The *Carbon* Cost of Going to College:
Estimating Students' Carbon Footprint and the Social Cost of Carbon at Reed College

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Economics 351: Environmental Economics
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December 15, 2022

Abstract

This paper seeks to understand a basic measure of students' carbon footprints and the consequent social cost of carbon at Reed College. We estimate that the average student's carbon footprint is approximately 9.00 tonnes of CO_2 equivalent per year, for a social cost of carbon of \$459 - \$1,665, using data on gas consumption, electrical usage, and travel information. Based on these findings, we recommend that Reed College institute a sustainability plan that brings more attention to how individuals' consumptive behavior impacts their carbon footprint and to change policies to allow students to remain on campus during summer and winter breaks. As it can be challenging to ascertain student's carbon footprints, due to the communal nature of university living, we also created an *rShiny* interactive dashboard where students can calculate their own carbon footprint using the data collected in this paper.

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Abbreviations:

CO_2: Carbon dioxide

CO_2e: Carbon dioxide equivalent

CF: Carbon footprint

IWG: United States Interagency Working Group on the social cost of greenhouse gasses

GHG: Greenhouse gas

NHANES: National Health and Nutrition Examination Survey

SCC: Social cost of carbon

UNEP: United Nations Environmental Programme

Introduction

A common measure of an individual's impact on the environment is their carbon footprint (CF). A carbon footprint, briefly, captures annual greenhouse gas (GHG) emission that results from an individual's consumption and habits.[1] These calculations can be useful as a basis of comparison between individuals and countries, and help show where consumption ought to be reduced. Typical CF calculations, in an academic setting, tend to focus on national scales and a comprehensive list of contributors (Pandey et al. 2011). Measuring students' CF, on the other hand, is challenging, as students often live in communal housing, do not prepare their own food, have irregular travel schedules, and are not responsible for their own utilities. It is likely that any given student would never know, say, how many kilowatt hours of electricity they use in a year. Even if one wanted to, it is unlikely that any individual student's consumption and CF could be measured due to the necessarily communal nature of attending university. The topic of CFs for university students has been, as a consequence, relatively understudied in the literature, though some studies have nonetheless been conducted (Li et al. 2015; Lin 2016; Ozawa-Meida et al. 2013; Sippel et al 2018; Yañez et al. 2019).

This paper seeks to aid in understanding university student's CF calculations by analyzing students at Reed College ("The College" or "Reed"). To do so, we collected data on The College's annual utilization of gas and electricity and students' travel habits in conjunction with outside sources and generalized carbon footprint calculations for both Oregon and the United States. From this estimation, we calculated the Social Cost of Carbon (SCC), in dollars, "to measure the economic damages that would result from emitting one additional ton of carbon dioxide into the atmosphere" per student at Reed College (Rennert and Kingdon 2022). This collected and manipulated data was then used to create an *rShiny* interactive dashboard where a student can insert their personal habits and learn about their CF in tons and their personal SCC. Beyond understanding the ecological impact of students' carbon footprints, our results could be of value to prospective Reed students. If the social cost of carbon is eventually fully priced into the economy, students would be incentivized to attend institutions where they would have a lower carbon footprint, as cost is a determining factor in choosing which college to attend.

[1] For the purposes of this paper, we will use the term "carbon footprint" to refer to an individual's total greenhouse gas emissions as a CO_2 equivalent (CO_2e).

Environmentally conscious students, likewise, would be able to more appropriately choose a college with these data.

This paper continues by providing relevant background information and review of the literature, detailing our data and collection process, presenting our findings and dashboard, and finally concluding with a proposed sustainability plan for Reed College based on our findings.

Background and Literature Review

Motivation

The United Nations Environmental Programme (UNEP) stated that there is "no credible pathway to 1.5C in place" (UNEP. 2022). In essence, there is no longer a way to avert climate change entirely. One of the ways to prevent a slow-down increase in temperature is to reduce greenhouse gas emissions (Hansen et al. 2008, 217). The scientific and academic communities clearly believe that human activity in producing greenhouse gasses is causing unprecedented, possibly catastrophic consequences to our planet. Franchetti et al. (2012, 4) further elaborated that measuring CO_2e output is "important for our civilization because it determines the extent of adverse impacts on Earth's systems."

Determining Carbon Footprint

Creating a comprehensive measure of one's carbon footprint is not trivial. One must not only consider their direct consumption and its carbon footprint, but also the indirect emissions that result from this consumption. The framework that many institutions use –Reed included– are the three emission scopes proposed by Greenhouse Gas Protocol. Scope 1 includes all those emissions that are produced directly (e.g. driving a car). Scope 2 comprises all those indirect emissions from energy consumption. Scope 3, the most nebulous to define, includes all additional indirect emissions, like from investments and support services.[2] As we will discuss further, scopes 1 and 2 are relatively easy to calculate, while scope 3 is substantially more difficult. The methodology we utilize only assesses parts of scopes 1 and 3, and the near totality of scope 2.

[2] See Greenhouse Gas Protocol and the EPA for more information on the three emissions scopes.

Moving to estimates of CF, the average American has a CO_2e footprint of 12.90 tons per year, as of 2020 (OECD 2022). The average Oregonian, by comparison, has a carbon footprint of 9.24 tons of CO_2e per year (U.S. DoE 2019). According to the U.S. EPA (2022c), the largest contributors to the average American's CF, as of 2020, are transportation, at 27%, followed by electrical usage, at 25%. The U.S. EPA, further, reports that commercial airplanes and large business jets contribute 10 percent of U.S. transportation emissions and account for three percent of the nation's total greenhouse gas production (Overton 2022, 1). The next two most significant sources are housing, specifically from the energy associated with heating and cooling. While not all communities within the United States have the same distribution of carbon factors, Portland, OR does follow broader national trends (Jones et al. 2011).

