Energy Conservation & Carbon Reduction At Princeton University

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Campus Energy Manager

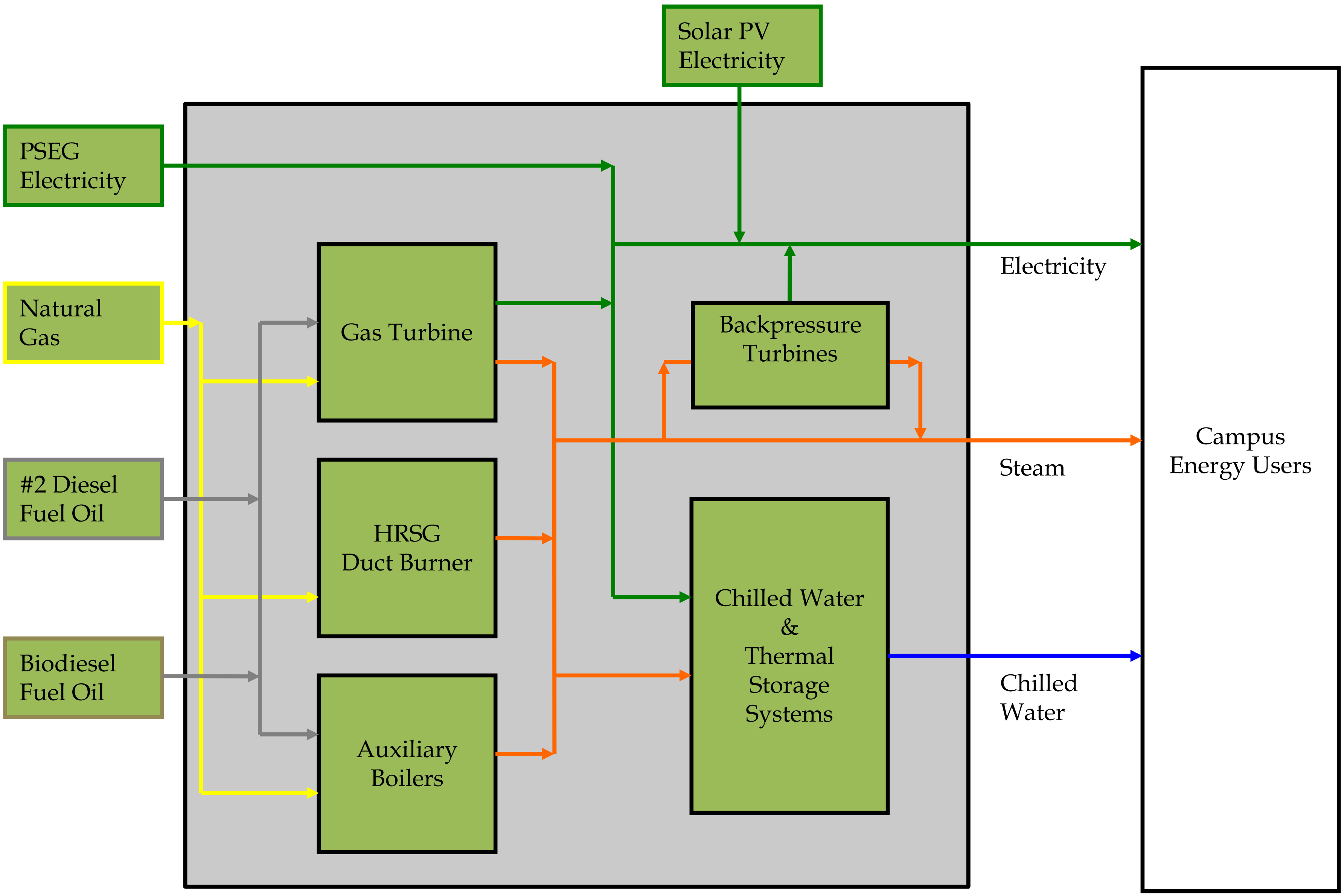
Energy Demands at Princeton

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

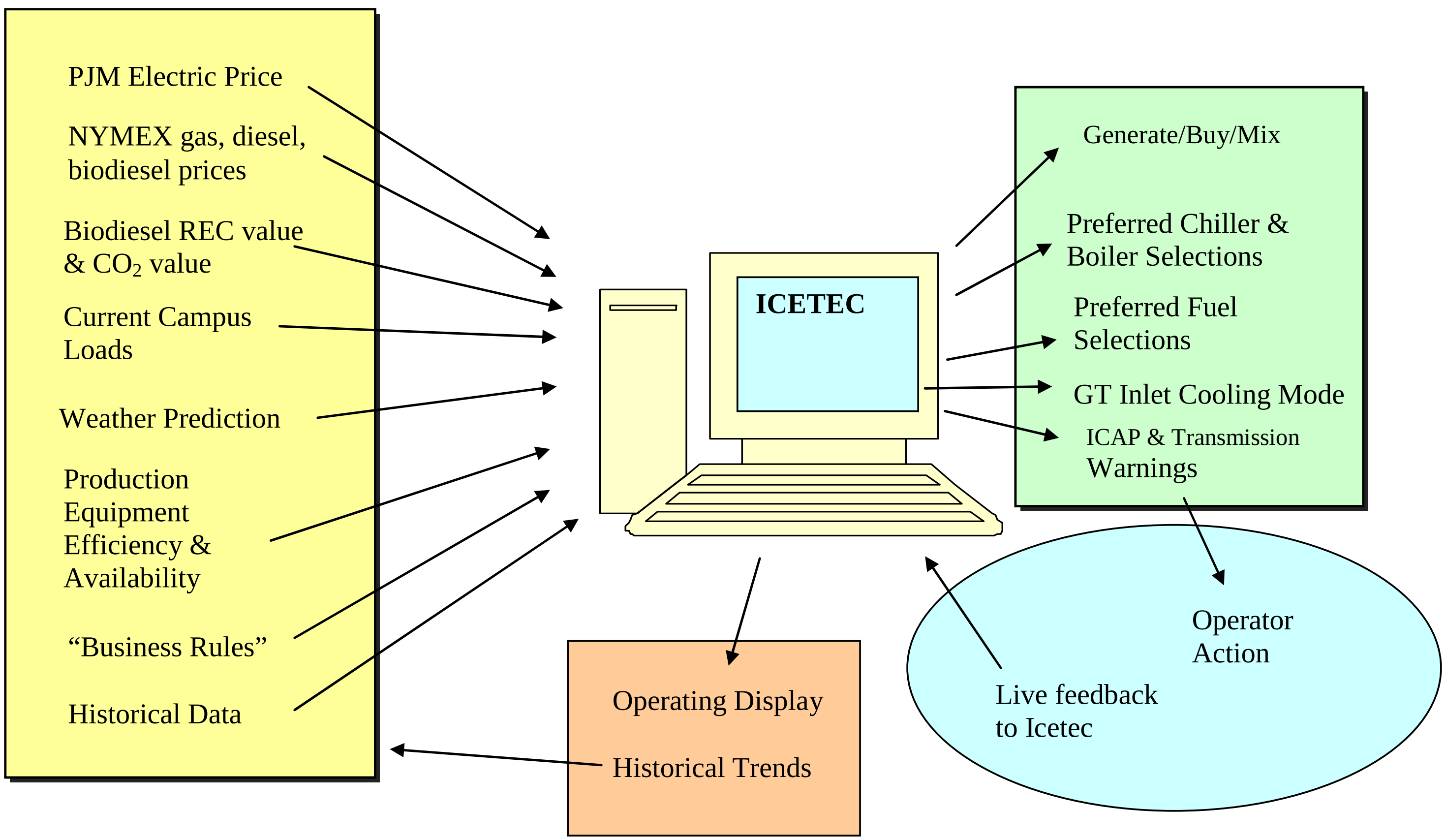
Energy Equipment & Peak Demands

	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)	

