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COLLEGE CAMPUS BUILDINGS UW-MADISON.

SUSTAINABILITY PERSPECTIVE

COORDINADO POR UNIVERSITY OF WISCONSIN-MADISON

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Sustainability perspective

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ABSTRACT

The project will assess all UW-Madison on-campus buildings GHG emissions, and focus on the 3 main gases that have the higher impact, CO_2, $CH_4$and N_2O. Moreover, this project will provide recommendations and ideas on how to reduce its GHG emissions in order to reach a better Leadership in Energy and Environmental Design (LEED) certification in the future constructed buildings.

LEED is an internationally recognized green building certification system created by the U.S. Green Building Council. *(Sustainability at American Colleges and Universities, n.d.)* The first prominent "sustainability" programs at colleges and universities focused on recycling of wastes such as paper, glass, and plastics. Recently attention to sustainability started encompassing the overall and perhaps greater impact that higher education plays in preparing future generations to address the impacts of human life on the planet. Therefore, some universities have already taken steps forward sustainability to achieve a better LEED certification.

At the beginning of the project, previous research about other concerned universities with the sustainable issue have been done. In addition, it has been payed more attention to the ones that have counted its GHG emissions somehow. With this information, the scope of the project it's been defined and the attention has focused on the universities which have similar dimensions to UW-Madison to find some relevant data. The results of this research is summarized in the following table:

Table 1: Summary from the universities students CO2 emissions.

University	Emissions per student (t CO2e/Student)
ANU (Phelps, 2009)	110,450 t CO2e. /21,113Students= 5.23
UIC *(Cynthia Klein-Banai&Thomas L. Theis, 2010)*	275,000 t CO2e. /29,048Students= 9.47
California State Polytechnic University *(Paul Wingco, 2013)*	29,516 t CO2e. /20,944Students= 1.41

College of Charleston *(P. Brian Fisher Ph.D., Spring 2012)*	67,812 t CO2e./11,619Students= 5.84
Drexel University *(Ms Barbara A.W. Clarke, 2009)*	41,369 t CO2e./12,529Students= 3.30
Penn State University *(Pennsylvania State University, n.d.)*	499,740 t CO2e./99,133Students= 5.04
University of Maryland *(David Tilley, 2007)*	352,000 t CO2e./38,140Students= 9.23

Secondly, since it is not easy to find relevant data to perform the GHG inventory, different methods that could be applied were analyzed in case of sufficient data provided for any of them. Eventually, the recruited data was enough to conduct a GHG emissions inventory of the UW-Madison campus applying one of the studied methods. EPA standards method is applied to analyze the CO_2, $CH_4$and N_2O releases by the on campus buildings. These releases are mainly, due to HVAC and electricity requirements. It has been chosen this method due to its simple amount of data required, that matches with the available data. On the other hand, water, food, transportation around the campus and hazardous waste won't be considered as there is not available such detailed information.

The buildings operate in different manners depending on their use. Therefore, each building is going to be classified within a category. The different categories considered are:

Dwelling buildings, Offices, School buildings (which are compound of labs, classrooms and offices), Schools without a lab, Laboratories, Retail, Restaurant, Sport building, Service(Garage, Police Station…), Historic, Leisure, Library, Greenhouse, Power plant and Hospital.

For each building category, it is going to be assumed a different energy consumption based on real data in KWh/SF.

Table 2 Categories and subcategories weighed with their corresponding energy ratio in KWh/SF

Category	Subcategory	KWh/SF per year
School	29%Office 50%Classroom 20%lab 1%Cafeteria	25.68

***School(without Lab)**	29%Offices 70%Classroom 1%Cafeteria	7.57
Offices	100%Offices	18.72
Offices&Lab	50% each	56.16
Dweling	85%Rooms 15%Kitchens	21.66
Restaurant	20%Kitchen 80%Living room	65.59
Lab	100% lab	93.6
Hospital	Surgery rooms/Patient Rooms/Offices	57.36
Hospital&Lab	80%Hospital 20% Lab	64.6
Leisure	75%Living rooms for events 10%Cafe 15%Offices	13.27
Sport	Can be dry, Combined(with pool), ice rink for Hokey.	41.62
Library	60%living rooms 40%Computer labs	26.84
Greenhouse	100% Plantation	67.2
Service	Police/Boat/Garage	25.88
Power Plant	100% Machinery and Labs	
Retail	Store 100%	13.8
Historic	100%Space	13.27

With the EPA standards and taking into account the categories which data is specifically obtained from California, which are: schools without a lab, Schools, hospitals and offices that need to include the conversion factor from California to Madison. It is applied the following:

$$SF_{Building} * \frac{MWh_{California}}{SF} * \left(\frac{lbCO_2}{MWh}\right)_{California} * \frac{lbCO_{2_{Madison}}}{lbCO_{2_{California}}} = lbCO_{2_{Madison}}$$

The other categories don´t require conversion factor so the equation is simplified as follows:

$$SF_{Building} * \frac{MWh_{Madison}}{SF} * \left(\frac{lbCO_2}{MWh}\right)_{Madison} = lbCO_{2_{Madison}}$$

The results obtained are shown in the table below:

Table 3 Total GHG emissions for each type of building.

Categories	Kg of CO2	Kg of CH4	Kg of N2O	Kg of CO2e
Dwelling	16,917,540	2,012,753	296,307	17,051,011
Greenhouse	1,747,236	207,876	30,602	1,761,021
Historic	334,163	39,757	5,853	336,799

Hospital	959,396	116,754	17,024	975,860
Hospital/Lab	37,890,426	4,507,989	663,643	38,189,364
Hospital/School	3,188,808	379,386	55,851	3,213,966
Lab	55,990,532	6,661,438	980,663	56,432,272
Leisure	5,509,875	655,534	96,504	5,553,346
Library	7,770,004	924,431	136,090	7,831,305
Office&Classrooms	60,895	7,245	1,067	61,375
Offices	794,404	96,675	14,097	808,036
Offices&Lab	29,544,216	3,515,004	517,461	29,777,306
Restaurant	3,522,559	419,094	61,697	3,550,351
Retail	70,081	8,338	1,227	70,634
School	13,404,523	1,631,267	237,861	13,634,545
School&SportsDry	130,626	15,541	2,288	131,657
School(Without Lab)	365,665	44,500	6,489	371,940
Service	688,011	81,856	12,050	693,439
Service & Leisure	100,677	11,978	1,763	101,471
Service & Offices	976,772	116,211	17,108	984,479
Sport Combined	5,026,530	598,028	88,039	5,066,187
Sport Dry	11,849,368	1,409,771	207,539	11,942,854
Sport Ice rink	6,926,029	824,020	121,308	6,980,672
Grand Total	**203,768,337**	**24,285,446**	**3,572,531**	**205,519,891**

In the end, some proposals are made to decrease the on-campus GHG emissions regarding each particular type of buildings. Consequently, LEED certification would take part at the end of the project as a target for the new constructed buildings or the renovating of the already existing ones to take these proposals into account to reach LEED certification standards.

Some conclusions have been drawn from above review:

- The quantities are not that consistent nor the way to reach the most dangerous gas for the atmosphere.
- Lab buildings category use more energy consuming equipment. For instance, fume hoods are necessary to clean the air in this areas and this equipment requires a high amount of energy.
- To control emissions there is a need of increasing awareness amongst stakeholder to adopt such methods, which aren't technologically better but environmentally safe.

- Shifting power generation technology from conventional sources to cogeneration or hybrid technology results into substantial reduction in carbon emission.
- Improvement in thermal performance of building envelope leads to reduction in carbon emission.
- Construction process should be made more environmental friendly.
- The materials used in the buildings and the processes used should be identified and assessed. This will help in improve energy efficiency *(Ralegaonkar, 2011)*
- Simulation methods should be used at design stage to improve energy efficiency of building system (Such as the proper shading device) which directly will result in reduction in carbon emissions. Simulation method proves to be best for predicting heating and cooling load *(Ralegaonkar, 2011).*
- Each university is different, many facts should be considered (size, location, type of college...) to make consistent comparisons.
- GHG emissions inventory gives more detailed information than carbon footprint as it keeps separated each gas releases. Nevertheless, carbon footprint results are easier to interpret as it only uses $\boldsymbol{CO_2e}$.
- Investing in greener HVAC equipment can save a lot of money, as in the average US buildings accounts for the 48% of the emissions.
- A proposal that can help to reduce easily GHG emissions is requiring all residential buildings to report their electricity and heating energy use.

Over 25 percent of Madison's yearly energy costs ($3.6 out of nearly $14 million dollars) are spent on buildings and facilities energy *(Eric Anderson, 2012)*. The average American household spends over $2000 per year on energy bills, the majority of which goes to heating and cooling *(EPA, Green building, 2016)*. Reducing building energy consumption can therefore reduce energy use and greenhouse gas emissions, while helping Madison habitants save money. *(Eric Anderson, 2012)*

In 1990 UW-Madison buildings used 995,299 therms of natural gas and 15,986,473 kWh of electricity for a total cost of approximately $1.3 million. Some upgrades have been applied to the UW buildings adding insulation systems, such as re-roofing, upgrading doors, replacing windows, etc. The energy savings from these measures has not been documented yet. The expenditures in measures to improve energy efficiency it's been between $300,000 to $500,000, and annual savings from these measures are estimated to be $40,000/year. *(Somers, 2002)*

None of the policy options considered in this report will, on their own, result in GHG emissions reductions on a scale large enough to achieve the Madison city's stated goal of an 80 percent reduction in GHG emissions by the year 2050. *(Lydersen, 2016).* However, if gradually we contribute to implement measures to improve the situation, the outcomes will be considerably appreciated. Furthermore, big amount of money will likely be necessary to achieve these goals. Therefore, in addition to considering the efficacy of a few of the many GHG reduction alternatives available, the economic impact should be considered.

RESUMEN

Este proyecto evaluará las emisiones de los gases efecto invernadero de todos los edificios del campus de la Universidad de Wisconsin-Madison. Se centrará en los 3 gases que producen el mayor impacto, CO_2, CH_4 y N_2O. Además, el proyecto dará recomendaciones e ideas de cómo reducir las emisiones de los gases para conseguir una certificación LEED (Leadership in Energy and Environmental Design) mejor en los edificios que se construyan en un futuro.

LEED es una certificación reconocida internacionalmente creada por U.S. Green Building Council. *(Sustainability at American Colleges and Universities, n.d.).* Los primeros programas llevados a cabo en favor de la sostenibilidad en las universidades americanas se enfocaron en el reciclado de papel, vidrio y envases. Recientemente, se ha prestado atención a la importancia de la educación en el tema de la sostenibilidad. Las futuras generaciones deben estar preparadas para combatir el problema y reducir el impacto de la contaminación en el planeta.

Al comenzar el proyecto se ha realizado un estudio de las universidades que se han preocupado anteriormente por el tema de la sostenibilidad. En particular, se ha prestado más atención a las universidades que de alguna manera han cuantificado las emisiones de gases de efecto invernadero. Con esta información se ha definido el alcance del proyecto y se han evaluado en mayor detalle las universidades que en tamaño se parecen más a UW-Madison. A

continuación, se muestra la tabla con las distintas universidades investigadas y una aproximación de sus emisiones de CO2 por estudiante.

Tabla 4: Resumen de las emisiones de CO2 por estudiante.

Universidad	**Emisiones por estudiante (t CO2e/Estudiante)**
ANU (Phelps, 2009)	110,450 t CO2e. /21,113Estudiantes= 5.23
UIC *(Cynthia Klein-Banai&Thomas L. Theis, 2010)*	275,000 t CO2e. /29,048Estudiantes= 9.47
California State Polytechnic University *(Paul Wingco, 2013)*	29,516 t CO2e. /20,944 Estudiantes= 1.41
College of Charleston *(P. Brian Fisher Ph.D., Spring 2012)*	67,812 t CO2e./11,619 Estudiantes= 5.84
Drexel University *(Ms Barbara A.W. Clarke, 2009)*	41,369 t CO2e./12,529Estudiantes = 3.30
Penn State University *(Pennsylvania State University, n.d.)*	499,740 t CO2e./99,133Estudiantes= 5.04
University of Maryland *(David Tilley, 2007)*	352,000 t CO2e./38,140 Estudiantes= 9.23

Por otro lado, ya que no es fácil recopilar la información necesaria para realizar un inventario de los Gases de efecto invernadero (GEI), se van a analizar diferentes métodos para, en función de la información recopilada, aplicar el más apropiado. Al final, la información disponible era suficiente para aplicar uno de los métodos relacionado con los estándares de la EPA (Environmental Protection Agency). Aplicando estos estándares obtenemos las emisiones de CO_2, CH_4y N_2O por los edificios del campus. Estas emisiones se deben principalmente a los sistemas de HVAC y la cantidad de electricidad requerida. Se ha elegido este método por la simplicidad de los datos necesarios para su aplicación, sin embargo, el consumo de agua, comida, el transporte alrededor del campus y los residuos peligrosos no serán considerados ya que no hay información tan detallada disponible.

Los edificios operan de diferentes maneras en función de su aplicación. Por lo tanto, se van a considerar distintas categorías de edificios y se van a clasificar cada uno en la que mejor define su función. Las categorías son:

Viviendas, Oficinas, Universidad, Universidad sin laboratorio, Laboratorios, Comercio, Restaurante, Edificio de deporte, Servicios varios (Garaje, policía,…), Edificio histórico, Ocio, Biblioteca, Invernadero, Central eléctrica y Hospital.

Para cada categoría de edificio se va a asumir un consumo diferente de energía basado en datos reales y expresado en KWh/SF.

Tabla 5 Categorias y subcategories de edificios y su correspondiente ratio de energía en KWh/SF

Categoria	Subcategoría	KWh/SF al año
Universidad	29%Office 50%Classroom 20%lab 1%Cafeteria	25.68
***Universidad sin lab**	29%Offices 70%Classroom 1%Cafeteria	7.57
Oficinas	100%Offices	18.72
Oficinas y Lab	50% each	56.16
Vivienda	85%Rooms 15%Kitchens	21.66
Restaurante	20%Kitchen 80%Living room	65.59
Laboratorio	100% lab	93.6
Hospital	Surgery rooms/Patient Rooms/Offices	57.36
Hospital&Lab	80%Hospital 20% Lab	64.6
Ocio	75%Living rooms for events 10%Cafe 15%Offices	13.27
Deporte	Can be dry, Combined(with pool), ice rink for Hokey.	41.62
Biblioteca	60%living rooms 40%Computer labs	26.84
Invernadero	100% Plantation	67.2
Servicio	Police/Boat/Garage	25.88
Central eléctrica	100% Machinery and Labs	
Comercio	Store 100%	13.8
Historico	100%Space	13.27

Con los estándares de la EPA y teniendo en cuenta las categorías en las que el dato de KWh/SF ha sido obtenido de California, se aplica el factor de conversión de California a Madison para dichas categorías con la siguiente fórmula:

$$SF_{Building} * \frac{MWh_{California}}{SF} * \left(\frac{lbCO_2}{MWh}\right)_{California} * \frac{lbCO_{2_{Madison}}}{lbCO_{2_{California}}} = lbCO_{2_{Madison}}$$

El resto de categorías en las que la información se ha obtenido directamente del estado de Wisconsin no necesitan facto de conversión. Luego la ecuación queda simplificada:

$$SF_{Building} * \frac{MWh_{Madison}}{SF} * \left(\frac{lbCO_2}{MWh}\right)_{Madison} = lbCO_{2_{Madison}}$$

Los resultados obtenidos se muestran a continuación:

Tabla 6 Emisiones de GEI totales por tipo de edificio.

Categorias	Kg de CO2	Kg de CH4	Kg de N2O	Kg de CO2e
Viviendas	16,917,540	2,012,753	296,307	17,051,011
Invernadero	1,747,236	207,876	30,602	1,761,021
Edificio Historico	334,163	39,757	5,853	336,799
Hospital	959,396	116,754	17,024	975,860
Hospital/Lab	37,890,426	4,507,989	663,643	38,189,364
Hospital/Universidad	3,188,808	379,386	55,851	3,213,966
Lab	55,990,532	6,661,438	980,663	56,432,272
Ocio	5,509,875	655,534	96,504	5,553,346
Biblioteca	7,770,004	924,431	136,090	7,831,305
Oficinas y clases	60,895	7,245	1,067	61,375
Oficinas	794,404	96,675	14,097	808,036
Oficinas & Lab	29,544,216	3,515,004	517,461	29,777,306
Restaurante	3,522,559	419,094	61,697	3,550,351
Comercio	70,081	8,338	1,227	70,634
Universidad	13,404,523	1,631,267	237,861	13,634,545
Universidad & deportes (seco)	130,626	15,541	2,288	131,657
Universidad sin Lab	365,665	44,500	6,489	371,940
Servicio	688,011	81,856	12,050	693,439
Servicio & Ocio	100,677	11,978	1,763	101,471
Servicio & Oficinas	976,772	116,211	17,108	984,479
Deportes combinados	5,026,530	598,028	88,039	5,066,187
Deportes seco	11,849,368	1,409,771	207,539	11,942,854

Deportes Patinaje sobre hielo	6,926,029	824,020	121,308	6,980,672
Total	**203,768,337**	**24,285,446**	**3,572,531**	**205,519,891**

Al final, se harán algunas propuestas para reducir las emisiones de GEI del campus para cada tipo de edificio en particular. Como consecuencia, la certificación LEED tendrá lugar al final del proyecto como objetivo a conseguir por los edificios de nueva construcción o las renovaciones de los edificios ya construidos.

Algunas conclusiones extraídas de la investigación anterior son:

- La cantidad de gas liberado no es un dato consistente para asegurar cuál de los gases es la mayor amenaza para la atmósfera puesto que cada uno afecta de una forma diferente.
- Los edificios empleados exclusivamente para laboratorios, son los que mayor energía consumen. Esto es debido a los equipos que utilizan y a la necesidad por ejemplo de chimeneas para limpiar el aire del ambiente que consumen mucha energía.
- Para disminuir las emisiones es necesario aumentar la concienciación de los accionistas de las partes interesadas para que utilicen métodos, aunque no sean mejores tecnológicamente, sean cuidadosos con el medio ambiente.
- Cambio del uso de fuentes convencionales de energía a sistemas de cogeneración o de tecnología híbrida disminuiría considerablemente las emisiones de carbono.
- La mejora del rendimiento térmico del aislamiento del edificio conduce a la reducción de emisiones de carbono.
- El proceso de construcción debe ser más respetuoso con el medio ambiente.
- Los materiales y los procesos utilizados en los edificios deben ser identificados y evaluados, ayudando de esta manera a mejorar la eficiencia energética *(Ralegaonkar, 2011)*
- Los métodos de simulación deben ser utilizados en la fase de diseño para mejorar la eficiencia energética del sistema de construcción dando lugar a la reducción de las emisiones de carbono. El método de simulación es el mejor para predecir la carga de calefacción y refrigeración *(Ralegaonkar, 2011).*
- Cada universidad es diferente, hay muchos factores que deben ser considerados (tamaño, ubicación, tipo de universidad) para hacer comparaciones consistentes.

