University of North Carolina at Chapel Hill

Integrating Standby Power and Steam Turbine Chillers for Better Resiliency at UNC Chapel Hill

IDEA 28th Annual Campus Energy Conference – Denver, Colorado

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THE UNIVERSITY of NORTH CAROLINA at CHAPEL HILL

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Delivering Solutions • Improving Lives

University of North Carolina at Chapel Hill

- Oldest Public University in United States
  - Established 1793
  - First Student 1795
  - First Degree Granted 1798
- Enrollment 29,127 (Fall 2013)
- Main Campus 729 Acres, 19.1 Million Sq. Ft.

Utility Infrastructure

- Steam Supply
  - Two Plants, Five Boilers (2 CFBs), 33.5 MVA Turbine Generator
  - Total Boiler Capacity – 1,150,000 pounds per hour
  - 45 Miles Underground Steam and Condensate Return Piping
- Chilled Water Supply
  - Four Plants - 48,000 Tons total capacity
  - 26 Miles Underground Chilled Water Supply and Return Piping
  - 40,000 ton-hr thermal storage tank
- Electric Distribution
  - Three Substations – 5 transformers (50 MVA ea.)
  - 77 miles of distribution cable – 95% underground

Project Drivers

- Steam Absorption Chillers Aging Out
- Continued Growth in Critical Electrical Loads
  - Hospital
  - Research Animal Quarters
  - High Security Labs
  - IT Enterprise and Research Servers
- Reduced Non-Winter Steam Load

Project Drivers, Continued

- Critical Event is Loss of Duke Energy
  - Hurricane
  - Ice Storm
  - Other “Black Swan” Event
- Potential Impacts Huge
  - $800 Million Annual Research Enterprise
  - Some genetic lines “priceless”
  - Regional Critical Care, Trauma Center, Burn Unit

Project Funding

- Receipt Supported – No Direct Appropriations
- Can Debt Fund within University's Debt Capacity and with Legislature Authorization
- Cash Funded Projects only need Board of Governors Authorization
- Campus Approval for Project through Treasury and Final Approval from Provost Led Committee

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Site Planning / Layout

UNC

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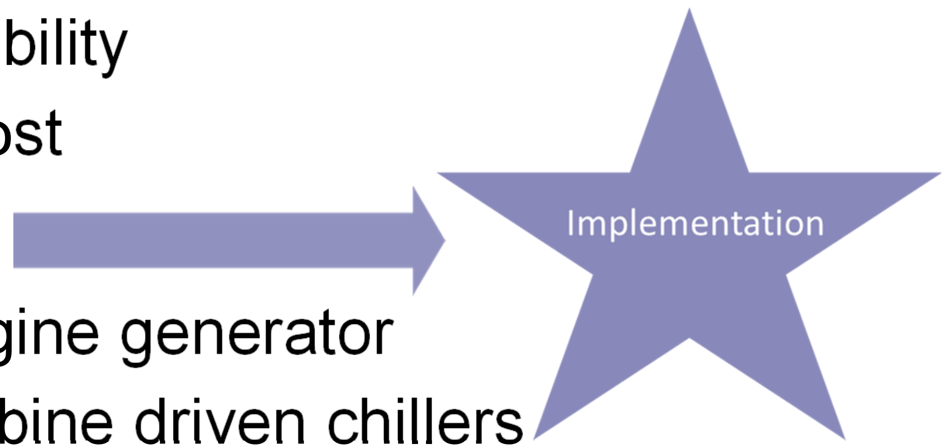
View from Upper Level of NC Cancer Hospital

GOAL: Integrated Solution for Campus Needs

- Campus Requirements
  - Additional electric generation capacity for critical loads
  - Retire/replace 10,000 tons of chiller capacity
- Consider benefits beyond immediate needs
  - Leverage operation of existing utility assets
  - Improve operational flexibility
  - Lower utility operating cost
- Recommended Solution
  - 18 MW reciprocating engine generator
  - 10,000 tons of steam turbine driven chillers



DEFINE: Critical Campus Loads - 2014

- Campus Building Electric – 24.5 MW
- Campus Chilled Water – 18,600 tons
- Typical Summer Steam Requirement
  - 17,000 PPH HP Steam (150 PSIG)
  - 90,000 PPH LP Steam (30 PSIG)
- Utility plant minimum load – 9.6 MW
- Recent growth of standby / critical loads of 0.5 to 1.0 MW/year for facilities and cooling

