

QUANTIFYING THE ECOLOGICAL FOOTPRINT OF THE OHIO STATE UNIVERSITY

A Thesis

Presented in Partial Fulfillment of the Requirements for  
the Honors Degree of Bachelor of Science in the  
School of Environment and Natural Resources

By

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## ABSTRACT

Ecological Footprint Analysis (EFA) was introduced in the 1990s to measure the environmental impact of individual nations by calculating their resource use and converting it into a measure of ecologically-productive land area. Since then, ecological footprint analyses have been applied to institutions, manufactured products, and even individual lifestyles. The purpose of this study was to quantify the Ohio State University's (OSU) use of energy, transportation costs, and generated waste by calculating the associated ecological footprints (EFs) of each of those sectors. Given its size, and composed of a complex system of energy and material inputs and outputs, OSU has a major impact on its surrounding environment in significant ways. Methods for calculating the EF of energy include data on electricity, oil, and natural gas use and converting these quantities of use to hectares (1 ha = 2.47 acres) of productive land. The transportation footprint was based on the number of vehicles and buses at OSU in one year, the fuels and maintenance associated with vehicles, and the space taken by parking lots. The waste footprint was calculated by converting trash and recycling tonnages by composition component to an associated footprint value. Data analysis was similar to such studies done elsewhere. The EF of energy, transportation, and waste at OSU was found to be 8.66 hectares per capita per year (ha/cap/yr). This means that each student, faculty member, and staff member requires 8.66 ha of land per year to sustain his/her use of energy, and transportation and disposal of waste at the university. The major portion of the footprint was attributable to electricity use (1.80 ha/cap/yr, or 20.83% of total footprint), and the impact of cars (5.41 ha/cap/yr or 62.53%). The findings of this study serve as indicators of practices that greatly

impact the local and global environment thus making a case that environmental costs should not be treated as externalities in the university's decision-making. With a goal to "reduce ecological footprint," OSU can further strive for environmental excellence in areas highlighted in this study.

Dedicated to (all of) my parents  
and those at Laurel School  
who taught me how to learn.

## ACKNOWLEDGEMENTS

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## LIST OF ABBREVIATIONS

<u>Abbreviation</u>	<u>of</u>
AEP	American Electric Power
EF	Ecological Footprint
EFA	Ecological Footprint Analysis
ESS	The Office of Energy Services and Sustainability
ha	hectares
ha/cap/yr	hectares per capita per year
kWh	Kilowatt-hours
OSU	The Ohio State University
T&P	Transportation and Parking
UC	The University of Cincinnati

## INTRODUCTION

As the largest higher education institution in the United States (Statistical Summary 2006), The Ohio State University (OSU) is a complex system of food and water inputs and waste and emissions outputs. According to the OSU Statistical Summary, in 2006 the Columbus campus had an enrollment of 51,818 students, 25,302 employees (excluding student employees), maintained 461 buildings, and 710.5 ha of developed land. Any institution that large is dependent not only on natural resources that it produces itself but also on numerous outside sources. As the university acquires these resources, the capability of what nature can provide for a given population and duration on the Columbus campus specifically, and worldwide generally, is frequently overlooked. How widespread is the largest university's environmental impact?

The Ecological Footprint (EF) concept was introduced in the 1990's by Mathis Wackernagel and William Rees in their book, *Our Ecological Footprint* (1996), which describes the method they used for calculating EF, Ecological Footprint Analysis (EFA). Wackernagel and Yount (1998) further described, "Ecological footprint analysis is an area-based indicator which quantifies the intensity of human resource use and waste discharge activity in a specified area in relation to the area's capacity to provide for that activity" (p. 512). Chambers *et al.* (2000) summarized Wackernagel and Rees' original application of EFA to 52 countries, accounting for 80% of human population. This area is quantified in global hectares per capita (ha/cap). Global EFA includes the calculations of cropland needed for food, animal feed, and other products, pasture land needed for animals, harvesting land for wood, fiber, and fuel, marine and freshwater fishing area, infrastructure area for housing, transportation, and industrial

production, and area needed to sequester carbon released from the burning of fossil fuels (Wackernagel *et al.* 2002). In 1995, Wackernagel and Rees found the overall human footprint to be 2.2 ha/cap (Chambers *et al.* 2000).

Wackernagel and Rees (1996) calculated the average North American ecological footprint to be 4-5 ha/cap. According to this figure, if everyone lived as North Americans do, human population would need the equivalent of three earths to maintain its lifestyle (Wackernagel and Rees 1996). The earth provides 1.9 ha/cap in available resources, which excludes the area needed to sustain all other species inhabiting the planet (Chambers *et al.* 2000). In the United States, there are 5.5 ha/cap available, but the actual calculated footprint is about 9.6 ha/cap (Chambers *et al.* 2000), resulting in what has been termed “overshoot.” Overshoot occurs when the EF is greater than the area available to sustain that region and regenerate resources (Wackernagel and Yount 1998). An overshoot figure can be used to imply the unsustainability of a given lifestyle. Human activity has exceeded the global capacity since the 1980’s, and with increasing technology, industrialization, development, and population, the human footprint may only grow (Hancock 2006).

EFA can be applied to households, communities, hospitals, schools, businesses, manufactured products, nations, and even for humanity as a whole. Two educational institutions, The University of Redlands and the Colorado College, have calculated their individual EFs, and related them to the overshoot developed area. The University of Redlands and the Colorado College have much smaller populations than the Ohio State University (Redlands used a population of 2,727 and Colorado used 2,500). The Columbus campus is not only significantly larger than these two institutions in population and area, but it is also situated in the greater urban environment of Columbus, Ohio.

## **Purpose of this Study**

The main objective of this study was to evaluate OSU's EFA by calculating the energy, transportation, and waste components. Another study, conducted by Sarah Schumacher, which adds food and water footprints to expand the parameters of the overall footprint, is in progress. Using the principles developed by Wackernagel and Rees, we will calculate how many hectares of land are required to sustain each member of the OSU community, students, staff, and faculty alike. In light of the findings of the University of Redlands and the Colorado College, I hypothesize that OSU's Columbus campus will also have a footprint that exceeds the capacity of the university area.

