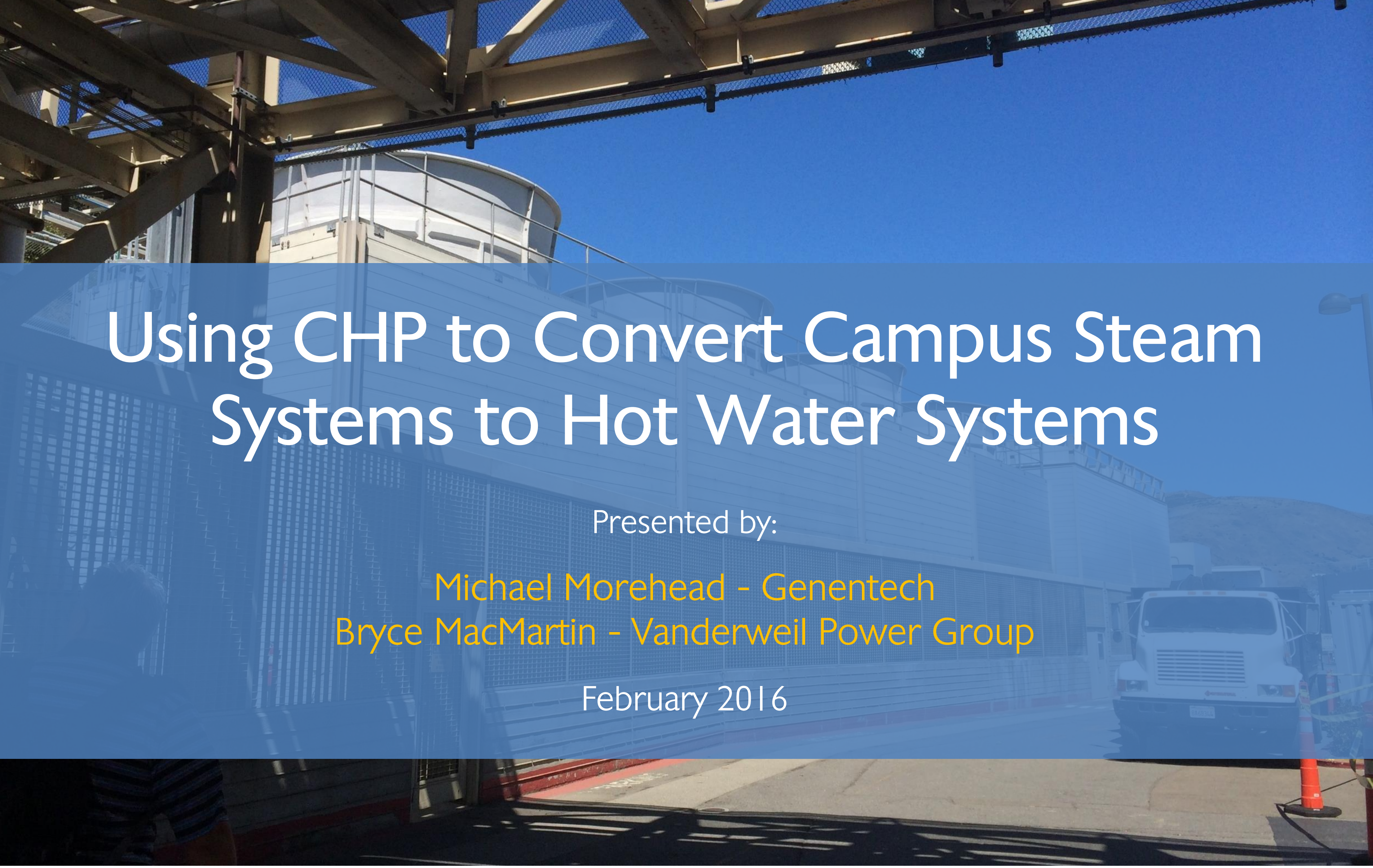

Using CHP to Convert Campus Steam Systems to Hot Water Systems

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INTERNATIONAL DISTRICT ENERGY ASSOCIATION

VANDERWEIL POWER GROUP

Agenda

01 The Challenges

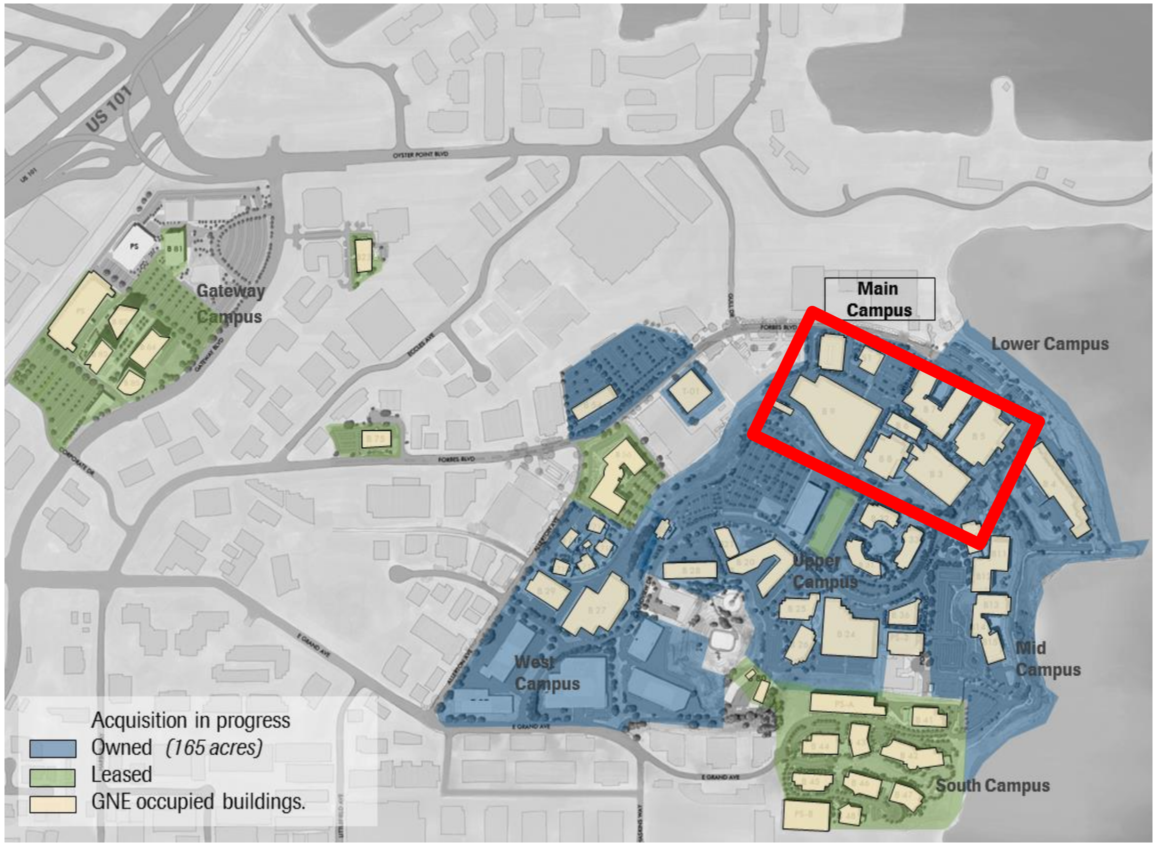
- Existing Campus Steam Distribution System
- High Steam Consumption for Mild Climate
- Corporate Energy Efficiency Goals

02 The Solution Approach

- Utility Reduction Goals
- Project Drivers
- Load Assessment Analysis
- System/Technology Options Evaluation

