Utility Master Plan

Prairie View A&M University

Project No. 98470

November 2017

Utility Master Plan

prepared for

Prairie View A&M University
Prairie View, TX

Project No. 98470

November 2017

prepared by

Burns & McDonnell Engineering Company, Inc.
Fort Worth, TX

CERTIFICATION

Prairie View A&M University
Utility Master Plan

Project 98470

Certification

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SECTION 1.0

INTRODUCTION

1.0 INTRODUCTION

1.1 INTRODUCTION

This Utility Master Plan (UMP) was created by Burns & McDonnell, Inc. (BMcD) to analyze a range of utility solutions that will aid in the expansion of infrastructure necessary to fulfill the vision of Prairie View A&M University (PVAMU) leadership. The UMP addresses the expansion of Chilled Water, Steam, Electric Distribution, Domestic Water, Sanitary Sewer, Storm Water, and Natural Gas systems as well as an analysis of the opportunities for the potential implementation of Thermal Energy Storage (TES), Combined Heat and Power (CHP), and Heat Pump Chillers to the PVAMU utility network. The study provides information regarding potential projects that will enable the University to meet its future utility needs.

Alternatives for improvements, upgrades, and modifications have been studied with accepted fundamentals of engineering and practical considerations of existing conditions and financial impact. Each recommendation is supported by a description of the proposed design strategy, estimated construction and installation costs, and life cycle cost analysis, where applicable.

Terminology used in this Utility Master Plan is defined as follows:

- ASHRAE – American Society of Heating, Refrigerating, and Air-Conditioning Engineers
- BHP – Boiler Horsepower
- BMcD – Burns & McDonnell
- Btu – British Thermal Units
- Btu/hr – British Thermal Units per Hour
- CHP – Combined Heat and Power
- CHW – Chilled Water
- CHWP – Chilled Water Pump
- CUP – Central Utility Plant
- CW – Condenser Water
- CWP – Condenser Water Pump
- ECM – Energy Conservation Measures
- ETC – Energy Transfer Company
- FTPP – Fry-Thomas Power Plant
- GHG – Greenhouse Gas
- GPD – Gallons per Day
- GPM – Gallons per Minute
- HHW – Heating Hot Water
- HP – Horsepower
- HRSG – Heat Recovery Steam Generator
- HVAC – Heating, Ventilation, and Air-Conditioning
- kW – Kilowatts
- kWh – Kilowatt hour

- lbs/hr – Pounds per hour
- LCCA – Life Cycle Cost Analysis
- MBH – One thousand British Thermal Units (Btu) per Hour
- MCF – Thousand Cubic Feet
- MGD – Million Gallons per Day
- MMBtu/hr – One million British Thermal Units (Btu) per Hour
- MW – Megawatts
- O&M – Operation and Maintenance
- PRV – Pressure Reducing Valve
- PSIG – Pound-force per Square Inch (Gauge)
- PVAMU – Prairie View A&M University
- SBEC – San Bernard Electric Cooperative
- SF – Square Feet
- TES – Thermal Energy Storage
- UMP – Utility Master Plan
- VFD – Variable Frequency Drive
- W - Watts

1.2 ACKNOWLEDGEMENTS

The staff of Burns & McDonnell extends its thanks and appreciation to Dr. Corey Bradford, Dr. Cynthia Carter, Brigid DeLoach, Derrick Elder, Pete Horn, Dr. Terence Finley, and all other personnel at the University who assisted in the gathering of facilities and systems data and provided insight into plant operations and systems requirements necessary to complete this study.

1.3 STATEMENT OF LIMITATIONS

In completing this study, information provided by PVAMU and additional third parties was utilized by Burns & McDonnell to make certain assumptions with respect to conditions that may currently exist or exist in the future. While Burns & McDonnell believes the assumptions made are reasonable for the purposes of this study, no representation is made that the conditions assumed will, in fact, occur. In addition, while Burns & McDonnell has no reason to believe the information provided by PVAMU, and on which Burns & McDonnell has relied, is inaccurate in any respect, Burns & McDonnell has not independently verified such information and cannot guarantee its accuracy of completeness. To the extent that actual future conditions differ from those assumed herein, the actual results will vary from those projected.

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SECTION 2.0

EXECUTIVE SUMMARY

2.0 EXECUTIVE SUMMARY

2.1 PURPOSE

The purpose of this master plan is to analyze options capable of meeting the future utility infrastructure needs of PVAMU. Potential improvements are evaluated based on first cost, life cycle cost, reliability, and redundancy.

This study includes an analysis of thermal utilities (chilled water, steam, and heating hot water), domestic water systems, sanitary sewer systems, storm water systems, natural gas distribution, and electric distribution. Contained within this executive summary are the recommended improvements, by system, for PVAMU utilities in five-, ten-, and twenty-year stages. Life cycle costs presented in this section are projected for a twenty-year period. Payback periods are defined in terms of simple payback. Expected project life assumes maintenance is performed in accordance with manufacturer’s recommendations.

2.2 PRIMARY GOALS

The goals for the Utility Master Plan are to analyze the existing utilities and future university expansion needs to determine impacts in five-, ten-, and twenty-year stages.

This study describes various utility solutions to accommodate expansion, including:

- The addition of a second central utility plant (CUP-2).
- The use of a Combined Heat & Power facility to meet campus electric and steam needs.
- The use of a Thermal Energy Storage tank to ease electric demand required by campus chilled water generating and distribution equipment.
- The use of heat pump chillers.
- The progressive conversion of the current steam system to a heating hot water system.
- The expansion of the Fry-Thomas Power Plant (FTPP).

This study also includes a general overview of the other utilities such as water, wastewater, storm water, and natural gas.

2.3 EXPANSION OVERVIEW

The PVAMU main campus is expected to grow at a rate that is consistent with the previous 30-year historical average over the next 20 years. The buildings included in the five-year plan were already planned and identified by PVAMU. The gross square footage building growth included in the ten- and twenty-year plans were estimated by PVAMU and BMcD based on the 30-year historical average growth and the anticipated buildings in the 5-year time frame. These planned expansions are shown by location in Figure 2-1 for the full twenty-year time frame. The red, yellow, and green buildings shown in the map are installed during the five-, ten-, and twenty-year plans, respectively. The total main campus square footage is estimated to grow by 191,000 SF by 2022, an additional 323,200 SF by 2027, and an additional 646,400 SF by 2037. The dashed black line in the figure below is a conceptual boundary hereby referred to as the Core Campus. This boundary was utilized for limiting thermal distribution extensions in Option 3.

Figure 2-1: Projected Future Building Growth of PVAMU Campus

A summary of the buildings shown in the future building growth map above is shown in Table 2-1 below.

Table 2-1: Load Density Factors

Key	Building	Area	Building Type	Year Constructed
New	School of Architecture Fabrication Design Center	32,500	Academic	2017
New	Welcome Center	8,000	Office	2017
New	University Square (Phase VIII)	140,000	Housing	2017
F1	Police Station	10,000	Office	2018
F2	Meat Processing Facility	20,000	Lab	2018
F3	ICCE Facility (lab)	6,667	Lab	2019
F3B	ICCE Facility (office)	13,333	Office	2019
F4	ROTC Building	10,000	Academic	2020
F5	Cultural Arts Center	21,000	Academic	2021
F6	Housing 2 (From 2011 Campus MP)	110,000	Housing	2022
F7	Future Academic Building	105,080	Academic	2023
F8	Future Lab Space / Building	32,320	Lab	2023
F9	Future Support Building	21,450	Support	2024
F10	Future Office	4,480	Office	2024
F11	Future Stud. Activities Building	18,860	Stud. Activities	2025
F12	Future Retail Office Building	3,450	Retail Office	2026
F13	Future Housing Building	137,560	Housing	2027
F14	Future Academic Building	105,080	Academic	2028
F15	Future Lab Space / Building	32,320	Lab	2028
F16	Future Support Building	21,450	Support	2029
F17	Future Office	4,480	Office	2029
F18	Future Stud. Activities Building	18,860	Stud. Activities	2030
F19	Future Retail Office Building	3,450	Retail Office	2031
F20	Future Housing Building	137,560	Housing	2032
F21	Future Academic Building	105,080	Academic	2033

F22	Future Lab Space / Building	32,320	Lab	2033
F23	Future Support Building	21,450	Support	2034
F24	Future Office	4,480	Office	2034
F25	Future Stud. Activities Building	18,860	Stud. Activities	2035
F26	Future Retail Office Building	3,450	Retail Office	2036
F27	Future Housing Building	137,560	Housing	2037

The total area by type of building is summarized in Figure 2-2.

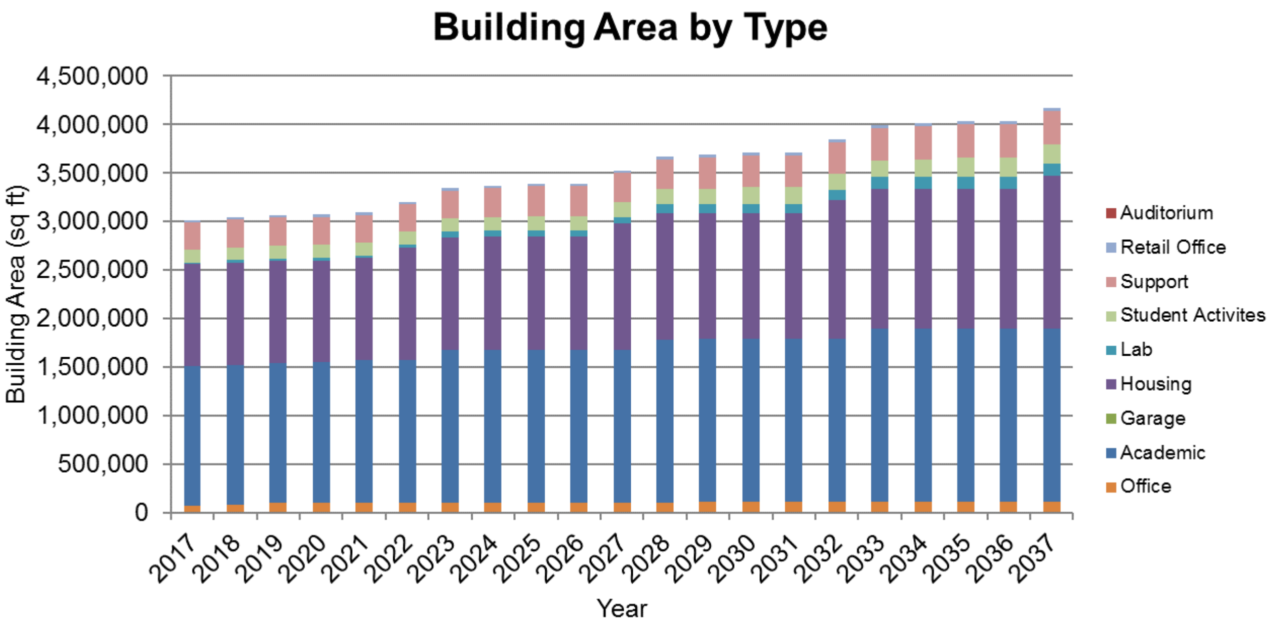

Figure 2-2: Total Building Square Footage by Type

Assumptions were made regarding the building heating, cooling, and electrical load densities for each building type and these assumptions were used to determine the estimated loads for existing and new buildings over the course of the next 20 years. The load density factors used to calculate cooling, heating, and electrical loads are summarized in Table 2-2 below. It is important to note that the load density factors are conservative in nature and, while suitable for planning purposes, should not be utilized as targets for new building energy performance. New buildings shall meet or exceed the ASHRAE 90.1-2013 efficiency standard by 6% and meet ASHRAE 90.1-2013 for existing building renovations. Achieving this target will require that cost-effective energy conservation measures be used which do not compromise building performance or occupant comfort. Energy modeling by the project team will be required to verify energy performance of buildings. Energy modeling shall be conducted with the latest version of Trane Trace 700, Carrier HAP, or IESVE for Engineers. The use of other energy modeling software shall only be permitted with prior approval from PVAMU. ASHRAE 90.1-2013 Appendix G shall be used for establishing the baseline building. Modeling to demonstrate compliance with this requirement shall be completed during the Design Development phase of a project. The designer shall submit information on the modeling including the software used, model inputs and outputs, as well as a brief project description including the design features that result in the additional 6% savings to the PVAMU project manager.

Table 2-2: Load Density Factors

Building Type	Descriptions	SF/TON	Btu/hr/ SF	W/SF
Academic	Lecture Halls, Classrooms, Art Studios, Recital Halls	275	15	3.25
Housing	Dormitories, Theme Housing, Apartments	300	15	2
Lab	Laboratories, Research Facilities	150	60	5.75
Office	Administrative Offices, Professorial Offices	325	15	3.25
Retail Office	Retail Spaces for Lease	275	15	3.25
Stud. Activities	Cafeterias, Dining, Recreation Centers	275	15	3.25
Support	Ancillary Structures, Library	325	15	3.25

As the campus expands, the FTPP thermal loads will increase. Based on the load density factors, the campus chilled water demand is projected to grow from 4,700 tons (current) to 5,700 tons in 2022, 6,400 tons in 2027, and 7,700 tons in 2037. The 4,700 tons listed as current is peak data based on 2016 data from Ameresco paired with feedback regarding recent load peaks from PVAMU. The campus cooling load is shown in Figure 2-3. This graph does not represent the cooling load that will need to be met by central utilities for any option, but rather presents the total cooling demand that the campus will experience over the range of this study. Whether this load is satisfied with central utilities or distributed equipment is option dependent and will be discussed in later sections.

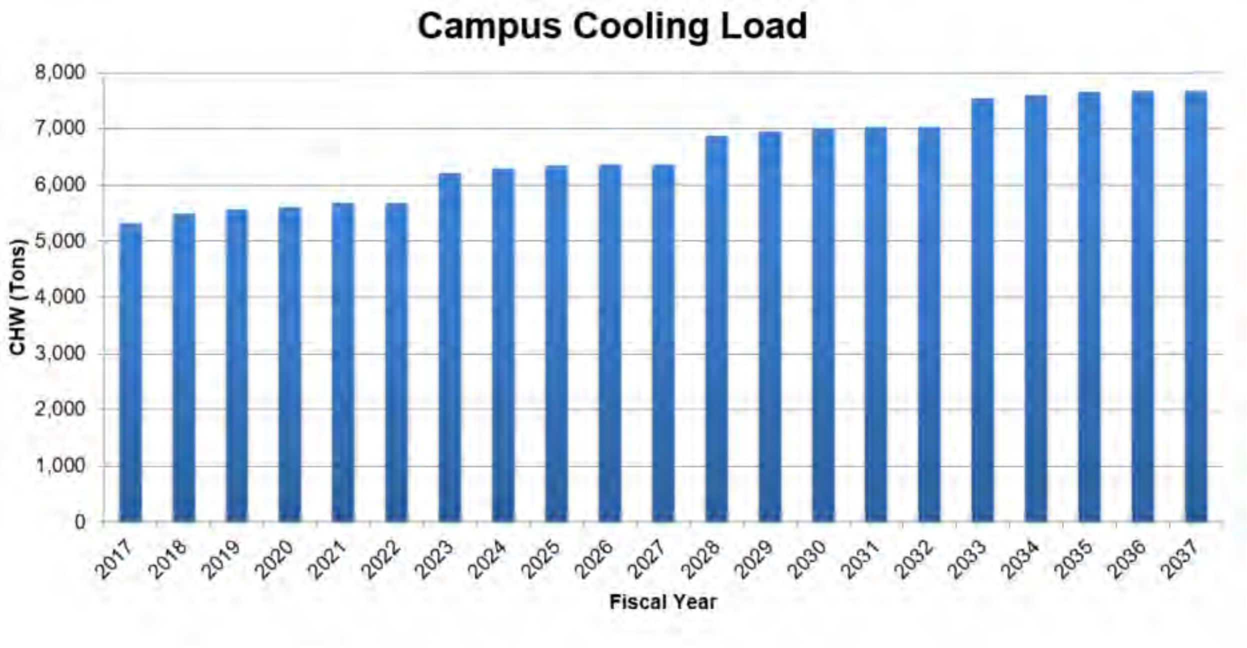

Figure 2-3: Projected Campus Cooling Load

Based on the load density factors, the heating load is projected to grow from 26,700 MBH (current) to 27,600 MBH in 2022, 31,300 MBH in 2027, and 38,400 MBH in 2037. The current campus heating load was estimated by general Btu/hr/SF load factors because steam generation and consumption data was not available. The Ameresco report states that winter heating loads typically represent less than 75 percent of the capacity of the largest (40,000 MBH) existing boiler. PVAMU did not provide metered steam data. Actual energy density data from a geographically similar university were used to predict the loads. The campus heating load is shown in Figure 2-4. Again, this graph presents the total heating demand that the campus will experience over the range of this study. Whether this load is satisfied with central utilities or distributed equipment is option dependent and will be discussed in later sections.

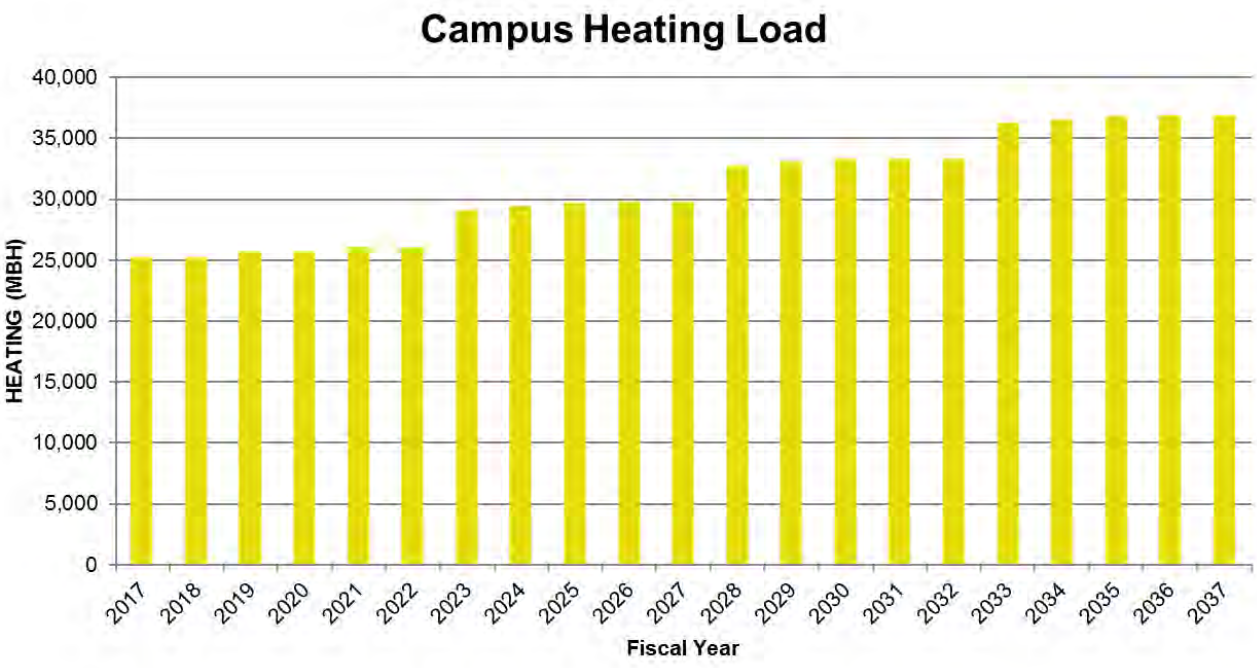

Figure 2-4: Projected Campus Heating Load

Based on the load density factors, the electrical load is projected to grow from 7.1 MW (current) to 8.1 MW in 2022, 8.9 MW in 2027, and 10.5 MW in 2037. The 7.1 MW listed as current is peak data based on 2016 data from Ameresco. The campus electrical load is shown in Figure 2-5.

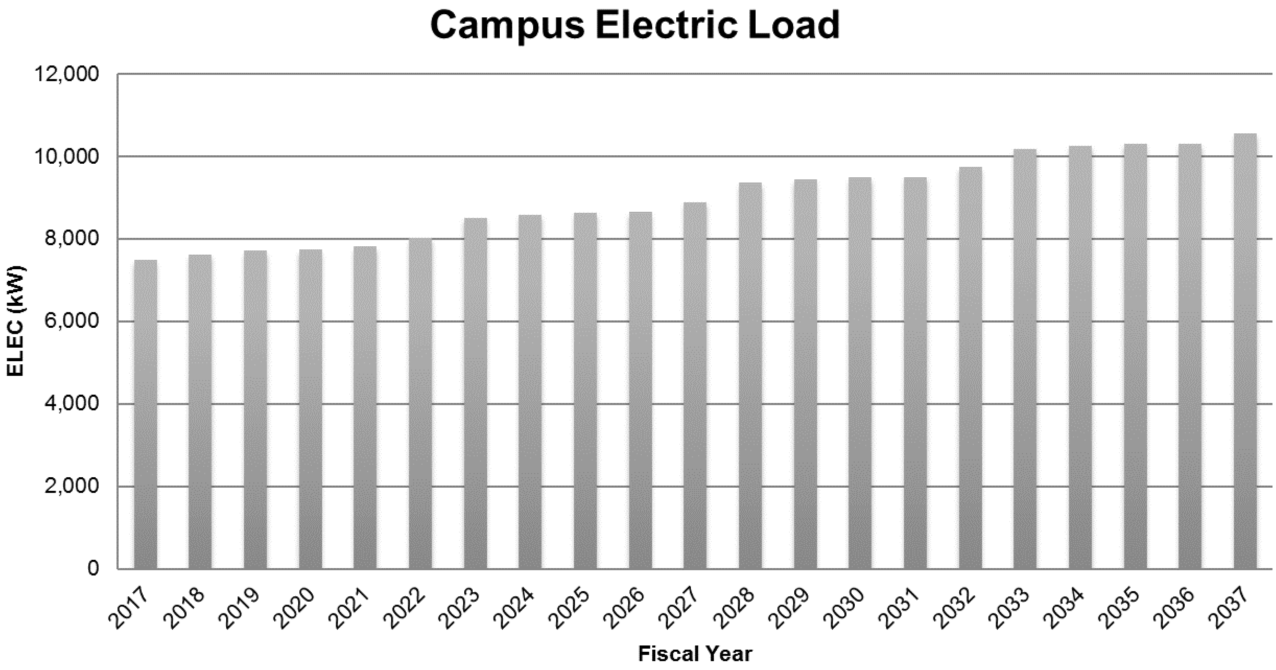

Figure 2-5: Projected Campus Electric Growth

2.4 EQUIPMENT REPLACEMENT

The expected useful life of equipment can be estimated using guidelines developed by ASHRAE. Table 2-3 contains information extracted from the 2015 ASHRAE Handbook – HVAC Applications and lists the service life expectancy for different types of equipment pertinent to PVAMU. Although these are guidelines, actual equipment operating life can be dependent on a number of factors, including: maintenance, operating hours, cycle time, and water treatment. Not all equipment at PVAMU has or will follow these guidelines. The exceptions are explained in the body of the report. Additionally, Option 3 Chiller replacements are based on PVAMU direction, not the ASHRAE life expectancies.

Table 2-3: ASHRAE Recommended Service Life

Equipment Type	Median Service Life Expectancy
Packaged Centrifugal Chiller	23 years
Fire-tube Steam Boiler	25 years
Fire-tube Hot Water Boiler	25 years

2.5 CHILLED WATER SYSTEM – BASE CASE

The current chilled water production system lacks redundancy and the ability to handle the University's capacity increases in the near-term. It is recommended that the distribution system be configured into loops rather than radial feeds so that portions of the campus may still receive chilled water utilities if part of the network is isolated or taken out of service. A looped system, as the name implies, loops through the service area and returns to the original point (FTPP). When additional chilled water sources (CUP-2) are added to the loop, the University has a way to reach the campus in the event of a failure at either source location.

2.5.1 Chilled Water System – 5 Year

2.5.1.1 Capacity Replacement/Expansion

At the Fry-Thomas Power Plant, Chiller 2, which was installed in 1999, will exceed its expected service life in 2022. Typically, when a chiller nears the end of its service life, the efficiency is no longer optimal, the refrigerants can be overdue for phase out, and maintenance costs can increase significantly. Some chillers may exceed their ASHRAE recommended service life. Chiller 2 is recommended to be replaced in 2018 based on operator feedback, system literature, and the need to increase reliable chilled water capacity. Even though this chiller is rated to provide 1,100 tons of chilled water, data from the Ameresco report suggests it is only capable of providing approximately 700 tons. The new chiller recommended to replace it will be rated for 1,100 tons. In addition, there are distribution upgrades and expansions to the chilled water system that are recommended to take place during this time. The existing chilled water distribution is in poor condition according to PVAMU staff and needs to be replaced. Future buildings will require expansion of the chilled water distribution network.

Due to campus load growth, an additional 1,100-ton chiller along with a cooling tower cell, chilled water pump, and condenser water pump are recommended to be installed at FTPP as shown in Table 2-4.

Table 2-4: Five Year Chiller Addition and Replacement List

Plant	Tag	Capacity (tons)	Year in Service	Replacement or Addition
FTPP	Chiller 2	1,100	2018	Replacement
FTPP	Chiller 6	1,100	2018	Addition

A packaged cooling tower system is recommended that can run in parallel with the existing cooling tower system. The existing cooling tower system consists of field erected cells and a common concrete basin. A packaged system is recommended because the existing towers are field erected and would require a costly expansion of the building structure. The installation of the additional chiller and chilled water pump will require a line stop at the end of the header inside the Utility Plant Annex to facilitate extension of the piping to the east, if an outage cannot be taken to perform the work. The expansion of the Utility Plant Annex building is estimated to require approximately 1,650 SF and should extend to the east of the existing building. A sketch layout of the 1,650 SF addition can be seen below in Figure 2-6. The costs for the equipment, installation, and building extension have been included in the cost estimates associated with this report. This addition allows the university to achieve N+1 redundancy relatively quickly and allows time for the installation of the new central utility plant.

Figure 2-6: FTPP Chiller Extension

2.5.2 Chilled Water System – 10 Year

2.5.2.1 Capacity Replacement/Expansion

Between 2023 and 2027, two additional existing chillers will exceed their ASHRAE service life. Chillers 3 and 4 were originally installed in 2004. These chillers will have exceeded their ASHRAE recommended service life during the 10-year time frame and are recommended for replacement in 2027, as shown in Table 2-5. Installing the two replacements at one time can improve construction cost efficiency and limit total disruptions to the campus. This phase also includes the construction of a new Central Utility Plant, CUP-2. A new chiller along with a cooling tower, chilled water pump, and condenser water pump are recommended to be installed in CUP-2 in 2023. In addition, there are distribution upgrades and expansions to the chilled water system that are recommended to take place during this time. According to PVAMU staff, the existing chilled water distribution is in poor condition and needs to be replaced. Future buildings will require expansion of the chilled water distribution network.

Table 2-5: 10 Year Chiller Addition and Replacement List

Plant	Tag	Capacity (tons)	Year in Service	Replacement or Addition
CUP-2	Chiller 7	1,000	2023	Addition
FTPP	Chiller 3	1,100	2027	Replacement
FTPP	Chiller 4	1,100	2027	Replacement

2.5.3 Chilled Water System – 20 Year

2.5.3.1 Capacity Replacement/Expansion

Between 2028 and 2037, one additional chiller will exceed its ASHRAE and/or industry recommended service life. Chiller 5 was originally installed in 2011. This chiller will have exceeded its ASHRAE recommended service life during the 20-year time frame and is recommended for replacement in 2034, as shown in Table 2-6. A new chiller along with a cooling tower, chilled water pump, and condenser water pump should be installed in CUP-2 in 2032. In addition, distribution expansions to the chilled water system are recommended to take place during this time to support the future campus growth.

Table 2-6: 20 Year Chiller Addition and Replacement List

Plant	Tag	Capacity (tons)	Year in Service	Replacement or Addition
CUP-2	Chiller 8	1,000	2032	Addition
FTPP	Chiller 5	1,100	2034	Replacement

2.6 HEATING SYSTEM – BASE CASE

2.6.1 Steam System

PVAMU does not currently have a metering system in place to measure the campus steam load. Based on the estimated steam loads generated for the campus, the boiler capacity at the FTPP meets current peak load and provides N+1 redundancy. If the largest steam boiler currently installed at the FTPP is unable to operate, the remaining boilers can meet the estimated peak demand.

PVAMU has indicated that their existing distribution network is in poor condition, returning approximately 30% of the produced steam as condensate. PVAMU has indicated that all distribution piping is nearing the end of its useful life and will need to be replaced. The distribution replacement cost was spread over ten years and is recommended to begin in 2018.

2.6.1.1 Steam System – Five Year

2.6.1.1.1 Capacity Replacement/Expansion

Within the next five years, several pieces of steam equipment (three boilers and associated auxiliaries) will exceed their recommended service life. Boiler 11 has already exceeded its ASHRAE service life. Boiler 11 was originally installed in 1991 and has been identified for replacement in 2018. Boiler 11 will be replaced with a smaller 20,000 MBH boiler instead of the existing 25,000 MBH boiler. Boiler 12 has also exceeded its ASHRAE service life, but due to the excess steam capacity available from the other boilers, Boiler 12 will not be replaced. Boiler 10 was originally installed in 1989 and has been identified for replacement in 2022. Boiler 10’s ASHRAE life ended in 2014, however, after conducting operator interviews, this boiler’s expected life was extended to 2022. The boiler replacement summary is shown in Table 2-7.

Table 2-7: Five Year Steam Equipment Addition and Replacement List

Plant	Tag	Capacity (MBH)	Year in Service	Replacement or Addition
FTPP	Boiler 11	20,000	2018	Replacement
FTPP	Boiler 10	20,000	2022	Replacement

The existing deaerator, feedwater pumps, RO skid, and other auxiliary equipment is recommended to be replaced in 2022. Burns & McDonnell does not have information on the age of the existing deaerator, feedwater pumps, etc. so replacement may need to occur in a different time frame. In addition, there will be distribution upgrades and expansions to the steam system that will take place during this time. According to PVAMU staff, the existing steam distribution is in poor condition and needs to be replaced. Future buildings will require expansion of the steam distribution network to serve the new campus development along Owens Road.

2.6.1.2 Steam System – 10 Year

2.6.1.2.1 Capacity Replacement/Expansion

Between 2023 and 2027, the Base Case does not require any additional boilers to meet the projected heating loads. Distribution upgrades and expansions to the existing steam system will take place during this time. According to PVAMU staff, the existing steam distribution is in poor condition and needs to be replaced. Future buildings will require expansion of the steam distribution network to serve the new campus development along Owens Road.

2.6.1.3 Steam System – 20 Year

2.6.1.3.1 Capacity Replacement/Expansion

Between 2028 and 2037, the Base Case does not require any additional boilers to meet the projected heating loads. Distribution expansions to the existing steam system will take place during this time to serve the new campus development along Owens Road.

2.6.2 Base Case Alternatives

A key topic evaluated in this study is the future use of heating hot water on the PVAMU campus. Currently, the campus operates on steam with individual steam to hot water heat exchangers at each building interface. Current steam usage results in increased energy and operations and maintenance costs in comparison to a distributed heating hot water system.

In total, four options were reviewed as a part of the UMP: The Base Case, Option 1, and Option 2, and Option 3. In the Base Case, the central utility service for steam will be extended to the campus expansion and individual steam to hot water heat exchangers will be installed in each new building. In Option 1, local hot water boilers will be installed at each new building to meet heating loads. In Option 2, a satellite utility plant for central heating hot water (HHW) will be installed and the existing steam boiler system will be replaced with HHW boilers. In Option 3, central utility service for steam and chilled water will be maintained and replaced. Fry Thomas power plant will undergo a substantial expansion to accommodate additional chilled water generation capacity. Point of use equipment for process steam loads was not included in any of the four options because these loads will vary across campus, however, the natural gas consumption necessary to meet projected process steam loads in Option 1 was accounted for in the sizing of natural gas building connections. The Base Case and Option 1 are consistent in that they include the same number of chillers and the same amount of chilled water piping. Option 2 has the same number of chillers as the Base Case and Option 1, but the CHW distribution piping routing is different. The chilled water piping for Option 2 is often in the same trench as HHW.

2.7 ELECTRICAL DISTRIBUTION SYSTEM

2.7.1 Switchgear #2 Replacement

Switchgear #2 was manufactured by Powell and installed in 1986. This 12.47kV switchgear is located on the southwest side of the existing Fry-Thomas Power Plant. Switchgear #2 is served from four 12.47kV distribution feeders that begin at the Main Campus Switchgear #1. This switchgear serves Switchgear #3, which is adjacent. Burns & McDonnell investigated Switchgear #2 on a site visit and assessed the condition. PVAMU personnel expressed their concerns regarding the reliability and age of the gear. Due to the age of the gear, most of the electrical parts will be difficult to replace due to availability. Also, most of the replacement parts are not manufactured anymore due to newer technology. BMcD recommends replacing this switchgear in-place and reusing the existing conductor.

2.7.2 Southeast Switchgear

BMcD analyzed the future building growth in the southeast area of campus for the next 5, 10, and 20 years. In order to serve this currently undeveloped southeast area, new 12.47kV primary electrical service will be required. To mitigate electrical ductbank and conductor costs from the Main Campus Switchgear #1, a new lineup of 12.47kV main-tie-main Southeast Switchgear will be placed adjacent to the southeast building development. A tap off the existing south feeder will serve one half of the switchgear. The other half of the switchgear will be served from a north feeder overhead extension. Thus, this switchgear will provide redundancy and serve the new southeast area of campus.

2.7.3 New Campus Distribution

Since existing electrical infrastructure does not exist directly in this area, new underground concrete encased ductbank and precast manholes need to be installed to serve these new buildings along with the new Central Utility Plant #2 (CUP-2). BMcD recommends that a new electrical distribution feeder loop serve the proposed southeast buildings and CUP-2. Option 3 does not require CUP-2 so this feeder loop would solely serve the southeast buildings.

BMcD recommends using four-way distribution switches that can be located outside of proposed buildings adjacent to building transformers. This is a common configuration among many university campuses. BMcD does not recommend placing these distribution switches in the manholes due to safety, reliability, and maintainability concerns.

A new 15kV-5kV, 1500kVA transformer and 5kV switchgear will be required to serve the new chiller at the Fry-Thomas Power Plant in 2018. The equipment associated with the chillers such as pumps and motors will need to be served from a new 480V switchboard. BMcD also recommends replacing the four existing 15kV-5kV, 1500kVA chiller transformers due to their age as the four new chillers are replaced. In addition, new 5kV switchgear for each chiller will need to be provided.

2.7.4 Campus Electrical Equipment Improvements

PVAMU personnel expressed safety concern for specific 480V electrical equipment such as MCCs, switchboards, and transformers located within the Fry-Thomas Power Plant and various buildings throughout campus. BMcD recommends replacing and relocating the 12.47kV-480V Hobart Thomas Taylor Sr. Hall silicone fluid transformer on the second floor and the John B. Coleman Library 12.47kV-480Y/277V transformer in the basement outside due to safety concerns based on age and location. The corresponding 480V switchboards need to be replaced due to age and reliability. The following MCCs need to be replaced at the Fry-Thomas Power Plant due to age and reliability issues: MCC-A, MCC-E, MCC-F, MCC-G, and MCC-H. In addition, a 480V MCC in the Agricultural Research Building Room 161 and 480V switchboard in Room 162 need to be replaced due to age and reliability. The Kohler ATS in Room 162 does not maintain the proper clearance per the National Electrical Code (NEC) and needs to meet code.

