Washington University in St. Louis
2014 ENERGY & EMISSIONS STUDY

TABLE OF CONTENTS

APPENDIX

EXECUTIVE SUMMARY

This study was conducted in fall 2014 as part of Washington University in St. Louis's update to its 2010 Strategic Plan for Environmentally Sustainable Operations. University administration and energy management leadership representing both the Danforth and the School of Medicine campuses were actively engaged participants. The study quantifies the university's progress towards its goal of reducing greenhouse gas (GHG) emissions by 2020 to the university's 1990 level (the 2020 Goal) and opportunities for further advancing emissions reductions. It recommends a course of action for the university to reach an expanded 2020 Goal and recommends additional activity for the university to further reduce its emissions beyond that threshold date.

The study addresses:

- **Campus energy data.** As a result of this study, the university has a more accurate building and energy use database and improved database management practices.
- **Progress towards the original 2020 goal.** The study finds that with the modifications to policies outlined in this report and planned financial investment in energy conservation in the next five years Washington University in St. Louis is currently on track to achieve the 2020 GHG reduction goal.
- **Pathways to an updated 2020 Goal with greater GHG emissions reductions.** The study uses the improved database in a campus energy model to predict the cost, return-on-investment, GHG emissions and energy use associated with a wide range of energy conservation measures (ECMs). The study packages the ECMs into a number of potential scenarios for updating the 2020 goal that vary based on campus boundary definition, baseline emissions level in 1990 (i.e., the emissions target to achieve by 2020), and the approach to campus growth.
- **Enhanced policies and practices.** The university is revisiting its energy-management policies and practices as a critical element of achieving the desired 2020 emissions reduction.

A key outcome of the study process was the development of twelve GHG reduction scenarios that the university reviewed as potential updates to the 2020 Goal. Ultimately, university leadership adopted the scenario shown in Figure 1 below as the updated 2020 Goal and pathway. The updated 2020 Goal requires the university to reduce its emissions by 51,300 metric tons of CO2 through a broad range of energy conservation measures shown as a series of colored wedges in Figure 1. Had the university kept the original 2020 Goal, it would have required a 26,400 MT CO2 reduction through energy conservation measures. The updated goal effectively doubles the university's commitment to reduce its emissions. Note that both the original goal and the updated goal assume the electrical utility will comply with its renewable portfolio standard, resulting in an additional ~32,000 MT reduction. This is shown as the gray wedge in Figure 1. The updated 2020 Goal has three important characteristics: it defines the geographic boundary for the 2020 Goal as the university's two primary campuses, the Danforth Campus and the School of Medicine Campus; it corrects baseline and miscellaneous other historical data inaccuracies; and it accounts for campus growth through 2020.

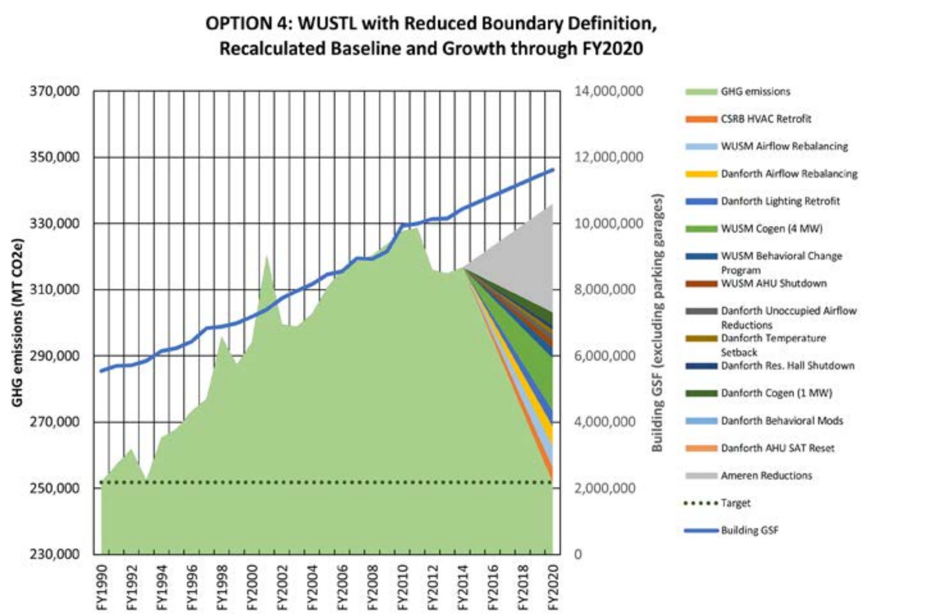


Figure 1: The updated greenhouse gas reduction pathway chosen by university leadership based on expected campus growth and modeled energy conservation measures.

QUANTIFYING THE UNIVERSITY'S GHG EMISSIONS GAP

Washington University in St. Louis is responsible for more than 15 million gross square feet (GSF) of buildings across ten land holdings[1]. As this number might be understood to suggest, the university's institutional structure, span of programs and occupancy arrangements are complex. The university maintains a database of building information, including size, program type and occupant profile, and utility use. This database is used for a number of planning and management purposes, including as the basis for tracking energy use and GHG emissions reduction trends. In 2014, the university asked for an independent review of the data. This effort was critical to the university's establishing a single understanding of energy use, GHG emissions, and the emissions reduction required to reduce university GHG emissions to 1990 levels by 2020 (the 2020 Goal).

The need for this effort is evident in examining two 2010 university documents – the *Strategic Plan for Environmentally Sustainable Operations*[2] and the *Energy Reduction Committee Report*[3]. These reports commit to the 2020 Goal, but the Strategic Plan lacks the specificity found in the companion document and can only be understood to make a larger commitment to expend staff and financial resources. Some key differences between the reports are shown in table 1.

During the term of this study, project leadership was presented[4] with a description and critique of the university database that has been used to track total energy use and calculate campus GHG emissions. The consultant team identified three primary means for making the database complete, including: 1) expanding the campus boundary definition, 2) adjusting the baseline emissions level in 1990 (i.e., the emissions target to achieve by 2020), and 3) counting all campus growth from 1990-2020.

FACTORS	STRATEGIC PLAN FOR ENVIRONMENTALLY SUSTAINABLE OPERATIONS	ENERGY REDUCTION COMMITTEE REPORT
Agreement	The goal is to be applied to properties on the Medical School Campus, the Danforth Campus, South 40, properties immediately adjacent to Danforth, West Campus, North Campus, South Campus, Tyson Center, and off-campus university housing[3] . The university's goal assumes that the utility provider will comply with state mandate to diversify energy sources.	
Divergence 1	Goal relates to scope 1, 2, and 3 emissions	Goal relates to scope 1 and 2 emissions (excepting leased assets)
Divergence 2	No specific numeric goal to achieve by 2020.	Specific numeric goal: 265,356 metric tons CO_2e
Divergence 3	Goal includes campus growth 1990-2020	Goal only includes campus growth 1990-2010

Table 1. Key differences between two university energy management plans adopted in 2010

With regard to campus boundary definition, the consultant team identified inconsistent decision rules regarding which emissions to include in the inventory (Appendix D outlines the rules adopted for this study) and missing energy consumption entries that potentially equate to the need to add data representing 3 million GSF to the database. Largely, this addition represents inclusion of Quadrangle and School of Medicine lease properties (leased by or to the school and which should be recognized as the university's responsibility depending on occupant and building management responsibilities).

The consultant team also identified that pass through utility use at the School of Medicine to the Barnes Jewish Hospital was included in the 1990 emissions count, but should not have been[5]. The impact is that the 1990 baseline emissions level decreases from 265,356 MT to 251,986 MT.

1 Danforth Campus, Medical School Campus, North Campus, Quadrangle Housing, South Campus, South 40, Tyson Center, West Campus, properties immediately adjacent to Danforth, and off-campus housing
2 Washington University in St. Louis, April 2010, the "Strategic Plan"
3 Washington University in St. Louis, July 2010, the "Committee Report"
4 August 2014
5 This energy pass through included electricity delivered to Children's Hospital from the School of Medicine, natural gas delivered to the East Pavilion Boiler plant through the Euclid Power Plant and steam supplied to the BJH campus from the Euclid Power Plant. Thus, the database undercounted total emissions for 1990.

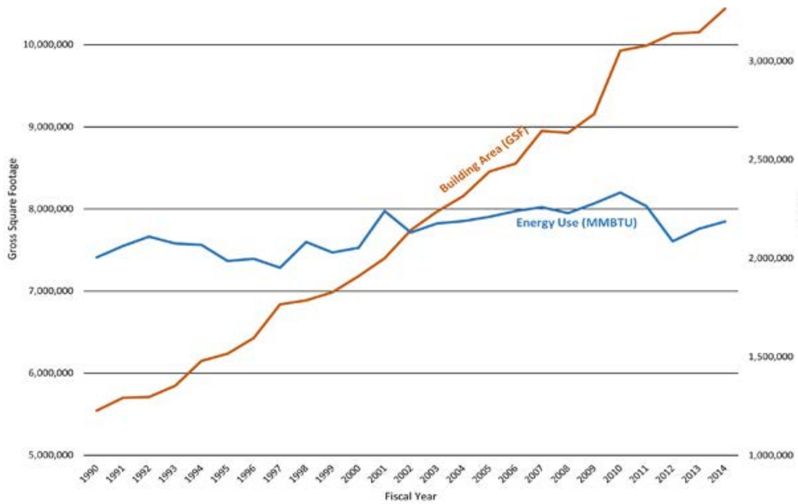


Figure 2: Washington University in St. Louis building growth and energy use 1990-2014

In addition to these critiques, the consultant team affirmed the accuracy of the database: it appears complete and accurate in accounting for energy demand reduction and corresponding analysis of the impact of university GHG emissions reduction efforts to date.

Campus growth presents a third important reason to newly interpret the 2020 Goal. Due to the disagreement between the two reports about the approach to growth, it is important to update the database with an accurate accounting of the 1,473,000 GSF that has been added since 2008 and model the impact that the 1,571,000 GSF expected to be added between 2015 and 2020 will have on emissions in 2020.

Twelve scenarios[6] were developed as a means of illustrating the implications of adjusting the boundary definition, adjusting the 1990 baseline emissions level, and including all campus growth. Each scenario represents a potential interpretation of the 2020 goal[7] and includes modeling of 1) the carbon reduction required, 2) cost to achieve, 3) simple payback, and 4) the NPV of the scenario with and without the cost of carbon. A subtle, but important aspect of the scenarios is the fact that the university's electric utility has one of the highest carbon emission factors in the US and has not yet reduced its carbon content as is called for by Missouri's Renewable Portfolio Standard (RPS). The Committee Report's calculations and strategies assumed a decrease in the emission factor of purchased electricity due to the RPS. Thus, energy conservation measures at Washington University in St. Louis that have reduced on-site natural gas combustion in favor of greater reliance on electricity have had limited impact on emissions reductions despite significantly decreasing total energy usage.

