Duke | Facilities Management
Utilities & Engineering Services

Looking Back and Looking Forward: Duke University's Changing Energy Infrastructure and the Pursuit of Climate Neutrality

Triangle ASHRAE
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Outline

- Overview of Campus Energy & Utility Profile
- Where Are We Headed and Why?
- How Are We Getting there? - Supply Side & Demand Side Options
- Climate Action Plan Energy Initiatives & Impact of Options
- Conclusions

Duke's Campus Energy Profile

A City Within a City

Portfolio Summary – Duke Customers that We Serve

Building Type	Building Gross Square Footage	# Buildings
University (classroom, admin., etc.)	7,071,293	172
Hospital & Center for Living	3,750,874	24
Dormitories	2,050,695	29
Central Campus	373,392	41
School of Medicine/ Nursing	2,864,617	51
Parking Structures	3,848,232	6
Utility Facilities	143,905	4
Total	**20,103,008**	**327**

Scale of Duke’s Campus Utilities

40,000+
People
on
Campus Daily

20 MGSF
of
Buildings &
garages

Steam/Hot Water
Space Heating,
Humidity Control, &
Equipment Sterilization

365K PPH

Chilled Water
Space Cooling,
Humidity Control, &
Equipment Cooling

42K tons

Electricity
Buildings, Site
Lighting, & Utility
Plants

83 MW

Domestic Water
Building Use, Steam
Plant, & Cooling
Towers

2M Gal/day

 = 10,000 Typical Homes (~2,000 SF)

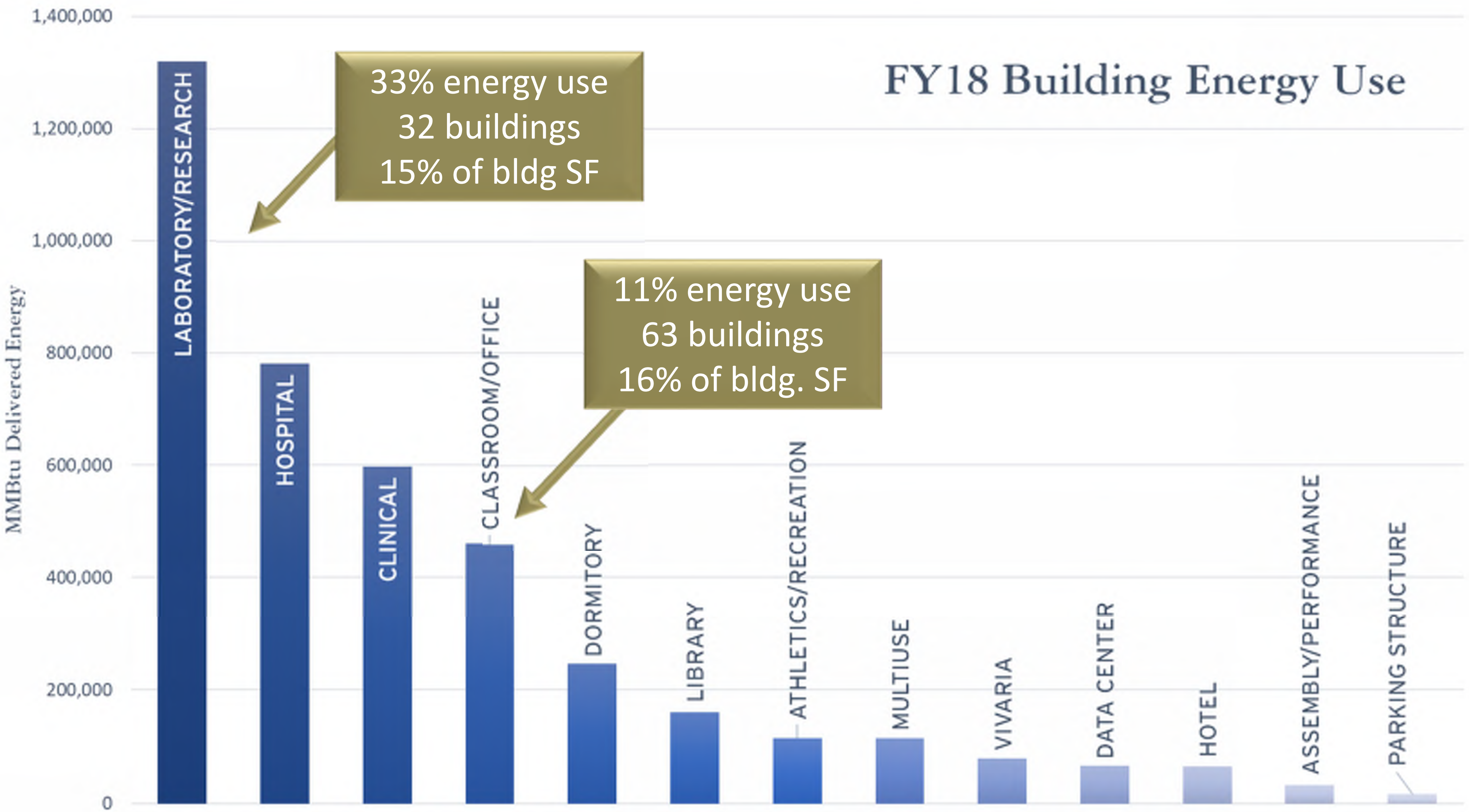
These Countries Use Less Energy Than our Durham Campus

Duke's campus uses more energy than 24 countries

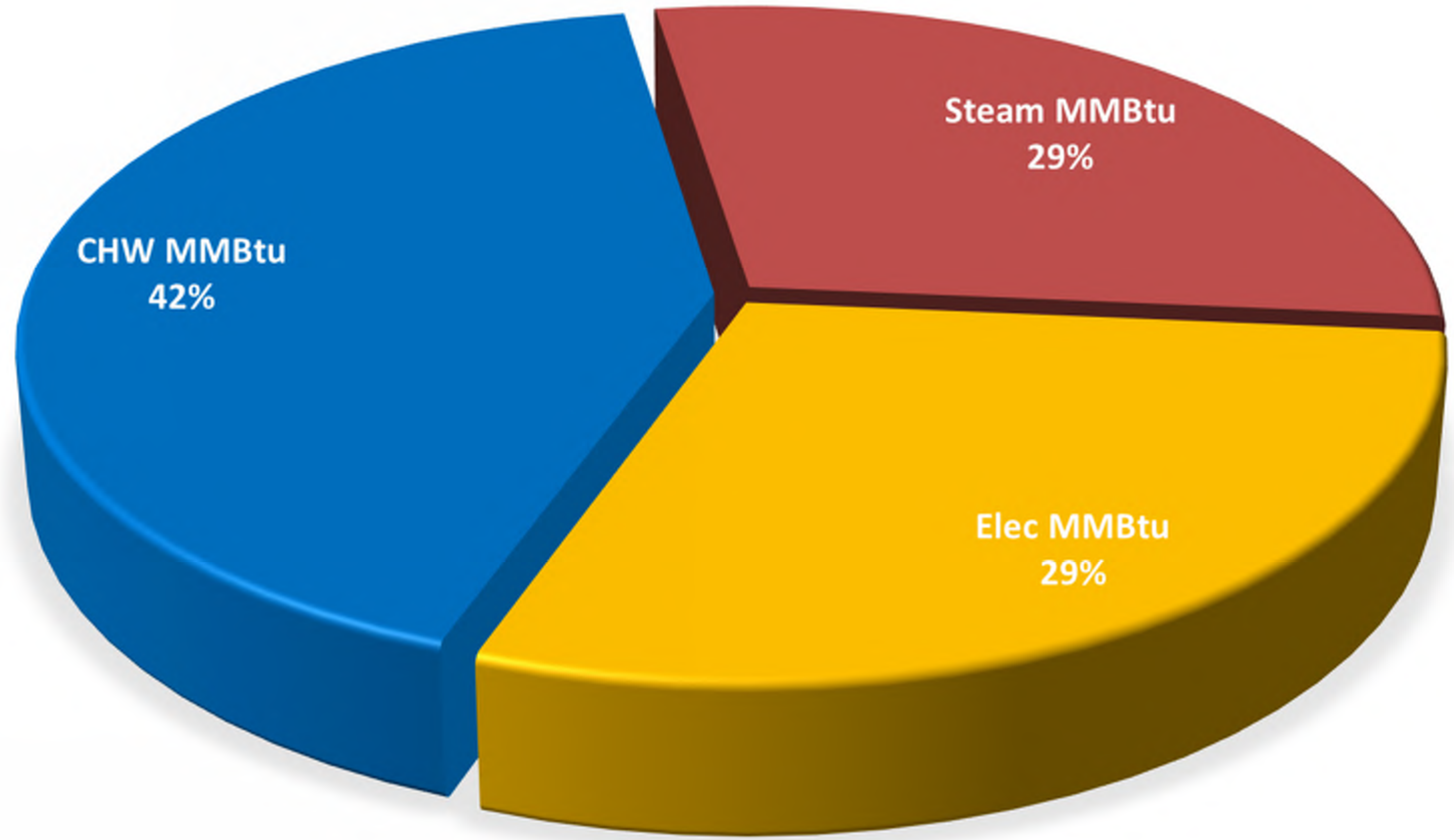
Rank (Ascending)	Country	Quad Btu (2015 Data)
1	Falkland Islands	0
2	Kiribati	0
3	Nauru	0
4	Niue	0
5	Saint Helena	0
6	Cook Islands	0.001
7	Montserrat	0.001
8	St. Pierre and Miquelon	0.001
9	British Virgin Islands	0.002
10	Dominica	0.002
11	Samoa	0.002
12	Sao Tome & Principe	0.002
13	Sierra Leone	0.002
14	Vanuatu	0.002
15	Comoros	0.003
16	St. Vincent & the Grenadines	0.003
17	Solomon Islands	0.003
18	Tonga	0.003
19	Turks & Caicos	0.003
20	Western Sahara	0.004
21	American Samoa	0.005
22	Chad	0.005
23	Grenada	0.005
24	Guinea-Bissau	0.005
25	**Duke University**	**0.0057**

Source: U.S. Energy Information Administration (EIA)