2.7.5 Recommendations

BMcD recommends a protective device coordination study be performed for the existing electrical system. An updated electrical model helps assist maintenance and facilities personnel to perform work on the system and will help assist in future PVAMU growth analysis. A short-circuit study is also recommended in order to avoid catastrophic events due to short-circuit over duty.

Arc-flash labels are required for electrical equipment per the National Electrical Code (NEC) and NFPA 70E. A protective device coordination study and a short-circuit study are required to perform an arc-flash study. BMcD recommends an arc-flash study be performed as a separate project for the existing low-voltage and medium-voltage electrical system. This study is a large effort since electrical equipment needs to be surveyed in detail to create an electrical model to analyze the system.

BMcD recommends that PVAMU eventually upgrade and reconfigure the distribution feeder loops so that they begin and end at the Main Campus Switchgear #1. This may require an additional lineup of switchgear and reconfigured feeder loops in order for each switchgear bus to serve one half of the loop. This will provide a simplified, reliable, and maintainable electrical system.

2.8 SUMMARY

By implementing these projects, the large-scale growth plan at PVAMU can be met proactively. The plan provides appropriate capacity, reliability, and efficiency to position PVAMU as a premier public university.

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SECTION 3.0

EXISTING SYSTEM DESCRIPTION

3.0 EXISTING SYSTEM DESCRIPTION

3.1 OVERVIEW

The PVAMU Main Campus utilizes one central utility plant to provide steam and chilled water to the campus. The Fry-Thomas Power Plant (FTPP) contains 110 MMBH of steam generating capacity via four fire-tube boilers and 5,495 tons of chilled water nominal capacity via five centrifugal, water-cooled chillers. Electricity is provided at primary service voltage solely by the San Bernard Electric Cooperative. Natural gas is supplied to the campus by the Energy Transfer Company (ETC) Katy Pipeline and is used primarily for the plant's steam boilers as well as space heating, domestic water heating, cooking, and pool heating.

3.2 CHILLED WATER

The chilled water system at the Fry-Thomas Power Plant is comprised of five chillers and five chilled water pumps arranged in a variable primary configuration. The condenser water system consists of five condenser water pumps and five cooling towers.

The chilled water system was designed to generate 42˚F supply water with a return temperature of 54˚F. Chilled water is delivered to the campus via a branch configuration distribution network. The existing chilled water equipment is summarized in the following tables.

Table 3-1 shows the existing Chillers installed at FTPP.

Table 3-1: Existing Chillers

LOC/ TAG	MANUF.	DRIVE/ TYPE	NOMINAL CAP. [TONS]	OPERATIONAL CAP. [TONS]	INST. YEAR	REFRIG.	PUBLISHED EFFICIENCY
Fry-Thomas Power Plant							
CH-1	TRANE	ELE/Centrifugal	1,100	1,100	2015	R-123	0.525 kW/ton
CH-2	TRANE	ELE/Centrifugal	1,100	700	1999	R-123	0.596 kW/ton
CH-3	TRANE	ELE/Centrifugal	1,100	900	2004	R-123	0.566 kW/ton
CH-4	TRANE	ELE/Centrifugal	1,100	900	2004	R-123	0.566 kW/ton
CH-5	TRANE	ELE/Centrifugal	1,095	1,000	2011	R-123	0.562 kW/ton
		Total:	5,495	4,600			

Note: Operational capacity estimates provided from Ameresco Investment Grade Audit

Table 3-2 describes the existing chilled water pumps located in FTPP.

Table 3-2: Existing Chilled Water Pumps

LOC/ TAG	MANUF.	TYPE	HEAD [FT]	FLOW [GPM]	SIZE [HP]
Fry-Thomas Power Plant					
CHWP-1	Peerless	VFD	115	2,450	125
CHWP-2	Peerless	VFD	115	2,450	125
CHWP-3	Peerless	VFD	115	2,450	125
CHWP-4	Peerless	VFD	115	2,450	125
CHWP-5	Peerless	VFD	115	2,450	125

Note: Head, flow, and size were given in the Ameresco report. Manufacturer was as listed for CHWP-3, 4, and 5 in Central Utilities Plant Expansion design drawings. CHWP-1 and 2 assumed to match.

Table 3-3 lists the existing cooling towers and their capacities installed at FTPP.

Table 3-3: Existing Cooling Towers

LOC/ TAG	MANUF.*	FAN CONTROL	FLOW [GPM]	DESIGN ECWT [°F]	DESIGN LCWT [°F]	FAN POWER [HP]
Fry-Thomas Power Plant						
Cooling Tower 1	Ceramic Cooling Tower Co.	Two Speed	3,300	96	86	75
Cooling Tower 2	Ceramic Cooling Tower Co.	Two Speed	3,300	96	86	75
Cooling Tower 3	Ceramic Cooling Tower Co.	Two Speed	3,300	96	86	75
Cooling Tower 4	Ceramic Cooling Tower Co.	Two Speed	3,300	96	86	75
Cooling Tower 5	Ceramic Cooling Tower Co.	Two Speed	3,300	96	86	75

Table 3-4 describes the existing condenser water pumps at FTPP.

Table 3-4: Existing Condenser Water Pumps

LOC/ TAG	MANUF.	TYPE	HEAD [FT]	FLOW [GPM]	SIZE [HP]
Fry-Thomas Power Plant					
CW Pump 1	Peerless	Constant Speed	75	3,300	75
CW Pump 2	Peerless	Constant Speed	75	3,300	75
CW Pump 3	Peerless	Constant Speed	75	3,300	75
CW Pump 4	Peerless	Constant Speed	75	3,300	75
CW Pump 5	Layne & Bowler	Constant Speed	75	3,300	100

Note: Head, flow, and size were given in the Ameresco report. Manufacturer was as listed for CW Pumps 3, 4, and 5 in Central Utilities Plant Expansion design drawings. CW Pumps 1 and 2 assumed to match pumps 3 and 4.

3.3 HEATING

The heating system at the Fry-Thomas Power Plant consists of four fire-tube steam boilers. Boiler 11 and Boiler 12 are ABCO boilers with a capacity of 25 MMBtu/hr. Boiler 10 is a Cleaver-Brooks boiler with a capacity of 20 MMBtu/hr. Boiler 7 is a Cleaver-Brooks boiler with 40 MMBtu/hr capacity. For purposes of this analysis, the steam pressure was assumed to be 150 psig saturated (365°F). PRV stations are located within the distribution network to reduce the produced steam pressure. Some individual buildings connected to the network typically have PRV stations that drop the steam pressure to 15 psi. Steam is then converted to hot water by local heat exchangers for distribution within the buildings. There is an additional hot water boiler located at Hobart Thomas Taylor Sr. Hall. The boiler provides 2.126 MMBtu/hr of heating capacity to the building. The steam equipment is summarized in Table 3-5.

Table 3-5: Existing Boilers

LOC/TAG	MANUF.	INST. YEAR	TYPE	PRODUCT	FUEL	NOMINAL CAP. (MMBtu/hr)
Fry-Thomas Power Plant						
B-10	Cleaver-Brooks	1989	Fire-tube	Steam	Natural Gas	20
B-11	ABCO	1991	Fire-tube	Steam	Natural Gas	25
B-12	ABCO	1991	Fire-tube	Steam	Natural Gas	25
B-7	Cleaver-Brooks	2015	Fire-tube	Steam	Natural Gas	40
					Total:	110
Hobart Thomas Taylor Sr. Hall						**Output (MMBtu/hr)**
B-1	RAYPACK	2016	Modulating Vertical	Hot Water	Natural Gas	2.126

3.4 ELECTRICAL DISTRIBUTION

3.4.1 Main Campus Switchgear #1

Two overhead 12.47kV San Bernard Electric Cooperative (SBEC) feeders transition to underground ductbank and serve the 12.47kV, 1200A Main Campus Switchgear #1 located on the northeast side of campus.

The Main Campus Switchgear #1 was manufactured by M&I Electric and was installed in 2007. The switchgear is in good condition and located in an air-conditioned weatherproof walk-in enclosure. The switchgear is split into two buses with two main breakers, a tie breaker, and seven distribution feeder breakers. This switchgear is in a main-tie-main bus arrangement with the tie breaker normally open. The tie provides redundancy for the two buses so that one bus will still be in operation in the event of a fault on the other bus.

This switchgear does not allow for future growth as there are not any spare buckets or breakers available. The enclosure does not allow for future expansion as there is not any physical space for extra vertical sections. All 12.47kV primary distribution circuits exit the bottom of the switchgear and serve campus via underground ductbanks.

3.4.2 Switchgear #2

Switchgear #2 was manufactured by Powell and installed in 1986. This 12.47kV, 1200A switchgear is located on the southwest side of the existing Fry-Thomas Power Plant and includes six vertical sections. Switchgear #2 is served from four 12.47kV distribution feeders that begin at the Main Campus Switchgear #1. This switchgear serves Switchgear #3, which is adjacent. Burns & McDonnell investigated Switchgear #2 on a site visit and assessed the condition. The gear contains antiquated electrical parts that will be difficult to replace due to availability. Most of the replacement parts are not manufactured anymore due to newer technology.

3.4.3 Switchgear #3

Switchgear #3 was manufactured by M&I Electric and was installed in 2007. This 12.47kV, 1200A switchgear is in good condition and located in an air-conditioned weatherproof walk-in enclosure adjacent to Switchgear #2 and southwest of the Fry-Thomas Power Plant. Switchgear #3 is served from Switchgear #2. The switchgear has one bus with a main breaker and seven breakers that serve the CUP Chillers 1-5 12.47kV-4160Y/2400V, 1500kVA transformers, MCC-C, MCC-D, and a 15kV-480Y/277V, 500kVA transformer. There is one space available for future growth. The enclosure does not allow for further future expansion as there is not any additional physical space for extra vertical sections. All 12.47kV primary distribution circuits exit the bottom of the switchgear and serve the adjacent FTPP chiller transformers.

3.4.4 Existing Electrical Campus Distribution System

The existing 12.47kV electrical distribution feeder circuits are routed from the Main Campus Switchgear #1 via underground concrete encased ductbank with 4” conduits to various Trayer switches located in approximately 75 manholes throughout campus. These circuits are radial feeders where some back-feed Switchgear #2 and some act as separate tie feeders. Many of the Trayer switches were installed in the 1970s and 1980s. PVAMU staff mentioned that the condition is poor for many manholes due to their age. In addition, the sump pumps within many manholes are broken and some manholes do not have them at all. PVAMU staff also mentioned many of the existing distribution feeder loops contain splices where parts of the feeder loop were replaced. The remaining parts of the feeders are aged, therefore creating possible reliability issues. The table below indicates the summary of the existing loops based on the one-line diagram received from PVAMU.

Table 3-6: Summary of Campus Electrical Distribution Loops

Feeder Loop	Size (AWG/KCMIL)	Conduit Size
F100	500	4"
F200	4/0	4"
F300	500	4"
F400	500	4"
F500	4/0	4"
F502	4/0	4”
F600	4/0	4"

The existing main electrical distribution feeders do not have meter data available. According to the Ameresco report, future meters will be installed to meter main distribution feeder and building loads.

3.5 THERMAL UTILITY DISTRIBUTION SYSTEM

Steam from FTPP is distributed throughout campus via direct buried piping and utility tunnels. The steam header leaving the FTPP is 12” on the south side and 6” on the north side as noted in the Steam and Domestic Hot Water Systems Distribution Systems Drawings located in the Physical Plant. The individual campus buildings use local heat exchangers to produce heating water from the steam distribution system fed by FTPP. Condensate is collected at the various use points and is pumped back to the central plant. The plant only receives approximately 30 percent of the steam supplied back as condensate per discussions with PVAMU staff.

Chilled water from FTPP is distributed throughout campus via direct buried piping. The chilled water header sizes leaving FTPP are 20” and 24” as noted in campus drawings and the Ameresco report.

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SECTION 4.0

METHODOLOGY

4.0 METHODOLOGY

4.1 ANALYSIS TOOLS

The following software packages were used in the Utility Master Plan.

4.1.1 Thermal Utilities Analysis– Microsoft Excel

Microsoft Excel was used to calculate the utility loads for the PVAMU main campus. A spreadsheet model was developed based upon the building square footage, building type, and the year constructed. Assumptions were made regarding the building heating, cooling, and electrical load densities for each building type and these assumptions were used to determine the estimated loads for existing and new buildings over the course of the next 20 years.

4.1.2 Thermal Distribution Analysis – Microsoft Excel

A Microsoft Excel based pipe sizing tool was used to determine the sizes of headers and branch connections necessary to supply the expected future building additions. The utility load analysis produced values for the additional peak heating and cooling load that campus utilities needed to be able to provide. These loads in addition to constraints on the desired fluid velocity were used to determine the appropriate pipe sizes. Estimates for future building loads were used to size the new branch connections.

4.1.3 Electrical Distribution Model

Microsoft Excel was used to determine the approximate feeder loads for each existing building and new load. The estimated kW based off W/sf values per building type were used to determine the kW, which was then converted to kVA using a 0.85 power factor.

4.2 BASELINE LOAD ESTABLISHMENT

4.2.1 Thermal Utilities Model

The first step in producing an energy model is to establish a baseline of energy consumption. Once established, the baseline can be used to measure the future growth and the effects of various plant improvement alternatives. The baseline period for all such energy models utilized in this study was based on load density factors determined by Burns & McDonnell and the Ameresco load profiles.

4.2.1.1 Heating System

4.2.1.1.1 Heating Load Development

The heating loads of the existing buildings were estimated using the building sizes, building use, and load density assumptions. Since steam generation and consumption data was not available, actual energy density data from a geographically similar university were used to predict the loads. The estimated heating loads for existing buildings that were used in analysis throughout this study are shown in Table 4-1.

Table 4-1: Existing Building Estimated Heating Loads

Building	MBH
Alvin I. Thomas Administration Building	309
G.R. Woolfolk Social & Political Science Building	248
Gilchrist Engineering Building	348
W.R. Banks Building	858
Jesse M Drew Memorial Complex	166
Hilliard Hall-Communication Building	575
Anderson Hall	251
Evans Hall	364
May Building - Home Economics	300
M.T. Harrington Science Building	892
William “Billy” J. Nicks Building	1512
Physical Plant Administration Building	174
Henrietta Farrell Hall	475
Owens-Franklin Health Clinic	546
C.L. Wilson Engineering Complex	949
Austin Greaux Chemical Engineering	194
Central Receiving	471
Utilities Plant Annex	150
Johnson-Phillip All Faiths Chapel	93
Wilhelmina Delco Building	876
Sam R. Collins Engineering Tech Building	1,184
John B. Coleman Library	2,236
Jesse H & Mary Gibbs Jones Building	527
Leroy G. Moore Jr. Gym	686
Carden-Waller Cooperative Extension	345
Elmer E. O'Banion Science Building	2,499
Willie A. Tempton Sr. Memorial Student Center Building	1,891
Nathelyne Archie Kennedy Architecture Building	1,551
Don K. Clark Juvenile Justice & Psychology Building	893
New Electrical Engineering Building	732
Student Recreation Center	1294
Agriculture and Business Multipurpose Building	1641

The load density projections of 60 Btu/hr/SF for lab buildings and 15 Btu/hr/SF for all other buildings are shown in Table 4-2. Lab buildings were assumed to require 30 Btu/hr/SF of heating and 30 Btu/hr/SF of process steam. Process steam loads were not included for campus buildings other than lab spaces because the process loads may vary from building to building or may not exist.

Table 4-2: Heating Density by Building Type

Building Type	Descriptions	Btu/hr/SF
Academic	Lecture Halls, Classrooms, Art Studios, Recital Halls	15
Housing	Dormitories, Theme Housing, Apartments	15
Lab	Laboratories, Research Facilities	60
Office	Administrative Offices, Professorial Offices	15
Retail Office	Retail Spaces for Lease	15
Stud. Activities	Cafeterias, Dining, Recreation Centers	15
Support	Ancillary Structures, Library	15

Future building heating loads were estimated using the same method as the existing building load estimations. To develop future buildings' heating demands, square footage was determined by analyzing PVAMU's 30-year historical growth average and the heating density load factors were applied to each building type. All future building load densities were reduced by 10% after 2017 and by an additional 2.5% every 5 years thereafter to account for assumed improvements in building efficiency with technological advances. Existing building loads were not reduced. The reduction factor for heating loads was applied sooner than for cooling loads because post-ECM data was not available.

In the event that the steam system is replaced by heating hot water, the approximate heating loads calculated using the load density factors will help estimate the demand of the heating hot water network and ensure that enough capacity exists to handle the transition.

4.2.1.2 Chilled Water System

4.2.1.2.1 Cooling Load Development

Chilled water peak data was measured and provided in the Ameresco report and did not need to be predicted through load density calculations. However, PVAMU provided clarification that the peak chilled water usage has risen to 4,700 tons rather than the 4,400 tons indicated in the Ameresco report. This data was used to develop average daily profiles.

Future buildings' cooling demands were calculated using energy density numbers by building type from a comparable university. All future building load densities were reduced by 10% after 2022 and by an additional 2.5% every 5 years thereafter to account for assumed improvements in building efficiency with technological advances. These load density reduction factors were based on post-ECM data provided in the Ameresco report. Existing building loads were not reduced. The cooling load densities are summarized in Table 4-3.

Table 4-3: Cooling Density by Building Type

Building Type	Descriptions	SF/ton
Academic	Lecture Halls, Classrooms, Art Studios, Recital Halls	275
Housing	Dormitories, Theme Housing, Apartments	300
Lab	Laboratories, Research Facilities	150
Office	Administrative Offices, Professorial Offices	325
Retail Office	Retail Spaces for Lease	275
Stud. Activities	Cafeterias, Dining, Recreation Centers	275
Support	Ancillary Structures, Library	325

4.2.1.3 Electrical Distribution System

4.2.1.3.1 Electrical Load Development

The future buildings planned for the PVAMU campus were assigned a standard Watts per square foot factor developed by building type by comparison to comparable university campuses. The associated Watts per square foot values developed are shown in Table 4-4.

Table 4-4: Electrical Density by Building Type

Building Type	Descriptions	W/SF
Academic	Lecture Halls, Classrooms, Art Studios, Recital Halls	3.25
Housing	Dormitories, Theme Housing, Apartments	2.00
Lab	Laboratories, Research Facilities	5.75
Office	Administrative Offices, Professorial Offices	3.25
Retail Office	Retail Spaces for Lease	3.25
Stud. Activities	Cafeterias, Dining, Recreation Centers	3.25
Support	Ancillary Structures, Library	3.25

Multiplying these values by the planned square footage for the future building provides an estimate of the projected peak load for each building. Summing building and HVAC loads resulted in the peak campus load for the full planned build out of the campus.

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SECTION 5.0

CAMPUS GROWTH

5.0 CAMPUS GROWTH

5.1 GENERAL

The Prairie View A&M campus currently accommodates over 9,000 students and 1,200 employees. In anticipation of current facility needs and future population growth, PVAMU is planning to construct many new buildings on campus. As the PVAMU campus increases in size, the overall utility demand will continue to increase requiring an upgrade to the existing infrastructure that serves these demands. This section describes the general growth of the campus and the growth of the chilled water, steam, and electrical loads which must be met by the utility system and distribution network.

5.2 BUILDING GROWTH

The PVAMU main campus consists of academic, laboratory, office, and support buildings as well as student housing complexes. As the University’s student body continues to grow, a series of future building projects are anticipated. The map in Figure 5-1 shows the growth trend along Owens Road of the future building projects. Figure 5-2 shows the projected growth of the campus buildings by type. The red buildings are projected to be built between 2018 and 2022. The orange buildings are projected to be built between 2023 and 2027. The green buildings are projected to be built between 2028 and 2037. The black-dashed boundary shows the area that PVAMU deems to be the Core Campus and was used to define which buildings would be served with central utilities in Option 3.

Figure 5-1: Projected Future Building Growth of PVAMU Campus

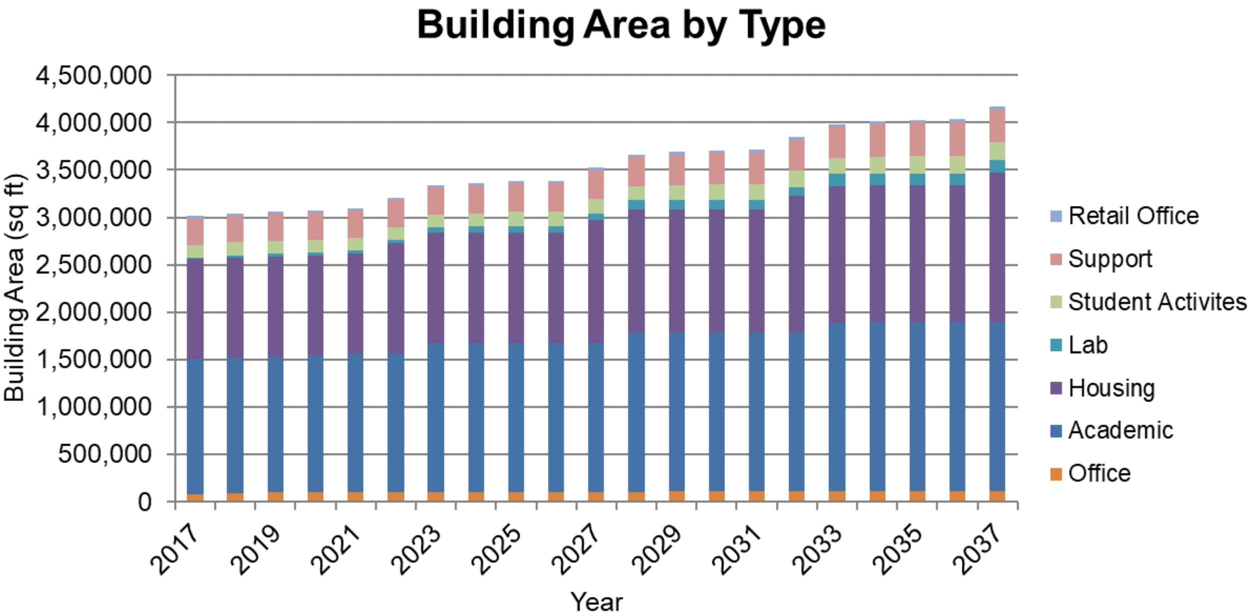

Figure 5-2: Projected Growth of Building by Type

The square footage is projected to grow from 2,900,000 SF (current) to 3,300,000 SF in 2022, 3,600,000 SF in 2027, and 4,200,000 SF in 2037.

5.2.1 Cooling Load Growth

The chilled water system at PVAMU is currently supported by the Fry-Thomas Power Plant. In the Base Case, Option 1, and Option 2 it is recommended that a new Central Utility Plant, CUP-2, be installed in 2023. The chilled water load will be served by CUP-2 and FTPP. In Option 3, however, the need for CUP-2 is mitigated by expanding Fry Thomas, replacing chillers with larger units, and serving buildingss outside of the Core Campus boundary with local assets.

Existing peak load data was provided in the Ameresco report. Peak load data for each future building was estimated based on a chilled water load density factor. The chilled water load factor is in terms of SF/ton and depends on space usage type as described in Section 4.0 Methodology. A load reduction factor was applied to the SF/ton load factor in the future to account for the improvements in building efficiency with technological advances also as described in Section 4.0 Methodology.

Projected housing additions to campus are not displayed below because they will not have a thermal utility connection.

The buildings' construction dates and their estimated peak cooling loads are shown Table 5-1.

Table 5-1: Future Building Additions (2018-2022)

Building #	Building	SF	SF/ton	Year Built	Load Reduction Factor	Tons
F3	ICCE Facility (lab)	6,667	150	2019	1	44
F3B	ICCE Facility (office)	13,333	325	2019	1	41
F5	Cultural Arts Center	21,000	275	2021	1	76
	Total	**41,000**				**162**

The buildings that are planned to come on line by between 2023 and 2027 and their projected peak loads can be seen in Table 5-2.

Table 5-2: Future Building Additions (2023-2027)

Building #	Building	SF	SF/ton	Year Built	Load Reduction Factor	Tons
F7	Future Academic Building	105,080	275	2023	0.9	344
F8	Future Lab Space / Building	32,320	150	2023	0.9	194
F9	Future Support Building	21,450	325	2024	0.9	59
F10	Future Office	4,480	325	2024	0.9	12
F11	Future Stud. Activities Building	18,860	275	2025	0.9	62
F12	Future Retail Office Building	3,450	275	2026	0.9	11
	Total	**185,640**				**683**

The buildings that are planned to come on line between 2028 and 2037 and their projected loads can be seen in Table 5-3.

Table 5-3: Future Building Additions (2028-2037)

Building #	Building	SF	SF/ton	Year Built	Load Reduction Factor	Tons
F14	Future Academic Building	105,080	275	2028	0.875	334
F15	Future Lab Space / Building	32,320	150	2028	0.875	189
F16	Future Support Building	21,450	325	2029	0.875	58
F17	Future Office	4,480	325	2029	0.875	12
F18	Future Stud. Activities Building	18,860	275	2030	0.875	60
F19	Future Retail Office Building	3,450	275	2031	0.875	11
F21	Future Academic Building	105,080	275	2033	0.85	325
F22	Future Lab Space / Building	32,320	150	2033	0.85	183
F23	Future Support Building	21,450	325	2034	0.85	56
F24	Future Office	4,480	325	2034	0.85	12
F25	Future Stud. Activities Building	18,860	275	2035	0.85	58
F26	Future Retail Office Building	3,450	275	2036	0.85	11
	Total	**371,280**				**1,308**

Figure 5-3 shows the projected growth of the campus cooling load.

The peak chilled water load is projected to grow from 4,700 tons (current) to 5,700 tons in 2022, 6,400 tons in 2027, and 7,700 tons in 2037. The 4,700 tons listed as current is a peak load provided by PVAMU staff. As noted before, This graph does not represent the cooling load that will need to be met by central utilities for any option, but rather presents the total cooling demand that the campus will experience over the range of this study. Whether this load is satisfied with central utilities or distributed equipment is option dependent and will be discussed in later sections.

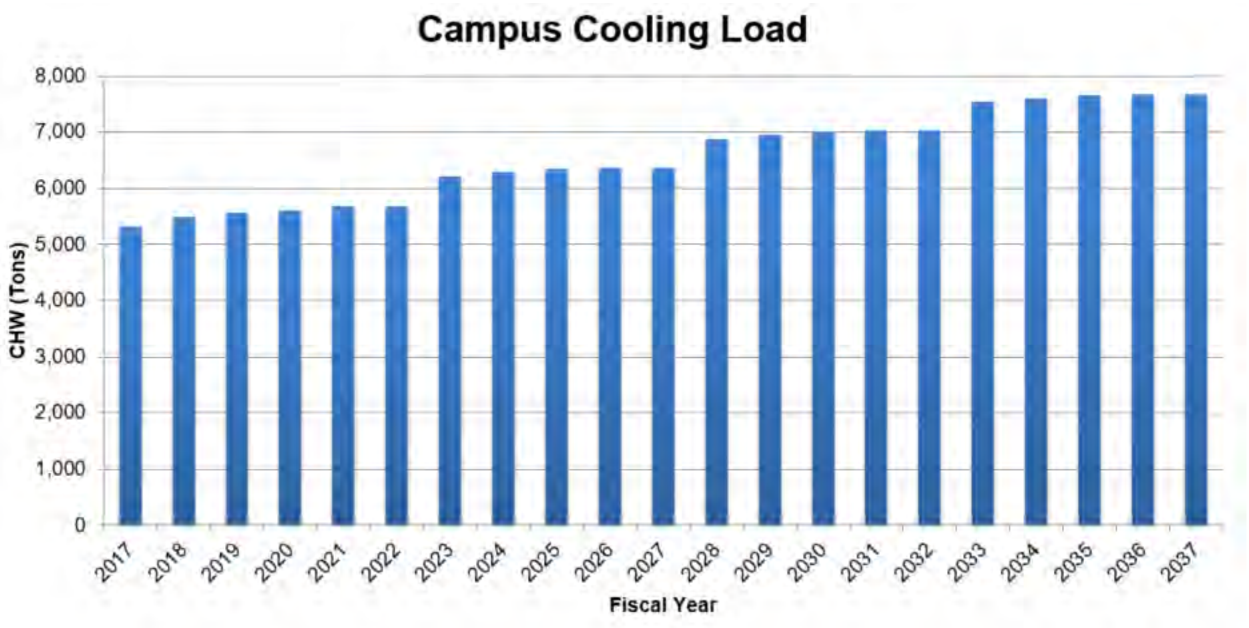

Figure 5-3: Projected Campus Cooling Load

5.2.1.1 Heating Load Growth

The heating load at is supported by the Fry-Thomas Power Plant. Currently, FTPP houses four steam boilers.

The projected heating load was calculated by multiplying each building's area by a specific heating load per unit area for its building type (academic, lab, housing, etc.). A more detailed description of how the existing and future heating loads were calculated can be found in Section 4: Methodology. A load reduction factor was applied to the Btu/hr/SF load factor in the future to account for the improvements in building efficiency with technological advances also as described in Section 4.0 Methodology.

Projected housing additions to campus are not displayed below because they will not have a thermal utility connection.

The existing buildings and their estimated peak heating loads are shown in Table 5-4.

Table 5-4: Existing Buildings

Building #	Building	SF	Btu/hr/SF	MBH
501	Alvin I. Thomas Administration Building	20,600	15	309
503	G.R. Woolfolk Social & Political Science Building	16,540	15	248
504	Gilchrist Engineering Building	23,213	15	348
508	W.R. Banks Building	57,225	15	858
535	Jesse M Drew Memorial Complex	11,058	15	166
537	Hilliard Hall-Communication Building	38,346	15	575
541	Anderson Hall	16,708	15	251
544	Evans Hall	24,270	15	364
658	May Building - Home Economics	20,024	15	300
668	M.T. Harrington Science Building	59,463	15	892
669	William “Billy” J. Nicks Building	100,768	15	1,512
674	Physical Plant Administration Building	11,570	15	174
687	Henrietta Farrell Hall	31,666	15	475
688	Owens-Franklin Health Clinic	36,397	15	546
689	Hobart Thomas Taylor Sr. Hall	100,158	15	1,502
704	C.L. Wilson Engineering Complex	63,268	15	949
724	Austin Greaux Chemical Engineering	12,934	15	194
727	Central Receiving	31,403	15	471
739	Utilities Plant Annex	10,000	15	150
741	Johnson-Phillip All Faiths Chapel	6,223	15	93
742	Wilhelmina Delco Building	58,422	15	876
743	Sam R. Collins Engineering Tech Building	78,945	15	1,184
744	John B. Coleman Library	149,095	15	2,236
745	Jesse H & Mary Gibbs Jones Building	35,118	15	527
758	Leroy G. Moore Jr. Gym	45,700	15	686
761	Carden-Waller Cooperative Extension	23,000	15	345
790	Elmer E. O'Banion Science Building	166,629	15	2,499
779	Willie A. Tempton Sr. Memorial Student Center Building	126,083	15	1891
783	Nathelyne Archie Kennedy Architecture Building	103,421	15	1,551
789	Don K. Clark Juvenile Justice & Psychology Building	59538	15	893
793	New Electrical Engineering Building	48,787	15	732
848	Student Recreation Center	86,290	15	1294
849	Agriculture and Business Multipurpose Building	109,418	15	1,641
	Total	**1,782,280**		**26,734**

The buildings that are planned to come on line between 2018 and 2022 and their projected peak loads can be seen in Table 5-5.

Table 5-5: Future Building Additions (2018-2022)

Building #	Building	SF	Btu/hr/SF	Year Built	Load Reduction Factor	MBH
F3	ICCE Facility (lab)	6,667	60	2019	0.9	360
F3B	ICCE Facility (office)	13,333	15	2019	0.9	180
F5	Cultural Arts Center	21,000	15	2021	0.9	284
	Total	**41,000**				**824**

The buildings that are planned to come on line between 2023 and 2027 and their projected loads can be seen in Table 5-6.

Table 5-6: Future Building Additions (2023-2027)

Building #	Building	SF	Btu/hr/SF	Year Built	Load Reduction Factor	MBH
F7	Future Academic Building	105,080	15	2023	0.875	1,379
F8	Future Lab Space / Building	32,320	60	2023	0.875	1697
F9	Future Support Building	21,450	15	2024	0.875	282
F10	Future Office	4,480	15	2024	0.875	59
F11	Future Stud. Activities Building	18,860	15	2025	0.875	248
F12	Future Retail Office Building	3,450	15	2026	0.875	45
	Total	**185,640**				**3,709**

The buildings that are planned to come on line between 2028 and 2037 and their projected loads can be seen in Table 5-7.

Table 5-7: Future Building Additions (2028-2037)

Building #	Building	SF	Btu/hr/SF	Year Built	Load Reduction Factor	MBH
F14	Future Academic Building	105,080	15	2028	0.85	1,340
F15	Future Lab Space / Building	32320	60	2028	0.85	1648
F16	Future Support Building	21,450	15	2029	0.85	273
F17	Future Office	4480	15	2029	0.85	57
F18	Future Stud. Activities Building	18,860	15	2030	0.85	240
F19	Future Retail Office Building	3450	15	2031	0.85	44
F21	Future Academic Building	105,080	15	2033	0.825	1,300
F22	Future Lab Space / Building	32320	60	2033	0.825	1600
F23	Future Support Building	21,450	15	2034	0.825	265
F24	Future Office	4480	15	2034	0.825	55
F25	Future Stud. Activities Building	18,860	15	2035	0.825	233
F26	Future Retail Office Building	3450	15	2036	0.825	43
	Total	**371,280**				**7,100**

Based on the load density factors, the heating load is projected to grow from 26,700 MBH (current) to 27,600 MBH in 2022, 31,300 MBH in 2027, and 38,400 MBH in 2037. The current campus heating load was estimated by general Btu/hr/SF load factors because steam generation and consumption data was not available. The Ameresco report states that winter heating loads typically represent less than 75 percent of the capacity of the largest (40,000 MBH) existing boiler. PVAMU did not provide metered steam data. Actual energy density data from a geographically similar university were used to predict the loads. Figure 5-4 shows the projected growth of the campus heating load. The heating load includes the steam and heating hot water loads. Again, this graph presents the total heating demand that the campus will experience over the range of this study. Whether this load is satisfied with central utilities or distributed equipment is option dependent and will be discussed in later sections.

