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CORNELL UNIVERSITY ENERGY MASTER PLAN

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Energy Master Plan (EMP) Study

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- History and Goals
- Current Thermal Energy Equipment
- Future Technologies Evaluated
- Methodology
- Financial Analysis
- Strategic Considerations
- Recommendations

History and Goals

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- Master planning since 1919
- Drivers for current EMP:
  - Campus growth
  - Capital renewal in Cornell's Central Heating Plant (CHP)
  - Volatile fuel and electric markets
  - Increasing environmental regulation and awareness
  - Need for predictable costs

Steam Load Forecasts

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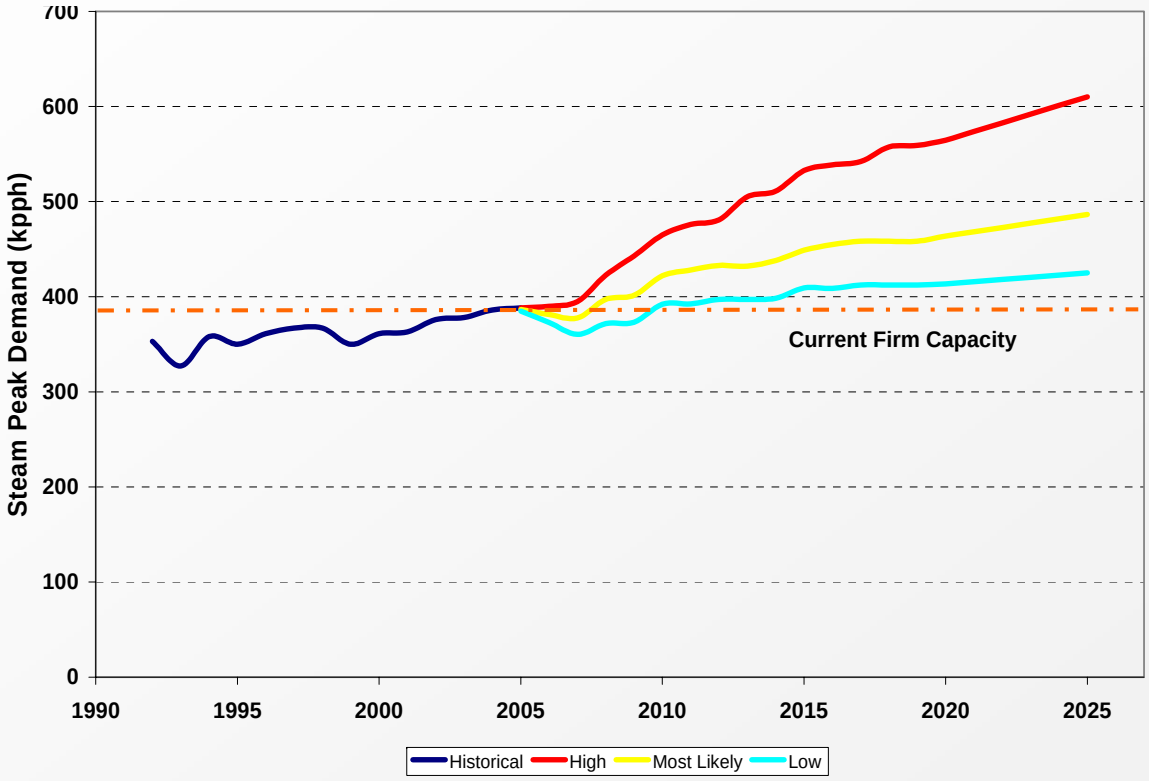

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CHP Boilers

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Boiler No.	Fuel	Capacity (klb/h)	Boiler Type	Year Installed	Outlet Conditions (psig/°F)
1	Coal	90	Spreader Stoker	1981	400/600
2	#6 Fuel Oil	70	Sterling Vibragate	1959	200/550
5	Natural Gas	100	D Type Package	1965	200/550
6	Natural Gas or #6 Fuel Oil	107.5/ 109.5	D Type Package	1992	400/640
7	Natural Gas or #6 Fuel Oil	107.5/ 109.5	D Type Package	1992	400/640
8	Coal	175	Overfeed Stoker	1949	400/600

Future Technologies Evaluated

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- Package boilers capable of burning natural gas or oil
- Atmospheric Circulating Fluidized Bed (ACFB) to replace Boiler 8
- Biomass boiler
- One or two Gas Turbines (GT) with Heat Recovery Steam Generators (HRSG)

Methodology

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- Statistical analysis of historical fuel and energy prices to determine volatility parameters
- Statistical analysis of campus loads to determine daily profiles and variability for each season
- Base scenario forecast of monthly fuel prices delivered to Cornell and nearby electric generators

Methodology (cont.)