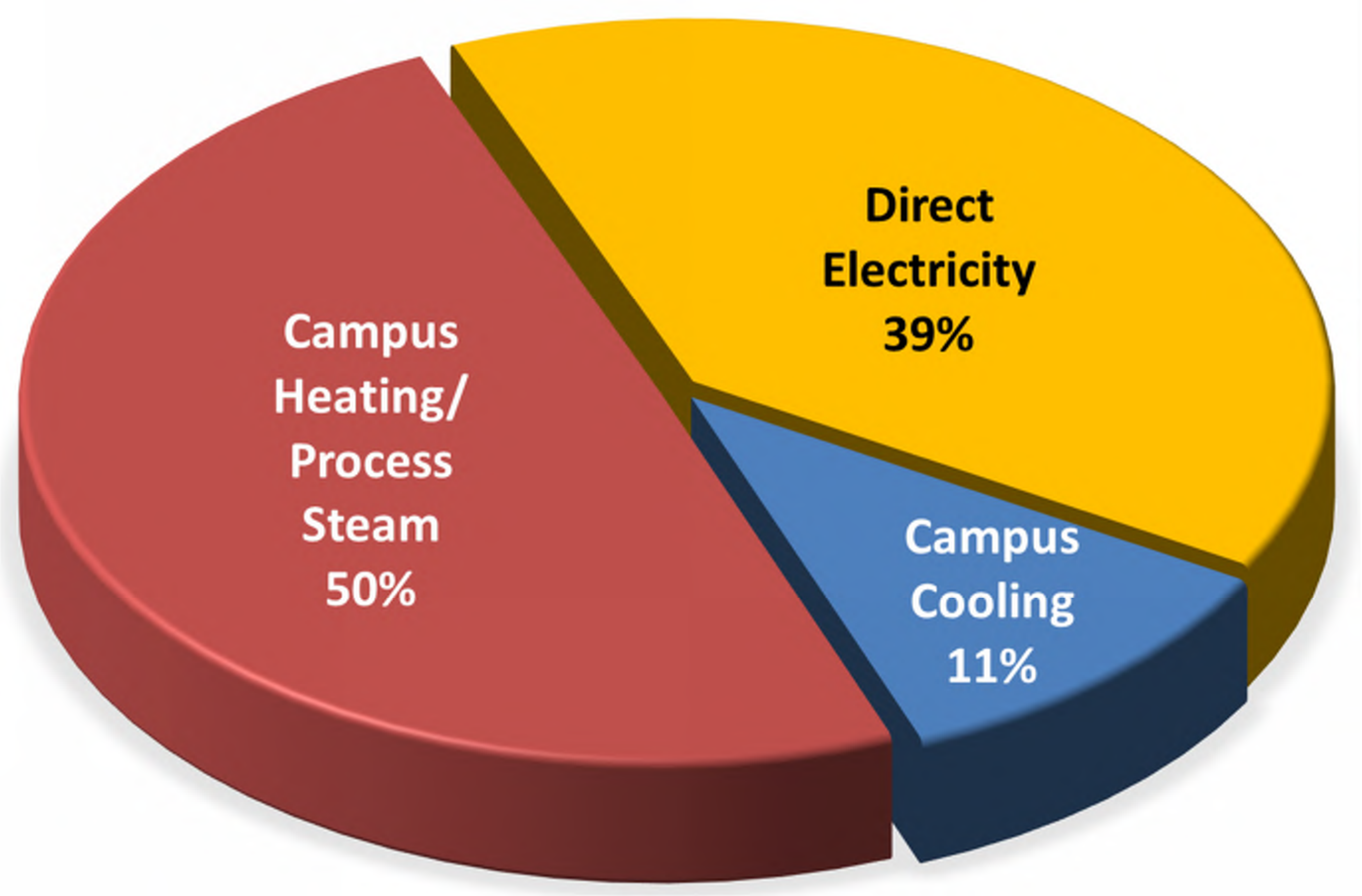
Where Does this Energy Go?