CONSIDER: 2014 Existing Utility Assets

- Electric (90 MW Peak Demand)
  - 33.5 MVA turbine generator at Cameron Cogen
  - Two 2 MVA black-start engine generator sets
- Chilled Water (40,000 Tons Peak Demand)
  - Primary electric chillers – 34,500 tons
  - Older CFC electric chillers – 6,000 tons
  - Single stage absorbers – 7,500 tons
  - 5 million gallon TES (43,000 ton-hr, 5 hrs. @ 8,600 tons)
- Steam (400,000 PPH Peak Campus Demand)
  - Two 250 KPPH CFB (1275 PSIG / 900 DegF) coal cogen
  - One 250 KPPH G/O at cogen – backup 400 PSIG
  - Two 200 KPPH G/O 150 PSIG at Manning

2014 Post-Outage Response - Critical Loads

- Restore campus utility assets to meet critical loads
  - Cameron Steam Turbine Generator (STG) can produce up to 33.5 MVA (28.5 MW) with blend of dual extraction and condensing.
  - Condensing capacity 19.76 + summer extraction 6.6 = 26.4 MW
  - 3.2 MW from diesel black start generators at Cameron
  - 110+ KPPH steam from Cameron or Manning Steam Plants
- Need standby capacity for:
  - Restore operation of Cameron, Manning, and TES: 9.6 MW
  - Meet campus building electric critical load of 24.5 MW
  - Cooling: run 10,000 tons of chiller capacity plus TES for 5 hours and then 18,600 tons of chiller capacity for duration of outage
- Electrical capacity shortfall: 10 – 15 MW

Step 1: Consider Replacement Chiller Capacity

- Required Capacity: 10,000 Tons
- Options: Electric vs. Steam Turbine Driven Chiller

Peak Load Conditions	Electric Chiller	Steam Turbine Drive Chiller
Chiller	0.50 kW/ton	11 LBS steam/ton
Auxiliaries	0.26 kW/ton	0.32 kW/ton
Total	0.76 kW/ton	0.32 kW/ton

Electric Peak Load Differential: 4,400 kW

*Steam usage cogenerates 7,700 kW of electricity (during normal extraction operation)

Standby Critical Electric Loads (kW)

	Steam Turbine Chillers		Electric Chillers	
	With TES	After TES	With TES	After TES
Utilities				
Substation Static Load	82	82	82	82
Cameron Plant				
Static	1,600	1,600	1,600	1,600
Running	4,320	4,320	4,320	4,320
Manning Steam Plant	1,588	1,588	1,588	1,588
Thermal Energy Storage	1,689		1,689	
Replacement Chillers	3,200	3,200	7,600	7,600
Balance of Critical CHW		6,536		6,536
Manning Generation	750	750	750	750
Sub-total	13,229	18,076	17,629	22,476
Campus Critical	24,525	24,525	24,525	24,525
TOTAL	37,754	42,601	42,154	47,001

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Step 2: Consider Types of Generation

- Combustion turbines / reciprocating engine
  - Generation on-line and loaded quickly, efficient, cost effective
- Potential benefits of expanded cogeneration
  - Additional / replacement steam capacity not needed on campus
  - Continue Cameron cogen operation — marginal economic benefit
- Selection: Reciprocating engine(s)
  - Full / part load efficiency (cost/kW)
  - Higher turn-down
  - < 10 minutes startup to full load
  - No gas compressor needed

Available Generation Capacity / Type of Chiller

Engine Generator Capacity (kW)	Chiller Type	Critical Load (kW)	Generation Margin (kW)
With Thermal Storage			
18,759	Steam Turbine	37,754	12,680
18,759	Electric	42,154	6,547
	Steam Turbine Benefit	4,400 less kW	*6,133 more kW
Without Thermal Storage			
18,759	Steam Turbine	42,601	7,833
18,759	Electric	47,001	1,700
	Steam Turbine Benefit	4,400 less kW	*6,133 more kW

*more capacity from 33.5 MVA cogen plant turbine generator

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Comparison of Capital Cost

	Electric Chillers	Turbine Chillers
Engine Generator: 18,759 kW	$ 24,000,000	$ 24,000,000
Chillers: 10,000 Tons	$ 9,000,000	$ 17,000,000
Substation Improvements	$ 3,000,000	
Tower Capacity		$ 500,000
Sub-Total	$ 36,000,000	$ 41,500,000
Generator Equivalence: 6,133 kW		
$725/kW	$ 4,446,000	
TOTAL	$ 40,446,000	$ 41,500,000