But why should the university be interested in an EFA? First, in each of these three sectors evaluated, OSU's use of all commodities (electricity, oil, natural gas, and automobiles) has increased, in addition to its overall waste stream, in the years of the data provided. However, the most recent recycling figure, from 2005, rests below the average recycling figure from 1997 to 2005 (Redman 2007). To meet the growth and development of the university with impact mitigation, OSU must first understand the potential scope of its impacts. EFA is one relevant and strong ecological measure that provides an understanding of how OSU's lifestyle equates in terms of resources necessary to sustain its practice (while of course understanding the presence of uncalculated impacts).

## BACKGROUND

### **Elucidation of the Concept**

While it is evident that the environment provides numerous goods and services to humanity, it is often difficult to know how to manage resources in the face of rapid progress and development. The integration of ecology into economic decisions is a necessary movement that takes on the daunting task of quantifying environmental values that are currently viewed as externalities in economics. How does one quantify these natural externalities, such as a forest providing habitat for thousands of species, or a wetland providing zero-maintenance water treatment? What is the going rate on the market for biodiversity or lasting freshwater resources? EFA attempts to minimize the gap between ecology and economics by considering the flows of energy and matter to and from a given economy and correlating them to ecologically-productive area required to sustain them. EFA measures the consumption of a certain good or service and estimates the ongoing ecological supply of that good or service (Wackernagel and Rees 1996). Where there is overshoot, EF can help to highlight the source of it. As Wackernagel and Rees (1996) put it, “the Ecological Footprint is not about ‘how bad things are.’ It is about humanity’s continuing dependence on nature and what we can do to secure Earth’s capacity to support a humane existence for all in the future” (p. 3).

EF calculations can be tailored to any region or institution (so there is no universal formula for what variables to include). The more inclusive method is the compound calculation developed by Wackernagel and Rees (1996), which uses the nation state as its primary unit. There is also the component-based method, which is used to calculate the footprints of more

precise units (Chambers *et al* 2000). Wackernagel and Rees' (1996) compound method is based on national data, which may vary in accuracy, but is assumed to be a reasonable estimate of the component at hand. Their first step is to estimate the average citizen's annual consumption of a certain component by dividing the total amount consumed by the population size. To correct for trade, exports are subtracted from how much is produced plus imports. This step is what distinguishes EF from carrying capacity. While carrying capacity measures the number of people a land can support, EF measures the current land area necessary to sustain a given population. EF allows for the trade factor, reaching beyond the inhabited region that limits carrying capacity calculations. The next step is to estimate the land designated per capita for the production of each component, which equals the annual consumption of a particular item per capita divided by the average annual productivity of that item. The summation of all of these land estimates for each component equals the EF per capita. To determine the EF of the population, Wackernagel and Rees simply multiplied this by the population size (Wackernagel and Rees 1996).

As calculated by Wackernagel and Yount (1998), for every person, the earth provides 0.25 ha of cropland, 0.6 ha of pasture, 0.6 ha of forest, 0.5 ha of ocean, and 0.03 ha of built-up land. Wackernagel and Rees (1996) defined eight major land/ecosystem types that a given consumption item, such as commercial energy, requires for production. These land types include land appropriated by fossil energy use, built environment (degraded land), gardens, crop land, pasture, managed forest, untouched forests, and non-productive areas (such as deserts). Taking commercial energy as an example, Wackernagel and Rees (1996) converted fossil fuels consumed per year into the amount of carbon dioxide (CO<sub>2</sub>) that can be sequestered in a certain area of average forest. CO<sub>2</sub> from 80-100 gigajoules (GJ) of fossil fuels requires one hectare of

average forest to be sequestered. This conversion requires average forest land, but other conversions may require multiple combinations of the eight major land/ecosystem types defined by Wackernagel and Rees (1996).

EF calculations will inevitably produce underestimates for several reasons. As stated above, commercial energy estimates assume a high efficiency of fossil fuel use. CO<sub>2</sub> from fossil fuels is also the only pollutant considered. Contributing to the food footprint are estimates of crop land use that assume sustainable practices in agriculture. Certainly, in a highly industrialized nation, it is not true that all or even the majority of harvesting is practiced sustainably. Also, only the basics of nature's services are included, so only the bulk items that contribute to consumption and waste are used (Wackernagel and Rees 1996).

Another factor that is difficult to monitor is ecological degradation over time. North American crop land soils are depleted ten to twenty times faster than they are able to regenerate (Wackernagel and Rees 1996). Environmental degradation alters the ability of nature to provide services, such as sequestration, that account for the practices monitored by EF. Many details such as environmental degradation are excluded from EF calculations, so there is no universal formula for what parameters to set. In studies of nation states, such as those performed by Wackernagel and Rees (1996), many details that did not significantly contribute to the main exports and imports of the countries had to be omitted. The EF calculation can be adapted to include these lost details in future studies if need be. Therefore, one can consider EF calculations to be very conservative estimates, so if overshoot exists, it should serve as a stark indicator for necessary adjustments.

The University of Redlands and the Colorado College studies allow us to see these principles at work on the university level. They are valuable in that they provide starting points for what to include in a study of the Ohio State University.

### **The University of Redlands Study**

At the University of Redlands, Jason Venetoulis (2001) evaluated the EFs associated with water, solid waste, energy, and transportation, coining the terms “hydroprint”, “wasteprint”, “energyprint”, and “transportprint.” Hydroprint was calculated by a methodology developed by Jason Venetoulis (2001), which estimates the amount of water available from the rainfall and reservoir capacity in one year on campus. The total estimated water use is divided by the total estimated hydrospace of the campus. An estimate for water use in lawn irrigation was taken from a similar study performed at the University of Southern California, equating 1,600 square feet of lawns with 50,000 gallons of water required. The energyprint measured by the kilowatt-hours (kWh) used by the university, and partitioning that figure by how much energy was provided by coal, natural gas, hydroelectric power, wind power, and solar power. Venetoulis (2001) used the estimation that 0.4 ha was required to sequester 3.5 tons of carbon dioxide. The transportprint was composed of transportation on campus as well as airline transportation to and from campus throughout the course of one year. Surveys were taken to estimate the amount of travel during the school year and over breaks. Wasteprint was calculated using Wackernagel and Richardson’s spreadsheets, factoring in a 39% recycling rate (Venetoulis 2001).

While teams of students and researchers worked to incorporate as many variables as possible into the calculations, there are several gaps in what was and/or could be collected. For instance, transportprint does not include the use of lawn mowers and on-campus vehicles. The

energyprint does not include nuclear or geothermal energy, since a way to incorporate these has yet to be developed. Gaps such as these will exist in EF calculations with the current understanding of various practices.

