Facilities Engineering

BURNS McDONNELL

A Path to Neutrality – Princeton University Infrastructure Master Plan

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INTERNATIONAL DISTRICT ENERGY ASSOCIATION

PRINCETON UNIVERSITY OVERVIEW

Utility System Key Attributes

- Chilled Water – 20,000 Tons
- Steam – 300,000 PPH
- Power Generation (CHP) – 15 MW
- Power Generation (Solar) – 4.5 MW (AC)
- Chilled Water TES – 40,000 Ton-Hours
- Chilled Water and Steam Piping – 70,000 LF

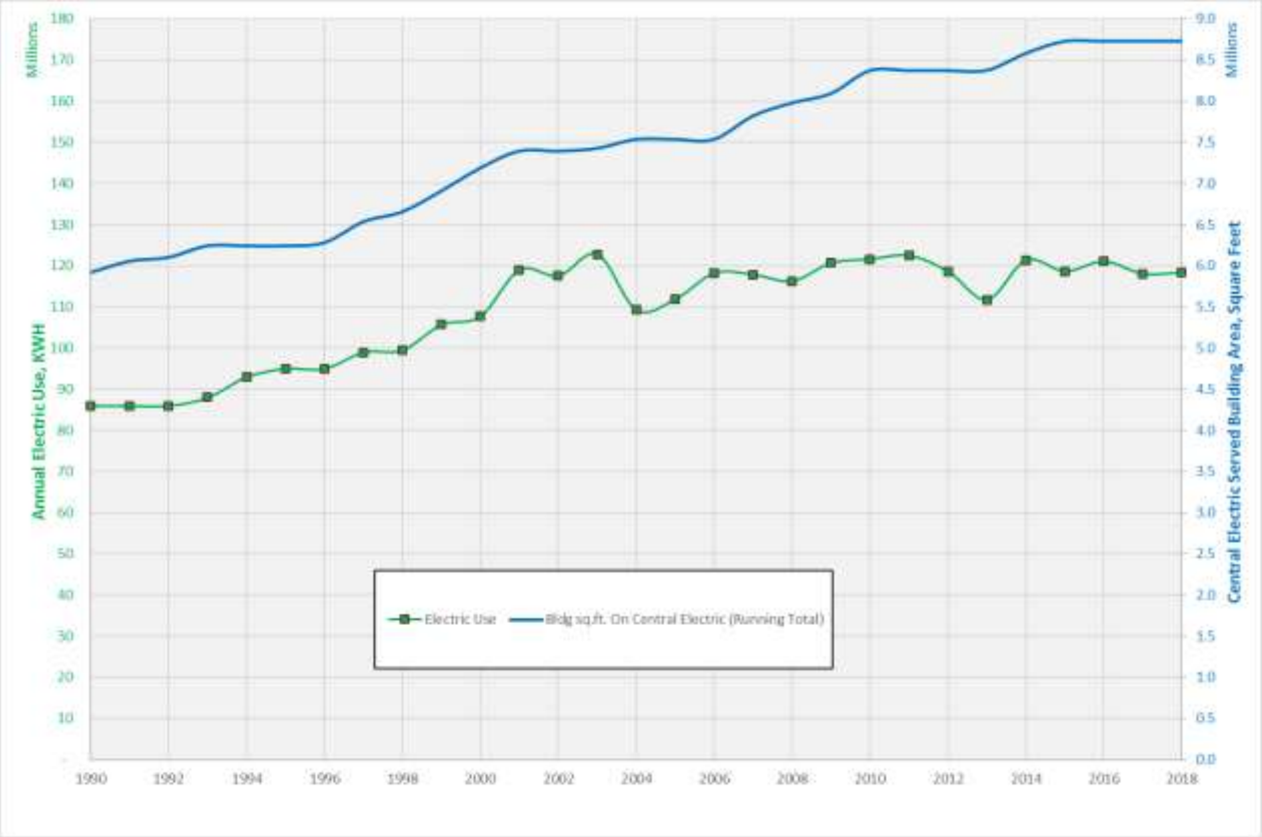
PRINCETON UNIVERSITY OVERVIEW

UTILITY AND ENERGY INITIATIVES

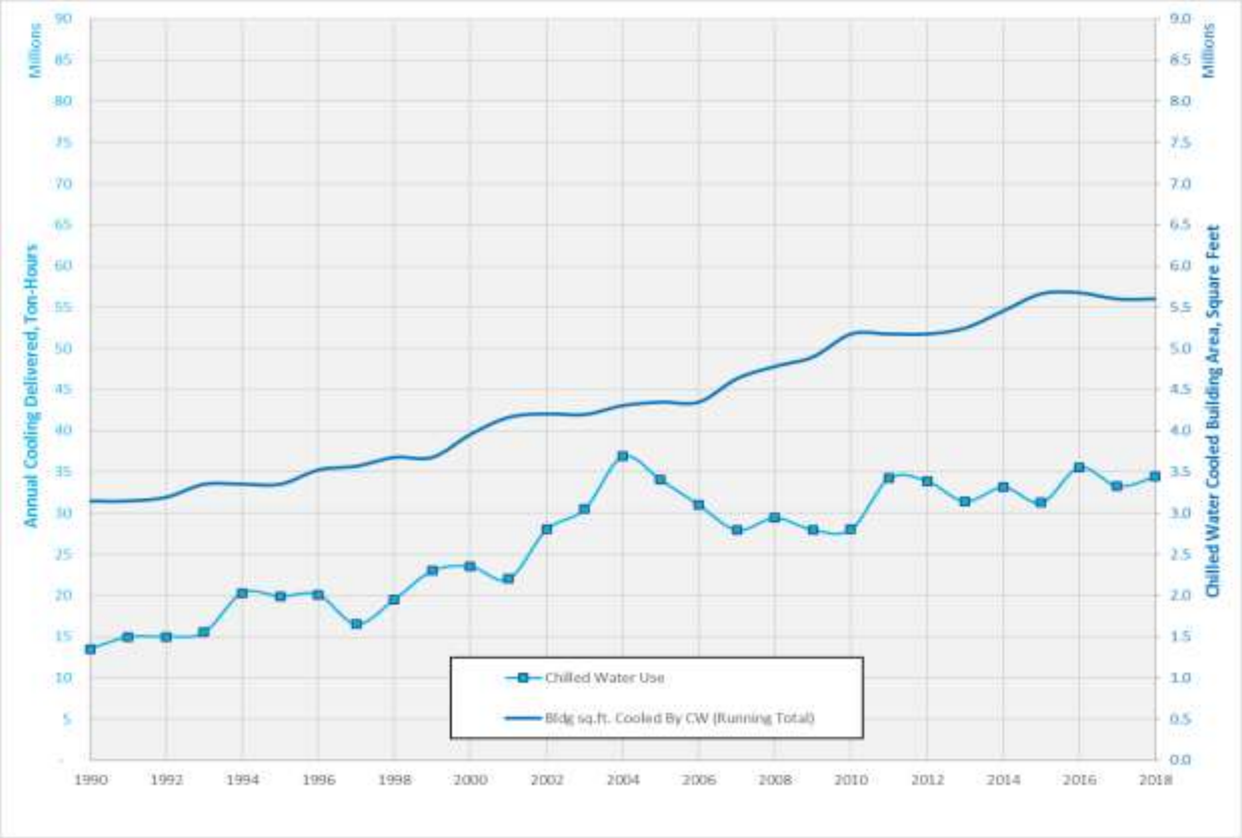
Recent Energy Conservation Modifications:

- CHW Pumps converted to high efficiency
- VFDs on CHW and Condenser Water Pumps
- VFD on Turbine Enclosure Fan
- Re-circuit chiller condenser water to series flow
- Energy studies & retrofits, re-commissioning
- Review & re-tune building energy controls
- > 100,000 lamp/fixture replacements with LEDs