Estimating Carbon Footprints on College Campuses

While somewhat sparse, a small literature has emerged attempting to estimate the carbon footprints of students on University campuses. Valls-Val and Bovea (2021), in a review of the field, found an average CF of 2.67 tons CO2e per student. In their analysis, they noted the unique challenges to characterizing and collating CF data from various institutions, as, for instance, different academic calendars can have a dramatic impact on CF calculations. As synthesizing data across institutions is rife with challenges and may even be somewhat inappropriate, looking at individual universities is more fruitful. Li et al. (2014), found an average CF of 3.84 tons of CO_2e per student, with, "65% attributable to daily life, 20% to transportation, and 15% to academic activities like studying… [further,] the top three individual uses were dining (34%), showering (18%), and dorm electricity loads (14%)." Ozawa-Mieda et al. (2013), looking at the CF of an entire college campus, found that "34% of the emissions originated from energy use, 29% were transport-related and 38% derived from procurement activities." The same authors, likewise, found an average CF of 2.37 tons of CO_2e per student. Sippel (2018), contrary to peer studies, found an average CF of 10.9 tons CO_2e per student, largely due to students having "...considerably more emission by aviation…" despite "...caus[ing] less emission through heating because of smaller living space per person."

The Social Cost of Carbon

The social cost of carbon (SCC) allows individuals and policy makers to understand the potential economic impact of carbon emissions (Rennert and Kingdon 2022). SCC is calculated by modeling the projected growth of the population, emissions, and economy by estimating our ability to mitigate and sequester carbon dioxide through the assumption about potential changes in technology. Models of the earth's climate assess the degree of warming resulting from a certain concentration of GHGs in the atmosphere. Calculations of SCC rely on discount rates and, as such, vary greatly depending on the discount rate utilized. The discount rate, briefly, is a measure of society's or an individual's willingness to trade off benefits in future for benefits now. Future costs and benefits are "discounted" and have lesser bearing on decision making than more proximate costs or benefits. Alternatively, "a high discount rate means that future effects are considered much less significant than present effects, whereas a low discount rate means that they are closer to equally significant" (Rennert and Kingdon 2022).

The value utilized in this paper was put forth by The Interagency Working Group on the Social Cost of Greenhouse Gases (IWG) using an estimated discount rate of 3% (Oregon Department of Energy. 2020, 2). This yielded a SCC of $53 per ton of CO_2 emissions, as of 2020 (Oregon Department of Energy. 2020, 2).[3] It is likely, however, that an SCC of $53 dollars per ton is not reflective of the true SCC, as numerous studies have estimated the value to be in excess of $144-$185 (Rennert and Kingdon 2022; Prest et al. 2022). Discussion of SCC is important to note because it is used in federal government benefit-cost analysis (Rennert and Kingdon 2022). Moreover, Portland General Electric, the company that provides Reed College electricity, has its own voluntary SCC system where they value each ton of carbon dioxide emission at $40 per ton (Oregon Department of Energy. 2020, 5).

Data Collection and Analysis

For this project, we utilized data collated information from Rachel Willis, Reed College's sustainability coordinator, and Mike Tamada from Reed College's Institutional Research office. The table below, Table 1, shows the information from Rachel Willis on Reed's annual gas and

[3] $53 per ton is the figure from the Oregon Department of Energy, and is the value we will utilize for our analysis as Reed College resides in Oregon. $51 per ton is a more commonly used national figure.

electrical consumption. For our calculations, we averaged the data across all three available years. It is important to note that we had no way of differentiating emissions from students, staff, and/or faculty, and therefore allocated all emissions to students. This overestimate reflects, partially, the fact that campus services are ostensibly designed to benefit and support students, perhaps capturing an element of “scope 3” emissions. We also have assumed that all students live on campus, as we could not calculate commute times for individual students nor assess their living conditions.

Year (college calendar year)	Students (number)	Natural Gas (MMBtu)	Electrical Generation (kWh)
2019	1,471	63,367	11,135,877
2020	1,385	58,921	10,159,517
2021	1,534	59,168	10,561,212
Average	1,463	60,485	10,618,869

Table 1: Reed College natural gas and electricity usage by year (2019-2021)

From Mike Tamada, we obtained information on the home-town zipcodes of all Reed College students with their names redacted. In addition to these, we used information from the International Council on Clean Transportation (Graver et al. 2020), the EPA (U.S. EPA 2018b), and the Energy Information Administration (U.S. EIA 2022) to estimate CO_2 equivalent production from natural gas, electricity, driving, and air travel. Combining these aforementioned data, we were able to find the carbon footprint of air and car emissions by individual and state of residence. The processes for obtaining these results can be found below. Important to note, however, is how we determined if a student drove or flew to campus. We assumed that a student who lives within 1000 km of Reed will drive to campus from home, while one who lives more than 1000 km from campus –or is an international student– will fly. The figure of 1000 km was selected as it is about the distance someone could travel in 10-12 hours at normal high-way speeds (65 mph) (see: Figure 1, below, for a visualization of this region). Lastly, we have decided to not calculate the daily commute of students to and from Reed as the patterns vary, and complexity cannot be accurately accounted for during the duration of this project. These data would no doubt change our findings, but must unfortunately be left to future research.[4]

