



THE AMERICAN UNIVERSITY IN CAIRO



OUR CARBON FOOTPRINT 2.0
NOVEMBER 2013

The black pyramid's dimensions, approximately eight times the size of the Great Pyramid by volume, represent the volume of AUC's greenhouse gas emissions in FY 2012.

Photo courtesy: au.businessinsider.com

MESSAGE FROM THE PRESIDENT

With the establishment of its Office of Sustainability in September 2011, the American University in Cairo reaffirmed its commitment to environmentally-responsible economic growth and stewardship of the earth's resources. In 2013, our decades-old Desert Development Center will be re-launched as the Research Institute for Sustainable Environments as yet another indication of AUC's dedication to sustainability. This, the second edition of the University's Carbon Footprint Report—still the only such report issued by a university in the Middle East and North Africa—conveys both our recent achievements and the necessity of continuing our efforts as we measure our impact and manage it responsibly.

Earlier this year, climate scientists confirmed that the concentration of carbon dioxide in the Earth's atmosphere has reached 400 parts per million for the first time in approximately 3 million years. Egypt's special vulnerability to the effects of climate change and its rising per capita carbon emissions makes this a particularly opportune time to address this crucial component of sustainability.

We at AUC believe that having a meaningful impact on climate change starts at home, with calculation and reduction of our own carbon footprint. This project represents the first attempt in the region to measure a university's impact on climate change. It not only enables AUC to work on the reduction of greenhouse gas emissions on its own campus, but to serve as a model and a challenge, encouraging others to address climate change as well.

Preparation of this report was an interdisciplinary effort, drawing on talent from across the University, including faculty in sciences and engineering, researchers, and administrative staff from a variety of departments, from the Office of Facilities and Operations to the Office of Data Analytics and Institutional Research. The report includes 7 sets of specific recommendations for reducing AUC's carbon footprint; in the coming months, we will be continuing our community conversations about how to implement those and other suggestions for managing our own resources more sustainably.

I would like to thank all those who worked with Marc Rauch, the Sustainability Director and Richard Tutwiler, the Director of the Desert Development Center, in development of this ground-breaking effort, and hope that it will continue to be model for future efforts at AUC and universities across Egypt and the region, ensuring that we all recognize our responsibilities to be trustworthy stewards of the Earth's resources.



Lisa Anderson
President
The American University in Cairo
November 2013



TEAM MEMBERS AND ACKNOWLEDGEMENTS

Research and Report Team

Desert Development Center	Office of Sustainability
Richard Tutwiler, Director Tina Jaskolski, Research Coordinator Sam Hile, Research Associate Jacob Eisenberg, Research Associate	Marc Rauch, Sustainability Director Mahmoud El Gamal, Contracts Manager Kate Reilly, Former Presidential Intern
School of Sciences and Engineering	
Khaled Tarabieh, Assistant Professor of Sustainable Design	

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Sam Hile not only played key roles in preparation of this report and in the underlying research, but he contributed the concept for the cover art. Dina Abulfotuh, Vice President for Communications, and Hanan Omary, Director of Creative Services, designed the cover based on Sam Hile's concept.

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The Desert Development Center (DDC)

The DDC is a non-profit research center established by the American University in Cairo in 1979. The center's mission is the ecologically, socially and economically sustainable development of Egypt's desert communities. The center conducts research and offers training and community services. As a reflection of the University's progress towards a more sustainable environment, the DDC will be succeeded by the new Research Institute for a Sustainable Environment (RISE) in 2013. RISE will incorporate the mission and programs of the DDC and extend its mission to cover environmental sustainability throughout Egypt and the region.

The Office of Sustainability

The Office of Sustainability, headed by the Sustainability Director, is responsible for addressing AUC's environmental challenges, including climate change, resource scarcity, pollution and waste management, in ways that also improve the University's operations, strengthen its finances and enhance its reputation. The Office of Sustainability is a division of the Office of the Executive Vice President for Administration and Finance.

CONTENTS

EXECUTIVE SUMMARY	1
1. INTRODUCTION	4
1.1. Why Do a Carbon Footprint Study at AUC?	4
1.2. Greenhouse Gas Emissions in Egypt and the MENA Region	5
1.3. Climate Change and Resource Scarcity: Interrelated Crises with Interrelated Solutions	5
1.4. University Overview	6
1.5. AUC's Central Utility Plant and Co-Generation	6
1.6. FY 2012: A Year of Progress in Reducing Carbon Emissions	7
2. OVERALL METHODOLOGY AND ORGANIZATION OF REPORT	11
2.1. Reference Carbon Calculator	11
2.2. Boundaries	11
2.3. Calculations.....	11
2.4. Organization of Report.....	12
3. HEATING, VENTILATION, AIR CONDITIONING (HVAC) AND DOMESTIC HOT WATER	12
3.1. Summary	12
3.2. Electricity for HVAC	13
3.3. Chilled and Hot Water	14
4. ELECTRICITY FOR LIGHTING AND EQUIPMENT (OTHER THAN HVAC).....	15
4.1. Summary	15
4.2. Emissions	15
5. TRANSPORTATION	15
5.1. Summary	15
5.2. Commuting by Bus and Car	17
5.3. Air Travel.....	19
5.4. University Fleet.....	20
5.5. Sponsored Field Trips	21
6. PAPER USE	22
6.1. Emissions	22
6.2. Methodology	22
6.3. Data Sources	22
6.4. Emission Factors	22
7. WATER SUPPLY	22
7.1. Summary	22
7.2. Emissions	22
7.3. Methodology for Calculating Carbon Emissions Attributable to Domestic Water Supply and Treated Water Supply	24
7.4. Data Sources	25
7.5. Emission Factors	25

8. REFRIGERANT LEAKAGE.....	25
8.1. Emissions	25
8.2. Methodology	25
8.3. Data Sources	25
8.4. Emission Factors	26
9. SOLID WASTE DISPOSAL.....	26
9.1. Emissions	26
9.2. Methodology	26
9.3. Data Sources	26
9.4. Emission Factors	26
10. NATURAL GAS FOR DOMESTIC AND LAB USE.....	26
10.1. Emissions	26
10.2. Methodology	27
10.3. Data Sources	27
10.4. Emission Factors	27
11. FERTILIZER.....	27
11.1. Emissions	27
11.2. Methodology	28
11.3. Data Sources	28
11.4. Emission and Other Relevant Factors	28
12. LANDSCAPING AS A CARBON OFFSET	28
12.1. Emissions Sequestered.....	28
12.2. Methodology and Data Sources	29
12.3. Sequestration Factors	30
13. AUC’s CARBON FOOTPRINT COMPARED TO OTHER UNIVERSITIES.....	30
14. RECOMMENDATIONS FOR REDUCING OUR CARBON FOOTPRINT	31
Appendix 1: New Cairo Campus Maps and Map of Greater Cairo.....	34
Appendix 2: How the Central Utility Plant Works.....	37
Appendix 3: Emission Factor Calculations	40
Appendix 4: Domestic Water Supply Delivery Path and Energy Calculation Example	42
Appendix 5: Treated Wastewater Supply and Delivery Path and Energy Calculations	43

EXECUTIVE SUMMARY

A carbon footprint is a widely accepted method of measuring the impact of human activity on climate change. A university's carbon footprint is the annual total of carbon dioxide (CO₂) and other significant greenhouse gases emitted into the atmosphere as a result of daily activities and campus operations. Carbon footprints are commonly measured in metric tons of carbon dioxide equivalents (MTCO₂eq). There are at least three good reasons to calculate The American University in Cairo (AUC)'s carbon footprint: first, the growing scientific consensus that climate change is a global concern and potentially catastrophic for Egypt; second, the University's commitment to innovative research in the field of sustainability; and third, the desire to make AUC's own operations more sustainable.

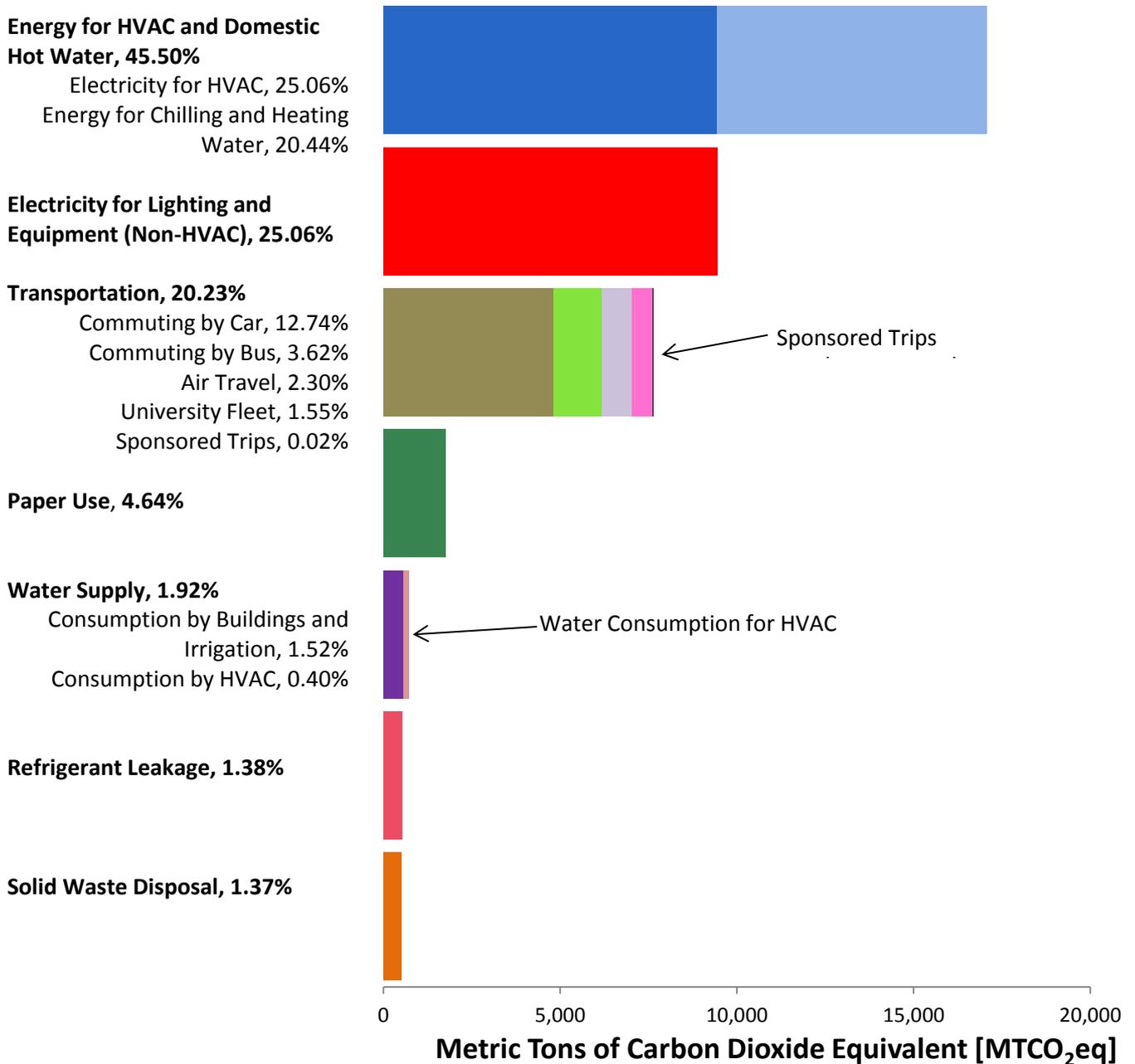
This study calculates the carbon footprint for AUC's New Cairo campus, where the majority of the University's activities now take place. It covers AUC's Fiscal Year 2012 (FY 2012), which ran from September 1, 2011 through August 31, 2012. FY 2012 will serve as the baseline from which all future changes to AUC's carbon footprint will be measured. The main activities contributing to AUC's carbon footprint (see **Box 1**), namely heating, ventilation and air conditioning (HVAC) and domestic hot water, lighting and use of electrical equipment, transportation, paper use and water supply, are shown in **Figure 1**, with the percentage contribution of each to the carbon footprint.

The paths to reducing AUC's carbon footprint are clear. In the report that follows, we set forth the methodology, data sources and assumptions that underlay our findings, and we describe specific, concrete steps that we are already taking or can take in the future to reduce our carbon footprint.

AUC's net carbon footprint for FY 2012 is 37,711.85 MTCO₂eq (see Figure 1).

AUC's Carbon Footprint, FY 2012

AUC's operations resulted in emissions of **37,711.85 MTCO₂eq**



AUC's Carbon Footprint,¹ Fiscal Year 2012². Percentages are of the total emissions. Not shown are minor contributions from natural gas for domestic and lab use (0.10%) and fertilizers (0.04%).

¹ Total emissions reflect a deduction for a carbon offset of approximately 99 MT from landscaping.

² FY 2012 ran from September 1, 2011 to August 31, 2012.

Box 1: The Key Contributors to the Footprint

More than 90% of AUC's carbon footprint is attributable to three main systems (see **Figure 1**): (1) heating, ventilation and air conditioning (commonly known as "HVAC") and domestic hot water; (2) lighting and use of other electrical equipment; and (3) transportation.

HVAC (Heating, Ventilation and Air Conditioning)

More than 45% of the carbon footprint comes from HVAC. Not surprisingly, given that the campus is located in a desert climate where air conditioning is needed more than half the year, the vast majority of these CO₂ emissions result from the consumption of energy for air conditioning. As discussed in Section 1.6, in September, 2011 (the beginning of FY 2012) the University created a working group tasked with drastically reducing the energy needed and associated CO₂ emissions caused by HVAC. As discussed in Section 1, this energy-saving initiative reduced emissions from energy and electricity used for HVAC by 27.5% in total in FY 2012.

Lighting

About 25% of the carbon footprint results from lighting and from the use of office and other electrical equipment on campus. In September 2012 (the beginning of FY 2013), the University began a project aimed at turning off the 30,000 lights constituting the public lighting system on campus, wherever and whenever possible.

Transportation

More than 20% of the carbon footprint can be traced to transportation, with the bulk of transportation emissions (more than 16% of the footprint) attributable to commuting by car and bus. Again, this is hardly surprising, since thousands of AUCians commute daily from all over Greater Cairo to AUC's New Cairo campus, 35 km east of Downtown. Encouraging more AUCians to commute by bus, and encouraging those who continue to drive to carpool, are critical steps if we are to significantly reduce our CO₂ emissions from transportation.

Paper

The use of paper contributes nearly 5% of the carbon footprint. Unfortunately, recycled paper for office use is not yet locally available in Egypt. Although we have greatly reduced paper consumption since moving from Downtown, we need to cut our paper use further.

Water

Nearly 2% of AUC's carbon footprint is attributable to supplying water to the New Cairo campus. In late FY 2012, the University began using treated wastewater for irrigation. This and other conservation measures have the potential to significantly reduce CO₂ emissions from supplying water.

1. INTRODUCTION

1.1. Why Do a Carbon Footprint Study at AUC?³

Of all the countries in the Arab world, Egypt is the most vulnerable to global warming. Climate change models and paleo-climatology findings predict rising sea levels that threaten to flood large swaths of the Delta, Egypt's breadbasket (see **Figure 2**), undermining Egypt's food security and threatening the livelihoods of millions of agricultural workers.⁴ Key population centers are also at risk, most notably the cities of Alexandria and Port Said. Additionally, rising mean temperatures will have a negative impact on Egypt's ability to grow enough food to feed its burgeoning population, causing further disruptions in the agricultural sector that presently employs over 30% of the workforce. Not least among the threats is the potential impact of changing rainfall patterns in highland Ethiopia, the source of over 80% of the Nile River flow water reaching Egypt. Given Egypt's near total dependence on the Nile for its fresh water, either a reduction in average precipitation or a greater variation in annual rainfall in Ethiopia would seriously challenge the sustainability of Egyptian society.

Displaced population: 3,800 000
Lost cropland: 1,800 km²



Displaced population: 6,100 000
Lost cropland: 4,500 km²



Figure 2: Potential impact of sea level rise: Egypt's Nile Delta.⁵

The potentially stark consequences of climate change for Egypt have led The American University in Cairo (AUC) to undertake the first carbon footprint study of an institution of higher education in the Middle East and North African region (MENA).⁶ This study also responds to concerns about the sustainability of AUC's own operations after the University moved most of its activities from a small 90-year-old campus in Downtown Cairo to a new 260-acre campus in the sprawling desert suburb of New Cairo, about 35 km to the southeast of the Downtown campus.

Carbon footprints are widely used as a measure of the impact of human activities on global warming.⁷ A carbon footprint calculates net greenhouse gas (GHG) emissions over time, typically one or more years. The World Resources Institute describes the term as "a representation of the effect you, or your organization, have on the climate in terms of the total amount of greenhouse gases produced (measured in units of carbon dioxide)."⁸ A carbon footprint identifies carbon emission sources, provides a guide for reducing carbon emissions and provides a means for evaluating progress in the reduction of those emissions.

³ Portions of Section 1.1 appeared initially in Tutwiler, R. and Rauch, M. (2012).

⁴ Gillis, 2013.

⁵ Simonett et al., 2005.

