Campus Ecological Footprint of Carnegie Mellon University

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Abstract

As Carnegie Mellon University is a rapidly growing and international educational institution with more number of campus members and visitors, the impacts of the school on ecological footprint are fast increasing. This condition brings the campus to have higher possibility to contribute to environmental impacts and also higher responsibility to decrease them as a green-design campus. However, there is no study about the environmental impact of Carnegie Mellon in terms of ecological footprint which would be a quantified index to show the environmental degree of a campus complex. Thus, to assess the campus footprint, this study mainly focuses on the estimation of Carnegie Mellon ecological footprint including campus building operation, public / private transportation, consumer goods and foods. The footprint calculation is based on the campus documents from facility management department and some experts associated with green campus movement. With the findings and calculation, this study proposed effective strategies that Carnegie Mellon could implement to contribute to the ecological footprint reduction.

1. Introduction

Carnegie Mellon University (CMU) is located in Pittsburgh, Pennsylvania of the U.S. It is a rapidly growing and increasingly international educational institution with a large student community of 10,000 undergraduate and graduate students. The total campus population is 14,487, including all faculty and staff. The campus occupies and contiguous area of 110 acres. The university consists of seven colleges and schools and is one of the most technologically advanced universities in the country. As the school increasingly has more numbers of educational events and programs with other institutes and other local people, the campus has higher possibility to contribute to environmental impacts including increasing ecological footprint. Simultaneously, the CMU campus also has a responsibility to minimize the environmental impacts as a green-design campus.

To achieve the environmental goal, ecological footprint analysis is essential to understand the impact of the campus on the natural resources of the country and the world and vital for making better decisions for the future. The quantitatively estimated footprint index would be used as a scale to measure the campus environmental impact and motivate the campus members to recognize each individual role to contribute to the environment in a positive way.

2. Methodology

To determine the ecological footprint of the university campus, the component-based method has been used. This method attempts to account for the different facets of a specific individual, institutional, or regional environmental impact. It incorporates basic lifecycle data for energy demand, material consumption (food, water, and manufactured goods), and the area of land that it occupies.

The embodied energy of buildings and other entities lasting more mare 10 years have not been accounted for. So, the current built constructions were not counted for the footprint estimation because the intent of this study has been to calculate the ‘running footprint’ or the ‘operational footprint’.

The land-use matrix by Mathis Wackernagel[1] has been used to further break down the components for the calculation of equivalent footprint hectares. For building operation, energy for electricity, heating, water, built-up are considered. The transportation includes personal vehicles, air, and public and campus bus for ecological footprint by energy and degrading land. For consumed goods on campus, office paper, computer, light bulbs and plastic bags used for trash collection are counted for the footprint by energy. Napkin and food components are also used for estimation.

For the energy component, this study uses primary energy to include the total energy and resources that is taken to provide / supply a certain service and commodity. To estimate the life cycle cost of the components for the footprint estimation, the life cycle model developed by the Green Design Institute[2] is used.

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[1] Mathis Wackernagel and William Rees. Our Ecological Footprint: Reducing Human Impact on Earth. New Society Publishers, British Columbia, Canada, 2006.
[2] Carnegie Mellon Green Design Team, http://www.eiolca.net/. Accessed in August,15 2007.

3. Ecological Footprint Calculation

Based on the existing information sources about the CMU campus, the author calculated the CMU ecological footprint as the below table shown.

Table 1. Detailed ecological footprint calculation[3]

Component	CMU Ecological Footprint (Ha/Capita), N=14,487				
	Energy	Degrade	Crop	Forest	Total
BUILDING					7.185
Electricity	5.617				
Heating	1.53				
Water	0.015				
Built-up	0.002				
TRANSPORTATION	2.0765	0.0105			2.0778
Car	0.517				
Bus	0.0299				
CMU Vehicle	0.1831				
Air	1.3373				
Degraded land		0.0105			
CONSUMER GOODS	0.013719			0.011	0.02424
Paper					
Computers	0.004674			0.011	
Light bulbs	0.008352				
Plastic bags	0.00069				
	0.000693				
FOOD					0.5994
Napkin	0.2592				
Food	0.0563		0.2839		
TOTAL					*9.89*

