable that these projects are “closer to home” where their presence can aid in sustainability modeling and education.

In fact, distance education, in addition to aiding in reduction efforts, may provide a more effective way to offset the remaining footprint through “handprinting” (Norris, 2013). Norris suggested that a net positive impact can be claimed if the “positive changes we purposefully bring about in relation to an impact category, are greater than [the] footprints for the same category” (Norris, 2013). Thus, it may be that by encouraging new students to pursue new opportunities in lower-impact distance education programs, the university can claim a positive “offset” of their footprint. Handprinting is not without its flaws and critics. As with the calculation of a footprint, the multiple attribution (double-counting) of responsibility in handprinting is an issue that is not resolved (Behm, Husgafvel, Hohenthal, Pihkola, & Vatanen, 2016; Gröschl, 2016). Even in this model, there are impacts that could be attributed to the individual, institution, private and public partners, or even the community. However, as long as these are clearly noted and the examination remains focused on one of these perspectives with direct and indirect impacts equally treated across the options, the accounting issues do not have to prevent the use of this perspective. Communicating leadership and direct contributions to benefit the community can be useful in maintaining momentum in the face of often daunting changes to achieve true sustainability and cause ripples of positivity and change (Behm et al., 2016).

UC Santa Cruz Pilot

To build, assess, and improve this triple-bottom line decision metric, it will be important to start with a single campus and then expand to the full system after a successful pilot. A deep and ongoing campus commitment to sustainability, environmental sciences, and social justice makes Santa Cruz an ideal test campus for the proposed model. The 2016 Sustainable Campus Index (SCI) recognized top-performing colleges and universities in 17 distinct aspects of sustainability, as measured by the Sustainability Tracking, Assessment & Rating System (STARS). UC Santa Cruz is a SCI "Gold" institution and ranked number 10 among all participating doctoral/research institutions (AASHE, 2016). The Princeton Review ranked Santa Cruz 7th on their list of "Green Colleges," higher than any other UC campus (Princeton Review, 2017).

Since its founding 50 years ago, Santa Cruz has prided itself on a campus commitment to avoiding the culture of conformity and risk aversion so prevalent in most large universities (UC Santa Cruz, 2016c). And, Santa Cruz dedicated an entire residential college to the theme of social justice and community, focusing on "the inequalities that exist in society, such as discrimination and poverty, and the role of community involvement in addressing social injustices" (UC Santa Cruz, 2017b). Sustainability and social justice feature prominently in the curriculum and mission statements of most academic departments, not just the expected places like Sociology and Environmental Studies. For these reasons, this campus is likely to be the most receptive to pilot efforts for an expanded sustainability metric.

In 2016, UC Santa Cruz expanded its Silicon Valley Extension campus. The new facility has the IT infrastructure in place and effectively delivers a small offering of online courses (UC Santa Cruz, 2017c) which could be expanded without costs.

To accommodate anticipated enrollment increases and better meet the needs of current students, UC Santa Cruz expects to expand the gross square footage (GSF) by 3,175,000 (UC Santa Cruz, 2005) in the coming years which facilitates beginning modeling of an expanded campus. Approximately 38% of this will be in expanded housing with a nearly equal expansion in instructional and research facilities. Other smaller expansions will occur in support and recreational areas. These new facilities represent an expected 66% increase in GSF over current levels. The Student Housing West project is currently in the Environmental Impact Review (EIR) public comment phase of development. If completed, this project will add 3,000 on-campus beds at two separate sites by 2022 (UC Santa Cruz, 2018e). Building on the second site, a cow pasture on the east side of campus, is proving very controversial. This is paired with a general community concern about student enrollment and campus growth. Given a lack of individual campus control on enrollment targets and agreements to provide adequate campus housing for students, this plan does appear to be the least impactful solution. And, the public-private-partnership (P3) model being used to deliver the new triple net-zero buildings may prove useful to meet demand, lower the per student footprint, and serve as a model for future developments in Santa Cruz and beyond.

Research Questions, Hypotheses and Specific Aims

The key questions to be examined in this study are:

- Will increased distance degree offerings help meet increasing student demand while reducing the university's environmental footprint to a level that meets UC carbon neutrality goals?

- Can outcomes of the above analysis be adopted into a multi-criteria decision analysis (MCDA) (Seager et al., 2017) with the goal of an optimized path toward sustainability?

I hypothesize that the direct effect of 10,000 enrolled UC Santa Cruz students completing their undergraduate degree remotely rather than in expanded traditional brick and mortar buildings will help meet state enrollment growth targets while significantly reducing environmental impacts. This shift will help achieve carbon neutrality goals for the campus without moving boundaries to outsource student and operational impacts. Further, the social and economic benefits from expanded access will outweigh potential negative impacts. The modeling tool developed to demonstrate that the university should significantly increase the development of high-quality online/distance programs to achieve long-term sustainability can then be applied to other critical sustainability issues like business travel and procurement.

To test these hypotheses, the aim of this study is to estimate the environmental impacts for:

- the current "brick and mortar" on-campus housing and classroom model
- an expansion of this traditional model to accommodate future enrollment; and,
- a distance learning model.

All impacts that are the direct result of university activities will be allocated to the university where data is available, regardless of the responsibilities dually born by students, staff and faculty, or other community members. Greenhouse gas (GHG) emissions, presented in terms of carbon dioxide equivalents (CO_2e), will be the primary focus of analysis given the university's stated goal to achieve a net-zero carbon footprint (UCOP, 2014).

The differences between the BAU, campus expansion, and distance learning models will be analyzed to determine if the hypothesis is correct and enrollment growth redirected into online education will lower the annual impacts of the UC Santa Cruz campus below the expansion model and to levels at or below the stated system-wide goals.

Chapter II

Methods

The calculations presented here were based on the GHG Protocol Corporate Accounting and Reporting Standard (World Resources Institute, 2015a) utilizing standard cross-sector calculation tools and 2014 IPCC Fifth Assessment Report (IPCC, 2014) GWP values. Product systems were modeled in Excel to facilitate statistical analyses. While a full LCA analysis would be preferable to capture data on a wider range of environmental impacts, data availability limited the completion of this more robust study. The advantage of this Excel model is that it did not require comprehensive data or extensive LCA training to undertake an initial analysis of the alternatives. Where there is no obviously superior option, it may be worth undertaking a more comprehensive analysis before determining the least impactful path forward.

The CO^{2}e impact modeling process consisted of the following steps:

1. Goal and scope definition, which included defining the system boundary and functional unit of analysis
2. Life cycle inventory, which included identification and quantification of inputs within the system boundary
3. Impact analysis to measure carbon dioxide equivalents (CO$_2$e) for inputs within the system boundary
4. Interpretation of the impact analysis

Goal and Scope of Environmental Life Cycle Assessment

Conducting an environmental impact assessment was key to determining how distance education compared to the current "business as usual" (BAU) campus as well as a model of expanded infrastructure to accommodate increased enrollments. The first step was to identify inputs that contributed significantly to the total impact over the full cradle-to-grave life of a university campus and identify those impacts that were excluded from the system due to lack of data or insignificant life-cycle impacts per functional unit. Finally, a comparative system was constructed to measure the potential offsets provided by distance education over campus expansion plans.

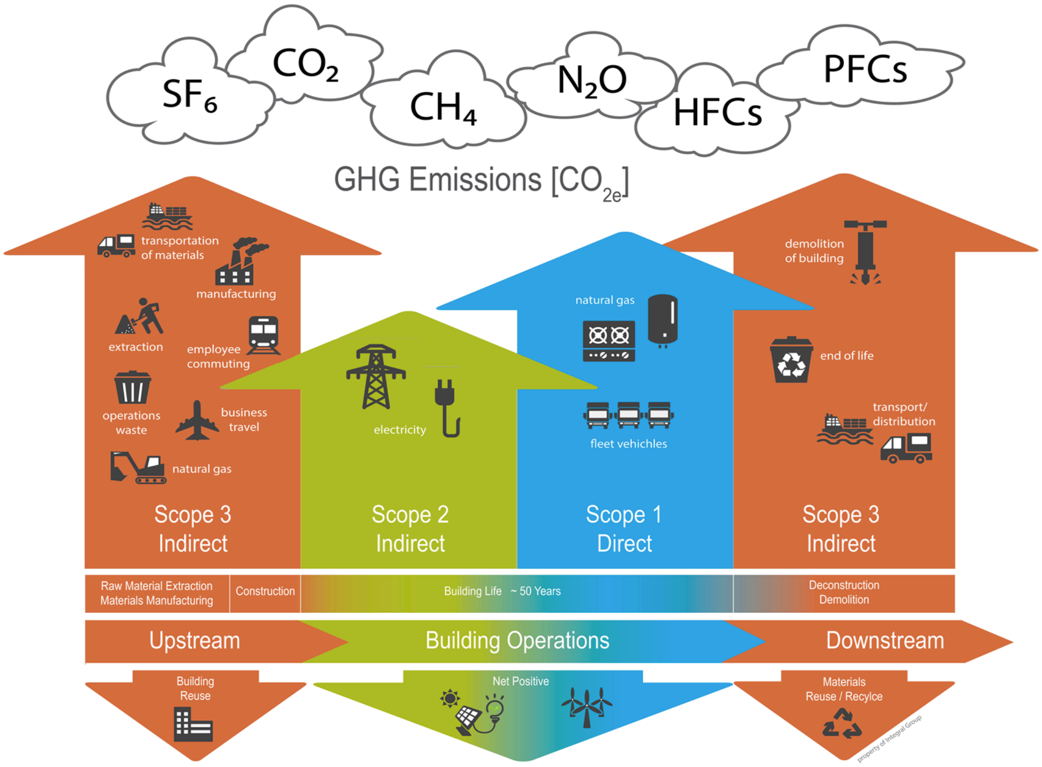


Figure 3. Total carbon study of scope 1, 2, and 3 emissions (UC Santa Cruz, 2017d).

System Definition and Boundaries

Initial system boundaries for this study were set to incorporate the use-phase energy and fuel impacts outlined in Figure 4. These boundaries were significantly wider than those used by the campus during the most recent Climate Energy Strategy assessment (Figure 3) (UC Santa Cruz, 2017d).

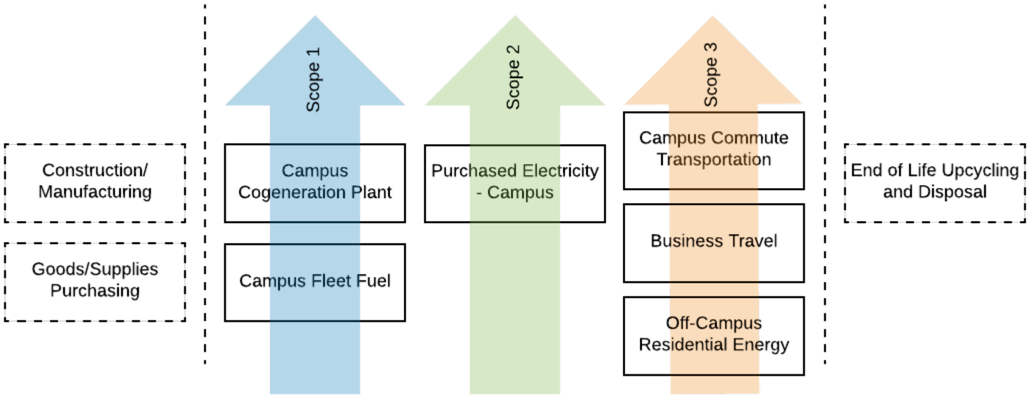


Figure 4. Campus model.

The impacts from supplies/material purchasing for routine campus operations are likely significant and critical to reduce to achieve overall campus sustainability. However, the lack of data and complexities put this category beyond the scope of this initial study. Campus leadership should be encouraged to capture data for this and campus business travel (another UC campus proxy was used in this study), moving these categories within the envelope of reported campus impacts. It is clear that these impacts would cease if the university ended operations and should, therefore, should be considered “direct” impacts.