⁶ The initial study, published in October 2012, covered AUC's FY 2011 (September 1, 2010 – August 31, 2011). The present study covers FY 2012 (September 1, 2011 – August 31, 2012) and shows changes in carbon emissions from FY 2011 to FY 2012 in every category in which the data permits useful comparisons to be made.

⁷ The initial study, published in October 2012, covered AUC's FY 2011 (September 1, 2010 – August 31, 2011). The present study covers FY 2012 (September 1, 2011 – August 31, 2012) and shows changes in carbon emissions from FY 2011 to FY 2012 in every category in which the data permits useful comparisons to be made.

⁸ World Resources Institute (WRI), 2013.

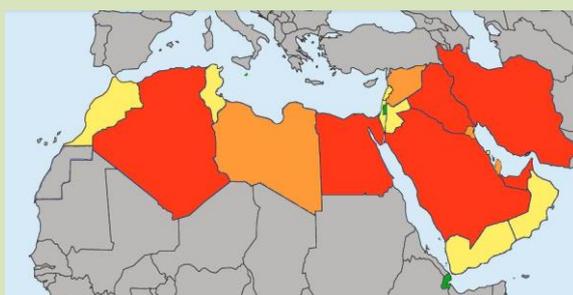
In AUC's case, a principal goal of these studies is to develop information that can be used to reduce AUC's own greenhouse gas emissions. A second important goal is to strengthen the University's finances by permanently reducing its appetite for carbon-based energy sources such as natural gas, electricity, gasoline and diesel fuel that must be purchased from third parties. Finally, we hope to provide a replicable model and methods that can be adopted by other institutions of higher education in the MENA region to quantify, evaluate and reduce their own carbon emissions.

1.2. Greenhouse Gas Emissions in Egypt and the MENA Region

More than 40% of Egypt's carbon emissions come from two sectors: power generation and road transport. This is comparable to other MENA countries (see **Box 2**), particularly those with a significant hydrocarbon (petroleum and natural gas) sector. In Egypt, the proportional shares of emissions from power, road transport and basic industry are expected to increase, while the proportional contributions from agriculture, solid waste and construction should decrease.⁹

Box 2: Carbon Emissions in the Middle East

Egypt's national greenhouse gas (GHG), or carbon, emissions profile is broadly similar to those of its neighbors. With an estimated total emissions of around 318.2 million MT_{CO₂eq} (carbon equivalent) in 2010, Egypt is among the highest in total emissions. However, its per capita emissions, given Egypt's large population of more than 85 million inhabitants, are less than half the regional average. Qatar heads the list of the world's highest per capita carbon emitters, while Kuwait, the Emirates and Bahrain occupy ranks three, four, and five; Saudi Arabia ranks 14th on the same list, while Egypt, at about 2.8 tons per person, ranks 124th. Nevertheless, predictions are for Egypt's emissions to increase at a faster pace than population growth: by the year 2030 Egypt's total emissions will have more than doubled and Egypt's share of world emissions is estimated to grow by 50%.



MENA annual CO₂ emissions per country (thousand metric tons).
 0-4,999; 5,000-49,999; 50,000-99,999; 100,000-550,000

Source: Carbon Dioxide Information Analysis Center (2008).

Source: Carbound Group, 2011; EEAA, 2012.

The obstacles to reducing emissions in Egypt and the region include arid to hyper arid desert ecosystems, lengthy summers with extreme temperatures, rapid urbanization and the limits of prevailing technologies. On the macro level, Egypt's potential for lowering emissions or at least reducing the rate of growth in emissions is slightly lower than in comparable developing economies because gains have already been made in the power generation sector: Egypt already has a high proportion of natural gas-fired power plants and uses no coal-fired plants. Overall, the best strategy may be to lower demand for electricity in buildings, while developing more power generating capacity from renewable sources, particularly wind and solar energy.¹⁰

1.3. Climate Change and Resource Scarcity: Interrelated Crises with Interrelated Solutions

In today's Egypt, any discussion of carbon emissions must acknowledge periodic shortages of fuel and electricity, as well as the longer-term but no less serious challenge of permanent water scarcity.¹¹ Earlier this year, long lines at gas stations to buy gasoline or diesel fuel were commonplace in and around Cairo, and phased blackouts that rotated from neighborhood to neighborhood during hours of peak electricity demand were a nearly everyday occurrence, particularly during hot weather.

⁹ Egypt Industrial Modernization Center, 2010.

¹⁰ Ibid.

¹¹ Sabry, 2012 and International Commission on Irrigation and Drainage, 2012.

Whatever the underlying causes of these fuel and power shortages, whether long-term structural imbalances, short-term market dislocations, or both, there is a high likelihood that they will recur.

As for water, each year, as Egypt’s population grows and its annual allocation of water from the Nile remains fixed at 55.5 billion m³,¹² availability of domestic (potable) water falls further below the United Nations and World Bank “water poverty” line of 1,000 m³ per person annually.¹³ At AUC’s New Cairo campus, water scarcity hit home during 2012 and 2013, as the City of New Cairo has on several occasions been unable to supply sufficient domestic water to assure continuity of the University’s operations.

If there is a bright side to the closely linked challenges of climate change and resource scarcity, it is that the solutions are also closely linked, as amply illustrated by this report: by learning to conserve our scarce resources, many of them carbon-based or ultimately dependent on carbon-based fuels, we will simultaneously reduce our carbon emissions and thus help to save our fragile climate. Conversely, it is impossible to make significant progress in combating global warming without learning to manage our scarce resources more wisely.

1.4. University Overview

AUC was founded in 1919. Accredited by the Commission on Higher Education of the Middle States Association of Colleges and Schools in the United States (MSCHE), it today offers American-style liberal arts education as well as graduate programs to Egyptians, other students from the MENA region and international study-abroad students. Through all their activities, AUC is dedicated to community service and promoting sustainable development. In September 2008, the University moved the bulk of its operations from nine acres of campuses centered on Tahrir Square in Downtown Cairo to an all-new, state-of-the-art 260-acre campus in the developing desert city of New Cairo (see **Appendix 1**). The amount of built space jumped from 68,000m² to 203,000m². In the past five years, the University’s operating budget has more than doubled, and the student, faculty and staff head counts have increased considerably. In short, the University’s activities are expanding to capitalize on its new facilities and to achieve its long-term strategic goals. **Table 1** shows the University’s population in 2012.

In FY 2012 (September 1, 2011 – August 31, 2012), the University’s operating budget was US \$180,116,000, including a utilities (energy and water) budget of US \$5,633,333.33 and a research budget of US \$10,086,496.

Table 1: AUC Student Body in FY 2012

Full-Time Students	5,214
Part-Time Students	1,289
Faculty (Full and Part-Time)	843
Staff	2,838
Total	10,184
Total Full-Time Equivalent (FTE) Students ¹⁴	5,859

1.5. AUC’s Central Utility Plant and Co-Generation

Since more than 70% of AUC’s greenhouse gas emissions are attributable to heating, ventilation and air conditioning (HVAC), domestic hot water and the use of lighting and other electrical equipment (see **Figure 1**), a basic understanding of how these vital services and utilities are delivered to the New Cairo campus is important for understanding AUC’s carbon footprint. In 2006, as part of the construction of the New Cairo campus, AUC entered into a long-term contract with the Egyptian Company for Refrigeration by Natural Gas (GasCool) to build and operate an on-campus central utility plant. The plant, which has a floor area of some 5,781m² (62,226ft²) and is illustrated

¹² Abdin and Gaafar, 2009.

¹³ United Nations Department of Economic and Social Affairs.

¹⁴ Includes full-time students and part-time students representing half of one full-time student.

schematically in **Appendix 2**, produces all of the chilled water used for air conditioning campus buildings, all of the hot water used for heating, most of the domestic hot water and 80% of the electricity¹⁵ used on campus. The manner in which each of these services and utilities, i.e. chilled water for air conditioning, hot water for heating and domestic hot water and electricity, is produced at the central utility plant is explained in **Appendix 2**.

The design of AUC's central utility plant is environmentally friendly in two important respects. First, the fuel used is natural gas, a relatively clean-burning (albeit carbon-based) fuel that, for the most part, is extracted domestically from relatively abundant reserves in Egypt. Second, the plant uses co-generation, a process of capturing and recycling waste heat from electricity generators, to produce a significant portion of the hot water used on campus for heating and domestic hot water. A more detailed explanation of how co-generation works at AUC's central utility plant is set forth in **Appendix 2**.

1.6. FY 2012: A Year of Progress in Reducing Carbon Emissions

At AUC, FY 2012 was a year of progress in reducing carbon emissions, most notably emissions attributable to HVAC, the heaviest energy-consuming sector. Additionally, programs were introduced that should significantly reduce future carbon emissions related to private car commuting and water supply.

Three-Year Energy-Saving Program

Commencing early in FY 2012, the University adopted a 3-year energy-saving program with the goal of reducing energy consumption University-wide¹⁶ by one-third over three years. During FY 2012, the first year of the 3-year program, the main focus was on managing HVAC more efficiently at the New Cairo campus, because an analysis of AUC's energy consumption University-wide during FY 2011 (the benchmark year for the energy-saving program) disclosed that approximately 70%¹⁷ of AUC's energy consumption in FY 2011 resulted directly from air conditioning and heating the New Cairo campus.¹⁸

Cooling and heating the New Cairo campus accounts for such a large proportion of AUC's energy consumption because of the large size of the New Cairo campus and the desert climate, which is very hot during the long summer (May through October), but also cold enough in winter (November through March) to require heating. On the positive side, managing HVAC more efficiently can result in a "triple-win" from the perspectives of energy consumption and carbon emissions: not only does it save energy (and emissions) from burning natural gas to produce chilled water for air conditioning and hot water for heating (see Section 3.3), but it saves electricity used to operate the HVAC system (see Section 3.2) and water needed for the AC (air conditioning) cooling towers (see below in this section and in Section 7).

During FY 2012, AUC implemented numerous measures aimed at reducing energy consumption for HVAC at the New Cairo campus. These included "retro-commissioning"¹⁹ the HVAC system

¹⁵ The remaining 20% comes from the public Egyptian Electricity Authority, as discussed in Section 3.2 and **Appendix 2**.

¹⁶ For this purpose "University-wide" includes the University's Downtown facilities as well as the New Cairo campus, but excludes energy consumed by transportation.

¹⁷ In FY 2011, AUC consumed a total of 103,494,910.39 kWh of energy University-wide. Producing chilled water for air conditioning and hot water for heating consumed 51,290,277.52 kWh of energy. The electricity required to operate the HVAC system consumed 20,954,400 kWh. The sum is 72,244,677.52 kWh, or 69.81% of the total, according to AUC's Maintenance Department—Office of Facilities and Operations and meter readings taken in FY 2012.

¹⁸ In FY 2011, air conditioning the New Cairo campus accounted for approximately 50% of the total energy consumed University-wide, while heating the New Cairo campus accounted for approximately 20%, according to AUC's Office of Facilities and Operations and meter readings taken in FY 2012.

¹⁹ "Retro-commissioning" means examining and adjusting all mechanical parts of the campus-wide HVAC system to ensure that they were installed properly and are being operated in accordance with manufacturers' recommendations for saving energy (Building Commissioning, 2013).

campus-wide, adjusting the “set points” (target temperatures) for air conditioning to a higher temperature and heating to a lower temperature, reducing hours of HVAC service, installing occupancy sensors in classrooms, installing automatic door closers to prevent cooled air from being released into the desert, and limiting cooling and heating of cavernous spaces such as auditoriums, theaters, sports facilities and large lecture halls to hours when those facilities are actually being used.

Energy Savings and Reductions in Carbon Emissions Relating to HVAC in FY 2012

The results of AUC’s efforts to manage HVAC more efficiently are shown in **Figure 3**. Energy consumption at the New Cairo campus decreased by 23.1% overall from FY 2011 to FY 2012.

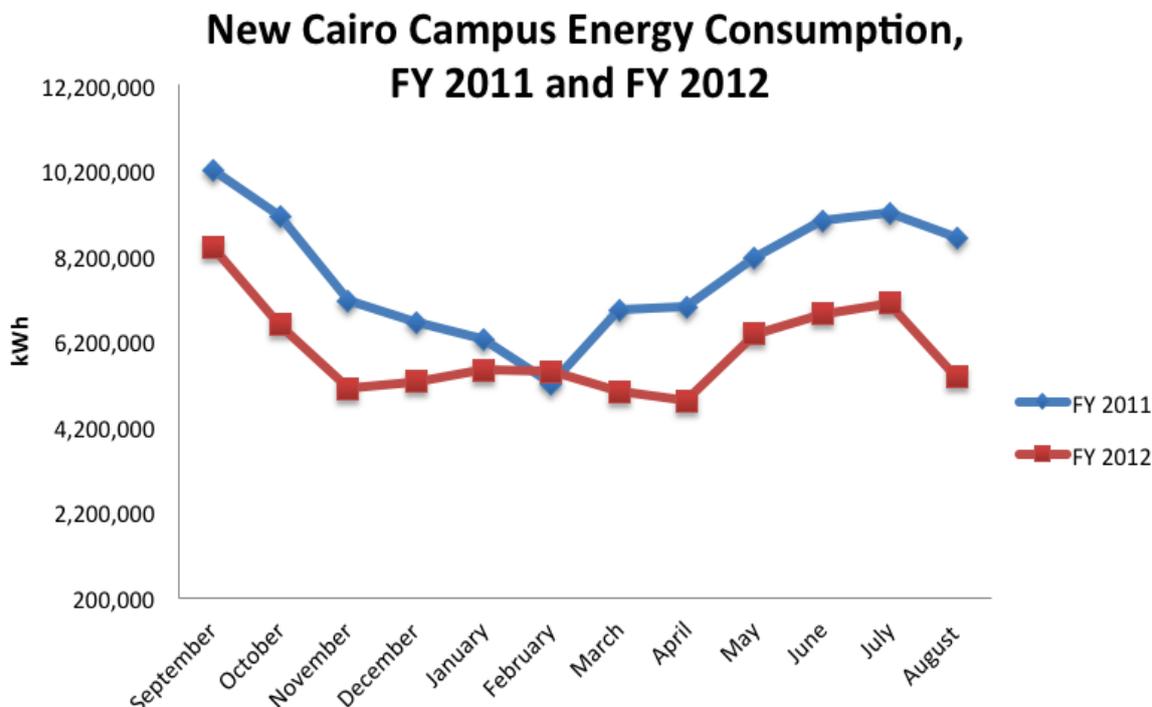


Figure 3: New Cairo Campus Energy Consumption, FY 2011 and FY 2012 Comparison.

This decrease in energy consumption is reflected in the reduction of carbon emissions resulting from HVAC. Emissions attributable to the production of chilled water for air conditioning and hot water for heating decreased from 11,573 MTCO₂eq in FY 2011 to 7,707.39 MTCO₂eq in FY 2012, a reduction of about 33%. Emissions from consumption of electricity used to operate the HVAC system decreased from 12,074.98 MTCO₂eq in FY 2011 to 9,450.11 MTCO₂eq in FY 2012 or almost 22% (see Section 3).

Free Parking for Carpoolers to Reduce Carbon Emissions from Private Car Commuting

In FY 2012, more than 16% of AUC’s carbon emissions resulted from commuting to the New Cairo campus by private car or bus (see **Figure 1** and Section 5.1). 78% of these emissions are from private car transport and only 22 % from University bus transport (see **Figure 9** and Section 5).

Nearly 70% of AUCians commuted by bus in FY 2012 and only 30% by private car (see Section 5). This means that the 30% who commuted by private car accounted for 78% of commuting-generated carbon emissions, while the 70% who took the bus accounted for only 22%. These statistics illustrate

a basic tenet of sustainable transportation, that bus travel is far more energy-efficient and produces far fewer carbon emissions per passenger mile traveled than travel by private car.²⁰

Carpooling is a well-known method for taking cars off the road and reducing carbon emissions from commuting by private car. Carpooling reduces fuel consumption, carbon emissions and pollution by making one car do the work of two, three or four cars. It also helps to reduce the traffic congestion that is ubiquitous in Greater Cairo. Yet at the time AUC's Transportation Sustainability and Safety Survey was conducted in March 2012, only 19% of those who commuted to the New Cairo campus by private car had ever carpooled.

In part to address these concerns and to reduce the demand for parking spaces at the New Cairo campus, in late FY 2012 the University adopted a policy, known as "High Occupancy Parking" (HOP), of waiving parking fees for carpoolers.²¹ It is anticipated that follow-up studies will be done in FY 2013 and beyond to determine the extent to which free parking for carpoolers increases the incidence of carpooling.

Reducing Carbon Emissions from Water Supply

Egypt is an arid country with minimal rainfall. It therefore has significantly less water per capita than the global scarcity benchmark of 1,000 m³ per capita per annum.²² Egypt is in a situation of constant water scarcity, and sustainable water management is one of the most important issues Egypt will face in the coming years.

Not only is water scarcity an ever-present concern in Egypt, but transporting water to a location like the New Cairo campus from a distant source also uses energy and produces carbon emissions (see **Figure 1** and Section 7), a phenomenon sometimes referred to as the "water-energy nexus."²³

In FY 2012, AUC used 607,883 m³ of water at the New Cairo campus.²⁴ The water was used for three purposes: buildings (e.g. kitchens, bathrooms, laboratories), which consumed 184,750 m³ or 30.39% of the total; the AC cooling towers, which consumed 123,471 m³ or 20.31% of the total; and landscape irrigation, which consumed 299,662 m³ or 49.30% of the total.