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- Consistent forecast of hourly regional electric prices based on chronological simulation model of regional electric market
- Base scenario forecast of Cornell's steam and electric loads based on monthly building requirements
- Alternative scenarios reflecting high and low fuel price forecasts and high and low growth projections

Fuel Price Forecast

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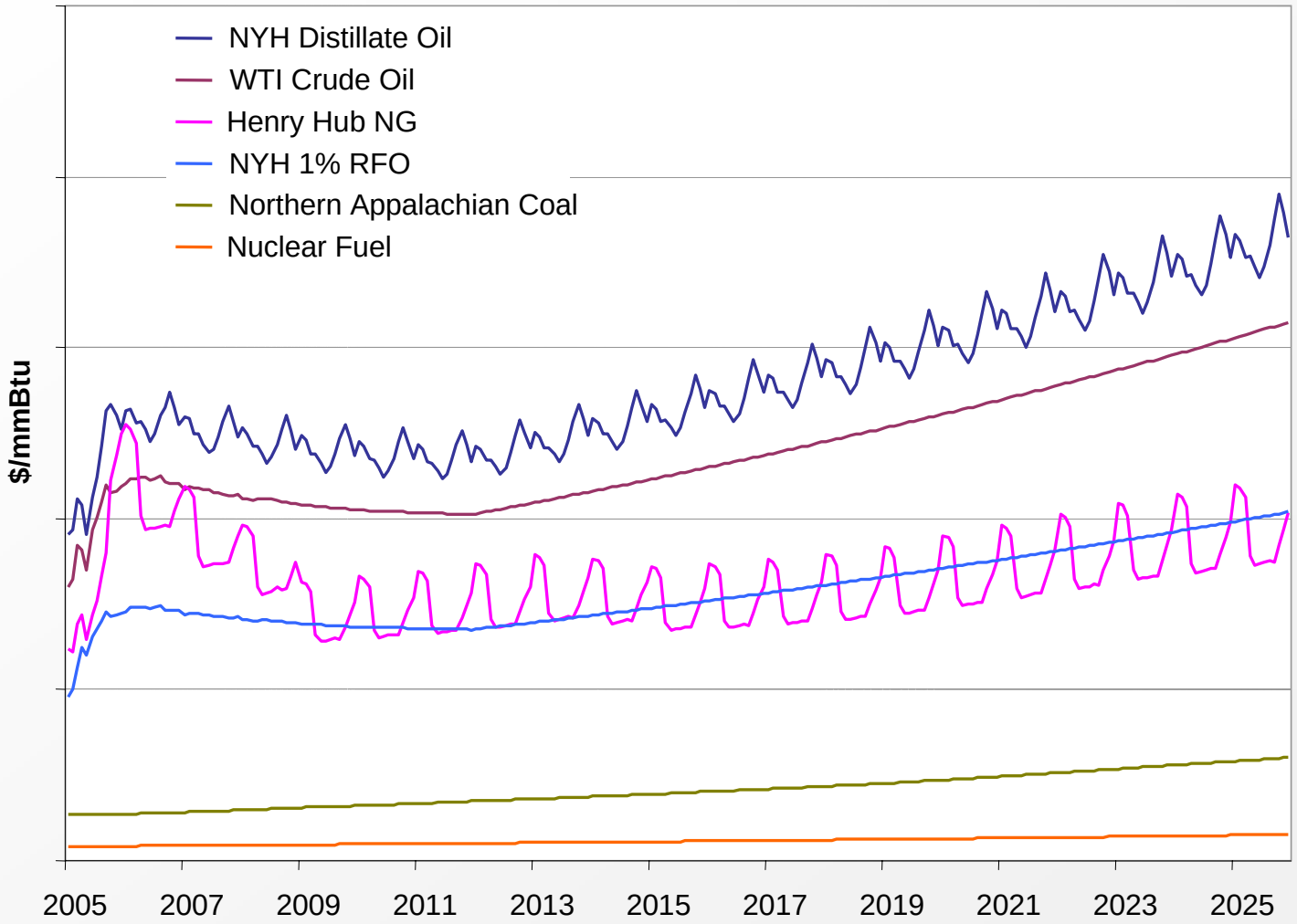