03 Recommended System and Conclusions

Northern California Biotech Campus



Multi-use Campus

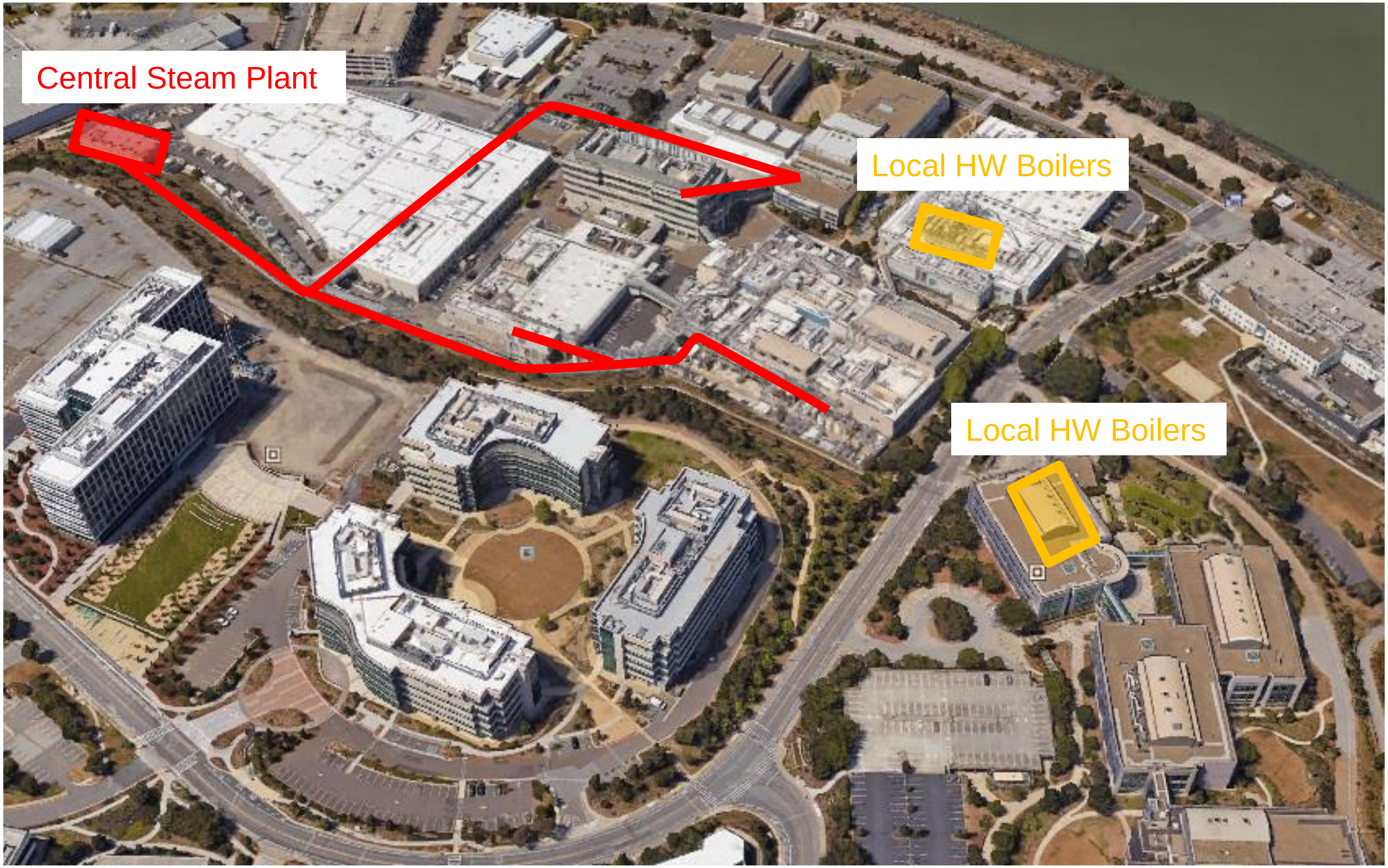
- Research
- Production/Manufacturing
- Office Space
- Corporate Headquarters

61 Total Campus Buildings

Control Over 5.3 MSF of Facilities

165 Acres Owned

Campus Utility Hub



RED = STEAM ORANGE = HOT WATER

Campus Energy Opportunities

- Mild Climate
- Campus Efficiency Improvement Potential
- High Cost of Electricity - 190,000,000 kWh annually = ***$26M+***
- Low Cost of Natural Gas for the Foreseeable Future
- Organic Campus Growth - Lack of Centralization
- Steam System Oversized & Serves Space Heating Loads
- Resiliency & Reliability is of Utmost Importance
  - High-value research and production facilities
  - Seismic zone

Utility Project Drivers

Corporate Directive / Mandate

- Cost-effective Energy Conservation Measures (ECMs)
- Annual & Short-Term (2020) Utility Usage Reduction Goals
- Optimize and Utilize Existing Assets
- Use Total Cost of Ownership (TCO) as Basis

Existing Steam Distribution System

- Central Steam Plant with three (3) 80,000 pph boilers
- Steam production averages ~35,000 pph, peak ~60,000 pph
  - Good metering data for steam production
- Steam distribution system serves five (5) production & manufacturing buildings
  - Serving both process and HVAC loads
  - Steam to hot water heat exchangers for building hot water systems
  - Limited metering data on building demand-side systems
  - Concern of high steam use - excessive reheat/preheat?
- Local hot water boilers in most remaining campus buildings
  - Large stand-alone HW boilers in two buildings in close proximity

Goals for Project Team

- Evaluate “Self-Generation”
  - Reduce annual electric utility costs
  - Improve system efficiency
  - Reduce global carbon generation
  - Increase resiliency

- Reduce Steam Use
  - Utilize waste heat associated with “self-generation”
  - Identify and evaluate hot water vs. steam systems in buildings
  - Understand demand-side loads of HW & steam systems

- Meet the NPV & TCO Financial Goals of Energy Projects

Challenges for Project Team

- High Cost of Capital Projects and Labor in Area
- Organic Campus / Site Development Over Time
  - Lack of distribution infrastructure and centralization
  - Spread-out, suburban campus with 100 ft+ elevation changes
  - Sub-campuses with distinctly different load profiles/needs
- Limited (but Improving) Metering Data
- Plan for Future Steam Reductions
- Site Master Planning / Limited Space Available