Until the final three months of FY 2012 (June, July, and August 2012), AUC used exclusively domestic (drinking quality) water for buildings, air conditioning cooling towers and landscape irrigation. As described more fully in Section 7 and **Appendix 4**, AUC's domestic water comes from the Ismailiya Canal, northeast of Cairo, and must be pumped across a distance of 54.45 km and up inclines totaling 308 meters to reach the New Cairo campus, passing through a number of pumping and purification stations along the way. This process consumes 2.55 kWh of energy for every m³ of domestic water delivered to the New Cairo campus, resulting in emissions of 1.27 MTCO₂eq per thousand m³ of water (see Section 7).

In FY 2012, as described more fully in Section 7, AUC took two significant steps to reduce carbon emissions attributable to water supply. First, as described earlier in this section, it managed air conditioning more efficiently, reducing the amount of domestic water needed for the AC cooling towers. Second, in the latter half of FY 2012, the University began using treated wastewater (a form of recycled water) instead of domestic water for irrigation of landscaping at the New Cairo campus.

²⁰ Hodges, 2009.

²¹ AUC, 2012.

²² United Nations Department of Economic and Social Affairs.

²³ International Energy Agency World Energy Outlook, 2012.

²⁴ AUC Office of Facilities and Operations, 2012.

Reducing Carbon Emissions by Reducing Water Consumption of the AC Cooling Towers

As noted earlier in this section, managing air conditioning more efficiently is a “triple win”: it reduces the amount of natural gas that must be burned to produce chilled water, limits the amount of electricity needed to operate the air conditioning system and decreases the amount of domestic water needed to operate the AC cooling towers (see Section 7 and **Figure 13**).

New Cairo Campus Cooling Tower Water Consumption, FY 2011 and FY 2012

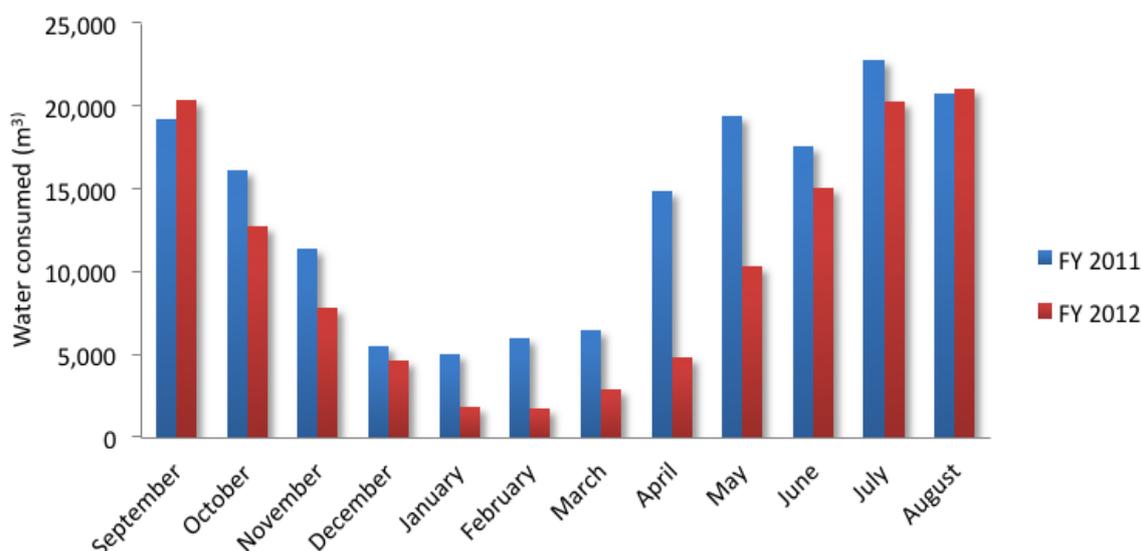


Figure 4: New Cairo Campus Cooling Tower Water Consumption, FY 2011 and FY 2012 Comparison.

In FY 2012, more efficient management of the air conditioning system resulted in a decrease from 165,011.50 m³ of domestic water used for the cooling towers in FY 2011 to 123,470.96 m³, or a reduction of 25.17% (see **Figure 4**).²⁵ Since bringing each 1,000 m³ of domestic water to the New Cairo campus causes carbon emissions of 1.27 MTCO₂eq, this reduction in domestic water used by the AC cooling towers reduced carbon emissions by 52.76 MTCO₂eq.

Reducing Carbon Emissions by Recycling Treated Wastewater for Irrigation

During the final months of FY 2012, the University began using treated wastewater to irrigate New Cairo campus landscaping. This change in water management policy was prompted by the failure of the municipal water authority to deliver domestic water to campus reliably during the hot summer months.

Treated wastewater is previously used water that enters the New Cairo sewer system and is then pumped to an off-site treatment plant approximately 10 km east of New Cairo. There it is processed until safe to use for purposes such as irrigation²⁶ and then delivered to the New Cairo campus (see Section 7.3).

AUC’s use of treated wastewater not only helps alleviate regional domestic water scarcity, but it also results in fewer carbon emissions because nearly 42% less energy is needed to pump, process and deliver a m³ of treated wastewater to the New Cairo campus compared to a m³ of domestic water.

²⁵ AUC Office of Facilities and Operations, 2011 and AUC Office of Facilities and Operations, 2012.

²⁶ AUC further treats the treated wastewater after it reaches the New Cairo campus, by adding chlorine to kill any remaining pathogens.

Thus, supplying 1,000 m³ of treated wastewater to the New Cairo campus results in emissions of only 0.74 MTCO₂eq compared to supplying the same volume of domestic water, which results in emissions of 1.27 MTCO₂eq.

Since irrigation accounted for nearly half of all water consumed by AUC in FY 2012, using treated wastewater for irrigation has significant potential for reducing carbon emissions attributable to supplying water to the New Cairo campus.

2. OVERALL METHODOLOGY AND ORGANIZATION OF REPORT

2.1. Reference Carbon Calculator

AUC's emission calculations are premised on the methodology used by Clean Air – Cool Planet Carbon Calculator (CA-CPCC) tool.²⁷ CA-CPCC is widely used by other universities and has been regularly upgraded. It is an Excel workbook designed to quantify an annual aggregate carbon footprint. Once data is collected, verified and formatted into proper units for entry, the software calculates emissions of carbon dioxide, methane and nitrous oxide, the three commonly reported greenhouse gas (GHG) emissions. The CA-CPCC is based on workbooks and protocols provided by the Intergovernmental Panel on Climate Change (IPCC), the GHG Protocol Initiative and the Climate Registry.

CA-CPCC had to be modified and supplemented for use at AUC. For example, the carbon footprint team had to identify and construct a number of emission factors specific to Egypt, to Cairo and to processes occurring uniquely at AUC's central utility plant. Moreover, CA-CPCC does not account for carbon emissions attributable to water supply, an issue of significant concern in an arid country like Egypt. The AUC team thus used CA-CPCC as its principal guide for constructing AUC's own emissions calculator. Whenever possible, however, this AUC-specific carbon footprint report uses categories and methods of analysis similar to those used by CA-CP to facilitate comparisons with the numerous other schools relying on CA-CPCC.

2.2. Boundaries

This report focuses exclusively on the New Cairo campus where the bulk of the University's operations now take place.²⁸ AUC's original historic campus in Tahrir Square, as well as smaller remote or satellite facilities, have consequently been excluded from this analysis.

2.3. Calculations

This report accounts for three of the six main GHGs: Carbon Dioxide (CO₂), Methane (CH₄) and Nitrous Oxide (N₂O). The main unit of measure is metric tons (MT) of carbon dioxide equivalents (CO₂eq) (see **Box 2**), which is the most widely used reporting method. Carbon dioxide equivalents of CH₄ and N₂O are based on the global warming potential (GWP) of each gas – which compares the amount of heat trapped by a similar mass of carbon dioxide. Methane has a GWP of 21 (i.e. 21 times the heat trapping effect of CO₂) and nitrous oxide has a GWP of 310.²⁹ Carbon dioxide equivalents (CO₂eq) are used here to express the relative global warming impact of each of the three greenhouse gases through a single unit of measure. The principal formula used in this report for calculating equivalents is as follows:

$$\text{Consumption of Energy (unit)} \times \text{Emission Factor (unit CO}_2\text{eq/unit of energy)} = \text{Units of CO}_2$$

²⁷ Clean Air-Cool Planet was established in 1999 as a non-profit organization and has published several versions of its carbon calculator software. To date, more than 1,000 universities in North America have used CA-CPCC to calculate their carbon footprints. CA-CPCC is also the calculator most commonly used by signatories to the American College and University Presidents Climate Commitment (ACUPCC). Additionally, most of AUC's peer institutions in the United States have relied on CA-CPCC.

²⁸ By way of example, in FY 2012, 87% of the energy consumed by the University as a whole was consumed at the New Cairo campus according to meter readings conducted by the AUC Maintenance Department—Office of Facilities and Operations.

²⁹ United Nations Framework Convention on Climate Change, 2013.

Box 2: What does 1 metric ton of carbon dioxide look like?

1 MT of carbon dioxide (CO₂) in its gaseous form as it is found in the atmosphere would amount to approximately 557 m³, represented here by a sphere of radius 5.1 meters.

Source:

<http://greenenergy.blogs.mydesert.com/2012/05/04/visualizing-a-ton-of-carbon-dioxide/>



2.4. Organization of Report

Sections 3 through 9 analyze the metric tons of carbon dioxide equivalent resulting from principal activities at AUC giving rise to carbon emissions, in descending order of emissions: (1) HVAC, (2) electricity used for lighting and equipment, (3) transportation, (4) paper use, (5) water supply, (6) leakage of refrigerants and (7) solid waste disposal. Sections 10 and 11 analyze the smaller, but still significant, carbon emissions from (8) burning natural gas for domestic and laboratory use and (9) fertilizer use. The analysis of emissions in Sections 3 through 11 is followed in Section 12 by an analysis of landscaping carbon sequestration. The final two sections of the report, Sections 13 and 14, compare AUC's emissions to those of other universities and offer twenty specific recommendations for further reducing AUC's carbon footprint.

3. HEATING, VENTILATION, AIR CONDITIONING (HVAC) AND DOMESTIC HOT WATER

3.1. Summary

As shown in **Figure 1**, more than 45% of AUC's carbon emissions in FY 2012 are attributable to HVAC and domestic hot water. These vital services are produced by using electricity, natural gas and water in various processes occurring at AUC's central utility plant (see **Appendix 2**).

Electricity is used to power pumps circulating chilled water throughout the campus for air conditioning and hot water for heating and domestic hot water. Electricity is also used to power air handling units, variable air volume (VAV) units and other equipment required for the HVAC system.

Chilled water for air conditioning (AUC's single largest sector of energy expenditure and one of its biggest sources of carbon emissions)³⁰ is produced by gas-fired chillers at the central utility plant. The waste heat given off by the gas-fired chillers is removed by a circulating water system that releases the waste heat from six cooling towers through evaporation. This process alone accounts for more than 20% of AUC's total water use during the hot summer months (see Section 7). Hot water for heating and domestic hot water is produced in one of two ways. When possible, exhaust fumes from gas-fired electricity generators are used to heat water in waste-heat boilers (a process known as co-generation, described in **Appendix 2**). When the waste heat boilers are not sufficient for producing the volume of hot water required, additional hot water is produced in conventional, gas-driven boilers.

³⁰ A recent New York Times article reported that Cairo has nearly twice as many "cooling degree days" (a common measure of the need for air conditioning) as Tokyo and nearly three times as many as New York City (Rosenthal, 2012).

3.2. Electricity for HVAC

3.2.1. Emissions

In FY 2012, the University emitted an estimated 3,703 MTCO₂eq through the consumption of electricity purchased from the Cairo grid and supplied by the Egyptian Electricity Authority (EEA). An estimated 15,197 MTCO₂eq was emitted as a result of electricity produced at the central utility plant (see **Figure 5**). Out of the total emissions from the consumption of electricity, **18,900.22 MTCO₂eq**, an estimated 50% or **9,450.11 MTCO₂eq**, resulted from operation of the HVAC system.³¹

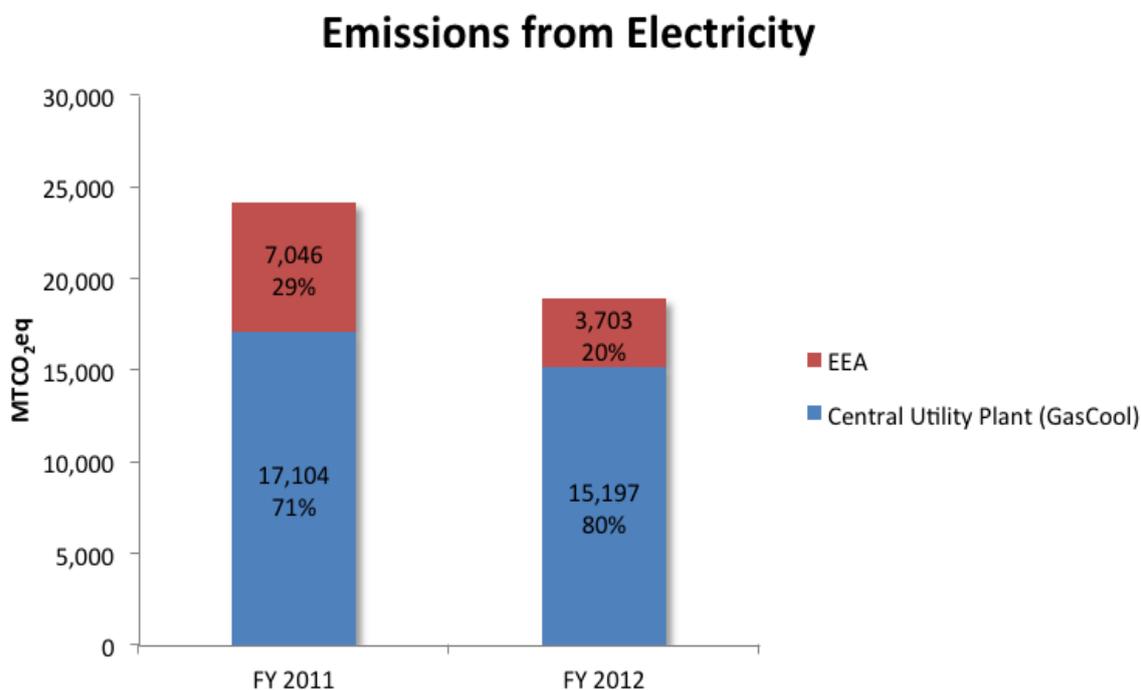


Figure 5: Emissions from electricity purchased from the grid (EEA) and generated in AUC’s central utility plant (FY 2011 and FY 2012 comparison).

3.2.1. Consumption

In FY 2012, the University consumed 7,399,200 kWh of electricity from EEA and 29,448,800 kWh from its own central utility plant.

3.2.2. Methodology

Emission factors for the energy inputs used to generate electricity are required to calculate the Cairo grid emissions factor. In the Cairo Zone, the fuel mix is 83.8% natural gas and 16.2% high-density fuel oil (HFO, referred to locally as *mazut*).³² The efficiency of electricity production is 43.10% (weighted average among the eight Greater Cairo power plants). The AUC central utility plant uses 100% natural gas and produces electricity at 39.53% efficiency. We calculated emission factors for the Cairo grid using the method in **Appendix 3**. For the central utility plant’s electricity the formula excluded HFO, since none was used. We used the same formulas to calculate the methane (CH₄) and nitrous oxide (N₂O) emissions.

3.2.3. Data and Sources

Data on electricity consumption was provided by AUC’s Office of Facilities and Operations based on monthly readings of AUC’s electric meters.

³¹ The basis for attributing approximately 50% of electricity-related emissions to the operation of the HVAC system is discussed in **Appendix 2**.

³² Egypt Environmental Affairs Agency, 2012.