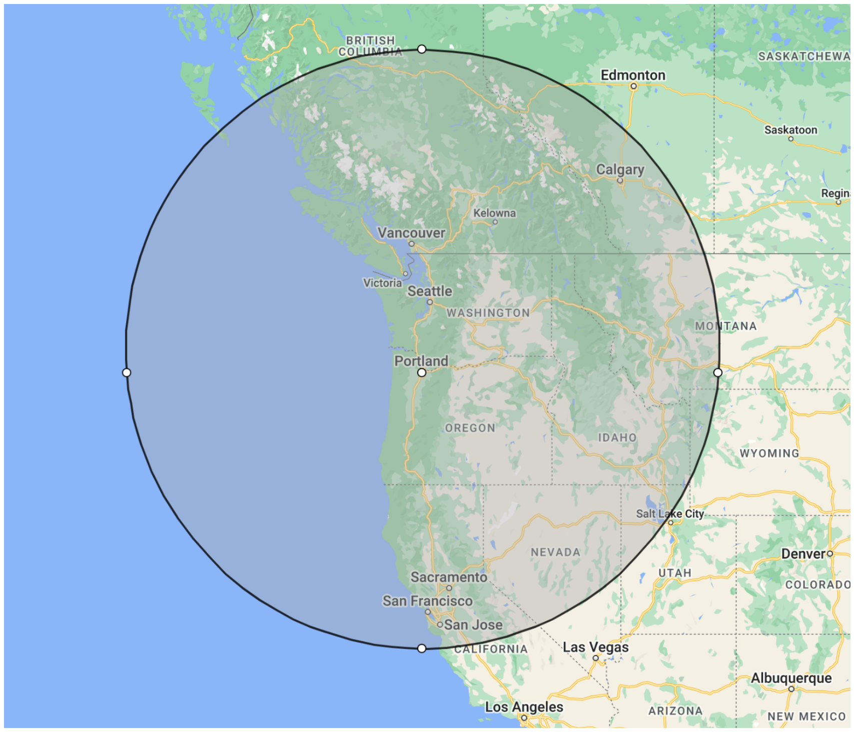


Figure 1: Visualization of locations within 1000 km of Reed College
Note: We assumed all students whose homes were within the shaded circle drive to and from Reed while those outside of the circle (or who are international students) fly.

Calculating Emissions by Source

The following lists how we calculated emissions from the various sources utilized in our analysis and show that the average breakdown of a Reed student's CF is: 55.32% from gas usage, 36.05% from electric usage, and 8.63% from air and road travel from all states to Reed College.

Air travel

CO_2e emissions from air travel were calculated by finding the distance from a student's home zip code (or city for international students) to Portland International Airport. This distance in kilometers was multiplied by 0.000099 (99 grams) to find the total CO_2e metric tonne

[4] In speaking with Rachel Willis, The College does not have data on commuting patterns from students, staff, or faculty. She did, however, note that there are active efforts to try and obtain these statistics.

equivalent per kilometer of flying (Graver et al. 2020). It was, then, assumed that international students would take one round-trip flight per year while domestic students would take two. This assumption was informed by conversations with several international and domestic peers of the authors and reflects that the college requires most students to leave for the summer and winter holidays. The average of all students' emissions from both car and air travel is at 0.80 tonnes of CO_2e per year. This relatively high value –that is a substantial part of a student's CF– is reflected in the literature (Sippel 2018).

Car Travel

CO_2e emissions from car travel were calculated by finding the distance from the centroid of a students' zip code to 97202 (Reed College). This distance in kilometers was multiplied by 0.00025 (250.0 grams) to find the total CO_2e metric tonne equivalent per kilometer of driving in an average car (U.S. EPA 2018b). It was assumed that students who drive would take two round-trips per year to reflect that students usually must leave campus for winter and summer break. In addition, driving distance was added to all students who flew by finding the distance from Reed College to Portland International Airport (19.31 km).

Gas and Electricity Usage

We calculated an average CO_2e per student from natural gas and electricity of 4.96 tonnes/year and 3.24 tonnes/year, respectively, using information from U.S. EIA (2022) This means that each student is responsible for ~8.20 metric tonnes of CO_2e per year from gas and electricity consumption on campus. These figures, however, are likely largely inaccurate on the individual level as they account for total consumption of gas and electricity on campus, not just that directly used by students. As such, usage by staff and faculty is being attributed to students.

Food Consumption

While we were not able to obtain data on students' consumption of food, this background is necessary as we account for food consumption in our dashboard and because food is a substantial part of the average person's CF. For our analysis we chose to only focus on the two largest contributors to most people's CF from food, red and white meat. For instance, for US adults, consuming Meat accounts for 56.6% of dietary emissions, based on NHANES 2005–2010

24 hour diet recall experiment (Heller et al 2018, 5). Further, while "...beef accounts for only 4% of the retail food supply by weight; it represents 36% of the diet-related GHG emissions" (Heller and Keoleian 2014, 391). This consumption has a significant carbon emission impact and we utilized figures of 2.99kg of CO_2e emitted per 4 ounces of red meat and 0.78kg of CO_2e for white meat or fish (Heller and Keoleian 2014, 398).

