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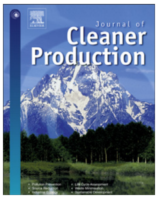

Carbon footprint analysis of student behavior for a sustainable university campus in China

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ABSTRACT

Sustainable urban design, systems-level organizational planning, and human behavior have all been recognized for their potentially important roles in helping to reduce energy costs and associated environmental impacts, including greenhouse gas emissions. University campuses, with their long planning timeframes, centralized organizations, and dense populations, are ideal places to examine these carbon mitigation strategies. In this study, we developed a novel methodology for estimating an average student's personal carbon footprint and deployed it at a university in Shanghai. Given the scarcity and uncertainty of existing information, we created and administered an online structured survey to capture students' energy consumption patterns, behavioral tendencies, and willingness to engage in energy conservation. Survey responses, combined with utility data and emissions calculations, indicated that the average annual carbon footprint was a relatively modest 3.84 tons of CO_2 equivalent per student, with 65% attributable to daily life, 20% to transportation, and 15% to academic activities like studying. The top three individual uses were dining (34%), showering (18%), and dorm electricity loads (14%). Men, graduate students, and students from metropolitan areas had higher footprints than women, undergraduates, and students from rural areas and small towns. Communal activities like dining in the dining halls, showering in communal showers, and studying in the library were all observed to lead to lower carbon footprints. These analyses can help identify student behavior changes that will be most effective at reducing aggregate carbon emissions. Awareness campaigns may be effective, given that 87% percent of respondents said they engaged in energy saving behavior, but only 22% reported turning off electronics when not in use. Survey responses and carbon footprint calculations were also used to identify actions the university could take to reduce emissions, both now and in terms of upgrades as the campus develops and Chinese living standards continue to rise.

1. Introduction

Anthropogenic greenhouse gas (GHG) emissions are the major reason for global climate change, an urgent problem that various countries and international organizations are trying to solve (IPCC, 2006). The atmospheric carbon dioxide (CO_2) concentration has increased from 279 to 397 ppm since 1800, primarily due to fossil fuel combustion (EPA, 2008). China is now the largest energy consumer and CO_2 emitter in the world. In 2011, China's energy consumption was reported to be 3.48 billion metric tons of standard coal equivalent, and its CO_2 equivalent emissions (CO_2e, including all six major GHGs) reached 9 billion tons, or 28% of the world total (National Bureau of Statistics of China (NBSC), 2012). For the time being, its gross emissions on a per capita basis are still much lower than in developed countries. However, as China continues to urbanize and modernize, even its size-normalized CO_2 emissions are growing rapidly; already it ranks 15th among nations on a per capita basis, and 2nd on a per-GDP basis (Olivier et al., 2013). As such, finding engineering, urban planning, and behavioral solutions to help mitigate emissions in the context of development constitutes a key challenge for China, and the world.

One sector that can help lead the way with these solutions is higher education, which is experiencing unprecedented growth in China, where there are more than 2700 universities and 30 million students (Ministry of Education (2012b)). The educational sector, including all levels, contributes approximately 40% of the total

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public sector energy consumption in China (Ministry of Education (2012a)). Around the world, many universities have been leaders in promoting sustainability, including trying account for and reduce GHG gas emissions. As organizational entities, universities are large enough to justify detailed, systems-level analyses—and, of course, they have the academics at hand to conduct them. For example, Saadatian et al. (2013) proposed different approaches to analyze sustainable campus development in a Malaysian university. In China, the China Green University Network (CGUN) was established in 2011 to reinforce cooperation among different campuses, promote innovation, and popularize energy saving ideas (China Green University Network, 2011).

In terms of GHG emissions, university-wide analysis also fits within a broader trend of designing, operating, and in some cases regulating low carbon organizations and communities. Such initiatives require methods for allocating emissions. Unlike in most existing studies just simply dividing gross emissions by the population size, these allocations must adjudicate *responsibility* for emissions, bringing into play a complex set of accounting, economic, social, political, and even ethical questions. The all-purpose term we will use for these calculations is *carbon footprint*, which has gained some currency largely due to private sector interest and to advocacy organizations (Weidema et al., 2008). The carbon footprint is simply the sum of GHGs emitted that can be attributed to an activity, process, organization, or entity. The idea is flexible, and depends heavily on specification of both *scope* and *methods*. The scope locates system boundaries and establishes a hierarchy of responsibility. It also includes temporal boundaries in terms of lifecycle *stages* or phases. The stages can include production (upstream emissions), operations or use (active stage emissions), and disposal (downstream emissions).

Currently, environmental Input-Output modeling has proven to be the most promising methodology in calculating carbon footprint on the target scope (Peters, 2010). Within the Input-Output based carbon footprint modeling, there have been many existing studies employing a wide variety of scopes and approaches, especially for university energy sustainable development (Abolarin et al., 2013; Alvarez et al., 2014; Güereca et al., 2013; Hesselbarth and Schaltegger, 2014; Larsen et al., 2013; Ozawa-Meida et al., 2013; Thurston and Eckelman, 2011; Townsend and Barrett, 2013). Most of these studies have focused on the university's overall design, operation, and supply chain strategies. For example, Ozawa-Meida et al. (2013) studied a UK university, combining a top-down supply-chain economic input–output estimation of emission factors and a bottom-up lifecycle assessment (LCA) inspired accounting of activity intensities. They found that the university's total carbon footprint was roughly evenly divided among building energy use, travel, and procurement. Baboulet and Lenzen (2010) took a very similar approach in assessing the carbon footprint of an Australian university. Güereca et al. (2013) reported a GHG emission study for the Universidad Nacional Autónoma de México. The total emissions was categorized into seven categories, such as electricity consumed, transportation, air travel, courier shipments, paper consumed, and solid waste treatments. They discovered that 42% of the total GHG emissions were from electricity use, and 50% from transportation. Alvarez et al. (2014) calculated the carbon footprint of the school of forestry engineering at the Technical University of Madrid based on the financial accounts. The total carbon footprint of this school in 2010 was 2147 tCO2e. Larsen et al. (2013) analyzed the carbon footprint of students from different departments of Norwegian University of Technology and Science. They found that students in social science and humanities have a much lower (around 50% less) carbon footprint than those from natural science or engineering.

Most of these studies have focused on overall school level GHG emission estimates and breakdowns. Little attention has been paid to the energy behaviors of students. It has been reported that behavioral factors account for about 30% of the variance in overall heating energy consumption and 50% in cooling energy consumption (Steemers and Yun, 2009), and that around 10–20% of energy can be saved through behavior adjustments alone, at minimal cost without adding or upgrading equipment (Langevin et al., 2013). Many recent studies have used interviews or surveys to identify the effect of people's energy behavior patterns on energy saving and GHG emission reduction. Nisiforou et al. (2012) used a structured questionnaire to study the energy usage habits and energy saving measures adopted in a large enterprise. They found many behavioral drivers of energy waste. For example, 28% of respondents did not turn off their computers when they left. They also revealed that most employees (around 90%) were aware of the energy waste in their organization, and were in theory willing to accept energy saving measures. Lillemo (2013) used an on-line survey to examine the effect of energy saving activities on energy consumption and CO_2 emissions, and reported a positive relationship between environmental awareness and engaging in everyday energy-saving activities. Jiang et al. (2013) presented a case study on university buildings, focusing on the influences of individual behaviors on overall energy consumption and CO_2 emissions. They proposed a low-carbon management system for encouraging behavior changes, with compoments including awareness raising, behavior forming and long-term engagement.