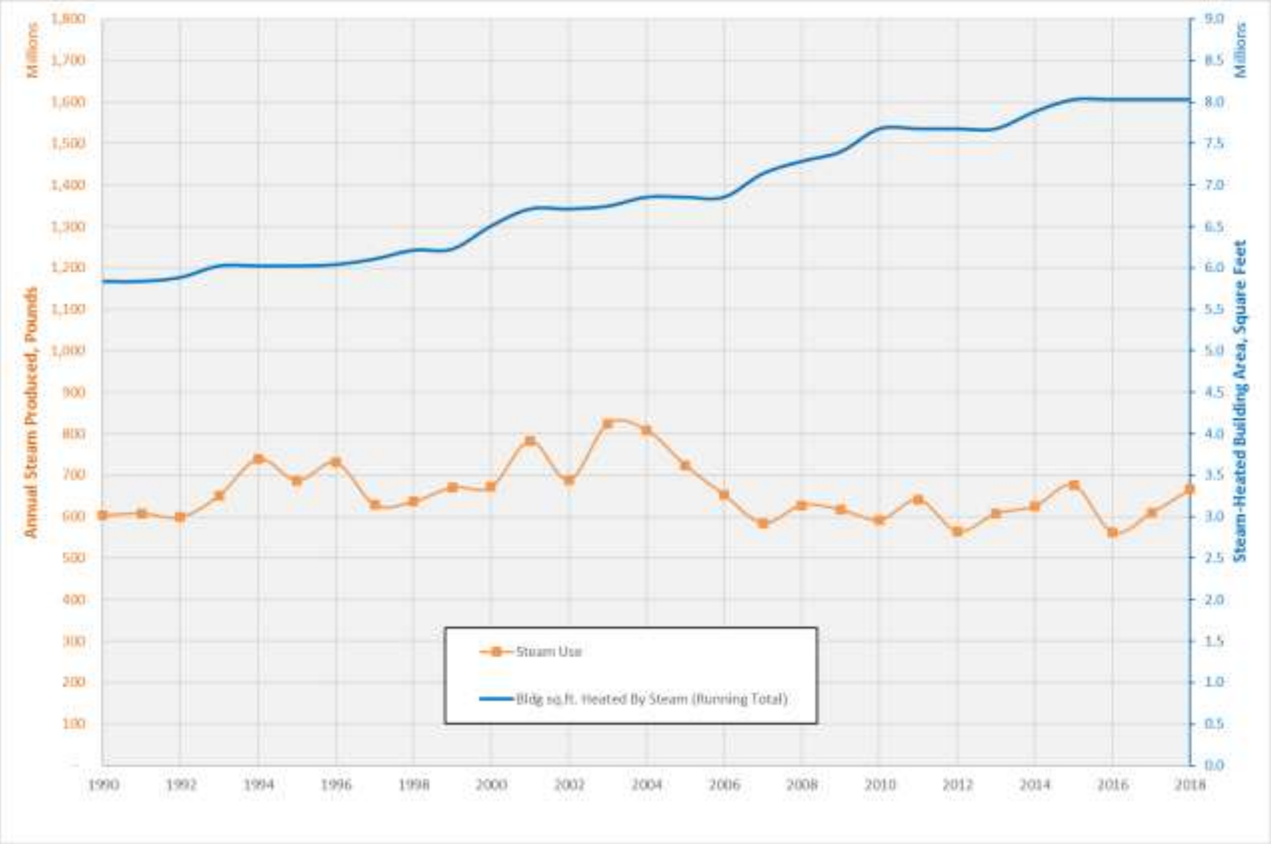
ELECTRICAL CONSUMPTION



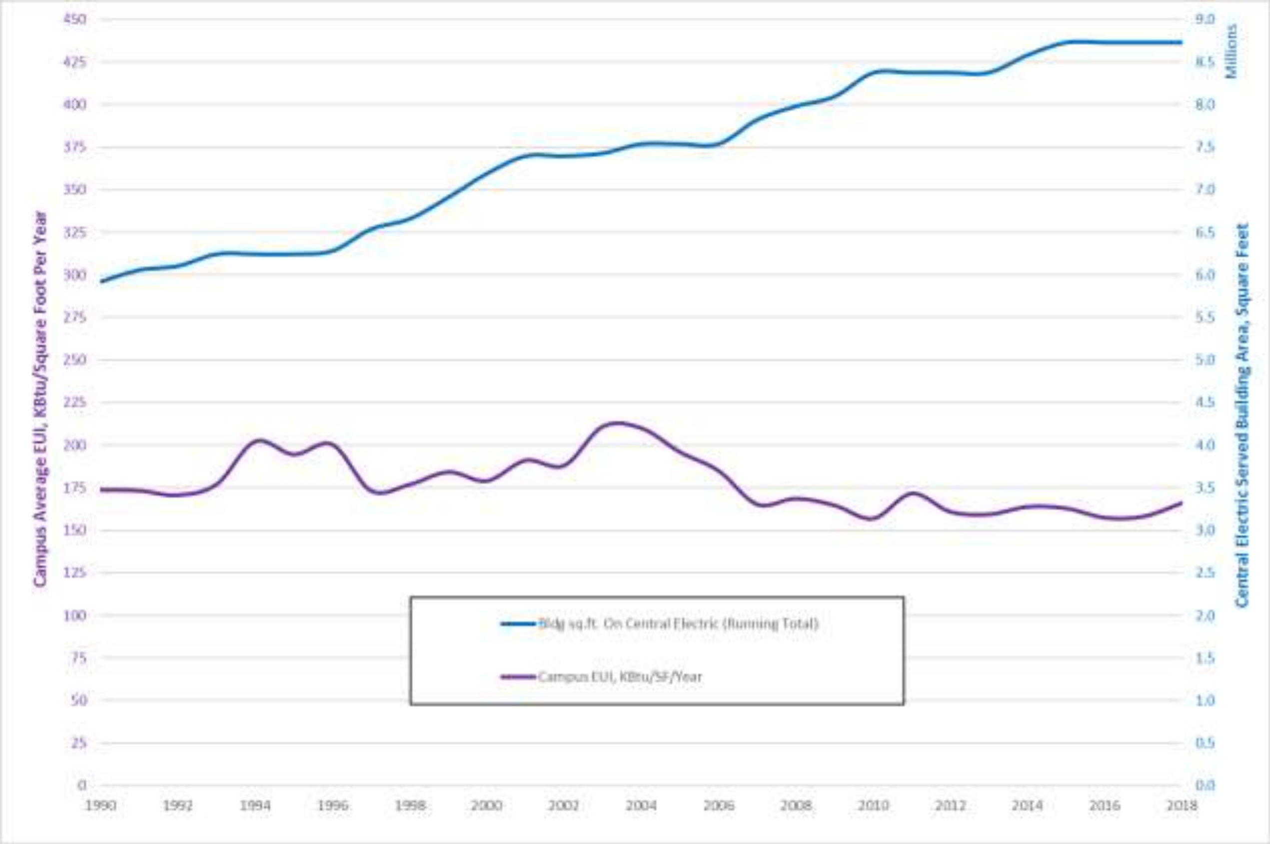
CHILLED WATER CONSUMPTION



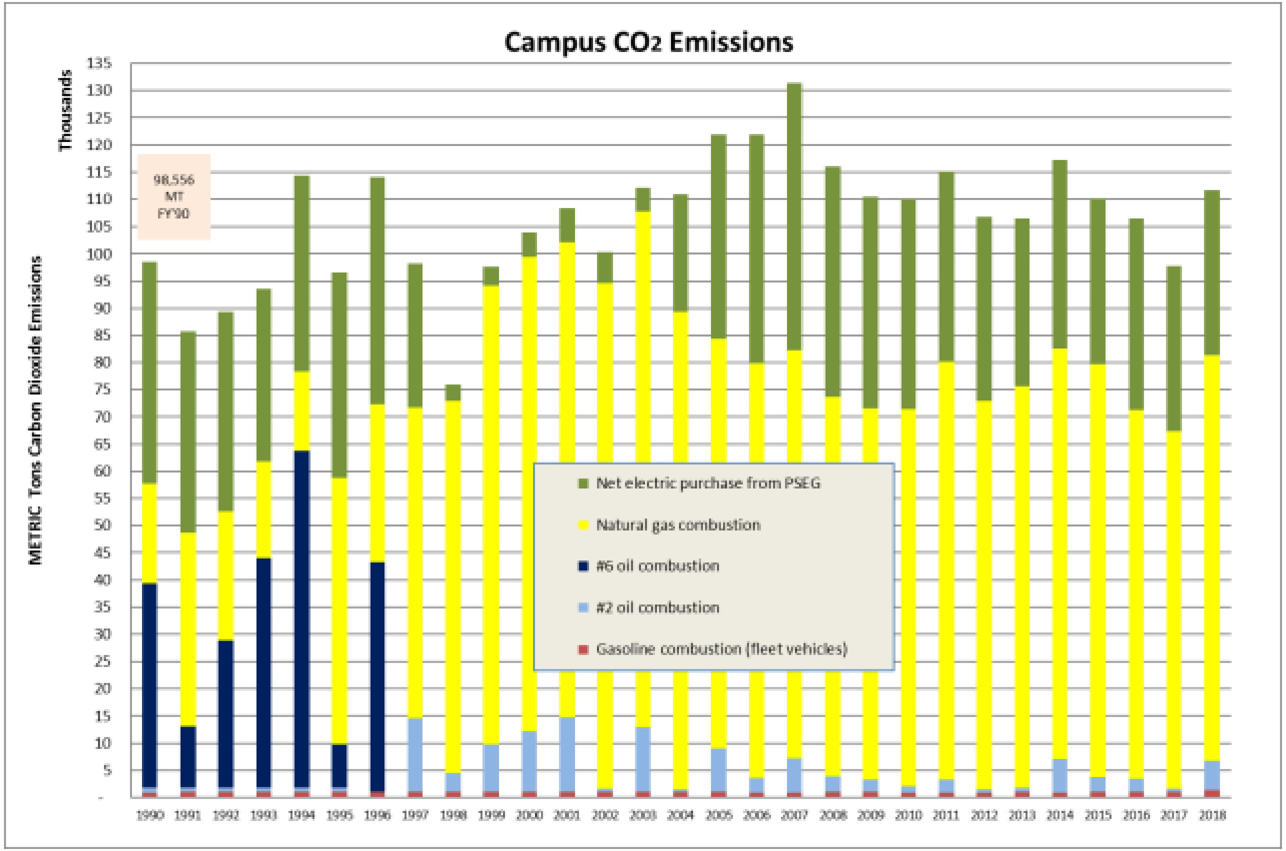
STEAM CONSUMPTION



CAMPUS ENERGY USE INTENSITY



REDUCED GHG EMISSIONS



INFRASTRUCTURE MASTER PLANNING