Venetoulis calculated the ecological footprint of the University of Redlands to be about 2.1 ha/cap, with a capacity of just under 1 ha/cap. Five percent of this footprint is from water use, 12.5% from waste and recycling, 18.5% from natural gas, 31% from electricity, and 32.5% from transportation. The total footprint of the university, 2,300 ha, is 40 times the area of the campus. Venetoulis compared the EF to three degrees of sustainability: weak, strong, and ideal. The calculated footprint lies between weak and strong sustainability, and it would require much improvement in each sector quantified in order to reach the ideal level (Venetoulis 2001).

### **The Colorado College Study**

Emily Wright, of The Colorado College, used similar methods as those used by Venetoulis (2001) at the University of Redlands, but focused her study on the following components: energy (natural gas, electricity, gasoline, and diesel fuel), water, food, solid waste, and campus area. For a population of 2,500, Wright found the EF of the Colorado College to be 2.24 ha/cap. Electricity accounted for 80% of this total, food for 10%, heating for 7%, transportation for 1.4%, and water for 1% (2002). Clearly, there is plenty of variation in what contributes most to the EF of a university.

The University of Redlands footprint of 2.1 ha/cap and the Colorado College footprint of 2.24 ha/cap are relatively close to the global 1995 world footprint of 2.2 ha/cap (Chambers *et al* 2000). Comparing the OSU EF to the typical American footprint of 9.6 ha/cap (Wackernagel

and Rees 1996) will determine if the functions of a large university raise or lower the country's average.

### **Criticisms of EFA and Responses**

EF has the ability to provide a modest estimate of the sustainability of a university, but EF is heavily criticized in several areas. Chambers *et al* (2000) have addressed a list of several critiques of EF and responses that recognize the shortcomings of EF.

A major criticism of EF is that it provides an incomplete account of the environmental impact of a given institution or activity. Along the same lines is the criticism that EF analyses often exclude pollutants other than CO<sub>2</sub>. To address these criticisms, Chambers *et al* (2007) admit that EF “prefers to offer a conservative underestimate whilst acknowledging that other impacts exist” (online). To eventually incorporate the effects of various other pollutants, further research that describes the interactions of these pollutants with bioproductivity must be performed to address the gaps in this knowledge base. As this information is collected, conversion factors can be derived to account for more footprint factors.

Critics may also claim that humans are continually increasing their carrying capacity to meet resource needs, which renders EFA a flawed application. The response of Chambers *et al* (2007) is that EF provides a “snap shot measure” (online) that does not account for future biocapacity increases or decreases. EF is based on a current measure of what ecologically-productive land is available to account for the uses of an institution, nation, or product.

One can also claim that EFA is more about survivability than sustainability. Survivability is concerned with “maximizing the time available on Earth for human species, independently of the quality of that existence” (Chambers *et al* 2007). Chambers *et al* describe

footprint estimates to be minimum requirements for a certain institution to be sustainable. If an institution manages to live within the means that are provided by the earth at a certain time, that lifestyle proves to be within carrying capacity, but not necessarily within sustainable standards (Chambers *et al* 2000).

Most footprint estimates of fossil fuel emission outputs are based on how much productive land is required to sequester carbon emitted. Some critics find this method to be inadequate, but one alternative is to consider the land required to produce an energy alternative to fossil fuels. If one were to consider the land required to produce enough ethanol to effectively substitute fossil fuel use, the EF would be even higher than the calculation based on carbon sequestration (Chambers *et al* 2000).

### **Overshoot and its Implications**

Overshoot indicates that “ecological capacity can be used beyond its regenerative capacity” (Chambers *et al* 2000). According to Wackernagel and Rees (1996), EFA can be used to determine the amount by which the footprint of a given region or institution overshoots its corresponding carrying capacity. Overshoot depletes the natural capital, and as the ecological capacity of the earth continues to decrease, the resources that once supported the global economy will cease to be available.

A certain region or institution can calculate its overshoot by comparing its footprint to the ecological capacity or area that it occupies. A high overshoot will indicate the use of resources beyond the capability of the natural capital to regenerate and thus continue to provide economic (and of course ecological) services.

## METHODOLOGY

**Table 1. Basic conversions to calculate several components of the Ecological Footprint of OSU**

	Unit	Equivalent
<b>BASIC</b>	1 hectare	2.47 acres
	1 ton	2000 lbs
	1 tonne	2205 lbs
<b>ENERGY</b>	1 g coal	20 kJ
	1 kWh	3412 Btu
	1 kWh	0.0009992 tonnes CO2 emitted
	1 tonne CO2	0.27 tonne C
	1 ha	1.8 tonnes C

The OSU EF was quantified using a combination of methodologies found in studies of Venetoulis (2001) and Wright (2002). Parameters were defined by data availability as well as previously-determined or reliable conversion factors. Energy, transportation, and waste were chosen for this study because they comprise the bulk of the “outputs” of the university. This study was designed to contribute to an overall EFA, which includes a second study on two of the bulk “inputs” to the university, water and food.

### Energy

The energy footprint was determined by the area of land required to sequester carbon from emissions due to campus energy use. Data from 1998 to 2006 were acquired from Wallace Giffen, Energy Programs Manager in the Office of Energy Services and Sustainability (ESS) of OSU. Conversions from electricity and oil quantities were derived from factors specific to the university, and conversion of natural gas used Venetoulis’ (2001) conversion factor (Table 3).

To calculate the EF of electricity, pounds (lbs) of CO<sub>2</sub> were converted from total kWh used by the university in one fiscal year (fy) based on the assumption that 1.82 lbs of CO<sub>2</sub> are emitted per kWh of electricity used (Giffen 2007). Pounds of CO<sub>2</sub> were converted to kilojoules (kJ) of energy in order to derive the grams of coal associated with that energy (Table 3). Total grams of required coal were calculated assuming a 29.4% efficiency of coal conversion to kWh. Grams of carbon were calculated from mass of coal that is 85% carbon by mass (Wright 2002).

The EF of oil was based on data given in millions of British thermal units (mmBtu). After being converted to Btu, these data were converted to kWh and to tonnes CO<sub>2</sub> emitted. Tonnes C were then equated to hectares required to sequester the quantity of carbon (Table 3).

Natural gas data, originally given in therms, were converted to acres of land required using Venetoulis' (2001) conversion of 0.00157 acres/therm (Table 3). These values were then converted to hectares.

