Energy Production and Distribution At Princeton University

Woman's Club of Cranbury

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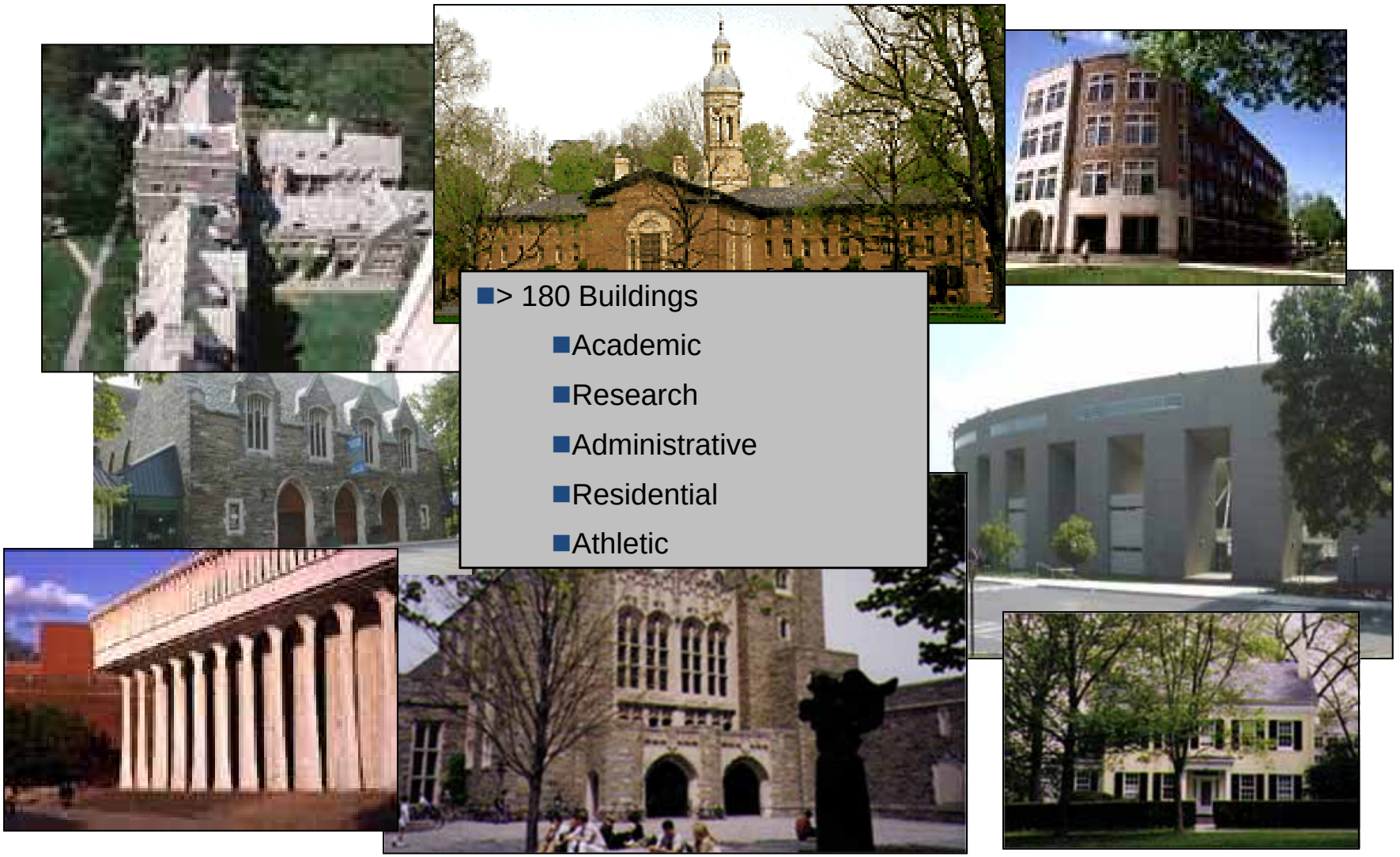
The Problem

Reduce CO_2 footprint & other negative environmental impact with:

- Good financial stewardship
- Existing buildings & campus aesthetics
- Space limitations
- Existing technologies
- Existing codes, tariffs
- No interruption of education and research
- Additionality
- Replicability
- No discomfort
- Reliability

Energy Demands at Princeton



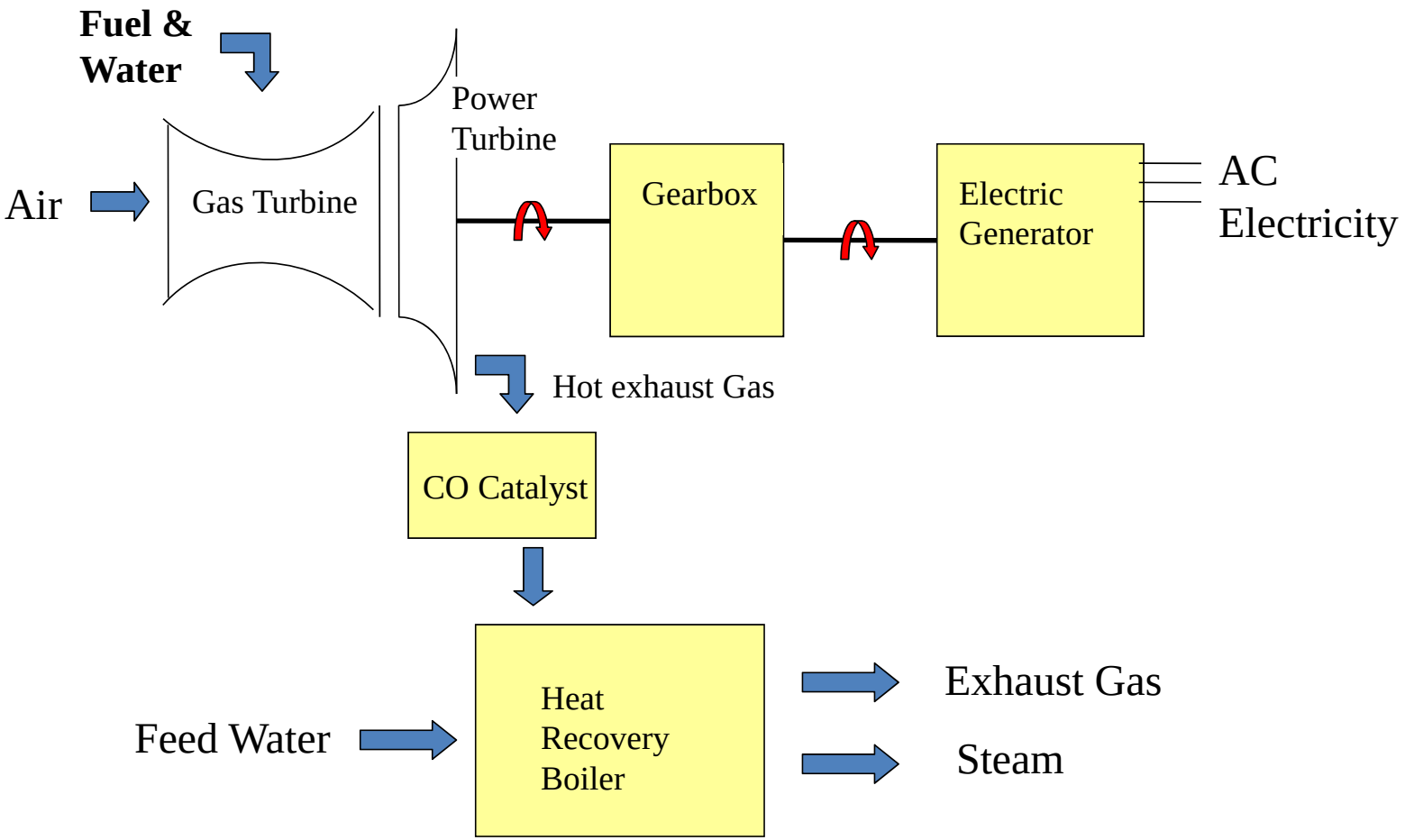
- > 180 Buildings
  - Academic
  - Research
  - Administrative
  - Residential
  - Athletic

Energy Equipment & Peak Demands

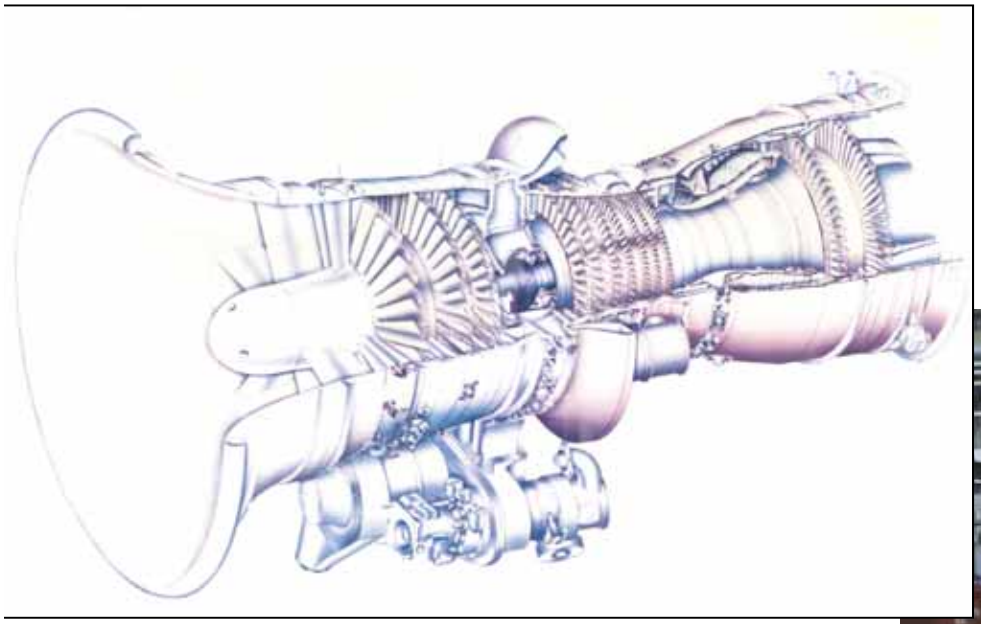
	Rating	Peak Demand
• **Electricity**		
– (1) Gas Turbine Generator	15.0 MW	27 MW
– Solar Photovoltaic System	4.5 MW	
• **Steam Generation**		
– (1) Heat Recovery Boiler	180,000 #/hr	
– (2) Auxiliary Boilers @ 150 ea.	300,000 #/hr	240,000 #/hr
• **Chilled Water Production**		
– (3) Steam-Driven Chillers	10,100 Tons	
– (5) Electric Chillers	10,700 Tons	15,000 Tons
– (1) Thermal Storage Tank	40,000 Ton-hours	
• *peak discharge	10,000 tons (peak)	