Other Benefits of Steam Turbine Chillers

- Added system operational flexibility
- Stabilize coal-fired CFB boilers
  - improve efficiency during low periods of steam demand
  - minimum fire for each CFB is 70,000 PPH
- Reduce campus electric costs
  - Control usage during periods of high Hourly Profile (HP) electric rates – rates are available day before.
- Potential benefits under Duke Energy contract
  - renegotiate rates or take advantage of current rate structure by controlling campus peak electrical loads including CBL

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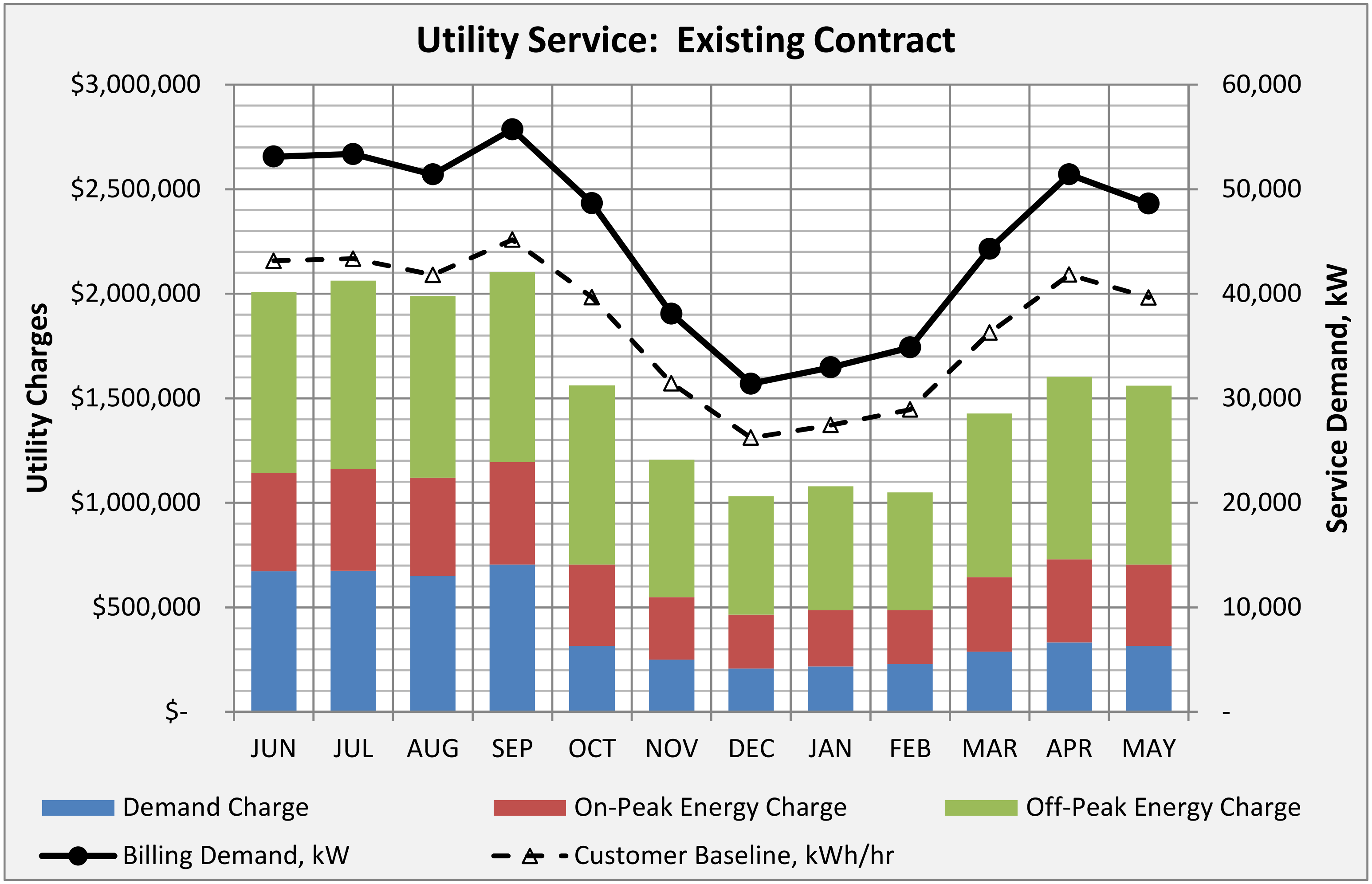
Potential Economic Benefit of Generation



