AC 2009-679: DETERMINING THE GREENHOUSE-GAS IMPACT OF UNIVERSITY-SPONSORED AIR TRAVEL

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Determining the Greenhouse Gas Impact of University Sponsored Air Travel

Abstract

The American College and University President's Climate Commitment (ACUPCC) has been signed by over 600 campus presidents in all 50 states, committing their campuses to move toward a climate-neutral footprint. In order to achieve this goal, greenhouse gas (GHG) emissions must be monitored to ensure compliance and to verify reductions. While some of the GHG data categories may be relatively easy to document, monitoring individual air travel events in the required detail is impractical on a campus wide basis. The method described in this paper blends published statistical data with available campus information to determine campus GHG emissions due to air travel.

What is ACUPCC?

In summer of 2007, Dr. Jerilynn S. McIntyre, President of Central Washington University (CWU), became a charter signatory to the American College and University Presidents Climate Commitment[1]. The basic intent of the climate commitment is an agreement to work toward a climate-neutral campus by a future target date, reducing greenhouse gas emissions effects to zero. In achieving this goal, universities are leading the way in determining practical ways to reduce the GHG effects, and along the way are training future professionals who may implement these changes in industry and society.

The ACUPCC commitment consists of three basic parts:

1) Develop an action plan to bring the campus to climate neutrality,
2) Immediately initiate two or more actions toward that goal while developing the plan,
3) Make the action plan, GHG inventory document, and progress reports publicly available, including reporting to the American Association for Sustainability in Higher Education (AASHE)[2].

In order to mark the progress toward campus climate-neutrality it is crucial to develop and regularly update the GHG inventory document. This inventory document tracks progress toward the goal of net zero GHG emissions. It can also help predict the impact of various changes along the way.

The Clean Air-Cool Planet (CA-CP) Campus Carbon Calculator

In evaluating the GHG impact, ACUPCC endorses the Clean Air Cool Planet (CA-CP) Campus Carbon Calculator, available from the CA-CP website[3]. This Excel spreadsheet application has been developed specifically for typical college and university campus situations so that undergraduate and graduate students from a variety of backgrounds can learn to use it quickly. At CWU most of the data gathering and reporting is performed by students from programs throughout the university, both undergraduate and graduate, guided by a steering committee of staff and faculty from throughout the university.

The CA-CP carbon calculator aggregates the global warming potential (GWP) of all regulated emissions and reports the total in terms of metric tons per year of CO_2 Equivalents (CO_2-e). The Global Warming Potential (GWP) of the various monitored gasses is assigned a value relative to CO_2 based on data from the Second Assessment Report[4] of the Intergovernmental Panel on Climate Change (IPCC). The emission of all the monitored gases is then converted into an equivalent amount of CO_2 and summed into a single CO_2-e value. Universities may also opt to use more recent IPCC data, using updated IPCC GWP numbers, as assessed over a 100-year time horizon.

The CA-CP carbon calculator summarizes campus-related emissions of all GHG gases, direct and indirect, including compounds like refrigerants and fertilizers. There are many parts to this inventory, including categories such as the direct purchase of fuels consumed on campus, determining the mix of energy sources used by the electricity provider, daily commutes of students, faculty and staff, effects of recycling and solid waste generated, and university-related air travel by students, faculty and staff. This paper focuses on the issues related to documenting university paid commercial air travel and preparing the inputs for the CA-CP Carbon Calculator.

University sponsored air travel fits under the category of Directly Financed Outsourced Travel (CA-CP Scope 3, part b, as defined in the Carbon Calculator Users Guide[5]). This data is required to be included in the inventory. For our university there are no other practical public transportation modes for this category other than air travel. The CA-CP carbon calculator data input for air travel is in units of passenger miles per year.

