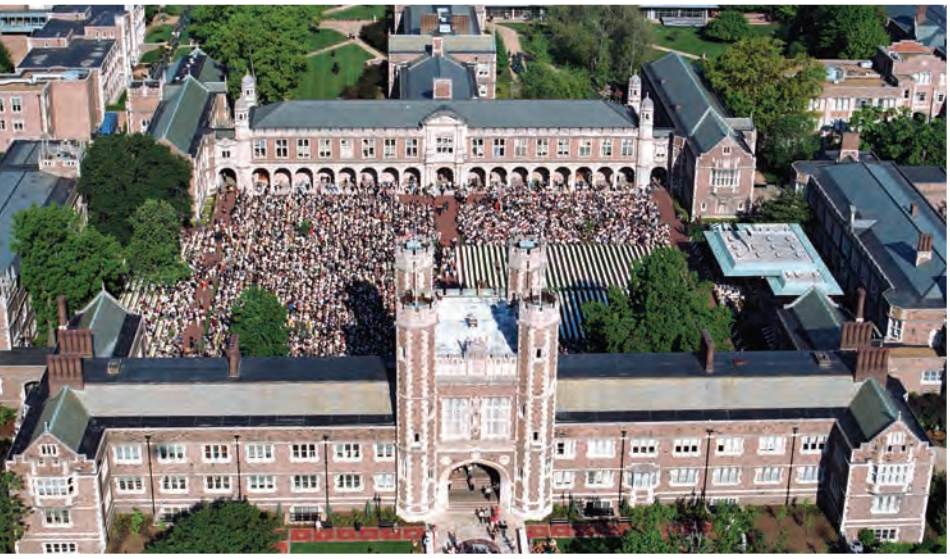
Greenhouse Gas Emissions Inventory

Volume 1: Fiscal Years 1990-2009

Published: October 2009



Washington University in St. Louis

ACKNOWLEDGEMENTS

The production of the first Greenhouse Gas Emissions Inventory for Washington University in St. Louis (WUSTL) was an important and significant undertaking. This inventory will be used to inform and guide a crucial part of WUSTL's sustainability strategic plan – its efforts to mitigate its impacts on and to adapt to the consequences of global climate change.

There are a number of individuals and groups whose talents and efforts were crucial to completing this inventory. Jerry Bauer and Pat Walters, professional engineers with Burns & McDonnell, provided tireless and experienced leadership in collecting, analyzing, and publishing this inventory. Much of their work required time consuming, and often tedious, pursuit of difficult to obtain data. Without their persistence and patience, the completeness of this inventory would have significantly suffered. Ed Barry (Danforth campus) and Jim Stueber (Medical campus), WUSTL's utility directors, and Bruce Backus, Asst. Vice Chancellor for Environmental Health and Safety, provided steadfast hands-on support of this project through data collection and review. School of Engineering Prof. Rudy Husar and Erin Robinson (Ph.D candidate in the Dept. of Energy, Environmental and Chemical Engineering), led the EECE 449/549 class that provided professional-grade data collection and analysis support of WUSTL's Scope 3 GHG emissions. Without them, the University's Scope 3 emissions simply would not have been estimated. Finally, many WUSTL staff members were diligent in collecting the needed, but often not readily available, data that enabled this report to be comprehensive and robust. A sincere and heartfelt "thank you" to all involved.

Let this work guide us toward a sustainable future.

Matthew B. Malten, MEM, LEED® AP
Asst. Vice Chancellor for Sustainability
Washington University in St. Louis

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ACRONYMS & KEY TERMS

ANSI: American National Standards Institute

ACUPCC: American College & University President's Climate Commitment

BTU: British Thermal Unit

CA-CP: Clean Air-Cool Planet

CCF: Hundred Cubic Feet (of Natural Gas)

CFC: Chlorofluorocarbon

CFR: Code of Federal Regulations

CH_4: Methane

CO_2: Carbon Dioxide

CO_2e: Carbon Dioxide Equivalent

DOE: Department of Energy

DOT: Department of Transportation

EPA: Environmental Protection Agency

EIQ: Emission Inventory Questionnaire

FY: Fiscal Year: July 1- June 30

GHG: Greenhouse Gas

GWP: Global Warming Potential

HCFC: Hydrochlorofluorocarbon

HFC: Hydrofluorocarbon

IPCC: Intergovernmental Panel on Climate Change

ISO: International Organization for Standardization

KG: Kilogram

KW-hrs: Kilowatt-hours

LB: Pound

MT: Metric Ton (equal to 1.102 short tons)

$MTCO_2e$: Metric Tons of Carbon Dioxide Equivalent

MPG: Mile Per Gallon rating (for a vehicle)

MW-hrs: Megawatt-hours

N_2O: Nitrous Oxide

PFC: Perfluorocarbon

SF_6:	Sulfur Hexafluoride
UNFCCC:	United Nations Framework Convention on Climate Change
US:	United States
VMT:	Vehicle Miles Traveled
WUSTL:	Washington University in St. Louis
WBCSD:	World Business Council for Sustainable Development
WRI:	World Resources Institute

EXECUTIVE SUMMARY

Washington University in St. Louis (WUSTL) worked with Burns & McDonnell to complete its Greenhouse Gas (GHG) Emissions Inventory for Fiscal Years 1990-2009 in general accordance with industry recognized standards, including the Greenhouse Gas Protocol (GHG Protocol), convened by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBSCD), ANSI/ISO/NSF E 14064-1:2006 Greenhouse Gases- Part 1: Specification with Guidance at the Organizational Level for Quantification and Reporting of Greenhouse Gas Emissions and Removals, and the Clean Air-Cool Planet (CA-CP) Campus Carbon Calculator™.

Fiscal year 1990 was selected as the baseline because it is the year that WUSTL began tracking the criteria air pollutants regulated under the 1990 Clean Air Act Amendments, and because 1990 is also the baseline in the Kyoto Protocol. Emissions are summarized below in Table ES-1 for the baseline and current year by the following "scopes" as defined by GHG accounting protocol:

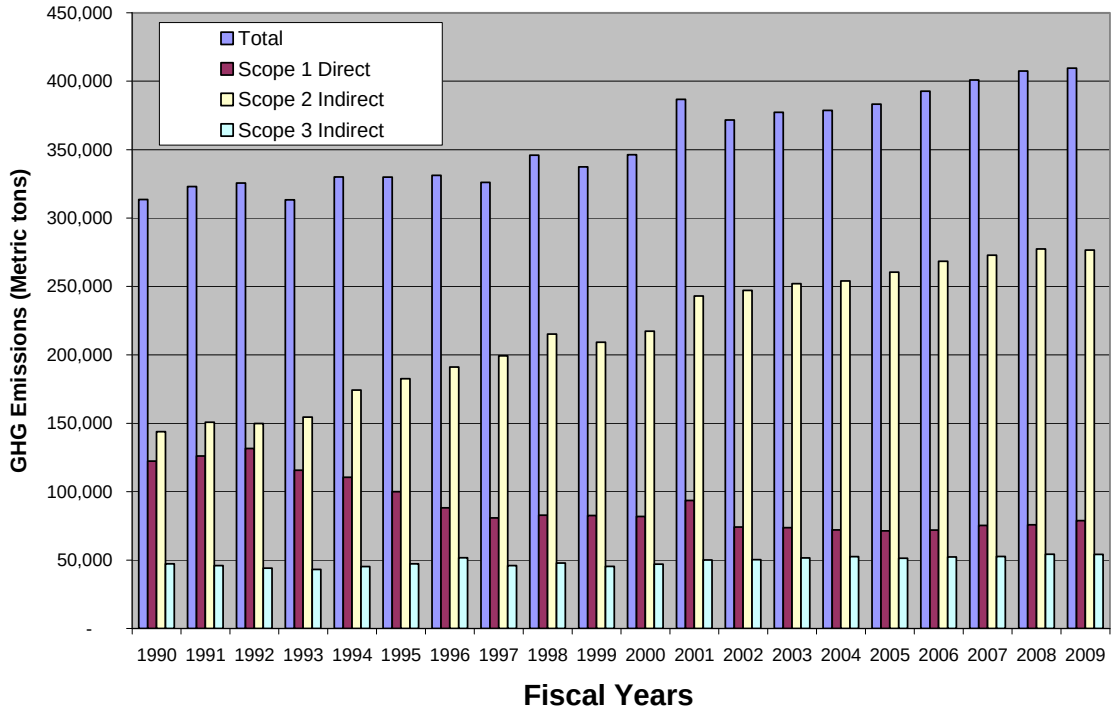
- **Scope 1: Direct emissions** from WUSTL sources, primarily fuel combustion.
- **Scope 2: Indirect emissions** entirely attributed to purchased electricity.
- **Scope 3: Indirect emissions** primarily from transmission and distribution losses from purchased electricity; faculty, staff, and student commuting to campus; and traveling by airline on WUSTL business.

Table ES-1: WUSTL GHG Emissions Summary (1990 & 2009)

Emission Source Category	FY 1990 Emissions (Metric Tons CO_2e)	FY 2009 Emissions (Metric Tons CO_2e)
Scope 1 - Direct Emissions	122,400	78,800
Scope 2 - Energy Indirect Emissions	143,900	276,500
Scope 3 - Other Indirect Emissions	47,200	54,200
TOTAL	**313,500**	**409,500**

FY 1990-2009 GHG emissions are plotted on the next page in Figure ES-1.

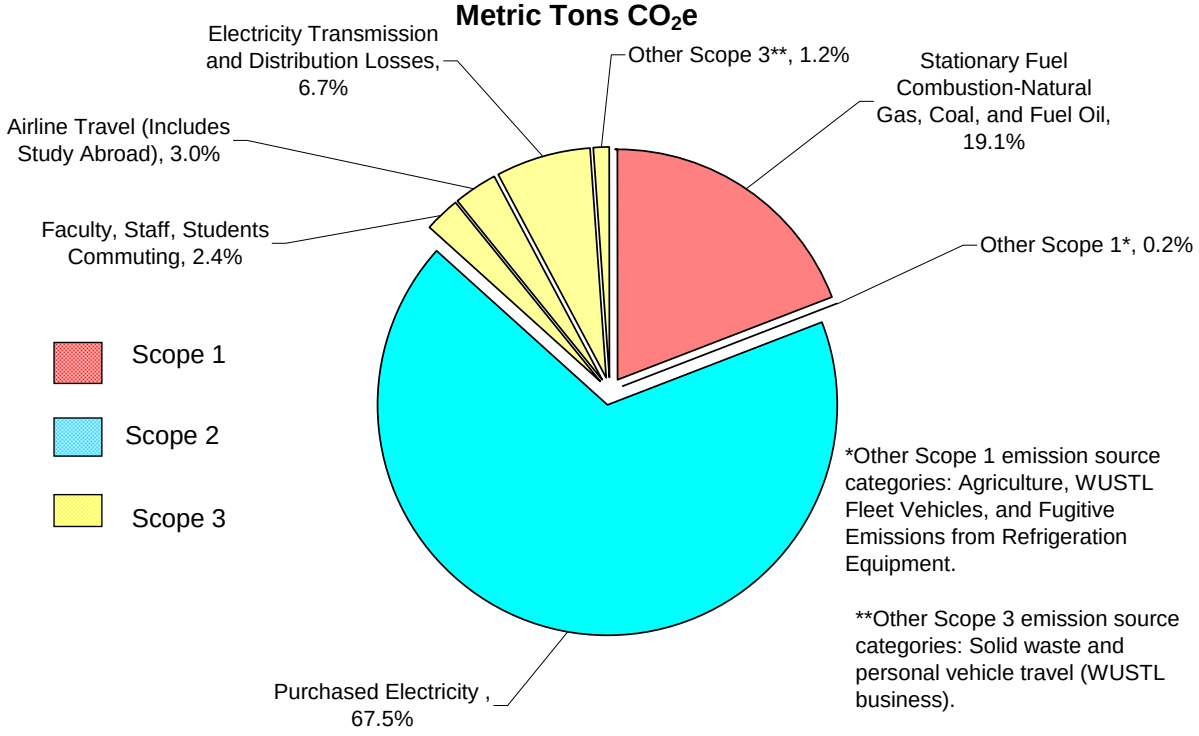
Figure ES-1 WUSTL GHG Emissions Summary



FY 2009 GHG emissions are broken down by source category in Figure ES-2. The combined totals of GHG emissions associated with purchased electricity and fuel combustion account for the majority of GHG emissions (more than 90% of total emissions) in all the subject years. The percentage of total GHG emissions associated with fuel combustion has steadily decreased since 1990 while the percentage of Scope 2 purchased electricity emissions has increased an approximately equal percentage. WUSTL also replaced coal with natural gas as its fuel source for some steam generation and some steam heating has been replaced with electric heat. The latter also contributed to the increase in WUSTL's Scope 2 emissions between FY 1990-2009.

The data, used to calculate emissions associated with fuel combustion and purchased electricity emissions, which accounts for more than 90% of total emissions, is believed to be highly accurate. Highly accurate data required to calculate emissions was not readily available for some Scope 3 emission categories. WUSTL derived data using conservative estimation and/or modeling techniques consistent with industry standards and approaches used by other universities to come up with its initial projections. Since these emission categories represent a small portion of total emissions, the overall GHG inventory is believed to be reasonably accurate. WUSTL will continue to work to further refine this data collection to make its GHG estimates as accurate as practical.

Figure ES-2
2009 GHG Emissions Summary by Source Category
Metric Tons CO_2e



GHG intensity ratios are a comparison of GHG emissions to a productivity or intensity parameter. The three intensity ratios evaluated as part of WUSTL's GHG emissions inventory are:

- **$MTCO_2e$ emissions per total population** (faculty, staff, and students)
- **$MTCO_2e$ emissions per total square footage** (WUSTL owned buildings)
- **$MTCO_2e$ emissions per total budget** (WUSTL operating, research, and energy dollars)

While WUSTL's absolute GHG emissions have increased from FY1990-2009, the intensity ratios indicate that when normalized to the productivity parameters (population, building square footage, and budget) and compared to the base year, the WUSTL's GHG emissions have decreased in relation to total building square footage and total operating budget. The comparisons are shown on the next two pages in Figures ES-3, ES-4, and ES-5.