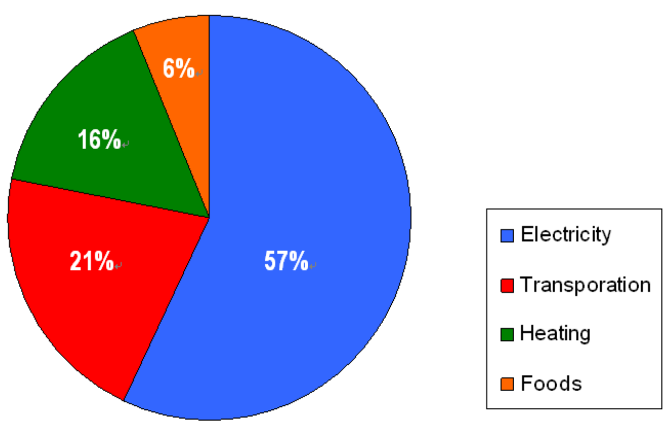

Fig. 1 Total major components of CMU ecological footprint

[3] For the detailed calculation, see the attached the excel spread sheet.

3.1. Building

The building component includes electricity and built up area. This accounts for the biggest portion of footprint CMU's ecological footprint. It accounts for 7.18 hectare/person/year, which corresponds to73% of the total ecological footprint per capita per year (Fig.1, Electricity + Heating). It represents the impact of energy for heating, cooling, lighting, plug-loads, and built-up-area.

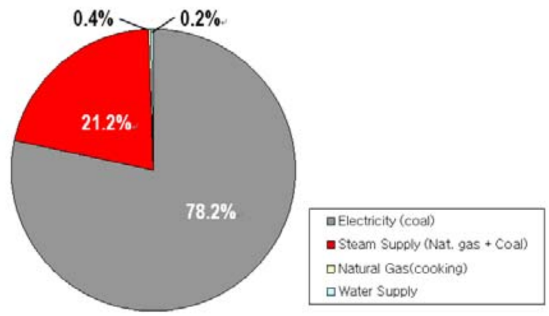

Fig. 2 Footprint distribution for energy consumption

The largest contributor to the building operational energy footprint is electricity production by coal, followed by steam supply from natural gas. Coal is inefficient for electricity generation and when process/supply losses are taken into account, it turns out to be an environmentally expensive fuel. Though natural gas is a relatively clean fuel in terms of carbon-dioxide produced in the combustion process, its production-supply is an energy intensive process.

3.2. Transportation

The transportation component accounts for approximately 2.1 hectare / capita / year. It corresponds to 21% of CMU's calculated ecological footprint (Fig. 1). The major contributor to ecological footprint of transportation is air travel. It is because of a lot of people at CMU are from other counties and other states.

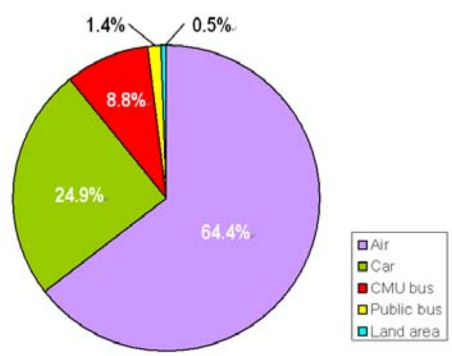

Fig. 3 Footprint distribution for transportation

The figure of cars' footprint is calculated based on the original faculty mailing address data and onsite-observation for types of cars. Bus and CMU vehicles' figures are also estimated by observation and surveys. Most faculty do not carpool rather they drive by themselves. That is the main reason why about 1700 faculty's footprint is larger by 250% than 12000 students', who mainly use CMU vehicles or public buses.

3.3. Consumer goods

The consumer good component of CMU's ecological footprint accounts for the smallest portion of footprint, 0.22% of the total ecological footprint per capita per year. The footprint supposed to be larger than what we calculated because there are additional variables to contribute to ecological footprints.