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Electricity Price Forecast

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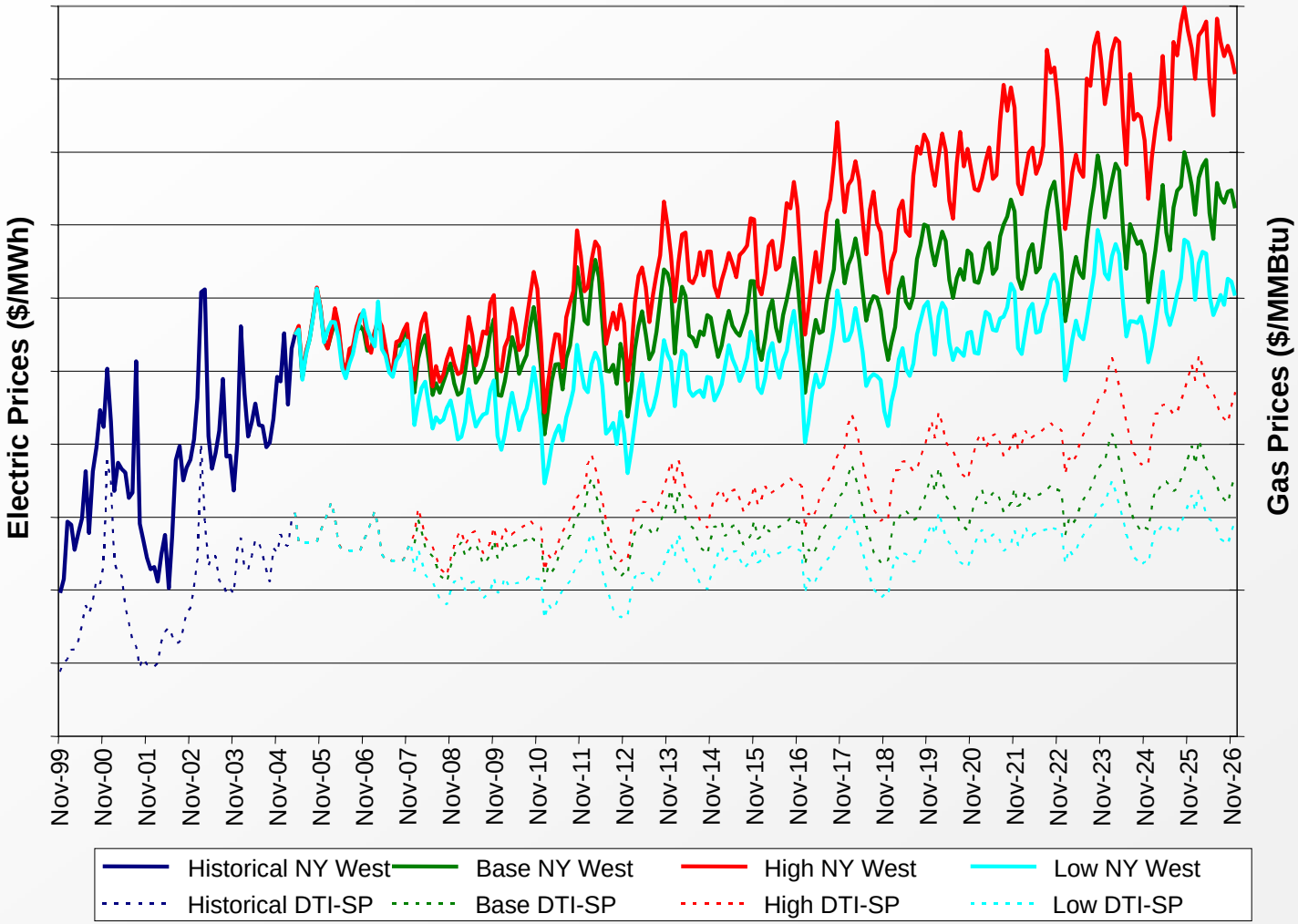

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Summer System Heat Rates

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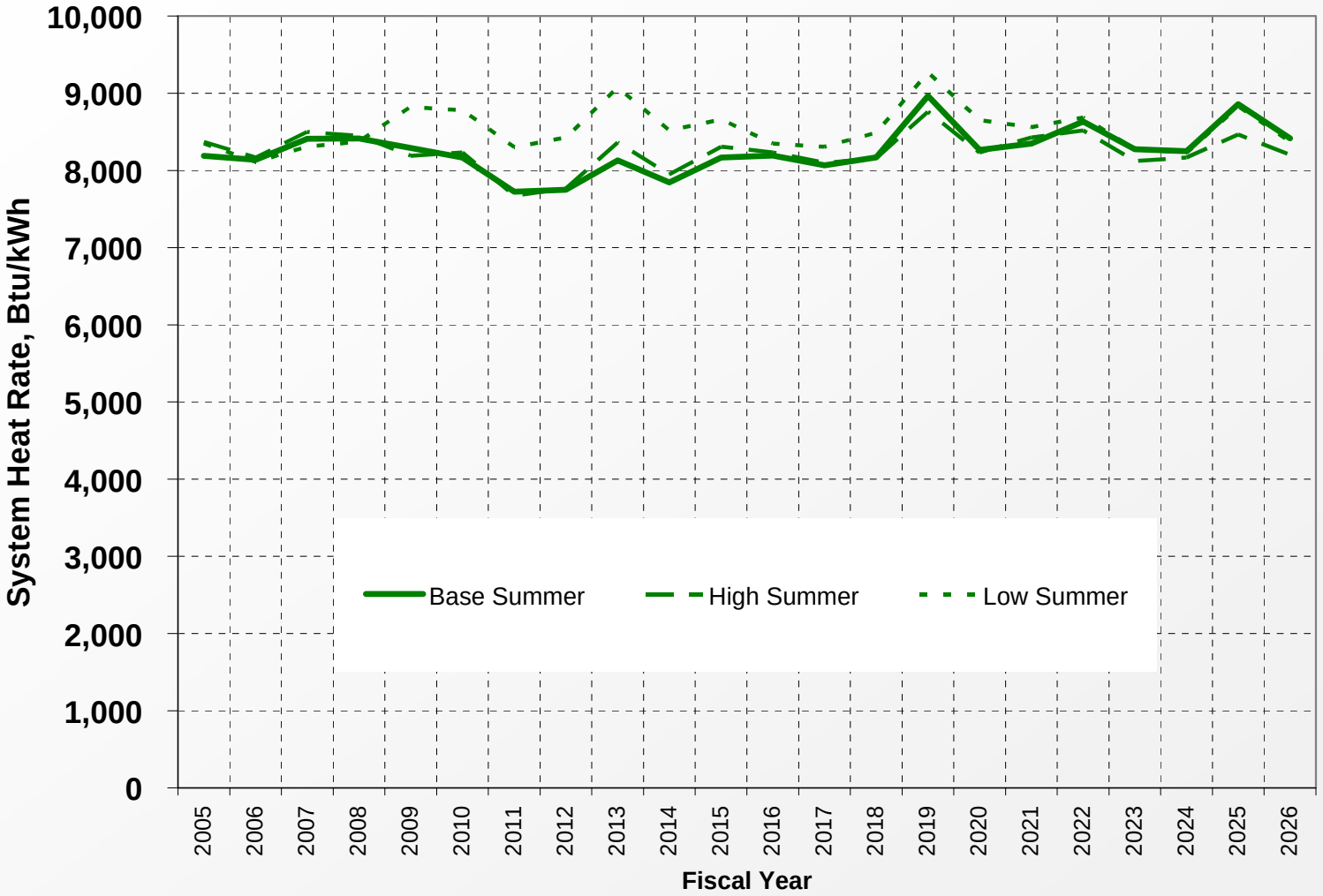