Campus District Energy Systems

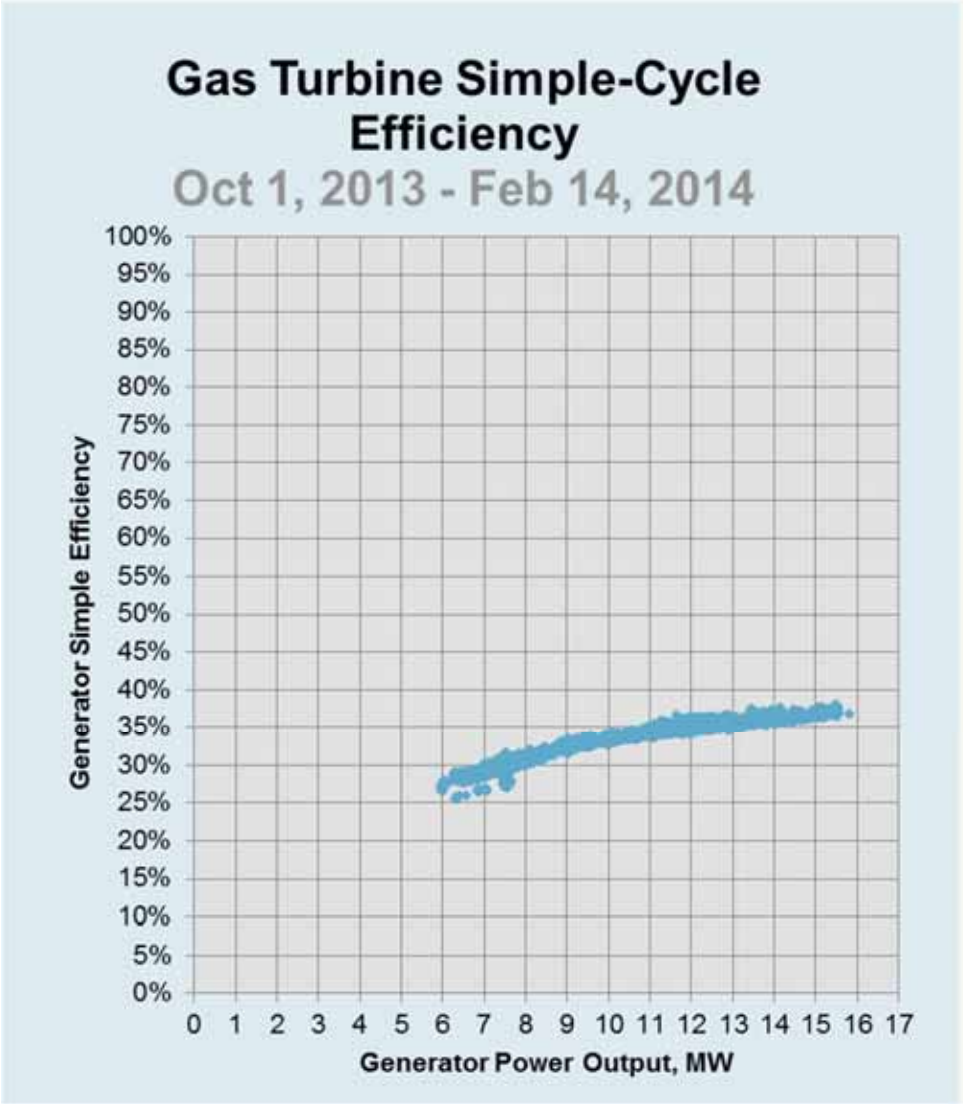
Combined Heat & Power, “Cogeneration”

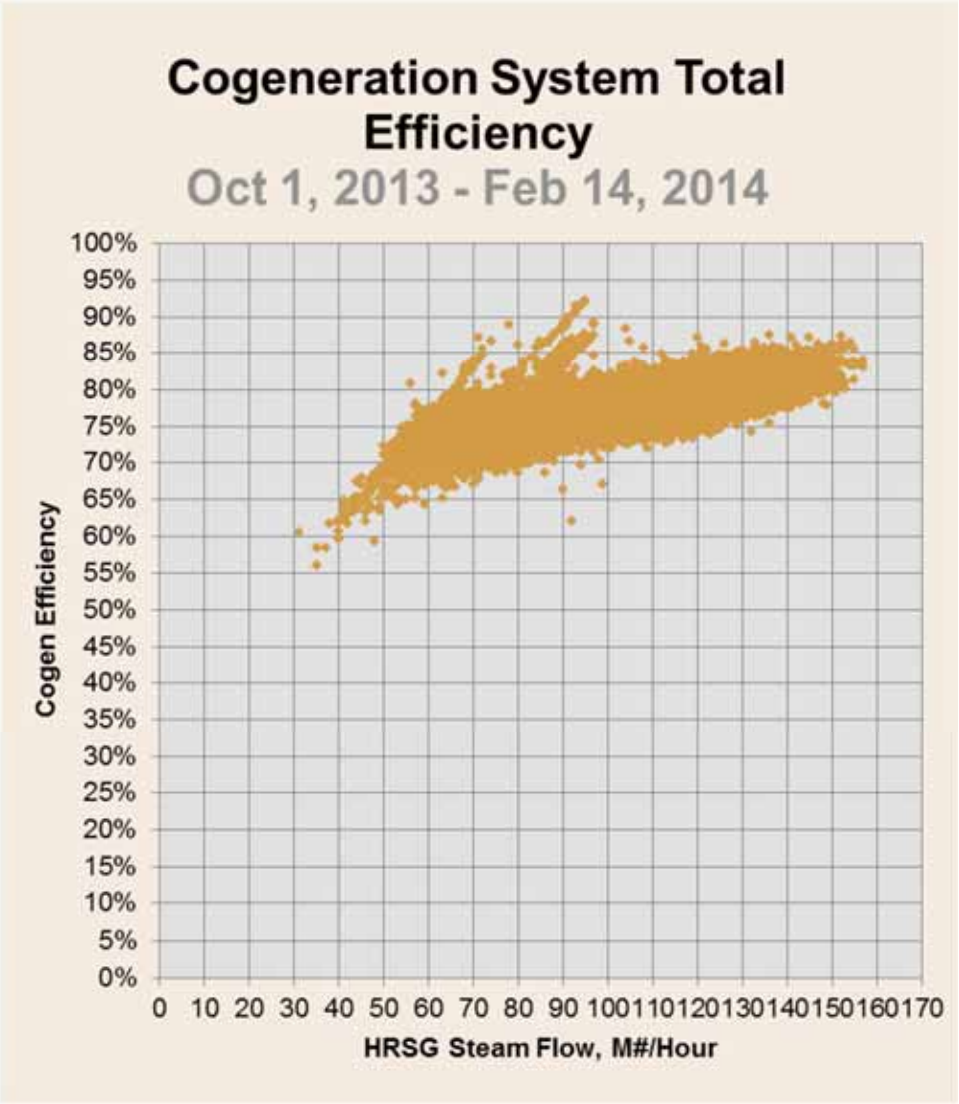


The GE LM-1600 Gas Turbine

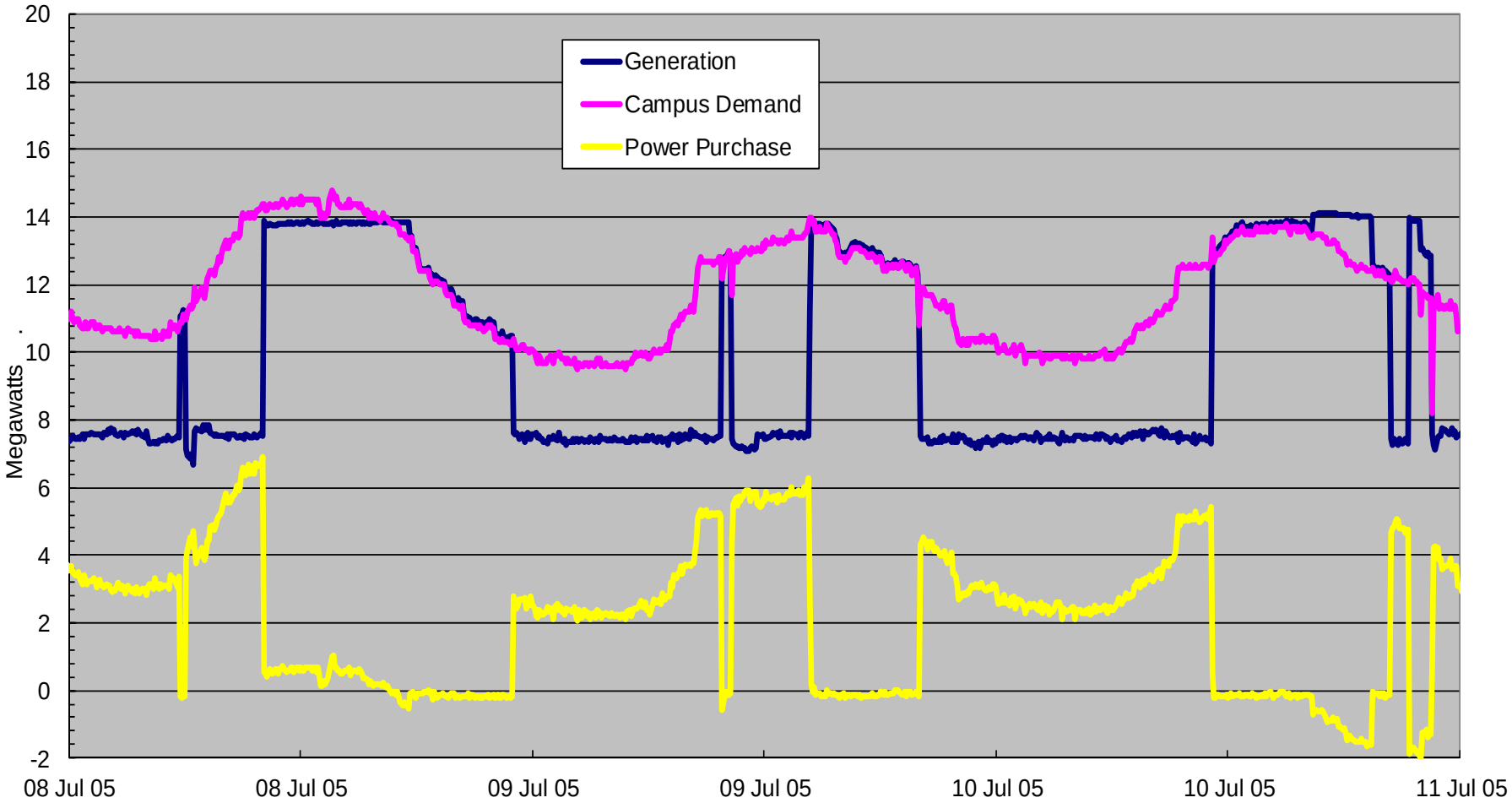


How Much More Efficient is Combined Heat & Power?

