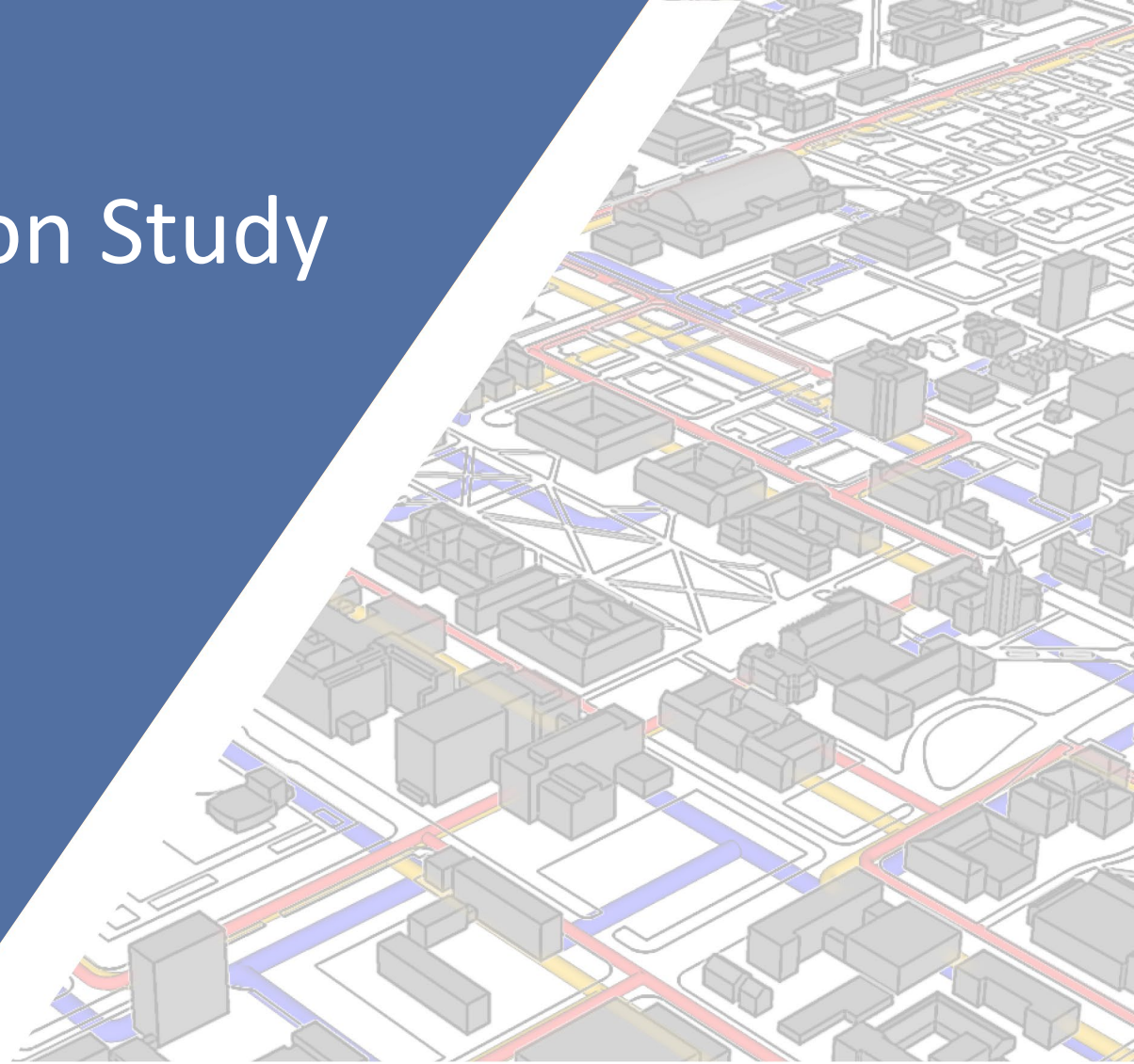
Pennsylvania State University
Steam to Hot Water Conversion Study
(Level 1 Investigation)



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PennState

Affiliated Engineers

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International District Energy Association
Campus Energy 2020
February 10-14, 2020

Penn State University System (All Campuses)

- 99,133 Students
- 6,470 Faculty
- 20,060 Staff
- 1,000+ Buildings
- 30 million sq ft of space
- 20+ Campuses

Penn State University Park Campus

- **1855** **Established by Land Grant**
- **45,000** **Students**
- **7,342 acres** **of Campus Area**
- **600** **Buildings on Campus**
- **20 million ft^2** **Building Space**
- **$4.3 billion** **Building Replacement Value**
- **34 years** **Average Age of Buildings**

Every Year, Penn State's University Park campus uses the same amount of heating and electrical energy as a Pennsylvania community with 30,000 homes.

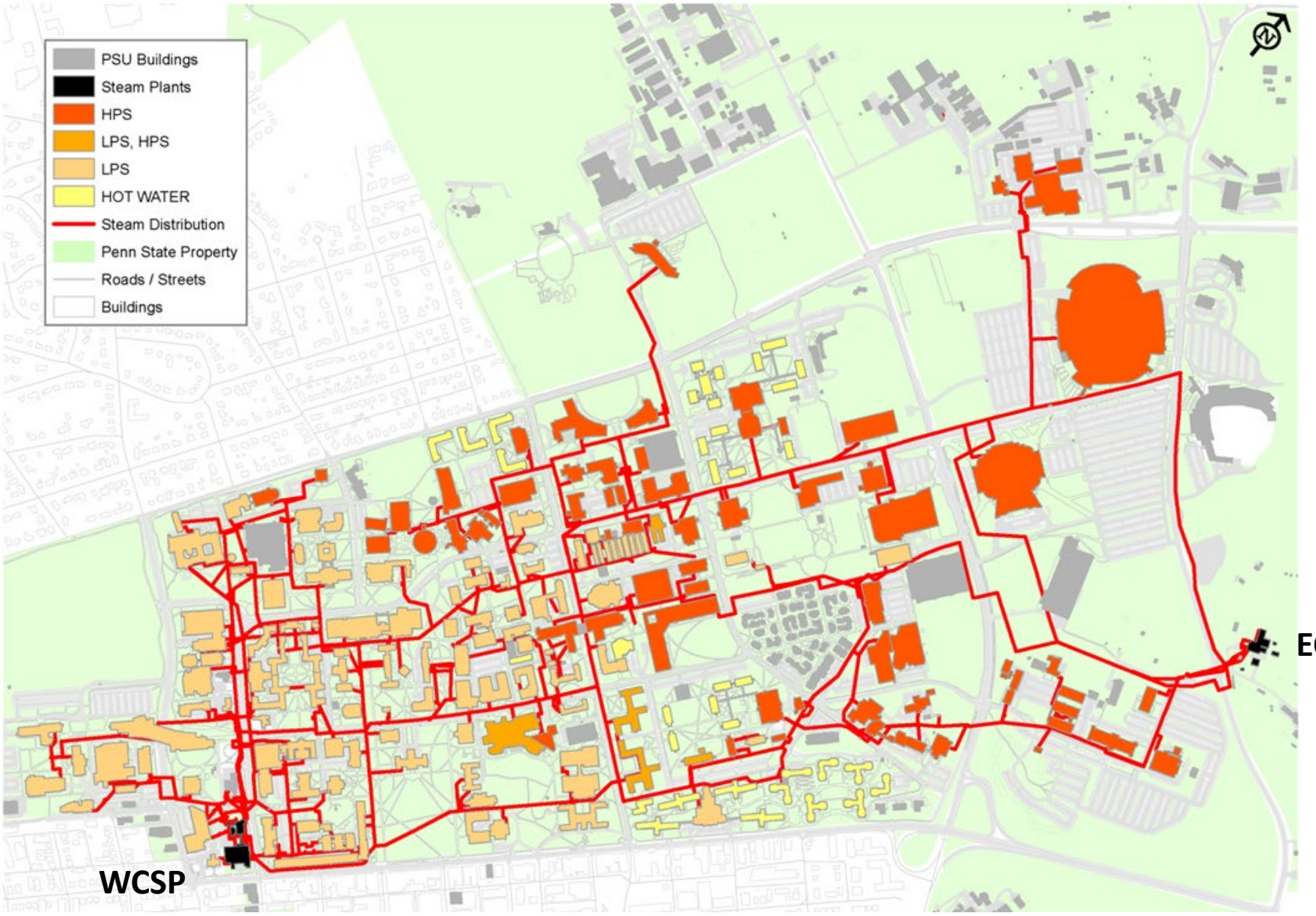
Penn State University Park Campus Energy