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System Heat Rate Profiles

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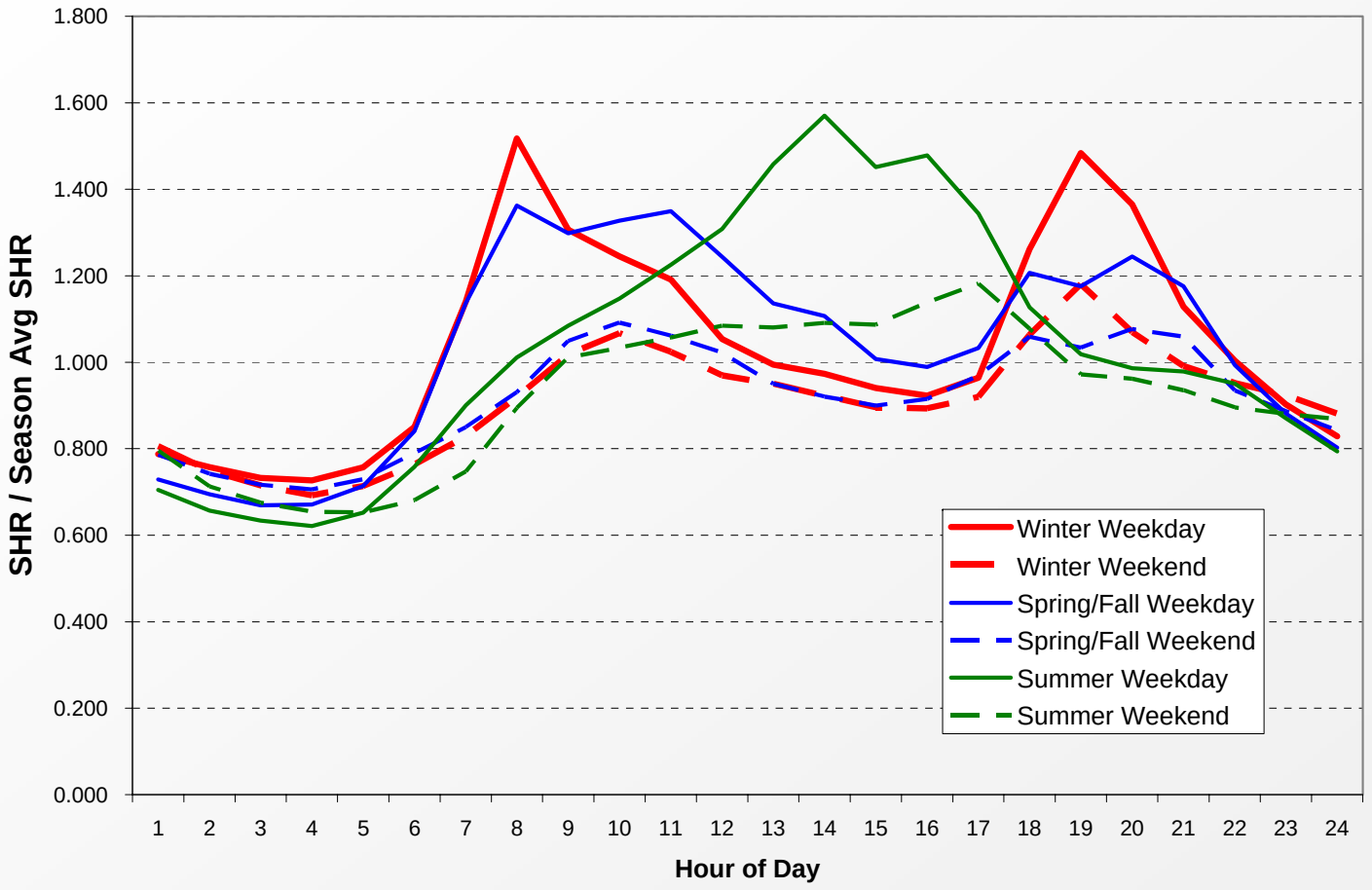