CA-CP Emissions Calculation, including GWP and RFI

Within the CA-CP calculation for commercial air travel, there are a number of assumptions made as outlined in Table 1. One assumption is that the fuel is incompletely burned, producing a component of unburned fuel in the exhaust stream that is treated like an equivalent amount of methane. Also it is assumed that the combustion creates some NO_2. According to the IPCC report, both methane and NO_2 have Global Warming Potential (GWP) values that far exceed the effect of an equivalent mass of CO_2. For CH_4, the GWP = 23; for NO_2, the GWP = 296 (GWP for CO_2 = 1)[4]. The CA-CP calculator assumes a constant value of 3940 BTU per passenger-mile from year 2000 on, and does not automatically update the value to reflect decreasing (or increasing) energy intensity per passenger mile. The Bureau of Transportation Statistics (BTS) tracks this data value[7], and it should be updated for current years in the CA-CP calculator (EF_Transportation sheet, column BF).

Data Point	Calculator Assumptions	Data value in CA-CP spreadsheet[3]
Fuel Efficiency	3940 BTU/Pass-mile => 34.42 Pass-MPG	.00394 MMBTU/pass-mile
Fuel Energy	135,640 BTU/gallon for Jet A Fuel	.135640 MMBTU/Gallon
CO_2 Emission	26.50 kg CO_2 / gallon (Includes 2.8 RFI)	0.77356924 kg CO_2-e/mile
CH_4 Emission	.000261 kg CH_4 /Gallon	7.61733E-06 kg CH_4/mile
NO_2 Emission	.0003 kg NO_2/Gallon	8.75556E-06 kg NO_2/mile
CO_2-e Total	1288 Pass-mile / MT CO_2-e	0.000776336 MT CO_2-e /Pass-mile

Table 1: CA-CP Air Travel Emissions Calculation Assumptions

One unique characteristic of commercial air travel is the altitude at which the combustion gases are emitted during the cruise portion of the flight. Along with the CO_2 emissions, water vapor is also created (the condensation in aircraft "contrails"). The effect of these emissions at high altitude magnifies their climate effect to an extent that is not yet understood clearly[12,13]. It is estimated that at altitudes above 9 km, the GWP of CO_2 emissions nearly triples. At high altitude the climate effect is magnified by the water vapor that is formed in combustion, which condenses to become a high altitude haze and may contribute to additional cirrus cloud formation. This effect is lessened to some extent due to the fact that a significant portion of fuel is consumed at takeoff, occurring mostly at low altitudes.

Taking these factors into account, the CA-CP calculator applies a Radiation Forcing Index (RFI) value of 2.8 to CO_2 emissions. The CA-CP calculator does not apply this factor to the CH_4 or NO_2 emission estimates. Some more recent sources put the RFI value at 1.9[14], but also caution that it is simplistic to just multiply the CO_2-e by a single global factor to determine the net climate effect [14,16]. It is also inappropriate to ignore the effect, so the 2.8 value for the RFI in the CA-CP calculator will continue to be used until consensus emerges supporting a different value or metric.

AASHE Guidance for Scope 3 Emissions: Air Travel

The guidance from the American Association for Sustainability in Higher Education (AASHE) for calculating campus related air miles suggests using accounting data and applying figures from the Air Transport Association (ATA) to determine the total miles traveled[15], currently amounting to around $0.13/ passenger-mile (detailed in Table 1). AASHE suggests adding 20% to the airfare cost per mile data to account for taxes and fees not accounted for in the ATA data. The previous AASHE guidance was to use a flat rate of $0.25 per passenger-mile. The AASHE guidance is the most commonly used method to determine university related air travel miles.

Available Data for Commercial Air Travel

The Bureau of Transportation Statistics (BTS) of the US Department of Transportation publishes data for domestic air travel, which is the air travel category consistent with the CA-CP calculator assumptions. The BTS data track revenue to the airlines per passenger mile[6], including the base ticket price but excluding taxes and other fees that are added to tickets. The BTS data for domestic revenue per passenger mile is essentially identical to the ATA Domestic Passenger Prices Yield per mile data recommended by AASHE.

Tickets in our small initial sample had taxes and fees ranging from 7% to over 22% of the base ticket price. In looking at a small random sample of air travel events, we found that there appeared to be a divergence from the BTS data due to these fees. As a result it became necessary to gather additional data to generate confidence in a campus-specific number for air travel cost per passenger-mile.