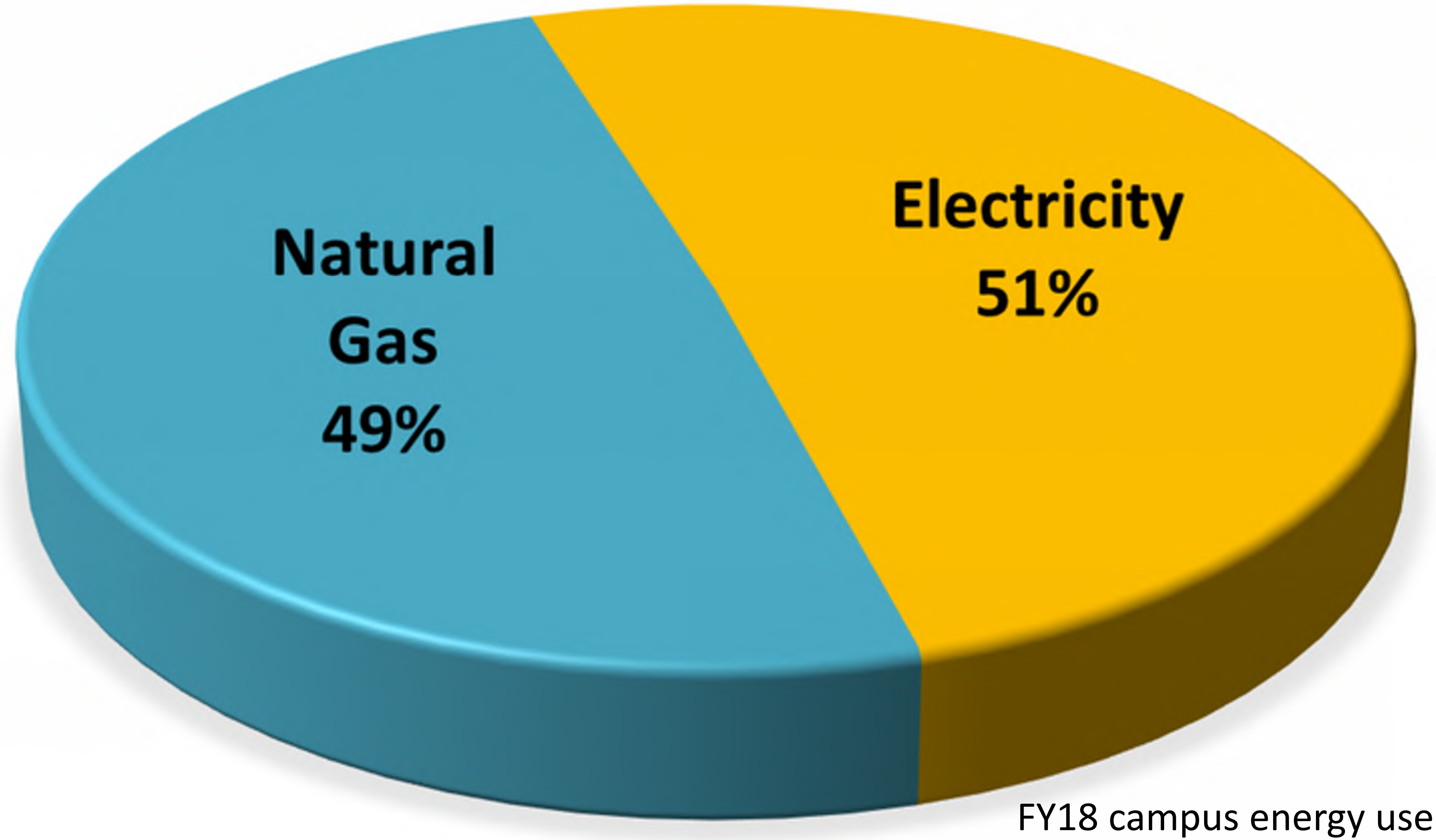
Campus Building **Site** Energy



Campus Utility **Source** Energy

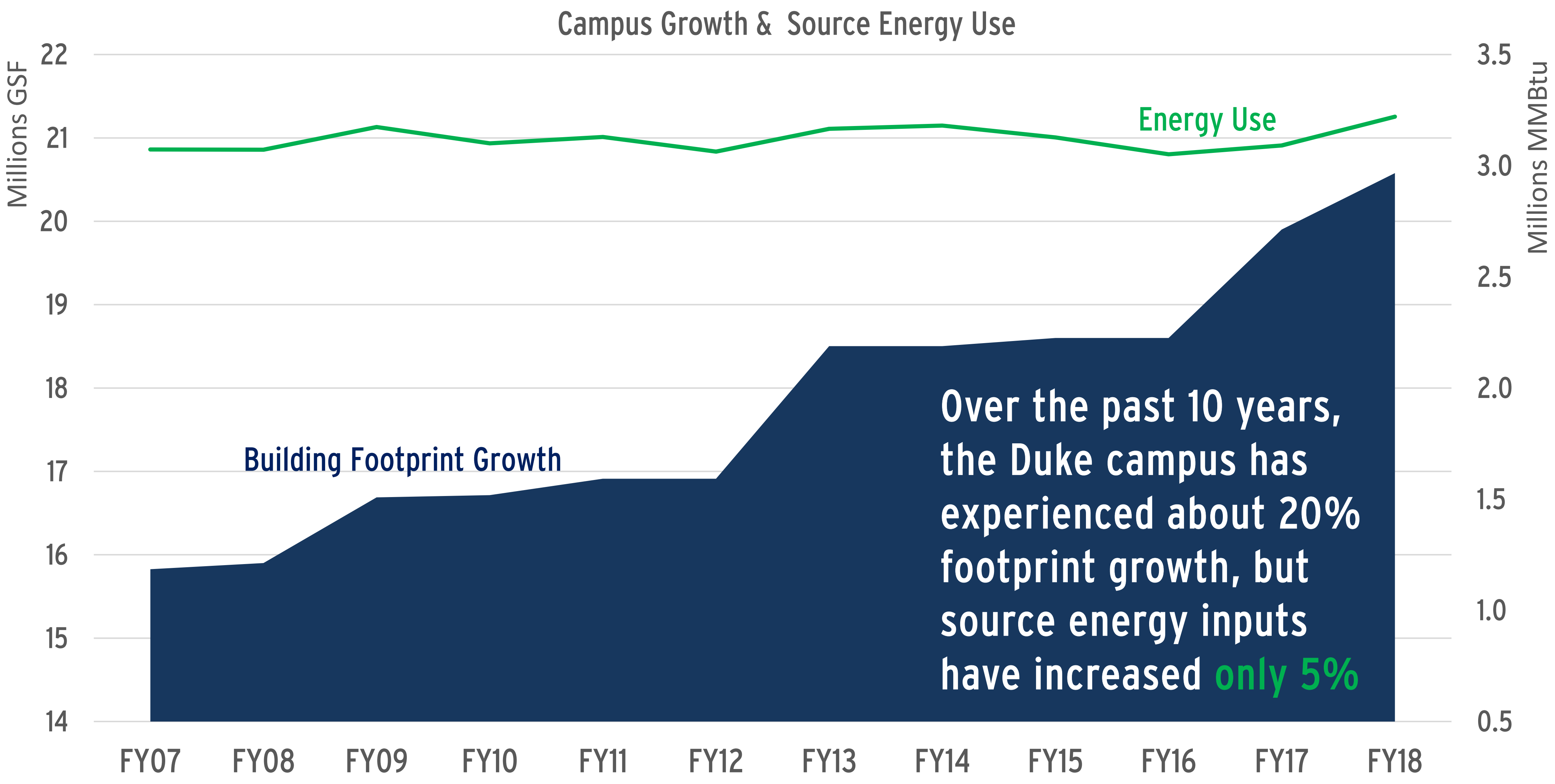


Campus Source Energy



FY18 campus energy use:
3,220,427 MMBtu

Balanced Portfolio of Energy Strategies = Effective Stewardship



Energy & Water Utility Systems

It's a lot more interesting than it looks.

Steam & Hot Water

System Purpose

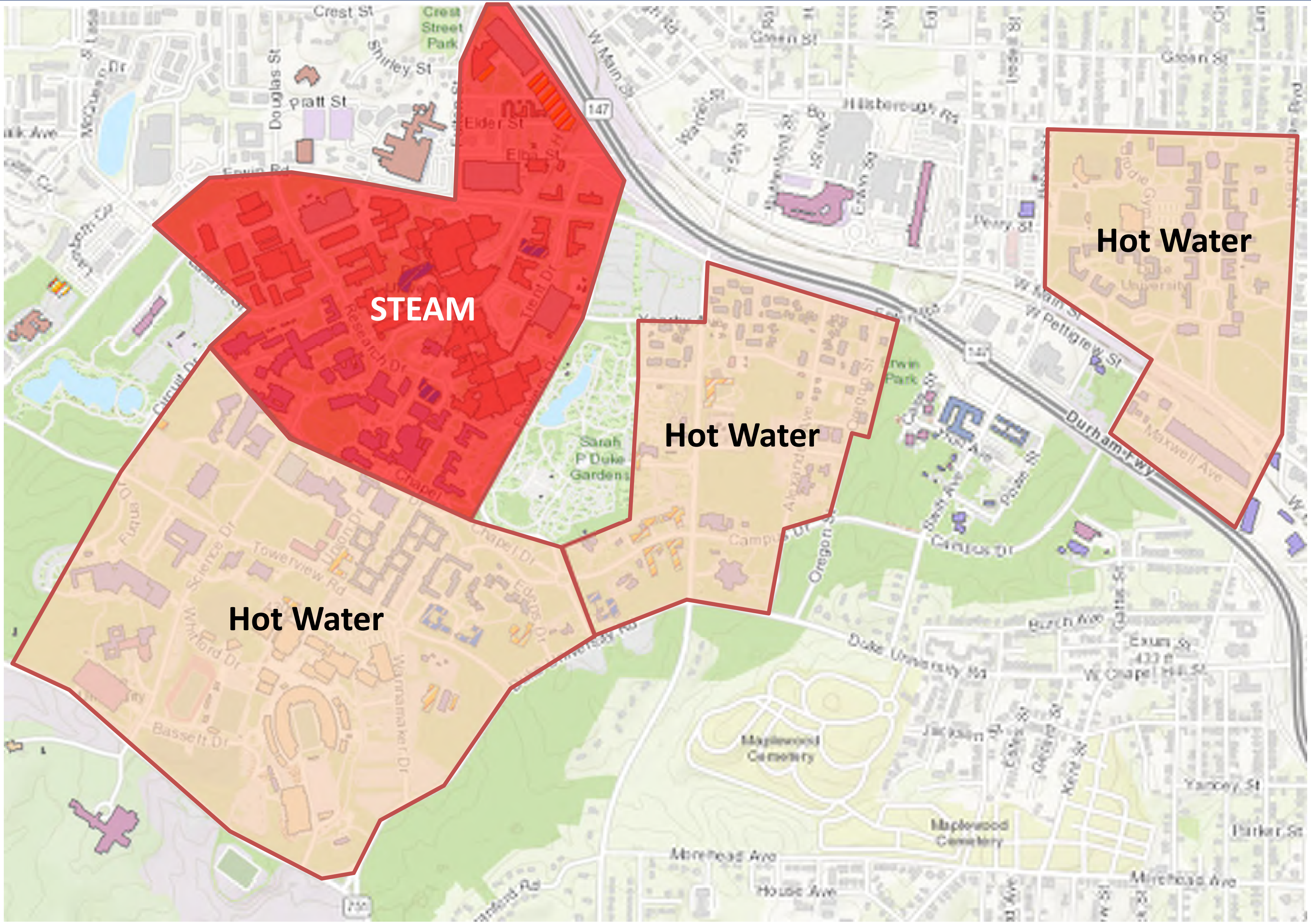
Steam/hot water provides building heat, humidity control, domestic hot water, and equipment sterilization

System Highlights

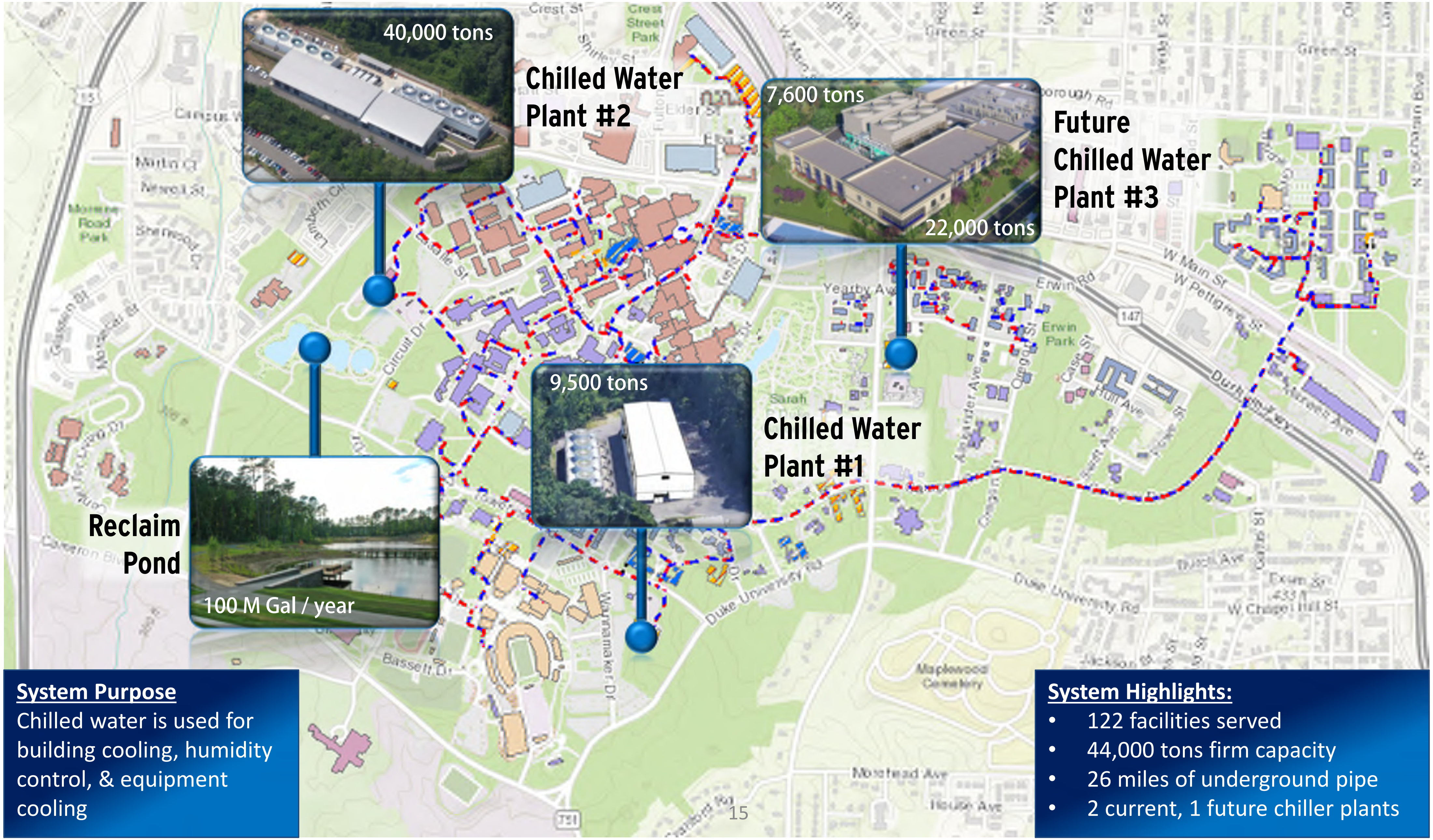
- 365K PPH peak demand
- 142 facilities served
- 29 miles of underground piping
- Coal as fuel used until 2011

Steam to Hot Water Conversion

- Began converting buildings in 2015
- Total conversion not cost effective or practical
- Conversion will take 10-20 years
- Benefits of Hot water
  - More efficient than steam
  - Lower construction cost
  - Lower maintenance cost
  - Takes up less space in buildings



Chilled Water



System Purpose

Chilled water is used for building cooling, humidity control, & equipment cooling

System Highlights:

- 122 facilities served
- 44,000 tons firm capacity
- 26 miles of underground pipe
- 2 current, 1 future chiller plants

