WISCONSIN
UNIVERSITY OF WISCONSIN–MADISON

2015 UTILITY MASTER PLAN

2015 CAMPUS MASTER PLAN UPDATE

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Photo Credits

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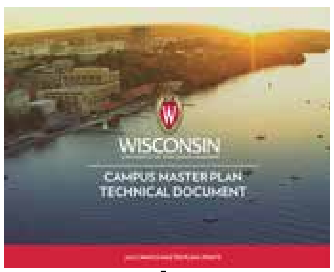
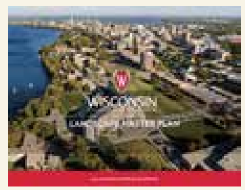
The "2015 Campus Master Plan Update" is comprised of the Executive Summary, the Techncial Document, which includes the four (4) supporting appendix documents; Landscape Master Plan, Utility Master Plan, Long Range Transportation Master Plan, and Green Infrastructure & Stormwater Management Master Plan, and the Campus Design Guidelines. It is important for planners, architects, designers, and engineers to familiarize themselves with the pieces of the plan to understand how they relate and inform each other in the physical development of the University of Wisconsin–Madison.

Big Picture

Executive Summary

Technical Document





Landscape Master Plan

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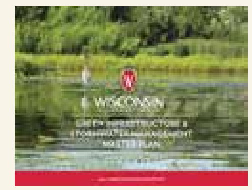
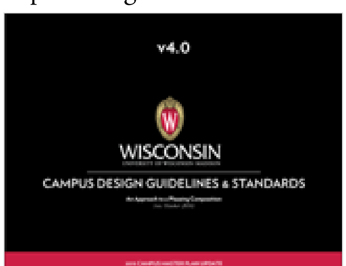
Utility Master Plan

Long Range Transportation Plan



Green Infrastructure & Stormwater Management Master Plan

Campus Design Guidelines & Standards



Technical Specifications

More Detail

2015 Campus Master Plan Executive Summary

A full color 24-page report that summarizes the major goals and guiding principles for the Master Plan. The document includes the Chancellor's vision and the major goals and initiatives for each of the identified focus topics (appendices to the Technical Document). Welcomes and sets the tone for users and viewers of the master plan document. It is both a marketing piece for future development and a summary of the planning process.

2015 Campus Master Plan Technical Document

The unabridged thought and support behind the goals and guiding principles for the Master Plan. This more than 250-page document presents a roadmap for campus development over the next 30-50 years by referencing what has come previously and embracing what the future holds. Together with the Campus Design Guidelines, the Technical Document strives to give physical form to the university's mission, vision, and programs through the effective use of human, environmental and fiscal resources.

UW–Madison Campus Design Guidelines

The site specific framework that has been established to create the ground rules for a fruitful dialogue between planners, architects, engineers, campus community, and city/state authorities. Divided into nine Campus Design Neighborhoods, the goal of the guidelines is to enhance the university's sense of place by creating well-defined, functional, sustainable, beautiful and coherent campus environments that promote intellectual and social exchange.

Appendices:

Landscape Master Plan
Establishes a 'sense of place' where phased growth and future development can occur while maintaining a cohesive environment.

Utility Master Plan:
Confirms status of the 2005 recommendations, acknowledges completed projects, and makes recommendations to meet the 2015 plan revisions.

Long Range Transportation Plan: Updated from the previous LRTP, the plan is the university's transportation vision and describes baseline conditions, travel behaviors, and trends all modes.

Green Infrastructure & Stormwater Management Master Plan: A campuswide plan that recommends solutions to meet stormwater management regulations as well as existing campus stormwater policy.

1. INTRODUCTION

Executive Summary

Introduction

Affiliated Engineers Inc. (AEI) was contracted as part of a team to provide the University of Wisconsin–Madison with an update to the 2005 Utility Master Plan Report. The update includes information regarding the existing utility distribution systems as well as recommendations as to how the UW–Madison campus utilities should be modified and expanded to accommodate the proposed ultimate campus build-out. AEI prepared the 2015 Utility Master Plan, specifically the steam, chilled water, electrical power, and renewable energy sections. The compressed air and information technology (IT) were not included in the 2015 Utility Master Plan. SmithGroupJJR updated the sanitary sewer and domestic water analysis recommendations, found in the Technical Report. SmithGroupJJR's stormwater analysis and recommendations are found in the Green Infrastructure and Stormwater Management Master Plan.

UW–Madison has a combination of self-generated and utility-owned systems that comprise the steam, chilled water, and electrical power services on campus. These utilities are distributed through a network of underground tunnels, box conduits, direct buried piping systems, and manholes/ductbanks for electrical power. In addition to the piping and wiring distribution systems, there are three generation plants for the production of steam, chilled water, and electrical power. The primary plant locations and capacities are summarized in Table 1-1.

There are over 25 miles of steam and condensate piping serving the campus with steam delivered to buildings at 175 PSIG or 10 PSIG. Almost every building on campus is connected to the steam system. The majority of the steam distribution piping is in box conduits and walkable tunnels with the remainder as direct buried installations.

The chilled water system consists of approximately 8 miles of piping consisting of a combination of direct buried pre-stressed concrete piping and ductile iron piping or steel piping installed in walkable tunnels.

The primary electrical system serving UW–Madison uses a combination of 4.16 kV and 13.8 kV distribution voltages. Electric power is purchased from MGE at 13.8 kV and transformed on campus where required to the distribution voltage. The power is distributed through a series of underground ductbanks and manholes to transformers at individual buildings.

Table 1-1 Existing Plant Capacity Summary

Plant	Primary Fuel Source	Steam Generation Capacity	Chilled Water Generation Capacity	Electric Generation Capacity
Charter Street Heating Plant (CSHP)	Natural Gas/ Fuel Oil	1,200,000 PPH	25,500 Tons[3]	9.8 MW
Walnut Street Heating Plant (WSHP)	Natural Gas/ Fuel Oil	600,000 PPH	20,200 Tons[3]	None
West Campus Cogeneration Facility (WCCF)[1]	Natural Gas/ Fuel Oil	500,000 PPH [2]	30,000 Tons Expandable to 50,000 Tons[3]	150 MW

1 This electrical capacity is owned and operated by MGE. The power production output is not dedicated to serving only the UW–Madison campus or the chiller plant. The chilled water assets and a portion of the "steam island" are owned by UW, but MGE operates and maintains the entire plant under a joint agreement with UW–Madison.
2 Includes supplemental firing of the heat recovery steam generator (HRSG) as documented in MGE data.
3 Refer to Table 3-1 for chiller type and size installed in each plant.

Existing System Upgrades

There are a number of existing utility system upgrades recommended to improve reliability and system efficiency of operations.. These deficiencies involve some renewal and replacement of old, aging distribution piping as well as correction of current system shortcomings. There are a substantial number of early phase projects required to support the new building growth and minimize any re-excavation of streets for future phased work. A brief listing of some of these items includes:

- Replace steam infrastructure along University Avenue from Henry Mall to Orchard Street.
- Upgrade the steam infrastructure along N. Charter Street from W. Johnson Street to University Avenue.
- Replace steam and electrical power infrastructure to the Lakeshore Residence Halls between Kronshage House and the Porter Boat House.
- Replace/upgrade steam and electrical power infrastructure along Elm Drive and Linden Drive from Observatory Drive to Babcock Drive.
- Relocate steam and chilled water infrastructure from underneath the future footprint of the Ingraham Hall addition.
- Upgrade the steam and electrical power infrastructure on W. Dayton Street from N. Charter Street to N. Park Street.
- Replace/upgrade the steam, chilled water and electrical power infrastructure on Lathrop Drive and Bascom Hill.
- Replace steam infrastructure from Helen C. White Library to Limnology.
- Replace steam infrastructure along N. Charter Street from University Avenue to Lathrop Drive.
- Replace steam and chilled water infrastructure along Linden Drive to accommodate new pedestrian corridor connections to Veterinary Medicine Addition. Replace chilled water lateral piping to the Livestock Laboratory.

Table 1-2 Estimated Steam and Chilled Water Load Growth

Service	Estimated Current (2015) Peak Load	Projected Ultimate Build-out Load	Current Production/ Firm Capacity
Steam/ Condensate	830,000 PPH	983,000 PPH	2,300,000 PPH / 2,000,000 PPH
Chilled Water	56,360 Tons	68,722 Tons	75,700 Tons / 67,200 Tons

Table 1-3 Estimated Electrical Load Growth

Service	Estimated Current (2015) Peak Load	Projected Ultimate Build-out Load	Estimated Available MGE Capacity
Electric Power	88,400 KVA	115,100 KVA	162,300 KVA

- Replace steam infrastructure along Willow Drive west of Dejope Residence Hall.
- Replace steam infrastructure along W. Johnson Street and N. Mills Street to Educational Sciences.
- Replace/extend steam and chilled water infrastructure to Enzyme Institute.
- Replace steam infrastructure near Agricultural Hall and Agricultural Bulletin Building.

Utility Load Impact of Master Plan

The planned campus expansion will significantly increase the demand on the utility infrastructure systems. The net campus increase in building area at ultimate build-out is estimated to be over 5,145,500 GSF which impacts the utility infrastructure. Refer to Figure 1-11-5 for the proposed building removal and construction maps. The current peak loads and projected loads at ultimate build-out are as shown in Tables 1-2 and 1-3.