3.2.4. Emission Factors³³

Source	Mass Emissions (kgCO ₂ eq/kWh)
EEA	0.497042581
GasCool	0.512269163

3.3. Chilled and Hot Water

Emissions from Chilled and Hot Water

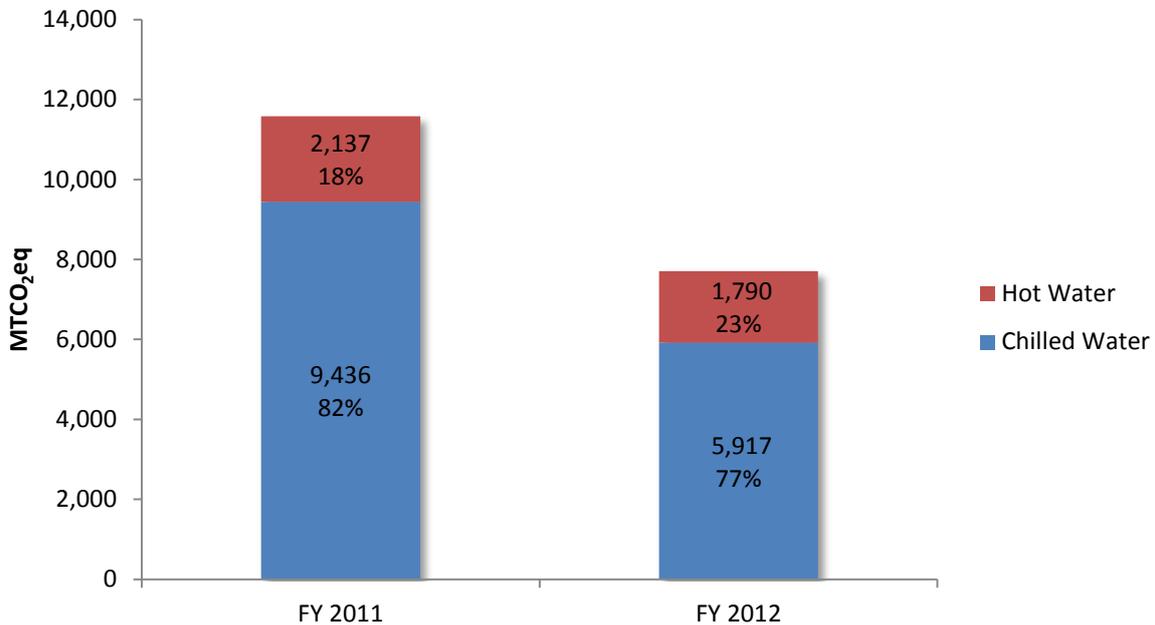


Figure 6: Emissions from chilled and hot water production, FY 2011 and 2012 comparison.³⁴

3.3.1. Emissions

In FY 2012, the University's emissions were calculated to be **7,707.39 MTCO₂eq** from the production of chilled water for air conditioning and the production of hot water for heating and domestic hot water (see **Figure 6**). Of the total emissions, 5,917.33 MTCO₂eq (77%) can be attributed to chilled water production and the remaining 1,790.06 MTCO₂eq (23%) to the production of hot water. Through co-generation, much of the hot water used for heating and domestic hot water is produced from waste heat in special waste heat boilers that do not generate additional carbon emissions.³⁵

3.3.2. Consumption

In total, the University consumed energy equivalent to 30,016,053.88 kWh for chilled and hot water produced by chillers and conventional boilers at the central utility plant. Of the total, 22,596,744.17 kWh are attributable to chilled water, and the remaining 7,419,309.71 kWh to hot water.

3.3.3. Methodology

We constructed emission factors for the production of chilled water by gas-fired chillers and hot water by gas-fired (conventional) boilers at the central utility plant (see **Appendix 3** for calculations).

³³ See **Appendix 3** for the calculation of these constructed values.

³⁴ The chart shows a different value for emissions from hot water than that reported in last year's report. This is because last year co-generation was treated as a direct emissions offset, whereas it is now considered as only a means of avoiding further emissions. The FY 2011 total for hot water was accordingly revised for comparison purposes.

³⁵ The 4,781,091 kWh of heat energy recovered through co-generation, and used for heating water, would have resulted in an additional 1,153.53 MTCO₂eq in 2012 if produced conventionally using natural gas. See discussion of co-generation in **Appendix 2**.

3.3.4. Data Sources

We obtained data on chilled and hot water use from the Maintenance Department—Office of Facilities and Operation’s monthly readings of hot and chilled water consumption meters.

3.3.5. Emission Factors³⁶

Source	Mass Emissions (kgCO ₂ eq/kWh)
GasCool (Hot Water Production)	0.241270254
GasCool (Chilled Water Production)	0.26186650

4. ELECTRICITY FOR LIGHTING AND EQUIPMENT (OTHER THAN HVAC)

4.1. Summary

As discussed in Section 3 and **Appendix 2**, it is estimated that half of all electricity consumed by AUC in FY 2012 was used to operate the HVAC system. The other half was used for lighting, office equipment and other electrical equipment. The electricity used to power lighting and electrical equipment accounts for about 25% of AUC carbon emissions in FY 2012 (see **Figure 1**).

4.2. Emissions

The University emitted an estimated 3,703.21 MTCO₂eq through electricity consumption from the Cairo grid (EEA) and an estimated 15,197.01 MTCO₂eq from electricity consumption from AUC’s central utility plant. In total, AUC emitted **18,900.22 MTCO₂eq** from electricity use in FY 2012, out of which about **9,450.11 MTCO₂eq** resulted from the use of lighting and other electrical equipment.

For the methodology, assumptions, data sources and emission factors for electricity, see Section 3.2.

5. TRANSPORTATION

5.1. Summary

More than 16% of AUC’s carbon emissions in FY 2012 can be attributed to commuting to the New Cairo campus by bus or car (see **Figure 1**). By moving its main operations from Downtown Cairo to the satellite city of New Cairo, located approximately 35 km from the city center, AUC has significantly increased the distances traveled by its faculty, students and staff to reach its campus (see **Appendix 1**). Fewer than 8% of the 2,036 respondents to AUC’s online Transportation Sustainability and Safety Survey carried out in March 2012 live in New Cairo. The largest contingents of AUCians live in Heliopolis and Maadi, followed by Nasr City, Zamalek, Mohandessin and Giza (see **Figure 7**). In order to reach the New Cairo campus and return home in the evening, AUCians travel an average of 65 km each day.

³⁶ See **Appendix 3** for calculations.

Commuting Distances for AUC Community

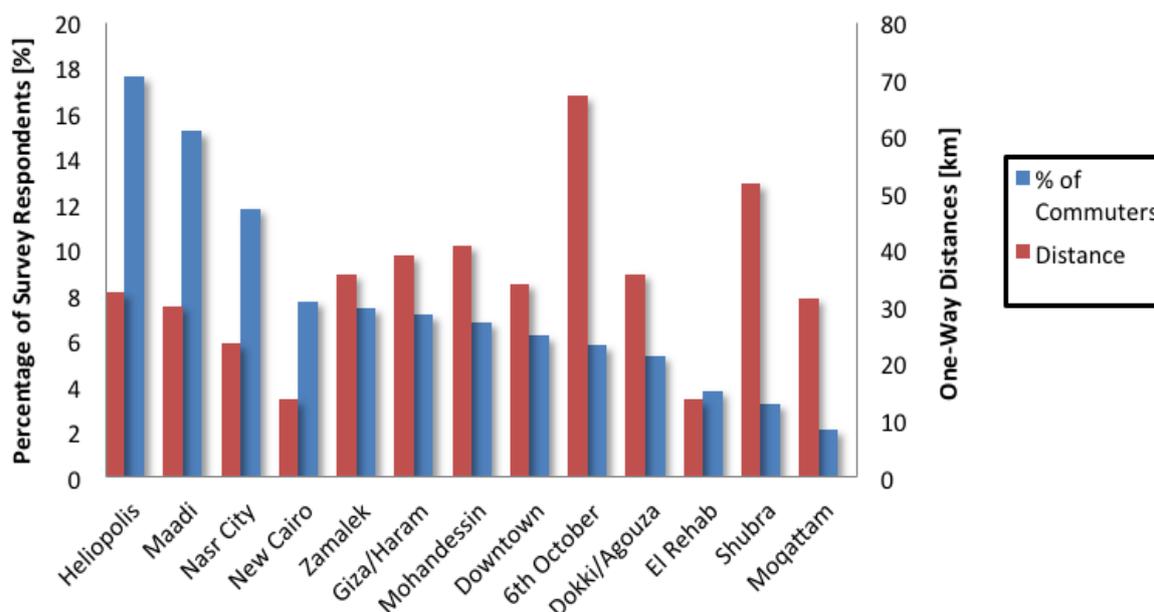


Figure 7: Commuting locations and distances for the AUC community.

To facilitate commuting, AUC offers its own bus service that is outsourced to two private transportation companies and connects the New Cairo campus to greater Cairo along 16 bus routes throughout the day and evening (see **Figure 8**). Apart from this bus service there is no public transport connecting the New Cairo campus to Cairo’s neighborhoods. Most commuters who do not make use of the bus service reach the New Cairo campus by private car.



Figure 8: AUC bus terminal with campus parking lot in rear.

While the bulk of AUC’s emissions from transportation are caused by daily commuting, the University also operates a fleet of cars, vans, minibuses and light duty trucks for use by AUC personnel. The operation of the fleet accounted for 1.55% of AUC’s overall carbon emissions in FY 2012 (see **Figure 1**).

Additionally, faculty and staff fly to destinations around the globe for meetings, conferences, research and other business purposes. This business air travel accounted for 2.30% of AUC’s overall carbon emissions (see **Figure 1**).

Finally, the University sponsors student field trips for educational purposes (generally by bus to destinations within Egypt). In FY 2012 (see **Figure 1**), these field trips accounted for 0.02% of AUC’s overall carbon emissions.

5.2. Commuting by Bus and Car

5.2.1. Emissions

In FY 2012, commuting to and from the New Cairo campus by AUCians contributed an estimated **6,171.54 MTCO₂eq** of carbon emissions to its carbon footprint. There are four types of vehicles used for commuting: private cars, regular coach buses, minibuses and a small number of staff and security buses.

Nearly 70% of AUCians and 80% of AUC students commuted by bus in FY 2012, while slightly more than 30% of AUCians commuted by private car. Bus service to and from the New Cairo campus amounted to an estimated 2,227,543 km traveled in FY 2012. Bus-related emissions are estimated to be **1,366.20 MTCO₂eq**. Of this total, the larger diesel coaches produced 932.35 MTCO₂eq with the remaining 433.85 MTCO₂eq produced by minibuses (see **Figure 9**).

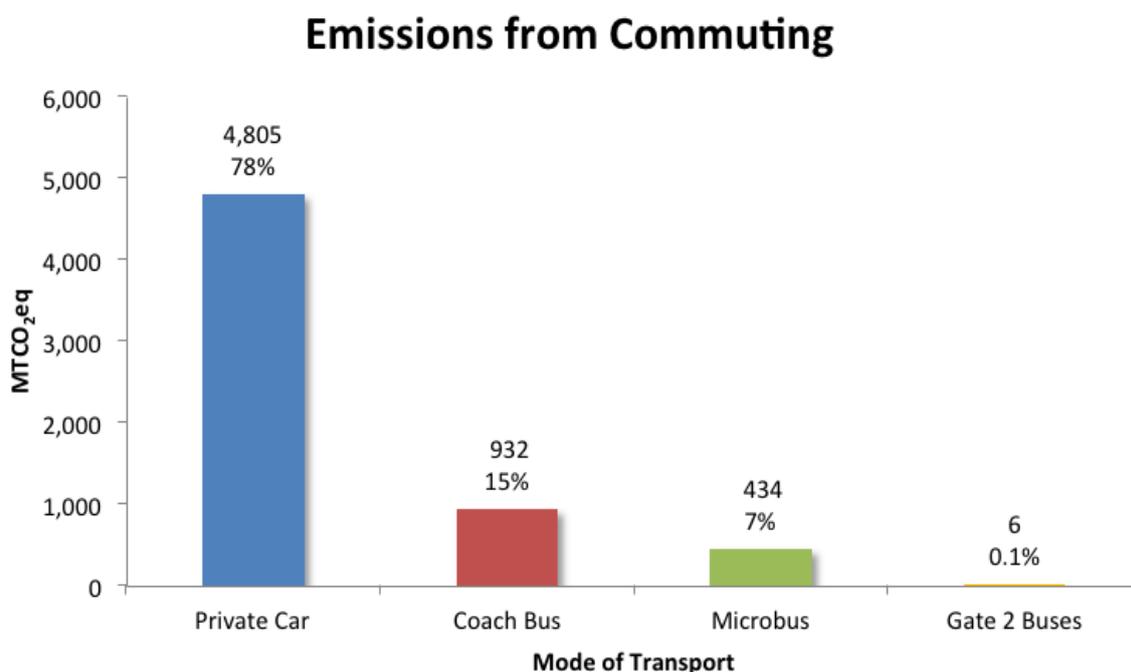


Figure 9: Emissions from commuting to and from AUC’s New Cairo campus, FY 2012.

Staff and security buses represent a combined six vehicles only, traveled approximately 5,400 km in FY 2012 and collectively emitted 6.41 MTCO₂eq.

Those commuting by private car drove an estimated 20,301,388 km in FY 2012. 69% of the private car km were traveled by students. We estimated that total emissions from private car commuting are **4,805.34 MTCO₂eq** (see **Figure 9**). Of this total, students account for 3,332.05 MTCO₂eq with the remaining 1,473.29 MTCO₂eq from faculty and staff commuting.

At the time of the transportation survey in March 2012, only 19% of those who drive to the University, or 6% of total commuters, had carpooling. However, without this carpooling activity, emissions from commuting by private car would have been even higher. Clearly, carpooling holds considerable potential for reducing AUC’s carbon footprint.

5.2.2. Methodology

The AUC transportation website displays all 16 bus routes on Google Maps and calculates trip lengths. The number of times each route was driven in FY 2012 was multiplied by the route's respective trip length to estimate the annual km traveled by diesel buses and minibuses. These km totals were then multiplied by the corresponding emission factors provided below.

The DDC in partnership with AUC's offices of Sustainability, Data Analytics and Institutional Research Office (DAIR) and Public Safety conducted the online Transportation Sustainability and Safety Survey in March 2012 to research private car commuting. The 2,036 responses were used to estimate total annual car commuting distances for the AUC community. Km totals were then multiplied by the corresponding emission factors. The reader will notice that the reported emissions for commuting by private car are identical to those reported in FY 2011. This is because the transportation survey was conducted in 2012 and its results were viewed as a reasonable basis for the emissions reported in FY 2011.

Emissions from diesel (coach) bus and microbus commuting in FY 2012 are significantly lower than those reported in last year's report for FY 2011. The primary reason is not that bus travel decreased significantly or that fuel efficiency increased, but that data collection improved. In FY 2011 we extrapolated from fragmented and sparse data maintained by the third party bus companies and from the AUC Transportation Survey. In FY 2012, the bus companies reported trips to AUC's Department of Transportation Services on a daily basis. This change has enabled much more accurate estimates of distances traveled. Even so, it must be noted that the results presented for FY 2012 are also estimates, since there are still some gaps in the data collected that require extrapolation (though to a much lesser extent).

5.2.3. Data Sources

The AUC Department of Transportation Services provided bus commuting data from trip reports by third party providers. Data on private car commuting was acquired through the University-wide online Transportation Sustainability and Safety Survey.

5.2.4. Emission Factors³⁷

Source	Mass Emissions (kgCO ₂ eq/km traveled)
Average Gasoline Vehicle (Car)	0.2408
Average Diesel Vehicle (Van/Microbus/Light Duty Truck)	0.3696
Diesel Bus (Coach)	0.8854

³⁷ Converted values from EIA, 2011 and EPA, 2012.

5.3. Air Travel

5.3.1. Emissions

Air travel by faculty and staff for business amounted to a total of 8,733,549.25 passenger km traveled in FY 2012 resulting in an estimated **867.68 MTCO₂eq** emissions. Long haul air travel accounted for 93% of the km traveled and 93% (804.89 MTCO₂eq) of the total GHG emissions (see **Figures 10 and 11**). Medium and short haul air travel accounted for a combined 7% of the km traveled and 7% of the emissions or 62.79 MTCO₂eq.

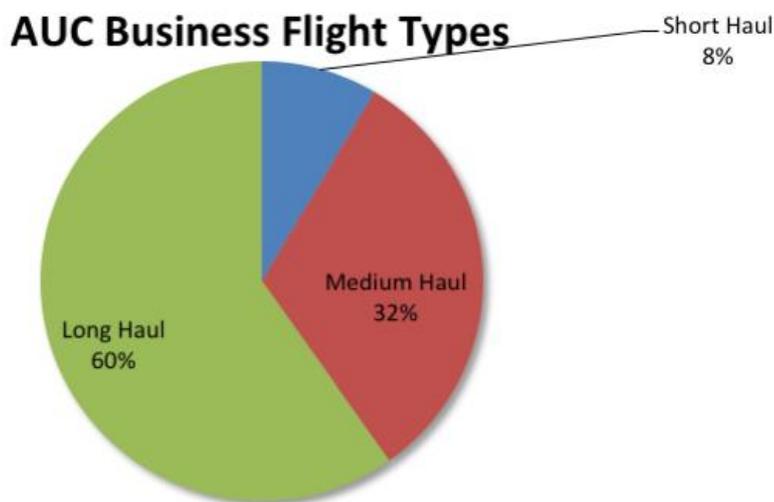


Figure 10: Short, medium and long haul business flights taken by the AUC community, FY 2012.