Total footprint

The following visualizations, Figures 2 and 3, show CO_2e emissions per capita and in aggregate, based on the calculations above. Looking first at the aggregate numbers in Figure 3, we can see that emissions at Reed are dominated by Californian, Oregonian, and International students. This is a direct result of the fact that a substantial portion of the student body resides in California or Oregon and that the average international student must travel farther than the average domestic student. Looking at emissions per capita, however, we see that Californians and international students are no longer dominant, and students from the farthest away domestic states, Hawaii and Maine, rise to the top. International students, though living farther away on average, are not responsible for the highest emissions per capita because of our assumption that they will only take one round-trip flight per year. Per capita emissions reveal another interesting relationship in how we chose to define what mode of travel certain students would take. For instance, despite being farther away, Wyoming students had a lower CO_2e per student than Idaho because we assumed all Idaho students would drive and that only some Wyoming students would. This reflects the fact that air travel, despite having high emissions, is more environmentally friendly (per passenger) than driving a car the same distance.

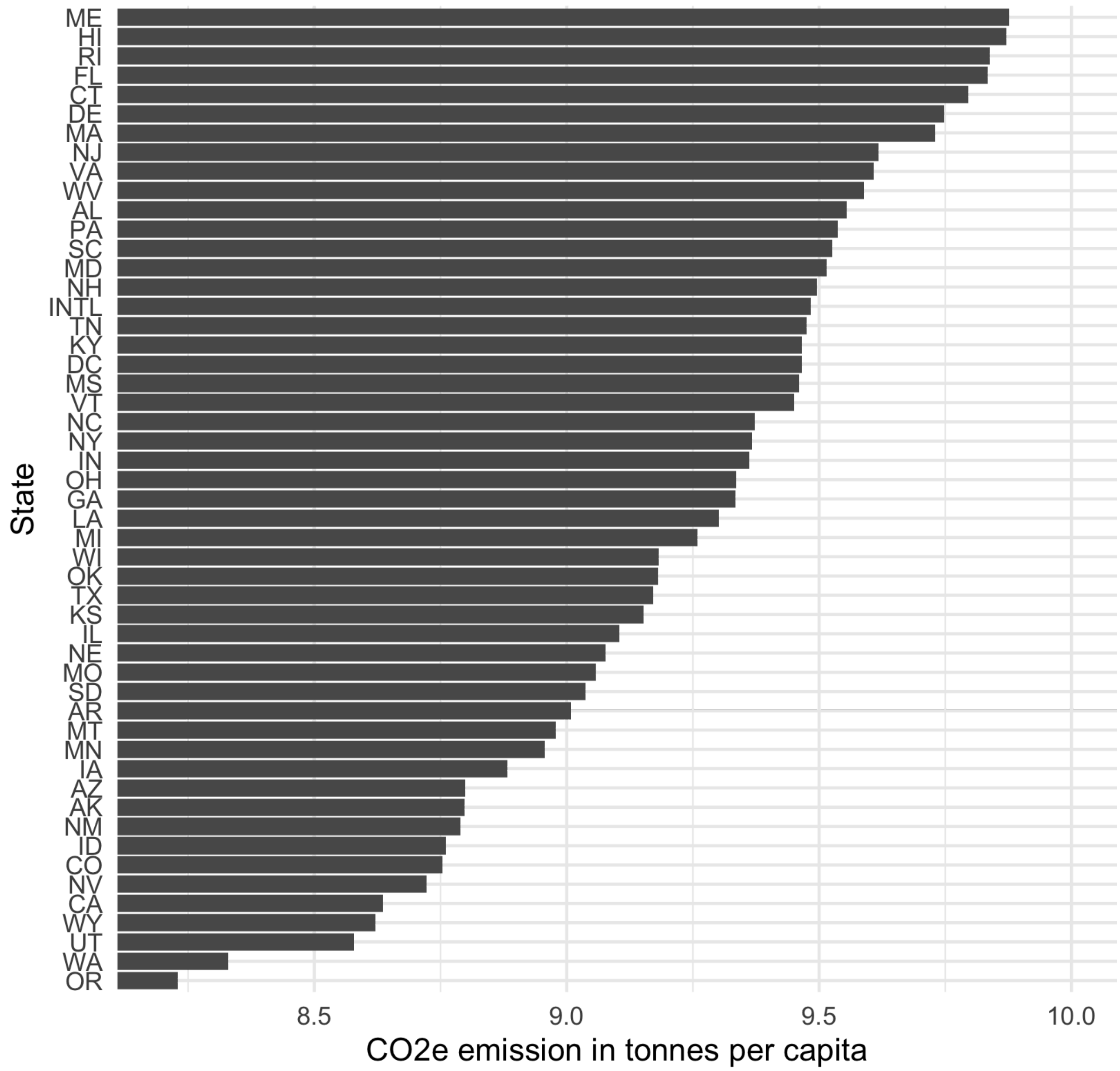


Figure 2: Per capita CO_2e from gas, electricity, and home to college transport

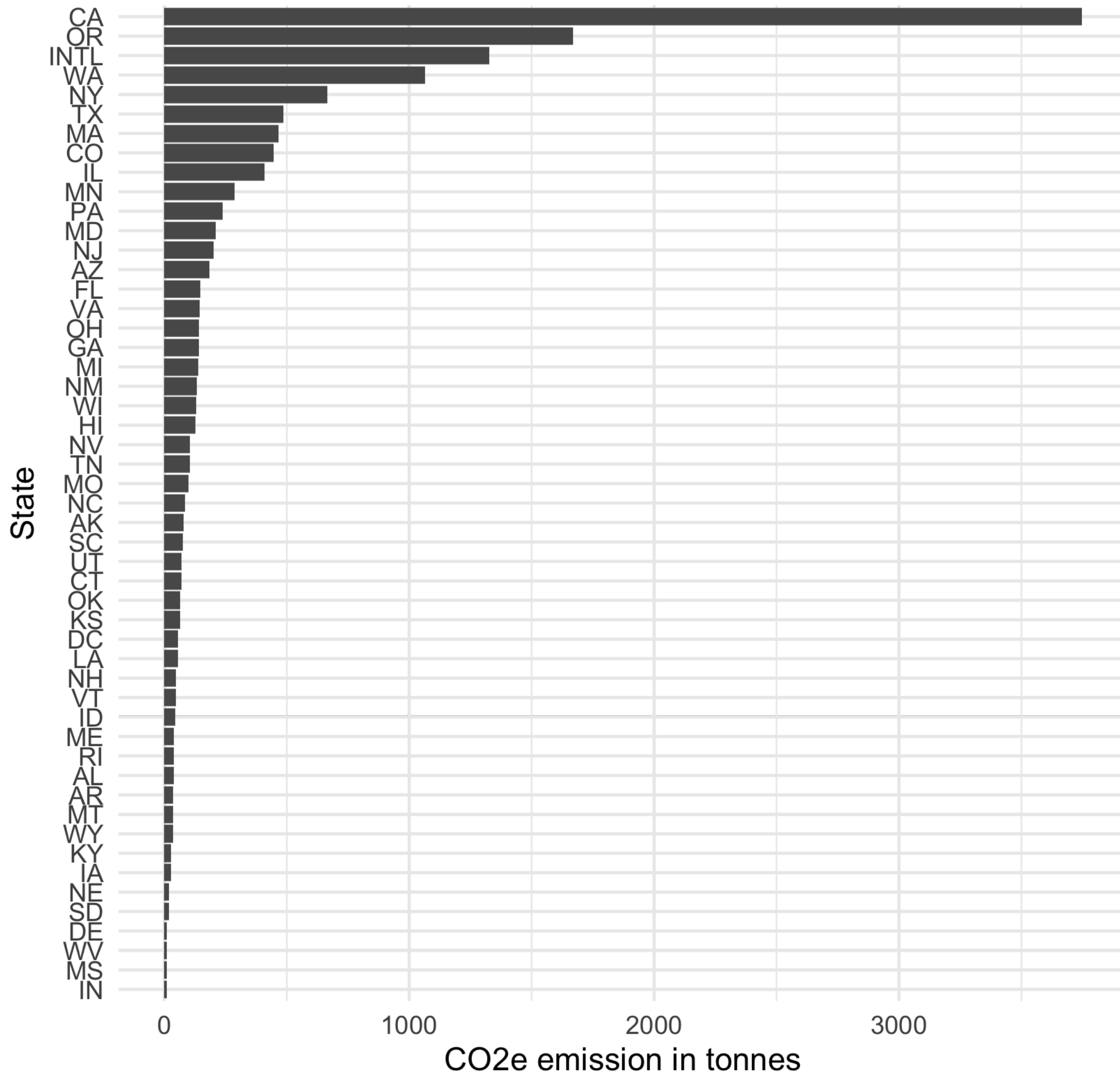


Figure 3: CO_2e from gas, electricity, and home to college transport

Next, multiplying the values in Figures 2 and 3 by \$53, we can obtain SCC per capita and by state (see: Appendix B for figures). These results show exactly what we would expect – CO_2e production for college students is a factor of their home distance from campus. Based on our findings, an average student has a carbon footprint from travel and residence at Reed