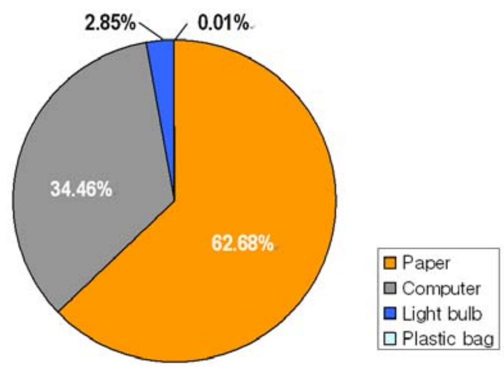

Fig. 4 Footprint distribution for consumer goods

However, because these variables are not available, the paper does not include other variables except computers, paper, light bulbs and plastic bags.

3.4. Food

The food component of an ecological footprint utilizes conversion factors supplied by Mathis Wackernagel, the founder of ecological footprint. They assume average global yields for various types of food, and make allowances for agricultural energy, transportation, and processing.

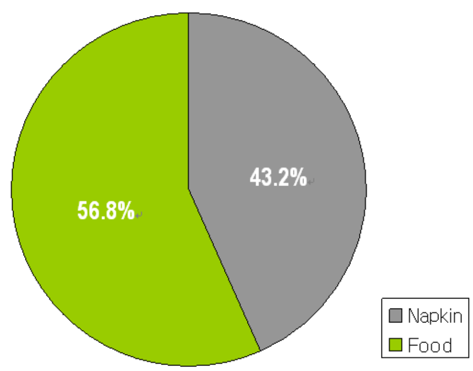

Fig. 5 Footprint distribution for food

A spreadsheet is provided for the calculation of the footprint due to food consumption. The CMU campus food footprint was calculated by plugging figures from the CMU Green practices community annual report. Certain data had to be assumed and calculated. The calculation assumed that the per capita campus footprint assumes the food intake of an adult by the U.S lifestyle. The total CMU food intake per capita per year was not broken down in individual categories (fruit, vegetable, grain, etc.) due to the limited data. Therefore a common (average) yield factor has been assumed for calculation.

4. Observations and Recommendations

4.1. Building Energy Consumption

4.1.1. Change Energy Source

The largest areas of the footprint comprise of electricity from coal and steam from natural gas. CMU has shown initiative to shift towards renewable energy sources and wind energy is 6% of the total electricity consumption. 29% of the electricity that we buy from Dusquene Lights[4] is nuclear energy.

However, there is a lot of scope for including other forms of renewable energy. Also the campus facilities do not use cogeneration systems and other efficiency energy cascade systems.

4.1.2. Increase Energy Savings

Only the CMU apartments and houses (87 kWh/m sq./yr) meet the US energy standard (165 kWh/m sq./yr) for public building. Rest are manifold higher consumers (e.g. Cyert Hall on campus - 1035 kWh/square meter/year)

Indoor air temperature settings:

Several buildings on campus have reported excessive temperatures in winter due to over heating while some complain to over-cooling in summer. At SUNY Buffalo, the heating policy is aimed at maximizing energy conservation both to save money and to decrease environmental impact. The policy requires keeping offices heated at 68 degrees F from 8:00 a.m. to 5:00 p.m., and dropping the temperature to 55 during off-hours, weekends and holidays.[5] Annual cost of overheating amount is about $100,000/degree on SUNY's two campuses (Comprising about 100 buildings as compared to 67 at CMU). The CMU

[4] Dusquene Lights Company, Pittsburgh in PA.
[5] The State University of New York at Buffalo, http://wings.buffalo.edu/ubgreen/content/programs/energyconservation/guide_energy.html. Accessed in July 27, 2008.

buildings named by students with excessive air-conditioning: Cyert Hall and University Center. Doherty Hall has problem of over-heating.

Lighting:

At study at University of Colorado, Boulder revealed that occupancy and motion sensors are more viable in classrooms and conference rooms. Daylight sensors in corridors can help achieve significant results. For example: Lighting of corridors and other public areas. Daylight sensors would deduct 0.053 hectares from the yearly footprint of all over the buildings.

Increase individual responsibility:

Central metering in dorms results in reckless user behavior. Through a study conducted at *Ball State University,* the students were given monthly feedback on their electricity and water consumption resulting in a 32% overall reduction in electricity use in the dorms 11 % fall in water consumption.