Figure ES-3 Intensity Ratio (WUSTL Population)

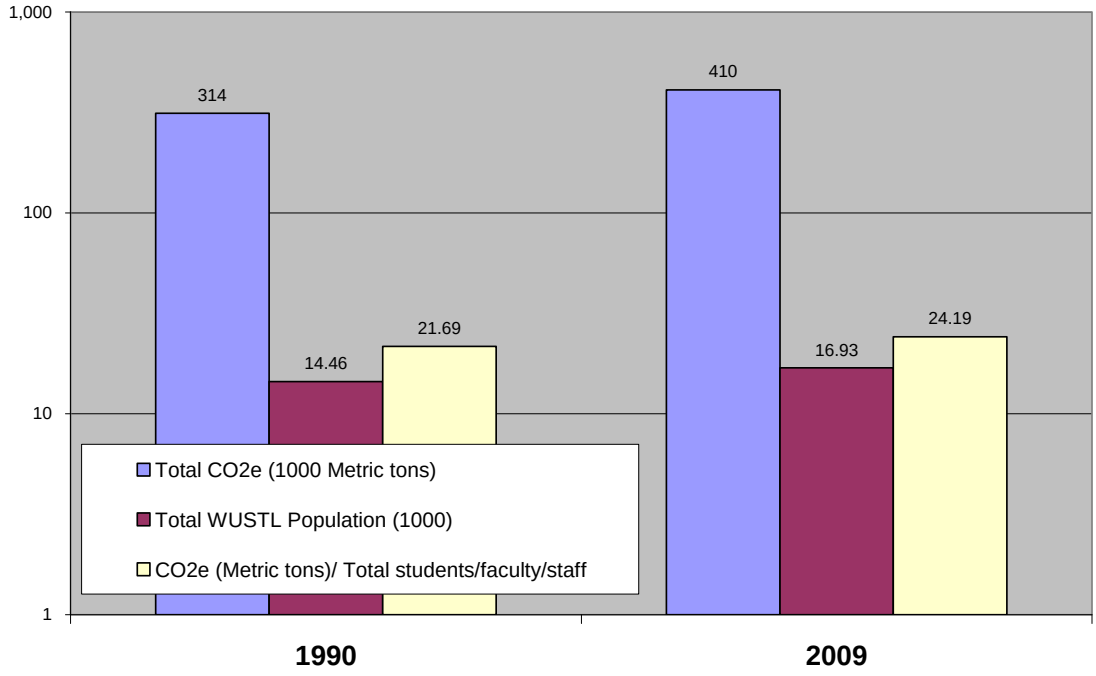


Figure ES-4 Intensity Ratio (Total Bldg Sq. Foot)

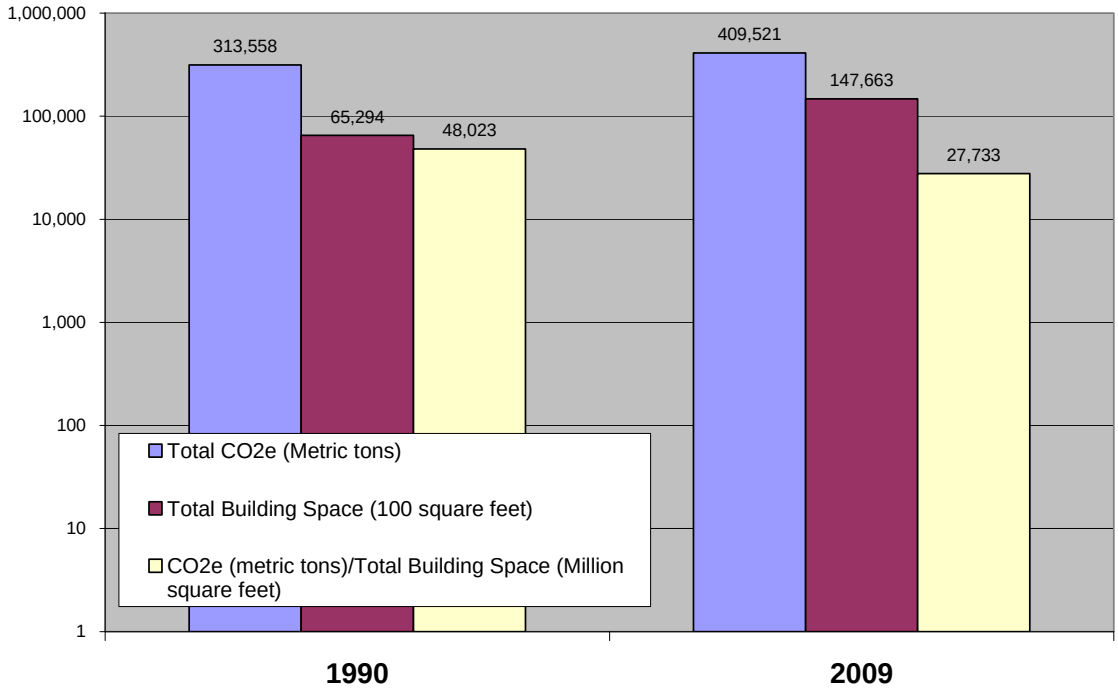
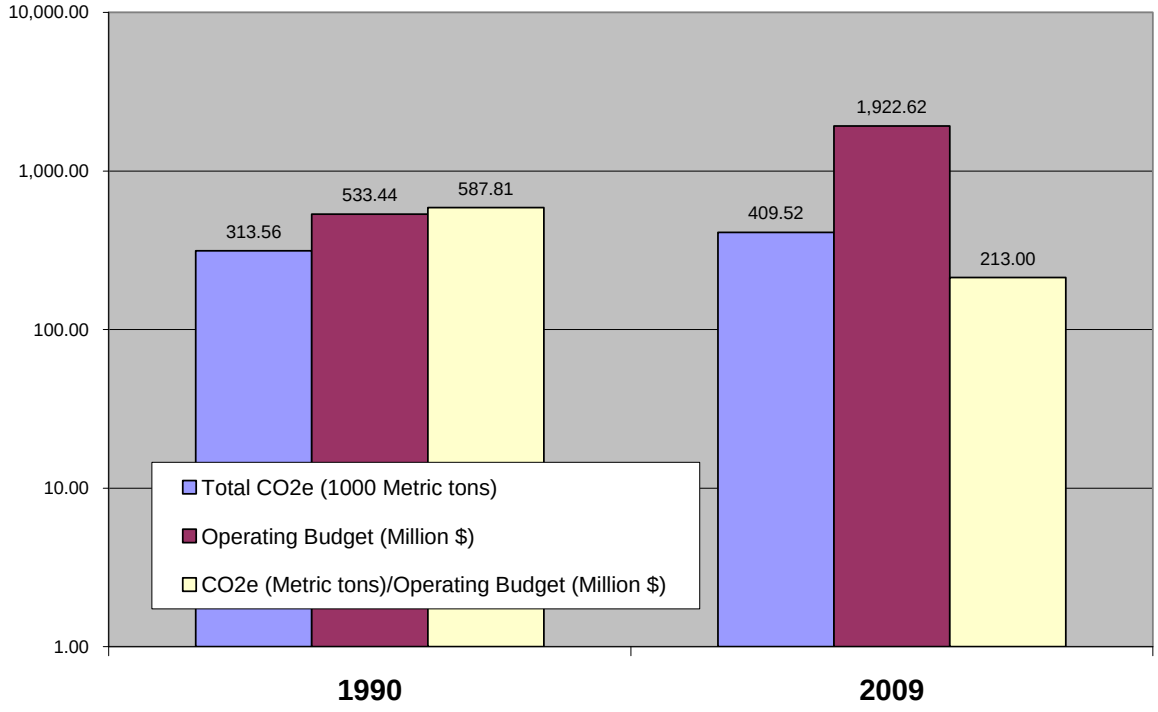


Figure ES-5 Intensity Ratio (Operating Budget)



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1.0 INTRODUCTION

Washington University in St. Louis (WUSTL) worked with Burns & McDonnell to complete its Greenhouse Gas (GHG) Emissions Inventory for Fiscal Years 1990-2009. Fiscal year 1990 was selected as the baseline because it is the year that WUSTL began tracking the criteria air pollutants regulated under the 1990 Clean Air Act Amendments, and because 1990 is also the baseline in the Kyoto Protocol. The Kyoto Protocol is the international treaty, part of the United Nations Framework Convention on Climate Change (UNFCCC), which has established legally binding GHG reduction targets for nations that have ratified the protocol. Although the United States (US) has not ratified the Kyoto Protocol, and it is unclear whether 1990 will be used as a baseline in federal regulations currently under development, WUSTL believes the selected timeframe provides a comprehensive understanding of its GHG emissions trends during several key decades of dramatic growth at WUSTL.

There are no federal, state, or local regulations that require WUSTL to conduct a GHG emissions inventory for the current year or any regulations that restrict or require WUSTL to reduce GHG emissions. The Greenhouse Gas Reporting Rule, 40 CFR Part 98, was finalized on September 22, 2009 and is expected to require WUSTL to begin reporting GHG emissions beginning with calendar year 2010. WUSTL determined it was imperative to voluntarily define its GHG emissions inventory for several reasons.

First, WUSTL reviewed the UNFCCC's Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report ("Climate Change 2007") and concluded that it shows clear evidence that our climate system is changing; that the changes are likely caused by man-made emissions of GHGs; and, that maintaining the status quo (i.e. not reducing global GHG emissions) will result in significant economic, environmental, and social harm. Upon release in 2007, the IPCC emphasized that its fourth report demonstrates a "scientific consensus regarding the quickening and threatening pace of human-induced climate change" and it called for the global response "to move much more rapidly…and with more determination."

Next, in 2007 WUSTL was asked to sign the American College & University President's Climate Commitment (ACUPCC). The ACUPCC requires signatories to:

- **"Initiate the development of a comprehensive plan to achieve climate neutrality as soon as possible."** As part of that work, within one year of signing the ACUPCC, signatories must complete a comprehensive inventory of all GHG emissions and update the inventory every year

thereafter. Within two years, signatories must determine a target date for achieving climate neutrality (i.e. zero net GHG emissions) as soon as possible and develop interim targets.

- **"Initiate two or more…tangible actions to reduce GHG emissions while the more comprehensive plan is being developed."**
- **"Make the action plan, inventory, and progress reports publicly available…"**

Finally, while the U.S. has not ratified the Kyoto Protocol or other regulations requiring the measurement and reduction of GHG emissions, the U.S. is currently developing several alternatives designed to align with the UNFCCC's goal of achieving "stabilization of GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." There are several states and regions establishing and pursuing GHG reductions goals (e.g. Regional Greenhouse Gas Initiative, U.S. Conference of Mayors Climate Protection Agreement, and the Western Climate Initiative). In addition, the American Clean Energy and Security Act of 2009 (H.R. 2454) is the latest proposed federal regulation to control GHG emissions. It was approved by the House of Representatives on 26 June 2009 and is under consideration in the Senate as this report is written.

The strong majority of scientific opinion is that global climate change is occurring at an increasing rate and it is being induced by man-made greenhouse gas emissions. The University has chosen to be a leader by demonstrating how to reduce our GHG emissions, our energy use and costs, and our impact on human-induced global climate change.

Completing this GHG emissions inventory in accordance with recognized industry standards was a necessary first step for WUSTL. The inventory provides the needed emissions baseline and trends that is crucial for the University to understand its "carbon footprint" in order to develop an effective GHG reduction strategy. The GHG emissions in this inventory are categorized (by emission source category) so that informed decisions can be made regarding both the potential for and strategies to reduce GHG emissions in the future.

WUSTL will voluntarily maintain and update this GHG emissions inventory each fiscal year. WUSTL also will use this inventory to develop and publish its GHG emissions reduction strategy by the end of 2009. Once its GHG emissions reduction strategy is published, WUSTL will publicly track and report its progress toward achieving its GHG emissions reductions goals.

* * * * *

2.0 INVENTORY PROTOCOL

WUSTL's GHG inventory was conducted generally in accordance with industry recognized standards for GHG emissions accounting, namely:

- **ANSI/ISO/NSF E14064-1:2006, Greenhouse Gases- Part 1 (ISO 14064)**: Specification with Guidance at the Organizational Level for Quantification and Reporting of Greenhouse Gas Emissions and Removals.
- **Greenhouse Gas Protocol (GHG Protocol)**, A Corporate Accounting and Reporting Standard, Revised Edition, World Business Council for Sustainable Development (WBCSD) and World Resources Institute (WRI).
- **Clean Air-Cool Planet Campus Carbon Calculator version 6.4 (CA-CP Calculator).**

The CA-CP Calculator facilitates collection, analysis, and presentation of GHG emissions data that has been specifically designed for colleges and universities. According to the CA-CP Calculator developers, it has been used by more than 200 schools across North America. The CA-CP Calculator is derived from the GHG Protocol, but includes some calculations and features that have been customized for universities. The CA-CP Calculator emission factors were used in estimating GHG emissions in this inventory unless otherwise noted in this report or the appendix A.

Other references used in developing this inventory and quantifying emissions included the following:

- **Technical Guidelines - Voluntary Reporting of Greenhouse Gases (1605(b)) Program**, Office of Policy and International Affairs, United States of Department of Energy (DOE) , March 2006.
- **Calculation Tool for Direct Emissions from Stationary Combustion, Version 3.0**, July 2005, A WRI/WBSCD Tool, Environmental Resources Trust.
- **The Climate Registry - General Reporting Protocol for the Voluntary Reporting Program**, October 29, 2007 Draft Copy.

Burns & McDonnell relied on fuel and electricity usage information, refrigerant data, vehicular miles traveled (VMT), and other pertinent operating information provided by WUSTL to calculate annual emissions of each of the six GHG categories recognized in E14064 (as well as the GHG Protocol and CA-CP Calculator) and described in Section 2.1 of this report for Fiscal Years 1990-2009. (Fiscal year 2009 covers July 1, 2008 to June 30, 2009). Emissions of each GHG recognized in ISO 14064 were converted to carbon dioxide equivalents (CO_2e) based on the Global Warming Potentials provided in Annex C to

ISO 14064. This report deviates from GHG Protocols by the fact that GHG emissions are reported on a fiscal year rather than calendar year basis. WUSTL will monitor proposed regulations on whether they will require inventories to be based on the fiscal or calendar year. At this time, WUSTL will maintain its inventory on the fiscal year because it most accurately reflects University operations and is the recommended approach in the CA-CP Calculator.

This report deviates from the CA-CP Calculator with respect to two assumptions/calculation methods:

- GHG emissions associated with purchased electricity are calculated using the eGRID post 2006 emission factor for all subject years (1990-2009); the CA-CP Calculator uses a different (lower) factor (eGRID pre 2006) for years 1990-2006. WUSTL deviated from the CA-CP Calculator on this emission factor because using the pre and post eGRID factors skews GHG emissions dramatically in FY 2007. WUSTL believes that using a constant emission factor over the study report provides a more accurate and meaningful representation of GHG emissions. The higher emission factor (eGRID post 2006) factor is being used (rather than the eGRID pre 2006) to ensure emissions are not being underestimated. The emission factors are compared in greater detail in Section 3.0 of this report.