Utility System Upgrade Approach

Develop Options

- Screen Self-Generation Technologies
- Existing Steam vs. New Hot Water Distribution
- Microgrid Distribution

Evaluation / Selection

- Local and Global System Efficiency Calculations
- Operational Cost/Savings Modeling
- NPV/TCO Financial Analysis

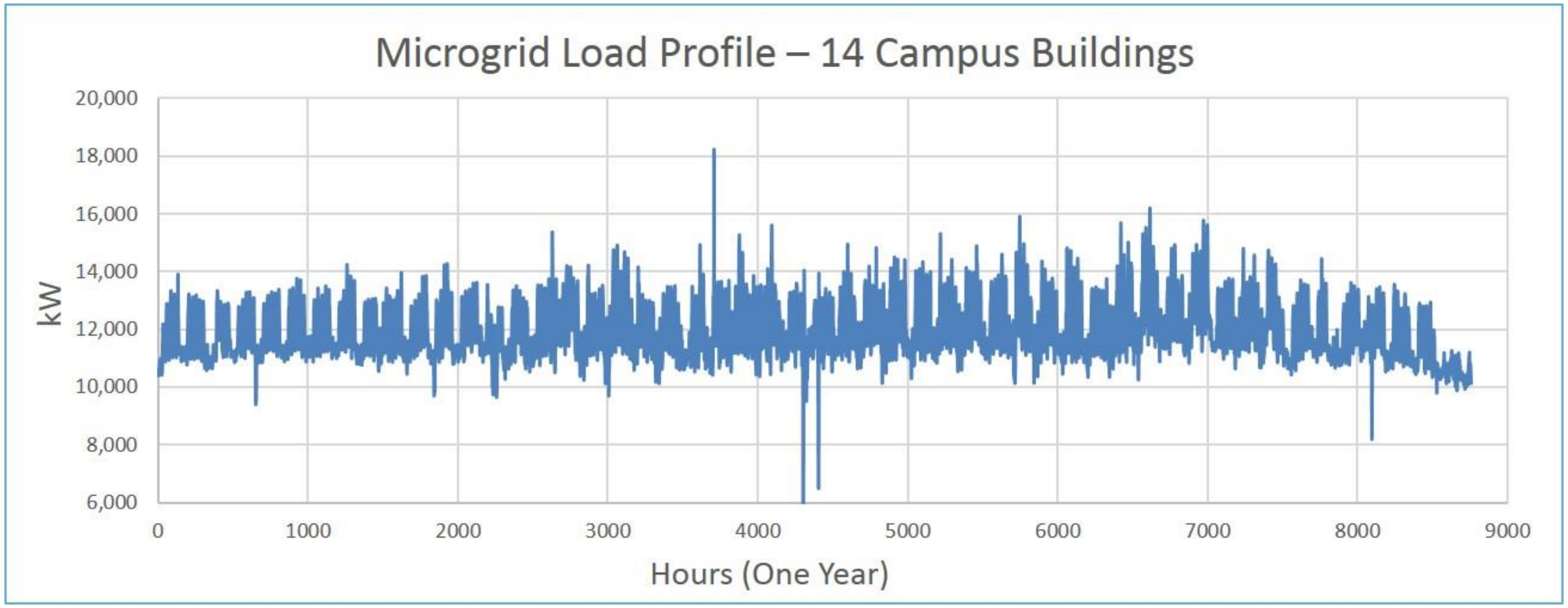
Load Development - Electrical

Quality Existing Data

- Electrical data repository available by building (hourly)
- Local Utility electrical data also available by meter (5 min)

Evaluation

- Understanding of different building rate tariffs (3 different)
- Building aggregation options to determine best Microgrid approach



Load Development – Steam & Hot Water

Existing Data

- Central steam boiler production data (15 min)
- Local hot water boiler production data (15 min)
- Monthly gas usage for all boilers (calibration)