Plant Energy Balance



Princeton Economic Dispatch System

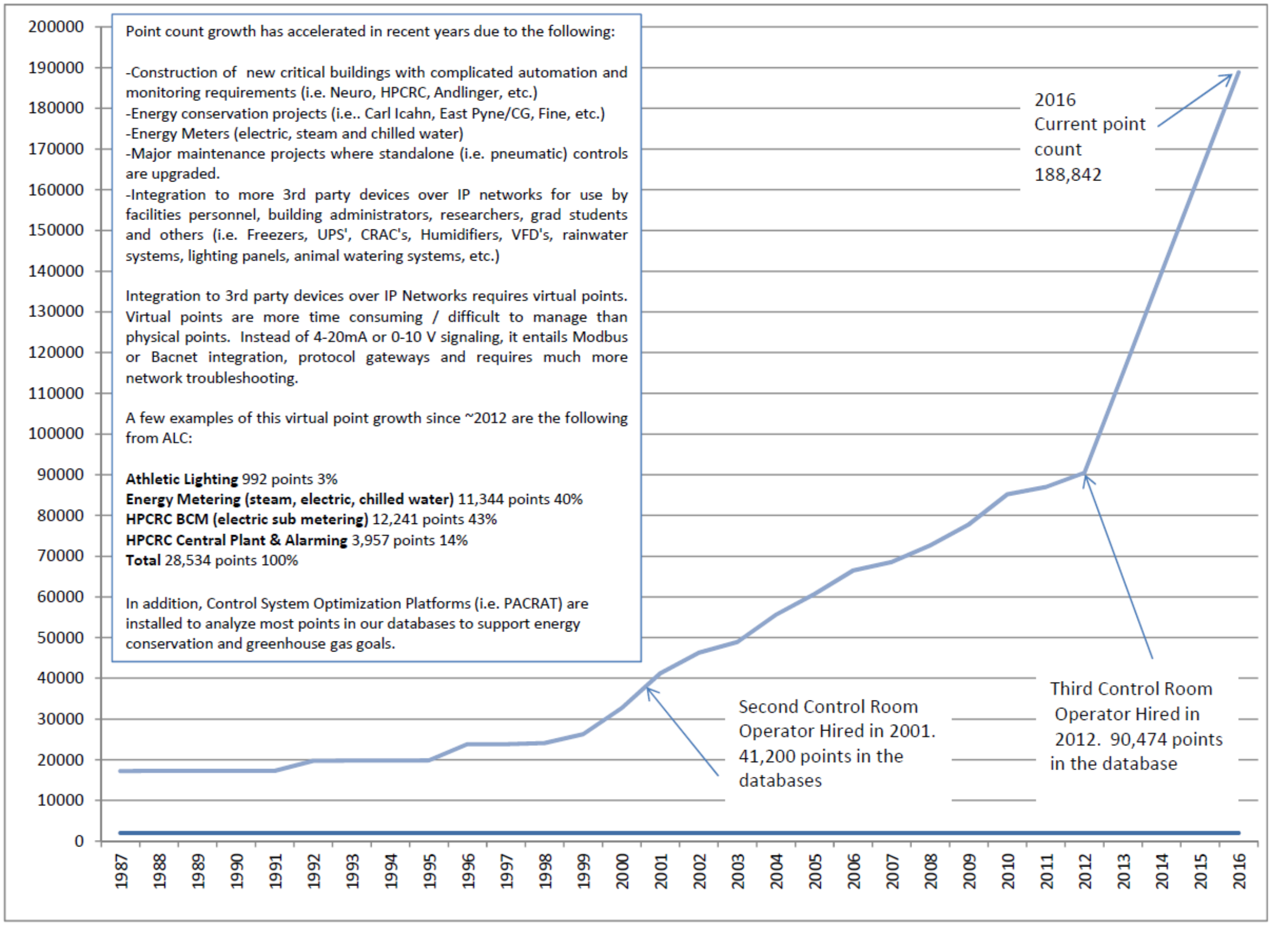


Energy Management Controls

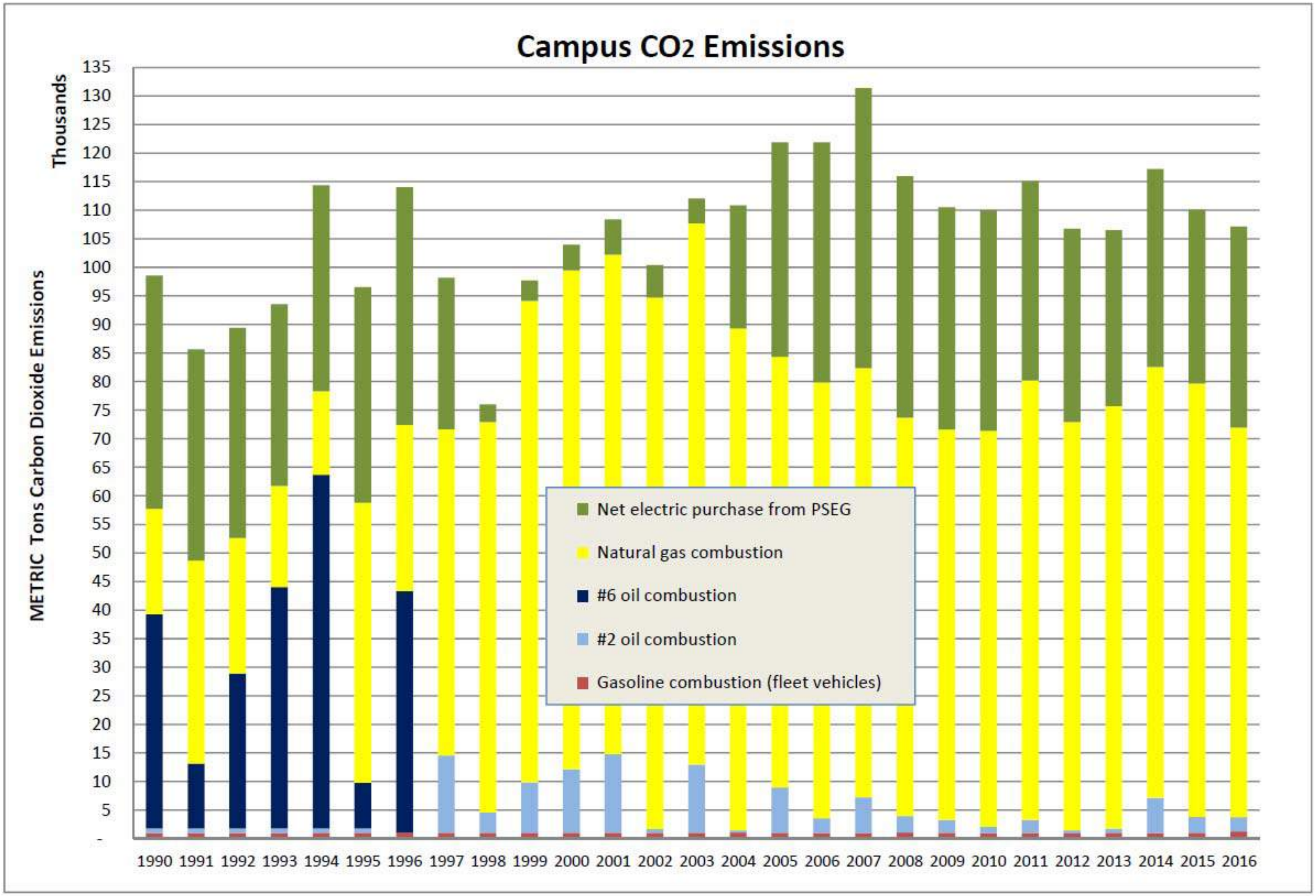
630AM-6PM Mon-Fri
On Call Policy Nights / Weekends