In order to explore the GHG emission reduction opportunities of students' energy behaviors in university campus, this project combines a focus on behavior with the methods of carbon footprinting, defining our scope as *an average student, and all emissions-related activities that can be affected by his or her behavior*. The personal carbon footprint includes all *active stage* emission contributions, including direct fuel consumption, electricity use, and transportation, but not including other indirect emissions like embodied energy. This GHG emission boundary was chosen consistent with the purpose of the study, which is to analyze the global warming impacts of student behavior. It would be very difficult to survey all the products consumed and wastes produced by each student, and the estimates would have high uncertainties.

To determine the footprint we combined emissions factors from input–output estimation and engineering judgment with a direct estimation of activity intensities. For the latter estimates, we used a unique combination of building energy monitoring data and an online, structured survey administered to 1029 students (Section 2.2–3.4). The development of carbon footprint calculation model is described in Section 3.1–3.6. The results of students' current carbon footprints including end-use breakdowns and demographics are analyzed and discussed in Section 4.1–4.3. After that a campus improvement plan on which both individual students and the university as a whole can focus is suggested and its related carbon reduction is predicted in Section 4.4.

2. Case study: Tongji University

2.1. University general information

Tongji University has two major campuses, one in central Shanghai, and the other in suburban Shanghai, with a total of more than 6000 faculty and staff members, 19,000 undergraduate students, and 28,000 graduate students. The total building area is 1.6×10^6 m^2, consuming more than 300 MWh energy in 2012 (Tan et al., 2012). Electricity and municipal natural gas are its two major energy sources. The electricity is provided through East China Grid, whose power is 70% coal, 18% oil, 4% natural gas, and 8% renewables (National Bureau of Statistics of China (NBSC), 2012). On campus, student dorms and research buildings account for over 50% of total

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energy consumption (Fig. 1). These are also two of the places most influenced by student behavior, such as operating personal electrical equipment and setting indoor temperatures.

In China, the average student's active stage GHG emissions are four times those of the population at large (Tan et al., 2014). On the other hand, compared to students in developed countries, Chinese students have a much smaller carbon footprint (Fig. 2). Chinese students typically live on campus or very close to it and walk more than their counterparts in many developed countries, who often commute by car. Furthermore, most Chinese students live in modest school dorms, which they typically share with two or three roommates.

On campus, much of the control of energy-related processes is out of students' control. For example, the university manages the HVAC and lighting systems in classrooms and libraries. In most of China, students cannot cook in their dorms. However, there are many behaviors students can affect their carbon footprints. They can control their personal electrical equipment, such as computers, desk lamps, drinking hot water heaters, and air conditioner temperature setting (if they happen to have one). They can also choose where to study: in denser groups in libraries or classrooms, or in their dorms or lightly occupied classrooms. Because the number of occupants will not affect lighting and HVAC energy consumption too much, the per capita energy consumption can change dramatically according to the number of occupants. They can also choose where to dine, how often and by what mode to visit home, and if they live off-campus, what mode of transit to use for commuting.

2.2. Student energy behavior patterns and categories

A student's personal carbon footprint is the sum of all emissions attributable to his activities directly, to the extent that is possible. These activities were divided into three broad categories: daily life, academics, and transportation. *Daily life* includes dining, showering, and most other dorm electricity use. *Academics* includes computer use for studying, printing, scanning, and the student's fractional contribution to the energy use in communal study and work spaces. *Transportation* includes daily transit, hometown traveling (visits to the student's family home), and vacationing. Each of these subcategories in turn comprises distinct activities linked to quantitative information that can be used to estimate GHG emissions. Table 1 lists the 17 activities considered in the carbon footprint model.

Table 1 also gives a brief description of the calculation procedure for each activity. Much greater detail on these calculations follows in Sections 3.1–3.6. As Table 1 makes clear, students' carbon-emitting activities span a variety of uses, locations, and fuel sources, not all of which show up on the university's utility bills. Assessing the magnitude of these contributions required information about students' behaviors. The crucial piece of this project was the gathering of this information through an online survey instrument of more than a thousand students. The following section describes the survey itself, and Section 3.4 describes its administration and scoring.

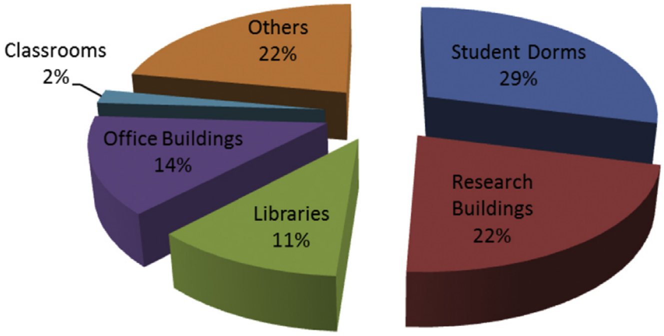

Fig. 1. Tongji University energy consumption breakdown (Tan et al., 2012).

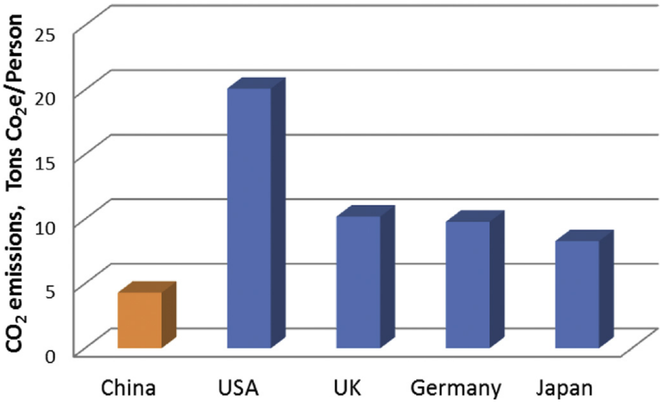

Fig. 2. CO_2 equivalent emissions of university students from different countries (Tan et al., 2012).

3. Method

3.1. Carbon footprint model: overview

As discussed earlier, this study estimates the *personal carbon footprint* (active stage emissions): CO_2 equivalent emissions (GHG emissions) that can be linked directly to students' activities. We call this a *personal carbon footprint*, because it truncates the system to the reasonable agency of a student. It includes the behaviors students can change, like where they dine, study, and shower, how they use personal electronics, and how they commute and travel. It does not include a person's share of emissions from upstream and downstream sources, since these are both uncertain and more reasonably placed in the scope of large organizations or nations. The general approach was to estimate in advance unit GHG emission factors F_i for each individual activity identified in Table 1. The unit in question depended on the activity: it could be a single meal, shower, money (RMB), hour, kWh, page, or km. The emission factors were the same for every respondent (with a few exceptions described below). What differed for each respondent was his or her activity intensity, or number of units per year U_i associated with the i-th activity, e.g. meals per year in the dining hall, RMB per year for showering fees, etc.