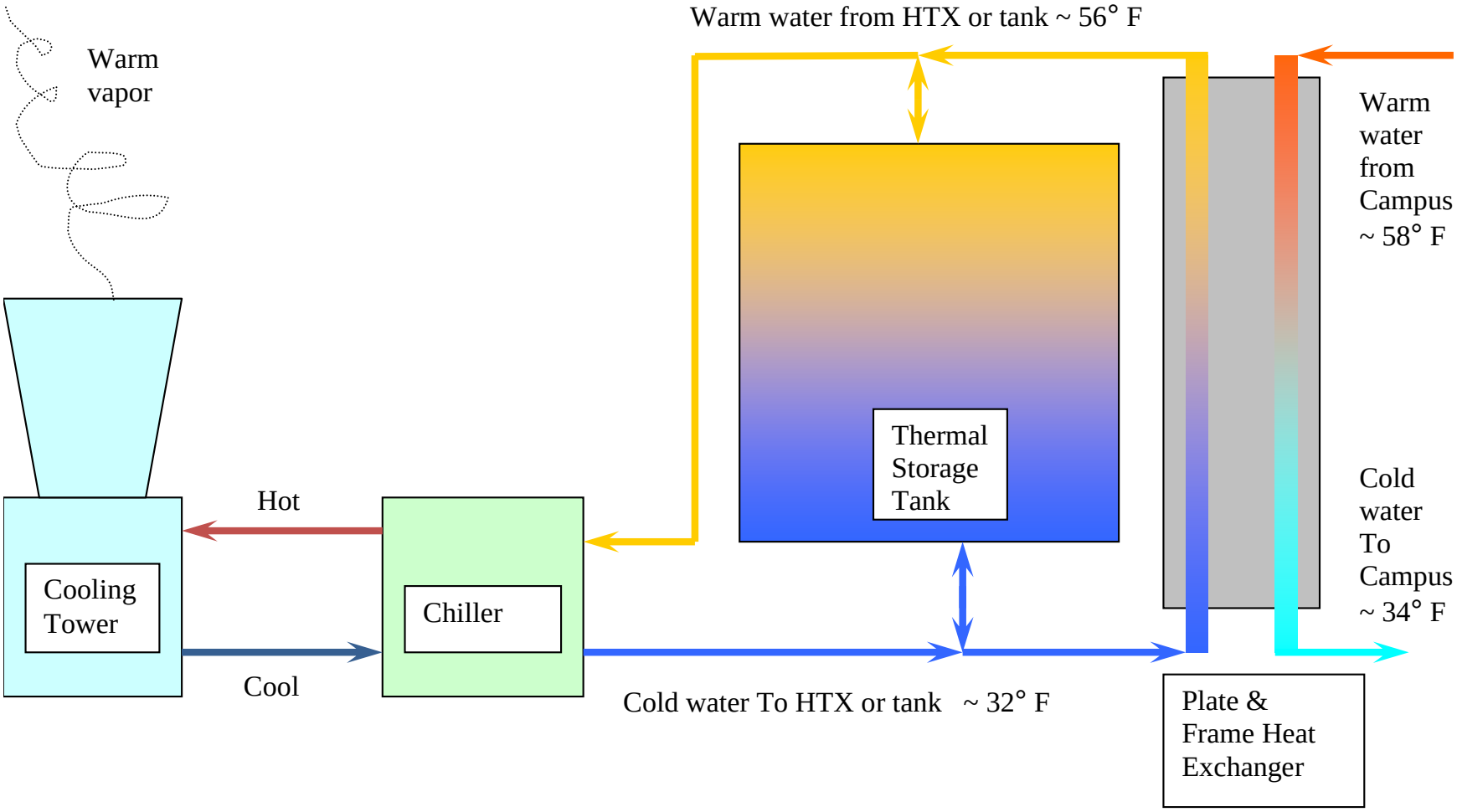




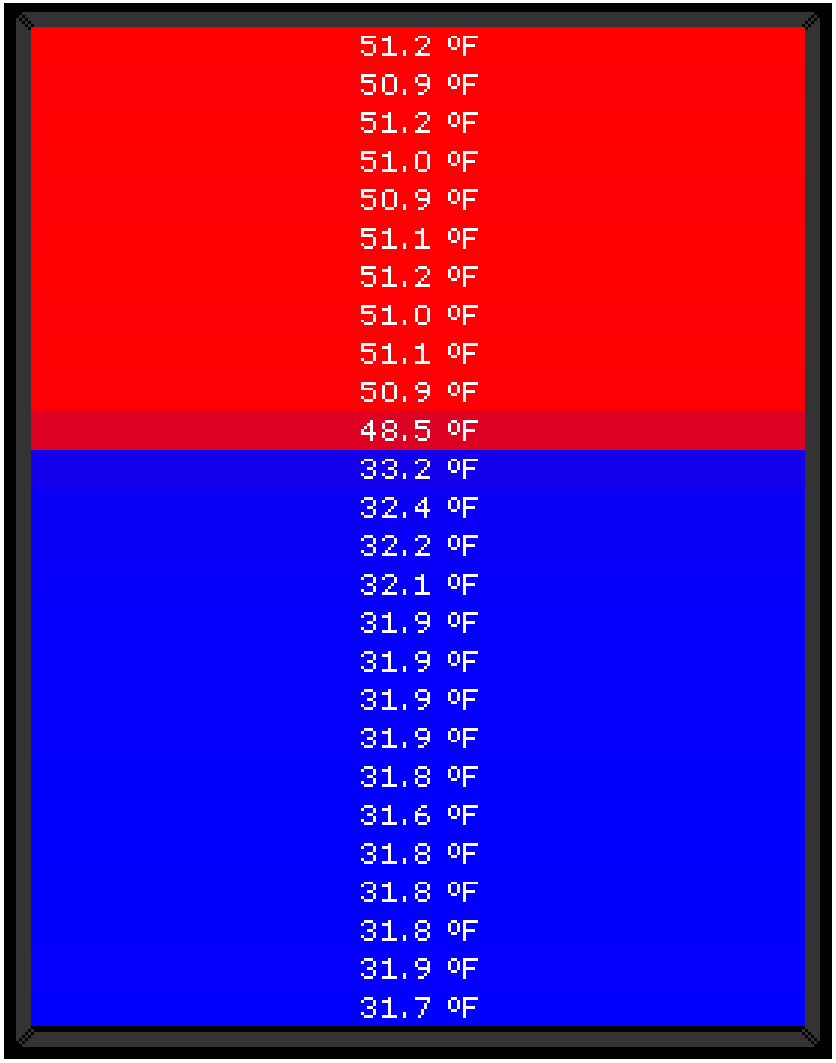
Princeton Power Demand
With Cogen Dispatch To Minimize Cost