X 5890 cscs@princeton.edu

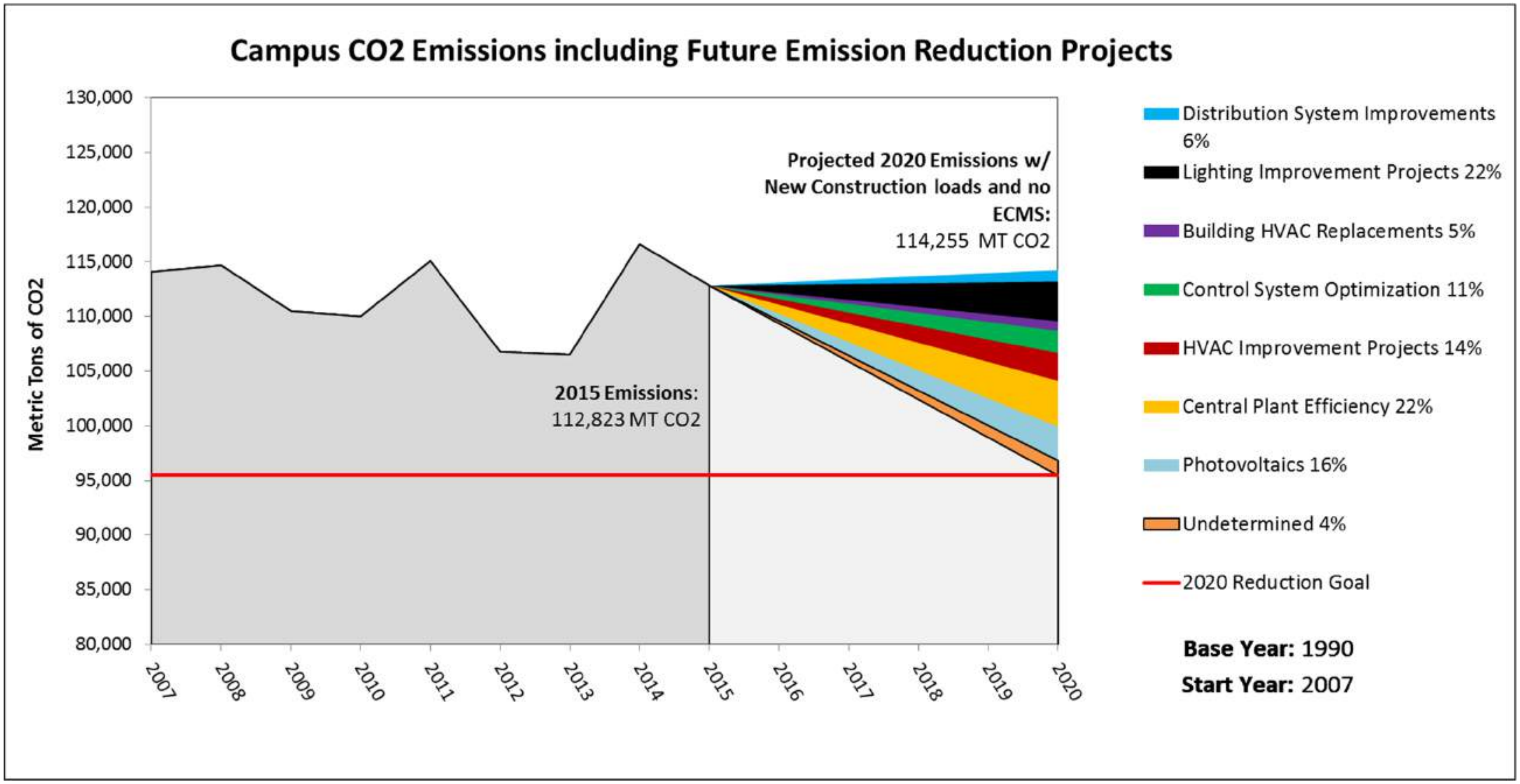
Energy Management Controls Point Count



Campus CO_2 Emissions by Source



Future Emission Reductions



Energy Saving Projects

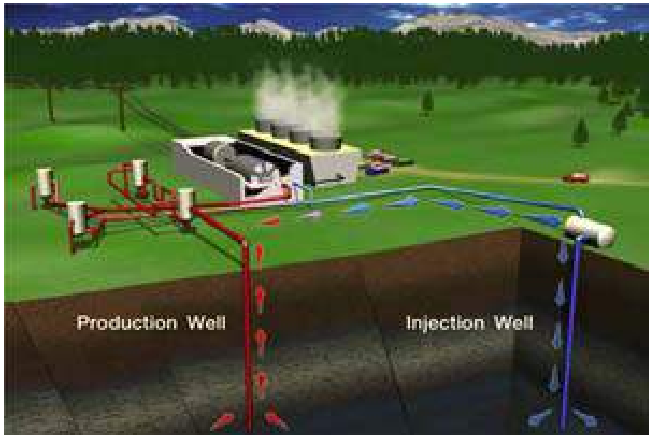
- Cogeneration Plant
- Thermal Storage
- Centralized EMS
- Backpressure steam turbines
- Building heat recovery
- Solar
- Pump / Motor / VFD / Controls
- Free cooling heat exchanger
- LED Lighting Retrofits
- Steam Traps
- Building Heat Recovery
- Control system optimization
- Lab air change reduction
- Occupancy Sensors

Thank you!

EXTRA MATERIAL

Ongoing Opportunities

- Retro-commissioning, continuous commissioning
- Ground Source Heat Pumps
- Variable Frequency Drives
- Chilled Water Controls Optimization
- Real-time emissions calculation
- Energy Star & Smart Start grants as applicable
- Use Condensate to pre-heat Domestic Hot Water
- Biodiesel
- District Hot Water
- CHW-HTW Heat Pumps
- Ultra-efficient buildings



Steam v. Hot Water District Energy

DISTRICT STEAM

- Smaller pipes (higher delta-T)
- Tunnels & vaults w/ supports & custom insulation
- Expansion/contraction
- Steam Traps, water loss
- Higher thermal losses
- Complex flow metering
- Easier/cheaper to design building mechanical equipment
- Can be noisier
- Very long history. Well-developed designs. Mature support industry.
- Poor maintenance can result in catastrophic failures
- Very hard to store

DISTRICT HOT WATER

- Larger pipes (smaller delta-T)
- Direct-buried, pre-insulated
- Minimal expansion/contraction
- Near zero water loss
- Lower thermal loss
- Straightforward flow metering
- Requires more careful design and possibly more investment in the building.
- Can be quieter
- Less common especially in US
- Not as much support industry
- Enables district ground-coupled heat pumps & solar hot water
- Easier to store