Air travel requests originate from the many departments within the four colleges and administration of the university. Though a uniform travel authorization form must be filled out for each travel event financed by the university, the final approvals for the various requests are made at different levels and various locations university-wide. A relatively local trip may need only department approval, while international air travel may require approval from the highest levels of the university administration. As a result, there is no single place where the travel authorization forms aggregate. Approved travel authorization forms are returned and catalogued in the files of over 50 individual department offices.

Available data does not directly record air miles. However existing accounting data includes categories for commercial air travel expenses paid by the university, and has the added benefit of an existing historical record to track data trends. In some records there is destination data noted, but this data is incomplete. We chose to use this accounting data, and follow the method outlined in the ASSHE guideline to correlate the dollars spent to passenger miles traveled.

For each of the five years studied, there were between 1300 and 1700 line items to review. Many of the entries did not note destination information. Some that did note destinations were not reporting the total airfare, but only a partial airfare allocated to a particular account, with the remaining fare distributed to one or more other accounts. Where possible we matched the corresponding line items and summed partial fares into a single entry. In selecting the data we deleted items with no destination, or where the value was obviously not a complete fare. The remaining data points that seemed to have enough information to be relevant ranged from 12% to 20% of the total line item entries. These values were used to calculate the average value for CWU airfare cost per mile for each year. This average value was then applied to the total account value of all line items to estimate the passenger-miles per year attributable to CWU. The airfare accounts we reviewed appear to include line items such as athletic team airfares paid by the university. The filtered data points that we used seemed to be reliably reporting the total airfares for the travel events reported.

Fiscal Year	Data Points Used	Average CWU $ per Pass-Mile	95% Confidence Interval[17]	Standard Deviation of Data Set
2003-4	170	0.1163	.1085 to .1241	.0518
2004-5	294	0.1288	.1221 to .1355	.0589
2005-6	166	0.1363	.1276 to .1450	.0575
2006-7	189	0.1331	.1248 to .1414	.0579
2007-8	208	0.1428	.1349 to .1507	.0583

Table 2: Statistical Results for CWU Air Fare Cost per Mile

In reviewing the data results, it became evident that the standard deviation values are large but comparable for the five annual data sets. In considering the relatively large standard deviation (typically 40 to 45% of the mean), it appears to reflect the wide variation in fares paid by passengers on a given flight, where adjacent seats may have paid fares that range by a factor of three or four as the airlines will use price discrimination to maximize revenue and also keep the flights full[17]. To get a sense of the range variability in the average value for the CWU cost per passenger-mile, a 95% confidence interval was calculated for each year's set of data[17]. Based on that result, the margin of error for the average value ranged between 5.2 and 6.7%, which was considered relatively small.

The air miles traveled by students and not paid by the university (ie, study abroad and foreign student travel) are not included in the accounting data we used (and not addressed in this paper), but can be accounted for in a separate category in Scope 3 emissions in the CA-CP calculator. In this case the miles traveled are determined not by accounting data but by individual student travel event origination and destination distances. This mileage data should be determined through the program offices for study abroad and foreign student programs. The student air travel mileage would be entered in the calculator, and the per-mile values for CO_2-e would use the same factors used for university paid air travel.

Converting Accounting Data into Air Travel Passenger Miles

Using accounting data with known destinations, we were able to determine the travel distance and thus cost per passenger mile. For these data points, we determined the airfare cost for each individual trip and the distance between airports. Our task was simplified because only one airport (Seattle-Tacoma International Airport, aka SEA-TAC) is practical to use for originating long distance commercial flights. We also assumed that all flights were round trip from that airport, using an internet source (http://www.world-airport-codes.com/) for distances between that airport and the destination. We were unable to determine how many segments individual flights might take that increase the travel miles (especially in the case of cancelled and rerouted flights), and assumed that the travel mileage was only between originating and destination airports. Travel between the university and the airport would be accounted for in other CA-CP categories (ie, mileage reimbursements paid out, or fuel used in university fleet vehicles, etc).