Weekly Electric Profiles by Month

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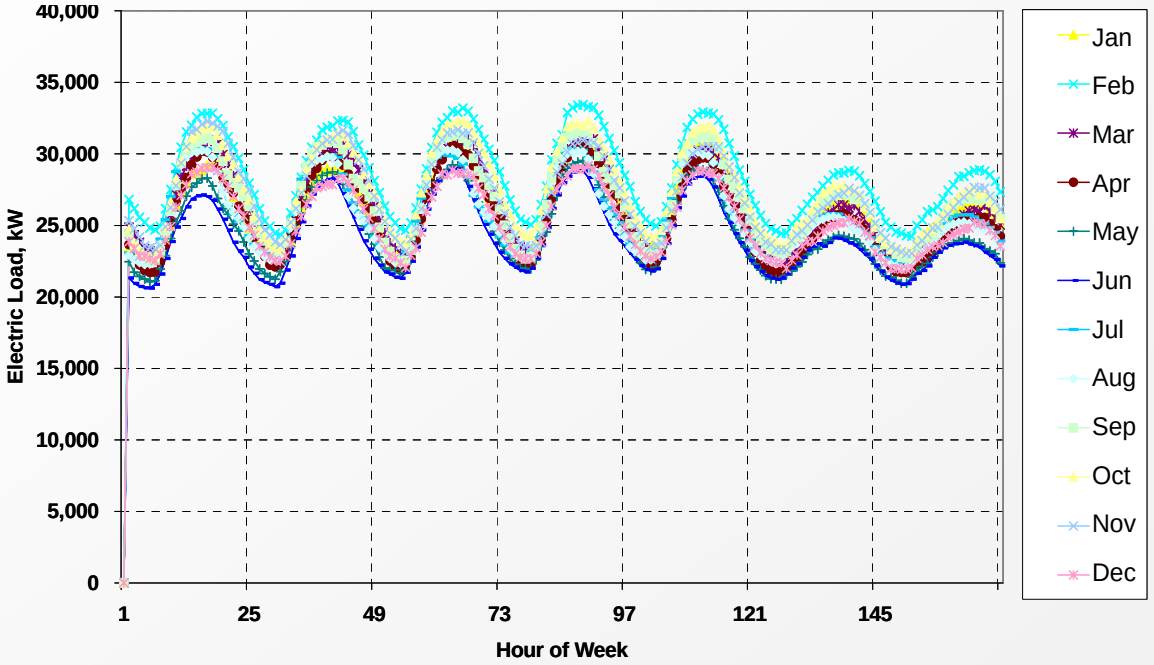

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Ambient Temperature by Month, Season

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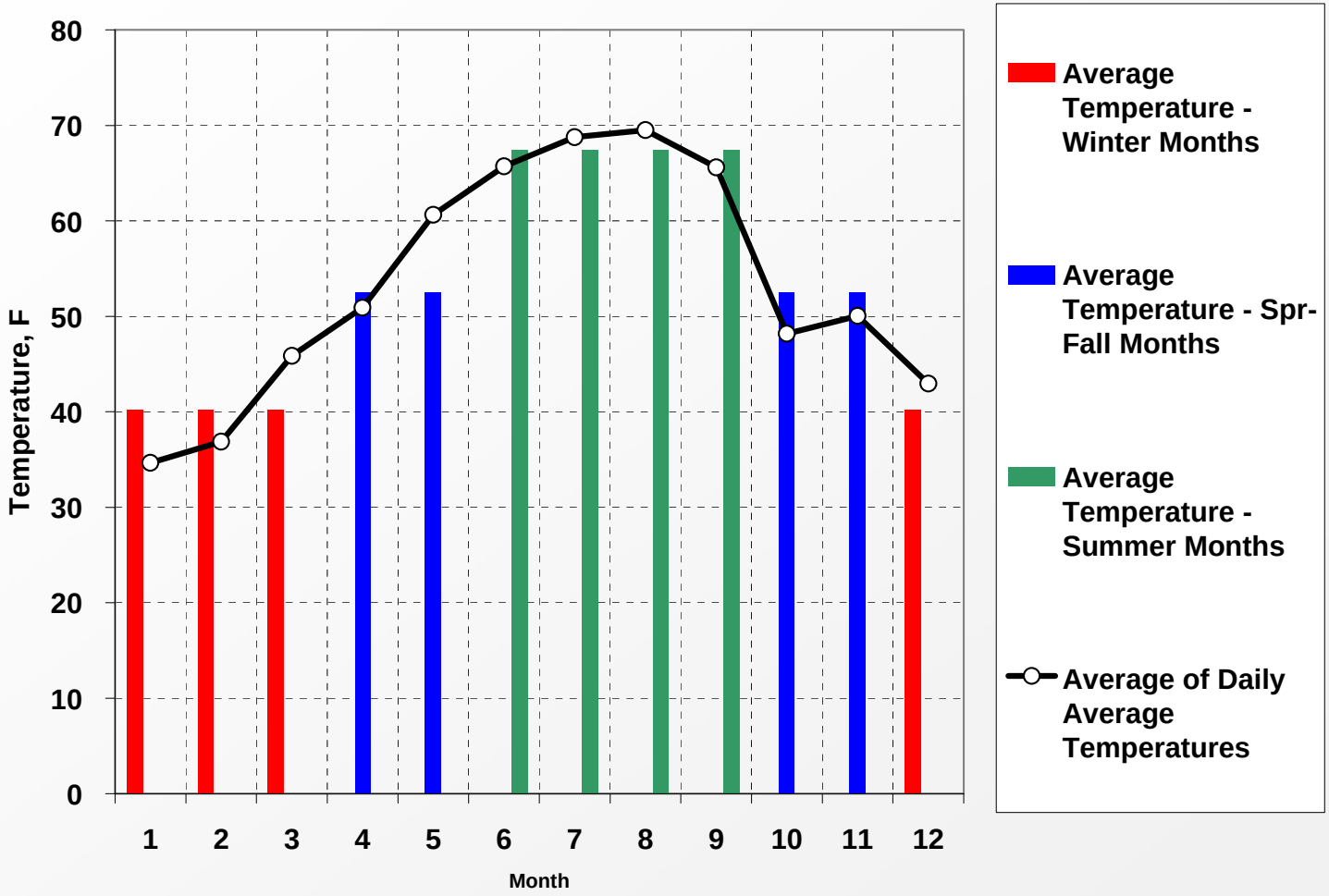