- El inventario de emisiones de GEI proporciona información más detallada que la huella de carbono, ya que mantiene separadas la liberación de cada gas. Sin embargo, los resultados de huella de carbono son más fáciles de interpretar, ya que sólo utiliza CO_2e.
- Invertir en equipos más ecológicos de HVAC puede ahorrar mucho dinero, ya que en los edificios de Estados Unidos de media representa el 48% de las emisiones.
- Una propuesta que puede ayudar a reducir fácilmente las emisiones de GEI es obligando a que todos los edificios residenciales recopilen la información sobre su consumo de energía eléctrica y de calefacción.

Más del 25 por ciento de los costos anuales de energía de Madison (3,6$ Millones sobre casi 14$ millones de dólares) se gastan en edificios e instalaciones de energía *(Eric Anderson, 2012).* Un hogar estadounidense promedio gasta más de 2000$ al año en facturas de energía, de donde la mayor parte corresponde al gasto destinado a calefacción y refrigeración *(EPA, Green building, 2016).* La reducción del consumo de energía en los edificios favorecería al medio ambiente reduciendo las emisiones de GEI, ayudando a su vez a la población de Madison a ahorrar dinero. *(Eric Anderson, 2012)*

En 1990 los edificios de UW-Madison utilizaron 995,299 termas (1 EEUU therm= 29 kWh) de gas natural y 15,986,473 kWh de electricidad por un coste total de aproximadamente 1,3$ millones. Se han aplicado algunas mejoras a los edificios del campus de UW-Madison mejorando los sistemas de aislamiento, como volver a techar, modernizando las puertas, reemplazando ventanas, etc. El ahorro de energía una vez aplicadas estas medidas aun no ha sido documentado. Los gastos, sin embargo, se sabe que han estado entre 300.000$ a 500.000$, y los ahorros anuales de estas medidas se estiman en 40.000$ / año. *(Somers, 2002)*

Ninguna de las políticas consideradas en este informe resultará, por sí sola, en reducciones de emisiones de GEI en una escala lo suficientemente grande como para alcanzar el objetivo propuesto para Madison de reducir en un 80% las emisiones de GEI para el año 2050. *(Lydersen, 2016)* . Sin embargo, si gradualmente contribuimos a implementar medidas para mejorar la situación, los resultados serán apreciados considerablemente. Grandes cantidades de dinero hace falta invertir para lograr estos objetivos. Por lo tanto, además de considerar la eficacia de algunas de las alternativas de reducción de GEI disponibles, se debe considerar el impacto económico.

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SUSTAINABILITY PERSPECTIVE

WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

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Introduction

Global overview

Since 1880 until 2015 the average temperatures in USA have follow a steady uptick significant and is expected to continue if action is not taken to greatly reduce greenhouse gas emissions *(Hasen, 2006).*

The World Meteorological Organization's (WMO) is working on this issue by reporting annually in the 'Greenhouse Gas Bulletin' the atmospheric concentrations of greenhouse gases. Emissions represent what goes into the atmosphere. Concentrations represent what remains in the atmosphere after the complex system of interactions between the atmosphere, biosphere, cryosphere and the oceans. About a quarter of the total emissions are taken up by the oceans and another quarter by the biosphere, reducing the amount of CO_2 in the atmosphere.

Thus, due to Greenhouse Gas (GHG) emissions there is a change in the energy present in the atmosphere called, Radiative Forcing (RF). The three major greenhouse gases that take part in the radiative forcing changes are, CO_2, CH_4 and N_2O and their presence have tend to increase during the past 31 years. According to the Greenhouse Gas Bulletin in 2015 *(World Meteorological Organization, 2016),* Carbon dioxide (CO_2) accounted for about 65% of radiative forcing by long-lived GHG. Methane (CH_4) contributes to about 17% of radiative forcing. Nitrous oxide (N_2O) accounts for about 6% of radiative forcing by long-lived greenhouse gases. Lastly, the other long-lived GHG such as Ozone-depleting chlorofluorocarbons (CFCs), together with minor halogenated gases, contribute about 12% to radiative forcing by long-lived greenhouse gases. *(Theis&Cynthia Klein-Banai and Thomas L., 2011)*

Buildings in the United States comprise the 40% of energy consumption and likewise carbon emissions. This means that some measures related with buildings should be considered. As a considerable amount of square feet in USA is referred to college, this is going to be the main concern of the project. The U.S. Environmental Protection Agency reported that: The Energy Department estimates that colleges and universities spend around $6 billion annually on energy. For the Madison area, colleges and universities represent a big range of building types including office, classroom, residential, laboratory, health care, and leisure or sporting buildings.

Background on different university campus

1- Campus Ecological Footprint Analysis (EFA) to Campus Carbon Footprint (CCF)

Since the 1960s, people on college and university campuses have made great strides toward making their campuses "greener" places. *(Venetoulis, 2001)* Consequently, in some campus areas more trees have been planted, a higher percentage of waste is being recycled or composted, energy is being conserved, there has been a decline in the use of some toxic products, and other applications are still being developed. For instance, the University of Redlands, California USA *(Venetoulis, 2001)* and Southeastern Louisiana University *(Caprice Lee, 2017)* have as a goal to reduce the negative impact their campuses have on the environment and working towards to reduce their dependence of the grid using renewable technologies.

An ecological footprint is the area of productive land and water required for a given population to maintain their consumption and absorb the ensuing waste over the course of one year at prevailing levels of technology. This definition was given by the University of Redlands, California. *(Venetoulis, 2001).* Another way to explain it would be that the EFA is a metric that measures how much nature we have and how much nature we use. Deepening, it measures the ecological assets that a given population requires to produce the natural resources it consumes and to absorb its waste, especially carbon emissions *(Network, 2017).*

The Environmental Studies Department of Redlands University worked out on a project using the uncompleted worksheet seen in Appendix A. The ecological footprint analysis starts with the observation that within a given period of time all consumption of energy and materials, and all discharge of wastes, require a finite amount of land and water area for resource production and waste absorption. Building upon previous studies, Wackernagel led a team in 1997 and again in 1999, of researchers that estimated the amount of ecologically productive land available and consumed in 52 countries and "the rest of the world". This approach *(Venetoulis, 2001)* held that consumption of ecologically productive land across most countries is above renewable rates and globally there is "consumption gap", which means that what it's been consumed is more than what the renewable services can provide over the course of a year (indefinitely).

After conducting a EFA for Vancouver (Canada), another EFA for 29 of the largest cities of the Baltic region of Europe, also for the five-county Los Angeles metropolitan area and for southern California, Venetoulis, it’s been revealed that the stock of nature's capital is being used up to fill the “consumption gap”. If this persists long time, the consequences would involve a decrease in the population carrying capacity. Improvements in technology should be studied because there is high probability that they could rectify this situation. *(Venetoulis, 2001)*

The University of Redlands has used a different method to pursue the campus ecological footprint analysis. This method takes into account, the ecological impacts associated with water (hydroprint), solid waste (wasteprint), energy (energyprint), and transportation (transportprint).

It should be noticed that the method considers the biggest ecological impacts, including hydroprint, wasteprint, energyprint, and transportprint. However, they are not explained in detail and do not provide a comprehensive estimate for all the potentially relevant as they are simplified to make it easier for data collection. Although the point remains, the findings presented in this paper only reflect part of the University's total ecological impact. As it can be expected, even this partial ecological footprint has important sustainability implications and encourage us to apply new methods to improve the current situation.

Once understood the EFA concept, it should be taken a step forward and explain the campus carbon footprint concept which is widely used. The CCF refers to the land area required to assimilate the entire CO2 produced by the mankind during its lifetime. The way of calculating it, requires almost the same data depending on the accuracy of the calculation. The results are also area units (square feet). An advantage of using CCF above EFA is that CO2 emission are a more representative and easier to interpret units than waste quantities. CCF is a quantitative expression of GHG emissions from an activity and can help in emission management and evaluation of mitigation measures. The following table present the total equivalent CO2 emissions (which accounts also for other GHG gasses besides CO2) of some universities around the world:

Table 7: CO2 equivalent emissions in 16 universities around the world. *(Thapelo C M Letete, 2011)*

University	No of Students	Emissions [Tons CO_2-eq]			Capita	Total Emissions/		Year
		Energy	Transp	Waste	Others	Total emissions	Tons CO2eq/student	
National Univ. of Lesotho	8 566	573						2007
City Univ. London	12 861	10 686	-		1 597	12 283	0.96	2007
University of Glasgow	23 590	27 000					0.00	2006
University of Cape Town	21 175	69 083	14	708	279	84 925	4.01	2007
Univ. of Texas at	25 297	88 830				98 700	3.90	2005
University of Delaware	19 359	116 614	33	2	54	152 542	7.88	2007
University of Maryland	36 014	224 733	118	4	3 386	351 145	9.75	2007
Rice University	5 061	31 986				69 032	13.64	2007
Harvard University	29 900	192 230						2007
University of Connecticut	20 229	171 993	24	487	1 025	197 753	9.78	2007
Purdue University	39 102	378 400				668 800	17.10	2007
Hollins University	1 039	16 874	1 000	75	137	18 086	17.41	2007
Univ.y of Pennsylvania	26 537	317 000	25	5	0.48	348 298	13.13	2007
Yale University	11 851	244 814	34		11	290 954	24.55	2002
Vanderbilt University	11 577	247 877	53	1	134	302 417	26.12	2007
Massachusetts IT	5 909	195 861	16	2	0	215 075	36.40	2003

The University of Purdue has the largest student population in this list and is the one that has the more similar dimensions to UW-Madison. UW-Madison has around 43,000 students so it could also be approximated to say that UW-Madison emissions are twice as much as University of Cape Town. This approximations could give an idea of the results over the university emissions.

Table 2: CO2 equivalent emissions in UW-Madison assuming similar emissions due to number of students coincidence from Purdue and Cape Town Universities.

University	No of Students	Emissions [Tons CO_2-eq]			Capita	Total Emissions/		Year
		Energy	Transp	Waste	Others	Total emissions	Tons CO2eq/student	
UW-Madison	39 102	378 400				668 800	17.10	2007
UW-Madison	42 350	138 166	28	1416	558	169850	8.02	2007

From the two assumptions above, we can appreciate that both of them are very far from each other so it could be concluded that the number of students give only the scale of the university but is not a good way of comparing universities. There are other facts that should be regarded when comparing two universities with apparently the same size when your interest is focus on the emissions. For instance, if the courses that the particular university offers require labs or not as if not the university is less environmentally intensive. Moreover, if the university offers many online courses or not. Besides, the quality of the university and the modernity of it, which would include more technology devices, installed therefore more emissions.

2- Previous studies

i. Australian National University (ANU)

The Australian National University (ANU) affirms that education for sustainable development (ESD) should pursue an integrative approach in modelling sustainability in the core functions and systems of the university. Some universities are beginning to attempt to model what a sustainable system might look like. *(Dyball, 2009)* As institutions, which prepare future leaders, it is imperative that they demonstrate environmentally responsible action. A number of higher education institutions have taken steps to integrate sustainability into the university community by signing the Talloires Declaration, which is a 10-point action plan for incorporating sustainability into the institution. A whole-of-university approach addresses the Talloires commitments to sustainability by explicitly linking research, educational and operational activities. *(Dyball, 2009)* It can be assumed that a university operates with the complexity of a mini-city, and all its interdependent parts must be considered if it is to develop in a sustainable manner. This approach seeks to break down currently existing barriers between functional units of the institution. For example, the university structure may not allow for research-led teaching or an education linked to campus operations. Campus operations and facilities management are generally viewed as an independent part of the university and as having little relevance to curriculum or research. A whole-of-university approach, however, recognizes that all functions of the institution can benefit from sharing knowledge and that each influences the student learning experience.

ANUgreen is the Sustainability Office of the Facilities and Services Division of the university. *(Dyball, 2009)* This office demonstrates that campus operations and management can play a vital role in increasing students' awareness and understanding of sustainability. The ANU is building a whole-systems educational program that links the principles of sustainability being taught in the classroom with the principles of sustainability being implemented on the campus. A good example of linking curriculum, research and operations at the ANU involves the university's 12-month trial of an in-vessel organic waste composting unit. Operationally, this trial seeks to divert from landfill 90 per cent of the organic waste on campus, including food waste from residence halls and campus cafes. On the curriculum front, students are analyzing the emissions offset by diverting this waste stream from landfill. In research, both students and academics are looking at the microbial communities in the compost to enhance understanding of the composting process and to improve the process itself. The convergence of education, research and operations in this trial shows an important link between the everyday practice of food consumption and actions that both the individual and the institution can take to achieve positive outcomes. Given the complex nature of sustainability issues, it is imperative that institutions of higher education pursue an integrative approach in modelling sustainability in their core functions and systems. A whole-of-university approach to sustainability ensures that core functions such as management and operations, which have traditionally been viewed as providing only logistical support to the academic mission of the institution, become an intentional part of the curriculum. *(Dyball, 2009)*

ii. Delft University of Technology (TU Delft), Netherlands.

The Delft University of technology divide the Campus management in four different perspectives. This division could help other universities such as UW-Madison to arrange their management to leave space for the environmental concern. The four perspectives are:

- The Strategic side use is related to competitive advantage of the management team.
- The financial statement is directly related to the profitability of the campus management.
- The physical area involves the sustainable development, which is our main concern.
- The functional part is the result of the campus management team productivity when dealing with operations.

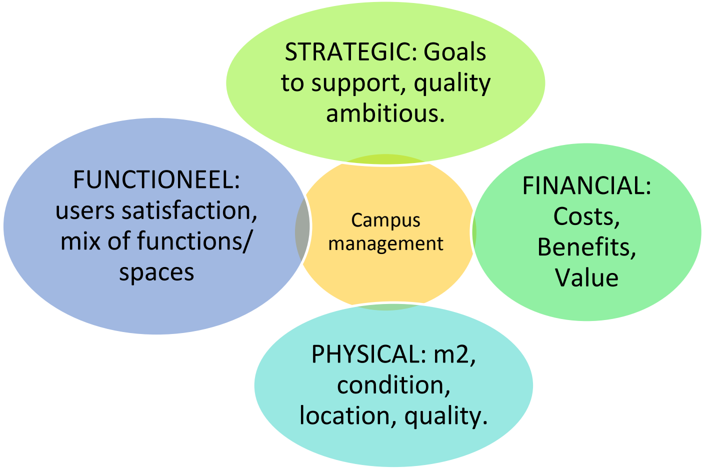


Figure 1: The 4 perspectives of campus management. *(Heijer, 2012)*

iii. The University of Illinois in Chicago UIC

The University of Illinois in Chicago (UIC) prepared a GHG inventory for fiscal years 2004–2008. UIC conducted a survey to obtain data regarding the commuting habits of its faculty, staff, and students. In the year 2008, UIC's carbon footprint was 275,000 metric tons of CO2 equivalent which is not significantly higher than the 2004 emissions that were 273,000 metric tons of carbon dioxide equivalents. The percentage of the three main sources of emissions were buildings, commuting and waste as shown in the figure:

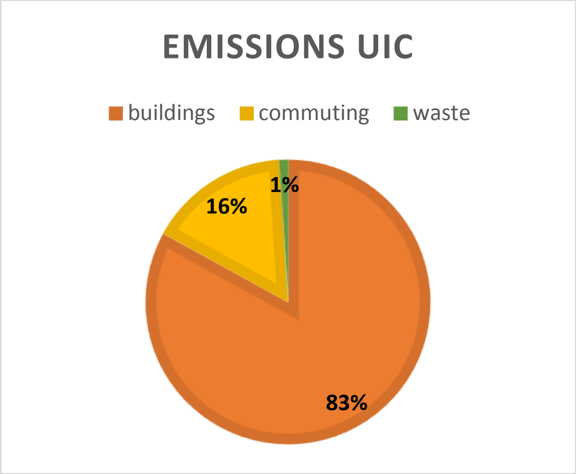


Figure 2 GHG Emissions 2008 data. *(Cynthia Klein-Banai&Thomas L. Theis, 2010)*

When compared to 85 other doctorate-granting universities, UIC's gross emissions per square foot are 21.4% lower than average. *(Cynthia Klein-Banai&Thomas L. Theis, 2010)* The variation in the emissions over the five years studied is largely influenced by the amount of electricity purchased and the mix of sources of that electricity (For instance: nuclear vs. coal). Conducting a baseline GHG inventory can serve as a measure of progress toward more sustainable practices within an institution and as a tool for developing goals, strategies and policies to reduce emissions.

iv. California State Polytechnic University

This university made a GHG inventory, to deliver a comprehensive emissions inventory for meeting the reporting requirements of the ACUPCC (American College & University Presidents Climate Commitment), which would be also a goal for UW-Madison approach. Besides, the University attain to establish an emission baseline to which it can be compared in future emission reduction efforts and track the progress over time towards our goal of climate neutrality. This objective can also be applied to UW-Madison to enlarge and summarize the data collected, to facilitate the data gathering process as well as accuracy of the data in future reports.

The main weakness of the 2010 report is the absence of emissions data from student commuting. CSULB (California State University, Long Beach) acknowledges that this missing piece of information is significant and must be addressed in future reports. A transportation demand management plan and study will directly address this shortfall by developing an all-inclusive transportation survey for faculty, staff and students. The survey will be conducted every spring and results from this annual survey will provide the needed data for a comprehensive greenhouse gas inventory.

The following graph represents the emissions inventory in The Polytechnic University of California in 2010.

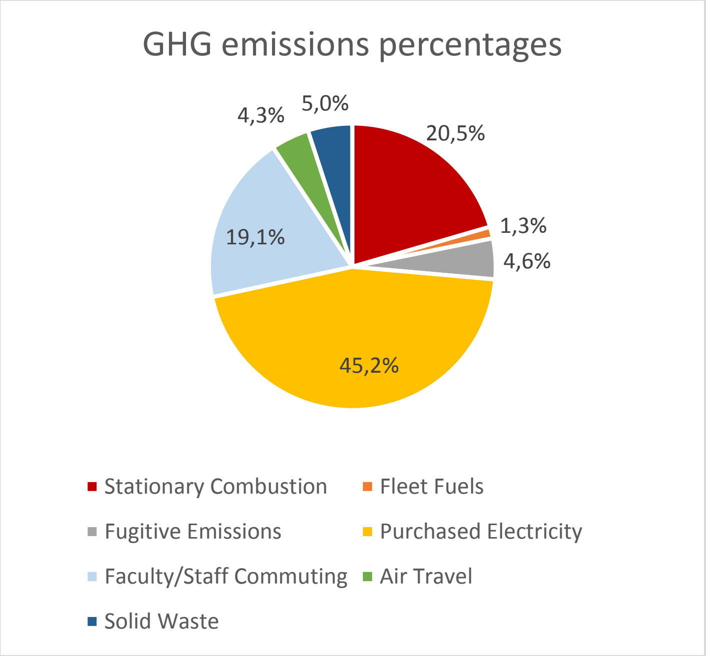


Figure 3 GHG Emissions in 2010 in CSULB *(Paul Wingco, 2013)*

Total 2010 GHG Emissions 29516 (In Metric Tons of equivalent CO2).