Backpressure Turbine - Generators

HRSG & Auxiliary Boilers

HRSG & Auxiliary Boilers

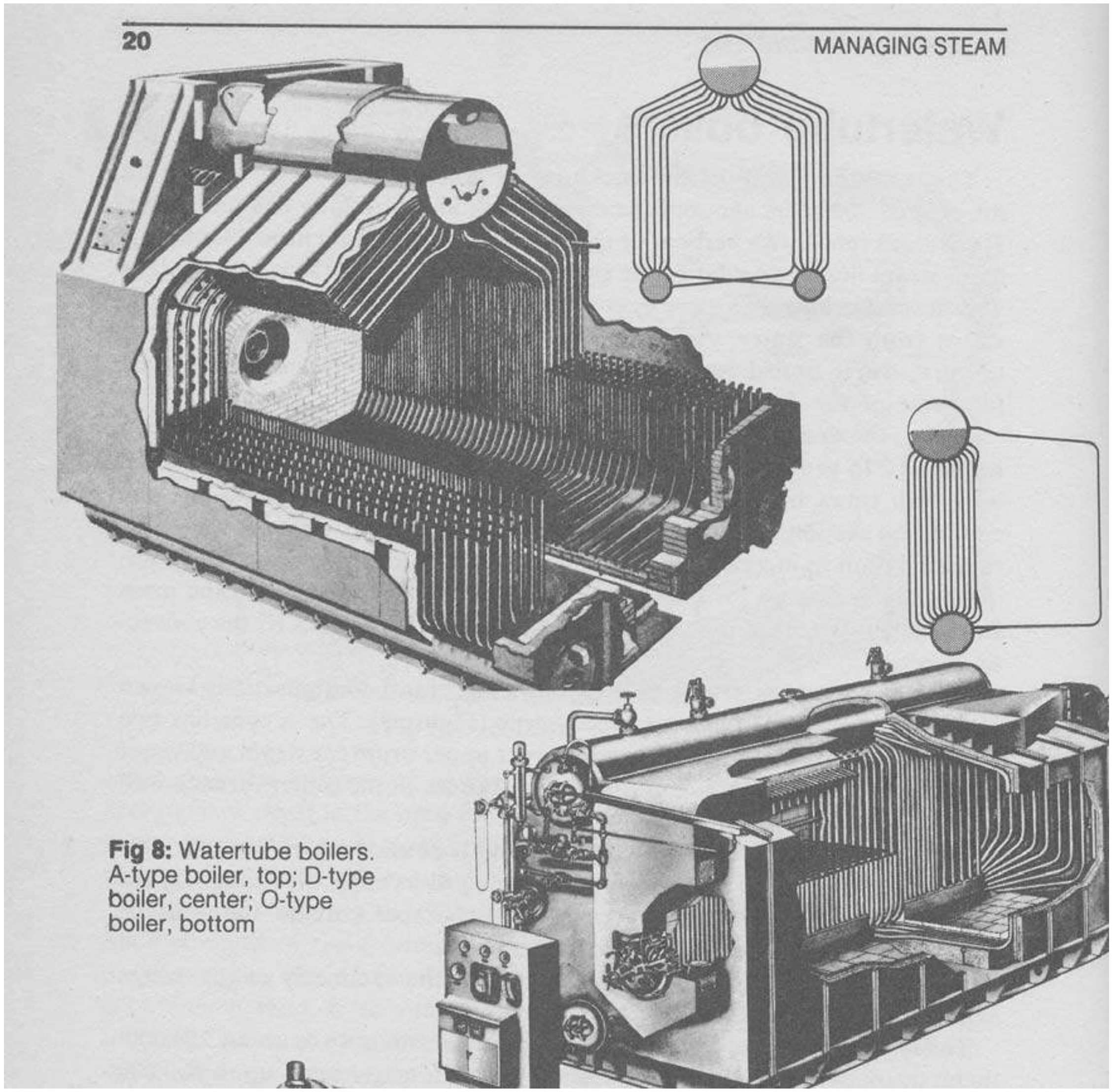
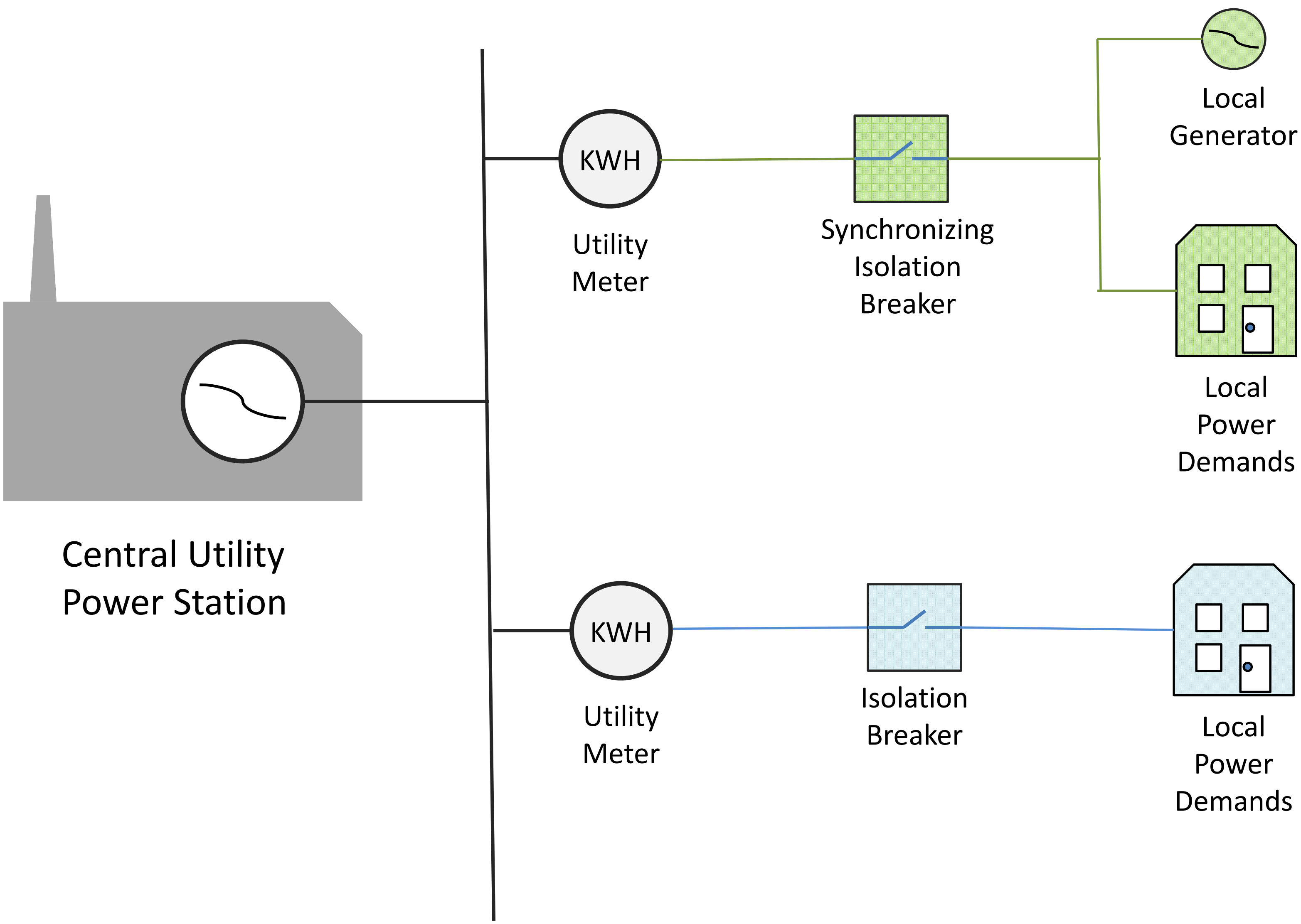