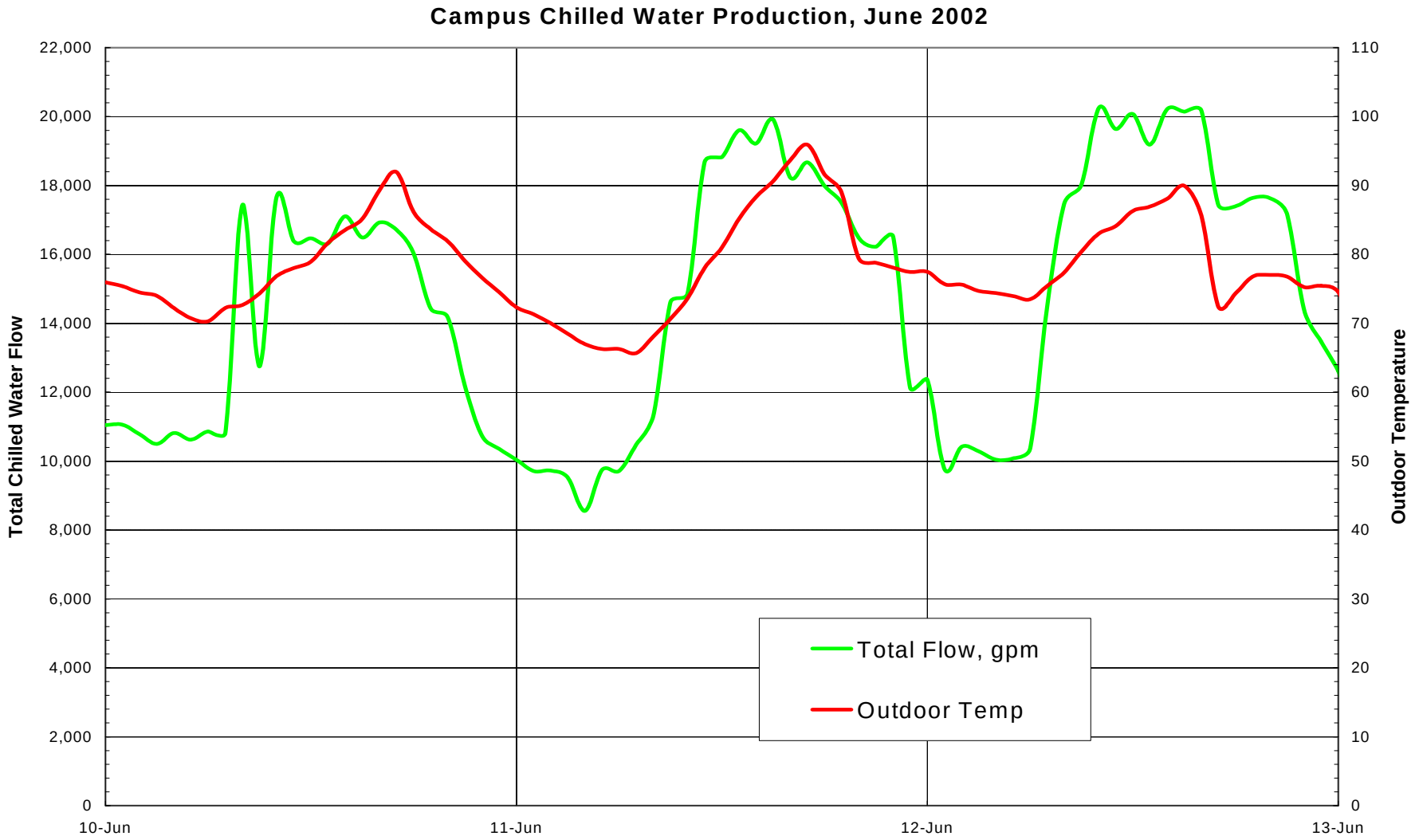
Chilled Water Thermal Storage



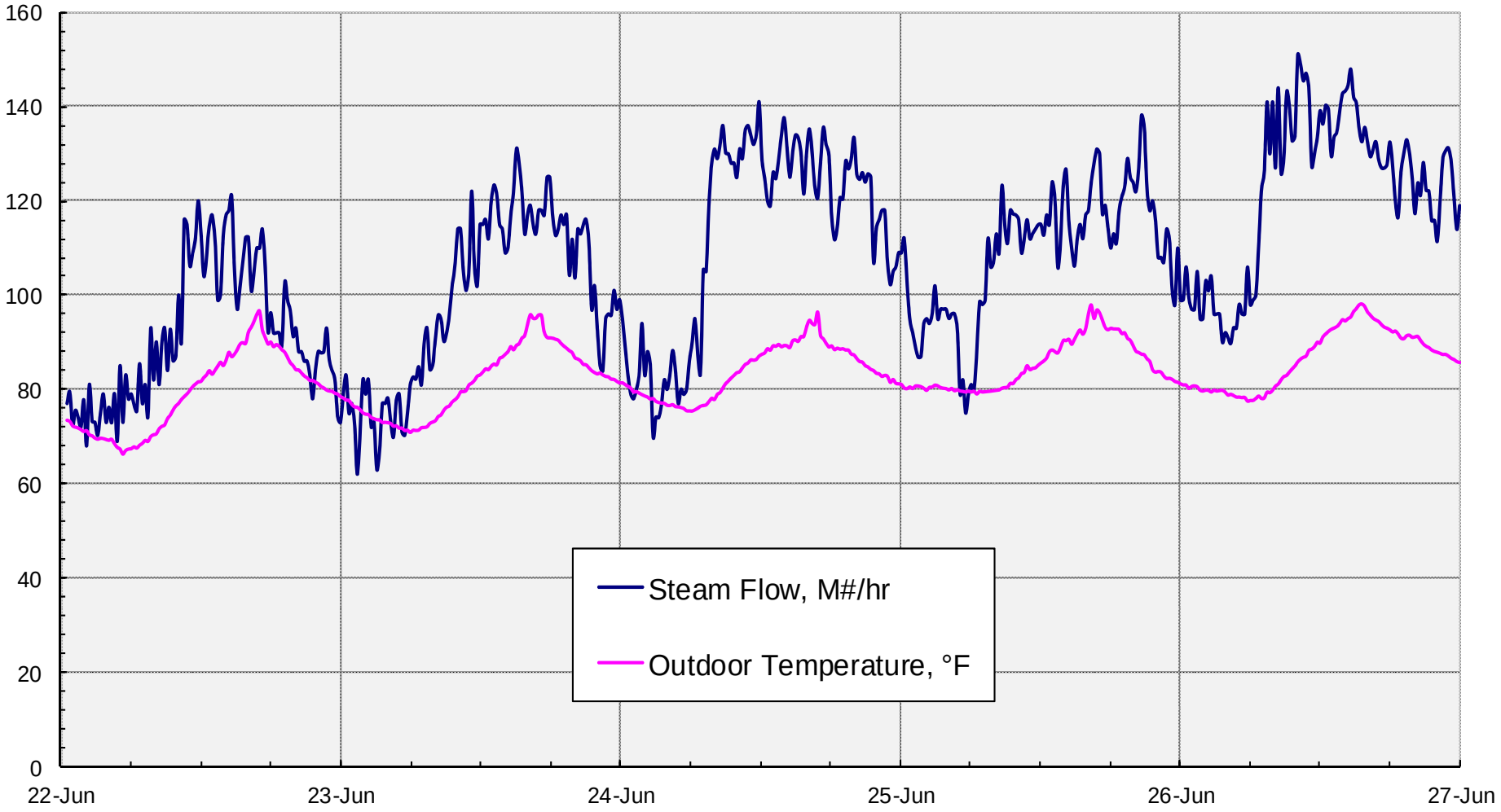
TES Tank Stratification



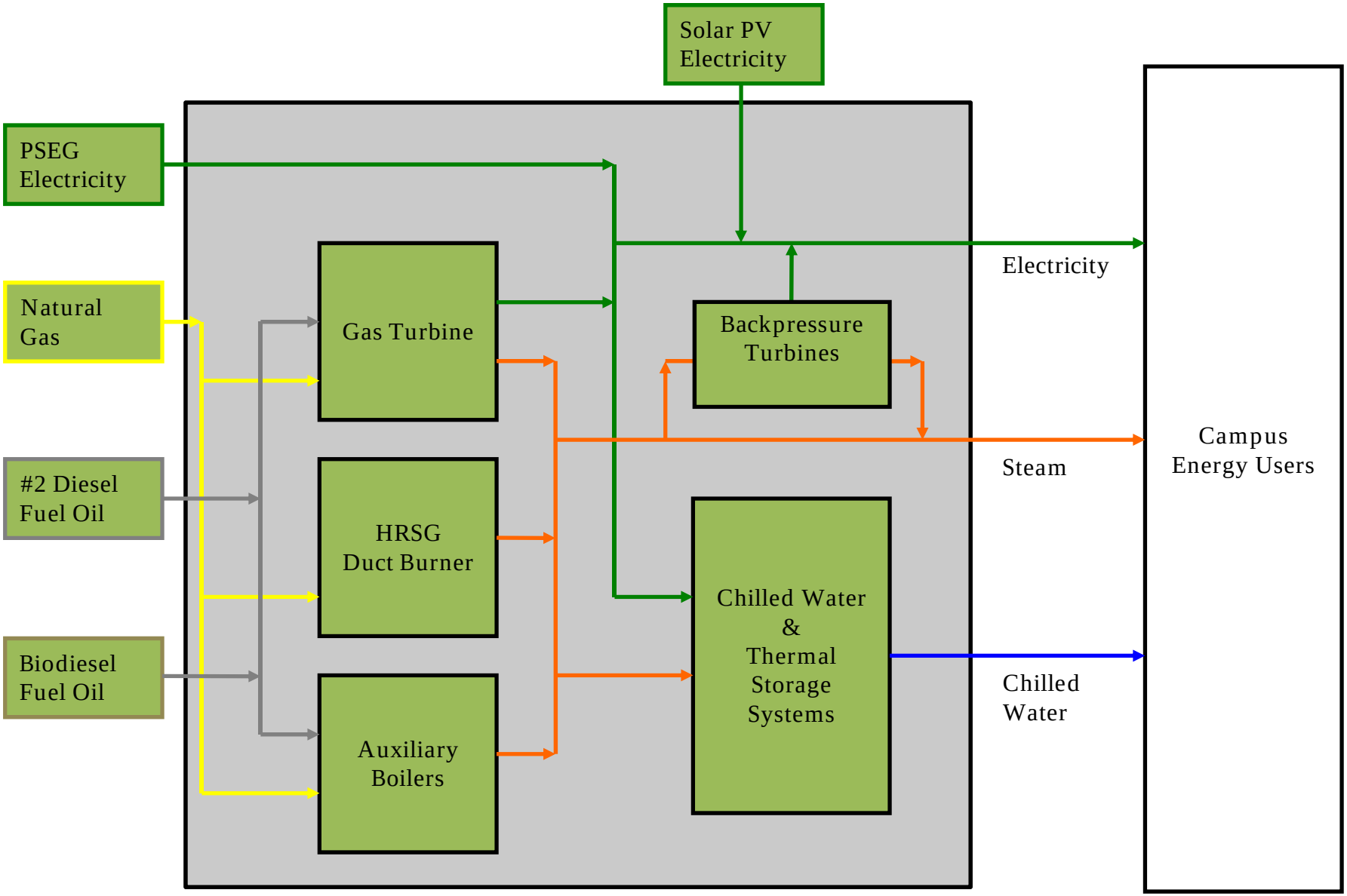
Princeton Chilled Water Use



Princeton Summer Steam Use



Plant Energy Balance



Princeton Solar PV -- Today

- 5.3 MW DC
- 27 Acres
- Lease equipment
- Own all power and Solar Renewable Energy Credits from day one
- Sell SRECs until system is paid for
- Eventually stop selling SRECs and claim all avoided CO_2


0466
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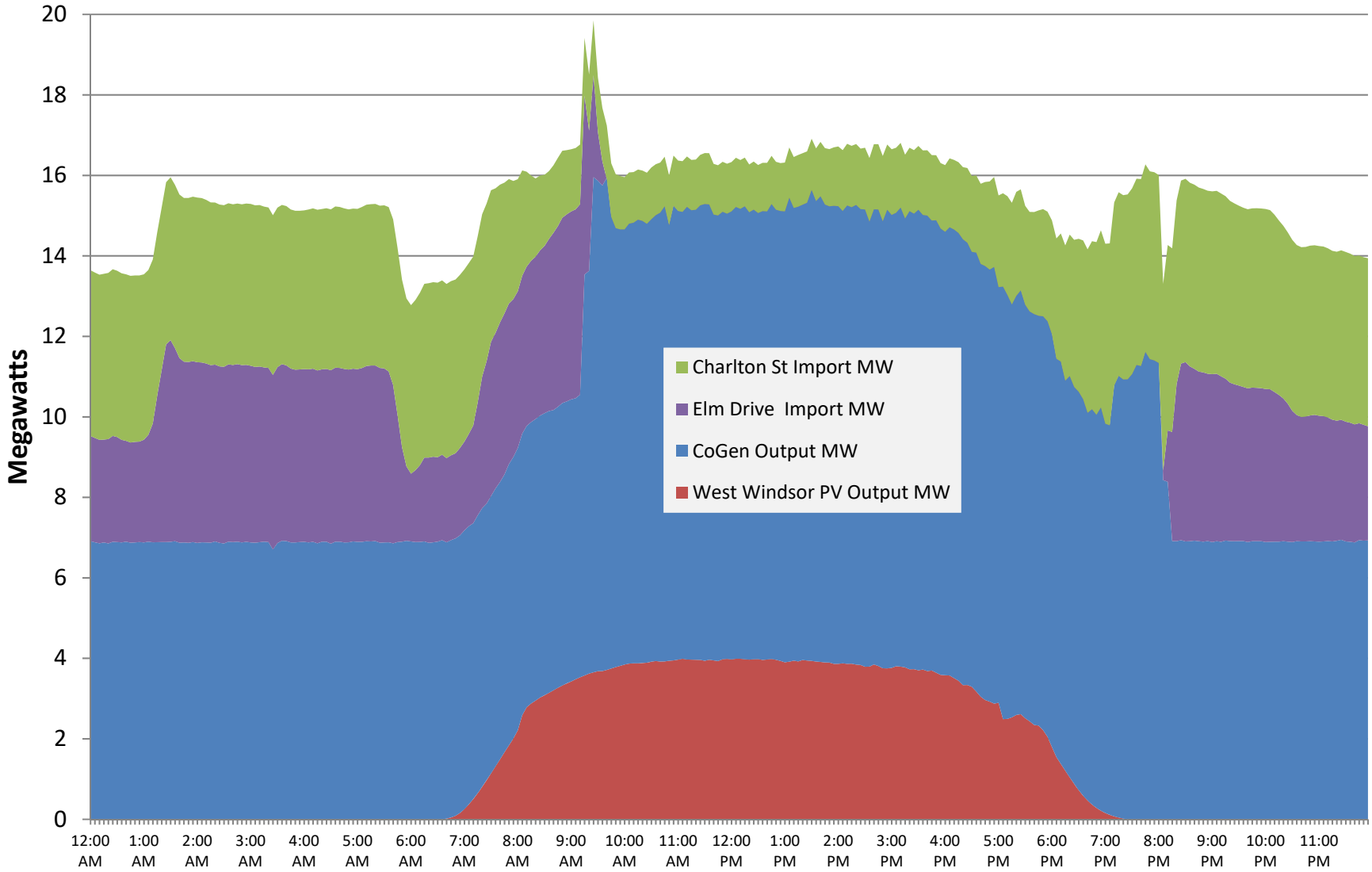
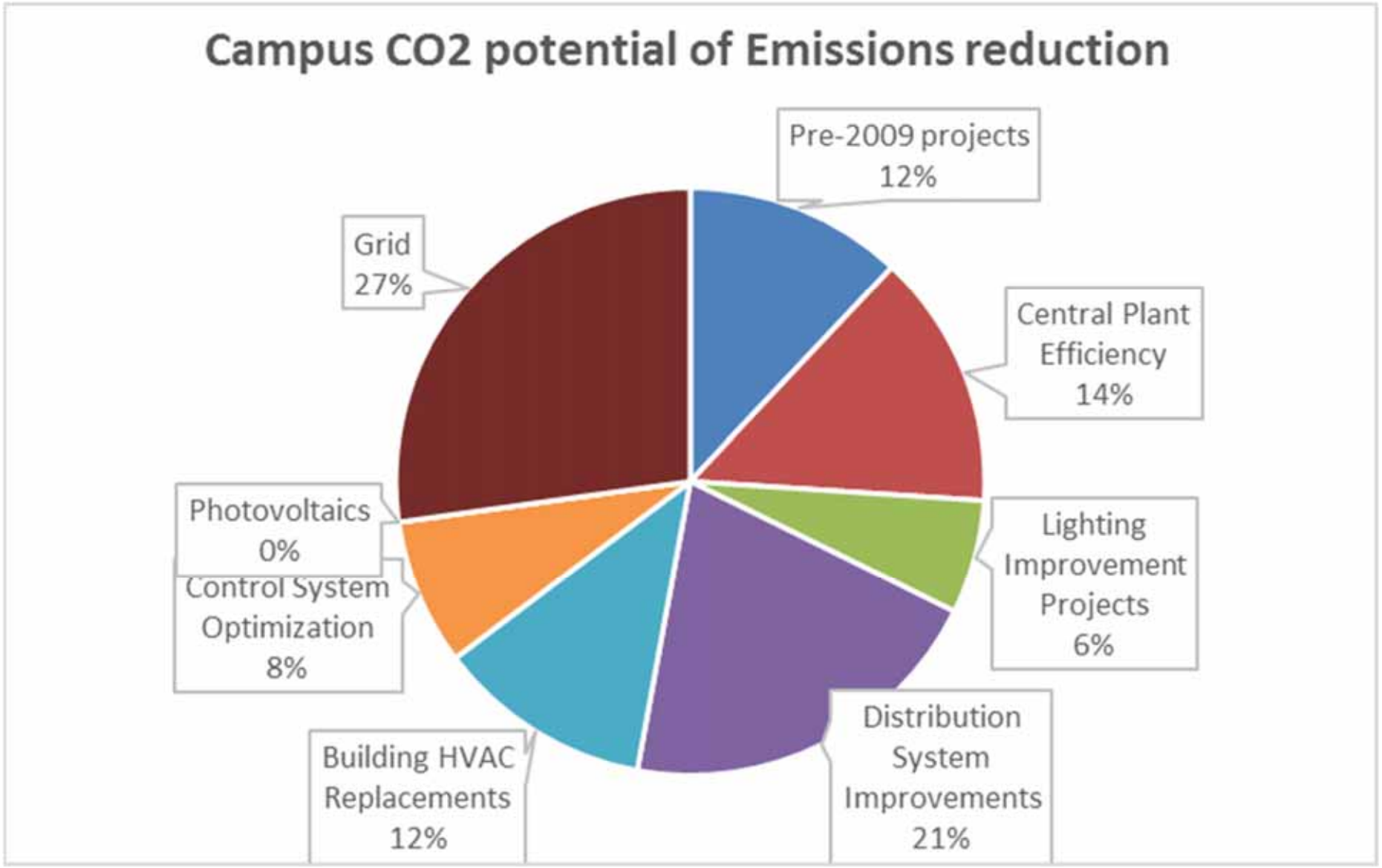
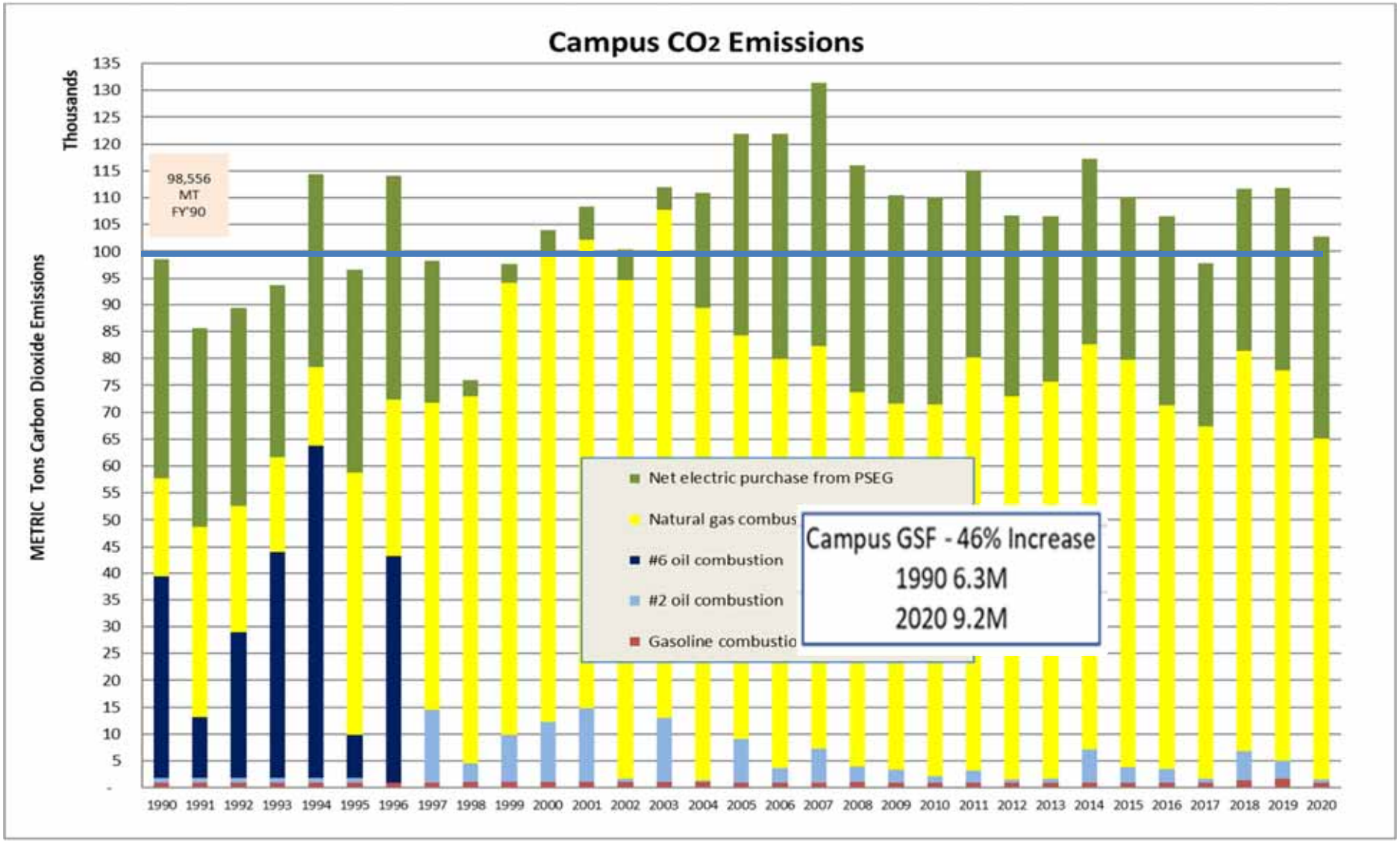
Main Campus Power, Generated & Purchased
During PV System Testing August 30, 2012