of 9.00 tonnes per year, for a SCC of \$477.00 per year. For the entire student body (1,565 students including students from both bachelors and masters programs), per year, we estimate 1250.72 tons of CO_2e (\$66,288.16) is produced from travel and 12,831.53 tons of CO_2e (\$680,071.09) is produced from gas and electricity, for a total carbon footprint of 14,082.25 tons (\$746,359.25).

This means that the Reed student body is causing nearly three-quarters of a million dollars in economic damage from consumption and travel per year. Using more liberal figures for SCC of $185 per ton places Reed's total impact at $2,605,216, $1664.67 per student or 0.3% of the college's endowment (Lydgate, 2022). The total emissions we calculated, though higher than a more typical average of 2.67 tons CO2e per student (Valls-Val and Bovea 2021), is within the range set forth in the literature (Sippel 2018).

Dashboard

We created the Reed Carbon Calculator, an *rShiny* dashboard, to help students better understand their own carbon footprint as well as to help rectify some deficiencies in our own data collection. Our intention for this app was to allow students to include consumptive habits that Reed did not have data on, chiefly commuting and food consumption. The data used in the app are the same as those presented in the previous section of this paper. The dashboard is accessible at https://mjdvl.shinyapps.io/Reed_Carbon_Footprint_Calculator/.

Looking at Figure 4, the dashboard's main page, we can see that the dashboard displays an individual's carbon footprint, SCC, and the emission comparison after a user inputs their consumptive behavior. A user is then able to compare their consumptive habits to those of an average Oregonian and an average American. It is important to note that, in lieu of better data, the proportions of consumption for an Oregonian and American are equivalent. Further, CF, SCC, and country comparison will update reactively as a user changes inputs to their consumption.