Facilities have an expected 50-year life span (UC Santa Cruz, 2017d), resulting in construction/manufacturing and disposal allocations per FTE that were insignificant relative to the energy consumed annually during the use phase (Loerincik, Sangwon Suh, & Jolliet, 2003). Therefore, this study similarly placed them outside of the system boundaries (as noted by the dotted lines).

Energy and transportation remained the two most significant and quantifiable impacts on a per FTE annualized basis in expansion models so they were the focus of this initial study. As in the BAU system, impacts from supplies purchasing and the construction and disposal of facilities were excluded (as noted by the dotted lines) given the insignificant impacts per FTE over the facilities life and the lack of credible data.

It is further assumed that on-campus residential square footage and subsequent energy demands expand with the student population. Estimates for the proposed Student Housing West facilities were included in the expanded campus model. These projections need to be adjusted as the EIR and permitting process is finalized. It will be assumed that given expanded student enrollment, housing expansion in some form will be required. Outsourcing construction and ownership as part of this project may be vital fiscally, but environmental impacts should be included for all impacts associated with direct university functions, regardless of ownership within the core campus footprint. At first glance, it may appear that this exclusion serves to reduce the energy footprint per FTE of the campus. However, the triple net-zero LEED building standards (USGBC, n.d.) proposed by the private builder might reduce energy use per FTE relative to silver certification minimum standards currently required by the UC system and will certainly be lower than the per FTE impacts of 50 year old core campus buildings. Therefore, it was important to include these impacts within the system boundaries to obtain an accurate comparison with the distance education option.

The total impacts of the expanded campus population were understated by the exclusion of potential non-residential facility expansions. Because peripheral facilities are already over-extended at current enrollment levels, expansion may occur regardless of projected future enrollment or potentially remain static and over-extended. When these decisions are finalized, the use-phase impacts for these additional buildings should be added to the model.

To understand the relative impacts from the two proposed options, a contrasting consequential model for a distance student was constructed (Figure 5). For this system, use-phase energy impacts were again the focus. In addition to university facilities dedicated to the production of online courses, there are network/cloud facilities involved in transmission, and off-campus residential energy use involved in the delivery and participation in courses. However, it was assumed that there were no longer transportation systems as the student is participating "in place" and transportation not related to degree course work was excluded across all models. As in the case of campus facilities, it was assumed that the per FTE impacts of site construction, maintenance, and disposal of all buildings are insignificant over the lifetime of the facilities and equipment. Recent corporate studies indicate that due to increased data transmissions across networks and cloud servers and increased efficiency of suppliers, the energy consumed per GB of data is now insignificant (Google, 2016) and was excluded.

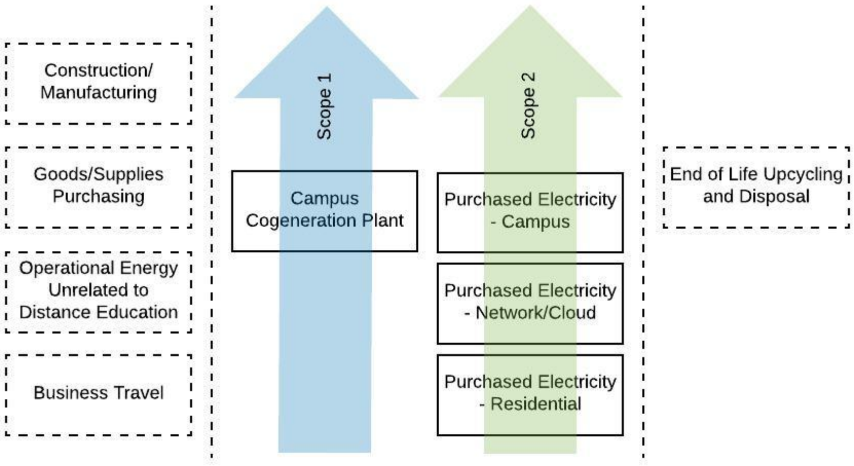


Figure 5. Distance student system boundaries.

Functional Unit

The functional unit was defined as one full-time equivalent student (FTE). UC defines this as a student who completes 45 quarter units annually (UCOP, 2017) or a minimum of 15 units during each of the 3 quarters in the standard academic year (excluding summer). Table 2 provides the FTE for UC Santa Cruz over the last five years. The 2016-2017 figures formed the basis for allocation of impacts per FTE functional unit in the BAU model. Expansion models utilized projections from the universities Long-Range Development Planning which estimated continued growth of 1.5 – 2 percent annually (approximately 450 students annually) until a planning maximum of 28,000 is reached in 2040 (Blumenthal, 2018).

Table 2. UC Santa Cruz FTE undergraduate enrollment, 2012-2017 (UCOP, 2017).

	2016-2017	**2015-2016**	**2014-2015**	**2013-2014**	**2012-2013**
UC Santa Cruz	16,962	16,231	16,277	15,695	15,978

Life Cycle Inventory (LCI) and Background Data

To calculate impacts from campus BAU and future impacts an excel model was created based on the following Scope 1-3 background data, assumptions, and proxies (Appendix 1).

Campus Scope 1

Direct emissions at UC Santa Cruz are predominantly from a natural-gas-powered combustion turbine generator which became operational in the summer of 2016 and currently generates over half of the core campus' electricity (UC Santa Cruz, 2017d). Exact data is not published or readily available nor is data available on the efficiency or heat generated from this Cogen facility to allocate impacts between the two functions. It is recommended that this be updated before a final decision analysis since attributing all impacts solely to electricity production greatly overstates the actual impact and this is a significant component of the total impacts.

A usage graph on the campus energy website indicates that about 5,000,000 therms of natural gas are utilized on campus (UC Santa Cruz, 2017e). It was assumed that the majority of this is for the Cogen facility. The current carbon neutrality plan is to transition from natural gas to biogas (UC Santa Cruz, 2017d). While biogas is often considered "zero" emissions because the CO_2 produced during combustion is assumed to equal the amount fixed by the plant material, the feedstock, conversion process, and timeframe examined can yield CO_2 emissions (Bracmort, 2016). Additionally, there are still CH_4 and N_20 additions which should be accounted for in Scope 1 impacts (World Resources Institute, 2015a) (Appendix 3). The uncertainty for biogas GHG emissions was high to reflect the absence of an accurate assessment of CO_2 emissions in the formula. Because the Cogen facility is currently operating at maximum capacity and no plans are currently being considered to build a larger facility as the campus population grows, the eventual conversion to biogas was the only change made from the BAU to campus expansion models. All data was entered into the GHG Stationary Combustion Excel tool (World Resources Institute, 2015d) to determine metric tonnes CO_2e (Appendix 3).

The second Scope 1 impact was from the campus fleet of vehicles. Because the exact make-up of the fleet is not publicly documented, impacts were approximated based on the 2010 annual consumption of compressed natural gas (CNG), B20 biodiesel, and gasoline (UC Santa Cruz, 2016a). Efforts to upgrade the fleet to higher fuel efficiency vehicles that utilize electricity and biofuels is underway. The goal is to reduce campus fleet emissions by 30% for 2025 (UC Santa Cruz, 2017d). No goals have been set beyond 2025 so it was assumed that the fleet will remain relatively static and any additional vehicles purchased due to campus expansions will be high efficiency, powered by renewable fuel sources. Because individual reductions for each fuel type were not known, the model reduced based on the total impact for 2010. These impact calculations were for the use-phase only and assume that the acquisition and disposal impacts were negligible each year given the life expectancy of the vehicle. Further study based on actual fleet composition and replacement vehicles should be considered to determine the full Scope 1 impact for the fleet. As with Cogen biogas, it was assumed that biofuels are carbon neutral. However, this again depends on the plant input, processing, and timeline. For this study, the total CO_2 was reported but not included in the final calculation model. All data was entered into the GHG Transport Excel tool (World Resources Institute, 2015b) to determine metric tonnes CO_2e (Appendix 5). Uncertainty for the BAU model was low initially because actual published data was used for fuel sources. In future years, success in achieving reduction targets through fleet upgrades is far less certain and uncertainty increased as the time horizon increased.

The final component of Scope 1 emissions was from agricultural activities. The campus includes a 30-acre teaching and research farm in addition to a 3-acre edible garden (UC Santa Cruz, 2018d), 135-acre arboretum and botanic garden (UC Santa Cruz, 2018b), and 409-acre natural reserve (UC Santa Cruz, 2018c). A small herd of cows graze in the farm pastures seasonally. However, because they are owned and managed by an outside organization, their impact was not allocated to the university. Nor was the impact from fertilizers measured and included. Through biodynamic and organic cultivation practices it may be that there is an overall sequestering benefit from these programs that ought to be included to more accurately measure the campus footprint and could lower the per FTE annual GHG emissions.

Campus Scope 2

Prior to 2015, UC Santa Cruz purchased electricity from Pacific Gas & Electric (PG&E). Through the additional purchase of renewable energy credits (REC), the electricity sourced was entirely from renewable sources. Recently, the UC system became a registered transmission-dependent Energy Service Provider (ESP) and contracts with Frontier Renewables for 206,000 megawatt-hours per year of energy from solar arrays (UCOP, 2015). UC Santa Cruz is one of the campuses participating in this sustainable energy procurement project.

Specific GHG datasets are not available for Frontier Renewables. Therefore, the Western Electricity Coordinating Council (WECC, n.d.) dataset from 2010 was utilized in the GHG Purchased Electricity Tool (World Resources Institute, 2015c) (Appendix 4) to calculate scope 2 impacts. Since these are dated impact averages based on the overall western grid mix, it overstated the impact of energy transitioning solely to renewable sources. In keeping with campus sustainability goals, it was assumed that, by 2025, all purchased energy will be renewable and impacts solely from WECC grid transmission. The World Bank estimates this impact at .0375 MT CO_2e per kWh (Madrigal & Spalding-Fecher, 2010). Given these assumptions, it was assumed that uncertainty was relatively high, increasing with the time horizon.

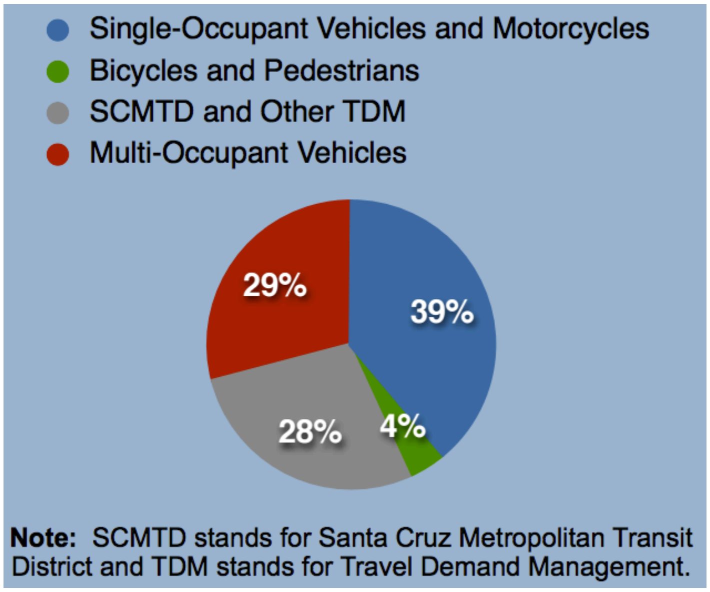
Approximately 22,000 kWh were purchased in 2016 for the core campus (UC Santa Cruz, 2017d). Beyond the main campus, there are additional university owned sites which were included in estimating Scope 2 impacts: 2300 Delaware consumed 293,609 kWh in 2016 and Coastal Science consumed 1,462.557 kWh (UC Santa Cruz, 2017d). The Silicon Valley campus in Santa Clara was not included in sustainability reporting although it is university owned and, therefore, should be included in Scope 2 impacts. For the purpose of this model it was assumed that this 90,000 square foot building utilizes 15.8 kWh per square foot, the average for an office building in the Pacific region (EIA, 2016). Although this may be inaccurate since this campus hosts the energy-intensive digital gaming program in addition to online education infrastructure. On the other hand, it was recently renovated in compliance with strict California building efficiency standards and may be more energy-efficient than the average western office building. Missing from this model was data on the 483 acre Monterey Bay Education Science and Technology Center near Monterey, California and UCO Lick Observatory on a 3,600 acre site atop Mount Hamilton in San Jose, California. As data is available for these sites, they should be added to the model.