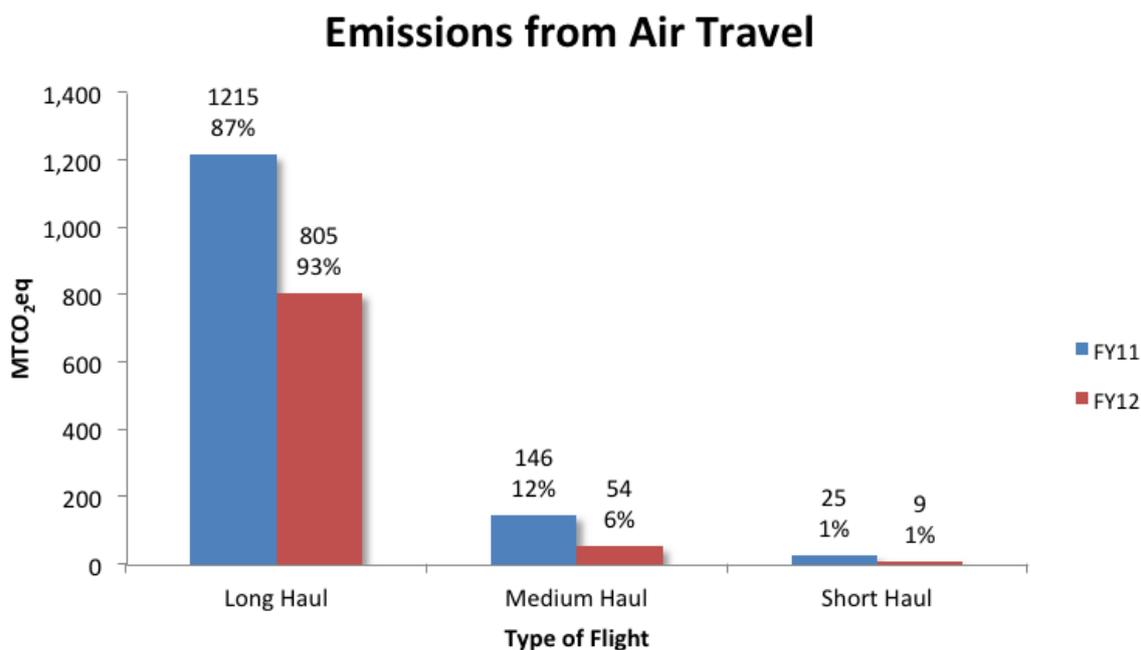


Figure 11: Comparison of carbon emissions caused by air travel, FY 2011 and FY 2012.³⁸

³⁸ Some of the reductions from FY 2011 to FY 2012 in km traveled and emissions may be due to year-to-year differences in record keeping by the University Travel Office and by outside travel agencies.

5.3.2. Methodology

The University Travel Office coordinates official University business travel and compiles all business flights in a database. Flight distances were calculated by inputting the coordinates of each airport flown to and from (usually available from airport websites) into an original program that calculates the distance between two points on a sphere (an approximation for the shape of the Earth). After determining the mileage, each flight was classified by its length (short, medium or long haul) and its booking class (First, Business or Economy).³⁹ For emission factor purposes, flights were subdivided into short haul (≤ 785 km), medium haul (between 785 km and 3,700 km) and long haul ($\geq 3,700$ km).⁴⁰ Booking class assignment practices vary by airline, so an index of booking classes by airline and booking class was compiled with the help of the AUC Travel Office.

The emission factors below were calculated by multiplying the base emission factors for CO₂, N₂O and CH₄ by their respective global warming potentials (GWPs) and summing the results together to arrive at kg of CO₂eq emitted per passenger km traveled.

5.3.3. Data Sources

Data was provided by AUC's Travel Office, in the form of flight logs and itineraries.

5.3.4. Emission Factors⁴¹

Source	Mass Emissions (kgCO ₂ eq/passenger km traveled)		
	Short Haul	Medium Haul	Long Haul
First Class	0.1818856	--	0.346801
Business Class	0.1818856	0.14845855	0.251561
Economy Class	0.1818856	0.09900813	0.08670

5.4. University Fleet

5.4.1. Emissions

The University operates a fleet of 73 vehicles (57 gasoline cars, 16 diesel vans, microbuses and light duty trucks) for the transportation of University personnel and other daily operations. Combined emissions from the gasoline vehicle fleet are 395.58 MTCO₂eq; and from the diesel fleet 190.44 MTCO₂eq (see **Figure 12**). The total emissions from the vehicle fleet are thus **586.02 MTCO₂eq**.

5.4.2. Methodology

Emission calculations were based on the vehicle composition of the fleet and km driven. It was estimated by AUC's Department of Transportation Services that the total number of km driven by the fleet increases by approximately 20% annually due to business demand. Due to a lack of odometer readings for the end of FY 2011, this assumption was used to work backwards from the odometer readings recorded at the end of FY 2012, in order to estimate what the odometer readings would have been at the end of FY 2011. The difference between these two sets of readings represents the approximate km driven by fleet vehicles during FY 2012.

For the gasoline fleet, almost entirely cars, we used an average emission factor for gasoline cars. For the diesel fleet, almost entirely microbuses, an average emission factor for diesel light duty trucks (vans) was used. For the few cars that run on diesel, an average emission factor for diesel cars was used. Total amounts of km driven were multiplied by their respective emission factors.

³⁹ As shown by the emission factors below, on long-haul flights business-class travel generates approximately three times the emissions of economy-class travel.

⁴⁰ England, DEFRA/DECC, 2012.

⁴¹ Ibid.

University Fleet Emissions

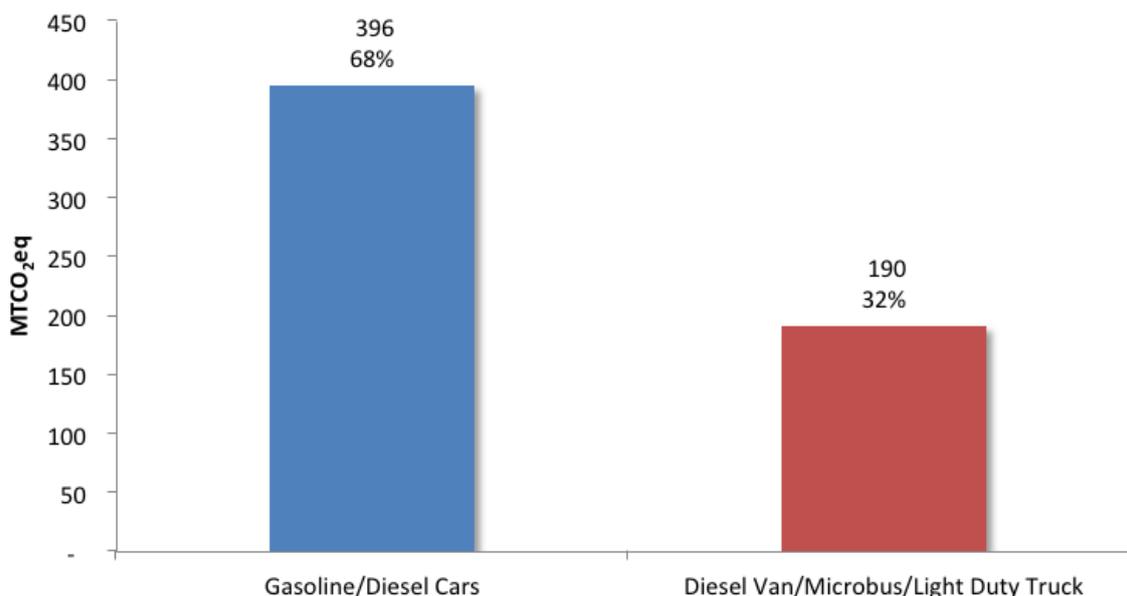


Figure 12: Carbon emissions caused by AUC's fleet of vehicles, FY 2012.

5.4.3. Data Sources

We obtained data for the km driven by the University fleet from the AUC Department of Transportation Services, based on odometer readings and other information.

5.4.4 Emission Factors⁴²

Source	Mass Emissions (kgCO ₂ eq/passenger km)
Average Gasoline Vehicle (Car)	0.2408
Average Diesel Vehicle (Car)	0.2735
Average Diesel Vehicle (Van/Microbus/Light Duty Truck)	0.3696

5.5. Sponsored Field Trips

5.5.1. Emissions

The University sponsored a number of field trips within Egypt in FY 2012, resulting in an estimated 10,219.6 km of road travel by bus. Total emissions caused by these field trips are **9.05 MTCO₂eq**.

5.5.2. Methodology

Distances to destinations were estimated using Google Maps with the departure point assumed to be AUC's New Cairo campus. Where the final destination was a city, distance was measured to the city center. It is assumed that travel was undertaken by a diesel fuel bus, given that this is the most commonly used method of transportation for field trips.

5.5.3. Data Sources

We obtained data on field trips from the AUC's Office of Public Safety, in the form of trip logs.

5.5.4. Emission Factors

Source	Mass Emissions (kgCO ₂ eq/km traveled)
Diesel Bus (Coach)	0.8854

⁴² Converted from EIA, 2011 and EPA, 2012.

6. PAPER USE

6.1. Emissions

The University purchased an estimated 615,657.89 kg of paper in FY 2012. The emissions from paper purchases for the New Cairo campus total **1,751.45 MTCO₂eq**. This represents a 2.5% decrease in the emissions from paper from FY 2011.

6.2. Methodology

The research team reviewed all paper purchase invoices, categorized paper by coated and uncoated paper and weighed the paper packages. More than 99% of the paper AUC purchases is uncoated and less than 1% is coated paper, which is used for brochures, among other uses.

All paper is 0% recycled, as recycled paper for office use is not yet available in Egypt. Recycled office paper would have to be imported, which is not only costly but would indirectly increase the University's carbon footprint because of energy used and related emissions from the shipping process.

6.3. Data Sources

We obtained information on paper purchases from the Office of Supply Chain Management and Business Support, which maintains records of quantities and types of paper purchased in the ordinary course of business.

6.4. Emission Factors⁴³

Source	Mass Emissions (MTCO ₂ eq/kg of paper)
Uncoated Paper	0.0028451
Coated Paper	0.0027417

7. WATER SUPPLY

7.1. Summary

Energy and water supply at AUC are intimately connected. The New Cairo campus is located on an elevated desert plain east of central Cairo. In order to supply domestic (drinking quality) water to AUC from the Ismailiya Canal northeast of Cairo, water must not only be purified, but it must be pumped across a distance of 54.45 km up inclines totaling 308 m. A key point is that reducing our water consumption, whether for the AC cooling towers, for irrigation of campus landscaping, or for domestic use, saves the energy needed to move water and thus reduces our carbon footprint in addition to saving scarce water. This section will address each of these sectors in turn.

7.2. Emissions

7.2.1. Overview

In FY 2012 the University consumed 123,471 m³ of water for the AC cooling towers, 184,750 m³ for use in buildings and 299,662 m³ for irrigation, for a total of 610,883 m³. The emissions resulting from this consumption amount to **723.10 MTCO₂eq**. Of this total, **148.97 MTCO₂eq** or 20.60% can be attributed to the AC cooling towers, with the remaining **574.14 MTCO₂eq** attributable to non-HVAC uses such as in buildings and for irrigation (see **Figure 14**). Note that the introduction of treated wastewater for irrigation in FY 2012 resulted in an emissions savings of approximately 5.22% of the emissions that would otherwise be attributable to water, compared to the emissions from using domestic water only (see Section 7.3).

7.2.2. Water for AC Cooling Towers

The gas-driven chillers that produce chilled water for air conditioning generate waste heat. The waste heat is dissipated through a circulating water system that releases it from six cooling towers through the evaporation of water. The consumption of water for HVAC increases considerably during the

⁴³Accounts for entire paper lifecycle, Environmental Paper Network, 2012.

summer months (May through October), exceeding, at times, 30% of the University’s total monthly water use (see **Figure 13**). We calculated carbon emissions resulting from the use of domestic water for the AC cooling towers by multiplying the volume of water consumed by the electricity required to bring each cubic meter of water to the New Cairo campus (see Section 7.3), then applying the emission factor (see Section 7.5) for electricity obtained from the Cairo grid.

AC Cooling Towers as Proportion of Total Monthly Water Consumption

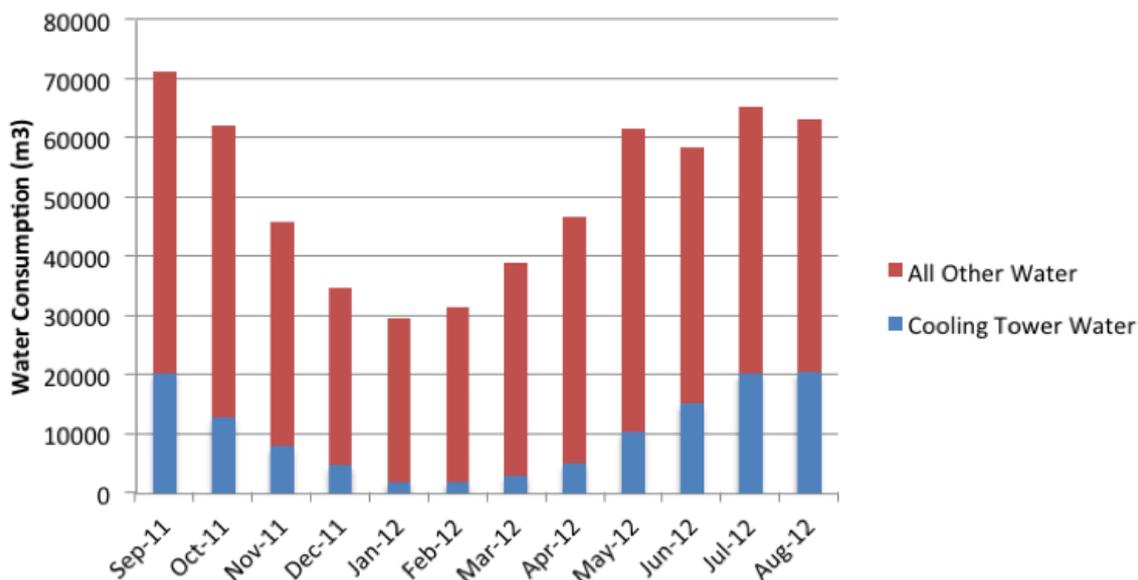


Figure 13: Proportion of water used for air conditioning (AC) cooling towers (of total monthly water consumption) in FY2012.

Emission Distribution by Type of Water Use

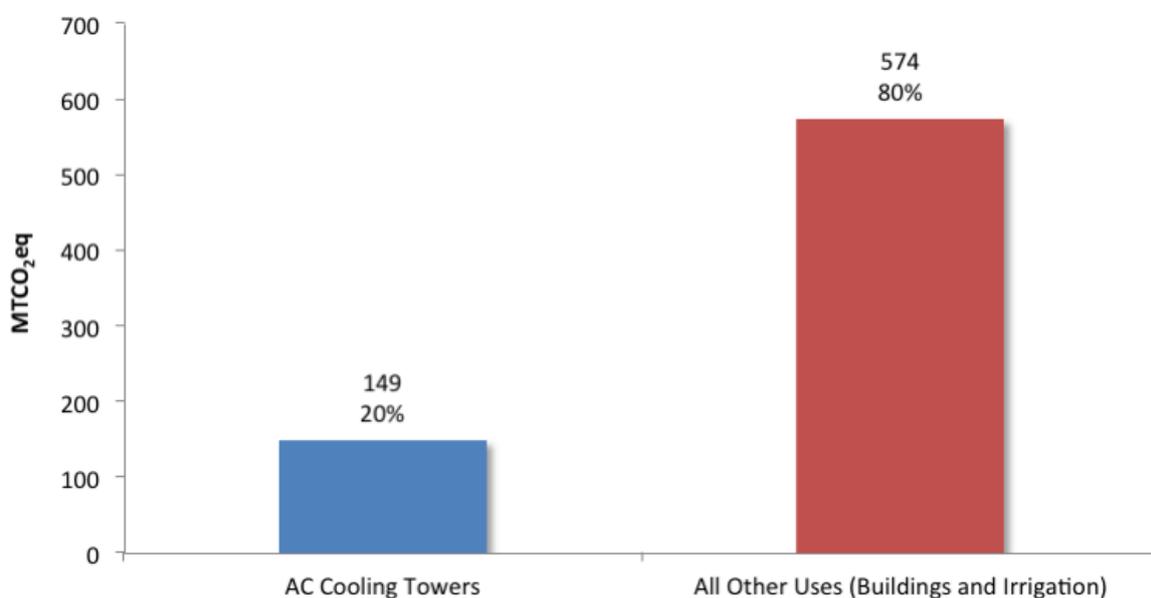


Figure 14: Emission distribution by type of water use, FY 2012.

7.3. Methodology for Calculating Carbon Emissions Attributable to Domestic Water Supply and Treated Water Supply

AUC made notable improvements in managing its water supply in FY 2012. Most significant was the introduction of treated wastewater for irrigation in the latter half of the year. Recycling water in this manner not only helps alleviate regional water scarcity but results in energy savings and fewer carbon emissions, due principally to a lower energy “pumping factor” for each m³ of treated wastewater compared to domestic water.

In FY 2011, Chemonics Egypt contributed significantly to AUC’s carbon footprint report by mapping the domestic water supply route from the original source and analyzing energy consumption en route. Chemonics concluded that 2.55 kilowatt hours (kWh) of electricity are required to bring each m³ of domestic water from the Ismailiya Canal to the New Cairo campus (see **Appendix 4**).

After the introduction of treated wastewater for irrigation on campus in FY 2012, Chemonics Egypt generously undertook a second comprehensive study, this time of the New Cairo municipal wastewater treatment system, and determined that the energy needed to deliver treated wastewater to the New Cairo campus is 1.49 kWh/m³ (see **Appendix 5**), a savings in energy consumption from that of domestic water of more than 40% and a comparable savings in carbon emissions.

The University also considerably improved its own water consumption data collection and analysis during FY 2012. Through examining water meter readings and producing a detailed monthly record of both domestic and treated wastewater consumption, it was determined that treated wastewater accounted for approximately 15% of AUC’s total water consumption and 9% of total emissions from water in FY 2012 (see **Figure 15**).