For all activities except studying (i = 11, 12, and 13, described below), the carbon footprint for each activity was the product of the emission factor (e.g., $kgCO_2/km$) and the activity intensity or number of activity units the student "used" (e.g., km flown per year):

$$GHG_i = F_i \cdot U_i, \quad i = 1 \cdots 17, \quad i \notin \{11,\ 12,\ 13\} \tag{1}$$

3.2. Carbon footprint model: GHG emission factors

The starting point for estimating unit emission factors was the inventory of factors issued by the National Reform and Development Commission of China (NRCC) (Info-Net, 2013), which is itself based on the Kyoto Protocol and its "Guidelines for National Greenhouse Gas Inventories" (IPCC, 2006), but with modifications

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Table 1
Student energy behaviors and CO_2e emission calculation summary.

Category		Subcategory	Activity	Calculation
Daily life		Dining (*additive*)	Dining in dining hall	Total dining hall GHG/day, divided by average daily number of students served, times self-reported number of meals per year
			Dining in restaurant	Total average restaurant GHG/day, divided by average daily number of students served, times self-reported number of meals per year
		Showering (*additive*)	Showering in dorm	Average GHG/shower (all-electric in-dorm water heater) based on reported operation time per shower, times self-reported showers per year
			Showering in communal facility	Average GHG/RMB, times student self-reported shower cost in RMB
		Dorm plug loads (*additive*)	Computer use (entertainment)	GHG/hour for a generic computer, times self-reported hours used for entertainment per year
			Hot drinking water	GHG/hour for a generic hot drinking water heater, times self-reported hours used per year
		Dorm electric miscellaneous, including lamps for study and studying if dorm is primary study location	Dorm GHG/year from utility bill, subtract computer use (both entertainment and study), hot drinking water, shower water heater in dorm	
Academics	Computer use (study)	Computer use in classroom, library, or personal office (study)	GHG/hour for a generic computer, times self-reported hours used for study per year	
	Printing	Printing	GHG/page for a generic printer, times self-reported pages printed per year	
	Scanning	Scanning	GHG/scan for a generic scanner times self-reported scans per year	
	Studying (*mutually exclusive*)	Classroom	Average classroom building GHG/hour as function of time divided by classroom design occupancy divided by reported fractional occupancy, integrated from reported study time start to end	
		Library	Average library building GHG/hour as function of time divided by library design occupancy divided by reported fractional occupancy, integrated from reported study time start to end	
		Personal office	Average office building GHG/room/hour as function of time divided by 4, integrated from reported study time start to end	
Transportation	Daily commuting	Commuting by shuttle bus, train, or car (modes are *mutually exclusive*)	Average GHG/km for mode, times self-reported distance traveled per year	
	Hometown traveling	Travel by driving, train, bus or airplane (modes are *mutually exclusive*)	Average GHG/km for mode, times self-reported distance traveled per year	
	Vacation traveling (*additive*)	Travel by car	Average GHG/km for driving, times self-reported distance traveled per year	
		Travel by airplane	Average GHG/km for flying, times self-reported distance traveled per year	

to account for the fuels that are used for local energy production in Shanghai. These resource factors, along with the more specific unit emission factors used in this study, are listed in Table 2.

The conversion factors' calculation methods were introduced in Table 1, but some bear additional explanation. For showering in the dorm room (SHD), the factor was calculated as:

$$F_{SHD} = P_{SHD}(N) \cdot F_e \tag{2}$$

where P_{SHD} is the average power of the dorm shower water heater, N is the number of showers per day, and F_e is the factor for electricity per kWh from Table 3. The average power P_{SHD} is a function

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Table 2
GHG emission factors for consumption of resources and specific end-use components.

i	Resource or activity	F_i (kgCO_2e per unit)	Unit	Reference
–	Coal	0.34	kWh	(IPCC, 2006)
–	Electricity (subscript: e)	0.79	kWh	
–	Gasoline	3.19	kg	
–	Natural gas (subscript: ng)	4.05	m^3	
–	Potable water	0.19	m^3	
–	Food production	0.47	kg	
1	Dining in dining hall	0.73	meal	(Tan et al., 2012)
2	Dining in restaurant	1.21	meal	
3	Showering in dorm	Eq. 2	shower	
4a	Showering in communal facility in summer	0.32	RMB	
4b	Showering in communal facility in winter	1.63	RMB	
5	Computer use (entertainment)	0.079	hour	Calculation from Table 1
6	Hot drinking water	0.41	hour	
7	Dorm electric miscellaneous	0.79	kWh	
8	Computer use (study)	0.079	hour	
9	Printing	0.0043	page	
10	Scanning	0.0013	page	
11	Studying: classroom	Eq. 5	hour	Calculation
12	Studying: library	Eq. 6	hour	
13	Studying: personal office	Eq. 7	hour	
14a	Traveling by shuttle bus	0.029	km	(Info-Net, 2013)
14b	Traveling by train	0.068	km	
14c	Traveling by personal car	0.27	km	
14d	Traveling by bicycle	0	km	

of number of showers each day because there are two operation modes: heating and standby. The electric power of these two modes is different, and the operation time of each mode is determined by the shower water usage. Per the manufacturer of the typical water heater on which we based our calculations, it takes two hours to heat a full tank of hot water, which is enough for two showers. Therefore we assumed a requirement of one hour of heating mode operation per shower taken, so that the average daily power was:

$$P_{SHD}(N) = \frac{P_w N + P_s(24 - N)}{24} \tag{3}$$

where P_w is the heater power in heating mode, P_s is the heater power in standby mode, and N is the number of showers per day. The total CO_2e emission per student from showering would be the number of showers per year multiplied by the showering factor F_{SHD}.

3.3. Data collection: survey instrument

The survey was designed to gather data about key energy behaviors, both for facilitating carbon footprint calculations and for informing the selection of energy saving measures and campaigns. The questions were in five categories, with the most substantive three categories corresponding to the categories in Table 1:

1. *Background information:* Questions about the student's major, degree level, hometown, and living situation.
2. *Daily life:* Questions about dorm room utility costs, shower use, home appliance and non-academic electronics use, dining, and thermal comfort in the dorm.
3. *Academics:* Questions about study hours and locations, as well as classroom thermal comfort.
4. *Transportation:* Questions about transportation modes, distances, and frequencies for daily commuting and longer trips.

Table 3
Top ten activities that contribute to the average student carbon footprint.

Activity	tCO_2e/person	% of total
Dining	1.24	33.80%
Showering	0.65	17.66%
Dorm plug loads	0.50	13.65%
Hometown traveling	0.36	9.80%
Computer use (studying)	0.24	6.60%
Daily commuting	0.24	6.60%
Printing and scanning	0.17	4.65%
Vacation traveling	0.14	3.80%
Studying, library	0.06	1.65%
Studying, classroom	0.04	1.05%

5. *Green campus*: Questions about how students regard various energy conservation recommendations or programs.