- The CA-CP calculator is using GWP values that appear to be based on the UNFCCC Third Annual Report (TAR) as opposed to the Second Annual Report (SAR). The TAR recommends using these updated values *beginning in 2012*. Other reporting protocols including the Climate Registry and ISO 14064 require using the SAR values for current inventories. The SAR values are used in this report because the TAR values are only recommended for use beginning in 2012.

WUSTL and Burns & McDonnell made diligent efforts to obtain the most accurate operational data. This included interviewing WUSTL personnel and contacting the natural gas and electric suppliers, facilities maintenance contractors, and vehicle fueling contractor. But, because the inventory covers a period of 20 fiscal years, highly accurate data was not available for some time periods for some of the WUSTL sub-organizations. For instance, natural gas data was not readily available for Quadrangle Housing facilities (see Organizational Boundaries) for all 20 years. Similarly, fertilizer application data was only available for the last several fiscal years. In such instances, where data was incomplete, reasonable assumptions were used to fill the data gaps. An evaluation was made for each data gap that was filled to ensure that the overall accuracy of the inventory was not compromised. Data gaps and the basis for filling them are documented in this report.

2.1 GHGs Covered in the Inventory

A GHG is defined in ISO 14064 as a gaseous constituent of the atmosphere, both natural and anthropogenic, that absorbs and emits radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere, and clouds. ISO 14064 (Section 2.1) recognizes six chemicals as GHGs; those in bold are the ones identified for the WUSTL inventory:

- **Carbon Dioxide (CO_2)**
- **Methane (CH_4)**
- **Nitrous Oxide (N_2O)**
- **Hydrofluorocarbons (HFCs)**
- Perfluorocarbons (PFCs)
- Sulfur Hexafluoride (SF_6)

WUSTL inventory covers all GHGs that were pertinent and relevant; there was no indication or expectation that WUSTL emitted either perfluorocarbons or sulfur hexafluoride. In addition, some of the emission categories made an insignificant contribution (less than 1%) of the total GHG emissions as listed below. For these emission categories, gap filling was assumed to have an insignificant affect on the accuracy of overall emissions because GHG emissions from the remaining source categories are orders of magnitude greater. Scope 1 emission categories that contribute less than 1% (each) to WUSTL's total GHG emissions are:

- Agriculture (Includes Fertilizer Application and Animal Agriculture)
- Solid, Hazardous, and Medical Waste Incineration
- University Fleet Vehicle Travel
- Refrigeration Losses.

Scope 3 emission categories that contribute less than 1% (each) to WUSTL's total GHG emissions are:

- Personal automobile travel (faculty and staff) for WUSTL business
- Solid Waste decomposition.

2.2 Global Warming Potential and Carbon Dioxide Equivalents

ISO 14064 recognizes that not all GHGs have the same properties. Global warming potential (GWP) describes the radiative forcing impact of a mass-burned unit of a given GHG relative to an equivalent unit of carbon dioxide over a given period of time. (ISO 14064, Greenhouse Gases - Part 1, Section 2.18)

The GHG emission quantities were converted to carbon dioxide equivalents (CO_2e). The GWP for CO_2 is by definition 1.0. GWPs for other GHGs range from 21 to 23,900. GWPs for all recognized GHGs are summarized below in Table 1. The CO_2e emissions for each GHG are calculated by multiplying GHG emissions by the corresponding GWP.

Table 1: GHG Global Warming Potentials

GHG	GWP
Carbon Dioxide (CO_2)	**1**
Methane (CH_4)	**21**
Nitrous Oxide (N_2O)	**310**
Hydrofluorocarbons (HFCs)	**Varies**
Perfluorocarbons (PFCs)	6,500-9,200
Sulfur Hexafluoride (SF_6)	23,900

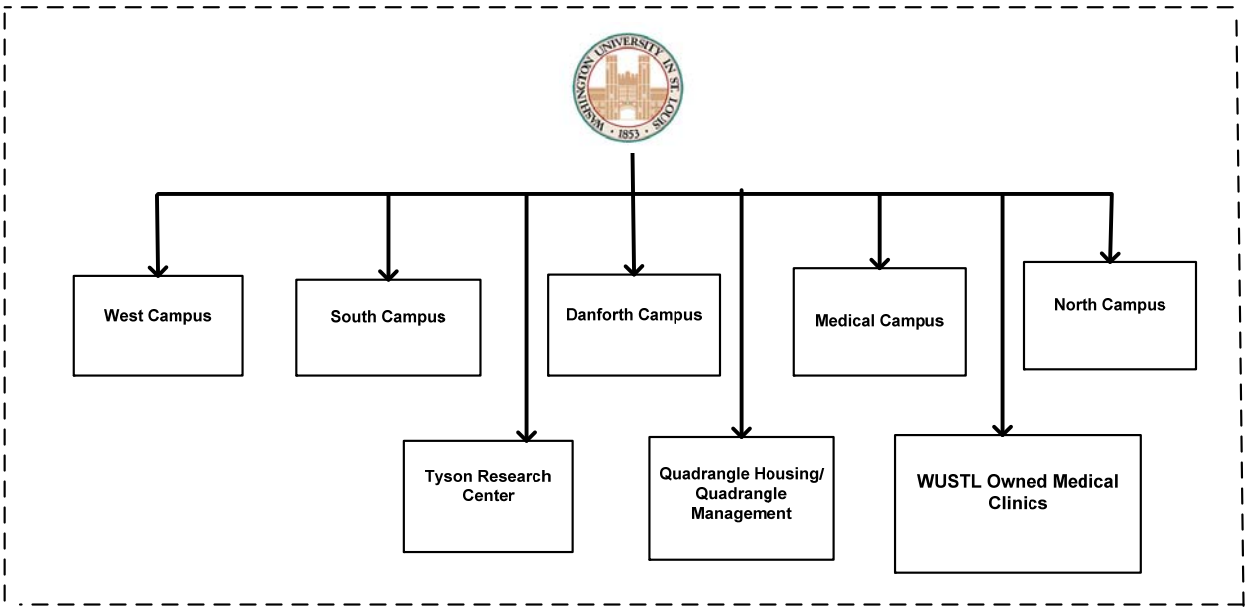
2.3 Organizational Boundaries

Organizational boundaries represent the distinction of GHG emissions that will be included or not included in the inventory. These boundaries define the portion of emissions for which an organization, in this case the University, is responsible. These boundaries can be complex if an organization has joint ventures and/or facilities in which an organization other than the owner is the operator. According to the GHG Protocol and other inventory reporting guidelines, there are generally two recognized approaches used to define these boundaries and consolidate GHG emissions:

- **Equity share**: Accounts for an organization's GHG emissions based on its percentage ownership.
- **Control**: Accounts for an organization's GHG emissions based on its financial or operational control.

WUSTL used the equity share approach to develop its GHG inventory. Organizational boundaries are shown schematically in Figure 1. **WUSTL included all the buildings, facilities, assets, and organizations that it owns (100% equity) in this GHG emissions inventory.** For instance, GHG emissions associated with WUSTL-owned vehicles are counted as Scope 1 sources, whereas GHG emissions associated with the student bus service (operated by an independent contractor in which the University has no ownership stake) are considered within Scope 3.

Figure 1- WUSTL GHG Organizational Boundaries



WUSTL is divided into the following sub-organizations for its GHG inventory. Maps showing the Medical Campus and Danforth Campus, West Campus, North Campus, South Campus, and Tyson Research Center are included in the Appendix A.

- **Danforth Campus**: This St. Louis County campus includes the facilities bordered by the streets of Skinker, Forsyth, Big Bend, and Forest Park Parkway as well as the adjacent South 40 residential housing. The main GHG emissions source categories from the Danforth campus are various **thermal plants**, miscellaneous **stationary combustion sources**, and **purchased electricity**.
- **Medical Campus and Medical Clinics**: These are the research facilities and clinics, associated with the WUSTL's School of Medicine, that are located in the City of St. Louis off of Highway 40 and Kingshighway and in various satellite buildings in the metropolitan area. The main GHG emissions sources are from the **power plant** and from **purchased electricity**.
- **North Campus**: This campus consists of one main commercial building at 700 Rosedale Avenue in the City of St. Louis with a parking garage and a few parking lots. GHG emissions result from **stationary combustion sources** and **purchased electricity**.
- **West Campus**: This campus on Forsyth Avenue in the City of Clayton consists of commercial office space, a main garage, and parking lots. WUSTL occupies most of the space but also leases to outside tenants. Besides the main buildings, there also is a strip mall

occupied by various small commercial tenants. GHGs result from **stationary combustion sources** and **purchased electricity**.

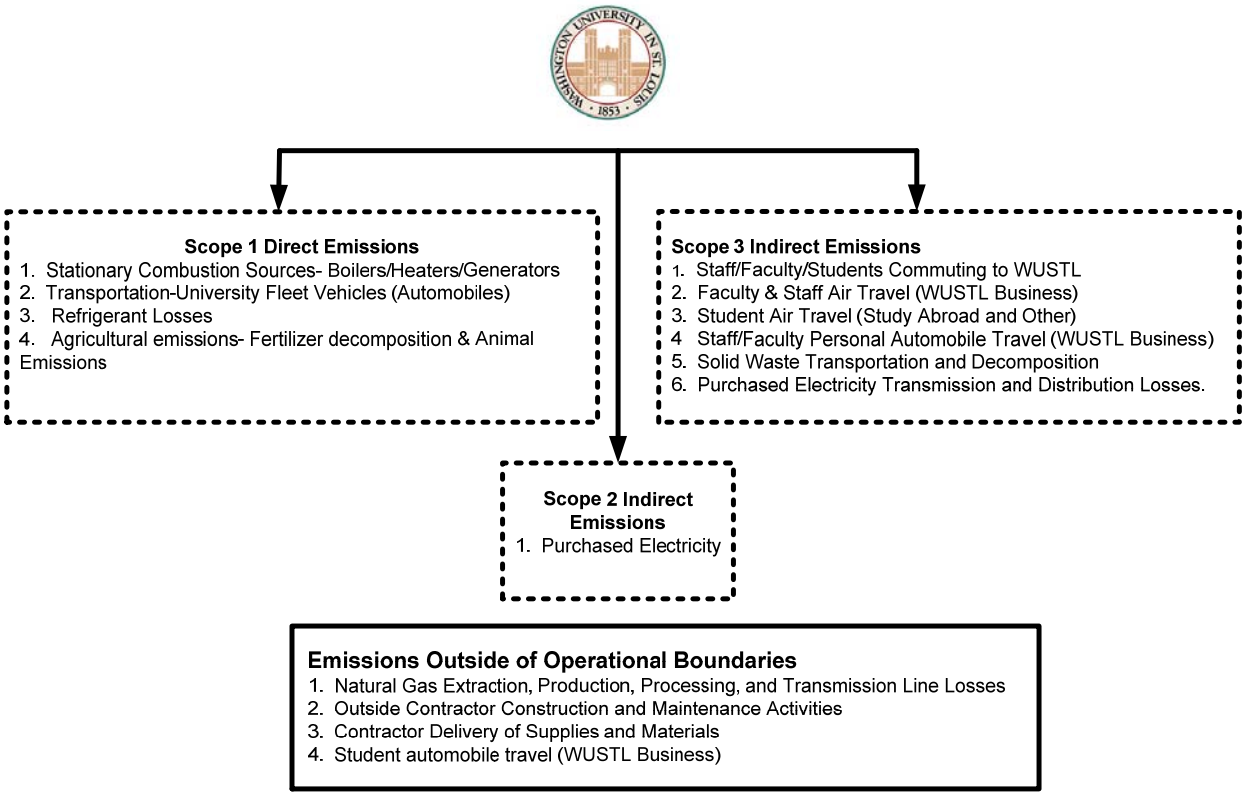
- **South Campus**: This campus is the former Christian Brothers College (CBC) High School property in the 6500 block of Clayton Road in Clayton that is currently being leased to Fontbonne College and the City of Clayton. Since this campus was purchased by WUSTL in Fall 2007, its emissions are included beginning in FY2008. GHG emissions result from **stationary combustion sources** and **purchased electricity**.
- **Tyson Research Center**: Located in Eureka, Missouri, Tyson is a 2,000± acre environmental research field station with several facilities. Several buildings there, also known as "bunkers", are used as storage space by various WUSTL departments while several other bunkers are leased to non-University tenants for storage purposes. Tyson's GHG emissions result from **space and comfort heating**, **purchased electricity**, and **propane combustion**.
- **Quadrangle Housing**: Located mostly near the Danforth and Medical campuses, these are numerous residential and some commercial properties for students and other tenants. The GHG emissions from this group of facilities are from **space and comfort heating** and **purchased electricity**.

The only other property or building identified that could potentially be considered within WUSTL's organizational boundaries (based on an equity approach) is Clopton Farm. The 429-acre farm has a house and the land is tended by a farmer who is not a WUSTL staff member. GHG emissions associated with the farm are assumed to be negligible since the quantity of fuel and electricity used to heat the house, the amount of fertilizer applied, and the number of animals managed are predicted to generate insignificant GHG emissions in comparison to the overall WUSTL GHG emissions.

2.4 Operational Boundaries

Operational boundaries represent the identification of emission sources that will and will not be included in the inventory. These boundaries include GHG emission sources and removals associated with operations and categorizing GHG emissions into direct emissions (Scope 1), energy indirect emissions (Scope 2), and other (Scope 3) indirect emissions (GHG Protocol, Chapter 4). The WUSTL operational boundaries are shown schematically below in Figure 2.

Figure 2- WUSTL Operational Boundaries



Establishing operational boundaries helps to verify that all applicable GHG emission sources are appropriately accounted for and to avoid "double counting". For instance, an emission associated with generating electricity that is supplied to WUSTL is counted as a Scope 1 direct emission by the WUSTL's electric utility provider, AmerenUE. Reporting these emissions as a Scope 1 direct emissions by WUSTL would equate to "double counting" the emissions. The community reviewing GHG emission inventories should be allowed to accurately consolidate GHG emissions from all sources with a clear distinction if the emissions are covered elsewhere. Scope 3 emissions associated with staff and faculty travel on airlines would be accounted for in the airlines' Scope 1 direct emissions.