This presentation of information and analysis enabled university leaders to understand the difference between the historic and current energy conservation practices as compared to those which are needed to reach the 2020 Goal. They were then able to identify the capital cost and ease-of-implementation associated with addressing a range of options for a 2014 re-interpretation of the 2020 Goal. Essentially, the university needs to move more aggressively and establish GHG emissions reduction as an explicit and critical criteria for investments in energy use reduction.


With the exception of the Living Building Challenge certified Living Learning Center, GHG emissions related to building growth has significantly outpaced the reductions gained through university investment in ECMs due, in part, to a greater reliance on high-carbon grid electricity as a percent of total energy use.

6 See Appendix A for details on the twelve scenarios.
7 Scenarios included calculating: investment in ECMs based on the existing means of NPV calculation or with bundled ECMs (with campus building from 1990 through 2010 and with campus building from 1990 through 2020); calculating investments in ECMs based on an NPV that provides for the cost of carbon (individually and bundled) and for the two campus growth terms (1990 through 2010 and 1990 through 2020); calculating investments in ECMs based on a carbon reduction prioritized system (individually and bundled) and for the two campus growth terms (1990 through 2010 and 1990 through 2020).

The response by university leaders was decisive: the university will adopt a new interpretation of the 2020 goal that increases its commitment to reduce its emissions. The working group quickly came to consensus on the following four issues:

1. Interpreting the goal to be exclusive to Scope 1 and 2 GHG emissions.
2. Incorporating the electric utility's state legislation-prescribed performance in reducing GHG emissions as an assumed element of the university's own GHG emissions reduction count.
3. Using the Committee Report's logic of establishing a specific MTCO2e emissions target for the 2020 Goal[8].
4. Improving its energy and emissions database to fully document university buildings and space use, eliminating inconsistencies and documenting nuances of interpretations.

Three issues were left for additional consideration and decision-making once the database enhancement was complete:

1. Whether to include new construction post-2010 in the 2020 Goal[9],
2. Whether to re-interpret the plans' suggested campus boundaries, and
3. Which numeric emissions target to select for 2020, i.e., the 1990 emissions baseline.

Figures 3 and 4 offer examples of data presented at the August 2014 meeting[10] which illustrate different calculations of GHG emissions gap options depending on which campus growth terms are addressed in the 2020 Goal calculation.

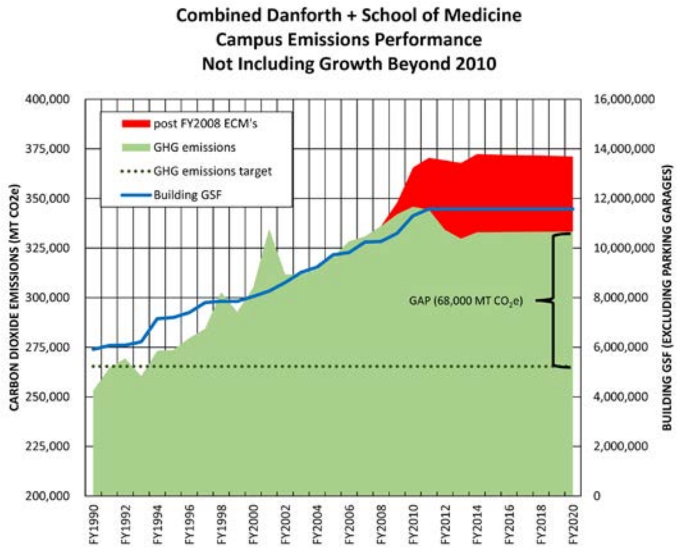


Figure 3 illustrates the greenhouse gas emissions gap if the university utilizes a boundary definition that excludes growth after 2010 and maintains the 1990 baseline as outlined in the 2010 ***Energy Reduction Committee Report***.

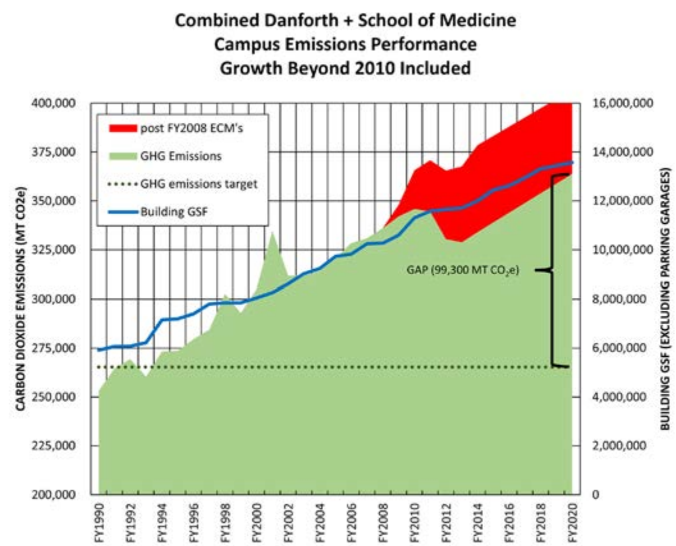


Figure 4 illustrates how the emissions gap grows if the university expands its boundary definition to include all anticipated growth through 2020.

8 University leadership's intention was to set a specific MTCO2e goal, though it might be different from that suggested in the Committee Report.
9 See Figures 3 and 4 for an early illustration of the implications of this decision.
10 The August 2014 presentation used the yet-to-be enhanced database: its illustrations should be recognized as directional and not accurate.

THE DECIDED PATH: UPDATING THE 2020 GOAL

A key outcome of the study is an update to the university's database of Scope 1 and 2 emissions that addresses the data discrepancies in the original database, as outlined on page 2 and 3. Table 2 below includes key data points from the updated database.

METRIC	NUMBER	DESCRIPTION
Building stock, 1990	6,198,581 GSF	All university owned and occupied building GSF for which the university has operational responsibility.[11]
GHG emissions, 1990	269,629 MTCO2e[14]	This is a calculation of all university owned and occupied buildings (as above), using best historic data to recalculate GHG emissions
Building stock, 2014	13,048,502 GSF	All university owned and occupied building GSF for which the university has operational responsibility.
GHG emissions 2014	367,356 MTCO2e	Modeled emissions based on total building stock.
Building stock, 2020	14,603,237 GSF	Based on university projection for 2020 of all university owned and occupied building GSF for which the university has operational responsibility.

Table 2: Profile of Total University GSF and GHG Emissions (Scope 1 and 2, corrected database)

With the campus database made complete and correct, university leadership reviewed the twelve GHG goal scenarios, focusing on four preferred options shown on Figure 5 on the following page. and made the final decision about how to scope the 2020 Goal. The goal will:

- Apply to Danforth on-campus buildings (including the South 40) and School of Medicine Campus buildings for which the majority of space is occupied by WUSM[13].
- Address all university building GSF growth within that defined boundary from 1990 to 2020 and
- Target a 2020 emissions level at or below 251,833 MTCO2e, the adjusted 1990 emission level for the defined boundary.

Table 3 outlines the key data points for the updated 2020 Goal.

2020 GOAL METRIC	NUMBER	DESCRIPTION
Building stock, 1990	5,544,112 GSF	Danforth on-campus buildings including the South 40 and School of Medicine campus buildings in which the majority of space is occupied by WUSM
GHG Emissions, 1990	251,833 MTCO2e	Based on utility data for set of buildings included in the 2020 Goal database
Building stock, 2010 (year the 2020 Goal was established)	9,156,752 GSF	Danforth on-campus buildings including the South 40 and School of Medicine campus buildings in which the majority of space occupied by WUSM
GHG Emissions, 2010 (WUSTL FY2009)	323,713 MTCO2e	Based on utility data for set of buildings included in the 2020 Goal database
Building stock, 2014	10,440,030 GSF	Danforth on-campus buildings including the South 40 and School of Medicine campus buildings in which the majority of space occupied by WUSM
GHG Emissions, 2014	316,745 MTCO2e	Based on utility data for set of buildings included in the 2020 Goal database
Planned building stock, 2020	11,621,408 GSF	Based on university data from 1990 to present combined with growth projections for 2020: Danforth on-campus buildings including the South 40 and School of Medicine campus buildings in which the majority of space occupied by WUSM
GHG Emissions, 2020 (without additional investments in energy conservation)	335,963 MTCO2e	Modeled emissions based on utility data for buildings included in the 2020 Goal database and estimated emissions of projected new construction.

Table 3. 2020 Goal: profile of university GSF and GHG emissions (Scopes 1 and 2)

11 Through this study, the university has adopted standard criteria relative to including building GSF in GHG analysis. This excludes Quadrangle Housing, buildings partially owned by Washington University in St. Louis where that ownership is less than or equal to 10%, building space that is leased from an unrelated party and is less than or equal to 10,000 GSF, and building space that is less than or equal to 10,000 GSF and is owned by the university and leased to an unrelated party. See Appendix D on page 25 for a full explanation of the adopted criteria.
12 Note that the October 2014 presentation to the university leadership used an incorrect number for the university's 1990 GHG emission. The value of the corrected number represents a reduction of emissions of 0.4%. It has been corrected in this text.
13 See page 19 in Appendix B for a more detailed explanation.

Appendix B provides a full presentation of the selected scenario's suggested energy conservation investments, including schedule, order-of-magnitude analysis of associated costs (capital, operations and maintenance), and return on investment.