Primary Issues Addressed

- Capacity
- Reliability and Resiliency
- Future Load Growth
- Heating Hot Water Conversion
- GHG Emissions Reduction
- Financial Stewardship

INFRASTRUCTURE MASTER PLANNING

Infrastructure/Utility Drivers

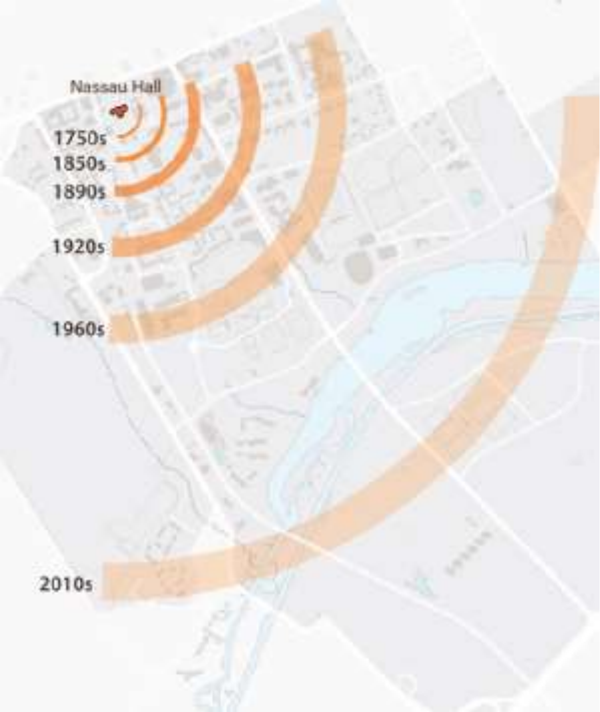
- Aging/inefficient infrastructure
- Steam >100 years with serious degradation
- CHP core engine reaching obsolescence
- Several chillers are 1960s and 1970s vintage
- Increasing interest in water stewardship
- Limited real-estate in suburban environment