Scope 1 GHG Emissions

WUSTL **does not have** the following Scope 1 GHG emissions that are common at other universities:

- **on-campus electric generation** (except for limited emergency electrical generation that is included with the stationary combustion category).

WUSTL's Scope 1 direct emissions, which have been categorized to align with CA-CP calculator, are:

- **Stationary combustion sources** (e.g. heating, laboratories, electric generators, waste combustion)
- **Transportation Vehicle (Automobile) fleet**
- **Agriculture -** Fertilizer application and Animal agriculture (e.g. vivariums)
- **Fugitive emissions from air conditioning equipment**

WUSTL's emission source categories and the methodology used to estimate the emissions are described in greater detail below.

Scope 1 (&2) GHG Emissions: Stationary Combustion and Purchased Electricity

WUSTL's sub-organizations use various fuels to provide direct heat and to generate steam. Coal was combusted at the Danforth campus in FY 1990-October 1992 and at the Medical campus to generate steam in FY 1990-March 2002. Natural gas has replaced coal on both campuses as the primary fuel source. Only small quantities of fuel oil, propane, and other fuels have been used with the exception of at the Tyson Research Center which only uses propane for heating because it has no natural gas supply. Fuel oil has been used primarily as a back-up fuel in boilers and as a fuel in emergency electrical generators (which are used on a very limited basis as a back-up for purchased electricity).

A brief description of the data collection is provided below.

Danforth Campus: Accurate monthly electric purchase data was available for the Danforth campus for FY1990-2009 with the exception of eleven months (July 1996-April 1997, and November 1997) where no electric usage data was available either from WUSTL or from AmerenUE. Purchased electricity for these months was estimated by taking an average of the usages for that particular month (May, August, etc.) over selected years that would best represent the missing data.

The natural gas, fuel oil #2, and coal data for the Danforth campus was available for all fiscal years in this study with the exception of fuel oil #2 used in the emergency generators during FY1994-1996. Fuel usage with the generators is known to be orders of magnitude lower than fuel used in the boilers because the generators have much lower heat input ratings than boilers and are typically operated less than 20 hours per year. GHG emissions associated with emergency electrical generators are insignificant compared to total GHG emissions.

Medical Campus and Medical Clinics: The medical school campus had accurate purchased electricity data from FY 1992-2009. Purchased electricity for FY 1990 and 1991 was estimated taking the average

of purchased electricity data from similar years. Accurate and complete fuel oil and coal usage data also was available for FY 1992-2009. The methodology described above for the Danforth campus was used to estimate fuel usage data for FY 1990 and 1991.

West Campus: Accurate gas and electric data was available for the main West campus buildings (i.e. 7425 Forsyth, 7501 Forsyth (garage) and 7511 Forsyth) from FY 1998-2009. Electric and gas usage for the West campus strip mall (tenant-occupied) was estimated using the same estimation approach as the units in Quadrangle Housing. Gas and electric usage for FY 1991-1997 was determined by averaging fiscal years 1998 and 1999 gas and electric usage. Since the West campus accounts for less than 3% of the total University purchased electricity and less than 0.2% of the total natural gas consumption, any inaccuracies in the assumptions are expected to have a negligible impact on the total GHG emissions.

North Campus: WUSTL acquired the North campus sometime in 2001 and occupied the space in November 2003. Gas data for the North campus was obtained from Laclede Gas Company for FY2001-2009. Electric data was obtained from AmerenUE for partial FY2004 and FY2005-2009. For the previous fiscal years, when WUSTL owned but did not occupy the buildings, the electric usage was estimated based on historical gas usage. (According to AmerenUE, WUSTL will have to obtain permission from the tenant who occupied the space before any electric usage data are released for FY2001-2003). Due to the time constraints of this study, this effort was not pursued. Since the North campus is expected to account for only 1% of the total WUSTL purchased electricity and less than 1% of the total natural gas consumption, any inaccuracies in the assumptions are expected to have a negligible impact on the total GHG emissions.

Quadrangle Housing: Electric data and natural gas data for the more than 200 Quadrangle Housing addresses is only partially available from WUSTL's records starting in FY2005. But, natural gas data is available for all housing units dating back to 1989 and can be obtained from Laclede Gas Company. Many of these buildings have multiple meters and account numbers. The available gas data is extensive and would require a great deal of effort to compile, especially on a fiscal year basis. The electric data is available, for a cost, from AmerenUE only for the past three years for each account.

For purposes of this study, the electric and natural gas usage data was estimated for all units in Quadrangle Housing. An estimation approach was developed using the electric (or gas) usage of one building which had accurate meter readings and was relatively large in size. The usage of each building was determined relative to the usage of the representative building adjusted by square footage and degree day ratios.

Tyson Research Center: The fuel and electric data for Tyson is accurate for FY2000-2009. Prior to FY2000, the data is sparse or not available. The only fuel used at Tyson is propane since there is no natural gas supply in that area. Propane usage was identified from actual bills found in records stored at Tyson and is complete for FY2000-2009. Electric data also was obtained from stored records of utility bills. Although 90% of the electric usage existed for FY2000-2009, there were quite of few months of missing data. Electric usage for these months was estimated where ever possible. The estimates were made based on similar months or seasonal usages or from records of usage that had only dollars amounts. Since the Tyson Research Center accounts for less than 0.1% of the total WUSTL purchased electricity, any inaccuracies in the assumptions are expected to have a negligible impact on the total GHG emissions.

Table 2- Total WUSTL Energy/Fuel Use

FY	Purchased Electricity (Million kW-hrs)	Coal (short tons)	Natural Gas (1000 MMBtu)	Fuel Oil (Gallons)	Propane (Gallons)	Incinerated Waste (Short tons)
1990	172	40,661	751	1,659	5,058	6,811
1991	181	40,547	809	1,659	5,058	6,811
1992	180	44,080	766	1,659	5,058	9,307
1993	185	30,991	988	24,899	5,058	4,153
1994	209	29,553	955	37,260	5,058	3,289
1995	219	27,309	846	22,659	3,580	1,938
1996	229	22,498	794	102,298	4,556	762
1997	239	21,401	695	108,586	5,470	2,098
1998	258	21,249	757	27,069	6,554	706
1999	251	20,961	743	141,181	4,601	58
2000	260	21,104	746	6,443	3,711	55
2001	291	19,539	805	1,219,255	5,217	44
2002	296	6,166	1,164	9,776	4,480	37
2003	302	0	1,353	152,248	4,823	48
2004	305	0	1,333	84,694	4,121	66
2005	312	0	1,335	8,044	4,494	64
2006	322	0	1,340	51,009	7,261	64
2007	327	0	1,363	164,840	6,139	64
2008	332	0	1,403	73,289	5,647	67
2009	331	0	1,476	7,166	5,223	67

Scope 1 GHG Emissions: University Vehicle Fleet

WUSTL has fleet vehicles that are owned and insured by WUSTL and used for a number of activities including, but not limited to: building and grounds maintenance, police activities, security, student transportation. The majority of these use gasoline. Diesel vehicles represent less than 2% of the total

vehicles. There are no natural gas powered vehicles in the fleet. WUSTL has a few electric vehicles (golf carts), but, for purposes of estimating GHG emissions, the electricity used to charge the battery is accounted for as purchased electricity.

WUSTL leases a small number of vehicles. The leased vehicles are not considered Scope 1 direct emissions under standard protocols and thus not counted as direct emissions. It should be noted that the leased vehicles accounted for less than 5% of the total WUSTL vehicles and would have made an insignificant contribution to total GHG emissions (less than 0.1%) had they been included.

GHG emissions from fleet vehicles were estimated using the CA-CP Calculator which requires fuel usage data. Tracking actual fuel usage was attempted but found to be impractical for the following reasons: More than 30 departments have one or more vehicles that use fuel. Most departments use a fueling service whereby a WUSTL credit card is used and the cost charged to one of the 30+ department accounts. The departments do not typically track fuel usage (in gallons) and the fueling services keep limited historical data regarding fuel use. Another limitation of trying to track fuel usage through the fueling services is that while the majority of fuel will be purchased using the card, faculty, staff, and/or students may periodically purchase fuel with cash and obtain reimbursement for the purchase. Due to these limitations, directly quantifying historical fuel usage in fleet vehicles was considered impractical.

Therefore, annual fuel usage had to be estimated indirectly based on the number of vehicles, the estimated miles driven per vehicle, and the estimated MPG rating. Annual fuel usage for each FY was estimated using the following equation:

FY Fuel Usage = # of vehicles x Avg. Miles Driven Per Vehicle / Avg. Vehicle MPG rating

A questionnaire regarding FY 2007 miles driven per vehicle was submitted to the department contacts that have assigned vehicles. Although only about 50% of the departments responded, the sample size was sufficient to obtain a reasonably accurate estimate of the total miles drive per vehicle. An EPA website (www.fueleconomy.gov) was used to estimate MPG for the fleet vehicles. The "City" rating was assumed to be the representative rating for the type of driving associated with WUSTL vehicles. Based on institutional knowledge, it was assumed that the MPG ratings and average mileage driven per vehicle for FY 2007 reasonably approximated the entire range of this study.

Vehicle insurance is administered through a single department, the WUSTL Insurance and Risk Management Group, so the number of vehicles for recent years was readily available. The list of automobiles insured by WUSTL is assumed to be accurate and complete for these years. It is reasonably

assumed that all WUSTL owned vehicles are insured and that faculty, staff, and/or students would ensure that the insurance costs are paid by the WUSTL (and not out of the faculty/staff/student's pocket). For FY 1990-2006 where the number of insured vehicles was not readily available, the number of insured vehicles was assumed to be proportional to the total WUSTL population (student, staff, and faculty). The pertinent data is summarized below in Table 3. Since this methodology involved assumptions regarding the number of vehicles, MPG rating per vehicle, and number of miles driven per vehicle, the associated GHG emissions have some potential inaccuracies built-in to the calculations. Although the methodology is less precise than preferred, the overall accuracy of the inventory is not materially affected since fleet vehicle emissions account for less than 0.5% of the Scope 1 Direct emissions and less than 0.3% of total GHG emissions.

Table 3- Pertinent Data Associated with Fleet Vehicles (Gasoline)

FY	Estimated annual miles per vehicle	Estimated number of insured vehicles	Estimated mpg rating (gasoline)	Estimated Gasoline usage (gallons)
1990	5,190	132	20.0	**34,300**
2009	5,190	163	20.0	**42,300**

Scope 1 GHG Emissions: Agriculture

Fertilizer Application

Fertilizers are currently applied to the WUSTL lawns and grounds for aesthetics and to promote plant growth in order to minimize soil erosion and water run-off. Nitrogen-containing fertilizers release a small percentage of the GHG nitrous oxide. The current landscape and grounds contractor provided estimated fertilizer application quantities, with estimated nitrogen content, for FY 2007-2009. GHG emissions were calculated for FY 2007-2009 using the CA-CP Calculator emission factors. GHG emissions from fertilizer application account for 0.1% of the WUSTL's total GHG emissions. Since accurate fertilizer application rates were not available for the entire period of the inventory, emissions are assumed to equal FY 2007 emissions for years prior to FY 2007. Since GHG emissions from fertilizer application were insignificant in comparison to the total GHG emissions, the assumption does not materially affect the accuracy of the overall GHG inventory.

Animal Agriculture

Many animals, especially dairy cows, release methane generated by microbes in the stomach and from decomposition of manure. Most universities have some animals, either for agricultural or laboratory use.

WUSTL has a small number of animals, primarily at the Medical campus. While the number of animals for FY 2007-2009 is known with reasonable accuracy, the number of animals present during previous fiscal years is unknown. Methane emissions from WUSTL animals were estimated based on the number of animals and the CA-CP Calculator emission factors for FY 2007-2009. GHG emissions from animal agriculture account for 0.1% of the total WUSTL GHG emissions. Since the number of animals for past fiscal years was not available for the entire period of the inventory, emissions for FYs prior to 2007 were assumed to equal FY 2007 emissions. Since GHG emissions from animal agriculture are insignificant in comparison to the total GHG emissions, this assumption does not materially affect the accuracy of the overall GHG inventory.

Scope 1 GHG Emissions: Waste Combustion

WUSTL incinerated medical and hazardous waste at the Medical campus during FY 1990-1998 and cadavers in the crematory from FY1990-2009. Combustion of these materials produces carbon dioxide. GHG emissions from incineration for fiscal years with known incineration quantities were calculated using the emission factors in the CA-CP Calculator and are included with the stationary combustion emissions. Records for hazardous waste incineration prior to 1999 have been purged; WUSTL personnel followed regulatory guidance and purged the files every three years. Other waste incineration information data is only available through the annual Emission Inventory Questionnaire (EIQ) reports covering CY1992-2009. There were no monthly breakdowns to convert this data to a fiscal year basis. In 1999, on-campus incineration of medical, pathological, chemical, and hazardous waste ceased as it was sent off-site. The only type of on-campus incineration from 1999 to present is associated with a small number of cadavers in the crematory. Data for the crematory is also reported on a calendar year basis. It was assumed that calendar year data would be equivalent to fiscal year data. GHG emissions associated with incineration account for less than 0.1% of the total GHG emissions from stationary combustion. Since GHG emissions from incineration are insignificant in comparison to the total GHG emissions, assuming that the calendar year is equivalent to a fiscal year basis does not materially affect the accuracy of the overall GHG inventory.

Scope 1 GHG Emissions: Fugitive Emissions from Air Conditioning Equipment

Air conditioning units and chillers typically used exclusively chlorofluorocarbons (CFCs) prior to the 1990s. As part of the Clean Air Act Amendment of 1990, CFCs were phased out and replaced with hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs). Only HFCs are considered GHGs. Air conditioning units and chillers typically lose a small percentage of the refrigerant charge on an ongoing basis or can lose the entire charge in a single catastrophic failure.

WUSTL has been closely tracking refrigerant usage quantities since approximately year 2000 for all WUSTL sub-organizations, except for Quadrangle Housing, and that data was used to estimate GHG emissions. A physical survey of the Quadrangle Housing air conditioning units was conducted in March 2008. All units observed used HCFCs. Although they are not GHGs, HCFCs are ozone-depleting compounds whose production is being phased out under EPA regulation 40 CFR Part 82. The primary refrigerant being used as a replacement is HFC, which is a GHG. HFCs have only been used in most refrigerant applications beginning (at the earliest) in the late 1990s and only as a replacement for HCFCs. Thus, based on knowledge of the regulatory background associated with HFCs and HCFCs, it is reasonable to assume that no HFCs have been used or emitted at Quadrangle Housing.