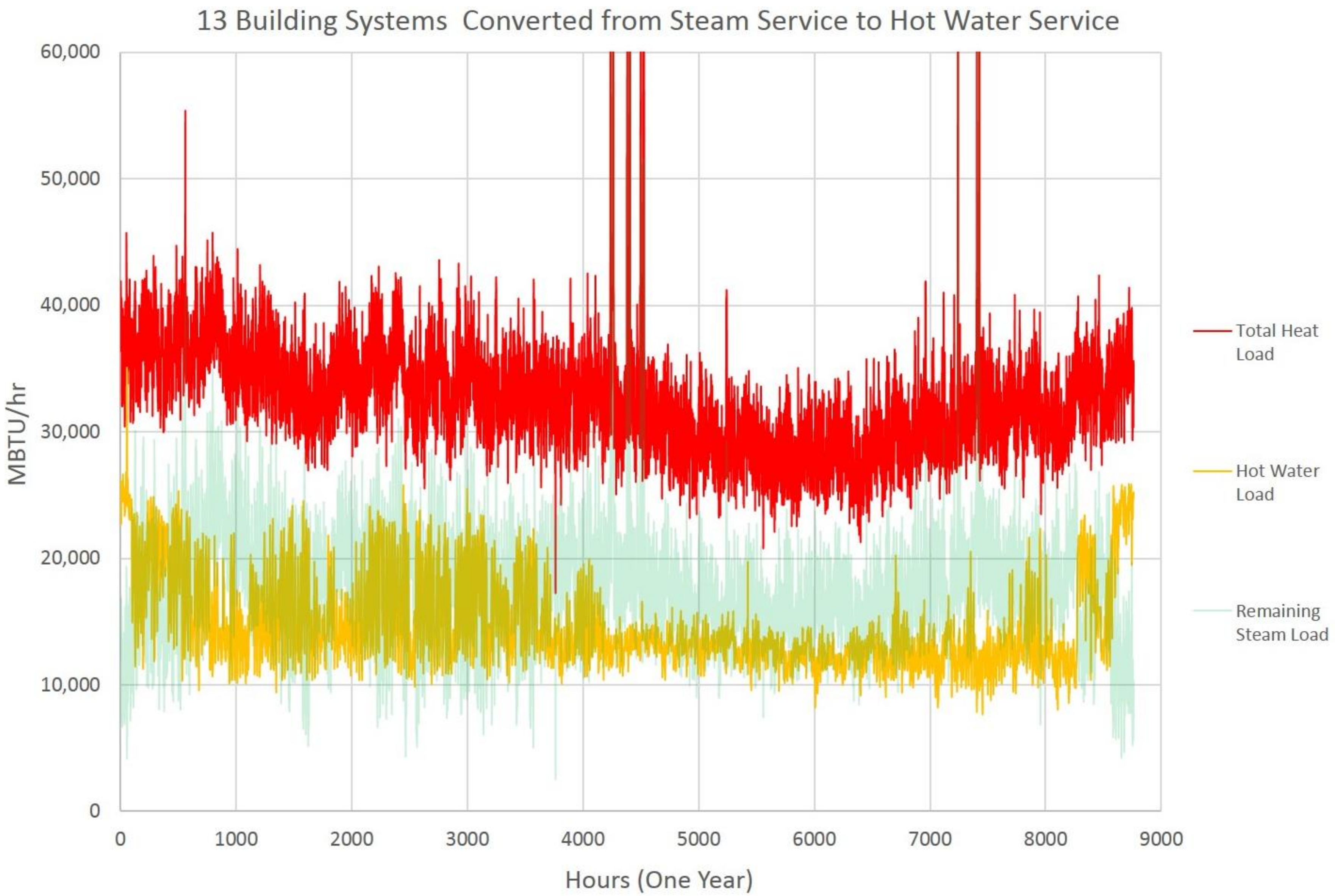
Data Challenges

- Limited demand-side data for building systems (steam or HW)
- Temporary metering required
- Scaled and normalized yearly profiles created

Evaluation

- Determine building conversion feasibility – Steam → Hot Water
- Cost of connection vs. load for financial justification (steam offset)