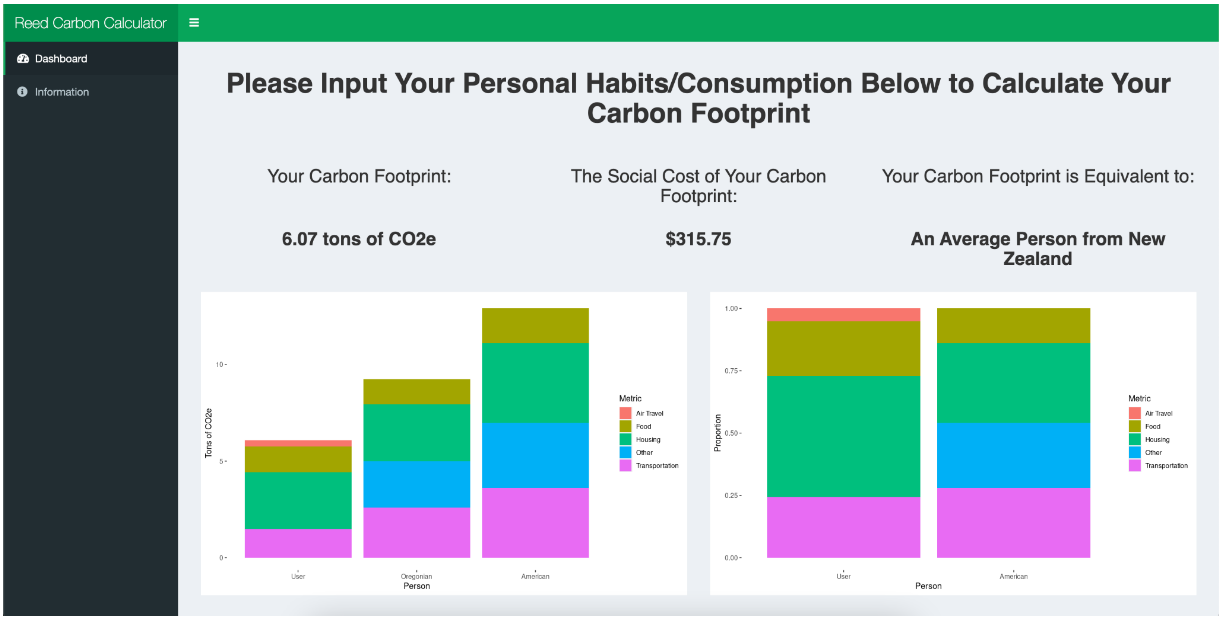


Figure 4: Dashboard Main Page

The subsequent figure, Figure 5, shows all of the input options available to users, including those for food, travel, driving/commuting, and housing. Food, driving/commuting, and housing are all toggleable and use a series of sliders to allow a user to input and adjust various parameters. Travel, on the other hand, allows a user to select either “drive” or “fly,” depending on how they travel to Reed from home, and then input their home zipcode or IATA airport code, respectively. Our app then calculates the distance between these locations and Reed and multiplies this by the number of round trips per year. Had time permitted, adding additional granularity would have allowed for more accurate results (e.g. other foods, consumption of clothes, etc.).

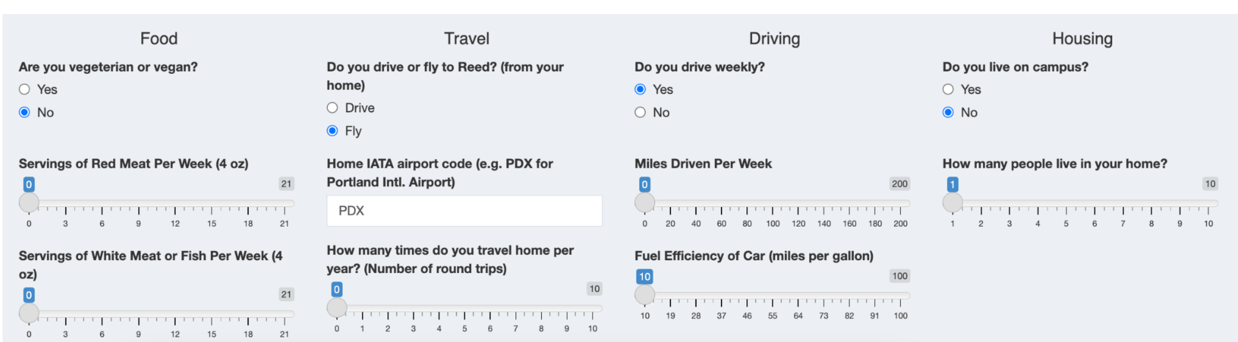


Figure 5: Dashboard Features

The Reed Carbon Calculator was intentionally designed to be updated by future student researchers, as more data and institutional support becomes available. As such, we have made the dashboard code public and given the Reed College sustainability coordinator the ability to make changes. The dashboard, however, is written in the R programming language and there is no statistical programmer in the sustainability office that could edit *rShiny* code. As such, for ease of management, the code for the dashboard is well documented and simplified where at all possible. Likewise, unnecessary or overly complicated features from the app (largely aesthetic changes) were omitted. It was our hope to make the dashboard accessible to manage and upkeep for an individual with one month of `R` experience.