Proposed Utility Expansion

The increased utility demands on campus needed to support the campus growth (refer to Figure 1-1) require several major utility system improvements. This will involve expanding existing utility plants and substations and expansion of the utility distribution systems. The major efforts are as described below:

- Addition of heavy tie-feeders between campus substations to improve reliability and provide redundancy.
- Addition of 5,000 tons to the West Campus Cogeneration Facility to increase the chilled water production output from 30,000 tons to 35,000 tons.
- Construction of major utility distribution system extensions to serve the proposed campus growth.

In addition to system expansions, several options for increasing efficiency and improving system reliability will be considered. These options are:

- Construction of new far east and far west substations on campus to improve system reliability and provide operational flexibility.
- Construction of a new 6,000 ton chilled water plant on the east end of campus (Lot 91) to provide operational flexibility and efficiency.
- Construction of a chilled water thermal energy storage system (Lot 45). The use of thermal storage will allow generation and storage of chilled water during non-peak hours for use during peak hours, helping to level the load

on the electrical consumption on campus and reduce energy costs.
- Providing backpressure steam turbine generators in larger buildings to act in parallel with pressure reducing stations as the primary method of reducing steam pressures in buildings.

Further to the above improvements, the university remains committed to investigating and expanding the existing use of renewable energy sources and sustainable design. The following options should be considered:

- Incorporate renewable energy systems into campus facility designs and purchase "green power" or renewable energy from the electrical grid:
  - Wind power (purchased off-site through utility provider)
  - Photovoltaics
  - Solar thermal hot water
  - Transpired solar collectors
- Increase efficiency usage of non-renewable energy:
  - Use of back pressure steam turbine generators at larger buildings to generate electricity.
  - Use of a chilled water thermal energy storage system to produce chilled water more efficiently via lower temperature condenser water.

Project Cost Summary

Sections 2, 3 and 4 have the detailed phased master project listings and descriptions, as well as preliminary estimates of probable construction cost. Due to the desire to keep street re-construction to a minimum, the Phase 1 utility project costs are significant to support the future buildings and replace existing, aged infrastructure. Table 1-4 summarizes the expenditures per phase to illustrate this fact.

Table 1-4 Phased Cost Summary

Phase (Years)	Building Net GSF Added Per Phase [1]	Total Project Costs per Phase from Master Utility Project List[2,3]
Phase 1 (2017-2023)	1,734,700	$ 121,253,000
Phase 2 (2023-2029)	-133,800	$ 25,117,000
Phase 3 (2029-2035)	583,000	$ 12,724,000
Phase 4 (2035+)	2,961,600	$ 128,860,000
Total for all Phases	5,145,500	$ 287,954,000

1 Net area includes proposed additional building area as well as reduction of proposed areas to be demolished.
2 Costs based on May 2016 dollars.
3 Costs do not include any site upgrades in the project area that may be recommended by other portions of the 2015 Campus Master Plan Update.

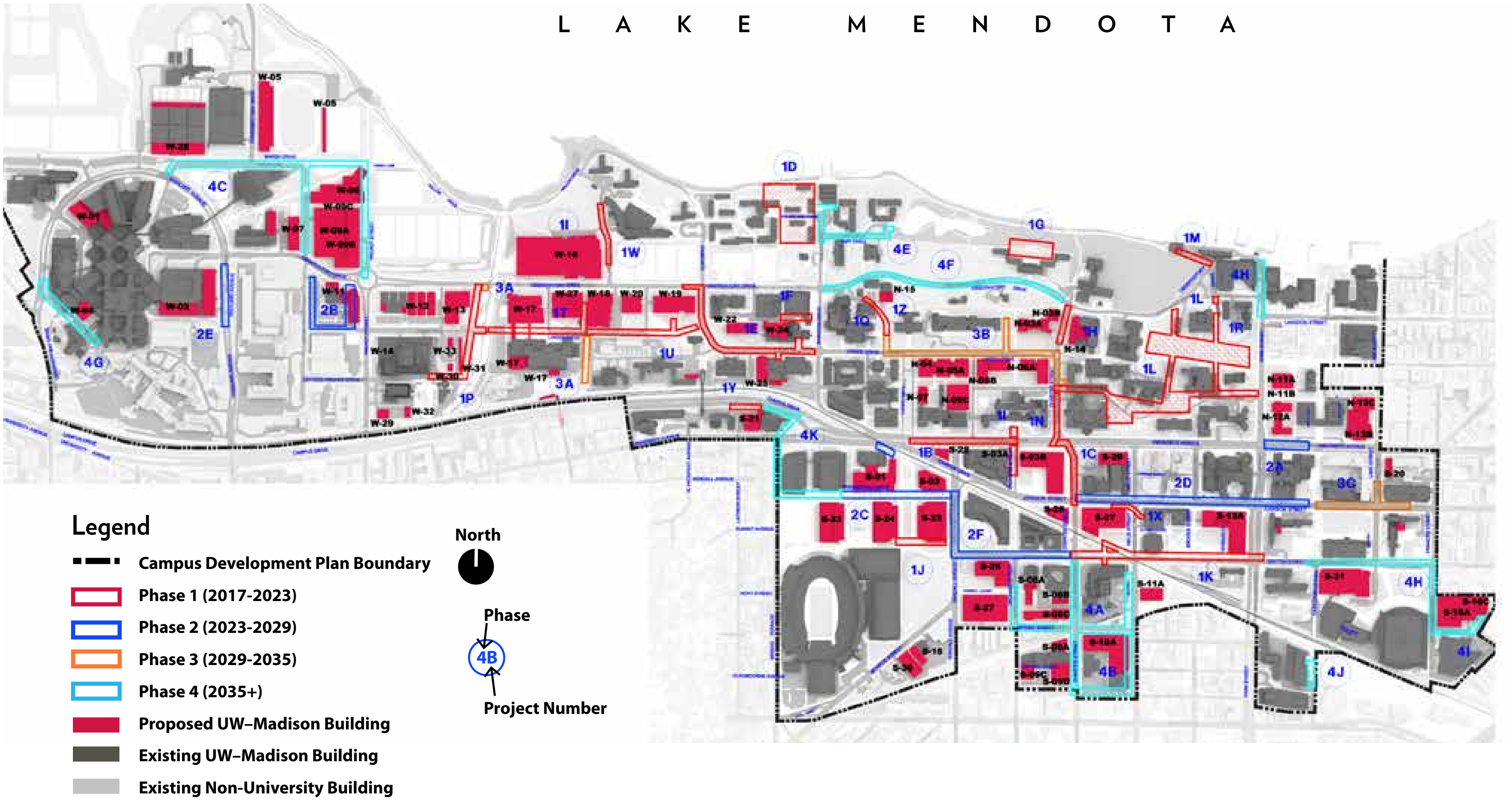


Figure 1-1 Proposed Projects (All Phases)

Introduction

Acknowledgements

AEI would like to thank the following University of Wisconsin–Madison, UW System, and Division of Facilities Development personnel for their invaluable assistance in obtaining and providing information and their system knowledge for use in this report:

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Background, Scope, and Purpose

The purpose of this report is to provide an update to the 2005 Utility Master Plan Report performed for the University of Wisconsin–Madison. The update begins with an overview of the current operating conditions as of 2015, and includes revisions to projected loads and phasing for the proposed ultimate campus build-out. Deficiency and project lists have been updated to reflect projects that have been completed since 2005, as well as new projects, identified as part of the 2015 Campus Master Plan Update. Utilities involved in the update include thermal (steam and chilled water), and electrical power. Analysis of the compressed air utility and information technology (IT) infrastructure was not included as part of the scope of the 2015 Utility Master Plan, but can be referenced in the 2005 Master Plan Report.

Existing systems were analyzed with regards to current capacity and ability to accommodate future growth. This report documents the current vintage of distribution systems, compares and adjusts existing loads to plant meter data, quantifies future loads, and establishes long term configuration of utility systems.

The 2015 Utility Master Plan process included meetings with UW–Madison operating and facilities management staff to further inquire about existing distribution systems relevant to master planning activities. Plant meter data and existing drawings were obtained to assist in master planning activities.

Navigating Through the Report

This report is organized with a specific utility in each section. Each section includes an overview of existing distribution systems and an estimate of existing loads, projected future loads, and recommended projects to address system deficiencies.

Project Improvements List

Each utility section of this report has a list of recommended projects. This section groups them together logically into a single "master phased project" developed by combining multiple utility specific projects occurring in the same street or specific section of campus. The intent of the master projects being that the street would only be opened once regardless of when the utility project required the work done. For example, if there was a chilled water project in University Avenue that did not have to occur until Phase 3, but an electrical power project required the work in Phase 1, the chilled water work was moved to Phase 1 in order to save overall project costs and reduce the amount of disruption on campus as much as possible.

Project construction costs are estimated and prioritized based on the projects identified in each utility section. Each project is identifiable with independent project numbers. A project naming system was developed that is discussed below. Projects are segregated into five (5) groups – Redundancy/Reliability (R); Obsolescence/Equipment Replacement (O); Safety/Code (S), Energy/Environmental/Maintenance (E) and Campus Expansion (X).