(Paul Wingco, 2013)

v. College of Charleston

The College of Charleston emitted a combined total of 67,812 Metric tons CO2e (carbon dioxide equivalent) in 2011. This represents a footprint in the higher range for similarly sized liberal arts & sciences institutions. *(P. Brian Fisher Ph.D., Spring 2012)***.** Relative to other schools of higher education, the College has emissions directly owned by the College comprise 9.7% of our footprint, while emissions indirectly controlled by the College such as energy production, comprise 52.2%, finally emissions affiliated with the College's operations such as travel and commuting, represent 38.1% of the footprint.

Energy represents the largest component of the College's footprint, comprising 61% of total emissions. Transportation comprises 28% of total emissions, with almost 17% of total emissions from commuting and 11.5% from College-supported air travel. The remaining 3.6% consists of various wastes generated by the College.

The current footprint suggests focus on energy and transportation, but future projections of CofC's (College of Charleston) footprint suggest that total emissions will more than double by the year 2050 with the majority of those emissions coming from energy usage. This suggests that reducing our footprint should focus on building efficiency, energy infrastructure and use, and finding ways to create more cost effectiveness for our energy trajectory. Therefore, measures should be taken also in UW-Madison to prevent 2050 forecasts. Hence, some energy efficiency recommendations will be made at the end of the report.

(P. Brian Fisher Ph.D., Spring 2012)

vi. Drexel University

Drexel University, as many others, in 2009 elected to perform a Greenhouse Gas Inventory. The purpose of this Inventory was to benchmark the University's greenhouse gas emissions and to provide a consistent methodology for inventorying its emissions on an annual basis, from then on. A Greenhouse Gas Inventory is necessary to set the most appropriate and efficient steps to reduce the institution's carbon footprint and potentially achieve carbon neutrality, so in this matter it is going to be performed for UW-Madison.

The total greenhouse gas emissions for Drexel University for fiscal year 2008 are 41,369 Metric tons eCO2 for the University City Main Campus. This equates to:

- Either, 3.30 Metric tons of eCO2 per full time equivalent student primarily enrolled at the University City Main Campus (12,529 students).
- Or, 12.5 Metric tons of eCO2 per 1,000 square feet.

Drexel's greenhouse gas emissions are due to:

- 739 Metric tons of eCO2 from 23,671 gallons of gasoline and 30,129 gallons of diesel fuel of University Fleet usage
- 33,068 Metric tons of eCO2 from 57,352 MWh of Electricity purchased.
- 5,792 Metric tons of eCO2 from 81,037 thousand pounds of Steam purchased.
- 1,770 Metric tons of eCO2 from 318,998 hundred cubic feet of Natural Gas and Oil used onsite. *(Ms Barbara A.W. Clarke, 2009)*

The relation (percentage) between the different main components that contribute to the greenhouse gases releases is very similar for all the university campus inventories, so it can be a benchmark to assess the overall amount of emissions considered in this project, as it is only going to consider the UW-Madison Campus buildings neglecting the transport emissions for instance.

vii. Pennsylvania State University

Pennsylvania State University is a public institution that was founded in 1855. It has a total undergraduate enrollment of 40,742, its setting is city, similar to UW-Madison conditions with the fact that UW has 43,192 students. Penn campus size is 8,556 acres 9 times bigger than UW Campus. *(Pennsylvania State University, n.d.)*

Penn State as UW-Madison, is working on different measures to reduce its greenhouse gas emissions by 35% (from its 2005 peak) by 2020. It has an even more ambitious target of an 85% reduction by 2050. UW has a similar target of reducing its carbon emissions by 80 percent by 2050.

The majority of Penn State’s emissions come from energy production and consumption. Through 2020, emissions will come from the production of purchased electricity and from the operation of the steam plants. Another large contributor to emissions would be commuter traffic.

Most of the University’s reductions have come from some strategies, with 56% coming through its Energy Program. The University has already dropped its energy usage, despite the fact that during that same time the University added more than 1 million square feet of building space.

An investment of almost $75M over a 10 year period in energy conservation initiatives ranging from tuning up existing buildings to optimize their performance, installing HVAC upgrades, updating temperature controls, retrofitting lighting fixtures, installing occupancy sensors, and improving building envelopes. These investments in energy efficiency will continue over the next three decades, as will the deployment of a targeted renewable energy sources.

Aerospace technology it’s been adapted as a way of creating steam and generating electricity, helping in this way to reduce energy consumption. A Combustion Turbine and Heat Recovery Steam Generator was installed in the East Campus Steam Plant improving the efficiency of the steam system, and reducing our emissions drastically.

Conversion from coal to natural gas has increased the reduction of the energy required. Three coal-fired boilers have been replaced by two, new, high-capacity, gas-fired boilers. The switch from coal to natural gas and upgrades to both East and West Campus Steam Plants will improve on Penn State’s already highly efficient District Energy System. In 2011 PSU’s system operated at 72%. At the time the project will be completed, the system will operate at 80%.

In addition to providing sustainable energy, the partnership offers exciting educational opportunities for students. Interns from engineering and environmental science are involved in areas such as design, management practices, power generation, economics, and environmental impact. The project currently supports five interns each year.

In order to influence behavior, the University adopted an Energy Conservation Policy designed to lower energy consumption through employee and student action. This policy establishes guidelines and practices for lighting use, interior space temperature setpoints, computer power management, and the use of office equipment, appliances, and fume hoods. *(The Pennsylvania State University, 2015)***.** This policy would be recommendable for UW to apply it as well. *(AASHE, n.d.)*

viii. University of Maryland

University of Maryland President Mote signed the American College and University Presidents Climate Commitment in 2007, which is a pledge to reduce campus GHG emissions and achieve carbon neutrality. Neutrality is defined as the process of reducing and offsetting carbon producing operations that makes the campus net carbon emissions equal to zero.

The University’s GHG emissions ranged from a high of 376,670 metric tons of CO2e in 2003 to a low of just under 352,000 metric tones of CO2e in 2007. The latter amount is equivalent to the GHGs emitted by 60,000 cars or sequestered by 105,000 acres of Maryland forest in a year. *(David Tilley, 2007)*

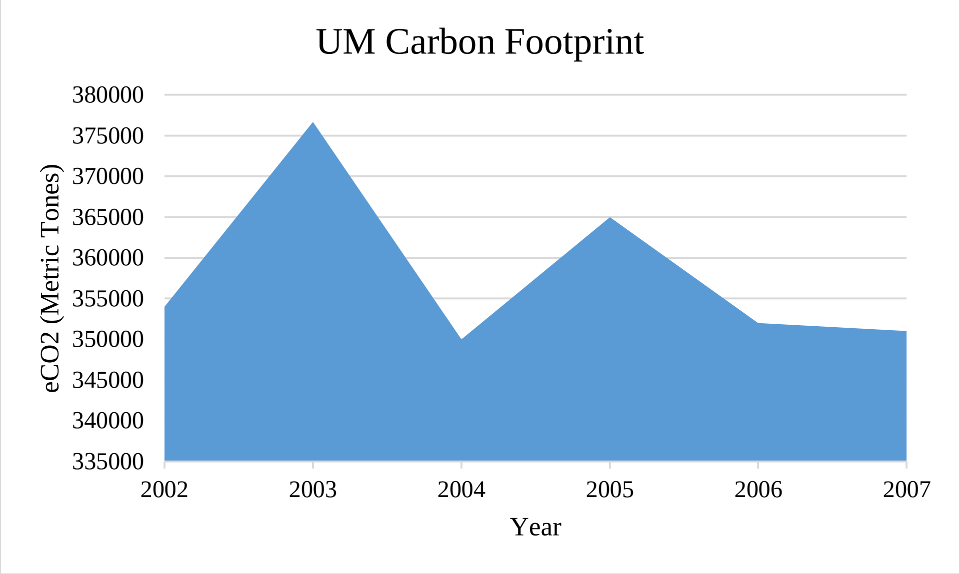


Figure 4 Total University greenhouse gas emissions (FY 2002-2007) associated with energy use, agriculture, solid waste and refrigerant releases. *(David Tilley, 2007)*

The inventory demonstrated that the major sources of GHG emissions were from the electricity (40%) and steam produced by the campus co-generation plant (23%), purchased electricity and transportation including daily commuting of the campus community, air travel and the University fleet (34%). In 2007, these sources accounted for 97% of the campus GHG emissions. Other emissions from small stationary sources, solid waste, refrigerant releases and agricultural operations together account for only 3% of total GHG emissions in 2007. *(David Tilley, 2007)*

3- Solutions to Implement due to background researches.

As not for-profit institutions, higher education has not been driven by the same lean operating principles as business and industry. Lean management is an approach to running an organization that supports the concept of continuous improvement, a long-term approach to work that systematically seeks to achieve small, incremental changes in processes in order to improve efficiency and quality. *(Rouse, n.d.)* Four things that have been applied in some higher education institutions due to Lean Management are: 1) led efforts to reduce confusion and rework by simplifying the school's programs and requirements; 2) conducted seminars for faculty on Lean management and important tools such as root cause analysis; 3) applied Lean principles and practices to the particular courses taught; and 4) gained the participation of faculty, staff, alumni, and senior managers to improve a graduate M.S. in management degree program using kaizen (a Japanese business philosophy of continuous improvement of working practices, personal efficiency, etc.) . *(Bob Emilani, 2005)* Yet, higher education typically owns, operate and maintain their facilities for decades, if not centuries. Academic institutions have recognized that they are well prepared to take on a leadership role in fighting climate change due to their role in educating future generations of leaders. *(Georges Dyer and Jennifer Andrews, 2014)* This responsibility extends to the institution's own greenhouse gas emission reductions, energy and water conservation, and other sustainability initiative. It's considered a sustainable university a higher educational institution, that addresses, involves and promotes, the decrease of negative environmental, economic, societal, and health impacts produced while using the necessary resources in order to fulfill the teaching, research, outreach and partnership functions, besides stewardship in ways to help society to change their habits to more sustainable lifestyles. Using a whole systems approach to the greening of the campus bridges academic content, administrative policies, and facilities management practices and enables campus wide opportunities for education for sustainability. Further, we can learn from what other universities are doing around the world to solve these global issues. Reducing greenhouse gas emissions to combat climate change is one way to minimize environmental impact. To begin with, the average consumption per student should decrease. The following table shows the CO2 emissions per student in the seven universities reviewed in the previous section.

Table 3. Summary from the universities students CO2 emissions.

University	Emissions per student (t CO2e/Student)
ANU (Phelps, 2009)	110,450 t CO2e. /21,113Students= 5.23
UIC *(Cynthia Klein-Banai&Thomas L. Theis, 2010)*	275,000 t CO2e. /29,048Students= 9.47
California State Polytechnic University *(Paul Wingco, 2013)*	29,516 t CO2e. /20,944Students= 1.41

College of Charleston *(P. Brian Fisher Ph.D., Spring 2012)*	67,812 t CO2e./11,619Students= 5.84
Drexel University *(Ms Barbara A.W. Clarke, 2009)*	41,369 t CO2e./12,529Students= 3.30
Penn State University *(Pennsylvania State University, n.d.)*	499,740 t CO2e./99,133Students= 5.04
University of Maryland *(David Tilley, 2007)*	352,000 t CO2e./38,140Students= 9.23

From this table we can assume that California State University sustainability measures should be regarded even though it has a very different climate from UW-Madison. Moreover, Drexel University students also emit little amount of CO2 and the climate conditions are quite more similar to UW-Madison. Therefore, some recommendations to apply in UW-Madison will be taken from Drexel University example.

A holistic university approach not only encourages the institution to look at its own EFA or CCF but it also recognizes that students learn from the entire experience of their university career, not only from what is taught within the classroom walls. Students learn from how energy, land and water are used (or misused) on campus. By modelling a sustainable system and ensuring that students are exposed to the concepts of sustainability in their everyday lives, a whole-of-university approach encourages awareness and environmentally responsible action. Given the importance of the shadow curriculum as demonstrated by student awareness of ANUgreen, overlooking the lessons offered by the campus itself neglects an important component of a student’s education. This is especially true if that student is a campus resident. Working to build a whole-of-university educational program that links the principles of sustainability being taught in the classroom with the principles of sustainability being implemented on the campus is one of the most tangible ways to help students see the connections between theory and practice and the relationship of their studies to the campus itself and to the broader world. Many universities are taking proactive steps towards reducing the environmental impact of their operations, and these initiatives can positively benefit from student input. By encouraging a collaborative space within the curriculum for students, academics and managers to critically reflect on university performance with regard to sustainability, many positive benefits can ensue including improvement in campus environmental performance and building the capacity of students to become agents of change.

Ultimately, it should be taken into consideration what a previous research on higher education found out. The study proved that distance learning High Education (HE) courses involve 87% less energy and 85% lower CO2 emissions than the full-time campus-based courses. Part-time campus HE courses reduce energy and CO2 emissions by 65% and 61% respectively compared to full-time campus courses. The research confirmed that the lower impacts of part-time and distance compared to full-time campus courses is mainly due to a reduction in student travel and elimination of much energy consumption of students' housing, plus economies in campus site utilization. On the other side, E-learning according to the research seems to offer only relatively small energy and emissions reductions (20% and 12% respectively) compared to mainly print-based distance learning courses, the reason is because online learning requires more energy for computing and paper for printing *(Roy & Potter, 2008).* This approach could open the door to new GHG emissions reduction methods rarely regarded.

LEED Certification

Leadership in Energy and Environmental Design (LEED) is an internationally recognized green building certification system created by the U.S. Green Building Council. *(Sustainability at American Colleges and Universities, n.d.)* The first prominent "sustainability" programs at colleges and universities focused on recycling of wastes such as paper, glass, and plastics. Recently attention to sustainability started encompassing the overall and perhaps greater impact that higher education plays in preparing future generations to address the impacts of human life on the planet.

Colleges and university new facilities are constructed to meet green building standards, and the administrators are developing green purchasing policies. Programs that promote public transit, carpooling, and bicycling are found on many campuses *(Cynthia Klein-Banai&Thomas L. Theis, 2010).* UW-Madison is committed to renovating and constructing buildings that aid in the success of its students and staff, and are sustainable for the years to come. In order to benchmark these practices, campus is pursuing a minimum of LEED Silver certification on most of its new and renovated facilities. In LEED certification, an effort is made to pursue points which have a strong return on investment *(University of Wisconsin-Madison, 2017)*. This initiative along with others, will gradually transform UW-Madison's campus to meet the needs of development today, without compromising the needs of future generations.

LEED Certified Projects

Table 4 LEED Certified Projects *(University of Wisconsin-Madison, 2017)*

Building	LEED Certification	Type
UW Medical Foundation Centennial Building	Gold	School
Education Building	Platinum	School
Wisconsin Institutes for Discovery	Gold	Lab
Union South	Gold	Leisure
Nancy Nicholas Hall	Gold	School
Student Athlete Performance Center - McClain Center	Silver	Sport
LaBahn Arena	Silver	Sport
Wisconsin Energy Institute	Gold	School
Lakeshore Residence Hall Phase II	Gold	Dwelling
Signe Skott Cooper Hall	Silver	School
Student Athlete Performance Center - Camp Randall North Addition	Silver	Sport

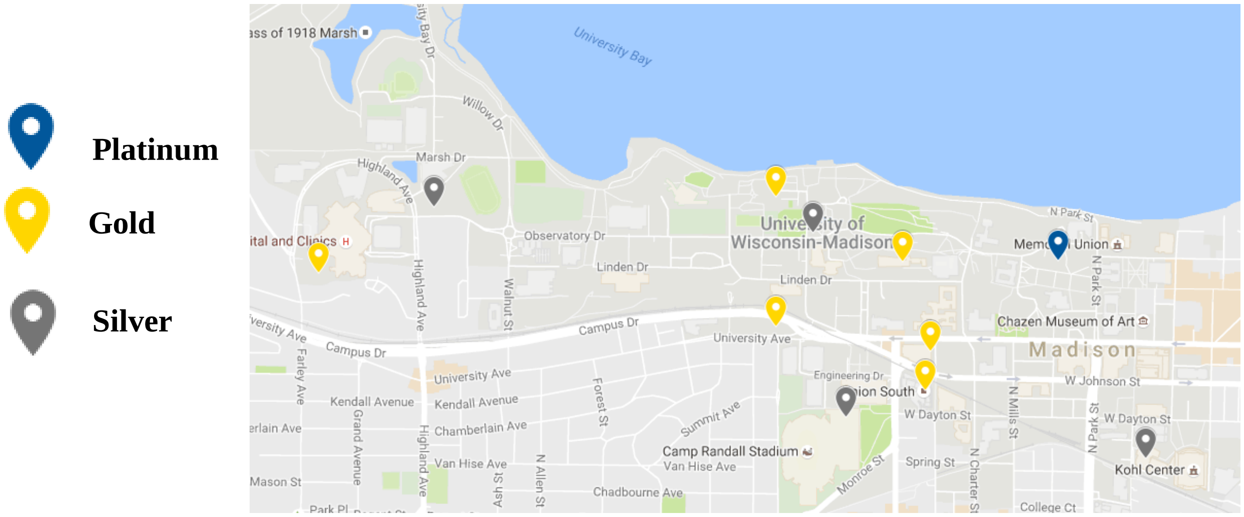


Figure 5 LEED Certified Projects *(University of Wisconsin-Madison, 2017)*

It is remarkable the platinum project, which renovated nearly 71,000 GSF in the existing Education building including a 37,000 GSF replacement and a four story addition. This project also included the reconstruction of the rear north facade.

- In June of 2011, The Education Building received LEED Platinum Certification and became an Energy Star rated building. This was the second building on the UW-Madison campus to achieve LEED Certification. LEED New Construction (version 2.2) was the rating system pursued for this renovation and addition and earned a total of 52 points.
- 77% of the core and shell of the previous Education Building were reused in the construction of the new building.
- The grand staircase and casework, including 40 doors from the original structure, were refurbished and restored for the new Education Building.
- The Education Building has a green roof which helps reduce the quantity and rate of storm water runoff.
- The Education Building is the first State-owned Energy Star-rated building in Wisconsin.
- Approximately 85% of the new wood content is Forest Stewardship Council (FSC) certified wood – which means the wood comes from a forest being managed in an environmentally responsible manner.
- During demolition and construction approximately 75% of non-hazardous materials were recycled and salvaged.
- Occupant controls for lighting and thermal comfort are located throughout the building so that occupants can control the settings for personal comfort while remaining as energy efficient as possible.
- Potable water consumption was reduced by 99.5% compared to a baseline building through the use of native plants, green roofs & harvesting rain water.
- Having green & reflective roofs along with underground parking helps reduce heat island effect by creating surfaces that do not readily absorb heat

- Compared to a baseline building, the Education Building uses 40% less water through many water-reduction strategies and conservation fixtures.
- Over 1500 buses stop each week day withing a quarter mile of the building and 318 bicycle stalls are located within 200 yards of the building providing easy commuter access.