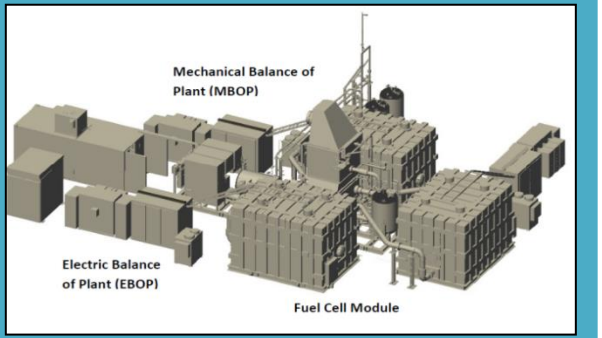
Steam & Hot Water Load Profiles



Technology / Self-Generation Options

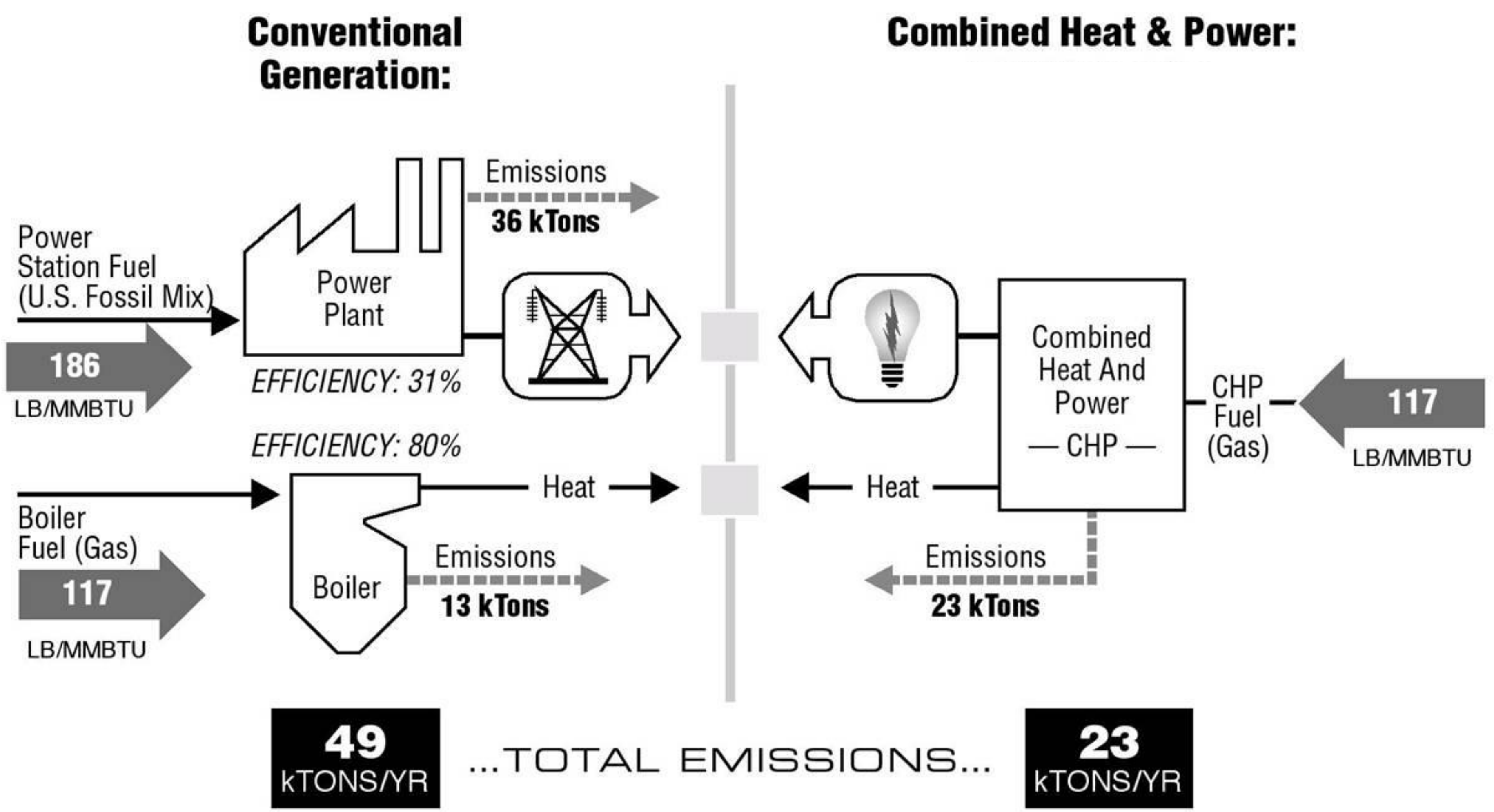
- Thermal System ECM’s
  - Ongoing efficiency and sustainability efforts
  - Minimal impact on achieving corporate goals
- CHP Options
  - Flexible mix of electrical and thermal production available
  - Most efficient if waste heat energy fully utilized
  - Requires new Microgrid and HW distribution
- Fuel Cell Options
  - Electrical production only, Very low thermal
  - System sizing and scale-up flexibility
  - Procurement/installation flexibility
  - Federal 30% ITC significant impact on Proforma

Technology Options Evaluation

Combustion Turbine	Reciprocating Engine	Fuel Cell
		
• Good electrical efficiency • Primary heat recovery medium is steam with some hot water • Excellent potential CHP efficiency	• Excellent electrical efficiency • Primary heat recovery medium is hot water with some steam • Excellent potential CHP efficiency	• Best electrical efficiency • Minimal heat recovery potential with low thermal output • System efficiency limits