Campus CO2 potential of Emissions reduction
Pre-2009 projects 12%
Central Plant Efficiency 14%
Lighting Improvement Projects 6%
Distribution System Improvements 21%
Building HVAC Replacements 12%
Control System Optimization 8%
Photovoltaics 0%
Grid 27%

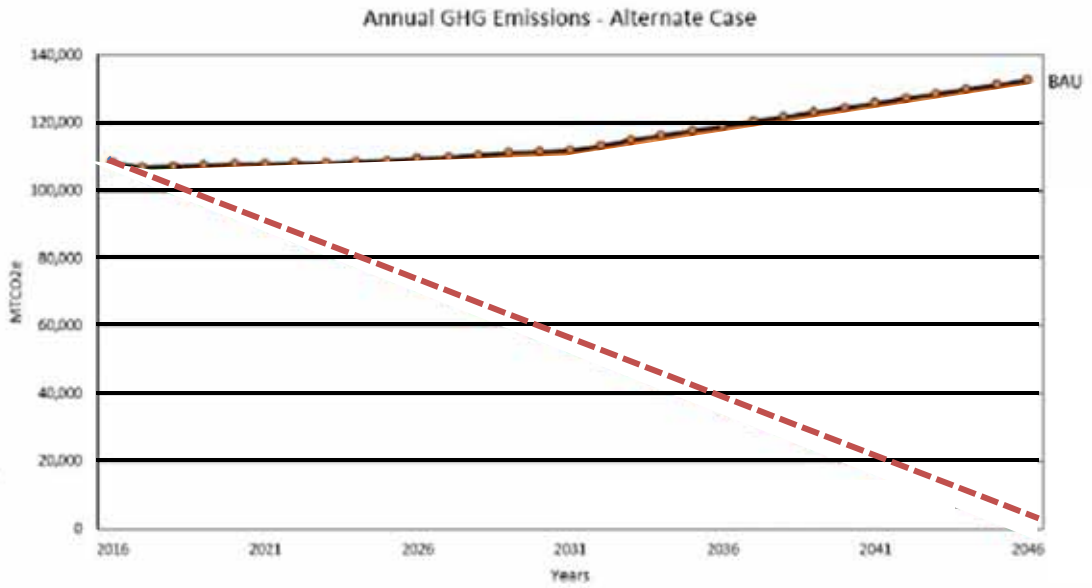
Campus 2020 Carbon Emissions Goal



What’s Next?

Goal: Carbon Neutrality

- Carbon Neutrality by 2046
- Continuous downward slope from present



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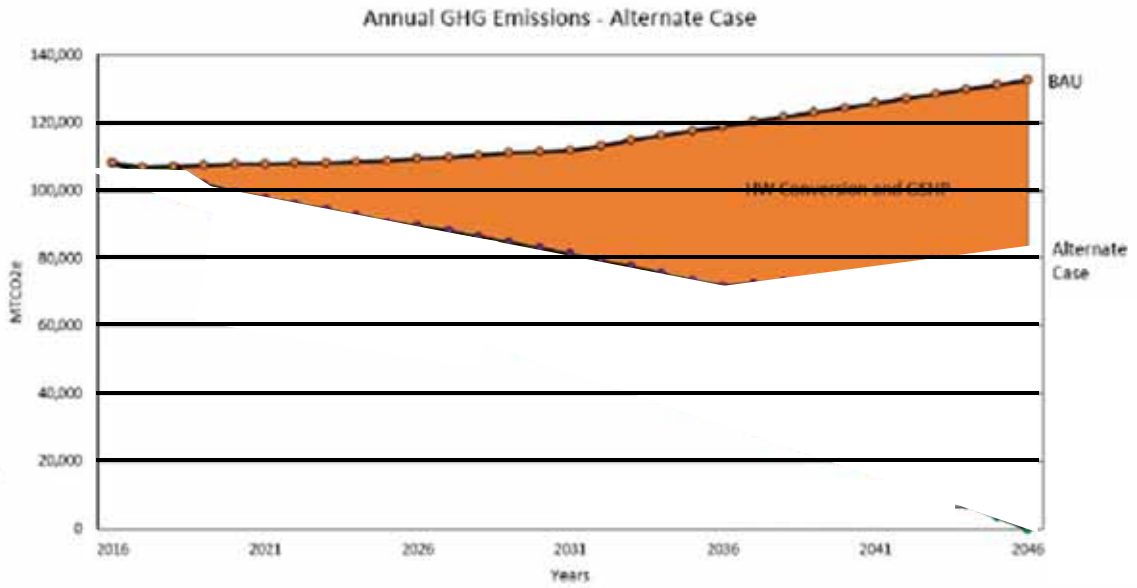

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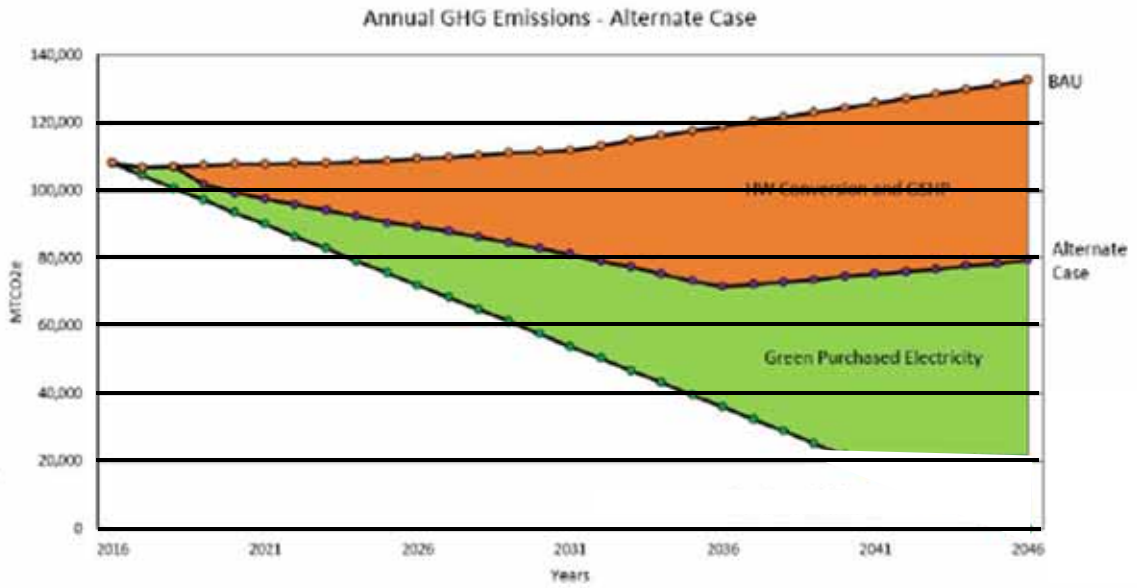