The refrigerant GHG emissions are calculated using a simple material balance approach. Although WUSTL does not have quality data prior to year 2000, based on institutional knowledge and understanding of the refrigerant regulations, it is known with a reasonable degree of certainty that HFCs were not used/emitted prior to 2000. Thus, GHG emission data for air conditioning equipment for FY 1990-2009 is known to be reasonably accurate.

GHG Removals and Sinks

Through photosynthesis, green vegetation removes carbon dioxide from the atmosphere and stores it in vegetative tissues such as stems, roots, bark, and leaves. Technical Guidelines, Voluntary Reporting of Greenhouse Gases 1605(b) Program, Office of Policy and International Affairs, United States Department of Energy (pages 223-248), provides methodologies for estimating emissions reduction and carbon sequestration, primarily associated with trees and forests.

WUSTL routinely plants and maintains trees as part of its landscaping program and has a particularly large number of trees at the Tyson Research Center. WUSTL is not currently claiming any GHG offsets, such as forest preservation projects or composting. WUSTL may consider estimating the carbon sequestration associated with Tyson Research Center in future years. In the examples illustrated in the reference cited above, the GHG removal quantity for a 500 acre forest provides a net GHG sink in the range of 500 tons per year. Based on these examples, the GHG sink potentially associated with Tyson Research Center is assumed to be insignificant (less than 1%) to the total FY 2009 WUSTL GHG emissions (Scope 1, 2, and 3). In addition, WUSTL is not actively pursuing terrestrial carbon sequestration or other carbon offset projects external to its operations because they are not believed to be the most appropriate (i.e. lowest cost, perpetual, etc.) carbon reduction strategy at this time. (WUSTL's GHG emissions reduction strategy will be presented in a forthcoming report in 2009.)

Scope 2 GHG Emissions: Purchased Electricity

The only Scope 2 indirect emission source for WUSTL is purchased electricity. WUSTL does not have other potential Scope 2 emissions such as purchased steam or chilled water. WUSTL purchases electricity from AmerenUE to power air conditioning, lighting, computers, laboratory equipment, etc. The methodology and procedures to fill any gaps in the data are discussed above under the Stationary Combustion and Purchased Electricity heading.

GHG emissions associated with purchased electricity are calculated using the CA-CP Calculator methodology using the following equation:

GHG Emissions (Metric tons CO_2e) = Purchased Elect. (kW-hrs) x Emission Factor (Metric tons CO_2e/kw-hrs)

Scope 3 GHG Emissions

Reporting of Scope 3 indirect emissions is optional under E14064 and the GHG Protocol (Chapter 9). WUSTL Scope 3 indirect emissions consist primarily of the following and are quantified in this GHG inventory to the extent practical. The emission categories are aligned with the CA-CP calculator.

- **Faculty/staff/student commuting** in personal vehicles to work
- **Faculty/staff airline travel** (WUSTL business)
- **Personal Automobile Use/Reimbursed mileage** (WUSTL business)
- **Student Airline Travel** (Study Abroad and Other)
- **Electricity Transmission and Distribution Losses** (Purchased Electricity)
- **Decomposition of solid waste** generated at WUSTL
- **Contracted transportation**, namely the bus service
- **Transportation of solid waste** from **and delivery of supplies and materials** to WUSTL
- **Contractor owned and operated construction vehicles**, construction equipment, and landscaping

Scope 3 indirect emissions are estimated for the categories of indirect emissions as described below. These are the Scope 3 indirect emission categories covered in the CA-CP Calculator and represent the emission categories which a university should typically address in a GHG inventory. WUSTL will continue to estimate these GHG emissions in future years.

Emission categories not quantified (delivery of supplies and materials to WUSTL and contractor owned and operated equipment) are assumed to be negligible or far removed from WUSTL's core function as a learning institution. For instance, GHG emissions can be linked to the food sold in the cafeterias at

WUSTL. WUSTL has no control over the GHG emissions involved in the production and delivery of mass-produced food. These Scope 3 emission sources are not included in the WUSTL inventory because the emissions are far removed from the function of educating students and WUSTL has limited ability to influence these emissions nor are these emissions covered under protocols such as the CA-CP calculator.

Scope 3 GHG Emissions: Faculty/staff/student commuting in personal vehicles to work

WUSTL collected data on the numbers of students, faculty and staff residing within each metropolitan St. Louis zip code for the FY 1991-2007. Accurate zip codes were not available for an estimated 20-30% of students. Local zip code data for faculty and staff for FY 2007-2009 was extrapolated for past years based on the historic data available for total University population. The point of origin was assumed to be the latitudes and longitudes (as given by U.S.Gazetteer (www.census.gov/cg-bin/gazetteer) and zipinfo.(www.zipinfo.com)) corresponding to the centroid of the zip code. The destination point at WUSTL was assumed to be the coordinates of Brookings Hall (38.648N, 90.305W). The distance between the zip code and Brookings Hall coordinates was calculated using the following equation:

Distance (in miles) = square root of (x*x+y*y); where: x = 69.1*(lat1-lat2); y = 53.0*(lon1-lon2)

It must be noted that the calculated distance represents the straight line distance between the point of origin and destination. Due to road directions and the fact that access to St. Louis is constrained on the east and north sides by bridges on the river, the calculated distances are less than the actual distance. Thus, correction factors (to covert from the straight-line distances to actual driving distances) were used based on the predicted driving route in Google Maps (http://maps.google.com):

- 40% for faculty travel.
- 18% for students for student travel.

The annual distance traveled was calculated assuming that every faculty and staff make one round trip to WUSTL each of the estimated 225 working days per year based on the academic calendar while students make 165 round trips per year.

Miles traveled were converted to fuel usage using the EPA report, Light Duty Automotive Technology and Fuel Economy Trends: 1975-2007 (epa.gov/otaq/cert/mpg/fetrends/420s07001.htmt3) assuming:

- 43% city
- 57% highway

The driving distance to WUSTL for faculty and staff was based the registered address for parking permit holders for FY 2008. The average distance for FY 2008 was assumed to be representative of all FY years. The average driving distance for students was calculated using data for both total students and students with parking permits for FY 1991-FY2009. It is conservatively assumed that carpooling associated with vehicle travel to WUSTL is negligible as well as alternative modes of transportation such as biking and riding the city bus.

The total mileage driven by faculty and staff/students was estimated using the following equation:

Total Mileage = Average Mileage x Total Number of staff/faculty/ students

Total mileage was converted to gallons of gasoline associated with the travel using the MPG ratings in the CA-CP calculator. The pertinent data associated with student and faculty and staff commuting is summarized below in Table 4.

Table 4- Pertinent Data Associated with Faculty, Staff, and Students Commuting

FY	Total Miles by Students	Total Miles by Faculty and Staff	Avg. MPG	Avg. Annual Mileage Per Student	Avg. Annual Mileage Per Staff/Faculty
1990	9,612,000	14,613,000	19.87	828	5136
2009	6,617,000	17,566,000	22.10	490	5136

Scope 3 GHG Emissions: Faculty/student/staff airline travel

Campus air travel was broken down into three categories: athletic air travel, student study abroad air travel, and faculty/staff air travel.

Athletic air travel was computed by calculating the number of miles from the Lambert-St. Louis International Airport to each city that WUSTL athletic teams have flown to for FY 2005-2007 and then multiplying this distance by the number of athletes on each trip. That data was then extrapolated for FY 1990-2004 and 2008-2009 based on the assumption that there were no significant changes in travel destinations for athletic events. This assumption is reasonable because WUSTL played in the same athletic conference (University Athletic Association) during the entire period of study (1990-2009) and thus generally traveled to the same locations at the same frequency. Flight distance was converted to GHG emissions using data from the CA-CP Calculator.

Student study abroad air travel was computed similarly. The total number of students that studied in each country for FY 2001-2009 was estimated. Mileage was calculated from Lambert-St. Louis International

Airport to each country and then multiplied by the number of students in each program. An average number of miles per study abroad student was calculated from the data for FY 2001-2009 and then extrapolated back for other years. Flight distance was converted to GHG emissions using data from the CA-CP Calculator.

Collecting reliable faculty and staff air travel data was difficult since each faculty and staff member typically arranges his or her flight plans and documentation of the flights is not available at a central location. Total airline miles was estimated using the following equation:

Faculty x Average Airline Miles/Faculty Member + # Staff x Average Airline Miles/Staff Member

A survey was submitted to a random sampling of faculty and staff members via email requesting airline travel data for FY 2009 including the number of trips and travel destinations. Travel distances were estimated using http://www.webflyer.com/travel/mileage_calculator/. Total travel miles per faculty/staff member were estimated by multiplying the average trip destination mileage by the number of trips. FY 2009 data was used to estimate travel for all other years. Airline mileage was converted to GHG emissions using the CA-CP calculator.

Pertinent information related to WUSTL airline travel- student travel (athletics), student study abroad, and staff/faculty air travel is summarized below in Table 5.

Table 5- Pertinent Data Associated with WUSTL Airline Travel

FY	Estimated Student Study Abroad Airline Miles	Estimated Other Student Airline Miles (Athletics)	Estimated Faculty Airline Miles	Estimated Staff Airline Miles
1990	4,087,000	790,482	16,542,000	2,221,000
2009	4,754,000	790,482	14,934,000	3,109,000

Scope 3 GHG Emissions: Decomposition of solid waste

Waste that is incinerated releases CO_2 in the oxidation process. Waste sent to landfills decomposes and releases methane (CH_4). The quantity of solid waste generated by WUSTL for the Danforth and Medical campuses for FY 2008-2009 was readily available. Solid waste generation quantities for fiscal years prior to 2008 were indexed to the total WUSTL population. GHG emissions were estimated using the CA-CP calculator and assuming that the waste is landfilled with methane recovery and electricity generation.

This assumption is based on WUSTL knowledge of the receiving landfill (Crown Excel/Fred Weber Landfill). Solid waste accounts for an insignificant portion (less than 0.1%) of total GHG emissions.

Scope 3 GHG Emissions: Transmission and Distribution Losses Associated with Purchased Electricity

A certain percentage of electricity generated at the power station is lost in transmission and distribution to the end customer. Transmission and distribution losses were calculated using the CA-CP calculator. Transmission and distribution losses are calculated as approximately 10% of the purchased electricity in accordance with the CA-CP calculator.

Scope 3 GHG Emissions: Contracted transportation (bus service)

Students, faculty, and staff use buses for transportation on and to and from the WUSTL campuses. The Campus Circulator and Medical Escort bus routes cover intra-campus transportation and are operated by an outside contractor, Veolia (Shuttleport). Veolia provided the estimated annual fuel usage associated with the two intra-campus bus transportation routes for FY 2007-2009. The data was extrapolated to FY 1990-2006. GHG emissions were then estimated using the CA-CP Calculator.

The Metro bus service operates bus lines that transport students, faculty, and staff to and from the WUSTL campuses. WUSTL financially subsidizes the transportation costs for members of its community. The bus routes are used heavily by, but not exclusively dedicated to WUSTL students, faculty, and staff. Therefore, this emission source category is **not** considered within the University's Scope 3 organizational boundaries.

2.5 General Inventory Guidelines

WUSTL's GHG Emissions Inventory was developed in accordance with industry standards and principles (GHG Protocol, Chapter 1):

- **Relevance**: The inventory appropriately reflects WUSTL GHG emissions and a relevant intensity ratio comparison is provided.
- **Completeness**: The inventory is complete with respect to the emission sources and activities within the operational boundaries selected.
- **Consistency**: This is the first GHG inventory conducted by WUSTL. In future years, consistent methodologies and emission factors will be used so that meaningful comparisons can be made.

- **Transparency**: The inventory addresses GHG inventory issues in a factual and coherent manner. Basis for emission estimates and assumptions are included in this report.
- **Accuracy**: The inventory is accurate as far as can be judged and is neither systematically over nor under actual emissions. The accuracy of GHG emissions from some categories, such as fertilizer application and fleet vehicles, is poor with respect to FY1990-2006. However, GHG emissions from each of these categories contribute less than 1% of the total GHG emissions. Thus, the fact that the accuracy is poor for these source categories has no material effect on the overall accuracy on the GHG inventory. Overall, this inventory is believed to be accurate within at least ±5% of WUSTL's GHG emissions.

2.6 Base Year Adjustments

Base year emissions are recalculated in accordance with the GHG Protocol (Chapter 5). Base year recalculation is required for structural changes in the organization that have significant impact on the University's base year emissions. The base year adjustments allow an organization to retroactively account for mergers and acquisitions that would otherwise distort the comparison between current and base year GHG emissions. As shown below, base year adjustments for WUSTL have only a minor impact on base year emissions because the GHG emissions associated with facility acquisitions (e.g. North and South campuses) after 1990 are insignificant compared to GHG emissions from facilities (Danforth and Medical campuses) that were included in the base year calculations.

Base year adjustments are required (allowed) for the following:

- **Mergers, acquisitions, and divestments**.
- **Outsourcing and in-sourcing of emitting activities**. **Changes in calculation methodology or improvements in the accuracy of emission factors** or activity data that result in a significant impact on base years emissions data.
- **Discovery of errors**.

The need to adjust WUSTL base year emissions stems from mergers and acquisitions that have occurred since 1990. A summary of sub-organizations that existed in the base year as well as mergers and acquisitions that have occurred since then are summarized below in Table 6. Adjusted base emissions are shown in Table 7. The base year adjustments have a small impact on the overall GHG emissions trend from FY 1990-2009 as WUSTL property acquisitions that occurred subsequent to 1990 have an approximate 4% impact on the total GHG emissions. The adjusted baseline year emissions reflect WUSTL acquisitions of the North, South, and West Campuses that have occurred since 1990. The

adjusted baseline will be used when establishing and evaluating progress in meeting GHG reduction targets. For instance, if WUSTL was attempting to reduce GHG emissions by 50% from FY 1990 emissions, the 50% reduction target would be measured against FY 1990 adjusted emissions of 325,000 $MTCO_2e$ rather than 313,500 $MTCO_2e$.

Table 6- WUSTL Acquisitions

University Sub-Organization	Fiscal Year Acquired	Adjustment to Base Year and Subsequent		
		Scope 1 Direct GHG Emissions ($MTCO_2e$)	Scope 2 Indirect GHG Emissions ($MTCO_2e$)	Scope 3 Indirect GHG Emissions ($MTCO_2e$)
Danforth Campus	<1990	NA - Acquired Prior to Base Year		
Medical Campus	<1990	NA - Acquired Prior to Base Year		
North Campus[1]	2001	**330**	**2970**	**290**
West Campus[2]	1991	**1080**	**5130**	**510**
South Campus[3]	2007	**180**	**930**	**90**
Tyson Research Center	<1990	NA - Acquired Prior to Base Year		
Quadrangle Housing	<1990	NA - Acquired Prior to Base Year		
TOTALS		**1590**	**9030**	**890**

Notes:

1. GHG inventory totals for FY1990 have been adjusted to reflect acquisition of the North Campus.
2. GHG inventory totals for FY1990 have been adjusted to reflect acquisition of the West Campus.
3. GHG inventory totals for FY1990 have been adjusted to reflect acquisition of the South Campus.