Currently Tracking LEED Certification

Table 5 Currently Tracking LEED Certification *(University of Wisconsin-Madison, 2017)*

Building	LEED Certification	Type
Charter Street Heating Plant Upgrades	Gold	Power plant
Memorial Union Reinvestment Phases I	Silver	Offices
School of Music	Silver	School
Wisconsin Institutes for Medical Research Phase II	Silver	Lab

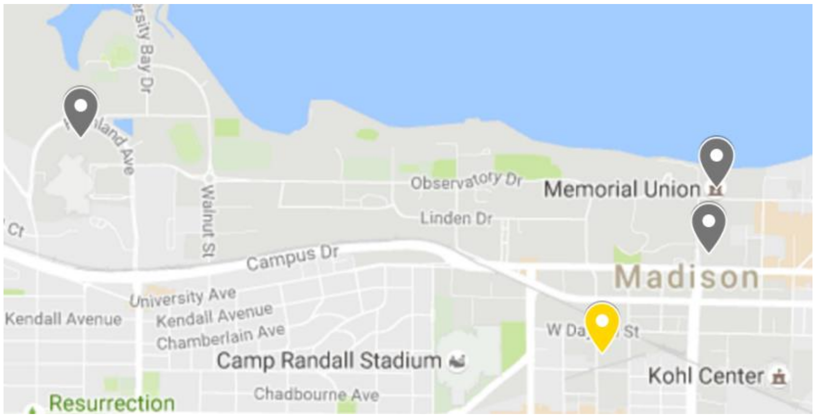


Figure 6 Currently Tracking LEED Certification *(University of Wisconsin-Madison, 2017)*

To explain the way these buildings work to implant measures to be more environmentally friendly it will be given the details of the gold tracking project. The campus Charter Street Heating Plant delivers heating and cooling to the campus. The project to track the gold certification includes providing a new water treatment system and mechanical, electrical and control system replacement and the following upgrades:

- There are four bus stops within a quarter mile of the building for public transportation.

- All plants and grass surrounding this site require no irrigation.
- Currently 80% of the construction waste has been diverted from the landfill.
- 70% of wood products are derived from sustainable forestry practices as certified by the Forest Stewardship Council (FSC).
- Low-emitting paints, sealants, adhesives, carpets and furnishings were used throughout this building to protect indoor air quality.
- No smoking is allowed around the building which also protects the indoor air quality.

UW-Madison concern

The University of Wisconsin–Madison is a public research university in Madison, Wisconsin, United States. It was first created when Wisconsin achieved statehood in 1848, UW–Madison is the official state university of Wisconsin, and the flagship campus of the University of Wisconsin System. It was the first public university established in Wisconsin and remains the oldest and largest public university in the state. It became a land-grant institution in 1866. The 933-acre main campus includes four National Historic Landmarks including The Wisconsin State Capitol. *(Academic Planning and Institutional, 2015)*

UW–Madison is organized into 20 schools and colleges, which enrolled 29,302 undergraduates, 9,445 graduate, and 2,459 professional students and granted 6,659 bachelors', 3,493 graduate and professional degrees in 2013–2014. The University employs over 21,796 faculty and staff. Its comprehensive academic program offers 136 undergraduate majors, along with 148 master's degree programs and 120 doctoral programs. *(Academic Planning and Institutional, 2015)*

The UW is one of America's Public Ivy universities, which refers to top public universities in the United States capable of providing a collegiate experience comparable with the Ivy League. UW–Madison has also a very high research activity in the Carnegie Classification of Institutions of Higher Education. In 2012, it had research expenditures of more than $1.1 billion, the third highest among universities in the country. Wisconsin is a founding member of the Association of American Universities. *(Britt, 2013)*

UW-Madison campus consists of approximately 250 different buildings. *(Somers, 2002)* For this project 219 have been found, however power plants are not going to be considered as buildings for our concern and neither two buildings which are considered as part of the university but they are not on the campus area. Hence, in the end 215 buildings are going to be studied. *(University of Wisconsin-Madison, n.d.).* The buildings operate in different manners depending on their use. Therefore, each building is going to be classified within a category. The different categories are:

Dwelling buildings, Offices, School buildings (which are compound of labs, classrooms and offices), Schools without a lab, Laboratories, Retail, Restaurant, Sport building, Service(Garage, Police Station…), Historic, Leisure, Library, Greenhouse, Power plant and Hospital.

This classification is based on a particular criteria that differentiates enough all the different buildings that integrate the UW-Madison Campus according to the energy consumption of each of it. The procedure on the selection of the most appropriate category for each building is looking what kind of building it is and what are its uses. Then a decision will be made over its category.

Each category require a different amount of energy per square foot as the utilities that the building require and the usage that will be given to them are very different from one to the other (e.g. The sports building over a Lab). This amount of energy per sq. ft. will be calculated with real data in the results section. Besides, the energy consumption of the buildings in the US are mostly due to heating, ventilation and air conditioning (HVAC) energy requirements. In Table 6 are shown the percentages that USA office buildings consumption usually follow.

Table 6: Energy consumption in offices in the USA by end use. *(Luis Perez-Lombard, 2009)*

Energy end uses	USA %
HVAC	48
Lighting	22
Equipment	13
DHW	4
Food preparation	1

Refrigeration	3
Others	10

These data could help to make a decision over future considerations of investing in better equipment for the different building energy uses. It can be concluded from table 4 that investing in a more environmentally friendly HVAC equipment would considerably reduce the energy consumption thus reducing CO2 emissions. On the other side, investing in a better cooking system wouldn't have a significant impact on the energy consumed.

Objective

The project will assess all UW-Madison on-campus buildings GHG emissions, and focus on the 3 main gases that have the higher impact, CO_2, $CH_4$and N_2O. Moreover, this project will provide recommendations and ideas on how to reduce its GHG emissions in order to reach a better LEED certification in the future constructed buildings.

First, previous research about other concerned universities with the sustainable issue have been done. In addition, it has been payed more attention to the ones that have counted its GHG emissions somehow. With this information, the scope of the project it's been defined and the attention has focused on the universities which have similar dimensions to UW-Madison to find some relevant data.

Secondly, the recruited data has been used to conduct a GHG emissions inventory of the UW-Madison campus. Since, it is not easy to find these data, different methods that could be applied are defined in case of sufficient data provided. EPA standards method will be applied to analyze the CO_2, $CH_4$and N_2O releases by the campus buildings. These releases are mainly, due to HVAC and electricity requirements. It has been chosen this method thankful to the available data. On the other hand, water, food, transportation around the campus and hazardous waste won't be considered as there is not available such detailed information.

Thirdly, some proposals are made to decrease the on-campus GHG emissions regarding each particular type of buildings. Consequently, LEED certification would take part at the end of the project as a target for the new constructed buildings or the renovating of the already existing ones to take these proposals into account to reach LEED certification standards.

Consequently, this report aims to encourage the students and policymakers of UW-Madison make better informed decisions regarding energy use and policy. This would come up with a mitigation of the effects of climate change. None of the policy options considered in this report will, on their own, result in GHG emissions reductions on a scale large enough to achieve the Madison city's stated goal of an 80 percent reduction in GHG emissions by the year 2050. *(Lydersen, 2016).* However, if gradually we contribute to implement measures to improve the situation, the outcomes will be considerably appreciated. Furthermore, big amount of money will likely be necessary to achieve these goals. Therefore, in addition to considering the efficacy of a few of the many GHG reduction alternatives available, the economic impact should be taken into account in future studies.

Methods

Greenhouse Gas (GHG) Emissions Inventory: 3 Scope system

First of all, to understand what a GHG emissions inventory is, the life cycle assessment (LCA) concept should be explained. LCA is a technique to assess environmental impacts associated with all the stages of a product's life from cradle to grave (i.e., from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling) *(ISO 14040, 2006)*. A GHG emissions inventory is a type of LCA that represents the environmental impact of several types of activities that are typically seen as targets for sustainability initiatives. In particular, this time the assessed product is going to be the campus buildings. It is going to be taken into account the energy used for heating, cooling and electricity. GHG inventories have some limitations as they do not account for hazardous waste disposal, air pollutants, water usage, or wastewater and storm water generation. A GHG emissions inventory allows to examine differences between energy sources, but major limitations of the approach are that other types of emissions, embodied energy, and material wastes associated with electricity generation are not. Although they do not account for all environmental impacts, they use a relatively simple, standardized methodology that is becoming a common measure of environmental impact and sustainability used by hundreds of universities across North America such as, California State Polytechnic University, Pomona, College of Charleston, University of New Hampshire and Washington University in St. Louis. *(Campus Ghg Inventories, n.d.)*

The basis for a climate action plan is a GHG inventory. The generally accepted methodology for conducting an inventory is based on the Greenhouse Gas Protocol developed by World Business Council for Sustainable Development and the World Resource Institute (WBCSD/WRI, 2001). Conducting a baseline GHG inventory can serve as a measure of progress toward more sustainable practices within an institution and as a tool for developing goals, strategies and policies to reduce emissions. Like many local governments around the country, the City of Madison is trying to reduce its emissions of heat-trapping greenhouse gases (GHG) such as carbon dioxide. *(Lydersen, 2016)* The university tries to accomplish the plan of reducing its carbon emissions by 80 percent by 2050, by reducing overall energy consumption by half by 2030, and get a quarter of its electricity, heating and transportation energy from clean sources by 2025.

These small-scale efforts can combine to have profound impacts. Through proactive measures around land use patterns, transportation demand management, energy efficiency, green building, waste diversion and more, local governments can lead the way to emissions reductions throughout the United States. To achieve that goal, the city of Madison partnered with the University of Wisconsin–Madison in 2010 to produce its first-ever emissions inventory. At the beginning of the process of inventorying emissions increased the city's efforts toward reducing GHG emissions. The city cataloged all energy use and resultant GHG emissions attributable to government operations.

A few years later when it was time to update that inventory with 2014 data, the UW–Madison graduate students team from the Nelson Institute for Environmental Studies, were pursuing an Energy Analysis and Policy (EAP) certificate in the spring of 2015. The outcomes verify that buildings are a major cause of GHG emissions as shown in figure 6 *(Carl Christiansen, 2015).*

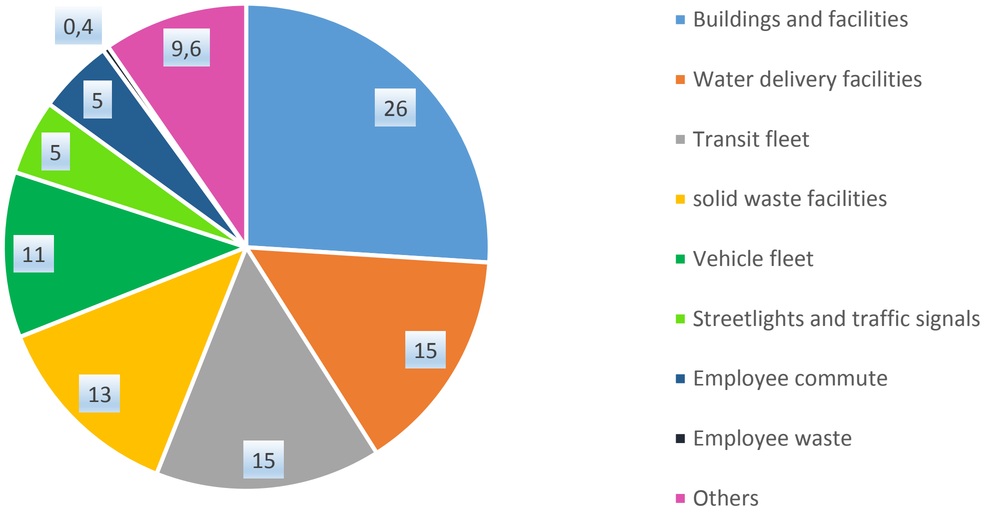


Figure 7. 2014 City of Madison greenhouse gas emissions by government activity sector in tons of carbon dioxide equivalents (1,000 tons of carbon dioxide equivalent) *(Carl Christiansen, 2015).*

On the other hand, when conducting an inventory, it is necessary to determine which sources the GHG emissions are attributed to as a way to prevent counting emissions twice. It will be explained a way of conducting a GHG inventory based on a set of accounting standards that classify the scope of the emissions based on the source. The classification also intends to help organizations categorize GHG into those that they control (e.g. Scope 1) versus those that they can influence (e.g. Scope 3). These standards provide concepts and systems that guarantee transparency, accuracy, and standardization for carbon management. These protocols are used by the majority of reporting institutions worldwide. *(Steve Boles, 2016)* The three scopes are defined as follows:

- Scope 1 includes GHG emissions from direct sources owned or controlled by the institution—production of electricity, heat or steam, transportation or materials, products, waste, and fugitive emissions. *(Steve Boles, 2016)*

i. Stationary Combustion: from the combustion of fossil fuels (e.g. natural gas, fuel oil, propane, etc.) for comfort heating or other industrial applications
ii. Mobile Combustion: from the combustion of fossil fuels (e.g. gasoline, diesel) used in the operation of vehicles or other forms of mobile transportation
iii. Process Emissions: emissions released during the manufacturing process in specific industry sectors (e.g. cement, iron and steel, ammonia)
iv. Fugitive Emissions: unintentional release of GHG from sources including refrigerant systems and natural gas distribution

For the majority of organizations, the stationary and mobile combustion sources of Scope 1 GHG will be the most relevant. *(Steve Boles, 2016)*

- Scope 2: are also referred to as Energy Indirect GHG. This scope includes GHG emissions from purchases of electricity, heat, or steam. (Importations)

- Scope 3 includes other indirect sources of GHG emissions that may result from the activities of the institution but occur from sources owned or controlled by another entity, such as: business travel, outsourced activities and contracts, emissions from waste generated by the institution when the GHG emissions occur at a facility controlled by another company (e.g., methane emissions from landfill waste), and the commuting habits of community members. Based on data from many companies that have conducted comprehensive assessments of their Scope 3 emissions, it is evident that Scope 3 GHG are by far the largest component of most organizations' carbon footprint.

The goal of using this method is to calculate emissions from all three scopes. Even though it is a very complete method that encompass energy emissions in detail from the all three scopes, to perform it in a good manner also requires a lot of detailed information which it hasn't been possible to achieve. Hence, this method is not going to be applied to UW-Madison. On the other hand, two more methods are going to be explained and only the EPA eGRID table method would be applied in this project.

Campus carbon footprint (CFP)

The main difference between carbon footprint and GHG inventory is that CFP is the total set of greenhouse gas emissions caused by an individual, event, organization or product expressed as CO_2e. While the GHG inventory reflects all the different gases separately. *(Carbon trust, n.d.)*. The UW-Madison students analyzed emission trends for specific energy sectors. Afterwards, they proposed policy tools for reducing Madison's carbon emissions. They identified transportation as a problem sector that accounts for 41% of CO_2e. emissions. This carbon footprint can be reduced by increasing the use of public transportation to commute to work. The traffic congestion during daily rush hours causes significant emission spikes, and as transportation is considered beyond the scope of the project, we will focus on the second and third main factors: commercial stores on campus 30% (retail buildings) and residential buildings on campus (dwelling type) which account for 17% of the total GHG emissions. *(Schmidt, 2015)*

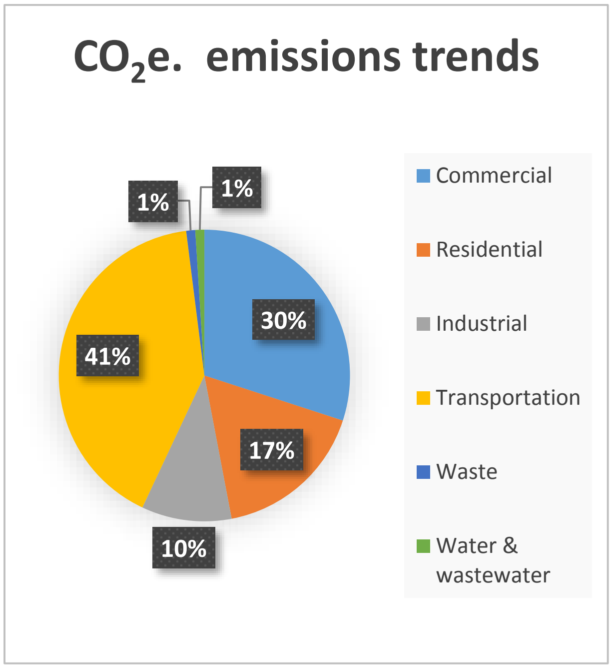


Figure 8, 2014 Madison's percentage of GHG consumption sectors . *(Schmidt, 2015)*

The aim of this project is UW-Madison emissions, therefore it should be regarded a very useful tool founded called: Campus Carbon Calculator . *(Campus Carbon Calculator, n.d.)* It's interesting because the name of the tool is exactly what we are looking for in this project. To operate the tool, the following major emissions sources data should be included: on-campus energy production; purchased electricity; natural gas service to buildings for laboratories and cooking; transportation (including air travel and commuting); waste; paper; agriculture; and refrigerants. Campus Carbon Calculator also includes the six GHGs defined by the Kyoto Protocol (carbon dioxide, methane, nitrous oxide, sulfur hexafluoride, hydrofluorocarbons, and perfluorocarbons). Each gas, based on its atmospheric chemistry, captures different amounts of reflected heat, thus contributing differently to the greenhouse effect, which is known as its global warming potential (GWP).Thus collaborating with different rates into the Carbon Footprint. *(Cynthia Klein-Banai&Thomas L. Theis, 2010)*

The Campus Carbon Calculator calculates emissions using this formula:

$$A \times Fg = Eg$$

Where A is the quantification of an activity in units that can be combined with emission factor of GHG g (Fg) to obtain the resulting emissions for that gas (Eg).