Electricity

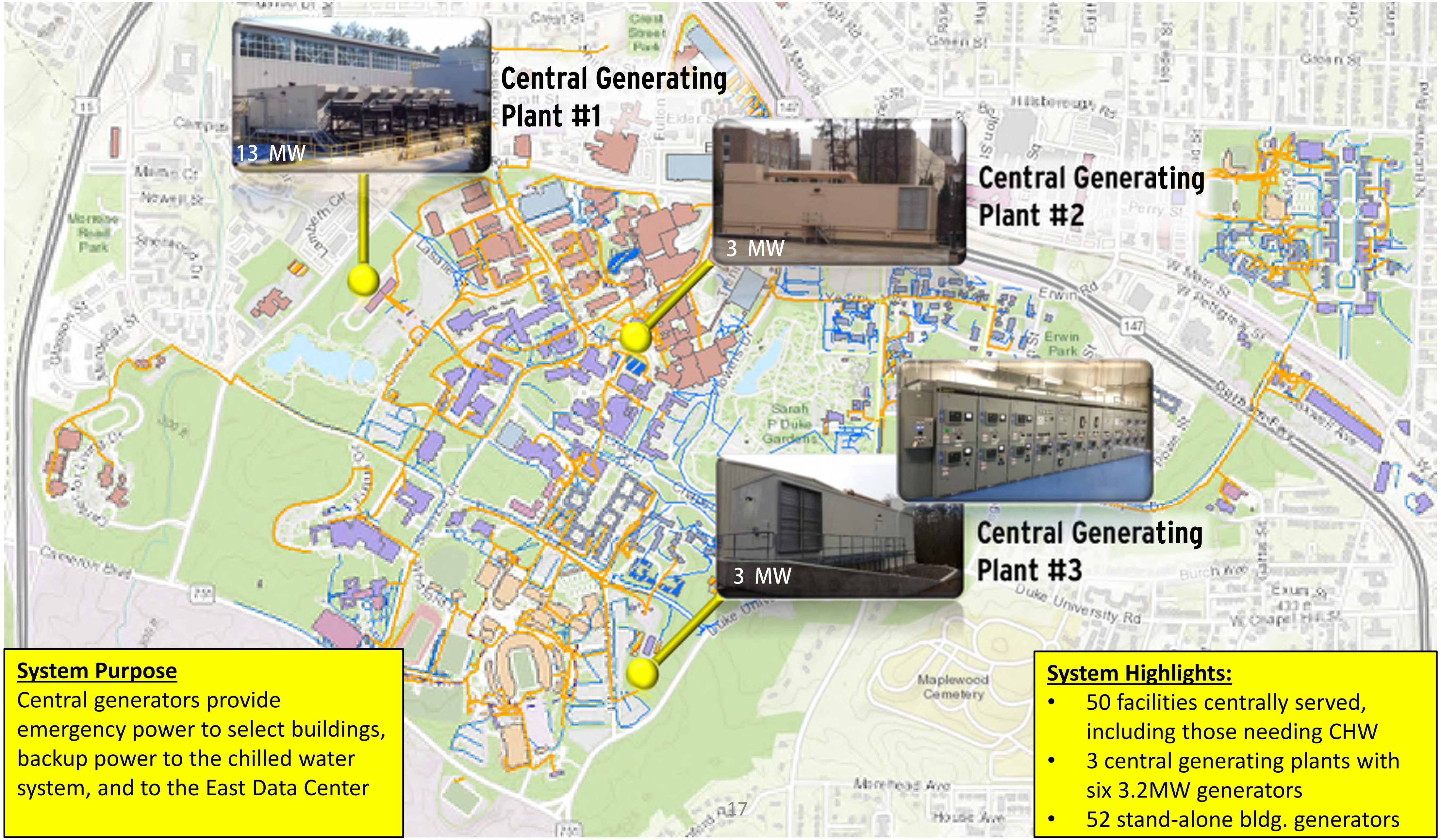
System Purpose

Electricity to buildings, site lighting, & utility plants. Majority is underground distribution at 12.5KV

System Highlights:

- 82 MW peak demand
- 252 facilities served
- 61 miles of ductbank
- Est. 500 miles of wire

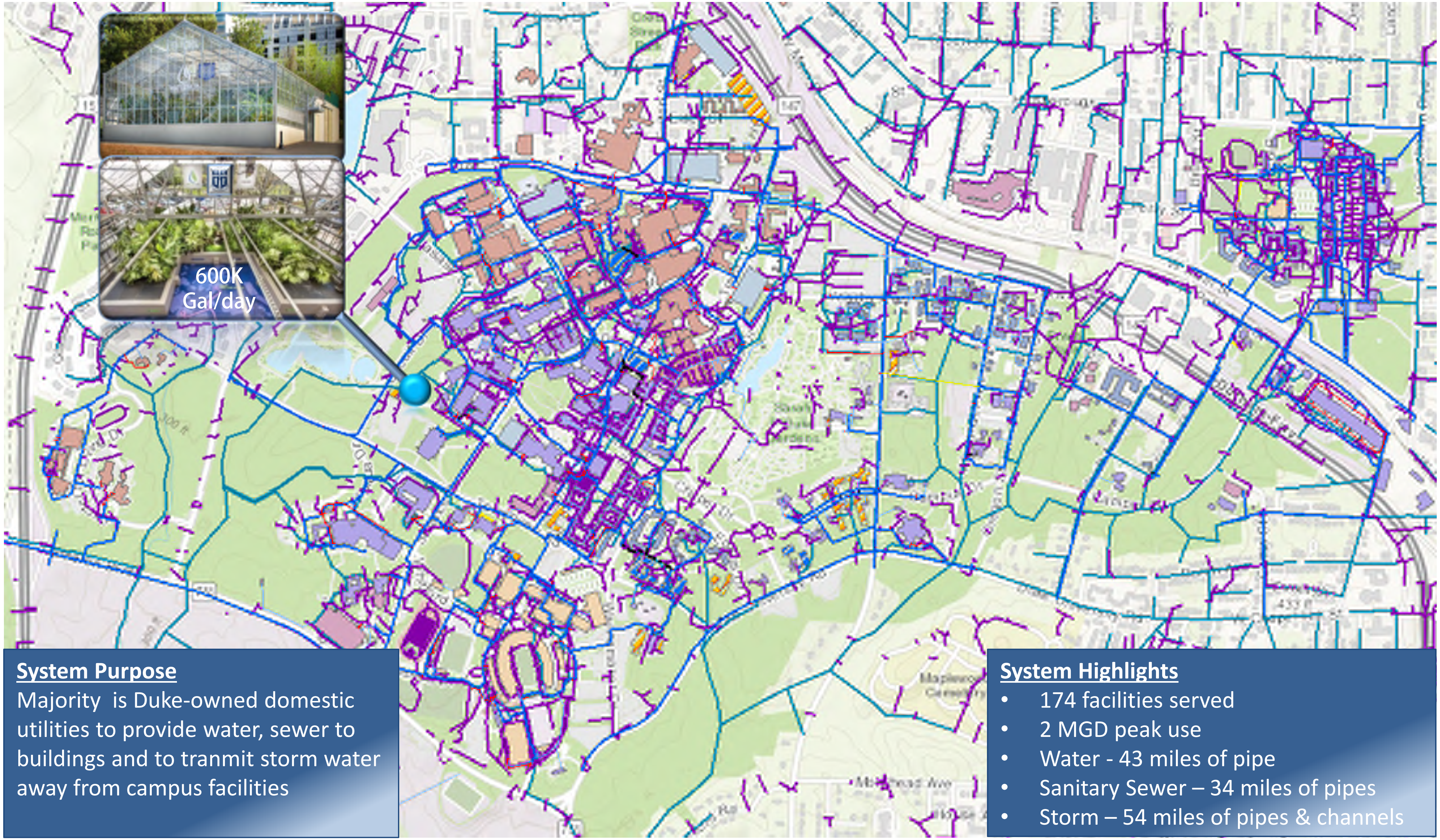
Emergency / Standby Power



System Purpose
Central generators provide emergency power to select buildings, backup power to the chilled water system, and to the East Data Center

System Highlights:
- 50 facilities centrally served, including those needing CHW
- 3 central generating plants with six 3.2MW generators
- 52 stand-alone bldg. generators