• 200+	Buildings Served w/steam
• 2	CHP Plants – ECSP, WCSP
• 430/80 kpph	Peak/Minimum Steam Demand
• 19 Miles	Steam Distribution Piping
• 50/30 MW	Summer/Winter Electrical Demand
• 12 MW	CHP Electrical Generation
• 300,000,000 kWh	$16 Million Annual Electric Purchase
• 350/50 kgal	ECSP/WCSP on site Diesel
• 2,000,000 DT	$7 Million Annual Natural Gas Purchase

Penn State University Steam Generation

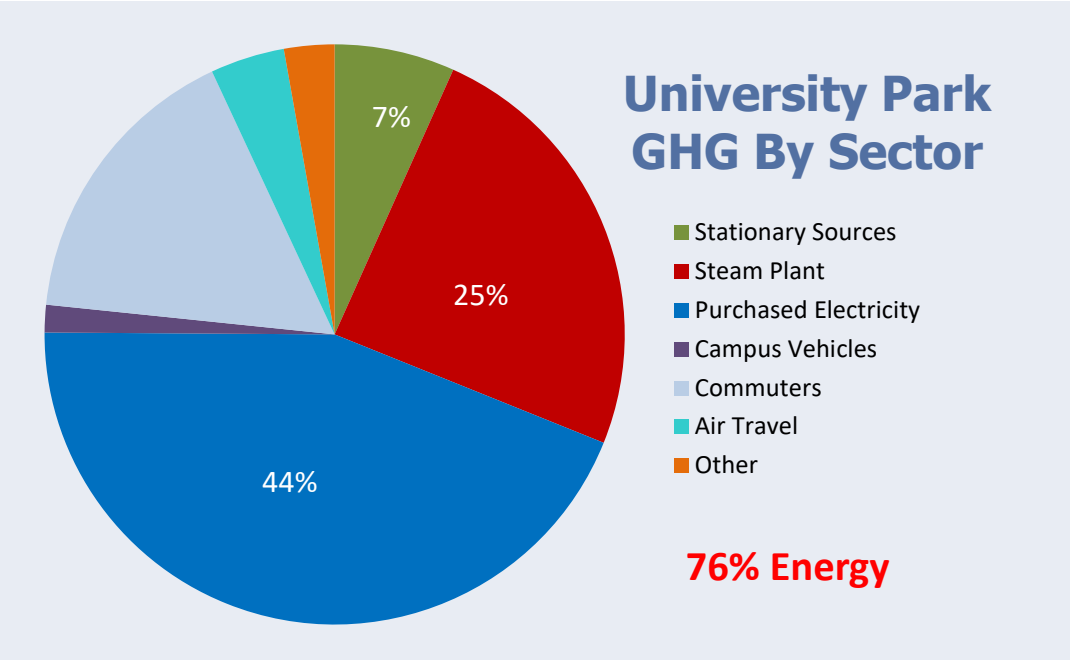
- **Two Interconnected Steam Plants**
  - **West Campus Steam Plant (WCSP)**
    - 338,000 pph of Available Boiler Capacity
    - Generates 250 psig / 530°F Steam
    - Distributes 150 psig (HPS) and 13 psig steam (LPS)
    - Two Steam Turbine Generators (5.0MW total)
      - Steam In (250 psig / 530°F)
      - Steam Out (13 psig)
  - **East Campus Steam Plant (ECSP)**
    - 317,000 pph of Available Boiler Capacity
    - Generates 250 psig saturated steam
    - Distributes 150 psig (HPS)
  - **655,000 pph Total Capacity**

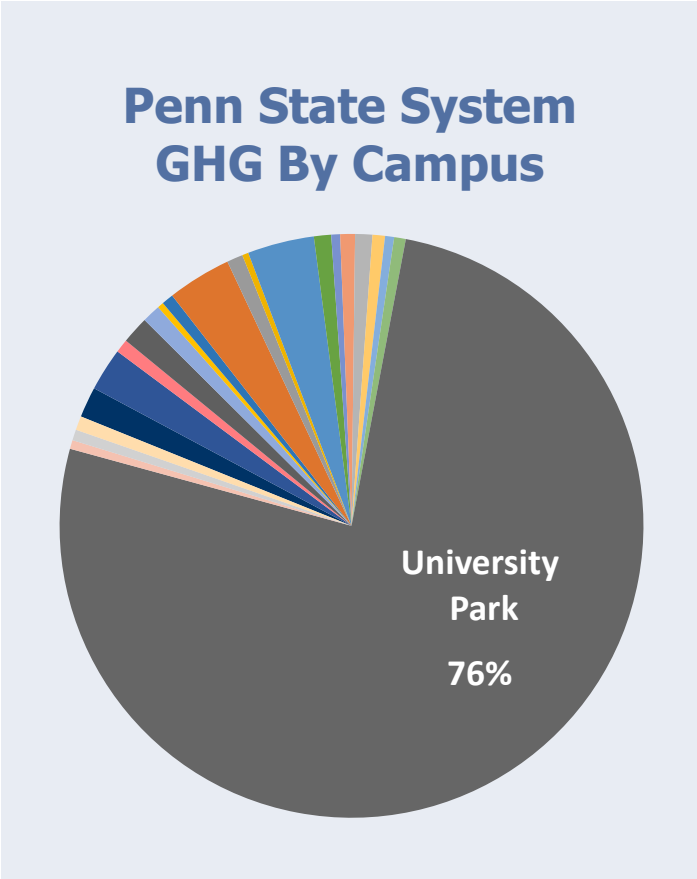
District Steam at University Park



Penn State University GHG Emissions

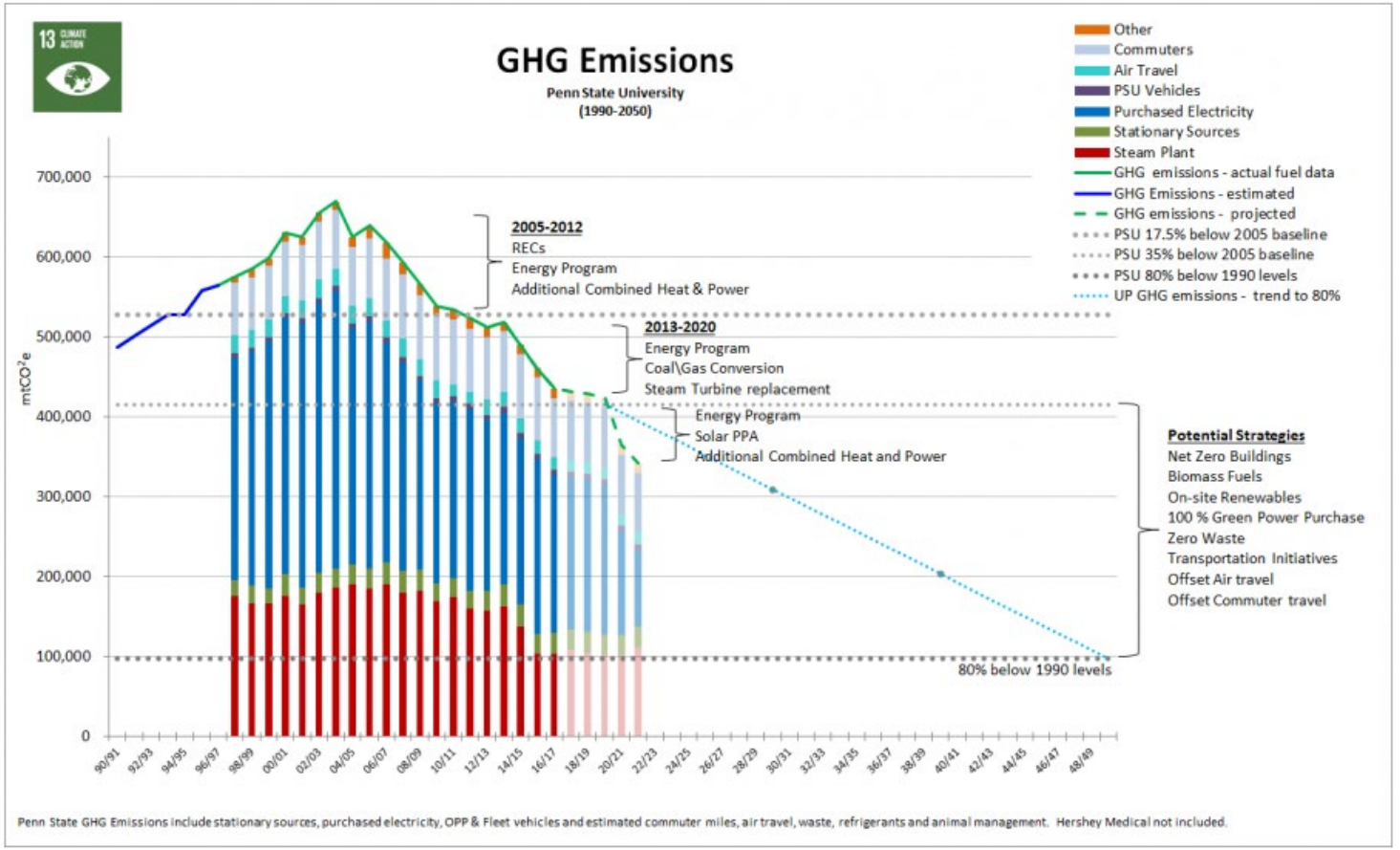
- **Penn State's GHG Inventory primarily includes direct emissions and emissions from purchased electricity**
- **Energy at University Park is the largest contributor**