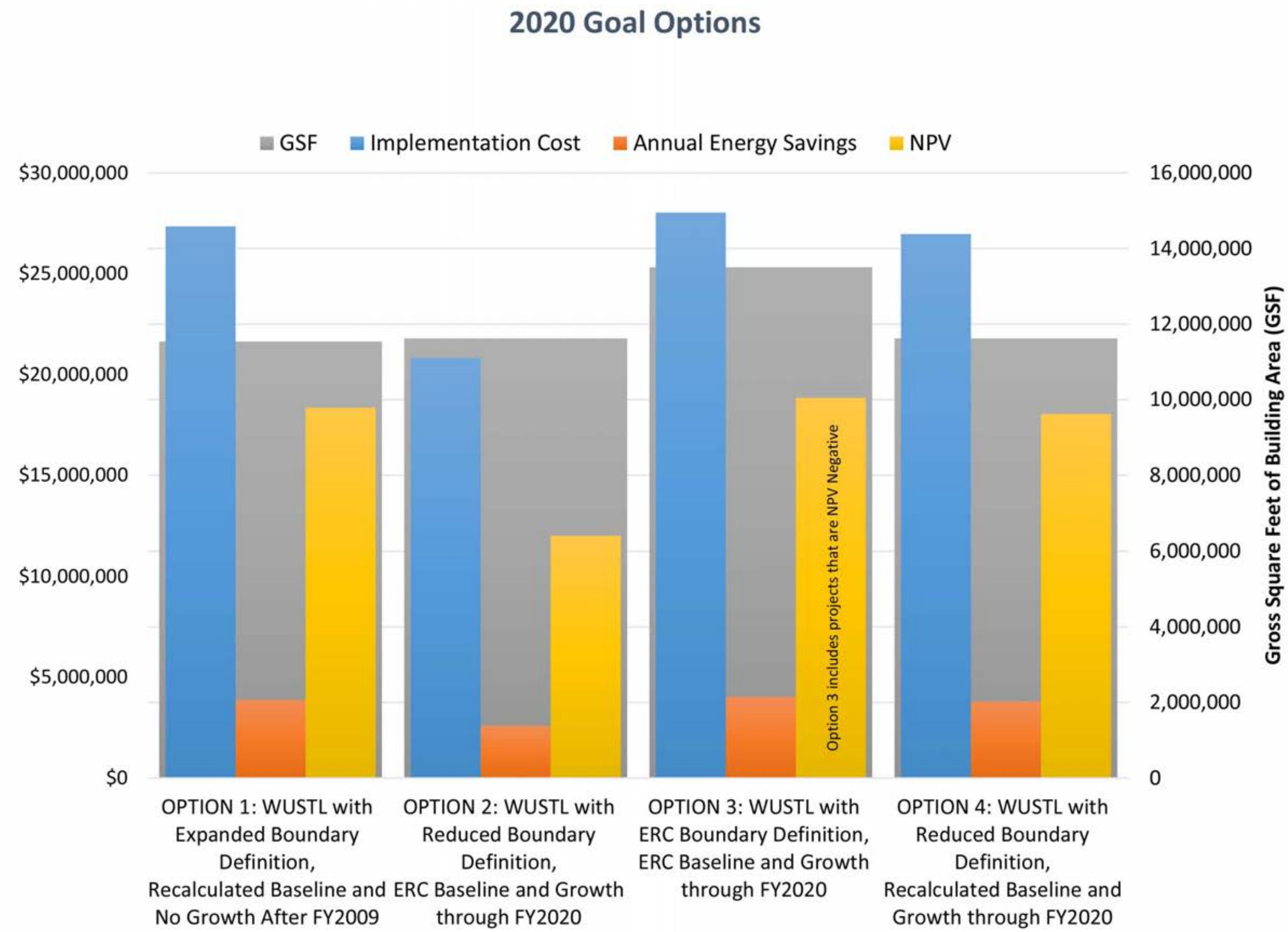


Figure 5, above illustrates the university's comparison of its preferred options for realizing the 2020 Goal. The university started with 12 options. Each provides for desired GHG emissions reduction and was considered for its combination of boundary definition, implementation cost, and energy use reduction. Option 4 is the selected option.

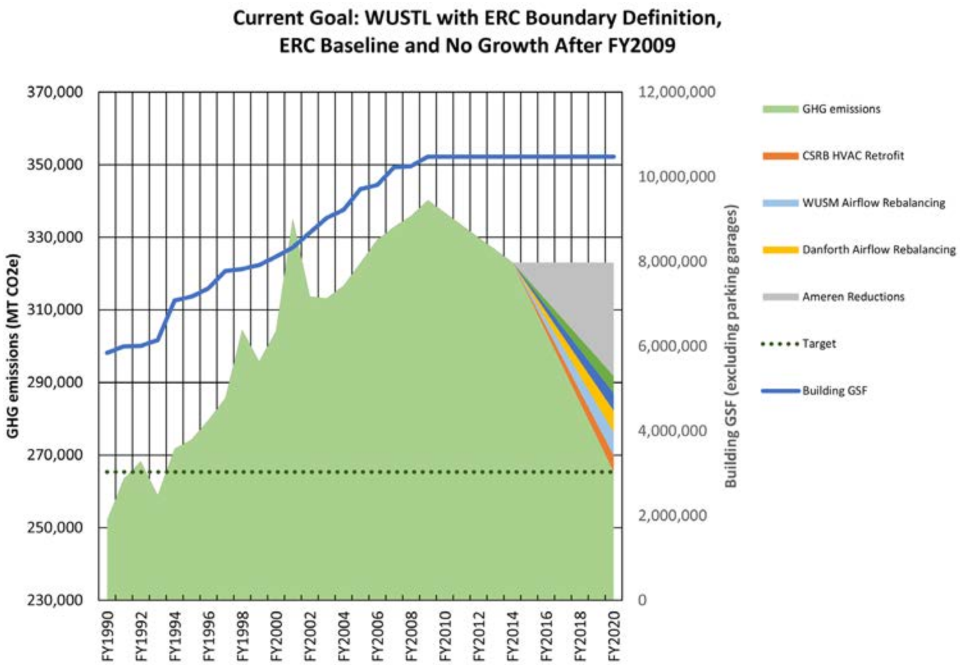


Figure 7 illustrates the pathway to achieving the current 2020 Goal. Note that the current goal does not include building growth after 2010 and includes a target emissions level, shown as a dotted line, that is higher than the corrected 1990 emissions level.

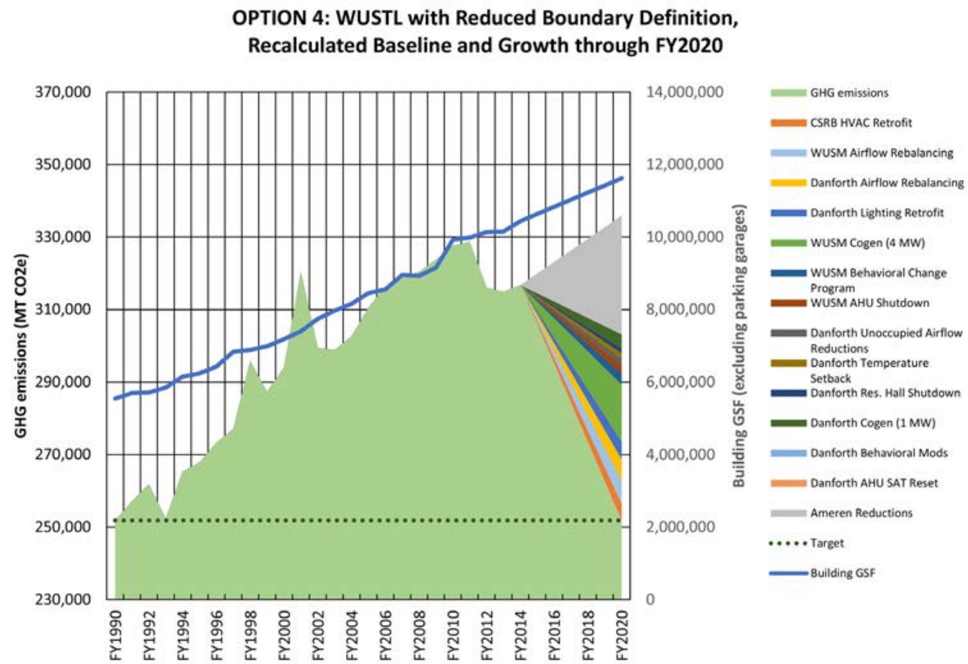


Figure 8 illustrates the pathway to achieving the updated 2020 Goal. Note that the updated goal includes building growth through 2020 and includes a corrected target emissions level, shown as a dotted line. The colored wedges represent energy conservation and carbon reduction measures.

The updated 2020 Goal requires the University to reduce its emissions by 51,300 metric tons of CO2 through a broad range of energy conservation and carbon reduction measures shown as a series of colored wedges in Figure 8. Had the university kept the original 2020 Goal, it would have required a 26,400 MT CO2 reduction through energy conservation measures shown as colored wedges in Figure 7. The updated 2020 goal effectively doubles the University's commitment to reduce its emissions by 2020. Note that both the original goal and the updated goal assume the electrical utility will comply with its renewable portfolio standard, resulting in an additional ~32,000 MT reduction. This is shown as the gray wedge in the figures above.

UNIVERSITY ENERGY MODEL

Campus energy modeling prepared for this study is an enhancement to that which the university employed in 2009 to support its original consideration and commitment to a 2020 emissions reduction goal. During the term of this study, this model was used to test scenarios for realizing the 2020 Goal. Its anticipated use is both as a repository for all changes in building GSF data and as a tool for ongoing testing of means of optimizing investments to reduce energy demand and campus GHG emissions. The energy model produces 8,760 hour load profiles for campus buildings according to attributes which logically group their building energy demand. This includes all of the university's major building types (i.e. labs, administration, classrooms, hospitals, athletics, student life, and residential).

The energy model characterized campus buildings on each of the campuses. School of Medicine Campus buildings are described as:

- Laboratory buildings with constant volume reheat HVAC (before and after airflow re-balancing).
- Laboratory buildings with variable volume reheat HVAC.
- Laboratory buildings with fan coil unit HVAC (before and after airflow re-balancing).
- Office/classroom buildings.
- Laboratory buildings constructed to a standard 30% better than ASHRAE Standard 90.1-2007.
- Office buildings constructed to a standard 30% better than ASHRAE Standard 90.1-2007.

Danforth Campus buildings are described in the energy model as:

- Older laboratory buildings with constant volume reheat HVAC, higher ACH rates, higher lighting levels, without energy recovery
- New laboratory buildings with constant volume reheat HVAC, lower ACH rates, lower lighting levels, some energy recovery
- Older office/classroom buildings with higher airflow rates; higher lighting levels; limited energy recovery
- Newer office/classroom buildings with higher airflow rates; lower lighting levels; energy recovery
- Older residence halls with higher airflow rates; higher lighting levels; limited energy recovery
- Newer residence halls with higher airflow rates; lower lighting levels; energy recovery

This categorization of building types by energy-related attributes was tested against actual FY2014 energy consumption, affirming the reliability of the correlation and establishing the model as a valuable tool for testing the energy impact of modifying campus systems and operations to predict energy use, operating savings and GHG emissions reduction. Figures 8 and 9 illustrate that the modeled data (red and black lines) closely track the actual gas and electric utility data (black squares and red circles).