Domestic Water, Sanitary Sewer & Storm Water



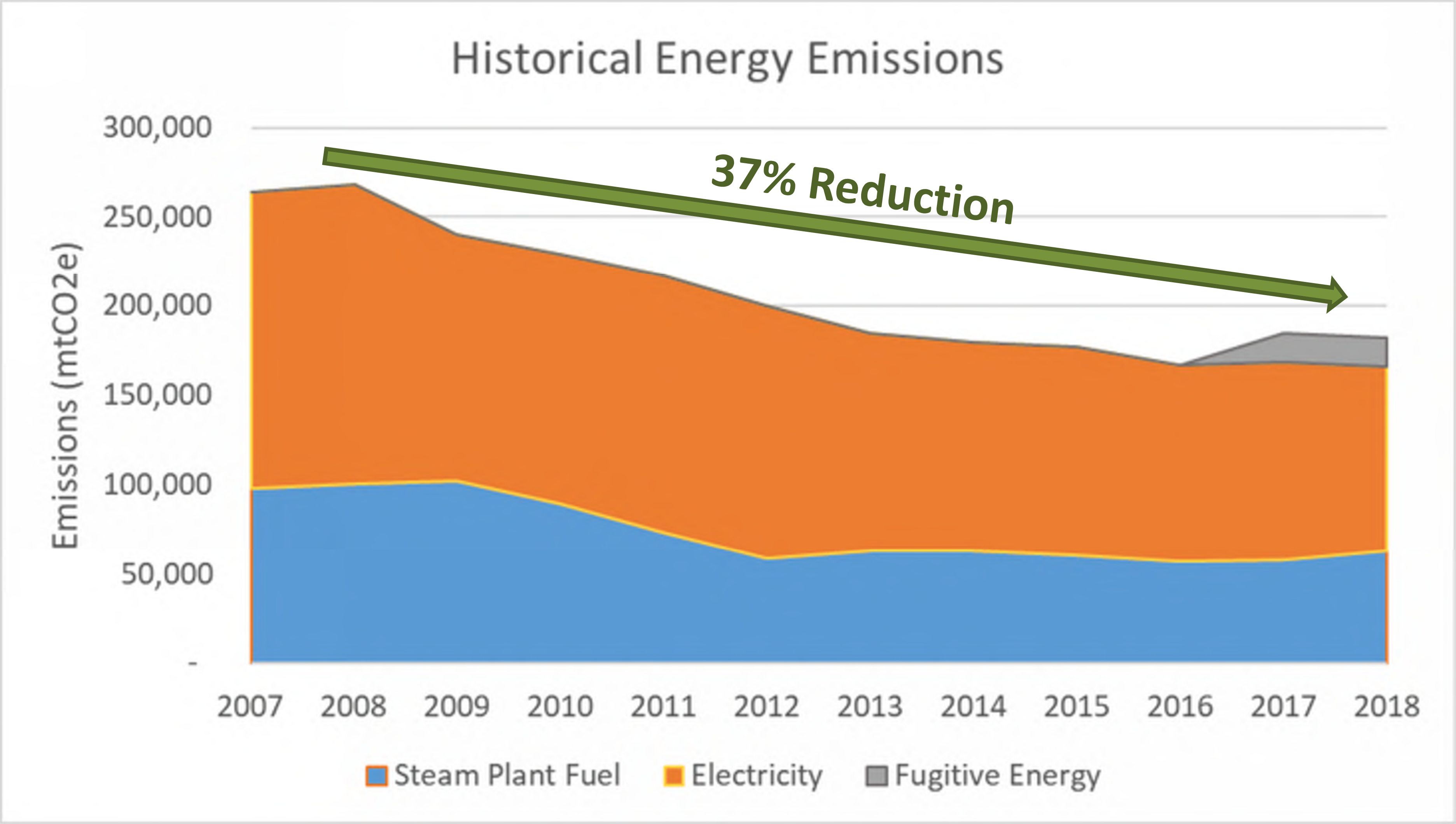
System Purpose

Majority is Duke-owned domestic utilities to provide water, sewer to buildings and to tranmit storm water away from campus facilities

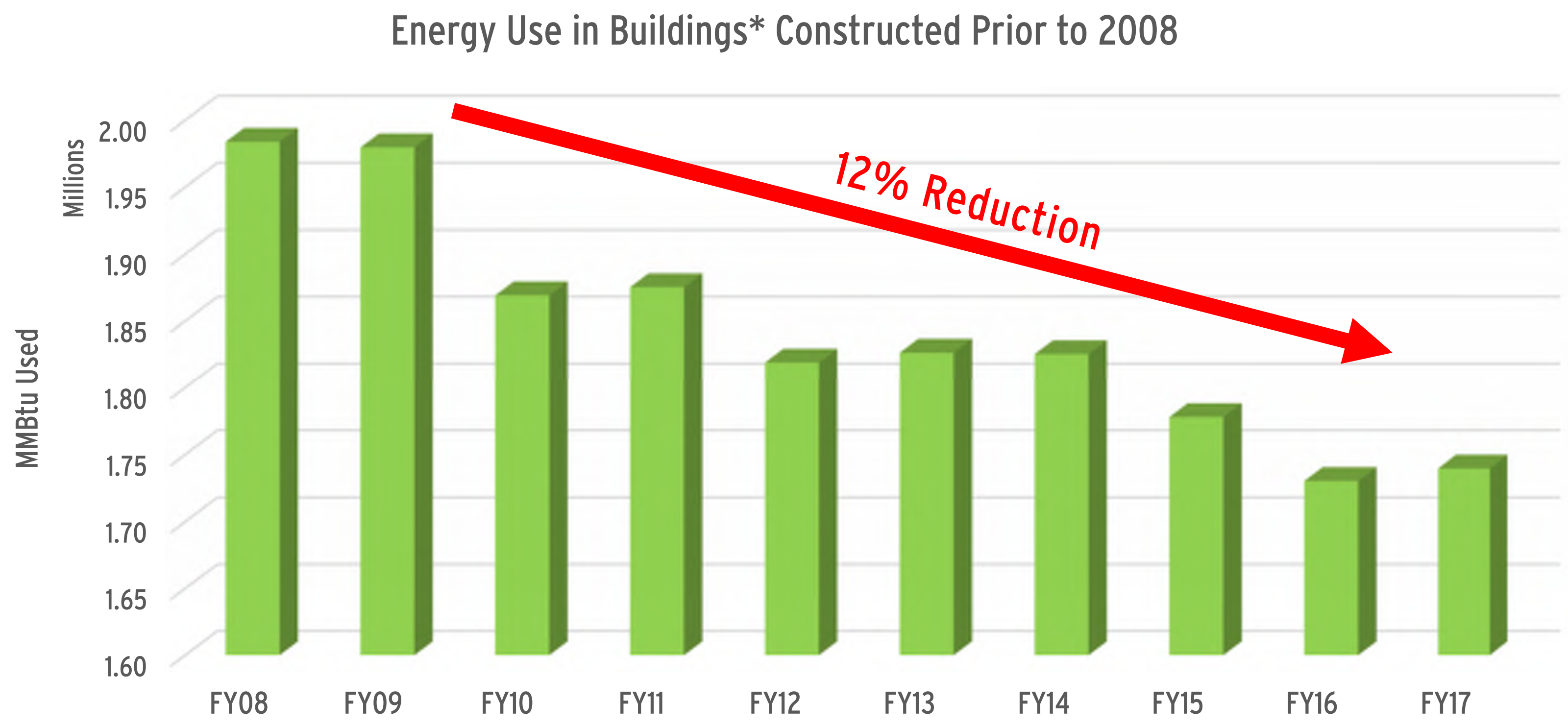
System Highlights

- 174 facilities served
- 2 MGD peak use
- Water - 43 miles of pipe
- Sanitary Sewer – 34 miles of pipes
- Storm – 54 miles of pipes & channels

Energy-Related GHG History



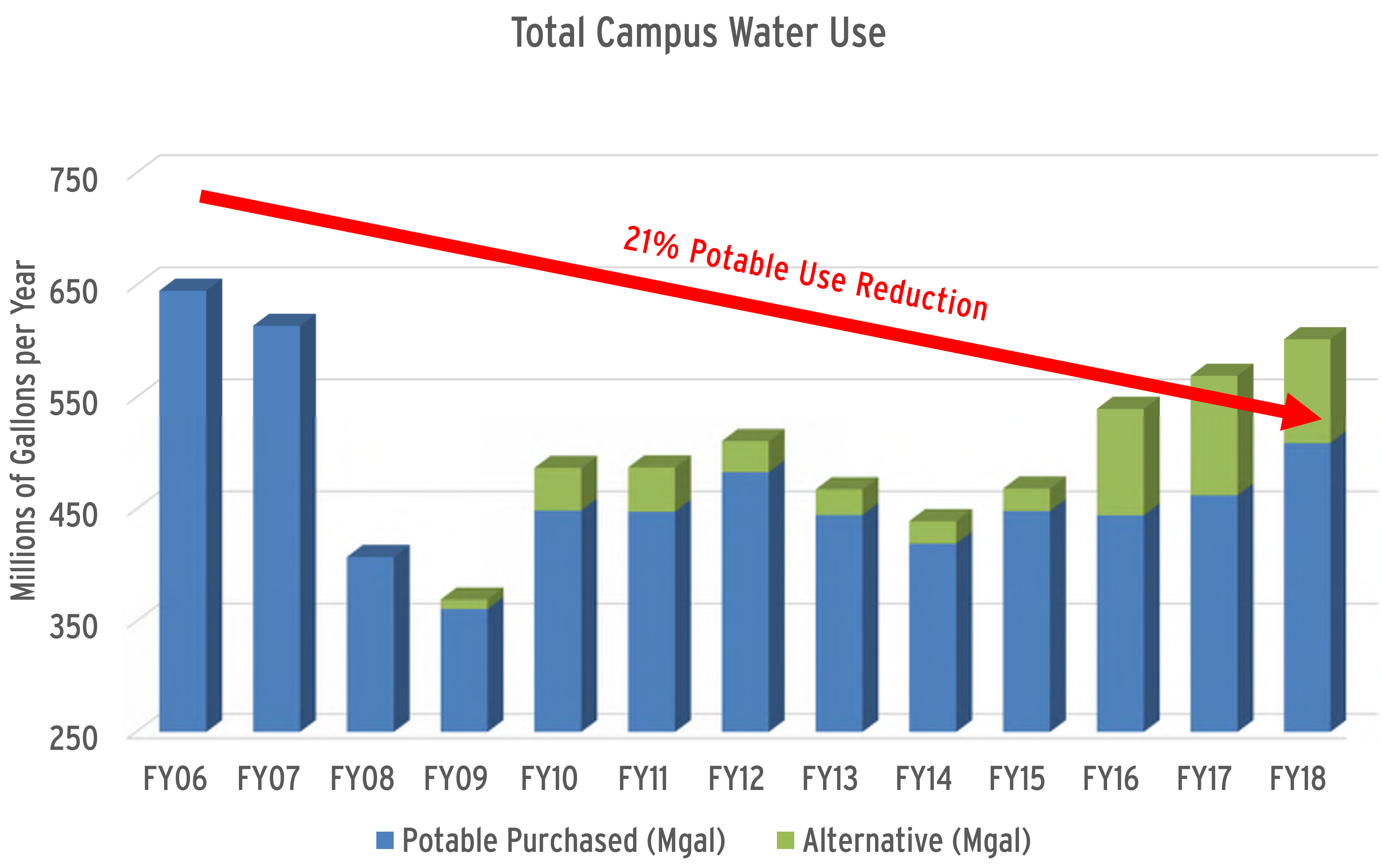
Energy Efficiency Improvements



- ✓ HVAC Temperature and Scheduling
- ✓ LED Site Lighting (ongoing)
- ✓ Retro-Commissioning (ongoing)
- ✓ Thermal Plant Efficiency
- ✓ Condensate Heat Recovery
- ✓ Parking Deck LED lighting (ongoing)
- ✓ Steam, Electric, Water metering upgrades
- ✓ Building Energy Audits
- ▪ District Steam to Hot Water Conversion
- ▪ Renewables Planning