Total GHG emissions can be expressed as the sum of the emissions for each gas multiplied by its GWP. GHG emissions are reported here in metric tons of carbon dioxide equivalents (metric tons CO2e).

$$GHG = \sum g \; Eg \times GWPg$$

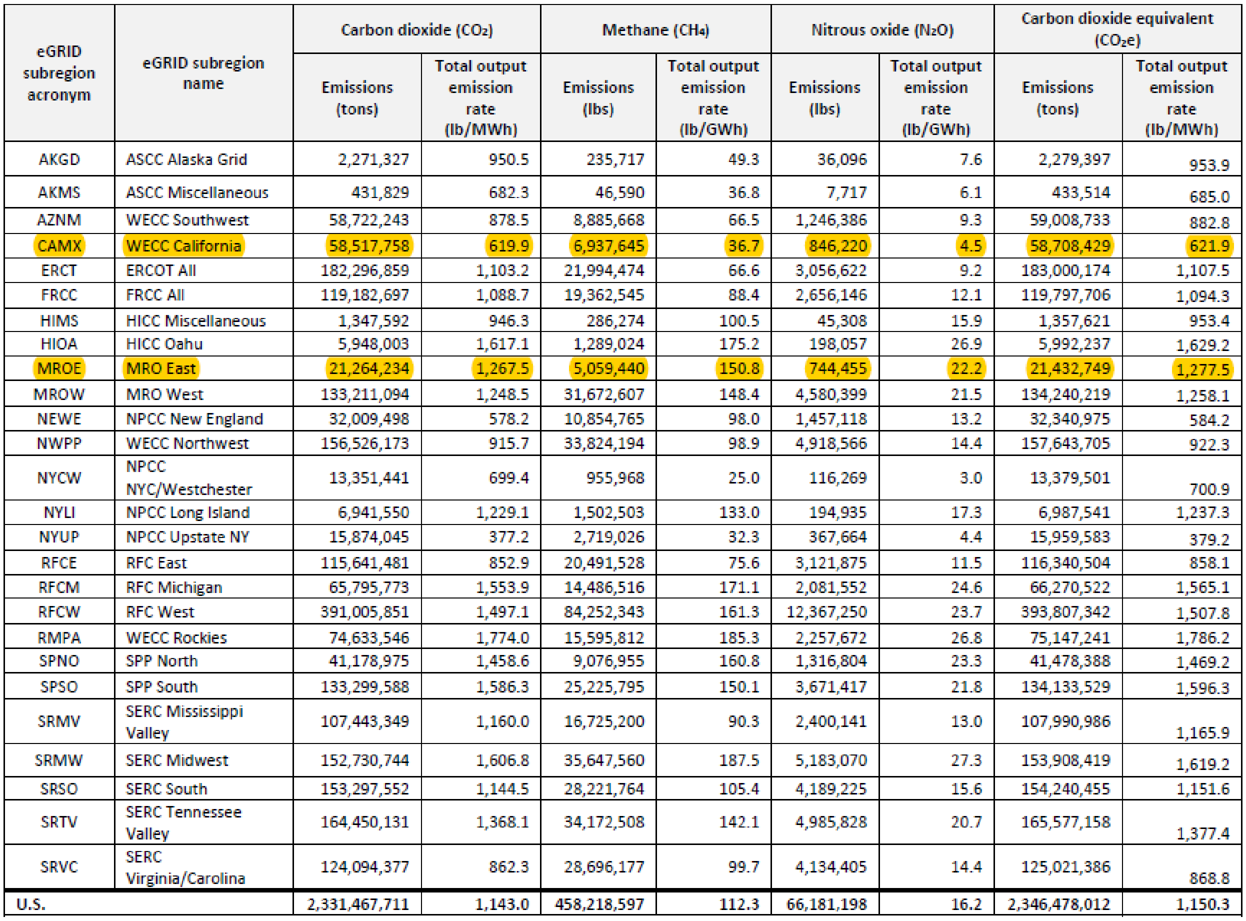
The 2012 carbon inventory provides estimations of the GHG mitigate impact of a few policy alternatives which only two of them are from this research concern. The increase in electricity production from solar panels and the electricity use reduction through building efficiency benchmarking. Over the solutions proposed, these alternatives were chosen based on the availability of evidence regarding their potential impact, the scale of that potential impact, and the political feasibility of their implementation in the Madison context. The analysis made used a new software capable of forecasting GHG emissions under various scenarios, therefore this it's been considered as a potential tool for the project performance. However, the quantity and variety of multiple scenarios and different possible actions are beyond the boundaries of this project. *(Adam Anderson, 2014)*

EPA GHG Standards

The last method that it's going to be considered in this project is calculating the GHG UW-Madison emissions using the Environmental Policy Agency (EPA) standards. *(US Environmental Protection Agency, 2012)*. With the little amount of data collected it would be the most appropriate approach to develop the total GHG emissions. It would be taken into account only CO_2, $CH_4$and N_2O of the UW-Madison campus for this project.

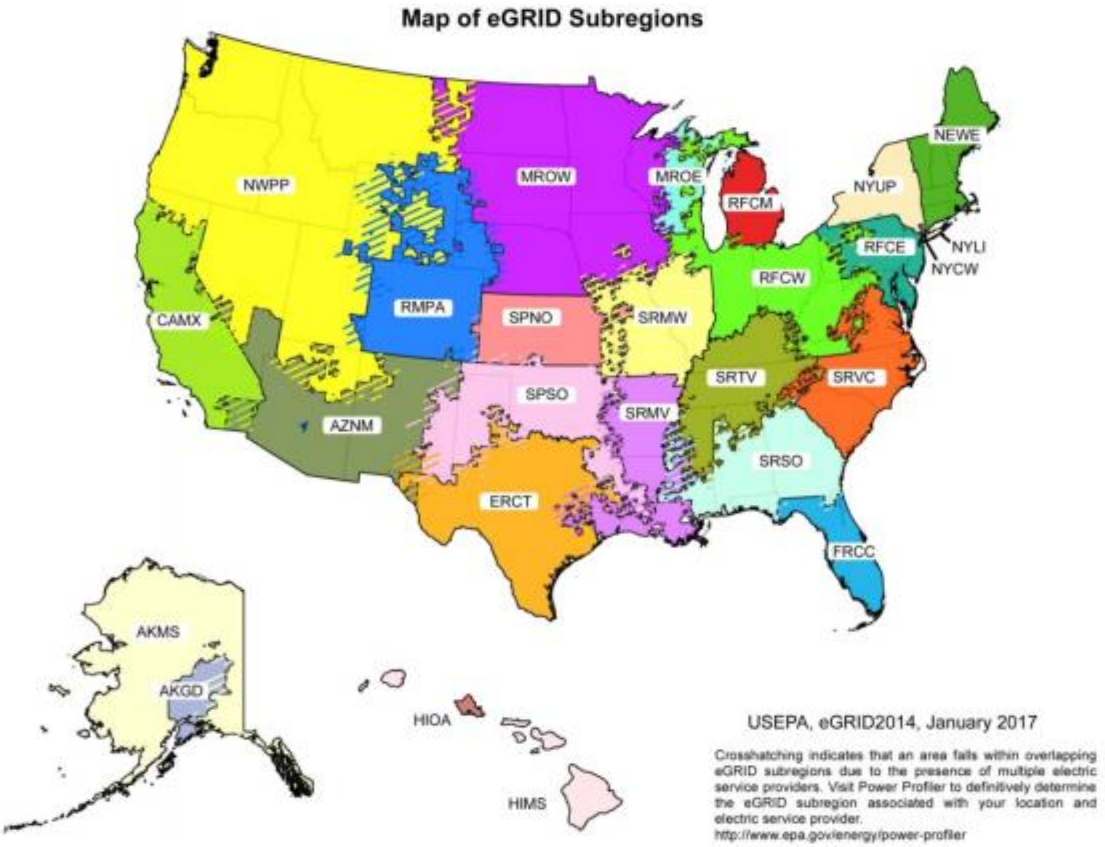
First of all, some assumptions should be made in order to be able to use the EPA eGRID2012 standards provided. *(US Environmental Protection Agency, 2012)*. These standards provide with the 3 mentioned above gases releases (in lb.) over the power consumed (MWh or GWh) depending on the USA area. MROE is the area that corresponds with Madison. Each type of building would be considered to have a different power consumption as depending on the kind of building and the usage that is given to them. The power required to operate would be different (e.g. Laboratories are going to consume much more than classrooms). These assumptions would be made according to reliable data.

Table 7 EPA data for GHG emissions over the different USA subregions. *(EPA government, n.d.)*



eGRID subregion acronym	eGRID subregion name	Carbon dioxide (CO_2)		Methane (CH_4)		Nitrous oxide (N_2O)		Carbon dioxide equivalent (CO_2e)	
		Emissions (tons)	Total output emission rate (lb/MWh)	Emissions (lbs)	Total output emission rate (lb/GWh)	Emissions (lbs)	Total output emission rate (lb/GWh)	Emissions (tons)	Total output emission rate (lb/MWh)
AKGD	ASCC Alaska Grid	2,271,327	950.5	235,717	49.3	36,096	7.6	2,279,397	953.9
AKMS	ASCC Miscellaneous	431,829	682.3	46,590	36.8	7,717	6.1	433,514	685.0
AZNM	WECC Southwest	58,722,243	878.5	8,885,668	66.5	1,246,386	9.3	59,008,733	882.8
CAMX	WECC California	58,517,758	619.9	6,937,645	36.7	846,220	4.5	58,708,429	621.9
ERCT	ERCOT All	182,296,859	1,103.2	21,994,474	66.6	3,056,622	9.2	183,000,174	1,107.5
FRCC	FRCC All	119,182,697	1,088.7	19,362,545	88.4	2,656,146	12.1	119,797,706	1,094.3
HIMS	HICC Miscellaneous	1,347,592	946.3	286,274	100.5	45,308	15.9	1,357,621	953.4
HIOA	HICC Oahu	5,948,003	1,617.1	1,289,024	175.2	198,057	26.9	5,992,237	1,629.2
MROE	MRO East	21,264,234	1,267.5	5,059,440	150.8	744,455	22.2	21,432,749	1,277.5
MROW	MRO West	133,211,094	1,248.5	31,672,607	148.4	4,580,399	21.5	134,240,219	1,258.1
NEWE	NPCC New England	32,009,498	578.2	10,854,765	98.0	1,457,118	13.2	32,340,975	584.2
NWPP	WECC Northwest	156,526,173	915.7	33,824,194	98.9	4,918,566	14.4	157,643,705	922.3
NYCW	NPCC NYC/Westchester	13,351,441	699.4	955,968	25.0	116,269	3.0	13,379,501	700.9
NYLI	NPCC Long Island	6,941,550	1,229.1	1,502,503	133.0	194,935	17.3	6,987,541	1,237.3
NYUP	NPCC Upstate NY	15,874,045	377.2	2,719,026	32.3	367,664	4.4	15,959,583	379.2
RFCE	RFC East	115,641,481	852.9	20,491,528	75.6	3,121,875	11.5	116,340,504	858.1
RFCM	RFC Michigan	65,795,773	1,553.9	14,486,516	171.1	2,081,552	24.6	66,270,522	1,565.1
RFCW	RFC West	391,005,851	1,497.1	84,252,343	161.3	12,367,250	23.7	393,807,342	1,507.8
RMPA	WECC Rockies	74,633,546	1,774.0	15,595,812	185.3	2,257,672	26.8	75,147,241	1,786.2
SPNO	SPP North	41,178,975	1,458.6	9,076,955	160.8	1,316,804	23.3	41,478,388	1,469.2
SPSO	SPP South	133,299,588	1,586.3	25,225,795	150.1	3,671,417	21.8	134,133,529	1,596.3
SRMV	SERC Mississippi Valley	107,443,349	1,160.0	16,725,200	90.3	2,400,141	13.0	107,990,986	1,165.9
SRMW	SERC Midwest	152,730,744	1,606.8	35,647,560	187.5	5,183,070	27.3	153,908,419	1,619.2
SRSO	SERC South	153,297,552	1,144.5	28,221,764	105.4	4,189,225	15.6	154,240,455	1,151.6
SRTV	SERC Tennessee Valley	164,450,131	1,368.1	34,172,508	142.1	4,985,828	20.7	165,577,158	1,377.4
SRVC	SERC Virginia/Carolina	124,094,377	862.3	28,696,177	99.7	4,134,405	14.4	125,021,386	868.8
U.S.		2,331,467,711	1,143.0	458,218,597	112.3	66,181,198	16.2	2,346,478,012	1,150.3

The founded data is from California State therefore CAMX is also highlighted as it corresponds with California data and will be used for future calculations.



USEPA, eGRID2014, January 2017

Crosshatching indicates that an area falls within overlapping eGRID subregions due to the presence of multiple electric service providers. Visit Power Profiler to definitively determine the eGRID subregion associated with your location and electric service provider.
http://www.epa.gov/energy/power-profiler

Figure 9: Map of eGRID Subregions *(EPA government, n.d.)*

Since is a very simplified approach to the GHG Madison campus releases, thus the method does not take into account: the campus fleet energy use, the commuting habits, refrigerant use, air travel, and waste disposal. For this reason, it will be easier to get results using this method.

Results

For each building category, it is going to be assumed a different energy consumption. The main aim is to calculate the KWh/SF for each category. The categories are compound of subcategories that altogether weighed depending on the percentage of the building considered of this subcategory it can be obtained the category power consumption per square foot. These percentages have been based on self-criteria after deepen in the buildings usage. The categories and subcategories are related as follows:

- **School**: 29%Office, 40%Classroom 30%Lab, 1%Cafeteria.
- ***School(without Lab):** 39%Offices, 60%Classroom, 1%Cafeteria.
- **Offices**: 100%Offices.
- **Offices&Lab**: 50% Offices, 50% Lab.
- **Dweling**: 85%Rooms, 15%Kitchens.
- **Restaurant:** 20%Kitchen, 80%Living room.
- **Lab**: 100% Lab.
- **Hospital**: Surgery rooms/Patient Rooms/Offices.
- **Hospital/Lab:** 80%Hospital, 20% Lab.
- **Leisure:** 75%Living rooms for events, 10%Cafe, 15%Offices.
- **Sport:** Can be dry, Combined (with pool), Ice rink for hokey.
- **Library:** 60%Living rooms 40%Computer labs.
- **Greenhouse:** 100% Plantation.
- **Service: Police/Boat/Garage**
- **Power Plant:** 100% Machinery and Labs.
- **Retail**: 100%Store.
- **Historic:** 100%Space.

Thus the subcategories are:

Office, Classroom, Lab/Computer Lab, Cafe/Kitchen, Living Room/Room/Patient room/Sports room/Space, Surgery room, Sport Dry, Sport Combination, Sport ice rink, Plantation, Store.

First, it has been found data from The University of California-Irvine for the Hospital, Office building and College energy ratios. These three categories are three of the main categories and hence, they are going to be explained in detail.

HOSPITAL

In the US, there are about 22,000 in-patient health care buildings, and around 16,400 outpatient buildings. The average hospital size is about 74,600 square feet and all in-patient health care buildings account for 1.6 billion square feet, which is about 3% of all commercial floor space in the U.S.

Health care buildings account for 11 percent of all commercial energy consumption, using a total of 561 trillion Btu of combined site electricity 38%, natural gas 46%, fuel oil 21%, and district steam or hot water 13%. They are the fourth highest consumer of total energy of all the building types. Using the above data it is going to be calculated the energy ratio for hospital buildings category:

$$561\ trillion \frac{Btu}{(22000+16400) buildings} = 1.46 * 10^{10} Btu/building$$

$$1.46 * \frac{10^{10} Btu}{building} * \frac{1KWh}{3412.14Btu} * \frac{1building}{74600SF} = 57.357 \frac{KWh}{SF}\ per\ year$$

The average end use of these energy sources in U.S. hospitals it is shown in the figure below:

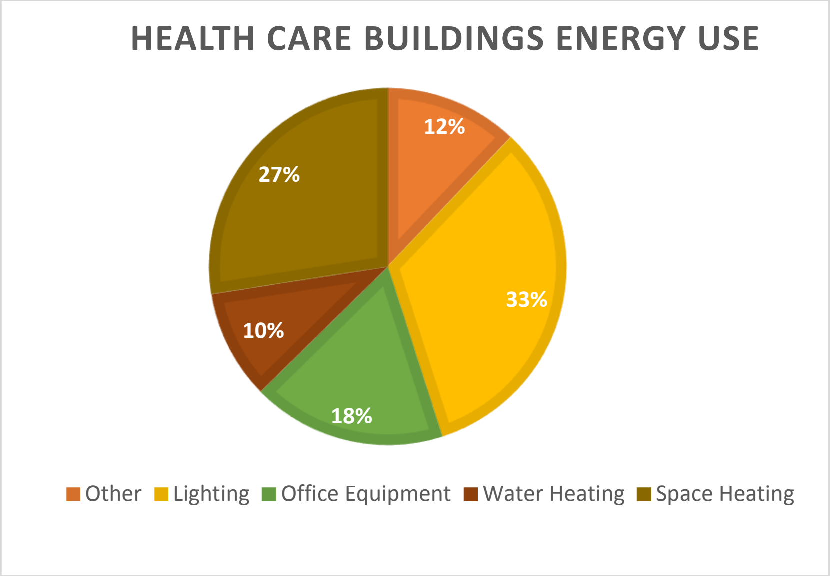


Figure 10: Health care buildings percentage of energy end use. *(University of California, 2007)*

The cost intensity for typical hospitals in California is more than twice as high as that for office buildings. Typical average electricity demands for hospitals are in the range 100 kW-5 MW.

OFFICE BUILDINGS

Although office buildings represent the second largest amount of buildings and floor space, they account for 19% of all commercial energy consumption due to the big amount of buildings of this type.

They use a total of 1.0 quadrillion Btu of combined site electricity 66%, natural gas 23%, fuel oil 3%, and district steam or hot water 7%.

The average office building is 14,900 square feet and office buildings represent 18 percent of the total commercial floor space in the US. Which is 87 billion SF *(CBECS, 2015)*

$$\frac{87billion\ SF * 18\%}{14900} = 1051007\ buildings$$

$$\frac{10^{15}Btu}{1051007\ buildings} * \frac{0.000293071KWh}{1Btu}\frac{1building}{14900SF} = 18.72\frac{KWh}{SF}\ per\ year$$

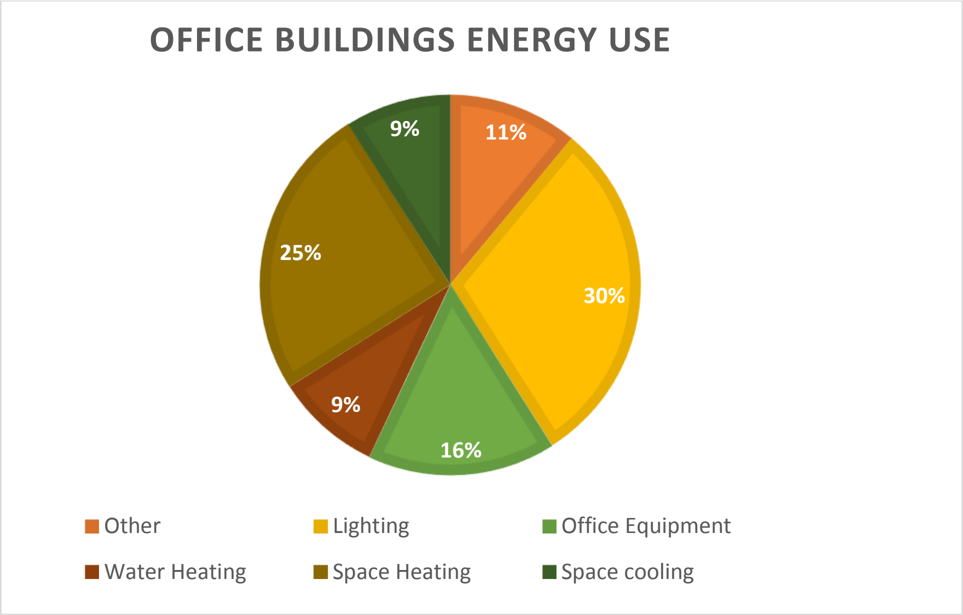


Figure 11: Office buildings percentage of energy end use. *(University of California, 2007)*

SCHOOL WITHOUT A LAB

Education buildings are the fifth most prevalent commercial building type in the U.S., with approximately 309,000 buildings. This category is considered as school without a lab. They are, on average, the largest commercial buildings, with 25,100 square feet per building, and they account for 13% of all commercial floor space.