Project Goals

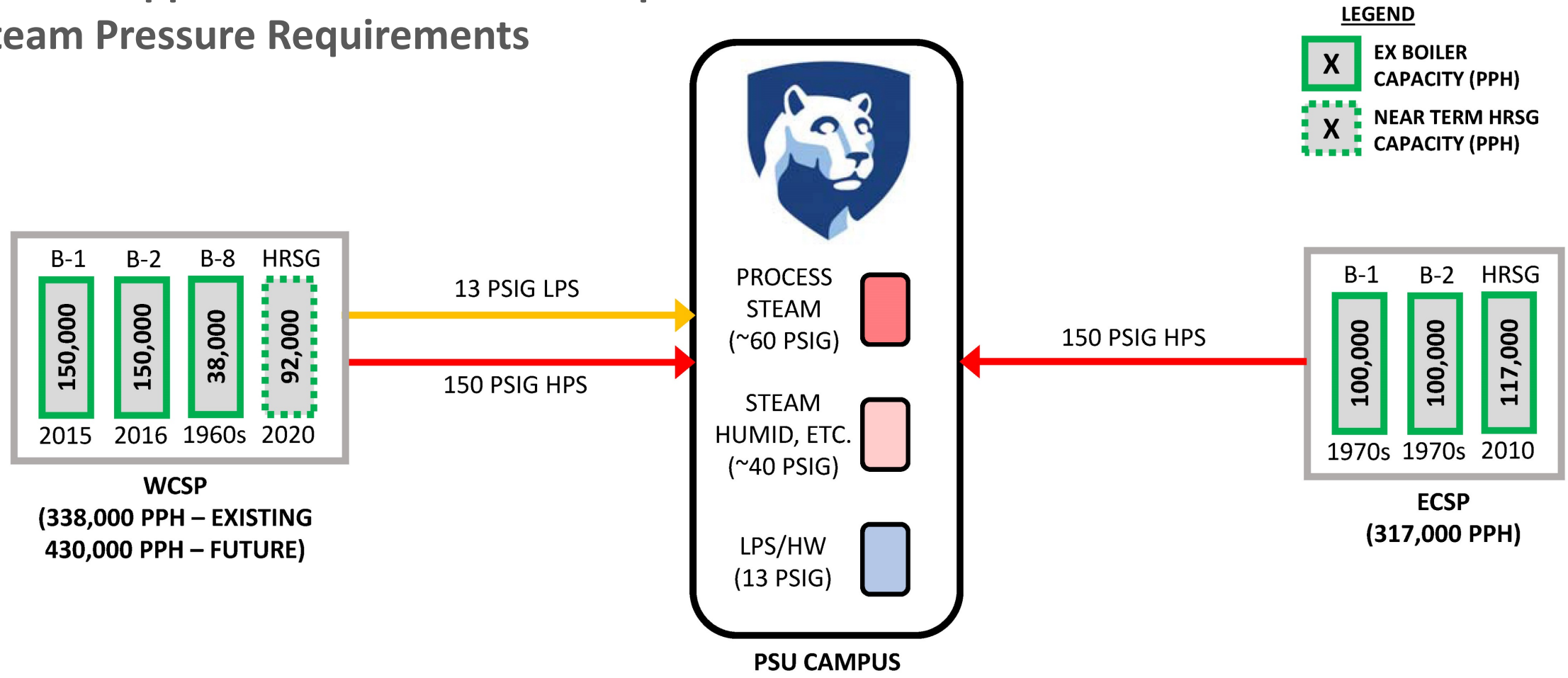
- Evaluate various hot water distribution conversion systems to **reduce energy and greenhouse gas emissions as well as maintenance costs**
- Compare to emission reductions forecasted with the implementation of a biomass boiler plant



Steam to Hot Water Conversion Analysis

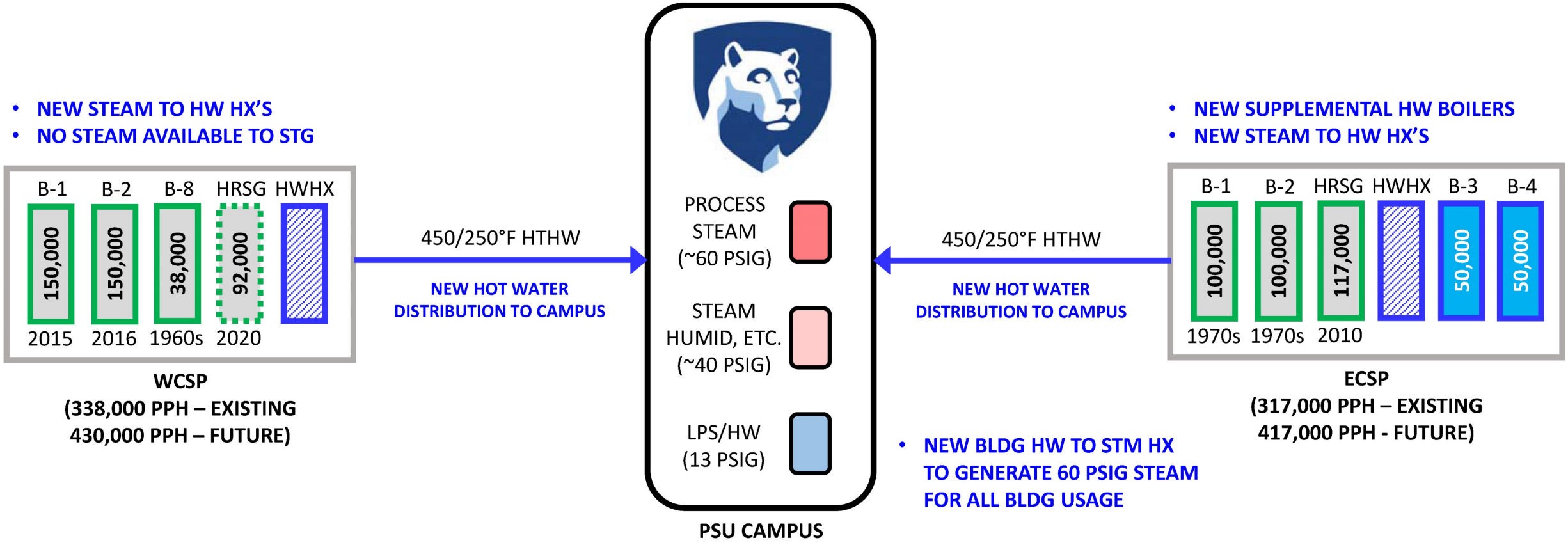
Hot Water Distribution Option 1 (Base Steam)