The Chemonics Egypt studies, together with AUC’s improved management of water data, have enabled AUC’s carbon footprint team to provide reliable and detailed estimates for emissions from water consumption. Chemonics Egypt used AUC’s data to arrive at an overall weighted energy pumping factor of 2.40 kWh/m³ for AUC’s water supply during FY 2012.

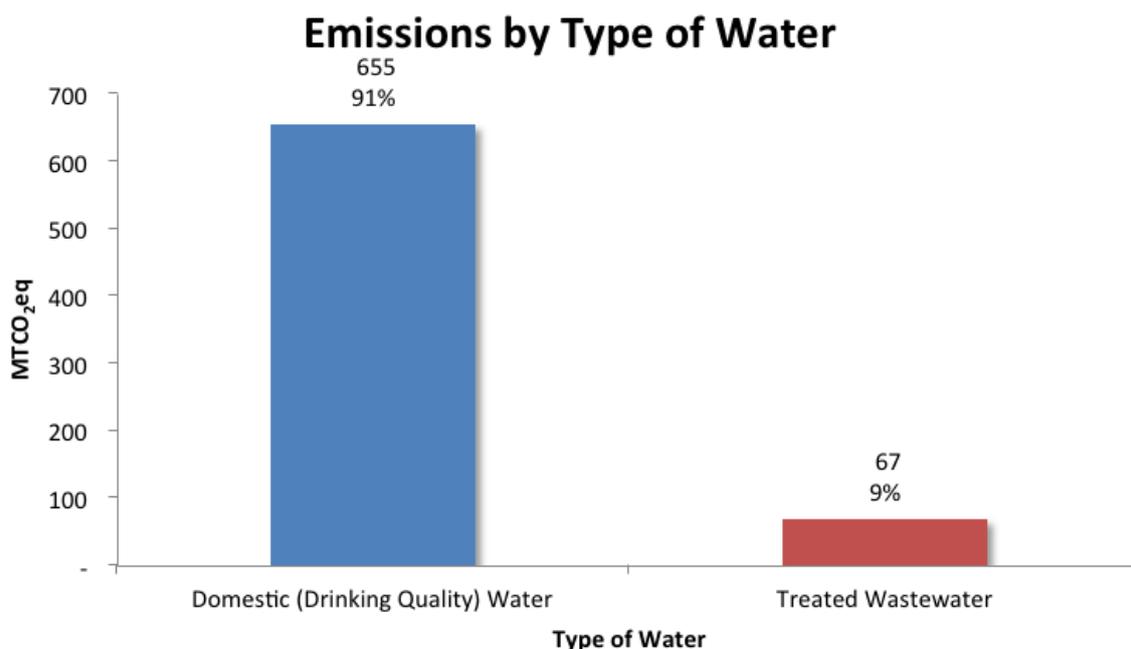


Figure 15: Emissions from supplying domestic and treated wastewater, FY 2012.

7.4. Data Sources

The consumption of water by the University is based on meter readings and estimates of water used on campus, including water used for buildings, irrigation and the cooling towers. We obtained energy consumption data for water delivery to the New Cairo campus from Chemonics Egypt and data on University water consumption from AUC’s Maintenance Department—Office of Facilities and Operations, AUC’s Office of Sustainability and the Desert Development Center.

7.5. Emission Factors

Source	Mass Emissions (kgCO ₂ eq/kWh)
Cairo Grid (Electricity)	0.497042581

8. REFRIGERANT LEAKAGE

8.1. Emissions

The University used two types of refrigerants in FY 2012: R22 (HCFC-22) for refrigerators, amounting to 202.5 kg; and R407c for stand-alone air conditioning units, amounting to 130 kg. The total refrigerant leakage (see **Figure 16**) is thus **522.27 MTCO₂eq** in FY 2012, the sum of emissions from R22 (332.44 MTCO₂eq) and R407c (189.84 MTCO₂eq).

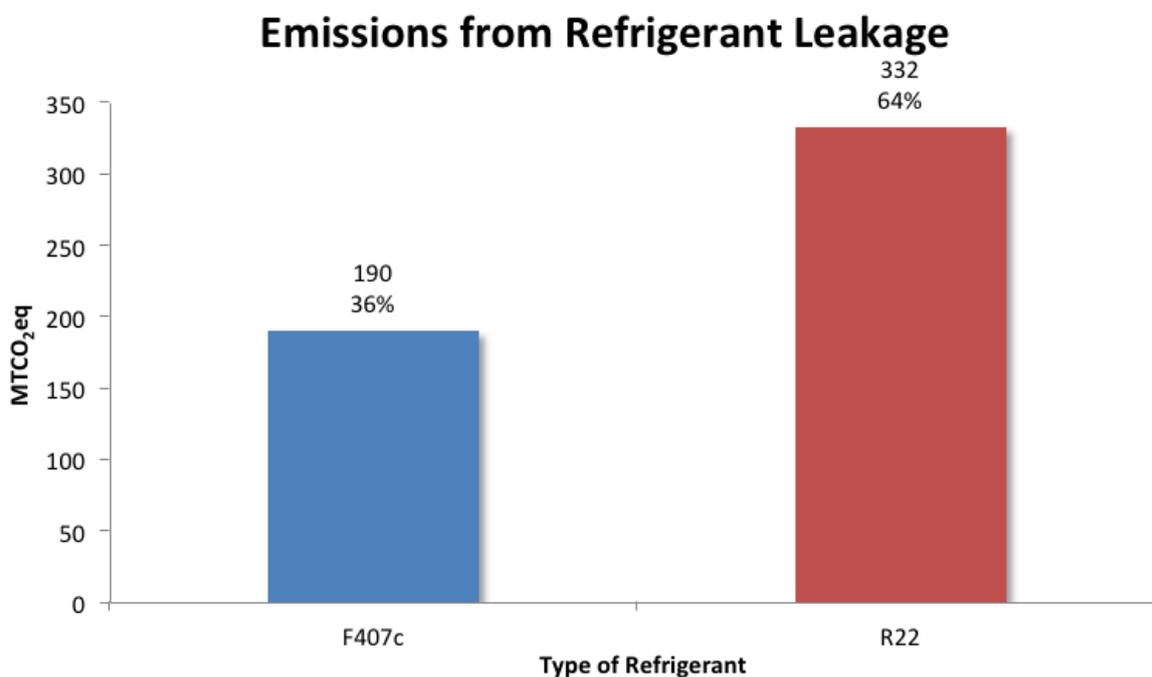


Figure 16: Emissions from the leakage of refrigerants R22 and 407c.

8.2. Methodology

The amounts of refrigerants lost to leakage or unintended releases were calculated by determining the capacity and number of refrigerant canisters that were used in order to “top-off” or recharge the refrigerant containers in FY 2012. The amounts were then multiplied by their respective emissions factors.

8.3. Data Sources

We obtained information from AUC’s Maintenance Department—Office of Facilities and Operations, which provided amounts and types of refrigerants for “topping off purposes” in FY 2012.

8.4. Emission Factors

Source	Mass Emissions (MTCO ₂ eq/kg)
R22 ⁴⁴	1.81
R407c ⁴⁵	1.774

9. SOLID WASTE DISPOSAL

9.1. Emissions

We estimate that the University produced 614 MT of solid waste in FY 2012. As the only emission from solid waste is methane (CH₄), this waste created 24.62 MT CH₄. With methane's global warming potential (GWP), **517.05 MTCO₂eq** were emitted from solid waste disposal.

9.2. Methodology

In order to estimate the total amount of solid waste produced in FY 2012, two one-week assessments were conducted. Waste leaving campus was weighed every day for one week during non-peak time (winter term) and peak time (spring semester). Solid waste weights were measured by weighing the trash trucks when fully loaded and when empty and then taking the difference in weight.

Throughout the year, and even throughout the week, there are days of low population density on campus (less than half the student body and fluctuating amounts of staff and faculty) and days of high population (most students, staff and faculty are present). We estimate that the New Cairo campus is relatively lightly populated 30.96% of the time and relatively densely populated 69.04% of the time, from data collected in the 2012 Transportation Survey. This fluctuation causes variation in the amount of solid waste produced per day. To account for this difference, a yearly average was calculated.

The emissions factor we chose assumes no CH₄ recovery from the waste and that all waste is land-filled. However, the trash collecting community in Cairo, the Zabaleen, is very efficient at sorting and recycling, and recycles an estimated 75% of all solid waste collected.⁴⁶ Consequently, the figure of 517.05 MTCO₂eq used here for AUC's emissions from solid waste is likely overstated.

9.3. Data Sources

Data on the amounts of solid waste were provided by AUC's Department of Environmental Services in collaboration with the Zabaleen who pick up solid waste from AUC's New Cairo Campus once or twice a day. Estimates of the proportion of waste recycled by the Zabaleen are provided by the Spirit of Youth Association, a local NGO that works in collaboration with the Zabaleen.

9.4. Emission Factors⁴⁷

Source	Mass Emissions (kgCO ₂ eq/MT)
Solid Waste (No CH ₄ Recovery, e.g. methane bio-gas production)	842.1

10. NATURAL GAS FOR DOMESTIC AND LAB USE

10.1. Emissions

The total natural gas consumption for the New Cairo campus for domestic and lab use was 19,457.7 m³ in FY 2012. The University emitted **39.19 MTCO₂eq** from this natural gas combustion. This reflects a similar consumption pattern to FY 2011, in which 42.23 MTCO₂eq were emitted.

⁴⁴ IPCC, 2007.

⁴⁵ Converted from IPCC, 2007 and The Comfort Environment Group.

⁴⁶ Ezzat, 2012.

⁴⁷ Converted from IPCC, 2006, Smith et al., 2001 and Ecometria, 2012.

10.2. Methodology

Volumes of natural gas consumed for domestic and lab use were multiplied by the emission factor in Section 10.4 to calculate carbon emissions.

10.3. Data Sources

We obtained data on natural gas consumption by the central utility plant and for domestic and lab purposes from gas meter readings taken by AUC’s Maintenance Department—Office of Facilities and Operations. Where meter readings were not available for domestic and lab purposes, quantities were estimated using manufacturer’s specifications and operating manuals for the equipment using the natural gas.

10.4. Emission Factors⁴⁸

Source	Mass Emissions (kgCO ₂ eq/m ³)
Natural Gas	2.014

11. FERTILIZER

11.1. Emissions

For New Cairo campus landscaping, AUC used 110,000 kg and 3,800 liters of solid and liquid synthetic fertilizers with varying nitrogen content and 115,000 kg of organic fertilizer (compost) with a nitrogen content of 0.16% in FY 2012. We estimated that emissions from synthetic fertilizers were 15.20 MTCO₂eq and from organic fertilizer application 0.73 MTCO₂eq. In total, **15.93 MTCO₂eq** were emitted as a result of fertilizer application on the New Cairo campus (see **Figure 17**).

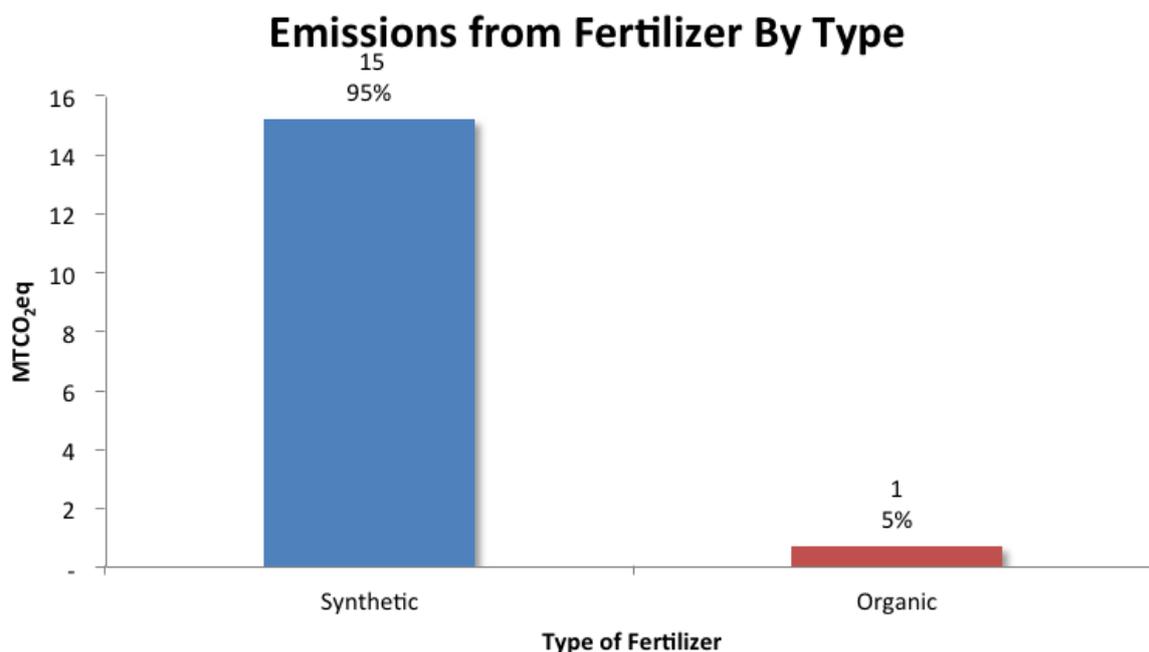


Figure 17: Emissions from the application of synthetic and organic fertilizers.

Emissions from fertilizers would have been approximately **36.1 MTCO₂eq** greater in FY 2012 if compost had not been used. The University produced 45 tons of compost on campus to avoid emitting 20.7 MT CO₂eq and purchased an additional 70 tons of compost to avoid 15.4 MTCO₂eq.

⁴⁸ Converted value from IPCC, 2006 and Ecometria, 2012.

11.2. Methodology

The amounts of synthetic and organic fertilizer used were multiplied by the respective percentages of nitrogen to calculate nitrogen applied. For nitric and humic acid fertilizers, the nitrogen density of the solution was multiplied by the volume applied. These values were then multiplied by the emission factor to convert nitrogen to N₂O. N₂O emissions from each source was then multiplied by 310, the global warming potential (GWP) of nitrous oxide, to determine the CO₂ equivalent emissions.

Compost used as fertilizer has associated emission factors.⁴⁹ “Soil storage” refers to the emissions avoided by burying organic matter underground instead of permitting it to decompose in the open where it emits greenhouse gases. “Compost Transportation and Production” refers to the emissions from diesel fuel used to transport compost and turn over its piles. “Displaced Chemical Fertilizer” refers to emissions avoided by using organic compost instead of synthetic chemical fertilizers.⁵⁰ The total emissions avoided by the use of compost were calculated by multiplying the amounts of University-produced and purchased compost-based fertilizers by the appropriate emissions and savings (see table in Section 11.4).

11.3. Data Sources

Fertilizer use data was provided by the Desert Development Center, which was responsible for the landscaping campus in FY 2012. Nitrogen content of fertilizers was taken from fertilizer packages.

11.4. Emission and Other Relevant Factors

Source	Conversion Factor
Synthetic/Organic Fertilizer ⁵¹	0.0125kg N ₂ O/kg N

Source ⁵²	Mass Emissions Savings (kgCO ₂ eq/MT compost)
Soil Storage	240
Displaced Chemical Fertilizer	260
Compost Transportation and Production	- 40 ⁵³

12. LANDSCAPING AS A CARBON OFFSET

12.1. Emissions Sequestered

For FY 2012, we have estimated that the landscaping on the New Cairo Campus has sequestered **99 MTCO₂eq** from the atmosphere. Of this, 82.6 tons were sequestered by campus trees and 16.4 MTCO₂eq were sequestered by groundcover including grass and shrubs (see **Figure 18**).

⁴⁹ We only counted compost produced by the University, not compost produced commercially off-site.

⁵⁰ Hermann, et al., 2011.

⁵¹ Environmental Protection Agency, 2011.

⁵² Ibid.

⁵³ This emission factor is presented as a negative value since it represents an increase in emissions.

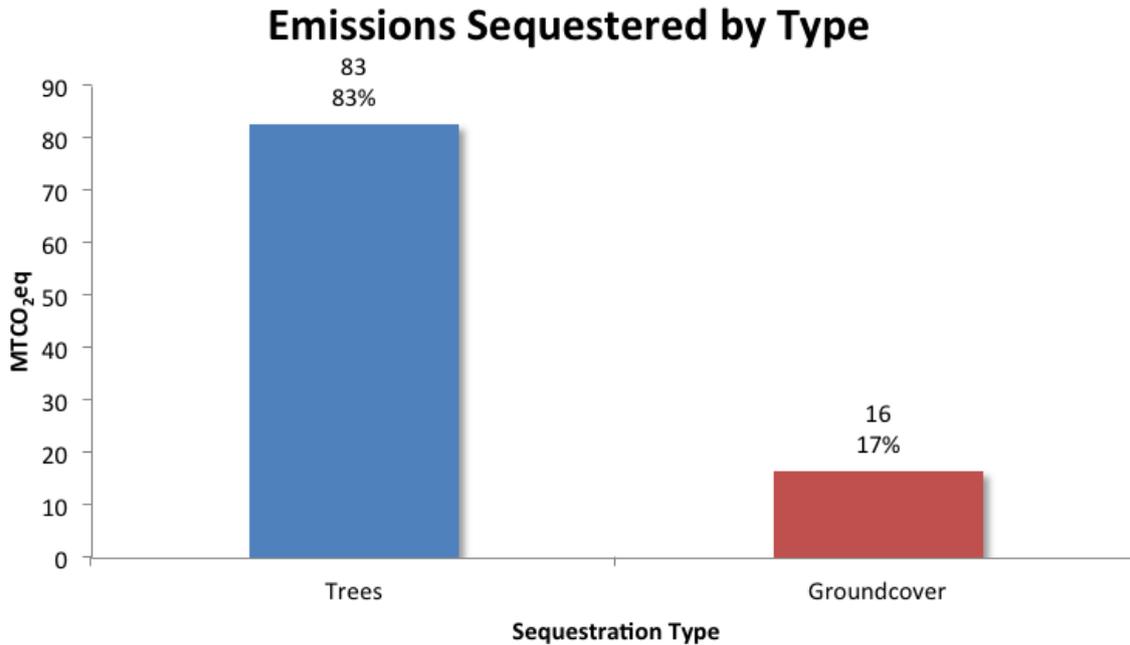


Figure 18: Carbon sequestration due to landscaping by type, FY 2012.