Table 7- WUSTL's Base Year Adjustments

	Baseline Year: FY1990	Baseline Year: FY1990 (Adjusted for Building Acquisitions)
Scope 1 - Direct Emissions	122,400	124,000
Scope 2 - Energy Indirect Emissions	143,900	153,000
Scope 3 - Other Indirect Emissions	47,200	48,000
TOTAL	**313,500**	**325,000**

* * * * *

3.0 GREENHOUSE GAS EMISSIONS INVENTORY SUMMARY

3.1 Absolute GHG Emissions

GHG emissions listed below reflect four (CO_2, CH_4, N_2O, & HFCs) of the relevant six GHGs (WUSTL does not emit PFCs or SF_6) and normalization to a CO_2e basis. Fiscal year 1990 has been selected as the base year because it is the year that WUSTL began tracking the criteria air pollutants regulated under the 1990 Clean Air Act Amendments, and because 1990 is also the baseline in the Kyoto Protocol.

Scope 1 GHG Emissions

Direct GHG emissions are defined as GHG emissions from GHG sources owned or controlled by the organization. Scope 1 direct emission sources at WUSTL include the following:

- **Stationary combustion sources** (heating, laboratories, electric generators)
- **University vehicle fleet**
- **Agriculture (Fertilizer application & Animals)**
- **Fugitive emissions from refrigeration equipment**

WUSTL does **not** have the following GHG emission sources that are common at some universities:

- **On-campus electric generation** (except for limited emergency electrical generation that is included with the stationary combustion category)

Although WUSTL routinely plants and maintains trees in its landscaping, the University is not claiming any GHG offsets, such as forest preservation (carbon sequestration) or composting.

Direct GHG emissions are plotted in Figure 3 and compared by source category in Table 8. As shown in Table 8, stationary fuel combustion sources (e.g. boilers) account for more than 99% of WUSTL's Scope 1 GHG emissions. Other activities that emit GHGs, namely the WUSTL vehicle fleet, agriculture (fertilizer application and vivariums), and fugitive emissions from air conditioning equipment are inconsequential to the Scope 1 as well as total WUSTL GHG emissions inventory.

Figure 3- WUSTL Scope 1 Direct Emissions

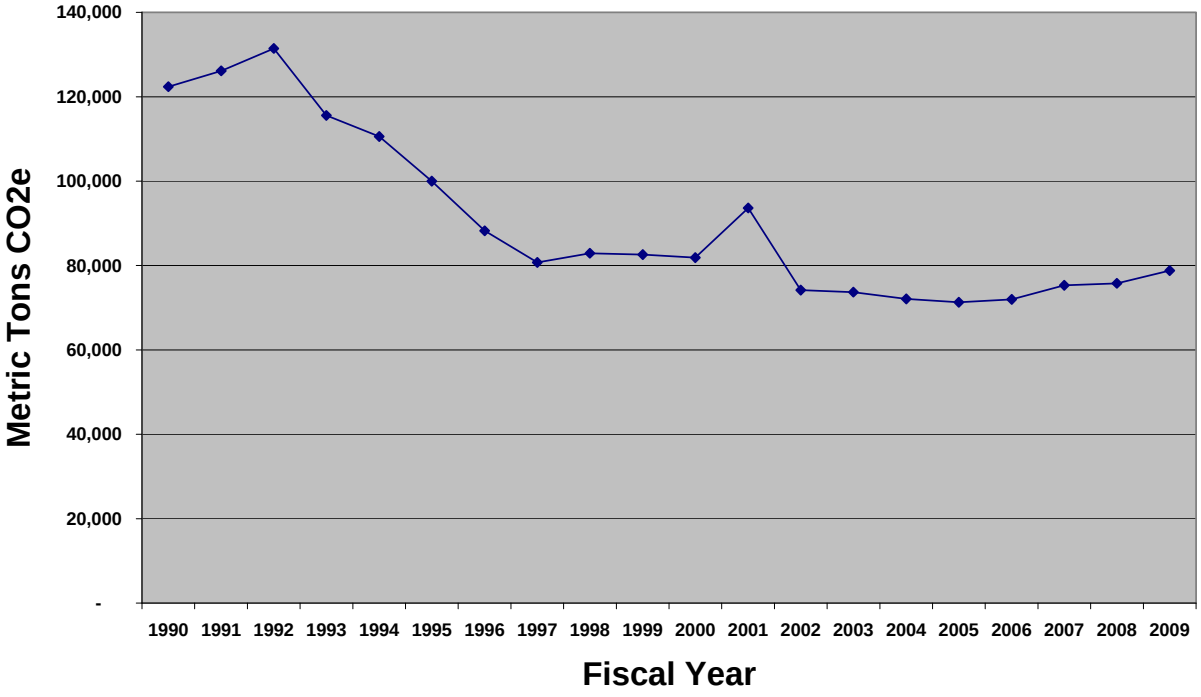


Table 8: WUSTL Scope 1 Emissions Breakdown

Emission Source Category	Scope 1 GHG Emissions (%)	
	Base Year: FY 1990	Current Year: FY 2009
Stationary Combustion Sources	99.71	99.24
University Vehicle Fleet	0.26	0.47
Agriculture	0.03	0.10
Fugitive Emissions from Air Conditioning Equipment	0.00	0.19

Scope 2 GHG Emissions

Scope 2 energy indirect greenhouse emissions are defined as GHG emissions from the generation of imported electricity, heat or steam consumed by the organization. WUSTL has Scope 2 indirect emissions associated with purchased electricity. Scope 2 energy indirect emissions are plotted in Figure 4.

The CA-CP Calculator purchased electricity emission factors are based on the eGRID (Emissions & Generation Resource Integrated Database) emission factors developed by US Environmental Protection

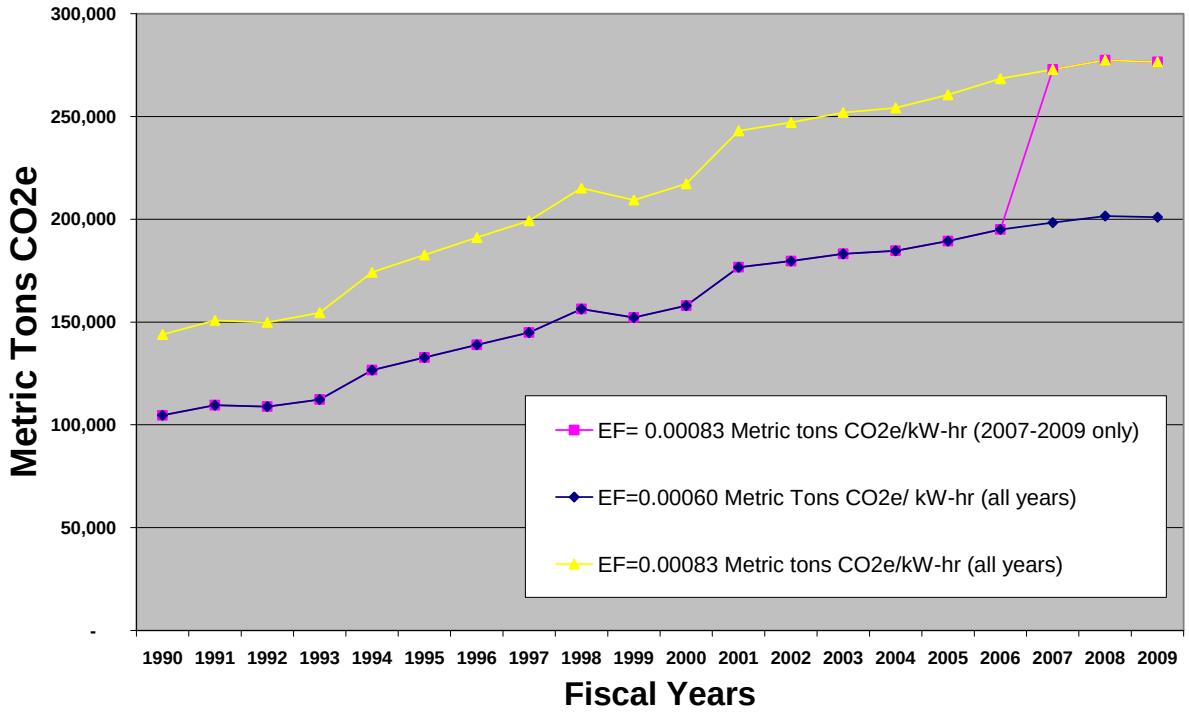
Agency as part of the US Greenhouse Gas Emissions and Sinks 1990-2006. The eGRID regions and the CA-CP Calculator changed in 2006. For FY 1990-2006, WUSTL was located in the region classified as "MAIN South". Beginning in FY 2007, WUSTL was considered to be located in the region classified as "SERC Midwest". The emission factors assigned to specific regions are based on the electric generation mix within the geographic area. As shown below, the emission factors increased by approximately 39% in FY 2007. Using these factors, WUSTL emissions would be shown to increase by 39% beginning in FY 2007 despite the fact that WUSTL's purchased electricity increased only slightly from FY 2006-2007.

Table 9- Comparison of Purchased Electricity GHG Emission Factors

FY	eGRID Region	CA-CP Calculator Designation	Emission Factor (Metric ton CO_2e/ kw-hr)
FY 1990-2006	MAIN South	eGRID pre 2006	0.000606
FY 2007-FY2009	SERC Midwest	eGRID post 2006	0.000834
Percent Change		**39%**	

Because WUSTL does not believe that the electric generation mix in our region has significantly changed from 2006 to 2007 and beyond, Scope 2 energy indirect emissions are plotted for three different scenarios in Figure 4 for comparison. The first plot assumes the 0.000606 Metric ton CO_2e/ kw-hr emission factor for FY 1990-2009. The second plot uses the 0.000606 Metric ton CO_2e/ kw-hr for FY 1990-2006 and the 0.000834 Metric ton CO_2e/ kw-hr for FY 2007-2009. The final plot uses the 0.000834 Metric ton CO_2e/ kw-hr for FY 1990-2009; WUSTL is using the final plot as its total GHG emissions estimate.

Figure 4 - WUSTL Scope 2 Indirect Energy Emissions



Scope 3 GHG Emissions

Scope 3 other indirect GHG emissions are GHG emissions, other than energy indirect GHG emissions, which are a consequence of an organization's activities, but arise from GHG sources that are owned or controlled by other organizations. Scope 3 indirect emissions include faculty, staff, and student commuting to WUSTL and air travel for WUSTL affairs, solid waste disposal and subsequent GHG emissions from decomposition, and contractor activities. Although reporting of Scope 3 indirect emissions is optional under E14064 and the GHG Protocol, estimated Scope 3 emissions are included in the WUSTL inventory. This data was derived using conservative estimation and/or modeling techniques consistent with industry standards and approaches used by other universities. Scope 3 indirect emissions are shown in Figure 5 and broken down by emissions category in Figure 6.

Figure 5- WUSTL Scope 3 Indirect Emissions

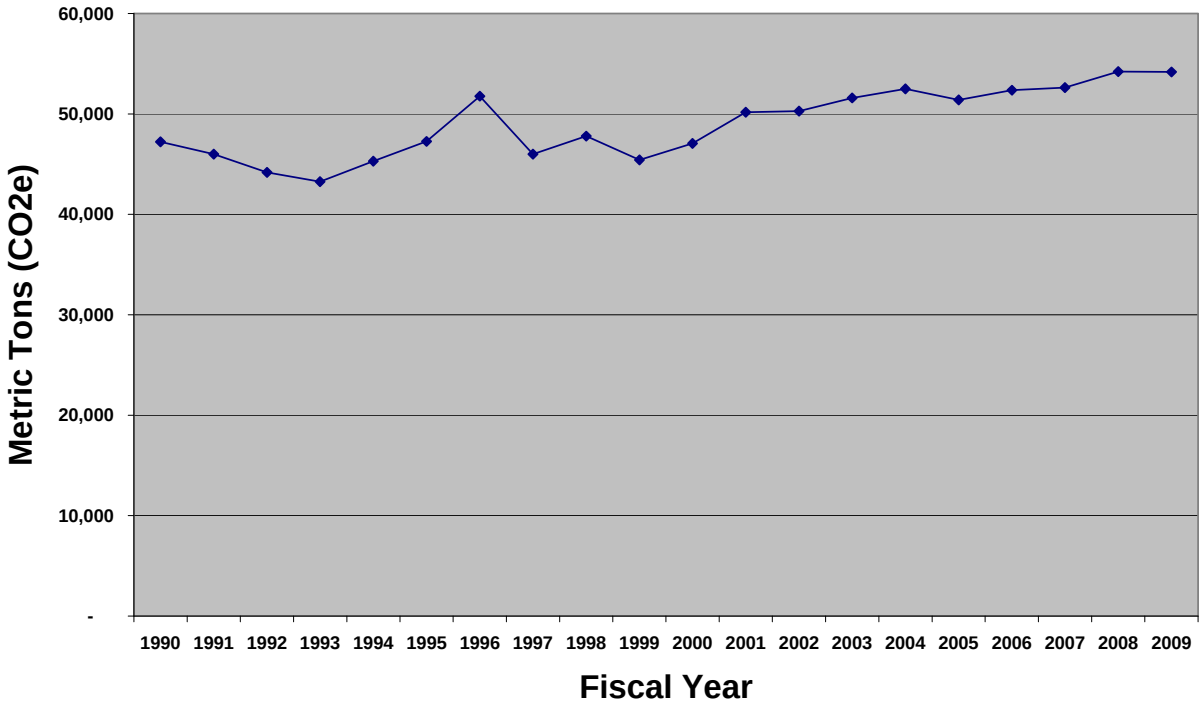
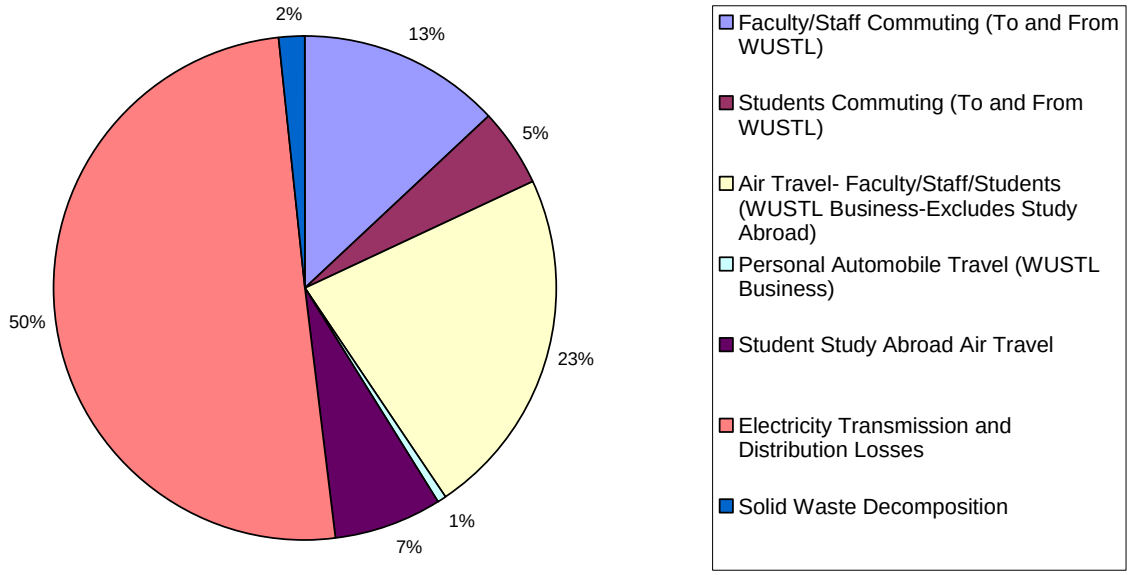