Environmental Benefits of CHP

CO_2 Emissions Reductions



LOCAL CA UTILITY

37 kTONS/YR TOTAL

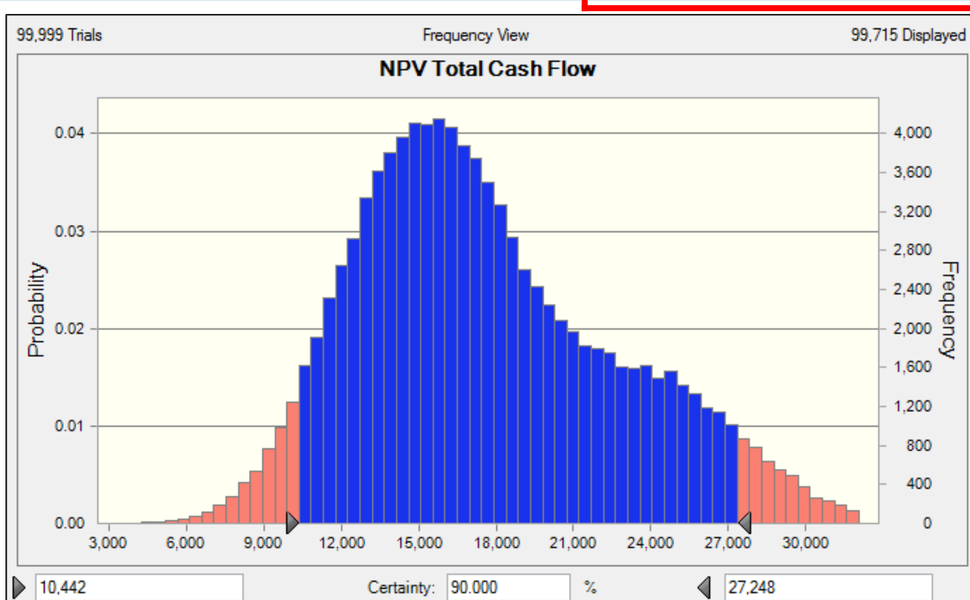
45% EFFICIENCY

Four Primary Technology Options

B9A CHP Technical Assessment	Units	Case 1	Case 2	Case 3	Case 4
Technology		Large Turbine	Large Recip Eng.	Fuel Cell	Small Turbine
CONFIGURATION					
Electricity Steam 160-180°F Hot Water (HHW)	MW lbs/hr MMBtu/hr	7.4 36.6k 7.2	8.4 9.3k 15.8	7.4 N/A 3.8	4.3 15.3k 4.8
Use of Power Use of Steam Use of High Temp Hot Water		LC + FRCs LC + ARU FRC1	LC + FRCs LC Steam Off Set	LC + FRCs N/A FRC1	LC ONLY LC FRC1
PERFORMANCE					
Total System Fuel Required	MMBtu/yr	1,048,000	961,000	1,089,000	1,106,000
Total System Energy Efficiency	%	67.0%	69.7%	60.4%	58.5%
Carbon Emissions (PG&E marginal)	mTon/yr	55.8	52.1	60.6	60.1
Capital	$M	$69.7	$66.4	$67.5	$51.3
Estimated Savings	$M/yr	$5.41	$5.42	$2.45	$2.70
ASSESSMENT					
Rank: Case 2 and 4 – further analysis Case 1 and 3 – deleted		# 3 Highest cost Equal savings Less efficient Too much heat	#1 Better cost Best savings High efficiency Good fit	#4 High cost Lowest savings Low efficiency Not a good fit	#2 Lowest cost Low savings Low efficiency (grid purchase) Lower output

TCO/NPV Analysis

CHP Financial Analysis	Case 2	Case 4
	Recip Engine	Merc-50
FIRST COST	$67.9M	$51.3M
OPERATING COST (in $ 2015)	$13.0M/yr	$15.5M/yr
Utilities (Gas & Power)	$9.6M/yr	$13.2M/yr
Labor & Overhead	$3.4M/yr	$2.3M/yr
SAVINGS ($ 2015)	$5.1M/yr	$2.8M/yr
TOTAL COST OF OWNERSHIP (NPV)	$11.2M	($11.4M)