Recommended Nomenclature for Utility Specific Projects

Tables 1-5 through 1-8 summarizes the separate deficiencies listed in each utility project and Figures 1-2 through 1-5 illustrate the physical extent of the projects. As can be seen, there is a great deal of Phase 1 infrastructure work to support the building growth outlined in the 2015 Campus Master Plan Update. A project naming system was developed to identify individual projects for prioritization as well as cost estimating purposes.

AAA-B-CC-DDD
Example: IT-R-01-P1

The first characters (AAA) would be the discipline identifier:

- CHW = Chilled Water
- CA = Compressed Air
- STM = Steam
- E = Electrical
- IT = Information Technology/Signal
- SS = Storm Sewer
- SAN = Sanitary Sewer
- WTR = City Water

The second character set (B) is the project type or the reason behind the project:

- E = Energy/Environmental/Maintenance
- O = Obsolescence/Equipment Replacement
- R = Reliability/Redundancy
- S = Safety/Code
- X = Campus Master Plan Expansion

The third character set (CC) is the sequential project number. For sake of simplicity, there is no relevance as to order (e.g., R-1 is not higher priority than R-12). These projects are not prioritized, only phased.

The last character set (DDD) is the minimum project phasing based on the building phasing timeline established by the 2015 Campus Master Plan Update. Some projects will extend over multiple phases and are denoted as such (e.g., P1-2 for Phases 1 and 2). Ultimately the projects may be moved to an earlier phase based on the synergies of other utility work in the same street that may have a higher priority:

- P1 = Phase 1 (2017 to 2023)
- P2 = Phase 2 (2023 to 2029)
- P3 = Phase 3 (2029 to 2035)
- P4 = Phase 4 (2035+)

Some identified projects were deemed too building specific (i.e., extend utility to new building) and were not estimated. These efforts would be accomplished as part of the cost and scope of the new building design and construction project. If a similar conflict occurred with a utility that served more than one building and therefore identified as a campus utility and not a building service branch (i.e., relocate utility due to new building footprint conflict extending over existing pathway) it was estimated as a project.

Recommended Nomenclature for Master Phased Projects

As stated earlier, the majority of the utility specific projects were combined together into logical "master phased projects" based on their geographic location for work in the same section of street or campus area. The master project number is two characters. The first character is a number that defines the phase the work should be completed in. The second character set is a sequential alphabetical value starting at "A" and ascending in order to a double digit character if the projects exceed 26 per phase or to the letter "Z". It should be noted that there is no order or priority reflected in the project number.

An example would be project number "1J". This project occurs in phase one and is the 10th project identified out of the 25 projects listed in this phase.

Some projects did not fit this phase specific mold, therefore two categories, Regional Campus Issues and Building Specific, were developed to quantify projects with major infrastructure impacts; and/or, a generic project that could not be assigned to a specific phased project number (e.g., adding chilled water meters to all large buildings or upgrading electrical cabling for a portion of campus). An example of this would be project number "Regional Campus Issues – AAA-B-CC-DDD". These projects have not been included in the Master Phased Project List, but are shown as a separate list.

Master Project List

All costs are project costs only represented in May 2016 dollars and include costs such as design fees, surveys, permits, testing, etc. Costs do not include any site upgrades in the project area that may be recommended by other portions of the 2015 Campus Master Plan Update. Final street restoration was estimated using Figures 1-2 through 1-5 as a guide.

The information technology (IT) infrastructure, domestic water (WTR), storm sewer (SS), sanitary sewer (SAN), and compressed air (CA) projects included in the project summary list were not reviewed, updated, or re-estimated as part of the scope of the 2015 Utility Master Plan. The information technology infrastructure, domestic water, storm sewer, sanitary sewer, and compressed air projects included in the project summary lists are repeated from the 2005 Utility Master Plan. For more information regarding these projects, reference the 2005 Utility Master Plan. Each steam project includes dollars for compressed air system upgrades/replacements.

Table 1-5 Project Summary List (Phase 1)

Master Phased Project No.	Project Description	Utility Specific Projects	Project Priority	Estimated Project Costs[1,2]
1B	University Avenue Steam Utilities	STM-O-21-P1 CA-O-09-P1[4]	Medium	$7,590,000
1C	Johnson Street Steam and Condensate Renovation (DFD Project #16E1D)	STM-O-23-P1 CA-O-11-P1[4]	High[3]	$5,000,000
1D	Lake Shore Resident Hall Steam Laterals	STM-X-05-P1 E-O-14-P1	Medium	$5,000,000
1E	Linden Drive Utilities	STM-O-09-P1 STM-O-36-P1 STM-O-29-P1 STM-O-35-P1 CA-O-04-P1[4] E-X-09-P1 IT-O-04-P1[4] WTR-R-07-P1[4]	Medium/ Enabling	$11,414,000
1F	Russell Labs Domestic Water Utilities	WTR-R-08-P1[4]	[4]	4
1G	Elizabeth Waters Storm Sewer Utilities	SS-R-12-P1[4]	[4]	[4]
1H	Ingraham Hall Addition Utility Relocations	CHW-X-10-P1 STM-X-03-P1 CA-X-01-P1[4] IT-O-08-P1[4]	Enabling	$3,842,000
1I	Orchard Street/University Avenue Signal Utilities	IT-O-07-P1[4]	[4]	[4]

Notes:
1. Costs based on May 2016 dollars.
2. Costs do not include any site upgrades in project area recommended by other portions of 2015 Campus Master Plan Update.
3. Project has been award to an A/E firm and is currently in the design phase.
4. Project includes utilities that were not studied or cost estimated in the 2015 Utility Master Plan, but were studied in the 2005 Utility Master Plan and remains to be completed.

Table 1-5 Project Summary List (Phase 1), continued

Master Phased Project No.	Project Description	Utility Specific Projects	Project Priority	Estimated Project Costs[1,2]
1J	Engineering Hall Storm Sewer Utilities	SS-R-11-P1[4]	[4]	[4]
1K	South Campus Utility Improvements (DFD Project #15K1F)	STM-O-14-P1 E-R-01-P1 IT-O-13-P1[4]	High[3]	$15,500,000
1L	North Campus Distribution Loop/Bascom Hill area	CHW-O-03-P1 STM-O-07-P1 STM-O-13-P1 STM-O-20-P1 CA-O-02-P1[4] CA-O-06-P1[4] E-X-02-P1 IT-O-09-P1[4] IT-O-11-P1[4] IT-R-05-P3[4] WTR-R-14-P1[4] WTR-R-15-P1[4] WTR-R-13-P3[4] SS-S-15-P1[4] SS-S-13-P1[4] SS-S-13-P3[4] SAN-R-15-P1[4]	High	$43,000,000
1M	Limnology Steam Utilities	STM-O-06-P1 CA-O-01-P1[4]	Medium	$926,000
1N	Charter Street Steam Utilities	STM-O-22-P1 CA-O-10-P1[4]	Medium	$7,358,000
1P	Walnut Street Substation Ductbank	E-X-07-P1	Enabling	$1,353,000
1Q	Bacteriology Substation Breakers	E-X-16-P1	Enabling	$626,000
1R	Radio Hall Substation Breakers	E-R-17-P1	Enabling	$313,000
1T	Linden Drive Utilities/ Veterinary Medicine Addition Utility Relocations	E-X-09-P1 IT-X-07-P1[4] IT-X-06-P1[4] IT-X-05-P1[4] CHW-X-17-P1 CHW-O-19-P1 STM-X-09-P1	Enabling	$10,579,000
1U	Linden Drive Utilities	E-X-09-P1 IT-X-06-P14 WTR-R-07-P14	Enabling	$1,276,000
1W	Dejope Hall Steam Utilities	STM-O-30-P1	Low	$2,551,000
1X	Educational Sciences Steam Utilities	STM-O-31-P1	Medium	$1,124,000
1Y	Enzyme Steam and Chilled Water Utilities	CHW-O-13-P1 STM-O-33-P1	Medium	$880,000
1Z	Ag Bulletin / Ag Hall Steam Utilities	STM-O-26-P1	Medium	$2,921,000
	TOTAL PHASE 1			$121,253,000

Notes:
1. Costs based on May 2016 dollars.
2. Costs do not include any site upgrades in project area recommended by other portions of 2015 Campus Master Plan Update.
3. Project has been award to an A/E firm and is currently in the design phase.
4. Project includes utilities that were not studied or cost estimated in the 2015 Utility Master Plan, but were studied in the 2005 Utility Master Plan and remains to be completed.