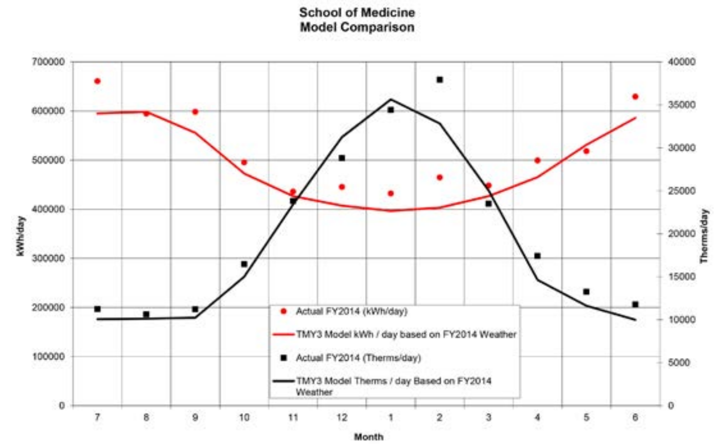


Figure 8: School of Medicine model test, modeled results versus actual

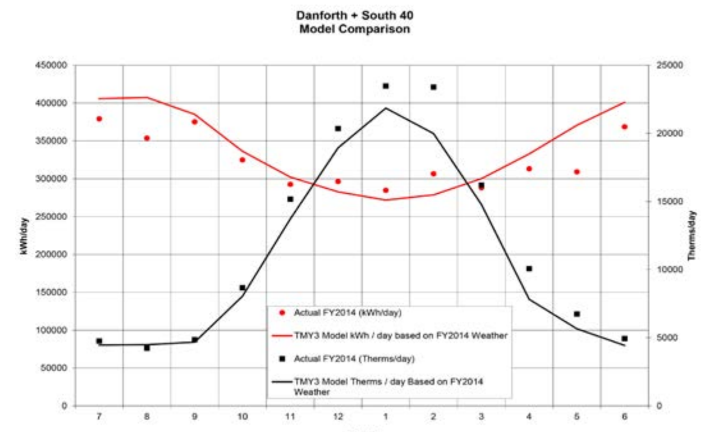


Figure 9: Danforth and South 40 model test, modeled results versus actual

Key assumptions of the model are:

1. Factors for GHG emissions resulting from Scope 1 on-campus combustion processes and Scope 2 off-campus production of electricity are the same as those used in the university's October 2009 GHG emissions inventory (FY1990-2009): an emissions rate of 0.000834 Metric Tons CO2e/kWh for Scope 2 electric usage and 0.0529 Metric Tons CO2e/MMBtu for Scope 1 natural gas usage[14].
2. Natural gas unit prices are based on an average cost of natural gas of $0.63/therm. Note that annual inflation for all utilities is addressed below in the discussion of net present value.
3. Electric unit prices in this analysis are based on the current Ameren Missouri rate schedules which include charges for usage and demand. An effective multiplier is also used to account for the various taxes and adjustments that are also applied on the typical electric bills.
4. Water and sanitary sewer costs associated with cooling tower operation are included. Energy conservation measures that reduce cooling demand also decrease cooling tower makeup and evaporation losses. Costs are based on the Metropolitan Sewer District published rates and the City of St. Louis Water Division and Missouri American water rates.
5. All new buildings are assumed to be constructed to achieve 30% more efficient than ASHRAE Standard 90.1-2010.

The model was used to predict energy savings and carbon emissions reductions for the following ECMs:

1. Retro-commissioning identifies operations and maintenance related energy savings investments, such as:
   - Supply air temperature reset strategies. Across each campus, air handling unit cold deck supply air temperatures are reset based on outside air temperature between the hours of 7 pm and 6 am. This will likely involve a minor effort to address hot spots in each building.
   - Turn off equipment during unoccupied hours. Programming is installed to turn off air handling units outside of normal working hours. This measure requires staff assignment to evaluate complaints that might occur as scheduling is developed and will require some implementation cost to provide supplemental cooling or heating in areas that require constant heating and cooling, such as data closets.
   - Additional retro-commissioning ECMs. The following opportunities should be investigated during the implementation phase. They have not been modeled because their savings cannot be quantified without performing detailed engineering analysis (beyond the scope of this study).
     - Repair heating and cooling valves that leak, causing simultaneous heating and cooling,
     - Implement thermostat deadband control,
     - Program VAV boxes to reduce to 0% flow during unoccupied operation,
     - Demand-controlled ventilation,
     - Monitoring based commissioning (fault detection and diagnostics, analytics package), and
     - Decommission redundant fume hoods.
2. Energy study and re-balancing. The following ECMs are implemented after a building-specific energy study and HVAC retrofit project.
   - Re-balance air systems. Office, classroom and laboratory airflows are balanced to match actual space heat loads. This

Washington University in St. Louis's investments in high efficiency lighting retrofits, including LEDs, accounts for a significant proportion of energy savings to date.

14 The university is employing the Ameren emission calculation for 2006 to the present and is applying that retroactively to the period 1990 to 2006. The university made this decision given that the Ameren actual numbers vary considerably from the USEPA modeled data for 1990 to 2006 (which is for both Missouri and Illinois).

requires engineering to determine the actual cooling and heating load of each space and a test and balance contractor to revise airflow settings. This ECM improves the payback of any ECM associated with reducing lighting levels.
- Convert constant volume labs to variable volume labs with constant air volume. HVAC systems are converted to variable air volume. This requires replacing pneumatic zone controls with DDC controls and installing tracking VAV boxes on exhaust ductwork and fume hoods.
- Laboratory night-time air change rate reductions. Lab controls are modified to allow fume hood airflow and makeup airflow to labs to be reduced to three air changes per hour during off-peak use hours. This requires installing fume hood control valves and programming at each lab to implement.
- Implement heat recovery. Exhaust air heat recovery systems are installed to transfer heat from building exhaust streams into makeup air. This involves installing run-around coils and a glycol pumping loop to move heat between the exhaust and makeup air streams.
- Additional ECMs to consider. The following ECMs that should be investigated during the implementation phase.
    - Use new ANSI Z9.5 closed sash airflow rates,
    - High performance fumehoods (VAV/Autosash) in labs,
    - VAV kitchen exhaust,

Green Hall is LEED Gold. It represents one of the university's 20 buildings and 1.8 million square feet of LEED projects.

    - Implement campus temperature set point standards,
    - Replace energy-inefficient freezers,
    - Replace air-cooled condensing units with water-cooled units, and
    - Convert pneumatic controls to DDC.

3. Lighting energy. The following ECMs reduce carbon emissions and maintenance costs:
    - Replace Lighting. Replace Danforth Campus lighting in locations where full T8 super long life lamp and ballast replacements have not been performed. LED conversion is not yet financially favorable, but the associated first cost is likely to continue to decrease such that this will be cost justified in the future. This ECM is only being considered at the Danforth Campus (the School of Medicine recently completed the full T8 conversion described in this ECM).
    - Install Lighting Controls. Occupancy sensors are installed to ensure that unoccupied spaces are not lit.
4. Reduce summer building energy demand. Summer conferences and programs can be better consolidated to limit summer building energy demand. Unused residence halls should have the outdoor and exhaust turned off, the HVAC controlled to maintain humidity limits, and cycled pumps and fans (rather than operate them continuously).
5. Install heat recovery chillers. Heat recovery chillers are installed to provide simultaneous heating and cooling for new and existing buildings that use reheat systems.
6. Behavioral change. A university-wide information/engagement campaign is implemented to motivate behavioral change with the expected result of a 10% reduction in plug load-related demand. Experiences at other campuses establish that behavioral change programs best perform when the engagement campaign

Green Cup is a 4-week long annual student competition to reduce energy use in their residential space and is planned to serve as a foundation for expanded university behavioral change initiatives.

ENERGY CONSERVATION MEASURE DESCRIPTION	IMPLEMENTATION COST FACTORS		MAINTENANCE COST	
Supply Air Temperature Reset Strategies	0.2	$/sf	N/A	
Turn Off Office Units at Night	0.9	$/sf	30,000	$/year
Aggressively Re-balance Air Systems to Reduce Reheat	2	$/sf	N/A	
Convert Constant Volume Labs to Variable Volume	25	$/sf	N/A	
Reduce Night-time ACH Rate	13.24 10	$/sf existing CAV $/sf existing CAV	N/A	
Implement Full Heat Recovery on Existing Labs	22	$/gsf	N/A	
Reduce Lighting Energy and Maintenance	0.8	$/sf	0.038	$sf/year
Install Lighting Controls	1.5	$/sf	N/A	
Turn Off Residence Halls During Summer	0.05	$/sf	10,000	$/year
Install Additional Heat Pump Chiller	7,000	$/Ton	20	$/Ton/year
Behavioral Modification	0.0295	$/sf	0.015	$sf/year
Natural Gas Co-generation Plant Size	2,666,667	$/MW	0.005	$/kWh
Install Photovoltaic Arrays on Campus Parking Garages	4,000,000	$/MW	863	$/MW/year
Geothermal System	15,000	$/well	25	$/well

Table 4. Modeled implementation and maintenance costs.

includes provision of regular information about building energy use and financial mechanisms to reward progress.

7. Cogeneration. A combined heat and power facility (CHP) that uses natural gas to power a gas turbine generator is installed on one of the campuses. Hot turbine exhaust will heat water and create steam for distribution to the campus.
8. Install photovoltaic arrays on campus. For this analysis, it is assumed that the arrays would only be installed on campus garages.

The costing model assumptions are provided in Table 4. These are based on unit costs from similar, recent university projects and include: a 30% markup over construction costs to account for project related expenses, such as contingency; engineering study/design/commissioning fees; and owner facilitation fees partnerships for financing and operating campus energy systems.

The model follows university protocol for calculation of net present value (NPV) where:

values = annual cash flows
rate = internal rate of return
j = the time of the cash flow

$$NPV = \sum^{n} \frac{values_j}{1+ rate^j}$$

This study employed an internal rate of return of 6%, a 3% rate of inflation for annual maintenance costs, a 3.5% rate of inflation for electric cost and a 1.65% rate of inflation for natural gas. Gas and electric rates of inflation were calculated based on the financial modeling guidelines described in the next section.

IMPROVED POLICIES AND PRACTICES

Energy Conservation Investments. Washington University in St. Louis now possesses a model to guide its investment in energy conservation that addresses both cost effectiveness and GHG emissions reduction. The model shows that the most important single investment to realize the 2020 Goal is installation of combined heat and power (CHP). Also referred to as co-generation, this technology is the simultaneous generation of heat and power, typically by a combustion engine. For Washington University in St. Louis, it is a critical device for needed carbon reduction. The financial viability of CHP is heavily influenced by the relative costs of natural gas and electricity. Historically, electric prices in Missouri have been low relative to the higher and more volatile cost of natural gas, making CHP in many locations financially unfavorable. The combination of rising costs of grid electricity and low cost for natural gas appears to have shifted CHP from NPV-negative to NPV-positive. The university's preliminary consideration of this recommendation from the campus energy model warrants further investigation. University energy managers identified the potential to develop a 4 megawatt CHP system on the School of Medicine Campus and a 1 megawatt CHP system on the Danforth Campus, which would provide approximately 13% of the university's annual electricity use. Potential locations include the WUSM power plant, the WUSM office building planned for the old coal bunker site, Danforth East End, Danforth Thermal Plant #2, and the South 40 chiller plant. Together, these plants show a reduced university operating cost of over $1.3 million and produce a $2 million positive NPV. The systems would reduce carbon emissions by approximately 20,000 metric tons of CO2 equivalent each year.

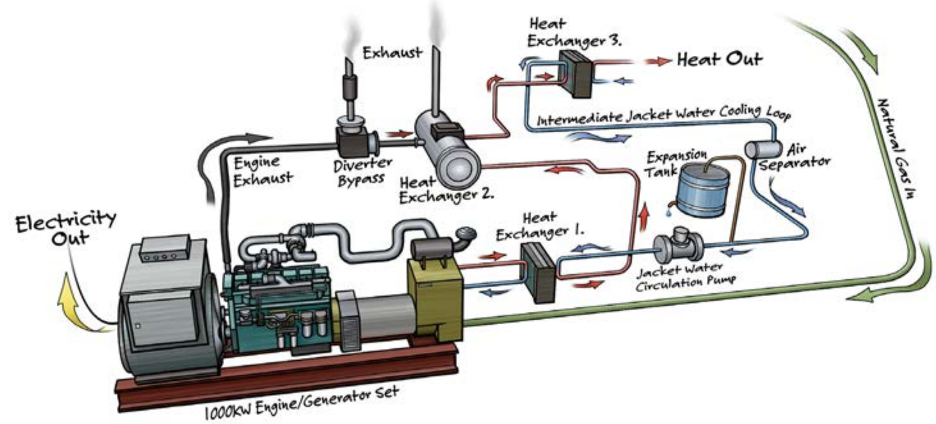


Figure 10: Combined Heat and Power Illustration, from Affiliated Engineers, Inc.