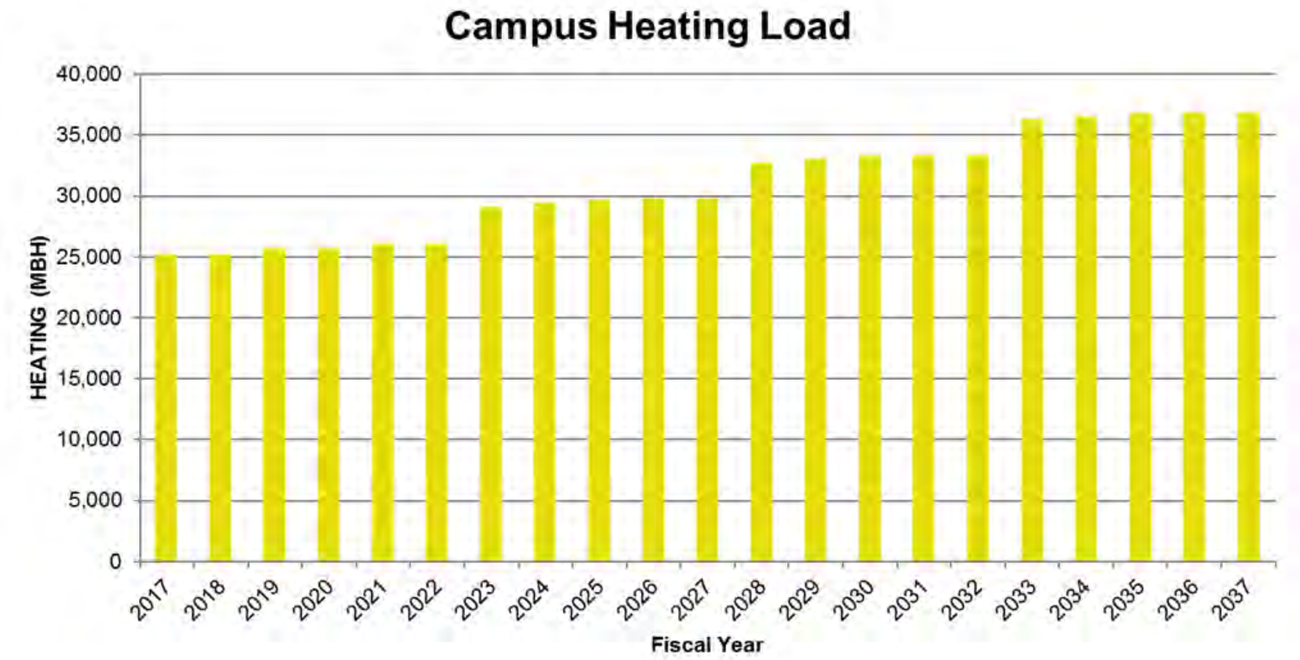

Figure 5-4: Projected Campus Heating Load

5.2.1.2 Electrical Load Growth

The PVAMU campus receives electricity from San Bernard Electric Cooperative (SBEC). Two 12.47kV overhead distribution feeders serve the Main Campus Switchgear #1 via underground ductbank located on the northeast side of campus.

The existing peak electrical load is 7 MW according to the post ECM data in the Ameresco report. The future buildings planned for the PVAMU campus were assigned a standard Watts per square foot value developed by building type according to comparable university campuses, as discussed in Section 4.0 Methodology. A load reduction factor was applied to the W/SF load factor in the future to account for the improvements in building efficiency with technological advances also as described in Section 4.0 Methodology. Buildings F1, F2, F3, and F4 are assigned higher W/SF load factors than described above because they have local HVAC. F1, F2, and F4’s W/SF factor is increased by 3 W/SF in the Base Case, Option 1, and Option 2. This updated factor is shown in the table below. Building F3 is increased by 3 W/SF only in Option 2. This increase is not shown in the table below, but is considered in the analysis. The future buildings’ construction dates and their estimated peak electrical loads between 2018 and 2022 are shown in Table 5-8.

Table 5-8: Future Building Additions (2018-2022)

Building #	Building	SF	W/SF	Year Built	Load Reduction Factor	kW
F1	Police Station	10,000	6.25	2018	1	63
F2	Meat Processing Facility	20,000	8.75	2018	1	175
F3*	ICCE Facility (lab)	6,667	5.75	2019	1	38
F3B*	ICCE Facility (office)	13,333	3.25	2019	1	43
F4	ROTC Building	10,000	6.25	2020	1	63
F5	Cultural Arts Center	21,000	3.25	2021	1	68
F6	Housing 2 (From 2011 Campus MP)	110,000	2	2022	1	220
	Total	**191,000**				**550**

*Note: To account for additional electrical load associated with buildings served locally, building F3's load factor is increased to 8.75 W/SF (lab) and 6.25 W/SF (office, academic, support, retail, activities) in Option 2 only, giving a total future load of 142 kW.

The buildings that are planned to be constructed between 2023 and 2027 and their projected peak loads can be seen in Table 5-9.

Table 5-9: Future Building Additions (2023-2027)

Building #	Building	SF	W/SF	Year Built	Load Reduction Factor	kW
F7	Future Academic Building	105,080	3.25	2023	0.9	307
F8	Future Lab Space / Building	32,320	5.75	2023	0.9	167
F9	Future Support Building	21,450	3.25	2024	0.9	63
F10	Future Office	4,480	3.25	2024	0.9	13
F11	Future Stud. Activities Building	18,860	3.25	2025	0.9	55
F12	Future Retail Office Building	3,450	3.25	2026	0.9	10
F13	Future Housing Building	137,560	2	2027	0.9	248
	Total	**323,200**				**863**

The buildings that are planned to be constructed between 2028 and 2037 and their projected loads can be seen in Table 5-10.

Table 5-10: Future Building Additions (2028-2037)

Building #	Building	SF	W/SF	Year Built	Load Reduction Factor	kW
F14	Future Academic Building	105,080	3.25	2028	0.875	299
F15	Future Lab Space / Building	32,320	5.75	2028	0.875	163
F16	Future Support Building	21,450	3.25	2029	0.875	61
F17	Future Office	4,480	3.25	2029	0.875	13
F18	Future Stud. Activities Building	18,860	3.25	2030	0.875	54
F19	Future Retail Office Building	3,450	3.25	2031	0.875	10
F20	Future Housing Building	137,560	2	2032	0.875	241
F21	Future Academic Building	105,080	3.25	2033	0.85	290
F22	Future Lab Space / Building	32,320	5.75	2033	0.85	158
F23	Future Support Building	21,450	3.25	2034	0.85	59
F24	Future Office	4,480	3.25	2034	0.85	12
F25	Future Stud. Activities Building	18,860	3.25	2035	0.85	52
F26	Future Retail Office Building	3,450	3.25	2036	0.85	10
F27	Future Housing Building	137,560	2	2037	0.85	234
	Total	**646,400**				**1,655**

The electrical load is projected to grow from 7.1 MW (current) to 8.0 MW in 2022, 8.9 MW in 2027, and 10.5 MW in 2037. The 7.1 MW listed as current is peak data based on 2016 data from Ameresco. Figure 5-5 shows the projected growth of the campus electrical distribution load.

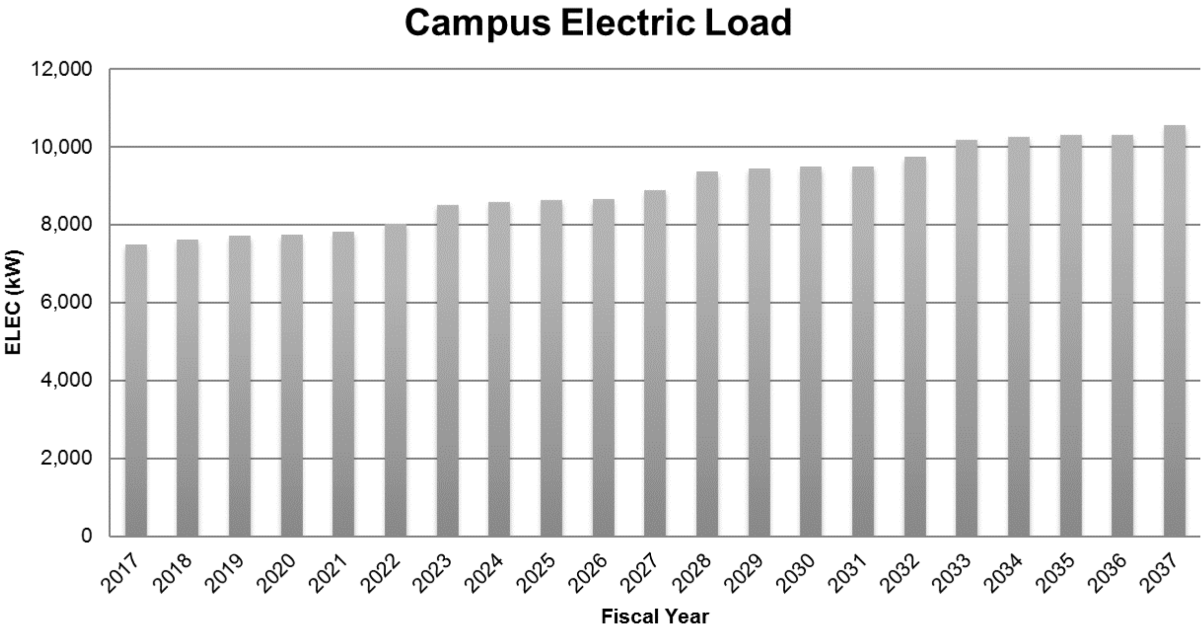

Figure 5-5: Projected Campus Electric Growth

Option 3 utilizes the increased load factor for more buildings than the other three options since Option 3 utilizes local heating and cooling assets for buildings outside of the Core Campus. The following three tables provide the electrical load assumptions for Option 3. To account for additional electrical load associated with buildings served locally, load factors for locally served buildings were increased to 8.75 W/SF (lab) and 6.25 W/SF (office, academic, support, retail, activities).

Table 5-11: Option 3 Future Building Additions (2018-2022)

Building #	Building	SF	W/SF	Year Built	Load Reduction Factor	kW
F1	Police Station	10,000	6.25	2018	1	63
F2	Meat Processing Facility	20,000	8.75	2018	1	175
F3*	ICCE Facility (lab)	6,667	8.75	2019	1	58
F3B*	ICCE Facility (office)	13,333	6.25	2019	1	83
F4	ROTC Building	10,000	6.25	2020	1	63
F5	Cultural Arts Center	21,000	3.25	2021	1	68
F6	Housing 2 (From 2011 Campus MP)	110,000	2	2022	1	220
	Total	**191,000**				**730**

The buildings that are planned to be constructed between 2023 and 2027 and their projected peak loads can be seen in Table 5-12.

Table 5-12: Option 3 Future Building Additions (2023-2027)

Building #	Building	SF	W/SF	Year Built	Load Reduction Factor	kW
F7	Future Academic Building	105,080	3.25	2023	0.9	307
F8	Future Lab Space / Building	32,320	5.75	2023	0.9	167
F9	Future Support Building	21,450	6.25	2024	0.9	121
F10	Future Office	4,480	6.25	2024	0.9	25
F11	Future Stud. Activities Building	18,860	3.25	2025	0.9	55
F12	Future Retail Office Building	3,450	6.25	2026	0.9	19
F13	Future Housing Building	137,560	2	2027	0.9	248
	Total	**323,200**				**943**

The buildings that are planned to be constructed between 2028 and 2037 and their projected loads can be seen in Table 5-13.

Table 5-13: Option 3 Future Building Additions (2028-2037)

Building #	Building	SF	W/SF	Year Built	Load Reduction Factor	kW
F14	Future Academic Building	105,080	3.25	2028	0.875	299
F15	Future Lab Space / Building	32,320	5.75	2028	0.875	163
F16	Future Support Building	21,450	6.25	2029	0.875	117
F17	Future Office	4,480	6.25	2029	0.875	25
F18	Future Stud. Activities Building	18,860	6.25	2030	0.875	103
F19	Future Retail Office Building	3,450	6.25	2031	0.875	19
F20	Future Housing Building	137,560	2	2032	0.875	241
F21	Future Academic Building	105,080	3.25	2033	0.85	290
F22	Future Lab Space / Building	32,320	5.75	2033	0.85	158
F23	Future Support Building	21,450	6.25	2034	0.85	114
F24	Future Office	4,480	6.25	2034	0.85	24
F25	Future Stud. Activities Building	18,860	6.25	2035	0.85	100
F26	Future Retail Office Building	3,450	6.25	2036	0.85	18
F27	Future Housing Building	137,560	2	2037	0.85	234
	Total	**646,400**				**1,904**

In Option 3, the electrical load is projected to grow from 7.1 MW (current) to 8.2 MW in 2022, 9.2 MW in 2027, and 11.1 MW in 2037. The 7.1 MW listed as current is peak data based on 2016 data from Ameresco. Figure 5-6 shows the projected growth of the campus electrical distribution load.

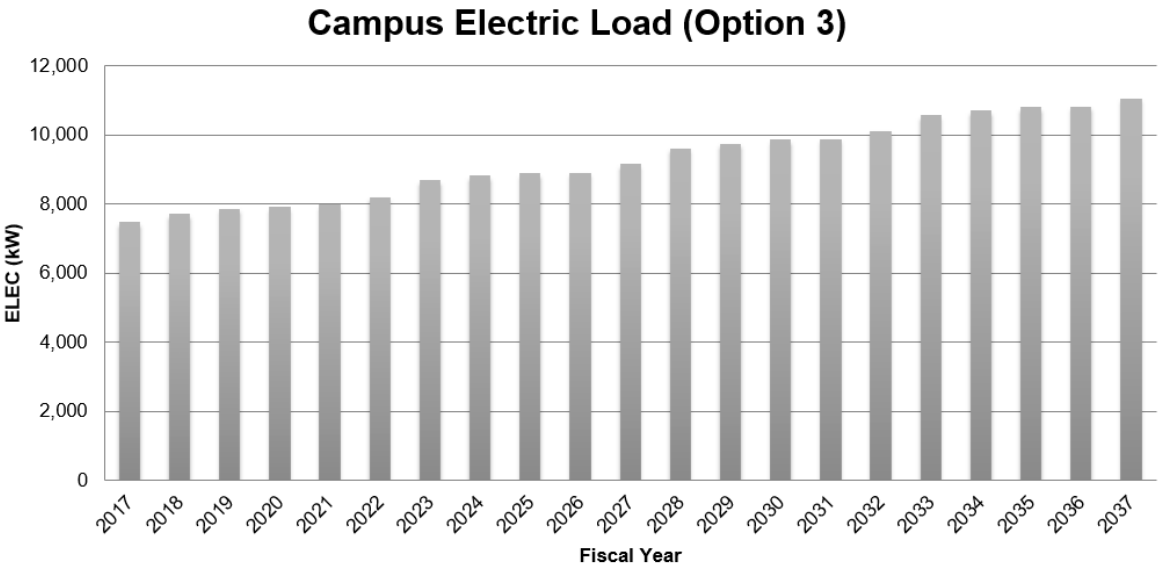

Figure 5-6: Projected Campus Electric Growth

5.2.2 Base Case

In the Base Case, the central heating system is steam. The steam distribution network will expand as future buildings come online. The existing chilled water distribution network will also expand as future buildings come online.

A select few of the campus' cooling and heating loads are serviced by local equipment within the individual buildings due to the lack of feasibility in extending current utility distribution systems to the buildings by the time they require service. Table 5-14 shows the future campus buildings that will be served by an extension of the existing utility system or by local heating and cooling.

Table 5-14: Future Building Heating and Cooling Loads

Building #	Building	Heating	Cooling
F1	Police Station	Local	Local
F2	Meat Processing Facility	Local	Local
F3	ICCE Facility (lab)	Central	Central
F3B	ICCE Facility (office)	Central	Central
F4	ROTC Building	Local	Local
F5	Cultural Arts Center	Central	Central
F6	Housing 2 (From 2011 Campus MP)	Local	Local
F7	Future Academic Building	Central	Central
F8	Future Lab Space / Building	Central	Central
F9	Future Support Building	Central	Central
F10	Future Office	Central	Central
F11	Future Stud. Activities Building	Central	Central
F12	Future Retail Office Building	Central	Central
F13	Future Housing Building	Local	Local
F14	Future Academic Building	Central	Central
F15	Future Lab Space / Building	Central	Central
F16	Future Support Building	Central	Central
F17	Future Office	Central	Central
F18	Future Stud. Activities Building	Central	Central
F19	Future Retail Office Building	Central	Central
F20	Future Housing Building	Local	Local
F21	Future Academic Building	Central	Central
F22	Future Lab Space / Building	Central	Central
F23	Future Support Building	Central	Central
F24	Future Office	Central	Central
F25	Future Stud. Activities Building	Central	Central
F26	Future Retail Office Building	Central	Central
F27	Future Housing Building	Local	Local

5.2.3 Option 1

In Option 1, the existing and future heating loads are met with local packaged natural gas hot water boilers at the individual buildings. The future buildings will be brought online at the same time as those listed in the Base Case. The existing buildings currently connected to central steam service are proposed to be converted to local systems in phases to eliminate the cost of existing steam system replacement, condensate system replacement, and steam generating equipment replacement over time. Placement of the boilers in each building is to be determined by PVAMU. N+1 redundant hot water pumps were assumed in each building. Other building side equipment was not included as a part of the Option 1 cost estimate.

New chilled water distribution matches the Base Case installation as shown in Table 5-14. Chilled water will be extended to the future campus buildings.

5.2.4 Option 2

In Option 2, the existing campus' central heating loads transition from steam service to HHW service and the future build out will be centrally produced heating hot water from FTPP. The boilers installed as a part of Option 2 are natural gas fired hot water boilers. The installation of the HHW system is proposed to occur in phases so for a period, PVAMU will operate on both steam and hot water. Option 2's heating loads will mimic the local and central distribution as shown in Table 5-14, however the Cultural Arts Building will be included on the central system.

Option 2 has the same number of chillers as the Base Case and Option 1, but the distribution piping routing is different. The chilled water piping for Option 2 is routed in the same trench as HHW where possible for construction efficiency and cost savings. The alternate corridor routing results in the future building F3 being placed on local cooling and heating systems rather than the central system because of its distance from the distribution header.

Utilizing or converting to heating hot water in lieu of steam is becoming more and more common at universities. Campus wide conversion from distributed steam to heating hot water heating will require a number of considerations. Such a conversion would not only affect the existing campus infrastructure, but also future design and renovation of existing building level systems. It is vital that the campus identify and assess all consequences, both positive and negative, before making a decision to move forward with such a conversion. Converting a campus from steam to hot water is a challenging process. It requires detailed evaluation of building system performance to determine optimal hot water supply and return temperatures, and strategic investments in new systems to obtain the optimized design points. This conversion also requires significant capital expenditure. However, it greatly expands access to low carbon or carbon-free energy sources. In addition, hot water conversion can provide:

- Reduced distribution heat losses.
- Reduced distribution maintenance costs. Maintenance, repair and replacement costs can be reduced with new piping infrastructure and the elimination of steam traps and condensate piping.
- The ability to store heat energy. Hot water can be stored on a daily or even seasonal basis to reduce peak demand and utilize energy sources that may be out of cycle with the related load.

5.2.5 Option 3

In Option 3, the existing campus' central heating loads will be served from the existing steam infrastructure. Future building heating loads outside of the Core Campus are met with local packaged natural gas hot water boilers at the individual buildings. The location and space required for the local boilers and accessory equipment is to be determined during building design. N+1 redundant hot water pumps were assumed in each building. Other building side equipment was not included as a part of the Option 1 cost estimate. The future buildings will be brought online at the same time as those listed in the Base Case.

Option 3 utilizes larger chillers and a substantial expansion of Fry Thomas Power Plant to meet chilled water load demands. Table 5-15 below indicates which new buildings are served locally and centrally for Option 3.

Table 5-15: Future Building Heating and Cooling Loads

Building #	Building	Heating	Cooling
F1	Police Station	Local	Local
F2	Meat Processing Facility	Local	Local
F3	ICCE Facility (lab)	Local	Local
F3B	ICCE Facility (office)	Local	Local
F4	ROTC Building	Local	Local
F5	Cultural Arts Center	Central	Central
F6	Housing 2 (From 2011 Campus MP)	Local	Local
F7	Future Academic Building	Central	Central
F8	Future Lab Space / Building	Central	Central
F9	Future Support Building	Local	Local
F10	Future Office	Local	Local
F11	Future Stud. Activities Building	Central	Central
F12	Future Retail Office Building	Local	Local
F13	Future Housing Building	Local	Local
F14	Future Academic Building	Central	Central
F15	Future Lab Space / Building	Central	Central
F16	Future Support Building	Local	Local
F17	Future Office	Local	Local
F18	Future Stud. Activities Building	Local	Local
F19	Future Retail Office Building	Local	Local
F20	Future Housing Building	Local	Local
F21	Future Academic Building	Central	Central
F22	Future Lab Space / Building	Central	Central
F23	Future Support Building	Local	Local
F24	Future Office	Local	Local
F25	Future Stud. Activities Building	Local	Local
F26	Future Retail Office Building	Local	Local
F27	Future Housing Building	Local	Local

* * * * *

SECTION 6.0

DISTRIBUTION SYSTEM ANALYSIS

6.0 THERMAL DISTRIBUTION SYSTEM EVALUATION

6.1 THERMAL DISTRIBUTION SYSTEM GROWTH

As the PVAMU campus grows, an expanded distribution network will be required to connect plant utilities with new building locations. The utility distribution network expansions are directly influenced by the location of new buildings on campus. These networks will grow steadily to meet new loads and anticipated future loads. Most of the future expansion of the campus will occur east of the current main campus along Owens Road. An alternative to distribution network expansion is to serve new buildings locally. Options 1 and 3 use this local approach for some if not all of their buildings.

The current chilled water production system lacks redundancy and the ability to handle the University's capacity increases in the near-term. It is recommended that the distribution system be configured into loops rather than radial feeds so that portions of the campus may still receive chilled water utilities if part of the network is isolated or taken out of service. A looped system, as the name implies, loops through the service area and returns to the original point (FTPP). When additional chilled water sources (CUP-2) are added to the loop, the University has a way to reach the campus in the event of a failure at either source location. Option 3 does not include chilled water distribution expansion or the addition of CUP-2. New buildings outside of the Core Campus in Option 3 will be served locally.

6.1.1 Base Case

In the Base Case, the four boilers in FTPP provide steam to the campus buildings to serve heating loads. The steam distribution network will expand as future buildings come online. A select few of the campus' heating and cooling loads are serviced by local equipment within the individual buildings. Chilled water is produced by chillers in FTPP or CUP-2 (after 2023 proposed install). The existing chilled water distribution network will expand as future buildings come online.

6.1.1.1 Base Case: Steam

PVAMU's existing steam system appears to be in poor condition, returning only approximately 30% of the produced steam as condensate per PVAMU staff. PVAMU has indicated that all distribution piping is nearing the end of its useful life and will need to be replaced. The distribution replacement cost was spread over ten years and is recommended to begin in 2018. Replacement of the existing distribution system requires the installation of a parallel system rather than the direct replacement of the existing distribution system. The existing system will be abandoned in place once the parallel system is operating. The cost of demolishing the existing system was not included in the cost estimate.

New steam distribution will also be extended to the future campus buildings. An advantage to expanding the steam distribution network is that steam pipelines are of a smaller diameter than heating hot water pipelines, and are generally less expensive. However, a steam system has additional operational and maintenance costs as compared to a heating hot water system. Condensate loss, steam trap maintenance and chemical treatment of make-up water can represent significant capital and operating expenses. In addition, all new buildings using HHW will require a heat exchanger to utilize steam. The building side heat exchanger is assumed to be included as a part of the construction of the new buildings. The heat exchangers were not included in the UMP capital cost estimate.

The new condensate piping is estimated to return 80% of the steam produced as condensate.

6.1.1.2 : Base Case: Chilled Water

PVAMU's existing chilled water system appears to be in poor condition. PVAMU indicated that all distribution piping is nearing the end of its useful life and will need to be replaced. The existing chilled water distribution in the Base Case is replaced by new chilled water piping over the first 10 years of the project recommended to begin in 2018. Replacement of the existing distribution system requires the installation of a parallel system rather than the direct replacement of the existing distribution system per PVAMU staff. The existing system will be abandoned in place once the parallel system is operating. The cost of demolishing the existing system was not included in the cost estimate.

New chilled water distribution will also be extended to the future campus buildings. An additional central utility plant, CUP-2, is recommended to be installed in 2023 to help the future campus loads. The future distribution piping and the addition of CUP-2 will complete a chilled water distribution loop for increased campus redundancy.

6.1.1.3 Base Case Distribution Expansion - 5 Year

Figure 6-1 shows the distribution expansion installed as a part of the 5-year time frame. The gray buildings represent existing campus buildings. The red distribution network, which represents steam and chilled water installation corridors, and red buildings are installed during the 5-year plan. The dark green distribution network represents the sanitary sewer installation corridor. A detailed map can be found in Appendix A.

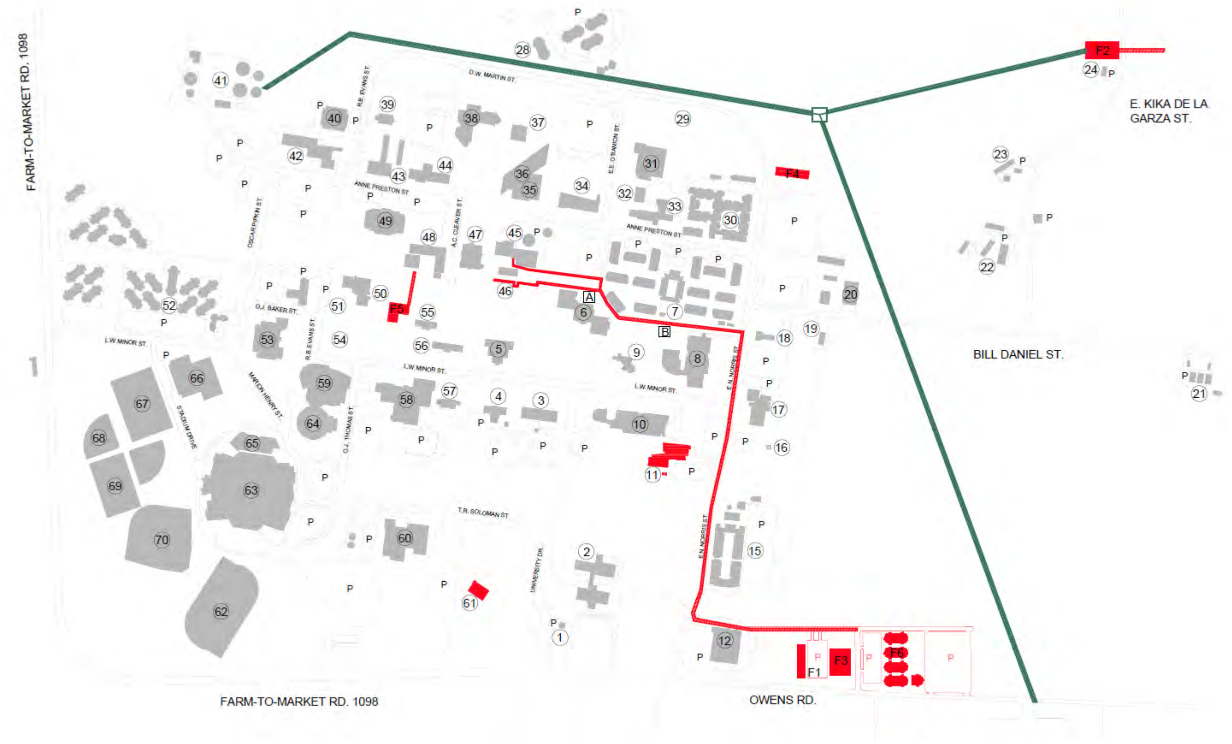

Figure 6-1: Base Case Distribution Expansion – 5 Year

6.1.1.4 Base Case Distribution Expansion – 10 Year

Figure 6-2 shows the distribution expansion installed as a part of the 10-year time frame. The orange distribution network, which represents steam and chilled water installation corridors, and orange buildings are installed during the 10-year plan. A detailed map can be found in Appendix A.

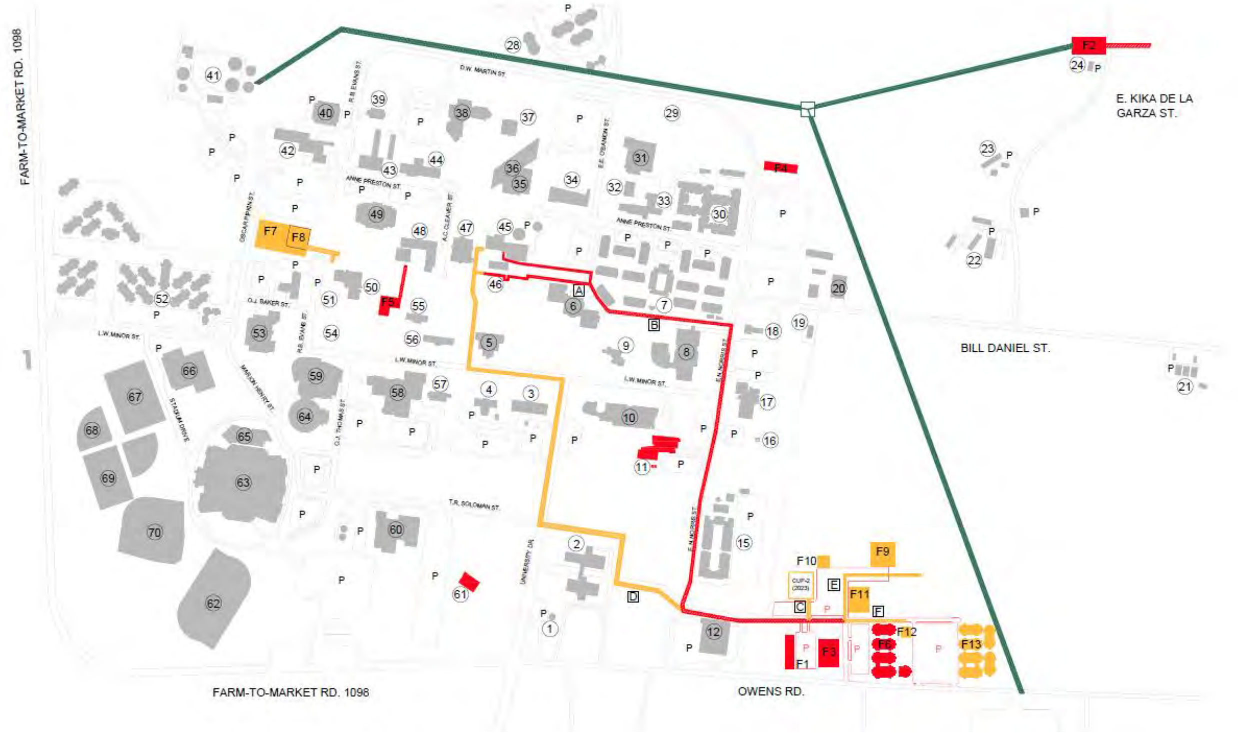

Figure 6-2: Base Case Distribution Expansion – 10 Year

6.1.1.5 Base Case Distribution Expansion – 20 Year

Figure 6-3 shows the distribution expansion installed as a part of the 20-year time frame. The green distribution network, which represents steam and chilled water installation corridors, and green buildings are installed during the 20-year plan. A detailed map can be found in Appendix A.

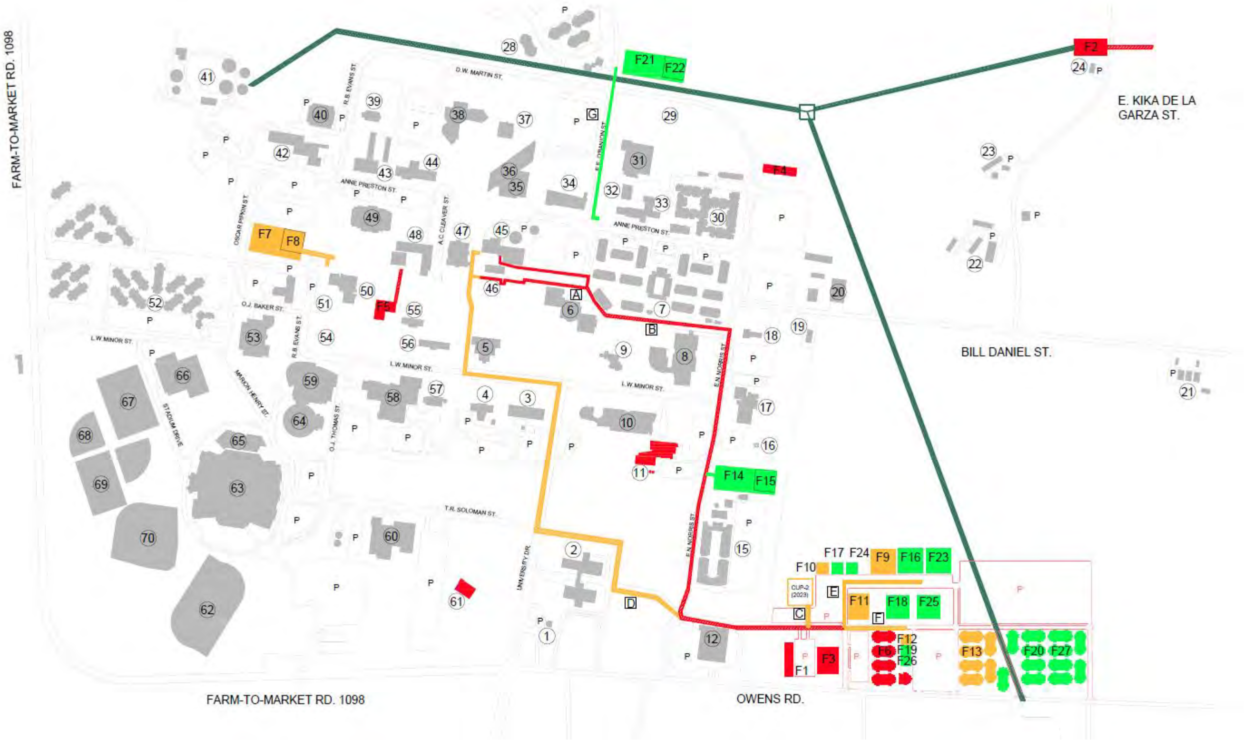

Figure 6-3: Base Case Distribution Expansion – 20 Year

6.1.1.6 Base Case Summary

The steam, condensate, and chilled water Base Case distribution piping expansion is summarized in Table 6-1.

Table 6-1: Base Case Distribution Summary

Phase	Size (in)	Service	Year Built	Length of Trench (L.F.)
A	10	STM	2018	800
A	4	CR	2018	800
A	24	CHW	2018	700
B	10	STM	2018	3700
B	4	CR	2018	3700
B	24	CHW	2018	3700
C	24	CHW	2023	200
D	10	STM	2023	3500
D	4	CR	2023	3500
D	24	CHW	2023	3500
E	10	STM	2024	800
E	4	CR	2024	800
E	24	CHW	2024	800
F	10	STM	2026	400
F	4	CR	2026	400
F	24	CHW	2026	400
G	6	STM	2033	1000
G	4	CR	2033	1000
G	24	CHW	2033	1000

6.1.2 Option 1

In Option 1, the existing and future heating loads are met with local packaged hot water boilers at the individual buildings. The future buildings will be brought online at the same time as those listed in the Base Case. The existing buildings currently connected to central steam service will be converted to local systems in phases to spread the cost of existing steam system replacement, condensate system replacement, and steam generating equipment replacement over time.

New chilled water distribution matches the Base Case installation. Chilled water will be extended to the future campus buildings.

6.1.2.1 Option 1: Steam Phase Out

The existing steam distribution equipment and distribution network is phased out and replaced with local hot water boilers over a span of the first 10 years.

6.1.2.2 Option 1: Chilled Water

The chilled water distribution installed in Option 1 is the same as the chilled water distribution described in the Base Case. The Base Case and Option 1 are consistent in that they are completed with the same number of chillers and the same amount of chilled water piping.