## **Transportation**

The transportation footprint was determined by data from 2001 to 2006 provided by the university's department of Transportation and Parking (T&P) (Blouch 2007). The footprint was comprised of the area of parking lots, cars use, and bus use.

The footprint due to parking lots and garages was as simple as taking the area occupied by them. Garage footprints were determined by the area of the bottom floor only.

The number of cars regularly in use on , to, and from campus in a given year was indicated by the sum of the number of parking passes issued, single day visitor passes, visitors in hourly garages, special events parkers, and the campus fleet (Blouch 2007, Table 3). The footprint due to cars assumed the following: (a) an average American car uses 12 liters of gas

per 100 kilometers, (b) indirect carbon consumption due to manufacturing and road maintenance increases emissions per car by 45%, (c) each liter of gas contains 35 megajoules (MJ) of energy, and (d) the typical commute is 10 kilometers per day for 230 work days per year (Wackernagel and Rees 1996).

OSU had 28 buses in its fleet (Blouch 2007, Table 3), and each bus requires 0.03 ha/cap/yr. The EF of a bus was based on the assumptions that: (a) the energy requirement of a short-distance bus is 0.9 MJ/cap/km, (b) indirect maintenance adds 45%, (c) the typical bus commute consists of two 5-km rides, and (d) the bus runs for 230 days per year (Wackernagel and Rees 1996).

## **Waste**

Waste data from 1997 to 2005 were acquired from Christina Redman, Sustainability Coordinator in ESS, and both trash and recycling figures were given in tons. In 1995, Engineering Design and Solutions, Inc., performed a study for the Ohio Department of Natural Resources (ODNR) on university waste stream composition, providing percentages by weight of paper, plastic, metals, food, and glass of trash, and paper, plastics, metals, and glass of recycling. Waste audits were performed at Ohio University, Capital University, Youngstown State University, The University of Cincinnati (UC), and the University of Toledo. Percentages of waste composition determined at UC were used to approximate OSU waste composition for several reasons. In 2005, at the time of the study, UC's population was 33,823 students and 2,214 full-time and part-time faculty members (Engineering 2005). Not only is UC the largest university used in the overall study, but it is also situated in the urban Cincinnati environment, a comparable placement to OSU's integration in Columbus.

Weights of trash and recycling were converted to acre footprints and further to ha/cap using Venetoulis' conversion factors, which were taken from Wackernagel and Richardson (1999), though I could not access this study directly. "Miscellaneous" waste was converted using an average of the conversion factors for specified components, and "other" recycling components were converted using an average of Venetoulis' glass and metals factors (Table 3).

## RESULTS AND DISCUSSION

### **Total EF**

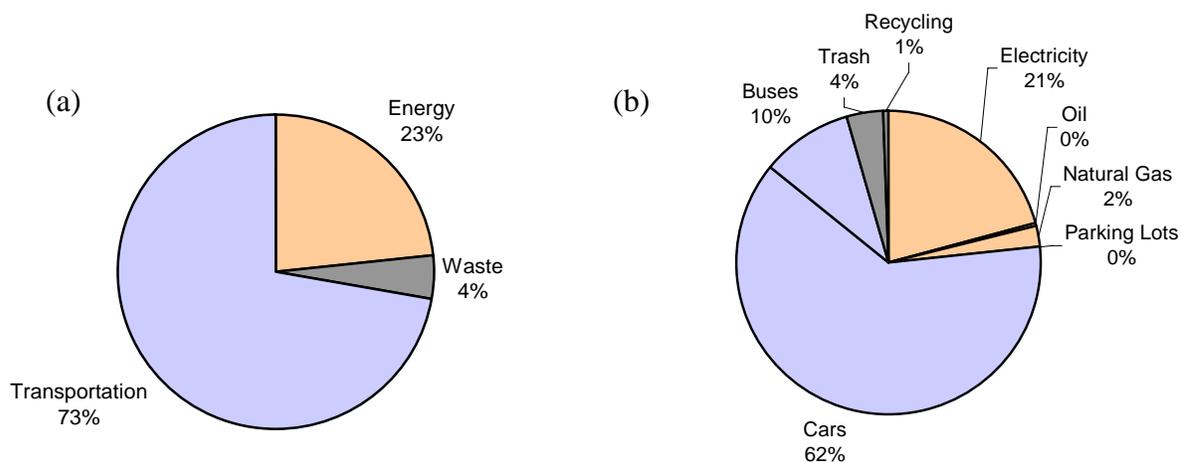
The total footprint of the energy use, generated waste, and transportation of the Ohio State University was 650,665.70 ha, or 8.66 ha/cap/yr (Table 2). The total area footprint was approximately 916 times as large as the area taken by the university itself. Contributing the greatest individual footprint to this figure were cars, which accounted for 62.53 %, or 5.41 ha/cap/yr (Figure 8). The total transportation footprint was only slightly greater than the figure for cars alone, which was 72.24% of the total footprint. Energy use accounted for 23.30% of this figure, or 2.02 ha/cap/yr. This percentage was primarily due to electricity use, which comprised 20.83% (1.80 ha/cap/yr) of the footprint. The average total campus population between 1998 and 2006 was 70,293 (Sikdar 2005 and Statistical 2006).

### **Area Equivalents**

Because the majority of OSU members or readers at large are not familiar with what 650,665.70 ha actually looks like, perhaps area comparisons will communicate this figure more effectively. A unit that most of the OSU community would appreciate is what I term the Ohio Stadium Unit (Osu). The current Ohio Stadium, home of the Buckeyes, contains 1.6 acres of playing surface (Ohio 2007). The EF of the OSU population is 1,004,465.18 Osu. Therefore, the footprint of one OSU member is 13.4 Osu per year. This area can also be equated to 1.3 times the area of the state of Delaware.