The questions were designed to provide sufficient information to make reasonably detailed carbon footprint estimates, without being excessively demanding on the respondents' time. A translation of the full questionnaire is reproduced in Appendix A.

Most activities were assessed independently and therefore are additive. For example, a student's reported dining in a dining hall and in restaurants are both included. However, to keep the survey length reasonable and the calculations manageable, some activities were mutually exclusive. Students could only choose their primary location of study, primary transportation mode for daily commuting, and primary transportation mode for visiting a family home.

3.4. Data collection: survey sampling and scoring

For maximum convenience, cost-effectiveness, and response rate, a self-administered online survey format was used. The online survey was designed to be quick and easy, taking respondents between five and ten minutes to complete. The survey website (Fig. 3) was created and released for Tongji students in July 2009 in order to test the website and gauge the efficacy of the survey protocol. After about 50 responses, the instrument and website were modified slightly and then released. Most of the responses were received in September 2009 and January 2010 in response to promotion campaigns intended to gather data in both summer and winter months. In order to get as many respondents as possible we sent the survey link to every student's email. Around 21,000 survey emails were sent in this study. The respond ratio is around 5%. There were 472 responses in September and 557 responses in January, and a total of 1029 responses. Of these, there were 923 useful responses which contain all information. Of these, 637 were

Fig. 3. The front page of the website for the carbon footprint survey and on-line calculator.

males and 286 females; 507 were undergraduate, 337 were master, and 79 were PhD students; 133 were from rural, 277 were from small town, and 513 were from metropolis. The respondents' distributions for the degree level and hometown are very close to the overall distribution of Tongji University. However, the male to female ratio for the respondents is large than the overall ratio.

After a student entered his/her responses, they were used to calculate his/her footprint in real-time. The results were both provided to the participant and stored for statistical analysis. One especially nice benefit of the online format was that the survey could double as an awareness-raising tool, serving as a calculator that allowed students to see the impact of their behaviors on GHG emissions. The model behind these calculations is the subject of the next four sections.

3.5. Carbon footprint model: student activities

In general, the activity intensity or number of activity units per year U_i "used" (eaten, taken, traveled) by a respondent was taken directly from his or her survey responses. In most cases, the only calculation required was to annualize the number, e.g. converting hours per day to hours per year or copies per month to copies per year. All of these scaling calculations were based on a nine-month school year. In addition, because the survey was designed to be simple, at least some of the unit uses were always zero: studying in locations other than the primary location, commuting by other than the primary mode, and hometown travel by other than the primary mode.

One activity did require a slightly more complicated procedure to determine how many units the student used. This was the number of kWh attributed to dorm plug loads (DP), which is the sum of non-showering electricity in the dorm. To avoid double-counting, it was calculated as:

$$U_{DP} = U_5 + U_6 + U_7 = \left(\frac{B_{DE}}{c_e} + S\right) \cdot N_{month} - E_{accounted} \tag{4}$$

where B_{DE} was the respondent's dorm electricity bill in RMB, c_e was the electricity price at the time of the study (0.61 RMB/kWh), N_{month} was the average number of months students live in the university dorm (nine months), and S was a subsidy from the university to each dorm room (5 kWh per month). $E_{accounted}$ was the electricity already accounted for by questions about computer use for studying and shower hot water heating. Further disaggregation of dorm plug loads into computer use for entertainment, drinking hot water heating, and dorm electric miscellaneous activities was based on a student's survey responses about computer use and drinking water heating. It is worth noting that if a student selected the dorm as his primary study location, there was no independent way to account for the studying-related electricity use, so that studying was by default lumped into the dorm electricity miscellaneous component.

3.6. Carbon footprint model: studying

The only activities that did not fit in the framework described so far and whose calculations did not follow Eq. (1) were those associated with studying ($i = 11$, 12, and 13). Here "studying" refers to the fraction of GHG emitted by a classroom building, library, or office building that can be attributed to a student because he or she was studying there. This activity was calculated differently because, unlike the other activities, it has an important time-resolved nature that there was enough information to assess.

At any given time, the fraction of the building's GHG emission rate due to an individual student is the building's total GHG emission rate divided by the number of students. From the University's energy monitoring systems, electricity and natural gas consumption histories were available for all academic buildings. For each type of academic building, average whole-building time-resolved GHG emission rates R (kgCO$_2$/h) were calculated in advance. For example, R_{CL} was the average GHG emission trajectory for classroom buildings. It was calculated at each time t by summing two terms: the product of the total electric power (kW) for classroom buildings at time t and the electricity emission factor F_e (kgCO$_2$/kWh), and the product of the total natural gas use rate (m^3/h) for classroom buildings at time t and the natural gas factor F_{ng} (kgCO$_2$/m^3).

For classrooms and libraries, the number of students was estimated as the product of design occupancy and fractional occupancy. The design occupancies N_{CL} and N_{LB} were assessed in advance by visual inspections, occupant counting, and examining design documents. Unlike R, N_{CL}, and N_{LB}, which were calculated before the survey was administered and were the same for all students, the fractional occupancy r was each respondent's own assessment of the average fractional occupancy while he or she studied.

The total emission of the student was his time-varying emission integrated over the time period the student reported being present, and multiplied by the number of days the student is present per year. For classrooms and libraries, the equations were:

$$GHG_{11} = \left\{ \begin{array}{ll} N_{month} \cdot 30 \cdot \int_{t_s}^{t_e} \frac{R_{CL}(t)}{N_{CL} r} dt, & \text{if classroom is primary study location} \\ 0, & \text{else} \end{array} \right\} \tag{5}$$

$$GHG_{12} = \left\{ \begin{array}{ll} N_{month} \cdot 30 \cdot \int_{t_s}^{t_e} \frac{R_{LB}(t)}{N_{LB} r} dt, & \text{if library is primary study location} \\ 0, & \text{else} \end{array} \right\} \tag{6}$$

where N_{month} is the number of months in the school year (again, nine months), 30 is the number of days per month, t_s and t_e are the respondent's self-reported study starting and ending times, and r is the respondent's assessment of the fractional occupancy during the studying period.

The calculation for personal offices, which are used primary by graduate students, was very slightly different:

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where R_{PO} was not the emission rate for the whole building but that for a single office, and N_{PO} was always taken as 4, a typical number of office occupants in graduate student offices.

$$GHG_{13} = \begin{cases} N_{month} \cdot 30 \cdot \int_{t_s}^{t_e} \frac{R_{PO}(t)}{N_{PO}} dt, & \text{if personal office is primary study location} \\ 0, & \text{else} \end{cases} \tag{7}$$

4. Results and discussion

4.1. Students' carbon footprint overview

The average annual personal carbon footprint was 3.84 tons CO_2e (tCO_2e), with a standard deviation (SD) of 1.01 tCO_2e. This is lower than findings for all Chinese university students, which have been estimated at 4.1 tCO_2e (Tan et al., 2012), and this is because a series measures have been applied in Tongji University campuses to improve the energy and resources efficiency. This is also lower that an estimate for the Norwegian University of Technology and Science, which was 4.6 tCO_2e (Larsen et al., 2013). By far the largest contributor was the daily life category, which represented 65% of the total. Transportation and academics each accounted for significantly fewer emissions, at 20% and 15% of the total, respectively. Fig. 4 shows the percentage breakdowns for the total footprint and each of the three overarching categories. As Fig. 4 indicates, the largest contributor to daily life was dining, followed by showering and then dorm plug loads. In the transportation category, about half of the emissions were due to hometown traveling, a third to daily commuting, and the remaining fifth to vacation travel. In academics, computer use for studying was the largest contributor, followed by printing and scanning, and distantly followed by emissions related to students' proportional contribution to energy use in communal study spaces.