6.1.2.3 Option 1 Summary

The chilled water Option 1 distribution piping expansion is summarized in Table 6-2.

Table 6-2: Option 1 Distribution Summary

Phase	Size (in)	Service	Year Built	Length of Trench (L.F.)
A	24	CHW	2018	700
B	24	CHW	2018	3700
C	24	CHW	2023	200
D	24	CHW	2023	3500
E	24	CHW	2024	800
F	24	CHW	2026	400
G	24	CHW	2033	1000

6.1.3 Option 2

In Option 2, the existing campus' heating loads will transition from steam service to heating hot water service. The installation of the HHW system is proposed to occur in phases so for a period, PVAMU will operate on both steam and hot water.

Because PVAMU needs to replace existing steam distribution piping, the installation of heating hot water as an alternative should be considered. The conversion from steam to hot water will require less maintenance, use fewer water treatment chemicals and less makeup water, and eliminate the possibility of dangerous steam line ruptures caused by an improperly installed steam system. In summary, a heating hot water system is typically safer and less expensive to operate when compared to a steam system.

Converting the existing PVAMU campus from steam to heating hot water will require expanding the underground distribution piping originating at FTPP. This will involve a significant amount of trenching through existing common areas, sidewalks, and roads which will be inconvenient for the whole campus. Detailed evaluation of existing utilities and conflicts was not included in this project's scope and could add significant cost to replacing steam with a hot water distribution system. If conversion is considered as a viable option, the University should consider a detailed investigation into final routing and associated costs during the design phase.

6.1.3.1 Option 2: Heating Hot Water

New heating hot water distribution piping will extend to future campus buildings and existing campus buildings. Additional hot water boilers are added in FTPP in 2019 and a new central utility plant, CUP-2, with hot water boilers will serve the campus and comes online in 2023. Buildings F1, F2, F3, and F4 will be served locally with hot water boilers and HHW piping will not connect to them.

The new hot water distribution network is installed in phases separate from the 5-, 10-, and 20-year phases of the Base Case. The install begins at the northwest corner of main campus. In the following map, the red corridor indicates the area where only HHW will be installed. The distribution in Phase A shall be completed by 2019 and is shown in the figure below.

Figure 6-1: Option 2 – 2019 Distribution Network

The HHW distribution network extends by 2023. Phase B is shown in the following figure. Phase B includes corridors that are CHW only (shown in blue) and corridors that contain both HHW and CHW (yellow).

Figure 6- 2: Option 2 – 2023 Distribution Network

The HHW distribution network expands further by 2024. Phase C is shown in the following figure. Phase C also includes corridors that are CHW only (shown in blue) and corridors that contain both HHW and CHW (yellow).

Figure 6- 3: Option 2 – 2024 Distribution Network

By 2025, Phase D shall be installed. Phase D includes corridors that are CHW only (shown in blue) and corridors that contain both HHW and CHW (yellow). The map below shows the network completed by 2025.

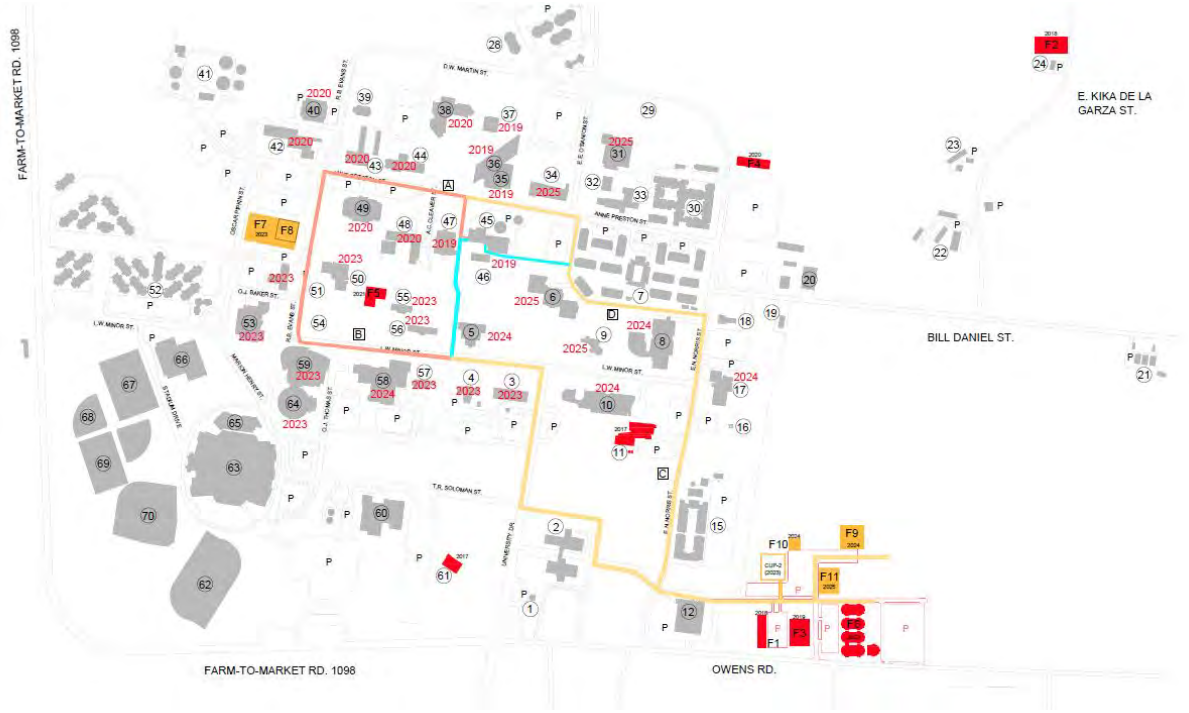

Figure 6- 4: Option 2 – 2025 Distribution Network

By 2033, Phase E shall be installed. Phase E contains a corridor with CHW and HHW.

Figure 6- 5: Option 2 – 2024 Distribution Network

6.1.3.2 Option 2: Chilled Water

The chilled water piping for Option 2 is routed in the same trench as HHW where possible for construction efficiency and cost savings. The alternate corridor routing results in the future building F3 being placed on local cooling and heating systems rather than the central system.

6.1.3.3 Option 2 Summary

The heating hot water and chilled water Option 2 distribution piping expansion is summarized in Table 6-3.

Table 6-3: Option 2 Distribution Summary

Phase	Size (in)	Service	Year Built	Length of Trench (L.F.)
A	14	HHW	2019	1,700
B	14	HHW	2023	6,700
B	24	CHW	2023	5,800
C	14	HHW	2024	1,800
C	24	CHW	2024	1,800
D	14	HHW	2025	2,100
D	24	CHW	2025	1,600
E	14	HHW	2033	1,000
E	24	CHW	2033	1,000

6.1.4 Option 3

In Option 3, the existing heating loads continue to be served by the existing steam infrastructure. Distribution additions only occur to serve five new buildings that will be constructed within the Core Campus area. Future heating loads outside of the Core Campus are met with local packaged hot water boilers at the individual buildings. The future buildings will be brought online at the same time as those listed in the Base Case. The cost of existing steam system replacement and condensate system replacement was estimated and spread uniformly over a 10 year period.

The existing cooling loads continue to be served by the existing chilled water infrastructure. Distribution additions only occur to serve five new buildings that will be constructed within the Core Campus area. Future cooling loads outside of the Core Campus are met with local DX units at the individual buildings. The future buildings will be brought online at the same time as those listed in the Base Case. The cost of existing chilled water system replacement was estimated and spread uniformly over a 10 year period.

6.1.4.1 Option 3: Steam

The existing steam distribution network is utilized and gradually replaced over a span of the first 10 years of the study. Five extensions of the distribution network will be necessary to serve future building within the core campus.

6.1.4.2 Option 3: Local Hot Water Boilers

New buildings outside of the Core Campus boundary will contain natural gas fired hot water boilers to provide local heating.

6.1.4.3 Option 3: Chilled Water

The existing chilled water distribution network is utilized and gradually replaced over a span of the first 10 years of the study. Five extensions of the distribution network will be necessary to serve future building within the core campus.

6.1.4.4 Option 3: Distribution Expansions

In Option 3, five extensions of the distribution network will be necessary to serve future buildings located within the core campus. These extensions will serve buildings F5, F7, F8, F11, F14, F15, F21, F22. These extensions are shown in the full buildout map below.

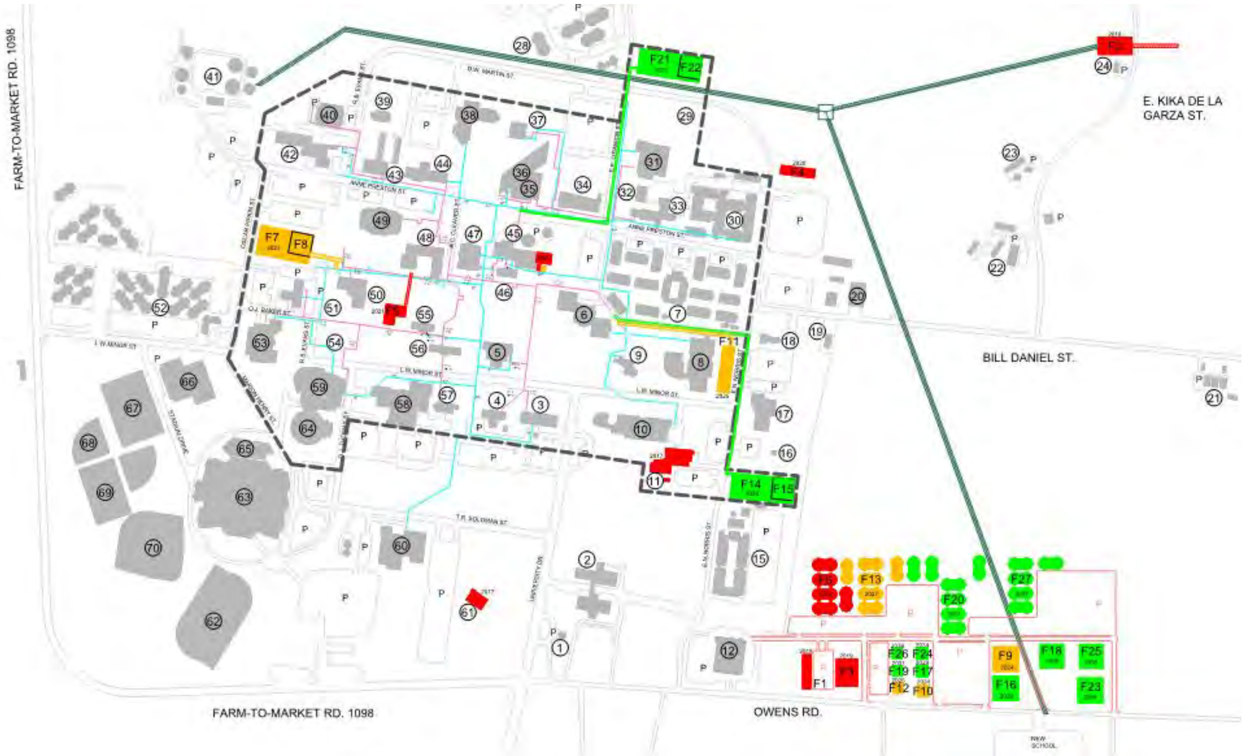

Figure 6- 6: Option 3 – 2037 Distribution Network

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SECTION 7.0

EQUIPMENT REPLACEMENT AND ADDITIONS

7.0 EQUIPMENT REPLACEMENT AND ADDITIONS

7.1 REPLACEMENT GUIDELINES

Within the twenty years analyzed as a part of this study, existing equipment will reach the end of its service life. A phased approach to replacing assets as they are retired is more effective than retroactively reacting to equipment failures and is a key component of developing a utility master plan.

The expected useful life of equipment can be estimated using guidelines developed by ASHRAE. Table 7-1 contains information extracted from the 2015 ASHRAE Handbook – HVAC Applications and lists the service life expectancy for some different types of equipment pertinent to PVAMU. Although these are guidelines, actual equipment operating life can be dependent on many factors, including: maintenance, operating hours, cycle time, and water treatment. Not all equipment at PVAMU has or will follow these guidelines. The exceptions are explained in the body of the report.

Table 7-1: ASHRAE Recommended Service Life

Equipment Type	Median Service Life Expectancy
Packaged Centrifugal Chiller	23 years
Fire-tube Steam Boiler	25 years
Fire-tube Hot Water Boiler	25 years

As a piece of equipment reaches the end of its service life expectancy, it may run less efficiently and require more maintenance. PVAMU should be prepared to replace equipment that is approaching the end of its life expectancy.

Deviations from the service life expectancies above were incorporated in Option 3 by request from PVAMU. Chiller life expectancies were shortened to provide a more consistent interval of replacement and prevent unforeseen equipment failures.

7.2 EXISTING EQUIPMENT

To create a future funding plan with discrete projects, it is first necessary to inventory the expected service life of the existing equipment at FTPP. This data was compared with the expected campus load growth to create an equipment funding plan and roadmap.

7.2.1 Fry-Thomas Power Plant

The five existing chillers in FTPP were brought online in 1999, 2004, 2004, 2011, and 2015. Chiller 1 will not need to be replaced in the 20-year time frame of the master plan. According to ASHRAE, Chiller 2 should be replaced in 2022, however, PVAMU staff noted that Chiller 2 is in poor condition and needs replacement in 2018. Chiller 3 and Chiller 4 should be replaced in 2027. Chiller 5 should be replaced in 2034. All existing chillers have capacities of 1100 tons, except Chiller 5 which has a capacity of 1095 tons. Option 3 takes a different approach than the aforementioned replacement guidelines. In Option 3, Chiller 2 should be replaced in 2018, Chiller 3 should be replaced in 2022, Chiller 4 should be replaced in 2025, and Chiller 5 should be replaced in 2028. These replacement dates were deemed appropriate by PVAMU and were incorporated into Option 3.

The four existing boilers in FTPP were brought online in 1989 (Boiler #10), 1991 (Boilers #11 and #12), and 2015 (Boiler #7). Boiler #10 has exceeded its recommended ASHRAE service life, however, it was serviced to extend its life and is anticipated to need replacement in 2022. Boilers #11 should be replaced in 2018. Boilers #11 has exceeded its recommended ASHRAE service life and should be replaced upon project initiation. Boiler #12 has also exceeded its recommended ASHRAE service life but will not be replaced due to excess steam capacity at FTPP. Boiler #7 was not identified for replacement during the 20-year span of the master plan. Boiler #10 has a capacity of 20,000 MBH, existing boilers #11 and #12 have a capacity of 25,000 MBH each, and Boiler #7 has a capacity of 40,000 MBH.

7.3 NEW EQUIPMENT SCHEDULE

Redundancy is an important consideration for utility master planning. The redundancy of a utility system can be calculated by subtracting the largest piece of equipment from the total capacity. This calculation produces the “firm capacity” which describes minimum capacity of the utility system if the largest piece of equipment is out of service. Generally, equipment is sized to maintain a firm capacity that is slightly greater than the peak load.

The following narratives describe the equipment planning roadmap recommended for the four growth options that were described in the Distribution Systems Analysis Section. The Base Case involves expanding the existing steam system to serve heating loads and the chilled water system for cooling loads. Option 1 involves expanding the existing chilled water system and replacing the steam system with local hot water boilers at individual buildings. Option 2 involves expanding the existing chilled water system to serve cooling loads and replacing the steam system with a heating hot water system.

7.3.1 Base Case

In this option, the steam system is expanded to meet future heating demands while the chilled water system is expanded to meet future cooling demands. Further steam and chilled water equipment is replaced as needed when it reaches the end of its service life.

7.3.1.1 Base Case: Steam

PVAMU does not currently have a metering system in place to measure the campus steam load. Based on the estimated steam loads generated for the campus, the boiler capacity at the FTPP meets current peak load and provides N+1 redundancy. If the largest steam boiler currently installed at the FTPP is unable to operate, the remaining boilers would still be capable of meeting the estimated peak demand.

7.3.1.1.1 Capacity Replacement/Expansion – 5 Year

Within the next five years, several pieces of steam equipment (three boilers and associated auxiliaries) will exceed their recommended service life. Boiler 11 has already exceeded its ASHRAE service life. Boiler 11 was originally installed in 1991 and has been identified for replacement in 2020. Boiler 11 will be replaced with a smaller 20,000 MBH boiler instead of the existing 25,000 MBH boiler. Boiler 12 has also exceeded its ASHRAE service life, but due to the excess steam capacity available from the other boilers, Boiler 12 will not be replaced. Boiler 10 was originally installed in 1989 and has been identified for replacement in 2022. Boiler 10's ASHRAE life ended in 2014, however, after conducting operator interviews, this boiler's expected life was extended to 2022. The boiler replacement summary is shown in Table 7-2.

Table 7-2: Five Year Steam Equipment Addition and Replacement List

Plant	Tag	Capacity (MBH)	Replacement Date	Replacement or Addition
FTPP	Boiler 11	20,000	2020	Replacement
FTPP	Boiler 10	20,000	2022	Replacement

The existing deaerator, feedwater pumps, RO skid, and other auxiliary equipment is recommended to be replaced in 2022. Burns & McDonnell does not have information on the age of the existing deaerator, feedwater pumps, etc. so replacement may need to occur in a different time frame.

7.3.1.1.2 Capacity Replacement/Expansion – 10 Year

Between 2023 and 2027, the Base Case does not require any additional boilers to meet projected heating loads.

7.3.1.1.3 Capacity Replacement/Expansion – 20 Year

Between 2028 and 2037, the Base Case does not require any additional boilers to meet projected heating loads.

7.3.1.1.4 Steam Summary

Table 7-3 shows the recommended steam boiler planning schedule.

Table 7-3: Steam Boiler Planning Schedule

Location	Boiler #	MBH	Install Date	Replacement Date
FTPP	10	20,000	1989	2022
FTPP	11	25,000*	1991	2020
FTPP	12	25,000	1991	None
FTPP	7	40,000	2015	2040

*Note: Boiler 11 is replaced with 20,000 MBH capacity.

Figure 7-1 shows the firm capacity of the steam system relative to the peak steam load on campus. PVAMU is N+1 redundant with their existing steam generating assets.

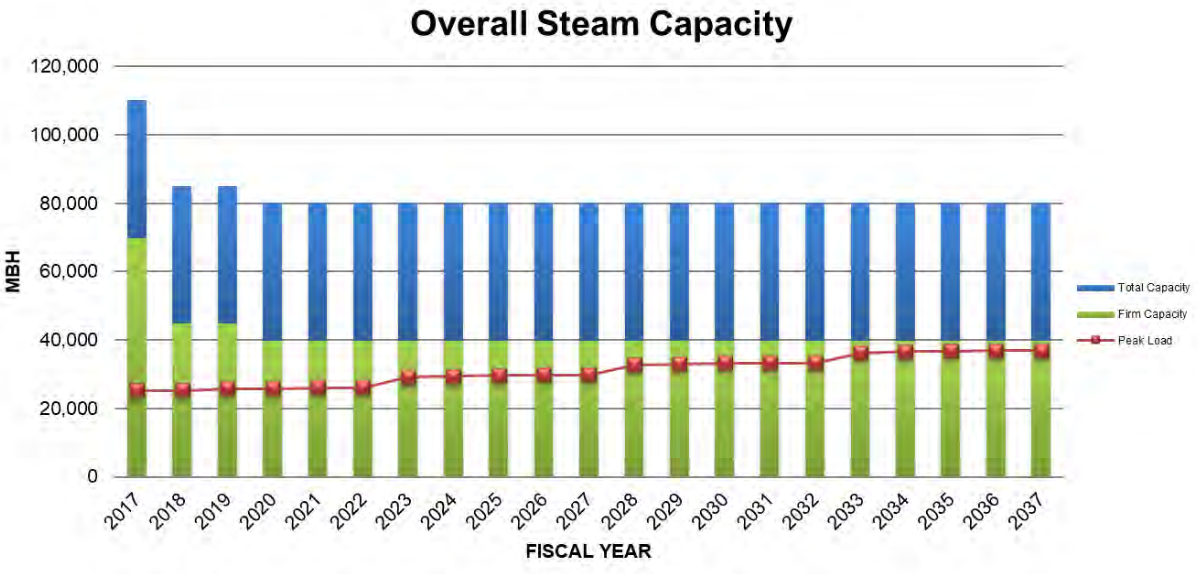

Figure 7-1: Steam Capacity Relative to Projected Load

Future buildings F1, F2, and F4 are served by local hot water boilers. Per information from PVAMU, future buildings F1 and F2 are to be served by local heating systems. Additionally, building F4 was chosen to be served by a local boiler due to its distance from the existing steam distribution piping.

7.3.1.2 Base Case: Chilled Water

The four options focus on different strategies for developing the heating utility infrastructure, but the chilled water expansion is the same throughout the Base Case, Option 1, and Option 2. The new chilled water system will include chiller additions to achieve N+1 redundancy, as the chilled water system is not currently N+1 redundant. If the largest chiller is out of service, peak loads cannot be met.

7.3.1.2.1 Capacity Replacement/Expansion – 5 Year

At the Fry-Thomas Power Plant, Chiller 2, which was installed in 1999, will exceed its expected service life in 2022. Typically, when a chiller nears the end of its service life, the efficiency is no longer optimal, the refrigerants are overdue for phase out, and maintenance costs will increase significantly. Some chillers may exceed their ASHRAE recommended service life. Chiller 2 is recommended to be replaced in 2018 prior to exceeding its ASHRAE service life based on operator feedback, system literature, and the necessary increase in reliable chilled water capacity. Even though this chiller is rated to provide 1,100 tons of chilled water, data from the Ameresco report suggests it is only capable of providing approximately 700 tons. The new chiller recommended to replace it will be rated for 1,100 tons. Due to campus load growth, an additional 1,100-ton chiller along with a cooling tower cell, chilled water pump, and condenser water pump are also recommended to be installed at FTPP as shown in Table 7-4.

Table 7-4: Five Year Chiller Addition and Replacement List

Plant	Tag	Capacity (tons)	Year in Service	Replacement or Addition
FTPP	Chiller 2	1,100	2018	Replacement
FTPP	Chiller 6	1,100	2018	Addition

A packaged cooling tower system is recommended that can run in parallel with the existing cooling tower system. The existing cooling tower system consists of field erected cells and a common concrete basin. A packaged system is recommended because the existing towers are field erected and would require a costly expansion of the building structure. The installation of the additional chiller and chilled water pump will require a line stop at the end of the header inside the Utility Plant Annex to facilitate extension of the piping to the east, if an outage cannot be taken to perform the work. The expansion of the Utility Plant Annex building is estimated to require approximately 1,650 SF and should extend to the east of the existing building. A sketch layout of the 1,650 SF addition can be seen below in Figure 7-2. The costs for the equipment, installation, and building extension have been included in the cost estimates associated with this report. This addition allows the university to achieve N+1 redundancy relatively quickly and allows time for the installation of the new central utility plant.

Figure 7-2: FTPP Chiller Extension

Chilled water and condenser water pumps will also be replaced and added over time in conjunction with the chiller projects. When a chiller is replaced, the chilled water and condenser water pumps serving that chiller will also be replaced.

7.3.1.2.2 Capacity Replacement/Expansion – 10 Year

Between 2023 and 2027, two additional chillers will exceed their ASHRAE recommended service life. Chillers 3 and 4 were originally installed in 2004. These chillers will have exceeded their ASHRAE recommended service life during the 10-year time frame and will be recommended for replacement in 2027, as shown in Table 7-5. Installing the two replacements at one time can improve construction cost efficiency and limit total disruptions to the campus. This phase also includes the construction of the new Central Utility Plant, CUP-2. A new chiller along with a cooling tower, chilled water pump, and condenser water pump will be installed in CUP-2 in 2023.

Table 7-5: 10 Year Chiller Addition and Replacement List

Plant	Tag	Capacity (tons)	Year in Service	Replacement or Addition
CUP-2	Chiller 7	1,000	2023	Addition
FTPP	Chiller 3	1,100	2027	Replacement
FTPP	Chiller 4	1,100	2027	Replacement

Chilled water and condenser water pumps will also be replaced and added over time in conjunction with the chiller projects. When a chiller is replaced, the chilled water and condenser water pumps serving that chiller will also be replaced.

7.3.1.2.3 Capacity Replacement/Expansion- 20 Year

Between 2028 and 2037, one additional chiller will exceed its ASHRAE service life. Chiller 5 was originally installed in 2011. This chiller will have exceeded its ASHRAE recommended service life during the 20-year time frame will be recommended for replacement in 2034, as shown in Table 7-6. A new chiller along with a cooling tower, chilled water pump, and condenser water pump should be installed in CUP-2 in 2032.

Table 7-6: 20 Year Chiller Addition and Replacement List

Plant	Tag	Capacity (tons)	Year in Service	Replacement or Addition
CUP-2	Chiller 8	1,000	2032	Addition
FTPP	Chiller 5	1,100	2034	Replacement

Chilled water and condenser water pumps will also be replaced and added over time in conjunction with the chiller projects. Similar to the 5-year time frame, the chilled water and condenser water pumps will also be replaced when a chiller is replaced.

7.3.1.2.4 Chilled Water Summary

Table 7-7 shows the complete recommended chiller replacement and addition schedule.

Table 7-7: Recommended Chiller Planning Schedule

Location	Chiller #	Tons	On-Line	Off-Line	Addition/Replacement
FTPP	2	1,100	1999	2020	Replacement
FTPP	3	1,100	2004	2027	Replacement
FTPP	4	1,100	2004	2027	Replacement
FTPP	5	1,095	2011	2034	Replacement
FTPP	1	1,100	2015	2038	Replacement
FTPP	2	1,100	2020	2043	Replacement
FTPP	6	1,100	2020	2043	Addition
CUP-2	7	1,000	2023	2046	Addition
FTPP	3	1,100	2027	2050	Replacement
FTPP	4	1,100	2027	2050	Replacement
CUP-2	8	1,000	2032	2055	Addition
FTPP	5	1,100	2034	2057	Replacement

Figure 7-3 shows the chilled water capacity growth for the PVAMU campus.

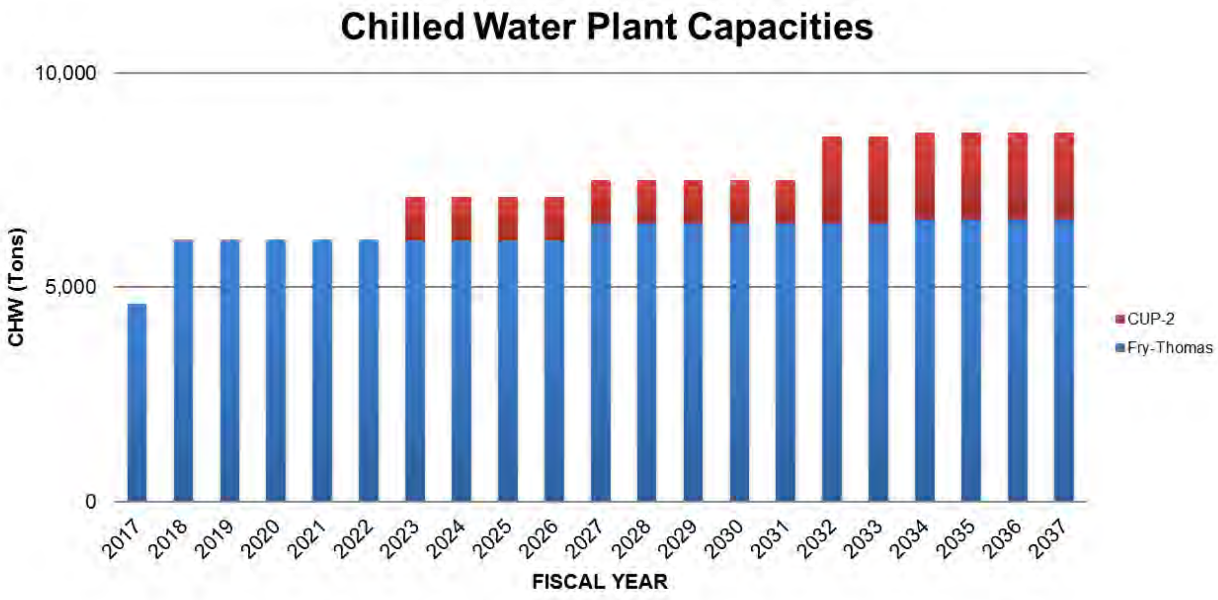

Figure 7-3: Projected Future Chilled Water Capacity

Figure 7-4 shows the firm capacity of the chilled water system relative to the peak chilled water load on campus.

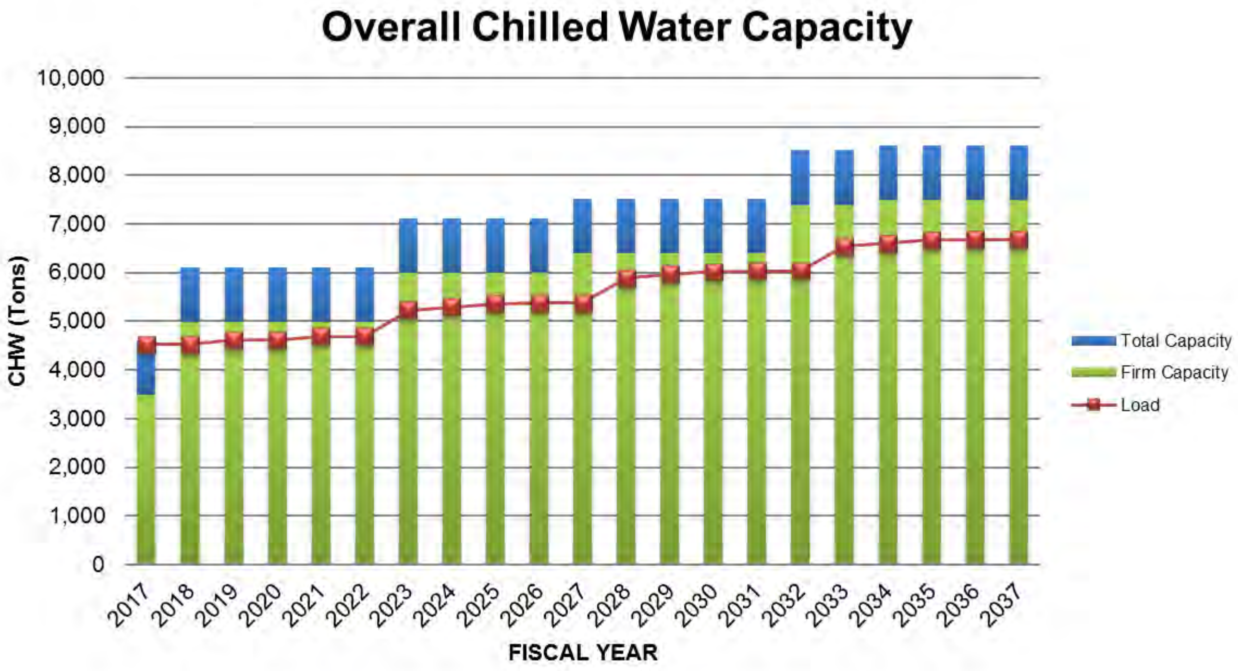

Figure 7-4: Chilled Water Capacity Relative to Projected Load

7.3.2 Option 1

In Option 1, the existing and future heating loads are met with local packaged natural gas hot water boilers at the individual buildings, and new chilled water distribution and equipment matches the Base Case installation.

7.3.2.1 Option 1: Hot Water

Local natural gas hot water boilers at each building come online when the new buildings are constructed. The existing buildings are proposed to be converted to hot water as described in Table 7-8. In the following table, existing buildings are shown in red and future buildings are shown in white.

Table 7-8: Local HHW Availability

Key	Building	Date Local HHW Available
501	Alvin I. Thomas Administration Building	2019
503	G.R. Woolfolk Social & Political Science Building	2019
504	Gilchrist Engineering Building	2019
506	Thomas E Gray Center	2019
508	W.R. Banks Building	2019
535	Jesse M Drew Memorial Complex	2019
537	Hilliard Hall-Communication Building	2019
541	Anderson Hall	2020
544	Evans Hall	2020
658	May Building - Home Economics	2020
668	M.T. Harrington Science Building	2020
669	William “Billy” J. Nicks Building	2020
674	Physical Plant Administration Building	2020
687	Henrietta Farrell Hall	2020
688	Owens-Franklin Health Clinic	2021
689	Hobart Thomas Taylor Sr. Hall	2021
704	C.L. Wilson Engineering Complex	2021
724	Austin Greaux Chemical Engineering	2021
727	Central Receiving	2021
739	Utilities Plant Annex	2021
741	Johnson-Phillip All Faiths Chapel	2021
742	Wilhelmina Delco Building	2021
743	Sam R. Collins Engineering Tech Building	2022
744	John B. Coleman Library	2022
745	Jesse H & Mary Gibbs Jones Building	2022
758	Leroy G. Moore Jr. Gym	2022
761	Carden-Waller Cooperative Extension	2022
790	Elmer E. O'Banion Science Building	2022
779	Willie A. Tempton Sr. Memorial Student Center Building	2023
783	Nathelyne Archie Kennedy Architecture Building	2023
789	Don K. Clark Juvenile Justice & Psychology Building	2023
793	New Electrical Engineering Building	2023
848	Student Recreation Center	2023
849	Agriculture and Business Multipurpose Building	2023

F1	Police Station	2018
F2	Meat Processing Facility	2018
F3	ICCE Facility (lab)	2019
F4	ROTC Building	2020
F5	Cultural Arts Center	2021
F7/F8	Future Academic Building	2023
F9	Future Support Building	2024
F10	Future Office	2024
F11	Future Stud. Activities Building	2025
F12	Future Retail Office Building	2026
F14/F15	Future Academic Building	2028
F16	Future Support Building	2029
F17	Future Office	2029
F18	Future Stud. Activities Building	2030
F19	Future Retail Office Building	2031
F21/F22	Future Academic Building	2033
F23	Future Support Building	2034
F24	Future Office	2034
F25	Future Stud. Activities Building	2035
F26	Future Retail Office Building	2036

Point of use equipment for process steam loads was not included in Option 1 because these loads will vary across campus. The natural gas consumption necessary to meet projected process steam loads in Option 1 was accounted for in the sizing of natural gas building connections. It is also assumed that all buildings have sufficient natural gas service to serve the process steam loads and the local hot water boilers. Burns & McDonnell recommends performing a survey to confirm this assumption prior to implementing the central steam to local heating hot water conversion in Option 1.

7.3.2.2 Option 1: Chilled Water

Option 1 and the Base Case focus on different strategies for developing the heating utility infrastructure, but the chilled water expansion is the same in each option. The chilled water comprehensive equipment replacement schedule will be the same as the Base Case.

7.3.3 Option 2

In this option, the steam system will be replaced by a central heating hot water system. The resulting heating hot water system will continue to expand to meet the future loads for the entire campus. The chilled water expansion will follow approximately the same installation path as the new HHW additions. The steam and heating hot water replacement strategy is discussed below.

7.3.3.1 Option 2: Steam

Steam production in FTPP will gradually be phased out by heating hot water as the heating hot water distribution network is expanded. The existing steam boilers and ancillary equipment will be replaced by hot water boilers and hydronic pumps. Table 7-9 shows the recommended steam boiler planning schedule.