Fiscal Year	BTS Domestic Data Revenue per Pass Mile[6]*	CWU Average Air Fare Cost per Passenger Mile	CWU / BTS Factor
2003-4	$0.1215	$0.1163	0.9572
2004-5	$0.1215	$0.1288	1.0601
2005-6	$0.1265	$0.1363	1.0775
2006-7	$0.130	$0.1331	1.0238
2007-8	No data	$0.1428	No Data

* Note: BTS data is averaged between adjacent calendar years for comparison to CWU fiscal year data

Table 3: BTS and CWU Air Travel Cost per Passenger Mile Compared

Table 3 presents results for the average CWU airfare cost per passenger mile. The calculated average for CWU data was compared to the BTS revenue data[6], and a ratio between the BTS and CWU data was calculated to see how much they differed. As a result we gained confidence in the data to use for estimating GHG emission effects. The difference between the CWU value and the BTS data ranged from 2.4% to 7.8%, which is also comparable to the range of the 95% confidence interval margin of error for the CWU data. The ASSHE guidance, using the ATA domestic revenue data and adding 20% to cover taxes & fees, appears to be a reasonable estimate for future year estimates though our data shows that the average difference between CWU costs and BTS revenue averages closer to 3%. We did however find in our initial inquiry that the sampled air fares were between 7% and 22% higher than the BTS values.

Fiscal Year	Air Travel Expense/Year	CWU Cost per Passenger-Mile	Estimated Passenger Miles/Yr
2003-4	$ 467,113.64	$0.1163	4,016,500
2004-5	$ 382,736.52	$0.1288	2,971,500
2005-6	$ 419,184.46	$0.1363	3,075,500
2006-7	$ 498,087.35	$0.1331	3,742,200
2007-8	$ 562,712.57	$0.1428	3,940,600

Table 4: CWU Air Travel Passenger Miles per Year

Table 4 shows the total air travel expense figures summed for all line item entries in the fiscal year. The value determined for airfare cost per mile was applied to the total account value to determine an estimate of annual air miles traveled on university business. This is the data that is needed for input into the CA-CP Campus Carbon Calculator.

Converting Commercial Air Transport Passenger Miles into GHG effect

Most reporting of GHG emissions is reported in terms of Metric Tons CO_2, which is 1000 kg or 2205 lb. The global warming effect of other gases is normalized to that of CO_2 by a factor called the Global Warming Potential factor (GWP) and reported as CO_2-equivalent amounts (CO_2-e). The GWP factors are based on data from the IPCC Second Assessment Report[4]. The CO_2-e value can be determined from data for passenger-miles traveled, energy intensity of air travel (BTU per passenger-mile), energy content of Jet A fuel (BTU/gallon), the actual CO_2 emission of the fuel (lb CO_2 per gallon), and the radiative forcing index factor (RFI).

Data for the energy intensity of domestic air travel comes from the National Transportation Statistics Report of the BTS[7]. The energy content of Jet A aviation fuel is defined by ASTM spec D1655; the CA-CP calculator uses a value of 135,640 BTU/gallon. The GWP sensitivity of high altitude emissions is accounted for with the RFI factor of 2.8.

The CA-CP calculator uses figures of 3940 BTU/passenger mile yielding .000776336 MT CO2-e per passenger mile, or 1288 Passenger-miles per MT CO_2-e. This value includes the GWP effect of estimated CH_4 and NO_2 emissions and the RFI factor. Table 5 below updates the BTU/Passenger-mile numbers in the CA-CP calculator based on BTS data[7] to determine the number of passenger miles per MT CO_2-e for each year. This last value is then used in Table 6 to convert passenger miles traveled (from Table 4) to give the estimated annual GHG footprint due to university sponsored air travel.