- **Existing Base Approach**
- **Several Opportunities with the Campus Steam Pressure Requirements**



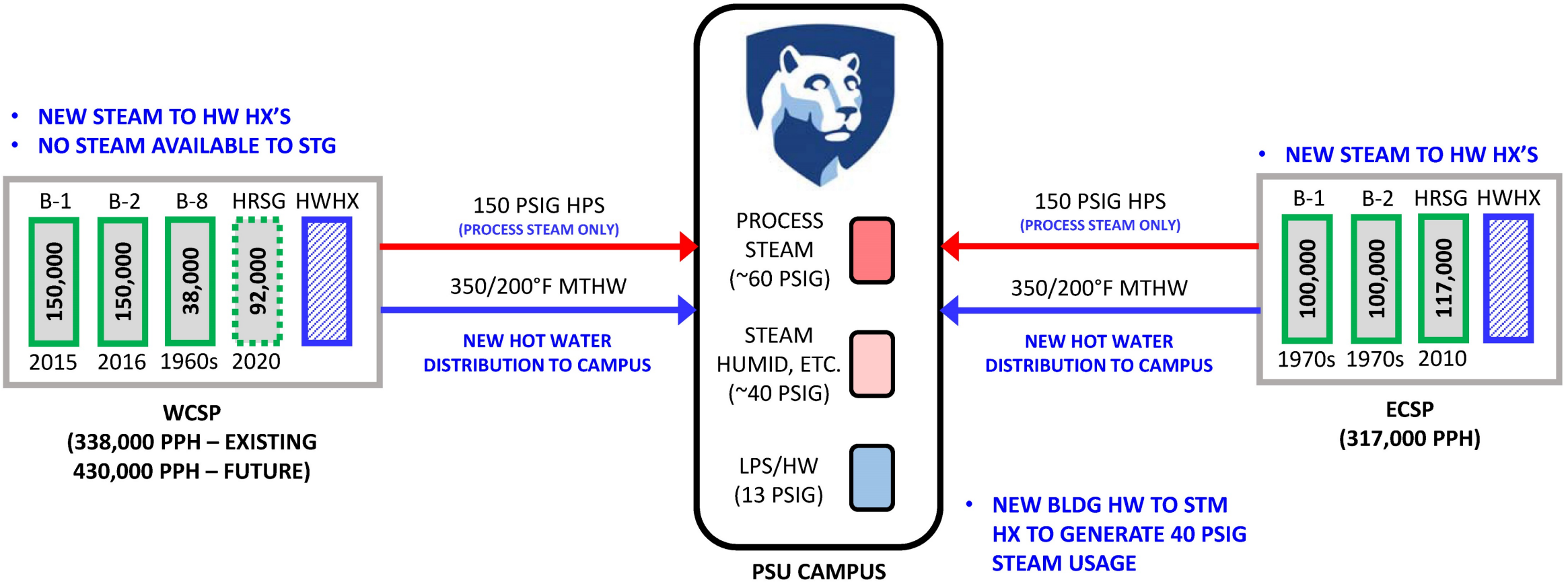
Hot Water Distribution Option 2 (HTHW)

- 450°F supply temperature selected to generate 60 psig in buildings
- Require HTHW generators in ECSP to generate 450°F
- Safest hot water option (ASME/ASHRAE)



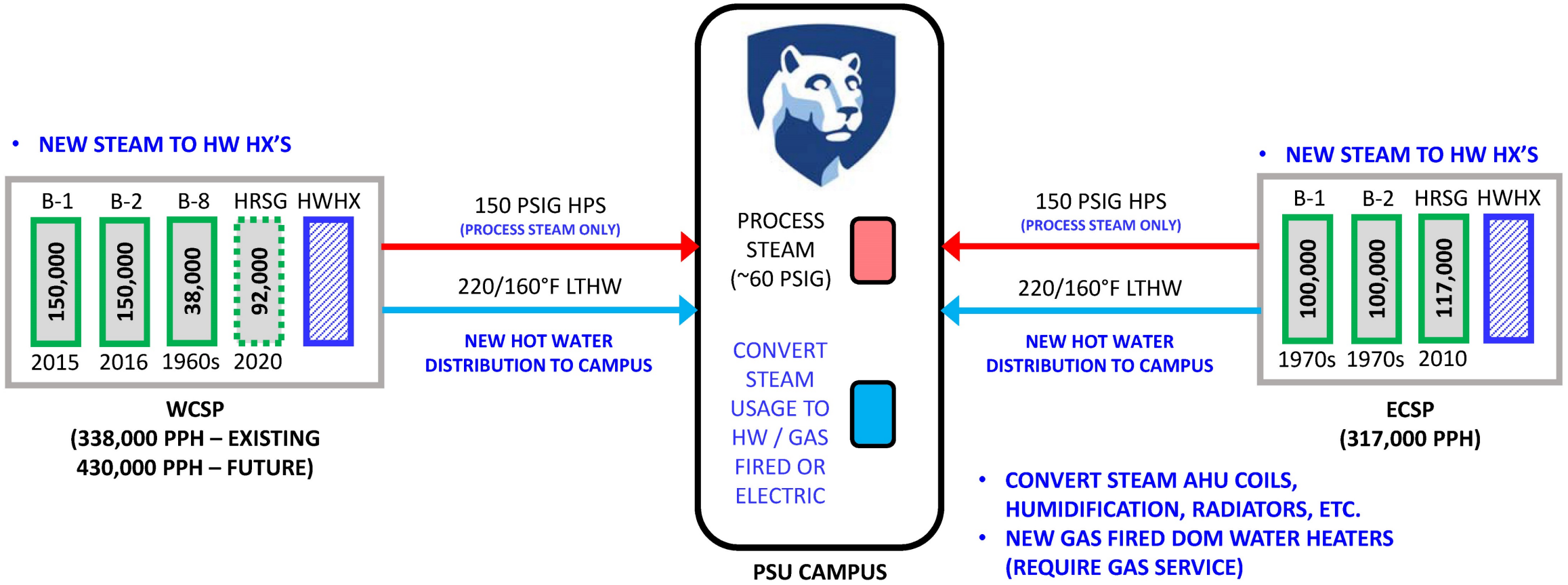
Hot Water Distribution Option 3 (MTHW)

- 350°F supply temperature selected to generate 40 psig in buildings
- Maintain portion of HPS system or install district HPS generation / distribution systems