**Table 2. Summary of the Ecological Footprint components of OSU**

Component	Total Footprint (ha)	Per Capita Footprint (ha)	Percentage of Total
<b>Energy</b>			
Electricity	126773.94	1.80	20.83
Oil	1957.56	0.03	0.32
Natural Gas	13147.61	0.19	2.15
<b>Total</b>	<b>141879.11</b>	<b>2.02</b>	<b>23.30</b>
<b>Transportation</b>			
Parking Lots	74.74	0.00	0.01
Cars	417541.04	5.41	62.53
Buses	64780.80	0.84	9.70
<b>Total</b>	<b>482396.58</b>	<b>6.26</b>	<b>72.24</b>
<b>Waste</b>			
Trash	22433.88	0.33	3.79
Recycling	3956.12	0.06	0.67
<b>Total</b>	<b>26390.00</b>	<b>0.39</b>	<b>4.46</b>
<b>Total</b>	<b>650665.70</b>	<b>8.66</b>	

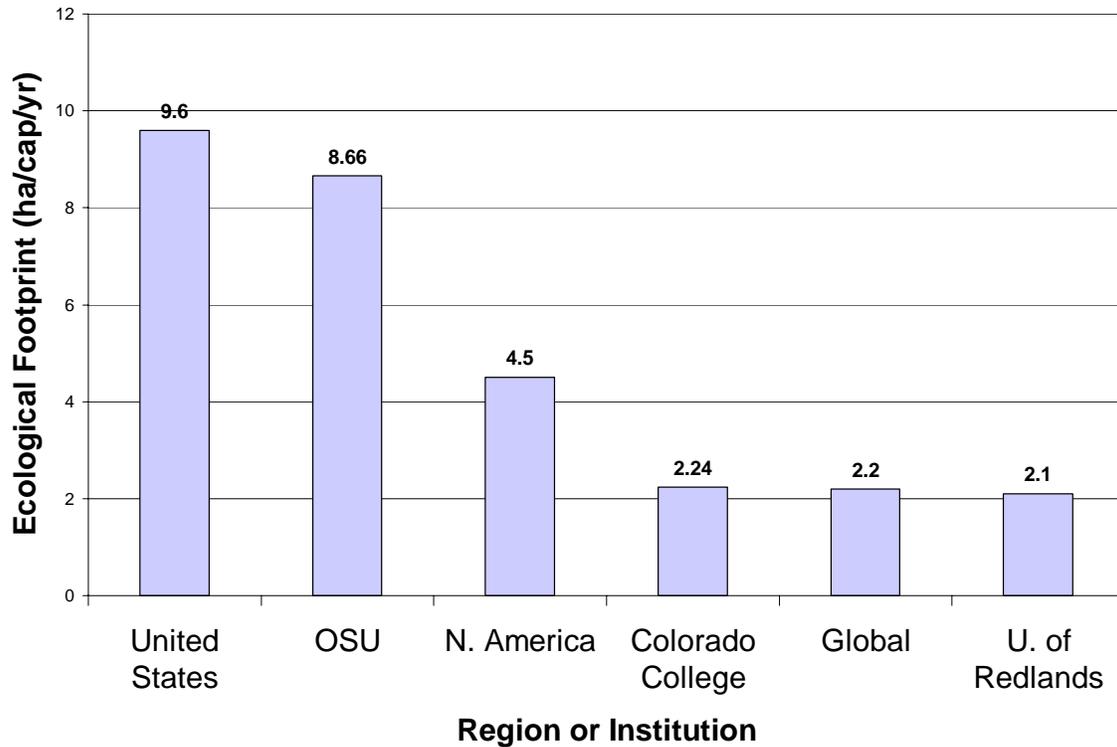


**Figure 1. Ecological Footprint sectors of energy, transportation, and waste by (a) major components and (b) subcomponents**

Clearly, transportation can be seen as the largest contributor to overall footprint, with cars and buses accounting for nearly the entire transportation footprint (Figure 9). Most of the energy footprint was attributable to electricity, and this area also contributed significantly to the overall footprint.

These results indicate the sectors that need to be targeted if OSU is to significantly reduce its EF. It is evident that campus transportation and electricity use would be good starting points. Perhaps OSU could adopt electricity-saving measures such as compact fluorescent light bulbs, which use at least 2/3 less energy and can last up to ten times longer than the typical incandescent bulb (Compact 2007). OSU could also install more motion sensor lights so that electricity is not being used at unnecessary times. Educational programs could target student life in residence halls, which uses electronics at nearly all times of the day for television, video games, computers, stereos, and various other appliances. This is certainly not an extensive list of solutions, but simply a start to thinking about footprint reduction. The life cycle footprint of, for instance, compact fluorescent light bulbs, should also be considered.

Campus transportation could be addressed by increased public transportation, smaller vehicles, and bicycle commutes. One positive aspect of OSU is that each student rides the Central Ohio Transit Authority (COTA) bus for free with a BuckID (OSU student identification card). This encourages students to use public transportation as much as needed. OSU could also attempt to organize a carpooling system for commuters, since many students, faculty, and staff are making the average 10-kilometer commute or more.