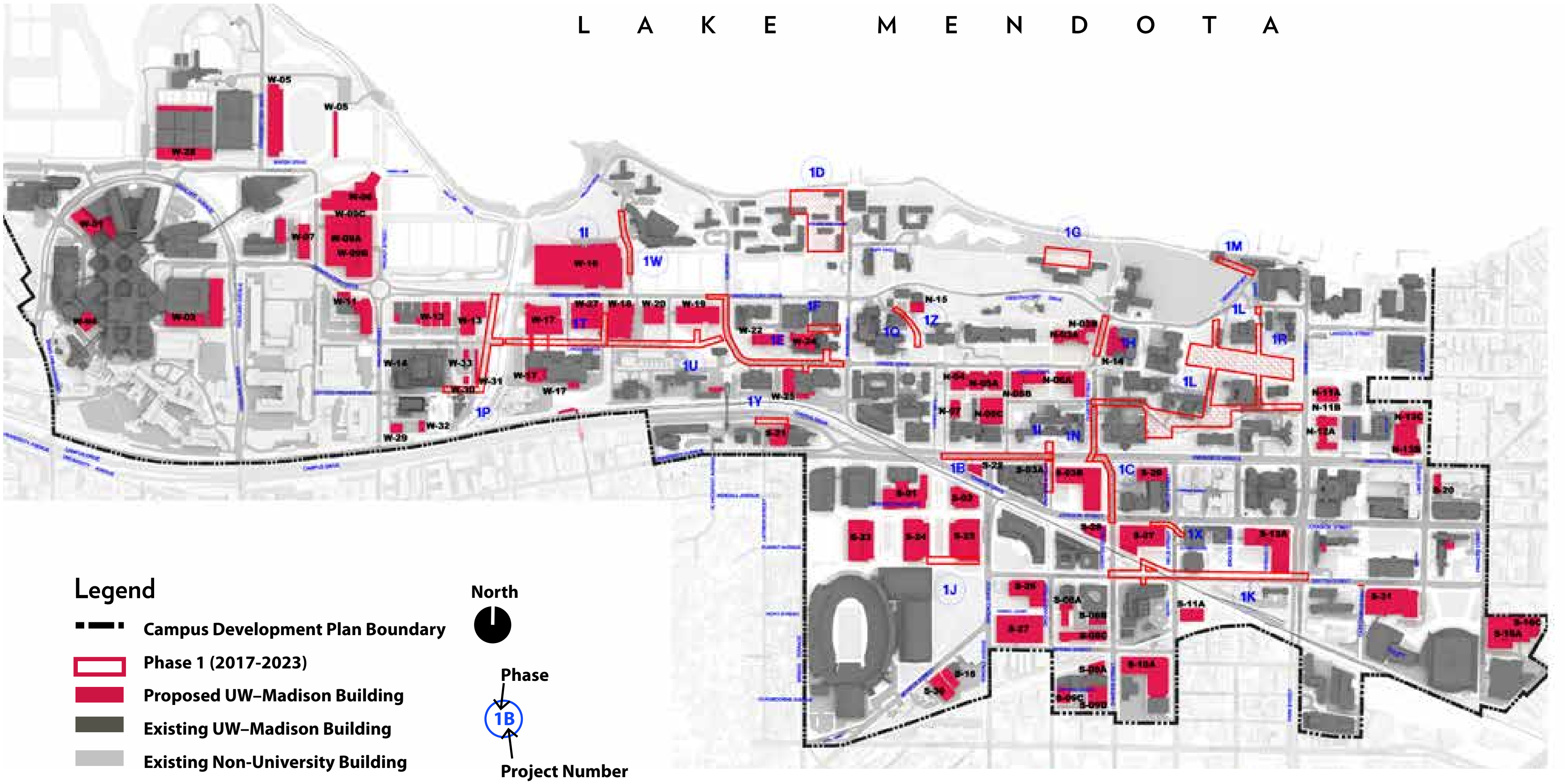


Figure 1-2 Proposed Projects (Phase 1)

Table 1-6 Project Summary List (Phase 2)

Master Phased Project No.	Project Description	Utility Specific Projects	Estimated Project Costs[1,2]
2A	East Campus Distribution Loop / University Avenue Utilities from N. Park Street to East Campus Mall	CHW-X-15-P2 IT-O-12-P2[3]	$984,000
2B	West Campus Distribution Loop / Utilities Routing Around WARF	CHW-O-12-P2 STM-O-37-P2 IT-X-03-P2[3]	$11,004,000
2C	South Campus Distribution Loop / Engineering Drive Utilities	E-X-01-P2 IT –O-06-P2[3] IT-X-08-P2[3] STM-O-34-P2 STM-O-28-P2 CHW-O-17-P2	$9,491,000
2D	South Campus Distribution Loop/W. Johnson Street /W. Johnson Street Utilities from Charter Street to East Campus Mall	IT-R-06-P2[3]	[3]
2E	West Campus Distribution Loop / Highland Avenue Utilities from Campus Drive to Observatory Drive	IT-X-01-P2[3]	[3]
2F	South Campus Utilities/N. Charter Street to Engineering Drive via Dayton Street and Randall Avenue	CHW-O-16-P2	$3,638,000
	TOTAL PHASE 2		$25,117,000

Notes:
1. Costs based on May 2016 dollars.
2. Costs do not include any site upgrades in project area recommended by other portions of 2015 Campus Master Plan Update.
3. Project includes utilities that were not studied or cost estimated in the 2015 Utility Master Plan, but were studied in the 2005 Utility Master Plan and remains to be completed.

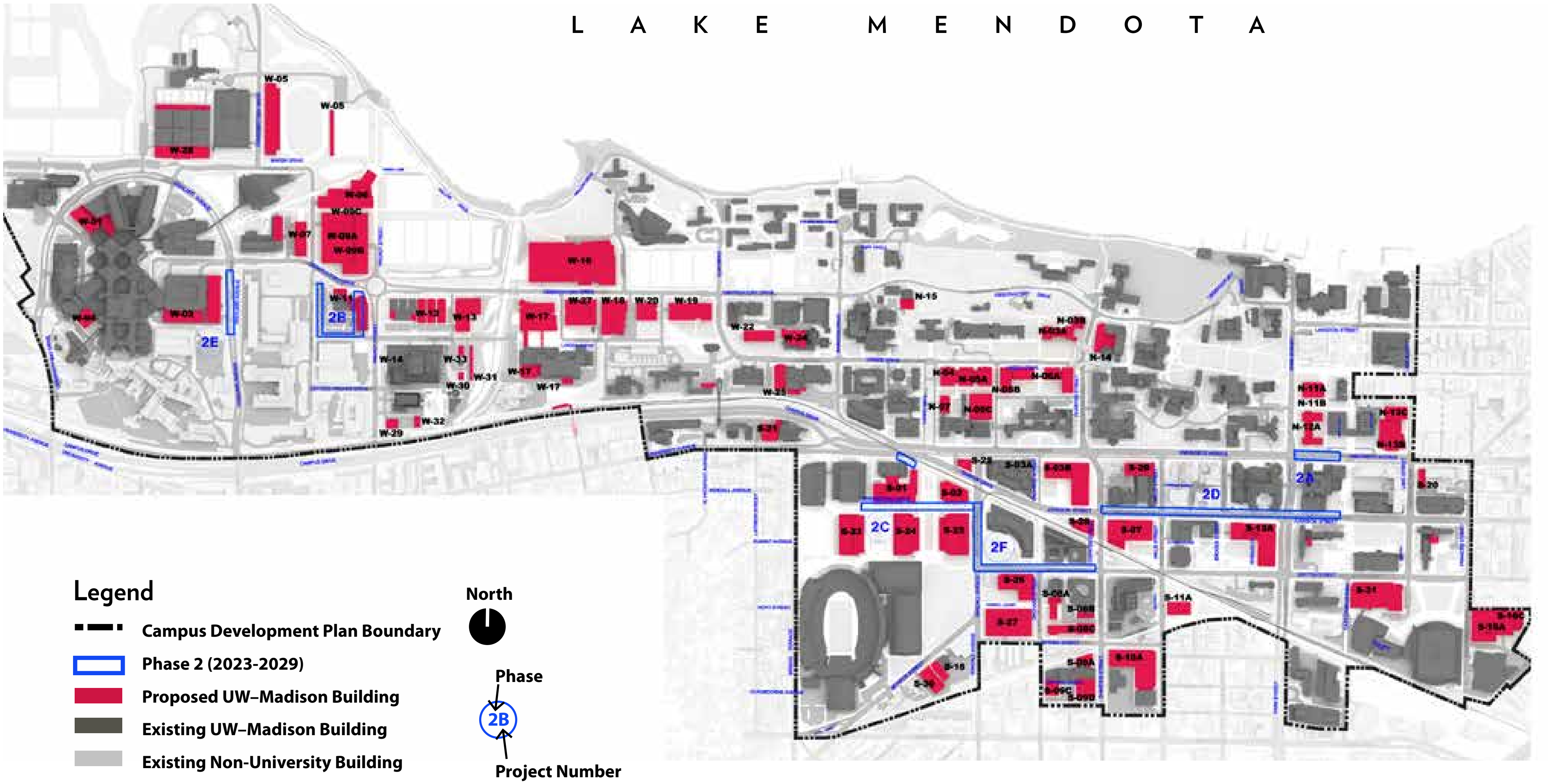


Figure 1-3 Proposed Projects (Phase 2)

Table 1-7 Project Summary List (Phase 3)

Master Phased Project No.	Project Description	Utility Specific Projects	Estimated Project Costs[1,2]
3A	West Campus Distribution Loop / Observatory Drive Utilities at Willow Creek	IT-X-04-P3 IT-O-03-P3	[3]
3B	North Campus Utilities / Linden Drive Utilities from N. Charter Street to Babcock Drive	STM-O-10-P3 STM-O-27-P3 CA-O-05-P3[3] CA-O-03-P3[3]	$12,724,000
3C	East Campus Distribution Loop / W. Johnson Street and Lakes Street Utilities	IT-O-14-P3[3] IT-X-02-P1[3]	[3]
	TOTAL PHASE 3		$12,724,000

Notes:
1. Costs based on May 2016 dollars.
2. Costs do not include any site upgrades in project area recommended by other portions of 2015 Campus Master Plan Update.
3. Project includes utilities that were not studied or cost estimated in the 2015 Utility Master Plan, but were studied in the 2005 Utility Master Plan and remains to be completed.