*Includes University & SOM Buildings only

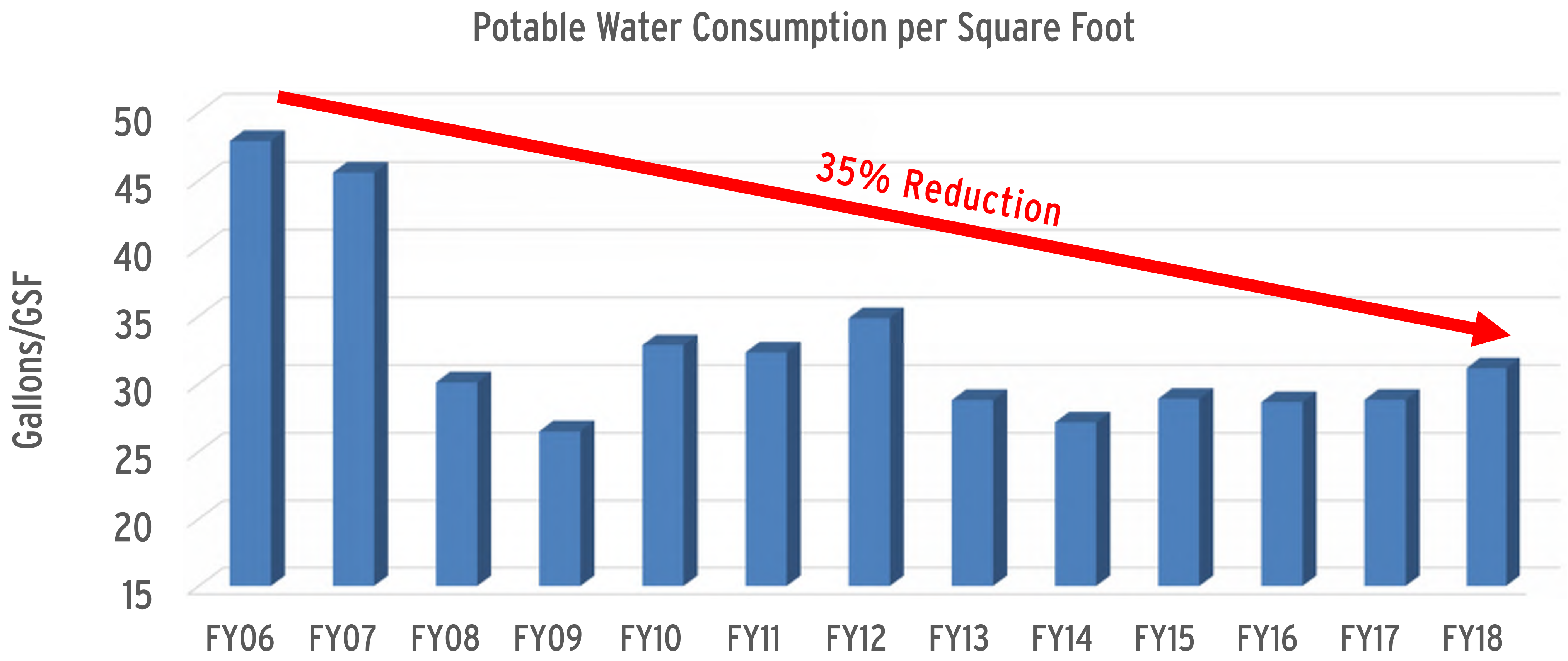
Water Efficiency Improvements



Water Project Highlights

- ✓ Building Audits
- ✓ Hardware Replacement
- ✓ Water Reclaim piping system
- ✓ Cyclical process water cooling
- ✓ Cooling tower water recovery
- ✓ Showerhead giveaway
- ✓ Condensing Economizer
- ✓ Water Reclamation Pond

Water Efficiency Improvements



2018 Energy & Utility Needs Analysis:

Let's Make it Better.

What Frames our Energy & Utility Plans and Design?

- Safety
  - Paramount to all system design and operation
- Campus Growth
  - Assess the ability of the campus utility infrastructure to meet the current demand and consumption for energy and water, and the near and long term future demand and consumption stemming from planned campus growth
- Resiliency & Reliability
  - Identify major infrastructure investments needed to maintain high level of reliability
  - Evaluate normal and emergency operational requirements for several different types of major utility system interruptions, the ability of the campus to recover from such an event, and particularly, the impact to hospital, clinic, research, and housing facilities
- Carbon Impact
  - Evaluates the carbon impact of meeting these energy and water needs, and how they relate to Duke's greenhouse gas neutrality commitment.

Energy & Utility Needs Analysis Categories

- Current Needs
  - Immediate needs due to campus growth and steam to hot water conversion
    - Hot Water Production
    - Chilled Water Emergency Power

- Resiliency / Reliability
  - Methods to provide back up utilities for major loss of an external utility (electricity, natural gas, city water)
  - Improvement to reliability of existing utility production or distribution assets

- Growth
  - Short term needs due to known projects
  - Long term needs based on annual growth projection and an assumed mix of building types

- Renewal
  - Replacement or retirement of utility production or distribution assets

- Efficiency Gains
  - Building & utility systems efficiency measures that can reduce demand

Other Energy or Utility Needs Impacting Planning

- Resiliency / Reliability
  - Second source of steam at North Pavilion zone
  - Ability to shutdown West Plant in summer for maintenance
  - Backup fuel or heating source for ECSP

- Renewal
  - Eliminate old poorly insulated steam distribution
    - Loses $350K per year in heat
    - Requires up to $10M investment to keep in operation
  - Retirement of aging boilers # 4 & 5 at WCSP
    - Nearing end of life
    - Oil-only boilers for back up use only
    - Air permit only allows operation of maintenance or an emergency

Options to Meet Needs & Recommendations

Energy & Utility Needs & Options

Immediate Needs

Future Needs

Energy & Utility Needs & Options

Hot Water

- Steam Hx — Heat exchangers used to produce hot water from steam produced by existing boilers
- Co-Gen — Co-generation of power with hot water and/or steam produced from waste heat
- HRC — Heat produced by Heat Recovery Chillers during the production of chilled water

Steam

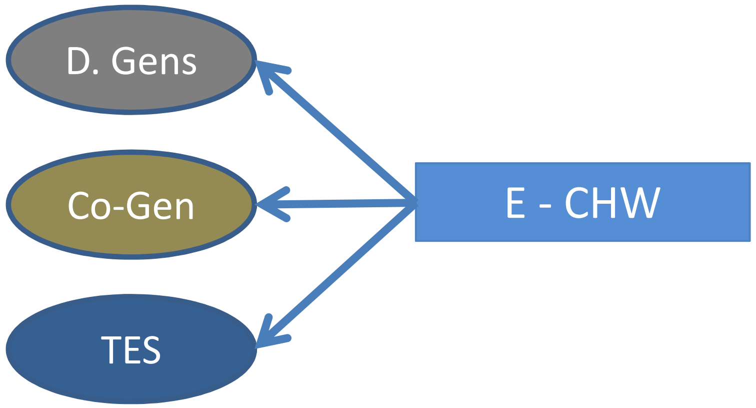
- G. Boilers — Gas-fired boilers to produce steam which can be fueled by biogas
- Co-Gen — Co-generation of power with hot water and/or steam produced from waste heat
- E. Boilers — Electric boilers to produce steam which can be supplied partially by solar power

Energy & Utility Needs & Options

Diesel generators distributed across campus to support particular buildings/systems

Co-generation of power with hot water and/or steam produced from waste heat

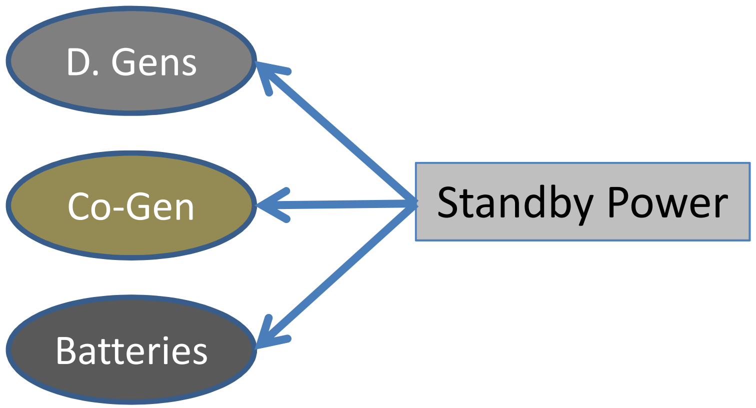
Chilled water Thermal Energy Storage tank, produced at night, used during the day



Diesel generators distributed across campus to support particular buildings/systems