4.2. Transportation

4.2.1. Improve campus commuting

81.1% faculty and staff and 6.1% student drive to CMU. Most of them are single-occupancy driving. However, CMU does not have enough incentives to discourage car usage. On the other hand, CMU is using a high cost policy for parking lot.

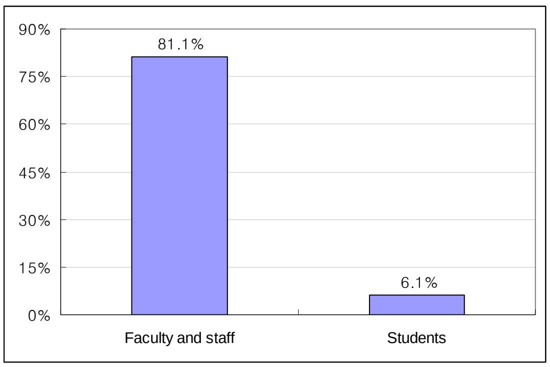

Fig. 6 Percentage of drivers to campus

A 50% decrease in car usage will reduce CMU footprint by 0.2585 ha/cap (that's over 12% reduction in the overall transportation footprint). There are only 32 carpool and rideshare reserved spaces. However, the number of spaces is not enough to meet the people's needs. USGBC recommends at least 5% of parking space should be provided to carpool users for its environmental building design guideline.[6] But, the current condition of CMU parking service covers at most 1% or less for the efficient vehicle users. Therefore, CMU should encourage more carpooling by giving reserved parking spaces or incentive on their parking passes.

Majority of CMU students are living off campus apartments or houses. The number of rides taken by CMU bus pass holders is 1,013,872 rides. This shows that there is a demand for public transportation. Currently, there is no housing provided for graduate students. As a result, an overwhelming 99.3% live off-campus and require transportation to campus. If CMU provides housing for graduate students, it is possible to reduce the overall percentage of student driving to campus from 6% to 3%. This reduction alone will reduce the overall transportation footprint by 0.1ha/cap (5% reduction).

On the other hand, most CMU faculty and staff are mainly using personal transportation rather than a public / CMU bus. According to a 2006 transportation study conducted by CMU Professor Cliff Davidson et al.[7], the primary reasons why CMU faculty and staff are not taking the bus to campus are because of inconveniency of bus stops and infrequency of buses. CMU can integrate their transit system to supplement the regional bus system (see Cornell University example below).

Using bicycle could be one of good strategies to reduce the ecological footprint. USGBC recommends installing at least 3% bicycle rack of the total number of the fulltime equivalent people in a building / campus. However, CMU campus has very limited incentives to encourage bicycle usage. CMU should include bicycle rack installation with bike paths as part of the campus master plan.

Air travel contribution to total footprint is over 64%. Due to the large number of national and international students, it will be difficult to reduce air travel necessary to bring them to campus. On the other hand, air travel taken by students, faculty and staff to attend

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[6] United State Green Building Council, Leadership in Energy and Environmental Design Reference Book, v. 2.2, 2008.
[7] Cliff Davison et al., 2006 Transportation survey, Survey summary included in appendix.

national and international conferences can be drastically reduced via the use of web-cast technology. According to Footprint Network[8], the amount of footprint (in ha/cap) increase due to air travel is as followed:

3 – 10 hrs of flying/yr = 1ha, 25 hrs = 3ha, 100 hrs = 13ha

This, the potential impact of reduced air travel frequency is very high and could significantly contribute to the footprint reduction. However, in order to accurately calculate the air travel footprint, a survey has to be conducted to find out the number of air miles traveled by student, staff and faculty in order to attend CMU, conferences and other academic related travels. But, this total mileage can not be used directly to calculate the footprint. In order to avoid double counting, the total air travel miles have to take into account the corresponding occupancy taken up by CMU related travels in each flight since not everyone on that flight is going to CMU. This consideration has to be taken for all national and international travels. On top of that, at least a survey has to be done on the gas mileage and CO2 intensity for different flight range.