Table 7-9: Steam Boiler Planning Schedule

Location	Boiler #	MBH	On-Line	Offline
FTPP	10	20000	1989	2025
FTPP	11	25000	1991	2020
FTPP	12	25000	1991	2018
FTPP	7	40000	2015	2040

Boiler 10 comes offline in 2025 in Option 2. In the Base Case, Boiler 10 is scheduled to come offline in 2022. Additional maintenance is suggested to extend the boiler’s service life to maintain firm capacity throughout the duration of the conversion to HHW. Maintenance is also recommended on Boiler 11 to extend operation until 2020 so that PVAMU maintains firm capacity in the conversion process. Boiler 11 comes offline in 2018 in the Base Case. Figure 7-5 shows the firm capacity of the steam system relative to the peak steam load on campus. As the steam system is phased out, N+1 redundancy is maintained.

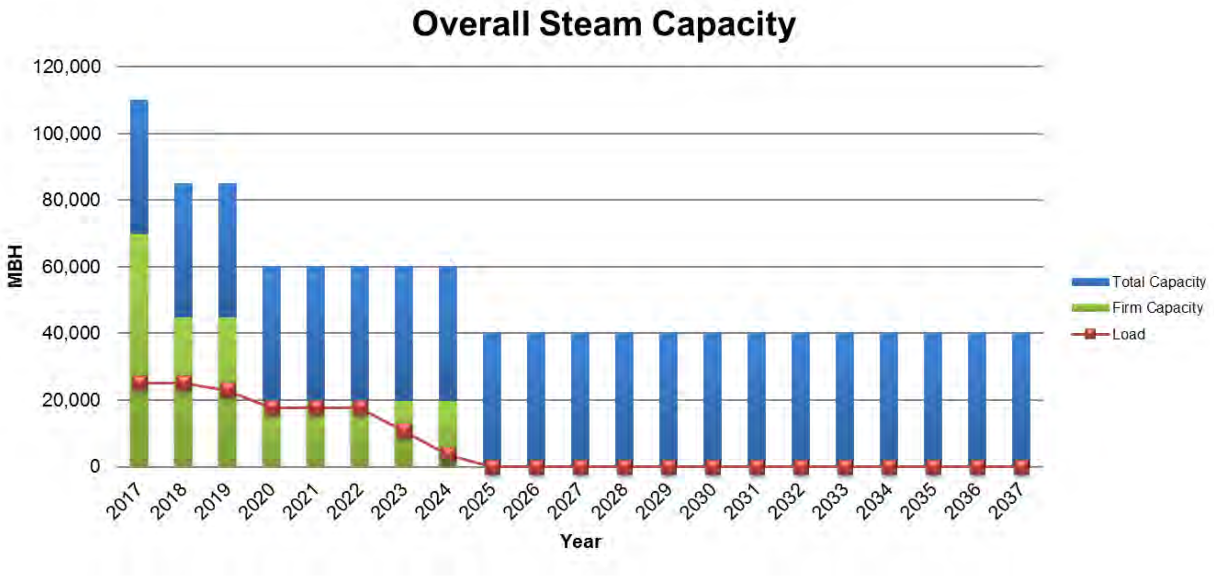

Figure 7-5: Steam Capacity Relative to Projected Load

Future buildings F1, F2, F3, and F4 are served by local hot water boilers. As within the Base Case, future buildings F1, F2, and F4 were served by local heating systems. However, in Option 2, future building F3 was chosen for local HHW heating due to the building's location and the phasing timeline of the new HHW system. If a conversion to central HHW is desired for any of these buildings in the future, a tap installation off the HHW header during initial installation should be considered to serve the appropriate buildings.

7.3.3.2 Option 2: Heating Hot Water

FTPP will begin to produce heating hot water to meet existing heating demands around the northwestern parts of the PVAMU campus. Eventually, an additional thermal energy plant, CUP-2, is proposed to be built. CUP-2 is proposed to be online in 2023. These two thermal energy plants will be connected to the same distribution network. Table 7-10 shows the recommended hot water boiler planning schedule.

Table 7-10: Hot Water Boiler Planning Schedule

Location	Boiler #	MBH	On-Line	Off-Line
FTPP	1	8,000	2019	2044
FTPP	2	8,000	2019	2044
CUP-2	3	8,000	2023	2048
CUP-2	4	8,000	2023	2048
CUP-2	5	8,000	2024	2049
CUP-2	6	8,000	2028	2053

Figure 7-6 shows the heating hot water capacity growth at each utility plant on the PVAMU campus.

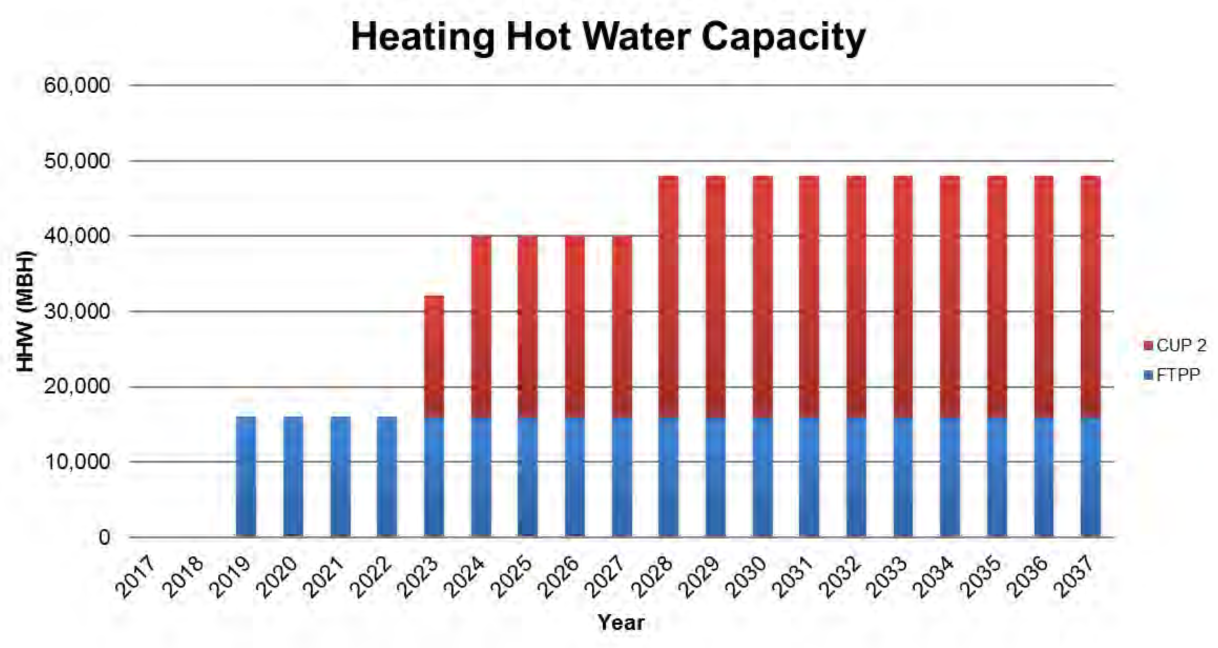

Figure 7-6: Projected Future Heating Hot Water Capacity

Figure 7-7 shows the firm capacity of the HHW system relative to the peak heating hot water load on campus. As the heating hot water system is phased in, N+1 redundancy is maintained.

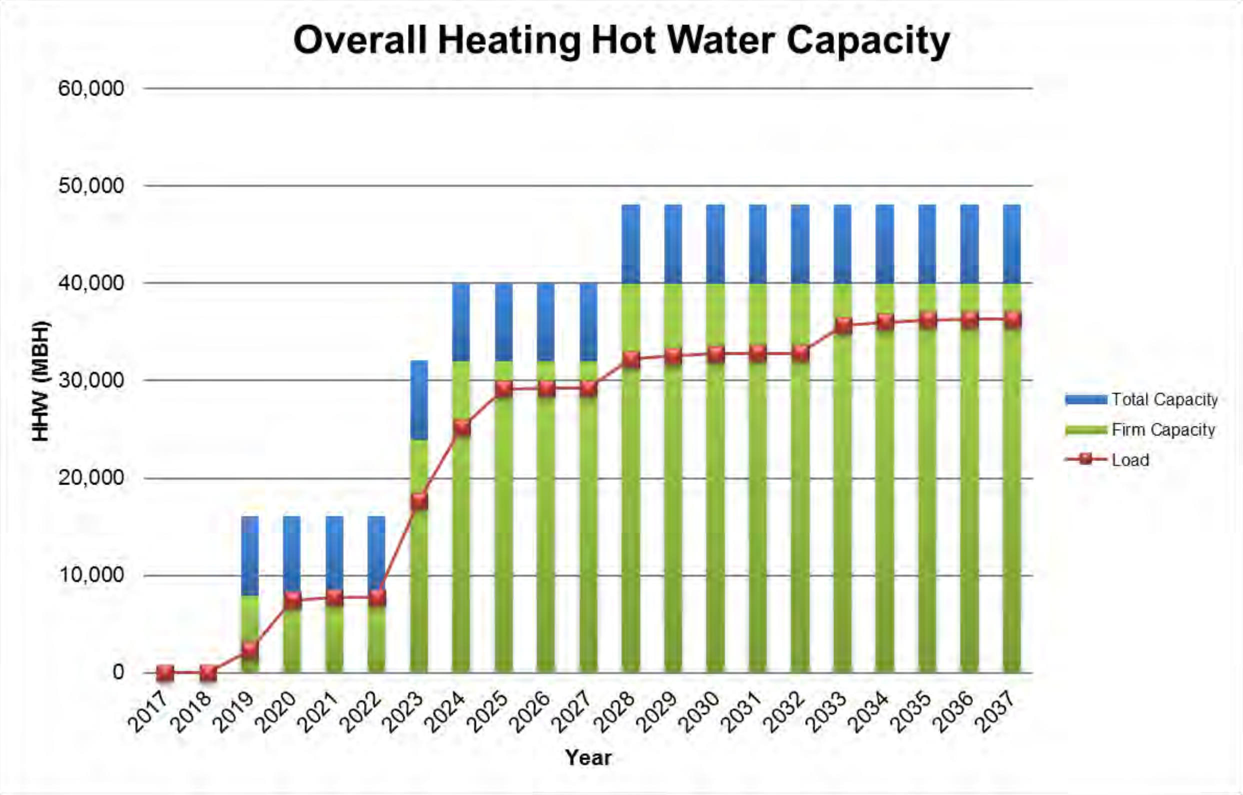

Figure 7-7: Heating Hot Water Capacity Relative to Projected Load

It is also assumed that all buildings have sufficient natural gas service to serve process steam loads. Burns & McDonnell recommends performing a survey to confirm this assumption prior to implementing the central steam to central heating hot water conversion in Option 2.

Point of use equipment for process steam loads was not included in Option 2 because these loads will vary across campus. It is assumed that all buildings have sufficient natural gas service to serve the process steam loads.

7.3.3.3 Option 2: Chilled Water

The chillers installed in Option 2 match the chiller installations in the Base Case and Option 1 even though the chilled water distribution piping is different in this option.

7.3.4 Option 3

In this option, the existing steam system and chilled water system is maintained to meet current and future heating and cooling demands within the Core Campus. An expansion to FTPP is necessary to provide redundant cooling capacity. Further steam and chilled water equipment is replaced as needed when it reaches the end of its service life.

7.3.4.1 Option 3: Steam

PVAMU does not currently have a metering system in place to measure the campus steam load. Based on the estimated steam loads generated for the campus, the boiler capacity at the FTPP meets current peak load and provides N+1 redundancy. If the largest steam boiler currently installed at the FTPP is unable to operate, the remaining boilers would still be capable of meeting the estimated peak demand.

7.3.4.1.1 Capacity Replacement/Expansion – 5 Year

Within the next five years, several pieces of steam equipment (three boilers and associated auxiliaries) will exceed their recommended service life. Boiler 11 has already exceeded its ASHRAE service life. Boiler 11 was originally installed in 1991 and has been identified for replacement in 2020. Boiler 11 will be replaced with a smaller 20,000 MBH boiler instead of the existing 25,000 MBH boiler. Boiler 12 has also exceeded its ASHRAE service life, but due to the excess steam capacity available from the other boilers, Boiler 12 will not be replaced. Boiler 10 was originally installed in 1989 and has been identified for replacement in 2022. Boiler 10’s ASHRAE life ended in 2014, however, after conducting operator interviews, this boiler’s expected life was extended to 2022. The boiler replacement summary is shown in Table 7-11.

Table 7-11: Five Year Steam Equipment Addition and Replacement List

Plant	Tag	Capacity (MBH)	Replacement Date	Replacement or Addition
FTPP	Boiler 11	20,000	2020	Replacement
FTPP	Boiler 10	20,000	2022	Replacement

The existing deaerator, feedwater pumps, RO skid, and other auxiliary equipment is recommended to be replaced in 2022. Burns & McDonnell does not have information on the age of the existing deaerator, feedwater pumps, etc. so replacement may need to occur in a different time frame.

7.3.4.1.2 Capacity Replacement/Expansion – 10 Year

Between 2023 and 2027, Option 3 does not require any additional boilers to meet projected heating loads.

7.3.4.1.3 Capacity Replacement/Expansion – 20 Year

Between 2028 and 2037, Option 3 does not require any additional boilers to meet projected heating loads.

7.3.4.1.4 Steam Summary

Table 7-12 shows the recommended steam boiler planning schedule.

Table 7-12: Steam Boiler Planning Schedule

Location	Boiler #	MBH	Install Date	Replacement Date
FTPP	10	20,000	1989	2022
FTPP	11	25,000*	1991	2020
FTPP	12	25,000	1991	None
FTPP	7	40,000	2015	2040

*Note: Boiler 11 is replaced with 20,000 MBH capacity.

Figure 7-8 shows the firm capacity of the steam system relative to the peak steam load on campus. PVAMU is N+1 redundant with their existing steam generating assets.

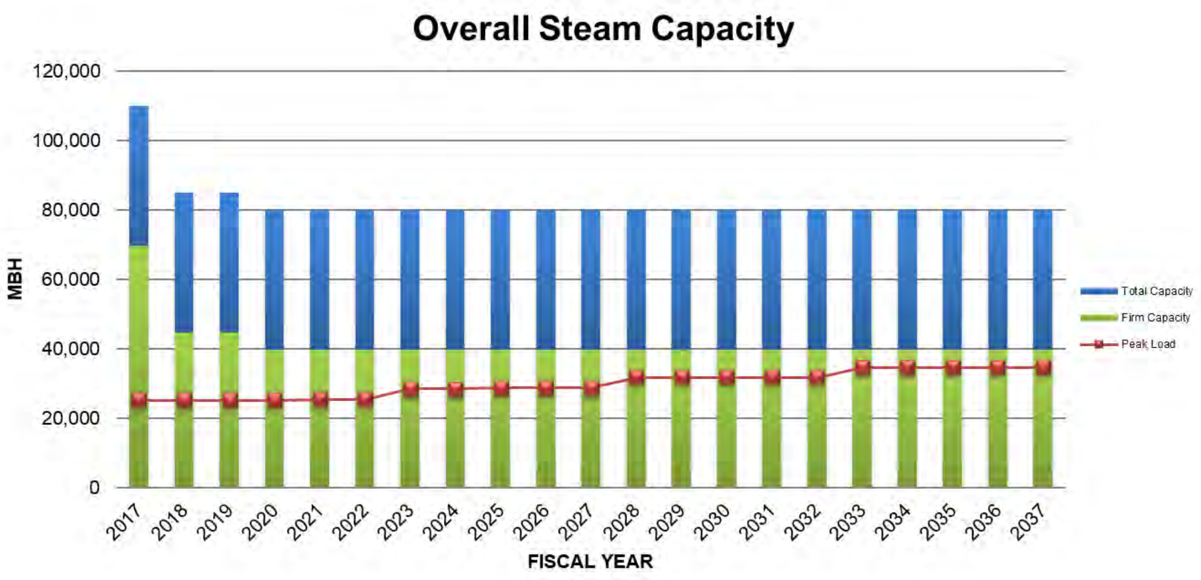

Figure 7-8: Steam Capacity Relative to Projected Load

7.3.4.2 Option 3: Local Heating and Cooling

Local natural gas hot water boilers for heating and DX units for cooling at each building come online when the new buildings outside of the Core Campus are constructed as shown in Table 7-13.

Table 7-13: Local HHW Availability

Key	Building	Date Local Heating / Cooling Available
F1	Police Station	2018
F2	Meat Processing Facility	2018
F3	ICCE Facility (lab)	2019
F4	ROTC Building	2020
F9	Future Support Building	2024
F10	Future Office	2024
F12	Future Retail Office Building	2026
F16	Future Support Building	2029
F17	Future Office	2029
F18	Future Stud. Activities Building	2030
F19	Future Retail Office Building	2031
F23	Future Support Building	2034
F24	Future Office	2034
F25	Future Stud. Activities Building	2035
F26	Future Retail Office Building	2036

Point of use equipment for process steam loads was not included in Option 3 because these loads will vary across campus. The natural gas consumption necessary to meet projected process steam loads in Option 3 was accounted for in the sizing of natural gas building connections. It is also assumed that all buildings have sufficient natural gas service to serve the process steam loads and the local hot water boilers. Burns & McDonnell recommends performing a survey to confirm this assumption prior to implementing the local hot water boiler installation recommended in Option 3.

7.3.4.3 Option 3: Chilled Water

Option 3 differs from the three other options in its approach to meet future chilled water demands. The new chilled water system will require a larger expansion to FTPP and will include chiller additions to achieve N+1 redundancy, as the chilled water system is not currently N+1 redundant. If the largest chiller is out of service, peak loads cannot be met. The chillers included in Option 3 are also larger than those included in the other three options.

7.3.4.3.1 Capacity Replacement/Expansion – 5 Year

At the Fry-Thomas Power Plant, Chiller 2, which was installed in 1999, will exceed its expected service life in 2022. Typically, when a chiller nears the end of its service life, the efficiency is no longer optimal, the refrigerants are overdue for phase out, and maintenance costs will increase significantly. Some chillers may exceed their ASHRAE recommended service life. Chiller 2 is recommended to be replaced in 2018 prior to exceeding its ASHRAE service life based on operator feedback, system literature, and the necessary increase in reliable chilled water capacity. Even though this chiller is rated to provide 1,100 tons of chilled water, data from the Ameresco report suggests it is only capable of providing approximately 700 tons. The new chiller recommended to replace it in this option will be rated for 1,700 tons. Due to campus load growth, an additional 1,700-ton chiller along with a cooling tower cell, chilled water pump, and condenser water pump are also recommended to be installed at FTPP in 2020 as shown in Table 7-14. Additionally, per the request of PVAMU, Chiller 3 should be replaced in 2022 five years ahead of its ASHRAE life expectancy.

Table 7-14: Five Year Chiller Addition and Replacement List

Plant	Tag	Capacity (tons)	Year in Service	Replacement or Addition
FTPP	Chiller 2	1,700	2018	Replacement
FTPP	Chiller 6	1,700	2020	Addition
FTPP	Chiller 3	1,700	2022	Replacement

Two packaged cooling towers are recommended that can run in parallel with the existing cooling tower system. The existing cooling tower system consists of field erected cells and a common concrete basin. A packaged system is recommended because the existing towers are field erected and would require a costly expansion of the building structure. The installation of the additional chiller and chilled water pump will require a bag stop at the end of the header inside the Utility Plant Annex to facilitate extension of the piping to the east, if an outage cannot be taken to perform the work. The expansion of the Utility Plant Annex building in Option 3 is estimated to require approximately 5,160 SF and should extend to the east of the existing building. A General Arrangement Drawing of the 5,160 SF addition can be seen below in Figure 7-9. The costs for the equipment, installation, and building extension have been included in the cost estimates associated with this report. This addition allows the university to achieve N+1 redundancy relatively quickly and removes the need to build a satellite utility plant.

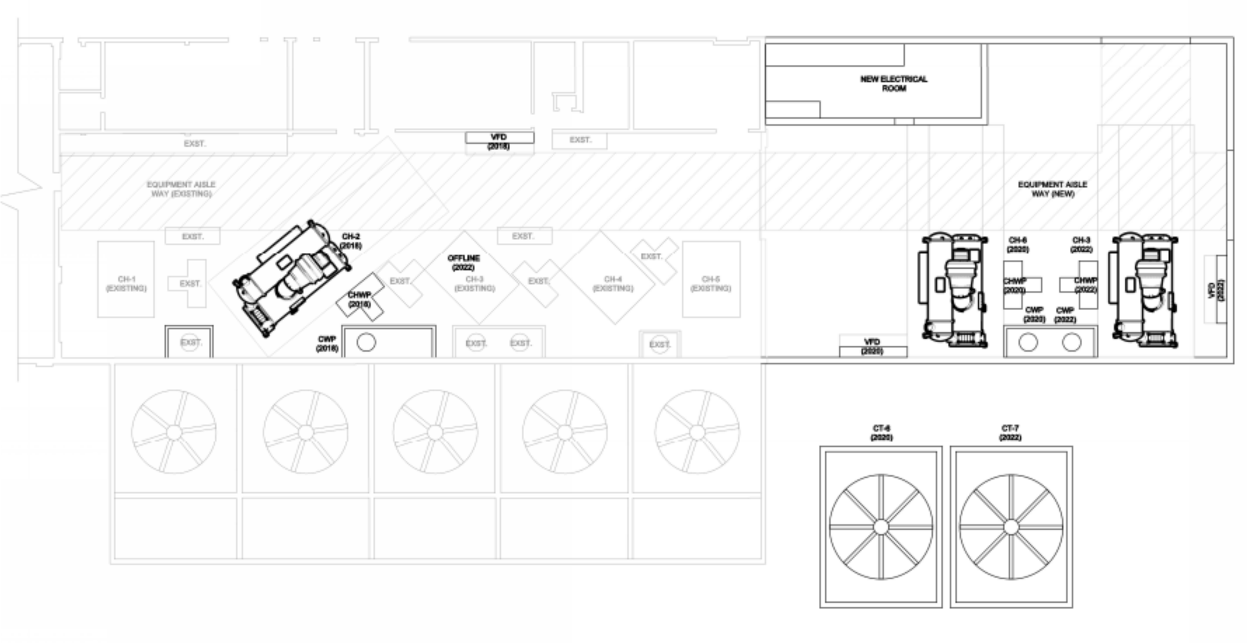

Figure 7-9: FTPP Chiller Extension

Chilled water and condenser water pumps will also be replaced and added over time in conjunction with the chiller projects. When a chiller is replaced, the chilled water and condenser water pumps serving that chiller will also be replaced.

7.3.4.3.2 Capacity Replacement/Expansion – 10 Year

Between 2023 and 2027, Chiller 4 will exceed its ASHRAE recommended service life. Chiller 4 was originally installed in 2004 and will exceed its ASHRAE recommended service life during the 10-year time frame. Although the life expectancy extends to 2027, Chiller 4 should be replaced in 2025 per direction from PVAMU, as shown in Table 7-15.

Table 7-15: 10 Year Chiller Addition and Replacement List

Plant	Tag	Capacity (tons)	Year in Service	Replacement or Addition
FTPP	Chiller 4	1,700	2025	Replacement

Chilled water and condenser water pumps will also be replaced and added over time in conjunction with the chiller projects. When a chiller is replaced, the chilled water and condenser water pumps serving that chiller will also be replaced.

7.3.4.3.3 Capacity Replacement/Expansion- 20 Year

Between 2028 and 2037, one additional chiller will exceed its ASHRAE service life. Chiller 5 was originally installed in 2011 and will exceeded its ASHRAE recommended service life during the 20-year time frame. Although the life expectancy extends to 2034, Chiller 5 should be replaced in 2028 per direction from PVAMU, as shown in Table 7-16.

Table 7-16: 20 Year Chiller Addition and Replacement List

Plant	Tag	Capacity (tons)	Year in Service	Replacement or Addition
FTPP	Chiller 5	1,700	2028	Replacement

Chilled water and condenser water pumps will also be replaced and added over time in conjunction with the chiller projects. Similar to the 5-year time frame, the chilled water and condenser water pumps will also be replaced when a chiller is replaced.

7.3.4.3.4 Chilled Water Summary

Table 7-17 shows the complete recommended chiller replacement and addition schedule.

Table 7-17: Recommended Chiller Planning Schedule

Location	Chiller #	Tons	On-Line	Off-Line	Addition/Replacement
FTPP	2	700	1999	2018	Replacement
FTPP	3	900	2004	2022	Replacement
FTPP	4	900	2004	2025	Replacement
FTPP	5	1000	2011	2028	Replacement
FTPP	1	1100	2015	2038	Replacement
FTPP	2	1700	2018	2041	Replacement
FTPP	6	1700	2020	2043	Addition
FTPP	3	1700	2022	2045	Replacement
FTPP	4	1700	2025	2048	Replacement
FTPP	5	1700	2028	2051	Replacement

Figure 7-10 shows the firm capacity of the chilled water system relative to the peak chilled water load on campus.

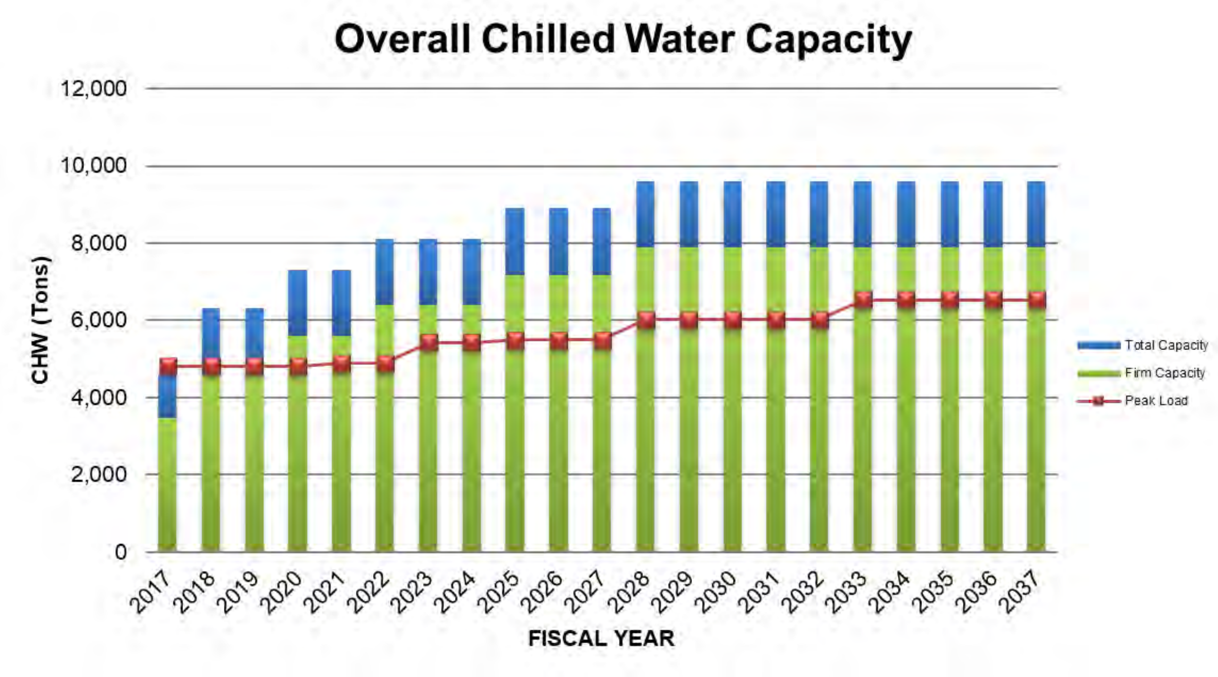

Figure 7-10: Chilled Water Capacity Relative to Projected Load

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SECTION 8.0

ELECTRICAL DISTRIBUTION SYSTEM IMPROVEMENTS

8.0 ELECTRICAL DISTRIBUTION SYSTEM IMPROVEMENTS

8.1 SOUTHEAST SWITCHGEAR

To accommodate for future growth, BMcD recommends installing a 12.47kV, 1200A, 3 phase, main-tie-main switchgear lineup located in a weatherproof walk-in enclosure. This Southeast Switchgear will be located north of the new southeast development. This switchgear will be served from both the existing north and south feeders. The north feeder will require an overhead line extension from the Main Campus Switchgear #1 to this new location. A tap off the nearby south feeder will serve the other half of the switchgear. Coordination with SBEC will be required to extend the existing north and south feeders to serve the Southeast Switchgear. Utility costs will be associated with extending these overhead lines.

This switchgear will include eleven vertical sections that will account for future campus growth. The breakers will be provided in the vertical sections in the year that the loop is installed. However, the switchgear section will be fully equipped to accept the circuit breaker. The walk-in enclosure should have additional room if ever needed for expansion in the future. This new equipment will allow a new feeder loop, F700, to serve the new CUP-2 and the new buildings in the southeast area of campus. It will also have spare capacity for future campus growth and two future feeder loops. Option 3 will not include CUP-2 so the feeder loop will solely serve the southeast buildings.

A single point in the loop will be open where the load is balanced between the two feeders from the main substation bus. The tie breaker on the secondary will be normally open. The load on each feeder will be less than 50% of the cable rating so that each feeder could support the full load of all the buildings. Please refer to Appendix B for the one-line diagram.

8.2 SWITCHGEAR #2 REPLACEMENT

BMcD investigated Switchgear #2 during a site visit and reviewed the existing one-line diagram. PVAMU personnel expressed their concerns regarding the reliability and age of the gear. BMcD recommends replacing this gear in-place and reusing the existing conductor. The lineup would be the same size with six vertical sections and a 1200A bus rating in order to serve Switchgear #3.

8.3 SWITCHGEAR #3

Switchgear #3 was installed in 2007 and is in good condition and has an equipped space available to serve a future FTPP chiller discussed below. A new 15kV breaker will be provided to serve a new 12.47kV-4160Y/2400V, 1500kVA transformer. This transformer can be placed on the existing pad available located east of Switchgear #3. The other chiller transformers are located on the same pad, as well. The pad is equipped with conduits that will stub-up into the transformer from Switchgear #3. A new concrete encased ductbank will be required to serve the new chiller located in the FTPP building extension on the east side from the new transformer.

8.4 FRY-THOMAS POWER PLANT

The new 4160V electrical switchgear and VFD associated with the new chillers will be located inside FTPP. The existing 15kV-480Y/277V, 500kVA transformer will not be sufficient to serve FTPP due to the additional loads associated with the new chiller. BMcD recommends replacing the existing transformer with a 15kV-480Y/277V, 1000kVA transformer for the Base Case and Option 1. Option 2 will require a 15kV-480Y/277V, 1500kVA transformer while Option 3 will require a 15kV-480Y/277V, 2000kVA transformer. This will provide capacity for the existing and future load. BMcD recommends metering the FTPP existing load to verify the transformer is sized properly.

The 480V, 1200A switchboards will vary slightly between the Base Case, Option 1, and Option 2. Option 2 will require four additional breakers than the Base Case and Option 1. Option 3 will require eight additional breakers than the Base Case and Option 1.

Switchgear #3 serves the existing 4160V chillers and associated loads in FTPP. For the Base Case, Option 1, and Option 2, four existing 1100 ton chillers and their associated equipment such as chilled water pumps, condenser water pumps, and cooling tower fan motors will be replaced in-place. These new 1100 ton chillers will have VFDs and 5kV switchgear. The existing condensing water pumps are 75HP and the replacement pumps will be 100HP, so an additional 75HP will be added. Also, an additional 1100-ton chiller with a VFD will be added and served from Switchgear #3.

For the Option 3, four existing 1100 ton chillers and their associated equipment such as chilled water pumps, condenser water pumps, and cooling tower fan motors will be replaced with four 1700 ton chillers. These new 1700 ton chillers will have VFDs and 5kV switchgear. The existing condensing water pumps are 75HP and the replacement pumps will be 160HP. The existing chilled water pumps are 125HP and the replacement pumps will be 160HP. Also, an additional 1700-ton chiller with a VFD will be added and served from Switchgear #3.

The existing 12.47kV-4160Y-2400V, 1500kVA chiller transformers appear aged. BMcD recommends replacing these transformers when the new chillers are replaced, as well, due to age. The Base Case, Option 1, and Option 2, will require 12.47kV-4160Y-2400V, 1500kVA transformers. Option 3 will require 12.47kV-4160Y-2400V, 2000kVA transformers.

8.5 ELECTRICAL DISTRIBUTION SYSTEM DESIGN

8.5.1 New Electrical Distribution System

BMcD analyzed the future building growth in the southeast area of campus for the next 5, 10, and 20 years. Since existing electrical infrastructure does not exist directly in this area, new underground ductbank and manholes need to be installed to serve these new buildings along with the new CUP-2. BMcD recommends that a new electrical distribution feeder loop serve the proposed southeast buildings and CUP-2. The new feeder loop and CUP-2 circuit will originate from two breakers at the Southeast Switchgear. Maintenance personnel will be able to operate this feeder from the Southeast Switchgear.

The new feeder loop and CUP-2 circuit cable sizing is recommended to be 15kV, 350kcmil copper single conductor shielded 133 percent insulation with 600V, #1/0 AWG ground conductor. This cable will be sufficient to serve the entire loop when fed from one end with normal loading. The loop will be split at the normally open (NO) point so each half of the loop will serve approximately fifty percent of the loop during normal loading conditions. This configuration also allows for the new feeder loop and CUP-2 circuit to be separated into two circuits in the future. Option 3 does not include CUP-2 and so this feeder loop will only include the southeast buildings. Please refer to the one-line diagram in Appendix B.

The new electrical ductbank will be routed from the Southeast Switchgear to the southeast buildings. BMcD recommends a concrete encased ductbank with a 3x3 configuration comprised of 6” Schedule 40 PVC conduits. This configuration will allow room for the new feeder loop, along with future circuits.

Due to pull tension and maintenance access, 17 precast manholes will be installed along the new ductbank route. Manholes will be equipped with Underground Devices Inc. or equal cable racks to facilitate feeder cable support and separation.

BMcD recommends using an air-insulated pad-mounted configuration for the 15kV electrical distribution switches to serve the new buildings. The recommended standard configuration is two dead-front mainline switch ways and two fused tap ways in order to simplify operations and maintenance. Each switch can be located outside of proposed buildings adjacent to building transformers. BMcD does not recommend placing these distribution switches in the manholes to match the existing electrical infrastructure due to safety, reliability, and maintainability concerns. PVAMU personnel expressed that many of the existing sump pumps in the manholes are broken and the manholes are full of water. This configuration eliminates the need to pump water out of the manholes to maintain a distribution switch and is a common design among many university campuses. Please refer to Table 8-1, Table 8-2, and Table 8-3 for the new buildings that will be added in 5, 10, and 20 years.