INFRASTRUCTURE MASTER PLANNING

The 2026 Campus Plan – *Next 10 Years in 30 Year Context*

- 10% Undergraduate Increase
- Expansion and Enhancement of Educational Mission
- Collaboration with Corporate and Non-Profit to Serve Teaching and Research



INFRASTRUCTURE MASTER PLANNING

The 2026 Campus Plan – Impacts to Utility Infrastructure

- Campus Growth – 812,400 GSF
- Heating – 17.4 MMBTU/hr
- Cooling – 2,300 Tons

Unmitigated Impacts from Growth

- GHG – 1,446 $MTCO_2e$ annually
- Water – 16.8 MGal annually

IMP STEPS – OUR PROCESS

Master Planning Approach

- Part of a Large, Multidiscipline Campus Plan
- Strategic Framework - Goals and Priorities
- Steering Committees/Advisory Groups
  - Staff and Students
  - Industry Leaders
  - Peer Institutions
  - Local Community

IMP STEPS – OUR PROCESS

PHASE 1

Baseline		Hot Water Conversion		Heat Recovery		Geoexchange	
1	Baseline	2	HHW Conversion with HHW Generators	3	Heat-Pump Chillers w/o Geo-exchange	4	Heat-Pump Chillers with Geoexchange
1A	Baseline with Solar PV	2A	HHW Conversion with Solar Thermal	3A	Heat-Pump chillers w/o Geo-exchange and Additional TES	4A	Heat-Pump Chillers with Geoexchange and Polar PV
1B	Baseline with Electricity Storage					4B	Heat-Pump Chillers with Geoexchange and Electricity Storage
1C	Baseline with Biofuels					4C	Heat-Pump Chillers with Geoexchange and Solar Thermal
						4D	Heat-Pump Chillers with Geoexchange and Additional CHP
						4E	Heat-Pump Chillers with Geoexchange and Additional CHP with Biofuels

On-Site Generation
EGS – Power
Biodiesel CHP – unfired
Biomass to Boiler then to Condensing STG
Biomass Gasified to GTG
NG Combined Cycle with BPT
NG CHP

IMP STEPS – OUR PROCESS

PHASE 2

Baseline		Heat Recovery		Geoexchange	
1	Baseline	3	Heat-Pump Chillers w/o Geoexchange	4	Heat-Pump Chillers with Geoexchange
1B	Baseline with Electricity Storage			4B	Heat-Pump Chillers with Geoexchange and Electricity Storage
1C	Baseline with Biofuels			4D	Heat-Pump Chillers with Geoexchange and Additional CHP
				4E	Heat-Pump Chillers with Geoexchange and Additional CHP with Biofuels

1	Baseline	3	Heat-Pump Chillers w/o Geoexchange	4	Heat-Pump Chillers with Geoexchange

IMP STEPS – OUR PROCESS

PHASE 3

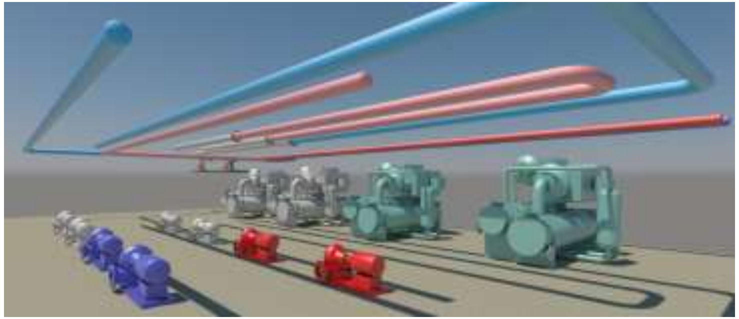
Baseline		Geoexchange	
1	Baseline	4	Heat-Pump Chillers with Geoexchange