The 2025 expansion model added in projected energy figures for the Student Housing West project and planned expansions to the 2300 Delaware and Coastal Science lab facilities. Student Housing West will be built on leased university land by a developer utilizing state-of-the-art triple-net-zero building standards (USGBC, n.d.). The model did not provide credits for the environmental benefit of reclaimed water use and other triple-net-zero benefits which will be important to note when accurately reporting on impacts. Traditionally, impacts from privately owned building on campus have not been included in reporting or goal reduction calculations. As was noted before, this is problematic since the ownership is a financial arrangement and the buildings are in direct support of the core university functioning. Again, uncertainties about procurement, estimations of per square foot impacts, and potential on-site solar energy resulted in medium to high uncertainty.

Additional expansions beyond these three will likely be necessary to accommodate student growth. Until those reach an EIR stage of development, it was impossible to predict energy consumption and model impacts. So, the energy consumed by the main and Silicon Valley campuses remained constant in 2025. By 2040, onsite solar capacity will reduce dependence on purchased renewable energy. Assuming that energy demand remains static, the solar capacity (UC Santa Cruz, 2017d) was subtracted from the 2025 kWh consumption rate. Impacts were calculated on these reduced estimates of purchased electricity using the World Bank estimate for impacts from transmission maintenance and energy loss outlined above (Madrigal & Spalding-Fecher, 2010).

Campus Scope 3

Transportation processes were based on the 2004 published distribution of campus travel modes (Figure 6). Unpublished data for more recent years may be available from the campus Transportation and Parking Services Department (TAPS) but this data is not available. The campus BAU systems assumed that 53% of all students live in on-campus housing (UC Santa Cruz, 2017a) using campus fleet transportation, a personal bicycle, or walking between buildings in order to complete their course participation. This left 47% of enrolled students in addition to 4,700 faculty and staff members commuting to campus.



Note: SCMTD stands for Santa Cruz Metropolitan Transit District and TDM stands for Travel Demand Management.

Figure 6. How people travel to campus (UC Santa Cruz, 2007).

It was assumed that the passenger vehicle is gasoline powered passenger car built in 2005 or later. Santa Cruz metro buses utilize CNG so this was the vehicle type selected in the GHG spreadsheet for these annual vehicle miles. Fuel efficiency for CAFE compliant passenger cars is now 34.2 mpg (U.S. Department of Transportation, 2016). However, the 2005-present average data was assumed to be more appropriate given the financial constraints faced by most students that might limit access to new or ideally maintained vehicles. Current data on the distribution of vehicle fuel sources is not available to determine utilization of electric, diesel and hybrid vehicles so a default of gasoline was assumed. Given the hilly terrain of the campus and distance between the entrance and central campus facilities, it was assumed that bicycles were in use by the full 29%, ignoring the small number of students who walk to and from campus and that there were zero impacts from this group, although this understated the impacts from the manufacturing of bicycles and assumed that all were solely pedal-powered with no electric-assist motors. These are significant assumptions that lead to high uncertainty in the GHG emission calculation.

For the purposes of calculating annual vehicle miles, it was assumed that every vehicle made 2 daily trips on the 146 annual instruction days (UCSC, 2018), traveling an average of 10 miles each way. This average was based on a 2003 Master Plan study for the City of Santa Cruz (UC Santa Cruz, 2011). GIS data based on a registered local address would yield a more accurate average which would be critical given the significant impacts of automobile fuel use. Privacy restrictions do not allow open access to personal student information to complete such a study. As it currently costs 109% of the average household income to afford a median-priced home in Santa Cruz (ATTOM Data Solutions, 2018), it is likely that students and state employees travel greater distances between campus and affordable housing. This data also omitted staff/faculty commutes on non-instructional days. Administrative staff likely work greater than 200 days annually however many faculty and academic program staff work remotely when students are not present and may not come to campus every instructional day if their classes only meet 2-3 times each week. Again, this supported high uncertainty in the outcome.

Average vehicle ridership (AVR) for multi-occupant vehicles (MOV) was set at 1.53 based on observational studies conducted by TAPS (UC Santa Cruz, 2007). Ridership for the seven bus routes serving campus averaged between 28 and 49 per trip (Santa Cruz METRO, 2013) with an overall daily trip average of 36 riders. It was assumed that all riders on UCSC routes are commuters although there may be individuals riding for other purposes thus overstating per person impacts attributed to university functioning.

These data assumptions resulted in 1,161 daily vehicles trips to transport the 12,672 students, staff, and faculty members in the BAU model (12,672/((.39*1) + (.29*1.53) + (.28*36)). SOVs accounted for 39% (453) of these daily vehicle trips which resulted in an average annual vehicle distance travelled of 1,322,760 (2*10*146*453). MOVs accounted for 29% (337) which resulted in an average annual vehicle distance travelled of 984,040 (2*10*146*337). Buses/TDM vehicles accounted for 28% (325) which resulted in an average annual vehicle distance travelled of 949,000 (2*10*146*325).

In the expanded campus model, total commuters increased from 12,672 to 14,688 in 2025 and 17,860 in 2040. This assumed that 47% of students continued to commute and staff and faculty numbers remained unchanged although it is likely that there will need to be additional teachers and administrators hired to meet the demands of a significantly larger student population if time to degree metrics are to remain as close to 4 years as possible. However, enrollment increased over the past years with few additional faculty members and reduced staff numbers due to budget cuts so it was uncertain how to adjust the model. A static assumption was utilized in the calculation and should be updated as more information is made available about staffing expansion plans. Paired with these population expansions was a targeted SOV reduction of 30% by and 80% by 2040 (UC Santa Cruz, 2004).

Using the same formulas outlined above for the BAU model, resulted in 1,346 total vehicle trips in 2025 and 1,772 in 2040. Assuming a 30% reduction in SOV trips in 2025 from the BAU 39% (367 trips rather than 525) and an equal split of former SOV drivers moving to MOV and TDM vehicles, MOV increased by 52 trips (390 to 442) and Buses/TDM increased by 2 trips (377 to 379). The resulting annual mileage calculations utilizing the same formulas as the BAU model were: SOV – 1,071,640; MOV – 1,290,640; TDM – 1,106.680.

Assuming an 80% reduction in SOV trips in 2025 from the BAU 39% (138 trips rather than 691) and an equal split of former SOV drivers moving to MOV and TDM vehicles, MOV increased by 181 trips (514 to 695) and Buses/TDM increased by 8 trips (496 to 504). The resulting annual mileage calculations utilizing the same formulas as the BAU model were: SOV – 402,960; MOV – 2,029,400; TDM – 1,471,680.

All of the above assumptions were entered in the GHG Protocol Mobile Combustion and Transportation tool as they were for the campus fleet (World Resources Institute, 2015b) Appendix 5.

The second component of Scope 3 impacts was purchased electricity for privately- owned facilities. These included the leased administrative offices in Scotts Valley and students living in off-campus private residences. As in the off-campus owned buildings in the BAU model, the calculations for the Scotts Valley facility were based on the Western Electricity Coordinating Council (WECC, n.d.) dataset from 2010 in the

GHG Purchased Electricity Tool (World Resources Institute, 2015c). It was further assumed that the 127,000 square foot leased wing utilized 15.8 kWh per square foot, the average for an office building in the Pacific region (EIA, 2016). Uncertainty was also medium to high given assumptions about actual energy procurement and usage of this privately-owned building.

Private residences which house 47% of current students have significant variability in energy use and occupancy. An average occupancy for a single-family residence of 2.81 persons was utilized (U.S. Census Bureau, 2003) for allocation of per person impacts. In 2009, Californians used an average of 62 million Btu of energy per housing unit, including 25 million Btu from electricity, 36 million Btu from natural gas, and 2 million Btu from propane (U.S. EIA, 2009). Due to limited financial resources, it is likely that students live in housing that may be less efficient than the average with corresponding higher impacts. On the other hand, these same financial constraints might result in students living in higher occupancy or multi-family housing units which would reduce the per person impact allocation. These average per household member energy factors were entered in the GHG purchased electricity and stationary combustion tools (World Resources Institute, 2015c, 2015d) (Appendices 3 & 4) and multiplied by the 47% of enrolled students living off-campus for the BAU and expanded 2025 and 2040 models.

Scope 3 Business Transportation cannot be accurately estimated for UC Santa Cruz because business travel is not centrally tracked outside of reimbursed costs. Post travel forms are only required where there is a reimbursable expense and no data is captured on the total vehicle or airline mileage for the trip, collection of data would require collecting all paperwork and calculating distances in addition to surveying staff, faculty, and students to gauge additional business trips and corresponding mileage figures beyond those with submitted paperwork. It is hoped that with the introduction of digital travel forms in the coming year, this data may be more readily available although it will still be limited to trips with an associated reimbursement request. In the meantime, estimated data from UC Santa Barbara's 2016 Climate Action Plan (UC Santa Barbara, 2016) was used as a proxy. Figures for 2016 and 2025 were estimates for business air travel only and do not account for the impact of trips made by personal or hired vehicles. No proxy is available for 2040 so it was assumed that it will remain constant to 2025 with increases in trips balanced out by campus reduction efforts. Unlike Santa Barbara, Santa Cruz staff and faculty travel to the UC Office of the President via vehicle rather than airplane. However, conference and other professional travel is likely comparable to this similarly sized and ranked campus. Given that this impact is over 30% of the total university impact, more accurate data is imperative for an assessment of relative impacts. It is likely that staff, faculty, and students in a distance model would be more comfortable in distance participation in outside meetings and academic enrichment events like conferences. Even a 10-20% reduction in this category would significantly alter the results of this modeling. Uncertainty across all models was high for this category.

Scope 3 impacts from procurement and solid waste were outside of the current system boundaries given the lack of data or suitable proxies. It is recommended that if an enhanced analysis is necessary to differentiate between options, proxies or rudimentary estimates be obtained and input into the model.

Distance Student Scopes 1-3

To contrast with the campus models, a distance student model was created (Appendix 2). As with the campus model, the GHG protocol tools (Appendices 3-5) were used to calculate the stationary combustion, electricity, and transportation impacts given the following inputs. To create a comparable distance student model, it was assumed that there were no mandatory on-campus meetings or events for distance students during the semester which would require travel and there were no other Scope 1 impacts. To calculate Scope 2 impacts for purchased energy, the model for the campus commuting student (BAU and expansion Scope 3 impacts) were replicated with 2.81 persons per household (U.S. Census Bureau, 2003) and an average of 62 million Btu of energy per housing unit, including 25 million Btu from electricity, 36 million Btu from natural gas, and 2 million Btu from propane (U.S. EIA, 2009). As in the campus models, uncertainty was deemed to be high given assumptions and proxies used in this estimation and impact attribution.

To determine the Scope 2 energy impacts from videoconference participation, lecture time was set per the Carnegie unit with one hour of instructional time per unit of credit which equals 15 quarter units during 30 weeks of annual instruction for a FTE student (UCSC, 2018). Due to a lack of standardization and high variability in requirements, participation in discussion sections, labs, or office hours were not included although they could add to the time spent on a videoconference and certainly might be required for successful completion of a course.