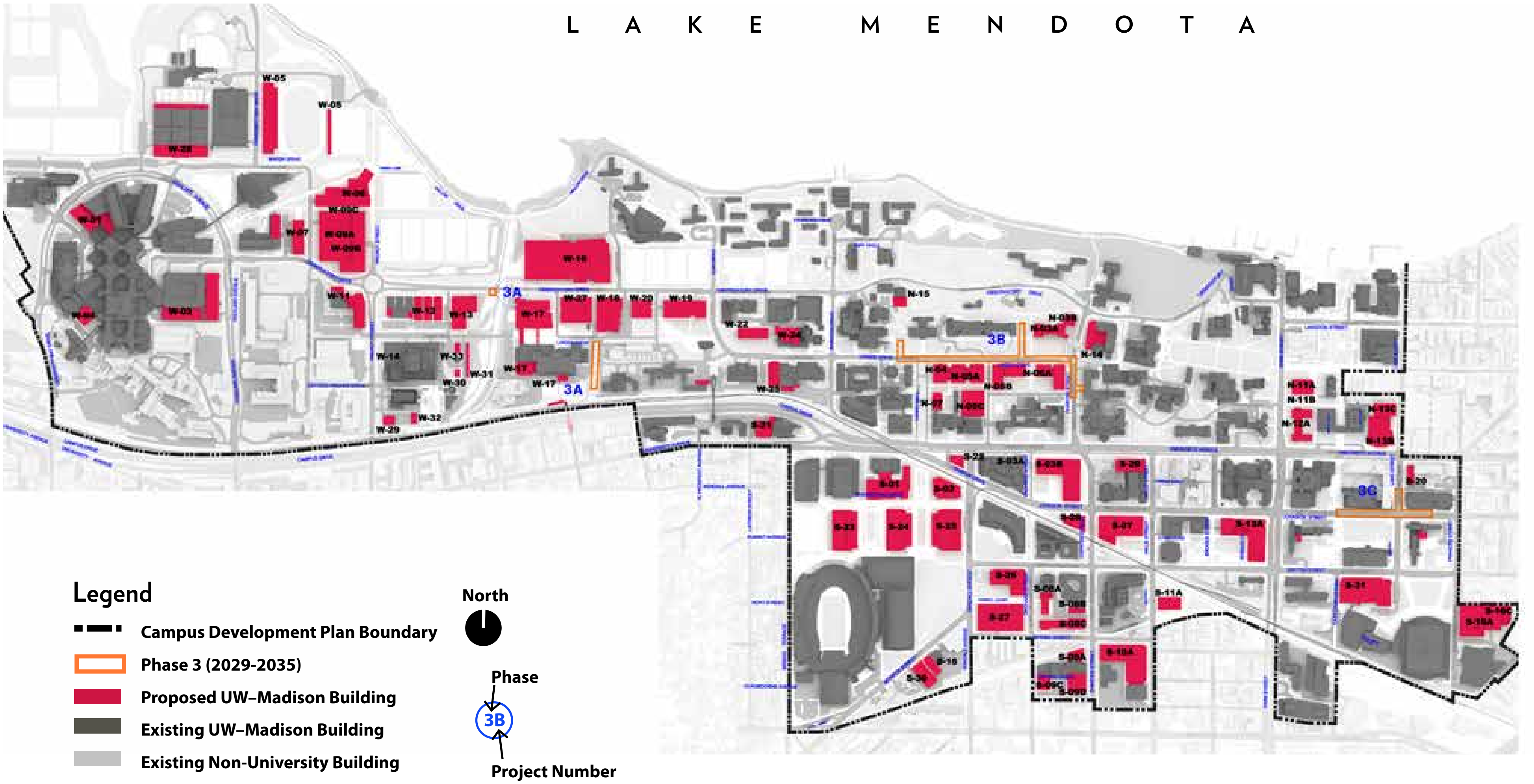


Figure 1-4 Proposed Projects (Phase 3)

Table 1-8 Project Summary List (Phase 4)

Master Phased Project No.	Project Description	Utility Specific Projects	Estimated Project Costs[1,2]
4A	South Campus Distribution Loop / Replace old piping from N. Charter Street to Primate	STM-R-01-P4 CA-R-01-P4[3] E-X-03-P4 IT-X-09-P4[3]	$6,116,000
4B	South Campus Distribution Loop/ Add redundant loop to Primate	STM-R-01-P4 CA-R-01-P4[3]	$3,400,000
4C	West Campus Distribution Loop / Utilities West of Walnut Street and North of Observatory Drive	CHW-X-14-P4 STM-X-08-P4 CA-R-03-P4[3] SS-X-03-P4[3]	$10,640,000
4D	West Campus Distribution Loop / Walnut Street Utilities North of Observatory Drive	WTR-X-03-P4[3] SS-X-04-P4[3] SAN-X-03-P4[3] E-X-05-P4	$2,217,000
4E	Lakeshore Residence Hall Distribution Loop	CHW-X-16-P4	$3,926,000
4F	North Campus Distribution Loop / Observatory Drive Utilities from Charter Street to Babcock Drive	IT-R-03-P4[3]	[3]
4G	Far West Substation	E-R-15-P4 E-R-16-P4 IT-R-01-P4[3]	$16,306,000
4H	South Campus Distribution Loop / Utilities to New Arts Complex[4]	CHW-X-05-P4 CHW-X-13-P4 STM-X-06-P4 CA-X-05-P4[3] E-X-01-P4 IT-X-10-P4[3]	$66,956,000
4I	Far East Substation	E-R-15-P4 E-R-17-P4	$16,306,000
4J	South Campus Utilities / Utilities to Environmental Health and Safety	CHW-O-14-P4 STM-O-32-P4	$863,000
4K	South Campus Utilities / Utilities from Engineering Drive to WEI	CHW-R-01-P4	$2,130,000
	TOTAL PHASE 4		$128,860,000

Notes:
1. Costs based on May 2016 dollars.
2. Costs do not include any site upgrades in project area recommended by other portions of 2015 Campus Master Plan Update.
3. Project includes utilities that were not studied or cost estimated in the 2015 Utility Master Plan, but were studied in the 2005 Utility Master Plan and remains to be completed.
4. An increase in chilled water capacity could be made via addition of a chiller at the West Campus Cogeneration Facility in lieu of construction of an East Chiller Plant.

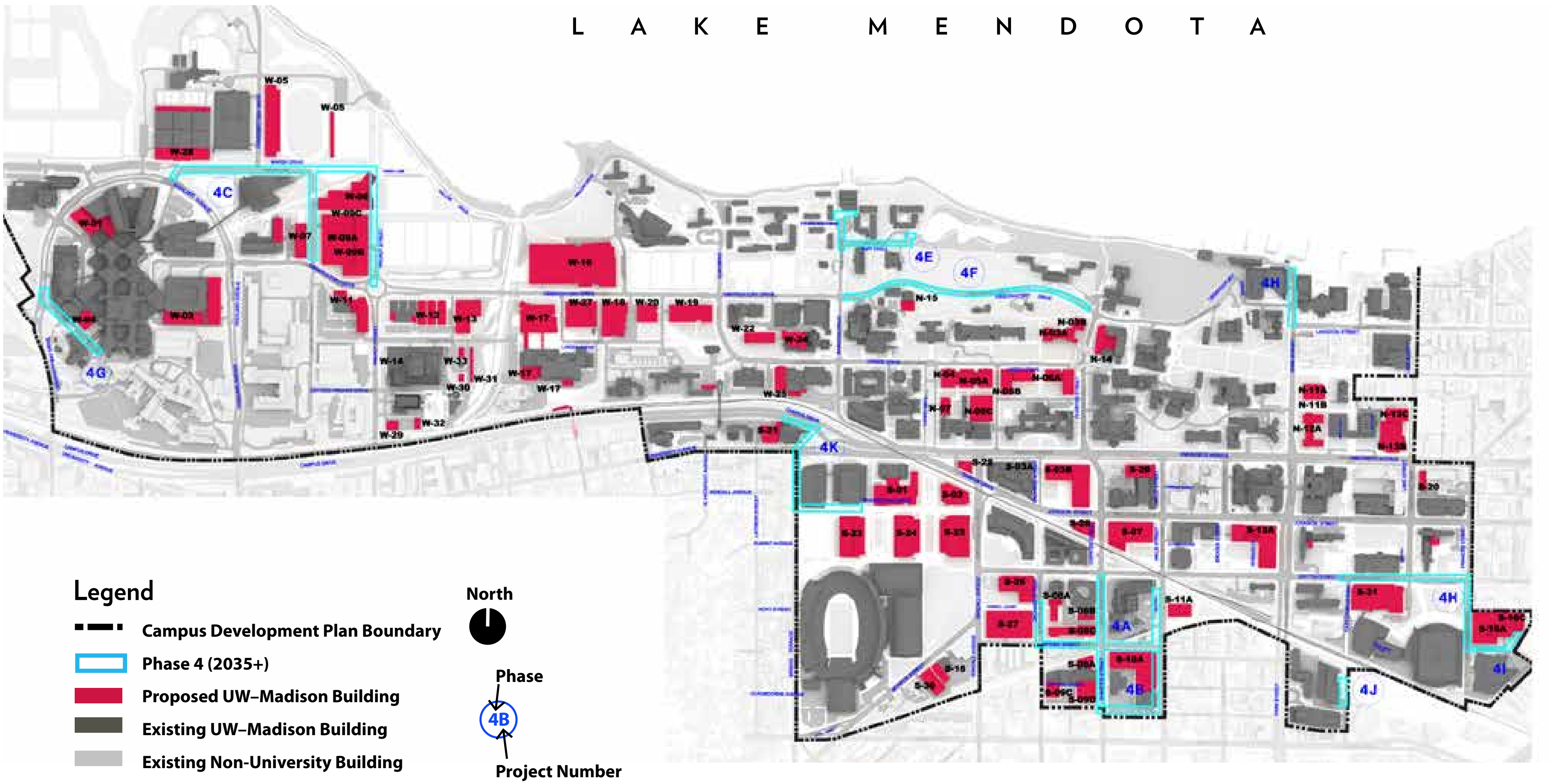


Figure 1-5 Proposed Projects (Phase 4)