** PV/Biofuels applied to all options*

IMP STEPS – OUR PROCESS

Final Recommendations

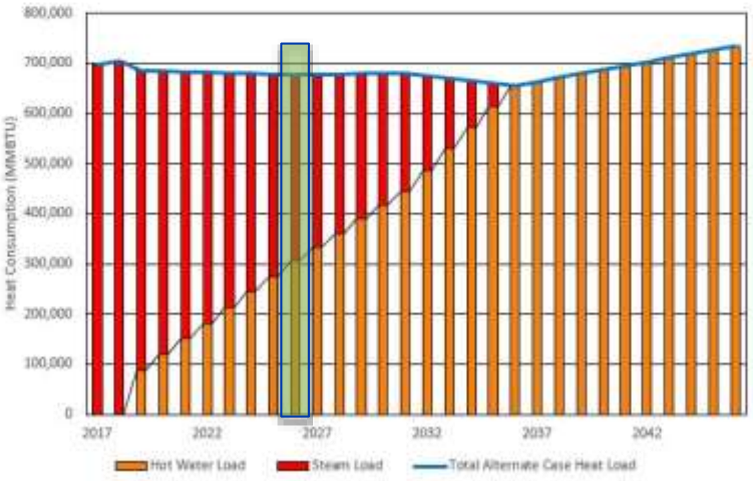
- Conversion from steam to hot water heating
- New 6,800 ton heat pump chiller East Plant
  - Designed for future expansion
  - No combustion/no cooling towers
- New heating hot water capacity at West Plant
- New heating hot water distribution network
- Installation of geoexchange well fields
- Hot and cold TES

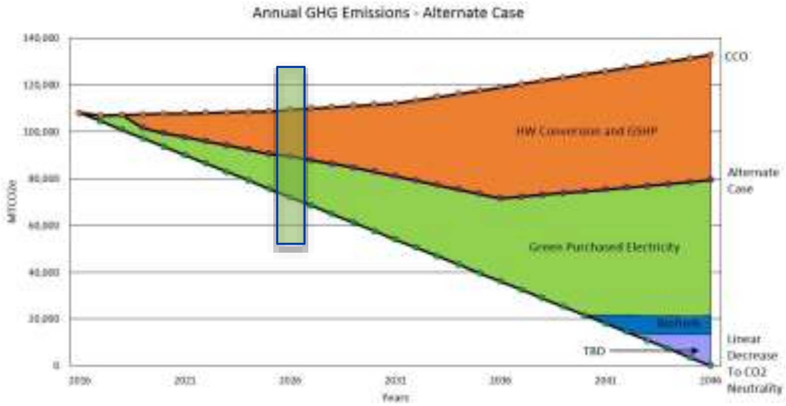


ENERGY AND GHG SAVINGS

Key Impacts of IMP by 2026:

- 380,000 MMBTU reduction in natural gas consumption
- 1.6 MW increase in peak electrical load
- 58.7 MGal annual reduction in domestic water consumption
- 20,000 $MTCO_2e$ annual reduction in GHG emissions





NEXT STEPS

Communicate and Sell the Plan!

- Finance, Administration, Campus Community

Implement Capital Projects

- Near-Term Projects are First Priority

Adjust Plans and Priorities as appropriate

- UMPs must be kept current and relevant
- Update UMP every five years

LESSONS LEARNED

- Thermal storage can maximize flexibility and minimize costs
- Maximize efficiency and energy source flexibility with CHP
- PPAs can be a cost effective GHG reduction measure
- Hot water heating provides substantial benefits
- Building conversions represent a large investment
- Phased conversion can ease campus burden and prevent overbuilding
- Value real estate in “3-D”
- CO_2 neutrality through on-campus means is a challenge

PROGRESS UPDATE

IMP Project Implementation

- Planning team selected for design
- Currently in early design phase
- Building conversion investigations – How Low Can You Go?

Increased Renewable Procurement

- On site and off site
- Solar

Facilities
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