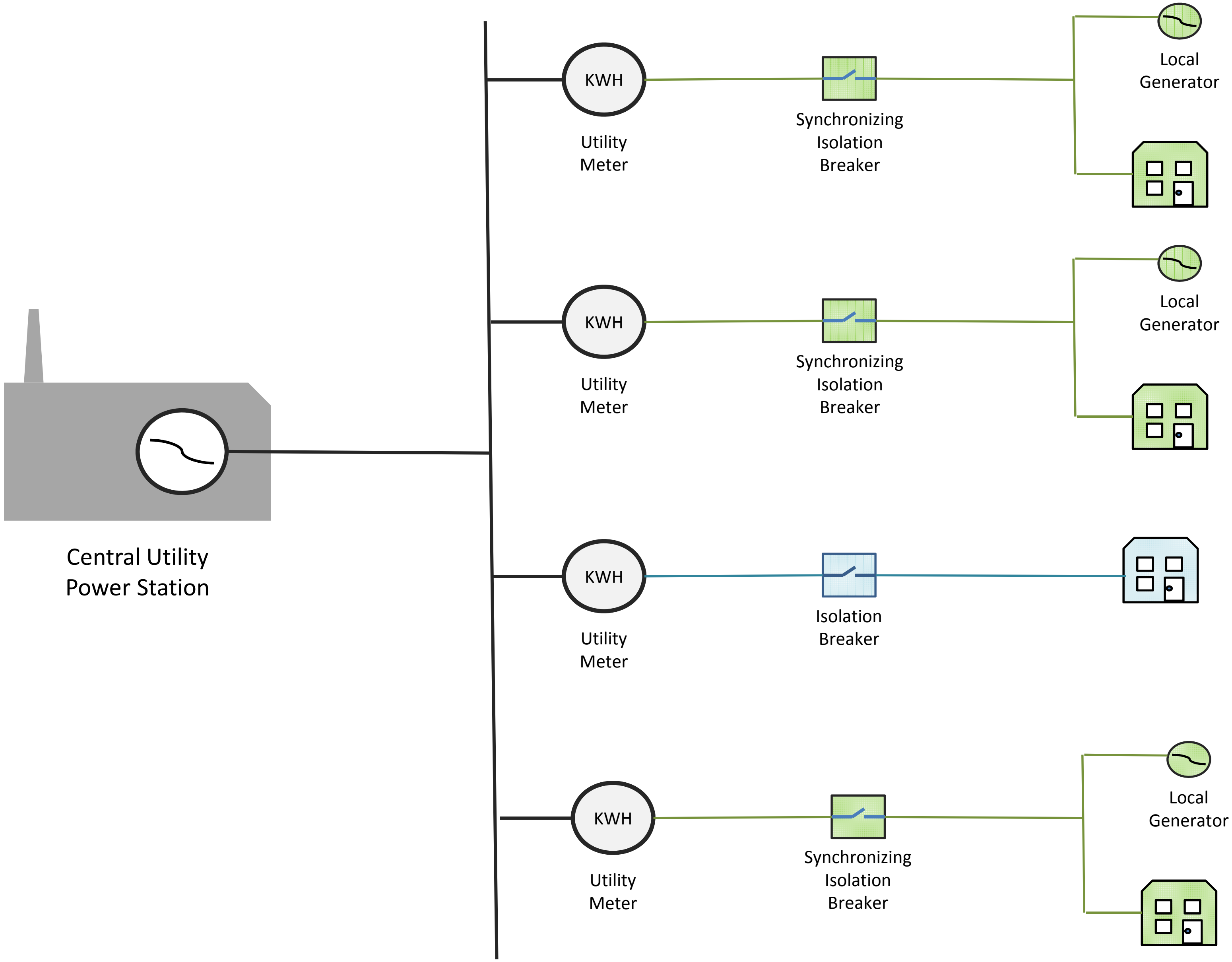
Fig 8: Watertube boilers. A-type boiler, top; D-type boiler, center; O-type boiler, bottom