In terms of targeting specific activities in order to reduce their emissions impacts, it may be more useful to assess the contributions of individual activities to the total student footprint. The top 10 carbon footprint contributors are summarized in Table 3. Dining was the single largest contributor to students' carbon footprints, by a factor of nearly two. It accounted for 1.24 tCO_2e/person every year, or more than a third of the total. Showering was the second largest contributor, producing 0.65 tCO2e/person every year. Dorm plug loads were third, accounting for 0.50 tCO2e/person per year, or nearly 13.7% of the footprint. The top transportation and academic sources are all below these three influential daily life sources.

The portion accounted for by transportation (20%) is much less than that of Universidad Nacional Autónoma de México (Güereca et al., 2013), where it is around 50%. However, it is the same as the share reported for De Montfort University in the UK (Ozawa-Meida et al., 2013), and close to the 16% share reported at the Norwegian University of Technology and Science (Larsen et al., 2013). In our study, around 50% of the total travelling emission is from student's hometown travel, and 32% is from daily commuting. This situation is quite different to the case in Universidad Nacional Autónoma de México, where GHG emissions from commuting corresponds to 90% of transportation, and the case in De Montfort University, which is also around 90%. This large discrepancy is from the differences in student living habits at the different universities. Most of students in Tongji University live on campus, commuting on foot, while the students from the other two universities live off campus, commuting by car or bus.

4.2. Students' carbon footprints: demographics

This section presents demographic patterns in the student footprints. We examined the differences in the footprint in the three main categories based on gender, on degree level, and on student hometown size (rural, small town, or metropolis). Table 4 summarizes the carbon footprint demographics of different student groups. Male students have a higher carbon footprint from

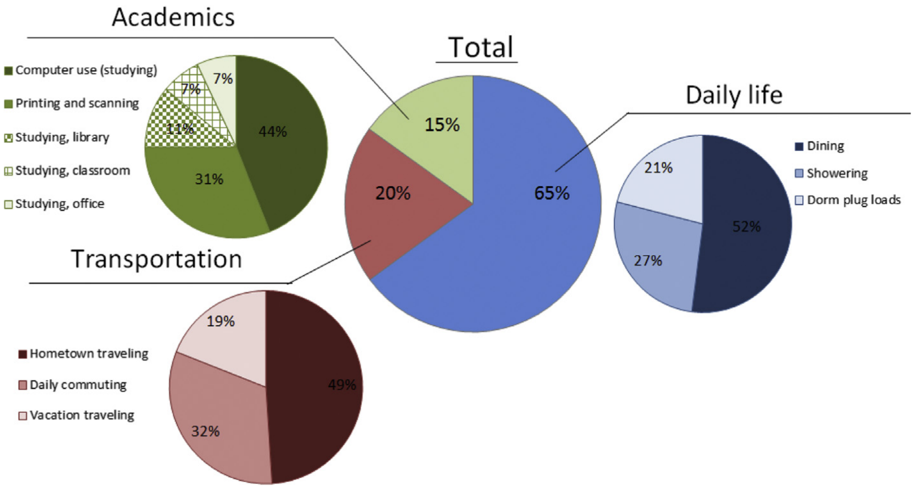

Fig. 4. Student carbon footprint from different activity categories, including the overall carbon footprint, and the portions attributable to daily life, transportation, and academics (pie labels going clockwise).

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Table 4
Daily life, academics, transportation, and total carbon footprints broken down by gender, degree level, and hometown size.

	Mean (SD) student footprint, tCO2e/person			Total	Percent of total carbon footprint		
	Daily life	Academics	Transportation		Daily life	Academics	Transportation
Male	2.61 (0.91)	0.64 (0.26)	0.83 (0.26)	4.08 (0.56)	63.9%	15.6%	20.4%
Female	2.24 (1.11)	0.43 (0.14)	0.62 (0.43)	3.29 (0.69)	67.9%	13.9%	18.9%
Undergraduate	2.40 (1.04)	0.54 (0.29)	0.61 (0.23)	3.55 (0.64)	67.7%	15.1%	17.2%
Master	2.58 (1.21)	0.61 (0.35)	1.01 (0.57)	4.20 (0.80)	61.4%	14.5%	24.0%
PhD	2.80 (0.83)	0.70 (0.47)	0.74 (0.35)	4.24 (0.59)	66.0%	16.5%	17.5%
Rural	2.30 (0.75)	0.32 (0.27)	0.63 (0.13)	3.13 (0.47)	70.7%	9.8%	19.4%
Small town	2.09 (0.98)	0.63 (0.44)	0.86 (0.44)	3.31 (0.67)	58.4%	17.6%	24.0%
Metropolis	2.47 (0.94)	0.45 (0.33)	1.33 (0.35)	3.84 (0.61)	59.5%	10.8%	29.6%

daily life and academics. The behavior survey data reveal that the primary reasons for these differences are that male students eat in off-campus restaurants more often, while female students most frequently eat at the school dining halls (Table 5). Because the school dining halls are large centralized facilities, they are more energy efficient. Table 5 also indicates another reason that male student have larger footprints. Male students more often reported studying in their dorm rooms, leading to more per-capita energy use. Female students, on the other hand, strongly preferred to study in the library, where lighting and space conditioning needs are shared among many more occupants. Male students did have significantly higher footprints from transportation, because their vacation travel distances were much longer than those of female students.

Students in different degree programs also had different carbon footprints. In general, as the degree level increased, so did the footprint; PhD students had the largest carbon footprint, followed by master-level students, and then undergraduate students. The daily life footprint of PhD students was highest primarily because they typically live alone. Undergraduate students, on the other hand, usually live in dorm units with four residents, and master-level students often live in groups of three or two. A similar reason explains why PhD students have a higher footprint in the academics category. They usually reported studying in a personal office, shared by three or four students. Master students' offices are public, shared by ten to twenty occupants, reducing per capita emissions. Undergraduate students can either study in their dorm rooms or in the library. About half reported that their primary study location was the library, where per-capita energy use is much lower. In the transportation category, master-level students had the highest transportation CO_2 emission, which, interestingly, was due to the fact that their annual vacation traveling distance was much longer than that of undergraduate and PhD students.