Each building consume a total of 0.19 Gigawatt hours of energy per year. The distribution of energy sources accounts for 36% of electricity, 40% of Natural Gas, 15% of district Heat and 9% for Fuel oil. From the data above it is obtained the KWh/SF per year of this category of buildings.

$$\frac{0.19GWh}{25100SF} = 7.57\frac{KWh}{SF} per\ year$$

Education buildings are on average less energy intensive than office buildings.

The average end use of these energy sources in U.S. education buildings can be classified as follows:

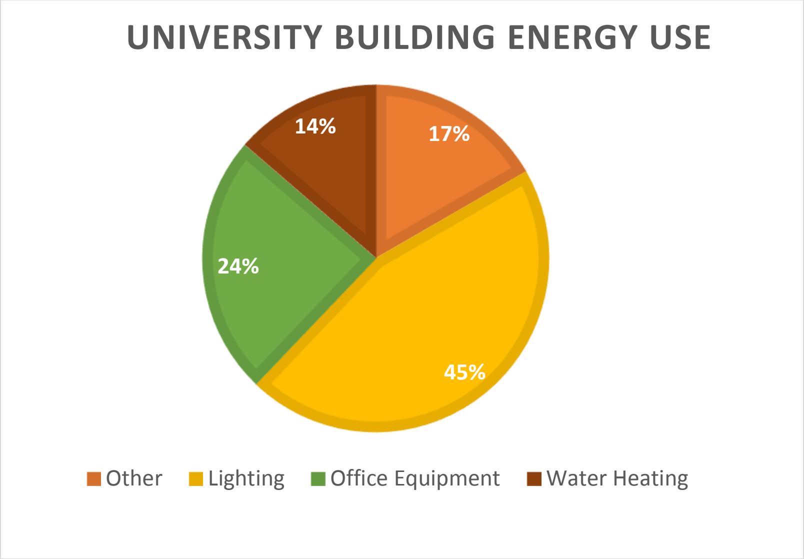


Figure 12: College buildings percentage of energy end use. *(University of California, 2007)*

Before converting these numbers into CO_2, CH_4 or N_2O emissions, the origin of these data should be regarded. As the data from the building categories above is from California State, it is necessary to add a conversion factor that would improve the quality of our results converting the values obtained from California to Wisconsin State. The argument that is going to be use is the following:

$$SF_{Building} * \frac{MWh_{California}}{SF} * \left(\frac{lbCO_2}{MWh}\right)_{California} * \frac{lbCO_{2_{Madison}}}{lbCO_{2_{California}}} = lbCO_{2_{Madison}}$$

California stands for the CAMX EPA egrid region.

The conversion factor will be calculated for each gas as follows:

$$\frac{lbCO_{2_{Madison}}}{lbCO_{2_{California}}}$$

Table 8 Conversion factor required for Hospital, School (without a lab) and offices data. *(EPA government, n.d.)*

Gas	Conversion factor from California data to Wisconsin
CO_2	0.36
CH_4	0.74
N_2O	0.88
CO_2e	0.365

<u>SPORT BUILDINGS</u>

Sport buildings Energy Consumption converted into KWh/SF:

Table 9 Energy ratio for sport building types *(Best Practice Programme, n.d.)*

Description	kWh/m^2 per year	kWh/SF per year
Local dry sports center	448	41.62
Combined center	750	69.68
Ice rink	472 (Remarkable +electricity than Heating Fuel then + expensive)	43.85

LABORATORIES

Laboratories in the U.S. are energy-intensive facilities that use anywhere from 30 to 100 kilowatt-hours (kWh) of electricity and 75,000 to 800,000 Btu of natural gas per square foot annually. Actual use varies with such factors as the age of the facility, the type of research done there, and the climate zone in which the lab is located. In a typical laboratory, lighting and space heating account for approximately 74 percent of total energy use, making these systems the best targets for energy savings. *(Business Energy Advisor, Managing energy costs in Laboratories, 2016)*

Laboratories typically consume 5 to 10 times more energy per square foot than the office buildings do. For the regular college labs it is going to be assumed an approximation of 5 times what the office buildings consume. *(EPA, Laboratories for the 21st Century: An Introduction to Low-Energy Design , 2008)*

$$18.72\frac{KWh}{SF}\ per\ year * 5 = 93.6\frac{KWh}{SF}$$

LIBRARY, RETAIL, HISTORIC, SERVICE (Such as Police station, Garage…), RESTAURANT

Conversion from the founded data for these categories from KBTU/SF into KWh/SF:

Table 10: Collected data for some building categories and its energy ratio converted into KWh/SF. *(US Enegy use intensity by energy type, n.d.)*

Category	KBTU/SF	KWh/SF
Dwelling	73.9	21.66
Restaurant	223.8	65.59
Hospital	196.9	57.36
Library	91.6	26.84
Service	88.3	25.88
Retail	47.1	13.8
Historic	45.3	13.27
Leisure	45.3	13.27

Once we have obtained most of the categories ratio, we proceed to calculate the rest with the total percentage of each of them:

SCHOOL:

From School without a lab it’s been obtained that classrooms and cafeterias consume a total of 3 KWh/SF then:

$$Shool = 0.29 * 18.72 + 0.51 * 3 + 0.2 * 93.6 = 25.68\ KWh/SF$$

HOSPITAL/LAB

From both results, by applying the percentage of each of the two categories it is obtained the following ratio:

$$Hospital\&Lab = 0.8 * 57.36 + 0.2 * 131 = 72 KWh/SF$$

GREENHOUSE

For 10000SF greenhouse, it consumes 56000KWh per month, that means:

$$\frac{56000}{10000} * 12 months = 67.2 \frac{KWh}{SF}\ per\ year$$

(Michael Bomford, 2010)

The following table collects all the data calculated above:

Table 11. Categories and subcategories weighed with their corresponding energy ratio in KWh/SF

Category	Subcategory	KWh/SF per year	
School	29%Office 50%Classroom 20%lab 1%Cafeteria	25.68	
***School(without Lab)**	29%Offices 70%Classroom 1%Cafeteria	7.57	California
Offices	100%Offices	18.72	California
Offices&Lab	50% each	56.16	
Dweling	85%Rooms 15%Kitchens	21.66	
Restaurant	20%Kitchen 80%Living room	65.59	
Lab	100% lab	93.6	
Hospital	Surgery rooms/Patient Rooms/Offices	57.36	California
Hospital&Lab	80%Hospital 20% Lab	64.6	

Leisure	75%Living rooms for events 10%Cafe 15%Offices	13.27		
Sport	Can be dry, Combined(with pool), ice rink for Hokey.	41.62	69.68	43.85
Library	60%living rooms 40%Computer labs	26.84		
Greenhouse	100% Plantation	67.2		
Service	Police/Boat/Garage	25.88		
Power Plant	100% Machinery and Labs			
Retail	Store 100%	13.8		
Historic	100%Space	13.27		

It is going to be applied a different equation for the categories which data is specifically obtained from California, which are: schools without a lab, Schools, hospitals and offices including the conversion factor from California to Madison:

$$SF_{Building} * \frac{MWh_{California}}{SF} * \left(\frac{lbCO_2}{MWh}\right)_{California} * \frac{lbCO_{2\,Madison}}{lbCO_{2\,California}} = lbCO_{2\,Madison}$$

For the other categories it will be applied the following equation:

$$SF_{Building} * \frac{MWh_{Madison}}{SF} * \left(\frac{lbCO_2}{MWh}\right)_{Madison} = lbCO_{2\,Madison}$$

In Appendix C it can be seen the results particularized for each building. The total amount of gases in Kg of each gas per type of building in UW-Madison is shown in the following table:

Table 12 Total GHG emissions for each type of building.

Categories	Kg of CO2	Kg of CH4	Kg of N2O	Kg of CO2e
Dwelling	16,917,540	2,012,753	296,307	17,051,011
Greenhouse	1,747,236	207,876	30,602	1,761,021
Historic	334,163	39,757	5,853	336,799
Hospital	959,396	116,754	17,024	975,860
Hospital/Lab	37,890,426	4,507,989	663,643	38,189,364
Hospital/School	3,188,808	379,386	55,851	3,213,966
Lab	55,990,532	6,661,438	980,663	56,432,272
Leisure	5,509,875	655,534	96,504	5,553,346
Library	7,770,004	924,431	136,090	7,831,305
Office&Classrooms	60,895	7,245	1,067	61,375

Offices	794,404	96,675	14,097	808,036
Offices&Lab	29,544,216	3,515,004	517,461	29,777,306
Restaurant	3,522,559	419,094	61,697	3,550,351
Retail	70,081	8,338	1,227	70,634
School	13,404,523	1,631,267	237,861	13,634,545
School&SportsDry	130,626	15,541	2,288	131,657
School(Without Lab)	365,665	44,500	6,489	371,940
Service	688,011	81,856	12,050	693,439
Service & Leisure	100,677	11,978	1,763	101,471
Service & Offices	976,772	116,211	17,108	984,479
Sport Combined	5,026,530	598,028	88,039	5,066,187
Sport Dry	11,849,368	1,409,771	207,539	11,942,854
Sport Ice rink	6,926,029	824,020	121,308	6,980,672
Grand Total	**203,768,337**	**24,285,446**	**3,572,531**	**205,519,891**

This table represents the total GHG emissions of UW-Madison due to buildings consumption.

Conclusions

The following conclusions have been drawn from above review:

- As the results show, the highest gas release is of CO2, contributing to global warming. Thus, there is a great need on developing measures to decrease CO2 emissions. Besides, Methane(CH4) contribute 8 times more than Nitrous oxide(N2O) in terms of quantity. However, the global warming potential is different for these three gases. According to EPA standards, methane is about 25 times more potent than CO2, and N2O is about 298 times more potent than CO2 *(Emission Factors for Greenhouse GasInventories, 2014)*. Thus the quantities are not that consistent nor the way to reach the most dangerous gas for the atmosphere.

- The category that release the biggest amount of GHG are the Lab buildings, where there are 22 buildings of this category. Thus, Hospital/Lab also has a considerable effect even though there are only 2 buildings of this type. This is due to the size of one of the two Hospital/Lab buildings considered which is 946,519 SF. The main reason is because lab buildings category use more energy consuming equipment. For instance, fume hoods are necessary to clean the air in this areas and this equipment requires a high amount of energy.
- The next one in the list would be the office&lab buildings which there are only 8 buildings but it can be concluded that considerably Laboratory spaces are the ones that emit the higher amount of gases.
- Advance Technology (Such as, automatic doors) implemented in the buildings and improved lifestyle (e.g. Everyone has his own computer) is responsible for increasing carbon emissions (Due to the increase in the electricity used per person). To control emissions there is a need of increasing awareness amongst stakeholder to adopt such methods, which are technologically better but environmentally safe.
- Shifting power generation technology from conventional sources to cogeneration or hybrid technology results in to substantial reduction in carbon emission.

- Improvement in thermal performance of building envelope leads to reduction in carbon emission. From research literature it's been found that retrofitting, reconstruction and selection of appropriate U-factors for building materials lead to a saving of carbon emission up to 31–36%. Furthermore, reuse, recycling and regeneration energy through combustion together can save up to 10% of total energy and subsequently emission.*(Ralegaonkar, 2011)*
- Construction process should be made more environmental friendly by replacing part of energy intensive building material by waste or recycled material. Use of prefabricated building elements, replacing energy intensive clinker in Portland cements (Fly ash, furnace slag), minimizing production energy in cement (dry process of clinker formation), minimizing production energy in masonry blocks (CMU, CSRE wall), using timber-based material and recycled steel can achieve substantial reduction in energy and emission. Sixty-five to 95% clinker to cement ratio results in around 32% reduction in CO2 emission. Use of recycled steel saves about 80% of energy in production process. *(Ralegaonkar, 2011)*
- The materials used in the buildings and the processes that are contributing to GHG emissions should be identified and assessed. This will help in improving energy efficiency and environmental performance of building at the same time. *(Ralegaonkar, 2011)*
- Simulation methods should be used at design stage to improve energy efficiency of building system (Such as the proper shading device) which directly will result in reduction in carbon emissions. Simulation method proves to be best for predicting heating and cooling load *(Ralegaonkar, 2011).*
- Background work has been made in the Sustainable concern in University Campuses. The conclusion is that each university is a world, after making comparisons between the other universities GHG emissions and UW campus emissions, it can be assure that many facts should be considered (size, location, type of college...) to make a consistent comparison.
- GHG emissions inventory gives more detailed information than carbon footprint as it keeps separated each gas releases. Nevertheless, carbon footprint results are easier to

interpret and to compare between different campuses emissions as it only uses one common unit which is CO_2e.

- Investing in greener HVAC equipment can save a lot of money throughout the building lifetime, as in the average US buildings accounts for the 48% of the emissions.
- A proposal that can help to reduce easily GHG emissions is requiring all residential buildings to report their electricity and heating energy use. While nobody would be fined for consuming too much energy, research studies have demonstrated the effectiveness of this peer pressure system for reducing GHG emissions. *(Schmidt, 2015)*
- Once applied the EPA standards method the results over the UW campus emissions have brought us some conclusions on the three sustainability aspects:

I. The impact of the GHG emissions on society

Overall, energy conservation interventions have shown confusing results arisen from the fact that approximately 80% of Americans regularly express strong environmental concern, however barely 20% of Americans actually translate this concern into concrete actions in their everyday practices. On the other hand, insights into potential pathways to avoid the “value-action gap” are emerging in the social sciences. Sustainability and environmental planning initiatives tend toward greater degrees of success as long as social capital and information networks are strong and well interconnected. By engaging individuals and groups in energy efficiency interventions via non-coerced commitment and the clear visualization of new social norms and peer performance can help people to view themselves as concerned about mitigating climate change and increase the speed of changing society behavior into a more active attitude. *(Hal S. Knowles)*

II. The impact of the GHG emissions on the environment

Zero net energy (ZNE) is a building with zero net energy consumption, meaning the total amount of energy used by the building on an annual basis is roughly equal to the amount of renewable energy created on the site. Thus, retrofitting or building a city facility that meets ZNE standards would cut municipal energy costs and carbon emissions from energy. *(P. Torcellini, 2006)*

The following bullet points are a summary of Madison's strongest environmental programs. Madison can build on these strengths to achieve its greenhouse gas reduction goals and continue with the intention of reaching ZNE standards in new building construction. *(Somers, 2002)*

- First curbside recycling program in the nation (began collecting newspapers in 1968). Madison currently recycles 50% of its waste.
- Extensive bicycle program with bike racks, lockers, and over 100 miles of bikeways.
- Extensive Metro Transit bus system with 164 buses daily.
- Methane gas utilization at sewerage plant and two largest landfills for electricity and steam generation.
- Streetlight conversion from mercury vapor and incandescent bulbs to high-pressure sodium (11,000 fixtures).
- Conversion of 200 red traffic signals to light-emitting diode (LED) fixtures.
- School District, City, and County participation in the EPA Energy Star Buildings Partnership.
- Full member in the ICLEI Cities for Climate Protection Campaign.
- Largest wind power project (11 MW) in the eastern United States. Implemented by the local utility, MG&E(Madison Gas & Electric) , production from the 17 wind turbines began in June 1999. The wind program sold out faster than any other green power program in the U.S.
- Rideshare Etc. program operates 67 vanpools with 900 riders.
- No pesticide or fertilizer use on green spaces or parks.
- 2500 trees planted per year.
- Sustainable Lifestyle Campaign started 40 neighborhood ecoteams.

III. The cost of the GHG emissions

Over 25 percent of Madison's yearly energy costs ($3.6 out of nearly $14 million dollars) are spent on buildings and facilities energy *(Eric Anderson, 2012)*. The average American household spends over $2000 per year on energy bills, the majority of which goes to heating and cooling *(EPA, Green building, 2016)*. Reducing building energy consumption can therefore reduce energy use and greenhouse gas emissions, while helping Madison habitants save money. *(Eric Anderson, 2012)*

The top energy-using buildings in Madison city have been tracked since 1988 using a software program called Fast Accounting System for Energy Reporting (FASER). *(Somers, 2002)*. In 1990 UW-Madison buildings used 995,299 therms of natural gas and 15,986,473 kWh of electricity for a total cost of approximately $1.3 million. Some upgrades have been applied to the UW buildings adding insulation systems, such as re-roofing, upgrading doors, replacing windows, etc. when remodeling, the equipment efficiency improves as soon as replacements are done. The energy savings from these measures has not been documented yet. The expenditures in measures to improve energy efficiency it's been between $300,000 to $500,000, with payback periods between 6 months to 20 years. The outcomes are expected to be worth it in terms of profitability besides the decrease on environmental impact. Thus, annual savings from these measures are estimated to be $40,000/year. *(Somers, 2002)*

Recommendations

Some highlighting recommendations to apply in the UW-Madison campus buildings are going to be explained and classified their application to the different building categories. Furthermore, for all kind of buildings would be recommendable to use the SPS 363 Energy conservation code in Wisconsin, which is a chapter that provides flexibility to permit the use of innovative approaches and techniques to achieve the effective use of energy. *(Legislative Reference Bureau, 2011)*

For Schools, Offices and Dwelling buildings

From Pennsylvania State it can be taken some ideas on actions that can be taken to conserve energy in buildings. *(The Pennsylvania State University, 2015)*. Some of them that have already been applied in Pennsylvania, would work as well for UW-Madison. These are the following measures:

- Installing room occupancy sensors which can automatically turn lights on when someone enters a room and off when someone leaves, are a smart and easy way to save energy in commercial applications. Sensors help meet the mandatory requirements set for building construction and renovation, as well as contribute to obtaining points in several LEED credit categories (Lutron Electronics Co., n.d.)
- Installing heat recovery equipment. This measure is particularly effective in northern climates *(Irving, n.d.)*
- Replacing inefficient lighting with higher efficiency fluorescent and LED technologies.
- Programming thermostats to a reasonable temperature including breaks shutdown systems. This means that during extended break periods like the winter holiday or spring break, the buildings conserve energy by reducing the temperature inside them to 55 degrees Fahrenheit and turning lights and computers off. Thus, the few people left in the city should dress with warmer clothes than usual to be comfortable inside.
- Upgrading/reprogramming control systems.