2. STEAM SYSTEM

Existing Facilities

The current university owned and operated plants are the Charter Street Heating Plant (CSHP), the Walnut Street Heating Plant (WSHP), and the West Campus Cogeneration Facility (WCCF). These three plants have a total maximum capacity of 2,300,000 pounds per hour (PPH) with a firm capacity of 2,000,000 PPH. The West Campus Cogeneration Facility (WCCF) has a capacity of 500,000 PPH[1] that may be dispatched to the distribution system at request of UW–Madison. The Charter Street Heating Plant has a capacity of 1,200,000 PPH and the Walnut Street Heating Plant (WSHP) has a capacity of 600,000 PPH.

The steam distribution system consists of two pressure classes and distribution systems – high pressure (HPS) delivered at 175 PSIG and low pressure (LPS) at 10 PSIG. Low pressure steam is generated through back pressure steam turbines on the air compressors at N. Charter Street. The low pressure steam system also has 5 locations where high pressure steam spikes or boosts the pressure.

As an energy provider, UW–Madison has great fuel diversity that enables them to keep the cost of generating steam as economical as possible. Charter Street Heating Plant (CSHP) may select from natural gas, and No. 2 ultra low sulfur fuel oil. The Walnut Street Heating Plant (WSHP) and West Campus Cogeneration Facility (WCCF) both have gas and oil fuels to select from.

Peak high pressure steam load is estimated at 694,000 PPH based on discussions with UW–Madison personnel and plant metering logs.[2] Adding in the low pressure steam usage, heat loss and plant usage the peak steam load is estimated at 830,000 PPH. The summer season minimum load is about 300,000 PPH due to building process and reheat loads.

1 Contractually the plant output is 400,000 PPH, there is a possible additional 100,000 PPH that is achievable through supplemental firing on the HRSG.

2 N. Charter Street measures exported steam and does not include the 175 PSIG used internally (DA tank heating, unit heaters, etc.) in the plant or the capacity of the distribution going south in N. Charter Street to Primate Center or the 10 PSIG system serving Weeks Hall. Hence, the plant records must be adjusted accordingly to reflect the actual steam produced. Steam metering at Walnut Street measures actual boiler output and therefore includes steam used internally for DA tank and unit heaters.

Existing Loads

Estimation Methodology

UW–Madison traditionally metered about 50% of buildings for condensate and only a handful of revenue producing buildings for steam. All newer buildings are metered for steam and condensate. Some, but not all, steam meters are trended for energy usage as a cumulative daily total. This method is acceptable for the purposes of billing of thermal energy use, but has no value in determining the actual hourly peak load of the building, especially for the condensate meters. Since all buildings are not metered on campus for energy use, a methodology was required in estimating their energy use.

The load estimation methodology used the load densities and diversities provided in the 2005 Utilities Master Plan. The peak loads were divided by building gross square footage (GSF) resulting in load density values per building function (classroom, dormitory, office, research lab, hospital, etc.).

These diversified loads were reviewed with UW–Madison Facilities personnel and adjusted again or the differences split where the discrepancies between previous university loads and AEI estimates could not be resolved. Table 2-1 illustrates the load density and diversity factors.

These diversification factors were applied across the entire campus, and then the loads and diversification factors were adjusted proportionally to the overall campus peak load.

Table 2-1 Heating Load Density & Diversity Estimate

Building Type	Heating Load Density (Btu/Sf)	Assumed Diversity
Agricultural Greenhouse	80	0.55
Animal/Veterinary	45	0.60
Broadcast Facility	45	0.70
Child Care Facility	25	0.75
Classroom – VAV	60	0.70
Classroom – CAV	50	0.65
Computer Facility	40	0.95
Computer Lab	40	0.90
Food Service Facility	65	0.60
Gym – Recreation Facility	33	0.70
Gym – Recreation Facility – Pool	40	0.75
Gym – Arena	55	0.70
Hospital	80	0.80
Lab – Extra Heavy	140	0.95
Lab – Heavy	125	0.90
Lab – Heavy – Old	145	0.90
Lab – Medium	95	0.85
Lab – Medium – Old	130	0.85
Lab – Light	65	0.85
Lab – Light – Old	92	0.85
Library	35	0.60
Museum	40	0.60
Office – CAV	50	0.60
Office – VAV	60	0.60
Outdoor Services	25	0.60
Residence Hall – Food Service	63	0.65
Residence Hall	30	0.65
Service/Grounds Facility	18	0.70

Building Type	Heating Load Density (Btu/Sf)	Assumed Diversity
Sports Arena	65	0.70
Sports Outdoor	30	0.60
Sports – Training Facility	65	0.60
Storage Facility	25	0.75
Unknown Building Type	18	0.60
Vehicle Service Facility	40	0.75

Existing Building Estimated Heating Load

The peak heating load for the year 2016 is estimated at 830,043 PPH, which includes both high pressure and low pressure loads as summarized in Table 2-2. The load consists of 180 buildings connected to the campus loop totaling over 19,385,000 square feet or ~90% of the campus building area is connected to the steam network. The high pressure steam (HPS) system serves about 14,625,000 square feet or 74% of the campus building area and 4,750,000 square feet or 25% of campus is served by low pressure steam (LPS).

There are over a dozen buildings that are served by both high and low pressure steam, but for the most part buildings are provided with either high pressure steam or low pressure steam. For the dual pressure steam served buildings, the heating equipment is served by the low pressure steam and process loads by the high pressure steam.

Table 2-2 Existing Heating Load Estimate By Building

Building Name	Bldg. No.	Building Type	Gross Square Feet	HPS Peak Demand (PPH)	LPS Peak Demand (PPH)
1800 University Ave (Survey Center)	113	Lab – Light	5,101	–	–
1848 University Ave (UW Foundation)	493		–	–	–
30 North Mills	124	Office – Vav	62,906	–	–
Adams Hall	564	Residence Hall	89,821	1,261	–
Agricultural Bulletin Building	78	Classroom – Cav	7,353	–	191
Agricultural Dean's Residence	72	Unknown Building Type	8,965	–	–
Agricultural Engineering Building	80	Classroom – Cav	23,909	–	620
Agricultural Engineering Laboratory	99	Service/ Grounds Facility	32,654	296	–
Agricultural Hall	70	Classroom – Cav	77,385	–	2,006
American Family Childrens Hospital (Phase 1)	1426	Hospital	309,847	14,724	–
Animal Science Building	118	Lab – Light	127,626	5,077	–
Armory & Gymnasium	20	Office – Cav	77,688	1,678	–
Art Lofts	220		78,974	–	–
Athletic Operations Bldg	584	Gym – Rec Facility	19,488	324	–
Atmospheric Oceanic & Space Sciences Bldg	156	Lab – Light	144,147	5,734	–
Babcock Hall	106	Lab – Light	136,071	5,413	–
Bardeen Medical Laboratories	451B	Lab – Heavy	69,344	–	5,617
Barnard Hall	560	Residence Hall	58,451	–	821

Table 2-2 Existing Heating Load Estimate By Building, continued

Building Name	Bldg. No.	Building Type	Gross Square Feet	HPS Peak Demand (PPH)	LPS Peak Demand (PPH)
Bascom Hall	50	Office – Cav	178,329	–	3,852
Below Alumni Center	489	Office – Vav	23,417	607	–
Biotron Laboratory	45	Lab – Medium	106,907	6,216	–
Birge Hall	54	Lab – Light	171,883	–	6,838
Bock Laboratories, Robert M	33	Lab – Heavy	73,739	5,973	–
Bradley Hall, Harold C	506	Residence Hall	56,270	790	–
Bradley Memorial Building	452	Lab – Light	23,363	–	929
Camp Randall Stadium	22	Broadcast Facility	97,990	1,204	–
Camp Randall Sports Center (Shell)	25	Gym – Rec Facility	107,372	–	–
Capitol Ct 1220	782	Lab – Light	85,988	3,421	–
Carillon Tower	487	Unknown Building Type	1,694	–	13
Carson Gulley Commons	565	Residence Hall – Food Service	30,245	892	–
Central Kitchen-Chadbourne And Barnard	562	Food Service Facility	31,459	–	883
Cereal Crops Research Unit	121	Lab – Heavy	34,000	2,754	–
Chadbourne Hall	557	Residence Hall	145,365	2,041	–
Chamberlin Hall, Thomas C	55	Lab – Light	339,672	–	13,512
Chamberlin House	571	Residence Hall	16,453	231	–
Charter St N 45	504	Office – Cav	22,110	478	–