Zoom videoconferencing, the preferred platform at UC Santa Cruz, was modeled with kW/hour estimates from the OpenLCA (GreenDelta GmbH, n.d.) Ecoinvent datasets provided in Table 3 below. More complex and interactive proprietary platforms are in use with strong educational outcomes (Harvard Business Extension, 2016). However, GB and other key IT data points are not readily available for these alternatives. Student IT data will be based on use of a personal laptop and standard network access device. Specific information was not available on campus IT delivery systems, so it was assumed that they utilize a comparable network access device and IP network for upload. Rather than a personal laptop, it was assumed that the university is using a more powerful desktop with monitors. Missing from this calculation was the equipment to record or livestream video content which could be energy intensive in addition to accounting for the relative differences in energy intensity associated with uploading versus downloading data to the cloud infrastructure. Given recent advances in efficiency in the digital cloud data centers/infrastructure, it was assumed that per kWh impact of this intermediate step was negligible (Google, 2016).

Table 3. Distance student IT infrastructure (Werner et al., 2016).

	kWh per hour	FTE Qtr Units	Annual Weeks	Annual kWh
Scope 2		15	30	
use, computer, laptop, videoconference	0.03			13.50
use, IP network, videoconference	0.09			39.69
use, network access devices	0.01			3.40
Scope 3				
use, computer, desktop with CRT monitor, active mode	0.15			67.50
use, IP network, videoconference	0.09			39.69
use, network access devices	0.01			3.40

Scope 3 impacts included campus owned and leased buildings involved in course production which at this time were represented by the Silicon Valley campus housing the UC Santa Cruz Extension program. Currently, there are staff/faculty spread across several central campus buildings but these are not tracked and cannot be accurately included in the model at this time. Were the program to expand, consolidation into one location would be the most efficient and the model assumed that the UNEX facility would be the designated site. The Silicon Valley facility is shared by UNEX in addition to the Games and Playable Media program and several administrative divisions. The allocation of energy use to online programming is not known so the energy approximation of the entire 90,000 square foot building was utilized at a rate of 15.8 kWh per square foot, the average for a building in the Pacific region (EIA, 2016). IT infrastructure as modeled in Table 3 was utilized for additional Scope 3 electricity impacts. All impacts were calculated with the GHG Purchased Electricity tool (World Resources Institute, 2015c) (Appendix 4) with high uncertainty.

The final Scope 3 impact was from indirect business commuters. These were staff/faculty commuting to the campus facilities for delivery of materials since it was assumed that the students are participating in place. UC Santa Cruz currently maintains a student to teacher ratio of 19:1 (UC Santa Cruz, 2018a). While there is no consensus on the ideal ratio for an online course and it is easier to deliver to a large audience when physical classroom size is not a limit, there are some concern that learning outcomes diminish if the ratio increases significantly (Inside Higher Ed, 2017). Teachers are no longer able to respond to questions or provide as much grading feedback as their enrollment increases and student have diminished opportunities for participation during allotted course time as their numbers increase. For this purpose, it was assumed that the campus maintained the same ratio to ensure comparable learning outcomes which resulted in 526 faculty members to reach 10,000 students and maintained the current administrative staff level of 50 FTE (UC Santa Cruz, 2016b).

As with the campus models, it was assumed that every vehicle made 2 daily trips on 146 annual instruction days (UCSC, 2018) in a SOV gasoline-powered vehicle built after 2005. However, in this model the 37 mile distance from campus to the Silicon Valley UNEX facility was used for a one-way mileage approximation rather than the 10 miles used in the campus models. The resulting annual vehicle miles was 6,223,104 (2*37*146*576). Again this omitted the impacts from staff/faculty commutes on non-instructional days and did not factor in variations in commute miles for staff who live closer or farther from the extension campus or who drive more or less efficient vehicles.

As with the campus models, procurement and solid waste were excluded from the system boundaries due to lack of data. And, business travel related to the delivery of online courses was also omitted due to a lack of data. It could be assumed that staff and faculty comfortable in digital learning environments might be more inclined to participate remotely in meetings and professional development opportunities. However, until all conferences, symposia, and meetings have digital participation options, this category is likely to have significant impacts as seen in the proxy modeling from Santa Barbara (UC Santa Barbara, 2016) and should be approximated in future refinements of the model.

Uncertainty Calculation

Numerical uncertainty values for the good, medium and high levels were based on the suggested data pedigree matrix from the GHG Protocol “Quantitative Uncertainty Guidance” (World Resources Institute, 2011). For each impact category, it was necessary to determine if the precision, completeness, temporal representation, geographical representation, and technological representation were very good, good, fair, or poor. The assignment of these values was indicated in the methodology for each background category. Each of these levels was assigned an uncertainty factor and total uncertainty was expressed at a 95% confidence interval (the square of the geometric standard deviation) in keeping with the GHG Protocol guidance (World Resources Institute, 2011).

$$SD_{g95} \cong \sigma^2{}_g = \exp^{\sqrt{[\ln(U_1)]^2+[\ln(U_2)]^2+[\ln(U_3)]^2+[\ln(U_4)]^2+[\ln(U_5)]^2+[\ln(U_b)]^2}}$$

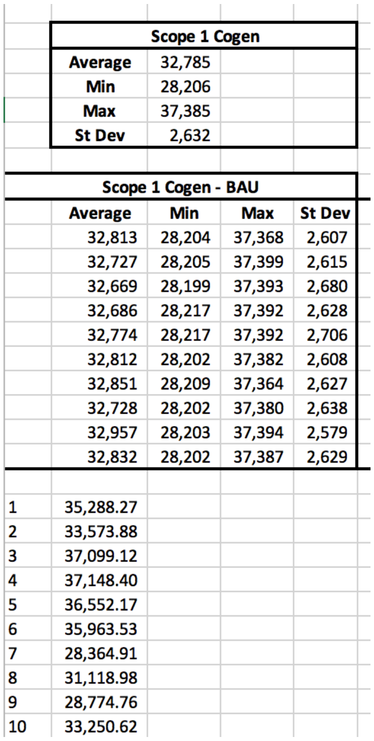
Applied to the pedigree matrix, the total uncertainty factors used in this study were calculated in Table 4. Assessing data quality for the campus and distance student models is subjective but it was assumed that no data was “Very Good.” Where background data was more recent or deemed more reliable, a “Good” uncertainty of 1.26 was utilized. As the time horizon increased or the data contained more assumptions, approximations, or proxies, uncertainty were increased to “Fair” - Medium (1.64) or “Poor” - High (2.52).

Table 4. GHG uncertainty.

INDICATOR SCORE	Very Good	Good	Fair	Poor
Precision	1.00	1.10	1.20	1.50
Completeness	1.00	1.05	1.10	1.20
Temporal Representation	1.00	1.10	1.20	1.50
Geographical Representativeness	1.00	1.02	1.05	1.10
Technological Representativeness	1.00	1.20	1.50	2.00
Basic Uncertainty Factor	1.05	1.05	1.05	1.05
TOTAL UNCERTAINTY	1.05	1.27	1.64	2.52

Monte Carlo Simulation

Using these uncertainties and the calculated GHG impacts, a Monte Carlo simulation was constructed for each of the background categories to generate 10,000 random numbers within the uncertainty distribution. Repeated calculations were expected to produce a normal distribution of predicted result values. Figure 7 provides an illustration of the table construct. At the top are the calculated statistical values for the simulation based on an Excel "What-If" data table which runs the 1,000 entry random number generator ten times. Only the first ten entries from the random number generator are shown in Figure 7 for the sake of space. However the =RAND()*((UCSC Campus Modeling Impact * Uncertainty Factor Upper) - (Impact * Uncertainty Factor Lower)) + (Impact * Uncertainty Factor Lower) formula were replicated 1,000 times in the original simulation spreadsheet.



Scope 1 Cogen	
Average	32,785
Min	28,206
Max	37,385
St Dev	2,632

Scope 1 Cogen - BAU

Average	Min	Max	St Dev
32,813	28,204	37,368	2,607
32,727	28,205	37,399	2,615
32,669	28,199	37,393	2,680
32,686	28,217	37,392	2,628
32,774	28,217	37,392	2,706
32,812	28,202	37,382	2,608
32,851	28,209	37,364	2,627
32,728	28,202	37,380	2,638
32,957	28,203	37,394	2,579
32,832	28,202	37,387	2,629

1	35,288.27
2	33,573.88
3	37,099.12
4	37,148.40
5	36,552.17
6	35,963.53
7	28,364.91
8	31,118.98
9	28,774.76
10	33,250.62

Figure 7. Monte Carlo simulation.

Proxy identification

Where data was unavailable or insufficient, substitutes/proxies were identified in the methodology. The most significant of these was the use of business air travel figures from UC Santa Barbara given the lack of data for Santa Cruz. At 30% of the total impact for that campus, even small differences could impact the accuracy of the modeling. The second most significant proxy was the modeling of private residential energy use (for commuting distance students). Given a lack of specific data on housing density, the census average of 2.81 was utilized. However, students often achieve affordability by increasing density and reducing energy use. The third most significant proxy was the use of WECC datasets for purchased electricity on the entire western grid when UC purchases energy directly from Frontier Renewables. These proxies were the focus of sensitivity studies to determine if their reduction shifted the outcome significantly.

Chapter III

Results

Appendices 1 and 2 provide a snapshot of the campus and distance student Excel calculation models after all background data outlined in the methodology was entered in the appropriate scope and the resulting GHG expressed in MT CO_2e calculated by the appropriate GHG Protocol Excel spreadsheet (World Resources Institute, 2015d, 2015c, 2015b).

Impact Assessment

A 10,000 iteration Monte Carlo scenario was run on random numbers generated within respective uncertainty boundaries. Total impacts were then converted to per FTE impact by dividing results by respective FTE estimates for each model group. Results for each model were summarized in Figure 8 with full data available in Appendix 6.

Combined standard deviations to set error bars were calculated according to the formula: $(s_z)^2 = (s_x)^2 + (s_y)^2$. The hypothesis model of BAU with 10,000 additional students enrolled in distance programs was calculated by adding the total impacts for these two groups divided by the new combined enrollment. A combined standard deviation was also calculated according to the above formula. A t-test of all 3 comparative scenarios (Table 5) demonstrated that the null hypothesis can be rejected in all scenarios with p-values less than .05.