Campus Microgrid and Other Models

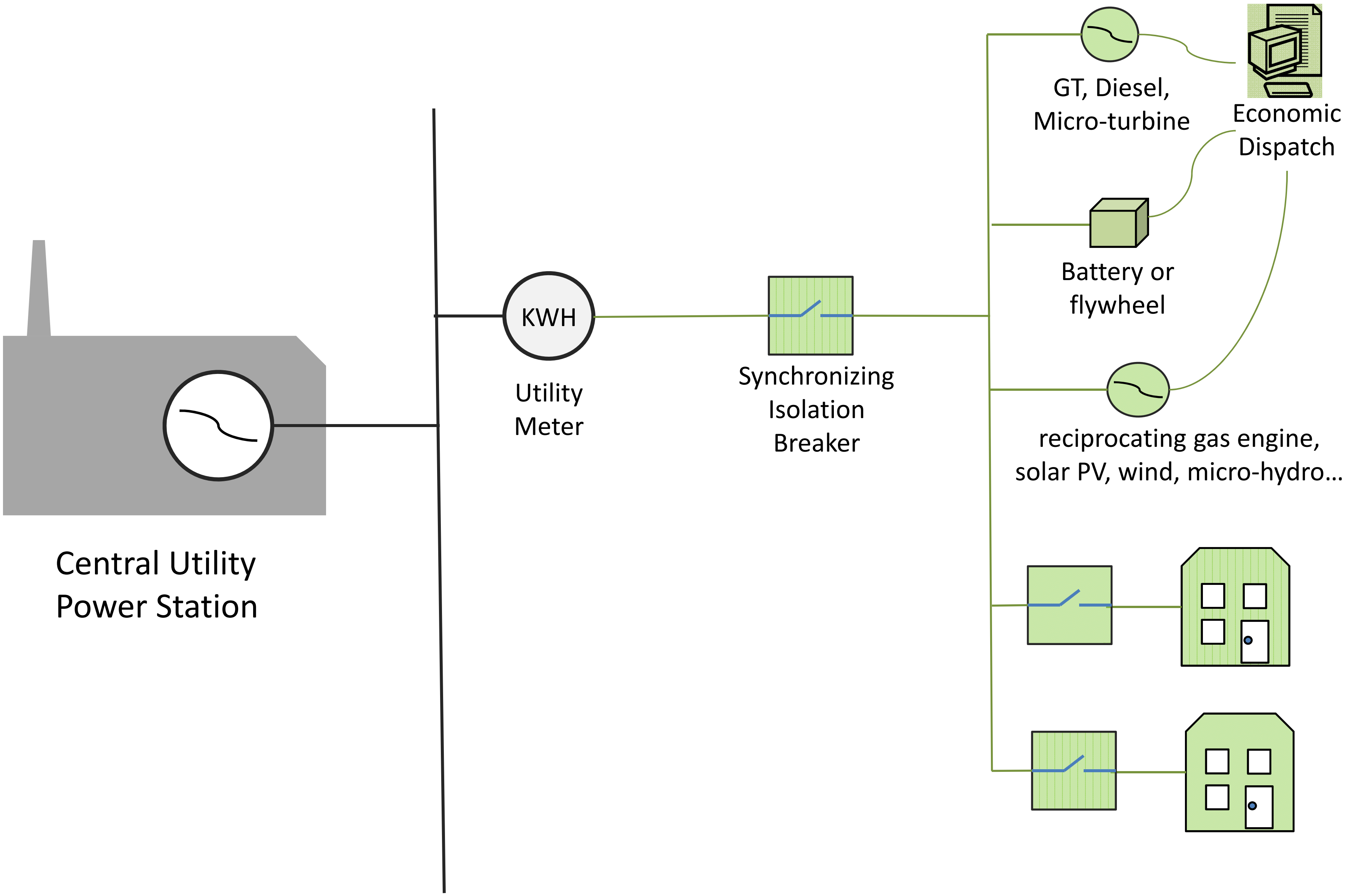
Simple Microgrid Concept



Microgrids Add Reliability



Microgrid Options

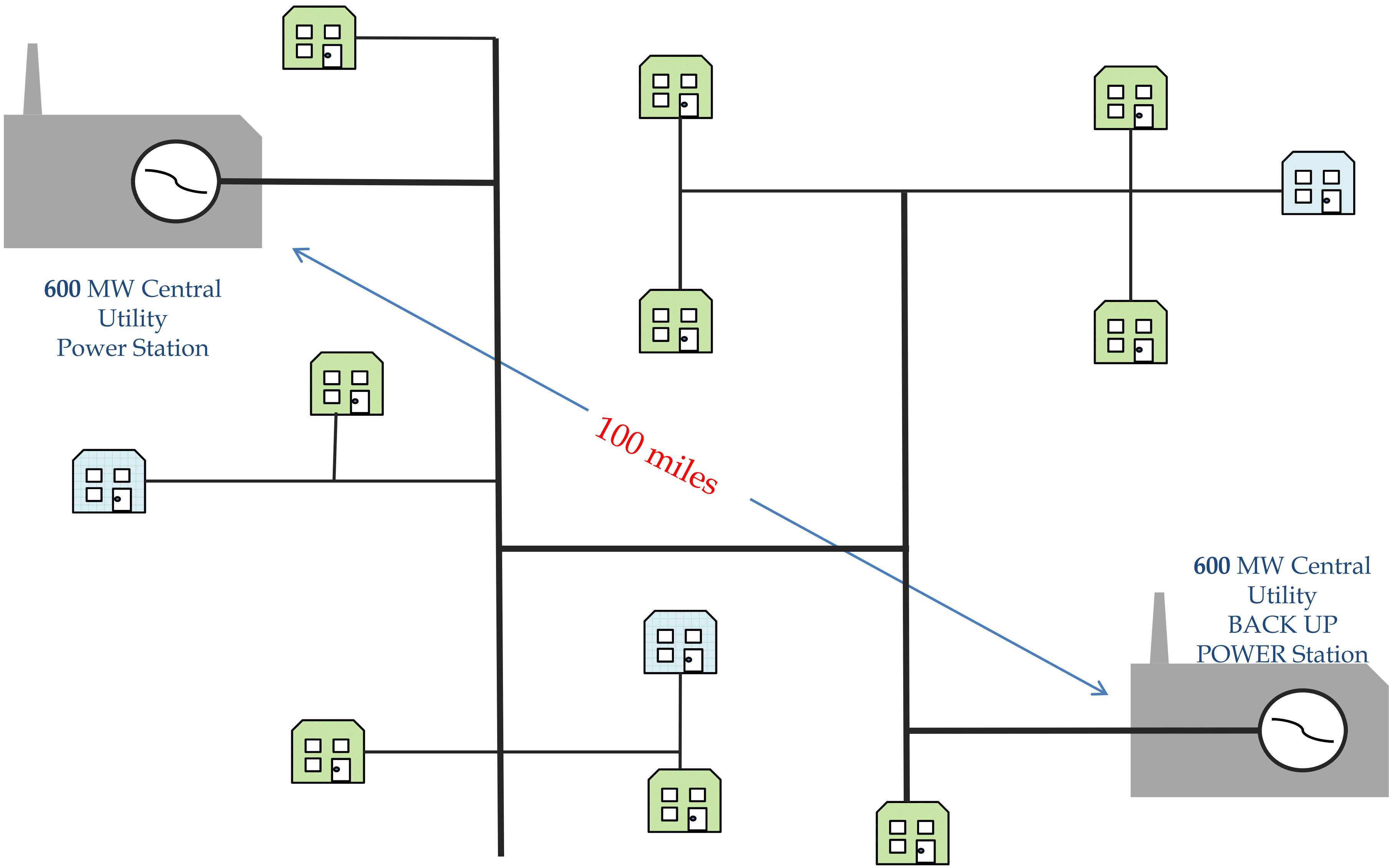


Utility Grid With Simple Redundancy

12 x 50 MW = **600 MW Demand**

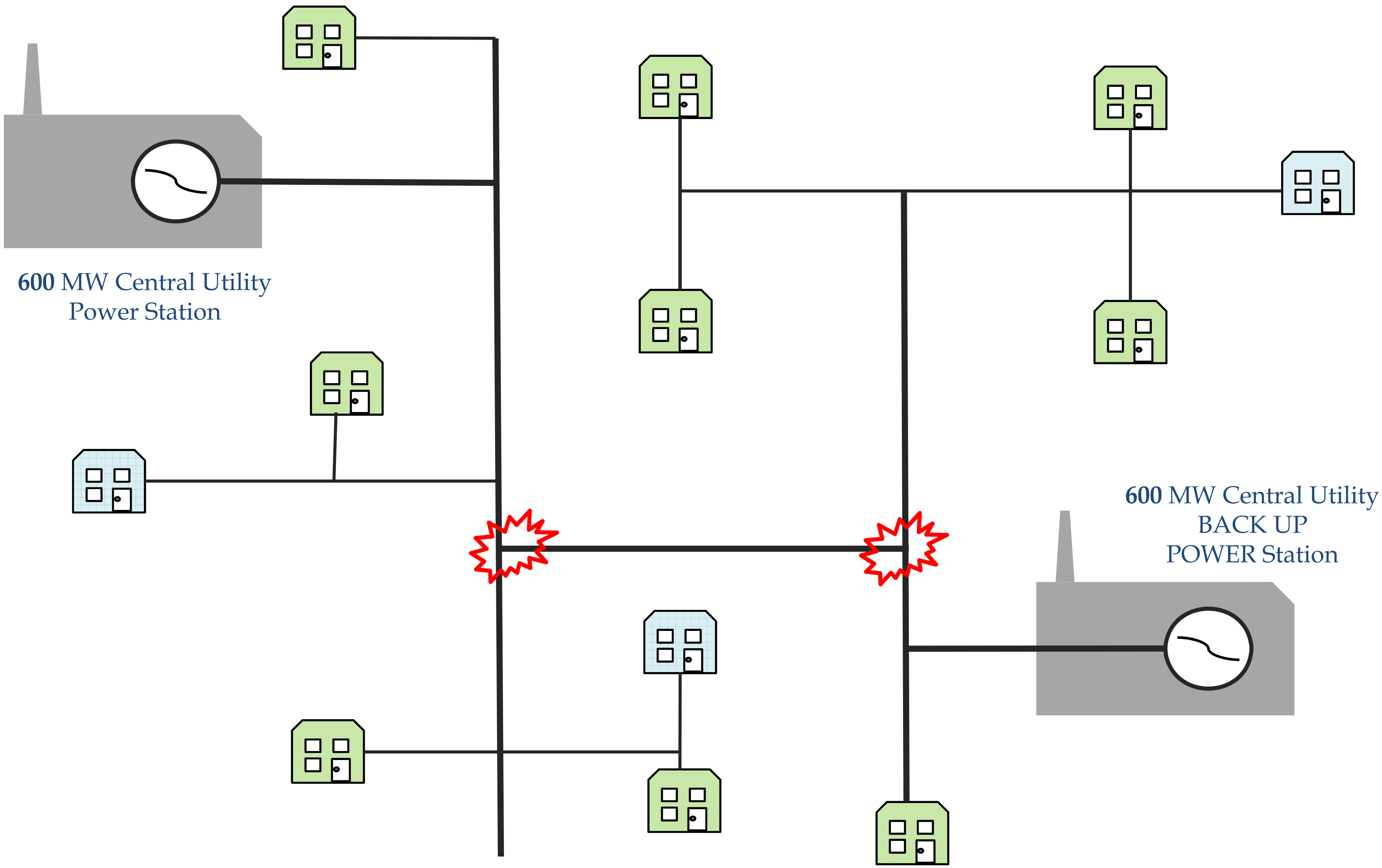
600 MW + 600 MW Back-Up = **1200 MW Installed Generation**