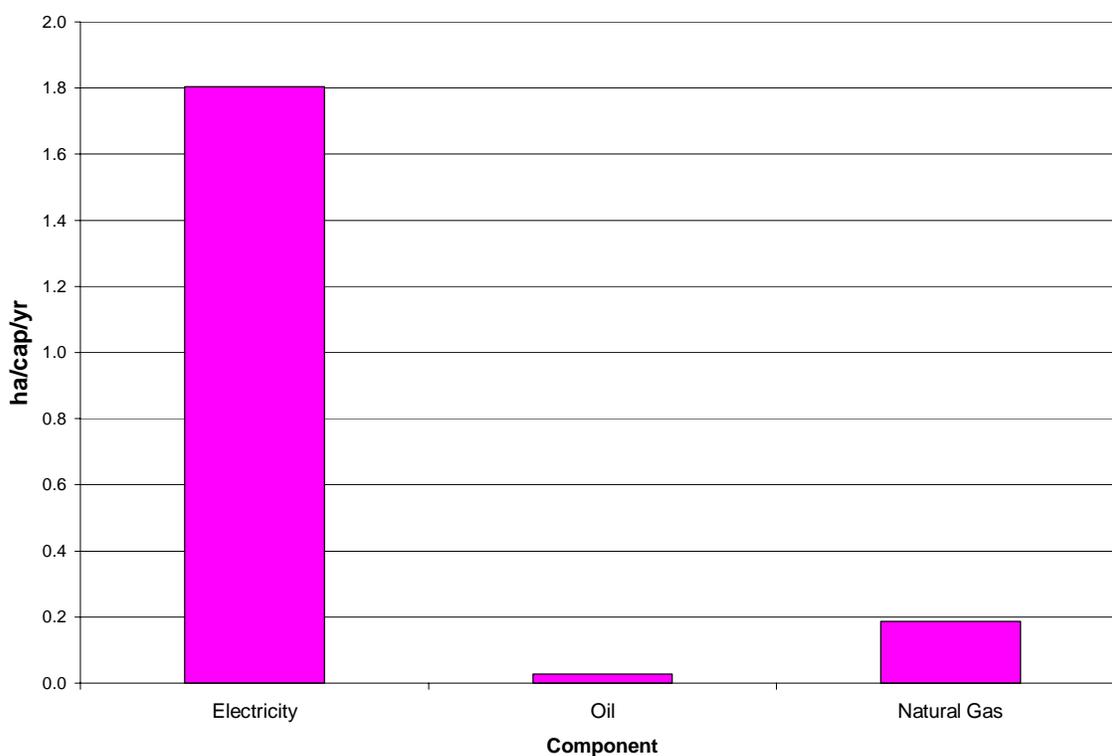


**Figure 2. The Ecological Footprint of OSU in comparison to other regions and institutions: United States, Wackernagel and Rees 1996; OSU, this study; North America, Chambers et al 2000; Colorado College, Wright 2002; Global, Chambers et al 2000; University of Redlands, Venetoulis 2001)**

In comparison to other institutions and general regions, OSU found itself on the high end of EF (Figure 10). Though it fell short of the typical footprint of someone living in the United States (Chambers *et al* 2000), it was almost double the typical North American footprint (Wackernagel and Rees 1996), and several times greater than other institutions of higher education. While the University of Redlands and the Colorado College were closely situated next to the average global footprint, OSU took on a more characteristic American value (Venetoulis 2001, Wright 2002, Wackernagel and Rees 1996).

## Energy EF

The total EF due to energy accounted for 2.02 of 8.66 ha/cap/yr. The major portion of this area was required by university electricity use, followed by natural gas and oil (Figure 11). Between 1998 and 2006, OSU used an average of 438,488,699 kWh of electricity per year. This number corresponds to about 361,927 tonnes of CO<sub>2</sub> emitted per year solely from electricity. This equivalent was based on the assumption that 1.82 lbs CO<sub>2</sub> are emitted per kWh, a figure calculated by American Electric Power (AEP) and referenced by Giffen (2007).



**Figure 3. Energy components of the Ecological Footprint of OSU**

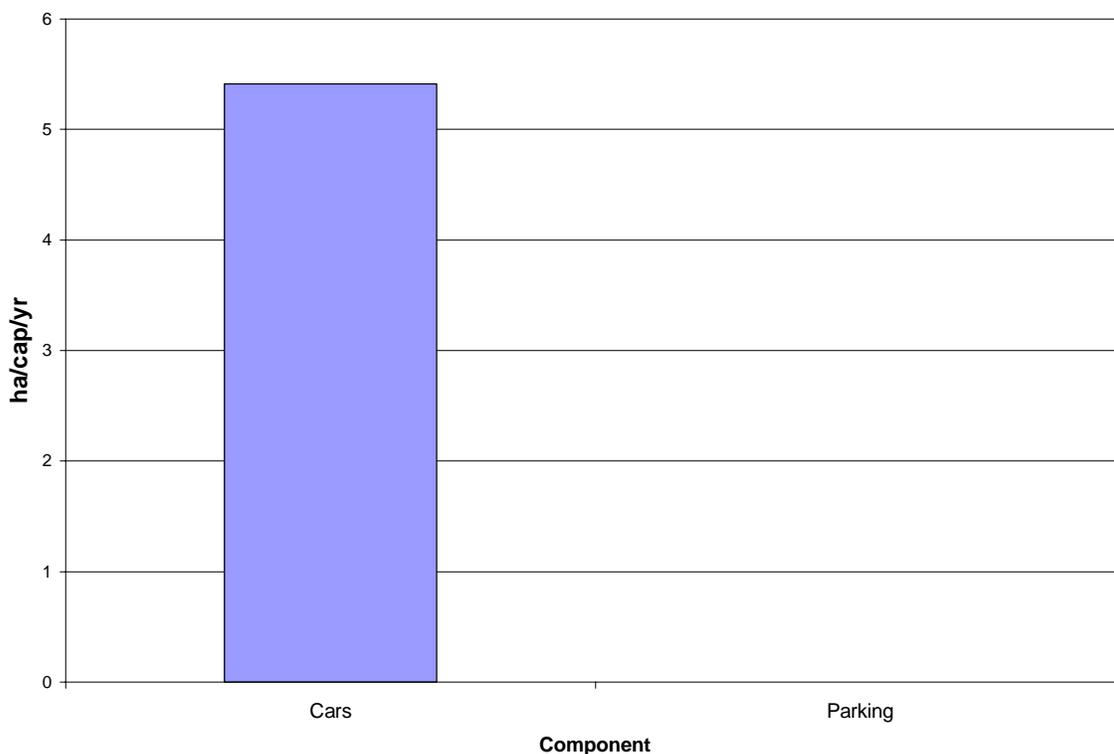
Electricity used on campus was supplied by Columbus Southern Power (part of AEP) via a 138,000 volt (V) underground transmission loop. OSU's own substation was located on Cannon Drive and 12<sup>th</sup> Avenue, which redistributed the electricity to OSU buildings at 13,200 V. Although coal was the main source of energy in electricity generation at AEP, some nuclear

energy and hydroelectric power were used to supplement it. Nuclear and hydroelectric energy were not considered in this study not only because they contribute only small amounts to the electricity provided by AEP (Giffen 2007) , but also because there were not reliable means of converting these energy sources to EF (Venetoulis 2001).

Coal was the source of electricity provided by Columbus Southern Power. According to Giffen (2007), Columbus Southern Power is 29.4% efficient between the energy embodied in a coal pile and the actual energy provided as electricity.

### **Transportation EF**

The transportation footprint accounted for the greatest portion (72.27%) of the total EF. Automobile use accounted for 5.41 ha/cap/yr of the total 6.26 ha/cap/yr due to transportation (Figure 12). The next greatest contributor was the bus fleet, requiring 0.84 ha/cap/yr. Since fuels were already determined by the conversions for cars and buses, they were not calculated separately. T&P had available data on the quantities of unleaded gasoline, diesel, and biodiesel (which OSU began using in 2003). Because this study excluded these quantities so as not to double-count what was already embodied in Wackernagel and Rees' (1996) conversions, it also excluded the portion of fuels for purposes other than the campus fleet, such as maintenance vehicles (i.e. lawn mowers and motorized carts).