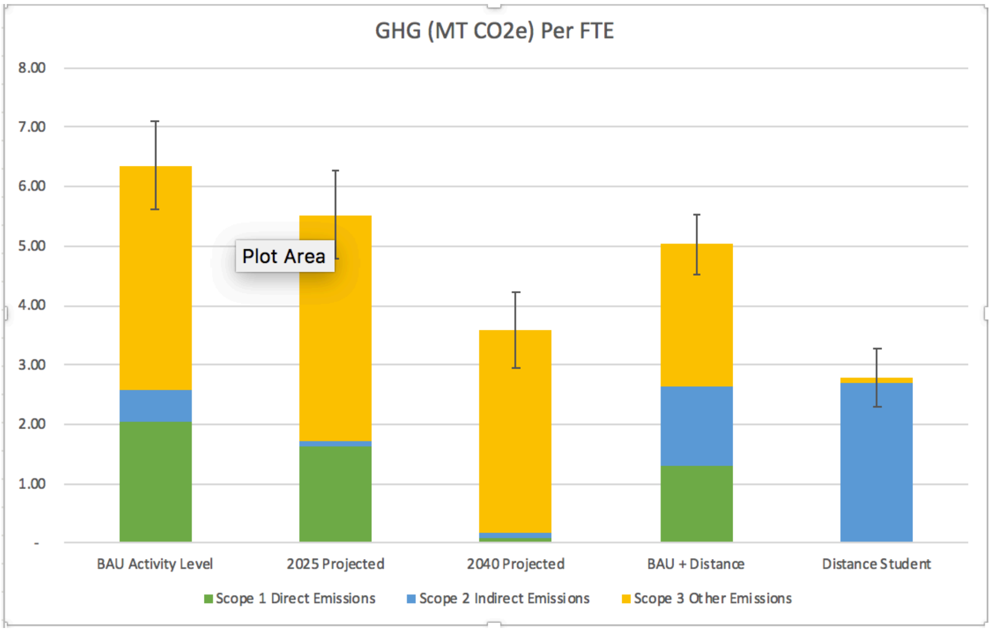
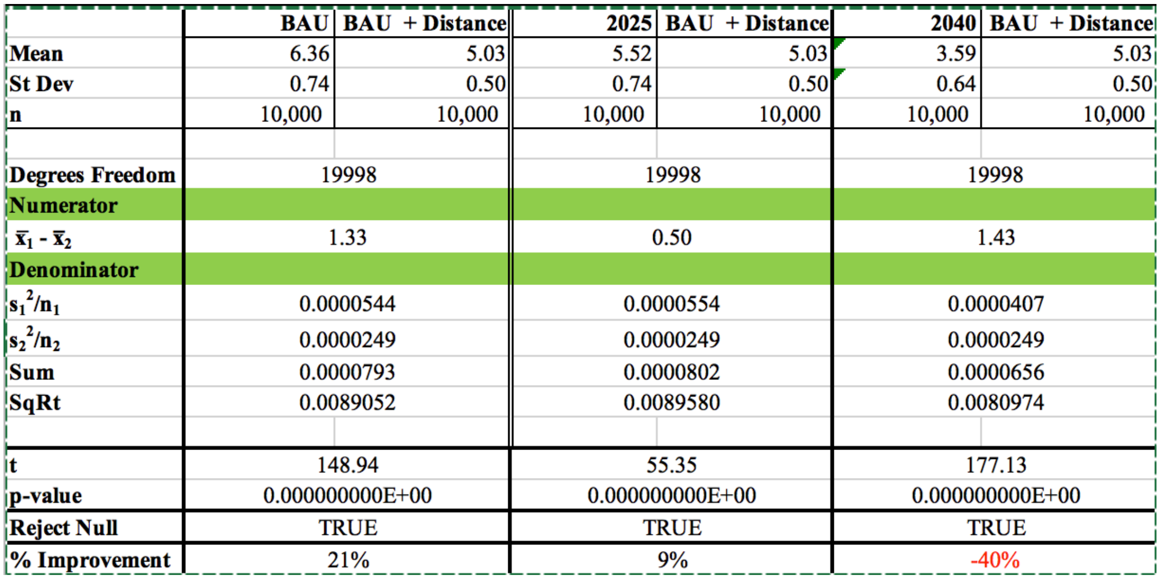


Figure 8. GHG per FTE.

Table 5. Statistical analysis of campus versus distance program expansions.



	BAU	BAU + Distance	2025	BAU + Distance	2040	BAU + Distance
Mean	6.36	5.03	5.52	5.03	3.59	5.03
St Dev	0.74	0.50	0.74	0.50	0.64	0.50
n	10,000	10,000	10,000	10,000	10,000	10,000
Degrees Freedom	19998		19998		19998	
Numerator						
$\bar{x}_1 - \bar{x}_2$	1.33		0.50		1.43	
Denominator						
s_1^2/n_1	0.0000544		0.0000554		0.0000407	
s_2^2/n_2	0.0000249		0.0000249		0.0000249	
Sum	0.0000793		0.0000802		0.0000656	
SqRt	0.0089052		0.0089580		0.0080974	
t	148.94		55.35		177.13	
p-value	0.000000000E+00		0.000000000E+00		0.000000000E+00	
Reject Null	TRUE		TRUE		TRUE	
% Improvement	21%		9%		-40%	

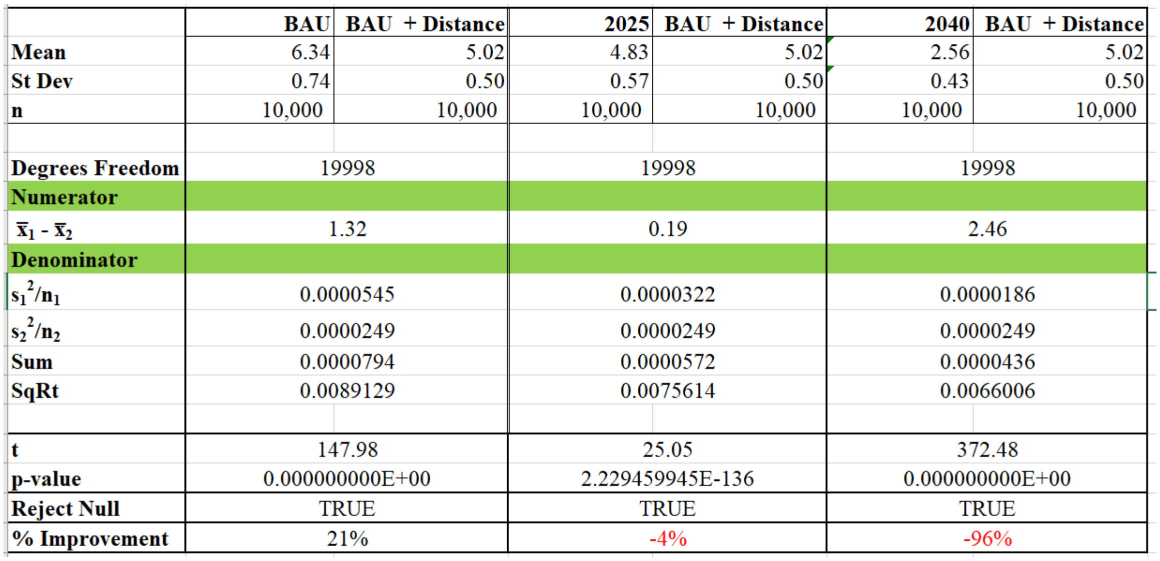
The resulting 5.03 MT CO2e per FTE in the combined model was a 21% improvement over the current BAU model and 9% better than the 2025 projection.

However, it was 40% worse than the 2040 projections. Therefore, my hypothesis could only be confirmed if expansion plans do not achieve projected sustainability objectives.

Sensitivity Analyses

As noted in the methodology, where data was unavailable or insufficient, substitutes/proxies were identified, some of which resulted in significant changes to the results. The most significant of these was the use of business air travel figures from UC Santa Barbara given the lack of data for Santa Cruz. At 30% of the total impact for that campus, even small differences change the outcome of the modeling. For example, a goal of 25% reduction in GHG emissions by 2025 and 50% by 2040, shifted the mean impact per FTE to 4.83 MT CO_2e in 2025 and 2.56 MT CO_2e in 2040. In this scenario, both campus expansion models were preferable to the hypothesis model (Table 6).

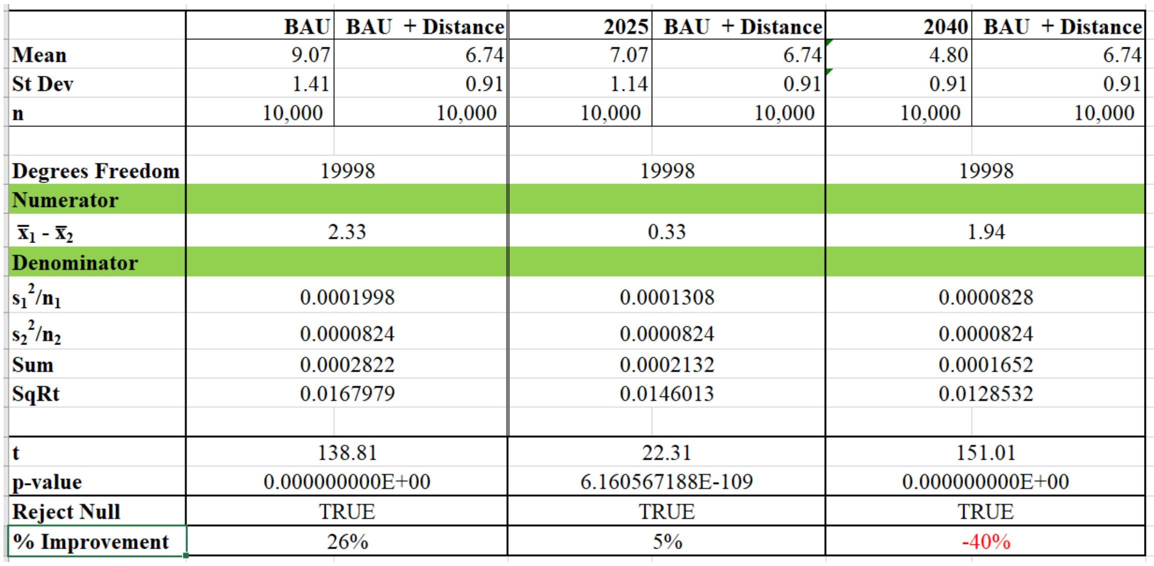
Table 6. Business travel 25% reduction by 2025 and 50% reduction by 2040.



	BAU	BAU + Distance	2025	BAU + Distance	2040	BAU + Distance
Mean	6.34	5.02	4.83	5.02	2.56	5.02
St Dev	0.74	0.50	0.57	0.50	0.43	0.50
n	10,000	10,000	10,000	10,000	10,000	10,000
Degrees Freedom	19998		19998		19998	
Numerator						
$\bar{x}_1 - \bar{x}_2$	1.32		0.19		2.46	
Denominator						
s_1^2/n_1	0.0000545		0.0000322		0.0000186	
s_2^2/n_2	0.0000249		0.0000249		0.0000249	
Sum	0.0000794		0.0000572		0.0000436	
SqRt	0.0089129		0.0075614		0.0066006	
t	147.98		25.05		372.48	
p-value	0.000000000E+00		2.229459945E-136		0.000000000E+00	
Reject Null	TRUE		TRUE		TRUE	
% Improvement	21%		-4%		-96%	

In a second scenario with business travel, it was assumed that the addition of passenger vehicle miles were included in the accounting, resulting in a doubling of BAU category emissions. Retaining the 25% and 50% reductions by 2025 and 2050, the BAU per FTE impact increased to 9.04 MT CO2e per FTE and both expansion models remained preferable to the hypothesis model. Assuming that no efforts are made to reduce these emissions, our hypothesis model was 5% better than the 2025 expansion but 40% worse by 2040 (Table 7). Therefore, while accuracy is important for tracking progress toward carbon neutrality goals, adjustments to this background category did not allow us to confirm our hypothesis that a distance program would be environmentally superior.

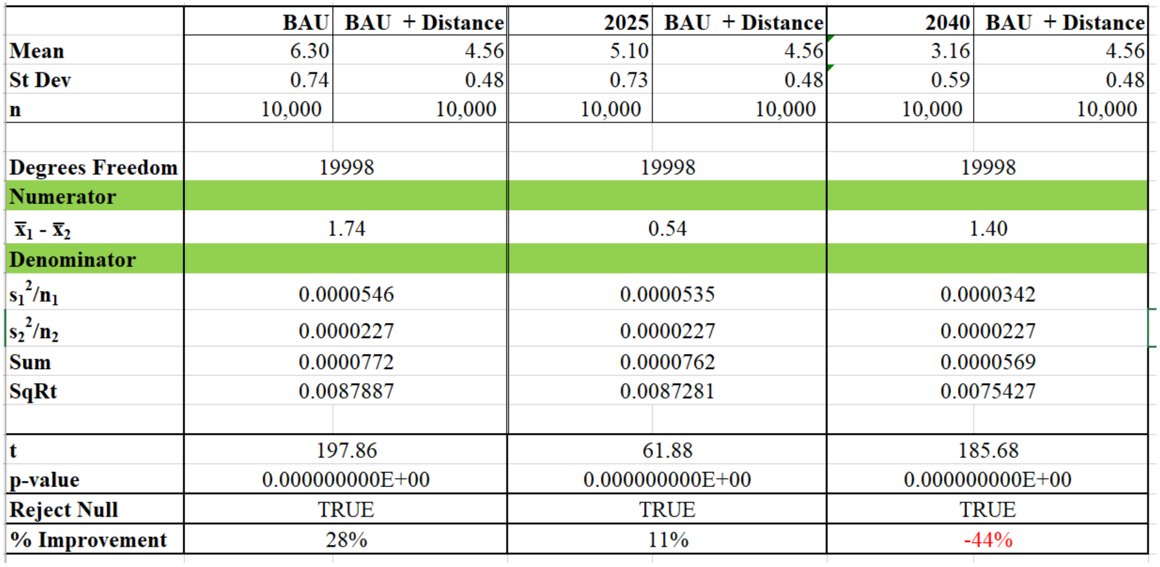
Table 7. Doubling of BAU business travel impacts to account for vehicle travel without reduction efforts.