Building Name	Bldg. No.	Building Type	Gross Square Feet	HPS Peak Demand (PPH)	LPS Peak Demand (PPH)
Chazen Museum Of Art	524	Museum	94,778	1,638	–
Chemistry Bldg, F Daniels & J H Mathews	47	Lab – Medium	409,067	25,667	1,211
Clinical Science Center	1400	Hospital	1,897,439	90,166	–
Cole Hall	555	Residence Hall	49,839	700	–
Computer Sciences And Statistics	155	Lab – Medium	244,096	14,192	–
Conover House	574C	Residence Hall	16,552	232	–
Dairy Barn	105	Unknown Building Type	40,782	317	–
Dairy Cattle Center	92	Animal/Vet.	34,049	662	–
Dairy Forage Research Center-Us	96	Animal/Vet.	58,898	1,145	–
Dejope Residence Hall	567	Residence Hall – Food Service	229,420	6,764	–
Deluca Biochemical Sciences	204	Lab – Medium	224,078	13,028	–
Deluca Biochemistry Building	84	Lab – Medium	82,100	4,773	–
Deluca Biochemistry Laboratories	205	Lab – Heavy	219,524	17,781	–
East Campus Mall 333	467	Residence Hall	237,277	–	–
East Campus Mall 432	515	Food Service Facility	34,075	957	–
Education Building	400	Classroom – Vav	120,889	–	2,611

Table 2-2 Existing Heating Load Estimate By Building, continued

Building Name	Bldg. No.	Building Type	Gross Square Feet	HPS Peak Demand (PPH)	LPS Peak Demand (PPH)
Educational Sciences	154	Classroom – Cav	178,004	4,614	–
Elizabeth Waters Hall	559	Residence Hall	143,626	–	2,017
Elvehjem Building, Conrad A.	544	Museum	94,262	–	1,629
Engineering Centers Building	481	Lab – Light	251,334	9,998	–
Engineering Drive 1410	486	Lab – Medium	63,561	3,695	–
Engineering Hall	408	Classroom – Cav	464,768	12,047	–
Engineering Mall	766	Outdoor Services	2,018	20	–
Engineering Research Building	762	Lab – Light – Old	157,510	8,868	–
Environmental Health And Safety Building	549	Service/ Grounds Facility	79,675	723	–
Enzyme Institute	479	Lab – Medium	69,684	4,051	–
Extension Building G (432 N. Lake St.)	500	Office – Cav	76,318	1,648	–
Field House	29	Gym – Rec Facility	123,830	2,060	–
Fleet And Service Garage	1077	Vehicle Service Facility	16,142	349	–
Fluno Center For Executive Education	139	Office – Vav	–	–	–
Forest Products Laboratory	36	Lab – Light	–	11,009	–
Genetics-Biotechnology Center Building	82	Lab – Heavy	247,746	–	20,067
Gilman House	569	Residence Hall	16,470	231	–
Goodman Softball Complex	175	Sports – Training Facility	8,007	–	–
Goodnight Hall, Scott H	508	Residence Hall	55,386	778	–
Gordon Dining And Event Center	1249	Residence Hall – Food Service	111,644	3,292	–
Grainger Hall	140	Classroom – Vav	439,491	9,493	–
Greenhouse-King Hall	75	Agricultural/ Greenhouse	15,051	–	477
Greenhouse-Walnut Street	122	Agricultural/ Greenhouse	47,007	1,489	–
Gymnasium-Natatorium	31	Gym – Rec Facility	249,579	4,151	–
Hanson Biomedical Sciences Building	94	Lab – Light	43,519	1,731	–
Hasler Laboratory Of Limnology	483	Lab – Light	15,245	606	–
Health Science Learning Center (Hslc)	1480	Classroom – Vav	284,436	6,144	–
Heating And Cooling Plant-Charter St	529	Central Plants	111,532	–	–
Heating And Cooling Plant-Walnut St	49	Central Plants	37,423	–	–
Henry Mall 445	102	Lab – Light	54,750	–	2,178
Henry Rust/David Schreiner Hall	158	Residence Hall	21,098	–	–
Herrick Dr 502	111	Office – Cav	8,617	–	–

Table 2-2 Existing Heating Load Estimate By Building, continued

Building Name	Bldg. No.	Building Type	Gross Square Feet	HPS Peak Demand (PPH)	LPS Peak Demand (PPH)
Herrick Dr 505	108	Service/ Grounds Facility	1,139	–	–
Herrick Dr 525 – Electrical Storage	222	Service/ Grounds Facility	3,630	–	–
Herrick Dr 550 – Incinerator	127	Service/ Grounds Facility	2,163	–	–
Holt Center	574H	Classroom – Cav	20,143	522	–
Horse Barn	95	Unknown Building Type	19,808	154	–
Horticulture	87B	Lab – Light	25,276	1,005	–
Humanities Building, Mosse George L	469	Classroom – Cav	333,363	8,641	–
Humphrey Hall	136	Residence Hall	16,523	232	–
Ingraham Hall, Mark H	56	Classroom – Cav	97,603	–	2,530
Jones House	572	Residence Hall	16,537	232	–
Jorns Hall	137	Residence Hall	16,820	236	–
Kellner Hall	460	Office – Vav	85,297	2,211	–
Kohl Center, The	225	Gym – W/ Spectators	472,906	11,066	–
Kronshage Hall	574	Residence Hall	17,249	242	–
LaBahn Arena	227	Sports – Arena	107,266	3,514	–
Lathrop Hall	32	Classroom – Cav	105,256	–	2,728

Building Name	Bldg. No.	Building Type	Gross Square Feet	HPS Peak Demand (PPH)	LPS Peak Demand (PPH)
Law Building	430	Classroom – Cav	236,081	3,060	3,060
Leopold Residence Hall	576	Residence Hall	64,719	909	–
Lift Station – Lot 76	1714	Unknown Building Type	–	–	–
Linden Dr 1645	91	Service/ Grounds Facility	3,210	29	–
Linden Dr 1910	103	Classroom – Cav	11,267	292	–
Linden Dr 2105	465	Unknown Building Type	1,860	–	–
Linden Dr 2115	128	Service/ Grounds Facility	8,756	79	–
Livestock Laboratory	115	Animal/Vet.	35,129	683	–
Lowell Center	502	Classroom – Vav	136,010	–	–
Mack House	570	Residence Hall	16,986	238	–
Materials Science And Engineering Bldg	520	Classroom – Cav	45,759	1,186	–
Mcardle Cancer Research Building	468	Lab – Heavy	96,657	7,829	–
Mcclain Athletic Facility	21	Gym – Rec Facility – Pool	169,320	3,657	–
Meat Science And Muscle Biology Lab	123	Lab – Light	30,190	1,201	–
Mechanical Engineering Building	407	Classroom – Cav	297,993	7,724	–
Medical Sciences	451C	Lab – Extra Heavy	72,499	3,471	3,471

Table 2-2 Existing Heating Load Estimate By Building, continued

Building Name	Bldg. No.	Building Type	Gross Square Feet	HPS Peak Demand (PPH)	LPS Peak Demand (PPH)
Medical Sciences Center	450	Lab – Light	443,530	8,822	8,822
Memorial Library	15	Library – Standard	573,454	8,671	–
Memorial Union	8	Residence Hall – Food Service	220,475	6,500	–
Merit House	575	Residence Hall	19,662	276	–
Microbial Science Building	60	Lab – Heavy	440,846	35,709	–
Middleton Building, W S	455	Library – Standard	45,217	–	684
Moore Hall-Agronomy	87A	Lab – Light – Old	34,609	–	1,949
Morgridge Institute For Research	211	Lab – Medium	226,752	13,183	–
Music Hall	485	Classroom – Cav	38,131	–	988
Nancy Nicholas Hall	85	Classroom – Cav	198,915	–	2,122
Newell J. Smith Residence Hall	1079	Residence Hall	158,733	2,229	–
Nicholas-Johnson Pavilion And Plaza	226	Sports – Arena	27,847	912	–
Nielsen Tennis Stadium	38	Gym – Rec Facility	140,673	–	–
Noland Zoology Building, Lowell E	402	Lab – Light	92,818	3,692	–
North Hall	52	Office – Cav	22,447	–	485
Nutritional Sciences	449	Classroom – Cav	56,502	–	1,465

Building Name	Bldg. No.	Building Type	Gross Square Feet	HPS Peak Demand (PPH)	LPS Peak Demand (PPH)
Observatory Hill Office Building	512	Unknown Building Type	6,964	–	54
Observatory, Washburn	510	Unknown Building Type	11,166	–	87
Ogg Hall	1243	Residence Hall	218,377	3,066	–
N. Park Street, 21 North	1078	Office – Vav	138,640	3,594	–
Parking Garage 6 – Helen C. White	9507	Parking	96,881	–	–
Parking Garage 7 – Grainger	9508	Parking	191,769	–	–
Parking Garage 23 – Van Hise	9522	Parking	–	–	–
Parking Garage 38 – Microbial	9537	Parking	66,704	–	–
Parking Garage 83 – Fluno Center	9577	Parking	120,582	–	–
Parking Garage 95 – Hslc	9585	Parking	71,360	–	–
Parking Ramp 17 – Engineering Dr	536	Parking	264,321	–	–
Parking Ramp 20 – University Ave	142	Parking	94,111	–	–
Parking Ramp 29 – 21 N. Park St	9530	Parking	–	–	–
Parking Ramp 36 – Observatory Dr	104	Parking	147,883	–	–
Parking Ramp 46 – Lake & W. Johnson	152	Parking	254,841	–	–
Parking Ramp 75 – CSC	751	Parking	443,766	–	–
Parking Ramp 76 – University Bay Dr	9573	Parking	409,650	–	–