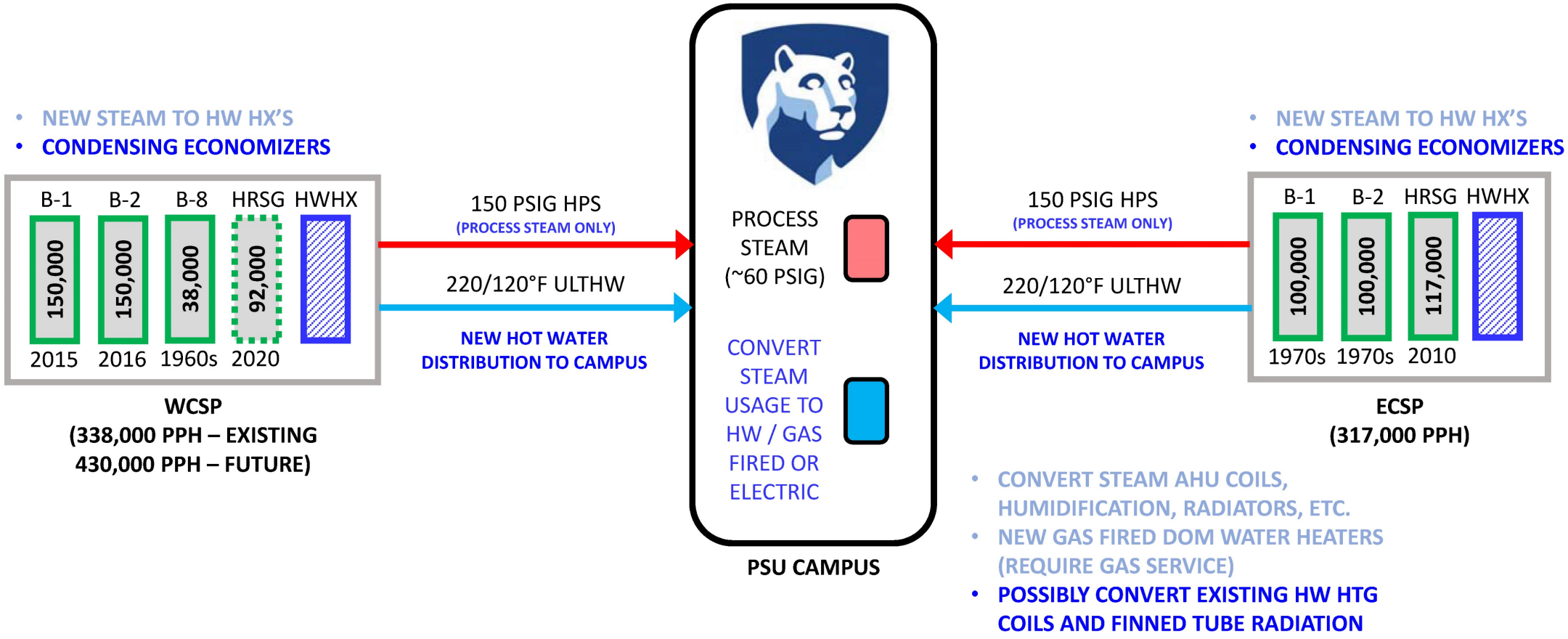
Hot Water Distribution Option 4 (LTHW)

- 220°F supply temperature selected as it can be generated by 13 psig steam at plants
- Continue use of WCSP steam turbine generators
- Maintain portion of HPS system or install district HPS generation / distribution systems



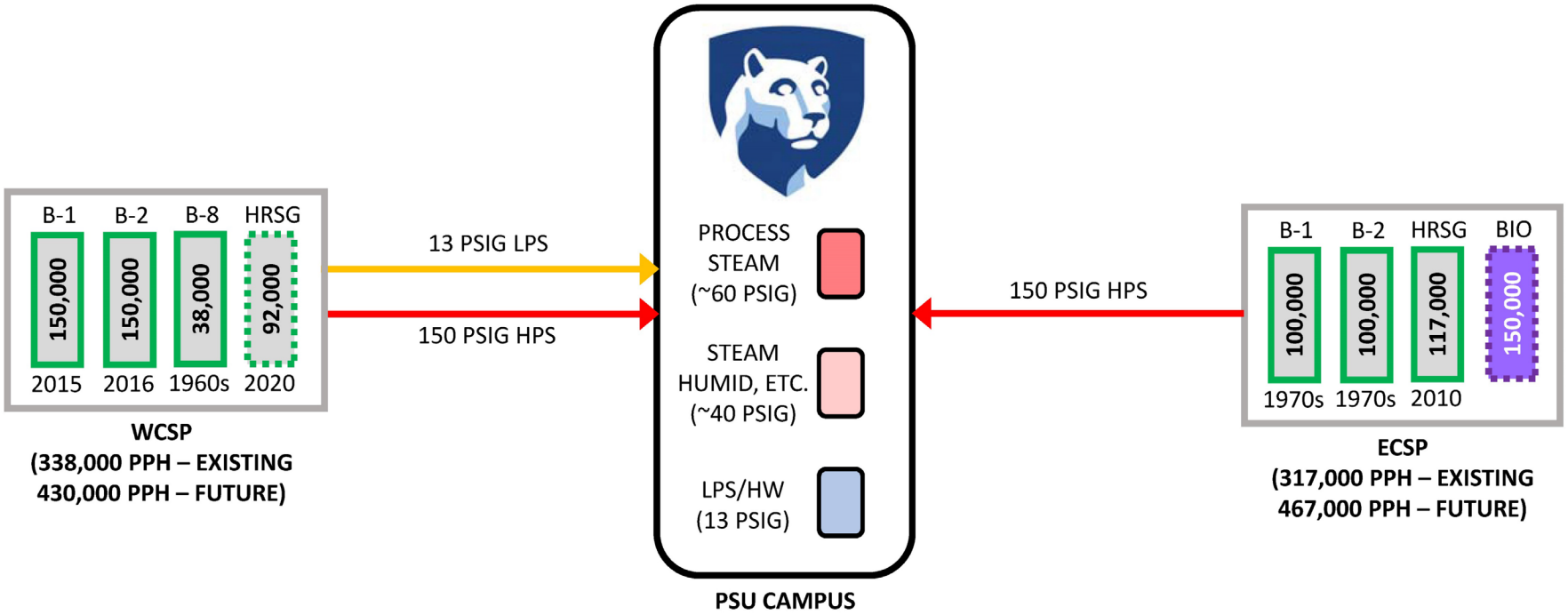
Hot Water Distribution Option 5 (ULTHW)

- 120°F return temperature selected to allow use of HRC or condensing economizers
- Continue use of WCSP steam turbine generators
- Maintain portion of HPS system or install district HPS generation / distribution systems

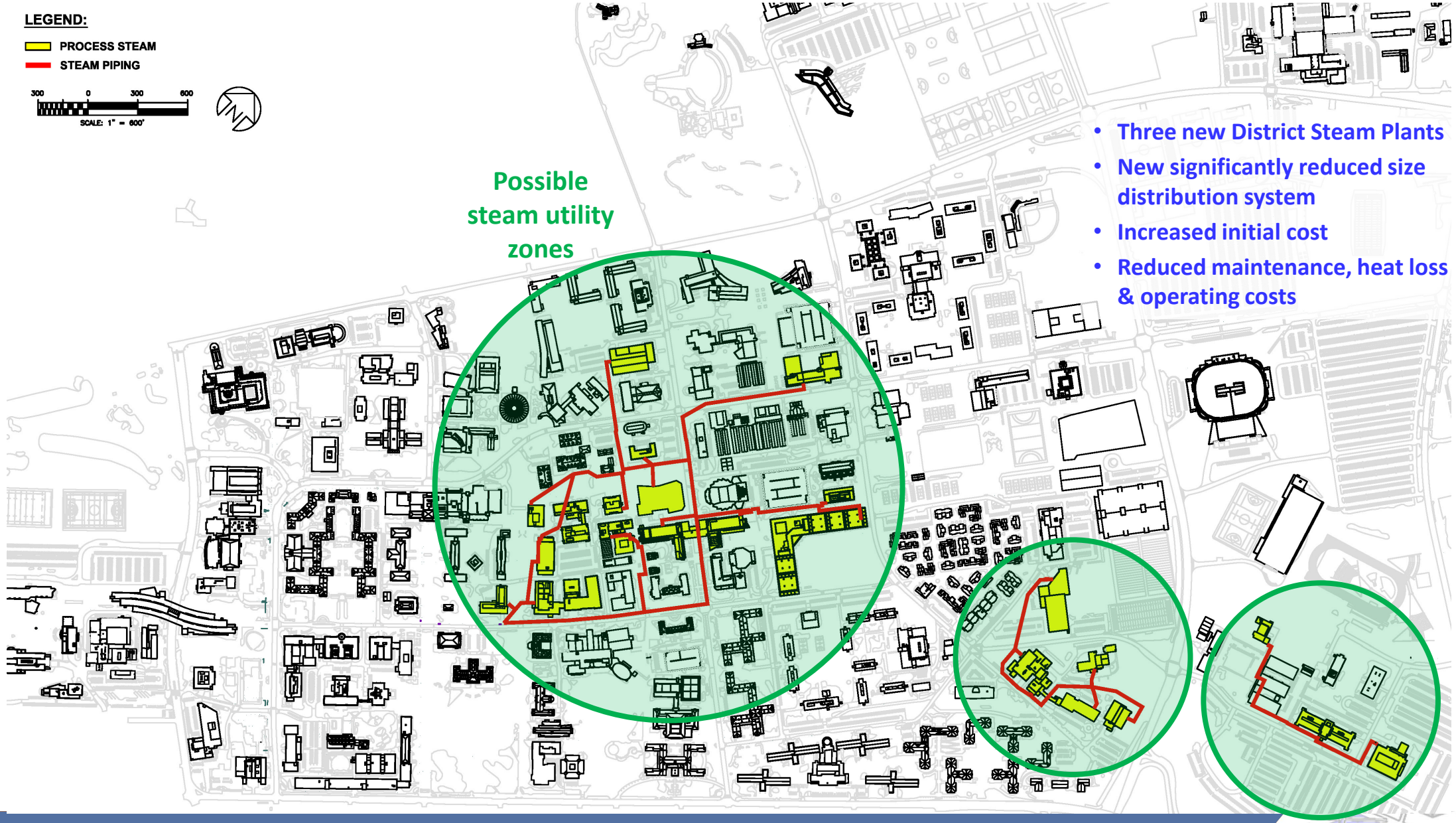


Option 6 (New 150,000 PPH Biomass Boiler)