- Steam system enhancements and improving steam traps. It is remarkable that more than 45% of all the fuel burned by U.S. manufacturers is consumed to raise steam. Steam is used to heat raw materials and treat semi-finished products. It is also a power source for equipment, as well as for building heat and electricity generation. But steam is not free. It costs approximately $18 billion annually to feed the boilers generating steam. Many manufacturing facilities can recapture energy through the installation of more efficient steam equipment and processes. A typical industrial facility can realize steam savings of 20 percent by improving their steam system. If steam system improvement were adopted industry-wide, the benefits would be $4 billion in fuel cost reduction and 32 million metric tons of emission reductions. *(Alan Bandes & Bruce Gorelick, n.d.)*
- Installing low-flow water fixtures: switching to water-efficient appliances and fixtures will also save money on energy costs, as you end up using significantly less hot water. You also extend the life of your water heater. *(Handyman Matters, 2017)*
- Lab ventilation improvements.
- Updating and replacing heating systems
- Motor replacement
- Variable frequency drives will allow you to match the speed of the motor-driven equipment to the process requirement resulting in energy savings. *(Hartman, 2014)*
- Cleaning, flushing and passivating HVAC piping: to remove debris such as slit, sand, scale, iron oxide deposits, weld slug and other contaminants that are present in a pipework system *(Webmaster, 2015)* and passivating also inhibits the system from corrosion.

For Sport buildings

The following actions require little or no capital investment and will considerably decrease the GHG emissions of a Sport facility either is combined, with ice-rink or only dry sports building. *(ENERGY CONSUMPTION GUIDE, 2001)*

- Review the standards of lighting, heating, ventilation and other energy-intensive functions required in each area, and how long these services are to be provided.
- For timed equipment, such as external lighting and most central ventilation plant, the automatic time settings should be at the minimum reasonable.
- Ensure that all plant is operated and maintained to work effectively.
- Make sure that small or local requirements, such as cleaning or ventilation, do not cause the rest of a large system to be brought into operation or cause inefficient use of central plant.
- Make sure that room air temperatures, and water temperatures in swimming pools, are set appropriately and checked regularly.
- If ventilation plant has high/low or variable settings, check that the plant normally runs at a low setting, and is only turned up when the facility is heavily occupied. Overnight, ventilation plant should normally be off, except for swimming pool ventilation systems, which may need to run at a reduced speed.
- Ensure that energy-saving equipment or features are used as intended. Any automatic lighting or plant controls should be fully understood and properly commissioned and set up.
- Water costs can be comparable to energy costs. Hence, constant effort and monitoring is required to control consumption and reduce water waste.
- Appropriate and effective maintenance is essential, including checking and re-calibrating controls.

Measures requiring significant expenditure should be reviewed from time to time and implemented if suitably cost-effective. Eligible technologies currently include: *(ENERGY CONSUMPTION GUIDE, 2001)*

- combined heat and power
- lighting systems
- boiler systems
- pipework insulation
- refrigeration
- high-efficiency motors

- variable speed drives.

Lighting: old lighting systems in sports areas, pools or general areas can be inefficient. Thus, replacement with efficient systems can sometimes be worth it. Most lighting should be high-frequency fluorescent tube or compact fluorescent fittings.

Heating systems: for central systems, high-efficiency (preferably condensing) boilers will provide substantial savings. Sometimes localized and locally controlled heating can use less energy, particularly where only occasional heat is required.

Heat recovery: Recovering heat from swimming pool exhaust air is generally cost-effective if appropriately designed.

Combined heat and power (CHP): is generally cost-effective in larger swimming pools, which have a suitable year-round heat load for pool heating. Assessing the costs and benefits of CHP in an accurately manner is important to be aware on the project inversion.

Building fabrication: improving insulation to current sport building, is cost-effective. Even new sports buildings are often far from airtight, so checking and sealing can often be justified, particularly where complaints of draughts have resulted in increasing the heat settings and hours of operation.

Ventilation fans: more efficient fans that can take advantage of low speed operation for most of the time can save well over 50% of the ventilation energy. *(ENERGY CONSUMPTION GUIDE, 2001)*

Pool covers: reduce heat losses from pool water, and avoid the need for ventilation at night. This further reduces heating and electrical costs in a well-designed, controlled and managed system.

For Laboratory buildings

As laboratories consume so much energy, the potential for energy and economic savings through energy efficiency improvements and energy conservation is very high, some studies estimate that implementing some measures can result in 50% savings for laboratories and clean-room facilities. *(Business Energy Advisor, Managing energy costs in Laboratories, 2016)*

The National Renewable Energy Laboratory's (NREL's) Science & Technology Facility (S&TF) is a 71,300-square-foot building with laboratories, office space, and common areas, in Golden, Colorado. The S&TF was designed to assist renewable-energy research and speed up the time to market for these technologies. Staying true to NREL's mission, the S&TF was also designed to use much less energy than a standard laboratory facility in fact, it uses 41% less energy by cost when compared to traditional labs. The S&TF accomplishes these savings by the following measures that are also recommended to be applied in UW Lab buildings: *(Colorado Laboratory Uses 41 Percent Less Energy than Traditional Labs, n.d.)*

- Using an efficient condensing boiler for space heating.
- Using a variable-speed chiller and both direct and indirect evaporative cooling system for space cooling.
- Using fan-coil units to provide heating and cooling directly to laboratories, reducing the need for inefficient reheat systems.
- Using an air-distribution system under the floor provides fan-energy savings and allows the economizer and evaporative cooling system to operate longer by increasing the supply-air temperature. The system uses variable-air-volume boxes under the floor as well, allowing offices individual temperature control and reducing overhead ductwork.
- The S&TF also uses daylighting in all occupied areas and takes advantage of exterior shading.
- Incorporating an automatic lighting control system to curb lighting waste.
- Using demand-controlled ventilation to eliminate unnecessary ventilation to unoccupied or lightly occupied spaces.

Other recommendations would be: *(Energy, 2015)*

- ➢ HVAC make up the majority of the building's energy demand. Hence, depending on how sophisticated the HVAC control is, and the occupant work schedule of the lab, the facility managers can program the building's HVAC system to operate at the minimum rate when the building is unoccupied, and raise it to the needed ventilation rate when the building is in use.

- Turning off the lights at the end of the day, utilizing task lighting, unplugging lab equipment and using appliance timers would reduce the operational costs of the lab.

- Switching an Ultra-Low Temperature Freezer used to store samples from -80 degrees Celsius to -70 degrees Celsius can potentially reduce the freezer’s energy consumption by 30%. This can save the lab a substantial amount of money and can be done without the risk of damaging most samples.

- A fume hood is a ventilation device installed in lab spaces, that protects workers from breathing in volatile chemicals by drawing in air from the lab space and pushing the air outside the building. The number of fume hoods in a lab is critical for the utility costs. With fairly simple behavioral changes, like using a sash (a moveable shield at the opening of the fume hood) when the fume hood is not in use. Also keeping fume hoods free of obstacles (wires, computers, etc.) that will prevent you from lowering the sash, especially when not in use. *(researchers, n.d.)*

For Greenhouse buildings

The principles of the developing field of building science applied to greenhouse designs include measures that are recommended to use in UW-Madison Greenhouse buildings: *(Larry Kinney and John Hutson, 2012)*

- Keep the time constant of the building long through insulation and thermal mass.
- Control the flow of solar flux, both light and heat.
- Control the temperature and flow of air.
- Integrate the systems of the greenhouse to optimize plant growth.
- Future designs should allow more sunlight, mostly diffuse, into the greenhouse during warm months.
- The next generation of shutters should employ fiberglass frames and better means to actuate them.

Personal recommended behaviors

If the UW-Madison concerned population follow these common tips, the campus carbon footprint would be considerably reduced: *(Reduce Your Carbon Emissions, n.d.)*

- Turn off your lights whenever leaving a room, even if it is for a short period of time.
- Unplug electronics when not in use.
- Set the thermostat two degrees cooler in the winter and two degrees warmer in the summer.
- Clean or replace air filters on the air conditioner at least once a month.
- Replace any incandescent light bulbs with Compact Fluorescent Light Bulbs (CFL) or Light-Emitting Diodes (LED).
- Turn off the faucet while brushing your teeth.
- Use dishwashers instead of washing the dishes by hand. Dishwashers use less hot water than washing by hand.
- Use low-flow showerheads in your showers and faucet aerators in your sinks to conserve water.
- Start a compost pile for grass clippings, leaves, vegetable peelings, fruit rinds, and barnyard animal manure.
- Recycling allows some materials to be reused and prevents other hazardous materials from contaminating our soil.
- Use recycled paper and recycle printer cartridges. Only print when necessary and print on both sides of the paper.
- Trying to use carpool to work and for personal trips would reduce the CO2 emissions due to transportation. Consider walking, biking, or using public transportation as an alternative.
- Try driving during non-peak hours.
- Consider purchasing a hybrid or more efficient car if need one.
- Buying local products when possible to reduce the number of products that are transported long distances.

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Appendix A. Footprint worksheet (Venetoulis, 2001)

Campus Ecology Footprint Worksheet

To use the worksheets: Enter figures for one year in the left hand column, complete the multiplication and division, and then add the results **(fp)** to get the corresponding ecological footprint for your campus. For a per person figure divide the campus's footprint by the number of faculty, staff, and students. Note: Figures are US standard.

Energy: Powerprint

⇒ Enter the amount of energy from each source (electricity, natural gas, gasoline, and jet fuel). Note: The US average kWh in 1999 was comprised of 54% coal, 23% nuclear, 9 % natural gas, 9% hydro 3%, oil, the remaining is wind, geothermal, and solar and other (EIA, 2000). To get a more accurate estimate, use the "local" energy blend.

Electricity

_________kWh from coal X 0.00063 = ________
_________kWh from natural gas X 0.00005 = ________
_________kWh from large hydroelectric X 0.000128= ________
_________kWh from solar X 0.0000025 = ________
_________kWh from wind X 0.000014 = ________
Subtotal for Electricity ____________ **Footprint component (fp)**

Natural Gas

______ Therms of natural gas X 0.00157 = ________________**(fp)**

Gasoline

Gallons of gasoline for private automobiles related to school activities during school week:
___X 19.6 X 37 = ____________ divide by 7,000 = ________ **(fp)**
Gallons of gasoline used during semester breaks, i.e. winter and spring break:
___X 19.6 = ____________ divide by 7,000 = ________ **(fp)**
Gallons of gasoline for grounds maintenance, i.e. lawn mowers and garbage pick-up:
___X 19.6 = ___________ divide by 7,000 = ________ **(fp)**

Air Travel

Total miles of air travel for school related activities and during breaks:
_______ divided by 587 = ________ X 0.5 = _______ **(fp)**

(or) **Hours** of air travel
________ X 0.5 = _______**(fp)**

Add up the footprints (fp) from this page____________________

Water: Hydroprint

⇒To calculate a hydroprint, first estimate the amount of hydrospace available and corresponding area based yield factor (#s 1-5) and consumption factor (#s6 &7).

HYDROPRINT

Calculate the yield and consumption factors

Step 1. Enter the average annual rainfall for you community or watershed __________inches
Step 2. Divide step 1 by 12 = __________
Step 3. Enter the area of the community or watershed in acres __________
Step 4. Multiply the results of step two by step three = __________
Step 5. Divide the result by the area or your community/watershed (step 3) = __________ **yield factor**

Step 6. Enter the total amount of water (gallons) consumed in one year __________
Step 7. Divide step six by 325,851 = __________ **consumption factor**

Step 8. Divide consumption factor (step 7) by yield factor (step 5) and enter the result:

Hydroprint__________Acres*

*To partially account for water needed by other species and wildlife, increase the Hydroprint by the corresponding percentage set aside for non-human purposes.

Wasteprint

Paper ________ pounds X 0.0045 = ________
Aluminum ________ lbs. X 0.02 = ________
Magnetic metal ________ lbs. X 0.0048 = ________
Glass ________ lbs. X 0.0012 = ________
Plastics ________ lbs. X 0.004 = ________
Subtotal for non-recycled waste____________ (fp)

Recycled Waste (39% average recycling rate

Paper ________ lbs. X 0.0032 = ________
Aluminum ________ lbs. X 0.0001 = ________
Magnetic metal ________ lbs. X 0.004 = ________
Glass ________ lbs. X 0. 0008 = ________
Plastic ________ lbs. X 0.0012 = ________
Subtotal for recycled waste ________________ (fp)

Add up the hydro and wasteprints ________________

Total Footprint

Sum all the Footprint (fp) categories from the worksheets

____

This is the campus ecological footprint in acres.

Divide by the campus community population

____

This is the campus' approximate per capita footprint in acres.
This figure can be compared to the amount of footprint space available per person in the world, your country, or on campus.

Appendix B (University of Wisconsin-Madison, n.d.)

UW-Madison buildings size and category.

Building	Size [SF]	Type
Capitol Ct 1220	49,666	Offices&Lab
Engineering Dr 1410	34,336	School
Monroe St 1433	7,814	School
University Ave 1610	17,975	School
Linden Dr 1645	2,441	Dwelling
University Ave 1800	3,170	Dwelling
Linden Dr 1910	6,752	School&SportsDry
Bernard Ct 206	2,414	Dwelling
Brooks St N 209	3,403	Dwelling
Brooks St N 215-217	2,436	Dwelling
Park St N 21	223,748	Offices
Mills St N 30	43,916	School
432 East Campus Mall	19,041	School(Without Lab)
Henry Mall 445	36,358	School
Charter St N 45	15,193	School
Herrick Dr 502	6,838	School
State St 711	8,833	Retail
University Bay Dr 901	1,587	Dwelling
Adams Residence Hall	6,932	Dwelling
	6,765	Dwelling
	5,932	Dwelling
	361	Offices
	6,183	Dwelling
	5,417	Dwelling
	7,339	Dwelling
	6,818	Dwelling
	6,860	Dwelling
Agricultural Bulletin Building	2,776	Offices
Agricultural Dean's Residence	5,134	Dwelling
Agricultural Engineering Building	14,325	School
Agricultural Engineering Laboratory	25,065	Lab
Agricultural Hall	51,406	School
American Family Children's Hospital	165,234	Hospital
Animal Science Building	75,441	School

Armory & Gymnasium	39,600	Leisure
Art Lofts	48,057	School
Athletic Operations Building	9,962	Offices
Atmospheric Oceanic & Space Sciences Bldg	79,598	School
Babcock Hall	80,314	School
Bardeen Medical Laboratories	42,038	Lab
Service Memorial Institute	71,177	Offices&Lab
Medical Sciences	39,803	School
Barnard Residence Hall	30,509	Dwelling
Bascom Hall	87,100	School
Below Alumni Center	14,768	School(Without Lab)
Biotron Laboratory	37,988	Lab
Birge Hall	97,080	School
Bock Laboratories, Robert M	40,907	Lab
Bradley Memorial Building	9,753	Office&Classrooms
Bradley Residence Hall, Harold C	36,558	Dwelling
Psychology Building, W J Brogden	64,281	School
Camp Randall Sports Center	97,722	Sport Dry
Camp Randall Stadium	172,066	Sport Dry
Carillon Tower	188	Historic
Schuman Shelter, Carl	807	Offices
Carson Gulley Center	21,047	Restaurant
Chadbourne Residence Hall	82,494	Dwelling
Chamberlin Hall, Thomas C	177,815	School
Chamberlin House	10,879	School
Heating and Cooling Plant-Charter St	4,967	Power plant
Chazen Building	43,612	Historic
Chemistry Bldg, F Daniels & J H Mathews	225,120	Offices&Lab
Cole Residence Hall	32,151	Dwelling
Computer Sciences	133,570	School
Kronshage Residence Hall	10,930	Dwelling
	10,917	Dwelling
	12,930	Dwelling
	8,586	Dwelling
Elvehjem Building, Conrad A	61,803	Leisure
Dairy Barn	35,344	Leisure
Dairy Cattle Center	27,218	School
Davis Residence Hall, Susan B	7,993	Dwelling

Smith Greenhouse, D C	8,088	Greenhouse
Dejope Residence Hall	129,159	Dwelling
Biochemical Sciences, DeLuca, Hector F	106,486	School
Biochemistry Building, DeLuca, Hector F	36,129	School
Biochemistry Laboratories, DeLuca, Hector F	113,206	Lab
Wisconsin Institute for Discovery	49,065	School
University Apartments Community Center	20,695	Dwelling
Educational Sciences	104,014	School
Education Building	74,084	School
Engineering Centers Building	113,519	School
Engineering Hall	271,602	School
Engineering Research Building	84,996	Lab
Environment Health and Safety	54,530	School
Enzyme Institute	40,123	Lab
Extension Building	43,505	School
Field House	79,352	Leisure
Fleet & Service Garage	14,196	Service & Offices
Fluno Center for Executive Education		School
Forest Products Laboratory		Lab
Genetics-Biotechnology Center Building	116,600	Lab
Gilman House	10,353	Dwelling
Goodman Softball Main Building	2,876	Leisure
Goodnight Hall, Scott H	33,200	School
Gordon Dining & Event Center	72,366	Restaurant
Grainger Hall	375,725	School
Gymnasium-Natatorium	150,587	Leisure
Biomedical Sciences Laboratories, Hanson, Robert P	27,654	Lab
Harlow Center	22,941	Lab
Hasler Laboratory of Limnology, Arthur D	11,084	Lab
Health Sciences Learning Center	236,371	School
White Hall, Helen C	253,308	School
Smith Annex, Hiram	7,722	School
Smith Hall, Hiram	11,716	School
Horse Barn	13,802	Leisure
Moore Hall-Agronomy	20,419	School
Horticulture	17,196	Lab
Plant Sciences	36,458	School
Humphrey Hall	10,092	School
Ingraham Hall, Mark H	55,479	School

Jones House	10,976	Offices
Jorns Hall	10,118	School
Kellner Hall	26,621	Leisure
King Hall	11,133	School
Soils	17,748	School
LaBahn Arena	21,831	Sport Ice rink
Lathrop Hall	51,236	School
Law Building	114,614	School
Leopold Residence Hall, Aldo	35,681	Dwelling
Livestock Laboratory	18,221	Lab
Lowell Center	80,397	School
Mack House	11,249	Dwelling
Materials Science and Engineering Bldg	27,652	School
McArdle Building	54,373	Lab
McClain Athletic Facility	130,009	Dry Sport
Meat Science and Muscle Biology Lab	16,528	Lab
Mechanical Engineering Building	154,365	School
Bardeen Medical Laboratories	42,038	Lab
Service Memorial Institute	71,177	School
Medical Sciences	39,803	School
Medical Sciences Center	237,271	School
Meiklejohn House	3,691	Dwelling
Memorial Library	362,719	Library
Memorial Union	128,800	Leisure
Merit Residence Hall	12,216	Dwelling
Microbial Sciences Building	248,728	School
Middleton Building, William S	28,601	School
Humanities Building, Mosse, George L	165,726	School(Without lab)
Music Hall	16,063	School(Without lab)
Nicholas Hall, Nancy	113,289	School
Nicholas-Johnson Pavilion and Plaza	22,309	Sport Ice rink
Nielsen Tennis Stadium	95,402	Sport Dry
Noland Zoology Building, Lowell E	56,574	School
North Hall	12,219	Dwelling
Nutritional Sciences	30,600	School
Observatory Hill Office Building	3,848	Office&Lab
Ogg Residence Hall, Frederic A	120,483	Dwelling