Table 8-1: New Building Loads on New Loop – 5 years

NEW BUILDINGS		kW	kVA (0.85 PF)
F3	ICCE Facility (lab)	58	69
F3B	ICCE Facility (office)	83	98
F6	Housing 2 (From 2011 Campus MP)	220	259
	SUM	**361**	**426**

* Phase 1- Red; Phase 2- Orange; Phase 3- Green

Table 8-2: New Building Loads on New Loop – 10 years

NEW BUILDINGS		kW	kVA (0.85 PF)
F3	ICCE Facility (lab)	58	69
F3B	ICCE Facility (office)	83	98
F6	Housing 2 (From 2011 Campus MP)	220	259
F9	Future Support Building	63	75
F10	Future Office	13	16
F12	Future Retail Office Building	10	12
F13	Future Housing Building	248	292
	SUM	**695**	**821**

* Phase 1- Red; Phase 2- Orange; Phase 3- Green

Table 8-3: New Building Loads on New Loop – 20 years

NEW BUILDINGS		kW	kVA (0.85 PF)
F3	ICCE Facility (lab)	58	69
F3B	ICCE Facility (office)	83	98
F6	Housing 2 (From 2011 Campus MP)	220	259
F9	Future Support Building	63	75
F10	Future Office	13	16
F12	Future Retail Office Building	10	12
F13	Future Housing Building	248	292
F16	Future Support Building	61	72
F17	Future Office	13	16
F18	Future Stud. Activities Building	54	64
F19	Future Retail Office Building	10	12
F20	Future Housing Building	241	284
F23	Future Support Building	59	70
F24	Future Office	12	15
F25	Future Stud. Activities Building	52	62
F26	Future Retail Office Building	10	12
F27	Future Housing Building	234	276
	SUM	**1441**	**1704**

* Phase 1- Red; Phase 2- Orange; Phase 3- Green

Table 8-4 reflects the same buildings for the full 20-year buildout as above, but accounts for the additional electrical load associated with buildings served locally in Option 3. Therefore, the load on the feeder loop will increase.

Table 8-4: New Building Loads on New Loop for Option 3 – 20 years

NEW BUILDINGS		kW	kVA (0.85 PF)
F3	ICCE Facility (lab)	58	69
F3B	ICCE Facility (office)	83	98
F6	Housing 2 (From 2011 Campus MP)	220	259
F9	Future Support Building	121	143
F10	Future Office	25	30
F12	Future Retail Office Building	19	23
F13	Future Housing Building	248	292
F16	Future Support Building	117	138
F17	Future Office	25	30
F18	Future Stud. Activities Building	103	122
F19	Future Retail Office Building	19	23
F20	Future Housing Building	241	284
F23	Future Support Building	114	135
F24	Future Office	24	29
F25	Future Stud. Activities Building	100	118
F26	Future Retail Office Building	18	22
F27	Future Housing Building	234	276
	SUM	**1769**	**2091**

* Phase 1- Red; Phase 2- Orange; Phase 3- Green

8.5.2 CUP-2

The new CUP-2 will be located within the southeast area of campus in 2023. BMcD recommends a 15kV, 1200A main-tie-main switchgear configuration to serve the plant. Each bus will serve a 1000 ton, 4160V CUP-2 chiller via a 15kV-4160V, 1500kVA step-down transformer. In addition, each bus will serve a 480V main-tie-main switchboard via a 15kV-480V step-down transformer. This main-tie-main configuration provides redundancy, reliability, and maintainability to the electrical system. This switchboard will serve each chiller's associated loads including (1) 100HP chilled water pump, (1) 100HP condensing water pump, and (1) 75HP cooling tower fan per chiller. The chilled water electrical loads remain the same between the Base Case, Option 1, and Option 2. Option 3 does not require CUP-2 so it is not included in this option.

The boiler options vary between the Base Case and Option 2. The boilers in Option 1 will not affect the electrical load as this option has local gas boilers installed for new buildings along with the conversion of local boilers at the existing buildings. Since these boilers are on the building side, this will not affect the medium voltage electrical distribution.

The Base Case has three 25,000 MBH steam boilers and minimal electric loads. Therefore, the electric load will not be significantly affected. Option 2 includes four 8000 MBH hot water boilers with a 480V motor fan and 25HP hot water pump per boiler. Thus, Option 2 has eight additional 480V loads than the Base Case. The Base Case will require a 480V, 2000A main-tie-main switchboard with two 15kV-480V, 1500kVA transformers. Option 2 will require a 480V, 2500A main-tie-main switchboard with two 15kV-480V, 2000kVA transformers. Please refer to Appendix B for the one-line diagram.

8.5.3 Existing Electrical Distribution System Modifications

Existing loads per feeder loop were estimated based on the one-line diagram and campus geography. A W/sf value was applied to each existing building type and loads were determined using a 0.85 power factor. These loads were summed to determine the existing feeder loop load. Without peak demand data, these loads are solely an estimate. Peak meter data is the best determinate of the actual load per feeder loop.

Certain new buildings installed in the future will be served from the existing system. Based on the estimated feeder loop loading, it seems there is sufficient capacity to serve the new buildings. However, BMcD recommends metering each distribution feeder loop before adding additional load. Please refer to Table 8-5, Table 8-6, Table 8-7 for the additional building loads that will be added to the existing electrical system in 5, 10, and 20 years.

Table 8-5: New Building Loads on Existing System – 5 years

NEW BUILDINGS		kW	kVA (0.85 PF)
New	School of Architecture Fabrication Design Center	106	125
New	Welcome Center	26	31
New	University Square (Phase VIII)	280	330
F1	Police Station	188	222
F2	Meat Processing Facility	263	310
F4	ROTC Building	63	75
F5	Cultural Arts Center	68	80
	SUM	**926**	**1173**

* Phase 1- Red; Phase 2- Orange; Phase 3- Green

Table 8-6: New Building Loads on Existing System – 10 years

NEW BUILDINGS		kW	kVA (0.85 PF)
New	School of Architecture Fabrication Design Center	106	125
New	Welcome Center	26	31
New	University Square (Phase VIII)	280	330
F1	Police Station	188	222
F2	Meat Processing Facility	263	310
F4	ROTC Building	63	75
F5	Cultural Arts Center	68	80
F7	Future Academic Building	307	362
F8	Future Lab Space / Building	167	197
F11	Future Stud. Activities Building	55	65
	SUM	**1523**	**1797**

* Phase 1- Red; Phase 2- Orange; Phase 3- Green

Table 8-7: New Building Loads on Existing System – 20 years

NEW BUILDINGS		kW	kVA (0.85 PF)
New	School of Architecture Fabrication Design Center	106	125
New	Welcome Center	26	31
New	University Square (Phase VIII)	280	330
F1	Police Station	188	222
F2	Meat Processing Facility	263	310
F4	ROTC Building	63	75
F5	Cultural Arts Center	68	80
F7	Future Academic Building	307	362
F8	Future Lab Space / Building	167	197
F11	Future Stud. Activities Building	55	65
F14	Future Academic Building	299	352
F15	Future Lab Space / Building	163	192
F21	Future Academic Building	290	342
F22	Future Lab Space / Building	158	186
	SUM	**2433**	**2869**

* Phase 1- Red; Phase 2- Orange; Phase 3- Green

In 2018, the Meat Processing Facility will be located on the northeast side of campus. Geographically, distribution feeder loop F600 makes the most sense to tie into. BMcD recommends adding a 15kV pad-mounted distribution switch to serve the Meat Processing Facility.

In 2020, the ROTC building will be located northeast of University Square and is geographically located near distribution feeder loop F600. BMcD recommends adding a 15kV pad-mounted distribution switch to serve the new ROTC building.

In 2021, the Cultural Arts Center will be added west of Anderson Hall. This building can be served from distribution feeder loop F300. BMcD recommends tying into F300 and adding a 15kV pad-mounted distribution switch to serve this new building.

In 2023, a Future Academic Building and Future Lab Space/Building will be added north of the Owens-Franklin Health Clinic. These buildings can be served from distribution feeder loop F300. BMcD recommends tying into F300 and adding a 15kV pad-mounted distribution switch to serve these new buildings.

In 2025, a Future Student Activities Building will be added on the northwest corner of E.N. Norris St. and L.W. Minor St. This building can be served from distribution feeder loop F300. BMcD recommends tying into F300 and adding a 15kV pad-mounted distribution switch to serve this new building.

In 2028, a Future Academic Building and Future Lab Space/Building will be added north of University View (Phase VII). These buildings can be served from distribution feeder loop F300. BMcD recommends tying into F300 and adding a 15kV pad-mounted distribution switch to serve these new buildings.

In 2033, a Future Academic Building and Future Lab Space/Building will be added north of Student Park and east of University Village North (Phase VIII). These buildings can be served from distribution feeder loop F600. BMcD recommends tying into F600 and adding a 15kV pad-mounted distribution switch to serve these new buildings.

According to the estimated feeder loading, F300 and F600 should have sufficient capacity to serve these loads. However, BMcD recommends metering each feeder loop to verify the actual loading to determine how much load can be added.

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SECTION 9.0

DOMESTIC WATER, SANITARY SEWER & STORM SEWER SYSTEM EXPANSION

9.0 DOMESTIC WATER, SANITARY SEWER, STORM SEWER, & NATURAL GAS SYSTEM EXPANSION

9.1 DOMESTIC WATER

This section presents the proposed domestic water development for the planned campus expansion. Planned campus expansion includes over 1.1 million square feet of building development phased over three development periods. Roughly two thirds of the planned building development are grouped together in the southeast portion of campus. The remaining planned building development is dispersed among the existing campus.

This evaluation assumes the buildings dispersed among the existing campus will be served by the existing system and buildings grouped in the southeast corner of campus will be served by recommended improvements. Although development is planned in phases, the recommended improvements should to be sized to meet the ultimate buildout conditions since water distribution systems have a typical useful life that spans beyond the planned construction phases. Therefore, the domestic water section will not specifically determine water demands for each of the three phases but rather look to the build out phase.

A review of the water use patterns for the campus in past studies indicates the irrigation demand is significantly higher than the consumptive water demand. A past water system analysis for Prairie View conducted in 1997 indicated the average daily irrigation demand during the first week in August 1996 was greater than a million gallons. This was more than twice the estimated consumptive water demand.

This evaluation disregards all future irrigation water demand because of the preliminary nature of planning and the nature of the proposed development footprint. The footprint for the planned campus expansion includes mostly impervious areas that will not require irrigation with impervious areas comprised primarily of expansive parking areas and building footprints.

The American Water Works Association (AWWA) design guidelines recommend water distribution and supply systems be sized based on the maximum daily demand plus the fire flow demand.

9.1.1 Existing System Review

Prairie View A&M's existing domestic water distribution system is composed of ductile iron and polyvinyl chloride pipes that range in size from 4 to 12 inches. Based upon discussions with representatives of Severn-Trent, the operator of the campus water and wastewater systems, the existing domestic water system has capacity and is able to meet the domestic water demand and irrigation demand for the Prairie View A&M campus.

The latest Water System Analysis for the campus that could be located was from October 1997. That analysis included a computer hydraulic analysis of the existing system, and the results indicated the existing system was not capable of meeting the necessary fire flow demands throughout campus.

The system pressure, which averages 56 psi, is maintained by six ground water wells with a cumulative design capacity of 3,450 gallons per minute (gpm) and a reported actual pumping capacity of 2,503 gpm. A million-gallon ground storage tank and a half million-gallon elevated storage tank provide added capacity for peak use periods.

9.1.2 Proposed Water Demand

The proposed water demand is composed of two components including consumptive water demand and fire flow demand.

9.1.2.1 Consumptive Water Demand

A data set of total daily wastewater flow from campus to the Prairie View wastewater treatment plant formed the basis of the projected consumptive water demand for the planned campus expansion. The data set included 91 daily totals from the period ranging from December of 2016 to April of 2017 and distinguished flow contributions from the two sources, the City of Prairie View and the Prairie View A&M campus. The maximum daily wastewater flow from campus was 0.601 million gallons (MGD), occurring on February 28th following six consecutive days with no measured precipitation.

Guidelines found in Metcalf and Eddy's *Wastewater Engineering* report 60 percent to 85 percent of per capita water consumption becomes wastewater. Applying a value of 80 percent results in 0.751 MGD, which represents the maximum daily consumptive water demand less an allowance for losses. Water losses typically range from 10 percent to 70 percent in a water distribution system. Assuming a 10 percent water loss rate is reflective of new modern system capabilities, the existing maximum daily consumptive demand is 0.826 MGD.

The existing maximum daily consumptive demand was calculated on a per capita basis. The per capita consumptive demand was then applied to the planned campus expansion based on the 20-year plan population projections.

The current population served includes 9,000 students and 1,200 employees. The existing per capita maximum daily consumptive demand is 81 gallons per day (gpd)/capita. Population projections through the 20-year plan in 2037 are 13,150 students and 1,750 employees. The projected population growth is 4,700 people. The maximum daily consumptive demand increase through 2037 is 380,700 gpd or 264 gpm.

9.1.2.2 Fire Flow Demand

Guidelines found in Appendix B of the 2015 *International Fire Code* formed the basis used to estimate the fire flow demand for the planned campus expansion. The planned campus expansion construction was assumed to include noncombustible exterior walls and fire resistant rated interior construction materials. In addition to materials of construction, the fire flow demand estimate is based on the building floor area.

With similar construction materials assumed for all the buildings the largest building has the highest fire flow demand. The Future Housing Buildings (F13, F20, and F27) are the largest planned buildings at 137,560 square feet each. The fire flow demand varies significantly depending on whether the buildings have sprinkler systems. Using B105.1 in Appendix B, the estimated maximum fire flow demand is 5,250 gpm with a flow duration of 4 hours if sprinklers are not installed in the Future Housing Buildings. Using Appendix B guidelines found in Section B105.3.1, the estimated maximum fire flow demand is 1,500 gpm with a flow duration of 4 hours if sprinklers are installed in the Future Housing Buildings.

9.1.2.3 Total Water Demand

The total water demand is the maximum daily consumptive demand (264 gpm) plus the estimated fire flow. If the planned buildings include sprinkler systems then the total water demand, neglecting irrigation demand, is 1,764 gpm. If the planned buildings do not include sprinkler systems then the total water demand, neglecting irrigation demand, is 5,514 gpm.

9.1.3 Recommended Improvements

These recommended improvements are offered without the benefit of hydraulic modeling. Hydraulic modeling should be used to confirm assumed system behavior and response. Since hydraulic modeling was outside the scope of this planning effort, it is recommended the next phase of improvement design include hydraulic modeling to confirm and refine the recommended improvements. General domestic water mains should be routed within the planned utility corridors.

Two AWWA design guidelines form the basis of recommended water main sizes. The guidelines used include:

1. Maximum flow velocities should be 5 feet per second or less.
2. Head loss due to friction should be less than 6 feet per 100 feet of pipe.

Typically, the fire flow component of the total water demand greatly impacts number, size, and type of improvements recommended for new development. Recommended improvements will be grouped into two categories depending on whether the buildings have sprinkler systems.

9.1.3.1 Sprinklered Buildings

If the new buildings grouped in the southeast corner of the existing campus have sprinkler systems then a new 12-inch water main is recommended. The new 12-inch water main would serve as the main feed for the new development. It would connect to the existing 12-inch water main located on E.N. Norris Street. Smaller branch mains would be sized as needed to serve individual buildings or groups of buildings. The distribution system would include valving at junctions to provide isolation capability. Fire hydrants would be located to provide adequate fire protection.

This alternative includes a new elevated 500,000-gallon storage tank. This storage tank is recommended to help meet peak demands and buffer ranges in system pressure. This volume of stored water would meet the maximum daily flow demand plus the fire flow demand for the four-hour period.

This alternative would rely on the existing ground water wells to meet the total water demand for all the proposed development. The existing pumping capacity is 3.6 MGD, based on the reported pumping capacities. A past water system analysis for Prairie View conducted in 1997 indicated the average total water consumption during the first week in August 1996 was 1.7 million gallons. This suggests existing capacity can meet existing and projected water needs.

9.1.3.2 Non-Sprinklered Buildings

If the new buildings grouped in the southeast corner of the existing campus do not have sprinkler systems then duel systems are recommended. One system would include a new water main connected to the existing 12-inch water main located on E.N. Norris Street as the main feed for the new development consumptive water demand. The consumptive demand would be met by the existing ground water supply system. The size of this water main would be either an 8 or a 6-inch, depending on the assumed level of irrigation demand.

The other component of the recommended improvements for this alternative is a stand-alone fire flow system. This system includes a million-gallon storage tank fed by two new groundwater wells sized at 500 gpm each. A 20-inch water main would connect the storage tanks to the system of dispersed fire hydrants. A future analysis of the ground water aquifer is recommended to confirm the feasibility of installing the two new groundwater wells.

Alternatively, hydraulic and water quality modeling could be performed to assess the feasibility of connecting the 20-inch water main to both the existing 12-inch water main located on E.N. Norris Street and to the new million-gallon storage tank. This alternative would still include the two new ground water wells sized at 500 gpm each to meet the fire flow demand. The 20-inch water main would serve to meet both the consumptive and fire flow demands. This alternative would make the overall campus water distribution system more robust by connecting the two new wells and the storage tank to the overall system but modeling would be needed to address water quality concerns to confirm this is a viable alternative.

9.2 SANITARY SEWER

This section describes the proposed sanitary sewer flows for each of the development phases, provides a review of the existing sanitary sewer system and provides recommendations on what improvements could be made to handle the increased flows.

9.2.1 Existing System Review

This section describes the existing sanitary sewer system, including the collection system and Wastewater Treatment Plant (WWTP). It also provides a basis for sanitary sewer flows generated by PVAMU's students and faculty.

9.2.1.1 Existing Sanitary Sewer System Overview

PVAMU's sanitary sewer system consists of a gravity sewer collection system that serves the entire campus, as well as a WWTP that treats wastewater generated from both PVAMU and the City of Prairie View, TX. A separate force main conveys the wastewater from the City directly to the WWTP while PVAMU's sewer collection system is only a gravity system. Appendix C provides a depiction of the entire system.

9.2.1.2 Existing Sanitary Sewer Flow Rates

To provide sanitary sewer flow projections for future development phases, provided sanitary wastewater flow data from the WWTP Operations was used. The data included combined flows from PVAMU and the City as well as rainfall information. Appendix C includes the provided wastewater flow data.

Flows for just the PVAMU campus were used for the analyzes. That data was analyzed for the highest dry weather flow occurrence and used to determine a flow per faculty and students. The highest flow was determined to be 0.601 MGD. With currently there being 9,000 students and 1,200 faculty members on campus, that translated to a 59 gal/person/day of wastewater generated.

The data was also analyzed for flow per square feet of building. There are approximately 2.9M square feet of building on campus. That would translate to about 0.207 gal/SF of building of sanitary sewer being generated.

The total combined recorded peak flow to the WWTP was 1.218 MGD which occurred during a 2-inch rainfall event.

9.2.1.3 Existing WWTP Capacity

PVAMU has been issued a permit (WO0011275002) to discharge treated wastewater from Texas Commission on Environmental Quality (TCEQ). The permit stipulates the following:

- Annual average flow not to exceed 2.0 MGD
- Average Discharge during any two-hour period not to exceed 5,555 gpm

Operations staff indicated that they would have treatment and hydraulic capacity available to treat future flows based on their current loadings and flows. During the July site visit, only one primary and secondary clarifier was operating as the other two were not needed due to the lower loadings and flows (see Figure 9-1).

Figure 9-1: Primary Clarifier

9.2.1.4 Existing Sanitary Sewer Collection System Capacity

From discussions with PVAMU operations staff, the existing sanitary sewer collection system has not experienced any major backups or had any issues with capacity throughout the campus.

The collection system ranges from 8” to 15” in sizes (see Appendix C). The actual pipe slopes are unknown at this point. Based on TCEQ’s Chapter 317 Design Criteria, the pipes could carry about **900 gpm (or 1.3 MGD)** of flow through them if they were installed at the minimum required slopes.

Based on the review of existing flow rates, that would indicate that the existing collection system could have an excess capacity of about **0.7 MGD**. This statement needs to be verified with actual collection system capacities based on actual installed slopes. Peak flows also need to be evaluated and determined if any bottle necks exist.

9.2.2 Proposed Sanitary Sewer Flows

Development will take place in three general phases as shown on Figure 5-1. To develop proposed flow rates, the gal/person or gal/SF developed in Section 9.2.1.2 was used.

The following provides anticipated sanitary sewer flow rates for each of the three development phases.

9.2.2.1 Phase 1 (2018 – 2022) Sanitary Sewer Projections

Phase 1 Improvements include the following Buildings:

- Police Station – 10,000 SF (F1)
- Meat Processing Facility – 20,000 SF (F2)
- ICCE Facility – 20,000 SF (F3)
- ROTC Building – 10,000 SF (F4)
- Cultural Arts Center – 21,000 SF (F5)
- Housing Units – 110,000 SF (F6)

Population is estimated to grow to 10,150 students and 1,350 employees which is an overall 1,300 person increase.

Using Population Projection

The overall projected flow rate increase based on a population increase of 1,300 people is projected to be 76,700 gpd. That number does not include the Meat Processing Facility. Based on industry knowledge, it is estimated that 42,800 gpd maximum could be generated at that facility alone. That would bring the total to 119,500 gpd or **0.12 MGD**.

Using SF Projection

It is assumed that Buildings F4 and F5 will be connected to the existing sanitary sewer system as they are being built on parts of the campus that are already fully developed.
Table 9-1 provides an overview of each building, square footage and how much flow is anticipated to be generated.

Table 9-1: Sanitary Sewer Projection Between 2018 and 2022

Building #	Building	SF	Anticipated Flow per SF	Anticipated Flow (gpd)
F1	Police Station	10,000	0.207	2,070
F2	Meat Processing Flow	20,000	*	42,800*
F3	ICCE Facility	20,000	0.207	4,140
F4	ROTC Building	10,000	0.207	2,070
F5	Cultural Arts Center	21,000	0.207	4,347
F6	Housing Units	110,000	0.207	22,770
	Total	**191,000**		**78,197**

*:Specialty Facility – did not use typical flow as it currently doesn't exist on campus. Used industry of slaughtering hogs and cattle instead to develop flow rate.

Recommended Flow Rate

Using the two different methods to determine the anticipated Phase 1 flow increase, it would be recommended to use the higher of the two or **0.12 MGD**.

Potential Impacts to Existing Sanitary Facilities

The Meat Processing Facility will include slaughtering of animals (cattle, goats, hogs). Information obtained from the project manager, Mr. Steve Monroe, indicates 15 cattle, 20 hogs, and 30 goats could be slaughtered at this facility per day.

Wastewater resulting from slaughtering activities can be very high in biochemical oxygen demand (BOD), nitrogen and total suspended solids (TSS). According to *Industrial and Hazardous Waste Treatment* by Nelson Leonard Nemerow and Avijit Dasgupta, BOD values could be as high as 2,240 mg/L, Nitrogen 324 mg/L, and TSS 929 mg/L (Table 26.18 on Page 439). As such, this waste would be considered high strength waste which would have an impact on the existing WWTP if directly discharged to it. It is recommended that this facility has its own wastewater pre-treatment plant.

9.2.2.2 Phase 2 (2022 – 2027) Sanitary Sewer Projections

Phase 2 Improvements include the following Buildings:

- Academic Building – 105,080 SF (F7)
- Lab Building – 32,320 SF (F8)
- Support Building – 21,450 SF (F9)
- Offices – 4,480 SF (F10)
- Student Activities Building – 18,860 SF (F11)
- Retail Office Building – 3,450 SF (F12)

- Housing – 137,560 SF (F13)

Population is estimated to grow to 11,150 students and 1,500 employees which is an overall 1,150 person increase from Phase I.

Using Population Projection

The overall projected flow rate increase based on a population increase of 1,150 people is projected to be 67,850 gpd or **0.07 MGD**.

Using SF Projection

Table 9-2 provides an overview of each building, square footage and how much flow is anticipated to be generated.

Table 9-2: Sanitary Sewer Projection Between 2023 and 2027

Building #	Building	SF	Anticipated Flow per SF	Anticipated Flow (gpd)
F7	Academic Building	105,080	0.207	21,750
F8	Lab Building	32,320	0.207	6,700
F9	Support Building	21,450	0.207	4,440
F10	Offices	4,480	0.207	1,000
F11	Student Activities	18,860	0.207	3,900
F12	Retail Office	3,450	0.207	700
F13	Housing	137,560	0.207	28,480
	Total	**323,200**		**66,970**

Recommended Flow Rate

Using the two different methods to determine the anticipated Phase II flow increase, it would be recommended to use the higher of the two or **0.07 MGD**.

9.2.2.3 Phase 3 (2027 – 2037) Sanitary Sewer Projections

Phase 3 Improvements include the following Buildings:

- Academic Building – 105,080 SF (F14)
- Lab Building – 32,320 SF (F15)
- Support Building – 21,450 SF (F16)
- Offices – 4,480 SF (F17)
- Student Activities Building – 18,860 SF (F18)
- Retail Office Building – 3,450 SF (F19)
- Housing – 137,560 SF (F20)
- Academic Building – 105,080 SF (F21)

- Lab Building – 32,320 SF (F22)
- Support Building – 21,450 SF (F23)
- Offices – 4,480 SF (F24)
- Student Activities Building – 18,860 SF (F25)
- Retail Office Building – 3,450 SF (F26)
- Housing – 137,560 SF (F27)

Population is estimated to grow to 13,150 students and 1,750 employees which is an overall 2,250 person increase to Phase 2.

Using Population Projection

The overall projected flow rate increase based on a population increase of 2,250 people is projected to be 132,750 gpd (**or 0.133 MGD**).

Using SF Projection

Table 9-3 provides an overview of each building, square footage and how much flow is anticipated to be generated.

Table 9-3: Sanitary Sewer Projection Between 2028 and 2037

Building #	Building	SF	Anticipated Flow per SF	Anticipated Flow (gpd)
F14	Academic Building	105,080	0.207	21,750
F15	Lab Building	32,320	0.207	6,690
F16	Support Building	21,450	0.207	4,440
F17	Offices	4,480	0.207	900
F18	Student Activities Bldg	18,860	0.207	3,900
F19	Retail Office Bldg	3,450	0.207	700
F20	Housing	137,560	0.207	28,500
F21	Academic Building	105,080	0.207	21,750
F22	Lab Building	32,320	0.207	6,690
F23	Support Building	21,450	0.207	4,440
F24	Offices	4,480	0.207	900
F25	Student Activities Bldg	18,860	0.207	3,900
F26	Retail Office Bldg	3,450	0.207	700
F27	Housing	137,560	0.207	28,500
	Total	**646,400**		**133,760**

Recommended Flow Rate

Using the two different methods to determine the anticipated Phase 3 flow increase, both flows were approximately identical. A flow rate of **0.133 MGD** is recommended.

Recommended Flow Rate Overview

Table 9-4 provides an overview of each building, square footage and how much flow is anticipated to be generated.

Table 9-4: Sanitary Sewer Projection for Each Phase

Phase	Anticipated Flow (gpd)
1	120,000
2	70,000
3	133,000
Total	**323,000**

9.2.3 Recommended Improvements

Based on the developed flow rates in Section 9.2.2 (see Table 9-4) the following recommendations are provided:

9.2.3.1 Phase 1 (2018 – 2022) Recommendations

Given the anticipated sanitary sewer generated of 0.120 MGD and the available existing sanitary sewer collection system excess capacity of 0.70 MGD (Section 9.2.1.4), the new sanitary sewer lines can be directly connected to the existing sanitary sewer system. The exact connection point(s) should be evaluated further to determine which sewer line can handle the peak flows.

The WWTP has an excess capacity of about 0.8 MGD and therefore should be able to handle the additional flow rate of 0.12 MGD. The Meat Processing Facility will be required to install a pre-treatment system since that flow will be considered high strength waste.

9.2.3.2 Phase 2 (2022 – 2027) Recommendations

Given the anticipated sanitary sewer generated of 0.07 MGD and the available existing sanitary sewer collection system excess capacity of 0.58 MGD (0.70 – 0.12 MGD from Phase I), the new sanitary sewer lines can be directly connected to the existing sanitary sewer system. The exact connection point(s) should be evaluated further to determine which sewer line can handle the peak flows.

The WWTP has an excess capacity of about 0.68 MGD (0.80 – 0.12 MGD from Phase I) and therefore should be able to handle the additional flow rate of 0.07 MGD.

9.2.3.3 Phase 3 (2027 – 2037) Recommendations

Given the anticipated sanitary sewer generated of 0.133 MGD and the available existing sanitary sewer collection system excess capacity of 0.45 MGD (0.58 – 0.13 MGD from Phase 2), the new sanitary sewer lines can be directly connected to the existing sanitary sewer system. The exact connection point(s) should be evaluated further to determine which sewer line can handle the peak flows.

The WWTP has an excess capacity of about 0.55 MGD (0.68 – 0.13 MGD from Phase 2) and therefore should be able to handle the additional flow rate of 0.133 MGD.

9.3 STORM SEWER

9.3.1 Proposed Storm Runoff

Stormwater runoff calculations for the planned campus expansion were performed using the Rational Method with design storm intensities from the Unified Stormwater Design Guidelines, City of Bryan City of College Station (August 2012). College Station, TX is approximately 50 miles southeast of Prairie View, and is the location of the main Texas A&M University campus. The stormwater requirements for College Station were compared to those of Houston, TX, which is the next adjacent larger City with specific stormwater requirements, and found that the College Station assumptions produced more conservative runoff values. The new campus growth area is approximately 3.8 acres and was assumed to be almost entirely impervious. For this reason, a rational coefficient in the upper range for “Commercial” land use of 0.90 was assumed. A conservative time of centration of 5 minutes was also assumed to calculate the 2-, 10-, 25-, and 100-year rainfall intensity. Table 9-5 summarizes the results of these calculations for the new campus growth.

Table 9-5: New Campus 10-Year Stormwater Runoff Calculations

Design Storm	Rainfall Intensity (in/hr)[1]	Design Flow Rate (cfs)
2-Year	8.22	28.24
10-Year	10.37	35.61
25-Year	12.51	42.94
100-Year	14.76	50.68

Unified Stormwater Design Guidelines, City of Bryan City of College Station (August 2012).

[1] Table C-1 Equations for Calculating Rainfall Intensities; assuming 5-minute time of concentration.

[2] Table C-2 Runoff Coefficients (c) By Land Use Type; assume "Commercial" land use.

9.3.2 Recommended Improvements

It is recommended that a storm sewer conveyance system be designed to convey the 10-year design storm runoff from the new development site. This would require a 24 to 30-inch diameter storm sewer pipe for conveyance of the peak flow rate from the new campus site, assuming a pipe slope between 0.5 and 2.0% can be achieved. It is recommended that additional analysis be completed to determine the size and location of inlets needed to collect the 10-year design storm, as well as a capacity evaluation of the existing streets to determine ability to convey the 100-year design storm within the street cross section without overtopping the curb.

It is also recommended that detention requirements be reviewed in relation to the future full campus expansion. Section 6.09 of the City of Prairie View Code of Ordinances requires detention to control any increases in stormwater resulting from an increase in the impervious surface of the site. Depending on future expansion grading and drainage path limitations, a single detention facility could potentially be designed for the entire expansion. Lastly, the capacity of the existing channel and lake to the north of the site should be evaluated to determine effect of additional flow from the new campus development on the downstream receiving water body.

9.4 NATURAL GAS DISTRIBUTION SYSTEM

Natural gas is supplied to the PVAMU main campus by the Energy Transfer Company (ETC) Katy pipeline. Natural gas is primarily used as fuel for the steam boilers in FTPP. Natural gas is also used to run the standby natural gas generator in Hobart Thomas Taylor Sr. Hall and to fuel local hot water boilers in the Nursing building and Hobart Thomas Taylor Sr. Hall that are not connected to the central steam distribution network.

- The campus buildings' demand is driven by the boilers, standby natural gas generators, water heaters and unit heaters around campus
- The yearly natural gas consumption on main campus is 131,262 MCF according to Ameresco.

It is assumed that this existing natural gas line has sufficient capacity for today's existing installed load and future campus expansion including the installation of CHP capacity.

It is also assumed that all buildings have sufficient natural gas service to serve local hot water boilers and/or process steam loads. BMcD recommends performing a survey to confirm this assumption prior to implementing the central steam to local heating hot water conversion in Option 1 and the central steam to central heating hot water conversion in Option 2.

PVAMU has mentioned the possibility of extending a new natural gas line to campus from Texas A&M. The bulk rate for gas from this line is approximately $3/MCF. The estimated gas rate PVAMU currently receives is $2.904/MCF, however, PVAMU has indicated that they pay a brokerage fee of 15-18%. With the brokerage fee, the PVAMU gas rate increases to at least $3.34/MCF. PVAMU should consider this gas line extension if the gas rate currently charged to PVAMU is enough to offset the capital costs to install the line. The gas rate used in the analysis within this report is $2.904/MCF, which does not include the brokerage fee. BMcD also assumed that the supply pressure available on campus is 45 psig based on info supplied by PVAMU.

There is not a published tariff for the natural gas service at PVAMU. The fuel is bought on a commodity market at varying rates. The natural gas rate in the Ameresco report was determined by taking the total cost of the gas service in the 12-month review period and dividing it by the total consumption over the 12-month period for an average rate of $2.904/MCF. For analysis purposes, BMcD used the natural gas rate as indicated by Ameresco.

9.4.1 Existing System Review

The existing system was reviewed to determine existing pipe sizes throughout the campus. A base file, in addition with a mylar drawing were used to generate an assume overall existing gas distribution plan and pipe sizes. In several locations, existing pipe sizes were not able to be determined as noted on the overall gas line plan in Appendix C. The existing metering station is located in the southeast corner of the existing campus. The existing base file drawings identify a 6-inch gas line upstream of the meter and feeding the campus.

Figure 9-2: Existing Gas Metering Station

Correspondence with Lee Papayoti of Energy Transfer, indicated they have capacity to deliver the proposed 31,000 MBtu/hr flow rate, in addition to the current flows, to the campus at the current delivery pressure. Historical data provided, indicated that 31,000 MBtu/hr would roughly triple the campus's natural gas usage. With the addition of this load, it was noted the metering station and some upstream facilities will likely require modifications.

9.4.2 Recommended Improvements

Phase 1, 2 and 3, were analyzed based on the proposed future facilities and associated loads. It was assumed that new metallic pipe would be used for the new gas line piping feeding the facilities. In addition, it was assumed that the facilities would not require more than 2psi of pressure. A geotechnical investigation would be required to determine if the area soils are corrosive, however, with Texas soils tending to be corrosive in nature, metallic buried pipe would likely require protection against corrosion.

Proposed pipe sizes associated with the three phases are located in exhibits found in Appendix C. In Table 9-6 below, a summary of proposed facilities, assumed loads, and associated proposed pipe sizes is shown.

Table 9-6: Proposed Natural Gas Loads and Pipe Sizes

Phase	Key	Building	Proposed Buliding Loads (MBH)	Proposed Pipe Size (inch)*
1	F1	Police Station	220	1-1/4"
1	F2	Meat Processing Facility	1690	3"
1	F3	ICCE Facility (lab)	570	2"
1	F3B	ICCE Facility (office)	290	1-1/2"
1	F4	ROTC Building	220	2"
1	F5	Cultural Arts Center	450	2-1/2"
1	F6	Housing 2 (From 2011 Campus MP)	2330	4"
2	F7	Future Academic Building	2160	4"
2	F8	Future Lab Space / Building	2660	3"
2	F9	Future Support Building	440	1-1/4"
2	F10	Future Office	100	3/4"
2	F11	Future Stud. Activities Building	390	1-1/4"
2	F12	Future Retail Office Building	80	1"
2	F13	Future Housing Building	2830	4"
3	F14	Future Academic Building	2100	4"
3	F15	Future Lab Space / Building	2580	3"
3	F16	Future Support Building	430	1-1/4"
3	F17	Future Office	90	1/2"
3	F18	Future Stud. Activities Building	380	1-1/4"
3	F19	Future Retail Office Building	70	1"
3	F20	Future Housing Building	2750	5"
3	F21	Future Academic Building	2040	3"
3	F22	Future Lab Space / Building	2500	4"
3	F23	Future Support Building	420	1-1/4"
3	F24	Future Office	90	1/2"
3	F25	Future Stud. Activities Building	370	1-1/4"
3	F26	Future Retail Office Building	70	1"
3	F27	Future Housing Building	2660	6"
Full Buildout		CUP-2 Capacity (full buildout)	50000	6"

*Assumes steel pipe and pressure under 2psi

With this being a planning effort, future calculations and discussions will be required to ensure all pressures meet the demand of future facilities at the time of installation.