Carbon sequestration is the capture and removal of carbon dioxide from the atmosphere in a stable, long-term reservoir⁵⁴ and is a direct offset of carbon emissions. However, if a plant is allowed to decompose naturally, anaerobically, a portion of the sequestered carbon will be released back into the atmosphere. This release can be avoided through carbon capture techniques or aerobic composting.

This year's 99.04 MT CO₂ of sequestered carbon is a 64% increase from last year's 60.16 MT CO₂. This increase is partially due to improvements in methodology. In FY 2011, our team measured carbon sequestration by trees per acre, using a general rate for all species. This year, as described below, we determined the rate of sequestration for the two most prevalent species on AUC grounds and applied the result to the number of trees on campus. The increase in sequestered carbon between the two report years is also attributable to the planting of more trees and groundcover.⁵⁵

12.2. Methodology and Data Sources

The AUC Office of Building and Grounds and the Landscape Unit of the Facilities and Operations Office provided estimates of trees and ground cover on the New Cairo campus: there are 8,227 trees planted on campus, of which 1,227 are date palms (*phoenix dactylifera*), and 14 acres of groundcover. The remaining 7,000 trees are a variety of other species, with the majority being valencia orange trees (*citrus sinensis*). Because the majority of trees on the New Cairo campus are orange trees, for the purpose of this report it was assumed that all trees other than date palms are orange trees.

Tree quantities multiplied by the annual mass emission savings rates in Section 12.3 results in carbon emissions sequestered by trees. Amount of ground cover multiplied by the annual mass emission savings in Section 12.3 results in the carbon emissions sequestered by ground cover.

⁵⁴ United Nations Framework Convention on Climate Change, 2012.

⁵⁵ Although the University's landscaping sequesters carbon from the atmosphere, the considerable energy costs associated with the planting, maintenance, fertilization and irrigation of campus trees and groundcover in a desert environment most likely result in net positive emissions from this sector.

The rate of carbon sequestration by date palms was obtained from the USDA Forest Service urban tree carbon calculator⁵⁶ and the rate of sequestration for orange trees was taken from a 2012 study on the sequestration potential of tree plantations⁵⁷.

12.3. Sequestration Factors

Source	Annual Mass Emissions Savings (kgCO ₂ eq/Unit)
Date Palm	6.3/tree
Valencia Orange	10.7/tree
Groundcover	1,172/acre

13. AUC's CARBON FOOTPRINT COMPARED TO OTHER UNIVERSITIES

In total, emissions produced by the University in FY 2012 amounted to **37,711.85 MTCO₂eq**. This amount is roughly equivalent to the CO₂ emissions from 87,702 barrels of oil, or the amount of carbon sequestered by 966,971 tree seedlings grown for 10 years.⁵⁸ To further put this into perspective, we have compared our emissions to those of other universities with published carbon footprint studies.

A useful way to compare AUC to other universities is by greenhouse gases emitted per Full-Time Equivalent Student (FTE).⁵⁹ **Table 2** compares AUC to a sample of higher education institutions that are similar in size, climate and/or institutional characteristics (e.g. size and level of programs).

Institution	Report Year	Total Student Enrollment	Total Emissions (MTCO ₂ eq)	Total Emissions (MTCO ₂ eq) / FTE
Pomona College (California)	2011	1,549	24,684	15.9
Tulane University (Louisiana)	2010	10,958	152,230	13.9
Rice University (Texas)	2009	4,993	53,084	10.6
University of California – San Diego	2010	29,899	282,453	9.4
University of New Mexico, Main Campus	2009	25,820	199,960	7.7
University of Arizona	2010	38,076	253,723	6.6
The American University in Cairo	2012	5,859	37,711	6.4
Brandeis University (Massachusetts)	2012	5,494	34,573	6.3
University of Cape Town (South Africa)	2007	21,231	84,926	4.0
University of Nevada – Las Vegas	2008	21,841	85,878	3.9
Santa Clara University (California)	2011	7,992	30,028	3.8
Arizona State University	2011	69,459	251,385	3.6

Table 2: Rankings of selected institutions of higher education by greenhouse gas emissions per full time equivalent student. Figures represent net emissions reflecting carbon offsets (where reported).⁶⁰

⁵⁶ Climate Change Resource Center, 2011.

⁵⁷ Kongsager et al., 2012.

⁵⁸ Environmental Protection Agency, 2013.

⁵⁹ Includes full-time students and part-time students representing half of one full-time student. See Section 1.

⁶⁰ American College and University Presidents' Climate Commitment.

14. RECOMMENDATIONS FOR REDUCING OUR CARBON FOOTPRINT

The twenty measures recommended in **Box 4** below were developed by the Carbon Footprint 2.0 research team, with assistance from the AUC community. They are not intended to be exhaustive, but address the seven activities contributing most significantly to AUC's carbon footprint, in descending order of emissions. Implementing these recommendations will help further reduce our carbon footprint. In addition, we have improved our data collection procedures. For example, we tested the accuracy of our water meters and improved the accuracy of our water consumption data. We will continue to look for ways to improve our data collection and calculation methods.

Box 4: Summary of Recommendations

1. Heating, Ventilation, and Air Conditioning (HVAC)

- Install presence sensors in meeting rooms, large lecture halls, and event spaces to turn off HVAC when these spaces are not being used.
- Improve scheduling of theaters, auditoriums, studios, large lecture halls, sports facilities and other event spaces, so that large interior spaces are only being cooled or heated when cooling or heating is actually needed.
- Adjust class schedules, consolidate activities, and consciously plan space utilization to reduce the need for cooling and heating, particularly during the summer and winter terms when the campus population is low but energy use on a per capita basis remains high.

2. Lighting and Electrical Equipment

- Reprogram the University's centralized lighting control system (known as "Lutron") to turn off the University's 30,000 lights in public and common areas, except where and when they are actually needed.
- Explore converting indoor lighting to LED and outdoor lighting to solar-powered lighting.
- Install signage throughout the New Cairo campus to encourage "day lighting" – the use of natural daylight (plentiful in Egypt) to illuminate interior spaces during daylight hours.
- Study replacing stand-alone office equipment (e.g. copiers, printers, scanners) with networked equipment to reduce drastically the number of pieces of equipment needed.

3. Transportation

- Improve bus service and adopt other incentives to encourage more students, faculty and staff to commute by bus rather than private car.
- Further encourage carpooling by creating preferred parking areas for carpoolers.
- Consider converting the University's own transportation fleet and its commuter buses from diesel and gasoline to natural gas, a more carbon-efficient fuel.
- Encourage living near the New Cairo campus to reduce the need for commuting.
- Encourage videoconferencing and other alternatives to air travel.

4. Paper Use

- Make two-sided printing and copying the "default option", and move towards entirely paperless operation by phasing out the use of hard copies.
- Use "smart" (networked) office equipment to discourage excessive printing and copying.
- Find local sources of affordable, high-quality recycled paper to reduce the net carbon footprint of purchased paper.

5. Water Supply

- Increase the number of times that water is circulated through the AC cooling towers to reduce consumption of domestic water for air-conditioning.
- Replace flush valves in all toilets and urinals with high-efficiency flush valves to reduce the amount of domestic water consumed in buildings.

6. Refrigerant Leakage

- Explore using more environmentally-friendly refrigerants.

7. Solid Waste Disposal

- Reduce the amount of food waste and minimize packaging used at food outlets.
- Install hydration stations and use refillable water bottles to reduce plastic waste generated on campus.

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Appendix 1: New Cairo Campus Maps and Map of Greater Cairo

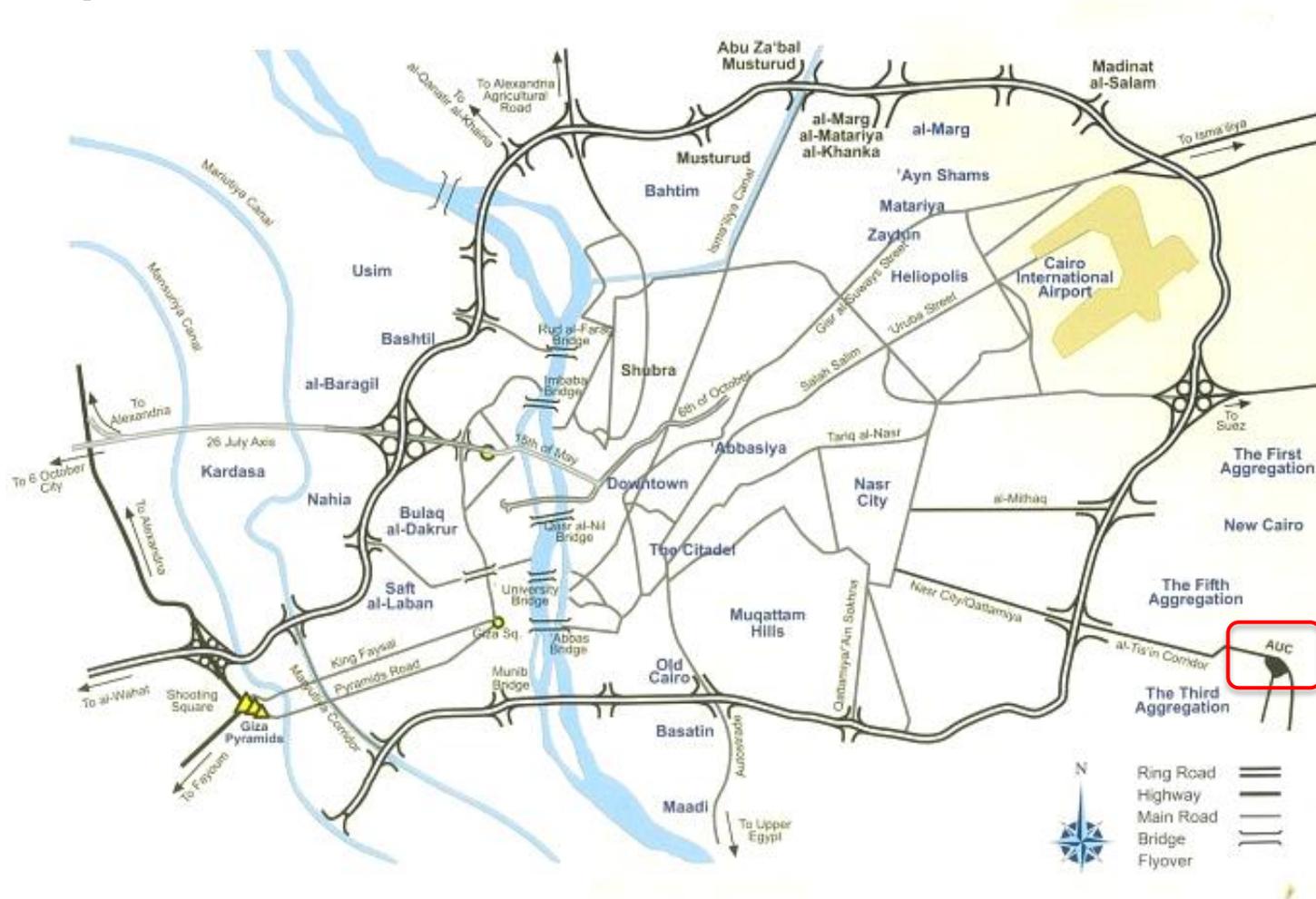
1a. Campus Map: Aerial Photo



1b. Campus Map: Schematic Overview



1c. Map of Greater Cairo



Commuting locations not labeled on map: Zamalek (the island crossed by Qasr al-Nil Bridge), Giza/Haram (area surrounding Giza Square), Mohandessin (to the left of 15th of May Bridge), Dokki/Agouza (to the left of Qasr al-Nil Bridge), El Rehab (to the right of The First Aggregation, on Suez Road) (*Cairo Practical Maps*, 2012)

Appendix 2: How the Central Utility Plant Works

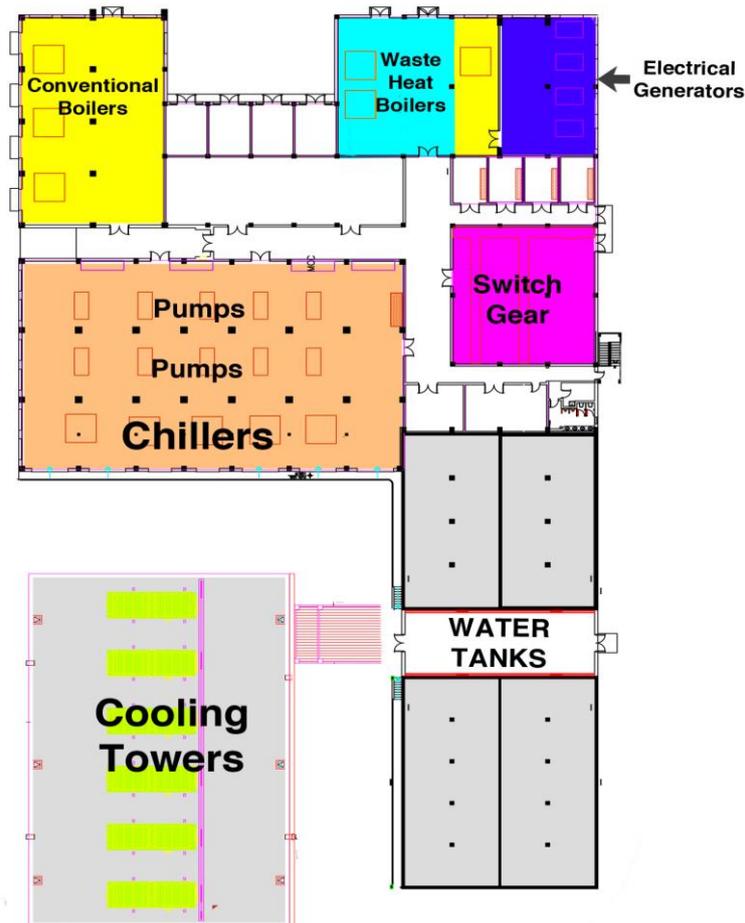


Figure 19: Schematic Diagram of the Central Utility Plant on the AUC campus.

Chilled Water for Air Conditioning

The central utility plant produces all of the chilled water used for air conditioning campus buildings, all of the hot water used for heating, most of the domestic hot water and most of the electricity used on campus. (A few areas, such as the library's rare books section, use stand-alone air-cooled AC units.)

Chilled water is produced by five gas-fired absorption chillers, shown in the schematic diagram above. Natural gas is burned to drive compressors that remove accumulated heat from circulating water, in a process not unlike what occurs in a home refrigerator. Waste heat produced by the gas-fired chillers is released through evaporation of water from six cooling towers shown adjacent to the gas-fired chillers in the schematic diagram. The cooling towers are shown in the photograph below.



Figure 20: Cooling towers form part of AUC’s AC system. Note the visible water evaporation.

Electric pumps (shown in schematic diagram next to the chillers) circulate the chilled water to a system of 150 electric-powered air handling units throughout the campus. The air handling units effectively convert chilled water to cool air, which is then circulated to air conditioned zones within campus facilities by a system of more than 1,200 electric-powered VAV (variable air volume) units.

Hot Water for Heating and Domestic Hot Water

All of the hot water used for heating campus facilities, and most of the domestic hot water used on campus, produced at the central utility plant. In locations where demand for domestic hot water is relatively light, such as hot water taps in bathrooms in campus office buildings, hot water is supplied by stand-alone electric hot water heaters.

Four conventional boilers (shown in yellow in **Figure 19**) and two waste heat boilers (shown adjacent to the electricity generators in the schematic diagram) produce hot water for heating and for domestic hot water. The four conventional boilers heat water by burning natural gas. Each of the waste heat boilers, by contrast, heats water by using hot exhaust fumes from a gas-fired electricity generator. This is a process known as “co-generation” and is explained more fully below. Hot water produced by the gas-fired boilers and the waste heat boilers is circulated to individual facilities throughout the campus by electric pumps, then converted to hot air for heating or used as domestic hot water, with additional pumps and other electrical equipment.

Electricity – Principal Uses

It is estimated that half of all electricity used on campus in FY 2012 was used for HVAC. This conclusion is based on surveys of major buildings on campus, which found that electricity used to power HVAC equipment accounts for approximately half of the electricity used for all purposes in the surveyed buildings.