Figure 6- WUSTL Scope 3 Indirect Emissions Breakdown by Category (2009)



GHG Emissions Summary

GHG emissions are summarized below in Table 10 as well as plotted in ES-1

Table 10- WUSTL GHG Emissions Inventory

FY	Total GHG Emissions ($MTCO_2e$)	Scope 1 GHG Emissions ($MTCO_2e$)	Scope 2 Energy Indirect GHG Emissions ($MTCO_2e$)	Scope 3 Indirect GHG Emissions ($MTCO_2e$)
1990	313,600	122,400	143,900	47,200
1991	322,900	136,100	150,700	46,000
1992	325,500	131,500	149,900	44,200
1993	313,300	115,600	154,500	43,300
1994	330,000	110,500	174,200	45,300
1995	329,900	100,000	182,600	47,300
1996	331,100	88,200	191,100	51,800
1997	326,000	80,700	199,300	46,000
1998	345,900	82,900	215,100	47,800
1999	337,300	82,600	209,300	45,400
2000	346,200	81,800	217,300	47,100
2001	386,800	93,600	243,000	50,200
2002	371,600	74,200	247,100	50,300
2003	377,300	73,700	251,900	51,600
2004	378,700	72,000	254,100	52,500
2005	383,300	71,300	260,600	51,400
2006	392,700	72,000	268,400	52,400
2007	400,800	75,300	272,900	52,600
2008	407,400	75,800	277,400	54,200
2009	409,500	78,800	276,500	54,200

3.2 GHG Emissions Intensity Ratios

Absolute GHG emissions can be deceptive as these emissions are not compared to production activity or output. Intensity ratios express GHG impact per unit of physical activity or unit of economic output. Intensity ratios are often called "normalized" environmental impact data (GHG Protocol, Chapter 9). According to the GHG Protocol, a declining intensity ratio reflects a positive performance improvement.

While the measure of production activity or output is an obvious selection for some industries (such as electricity generated for a power plant), a university is more complex and difficult to assign an obvious measure of production activity or output. Thus, intensity ratios are compared as a function of three activity parameters in Table 11. These activity parameters are consistent with the approach in the CA-CP Campus Carbon Calculator.

GHG emission intensity ratios are presented below in Table 11 for WUSTL relative to the following parameters:

- **$MTCO_2e$ emissions per total population** (faculty, staff, and students)
- **$MTCO_2e$ emissions per total square footage** (total space of WUSTL. owned buildings)
- **$MTCO_2e$ emissions per total budget** (WUSTL operating, research, and energy)

Table 11 – WUSTL's GHG Emissions Intensity Ratios

FY	Intensity Ratios		
	$MTCO_2e$[1] / total building space (sq. ft)	$MTCO_2e$ / population[2]	$MTCO_2e$ / budget (1000 $)[3]
1990	0.048	21.7	0.588
1991	0.048	21.6	0.536
1992	0.048	22.6	0.492
1993	0.046	22.2	0.468
1994	0.041	23.2	0.464
1995	0.040	23.1	0.420
1996	0.040	22.8	0.416
1997	0.037	23.0	0.391
1998	0.039	24.3	0.392
1999	0.038	23.0	0.354
2000	0.038	23.3	0.338
2001	0.042	26.0	0.363
2002	0.038	24.6	0.306
2003	0.036	24.0	0.284
2004	0.036	23.6	0.267
2005	0.035	23.3	0.253
2006	0.035	23.7	0.242
2007	0.032	24.1	0.233
2008	0.029	24.3	0.227
2009	0.028	24.2	0.213

Notes:

1. GHG emissions are based on the total of Scope 1 direct, Scope 2 indirect, and Scope 3 indirect emissions.
2. Total population includes faculty, staff, and students.
3. Total budget includes operating, research, and energy.

* * * * *

4.0 REFERENCES

1. **The Greenhouse Gas Protocol (GHG Protocol)**, A Corporate Accounting and Reporting Standard, Revised Edition, World Business Council for Sustainable Development (WBCSD) and World Resources Institute (WRI).

2. Greenhouse Gases – Part 1: Specification with Guidance at the Organizational Level for Quantification and Reporting of Greenhouse Gas Emissions and Removals, **ANSI/ISO/NSF E14064-1:2006**.

3. **Clean Air-Cool Planet Campus Carbon Calculator** Excel Program and User's Guide, CA-CP Calculator v 6.4, 2009.

4. **Technical Guidelines, Voluntary Reporting of Greenhouse Gases 1605(b) Program**, Office of Policy and International Affairs, United States Department of Energy, March, 2006.

5. **Calculation Tool for Direct Emissions from Stationary Combustion, Version 3.0**, July 2005, A WRI/WBSCD Tool, Environmental Resources Trust.

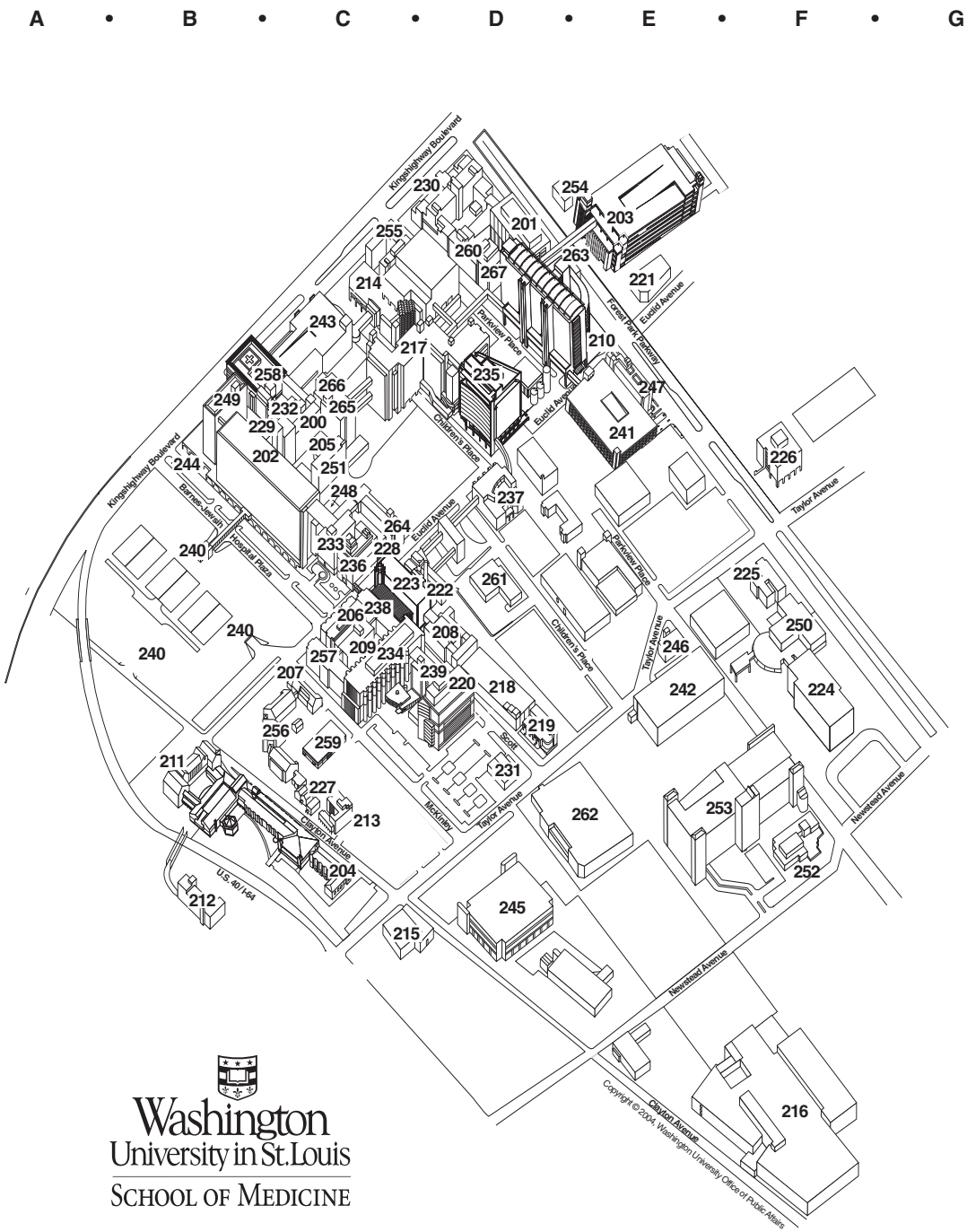
6. **The Climate Registry General Reporting Protocol** for the Voluntary Reporting Program, The Climate Registry Draft for Public Comment, October 29, 2007.

* * * * *

Appendix A

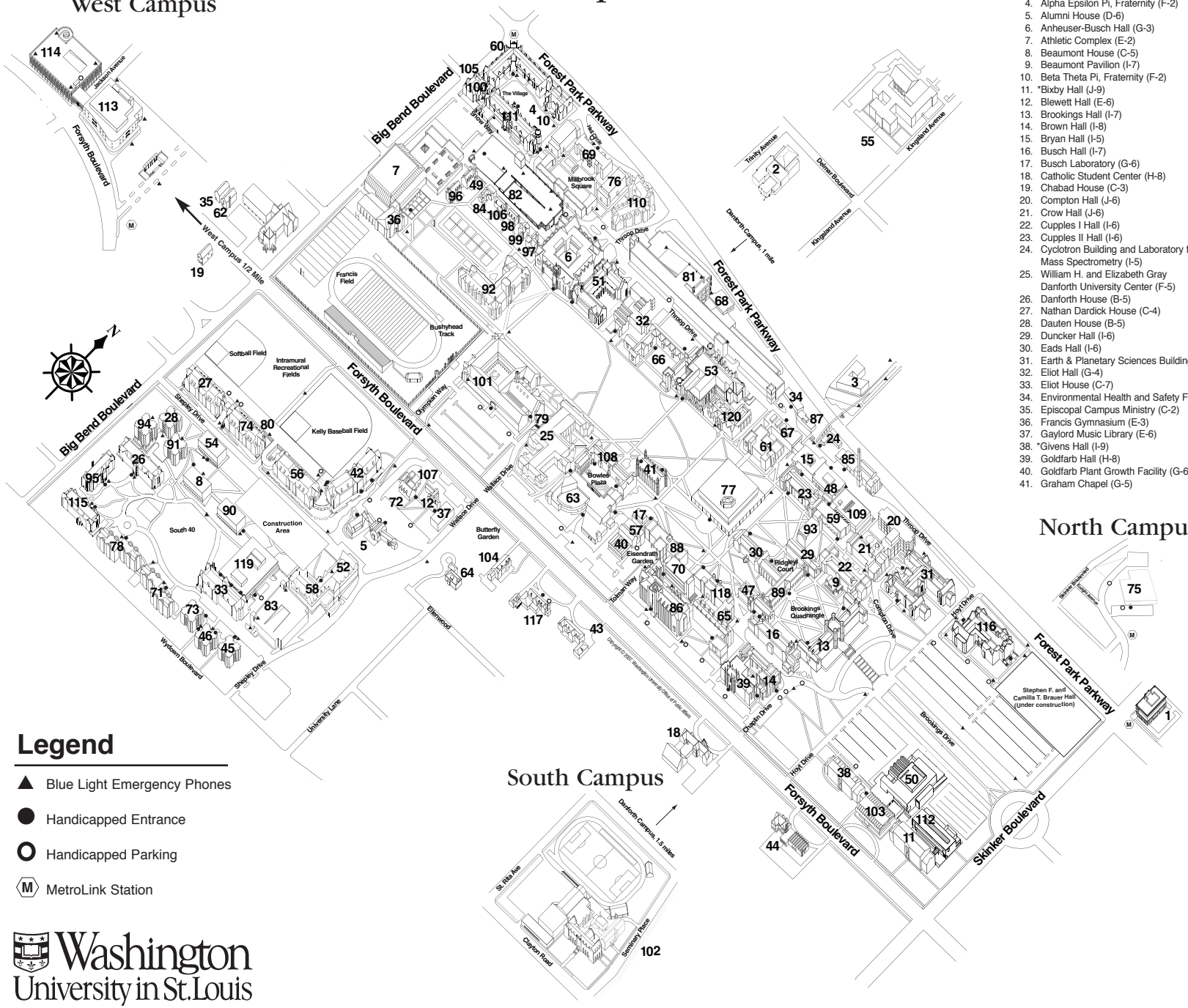
Medical Campus Map
Danforth Campus Map
Tyson Research Center Map