Phillips Residence Hall, Vel	33,686	Dwelling
Police and Security Facility	8,739	Service
Porter Boathouse	37,501	Service
Poultry Research Laboratory	18,129	Lab
Pyle Center	79,624	Offices
Radio Hall	8,500	School
Rennebohm Hall	120,714	School
Russell Laboratories	93,167	Lab
Rust, Henry & Schreiner, David Hall	12,345	
School of Social Work Building	21,083	School(Without lab)
Science Hall	58,054	School
Seed Building	16,340	School
Sellery Residence Hall	151,928	Dwelling
Service Building	37,191	Service & Offices
Service Building Annex	24,799	Service & Offices
Social Science Bldg, Sewell, William	120,387	School
Cooper Hall, Signe Skott	87,931	School
Slichter Residence Hall	39,448	Dwelling
Smith Residence Hall, Newell J	97,135	Dwelling
Southeast Recreational Facility (SERF)	125,472	Sport Combined
Southeast Residence Halls		Dwelling
South Hall	13,513	Dwelling
Historical Society, State		Historic
Steenbock Memorial Library	88,037	Library
Sterling Hall	90,480	School(Without lab)
Stock Pavilion	33,668	School
Stovall Building, William D-Hygiene Lab	47,377	Lab
Sullivan Residence Hall	33,541	Dwelling
Swenson House	10,419	Dwelling
Taylor Hall, Henry	18,756	School
Teacher Education	63,111	School
Kohl Center, The	230,587	Sport Ice rink
Tripp Residence Hall-Botkin House	7,511	Dwelling
Tripp Residence Hall-High House	5,321	Dwelling
Tripp Residence Hall-Fallows House	5,951	Dwelling
Tripp Residence Hall-Frankenburger House	7,029	Dwelling
Tripp Residence Hall-Mail Room & Main Desk	711	Dwelling

Tripp Residence Hall-Bashford House	7,184	Dwelling
Tripp Residence Hall-Vilas House	6,816	Dwelling
Tripp Residence Hall-Gregory House	5,906	Dwelling
Tripp Residence Hall-Spooner House	6,385	Dwelling
Turner House	10,588	Dwelling
Union South	183,415	Leisure
Apartment Facilities Office	2,733	Offices
University Club	8,948	Service & Leisure
University Houses 1	3,744	Dwelling
Dairy Forage Research Center-US		
University Ave 1848		Offices
Clinical Science Center	946,519	Hospital/Lab
UW Medical Foundation Centennial	73,677	Hospital/Lab
Van Hise Hall	133,467	School
Van Vleck Hall, E B	56,478	School
Veterans Administration Hospital		Hospital
Veterinary Medicine Building	144,270	Lab
Vilas Communication Hall	150,036	School(Without lab)
Waisman Center	133,585	Hospital/School
Greenhouse-Walnut St	37,136	Greenhouse
WARF Office Building	88,237	Offices
Observatory, Washburn	3,100	School
Water Science and Engineering Laboratory	26,559	Lab
Waters Residence Hall, Elizabeth	93,135	Dwelling
Weeks Hall for Geological Sci, Lewis G	82,652	School
Wendt Commons, Kurt F	52,774	Library
West Campus Cogeneration Facility	Gross: 94,200	
Wisconsin Energy Institute	53,305	Offices&Lab
Wisconsin Institutes for Medical Research	438,539	Offices&Lab
Primate Center, Wisconsin	17,435	School
Veterinary Diagnostic Lab-WI	47,374	Offices&Lab
Witte Residence Hall	149,522	Dwelling
Bayliss Co-Op, Zoe	7,400	Dwelling
Zoology Research Building	25,994	Offices&Lab

Appendix C

GHG released by each UW-Madison building.

Building	CO2	CH4	N2O	CO2e
Capitol Ct 1220	1603613.3	190789	28087	1616265.04
Engineering Dr 1410	89255.347	10862	1583.82	90786.9711
Monroe St 1433	20312.246	2471.9	360.437	20660.8048
University Ave 1610	46725.445	5686.26	829.134	47527.2544
Linden Dr 1645	30397.62	3616.54	532.408	30637.4437
University Ave 1800	39475.812	4696.61	691.411	39787.258
Linden Dr 1910	130626.37	15541.2	2287.89	131656.952
Bernard Ct 206	30061.391	3576.53	526.519	30298.5617
Brooks St N 209	42377.346	5041.82	742.23	42711.6842
Brooks St N 215-217	30335.356	3609.13	531.317	30574.6878
Park St N 21	423988.94	51597.4	7523.6	431264.603
Mills St N 30	114158.25	13892.5	2025.72	116117.213
432 East Campus Mall	14590.667	1775.61	258.908	14841.0436
Henry Mall 445	94511.472	11501.6	1677.09	96133.2915
Charter St N 45	39493.723	4806.2	700.808	40171.4368
Herrick Dr 502	17775.165	2163.15	315.417	18080.1872
State St 711	70081.061	8337.85	1227.46	70633.9692
University Bay Dr 901	19762.812	2351.27	346.142	19918.7313
Adams Residence Hall	86323.762	10270.3	1511.94	87004.8177
	84244.122	10022.9	1475.52	84908.7697
	73870.825	8788.73	1293.83	74453.6322
	684.07319	83.2485	12.1387	695.811903
	76996.512	9160.61	1348.58	77603.9798
	67457.562	8025.72	1181.51	67989.7717
	91392.108	10873.3	1600.71	92113.1502
	84904.128	10101.4	1487.08	85573.9826
	85427.151	10163.6	1496.24	86101.1324
Agricultural Bulletin Building	5260.3523	640.16	93.3439	5350.62006
Agricultural Dean's Residence	63933.381	7606.43	1119.78	64437.7862
Agricultural Engineering Building	37237.385	4531.61	660.77	37876.3794
Agricultural Engineering Laboratory	1348829.1	160476	23624.5	1359470.7
Agricultural Hall	133628.27	16261.9	2371.21	135921.337
American Family Children's Hospital	959396.4	116754	17024.3	975859.663
Animal Science Building	196106.5	23865.2	3479.87	199471.688

Armory & Gymnasium	302119.99	35944.5	5291.57	304503.581
Art Lofts	124922.65	15202.5	2216.73	127066.329
Athletic Operations Building	18877.388	2297.29	334.975	19201.3246
Atmospheric Oceanic & Space Sciences Bldg	206912.49	25180.3	3671.62	210463.11
Babcock Hall	208773.71	25406.8	3704.65	212356.267
Bardeen Medical Laboratories	2262201.3	269144	39622	2280049.05
Service Memorial Institute	2298159.3	273422	40251.8	2316290.75
Medical Sciences	103466.64	12591.4	1835.99	105242.131
Barnard Residence Hall	379926.67	45201.5	6654.34	382924.118
Bascom Hall	226413.7	27553.5	4017.67	230298.963
Below Alumni Center	11316.369	1377.15	200.807	11510.5578
Biotron Laboratory	2044257.7	243214	35804.7	2060385.92
Birge Hall	252356.39	30710.6	4478.01	256686.835
Bock Laboratories, Robert M	2201338.5	261903	38556	2218706.09
Bradley Memorial Building	60894.968	7244.94	1066.56	61375.4013
Bradley Residence Hall, Harold C	455254.49	54163.6	7973.69	458846.239
Psychology Building, W J Brogden	167096.43	20334.8	2965.09	169963.807
Camp Randall Sports Center	2338340.6	278203	40955.6	2356789.08
Camp Randall Stadium	4117280.9	489851	72113.3	4149764.33
Carillon Tower	1434.307	170.646	25.1216	1445.62306
Schuman Shelter, Carl	1529.2162	186.098	27.1356	1555.45763
Carson Gulley Center	793672.23	94426.6	13901	799933.946
Chadbourne Residence Hall	1027292.6	122221	17992.8	1035397.49
Chamberlin Hall, Thomas C	462224.47	56250.5	8202.08	470156.258
Chamberlin House	28279.617	3441.5	501.816	28764.8957
Chazen Building	332728.71	39586.2	5827.67	335353.792
Chemistry Bldg, F Daniels & J H Mathews	7268663	864785	127309	7326009.45
Cole Residence Hall	400374.39	47634.3	7012.47	403533.164
Computer Sciences	347210.99	42253.9	6161.19	353169.144
Kronshage Residence Hall	136110.61	16193.7	2383.95	137184.457
	135948.72	16174.4	2381.11	137021.292
	161016.48	19156.8	2820.17	162286.828
	106920.92	12720.8	1872.7	107764.478
Elvehjem Building, Conrad A	471513.18	56098	8258.46	475233.202
Dairy Barn	269649.72	32081.4	4722.86	271777.135
Dairy Cattle Center	70752.331	8610.22	1255.49	71966.4428
Davis Residence Hall, Susan B	99536.329	11842.3	1743.36	100321.626
Smith Greenhouse, D C	312481.11	37177.2	5473.04	314946.445
Dejope Residence Hall	1608408.9	191359	28170.9	1621098.56

Biochemical Sciences, DeLuca, Hector F	276806.99	33686.1	4911.88	281557.007
Biochemistry Building, DeLuca, Hector F	93916.194	11429.2	1666.52	95527.7982
Biochemistry Laboratories, DeLuca, Hector F	6091982.5	724790	106700	6140045.5
Wisconsin Institute for Discovery	127542.92	15521.4	2263.22	129731.557
University Apartments Community Center	257713.54	30661.3	4513.8	259746.783
Educational Sciences	270381.11	32904.1	4797.86	275020.853
Education Building	192579.02	23436	3417.28	195883.678
Engineering Centers Building	295089.05	35910.9	5236.3	300152.789
Engineering Hall	706020.82	85919.4	12528.2	718136.153
Engineering Research Building	4573910.8	544178	80111.1	4609996.88
Environment Health and Safety	141749.01	17250.2	2515.31	144181.429
Enzyme Institute	2159148.9	256883	37817	2176183.64
Extension Building	113089.87	13762.5	2006.76	115030.498
Field House	605399.63	72027	10603.4	610175.963
Fleet & Service Garage	182005.37	21654	3187.79	183441.312
Genetics-Biotechnology Center Building	6274624.7	746519	109899	6324128.62
Gilman House	128925.26	15338.8	2258.1	129942.423
Goodman Softball Main Building	21941.846	2610.52	384.307	22114.957
Goodnight Hall, Scott H	86302.351	10502.6	1531.42	87783.3015
Gordon Dining & Event Center	2728887	324668	47795.9	2750416.68
Grainger Hall	976685.27	118858	17331.1	993445.21
Gymnasium-Natatorium	1148872.3	136686	20122.3	1157936.38
Biomedical Sciences Laboratories, Hanson, Robert P	1488151.6	177052	26064.7	1499892.39
Harlow Center	1234529.7	146877	21622.5	1244269.59
Hasler Laboratory of Limnology, Arthur D	596466.04	70964.2	10447	601171.884
Health Sciences Learning Center	614438.95	74774.3	10903.1	624982.734
White Hall, Helen C	658466.14	80132.2	11684.3	669765.438
Smith Annex, Hiram	20073.095	2442.8	356.193	20417.5498
Smith Hall, Hiram	30455.372	3706.27	540.424	30977.9868
Horse Barn	105299.5	12527.9	1844.3	106130.263
Moore Hall-Agronomy	53078.545	6459.41	941.868	53989.3745
Horticulture	925372.61	110096	16207.7	932673.377
Plant Sciences	94771.419	11533.2	1681.7	96397.699
Humphrey Hall	26233.835	3192.53	465.514	26684.0084
Ingraham Hall, Mark H	144215.91	17550.4	2559.08	146690.656
Jones House	20798.857	2531.12	369.072	21155.7658
Jorns Hall	26301.421	3200.76	466.713	26752.7544
Kellner Hall	203099.4	24163.6	3557.24	204701.763
King Hall	28939.882	3521.85	513.532	29436.4908

Soils	46135.365	5614.46	818.663	46927.0493
LaBahn Arena	550372.32	65480.2	9639.66	554714.505
Lathrop Hall	133186.36	16208.1	2363.37	135471.845
Law Building	297935.47	36257.3	5286.8	303048.052
Leopold Residence Hall, Aldo	444333.26	52864.3	7782.41	447838.849
Livestock Laboratory	980531.19	116658	17173.8	988267.133
Lowell Center	208989.46	25433	3708.48	212575.726
Mack House	140083.09	16666.3	2453.53	141188.285
Materials Science and Engineering Bldg	71880.5	8747.52	1275.5	73113.9715
McArdle Building	2925987.7	348118	51248.1	2949072.43
McClain Athletic Facility	3110920	370120	54487.1	3135463.78
Meat Science and Muscle Biology Lab	889425.36	105819	15578.1	896442.521
Mechanical Engineering Building	401266.94	48832.3	7120.4	408152.691
Bardeen Medical Laboratories	2262201.3	269144	39622	2280049.05
Service Memorial Institute	185022.36	22516.3	3283.18	188197.351
Medical Sciences	103466.64	12591.4	1835.99	105242.131
Medical Sciences Center	616778.47	75059	10944.6	627362.402
Meiklejohn House	45963.792	5468.51	805.046	46326.4256
Memorial Library	5597140	665916	98032.7	5641298.91
Memorial Union	982652.9	116910	17211	990405.586
Merit Residence Hall	152125.08	18099	2664.44	153325.282
Microbial Sciences Building	646560.58	78683.4	11473.1	657655.573
Middleton Building, William S	74347.396	9047.73	1319.28	75623.199
Humanities Building, Mosse, George L	126991.91	15454.3	2253.45	129171.093
Music Hall	12308.696	1497.91	218.415	12519.914
Nicholas Hall, Nancy	294491.18	35838.2	5225.69	299544.652
Nicholas-Johnson Pavilion and Plaza	562422.98	66913.9	9850.72	566860.24
Nielsen Tennis Stadium	2282826.5	271598	39983.2	2300836.99
Noland Zoology Building, Lowell E	147062.33	17896.8	2609.59	149585.919
North Hall	152162.44	18103.4	2665.09	153362.935
Nutritional Sciences	79543.733	9680.09	1411.49	80908.7056
Observatory Hill Office Building	124244.03	14781.9	2176.11	125224.255
Ogg Residence Hall, Frederic A	1500367.3	178505	26278.6	1512204.48
Phillips Residence Hall, Vel	419489.65	49908.5	7347.27	422799.234
Police and Security Facility	130028.74	15470.1	2277.43	131054.611
Porter Boathouse	557982.37	66385.6	9772.95	562384.595
Poultry Research Laboratory	975580.37	116069	17087.1	983277.254
Pyle Center	150882.67	18361.7	2677.38	153471.82
Radio Hall	22095.481	2688.92	392.08	22474.6405

Rennebohm Hall	313792.23	38187	5568.18	319176.912
Russell Laboratories	5013618.8	596492	87812.5	5053174.03
School of Social Work Building	16155.404	1966.04	286.674	16432.6307
Science Hall	150909.54	18365	2677.86	153499.15
Seed Building	42475.314	5169.04	753.716	43204.1912
Sellery Residence Hall	1891949.9	225094	33137.1	1906876.51
Service Building	476821.77	56729.6	8351.43	480583.675
Service Building Annex	317945.28	37827.3	5568.75	320453.727
Social Science Bldg, Sewell, William	312942.2	38083.6	5553.1	318312.299
Cooper Hall, Signe Skott	228573.86	27816.4	4056	232496.189
Slichter Residence Hall	491243.48	58445.4	8604.03	495119.165
Smith Residence Hall, Newell J	1209616.1	143913	21186.2	1219159.4
Southeast Recreational Facility (SERF)	5026530.4	598028	88038.6	5066187.48
South Hall	168276.54	20020.6	2947.33	169604.169
Steenbock Memorial Library	1358504.6	161627	23793.9	1369222.55
Sterling Hall	69332.681	8437.46	1230.29	70522.4317
Stock Pavilion	87518.902	10650.6	1553.01	89020.7288
Stovall Building, William D-Hygiene Lab	2549510.2	303326	44654.1	2569624.72
Sullivan Residence Hall	417683.97	49693.7	7315.65	420979.312
Swenson House	129747.16	15436.6	2272.49	130770.801
Taylor Hall, Henry	48755.629	5933.33	865.159	49592.2772
Teacher Education	164055.05	19964.7	2911.12	166870.239
Kohl Center, The	5813233.5	691626	101818	5859097.32
Tripp Residence Hall-Botkin House	93534.013	11128.1	1638.23	94271.9541
Tripp Residence Hall-High House	66262.08	7883.49	1160.57	66784.8579
Tripp Residence Hall-Fallows House	74107.431	8816.88	1297.98	74692.1048
Tripp Residence Hall-Frankenburger House	87531.697	10414	1533.1	88222.2827
Tripp Residence Hall-Mail Room & Main Desk	8854.0385	1053.4	155.077	8923.89287
Tripp Residence Hall-Bashford House	89461.903	10643.7	1566.91	90167.7165
Tripp Residence Hall-Vilas House	84879.222	10098.5	1486.64	85548.8802
Tripp Residence Hall-Gregory House	73547.049	8750.21	1288.16	74127.3014
Tripp Residence Hall-Spooner House	79512.006	9459.89	1392.64	80139.3193
Turner House	131851.7	15687	2309.36	132891.952
Union South	1399326.7	166484	24508.9	1410366.77
Apartment Facilities Office	5178.8699	630.244	91.898	5267.73942
University Club	100676.97	11978	1763.34	101471.27
University Houses 1	46623.798	5547.04	816.606	46991.6384
Clinical Science Center	35154037	4182429	615716	35431386.7
UW Medical Foundation Centennial	2736388.8	325560	47927.3	2757977.68

Van Hise Hall	346943.25	42221.3	6156.44	352896.804
Van Vleck Hall, E B	146812.78	17866.4	2605.16	149332.087
Veterinary Medicine Building	7763637.2	923674	135978	7824888.82
Vilas Communication Hall	114969.03	13991.2	2040.1	116941.905
Waisman Center	3188808.2	379386	55851.3	3213966.42
Greenhouse-Walnut St	1434755	170699	25129.4	1446074.58
WARF Office Building	167203.78	20347.9	2967	170073.005
Observatory, Washburn	8058.352	980.663	142.994	8196.63358
Water Science and Engineering Laboratory	1429226	170041	25032.6	1440501.99
Waters Residence Hall, Elizabeth	1159804.3	137987	20313.7	1168954.66
Weeks Hall for Geological Sci, Lewis G	214851.26	26146.4	3812.49	218538.116
Wendt Commons, Kurt F	814358.96	96887.8	14263.3	820783.882
Wisconsin Energy Institute	1721109.1	204768	30144.9	1734687.87
Wisconsin Institutes for Medical Research	14159525	1684620	248001	14271236.9
Primate Center, Wisconsin	45321.732	5515.44	804.225	46099.4537
Veterinary Diagnostic Lab-WI	1529609.3	181984	26790.8	1541677.2
Witte Residence Hall	1861988.1	221529	32612.3	1876678.35
Bayliss Co-Op, Zoe	92151.737	10963.7	1614.02	92878.7725
Zoology Research Building	839292.94	99854.3	14700	845914.577