Electricity used for HVAC drives pumps circulating chilled water and hot water throughout the campus for air conditioning, heating and domestic hot water. It also powers air handling units, VAV units, ventilation equipment and other electrical equipment that is part of the HVAC system. The remaining electricity used on campus is used for lighting, office equipment and other types of electrical equipment.

Electricity – From Two Sources

80% of the electricity used on campus in FY 2012 was produced by four gas-fired electricity generators located in the area shown in dark blue in the schematic diagram. As noted above, two of the four gas-fired electricity generators feed their exhaust fumes to waste heat boilers for co-generation, a process explained more fully below. The remaining 20% of the electricity used on campus in FY 2012 was obtained from EEA, the public utility. The precise mix of electric power

drawn from the on-site electricity generators and electric power drawn from the public utility depends on the size of the demand for electricity on campus, the power available from each source when demanded and the cost per kWh from each source. The electric switch gear referenced on the schematic diagram enables technicians continuously to adjust the precise amount of electric power drawn by AUC from each source.

Co-Generation

Co-generation is the design, construction and operation of a power plant to generate electricity and to recapture waste heat that can be used for production of hot water for heating and domestic hot water. The main benefits of co-generation are reduced fuel consumption, reduced energy costs and reduced carbon emissions compared to using exclusively conventional (e.g. gas-fired) boilers.

As discussed in Section 1 and above in this appendix, at AUC's central utility plant two of the four gas-fired electricity generators feed hot exhaust fumes to waste heat boilers which produce hot water for heating and domestic hot water. In FY 2012, approximately 39% of the hot water produced for heating and domestic hot water was produced by co-generation. If the same amount of hot water had been produced by conventional gas-fired boilers, then the University would have consumed 4,781,091 kWh more of heat energy and would have produced an additional 1,153.53 MTCO₂eq of emissions. Thus, co-generation avoided approximately 39% of the carbon emissions that would have resulted had all of AUC's hot water for heating and domestic hot water been produced by conventional gas-fired boilers in FY 2012.

AUC's total carbon footprint in FY 2012 was approximately 3% smaller than it would otherwise have been without co-generation. Since the potential at AUC for co-generation exists only if electric power is produced at AUC's central utility plant (as opposed to drawn from EEA, the public utility), a possible long-term strategy for reducing AUC's carbon footprint is to increase the proportion of AUC's electric power produced by the on-site generators at the central utility plant (about 80% of all electricity consumed in FY 2012) and to decrease the proportion consumed from EEA (about 20% in FY 2012) in order to maximize the benefits from co-generation.

Appendix 3: Emission Factor Calculations

Base Factors

- **Natural Gas (NG) emission factors**⁶¹ (primarily composed of CO₂, CH₄ and N₂O):
 - $EF_{NG_CO2} = 0.2025 \text{ kg CO}_2/\text{kWh}$
 - $EF_{NG_CH4} = 1.80e-5 \text{ kg CH}_4/\text{kWh}$
 - $EF_{NG_N2O} = 3.60e-7 \text{ kg N}_2\text{O}/\text{kWh}$
- **High-density fuel oil (HFO) # 6 emission factors:**
 - $EF_{HFO_CO2} = \frac{76.6 \text{ MT CO}_2}{\text{TJ}} \times \frac{1 \text{ TJ} 277777.7 \text{ kWh}}{1} \times \frac{1000 \text{ kg}}{1 \text{ MT}} = 0.275 \text{ kgCO}_2/\text{kWh}^{62}$
 - $EF_{HFO_CH4} = 3.60e-5 \text{ kg CH}_4/\text{kWh}$
 - $EF_{HFO_N2O} = 2.16e-6 \text{ kg N}_2\text{O}/\text{kWh}$

Calculating the Electricity Grid (EEA) Emission Factors

- **Efficiency of electricity production:** 43.1% (weighted average of 8 Greater Cairo station plants)
- **Fuel mix:** 83.8% Natural Gas, 16.2% HFO
- **Custom factors:**^{63 64}

For each of the three greenhouse gases (GHG),

$$EF_{EEA_GHG} = \frac{(Emission\ Factor_{NG_GHG} \times \% \text{ Natural Gas}) + (Emission\ Factor_{HFO_GHG} \times \% \text{ HFO})}{Production\ Efficiency}$$

- $EF_{EEA_CO2} = \frac{(0.202 \frac{\text{kgCO}_2\text{eq}}{\text{kWh}} \times 0.838) + (0.275 \frac{\text{kgCO}_2\text{eq}}{\text{kWh}} \times 0.162)}{0.431} = 0.497 \text{ kg CO}_2/\text{kWh}$
- $EF_{EEA_CH4} = \frac{(1.80e-5 \frac{\text{kgCO}_2\text{eq}}{\text{kWh}} \times 0.838) + (3.60e-5 \frac{\text{kgCO}_2\text{eq}}{\text{kWh}} \times 0.162)}{0.431} \times 21 = 1.02e-3 \text{ kgCO}_2\text{eq}/\text{kWh}$
- $EF_{EEA_N2O} = \frac{(3.60e-6 \frac{\text{kgCO}_2\text{eq}}{\text{kWh}} \times 0.838) + (2.16e-6 \frac{\text{kgCO}_2\text{eq}}{\text{kWh}} \times 0.162)}{0.431} \times 310 = 2.42e-3 \text{ kgCO}_2\text{eq}/\text{kWh}$

Calculating the Central Utility Plant Natural Gas Emission Factors

- **Fuel mix:** 100% Natural Gas
- **Efficiency of electricity production:** 39.53%
- **Custom factors:**
 - $EF_{CUP_CO2} = \frac{(0.202 \frac{\text{kgCO}_2}{\text{kWh}} \times 100\%)}{0.3953} = 0.51 \text{ kg CO}_2/\text{kWh}$
 - $EF_{CUP_CH4} = \frac{(1.80e-5 \frac{\text{kgCO}_2\text{eq}}{\text{kWh}} \times 100\%)}{0.3953} \times 21 = 9.56e-4 \text{ kgCO}_2\text{eq}/\text{kWh}$
 - $EF_{CUP_N2O} = \frac{(3.60e-6 \frac{\text{kgCO}_2\text{eq}}{\text{kWh}} \times 100\%)}{0.3953} \times 310 = 2.82e-3 \text{ kgCO}_2\text{eq}/\text{kWh}$

⁶¹ IPCC, 2006.

⁶² Helwan Cement Plant, 2006.

⁶³ For CH₄ and N₂O, must multiply the base emission factor by 21 and 310 (Global Warming Potentials, "GWP") respectively to convert to carbon dioxide equivalents (CO₂e). See IPCC, 2007.

⁶⁴ Dividing by the efficiency of production (in this case, 43.1%) accounts for the total amount of energy put into producing the electricity, including that which was wasted due to production inefficiency.

Calculating the Central Utility Plant Heated and Chilled Water Emission Factors

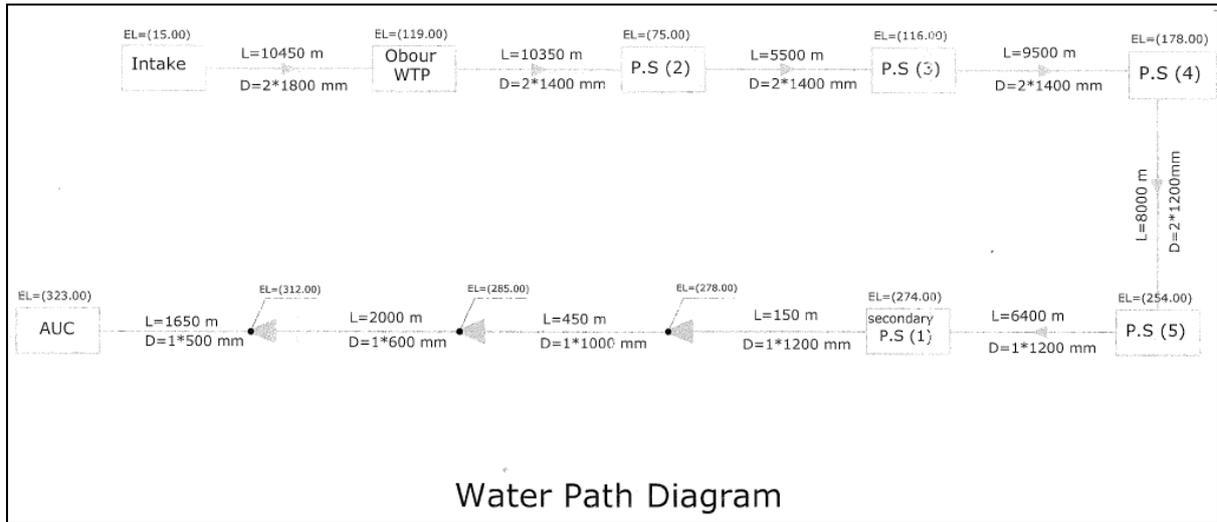
- **Fuel mix:** 100% Natural Gas
- **Efficiency of hot water production:**⁶⁵ 84.55%
- **Efficiency of chilled water production:** 77.9%
- **Custom factors:**

$$\circ \text{EF}_{\text{Hot Water}} = \frac{\left(0.202 \frac{\text{kgCO}_2}{\text{kWh}} + 1.80e-5 \frac{\text{kgCO}_2\text{eq}}{\text{kWh}} \times 21 + 3.60e-6 \frac{\text{kgCO}_2\text{eq}}{\text{kWh}} \times 310\right) \times 100\%}{.08455} = 0.241270254 \text{ kgCO}_2\text{eq/kWh}$$

$$\circ \text{EF}_{\text{Chilled Water}} = \frac{\left(0.202 \frac{\text{kgCO}_2}{\text{kWh}} + 1.80e-5 \frac{\text{kgCO}_2\text{eq}}{\text{kWh}} \times 21 + 3.60e-6 \frac{\text{kgCO}_2\text{eq}}{\text{kWh}} \times 310\right) \times 100\%}{0.779} = 0.26186650 \text{ kgCO}_2\text{eq/kWh}$$

⁶⁵ AUC Maintenance Department—Office of Facilities and Operations, 2012.

Appendix 4: Domestic Water Supply Delivery Path and Energy Calculation Example



Water Path Diagram

Link from P.S(4) to P.S(5), D1200 mm

Power Calculations:

Pressure head (H) = Static Head + Friction Losses * 1.15 + Residual pressure

$$\begin{aligned} \text{Static Head} &= (254-178) \\ &= 76 \text{ m} \end{aligned}$$

Assume $V=1.15 \text{ m/sec}$

$$\begin{aligned} \text{Friction Losses} \quad H_f &= \frac{6.78 * L * (V/C)^{1.85}}{(D^{1.165})} \\ &= 8.089 \text{ m} \end{aligned}$$

$$\begin{aligned} H &= 76 + (8.089 * 1.15) + 7 \\ &= 92.30 \text{ m} \end{aligned}$$

Power Consumed for each 1L/sec

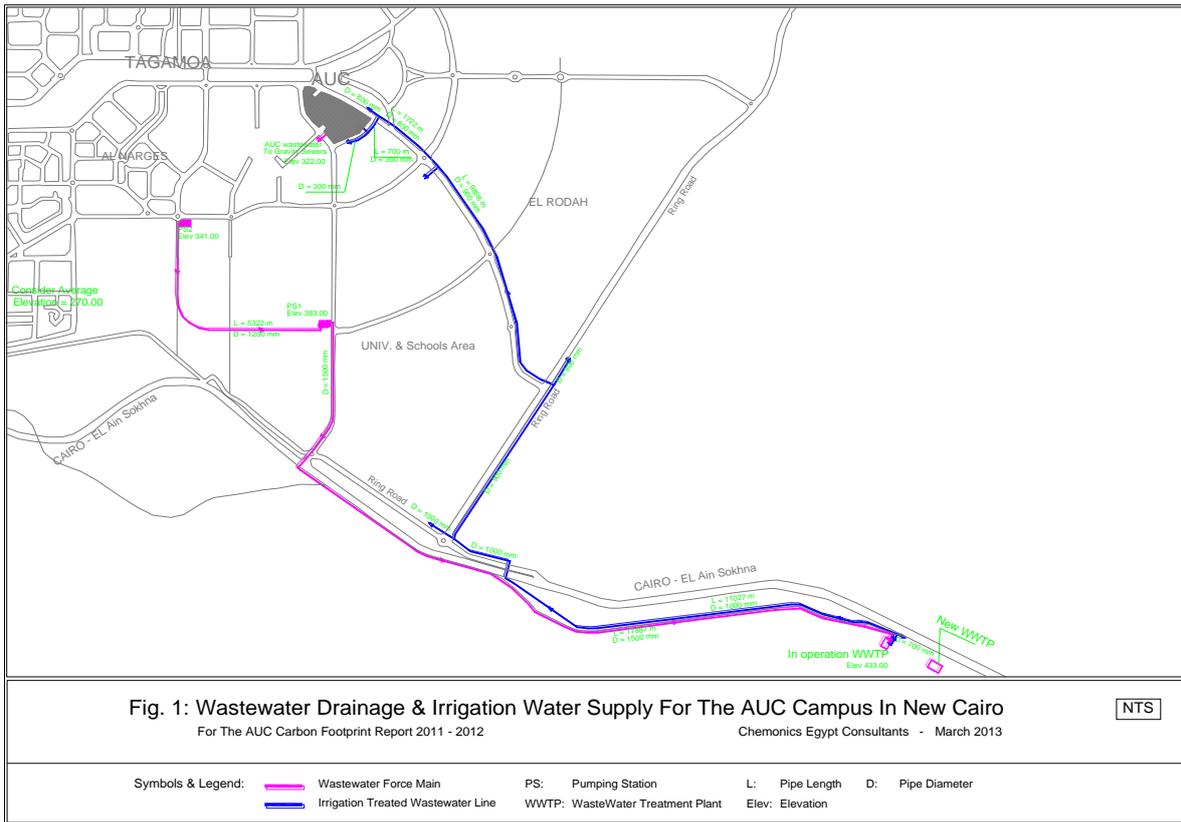
$$P = \frac{H \text{ (m)}}{75 * \eta * 1.34 * 0.85}$$

$$P = 1.662 \quad (\text{kw/1L/sec})$$

Energy Consumption (kw.hr) to let through 1m³

$$\begin{aligned} &= P * (1000/3600) \\ &= 1.662 * (1000/3600) \\ &= 0.461743 \quad \text{kw.hr /m}^3 \end{aligned}$$

Appendix 5: Treated Wastewater Supply and Delivery Path and Energy Calculations



Energy Calculations:

The following expression is a simple units' conversion to calculate the pumping energy in kWh after incorporating the efficiency and power factors:

$$\text{Energy in kWh/m}^3 = \gamma(\text{kg/m}^3) * 1(\text{m}^3) * \text{Pressure Head}(\text{m}) * 9.81 / (1000 * 3600 * \eta * .9)$$

a. Pumping energy consumed in wastewater collection and transmission:

- Case 1 (WW originated from the AUC campus) =
 $1000 * 1 * 161.8 * 9.81 / (1000 * 3600 * 0.55 * 0.9) = 0.891 \text{ kw.hr}$
- Case 2 (WW from other average source point)
 $= 1000 * 1 * 213.8 * 9.81 / (1000 * 3600 * 0.55 * .9) = 1.177 \text{ kw.hr}$

b. Pumping energy for Treated wastewater supply from the WWTP up till the Campus site:

- Energy consumed in supplying Treated Wastewater to the AUC Campus location is considered zero.

c. Energy consumed in wastewater Treatment process :

- Energy consumed in activated sludge treatment process is estimated according to the given figures deduced out of design and operation records and the long experience in the field of wastewater treatment:
 - o Energy consumed by air blowers for each $1\text{m}^3 = 0.4 \text{ kw.hr}$
 - o Energy consumed by other treatment facilities and sludge pumping and site lighting for each $1\text{m}^3 = 0.2 \text{ kw.hr}$

Over all energy factor for collecting and furnishing treated wastewater to the AUC Campus is:

- Case 1 (WW originated from the AUC campus) $= 0.891 + 0.6 = 1.49 \text{ kw.hr/m}^3$
- Case 2 (WW from other average source point) $= 1.177 + 0.6 = 1.78 \text{ kw.hr/m}^3$

(Over all energy factor previously calculated for fresh water supply = 2.55 kw.hr/m^3)

Equivalent Overall Energy Factor:

The equivalent overall energy factor is driven for the purpose of comparing and sensing the energy present and future savings / losses when introducing treated wastewater to water utilities within the AUC New Cairo Campus. The energy factor here is calculated for mixed use of different types of supplied water:

- o Equivalent energy factor before introducing Treated wastewater to service = **2.55 kw.hr/m³**
- o Equivalent energy factor for year 2011-2012 (after partial use of treated wastewater)
 $= 2.55 * 86\% + 1.49 * 14\% = \mathbf{2.40 \text{ kw.hr/m}^3}$
- o Equivalent future energy factor (after fully covering irrigation needs by treated wastewater) =
 $2.55 * 53\% + 1.49 * (47\% * 0.843) + 1.78 * (47\% * 0.157) = \mathbf{2.07 \text{ kw.hr/m}^3}$