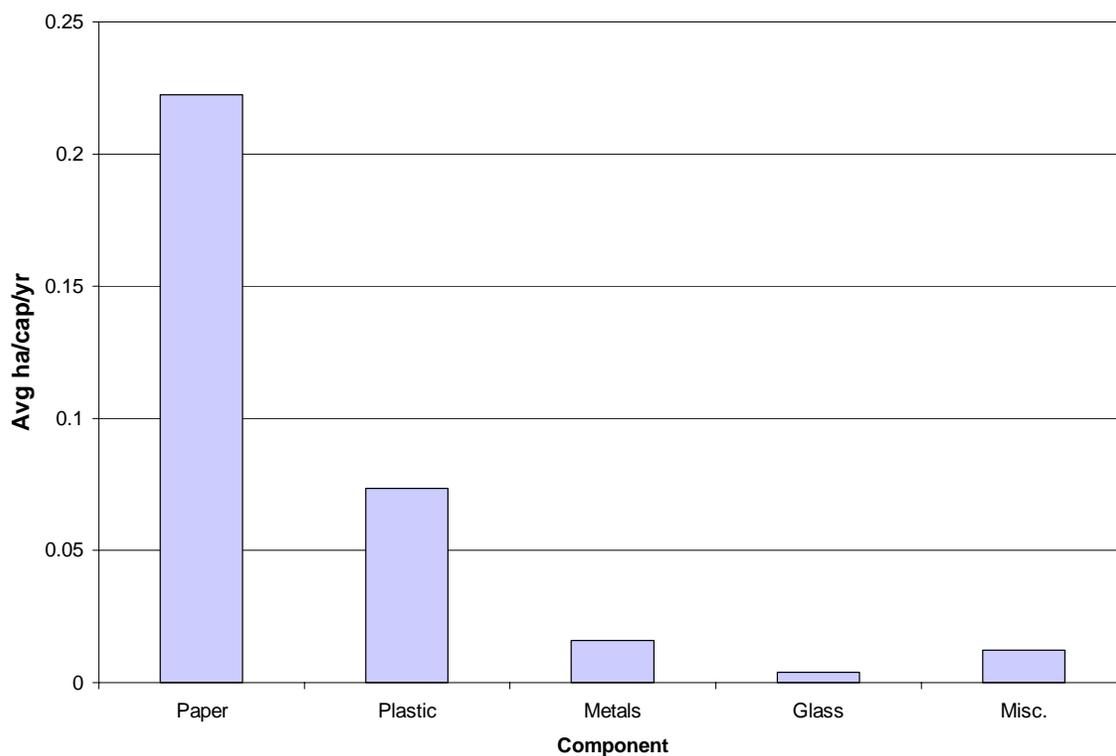
**Figure 4. Transportation components of the Ecological Footprint of OSU**

## Waste EF

### Trash

Though a study has not been performed on waste stream composition at OSU, total waste tonnages were found in UC's waste stream study and delineated into paper, plastic, metals, food, and glass by weight percentages. According to UC, a typical urban university waste stream is comprised of 57.29% paper, 21.33% plastics, 3.88% metals, 11.60% food, and 3.83% glass (Engineering 2005). The remaining percentage of waste was labeled "Miscellaneous," and a footprint value was calculated based on an average of the conversion factors for the other components, since this portion of the waste may have contained any of these recognized components. Conversions of recognized waste components were performed using Venetoulis'

(2001) factors, which indicated that paper accounted for the greatest waste component with a footprint value of 0.22 ha/cap/yr (Figure 13).



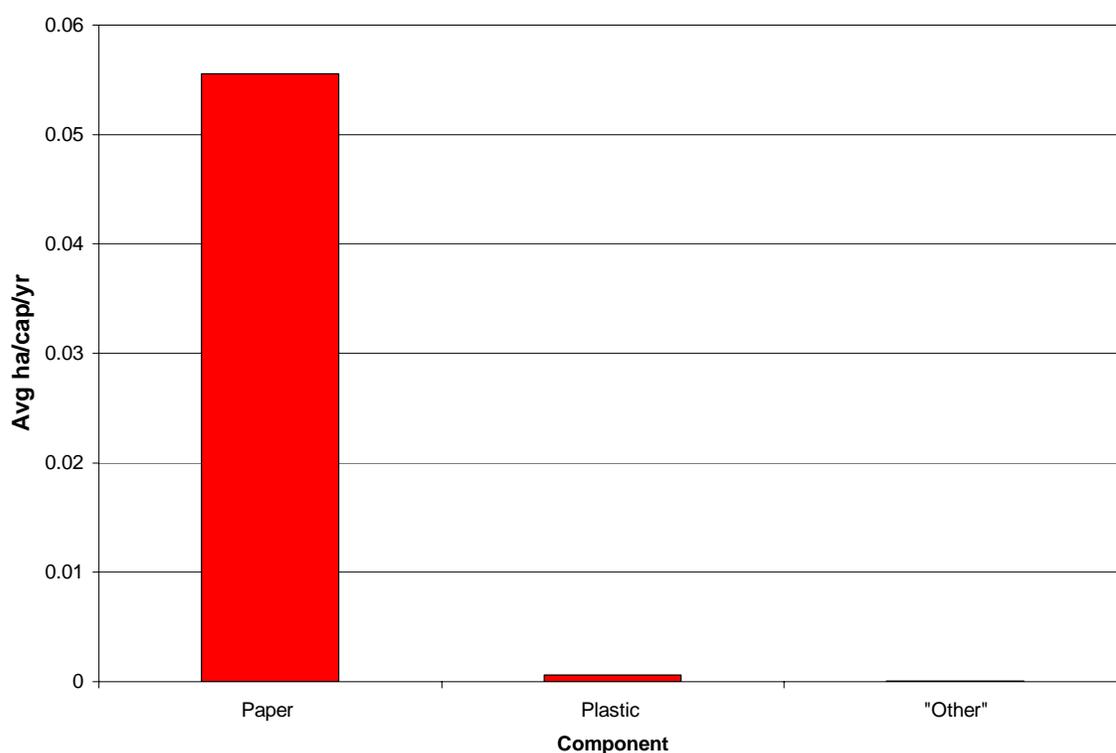
**Figure 5. Trash composition components of the Ecological Footprint of OSU**

Food waste was not given a corresponding footprint value because of the difficulty of calculation as well as the risk of double-counting that commodity. Since Schumacher's study will address food purchased at the university, a portion of its area requirement would already be considered.