Recommended System Approach

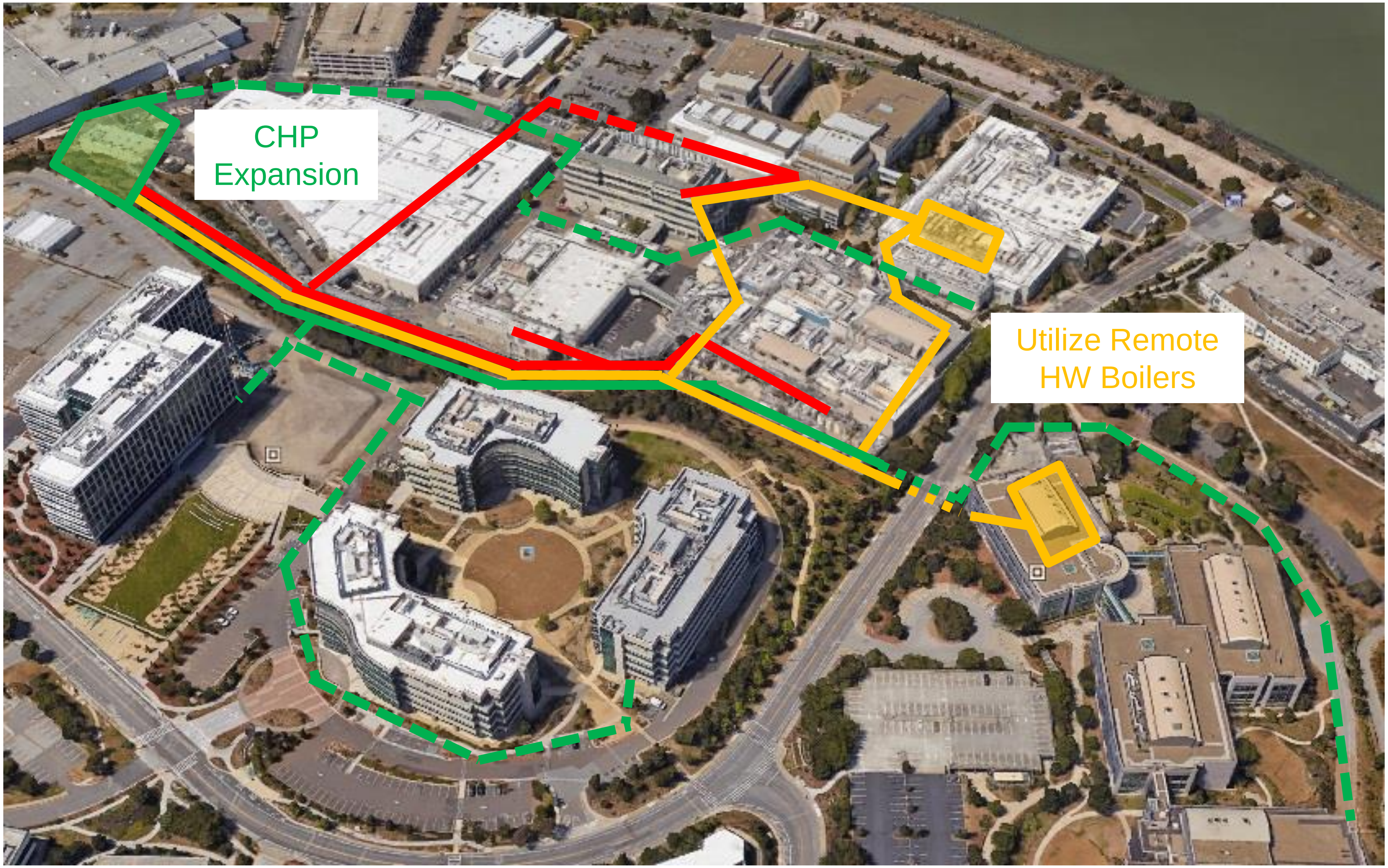
1. Reciprocating Engine (GEJ-920) CHP Prime Mover
   – Electrical efficiency (49%+)
   – Waste heat is good fit for campus loads

2. New Microgrid and Hot Water Distribution Systems
   – Connect 14 buildings to Microgrid
   – Convert 13 building systems from steam to hot water connections

3. New Right-Sized Steam Generation Assets
   – Supplemental steam production for reduced steam demand
   – Add quick start, high efficiency smaller steam boilers for improved load following

4. Utilization of Existing Local HW Generation Assets
   – Supplemental hot water production for large load periods

CHP & Microgrid System Recommendation



RED = STEAM ORANGE = HOT WATER GREEN = MICROGRID

Recommended System Approach

	Units	System Options		
Energy Analysis		**BAU (No CHP)**	**Recip Engine CHP (8.2 MW Net)**	**Recip Engine CHP (9.0 MW Net)**
CHP Efficiency	%	N/A	73.2%	72.6%
Overall System Efficiency	%	53.5%	68.3%	69.4%
Annual Carbon Production (includes Utility Carbon)	Metric Tons	71,400	55,300	54,500
Annual Savings		**BAU (No CHP)**	**Recip Engine CHP (8.2 MW Net)**	**Recip Engine CHP (9.0 MW Net)**
Total Savings (Direct Access)	$M/yr	$0.00	$5.9	$6.1
Total Savings (Primary Rate)	$M/yr	$0.00	$4.4	$4.7

Conclusions & Lessons Learned

- Increased efficiency
- Global carbon reduction
- Utility cost savings
- Increased resiliency and reliability of campus utilities

- Demand-side load investigation
- Additional metered data early and more in-depth

Questions & Answers