Year	BTU Per Passenger Mile[7]	Passenger Miles Per Gallon Jet A Fuel	Passenger Miles Per Metric Ton CO_2-e
2003	3463	38.98	1466
2004	3296	40.95	1540
2005	3182	42.43	1595
2006	3070	43.97	1653
2007	No Data	No Data	1710 (Projected)

Table 5: Energy Intensity and CO_2 Emissions of Domestic Air Travel

Fiscal Year	Estimated Passenger Miles Traveled	Passenger Miles per Metric Ton CO_2	Estimated Air Travel GHG footprint, MT CO_2-e
2003-4	4,016,500	1466	2739
2004-5	2,971,500	1540	1930
2005-6	3,075,500	1595	1928
2006-7	3,742,200	1653	2264
2007-8	3,940,600	1710 (Projected)	2304

Table 6: CWU Air Travel CO_2-e Emission Estimates

Tables 5 & 6 show that the fuel efficiency (and GHG emission rates) of domestic air travel has been steadily improving. It is also apparent that the demand for air travel has been growing faster than the fuel efficiency has improved, and net emissions and resulting climate effect are increasing. This general data trend is reflected in the data for the university.

The CA-CP calculator does not update the BTU per Passenger Mile values automatically. The Version 5 CA-CP calculator uses values of .003940 MMBTU/passenger mile (ie, 3940 BTU/Pass-mile) after 2001. Updating this input for current values[7] (in column AK of the EF_Transportation sheet) can result in a significant correction to the university CO_2-e footprint.

Reducing GHG Emissions Due to Campus Air Travel

There is not much that can be done to reduce the impact of a trip to the given destination. Reduction in actual emissions is best accomplished by reducing the number of air travel events or distance of travel. There may be opportunities to increase the use of video conferencing, or an opportunity to emphasize regional conferences in preference to national events in more distant locations. In many cases video conferencing is only marginally effective, and sometimes the informal contact with colleagues at a major event can be more valuable than the program content. Often the visibility of the university and its participation within various professional fields is directly linked to the participation of university representatives in off-campus events and conferences.

While it is always possible to trim the volume of air travel, it would be impractical to eliminate university-sponsored air travel in order to eliminate related GHG emissions. It is possible to purchase Renewable Energy Certificates (RECs) to offset GHG emissions of travel that cannot be avoided. The RECs amount to a payment to a renewable energy project that helps them recover the capital cost of equipment that generates emission-free power or reduces a GHG emissions source. Typical projects include wind farms, solar PV arrays, efficiency improvements at hydro projects, and methane recovery projects at landfills and dairies. Typically these projects sell RECs to generate revenue, but in so doing are then ineligible to claim the credit themselves to meet renewable portfolio standards etc. The auditing of projects by reputable REC marketers is crucial for this system to work without generating double credits and fraudulent CO_2 emissions avoidance claims.

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Campus Air Travel GHG Emissions REC Liability

One significant concern of campus administration is to define the outstanding liability if they bring emissions to zero by buying Renewable Energy Certificates (RECs). The Chicago Climate Exchange (CCX) has been set up to create a voluntary market for RECs in the United States. The value of one REC (representing 1 MT CO_2 avoided by a renewable energy producer) has varied over the past 5 years from $1 to a peak of over $7 in summer 2008[9]. The current REC price (as of this writing January 2009) is around $2.00.

In Europe carbon emission limits are enforced and carbon credit trading can be compulsory. The Feb 2009 value of RECs at the European Climate Exchange (ECX) is around 11.5 Euros, which is close to $15. The cost of RECs at ECX approached 30 Euros ($39) in summer 2008. It appears that the valuation of European Climate Exchange RECs runs at about a multiple of 7 to the Chicago Climate Exchange RECs.

Retail RECs are also available, marketed to individuals and businesses. Two such retailers are Terrapass (http://www.terrapass.com) and Bonneville Environmental Foundation (https://www.b-e-f.org/offsets/). The rates for these retail carbon offset products range from about $13 to $35 per MT CO_2 (as of January, 2009).