Policy Enhancements to Meet the 2020 Goal. During the fall of 2014, university energy managers reflected on their policies and practices, identifying means of ensuring that they would better position the university to reach its 2020 Goal and continue afterwards with similarly aggressive GHG emissions reduction. The following were instituted as immediate improvements:

1. The university will continue to maintain its building energy use database, but with tighter definitional control and enhanced quality control. A single office will be tasked with managing this database in a way which provides easy access to the many who need to employ its data.
2. The university will update the current building policy requiring all new buildings achieve 30% better than ASHRAE 90.1-2007 to the higher standard of 30% better than ASHRAE 90.1-2010 for all new construction and 20% better than ASHRAE 90.1-2010 for all major renovations. The percent improvement will be measured in energy units.
3. The university will ensure uniform application of the ASHRAE standard and use USGBC LEED® Silver as a base requirement. It will do so by issuing such guidance in writing as a formal policy and incorporating this policy into relevant staff training.

The current version of the university Design Sustainability Guidelines say the following relative to energy and emissions:

- Applicable to all projects under $2 million: compliance with USGBC standards for design and construction practices and all material selections and their installation.
- Applicable to all projects between $2 million and $5 million: same as above with option to submit for LEED® certification.
- Applicable to all projects over $5 million: projects shall achieve a minimum of LEED® Silver under one of the following rating systems: LEED NC for new construction, LEED CI for commercial interiors and LEED CS for Core & Shell. Projects will be reviewed in detail on an individual basis seeking silver to platinum status. The level of potential achievement will be determined for each project during the conceptual or preliminary design phase after completing a LEED Scorecard. All material selections and their installation shall comply in strict accordance with the U.S. Green Building Council (USGBC).

4. Using data from the recently completed university-wide energy metering project and relevant benchmarking data, the university will establish energy use intensity (EUI) targets for new construction and existing buildings based on specific building types. The EUI targets will be objective ongoing measurements of building performance.

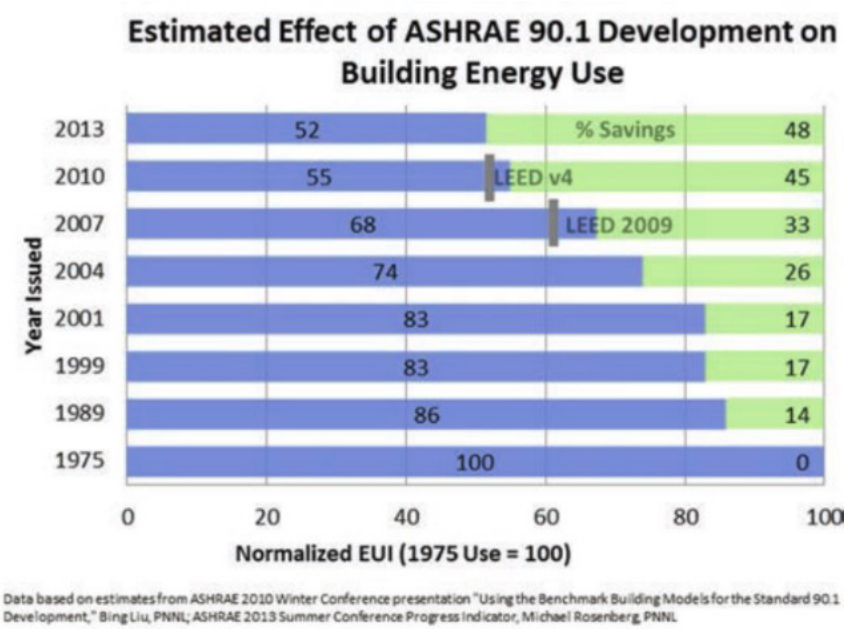


Figure 11: Estimated effect of ASHRAEI 90.1 updates on building energy use.

5. The School of Medicine and Danforth campuses employ different means of calculating net present value of potential ECMs and will continue to do so. The Danforth Campus calculations will make affirmative efforts to recognize situations where bundling of ECMs in a single NPV calculation are compelling, such as when an ECM supports more than one programmatic objective[15], where proposed ECMs have a favorable interactive effect, and/or where the project budget can otherwise comfortably justify such bundling.
6. Even with different tests for financial vitality of ECMs, the Medical School Campus and the Danforth Campus will employ standard metrics, such as the current and projected cost of utilities, discount rates, and assumed longevity of different capital investments. As part of the energy and emissions planning effort, the university developed Financial Modeling Guidelines to serve this purpose. The guidelines will be issued to all relevant staff and consultants to ensure consistent variables are used in financial tests.
7. Advance the university's energy and emissions related education and involvement with students, faculty, and staff. It was suggested that a tenet of this is the "democratization" of energy and GHG emissions data. At the broader scale, this is a university commitment to leadership on energy efficiency within the region and within the higher education sector.

15 An example of this would be replacing antiquated fume hoods both to reduce building energy demand and to address air quality concerns.

8. Identify an individual to lead and coordinate the university's progress towards the 2020 Goal.
9. Building scale modeling is critical to design decision-making for new construction and major renovations. Building scale modeling is advancing at a quick pace and it is critical for Washington University in St. Louis to stay current with these innovations to ensure that the modeling its design consultants perform is as reliable a predictor of building performance as is possible. The most advanced modeling references benchmark projects and incorporates concern for energy with that of water use and climate change. In so doing, the modeling and life cycle cost analysis is appropriately forward looking. Institutional-scale entities that develop and manage their own properties often provide written guidance to their design teams on how to model building energy performance. They employ one of three devices for guiding the modeling process to ensure that it is appropriately consistent and sophisticated. Each of these options has merits and one should be employed to ensure that Washington University in St. Louis has excellent modeling in each of their design projects:
   - Assign one or a few staff members to manage all building-scale modeling,
   - Potentially access independent guidance and greater sophistication in the review through an open contract with an engineering firm to manage this process on the owner's behalf, or
   - Through careful staff guidance that places responsibility with each project manager for the development of their projects' building modeling as part of the design process.

The Green Ambassador peer educator program is an important example of a co-curricular student and staff partnership for advancing the university's energy and emissions education.

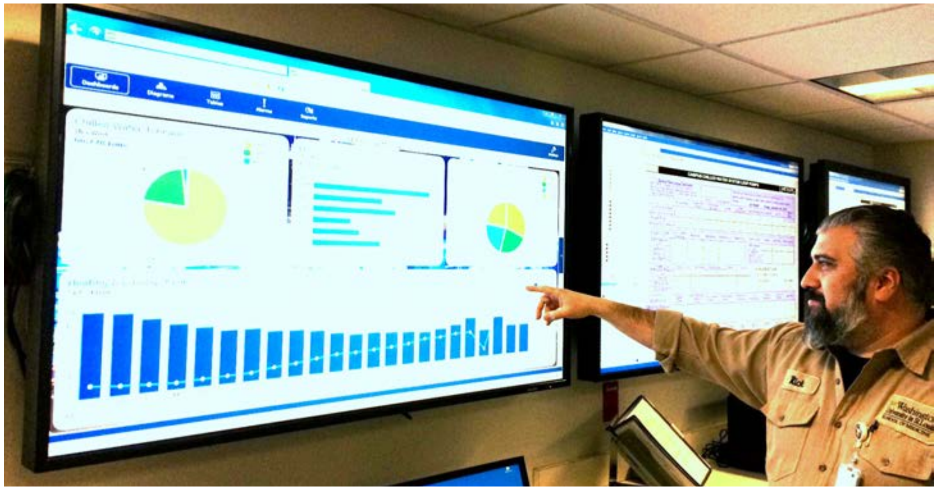
10. Impactful practices outside of building ECMs will be considered as standard practice. These can include:
    - Improving building scheduling to moderate temperatures during low and no-use times
    - Articulating, or improving space standards so that renovations and new construction projects will generate greater efficiency of occupants-to-building GSF.
    - Designing to plug load standards. Recent studies document a trend of designing buildings to a greater plug load than what is needed. A deliberate analysis during the design process can avoid this while optimizing the opportunity for shared equipment (avoiding redundant equipment).
    - Supporting plug load management in existing buildings through purchase of simple devices and a program to remove redundant equipment.

The following are recommended as longer-term considerations:

1. The university should measure emission scopes 1, 2, and 3 as this is the standard practice for governments, corporate entities, and higher education institutions. Refraining from measuring scope 3 emissions may seriously undercount Washington University in St. Louis' GHG emission impact. A recent survey undertaken of masters and doctorate degrees-granting institutions who are members to the American College and University Presidents' Climate Commitment (ACUPCC) suggests that 34% of these entities' collective GHG emissions are from scope 3 sources. This contrasts to Washington University in St. Louis' only scope 3 survey (2009) which reported 13% of total GHG emission assigned to scope 3. Note that this discrepancy is explained both by the fact that the Washington University in St. Louis report on emissions described its accounting as incomplete and the possibility that

the university's actual scope 3 emissions may be lower than the average of the surveyed ACUPCC entities as a percentage of overall emissions. The university might commit to public release of scope 3 emission data as of 2021. The university might consider employing the Clean Air-Cool Planet tool to house this data[16]. Because it typically takes a few years to create reliable systems to gather data about scope 3 emissions, Washington University in St. Louis should start this effort a few years in advance of the first planned public release of the information.

2. During this study, the university considered the federal government's standard for the social cost of carbon and the example set by Princeton University which employs a cost of carbon in considering its ECM investments. This has the intent of recognizing the climate benefits of investments. The university Financial Modeling Guidelines require that projects model NPV both with and without the social cost of carbon as a decision-making tool. Including the social cost of carbon has the modeling outcome of re-sorting the relative value of a group of ECMs through escalating those with greater carbon impact. The university will continue to hold a cost of carbon requirement as a potential additional tool for use in the future.


Energy dashboards democratize access to energy performance information and present data in ways which have been proven to result in significant energy demand reductions.


The 680,000 square-foot BJC Institute of Health hosts the university's research to rapidly translate basic research findings into advances in medical treatment. Opened in 2009 and certified as LEED Gold, it is the university's largest building.