The survey results and calculations also revealed that students hailing from metropolises had higher GHG emissions than those from small towns or rural areas. The central reason for this trend was that most of the students from metropolitan areas were actually from Shanghai and its suburbs. This meant that their family homes were within easy travel distance, and they reported frequent travel to visit their families. In addition, many students who hail from the Shanghai area continue to live with their parents, which increases the carbon burden of their daily commute. Students from rural or small towns were, by definition, from farther away than metropolitan Shanghai. They reported fewer trips home, and were more likely to stay on campus during the weekends. They were also more likely to live in dorms and have very low daily commuting footprints. In short, the students from farther away were more likely to live in a manner typically thought of as urban, with short commutes and denser cohabitation, while the students originally from Shanghai, on average, had something closer to a suburban activity pattern.

The carbon footprint calculations, breakdowns by end use, and demographic splits all help to identify the most promising emission reduction opportunities. In this section, we discuss opportunities that can be realized through student behavior changes and conservation, perhaps augmented by awareness campaigns. In the following section, we use the results to discuss actions the university can take, including technological opportunities for improvements as the campus continues to develop.

4.3. Carbon reduction opportunities: student behavior

The analysis of these breakdowns shows that the dining in the daily life category was the single largest GHG contributor, accounting for just over a third of the total. Based on our survey of local restaurants and analysis of dining hall energy consumption, off-campus restaurants account for about 80% more GHG emissions per meal than the dining halls (see Table 2). Choice of eating places, therefore, has a strong impact on the overall CO_2 emissions. At the limit, the difference between eating all meals during the school year at the dining hall versus at an off-campus restaurant is about 0.4 tCO_2e, or about 10% of the average student footprint. Students who want to reduce their footprints should more frequently dine on campus, where the centralized facilities allow greater energy efficiency.

Student showering was the second largest contributor to the average student carbon footprint, at 0.65 tCO2e, or 17.3% of the total. Many students have the options to shower in either a private shower in the dorm room or in a communal shower facility. The communal facilities use centralized heat pumps, furnaces, and solar thermal equipment, and are much more efficient, per shower, than the small electric shower water heaters in dorm rooms. On average, assuming one shower per day, a dorm shower contributes about three times more GHG emissions than a communal shower. Therefore, awareness or incentive campaigns to encourage

Table 5
Student study and dining choice preference by gender.

	Dining		Study	
	Eat at dining hall	Eat off-campus	Study in dorm	Study in library
Male	45%	55%	60%	40%
Female	67%	33%	20%	80%

Table 6
Emissions from shower water heater operation scenarios.

Water heater operation	tCO_2e/person
On all the time	0.78
Turn on 1 h before use	0.46
Current average	*0.65*

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students to use the communal showers would help reduce the footprint of showering.

Of course, as student expectations evolve, many will want to be able to take private showers. In the following section, we analyze upgrade scenarios to allow students to shower in their rooms with fewer GHG impacts. But even with the existing electrical hot water heaters in the dorms, there are opportunities for behavior-based carbon footprint reduction by conservation. This is because the electrical hot waters in the dorms have relatively poor insulation, and so if left on all day will consume significant electricity simply to keep their tank of water hot. Students could reduce their GHG emissions by simply turning off their shower hot water heaters when not in use. Table 6 compares the carbon footprint of the shower water heater under two different operation schemes (and the current average). Compared to continuous operation ("On all the time"), intermittent operation ("Turn on 1 h before use") reduces CO_2e emissions by about 53%. Compared to the current average, it still reduces it by a meaningful 0.19 tCO_2e/person, which represents about 5% of the total average footprint.

The third largest contributor to the footprint was dorm plug loads, with 0.50 tCO_2e per student, or about 13.7% of the total on average. Based on the survey questions and the carbon model, the dorm plug loads captured nearly all electricity use in the dorm, but excluded self-reported computer use attributed to studying and hot water heating for showering. There is substantial room for reducing these plug loads. Students' computer and lighting using habits reported on the survey are summarized in Table 7. Approximately half of students reported not turning their computers and lights off when leaving their rooms, and only a fifth said they did so regularly. Interestingly, when even a short specific time was attached to the question, students were more likely to say that they did turn off their electronics, with a third responding they did so regularly. Just over half of students said they did turn off their electronics when leaving for periods longer than an hour. The university could help reduce student footprints with little or no meaningful tradeoff simply by encouraging them to turn off electronics when they are not at home. Converting the "no" responses to "sometimes" and the "sometimes" responses to "yes" would have a significant cumulative impact, although it is hard to project quantitatively. Furthermore, such conservation measures would be in line with students' self-conceptions, since 87% of them already report that they do engage in (unspecified) energy saving behavior.

The opportunities for footprint reductions in the academics category appear to be more limited. The largest contributor was computer use for studying, which would be hard (and possibly undesirable) to reduce. The university could use its procurement weight to help ensure that the computers it recommends that students buy are efficient models, with effective sleep and standby modes. Reducing printing and scanning could also be the target of an awareness campaign, but given that they accounted for about 5% of the carbon footprint, reducing their frequency is not likely to have a large impact. As we noted above in the demographic analysis, the choice of study place can play a significant role in reducing student carbon footprints. This is because common spaces have more efficient lighting and mechanical systems and, moreover, much greater occupant densities. The effect is additive, in that the more students studying in the library, the more efficient the library is on a per capita basis. For example, the survey and model show that studying in a classroom or library that is 20% full will produce per capita CO_2 emissions 75% greater than studying in one that is 80% full, leading to an additional 0.05 tCO_2e emissions. Although this change represents a relatively small portion of the entire footprint, it nonetheless represents another behavior change that students can undertake and the university can encourage.

Table 7
Student computer and lighting using habits.

	Answers	Percentage
Do you engage in energy saving behavior?	Yes	87%
	No	5%
	No idea	8%
Do you turn off computers, lights and other electrical equipment when you are away from your room?	Yes	22%
	No	43%
	Sometimes	35%
Do you turn off computers, lights and other electrical equipment when you are away less than 10 min?	Yes	37%
	No	38%
	Sometimes	25%
Do you turn off computers, lights and other electrical equipment when you are away more than 1 h?	Yes	53%
	No	17%
	Sometimes	30%

Transportation did account for a reasonable portion of the average footprint, with the largest two activities being visits to student's hometown (9.8% of the total) and daily commuting (6.6%). In both cases, students can reduce their impact by selecting lower-intensity modes of transit. On campus, bicycling, public transit, and shuttle buses are good options. For hometown visits, trains and buses would reduce GHG emissions vis-à-vis traveling alone in a car. All of the carbon footprint reduction opportunities discussed can be achieved by small to moderate refinement of student behavior. Such behavioral adjustments appear like they should be feasible among Chinese students. In a survey of students at another Chinese university reported by Jiang et al., 98% agreed that climate change was "mainly caused by human activities" and 98% also responded that they wanted to "take actions to reduce energy use and carbon emissions". (Only 60% thought new technologies could "tackle climate change.") This is consistent with our own finding, in which 87% of students already reported seeing themselves as engaging in energy saving behavior (see Table 7). Therefore, without too much investment in upgrading the energy equipment and system, the behavior change could achieve more than 0.2 tCO_2e emissions (from shower water heater using habit, study place choosing changing).