Co-generation of power with hot water and/or steam produced from waste heat

Batteries store power and discharge when needed



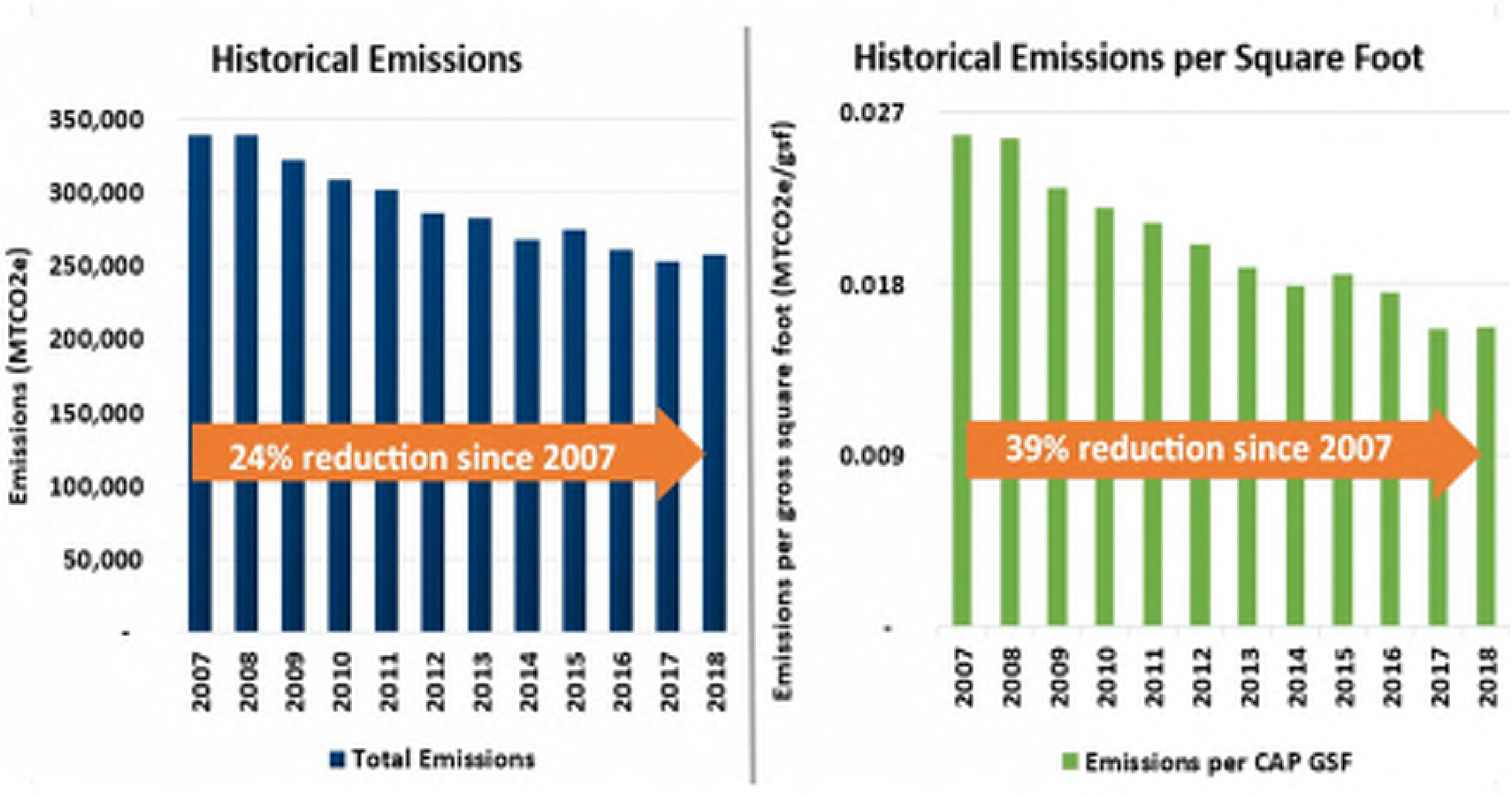
Overview of Potential Solutions

- Steam/Hot Water
  - Continue steam to hot water conversions, expand scope if possible
  - To maximize reliability and to increase efficiency while optimizing investment & minimizing disruption, separate campus heating zones to match building types: West Campus, Central Campus, & East Campus
  - Move steam generation from East Campus to West Campus
  - Use Heat Recovery Chillers to heat East Campus & future Central Campus buildings

- Chilled Water
  - Add Thermal Energy Storage (TES) tank to provide emergency backup in lieu of diesel generators
  - Continue with capacity addition at new Chilled Water Plant #3

- Power
  - Add diesel generators at chilled water plants as emergency cooling demand grows
  - Add co-generation facility of at least 10MW to provide a flexible power supply on campus to support critical loads and to replace end-of-life boiler capacity

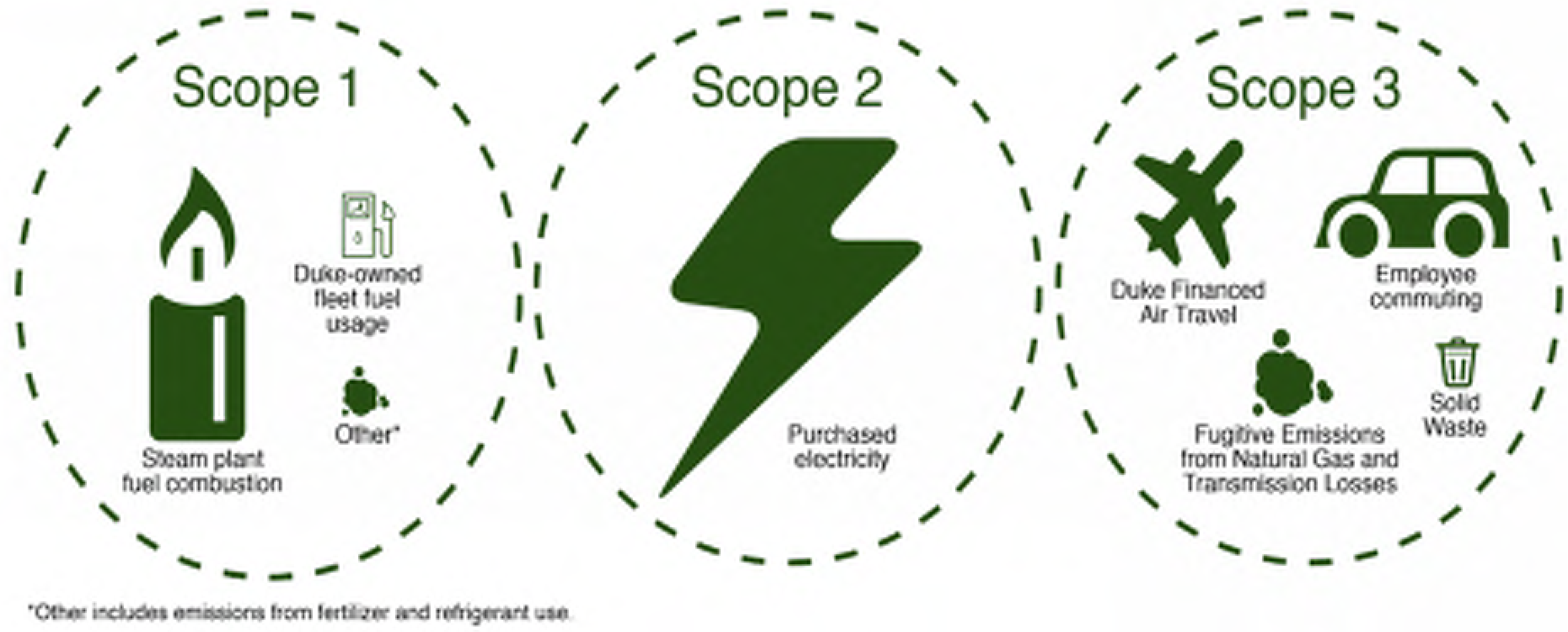
- Water
  - Add storage capacity on campus for potable water
  - Continue development of Water Hub non-potable reclaim water facility to provide water to chilled water & steam plants
  - Make provisions to use TES water if needed in cooling towers



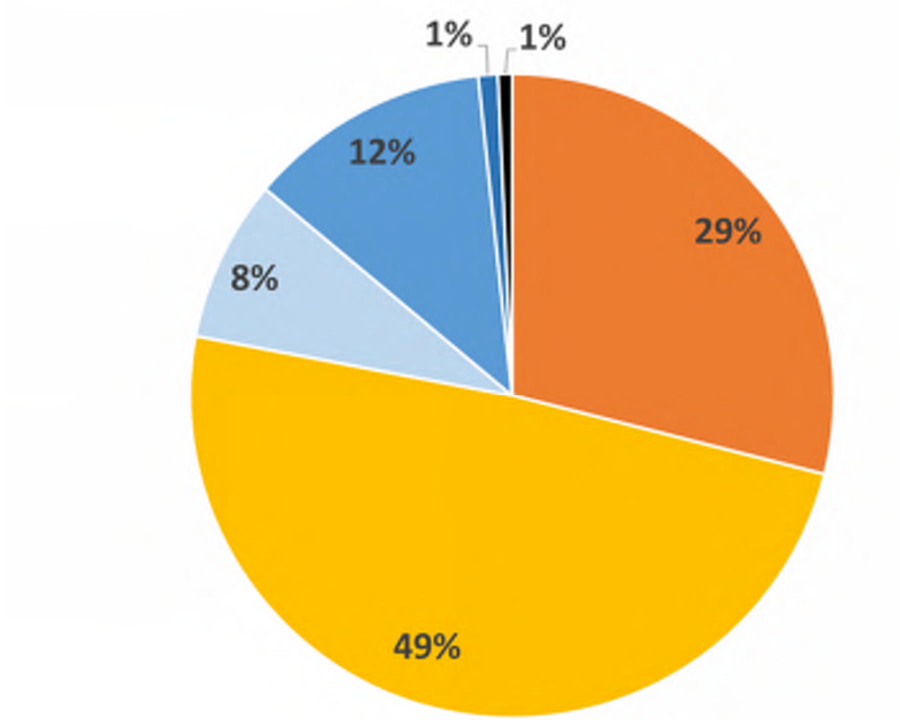
Energy & Green House Gas Reductions

It's Hard Work.