	BAU	**BAU + Distance**	**2025**	**BAU + Distance**	**2040**	**BAU + Distance**
Mean	9.07	6.74	7.07	6.74	4.80	6.74
St Dev	1.41	0.91	1.14	0.91	0.91	0.91
n	10,000	10,000	10,000	10,000	10,000	10,000
Degrees Freedom	19998		19998		19998	
Numerator						
$\bar{x}_1 - \bar{x}_2$	2.33		0.33		1.94	
Denominator						
s_1^2/n_1	0.0001998		0.0001308		0.0000828	
s_2^2/n_2	0.0000824		0.0000824		0.0000824	
Sum	0.0002822		0.0002132		0.0001652	
SqRt	0.0167979		0.0146013		0.0128532	
t	138.81		22.31		151.01	
p-value	0.000000000E+00		6.160567188E-109		0.000000000E+00	
Reject Null	TRUE		TRUE		TRUE	
% Improvement	26%		5%		-40%	

The second most significant proxy was the modeling of private residential energy use (for commuting distance students). Given a lack of specific data on housing density, the census average of 2.81 was utilized. However, students often achieve affordability by increasing density and reducing energy use. To test the outcomes versus a higher housing density, the model was re-run with 5 household occupants rather than 2.81. This reduced overall GHG emissions but did not alter the rejection of the hypothesis model over the 2040 expansion model (Table 8).

Table 8. Increase off-campus housing density from 2.81 to 5.



	BAU	BAU + Distance	2025	BAU + Distance	2040	BAU + Distance
Mean	6.30	4.56	5.10	4.56	3.16	4.56
St Dev	0.74	0.48	0.73	0.48	0.59	0.48
n	10,000	10,000	10,000	10,000	10,000	10,000
Degrees Freedom	19998		19998		19998	
Numerator						
$\bar{x}_1 - \bar{x}_2$	1.74		0.54		1.40	
Denominator						
s_1^2/n_1	0.0000546		0.0000535		0.0000342	
s_2^2/n_2	0.0000227		0.0000227		0.0000227	
Sum	0.0000772		0.0000762		0.0000569	
SqRt	0.0087887		0.0087281		0.0075427	
t	197.86		61.88		185.68	
p-value	0.000000000E+00		0.000000000E+00		0.000000000E+00	
Reject Null	TRUE		TRUE		TRUE	
% Improvement	28%		11%		-44%	

The third most significant proxy was likely the use of WECC datasets for purchased electricity on the entire western grid when UC purchases energy directly from Frontier Renewables. Assuming that the only emissions were from transmission losses, the BAU model reduced to 5.91 MT CO$_2$e from 6.36, not enough of a difference to confirm the hypothesis model as superior to a 2040 expansion model.

The final sensitivity examined outcomes if expansion did not occur but other sustainability initiatives reduced the BAU per FTE impacts from current levels. These included continued conversion to Biogas in the Cogen facility, development of on-site solar arrays with purchased renewable energy where demand exceeds production, and campus fleet efficiency improvements of 30%. Results are summarized in Figure 9 with full data provided in Table 9.

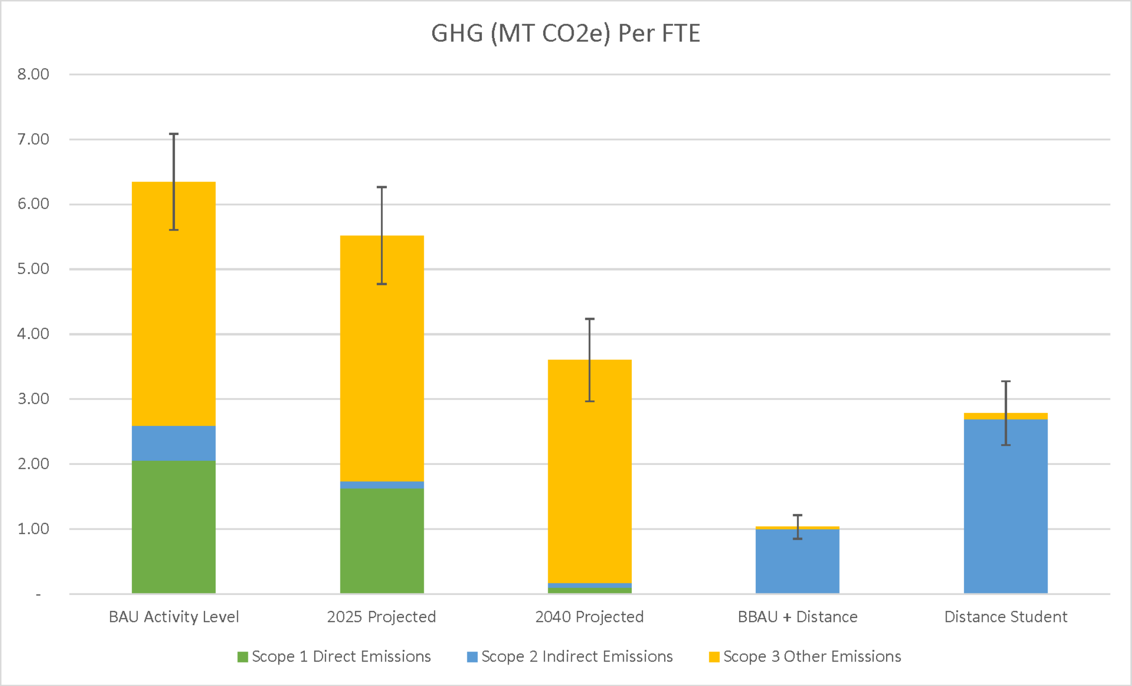
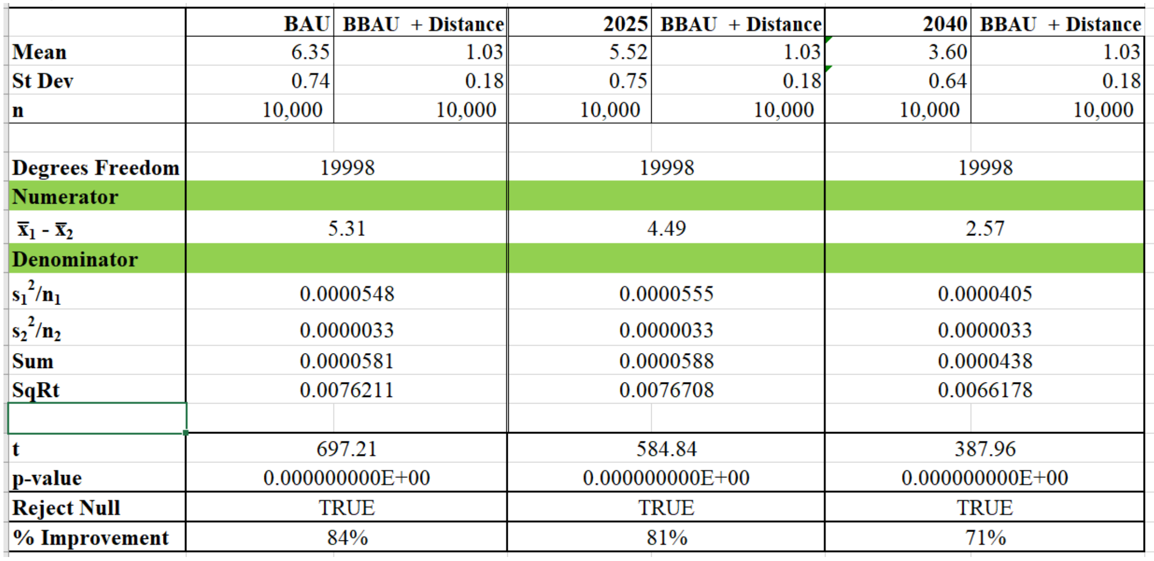


Figure 9. Scenario pairing a more sustainable campus with distance expansion.

In this scenario, the new campus model emits 3.98 MT CO2e per FTE. Paired with a distance program to meet campus enrollment demands, per FTE emissions were only 1.03 MT CO2e. This resulted in an 84% improvement over BAU and still 71% better than the campus expansion model.

Table 9. Statistical analysis of a more sustainable campus (BBAU) plus distance program expansion versus campus expansion plans.



	BAU	BBAU + Distance	2025	BBAU + Distance	2040	BBAU + Distance
Mean	6.35	1.03	5.52	1.03	3.60	1.03
St Dev	0.74	0.18	0.75	0.18	0.64	0.18
n	10,000	10,000	10,000	10,000	10,000	10,000
Degrees Freedom	19998		19998		19998	
Numerator						
$\bar{x}_1 - \bar{x}_2$	5.31		4.49		2.57	
Denominator						
s_1^2/n_1	0.0000548		0.0000555		0.0000405	
s_2^2/n_2	0.0000033		0.0000033		0.0000033	
Sum	0.0000581		0.0000588		0.0000438	
SqRt	0.0076211		0.0076708		0.0066178	
t	697.21		584.84		387.96	
p-value	0.000000000E+00		0.000000000E+00		0.000000000E+00	
Reject Null	TRUE		TRUE		TRUE	
% Improvement	84%		81%		71%	

Chapter IV

Discussion

The results of this analysis were impacted both by the quality of the data and the modeling. Inaccurate foreground data led to error across all background inputs and outputs. Monte Carlo simulations did help assess the uncertainty of impact results and increased the confidence of rejecting the null hypotheses. Further, items that are excluded or represented erroneously in the model impacted the accuracy of both foreground and background data. It is already known that several key processes like purchasing will need to be excluded due to a lack of data and others like business travel are represented by airlines miles that were estimated by another campus' cost of travel leading to potentially significant errors.

It is often the case that rebound impacts are not well known and excluded from the modeling. For example, in telecommuting studies, it was found that workers often used the time gained from eliminating a commute to drive to other activities, eliminating some of the reduced transportation impacts (URS, 2008). Or, they might utilize home appliances during peak electricity hours when the sourcing is more impactful. It may also be that as additional students have access to a university education, their socio-economic opportunities improve and they consume more than they would have without the education. The rebound impacts were not quantified and included in the assessment although they may be significant and should be addressed in a future model improvement.

Conclusions

The key questions for this study were whether increased distance offerings could help meet increasing student enrollment demand while reducing the footprint and whether these outcomes could be adopted into a MCDA framework to optimize the path forward. I hypothesized that the direct effect of 10,000 enrolled UC Santa Cruz students completing their undergraduate degree remotely rather than expanding the traditional brick and mortar campus to meet these growth targets would reduce environmental impacts.

The results indicated that only in one scenario would this hypothesis be confirmed. It would be necessary to improve on a "Business as Usual" model for campus by investing in sustainability initiatives within the existing footprint paired with expanded distance programs to accommodate 10,000 FTE. The included measures were conversion of the Cogen facility to biogas rather than natural gas, expansion of on-site solar capacity paired with sourcing of additional needs from entirely renewable providers, and campus fleet efficiency improvements to achieve a 30% emissions reduction in this category. Paired with additional measures such as incentives to reduce business travel, the campus could meet demand without facilities growth.