Current Annual Profiles

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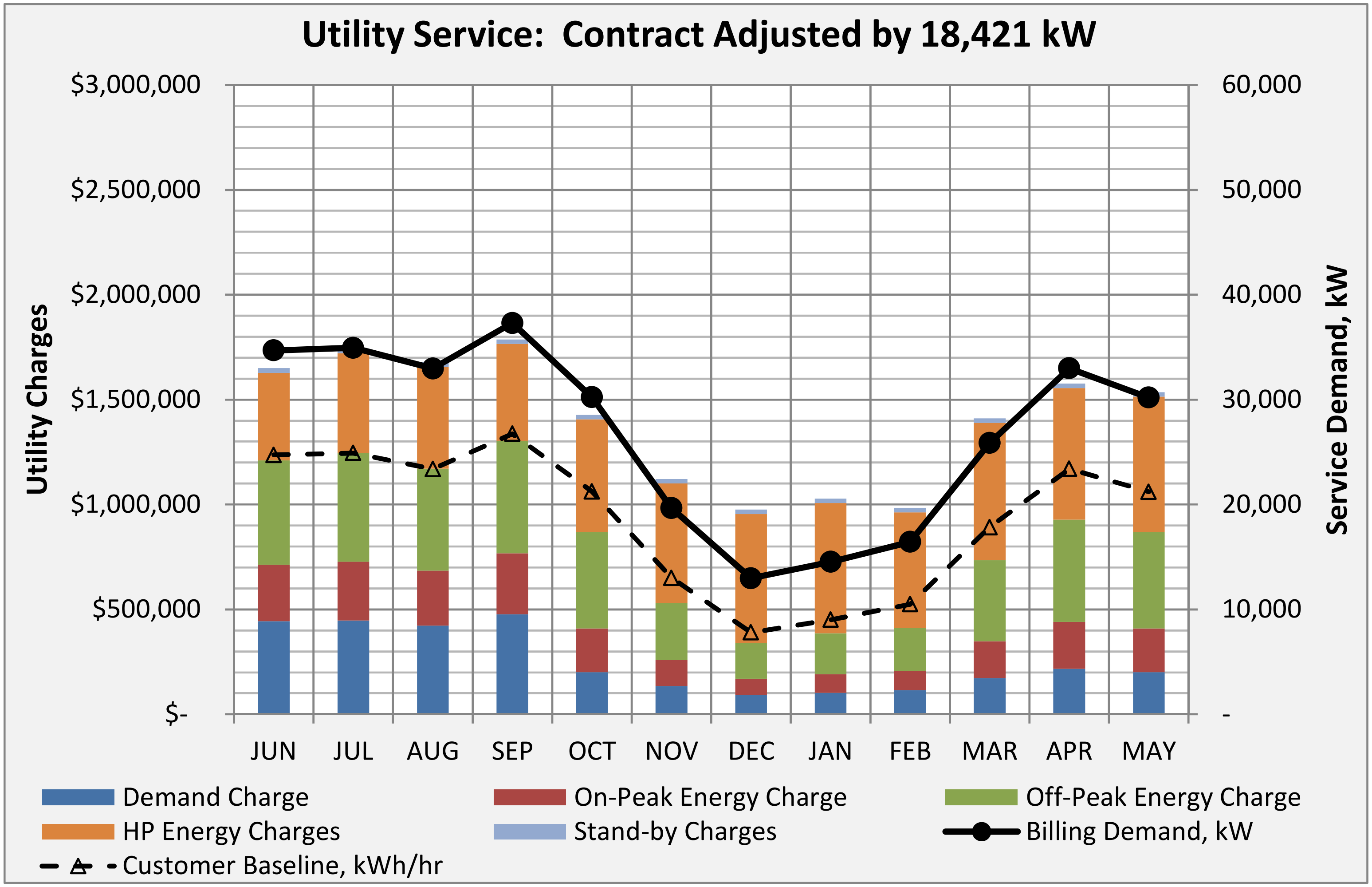
Potential Economic Benefit of Generation



Differential from Existing Contract: $1.76M

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Summary: Elements of Resiliency

- Ability to meet campus critical loads if Duke Grid is unavailable
- Diversity of chilled water energy source
- Generation located at more than one substation
- Ability to rapidly start up and load substantial new electrical generation capacity

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Maximize Benefits While Meeting Critical Campus Requirements

QUESTIONS