Comparison to other campus:

- The total transportation footprint of Colorado College is 0.0312 ha/cap. This calculation did not include impact from personal vehicles nor air travel. For the University of Vermont study [9], their transportation footprint was calculated for car only and it is 14,284.31 acres or 5780.66 ha, which is 0.434 ha/cap with 13,317 people. In our CMU study, the car footprint is 0.517ha/cap. In both of these comparisons, the calculation methodologies are not provided to verify what was included. Hence, it is difficult to compare with other campus studies unless the studies do not use a same component and assumption for estimations.

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[8] Global Footprint Network, http://www.footprintnetwork.org. Accessed in July 27, 2008.
[9] National Wildlife Federation. Campus Ecology Yearbook. 2001-2002. University of Vermont (footprint) Assessment.

- The University of California adopted a comprehensive sustainable transportation policy in Sept. 2007[10] that includes a set of guidelines which will, among other things: establish benchmarks for reducing GHG emissions; evaluate monetary and environmental cost of petrol and make least cost proposals for campus fleets; set goals for increasing low and zero emission vehicles in the University fleets; and collect and interpret data to track their progress.
- Cornell University charges high parking fees to deter vehicles to campus.[11] The parking system provides financial incentives for carpooling. Cornell works with surrounding municipalities to integrate seamlessly with their transit systems. Faculty, staff and students who forego a parking pass can use unlimited, free public transportation in Tompkins County. As a result, Cornell saves 417,000 gallons of fuel and 10,000,000 vehicles miles each year. Over 12 years, Cornell's transportation programs have saved over $36 million in construction, infrastructure maintenance, and transportation cost.
- The University of Oregon in Eugene encourages bicycling by building an interlocking network of bike paths. The school complements this infrastructure by providing tandem bike taxi service and awarding credits to students and faculty who bicycle or walk to campus. These credits can be exchanged for product discounts.

[10] University of California, An alternative route: Sustainable Transportation, http://ww.universityofcalifornia.edu/news/sustainabletrans0907.pdf. Accessed in July 27, 2008.
[11] Cornell University, http://www.sustainablecampus.cornell.edu/transport.htm. Accessed in September 2007.

4.2.2. Switch to alternative fuels

Fuel type used by CMU vehicles are: Gasoline, diesel, CNG, electric. CMU should replace its fleet with electric hybrid vehicles or vehicles that uses alternate fuels. If CMU uses 20% biodiesel / 80% ultra low sulfur diesel mix, it will reduce 16% CO_2 and 13% hydrocarbon.

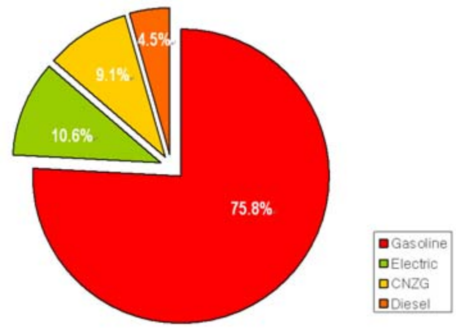

Fig. 7 Fuel type used by CMU - number of sampled vehicles

The current percentage of SUV used on campus is approximately 17%. CMU should encourage the use of high fuel efficient vehicles by offering reduced parking discount.

Comparison to other campus:

- The University of Michigan has implemented the following student led initiatives[12]: A vanpool program operates for commuters; free bus passes are available for faculty & staff; all busses and trucks run on B20 (20% biodiesel, 80% regular diesel); an electric vehicles pilot program (6 Ford Rangers) is in place; all new cars/mini-vans/light pick-ups to be purchased in the future will run on E85 (E85 is a fuel blend of 15% gasoline, 85% ethanol).
- Stanford University currently runs its shuttle 'Marguerite' on a blend of regular diesel and biodeisel, and plans are underway to convert the campus waste cooking oil into fuel.[13] The University receives funding from the local shopping center to enable it to provide a free shuttle service for students from campus to the shopping center and train station.
- **University of Miami** offers a 50% parking discount for hybrid vehicles. The savings can be as high as $352 per year. (New energy for campuses. Original source from: https://www.miami.edu/greenu/web-pages/sun-sentinel-1.htm)

[12] University of Michigan, www.umich.edu/~usustain/sustain.html. Accessed in September 2007.
[13] Stanford University, http://news-service.stanford.edu/news/2006/january25/biodiesel-012506.html. Accessed in September 2007.