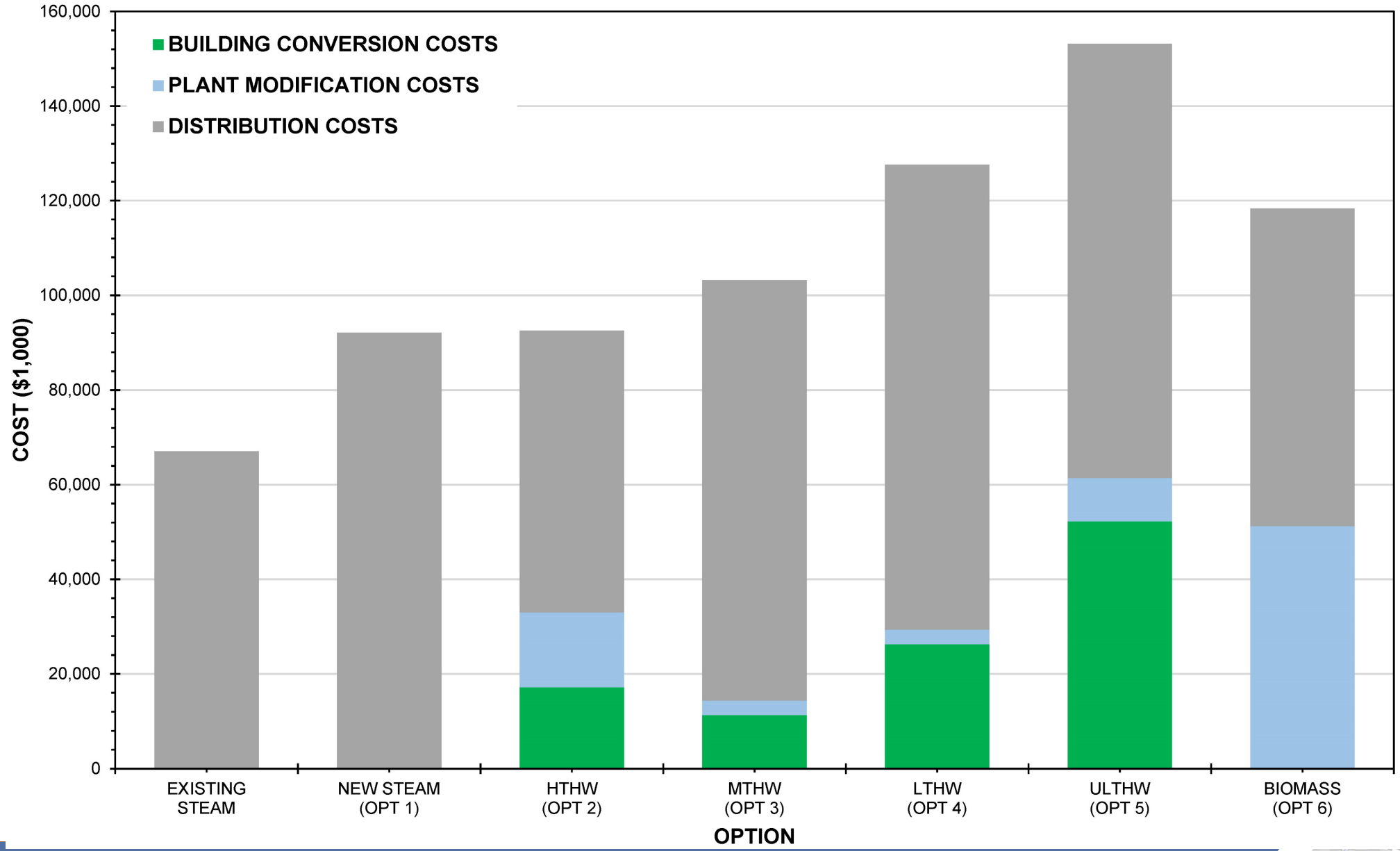
- Based on ECSP Master Plan costs and performance
- Initial cost of biomass option is $51,250,000 (before mark-ups)
- Stoker boiler efficiency = 72%
- Biomass fuel cost = $4.28/MMBtu
- Additional fixed plant annual costs of $650,000 (i.e. additional operators, maintenance)



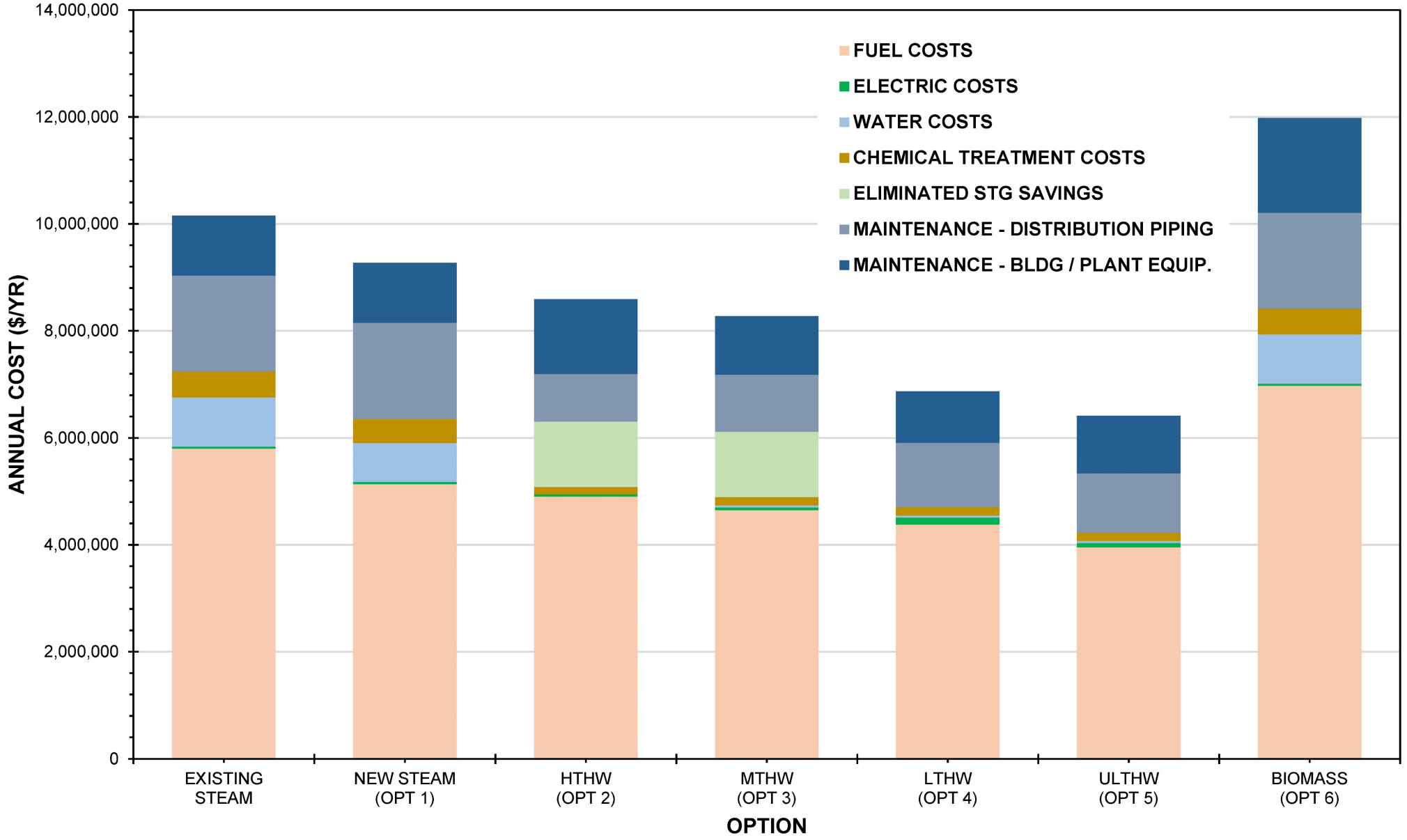
District Process Steam System (Alternative)