Steam and Electric Load Growth Factors

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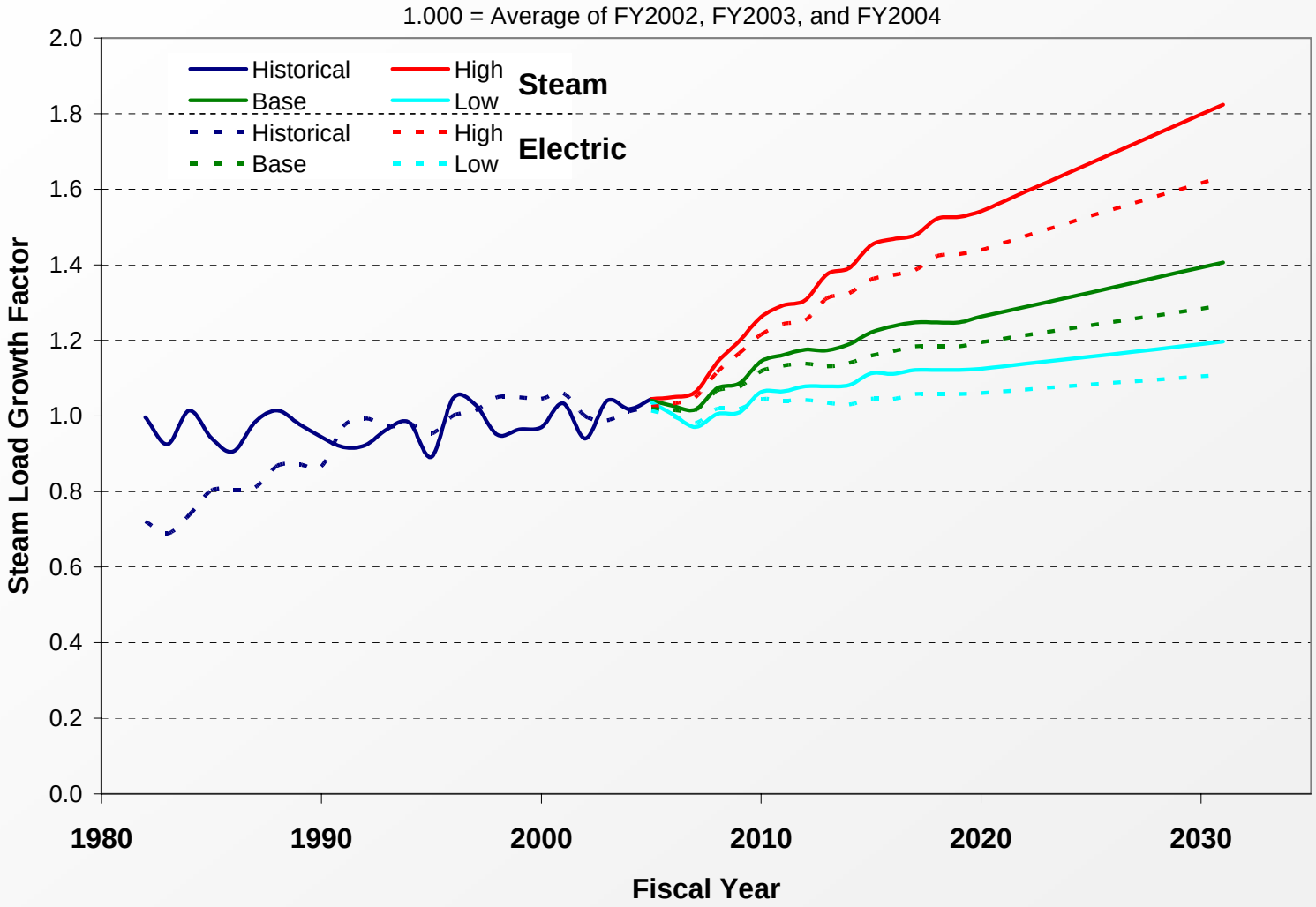

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Financial Analysis

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- Simulated 25 years of operation (2007-2031)
- Used Monte Carlo simulation to capture short term variability and volatility effects on
  - loads
  - fuel prices
  - electric energy market heat rate
  - steam unit availability

Financial Analysis (cont.)