Medical Campus



200. Barnard Hospital (C-3)
201. Barnes-Jewish Hospital North (D-2)
202. Barnes-Jewish Hospital South (B-3)
203. Barnes-Jewish Hospital Reserved Parking (E-2)
204. Barnes Lodge (C-6)
205. Barnes Service Building (C-3)
206. The Bernard Becker Medical Library (C-5)
207. Biomedical Computer Laboratory (C-5)
208. Biotechnology Center (D-5)
209. Cancer Research Building (C-5)
210. Center for Advanced Medicine (CAM)/ Siteman Cancer Center (D-2)
211. Central Institute for the Deaf (CID) (B-6)
212. CID Clinic/Research Building (B-6)
213. CID Residence Hall (C-6)
214. St. Louis Children's Hospital (C-2)
215. 4480 Clayton (C-7)
216. Clayton Avenue Building (F-8)
217. Clinical Sciences Research Building (C-3)
218. East Building (D-5)
219. East Imaging Building (D-5)
220. East McDonnell Specialized Research Facility (D-5)
221. Ettrick Building (E-2)
222. Euclid Power Plant (C-4)
223. Farrell Learning and Teaching Center (C-4) (Under construction)
224. 4444 Forest Park (F-5)
225. 4488 Forest Park (F-4)
226. 4511 Forest Park Medical Building (F-3)
227. Health Administration Program (C-6)
228. Irene Walter Johnson Institute of Rehabilitation (C-4)
229. Rand Johnson Building (B-3)
230. Kingshighway Building (D-1)
231. Library Annex (D-6)
232. Mallinckrodt Institute of Radiology (C-3)
233. Maternity Hospital (C-4)
234. McDonnell Medical Sciences Building (C-5)
235. McDonnell Pediatric Research Building (D-3)
236. McMillan Hospital Building (C-4)
237. Eric P. Newman Education Center (D-4)
238. North Building (C-4)
239. Spencer T. Olin Residence Hall (C-5)
240. Parking Facility, Barnes-Jewish Hospital Plaza (underground) (B-4)
241. Parking Facility, Barnes-Jewish Hospital (North) (Euclid Avenue) (E-3)
242. Parking Facility, Barnes-Jewish Hospital (Taylor Avenue) (E-5)
243. Parking Facility, St. Louis Children's Hospital (C-3)
244. Parking Facility, Queeny Tower (B-3)
245. Parking Facility, School of Medicine (Taylor and Clayton) (D-7)
246. Parkview Building (E-5)
247. Parkview Hotel (E-3)
248. Peters Building (C-4)
249. Queeny Tower (B-3)
250. Rehabilitation Institute of St. Louis (F-5)
251. Renard Hospital (C-3)
252. St. Louis Children's Hospital Child Development Center (F-6)
253. St. Louis Children's Hospital Employee Parking (E-6)
254. Shoenberg Research Building (D-2)
255. Shoenberg School of Nursing (C-2)
256. Shriners Building (B-5)
257. South Building (C-5)
258. Southwest Tower/Charles F. Knight Emergency Center (B-3)
259. Specialized Interim Research Facility (C-5)
260. Steinberg Building (D-2)
261. Storz Building (D-4)
262. Taylor Avenue Building (E-6)
263. Waldheim Ambulatory Care Facility (D-2)
264. West Building (C-4)
265. Wohl Clinic (C-3)
266. Wohl Hospital Building (C-3)
267. Yalem Research Building (D-2)

Danforth Campus



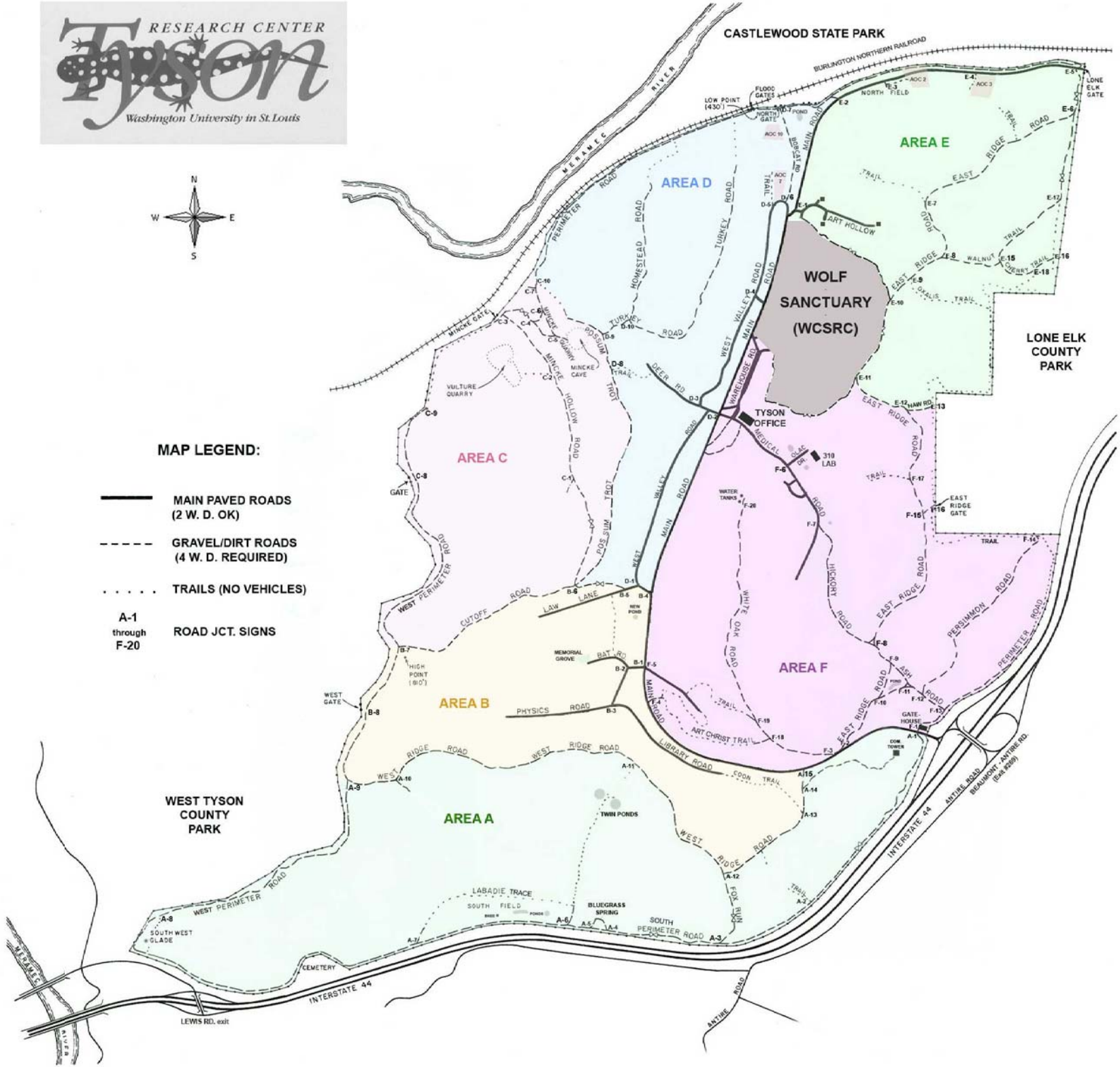
Legend

- ▲ Blue Light Emergency Phones
- ● Handicapped Entrance
- O Handicapped Parking
- Ⓜ MetroLink Station

Washington University in St. Louis

1. 276 N. Skinker (M-8)
2. 560 Music Center (I-2)
3. Academy Building (J-4)
4. Alpha Epsilon Pi, Fraternity (F-2)
5. Alumni House (D-6)
6. Anheuser-Busch Hall (G-3)
7. Athletic Complex (E-2)
8. Beaumont House (C-5)
9. Beaumont Pavilion (I-7)
10. Beta Theta Pi, Fraternity (F-2)
11. *Bixby Hall (J-9)
12. Blewett Hall (E-6)
13. Brookings Hall (I-7)
14. Brown Hall (I-8)
15. Bryan Hall (I-5)
16. Busch Hall (I-7)
17. Busch Laboratory (G-6)
18. Catholic Student Center (H-8)
19. Chabad House (C-3)
20. Compton Hall (J-6)
21. Crow Hall (J-6)
22. Cupples I Hall (I-6)
23. Cupples II Hall (I-6)
24. Cyclotron Building and Laboratory for Mass Spectrometry (I-5)
25. William H. and Elizabeth Gray Danforth University Center (F-5)
26. Danforth House (B-5)
27. Nathan Dardick House (C-4)
28. Dauten House (B-5)
29. Duncker Hall (I-6)
30. Eads Hall (I-6)
31. Earth & Planetary Sciences Building (J-7)
32. Eliot Hall (G-4)
33. Eliot House (C-7)
34. Environmental Health and Safety Facility (I-5)
35. Episcopal Campus Ministry (C-2)
36. Francis Gymnasium (E-3)
37. Gaylord Music Library (E-6)
38. *Givens Hall (I-9)
39. Goldfarb Hall (H-8)
40. Goldfarb Plant Growth Facility (G-6)
41. Graham Chapel (G-5)
42. Gregg House (D-5)
43. Harbison House (G-7)
44. Hillel Center (I-9)
45. Hitzeman House (C-7)
46. Hurd House (C-7)
47. January Hall (H-7)
48. Jolley Hall (I-6)
49. Kappa Sigma, Fraternity (F-2)
50. *Kemper Art Museum (J-9)
51. Knight Executive Education and Conference Center (G-3)
52. Koenig House (D-6)
53. Laboratory Sciences Building, Arts & Sciences (H-4)
54. Lee House (C-5)
55. Lewis Center (725 Kingsland, University City) (J-2)
56. Lien House (D-5)
57. Life Sciences Building (G-6)
58. Liggett House (D-7)
59. Lopata Hall (I-6)
60. Lucy and Stanley Lopata House (F-1)
61. Louderman Hall (I-5)
62. Lutheran Campus Center (C-2)
63. Mallinckrodt Student Center and Edison Theatre and Campus Bookstore (G-6)
64. McCarthy House (E-6)
65. McDonnell Hall (H-7)
66. McMillan Hall (H-4)
67. McMillen Laboratory (I-5)
68. Millbrook Building (H-4)
69. Millbrook Square Apartments (G-2)
70. Monsanto Laboratory (H-6)
71. Mudd House (B-7)
72. Music Classrooms Building (E-6)
73. Myers House (C-7)
74. Nemerov House (C-5)
75. North Campus (M-6)
76. Nursery School (G-2)
77. Olin Library (H-6)
78. Park House (B-6)
79. Parking Facility, Forsyth (Subsurface) (F-5)
80. Parking Facility, Lien (C-5)
81. Parking Facility, Millbrook (H-3)
82. Parking Facility, Snow Way (F-2)
83. Parking Facility, Wohl
84. Phi Delta Theta, Fraternity (F-2)
85. Power Plant (J-5)
86. Psychology Building (H-7)
87. Radiochemistry Building (I-5)
88. Rebstock Hall (H-6)
89. Ridgley Hall and Holmes Lounge (I-7)
90. Rubelmann House (C-6)
91. Rutledge House (B-5)
92. Harry and Susan Seigle Hall (F-3)
93. Sever Hall (I-6)
94. Shanedling House (B-5)
95. Shepley House (B-5)
96. Sigma Alpha Epsilon, Fraternity (E-2)
97. Sigma Alpha Mu, Fraternity (F-3)
98. Sigma Chi, Fraternity (F-3)
99. Sigma Nu, Fraternity (F-3)
100. Sigma Phi Epsilon, Fraternity (F-1)
101. Simon Hall (F-4)
102. South Campus (G-10)
103. *Steinberg Hall (J-9)
104. Stix International House (F-6)
105. Tau Kappa Epsilon, Fraternity (F-1)
106. Theta Xi, Fraternity (F-3)
107. Tietjens Hall (E-5)
108. Umrath Hall (G-5)
109. Urbauer Hall (J-6)
110. Village East (Under construction) (G-3)
111. Village House (F-2)
112. *Walker Hall (J-9)
113. East Building, West Campus (A-1)
114. West Building, West Campus (A-1)
115. Wheeler House (A-6)
116. Whitaker Hall for Biomedical Engineering (K-7)
117. Whittemore House (F-7)
118. Wilson Hall (H-7)
119. Wohl Student Center (C-6)
120. Women's Building, Ann W. Olin (H-5)

*Part of the Sam Fox School of Design & Visual Arts


RESEARCH CENTER
Tyson
Washington University in St. Louis
CASTLEWOOD STATE PARK
BURLINGTON NORTHERN RAILROAD
MERAMEC RIVER
LOW POINT (430')
FLOOD GATES
NORTH GATE
NORTH FIELD
AOC 1
AOC 2
AOC 3
AOC 10
MAIN ROAD
BOBCAT RD
AREA E
EAST RIDGE ROAD
TRAIL
LONE ELK GATE
AREA D
PERIMETER ROAD
HOMESTEAD ROAD
TURKEY ROAD
ART HOLLOW
WOLF SANCTUARY (WCSRC)
WEST VALLEY MAIN ROAD
WALNUT TRAIL
CHERRY TRAIL
OXALIS TRAIL
LONE ELK COUNTY PARK
MINCKE GATE
MINCKE QUARRY
POSSUM TROT
MINCKE CAVE
DEER RD
WAREHOUSE RD.
TYSON OFFICE
VULTURE QUARRY
AREA C
HOLLOW ROAD
MEDICAL GLADE DR.
310 LAB
HAW RD.
WATER TANKS
EAST RIDGE GATE
GATE
WEST PERIMETER ROAD
VALLEY MAIN ROAD
HICKORY ROAD
WHITE OAK ROAD
CUTOFF ROAD
LAW LANE
NEW POND
MEMORIAL GROVE
BAT RD
HIGH POINT (910')
AREA F
PERSIMMON ROAD
ASH ROAD
WEST GATE
AREA B
PHYSICS ROAD
MAIN ROAD
ART CHRIST TRAIL
GATE-HOUSE
COM TOWER
LIBRARY ROAD
COON TRAIL
WEST RIDGE ROAD
RIDGE ROAD
WEST TYSON COUNTY PARK
AREA A
TWIN PONDS
LABADIE TRACE
SOUTH FIELD
BLUEGRASS SPRING
FOX RUN
SOUTH PERIMETER ROAD
ANTIRE ROAD
BEAUMONT - ANTIRE RD. (Exit #226B)
INTERSTATE 44
SOUTH WEST GLADE
CEMETERY
LEWIS RD. exit
MERAMEC RIVER
N
W
E
S
MAP LEGEND:
MAIN PAVED ROADS (2 W. D. OK)
GRAVEL/DIRT ROADS (4 W. D. REQUIRED)
TRAILS (NO VEHICLES)
A-1 through F-20
ROAD JCT. SIGNS

Washington University in St. Louis

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SINCE 1898