### Recycling

Percent composition of recyclables was also found in the UC waste stream study and used to calculate tonnages of paper, plastics, and "other" recyclables at OSU. The UC waste stream was found to be composed of 96.85 % paper, 2.96 % plastics, and 0.19% "other

categories” (Engineering 2005). Again Venetoulis’ (2001) conversion factors were used to equate the amount of recyclables with a footprint area. Paper accounted for the greatest percentage of the recycling stream as well as the largest footprint component, averaging 0.06 ha/cap/yr (Figure 14).



**Figure 6. Recycling composition components of the Ecological Footprint of OSU**

OSU has been attempting to implement a uniform recycling program on campus for several years. Recycling is hindered by lack of bins in several buildings, uninformed personnel on the method of trash and recycling disposal, and difficulty in educating the campus body. In the past year, ESS has carried out a pilot program in nine buildings for All-in-One recycling. This program has the potential to increase the recycling stream from 2006 onward.

## UNCALCULATED IMPACTS

Due to its size, complexity, and integration in an urban environment, OSU would be impossible to model in such a way so as to determine an exact EF. Therefore, this study's parameters were drawn with the intention to include those factors that (a) could be assessed because of available data, (b) could be converted thanks to previously-determined conversion factors, and (c) contributed a relatively significant footprint figure.

These parameters left many environmental impacts uncalculated, and even those factors that were quantified excluded some of the energy costs of a particular component. Each function had much more embodied energy than the determined conversion factors allowed. For instance, the conversion to coal did not include the maintenance required to build the infrastructure that allows for electricity conveyance. The parking lot EF did not include energy consumed to construct the lots. In the case of garages, the energy cost could be significant, but it could not be quantified with the data collected for this study.

Other uncalculated impacts were due to limited data or unknown estimations of activities specific to the OSU population. Among these impacts were the footprints due to food waste, biodiesel use, travel due to athletics, field trips, extension programs, and international programs, car travel during vacations, and many practices associated with the OSU Medical Center. What had also been excluded from this study were the EFs of OSU regional campuses, the OSU airport, and OSU-owned properties throughout the United States.

## CONCLUSION

With increased trade and globalization, the United States, and indeed an institution such as OSU, is drawing more resources from distant parts of the world. Much of the time, members of institutions this large are unaware of the origins of their energy, transportation, manufactured products, and food as well as the destination of their waste. Catarina Borgstrom Hansson (1999) describes this modern dynamic as societal “disembedding” (p. 203). Borgstrom Hansson declares: “...through modernization, previously important relationships between populations and local ecosystems are losing their significance and local lifestyles are becoming less adapted to the existing context, e.g. the specific soil, climate, and culture” ( p. 204). As relationships between cultures and ecosystems are lost, so is the sight of the energy necessary to progress as well as the waste associated with development, which means that only a limited view of ecological effects can be considered in economic decision-making.

In Germany, the “hidden history” of manufacturing is termed “ecological rucksack” (p. 50), which is where many ecological effects are stored when we regard our practices and products (Hawken *et al*). For instance, Hawken *et al* (1999) note that the amount of waste accompanying the manufacture of a semiconductor chip is over 100,000 times the chip’s weight. Borgstrom Hansson (1999) would attribute this “ecological rucksack” to money, which implies a message of substitutability: market exchanges and manufactured goods can equate natural services. As societal demands, especially those of urban cultures, necessitate vast expanses of ecologically-productive land, they are also growing more distant from the places that meet those demands. To counter this growing trend, it is imperative that we continue to incorporate ecological values into economic decisions, no matter how daunting the task may be. As

Borgstrom Hansson (1999) states, "... the human mind – and economy – need to be re-embedded, if not in a bioregional, then at least in a biospheric context" (p. 209).

This study evaluated current inputs and outputs to ascertain where adjustments are needed. It also serves as an indicator of what costs the institution can incur that will grow more costly over time if not addressed in current economic decisions. These costs would include those to the local and global ecology, whose services are needed by OSU's 2006-2007 population as much as to its 2026-2027 population.

Sustainability of resources is an increasingly important focus of attention as the average American finds him/herself in an era of excessive resource use and consumption. OSU has the potential to be a pioneer in the development of sustainable practices that will influence students' habits well beyond their college years. University life across the U.S. already perpetuates increased resource use and unsustainable habits, with many on-campus dining areas offering only take-out options, an increased use of technology for both educational and entertainment purposes, and a high demand for supplies, like paper, necessary to university functions. A comprehensive estimate of OSU's current EF is useful in assessing what practices need to be targeted, indeed revolutionized, to allow the university to sustain future students in both economic and environmental consciousness.

To reiterate, EFA is not about "how bad things are" at an institution (Wackernagel and Rees 1996), but it is about providing a means to see our situation in the big picture, incorporating the needs of Ohio State students, faculty, and staff to come. EFA is both "analytical and educational" (Wackernagel and Rees 1996), and can be used to assess the sustainability of this institution. "Sustainability" arises more and more in classrooms and everyday conversation as we continue in an era of excessive resource consumption, especially in the United States. Despite

efforts to reduce, reuse, and recycle, we still extract 101 kilograms (kg) of raw materials daily, compared to the global average of 4 kg daily. This figure makes our consumption about 25 times the global average (Chambers *et al* 2000). The university setting, with several active environmental organizations and plenty of classes related to the environment and natural resources, is a key location for the reformation of our lifestyle when we see it needs reforming. But first, we must estimate how these 149,960 feet impact the world at large.

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## CONVERSIONS

Table 3. Conversion factors to calculate the Ecological Footprint of OSU

	Unit	Multiplied By	Equivalent
<b>ENERGY</b>			
	therms	0.00157	acres
	g coal	1/0.294	g coal at 29.4% efficient conversion*
	g coal at 29.4% efficient conversion	0.85	g C
<b>TRANSPORTATION</b>			
	2,982,464 cars	0.14	ha/cap
	28 buses	0.03	ha/cap
<b>WASTE</b>			
	Trash (lbs)		
	paper	0.0045	acres
	plastic	0.004	acres
	metals	0.0048	acres
	glass	0.0012	acres
	misc.	0.0069	acres
	Recycling (lbs)		
	paper	0.0032	acres
	plastic	0.0012	acres
	other	0.0024	acres

\* Because of coal use having only a 29.4% efficiency, the total coal needed to produce a certain number of kilowatt-hours is greater than the coal calculated per kilowatt-hour.