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- Phase 1 screening
  - Package boiler and GT cases have very similar total costs
  - ACFB has higher cost
  - Biomass boiler is the most expensive
- Phase 2 probabilistic analysis on three types of variables:
  - Short-term
  - Near-term event
  - Long-term

Phase 2 Near-Term Technology Choices

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- Package boilers as needed to meet reliability criterion
- Single GT for FY2008
- Two GTs for FY2008
- Boiler 8 replaced with ACFB boiler for FY2008

Phase 2 Decision Tree

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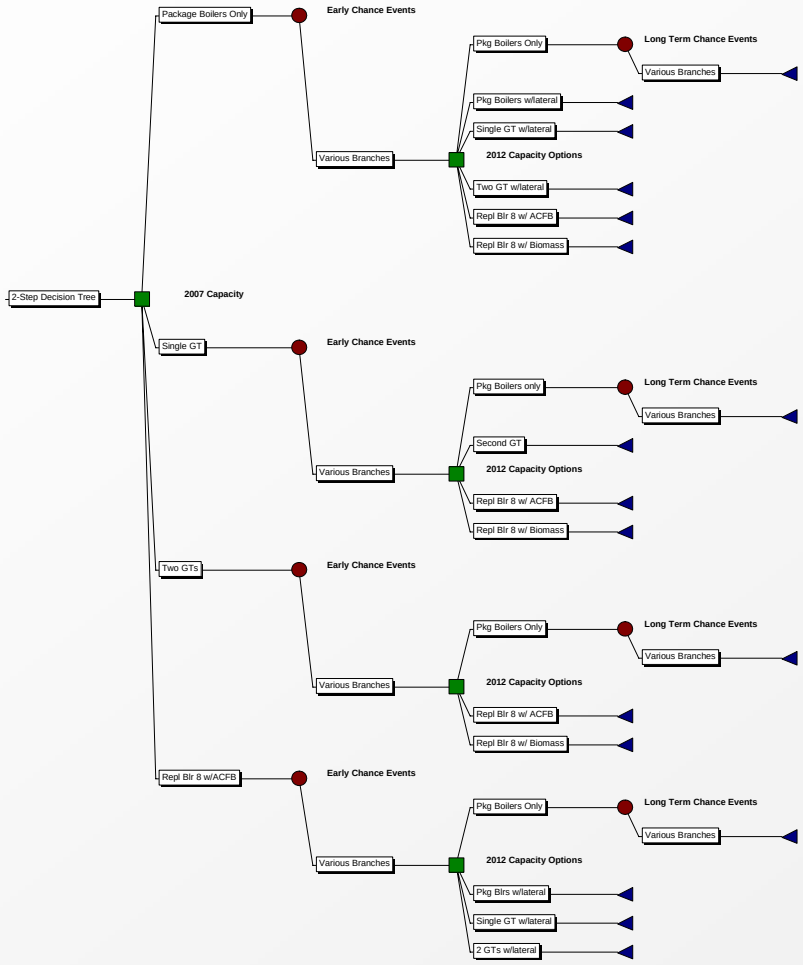

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EVA Confidence Intervals – All Variables

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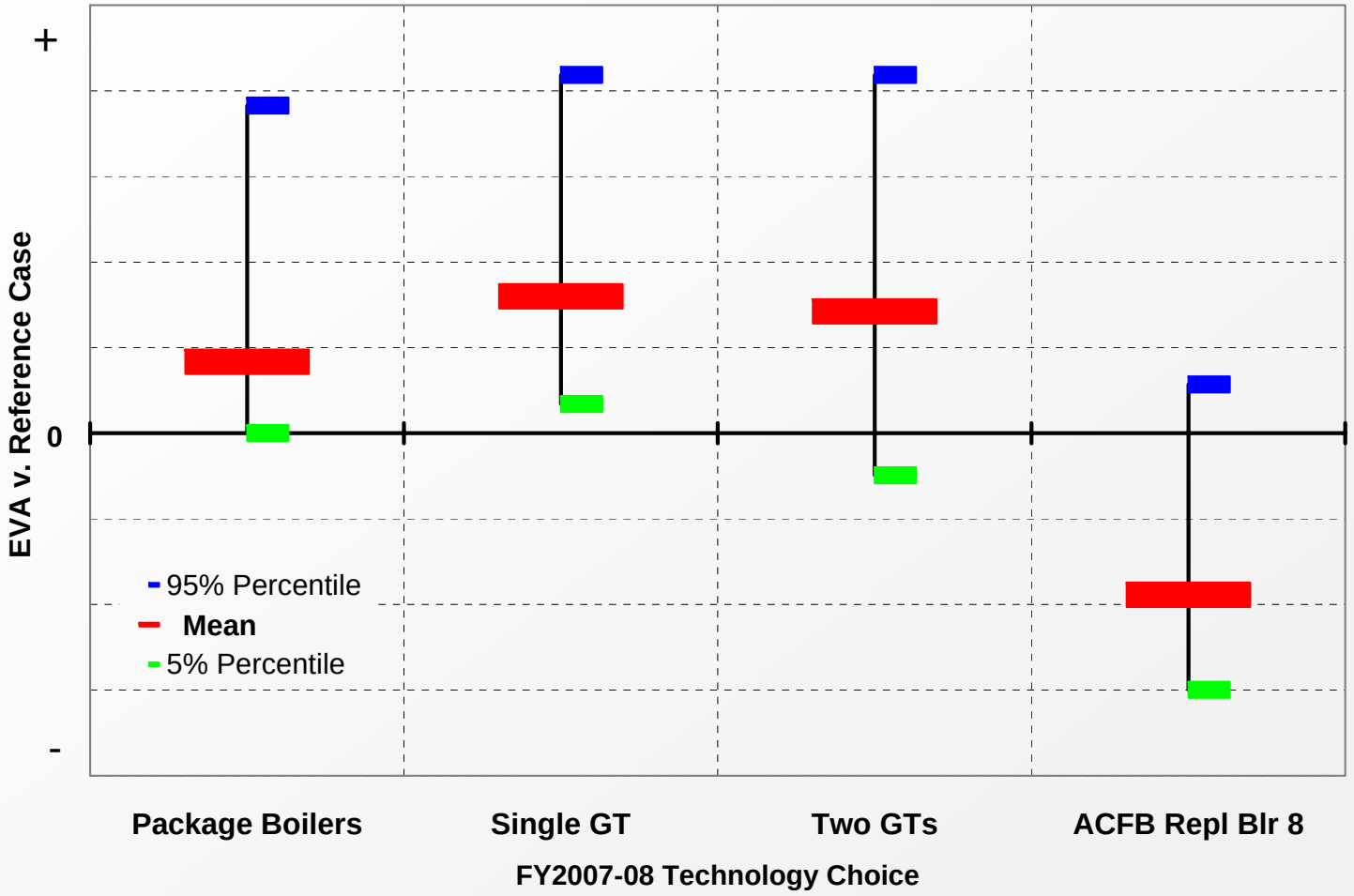