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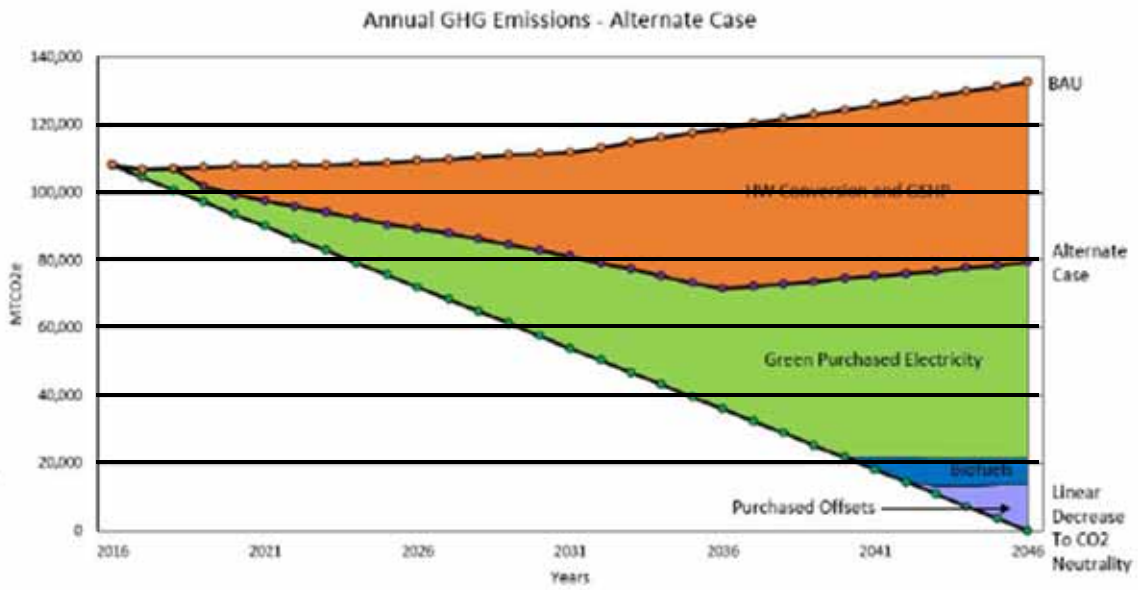
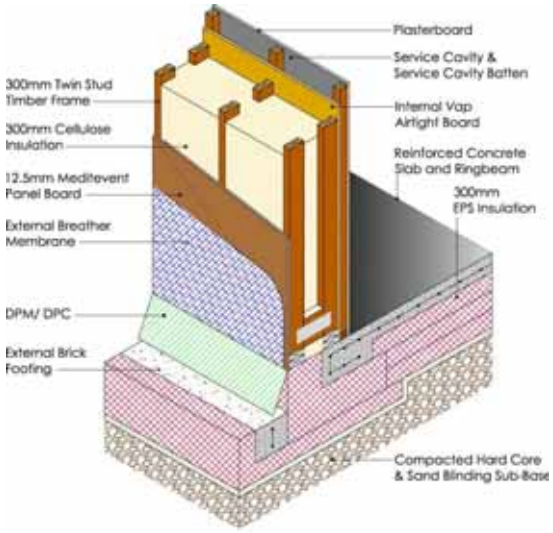


Major Areas of Work to Minimize Carbon Footprint:

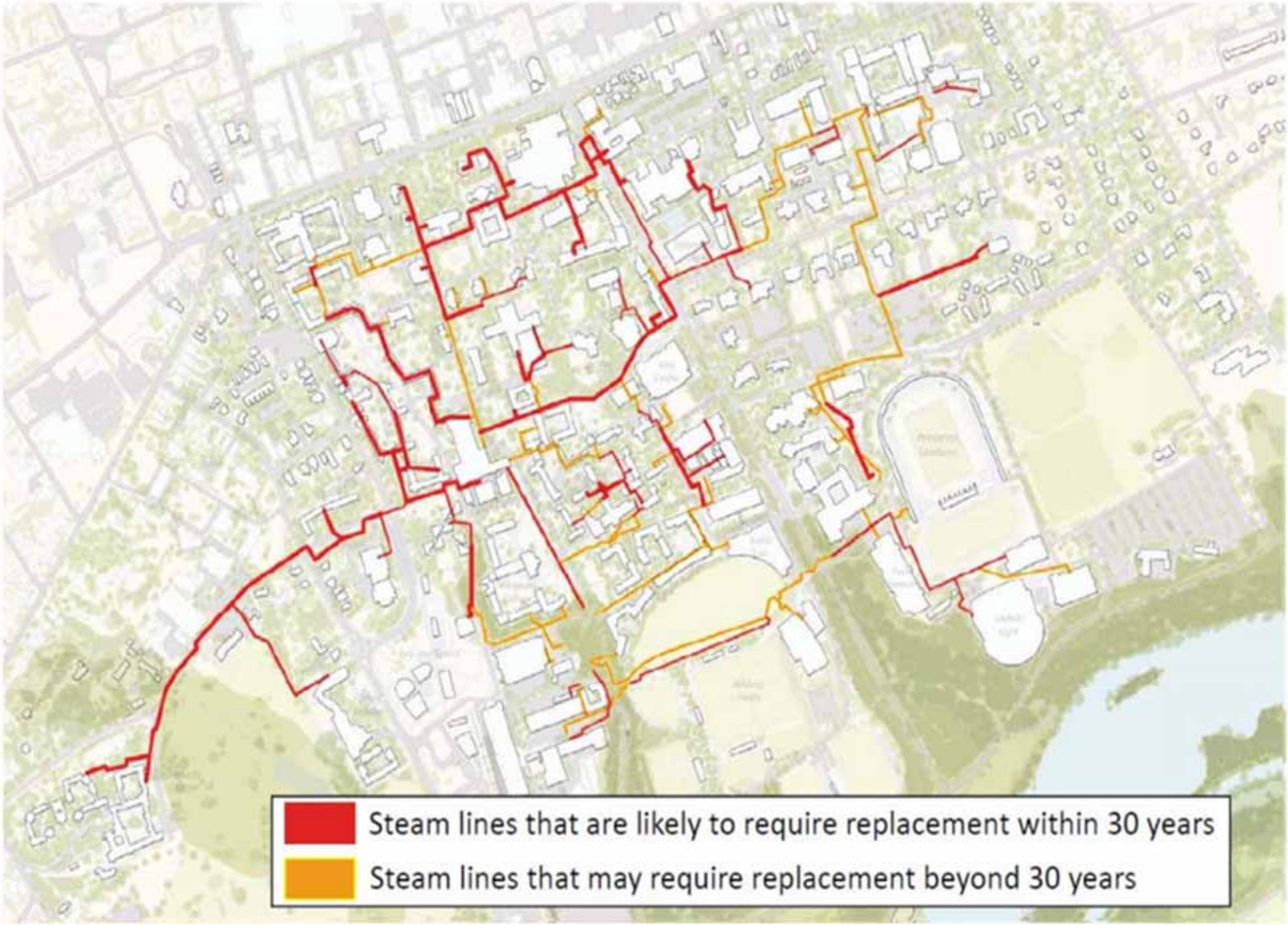
- High performance envelope, passive design, use of hot water for heating
- Replace district steam system with district hot water system
- Create electric-powered Heat Pump facility
- Create daily thermal storage – tanks
- Create seasonal thermal storage – geoexchange
- Install on-site renewable energy production – solar PV
- Supplement with off-site renewable energy

High performance envelope, Passive design, Hot water for heating

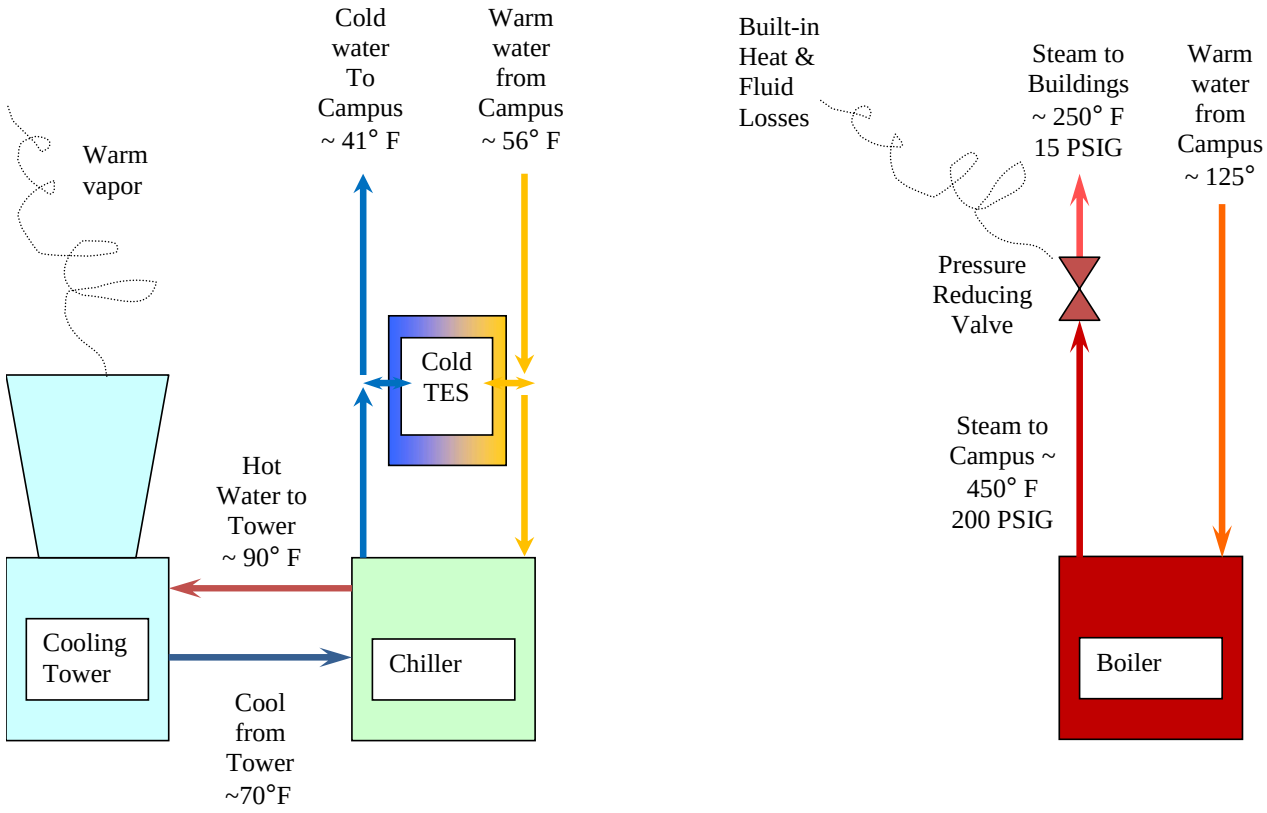


Passive Wall & Foundation Junction

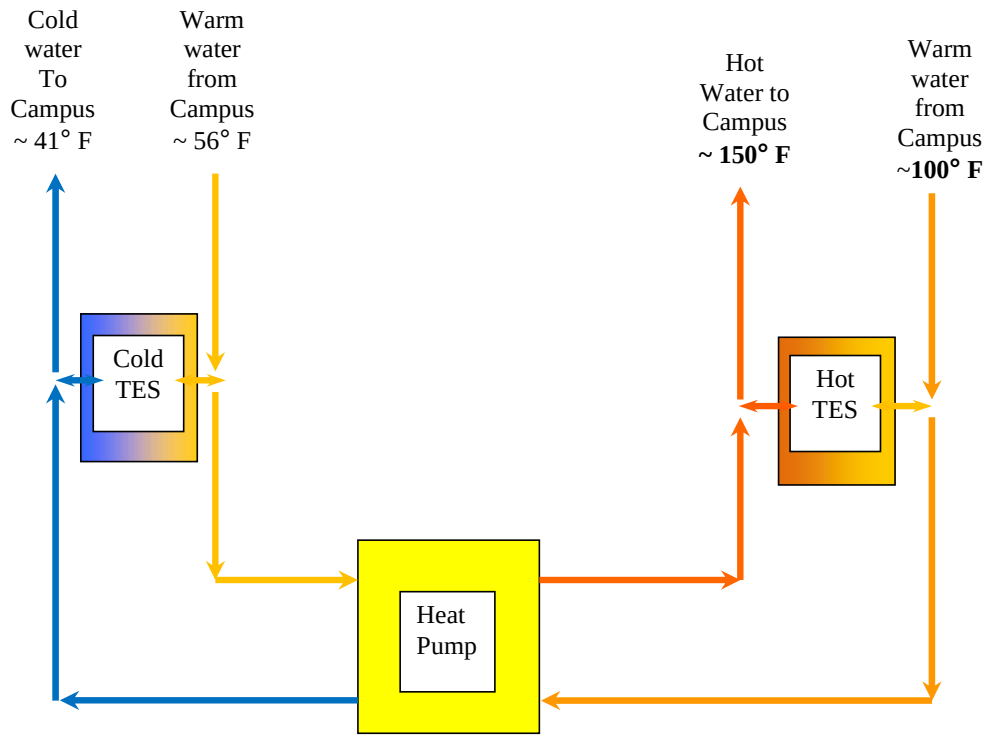
Plate and Frame Heat Exchanger System


Steam lines that are likely to require replacement within 30 years
Steam lines that may require replacement beyond 30 years