4.4. Campus sustainable development

4.4.1. Campus improvements

The survey results and carbon footprint model can be used to identify energy-saving student behaviors and quantify the associated emission reductions, given current living standards and campus infrastructure. As China continues to develop, though, living standards will rise. Tongji's infrastructure and equipment will need to be improved to meet these needs, and student consumption patterns will also change. The carbon footprint model can also be used in this context, to inform campus development and help decide among improvement options for meeting increased demand for privacy, convenience, and comfort. To this end, we considered three living standard improvements (Table 8) that,

Table 8
Tongji University student living standard improvement scenarios.

	Improvement	Implementation scenario
1a	Dorm in-room showering	Electric water heaters in each room
1b		Central solar thermal heater with electric backup
1c		Use campus district hot water
2a	Dorm thermal comfort	Unitary air conditioners (AC)
2b		Central air conditioning system (AC)
3a	Classroom thermal comfort	Unitary air conditioners (AC)
3b		Central air conditioning system (AC)

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though far from exhaustive, we felt our data and model could help elucidate: private showers in all dorm rooms; air-conditioning (AC) for cooling in all dorm rooms; and AC in all classrooms. Table 8 provides a summary.

For showering in the dorms, we considered three water heating options: installing electric hot water heaters in all rooms that do not currently have them, installing a central solar thermal water heater with electric backup in each building, or making use of the campus' existing district hot water. The campus district supply is primarily heated by natural gas boilers, augmented by some solar thermal heating. The GHG impact from the three options were calculated according to Equation (2), with different values of F_{SHD} according to the efficiency of the equipment, and with the assumption that all students shower in the dorm one time per day.

To provide cooling in the dorms and classrooms, two scenarios were considered: installing individual unitary AC units in each dorm, or installing a central cooling system for each building. We used a simplified model to calculate the carbon footprint impacts of each. For the individual unitary AC units, the emissions were calculated as

$$GHG_{AC} = DTPF_e \tag{8}$$

where D is the days of AC operation, T is the time of AC operation each day, P is the average unit power (from the manufacturer specifications for a typical model), and F_e is the emission factor for electricity. For the central AC systems' GHG emissions, we relied on the energy consumption estimates made for the university in (Xu, 2010), which were based on comparisons to similar buildings in Shanghai.

4.4.2. *Carbon reduction prediction and suggestion*

In addition to awareness campaigns to try to influence student behavior, the university itself can undertake actions to help reduce the average student carbon footprint. First and foremost, the university should encourage dining on campus. Incentives could include better food, more variety, lower prices, better locations, more generous hours, etc. Dining not only represents a third of the total active stage carbon footprint, but also without doubt has significant procurement (embodied energy) impacts, which can add up to another 50% on top of the active stage footprint (Ozawa-Meida et al., 2013). The centralized nature of the university's dining facilities should allow the university to move toward actively managing its supply chain in order to reduce the carbon impacts of food production and transportation—steps that the smaller restaurants off campus are unlikely to be able to take as effectively.

In the transportation category, daily commuting is intimately related to campus planning. Indeed, compared to some universities in developed countries, Tongji students' GHG emissions from commuting are quite low precisely because the campus is centralized and most undergraduate students live in school dorms near campus. As the university grows, it can continue to keep the carbon load related to commuting low by developing walkable campus communities, locating facilities near public transit stations, and providing appropriate shuttle bus service. Furthermore, the university should consider integrating other typical amenities, like shopping, exercise facilities, and entertainment, into the campus so that students do not have to travel to them.

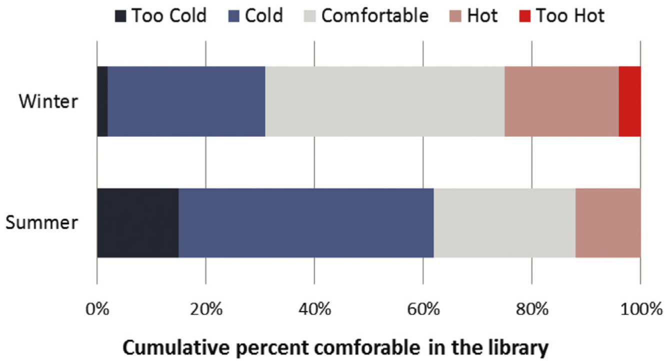

Fig. 5. Student thermal comfort in the library.

The survey responses also revealed opportunities for better mechanical control of common spaces like classrooms and libraries, to both reduce GHG impacts and improve thermal comfort. Fig. 5, for example, shows the students' reported thermal satisfaction in the library. More than 60% of the respondents said they were cold or too cold in the library in summer, and more than 20% felt hot or too hot in the winter. These too-cold-in-summer and too-hot-in-winter conditions are energy wasteful, in addition to being uncomfortable, and are easily corrected by adjusting temperature setpoints and increasing the attentiveness of facility management.

As living standards of Chinese people and students continue to improve, students will demand more private showering, better thermal comfort, and other potentially resource intensive improvements. Campuses must also be assessed in the context of future GHG emissions in order to meet these increased demands sustainably. To this end we combined the survey results and carbon model with simple engineering calculations to evaluate a number of equipment upgrades that Tongji University could implement. The scenarios themselves are described in Section 3.8; the results are in Table 9.

For showering, installing central solar thermal systems with electric backup in each building is the best option in terms of producing the smallest CO_2 emission. In fact, it could provide the living standard improvement at the same time as a slight decrease in the average student carbon footprint. For classroom and dorm thermal comfort improvement, central air conditioning systems provide the least carbon-intensive options. In these cases, the addition of air-conditioning does come at a carbon cost (since the current situation has zero emissions), but the central air systems help keep that cost lower.

Table 10 shows the student carbon footprint prediction under a “sustainable improvement” based the total impact of the best option for implementing each improvement (i.e., 1b, 2b, and 3b). Table 10 also shows the impact of “unsustainable improvement,” or the minimal planning options (i.e., 1a, 2a, and 3a). Under unsustainable improvements, the total footprint would increase nearly 80%, but with the sustainable improvements the increase would be

Table 9
Student living standard improvement options and their carbon impacts.

	Use	Option	tCO_2e/person
Showering	Current: in-dorm/ communal	–	0.65
	Improvement: add in-dorm showing	1a: Electric water heaters in each room	1.89
		1b: Central solar thermal heater with electric backup	0.56
		1c: Use campus district hot water	1.24
Dorm comfort	Current: no AC in dorm	–	0
	Improvement: add AC in dorm	2a: Unitary AC	1.16
		2b: Central AC system	0.86
Classroom comfort	Current: no AC in classroom	–	0
	Improvement: add AC in classroom	3a: Unitary AC	0.66
		3b: Central AC system	0.46

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Table 10
Student carbon footprint improvement prediction (tCO_2e/person).

Category	Current	Sustainable improvement	Unsustainable improvement
Daily life	2.50	3.27	4.90
Academics	0.58	1.04	1.24
Transportation	0.77	–	–
Total	3.84	5.08	6.91

a more modest 32% to 5.08 tons CO_2e/person—still relatively modest by the standards of much of the developed world.