Answering the second question involved an examination of the economic and social costs and benefits involved in the environmentally-preferred scenario versus the alternatives. Many of the economic costs involved in sustainability initiatives are known as the campus is already in the planning stages for current campus expansion models. Indeed, some projects already under construction like the solar arrays over the east remote parking lot so estimates can be replaced with actual costs in the discussion. And, the campus committed to fleet vehicle replacement guidelines that encourage the most environmentally-friendly, fuel-efficient option be purchased where economically feasible, moving the campus toward a slow phase out of less efficient vehicles to achieve the emissions reduction targets (UC Santa Cruz, 2004). Costs associated with the expansion of distance learning programs are not publicly available but have been calculated in the past few years. The high start-up costs are often quoted as a barrier given the assessed "return-on-investment" horizon. However, these budgetary assessment are focused solely on one MCDA criteria and do not factor in the environmental and societal criteria.

Indeed, an analysis of the social-justice benefits might also steer the campus toward distance-learning programming rather than brick and mortar expansions. Proponents of distance and e-learning note that its flexibility can allow for wider access, reduced delocalization/migration ("brain drain") impacts on communities; and, increased flexibility to balance work, family and other obligations (Negrut et al., 2010) that preclude traditional university participation.

. Learning outcomes can still be achieved (Clark & Mayer, 2016; Crews, Wilkinson, & Neill, 2015). And, in many programs, e-learning can be more cost effective per passing student than traditional models (Bishop, 2012) with potentially lower total attendance costs, a benefit to both the university and the student. This achieves societal goals of an educated citizenry with members trained in the skills necessary to fully participate in our modern economy. Although this needs to be balanced with a conversation about the correlation of continued environmental degradation with economic development (Lu et al., 2017).

Focus on this path also helps alleviate community stakeholder concerns about continued expansion of the UC Santa Cruz population and built-environment. Student housing demand already exceeds supply and this year all employees received a request to house students (San Jose Mercury News, 2018) who may not be able to enroll if they cannot find housing in the next few weeks. Additionally, traffic is significant, and water resources are quickly depleting (Cline, 2012) without adequate rainfall to replenish aquifers and local groundwater supplies.

Outcry during the EIR public comment phase for Student Housing West highlight all of these concerns (UC Santa Cruz, 2018e). And, the conversation has grown beyond Santa Cruz. The LA Times covered the growing controversy in August (Watanabe, 2018) noting that many prominent alumni have threatened donor boycotts and lawsuits (potential costs to be included in the financial analysis) if the campus moves forward with its plans to build on the pasture. While its characterization as a meadow may be a stretch since it is a disturbed site currently home to pastured beef cows (UC Santa Cruz, 2018e), it certainly is part of the first-impression as you enter campus and helps distinguish UC Santa Cruz from other urban campuses.

Thus it is clear that campus and system-wide leadership need to examine the paths forward within a MCDA framework to look at each option through the lens of financial, social, and environmental sustainability. Distance and e-learning programs when paired with other initiatives to improve overall sustainability can help meet enrollment targets, fulfill the mission of educating Californians, and achieve sustainability goals.

Appendix 1

Campus Model

	2017 Actual				
Scope 1 Co-Gen	Amount	Units	All GHGs (MT CO_2e)	2025	2040
Natural gas	5,000,000	Therm	29,683	29,683	-
Biogas	5,000,000	Therm			232
TOTAL			**29,683**	**29,683**	**232**
		Uncertainty Factor	**1.26**	**1.26**	**2.52**

	2010 Actual				
Scope 1 Campus Fleet	Amount	Units	Fossil Fuel (MT CO_2e)	2025 Goal, 30% Reduction	2040 Projected
CNG	3,253	US Gallon	22		
B20 Biodiesel/Diesel	77,886	US Gallon	632		
Gasoline/Petrol	139,306	US Gallon	1,227		
TOTAL			**1,882**	**1,317**	**1,317**
		Uncertainty Factor	**1.26**	**1.64**	**2.52**

Scope 1 Agriculture	Amount	Units	All GHGs (MT CO_2e)	2025	2040
Livestock					
Fertilizer					
TOTAL			**-**	**-**	**-**
		Uncertainty Factor	**1.26**	**1.26**	**2.52**

	2016 Estimated			2025 Goal, Renewable Grid		2040 Proposed, On-Site Solar	
Scope 2 Electricity	Amount	Units	All GHGs (MT CO_2e)	Amount	GHGs (MT CO_2e)	Solar Capacity	GHGs (MT CO_2e)
Main Campus	22,000,000	kWh	6,119	22,000,000	825	2,674,456	725
Student Housing West	-	kWh	-	2,716,000	102		102
2300 Delaware	293,609	kWh	82		*n/a*		n/a
Remodeled Delaware Lab	-	kWh	-	984,300	369	2,160,416	- 44
Coastal Science	1,462,557	kWh	407	1,462,557	55	861,560	23
Coastal Science Expansion	-	kWh	-	869,062	33	464,808	15
Silicon Valley - UNEX	1,422,000	kWh	396	1,422,000	396	-	396
TOTAL			**7,003**		**1,779**	**6,161,240**	**1,216**
		Uncertainty Factor	**1.64**		**1.64**		**2.52**

	2016 Estimates				
Scope 3 Private Transportation	Amount	Units	Fossil Fuel (MT CO_2e)	2025 Goal, 30% SOV Reduction	2040 Proposed, 80% SOV Reduction
BAU SOV Commuters	1,322,760	Vehicles Miles/Yr	521	422	159
BAU MOV Commuters	984,040	Vehicles Miles/Yr	388	509	800
BAU Bus Commuters	949,000	Vehicles Miles/Yr	96	112	149
TOTAL			**1,005**	**1,043**	**1,108**
		Uncertainty Factor	**2.52**	**2.52**	**2.52**

Scope 3 Business Transportation	2016 Estimates			2025 Projection	2040 Estimate
	Amount	Units	Fossil Fuel (MT CO_2e)		
Personal Vehicle	-	Vehicles Miles/Yr	-		
Shuttle/Taxi	-	Vehicles Miles/Yr	-		
Domestic Airline	-	Passenger Miles/Yr	-		
International Airline	-	Passenger Miles/Yr	-		
TOTAL			**26,227**	**33,504**	**33,504**
		Uncertainty Factor	**2.52**	**2.52**	**2.52**

Scope 3 Non-University Owned Building Energy	2016 Estimated			2025 Estimated		2040 Estimated	
	Amount	Units	All GHGs (MT CO_2e)	Amount	GHGs (MT CO_2e)	Amount	GHGs (MT CO_2e)
Scotts Valley	2,006,600	kWh	558	2,006,600	558	-	558
Off-campus student housing	51,550,530	kWh	12,224	64,582,523	15,314	85,096,972	20,179
TOTAL			**12,782**		**15,872**		**20,737**
		Uncertainty Factor	**1.64**		**1.64**		**2.52**

Scope 3 Procurement - **OUTSIDE OF CURRENT SYSTEM BOUNDARIES**	2016 Estimates			2025 Goal	2040 Proposed
	Amount	Units	Fossil Fuel (MT CO_2e)		
TOTAL			-	-	-
		Uncertainty Factor	**1.26**	**1.26**	**1.26**

Scope 3 Solid Waste - **OUTSIDE OF CURRENT SYSTEM BOUNDARIES**	2016 Estimates			2025 Goal	2040 Proposed
	Amount	Units	Fossil Fuel (MT CO_2e)		
TOTAL			-	-	-
		Uncertainty Factor	**1.26**	**1.26**	**1.26**

Appendix 2

Distance Student Model

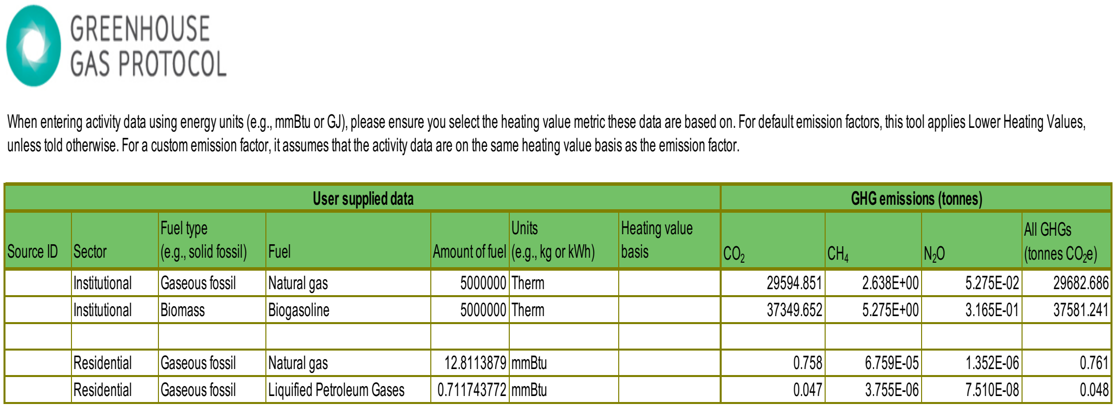
Scope 1	Amount	Units	Fossil Fuel (MT CO$_2$e)
Personal Vehicle	-		
TOTAL			**-**
		Uncertainty Factor	**1.26**

Scope 2	Amount	Units	GHGs (MT CO$_2$e)
Private Residence Electricity	26,073,932	kWh	7,252.43
Private Residence Heating	135,231	mmBtu	8,081
Videoconference Participation	565,920	kWh	157
TOTAL			**15,491**
		Uncertainty Factor	**2.52**

Scope 3	Amount	Units	Fossil Fuel (MT CO$_2$e)
UNEX Building Energy	1,422,000	kWh	396
IT Course Delivery	111	kWh	0.03
Staff/Faculty Commute	6,223,104	Vehicles Miles/Yr	149
Supplies Procurement			
Solid Waste			
Business Travel		Vehicle Miles/Yr	
TOTAL			**545**
		Uncertainty Factor	**2.52**

Appendix 3

GHG Protocol Stationary Combustion



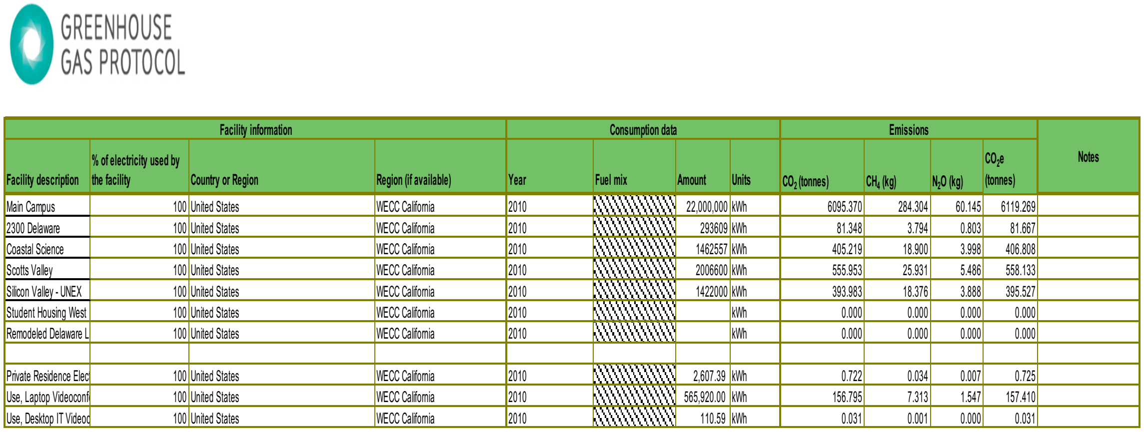
GREENHOUSE GAS PROTOCOL

When entering activity data using energy units (e.g., mmBtu or GJ), please ensure you select the heating value metric these data are based on. For default emission factors, this tool applies Lower Heating Values, unless told otherwise. For a custom emission factor, it assumes that the activity data are on the same heating value basis as the emission factor.