- **Duke University** secured a $28,000 grant to fund a pilot program to investigate fueling campus buses with a 20% biodiesel blend.[14] Due to the success of this pilot program, Duke's entire bus fleet and several maintenance vehicles presently use biodiesel. (New energy for campuses)
- The **University of Wisconsin** uses a 20% biodiesel/80% ultra low sulfur diesel mix in its diesel fleet.[15] The blend is expected to reduce particulate emissions by 15%, CO2 emissions by 16%, and cut hydrocarbon use by 13%.

4.3. Footprint for Consumer Goods

4.3.1. Paper resource - observation

According to "Environmental indicators for Carnegie Mellon University (2004) report, Carnegie campus consumes 222,800 lbs of office paper in a year, which corresponds to 113.8 hectare. In addition, the campus consumes 54,000 lbs of paper tower, 61,750 toilet paper, and 84,657 lbs of newspaper annually.

The recycled ratios of each paper in manufacturing process are 30% for office paper, 40% for paper towel, 20% for toilet paper, and 40% for newspaper. Tepper and Heinz Schools provide free paper for printing. It allows students to make prints as much as they want. Their department computers are not set as "Double side print" option. If students do not select the option individually when they make prints, the default printing is on "Single side".

The computers in the departments of Architecture and Civil engineering are set to the option of "double side printing". It make student to save paper through printing on the both sides of paper. However, the printing option settings of laptops are totally depending

[14] The Apollo Alliance, New energy for Campuses: Energy-saving policies for colleges and universities, http://www.apolloalliance.org/downloads/resources_new_energy.pdf. Accessed in July 27, 2008.

[15] University of Wisconsin, http://www.news.wisc.edu/releases/10691.html. Accessed in September 2007.

on individual owner’s setting. In spite of “double side printing options” for school computer, if each user’s laptop is not set, office paper cannot be saved.

Double side printing

The author estimate the annual consuming paper can be saved by 40-50% by double side printing. Therefore, all the computers in every colleges and department should be set as “double side” for print options. Further, each individual laptop / computer that can make prints in the campus should be set as school computers.

- Recalculated footprint (0.00638 hac/cap) = Existing footprint of office paper (0.01063 hac/cap × (1 - 40% saved))

Replace paper towel with hand dryer

For the paper towel and toilet paper are equipped in all toilets on the campus. The circulation number of campus newspaper is 6,000 per week for 32 weeks in a year. One piece of paper is roughly 0.02-0.03 kg. It is recommended to replace paper towel with hand dryer machine. The device requires electricity for operating and manufacturing, but takes smaller footprint. Paper towel causes wood and energy consumption for manufacturing, and lots of disposed trash. It also needs transportation.

Recalculated footprint

- Assume using 2ft paper towel / each time.
- Energy use by hand dryer : 300GJ = 1800 cases (→ 30lb/case) × 6 roll / case × 800 feet/roll × 2feet / Each dryer × 0.0036GJ / kWh × 0.0048 kWh/Each dryer.

Footprint (ha/cap)	Hand dryer	Paper towel
Energy	0.00021	0.0006
Forest	N/A	0.0013
Total	*0.00021 (11% of paper towel)*	*0.00195*

- For the study, the author did not include the energy and materials consumed by manufacturing a hand drying machine because there is no information about the number of restrooms of the campus.

Online campus newspaper

A lot of newspapers are disposed without being read. It is highly recommended that CMU campus should reduce the number of circulation by up to 50%, and use an electrical newspaper subscription for students by sending an email or the link of the newspaper.

Increase recycling rate

According to GreenPractices (2004), the percentage of the recycled on CMU campus is average 19%. The below table summarizes the recycled materials in tons compared with consumed materials.

In the study, the author could not find any information how much recycled materials can contribute to energy saving in manufacturing, resulting in footprint reduction. However, this study does not consider the footprint reduction of consumer goods by recycling due to the limit of information.