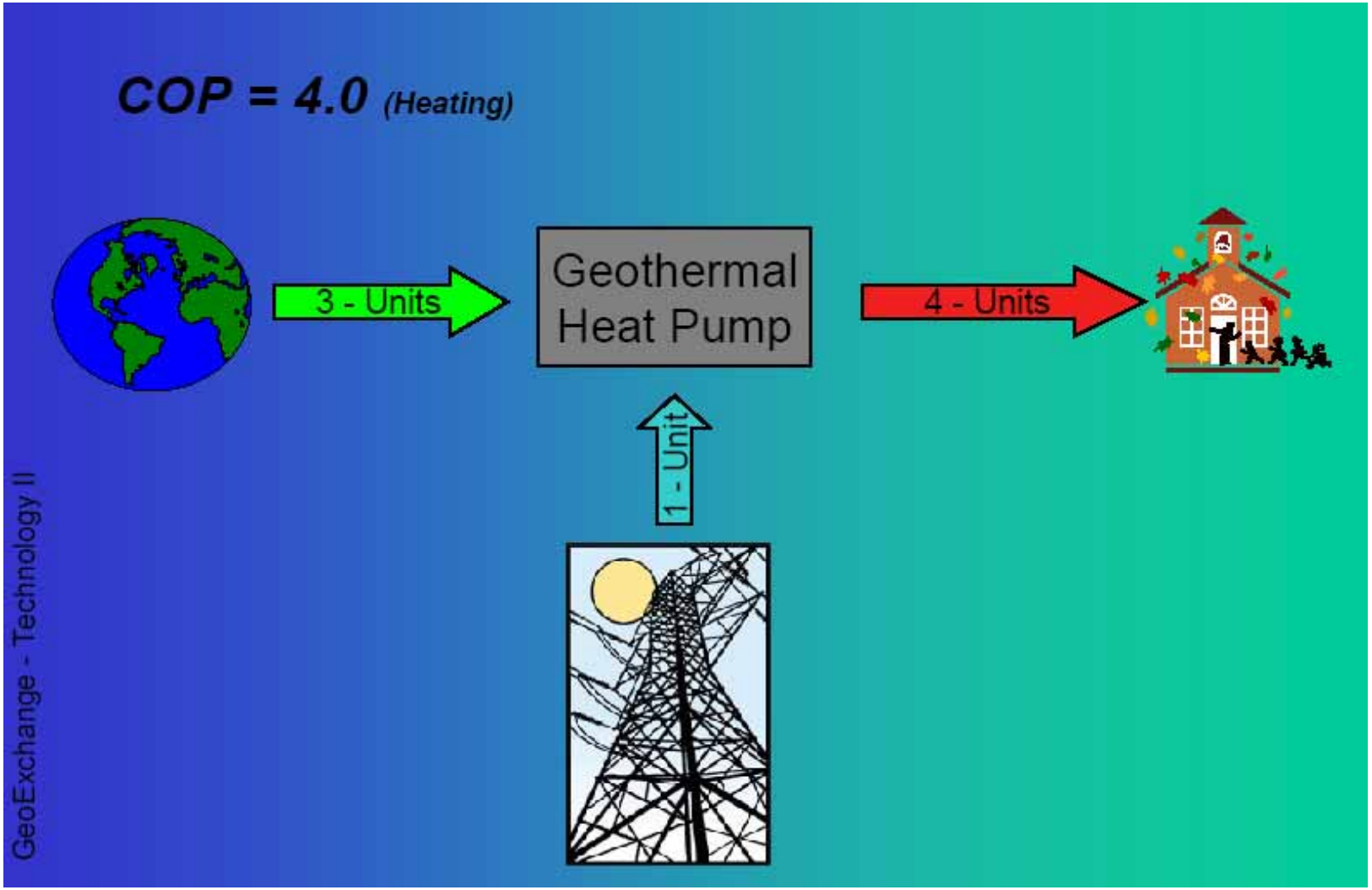
Separate Heat Removal (CHW) & Addition (Steam)



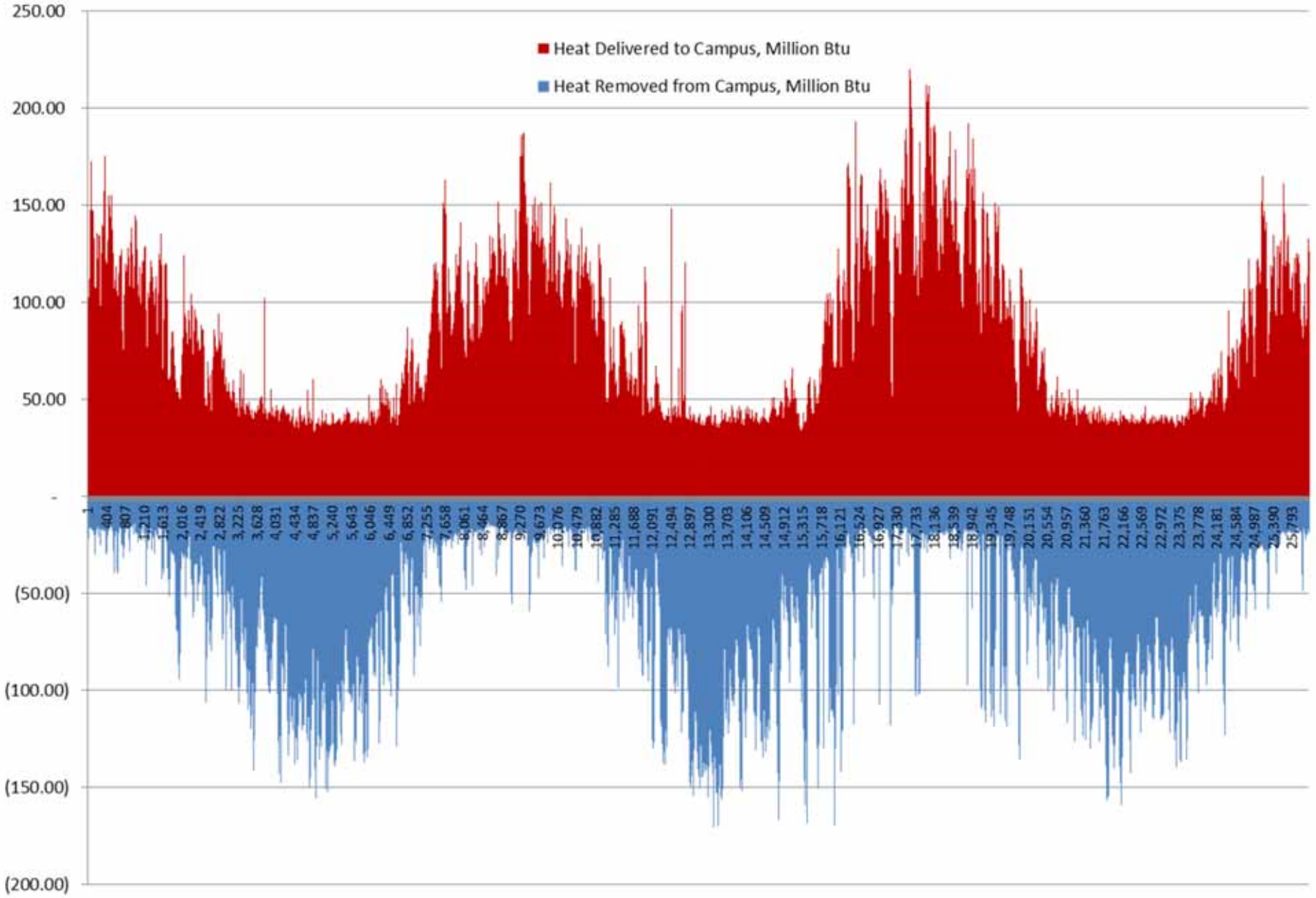
Combined Heat Removal (CHW) & Addition (HTW)