"N-1 Redundancy"



Utility Grid Vulnerability Points

12 x 50 MW = 600 MW Demand, 600 MW + MW Back-Up

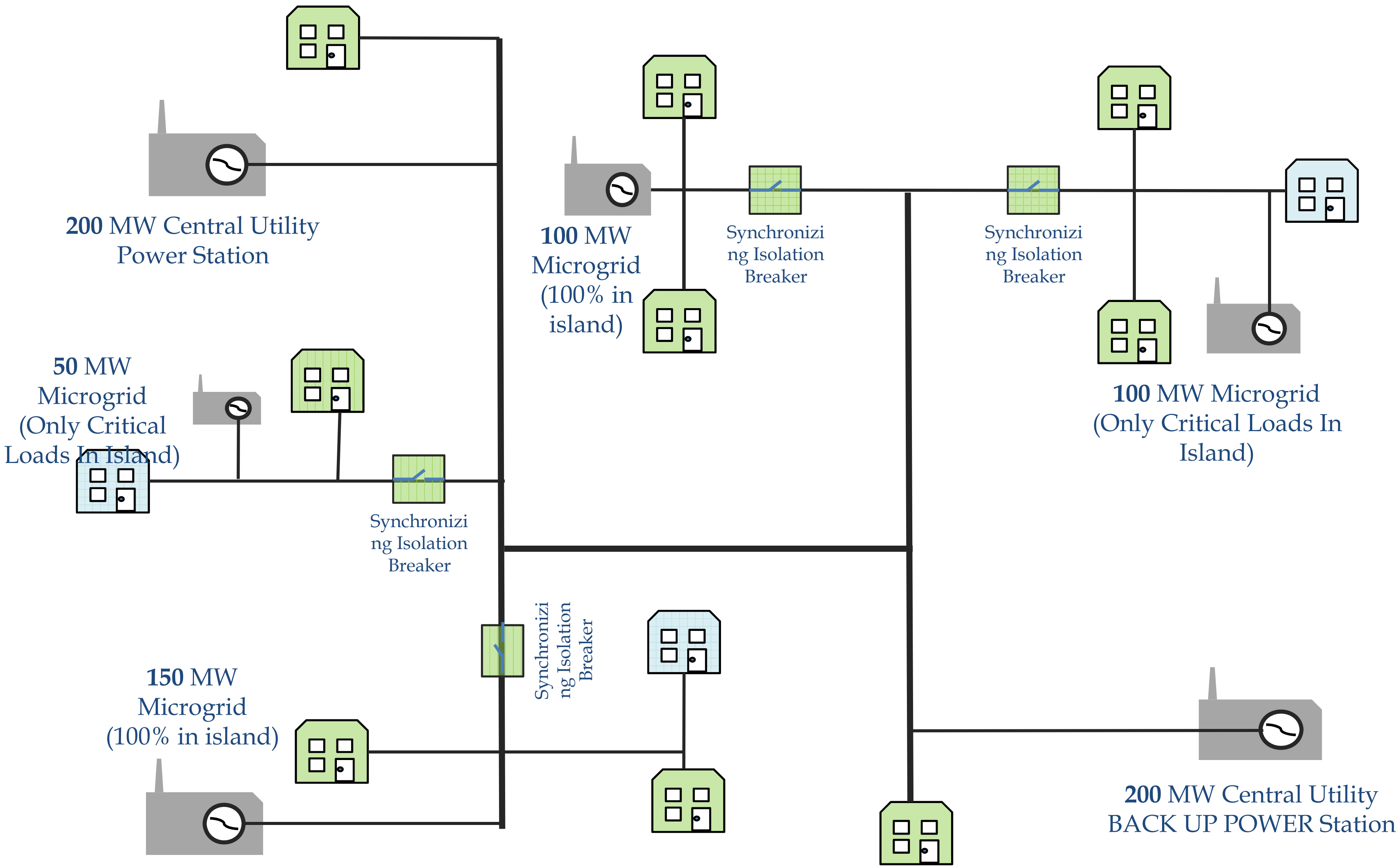


Utility + Distributed Microgrids = Diversity
Increased Resiliency, Less Idle Capacity