Based on the estimated emissions of CWU sponsored air travel and the current cost of CCX RECs, the university could offset the air travel GHG emissions at an additional cost of around 3% of the total air fare expense. In 2007-8, the total airfare expense was $562,700 (Table 3), generating an estimated 2304 MT CO_2 (Table 5). At the highest peak value for CCX RECs in summer of 2008, this amount of GHG emissions could be offset at a cost of $16,130. At the summer 2008 peak value for ECX RECs, this amount could be as much as $89,850, or about 16% of the air fare expense.

According to the initial draft version of the Campus Carbon Calculator, the entire campus GHG emissions in 2008 totaled 20,120 MT CO_2-e[10]. Commercial air travel accounts for 11.5% of this total. Worldwide, the impact of commercial aviation is estimated at 3.5% of the annual man-made GHG effect. With an enrollment of around 9,100 full-time equivalent (FTE) students the total GHG emissions footprint of the university averages 2.21 MT CO_2-e per FTE, which could be offset with CCX RECs costing between $4.40 and $15.50 per year per student, or around $0.10 to $0.35 per credit hour (based on 45 quarter hours per FTE-year). If GHG emission reductions become compulsory, these costs might eventually rise to meet the European ECX REC prices, which are 6-7 times higher than the CCX prices. At the current record value of around $40 for ECX RECs from summer 2008, the annual cost of carbon offsets would be $88 per FTE, or around $1.96 per quarter credit hour.

CWU Aviation Program GHG Impact

CWU also has a program training commercial pilots and aviation managers, leading to a BS in Flight Technology with various certifications. Though this program is an academic program and not university paid commercial transportation, it does generate GHG emissions related to the mission of the university. The aviation program generates around 8000 flight hours a year in single and dual engine planes that consume a weighted average of 8.3 gallons of aviation gasoline per hour. According to the EIA, the emissions coefficient of aviation gasoline is 18.355 lb CO_2 per gallon[8]. For these planes, no RFI factor need be used because they mostly fly at low altitudes, and much of that is touch-and-go landing practice. Based on these numbers, the aviation program generates 552.7 MT CO_2 per year. Based on the price range for CCX RECs in 2008, carbon offset RECs could be purchased for a total cost of between $1,100 to $3,900 (about $0.14 to $0.48 per flight hour). At the current record price of $40 for ECX RECs from summer 2008, the cost of carbon offsets could be as high as $2.75 per flight hour.

Some Observations Regarding the GHG Effect of Air Travel

One basic finding of this study is that the fuel intensity of air travel (in 2007) has been improving steadily, but the demand has been increasing faster resulting in a net increase in total emissions. In 2007 the fuel "economy" of air travel was equivalent to 43.97 passenger-miles per gallon (P-MPG) of aviation Jet-A fuel, but that the climate effect is amplified by a Radiative Forcing Index (RFI). As a result the net climate effect of commercial air travel is estimated to be equivalent to a ground level fuel consumption rate of 15.70 P-MPG (based on RFI = 2.8), roughly equivalent to the fuel economy of a typical 6-cyl SUV with a single occupant. At this rate, 2300 passenger-miles in a commercial flight will result in a GHG effect equivalent to 1 MT CO_2-e.

Educational Component of the GHG Inventory Process

Most of the GHG inventory efforts on university campuses are conducted largely with student efforts, guided by faculty and assisted by the staff. Student interns and graduate assistants are employed in identifying missing data, chasing down and processing the data, filling in the forms and resolving problems. Much of the data for this report was gathered by the coauthor, an undergraduate student in Mechanical Engineering Technology.

The process of developing and implementing the ACUPCC documents at CWU brings together students and faculty from engineering technology, environmental chemistry, geography, economics, and communications programs, along with representatives from various parts of the administration. The continued monitoring process will continue to expand opportunities for interdisciplinary interaction, as does the more important process of implementing changes to reach the goal of campus climate neutrality. Developing the campus GHG inventory and implementing and Carbon Reduction Plan has proven to be a good forum for interdisciplinary interaction and education across the campus. The process has helped (and will continue to help) prepare students for similar initiatives in the organizations they join after graduation.

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