3. Washington University in St. Louis compares itself to 26 peer institutions to understand its sustainability performance within a context. Generally, these include colleges and universities that might also be considered as peers in terms of national rankings of academic standing. These institutions represent very different climate conditions, utility costs and carbon intensity of their energy. It is therefore recommended that the university enlarges its consideration of peer institutions as relates specifically to GHG emissions reductions.
4. The campus energy model would suggest that building integrated photovoltaic installations on campus have more educational value than cost effectiveness at the time of this study. Currently, the university is exploring the financial viability of installing over 1 MW of rooftop photovoltaics. This may involve up to six buildings. At this writing, candidate buildings are most of the North Campus, the Taylor Avenue Building, and the Athletic Complex. Each 1 MW of photovoltaics installed would reduce carbon emissions by approximately 1,000 metric tons of CO2 equivalent each year.

16 This tool works well and is generally used by higher education institutions that report on GHG emissions.

APPENDIX A: WASHINGTON UNIVERSITY IN ST. LOUIS FINANCIAL MODELING GUIDELINES (SPRING 2015)

These guidelines are regularly revisited. Staff and contractors should contact the Office of Sustainability to ensure that they are using the most current version of university financial modeling guidelines.

The financial modeling guidelines were developed to ensure that all financial models developed by and for Washington University in St. Louis use the same set of defensible assumptions. Use of these guidelines by staff and consultants is mandatory. Should a project manager or consultant feel that a specific project warrants an adjustment to the financial modeling assumptions, the change must be approved by the AVC for Finance & Director Financial Planning and well-documented within the model.

The guidelines will be reviewed and updated annually by a committee consisting of finance, facilities, operations and sustainability staff from both campuses and approved by the Executive Vice Chancellor for Administration.

All financials models will include both Complex Payback[17] and Net Present Value analyses.

Cost of Capital
- Assume 6% over the life of a project

NPV Duration
- The number of years used for NPV calculations will be based on the useful life of the equipment as defined by ASHRAE

Life Cycle Assessment
- Include labor and maintenance cost savings/increases in projections, assuming 3% annual increase for inflation
- Include water and sewer savings/increases in projections

Carbon Reduction and Cost of Carbon
- Include the estimated annual carbon reduction
- Calculate NPV without and with the Social Cost of Carbon (SCC) as a decision-making tool
- Use $39/MTCO2e beginning in 2015 with a 3% annual increase[18]
- Calculate the carbon reduction per dollar spent as (Annual kg CO2 Reduction)*(Useful Life)/(Project Cost)

Utility Projections
- Utility rate projections will be updated annually in October.
- Cap projected annual utility rate increase at 8% Maximum.
- Natural gas prices are highly volatile. The goal is defensible logic. Use the actual December New York Mercantile Exchange (NYMEX) gas cost projections for each year out 10 years at the time of analysis. For years beyond Y10, calculate the trend line of Y1-10 and apply that annual percent change to the years beyond Y10. Data is available on the following website from the CME Group, the owner and operator of NYMEX: http://www.cmegroup.com/trading/energy/natural-gas/natural-gas.html

17 Complex Payback includes 1) costs/savings for all utilities impacted by a project calculated using the utility escalators outlined in this document, 2) 3% annual inflation, and 3) maintenance costs/savings.
18 Source: Fact Sheet: Social Cost of Carbon, published by the EPA, dated November 2013. http://www.epa.gov/climatechange/Downloads/EPAactivities/scc-fact-sheet.pdf

These guidelines are regularly revisited. Staff and contractors should contact the Office of Sustainability to ensure that they are using the most current version of university financial modeling guidelines.

- Base the Y1 electric rate on the actual rate for the specific electric account. The following is a list of the all-in blended rate for Washington University in St. Louis' main accounts, updated November 2014. For rate data for other Washington University in St. Louis accounts, contact either the Danforth or School of Medicine Facilities Department.

LOCATION	ACCOUNT ADDRESS	ACCOUNT TYPE	RATE (COST/KWH)
Danforth Campus	6500 Forest Park Pkwy	11M	$0.0628
South Forty	6515 Wydown Blvd	4M	$0.0692
West Campus	7425 Forsyth Blvd	4M	$0.0680
North Campus	700 Rosedale Ave	3M	$0.0876
Medical School	4540 Children's Pl	11M	$0.0638
Medical School	500 S Euclid Ave	11M	$0.0621
Medical School	4550 McKinley Ave	11M	$0.0610
Medical School	4444 Forest Park Ave	4M	$0.0628

- Use a 10-year look-back on the percent rate change for the specific electric account type (e.g., Large Primary) to get an average annual change to apply to future years.
- 10 yr. avg. annual change to be updated annually and when rate changes go into effect.
- The actual Ameren rate history is shown below by account type. The average annual rate increase projection is shown in the last row.

EFFECTIVE CHANGE DATE	OVERALL CHANGE	RESIDENTIAL 1(M)	SMALL GS 2(M)	LARGE GS 3(M)	SMALL PRIMARY 11(M)	LARGE PRIMARY 11(M)	LARGE TRANSMISSION 12(M)
Apr-04	-1.60%	-1.60%	-2.00%	-1.50%	-1.50%	-3.20%	
Jul-07	2.10%	3.20%	2.80%	1.20%	3.10%	2.70%	-5.40%
Mar-09	7.80%	8.10%	7.70%	7.70%	7.70%	7.90%	6.10%
Jun-10	10.40%	11.90%	12.10%	9.90%	9.90%	11.90%	0.10%
Jul-11	7.11%	9.25%	5.20%	5.20%	5.20%	5.20%	5.20%
Jan-13	10.10%	10.90%	8.80%	9.90%	10.50%	9.80%	6.60%
10 yr. Avg.	**3.59%**	**4.18%**	**3.46%**	**3.24%**	**3.49%**	**3.43%**	**1.26%**

- Metropolitan Sewer District (MSD) is in the middle of major infrastructure investments due to regulatory requirements. Build to a 10-year look-back on rates changes to get an average annual change to apply to future years. The rate increase planned for FY15 is 12.8% based on actual invoices and published guidance. The actual MSD rate history is shown below for the years that data is available. For this period, the average annual rate increase projection would be 7.05%.

These guidelines are regularly revisited. Staff and contractors should contact the Office of Sustainability to ensure that they are using the most current version of university financial modeling guidelines.

EFFECTIVE DATE	RAW RATE ($/CCF METERED WATER USE)	% INC
7/1/2008	$1.88	-
7/1/2009	$1.92	2.13%
7/1/2010	$2.02	5.21%
7/1/2011	$2.11	4.46%
4/1/2012	$2.28	8.06%
5/1/2013	$2.50	9.65%
7/1/2014	$2.82	12.80%
Average Rate Increase over available data period		**7.05%**

- The university's two water providers, St. Louis City and Missouri American, present a noticeable difference in unit cost. Calculations shall use the rate projections from the applicable provider. Build to a 10-year look-back on rates to get an average annual rate change to apply to future years. The actual water rate history is shown below for the years that data is available. For this period, the average annual rate increase projection would be:
- St. Louis City Water – 3.76%
- Missouri American Water – 8.00% (due to cap)

ST. LOUIS CITY WATER:

EFF. DATE	RAW RATE ($/CCF)	% INC
4/1/2008	$0.84	-
7/1/2009	$0.93	10.71%
7/1/2010	$1.04	11.83%
7/1/2011	$1.04	0.00%
7/1/2012	$1.04	0.00%
7/1/2013	$1.04	0.00%
7/1/2014	$1.04	0.00%
Average Rate Increase over available data period		**3.76%**

MISSOURI AMERICAN WATER:

EFF. DATE	RAW RATE ($/CCF)	% INC
10/22/2007	$0.8034	-
11/28/2008	$0.9665	20.30%
7/1/2009	$0.9665	0.00%
7/1/2010	$1.0767	11.40%
7/1/2011	$1.0767	0.00%
4/1/2012	$1.1595	7.69%
5/1/2013	$1.5501	33.69%
7/1/2014	$1.5501	0.00%
Average Rate Increase over available data period		**10.44%**

APPENDIX B: WASHINGTON UNIVERSITY IN ST. LOUIS GHG EMISSION REDUCTION SCENARIOS

The following illustrations and presentation of metrics provide detail to support Table 2. Profile of Recommended ECMs: Options.

SF: A Variety of Ways to Define Campus Boundaries			
	Danforth + South 40 and SOM (sf as with ERC)	Energy Reduction Committee*	ERC adjusted to account for Danforth Off Campus, SOM campus properties partially owned by SOM and Leased by SOM (>10000 gsf).
FY1990 SF	5,544,000	5,842,000	6,199,000
FY2009 SF	9,157,000	10,477,000	11,540,000
FY2014 SF	10,440,000	11,950,000	13,049,000
FY2020 SF**	11,621,000	13,505,000	14,603,000

*Energy Reduction Committee (ERC) boundary: Med School Campus, Danforth Campus, South 40, West Campus, North Campus, South Campus, Tyson Center, off-campus university housing.

** This is calculation of 2014 SF with planned SF growth (identified by the university) added to it.

Modeled Emissions* for University SF			
	Danforth + South 40 and SOM (sf as with ERC)	Energy Reduction Committee	ERC adjusted to account for Danforth Off Campus, SOM campus properties partially owned by SOM and Leased by SOM (>10000 gsf).
ERC Emissions Rates (Based on ERC Report Methodology)			
FY1990 Emissions (ERC Calc)	265,000	265,000	265,000
FY1990 Emissions Corrected	252,000	252,000	270,000
2020 Emissions for FY1990 through FY2009 Growth	277,000	292,000	323,000
2020 Emissions for FY1990 through FY2020 Growth	303,000	321,000	352,000
Emissions Rates Corrected for Actual Ameren Missouri Performance			
FY1990 Emissions	213,000	213,000	228,000
2020 Emissions for FY2009 SF	240,000	253,000	279,000
2020 Emissions for 2020 SF	262,000	277,000	305,000

*Average Scope 1+2 GHG emissions per sf for each campus (2014) have been applied. Where relevant, post 2014 new construction has been modeled for improved energy performance.

Matrix of twelve greenhouse gas reduction scenarios to achieve 1990 emissions levels. The scenarios vary based on campus boundary definition, the 1990 baseline emission level (the 2020 goal), and the approach to campus growth. The University focused on the four preferred options outlined in red before adopting the bottom left scenario, shown in graph format as “Option 4” on page 22.