12 x 50 MW = **600 MW Demand**

400 MW Utility + 400 MW Microgrids = **800 MW Installed Capacity**

"*Near* N-2 Redundancy" + Reduced *Scale* of Emergencies



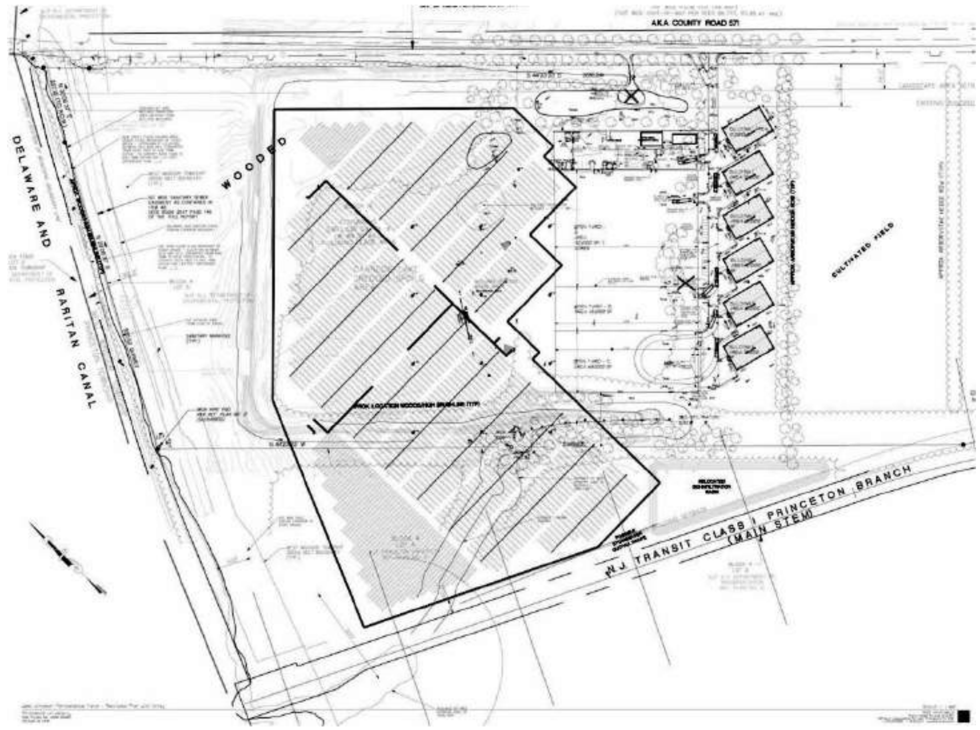
Princeton Solar Photovoltaic System

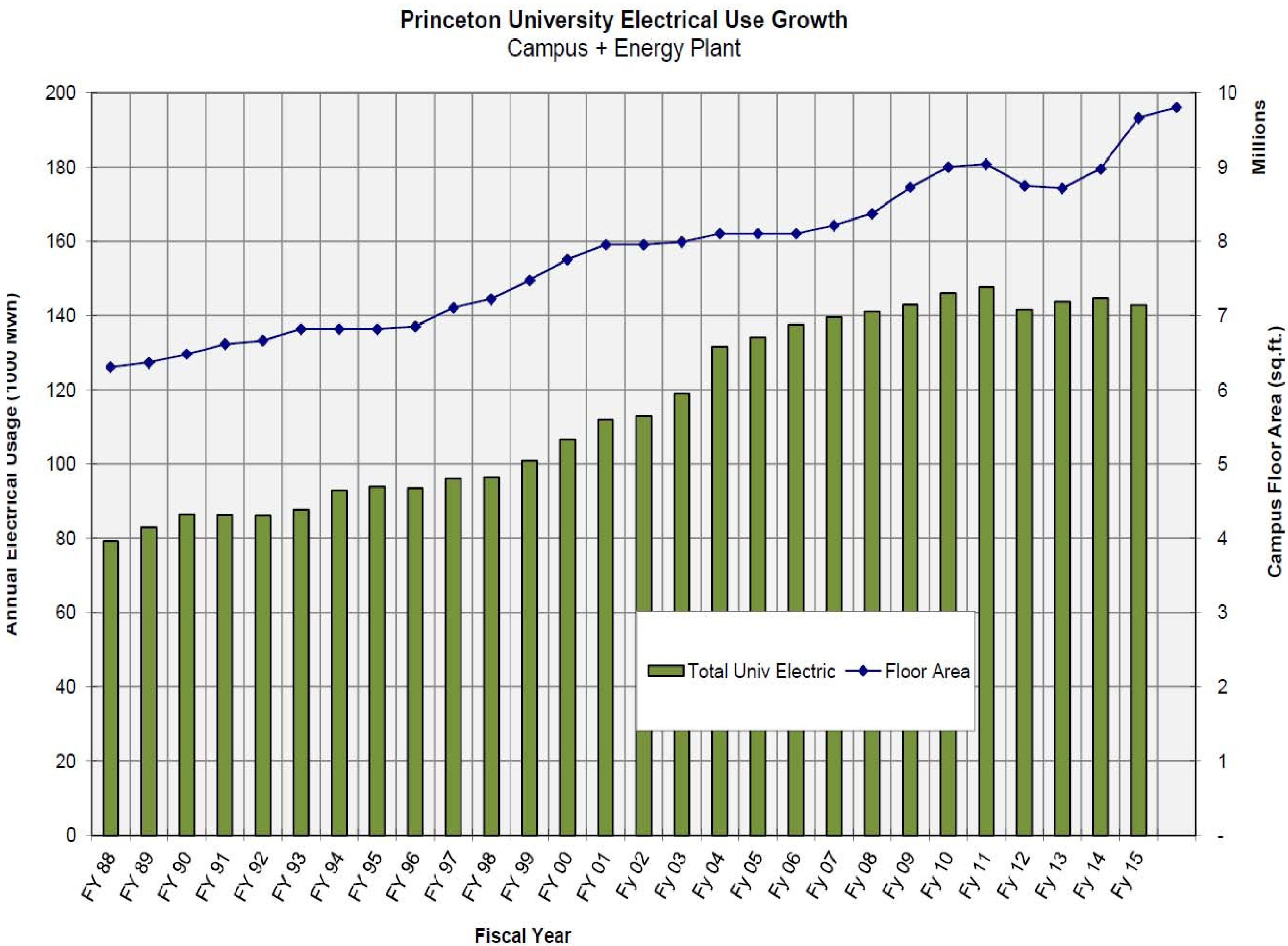
Project Scope

- 5.2 Megawatts
- 8.2 Million kWh (enough to power 700 Homes)
- 27 Acres
- 16,500 Panels
- Operating Lease structure

Project Benefits

•3091 Metric Tons Annual CO2 reduction (6% of Goal)
•Stable, long term, low cost power
•Large Scale, on Campus project





Princeton University Electrical Use Growth
Campus + Energy Plant
Annual Electrical Usage (1000 Mwh)
Campus Floor Area (sq.ft.)
Millions
Total Univ Electric
Floor Area
Fiscal Year
FY 88
FY 89
FY 90
FY 91
FY 92
FY 93
FY 94
FY 95
FY 96
FY 97
FY 98
FY 99
FY 00
FY 01
Fy 02
Fy 03
Fy 04
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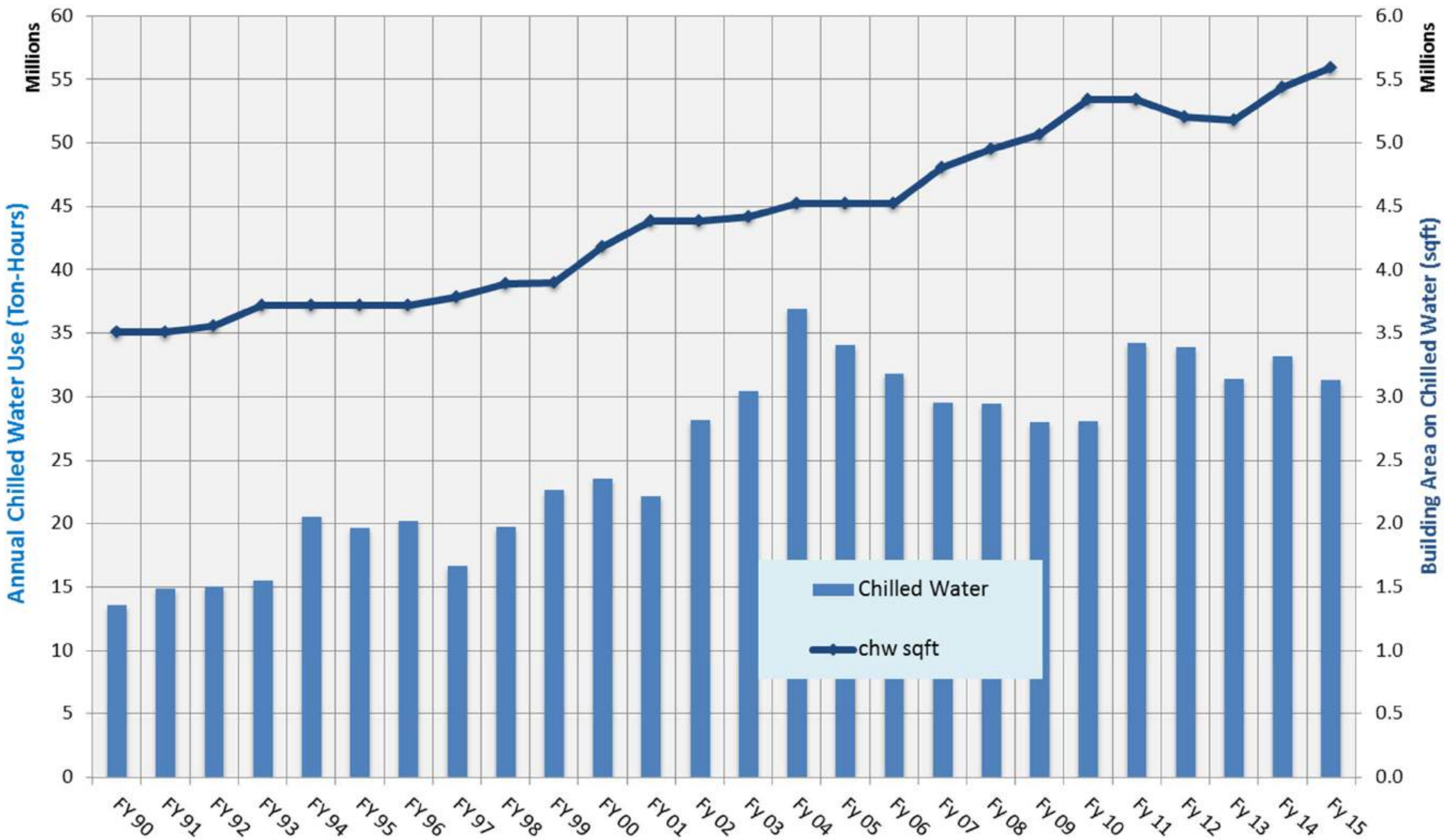
Fy 15

Reduced Chilled Water Use



Reduced Annual Steam To Campus