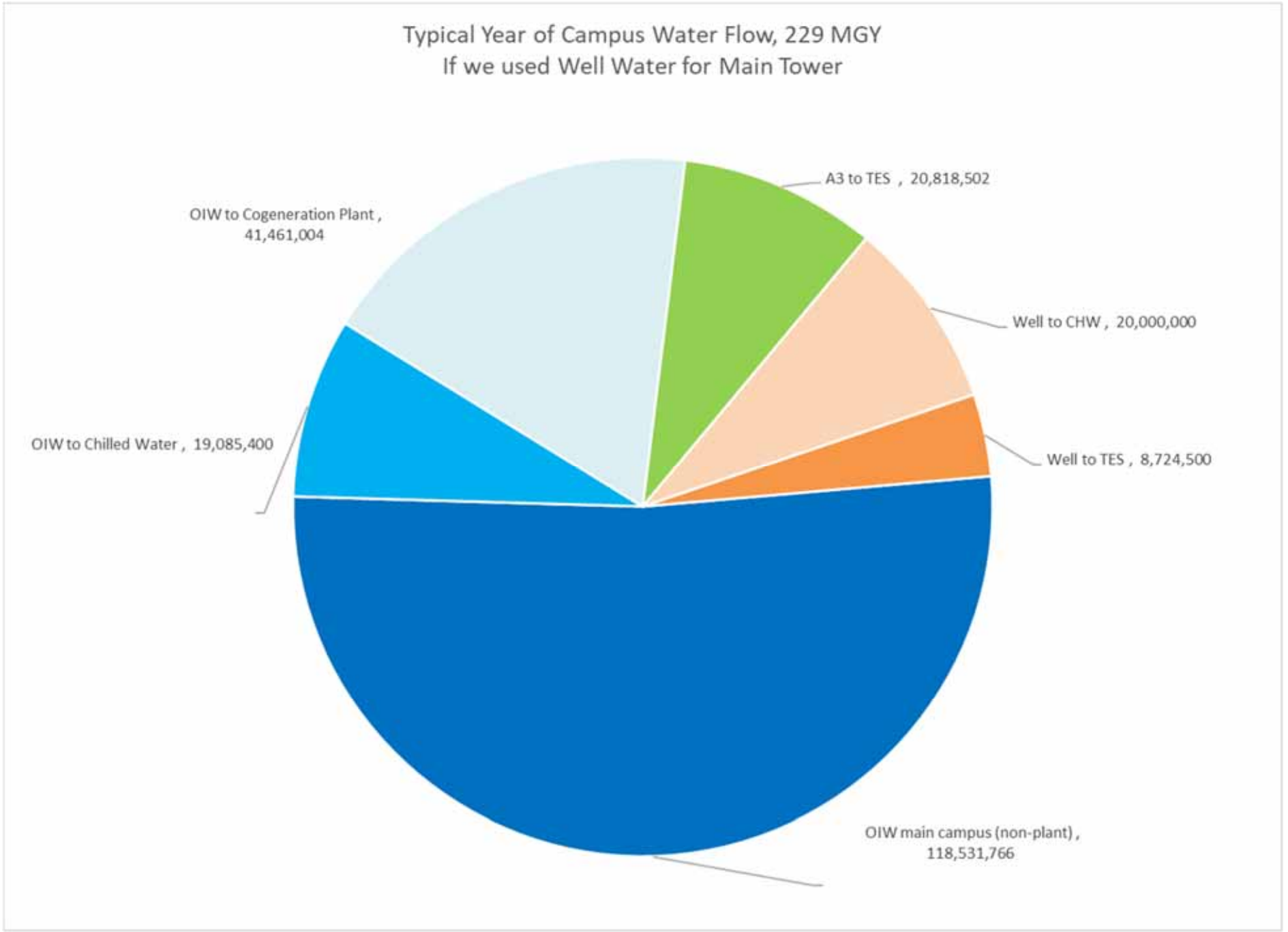
Ground Source Heat Pump
Heating Mode

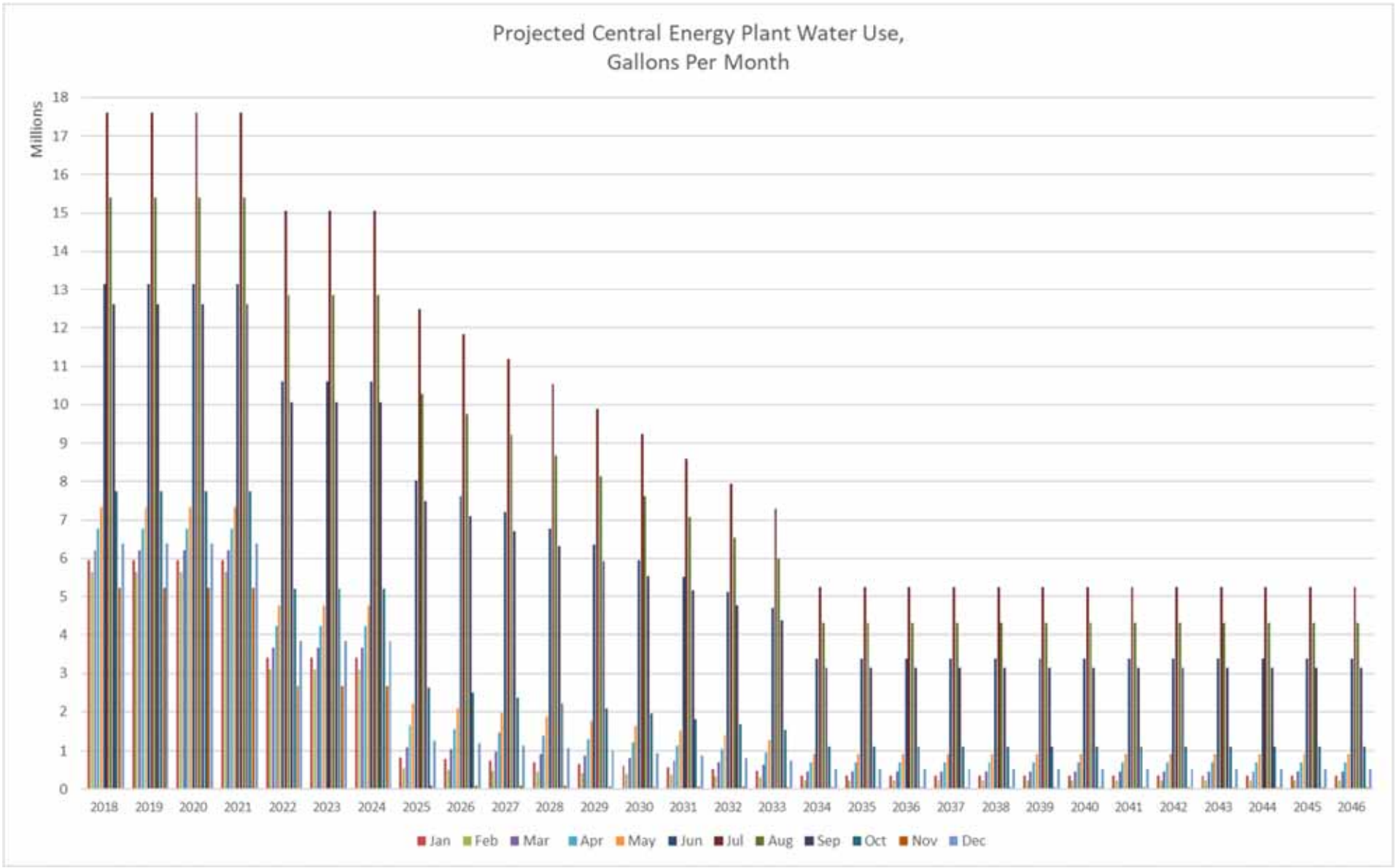


Hourly Heat Addition to campus and heat removal from campus
3-year period, Jan 2012 - Dec 2014



TIGER Plant Rendering


Typical Year of Campus Water Flow, 229 MGY
If we used Well Water for Main Tower
A3 to TES , 20,818,502
OIW to Cogeneration Plant , 41,461,004
Well to CHW , 20,000,000
OIW to Chilled Water , 19,085,400
Well to TES , 8,724,500
OIW main campus (non-plant) , 118,531,766


Projected Central Energy Plant Water Use,
Gallons Per Month
Millions
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
2018
2019
2020
2021
2022
2023
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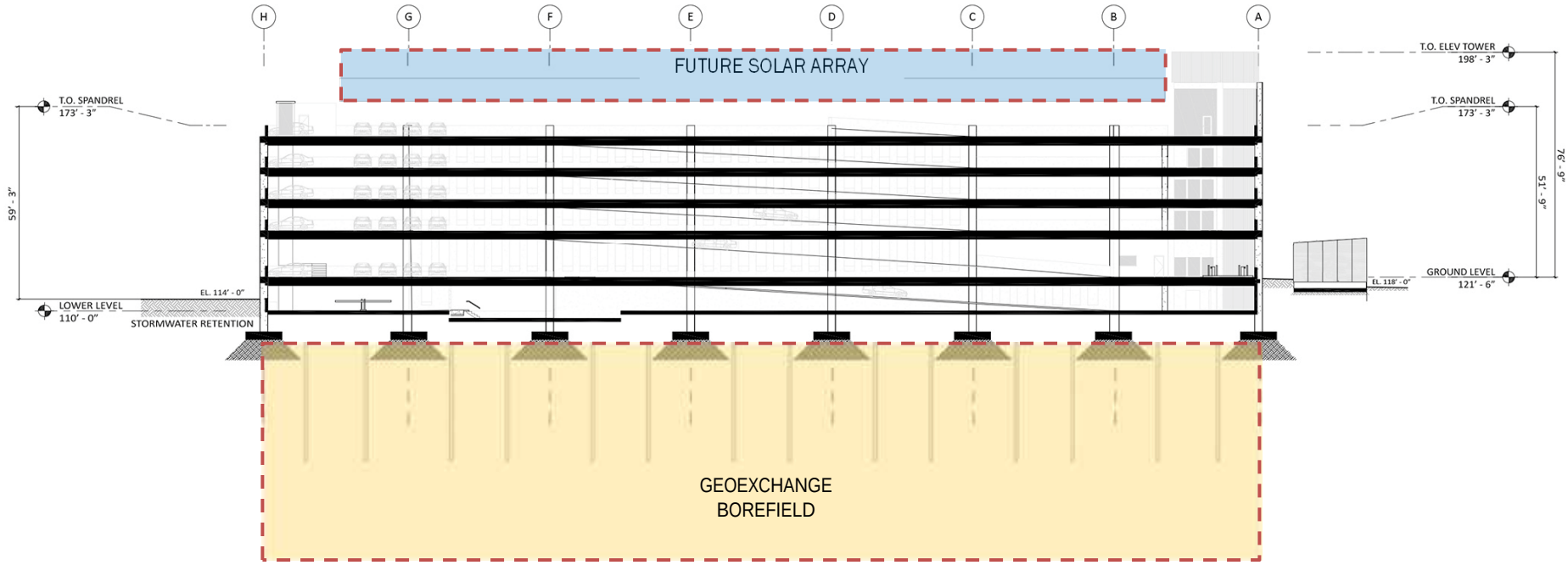
Dec

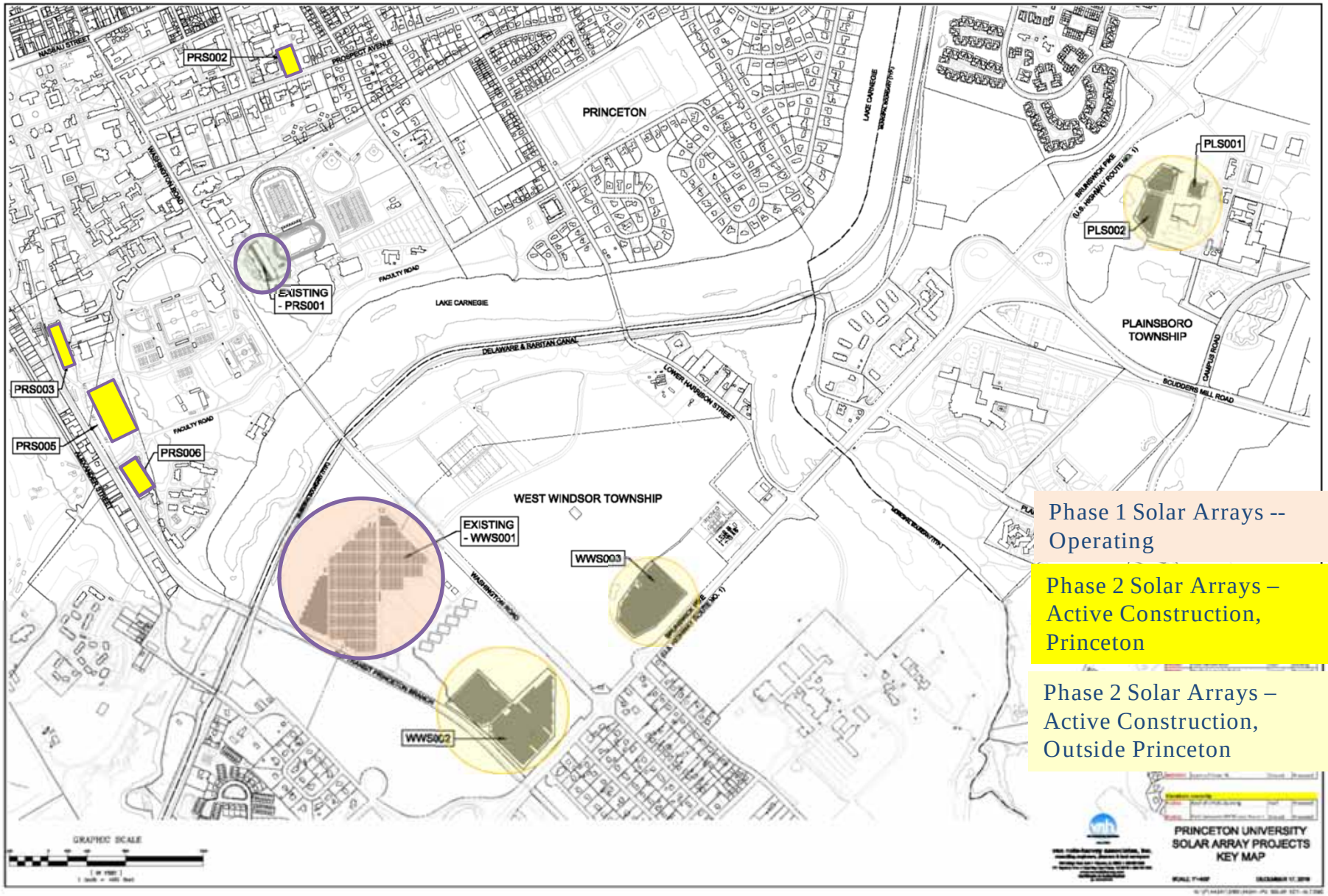
Multiple Concurrent Uses For Land



Campus-Scale Solar Energy – Via PPA

- **Phase 1:** Existing: 4.5 Megawatts
  Delivers 5 ½% of current campus electric demands
- **Phase 2:** Active Construction: 12 Megawatts
  Will reach ~ 19% of current campus electric demands
  Output from 16.5 MW of solar arrays could power 3600 average US homes.
- **Phase 3:** Parking deck, TIGER, others…
- **"Solar Ready"**
  - Structural design for loads
  - Conduit to electrical room
  - Space for inverter & transformer
  - Campus power distribution network
  - Campus Data Network
- **What is a PPA?**

Campus PV Locations



Phase 1 Solar Arrays -- Operating

Phase 2 Solar Arrays – Active Construction, Princeton

Phase 2 Solar Arrays – Active Construction, Outside Princeton