Minimum Cost to Reach Goal: Combined ECM Options*			
	Boundary Definitions		
	Danforth + South 40 and SOM (sf as with ERC)	Energy Reduction Committee (ERC)	ERC adjusted (Danforth off-campus, SOM campus properties partially owned by and/or lLeased by SOM (>10000 gsf)
FY1990 through FY2009 Growth, ERC Emissions Methodology, ERC FY1990 Baseline			
Emissions Gap	12,000	26,000	57,000
Implementation Cost	$2,500,000	$13,300,000	$30,500,000
NPV**	NA	$10,900,000	$18,200,000
NPV with Cost of Carbon at $39/MT	NA	$20,600,000	$41,500,000
Simple Payback	3.5	6.6	7.8
FY1990 through FY2009 Growth, ERC Emissions Methodology, Recalculated FY1990 Baseline			
Emissions Gap	25,000	40,000	53,000
Implementation Cost	$12,400,000	$20,900,000	$27,400,000
NPV**	$10,800,000	$12,800,000	$18,300,000
NPV with Cost of Carbon at $39/MT	$19,900,000	$28,400,000	$39,700,000
Simple Payback	6.4	7.8	7.4
FY1990 through FY2020 Growth, ERC Emissions Methodology, ERC FY1990 Baseline			
Emissions Gap	38,000	56,000	87,000
Implementation Cost	$20,800,000	$28,000,000	$100,700,000
NPV**	$12,000,000	$18,800,000	-$24,500,000
NPV with Cost of Carbon at $39/MT	$26,700,000	$41,400,000	$12,000,000
Simple Payback	8.0	7.4	17.1
FY1990 through FY2020 Growth, ERC Emissions Methodology, Recalculated FY1990 Baseline			
Emissions Gap	51,000	69,000	83,000
Implementation Cost	$27,000,000	$52,600,000	$89,300,000
NPV**	$18,000,000	$6,400,000	-$17,200,000
NPV with Cost of Carbon at $39/MT	$38,700,000	$34,800,000	$17,400,000
Simple Payback	7.4	11.3	16.0

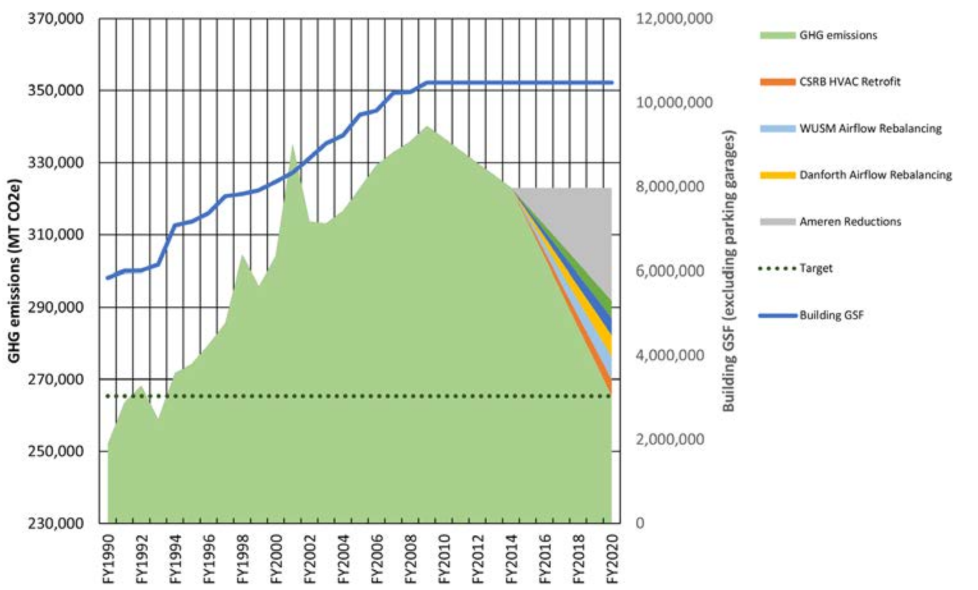
* This applies ECMs in rank order of their ability to optimize GHG emissions with sorting stopped at point that 2020 Goal is met.

** NPV is based on 15 year period, a 6% cost of capital, an electric rate of inflation of 3.5% and a natural gas rate of inflation of 1.65%.

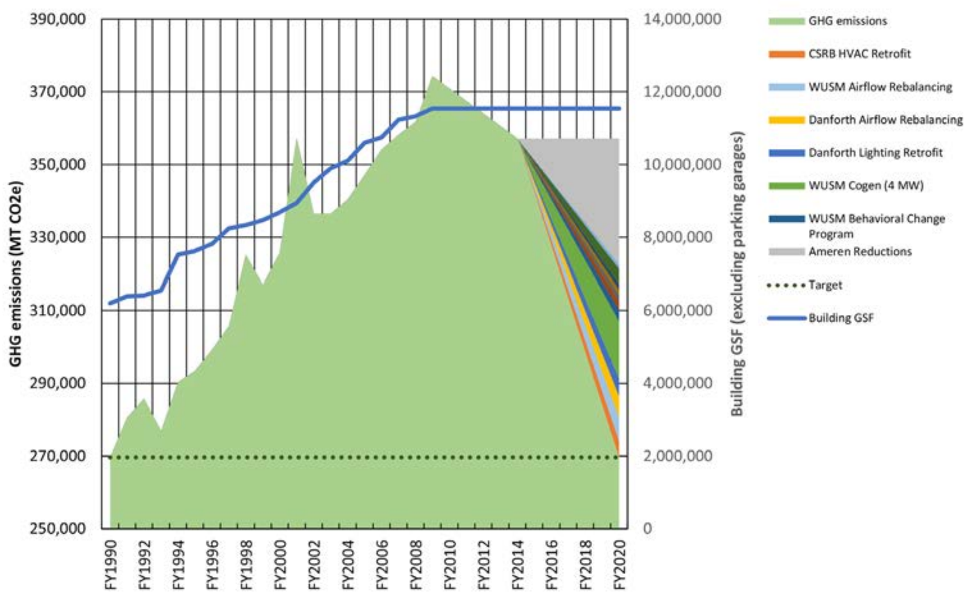
Highlighted cell indicates that project is NPV negative from micro-bundling perspective.

Emissions trajectories of the original goal established in 2010 (top of this page), as well as the four scenarios shown on the previous page outlined in red. The scenario labeled Option 4 was ultimately adopted as the updated 2020 Goal.

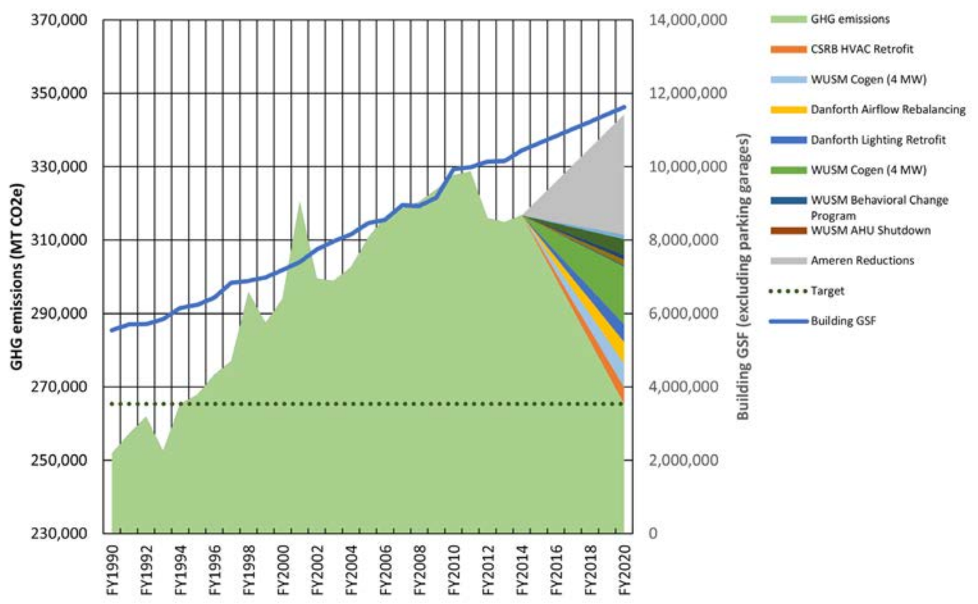
Current Goal: WUSTL with ERC Boundary Definition, ERC Baseline and No Growth After FY2009

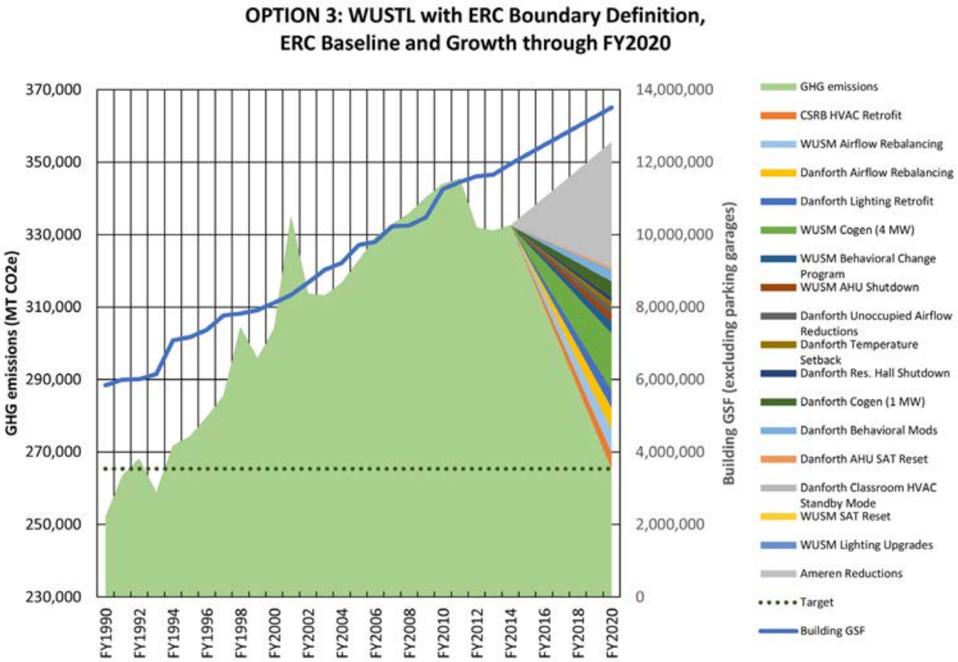


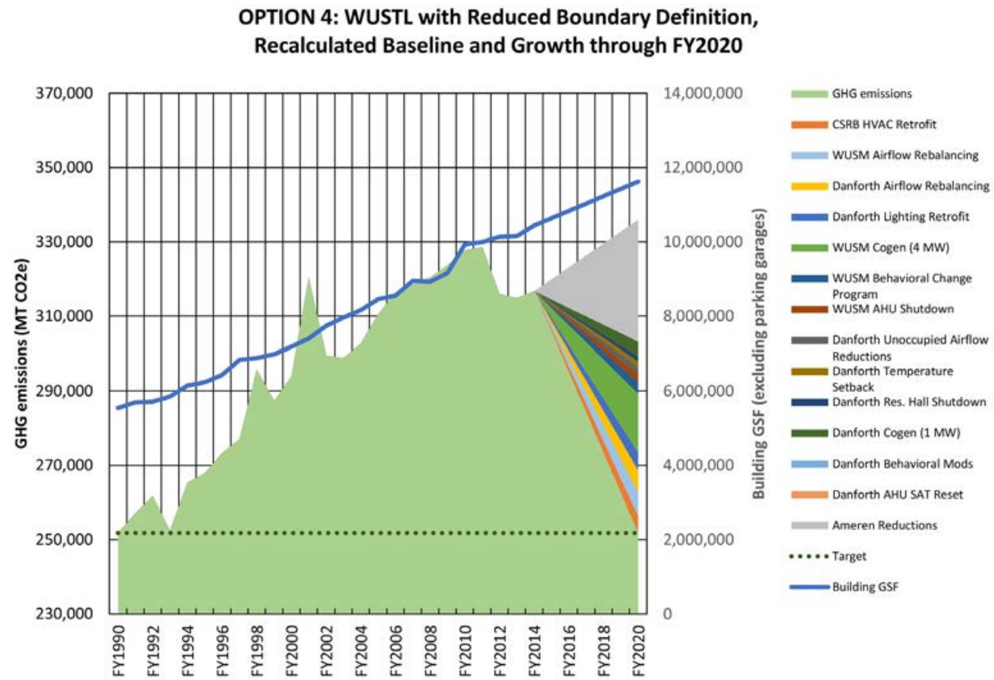
OPTION 1: WUSTL with Expanded Boundary Definition, Recalculated Baseline and No Growth After FY2009