* * * * *

SECTION 10.0

THERMAL ENERGY STORAGE

10.0 THERMAL ENERGY STORAGE EVALUATION

10.1 PURPOSE

The purpose of the thermal energy storage (TES) analysis is to determine if TES can potentially be a viable solution for PVAMU to offset or delay capital costs and improve operating costs. The analysis provides information related to total cost of ownership – capital costs, energy costs, and operation & maintenance (O&M) costs for TES to offset the planned capital improvement of additional electric driven chillers on campus.

10.2 DEVELOPMENT OF OPTIONS

PVAMU currently has one central utility plant (Fry-Thomas Power Plant) which was built in 1916. The Fry-Thomas Power Plant has five electric chillers with a total operating capacity of 4,600 tons. The analysis has indicated that Prairie View expects their annual chilled water demand to increase from 12,643,740 ton-hrs in 2017 to 15,155,219 ton-hrs by the year 2023, with the peak growing from 4,400 tons to 5,300 tons respectively.

To meet the additional demand for chilled water, thermal energy storage (TES) is evaluated to handle the increased chilled water demand in lieu of additional chiller capacity.

10.3 TECHNICAL EVALUATION

10.3.1 Methods

The thermal energy storage tank is sized to offset additional cooling capacity needed to meet chilled water demand at peak load. This approach projects that a 10,000 ton-hr tank be used. A thermal energy storage tank is added to the model and analyzed in three different options (Full Load Shed, Partial Load Shed, and Load Leveling Load Shed). The chosen strategy allows for a portion of the load to be shifted to non-peak hours of the day for everyday of the year. The charge and discharge strategy of the tank is optimized based off current equipment capacities, efficiencies, daily peak tonnage, and utility costs.

10.3.1.1 Operations with Thermal Energy Storage

10.3.1.1.1 Pumping Configuration

The estimates include the installation of a TES dedicated pumping station, as location of the plant would be defined at a later development stage. This is the conservative approach allowing the tank to be placed anywhere in the campus as long as the distribution mains are adequate in that area to get the water distributed as need be. For the cost estimate, it was assumed that the location would be within 100' of large mains.

The TES tank should be located adjacent to the future CUP-2. Then as that plant is built out, the distribution pumps of that plant could be used with the thermal storage system. This becomes the easiest system to operate with the tank system becoming self-balancing and only one set of new distribution pumps in a primary/secondary pumping configuration is required overall.

10.3.1.1.2 Static Height / Elevation of the Tank

As siting is developed in the next development stage, the height of the tank and the elevation of the site become items for consideration. As the tank is open and operates at atmospheric pressure, it will effectively “reset” the base reference pressure of the campus chilled water system. For coils at an elevation at or below the tank height, this is not an issue. For tall buildings, that are currently connected directly to the distribution system (not decoupled by a heat exchanger), evaluation of modifications will be required. These changes could include decoupling those buildings or adding pressure sustaining valves at those locations. Based on a preliminary review of data and input, it appears that this would be a limited number of locations.

10.3.2 Results

The 2017 base case as provided by Prairie View A&M has a maximum peak load of 4,405 tons of cooling. The graph below provides a curve of the 2017 yearly campus cooling load.

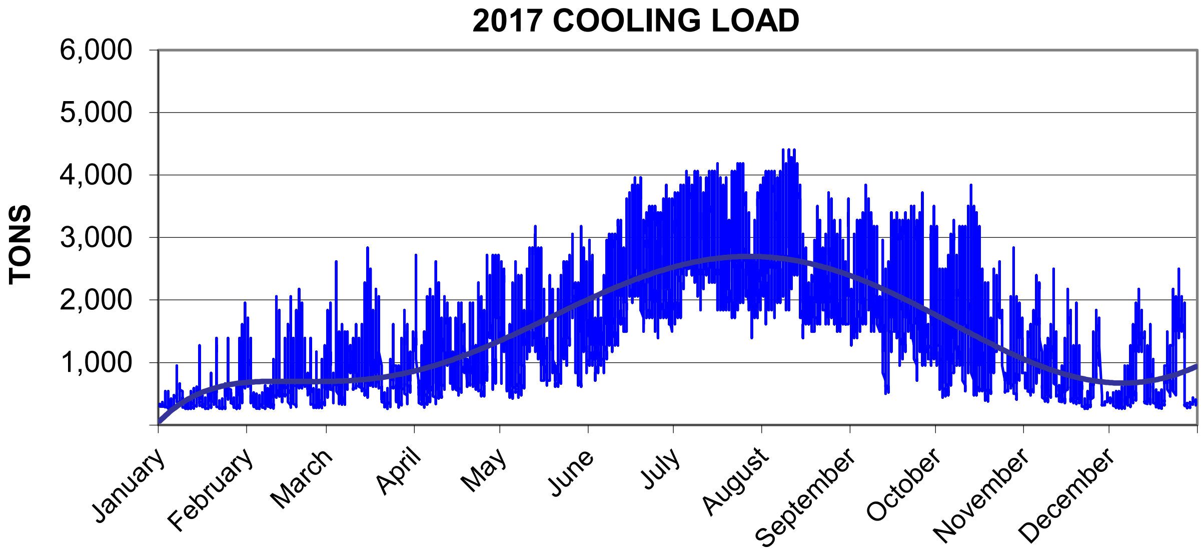

Figure 10-1: 2017 Campus Cooling Load

Based on 2023 projected cooling loads, the maximum projected campus cooling load is 5,259 tons of cooling. The graph below provides a projected curve of the 2023 yearly campus cooling load. This load is used to analyze if TES is a viable solution.

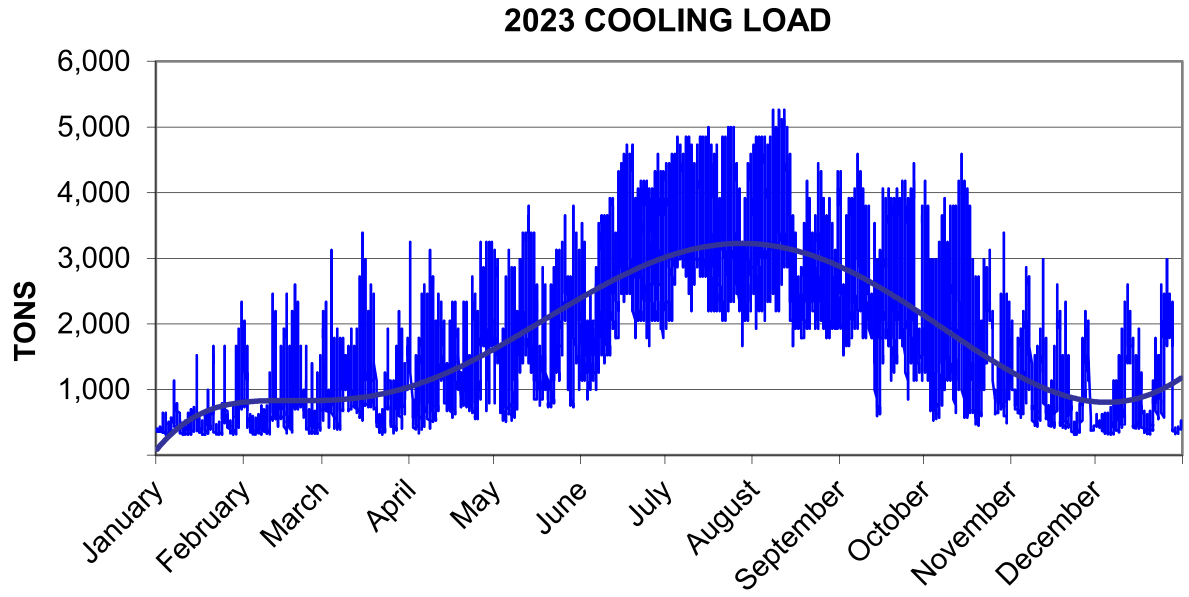

Figure 10-2: 2023 Campus Cooling Load

Using the 2023 projected load, the graph below represents how cooling capacity is produced on the peak day while using TES. Utilizing the firm chiller capacity of 4,600 tons in conjunction with 10,000 ton-hr TES tank, the maximum cooling load of 5,259 tons is able to be handled with 3,720 tons of chiller capacity, which is less than the projected total chiller capacity required without TES. The TES tank makes up the 1,539 tons of capacity needed by shifting that cooling load to non-peak hours of the day. The shift in cooling load reduces the need for chiller capacity during the peak period of the day and shifts it to chiller production during non-peak periods. Under this situation, the TES tank will charge from 10pm to 9am (non-peak hours) and discharge from 10am to 9pm (peak hours). If the same graph were used without TES, the cooling load will need to be met with firm capacity requiring additional chillers.

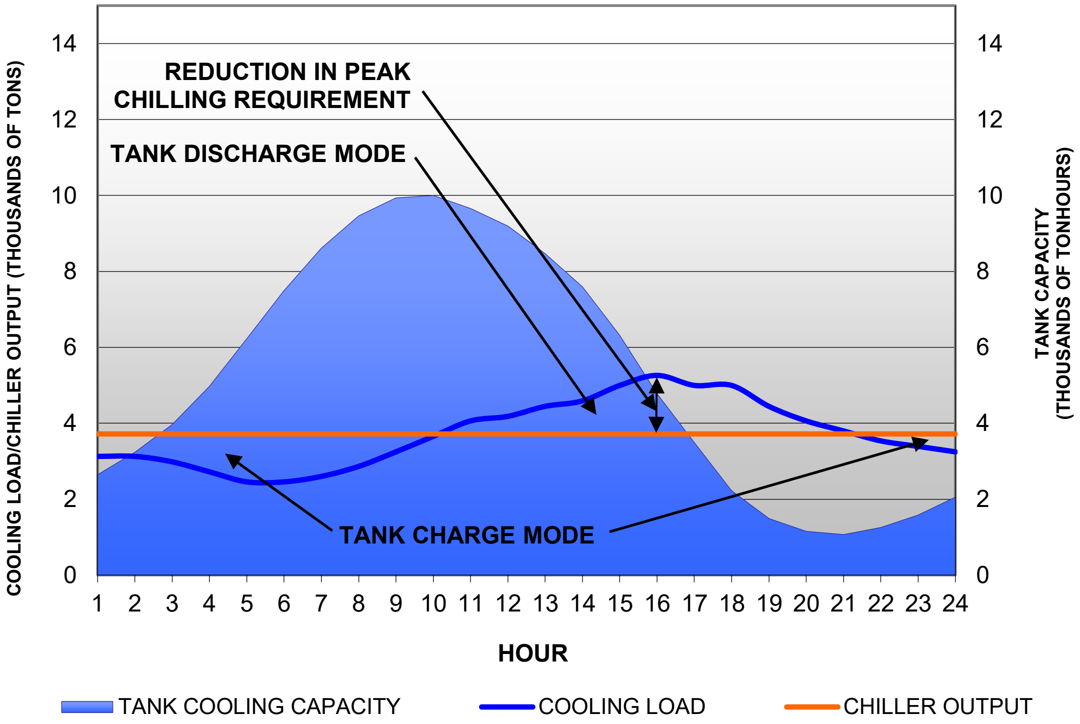

Figure 10-3: Daily Cooling Loads

10.4 COST ESTIMATE

Cost estimates presented in this section are based on budget information received from vendors, unitized costs from recent projects, and/or industry standard and references.

The estimated capital cost for a remote thermal energy storage tank is $3,753,470. The capital cost is shown in Table 10-1.

Table 10-1: TES Capital Cost Estimate

2023 LOAD LEVELING TES - 10k TON-HRS						
Thermal Energy Storage	**Qty.**	**Capacity (Each)**	**Total Capacity**	**Units**	**Unit Estimate**	**Total Estimate**
10,000 Ton-hr Thermal Energy Storage Tank	1	1,333,333	1,333,333	gallons	$1.50	$2,000,000
TES Chw pumps (for remote location only) with VFDs - 4000 gpm, 240 ft head	2	300	600	hp	$135	$81,000
500 sf building for pumps, VFDs	1	500	500	sf	$325	$162,500
14" Piping and Fittings	150	1	150	lf	$600	$90,000
Plant Control System	1	27	27	pts	$1,500	$40,500
Controls	**Qty.**	**Capacity (Each)**	**Total Capacity**	**Units**	**Unit Estimate**	**Total Estimate**
Pump Controls	2	6	12	pt.	$1,500	$18,000
Electrical Controls	1	30	30	pt.	$1,500	$45,000
Electrical	**Qty.**	**Capacity (Each)**	**Total Capacity**	**Units**	**Unit Estimate**	**Total Estimate**
15kV Medium Voltage Cable/Raceway - TES	1	600	600	ft	$100	$60,000
480V Transformer	1	1	1	Ea.	$75,000	$75,000
480V Motor Control Centers	1	1	1	Ea.	$75,000	$75,000
Low Voltage Equipment Balance of Plant	1	1	1	Ea.	$15,000	$15,000
Low Voltage Cables/Raceway	1	1	1	Ea.	$25,000	$25,000
Sub-Total						**$2,687,000**
Soft Costs & Contingencies				**Cost**	**Sub-Total**	**Total Estimate**
General Conditions				2.0%	$53,740	$2,740,739
Design Contingency (10%)				10%	$268,700	$3,009,439
Construction Contingency (10%)				10%	$268,700	$3,278,139
Total with Contingencies						**$3,278,139**
Design & CA				8%	$262,251	$3,540,391
Construction Management				5%	$163,907	$3,704,298
Commissioning				1.5%	$49,172	$3,753,470
Total with Contingencies & Professional Services						**$3,753,470**

* Cost are estimates of probable construction cost and are estimated in 2017 dollars.

* 50' piping assumed for piping to and from TES tank to nearest header.

* TES cost includes simple ring foundation (no pilings, piers, etc.)

* Cost opinions, financial opinions, and projections prepared by ENGINEER relating to construction costs and schedules, operation and maintenance costs, equipment characteristics and performance, and operating results are based on ENGINEER'S experience, qualifications, and judgment as a design professional. Since ENGINEER has no control over weather, cost and availability of labor, material and equipment, labor productivity, construction Contractors' procedures and methods, unavoidable delays, construction Contractors' methods of determining prices, economic conditions, competitive bidding or market conditions and other factors affecting such cost opinions or projections, nor is ENGINEER a financial advisor, ENGINEER does not guarantee that actual rates, costs, performance, schedules, financial and related items will not vary from cost opinions and projections prepared by ENGINEER.

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SECTION 11.0
HEAT PUMP CHILLER EVALUATION

11.0 HEAT PUMP CHILLER EVALUATION

11.1 HEAT PUMP CHILLER

11.1.1 Purpose

The purpose of this evaluation is to determine the relative benefit of installing a heat pump chiller in Option 2 at PVAMU as compared to the use of only boilers and chillers to meet heating and cooling loads. Utilizing a heat pump chiller will decrease the efficiency on the cooling side, but will increase the efficiency on the heating side, resulting in an overall efficiency much greater than a chiller and boiler alone.

11.1.1.1 Background

In large chilled water applications, water cooled chillers extract heat from the warmer chilled water return flowing into the evaporator and reject it into the water flowing through the condenser. In a typical chiller, this heated condenser water is pumped to a cooling tower where the heat is rejected to atmosphere and essentially “wasted”. In a heat pump chiller application, this rejected heat is harnessed to and injected into the heating hot water system. A heat pump chiller works by extracting the heat from the return chilled water into the refrigerant of the heat pump chiller. The vaporized refrigerant is then sent to the compressors where energy is added that raises the pressure and temperature of the refrigerant. The high temperature refrigerant is then sent to the condenser where it heats the hot water returning from campus.

The useful energy in a heat pump chiller is the energy rejected to the hot water source as well as the chilled water output. The input energy is the electricity used to power the heat pump chiller. By utilizing the normally wasted energy to the cooling tower, heat pump chillers can be much more efficient than gas boilers. This can result in considerable net energy savings.

Heat pump chillers also do not require cooling tower capacity to run, so there are maintenance and ancillary cost benefits. Running less towers decreases the makeup water load and subsequently chemical costs because cooling tower evaporation losses do not have to be replenished. When adequately sized, heat pump chillers can also sometimes cover the campus winter cooling load which eliminates the need to run the towers in cold weather when freezing and plume are of greater concern.

However, a heat pump chiller's effectiveness relies on the balance of heating and cooling loads on campus. During cold days, the chilled water load may be too small to adequately reject heat to the hot water side of the heat pump chiller. Likewise, during hot days, the heating hot water load may be too small to accept rejected heat from the chilled water side of the heat pump.

Various sizes were reviewed to add thermal capacity. Units larger than 700 tons resulted in reduced financial benefits due to limits in run hours associated with less coincident loads. Eventually, the campus heating hot water load will increase so that one 700-ton heat pump chiller will be viable.

11.1.1.2 Technology

Heat pump or "heat recovery" chillers allow waste heat generated during the production of chilled water, which is normally rejected through a cooling tower, to be recovered and used to produce "free" heating hot water. This can result in substantial natural gas savings for the University, resulting from reduced boiler run hours. These chillers are capable of producing heating water temperatures from 110°F to 170°F, with a typical supply temperature of approximately 140°F to 155°F. Heat pump chillers are available in various sizes ranging from small 30 ton packaged units to large 6200-ton field erected machines. There are many benefits to heat pump chillers aside from the natural gas savings, including:

- Reduced required makeup water due to cooling tower evaporation
- Reduced boiler carbon footprint
- Reduced usage of water treatment chemicals

Equipment first cost is a major consideration when evaluation the feasibility of any heat pump chiller project. While most commercial electric centrifugal chillers can be purchased for approximately $300/ton, it is not uncommon for a heat pump chiller's first cost to exceed $1,000/ton. Some of this additional first cost can be offset when cooling tower costs are considered. If the chiller is to be operated with a coincident heating and cooling load only, the chiller can operate with no cooling tower as all heat will be rejected to the heating hot water loop. However, a cooling tower, heat exchanger, or other means of heat rejections will be required if load or operational conditions require the chiller be operated to produce chilled water only.

The efficiency of a heat pump chiller is heavily dependent on the temperature of the hot water produced. As the required temperature of the hot water is increased, the chiller's efficiency will generally decrease. The typical efficiency of a heat recovery chiller, supplying 150°F water, is approximately 1.4 kW/ton. This efficiency is much lower than typical electric chillers, which typically operate at or below 0.6 kW/ton. The cost of the additional electricity consumed is typically more than offset by the gas costs avoided through the production of "free" hot water.

11.1.1.3 Analysis

To maximize chiller efficiency and potential payback periods, a heat pump chiller should operate as close as possible to 100% capacity, as often as possible. As such, correct sizing of the chiller is critical for proper operation. An analysis using the 5-year (2023) heating and cooling loads resulted in a recommended chiller size of 500 tons. This use of a heat pump chiller will only be ideal during the Option 2 scenario. As discussed above, elevated hot water supply temperatures reduce the chiller's efficiency. It is recommended that the heat pump chiller produce a supply temperature not to exceed 155°F to maximize efficiency. As a result, the heat pump chiller would be used to pre-heat boiler return water thus resulting in a more efficient boiler operation when supply temperatures exceed 155°F. During non-heating season where heating water supply temperatures are not as high, the heat pump can supply heating hot water directly to the campus.

A graph of the campus 2023 chilled and heating hot water loads with and without the 500-ton heat pump chiller is presented below in Figure 11-1.

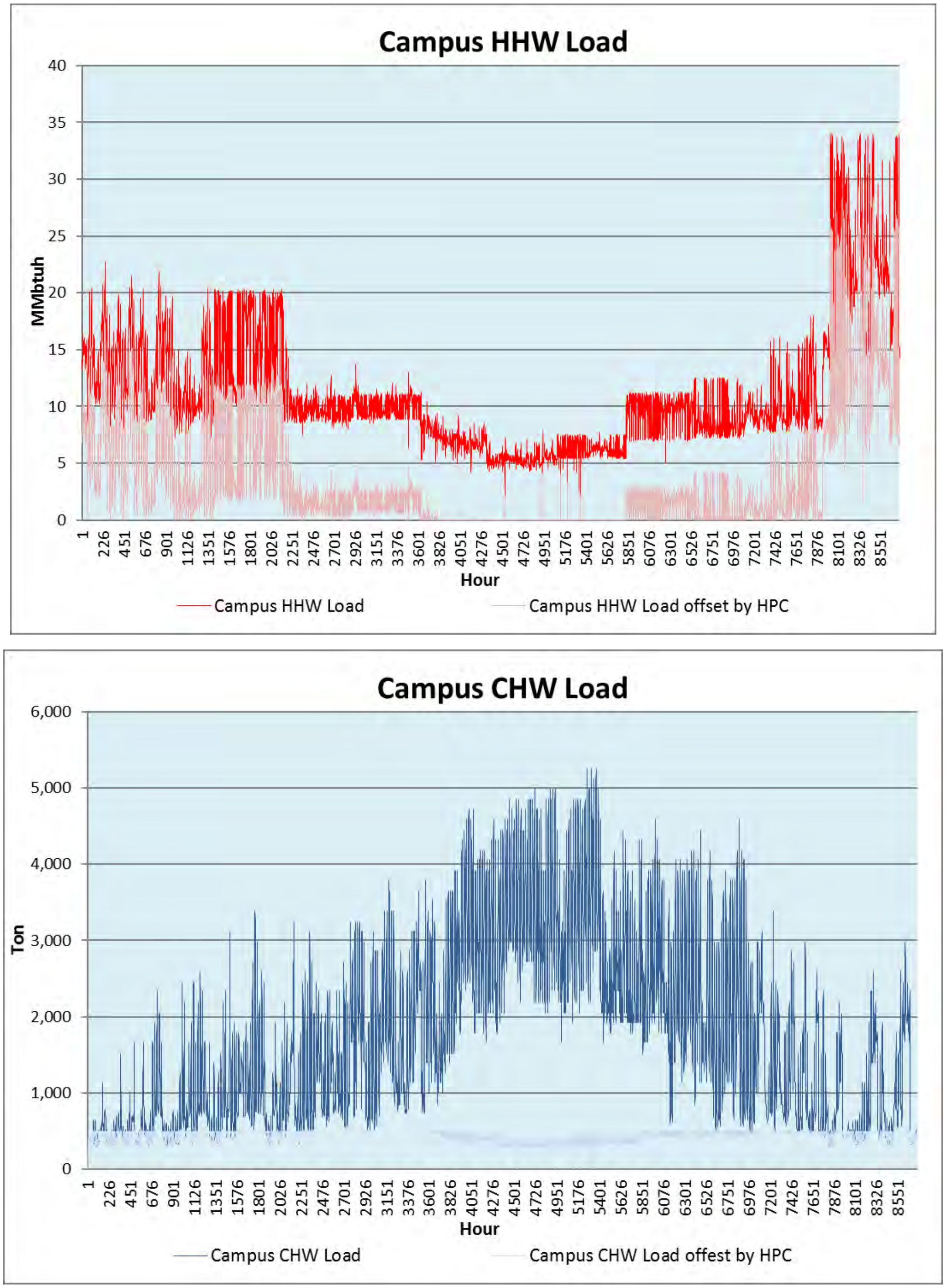

Figure 11-1: Campus CHW and HHW Load with HPC

SECTION 12.0

COMBINED HEAT AND POWER

12.0 COMBINED HEAT AND POWER

12.1 PURPOSE

The purpose of this evaluation is to determine the benefit of installing combined heat and power (CHP) capacity to serve the energy needs of Prairie View A&M University. This high-level look focuses on the simple payback of a single CHP option.

Figure 12-1, found in the EPA's "Catalog of CHP Technologies," shows the efficiency advantage of CHP compared with conventional central station power generation and onsite boilers. When considering both thermal and electrical processes together, CHP typically requires 75 percent of the primary energy that separate heat and power systems require. CHP systems utilize less fuel than separate heat and power generation, resulting in the same level of output with fewer greenhouse gas (GHG) emissions. The CHP unit will use natural gas as fuel, which generates less GHG emissions than the combination of natural gas, coal, and other fuels that are burned by the utility to generate the electricity that PVAMU would otherwise be purchasing from the grid.

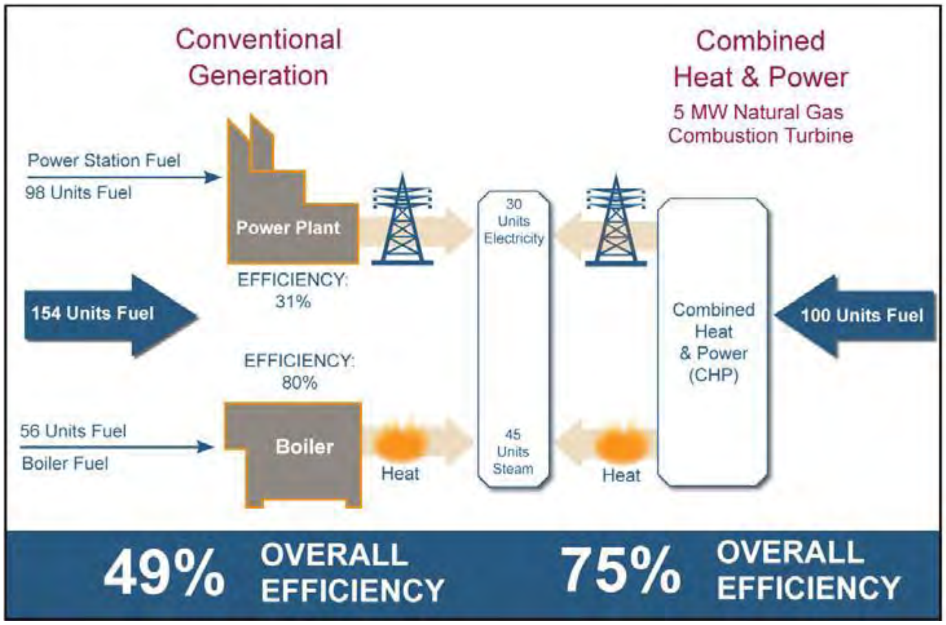

Figure 12-1: CHP versus Separate Heat and Power Generation

Note: Assumes national averages for grid electricity and incorporates electricity transmission losses.

Combined heat and power technology is used to generate electricity to offset electrical purchases from the grid while capturing the exhaust energy to meet the heat demand of the campus. For the current campus loads, BMcD used a reciprocating engine and a heat recovery steam generator (HRSG) as the CHP train. A reciprocating engine was chosen over a combustion turbine because of the reciprocating engine's lower heat output.

12.2 CAMPUS LOADS

BMcD analyzed the existing campus loads to select the recommended CHP train. Metered steam data was not available. PVAMU should consider implementing a steam metering program to better understand the steam loads on campus. Originally, the provided natural gas consumption was used to estimate the steam production of the campus boilers. The natural gas consumption was only provided in monthly increments from September 2010 – February 2016. For analysis purposes, BMcD used the natural gas loads from the most recent, full year (January – December 2015). The summary of natural gas consumption and associated production of 150 psig saturated steam by boilers assumed to be 80% efficient is shown in the following table.

Table 12-1: Natural Gas Consumption and Associated Steam Load

	NG Consumption	Assumed PVAMU Steam Load
	(MCF)	(lbs/hr)
Max	16,454	18,288
Avg	10,614	12,031
Min	5,637	6,266

For a campus the size of PVAMU and the given boiler firm capacity of 56,000 MBH (approximately 56,000 lb/hr), the maximum campus steam load calculated from the natural gas consumption appears to be low. A paragraph in the Ameresco report (pg. 52) states:

> *The plant is reportedly in operation year-round. Summer heating loads are typically handled by one of the 600- to 750- HP boilers, which typically operate at less than 50 percent of capacity. Winter heating loads are handled by a combination of the smaller units or by the larger unit alone. Winter heating loads typically represent less than 75*

> *percent of the capacity of the largest (1,200 HP) boiler. Winter operation is reportedly limited to mid-December to mid-February.*

Given the constraints listed in the Ameresco report, the PVAMU steam loads appear to be closer to:

Table 12-2: PVAMU Assumed Steam Loads

	Assumed PVAMU Steam Load (lbs/hr)
Max	30,137
Avg	N/A
Min	10,046

However, after the original CHP analysis performed by Burns & McDonnell, a steam load factor was agreed upon and implemented to estimate calculate campus loads. Burns & McDonnell adjusted peak loads to match those calculated by the steam load factor. The steam load factor assumed for each campus building type is summarized in Table 4-2.

Given the steam load factors, the PVAMU steam loads used in the CHP analysis are:

Table 12-3: PVAMU Assumed Steam Loads for CHP Analysis

	Assumed PVAMU Steam Load (lbs/hr)
Max	25,232
Avg	N/A
Min	8,645

Using a ratio of the steam loads calculated by load factor to steam loads calculated by natural gas consumption, the following monthly steam loads were predicted.

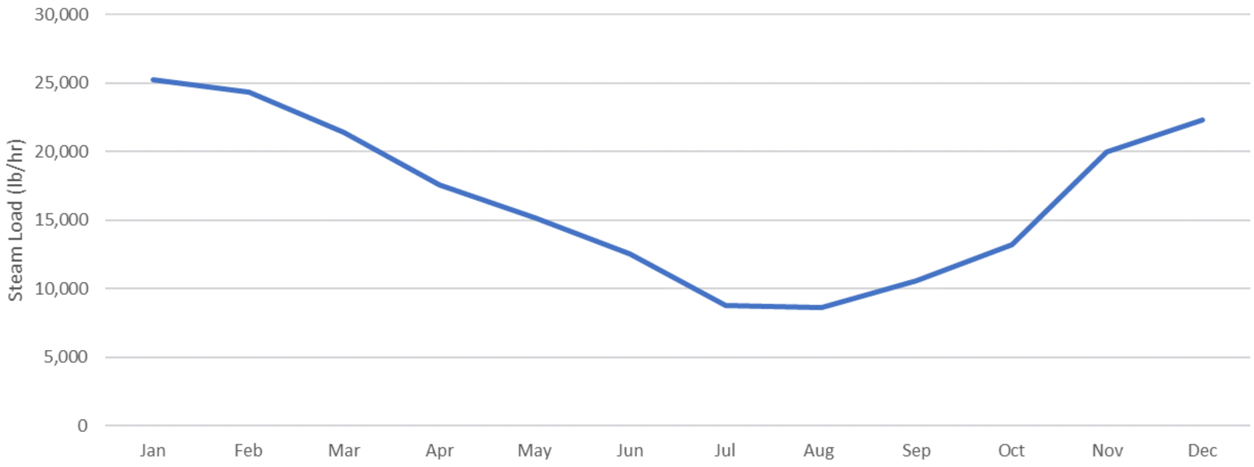

Figure 12-2: Monthly Steam Loads

If PVAMU implemented new steam metering technology, the campus would have an accurate account of steam consumption and would be better suited to confidently select CHP technology. Without the metered data, the steam loads above are based off assumptions.

The existing campus electric loads were based on 8760 data provided by Ameresco. This data assumes the Energy Conservation Measures (ECM) proposed in the Ameresco report have been completed. The summary of the campus electric load is summarized in the table below.

Table 12-4: PVAMU Electric Loads

PVAMU Electric Load (kW)	
Max	7,051
Avg	3,842
Min	1,618

An annual hourly graph of the campus electric load is shown below.

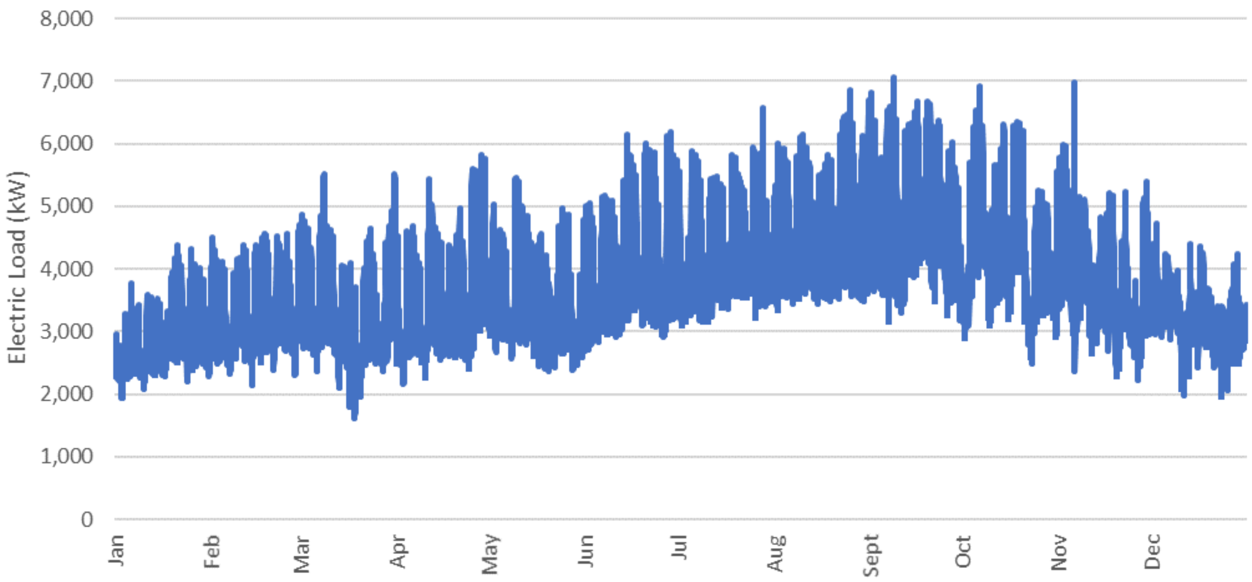

Figure 12-3: Electric Loads

12.3 CHP TECHNOLOGY

Given the estimated loads, the installation of (1) Jenbacher J624 4.4 MW reciprocating engine and (1) 4,250 lb/hr HRSG was analyzed. CHP was only analyzed for the Base Case, when steam is used for heating. The engine's heat output at 4,250 lb/hr is under the campus minimum steam load. A turbine that generates approximately the same amount of electricity as the J624 has a steam generating capacity of approximately 17,000 lb/hr. The turbine would be thermally limited the majority of the year months unless excess steam was vented. When the turbine is thermally limited and operating at part load, CHP does not have the ability to make up for its high capital cost. The benefit of reduced utility costs only comes when the CHP equipment is online and offsetting electricity purchases with natural gas consumption. In the current installation, the CHP train will load follow. The CHP unit will not generate excess power to sell back to the grid.

With the proposed reciprocating engine configuration, the existing campus boilers will still be necessary to meet campus steam load. The CHP installation will reduce current steam production by the campus boilers by 23%. Current electricity purchases will be reduced by 93%, and the amount of natural gas consumed will increase by 122%.