Annual Cost Comparison

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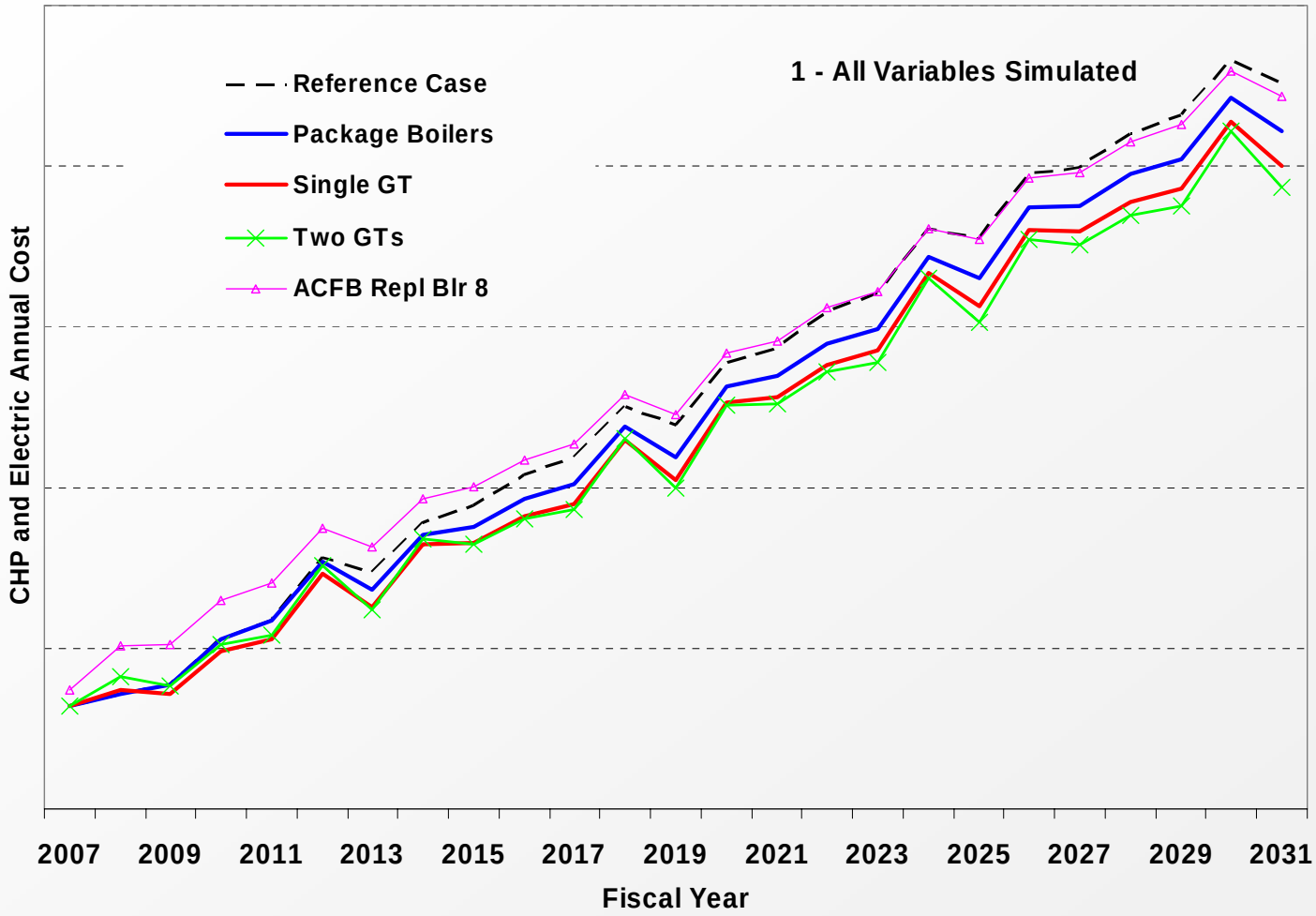

Strategic Considerations

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- Electric reliability
  - Black start capability for most campus electric loads
  - Benefits of “islanded” operation

Recommendations

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- Replacing Boiler 8 with Biomass or ACFB does not make sense
- Most attractive initial choice is installation of single 14 MW GT with infrastructure to support second GT in future