User supplied data							GHG emissions (tonnes)			
Source ID	Sector	Fuel type (e.g., solid fossil)	Fuel	Amount of fuel	Units (e.g., kg or kWh)	Heating value basis	CO_2	CH_4	N_2O	All GHGs (tonnes CO_2e)
	Institutional	Gaseous fossil	Natural gas	5000000	Therm		29594.851	2.638E+00	5.275E-02	29682.686
	Institutional	Biomass	Biogasoline	5000000	Therm		37349.652	5.275E+00	3.165E-01	37581.241
	Residential	Gaseous fossil	Natural gas	12.8113879	mmBtu		0.758	6.759E-05	1.352E-06	0.761
	Residential	Gaseous fossil	Liquified Petroleum Gases	0.711743772	mmBtu		0.047	3.755E-06	7.510E-08	0.048

Appendix 4

GHG Protocol Electricity



Facility information				Consumption data				Emissions				Notes
Facility description	% of electricity used by the facility	Country or Region	Region (if available)	Year	Fuel mix	Amount	Units	CO_2 (tonnes)	CH_4 (kg)	N_2O (kg)	CO_2e (tonnes)	
Main Campus	100	United States	WECC California	2010	▨	22,000,000	kWh	6095.370	284.304	60.145	6119.269	
2300 Delaware	100	United States	WECC California	2010	▨	293609	kWh	81.348	3.794	0.803	81.667	
Coastal Science	100	United States	WECC California	2010	▨	1462557	kWh	405.219	18.900	3.998	406.808	
Scotts Valley	100	United States	WECC California	2010	▨	2006600	kWh	555.953	25.931	5.486	558.133	
Silicon Valley - UNEX	100	United States	WECC California	2010	▨	1422000	kWh	393.983	18.376	3.888	395.527	
Student Housing West	100	United States	WECC California	2010	▨		kWh	0.000	0.000	0.000	0.000	
Remodeled Delaware L	100	United States	WECC California	2010	▨		kWh	0.000	0.000	0.000	0.000	
Private Residence Elec	100	United States	WECC California	2010	▨	2,607.39	kWh	0.722	0.034	0.007	0.725	
Use, Laptop Videoconf	100	United States	WECC California	2010	▨	565,920.00	kWh	156.795	7.313	1.547	157.410	
Use, Desktop IT Videoc	100	United States	WECC California	2010	▨	110.59	kWh	0.031	0.001	0.000	0.031	

Appendix 5

GHG Protocol Transportation

GREENHOUSE GAS PROTOCOL

Total GHG Emissions, exclude Biofuel CO2 (metric tonnes CO2e)	7490.405
Biofuel CO2 Emissions (metric tonnes)	147.360

Activity Data

The default emission factors are sourced from the US EPA Climate Leaders program or from the UK DEFRA (for air travel only).

Status	Source Description	Region	Mode of Transport	Scope	Type of Activity Data	Activity Data								Error Messages	GHG Emissions				
						Vehicle Type (For air transport, see footnote)	Distance Travelled	Total Weight of Freight	# of Passenger	Units of Measurement	Fuel Used	Fuel Amount	Unit of Fuel Amount		Fossil Fuel CO2 (metric tonnes)	CH4 (kilograms)	N2O (kilograms)	Total GHG Emissions, exclude Biofuel CO2 (metric tonnes CO2e)	Biofuel CO2 Emissions (metric tonnes)
		US	Road	Scope 1	Fuel Use						CNG	3253	US Gallon		22.251			22.251	0
		US	Road	Scope 1	Fuel Use						B20 Biodiesel/Diesel	77886	US Gallon		632.434			632.434	147.360
		US	Road	Scope 1	Fuel Use						Gasoline/Petrol	139306	US Gallon		1227.286			1227.286	0
	BAU SOV Commuters	US	Road	Scope 3	Vehicle Distance (e.g. Road Transport)	Passenger Car - Gasoline - Year 2005-present	1322760			Mile					517.934	19.445	10.450	521.248	0
	BAU MOV Commuters	US	Road	Scope 3	Vehicle Distance (e.g. Road Transport)	Passenger Car - Gasoline - Year 2005-present	984040			Mile					385.306	14.465	7.774	387.771	0
	BAU Bus Commuters	US	Road	Scope 3	Vehicle Distance (e.g. Road Transport)	Bus - CNG	949000			Mile						1865.734	166.075	96.250	
	2025 SOV Commuters	US	Road	Scope 3	Vehicle Distance (e.g. Road Transport)	Passenger Car - Gasoline - Year 2005-present	1,071,640			Mile					419.607	15.753	8.466	422.291	0
	2025 MOV Commuters	US	Road	Scope 3	Vehicle Distance (e.g. Road Transport)	Passenger Car - Gasoline - Year 2005-present	1,290,640			Mile					505.357	18.972	10.196	508.590	0
	2025 Bus Commuters	US	Road	Scope 3	Vehicle Distance (e.g. Road Transport)	Bus - CNG	1,106,680			Mile						2175.733	193.669	112.243	
	2040 SOV Commuters	US	Road	Scope 3	Vehicle Distance (e.g. Road Transport)	Passenger Car - Gasoline - Year 2005-present	402,960			Mile					157.781	5.924	3.183	158.791	0
	2040 MOV Commuters	US	Road	Scope 3	Vehicle Distance (e.g. Road Transport)	Passenger Car - Gasoline - Year 2005-present	2,029,400			Mile					794.623	29.832	16.032	799.707	0
	2040 Bus Commuters	US	Road	Scope 3	Vehicle Distance (e.g. Road Transport)	Bus - CNG	1,471,680			Mile						2893.323	257.544	149.262	
	Personal Vehicle	US	Road	Scope 3	Vehicle Distance (e.g. Road Transport)	Passenger Car - Gasoline - Year 2005-present	0			Mile					0	0	0	0	0
	Shuttle/Taxi	US	Road	Scope 3	Vehicle Distance (e.g. Road Transport)	Passenger Car - Gasoline - Year 2005-present	0			Mile					0	0	0	0	0
	Domestic Airline	US	Aircraft	Scope 3	Passenger Distance (e.g. Public Transport)	Air - Domestic	0			Passenger Mile					0			0	0
	International Airline	US	Aircraft	Scope 3	Passenger Distance (e.g. Public Transport)	Air - Long Haul - Seating Unknown	0			Passenger Mile					0			0	0
	Personal Vehicle Commute	US	Road	Scope 1	Vehicle Distance (e.g. Road Transport)	Passenger Car - Gasoline - Year 2005-present	0			Mile					0	0	0	0	0
	Staff/Faculty Commute	US	Road	Scope 3	Vehicle Distance (e.g. Road Transport)	Passenger Car - Gasoline - Year 2005-present	6223104			Mile					2436.691	91.480	49.163	2452.280	0
	Personal Vehicle - Business	US	Road	Scope 3	Vehicle Distance (e.g. Road Transport)	Passenger Car - Gasoline - Year 2005-present	0			Mile					0	0	0	0	0
	Shuttle/Taxi	US	Road	Scope 3	Vehicle Distance (e.g. Road Transport)	Passenger Car - Gasoline - Year 2005-present	0			Mile					0	0	0	0	0
	Domestic Airline	US	Aircraft	Scope 3	Passenger Distance (e.g. Public Transport)	Air - Domestic	0			Passenger Mile					0			0	0
	International Airline	US	Aircraft	Scope 3	Passenger Distance (e.g. Public Transport)	Air - Long Haul - Seating Unknown	0			Passenger Mile					0			0	0

Appendix 6

Calculated GHG Impacts

BAU Activity Level		**Monte Carlo**		**Per FTE**	
		Average MT CO2e	**Std Dev**	**Avg / 16,962**	**Std Dev**
Scope 1 Direct Emissions	Stationary Combustion	32,814	2,646	1.93	0.16
	Campus-owned fleet of vehicles	2,079	168	0.12	0.01
	Agriculture	-	-	-	-
	Sub-Total	**34,892**	**2,651**	**2.06**	**0.16**
Scope 2 Indirect Emissions	Purchased Energy				
	Electricity	9,027	1,391	0.53	0.08
	Sub-Total	**9,027**	**1,391**	**0.53**	**0.08**
Scope 3 Other Emissions	Commute	1,752	458	0.10	0.03
	University-Sponsored Travel	45,549	11,876	2.69	0.70
	Electricity (Privately Owned Buildings)	16,576	2,531	0.98	0.15
	Procurement	-	-	-	-
	Solid Waste	-	-	-	-
	Sub-Total	63,877	**12,151**	**3.77**	**0.72**
	TOTAL	**107,796**	**12,515**	**6.36**	**0.74**

2025 Projected		**Monte Carlo**		**Per FTE**	
		Average MT CO2e	**Std Dev**	**Avg / 21,250**	**Std Dev**
Scope 1 Direct Emissions	Stationary Combustion	32,756	2,660	1.54	0.13
	Campus-owned fleet of vehicles	1,706	261	0.08	0.01
	Agriculture	-	-	-	-
	Sub-Total	**34,462**	**2,672**	**1.62**	**0.13**
Scope 2 Indirect Emissions	Purchased Energy				
	Electricity	2,301	352	0.11	0.02
	Sub-Total	**2,301**	**352**	**0.11**	**0.02**
Scope 3 Other Emissions	Commute	1,814	477	0.09	0.02
	University-Sponsored Travel	58,266	15,247	2.74	0.72
	Electricity (Privately Owned Buildings)	20,556	3,179	0.97	0.15
	Procurement	-	-	-	-
	Solid Waste	-	-	-	-
	Sub-Total	80,636	**15,582**	**3.79**	**0.73**
	TOTAL	**117,399**	**15,814**	**5.52**	**0.74**

2040 Projected		**Monte Carlo**		**Per FTE**	
		Average MT CO2e	**Std Dev**	**Avg / 28,000**	**Std Dev**
Scope 1 Direct Emissions	Stationary Combustion	400	104	0.01	0.00
	Campus-owned fleet of vehicles	2,280	597	0.08	0.02
	Agriculture	-	-	-	-
	Sub-Total	**2,680**	**606**	**0.10**	**0.02**
Scope 2 Indirect Emissions	Purchased Energy				
	Electricity	2,094	550	0.07	0.02
	Sub-Total	**2,094**	**550**	**0.07**	**0.02**
Scope 3 Other Emissions	Commute	1,914	503	0.07	0.02
	University-Sponsored Travel	57,888	15,136	2.07	0.54
	Electricity (Privately Owned Buildings)	36,071	9,439	1.29	0.34
	Procurement			-	-
	Solid Waste			-	-
	Sub-Total	95,873	**17,845**	**3.42**	**0.64**
	TOTAL	**100,647**	**17,863**	**3.59**	**0.64**

Distance Student		**Monte Carlo**		**Per FTE**	
		Average MT CO2e	**Std Dev**	**Avg / 10,000**	**Std Dev**
Scope 1 Direct Emissions	Personal Vehicle	-	-	-	-
	Sub-Total	**-**	**-**	**-**	**-**
Scope 2 Indirect Emissions	Private Residence	12,573	3,270.78	1.26	0.33
	Private Residence Heating	14,001	3,662	1.40	0.37
	Videoconference Participation	272	70.87	0.03	0.01
	Sub-Total	**26,845**	**4,911**	**2.68**	**0.49**
Scope 3 Other Emissions	Commute	259	67	0.03	0.01
	University-Sponsored Travel	-	-	-	-
	Electricity (Campus Owned Buildings)	687	180	0.07	0.02
	Electricity (IT Infrastructure)	0	0	0.00	0.00
	Procurement			-	-
	Solid Waste			-	-
	Sub-Total	946	**192**	**0.09**	**0**
	TOTAL	**27,791**	**4,915**	**2.78**	**0.49**

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