OPTION 2: WUSTL with Reduced Boundary Definition, ERC Baseline and Growth through FY2020




OPTION 3: WUSTL with ERC Boundary Definition, ERC Baseline and Growth through FY2020
GHG emissions (MT CO2e)
Building GSF (excluding parking garages)
370,000
350,000
330,000
310,000
290,000
270,000
250,000
230,000
14,000,000
12,000,000
10,000,000
8,000,000
6,000,000
4,000,000
2,000,000
0
FY1990
FY1992
FY1994
FY1996
FY1998
FY2000
FY2002
FY2004
FY2006
FY2008
FY2010
FY2012
FY2014
FY2016
FY2018
FY2020
GHG emissions
CSRB HVAC Retrofit
WUSM Airflow Rebalancing
Danforth Airflow Rebalancing
Danforth Lighting Retrofit
WUSM Cogen (4 MW)
WUSM Behavioral Change Program
WUSM AHU Shutdown
Danforth Unoccupied Airflow Reductions
Danforth Temperature Setback
Danforth Res. Hall Shutdown
Danforth Cogen (1 MW)
Danforth Behavioral Mods
Danforth AHU SAT Reset
Danforth Classroom HVAC Standby Mode
WUSM SAT Reset
WUSM Lighting Upgrades
Ameren Reductions
Target
Building GSF


OPTION 4: WUSTL with Reduced Boundary Definition, Recalculated Baseline and Growth through FY2020
GHG emissions (MT CO2e)
Building GSF (excluding parking garages)
370,000
350,000
330,000
310,000
290,000
270,000
250,000
230,000
14,000,000
12,000,000
10,000,000
8,000,000
6,000,000
4,000,000
2,000,000
0
FY1990
FY1992
FY1994
FY1996
FY1998
FY2000
FY2002
FY2004
FY2006
FY2008
FY2010
FY2012
FY2014
FY2016
FY2018
FY2020
GHG emissions
CSRB HVAC Retrofit
WUSM Airflow Rebalancing
Danforth Airflow Rebalancing
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WUSM Cogen (4 MW)
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Danforth Cogen (1 MW)
Danforth Behavioral Mods
Danforth AHU SAT Reset
Ameren Reductions
Target
Building GSF

APPENDIX C: ENERGY SAVINGS COST MODEL AND ORDER OF IMPLEMENTATION

This table reports on the modeled profile for energy conservation measures (ECMs) recommended to support the selected scenario. Marginal net present value drives this information (ECMs are listed in descending order according to marginal net present value).

Order of Implementation	ECM Description	Estimated Implementation Cost	Maintenance Cost	Annual Energy Savings Estimate	Marginal Net Present Value	Marginal Simply Payback (years)	Marginal Annual Electric Reduction (kWh)	Marginal Annual Natural Gas Reduction (MMBtu)	Cumulative Implementation Cost
1	CSRB HVAC Retrofit	$1	$0	$475,251	$5,255,160	0.0	3,565,913	35,797	$1
2	WUSM Airflow Rebalancing	$2,120,000	$0	$654,723	$5,201,425	3.2	4,861,593	53,457	$2,120,001
3	Danforth Airflow Rebalancing	$3,700,624	$0	$650,899	$3,635,665	5.7	4,024,365	56,668	$5,820,625
4	Danforth Lighting Retrofit	$4,307,194	-$201,900	$272,897	$1,645,774	9.1	8,191,964	-23,098	$10,127,819
5	WUSM Cogen (4 MW)	$10,670,000	$175,200	$996,190	$1,395,779	13.0	35,092,112	-188,203	$20,797,819
6	WUSM Behavioral Change Program	$150,000	$75,888	$177,038	$1,287,483	1.5	5,845,023	-22,543	$20,947,819
7	WUSM AHU Shutdown	$1,930,000	$30,000	$329,789	$1,213,475	6.4	-879,457	54,331	$22,877,819
8	Danforth Unoccupied Airflow Reductions	$287,967	$30,000	$155,119	$1,059,465	2.3	1,329,635	16,459	$23,165,786
9	Danforth Temperature Setback	$694,566	$0	$153,579	$997,810	4.5	862,872	16,456	$23,860,352
10	Danforth Res. Hall Shutdown	$99,189	$10,000	$98,371	$925,024	1.1	1,521,247	2,627	$23,959,541
11	Danforth Cogen (1 MW)	$3,334,000	$40,000	$341,204	$750,496	11.1	8,595,418	-36,670	$27,293,541
12	Danforth Behavioral Mods	$150,000	$75,000	$124,037	$616,490	3.1	5,374,846	-16,253	$27,443,541
13	Danforth AHU SAT Reset	$858,866	$0	$90,206	$157,551	9.5	626,709	10,005	$28,302,406
14	Danforth Classroom HVAC Standby Mode	$758,849	$0	$72,202	$77,721	10.5	505,694	5,954	$29,061,256
15	WUSM SAT Reset	$1,010,000	$0	$33,435	-$598,350	30.2	159,855	4,167	$30,071,256
16	WUSM Lighting Upgrades	$7,590,000	$0	$330,882	-$2,866,108	22.9	11,863,180	-43,864	$37,661,256
17	WUSM Solar (2 MW)	$6,000,000	$40,000	$233,147	-$3,373,426	31.1	3,084,393	0	$43,661,256
18	Danforth Solar (3 MW)	$9,000,000	$60,000	$288,778	-$5,776,432	39.3	4,626,590	0	$52,661,256

Notes:
- Solar project costs assume that the project will obtain 30% federal tax credits.
- Project costs do not include an allowance for Ameren energy efficiency incentives.
- Project costs do not include 10% federal tax credits available for Cogen.
- Project costs include soft costs such as Design and Commissioning fees, WUSM administration fees, 10% contingency.
- Project costs, energy savings and maintenance costs are based on November 2014 dollars.
- Energy savings include water and sewer cost reductions.
- NPV values are based on 15 year duration, 3.5% rate of inflation for electricity, 1.65% rate of inflation for natural gas and 6% cost of capital. Annual cost of maintenance is included.
- Simple Payback values are adjusted based on annual cost of maintenance, but do not include and rate of inflation adjustment.
- New construction – Using modeled EUI when available. If not available, using an approximation of 30% better than ASHRAE 90.1-2010 (roughly equivalent to 42% better than ASHRAE 90.1-2007).

Sensitivity Analysis: Impact of utility inflation on net present values of energy conservation measures. The column shown in red employed the utility inflation assumptions from the university's financial modeling guidelines that were current at the time of the analysis (2014).

ECM Description	New NPV (based on WUSTL Standard, 3.5% electric inflation, 1.65% natural gas inflation)	NPV (based on 3% electric inflation, 3% natural gas inflation)	NPV (based on 5% electric inflation, 3% natural gas inflation)	NPV (based on 3% electric inflation, 1.65% natural gas inflation)
CSRB HVAC Retrofit	NA	NA	NA	NA
WUSM Airflow Rebalancing	$5,201,425	$5,420,439	$5,991,098	$5,067,951
Danforth Airflow Rebalancing	$3,635,665	$3,885,948	$4,413,438	$3,512,288
Danforth Lighting Retrofit	$1,645,774	$1,317,820	$2,068,804	$1,470,123
WUSM Cogen (4 MW)	$1,395,779	-$761,169	$3,154,950	$479,819
WUSM Behavioral Change Program	$1,287,483	$1,004,895	$1,577,556	$1,153,541
WUSM AHU Shutdown	$1,213,475	$1,576,973	$1,554,544	$1,218,721
Danforth Unoccupied Airflow Reductions	$1,059,465	$1,146,400	$1,238,710	$1,037,875
Danforth Temperature Setback	$997,810	$1,085,364	$1,174,942	$976,858
Danforth Res. Hall Shutdown	$925,024	$907,997	$1,054,853	$890,675
Danforth Cogen (1 MW)	$750,496	$268,477	$1,295,531	$510,274
Danforth Behavioral Mods	$616,490	$414,261	$820,671	$521,432
Danforth AHU SAT Reset	$157,551	$212,113	$260,889	$146,143
Danforth Classroom HVAC Standby Mode	$77,721	$102,418	$164,683	$63,157
WUSM SAT Reset	-$598,350	-$573,893	-$560,996	-$601,366
WUSM Lighting Upgrades	-$2,866,108	-$3,410,258	-$2,320,383	-$3,121,024
WUSM Solar (2 MW)	-$3,373,426	-$3,471,302	-$3,052,839	-$3,471,302
Danforth Solar (3 MW)	-$5,776,432	-$5,897,662	-$5,379,350	-$5,897,662

APPENDIX D: UNIVERSITY GHG PROTOCOL

Washington University in St. Louis examined multiple sources for guidance on an appropriate GHG protocol for its space use, including The World Resources Institute, the World Business Council for Sustainable Development, U.S. General Services Administration, and other universities with a similar range of complexity of ownership and leasing. This research suggests the following as the most responsible and best fit for the many forms of building ownership, leasing and lessor relationships that characterize Washington University in St. Louis:

- Except in spaces smaller than 10,000 GSF (considered de minimis), Washington University in St. Louis is responsible for GHG emissions where it owns (fee simple), operates and occupies buildings. In the case of buildings for which it has partial ownership, such responsibility is proportionate to the space that Washington University in St. Louis owns.

- Except in spaces smaller than 10,000 GSF (considered de minimis), Washington University in St. Louis has no GHG emissions responsibility as lessee of a property where it does not pay utilities and the building owner controls operations and maintenance.

- Except in spaces smaller than 10,000 GSF (considered de minimis), Washington University in St. Louis has responsibilities for GHG emissions associated with utility payments (may be exclusive to a subset of all utilities) where it is a lessee and the terms of the lease pass utility payment to the university.

- As a lessor (to other entities), and except in spaces smaller than 10,000 GSF (considered de minimis), Washington University in St. Louis has responsibilities for GHG emissions associated with utility payments where it has O&M and utility generation-or-payment responsibility. This is the case for all of the utility services for which Washington University in St. Louis maintains responsibilities.

- As a lessor (to other entities), and except in spaces smaller than 10,000 GSF (considered de minimis), Washington University in St. Louis does not have responsibilities for GHG emissions associated with utility payments where the lessee has such payment responsibility.