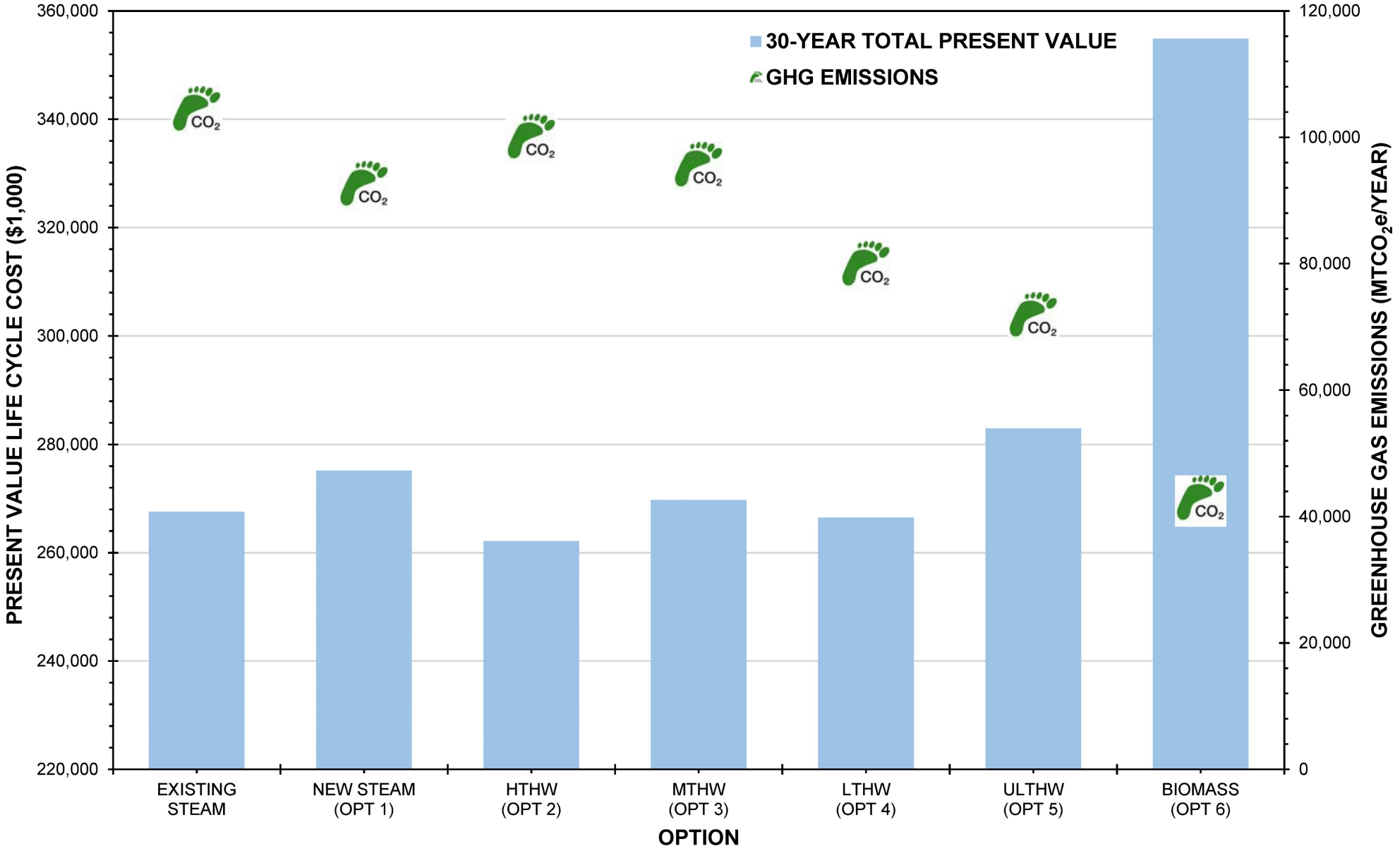
Capital Expenditure Comparison



Annual Operating Cost Comparison

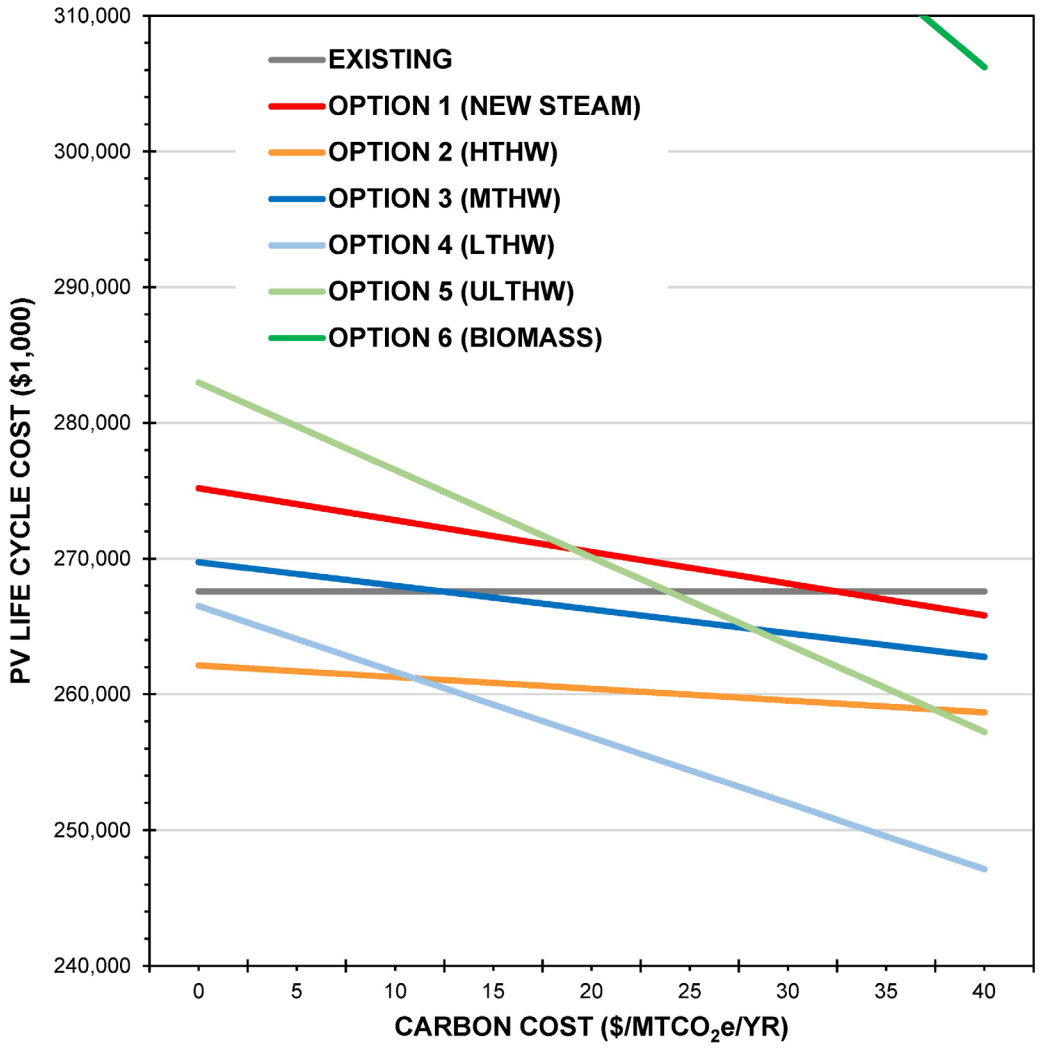


PV Life Cycle Cost and Emission Comparison

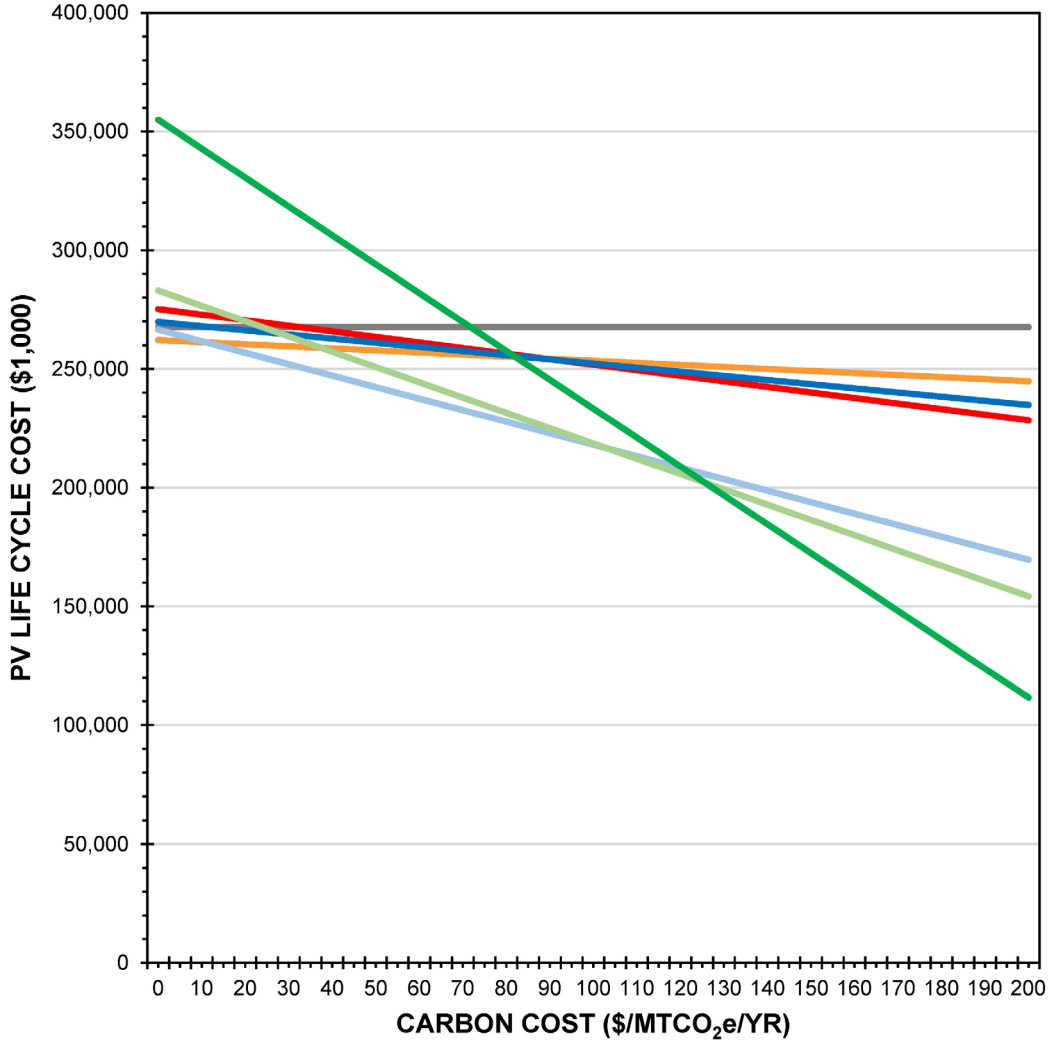


Life Cycle Cost Sensitivity – Carbon Tax

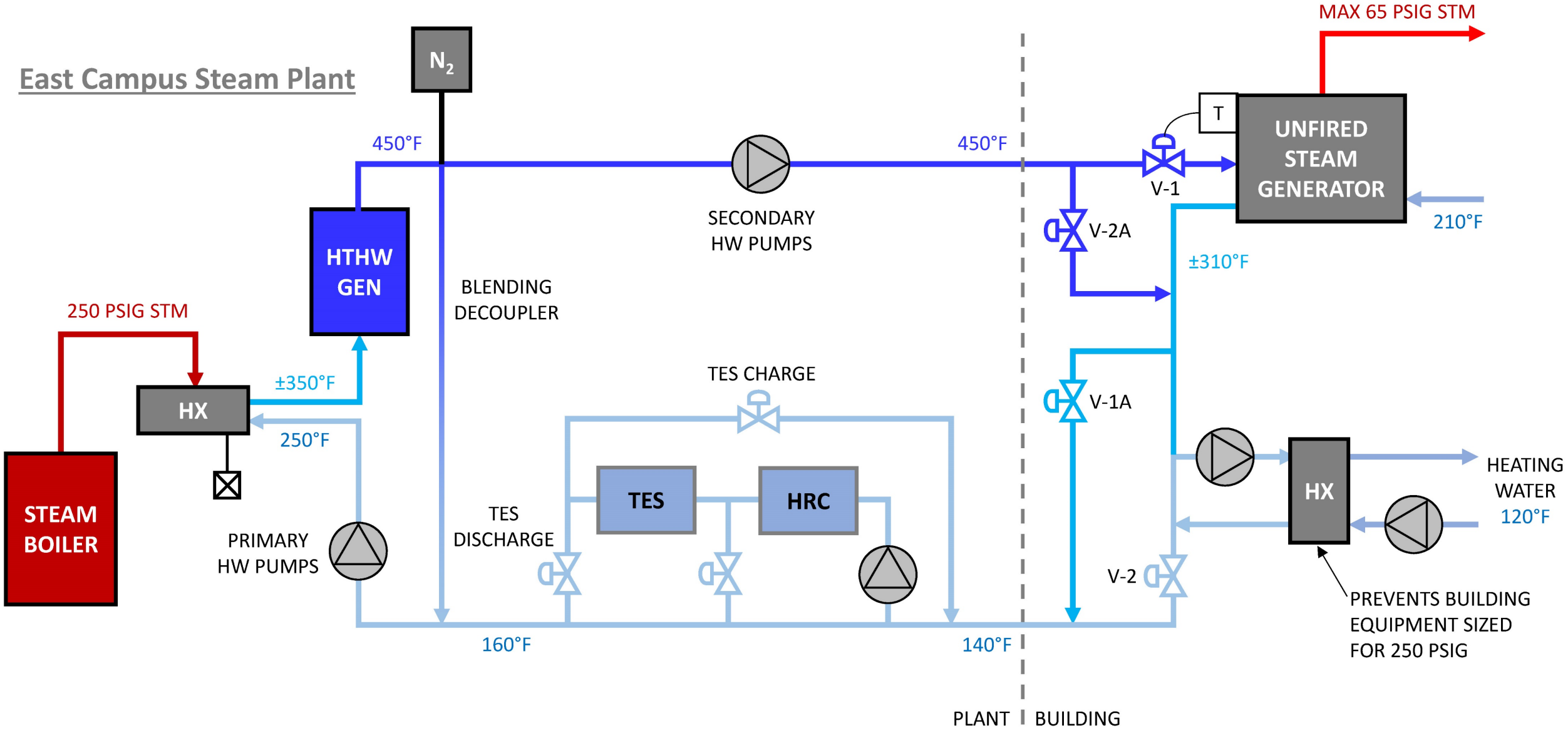
$0 – $40/MTCO$_2$e Carbon Tax



$0 – $200/MTCO$_2$e Carbon Tax



Hybrid Systems – HTHW / LTHW



Conclusions (Level 1 Investigation)

- Hot water conversion is a cost effective approach
- Optimal approach may be a combination of the options:
  - HTHW is most cost effective but minimal CO_2 reduction
  - ULTHW results is largest CO_2 reduction (of the hot water options)
- Biomass results in largest CO_2 reduction but unit cost of carbon reduction is greater than hot water approaches
- Biomass boiler generation and hot water distribution are not exclusive
- Next Step: Optimal approach developed through Level 2 Study

Questions?

Thank You!

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