Our GHG Footprint – What We Account For



GHG Emissions Reduction Progress



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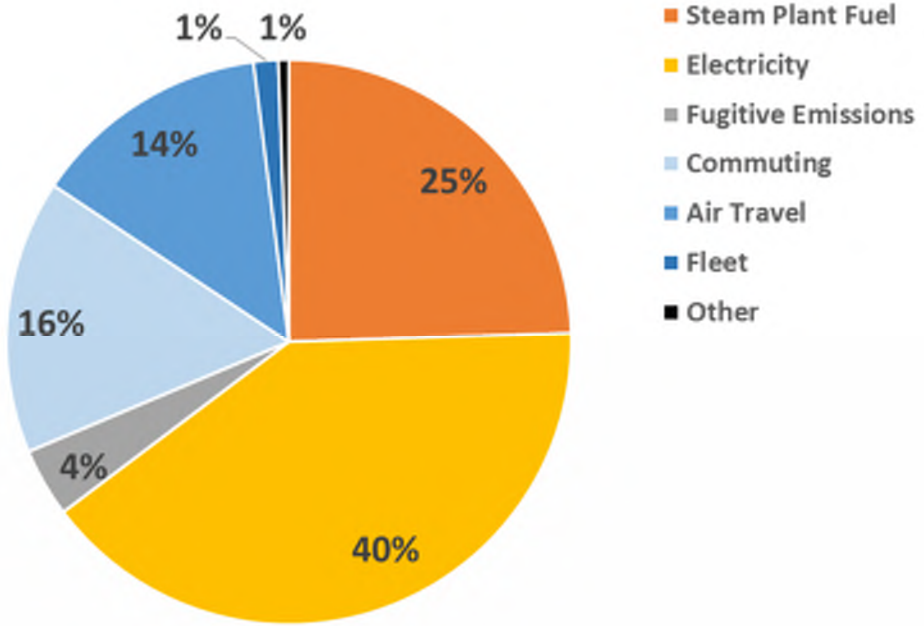
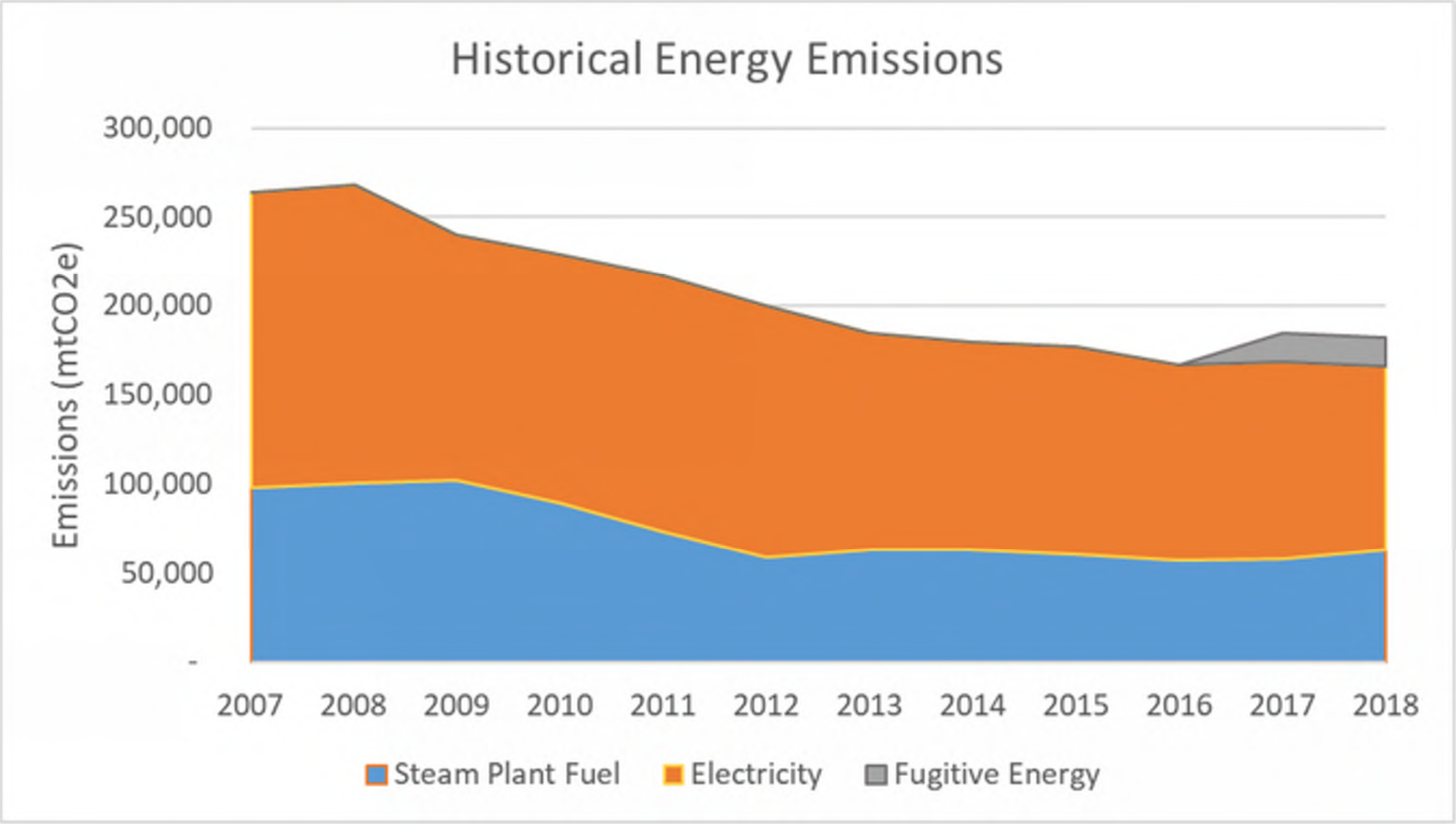


2018 Emissions Breakdown

- Energy – 68%
- Transportation – 31%
- Other – 1%

Our GHG Footprint – What We Account For



Energy Goals – Excerpt from Climate Action Plan

Progress

1. Establish green building energy consumption standards and an approval protocol for building energy consumption review -- implement, measure and report on energy use targets by Building Tech Rating

2. Beginning in 2010, implement energy conservation measures (ECMs) in existing buildings with the goal to realize a 15% reduction in energy use over a 20 year period (2010 – 2030)

3. Discontinue the use of coal as soon as possible. Duke should complete the gas-fired East Plant steam plant construction and start-up in 2010 and initiate the West Campus steam plant conversion from coal in 2012

4. Continue to urge, monitor and review Duke Energy's progress towards emissions reductions while exploring on-campus electricity generation options. Additionally, Duke should install 4MW solar PV array by 2012

5. Leverage research into alternative technologies and explore and implement conversion to biogas, solar PV, solar thermal, combined heat and power, or other technologies by 2030

6. Pursue plant efficiency improvements with tactics such as: distribution system upgrades, thermal storage, chilled water expansion and upgrade, and boiler plant heat recovery

Updated Climate Action Plan Energy GHG Reduction Technologies Planned

In late 2017, we refreshed the Climate Action Plan “Energy” section goals, to include evaluate GHG reduction potential if the following technologies are pursued:

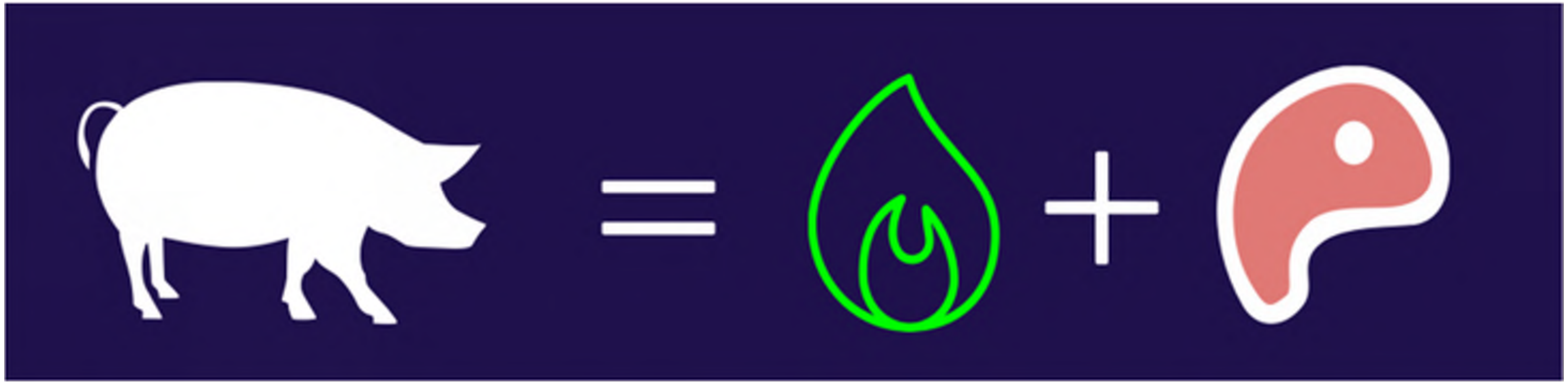
- **Demand-Side Measures (Buildings)……………………………………………12,000 MT**
  - New Efficient Buildings (Target EUI)
  - Building HVAC Optimization
  - LED Lighting

- **Supply-Side (Campus Utilities)……………………………………………........12,000 MT**
  - On-site solar PV
  - Chilled Water System Improvements
  - Solar Thermal
  - District Steam-to-Hot Water Conversion
  - Cogeneration

Less than 10% of total CO2 footprint

- ***Energy Measures External to campus***
  - Agricultural methane-capture biogas supply…………………..**115,000 - 350,000 MT**
  - Utility-scale solar PV…………………………………………......**45,000 - 50,000 MT**
  - Duke Energy scope 2 emissions reductions……………………..**17,000 - 40,000 MT**

- **Note: Total est. FY18 CAP GHG footprint…………….............…..262,000 MT**



- Compatibility with existing fuel supply networks
- Compatibility with existing combustion equipment
- Huge carbon footprint reduction opportunities
- Engages with other state-wide issues that are important to Duke

GHG Reduction Technologies – "CarbonSpeak Translator"

- **Demand-Side Measures (Buildings)**
  - New Efficient Buildings (Target EUI)
  - Building HVAC Optimization
  - LED Lighting

"Turn off the lights, stay out of the refrigerator, close the blinds, shut the front door, and don't touch the thermostat."

- **Supply-Side Measures (Campus Utilities)**
  - On-site solar PV
  - Chilled Water System Improvements
  - Solar Thermal
  - District Steam-to-Hot Water Conversion
  - Cogeneration

"It's time to replace the air conditioner and heater!"

- ***Energy Measures External to campus***
  - Agricultural methane-capture biogas supply
  - Utility-scale solar PV
  - Duke Energy scope 2 emissions reductions

"Hey y'all, time for a road trip around the state!"

Note: In late 2017, we refreshed the Climate Action Plan "Energy" section goals, to include evaluating GHG reduction potential if the above technologies. The CAP will be getting a full review through the Spring via the Campus Sustainability Committee.

Conclusions

It's kind of fun and kind of scary at the same time

https://eol.jsc.nasa.gov/DatabaseImages/ESC/large/ISS055/ISS055-E-59361.JPG

Conclusions

- **Technology**
  - No single technology or system design approach effectively meets *all* of our needs
  - Solutions need to be tailored to the unique differences of parts of campus
  - Operability of selecting technologies is critical to maintaining a high level of system reliability

- **Costs**
  - Based on the analysis, all of the technologies over a 30-year life cycle are within 5%
  - Annual investments can be best managed by making incremental improvements to systems versus a whole-sale implementation of a single system

- **Carbon Reduction**
  - No single on-campus technology makes a significant impact to carbon reduction
  - **Only off-campus large-scale solar and methane-capture biogas can drive us to carbon neutrality without purchased offsets**


Discussion