Sustainability Plan

Our analysis of students' carbon footprints at Reed College points to two clear avenues for reducing the college's overall carbon footprint: reducing gas and electrical usage, and limiting the need to travel to and from Reed. Beginning with the latter point, our research would support The College allowing students to stay on campus for summer and winter break. Carbon emission generated by travels to and from home and Reed College is relatively high, and this could be reduced if students are given the option to stay in their dormitories during breaks. While we are, of course, not recommending that Reed restrict student travel, this option would allow eco-conscious students to reduce their carbon footprints (not to mention the auxiliary benefits to students who are unable to reasonably afford transport home for breaks).

The current deficits in on-campus housing over breaks, from conversations with knowledgeable persons in the administration, is that "Res-life" (Reed's on-campus housing division) is facing high staff turnovers and relatively low pay of the residential life staff. This led to the lack of winter and summer housing due to staffing shortage despite rooms being available. There is room for quelling the residential issue at Reed College, if it can generate more profit from winter and summer housing by including SCC and cost of travel to calculate the willingness to pay to get the efficient price for winter and summer housing. It would satisfy three things. First, it would allow students to stay at Reed College using the previously unused infrastructure during the summer and winter. Second, the reduction of travel to and from college will reduce emissions coming from long-distance travel. Lastly, it would provide additional financial funding from the profit generated from the housing to effectively run the residential life office. This could incentivize Reed College to provide more summer and winter break housing to students.

The second aspect to our sustainability plan is targeted at reducing on-campus usage of gas and electricity. Literature has shown that increased awareness of one's carbon footprint and consumptive habits can lead to short and long term increases in low-carbon activities (Lin 2016). As such, we would recommend that The College investigate efforts to increase student awareness, like sending out weekly "environmental health checks" modeled after the COVID "daily health checks." This would prompt students to answer a range of questions –and perhaps utilize a carbon footprint calculator like the dashboard we made– and would then return their weekly CF. This value could be tracked over time, and incentives could be given for participation or reductions in consumption. Additionally, The College could require our on-campus food service company, Bon Appetit, to report the carbon footprint of all dishes served, allowing students to make more informed climate decisions regarding food.

Conclusion

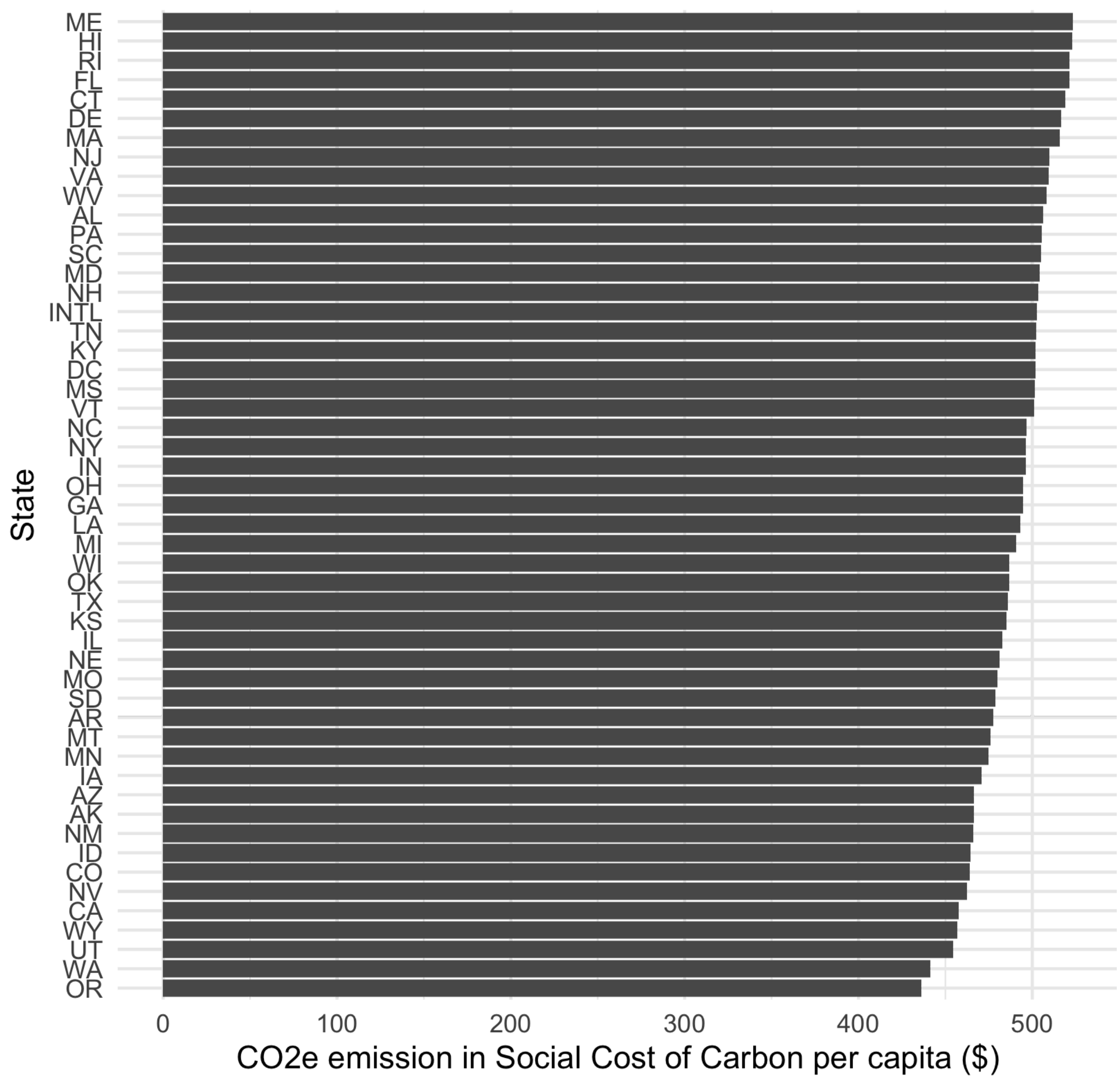
In this paper we sought to calculate a portion of the average Reed College student's carbon footprint and show that it is largely a function of electrical and gas usage, and travel to and from Reed. In doing so, we found that the average Reed student may have a higher carbon footprint than a typical university student. From these results, in aggregate, Reed's social cost of carbon (SCC) is $746,359.25 – $2,605,216 per year or $459 - $1,665 per student per year. Based on these findings, we propose that Reed pursue a sustainability plan that allows students to stay on campus during breaks, thereby reducing travel, and promote ways for students to learn about their carbon impact on campus.