5. Conclusions

This study demonstrated the use of a structured online survey, combined with utility information, to examine the energy behavior and carbon footprint of college students—an area that has not been well covered in existing studies. The student carbon footprint estimates can serve two roles, both increasing student consciousness of the GHG emissions due to their activities and providing a comprehensive basis for campus-wide university sustainable development and decision-making. This structured online survey format can enable other schools or companies to study their own carbon footprints for energy saving and development, even if the categories of behavior activities may be different.

We applied the survey and calculation approach at Tongji University and received more than a thousand responses. The average student carbon footprint—including direct and indirect energy and transportation, but not upstream or downstream impacts of consumption—was relatively low at 3.84 tCO_2e/person. The major contributor was the daily life category, accounting for 65% of the total and including the top three activities: dining, showering and dorm plug loads. Transportation, including commuting and longer trips, was the second largest category at 20%, and academics accounted for the remaining 15%. Overall, women, undergraduates, and rural students had lower footprints than men, graduate students, and students from Shanghai and its suburbs.

These breakdowns were used to identify carbon "hotspots," or activities to target with behavior changes and awareness campaigns. The largest of these was dining, and dining on campus was found to be significantly less carbon intensive than dining off campus. Other identified behavior changes to be targeted included turning off electrical equipment including water heaters when not in use, using communal showers, commuting by less-intensive transit modes, and studying in common areas. In general, we found that more communal behaviors—including in dining, showering, studying, and commuting—can help reduce the carbon footprint. The surveys also revealed that the university can reduce GHG impacts by improving control of thermal comfort in common spaces like libraries, where more than 60% of students were cold in the summer, and around 25% were hot in the winter.

The results also indicated that the current low student carbon footprint is not due to high equipment efficiency and good management, but to sacrificing some of the students' comfort and basic needs, such as indoor thermal comfort and reliable provision of hot water. As China continues to develop, meeting these needs with the least GHG emission possible will be a challenge. To this end, several student living standard improvement scenarios were analyzed to project their carbon footprints. Under the best-case sustainable development scenario, the average student carbon footprint increased, but only modestly to 5.08 tons CO_2/person. We believe the personal carbon footprint developed here will help foster the combination of behavior changes, conservation awareness, urban planning, informed engineering calculations, and organizational decision-making that is needed to address climate change.

This survey based student carbon footprint study makes clear the current situation of student personal behavior related GHG emissions, and provides sustainable university improvement scenarios and predictions. The online survey tool developed in this project can be used by other universities or organizations. Due to the scope of this study, the personal GHG emissions are just included the activities related emissions without considering the upstream (product process) and downstream (waste treatment) emissions. In the survey of this study, the respondents' male to female ratio is higher than the real ratio of the university. The personal carbon footprint doesn't include the upstream or the downstream emissions, just focuses on the student active emissions. Future work will follow these two directions to encourage more female student respond the survey and include embody emission into the calculation.

Acknowledgments

The authors would like to thank Tongji University Research Center of Green Building and New Energy for their support in data collection.

Appendix A

Table 1
Student energy behavior semi-structure survey questions

Question and answer	Category
Gender: ____ A. male, B. female	General information
Grade: ___ A. undergraduate, B. master, C. PhD	
School: ___	
Department: ___ A. Engineering, B. Science, C. Art, D. others	
Hometown: ___	
Dorm: ___	
Number of roommates: ___	
Electricity fee per month: ___	
How many months do you usually stay in a university dorm: ___	Daily life
Shower water heater in dorm: ___ A. Yes, B. No	
Showers per week in summer: ___ (0–14)	
Showers per week in winter: ___ (0–14)	
Shower heater operation: ___A. Keep on all the time, B. Turn on 3 h before a shower, C. Turning on 2 h before a shower, D. Turning on 1 h before a shower	
Showers per week in school shower room: ___ (0–14)	
Shower fee in school shower room per time: ___	
Hot water heater in dorm: ___ A. Yes, B. No	

(*continued on next page*)

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Table 1 (*continued*)

Question and answer	Category
Hot water heater operation time: ___ (0–24 h)	
Drinking water usage per week: ___ (0–20 gallon)	
How long do you use AC in your dorm every day:___	
How long do you use your personal computer for entertainment every day: ___	
What is your meal expense at school dining hall: ___ (0–800 RMB)	
What is your meal expense at other restaurants: (0–800 RMB)	
How do you feel in your dorm in the summer: ___ A. Very hot, B. Hot, C. Comfortable, D Cold	
How do you feel in your dorm in the winter: ___ A. Very cold, B. Cold, C. Comfortable, D. Hot	
How many times do you use a clothes washer per week: ___ (0–7)	
How many classes do you have each week: ___	Academics
Where do you usually study on campus: ___ A. Library, B. Classroom, C. Dorm, D. Personal office	
When do you usually study every day: from ___ to ____	
How full is the room when you study: ___ A. 100%, B. 80%, C. 60%, D. 40%, E. 20%, F. below 20%	
How do you feel in a typical classroom in the summer: ___ A. Too hot, B. Hot, C. Comfortable, D Cold, E Too cold	
How do you feel in the library in the summer: ___ A. Too hot, B. Hot, C. Comfortable, D. Cold, E Too cold	
How do you feel in a typical classroom in the winter: ___ A. Too cold, B. Cold, C. Comfortable, D. Hot, E Too hot	
How do you feel in the library in the winter: ___ A. Too cold, B. Cold, C. Comfortable, D. Hot, E Too hot	
How many pages of copy paper do you use every month: ___	
How do you print: ___ A single sided, B double sided	
How long do you use your personal computer for working each day: ___	
How long do you use your desk lamp each day: ___	
How long do you use your dorm lamp each day: ___	
How many times do you commute to school per week: __ (0–14)	Transportation
How long is your commute to your school: ___	
How do you commute to school: ___ A. Shuttle bus, B. Train, C. Personal car, D. Bicycle	
How many times do you travel to hometown per year:___	
How far away is your hometown: ___	
How do you travel to your hometown: ___ A. Bus, B. Train, C. Airplane	
How many times do your travel for vacation every year: ___	
How far do you typically travel for your vacation: ___	
How do you travel for your vacation: ___ A. Personal car, B. Train, C. Bus, D. Airplane	
How far do you drive every year for vacation: ___	
How far do you fly every year for vacation: ___	
Do you turn off your computer and light whenever you are away: ____ A. Yes, B. No, C. Sometimes	Green campus
Do you turn off your computer and light when you are away for more than 10 min: ___ A. Yes, B. No, C. Sometimes	
Do you turn off your computer and light when you are away for more than 1 h: ___ A. Yes, B. No, C. Sometimes	
Do you engage in energy saving behavior: ___ A. Yes, B. No, C. No idea	
Which reward do you like from Green-tip system: ___ A. Gym access hours, B. Movie ticket, C. Library book use, D. others	
Do you have any suggestions for school energy saving: _____	

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