While PVAMU has mentioned the possibility of extending a new natural gas line to campus from Texas A&M, this was not included in this CHP analysis. BMcD assumed for sake of this analysis that the existing natural gas supply on campus has sufficient capacity to serve the CHP installation. If CHP progresses to the next level of design, this assumption will need to be verified. BMcD also assumed that the supply pressure available to the reciprocating engine is 45 psig based on info supplied by PVAMU. A natural gas compressor will be required to increase the pressure of the natural gas up to the level required by the engine (at least 87 psi).

12.4 ECONOMIC ANALYSIS

According to the Ameresco report, electrical service for main campus is provided via a primary voltage service account by San Bernard Electric Cooperative (SBEC). The blended electricity rate for the main campus is $0.0814/kWh. If CHP progresses into the next level of design, the full electric tariff structure should be included in the analysis rather than the blended rate.

There is not a published tariff for the natural gas service at PVAMU. The fuel is bought on a commodity market at varying rates. The natural gas rate in the Ameresco report was determined by taking the total cost of the gas service in the 12-month review period and dividing it by the total consumption over the 12-month period for an average rate of $2.904/MCF. For analysis purposes, BMcD used the natural gas rate as indicated by Ameresco. PVAMU staff noted that a 15-18% brokerage fee was included on top of the natural gas costs, however, this fee was not included as part of the analysis. However, if CHP progresses into the next level of design, the most recent year’s natural gas rates are provided to recalculate the gas rate.

Given the current electricity and natural gas prices, the campus utility costs will be reduced by approximately $1.8 million dollars per year. With an assumed capital cost of $25 million for the CHP installation within a new plant, the estimated payback of this CHP installation is roughly 13.5 years.

* * * * *

SECTION 13.0

ADDITIONAL CAMPUS IMPROVEMENTS

13.0 ADDITIONAL CAMPUS IMPROVEMENTS

The following services were not included within the scope of the Utility Master Plan, however, PVAMU could benefit from each of the following services. Burns & McDonnell can provide a proposal for these items upon request as an additional service.

13.1 CAMPUS BUILDING IMPROVEMENTS

PVAMU personnel expressed safety concern for specific 480V electrical equipment such as motor control centers (MCCs), switchboards, and transformers located within various buildings throughout campus. BMcD recommends replacing this equipment due to safety concerns based on age and location of the equipment.

There is a 12.47kV-480V, 1500kVA GE silicone fluid transformer located on the second floor of the Hobart Thomas Taylor Sr. Hall. PVAMU personnel expressed safety concern that there is no ventilation in this electrical room and the transformer is aged. There is also an aged GE 480/277V, 2000A switchboard with antiquated electrical parts that will be difficult to replace due to availability and age. BMcD recommends replacing the 480V building switchboard, removing the existing transformer, and providing a new properly sized transformer outside the building on the west side.

There is also a 12.47kV-480Y/277V, 2000kVA Square D oil-filled transformer in the basement of the John B. Coleman Library. This is a safety concern due to its age and location within the building. The lobby is above the transformer and PVAMU personnel believe this a safety risk. BMcD recommends removing this transformer from the basement and providing a new properly sized transformer outside on the east side. In addition, there is an existing 480Y/277V, 3000A Square D switchboard that is aged, as well. BMcD recommends replacing this switchboard.

PVAMU also expressed concern for electrical equipment in the Fry-Thomas Power Plant. The following equipment is aged and has had some reliability issues: MCC-A, MCC-E, MCC-F, MCC-G, and MCC-H. BMcD recommends replacing these MCCs with properly sized MCCs.

The Jessie and Mary Jones Cooperative Agricultural Research building has some electrical equipment that is aged and unreliable. PVAMU expressed concern regarding the Agricultural Research 480V, 600A Siemens MCC in Room 161 in the main mechanical room and the

Agricultural Research 480Y/277V, 1200A ITE Main Switchboard in Room 162 in the electrical room. BMcD investigated this equipment on a site visit and recommends replacing this equipment. In addition, the Kohler ATS does not maintain proper clearance per National Electrical Code (NEC). The switchboard violates this front clearance.

13.2 ARC-FLASH, COORDINATION, AND SHORT-CIRCUIT STUDIES

BMcD recommends a protective device coordination study for the existing system to a certain voltage level as determined by PVAMU. Protective device coordination is essential to any facility. Selective coordination ensures the proper clearing of downstream faults. A properly coordinated electrical system will clear a fault with the protective device closest to it while leaving the rest of the system operating normally. An updated electrical model also helps assist maintenance and facilities personnel to perform work on the system and will help assist in future PVAMU growth analysis. In addition, arc-flash labels indicate the proper PPE required to work on electrical equipment.

BMcD recommends a short-circuit study be performed on the existing system. Catastrophic equipment failures can result from short circuit over duty. Determining equipment that might fail under short-circuit conditions is vital to maintaining a healthy electrical system. These studies will help in future PVAMU growth analysis.

Arc-flash labels are required for electrical equipment per the National Electrical Code (NEC) and NFPA 70E. A protective device coordination study and short-circuit study are required before an arc-flash study can be performed. BMcD recommends an arc-flash study be performed as a separate project for the existing low-voltage and medium-voltage electrical system, along with any future electrical equipment. These studies require breaker ratings and settings, cable lengths and sizes, equipment ratings such as transformers, switchgear, switchboards, panelboards, and load ratings such as motors, pumps, and chillers. This study is a large effort since electrical equipment needs to be surveyed in detail to create an electrical model to analyze the system.

13.3 DOCUMENT MANAGEMENT

Prairie View A&M's existing document management system contains scanned copies of most of the campus drawings stored at the Physical Plant. However, several of the documents were incompletely scanned and the majority of the newer documents have yet to be scanned. These scanned documents are searchable through one of two databases. One database is through the A&M system and includes projects over $10 million. The other database is local to PVAMU and includes projects less than $10 million.

All University employees including the utilities group and the Physical Plant have access to both databases, but, only a few, experienced personnel can use the database effectively. The existing search criteria is by building name, year, and keywords, respectively. If the building name on campus has changed since the documents were scanned in the system, the building name has not been updated. The year associated with the documents is the year the drawings were added to the database, not when the drawings were completed. For those two reasons, the existing databases are not intuitive and simple searches are difficult. Also, there are several different file types stored in the database, including JPG and PDF.

Burns & McDonnell can assist Prairie View A&M in organizing and improving the existing document management system. Burns & McDonnell could provide a new platform that is user friendly with wide access for all Prairie View A&M personnel. Documents that are missing information would be rescanned and new documents would be scanned in as well. As a part of this upgrade, the two data bases could be combined into one and all the files could be changed to PDF format. Old building names and drawing completion dates would be updated and additional keywords would be assigned to shorten the amount of time spent searching for an individual document.

The document management upgrade is not included as a part of the Utility Master Plan scope; however, Burns & McDonnell believes that the completion of this upgrade would greatly benefit PVAMU.

13.4 CAMPUS-WIDE GIS MAPPING

Campus-wide GIS mapping is useful for identifying the location and depth of existing underground infrastructure and utilities such as natural gas, chilled water, sewer, steam, electrical conduit, and ductbank. This technology assists facility personnel, maintenance personnel, and engineers in future projects where underground utilities need to be determined. PVAMU staff has communicated that less than 10% of campus has accurate utility location information and drawings. Burns & McDonnell recommends that PVAMU obtain GIS mapping (including invert elevations) for the entire campus along with the newly developed areas like the southeast campus development. Burns & McDonnell also recommends information to be stored in a geodatabase using Esri ArcGIS, or similar. Maintaining a record of underground campus utilities is vital for efficiency in future projects and can mitigate costs associated with survey.

* * * * *

SECTION 14.0

LIFE CYCLE COST ANALYSES

14.0 ECONOMIC ANALYSES

Burns & McDonnell conducted an economic analysis of the alternatives presented in the previous sections of this report and summarized the results in the form of a life cycle cost analysis (LCCA). The various alternatives' project capital costs, operation and maintenance costs, and projected utility costs were integrated into the life cycle cost analysis. Costs for each option were compared to the Base Case costs to determine relative economic performance.

14.1 COST ESTIMATES

The capital cost estimates were developed for each of the following options: The Base Case, Option 1, and Option 2, and Option 3. The estimates were prepared in 2017 dollars. Table 14-1 below summarizes the costs for each option divided into four major categories of utility improvements. Distribution Expansion includes the costs to extend thermal utilities to the new campus development along Owens Road. Existing Distribution Replacement includes the costs associated with replacing the existing distribution infrastructure and building connections. Mechanical Equipment includes the costs associated with chillers, boilers, pumps, motors, cooling towers, and building construction or additions necessary to support the installation of the mechanical projects. Electrical Equipment & Distribution includes costs associated with ductbank, cable, electrical switchgear and switchboards, transformers, and distribution switches.

Table 14-1: Total Capital Costs by Option

Option	Distribution Expansion	Existing Distribution Replacement	Mechanical Equipment	Electrical Equipment & Distribution Cost	Total Cost
Base Case	$30,452,000	$30,410,000	$16,698,000	$20,090,000	$97,650,000
Option 1	$22,774,000	$20,660,000	$16,304,000	$20,090,000	$79,828,000
Option 2	$38,182,000	$22,210,000	$18,471,000	$20,232,000	$99,095,000
Option 3	$5,231,000	$30,520,000	$16,607,000	$18,256,000	$70,614,000

The following assumptions were applied in each category for all cost estimates:

Distribution Expansion:

- Assumed utilities routed together when possible.
- Assumed 6 steam fittings per 500 ft for expansion loops.
- Assumed 6 fittings per 800 ft for turns/tees (all utilities)
- Assumed 2 valves per 800 ft (all utilities)

- Assumed 1 joint kit per 40 ft (all utilities)

Existing Distribution Replacement:

- Assumed approximate header lengths in the absence of detailed utility header maps.
- Assumed existing system would be abandoned in place during replacement.
- Assumed total cost of existing system replacement was spread uniformly over 10-year period.
- Did not include cost for buildings for which it was reported that construction would complete in 2017 (School of Architecture Fabrication Design Center, Welcome Center, University Square (Phase VIII)

Mechanical Equipment:

- Assumed replace in kind for existing chillers as equipment comes to end of useful service life.
- Boiler 12 will not be replaced once retired. Boiler 11 will be replaced with a lower capacity when it comes to the end of its useful service life.
- Assumed cooling tower refurbishment recommendation previously made by Ameresco is not covered under the scope of this cost estimate.
- Chillers, pumps, and fan motors were assumed to be installed with VFDs.
- All use the same strategy for the cooling utility infrastructure. Thus, the chilled water equipment is the same for each option and is not a differentiating factor for the overall cost.

Electrical Equipment & Distribution:

- Assumed additional main incoming switchgear adjacent to the existing main incoming switchgear to allow for future growth. This gear will serve the new CUP2 and the new infrastructure in the southeast area of campus.
- Assumed electrical scope costs would stop at the building transformer.
- Assumed S&C pad-mounted PME-9 switches for electrical distribution to new buildings.
- Assumed SCADA fiber and programming for distribution loop.
- Assumed 3x3 ductbank with 9-6” conduits and 2-2” communications conduit.
- Assumed 0.85 power factor.

The detailed cost estimates are included in Appendix D along with project by project cost estimates that were used to develop the summary tables below.

A more detailed explanation of capital costs by year for each option is presented below. Table 14-2 details the year by year expenditures for the Base Case, Table 14-3 details the year by year expenditures for Option 1, Table 14-4 details the year by year expenditures for Option 2, and Table 14-5 details the year by year expenditures for Option 3.

Table 14-2: Base Case Capital Costs by Year

Base Case Capital Cost						
Phase	Year	Distribution Expansion	Existing Distribution Replacement	Mechanical Equipment	Electrical Equipment & Distribution	Total
		Total Cost	Total Cost	Total Cost	Total Cost	
PH1	2018	$ 12,114,000	$ 3,041,000	$ 363,000	$ 536,000	$ 16,054,000
	2019	$ 198,000	$ 3,041,000	$ 24,000	$ 3,676,000	$ 6,939,000
	2020	$ -	$ 3,041,000	$ 5,134,000	$ 1,555,000	$ 9,730,000
	2021	$ 195,000	$ 3,041,000	$ 18,000	$ 515,000	$ 3,769,000
	2022	$ -	$ 3,041,000	$ 1,612,000	$ 486,000	$ 5,139,000
PH2	2023	$ 10,112,000	$ 3,041,000	$ 4,142,000	$ 3,007,000	$ 20,302,000
	2024	$ 2,446,000	$ 3,041,000	$ 30,000	$ 1,528,000	$ 7,045,000
	2025	$ 122,000	$ 3,041,000	$ 16,000	$ 515,000	$ 3,694,000
	2026	$ 1,324,000	$ 3,041,000	$ 14,000	$ 349,000	$ 4,728,000
	2027	$ -	$ 3,041,000	$ 2,125,000	$ 1,728,000	$ 6,894,000
PH3	2028	$ 176,000	$ -	$ 121,000	$ 565,000	$ 862,000
	2029	$ 226,000	$ -	$ 30,000	$ 565,000	$ 821,000
	2030	$ 120,000	$ -	$ 16,000	$ 515,000	$ 651,000
	2031	$ 173,000	$ -	$ 14,000	$ 515,000	$ 702,000
	2032	$ -	$ -	$ 1,783,000	$ 536,000	$ 2,319,000
	2033	$ 2,727,000	$ -	$ 117,000	$ 929,000	$ 3,773,000
	2034	$ 226,000	$ -	$ 1,109,000	$ 1,285,000	$ 2,620,000
	2035	$ 120,000	$ -	$ 16,000	$ 349,000	$ 485,000
	2036	$ 173,000	$ -	$ 14,000	$ 349,000	$ 536,000
	2037	$ -	$ -	$ -	$ 587,000	$ 587,000
Total		$ 30,452,000	$ 30,410,000	$ 16,698,000	$ 20,090,000	**$ 97,650,000**

Table 14-3: Option 1 Capital Costs by Year

Option 1 Capital Cost						
Phase	Year	Distribution Expansion	Existing Distribution Replacement	Mechanical Equipment	Electrical Equipment & Distribution	Total
		Total Cost	Total Cost	Total Cost	Total Cost	
PH1	2018	$ 8,987,000	$ 2,066,000	$ 360,000	$ 536,000	$ 11,949,000
	2019	$ 121,000	$ 2,066,000	$ 257,000	$ 3,676,000	$ 6,120,000
	2020	$ -	$ 2,066,000	$ 4,506,000	$ 1,555,000	$ 8,127,000
	2021	$ 121,000	$ 2,066,000	$ 298,000	$ 515,000	$ 3,000,000
	2022	$ -	$ 2,066,000	$ 514,000	$ 486,000	$ 3,066,000
PH2	2023	$ 7,796,000	$ 2,066,000	$ 4,763,000	$ 3,007,000	$ 17,632,000
	2024	$ 1,811,000	$ 2,066,000	$ 41,000	$ 1,528,000	$ 5,446,000
	2025	$ 69,000	$ 2,066,000	$ 27,000	$ 515,000	$ 2,677,000
	2026	$ 979,000	$ 2,066,000	$ 12,000	$ 349,000	$ 3,406,000
	2027	$ -	$ 2,066,000	$ 2,125,000	$ 1,728,000	$ 5,919,000
PH3	2028	$ 106,000	$ -	$ 194,000	$ 565,000	$ 865,000
	2029	$ 125,000	$ -	$ 41,000	$ 565,000	$ 731,000
	2030	$ 67,000	$ -	$ 26,000	$ 515,000	$ 608,000
	2031	$ 105,000	$ -	$ 12,000	$ 515,000	$ 632,000
	2032	$ -	$ -	$ 1,783,000	$ 536,000	$ 2,319,000
	2033	$ 2,190,000	$ -	$ 188,000	$ 929,000	$ 3,307,000
	2034	$ 125,000	$ -	$ 1,119,000	$ 1,285,000	$ 2,529,000
	2035	$ 67,000	$ -	$ 26,000	$ 349,000	$ 442,000
	2036	$ 105,000	$ -	$ 12,000	$ 349,000	$ 466,000
	2037	$ -	$ -	$ -	$ 587,000	$ 587,000
Total		$ 22,774,000	$ 20,660,000	$ 16,304,000	$ 20,090,000	**$ 79,828,000**

Table 14-4: Option 2 Capital Costs by Year

Option 2 Capital Cost						
Phase	Year	Distribution Expansion	Existing Distribution Replacement	Mechanical Equipment	Electrical Equipment & Distribution	Total
		Total Cost	Total Cost	Total Cost	Total Cost	
PH1	2018	$ -	$ 2,221,000	$ -	$ 536,000	$ 2,757,000
	2019	$ 2,374,000	$ 2,221,000	$ 768,000	$ 3,676,000	$ 9,039,000
	2020	$ -	$ 2,221,000	$ 4,282,000	$ 1,569,000	$ 8,072,000
	2021	$ 161,000	$ 2,221,000	$ 12,000	$ 515,000	$ 2,909,000
	2022	$ -	$ 2,221,000	$ -	$ 486,000	$ 2,707,000
PH2	2023	$ 19,438,000	$ 2,221,000	$ 7,352,000	$ 3,135,000	$ 32,146,000
	2024	$ 5,850,000	$ 2,221,000	$ 402,000	$ 1,528,000	$ 10,001,000
	2025	$ 5,930,000	$ 2,221,000	$ 82,000	$ 515,000	$ 8,748,000
	2026	$ 140,000	$ 2,221,000	$ 9,000	$ 349,000	$ 2,719,000
	2027	$ -	$ 2,221,000	$ 2,125,000	$ 1,728,000	$ 6,074,000
PH3	2028	$ 163,000	$ -	$ 444,000	$ 565,000	$ 1,172,000
	2029	$ 176,000	$ -	$ 18,000	$ 565,000	$ 759,000
	2030	$ 94,000	$ -	$ 10,000	$ 515,000	$ 619,000
	2031	$ 140,000	$ -	$ 9,000	$ 515,000	$ 664,000
	2032	$ -	$ -	$ 1,783,000	$ 536,000	$ 2,319,000
	2033	$ 3,306,000	$ -	$ 59,000	$ 929,000	$ 4,294,000
	2034	$ 176,000	$ -	$ 1,097,000	$ 1,285,000	$ 2,558,000
	2035	$ 94,000	$ -	$ 10,000	$ 349,000	$ 453,000
	2036	$ 140,000	$ -	$ 9,000	$ 349,000	$ 498,000
	2037	$ -	$ -	$ -	$ 587,000	$ 587,000
Total		$ 38,182,000	$ 22,210,000	$ 18,471,000	$ 20,232,000	**$ 99,095,000**

Table 14-5: Option 3 Capital Costs by Year

Option 3 Capital Cost						
Phase	**Year**	**Distribution Expansion**	**Existing Distribution Replacement**	**Mechanical Equipment**	**Electrical Equipment & Distribution**	**Total**
		Total Cost	**Total Cost**	**Total Cost**	**Total Cost**	
PH1	2018	$ -	$ 3,052,000	$ 1,824,000	$ 1,122,000	$ 5,998,000
	2019	$ -	$ 3,052,000	$ -	$ 3,676,000	$ 6,728,000
	2020	$ -	$ 3,052,000	$ 6,741,000	$ 1,173,000	$ 10,966,000
	2021	$ 195,000	$ 3,052,000	$ -	$ 515,000	$ 3,762,000
	2022	$ -	$ 3,052,000	$ 4,394,000	$ 769,000	$ 8,215,000
PH2	2023	$ 377,000	$ 3,052,000	$ -	$ 927,000	$ 4,356,000
	2024	$ -	$ 3,052,000	$ -	$ 1,528,000	$ 4,580,000
	2025	$ 270,000	$ 3,052,000	$ 1,824,000	$ 797,000	$ 5,943,000
	2026	$ -	$ 3,052,000	$ -	$ 349,000	$ 3,401,000
	2027	$ -	$ 3,052,000	$ -	$ 1,191,000	$ 4,243,000
PH3	2028	$ 2,145,000	$ -	$ 1,824,000	$ 847,000	$ 4,816,000
	2029	$ -	$ -	$ -	$ 565,000	$ 565,000
	2030	$ -	$ -	$ -	$ 515,000	$ 515,000
	2031	$ -	$ -	$ -	$ 515,000	$ 515,000
	2032	$ -	$ -	$ -	$ 536,000	$ 536,000
	2033	$ 2,244,000	$ -	$ -	$ 929,000	$ 3,173,000
	2034	$ -	$ -	$ -	$ 1,017,000	$ 1,017,000
	2035	$ -	$ -	$ -	$ 349,000	$ 349,000
	2036	$ -	$ -	$ -	$ 349,000	$ 349,000
	2037	$ -	$ -	$ -	$ 587,000	$ 587,000
Total		$ 5,231,000	$ 30,520,000	$ 16,607,000	$ 18,256,000	**$ 70,614,000**

Of the four proposed options, Option 2 has the largest distribution expansion capital cost. This is due in part to the fact that the HHW distribution loop would be an entirely new installation. The header loop that branches off to serve existing and new buildings represents an intensive construction effort that will span a 6-year period.

Of the four proposed options, Option 3 has the largest existing distribution replacement capital cost since both steam and chilled water utilities are being replaced.

Of the four proposed options, Option 2 has the greatest mechanical equipment capital cost. This is due to the installation of new HHW boilers that pick up the entire campus capacity rather than relying on existing steam generating equipment for the duration of this study as did the Base Case.

All four options are relatively similar from an electrical equipment and distribution perspective. The only difference is that Option 2 accommodates for the additional mechanical equipment that will be installed as a part of the HHW system installation. The recommendations provided as a part of the electrical section of this report are largely consistent regardless of the course of action that PVAMU implements.

Of the four proposed options, Option 2 has the highest total capital cost and Option 3 has the lowest total capital cost. Option 2 presents high costs for distribution expansion and mechanical equipment. It does present savings when compared to the existing distribution replacement cost included in the Base Case, as it does not require an overhaul of the existing steam system. Option 3 has the cost advantage of avoiding expensive distribution expansions down to the new buildings along Owens Road as well as avoiding the capital-intensive process of constructing a second central plant. While there are operation and maintenance disadvantages associated with the local heating and cooling equipment in Option 3, those costs are not captured here in the capital cost estimate, but rather will be reflected in the Life Cycle Cost Analysis that follows.

14.2 LIFE CYCLE COST ANALYSIS

Life cycle cost analysis is a method of evaluating the economic viability of a project. The analysis includes all costs associated with the project under assessment, from its initial cost to operation and maintenance to residual value. The goal of an LCCA is to compare several alternatives to each other and to a base case to determine the most cost effective option over an extended period of time. This is done by evaluating all of the costs incurred in each alternative. The most cost effective is the option with the lowest life cycle cost, independent of non-economic factors. The study period does not need to include the whole life of a project, but it must be the same for each alternative.

An LCCA enables fair comparison of different alternatives through the use of the time value of money. This reflects the opportunity cost of using capital to fund a project instead of investing it at the discount rate or rate of interest. The capital, if invested outside of the project alternatives, could potentially accrue interest to offset the higher operating cost of business as usual.

A life cycle cost analysis was created to study the effect of each alternative. Campus electrical load data was used to generate respective energy costs for a given alternative. 8,760 data was calculated by taking the estimated existing campus electrical data and escalating it with estimated electrical loads for 2022, 2027, and 2037.

The analysis used the following financial criteria:

- Study term: 20 years
- University is tax-exempt, no consideration for taxes
- End-of-year accounting convention
- Capital costs are met with financing, using an APR of 4.0%
- The discount rate is 4.0%
- The inflation rate is 2.5%
- The operations, maintenance, and repair escalation rate is the same as the inflation rate, 2.5%
- The rate structures utilize Schedule LP-8 Large Power Service for electricity (San Bernard Electric Cooperative, Inc.) and a varying commodity market value for natural gas where the rate is determined by natural gas cost of the previous 12 months divided by total consumption over 12 months.
- There is not a published tariff for the natural gas service at PVAMU. The fuel is bought on a commodity market at varying rates. The natural gas rate in the Ameresco report was determined by taking the total cost of the gas service in the 12-month review period and dividing it by the total consumption over the 12-month period for an average rate of $2.904/MCF. For analysis purposes, BMcD used the natural gas rate as indicated by Ameresco. PVAMU staff noted that a 15-18% brokerage fee was included on top of the natural gas costs, however, this fee was not included as part of the analysis.
- According to the Ameresco report, electrical service for main campus is provided via a primary voltage service account by San Bernard Electric Cooperative (SBEC). The blended electricity rate for the main campus is $0.0814/kWh
- The escalation rate for electricity is based on EIA West South Central predictions from January 2017
- The escalation rate for natural gas is based on EIA West South Central predictions from January 2017
- Based on past project experience, $0.74/MMBtu was assumed for maintenance costs for boilers at the central plant in the Base Case. The local heating hot water

maintenance costs in Option 1 were assumed to be 1.5 times the maintenance cost of the Base Case due to the increased number of boilers and the larger footprint. Option 2's maintenance costs were assumed to be 90% of the Base Case's maintenance costs because central hot water boilers will require less maintenance than steam boilers. Option 3's maintenance costs were calculated based on a ratio of central steam boilers and local hot water boilers.

- Based on past project experience, $0.006/ton-hour was assumed for maintenance costs for chillers at the central plant in the Base Case, Option 1, Option 2, and Option 3. Chiller maintenance is less in Option 3 because the new buildings along Owen's Road are served locally.

Additionally, the analysis utilized the following technical assumptions:

- Constant-value fees and other charges account for inflation
- Sewer use is not analyzed
- Water use is not analyzed. PVAMU uses local wells.
- O&M costs are from vendors and recent project experiences and are blended to include both annual and non-annual recurring costs
- Personnel costs could vary by option. These costs were not accounted for in the LCCA.
- First costs are from vendors and recent project experiences
- ASHRAE lifespans are utilized. 23 years are assumed for chiller operation and 25 years are assumed for boiler operation, except:
    - Chiller 2 is in poor condition and will experience a shorter life span of approximately 19 years
    - Boilers 11 and 12 are replaced after 27 years (during the first year of UMP implementation) because the boilers were not replaced in 2016 after a 25-year life span
    - Boiler 10 has an extended service life of approximately 33 years due to equipment upgrades according to plant operators
    - Option 3 contains shorten Chiller lifespans per PVAMU direction.
- Individual chilled water and condenser water pumps are replaced with corresponding chillers
- Existing cooling towers were not replaced as a part of this utility master plan

- Deaerators, feedwater pumps, and other common equipment used by the existing boilers were replaced in 2022

The twenty-year LCCA study demonstrates the benefits of several approaches to future energy use on campus. A summary of its results is shown in Table 14-6. In this table, the capital costs are incremental for each model (five, ten, and twenty). These cases do not include TES, CHP, or heat pump chillers. A detailed LCCA can be found in Appendix E.

Table 14-6: Life Cycle Cost Analysis Summary

Life Cycle Cost Analysis (LCCA)	**2018**	**2022**	**2027**	**2037**	Total LCC	Present Value
Base Case - Central Steam	**1**	**5**	**10**	**20**		
Capital Investments						
Initial Cost / Payments	$16,455,350	$5,814,307	$8,824,903	$961,868	**$114,993,007**	**$89,240,090**
O&M - Annually Recurring Costs						
Boiler Maintenance	$73,708	$84,015	$108,587	$172,160	**$2,449,918**	**$1,592,651**
Chiller Maintenance	$79,873	$91,319	$118,374	$188,464	**$2,669,599**	**$1,734,060**
Utility Costs						
Natural Gas	$382,531	$507,410	$690,824	$1,116,438	**$15,418,644**	**$9,897,363**
Electricity	$2,864,569	$3,767,336	$4,822,821	$6,887,087	**$101,602,740**	**$66,190,361**
Total Base Case Operating Expense	$19,856,031	$10,264,388	$14,565,509	$9,326,016	**$237,133,908**	**$168,654,525**
Option 1 - Local Heating	**2018**	**2022**	**2027**	**2037**	Total LCC	Present Value
Capital Investments						
Initial Cost / Payments	$12,247,725	$3,468,898	$7,576,820	$961,868	**$94,584,633**	**$72,718,327**
O&M - Annually Recurring Costs						
Boiler Maintenance	$110,562	$126,023	$162,881	$258,239	**$3,674,877**	**$2,388,976**
Chiller Maintenance	$79,873	$91,319	$118,374	$188,464	**$2,669,599**	**$1,734,060**
Utility Costs						
Natural Gas	$344,278	$456,669	$621,742	$1,004,794	**$13,876,780**	**$8,907,627**
Electricity	$2,864,569	$3,767,336	$4,822,821	$6,887,087	**$101,602,740**	**$66,190,361**
Total Option 1 Operating Expense	$15,647,007	$7,910,245	$13,302,638	$9,300,452	**$216,408,628**	**$151,939,350**
Option 2 - Central HHW	**2018**	**2022**	**2027**	**2037**	Total LCC	Present Value
Capital Investments						
Initial Cost / Payments	$2,825,925	$3,062,722	$7,775,234	$961,868	**$118,677,411**	**$89,490,008.82**
O&M - Annually Recurring Costs						
Boiler Maintenance	$66,337	$75,614	$97,729	$154,944	**$2,204,926**	**$1,433,386**
Chiller Maintenance	$79,873	$91,319	$118,374	$188,464	**$2,669,599**	**$1,734,060**
Utility Costs						
Natural Gas	$344,278	$456,669	$621,742	$1,004,794	**$13,876,780**	**$8,907,627**
Electricity	$2,864,569	$3,767,336	$4,822,821	$6,887,087	**$101,602,740**	**$66,190,361**
Total Option 2 Operating Expense	$6,180,982	$7,453,660	$13,435,899	$9,197,157	**$239,031,455**	**$167,755,442**
Option 3 - Central/Local Heating Combination						
Capital Investments						
Initial Cost / Payments	$6,147,950	$9,294,518	$5,431,399	$961,868	**$83,503,069**	**$64,346,746.10**
O&M - Annually Recurring Costs						
Boiler Maintenance	$75,879	$86,490	$111,785	$177,230	**$2,522,068**	**$1,639,554**
Chiller Maintenance	$68,463	$78,274	$101,463	$161,541	**$2,288,228**	**$1,486,337**
Utility Costs						
Natural Gas	$380,236	$504,366	$686,680	$1,109,739	**$15,326,133**	**$9,837,979**
Electricity	$3,004,817	$3,951,976	$5,059,646	$7,226,232	**$106,594,452**	**$69,440,841**
Total Option 3 Operating Expense	$9,677,344	$13,915,623	$11,390,973	$9,636,609	**$210,233,950**	**$146,751,457**

The financial results for each option demonstrate that there is a significant spread between the overall costs.

Option 3 has the lowest life cycle cost; however, it does not provide redundancy in buildings outside of the Core Campus as offered by the Base Case and Option 2.

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SECTION 15.0

FINANCING OPPORTUNITIES

15.0 FINANCING OPPORTUNITIES

As PVAMU moves forward with the extensive expansion of the campus, the mechanisms for funding and executing projects will need to be considered. Beyond the traditional Design/Bid/Build approach, performance contracting and Design/Build can be considered. Further, opportunities for enhanced utility cost allocation and recovery may be warranted.

15.1 PERFORMANCE CONTRACTING

In lieu of allocating capital budget to execute projects, performance contracting is an optional financing vehicle. With performance contracting, project costs are no longer capital costs; the projects are financed as operating costs. Third party contractors/performance contractors provide the capital for the projects with the University paying for the project through the savings generated by the project while maintaining overall operating budgets. For instance, if a $1,000,000 capital project can save $100,000 per year in energy savings, it is a candidate for performance contracting. The performance contractor funds the project and after it is operational, the University would have $100,000 per year less in utility costs. If the budget is held constant for the utility costs, the surplus dollars would be paid to the performance contractor. After a set number of years (typically beyond 10 in this example as there is a profit component to the performance contractor’s efforts), the contract would be completed and PVAMU would fully own the assets and the savings going forward.

This approach is typically used when capital dollars are not available. One drawback is that performance contracting is a “for profit” business, and this will extend the payback period to some degree. However, if capital is not available, it is better to do the project with a performance contractor than to not do it at all. Delayed savings and new equipment is always better than no savings and old equipment. At times, there are other avenues for such funding, without the direct payment to a performance contractor, such as the LoanSTAR program through SECO. This may warrant investigation for PVAMU pending available funding.

15.2 DESIGN/BUILD

Traditional project execution involves selecting an architect/engineer and having a design completed. Then this design is bid out and a contractor is selected to build the project. An alternative to this is moving forward with a Design/Build approach. With this approach, a single entity is selected to both design and construct the project. This can provide benefits in terms of costs, schedule, and reduced management and staffing by PVAMU.

With one entity responsible for the entire project, finger pointing is eliminated between the contractor and the engineer. Further, budgets can be set from the very beginning and locked in or budgets can be handled in an open book manner with the contractor and owner sitting “side by side” to make decisions on how dollars are allocated. Without an open book approach, a low-cost mentality could come into play. Often the “book” is held open until the design advances to around 55 - 75% completion and then a hard number is agreed to between the owner and the Design/Build firm.

Pending PVAMU’s needs for costs, schedule, and internal staffing, a Design/Build approach may fit well for the implementation of utility projects.

15.3 ADDITIONAL ISSUES FOR CONSIDERATION

15.3.1 Reconciliation

At the end of each year, total actual costs of the campus utilities system should be compared to and reconciled with the billed costs. As the campus utility charges to the end users/departments are based on annual projections of costs from the grid utility, operations, and maintenance, they will never match exactly with the actual true costs. The differential between the projected costs and the actual costs should be built into the following year’s rate so that each year is reconciled.

15.3.2 Infrastructure Renewal and Expansion

Including an infrastructure renewal fee into the campus utility charges is important for long term equality in building and maintaining the campus systems. Building in a certain fee each year (5%± pending projected projects) to create an infrastructure renewal and expansion fund provides a resource for projects that would previously be burdened to individual new building construction projects.

For instance, a building is being constructed that only would require a 4” chilled water line service. However, it is planned that within the coming years an additional two buildings will be built between this new building and its connection to the distribution system. For the long-term benefit of the campus, a 12” line should be installed. This added cost should not be burdened to the current new building, but could rather be funded with the infrastructure renewal account.

15.3.3 Recommendation

The challenges of maintaining the system along with allocating new infrastructure costs and incentivizing improved end user behaviors will be significant. Enhanced cost allocation can play a big role in managing these challenges at PVAMU. It is recommended that the University look to move toward Consumption Metering for as much of the campus as possible with a long-term goal of Consumption and Demand Metering. The benefits will include:

- Energy conscious/motivated end users
- Equitable allocation of new infrastructure costs in lieu of an individual building or project unfairly burdened with the cost
- Reconciled utility costs for balanced annual expenses

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SECTION 16.0

RECOMMENDATIONS

16.0 RECOMMENDATIONS

16.1 CONCLUSIONS

As a result of this analysis, Option 3, the option involving the large expansion of FTPP and maintaining existing chilled water and steam distribution, presents the most favorable net present value for PVAMU. However, the lower costs do not include redundancy for buildings served with local equipment in the event of equipment failure. The Base Case and Option 2 have similar life cycle costs to each other and include the associated redundancy to lower the risk of unplanned outages. Option 1 has a life cycle cost marginally larger than Option 3, however Option 1 includes the large distribution expansions necessary to serve the campus expansions outside of the core campus with central utility service for chilled water.

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