Appendix A: Code, Data, and GitHub Repository

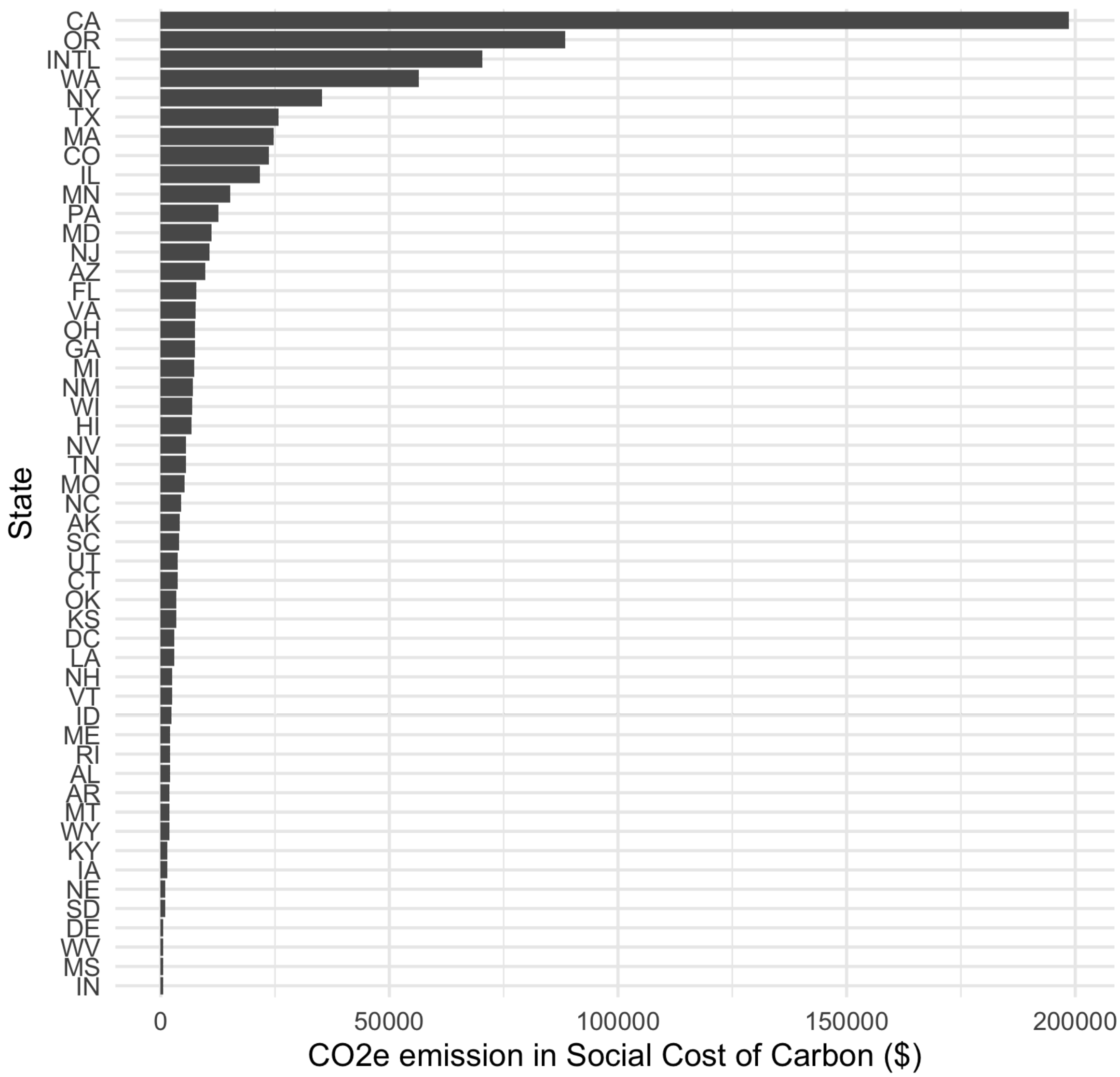
All of the code and data used for this project can be found at:
https://github.com/ahnsb5117/reed_carbon/.
Code used for the dashboard, specifically, can be found at:
https://github.com/ahnsb5117/reed_carbon/tree/main/dashboard_codebase.

For further information on the code used in the dashboard, please contact maxvanlan@reed.edu.
All other code related inquiries should be directed to ahns@reed.edu.

Appendix B: Additional Graphs for SCC



Per capita SCC from gas, electricity and home to college transport



Social Cost of Carbon from gas, electricity and home to college transport

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