Recycled materials	Office paper	Computer equipment	Fluorescent tubes	Newsprint
Consumed weight (tons)	104	40 (Assume 50 lbs/set)	N/A	38
Recycled weight (tons)	182	29.35	2.83	0

4.3.2. Light bulb

The campus consumes 17,349 lbs of electric light bulbs in a year. Among them, 7,003 lbs are green light bulbs that are energy efficient and save electricity energy for lighting. Based on observation, most of electric light bulbs are fluorescent lights. Replacing with energy efficient lighting such as T-5 or T-8 could contribute to the footprint reduction by electricity.

4.3.3. Computer

According to Carnegie Mellon Factbook 2005, the number of computers purchased for public clusters are 388, and for department 981. For this study, the author assumed every faculty (1,227 people) has their own desktop computers in their offices and the value is

$1,500 / computer and the life cycle is 3 years. Increasing recycling rate and using Energy star rated devices would be a effective way to reduce the footprint by electricity.

4.3.4. Plastic bag

The campus consumes 1,277 lbs of plastic bags in a year. It is mainly for janitorial things and for facility maintenance. Instead of plastic bags, degradable bags could drastically reduce the footprint by more than 70%.

4.3.5. Uncalculated goods

For the footprint of consumer goods, this project includes paper products, computers, plastic bags, and light bulbs. There are several other materials and projects consumed on the campus as consumer goods such as paints, detergent for janitorial things, batteries, furniture, etc. However, because of the lack of the information, these goods are not included in the study.

4.4. Footprint for Food

4.4.1. Use organic food

The current campus dining services has 0 % organic food purchase. Undoubtedly, using chemical fertilizer and pesticide for crop could increase the footprint. The campus dining service should increase the % of local shopping and incorporate purchase of organic food (free from fertilizers and pesticides). An increase of 30% in shopping in local vegetable markets (Farmer's Markets) can reduce the footprint by 0.1 ha/person.

4.4.2. Use organic food

To enhance the efficiency of building footprints, developing green roofs on campus buildings would be a good strategy for growing vegetables. It would contribute to heating and cooling energy efficiency in each building while growing eatable plants as a green roof. Because of plenty of solar radiation without any shading, the roofs could be conductive field for growing rare herbs and condiments or even tomatoes all year round. Averagely, 48 lb of tomatoes can be produced per square meter in one year.

In the dinning service, the service provides use plastic / paper food container to the customers. Such a single-use bowl also contributes to increasing footprint. This situation could improve by giving any incentive to customers when they re-use food containers or bring their own bows. So, the management at various food outlets on campus should have discount rates for customers who get their own carry away boxes or reuse the containers used on campus.

5. Recommendation for Future Footprint Calculation

The facts and the data this study found can be used as a baseline to improve or to reduce the ecological footprint of Carnegie Mellon University Campus. Due to the relative short history of ecological footprint, previous campus environment evaluation is mainly based on energy efficiency in facilities and machinery things, which is almost micro-scale measurement and verification. The concept of ecological footprint is much larger index to show the impact of each physical human / design performances which generate inter-dependent impacts on the environments. Thus, the estimation of ecological footprint is very important in terms of qualifying environmental impact, and resultantly gives a warning sign for environmental risks.

As such, due to the importance of footprint calculation, the methodology for estimation is very important to get a correct and significant assessment. This study was started from collection data and communicating with people who are associated with the campus facilities and services. However, there was a limit to access appropriate data and to obtain information from campus staff. In addition, because of different assumption and components used in the footprint estimation, it is almost impossible to compare CMU calculation with other schools'. This limitation could not provide any sense of the environmental impact degree of each campus.

In the case of Carnegie Mellon campus, if the university is committed to calculating its ecological footprint, then, it should take a proactive approach to generate the data. For example, for food data, food delivered to CMU can be weighed after they are unloaded from the truck. For transportation data, CMU can continue to keep track of their fleet total mileage, and student, staff and faculty can self-report their driving mileage. For building data, CMU can keep track of the kilo watt hours of all their fuel sources and for consumer goods, CMU can create a centralize database of all consumer goods purchased for the university. If all the required data is available, it would make correct footprint estimation much easier while it is much simpler. Thus, with the help of Internet website use, all the campus members' voluntary and periodical participation under the school government's direction would contribute to footprint reduction and effective policy making.

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