Table 2-2 Existing Heating Load Estimate By Building, continued

Building Name	Bldg. No.	Building Type	Gross Square Feet	HPS Peak Demand (PPH)	LPS Peak Demand (PPH)
Phillips Residence Hall	507	Residence Hall	54,983	772	–
Physical Plant – Grounds Storage	125	Plant	2,560	–	–
Physical Plant – Grounds Storage 2	223	Plant	480	–	–
Plant Sciences	87C	Lab – Light	62,173	2,473	–
Police And Security	550	Classroom – Vav	17,323	–	–
Porter Boathouse	172	Gym – Rec Facility	49,996	832	–
Poultry Research Laboratory	110	Animal/Vet.	24,013	467	–
Primate Center, Wisconsin	526	Lab – Extra Heavy	31,606	3,027	–
Primate Lab, Harlow	527	Lab – Heavy	36,944	2,992	–
Psychology Building, W J Brogden	470	Classroom – Cav	115,071	–	2,983
Pyle Center	6	Classroom – Cav	148,235	3,842	–
Radio Hall	405	Classroom – Cav	21,397	–	555
Rennebohm Hall	34	Lab – Heavy – Old	222,517	20,908	–
Residence Halls Garage	566	Vehicle Service Facility	1,361	29	–
Russell Laboratories	114	Lab – Light – Old	154,675	8,709	–
School Of Social Work Building	453	Classroom – Cav	41,344	–	1,072
Schuman Shelter	116	Outdoor Services	960	5	5
Science Hall	53	Classroom – Vav	101,646	1,098	1,098
Seeds Building	119	Classroom – Cav	17,744	460	–
Sellery Hall	1245	Residence Hall	230,408	3,235	–
Service Building	530	Service/ Grounds Facility	51,066	–	463
Service Building Annex (H)	534	Service/ Grounds Facility	38,356	–	348
Service Memorial Institute	451A	Lab – Heavy	122,474	9,920	–
Showerman House	574S	Residence Hall	16,497	232	–
Signe Skott Cooper Hall	44	Classroom – Vav	169,924	3,670	–
Slichter Hall	558	Residence Hall	63,180	887	–
Smith Annex (H), Hiram	77	Classroom – Cav	12,755	331	–
Smith Greenhouse, D C	206	Agricultural/ Greenhouse	13,057	–	414
Smith Hall, Hiram	76	Classroom – Cav	19,833	–	514
Social Science Building	46	Classroom – Vav	204,205	–	4,411
Soils And King Hall – Soils	74B	Lab – Medium	26,696	–	1,552
Soils And King Hall – King Hall	74A	Lab – Medium	21,478	–	1,249
South Hall	51	Office – Cav	22,522	–	486

Table 2-2 Existing Heating Load Estimate By Building, continued

Building Name	Bldg. No.	Building Type	Gross Square Feet	HPS Peak Demand (PPH)	LPS Peak Demand (PPH)
Southeast Recreational Facility	28	Gym – Rec Facility – Pool	191,254	4,131	–
State Historical Society	16	Office – Vav	237,700	6,161	–
Steenbock Memorial Library	79	Library – Standard	113,343	1,714	–
Sterling Hall	57	Classroom – Cav	170,190	–	4,411
Stock Pavilion	90	Unknown Building Type	94,775	737	–
Stovall Building, William D-Hygiene Lab	476	Lab – Light	80,939	–	3,220
Sullivan Hall	556	Residence Hall	49,023	688	–
Susan B. Davis Residence Hall	578	Residence Hall	11,967	–	–
Swenson House	573	Residence Hall	16,558	232	–
Taylor Hall, Henry	464	Classroom – Cav	34,504	–	894
Teacher Education	153	Classroom – Cav	97,103	2,517	–
Tripp Hall	563	Residence Hall	90,770	1,274	–
Turner House	568	Residence Hall	16,552	232	–
Union South	88	Residence Hall – Food Service	307,098	9,054	–
University Ave 1610	129	Classroom – Cav	24,589	637	–
University Club	515B	Gym – Rec Facility	15,969	266	–
UW Medical Foundation Centennial Building	1435	Lab – Light	136,060	5,412	–
Van Hise Hall	482	Classroom – Cav	226,940	–	5,882
Van Vleck Hall, E B	48	Classroom – Cav	109,914	–	2,849
Veterans Administration Hospital	1055	Hospital	618,517	29,392	–
Veterinary Diagnostic Lab	126	Lab – Heavy	81,777	6,624	–
Veterinary Medicine Building	93	Lab – Light	248,852	9,899	–
Vilas Communication Hall	545	Broadcast Facility	253,043	5,739	–
Waisman Center	459	Lab – Light – Old	166,143	9,355	–
WARF Office Building	39	Office – Cav	155,085	3,350	–
Water Science And Engineering Laboratory	403	Lab – Light	41,947	–	1,669
Weeks Hall For Geological Sciences, Lewis G	521	Lab – Medium	146,474	–	8,516
Wendt Library, Kurt F	404	Library – Standard	74,459	1,126	–
West Campus Cogeneration Facility	120	Central Plants	120,000	–	–
White Hall, Helen C	18	Library – Standard	245,710	3,715	–
Wisconsin Energy Institute	752	Lab – Medium	110,636	6,432	–

Table 2-2 Existing Heating Load Estimate By Building, continued

Building Name	Bldg. No.	Building Type	Gross Square Feet	HPS Peak Demand (PPH)	LPS Peak Demand (PPH)
Wisconsin Institute For Discovery	212	Lab – Medium	88,931	5,170	–
Wisconsin Institutes For Medical Research	1485	Lab – Medium	701,343	40,776	–
Witte Hall	1246	Residence Hall	230,799	3,240	–
Zoe Bayliss Co-Op	577	Residence Hall	11,603	–	–
Zoology Research Building	401	Lab – Medium	44,256	2,573	–
		Total	25,683,925	693,539	136,504

Projected Future Loads

The following list of buildings, areas, functions, and phasing is based on the May 17, 2016, phasing spreadsheet developed by SmithGroupJJR for the 2015 Campus Master Plan Update. The loads were estimated using the identical density factors used for the existing buildings in Table 2-1. The future phases are divided into individual tables, staring with Table 2-3 for Phase 1. Each table summarizes both the construction and removal of buildings for that phase. All phases have six year durations. Buildings shown without an increase or decrease in load are not currently connected to the campus steam system, nor will they be in the future. Unless indicated by UW–Madison to serve a future building using low pressure steam all future buildings were added to the high pressure steam system.

In addition to the university campus buildings, steam is also provided to the Forest Products Laboratory, UW Hospital and Clinics-Clinical Science Center, and the Veterans Administration Hospital. Analysis of future expansion of these facilities was not part of the scope of the 2015 Utility Master Plan, therefore no steam loads were estimated for these facilities. Existing steam loads for these facilities were included in Table 2-2 Existing Heating Load Estimate by Building.

Table 2-3 Future Heating Load Estimate By Building (Phase 1)

Building Name	Bldg. No.	Building Type	Gross Square Feet	HPS Peak Demand (PPH)	LPS Peak Demand (PPH)
Greenhouse-Walnut Street	122	Agricultural/ Greenhouse	47,007	1,489	–
Gymnasium-Natatorium	31	Gym – Rec Facility	249,579	4,151	–
Linden Dr 1645	91	Service/ Grounds Facility	3,210	29	–
Linden Dr 1910	103	Classroom – Cav	11,267	292	–
Seed Building	119	Classroom – Cav	17,744	460	–
Southeast Recreational Facility	28	Gym – Rec Facility – Pool	191,254	4,131	–
Susan B. Davis Residence Hall	578	Residence Hall	11,967	–	–
University Ave 1610	129	Classroom – Cav	24,589	637	–
Zoe Bayliss Co-Op	577	Residence Hall	11,603	–	–
Added					
Babcock Hall Center for Dairy Research Addition	W-25	Classroom – Vav	31,300	676	–
Chemistry Bldg Expansion	S-29	Classroom – Vav	173,169	–	3,740
College of Engineering Research Building	S-21	Lab – Medium	156,364	9,091	–
Gymnasium-Natatorium Replacement	W-16	Gym – Rec Facility	471,417	7,832	–
Hamel Music Center P1&2	N-13B	Broadcast Facility	135,000	3,062	–
Ingraham Hall Additions	N-14	Classroom – Vav	56,000	–	1,210
Academic/Research (W. Johnson/N. Park Site)	S-13A	Classroom – Vav	348,000	7,334	–
Meat Science And Muscle Biology Lab	W-18	Lab – Light	228,000	9,070	–
Officer Education Facility	S-30	Classroom – Vav	65,000	–	–
Parking Structure	S-13	Parking	–	–	–
Parking Structure	W-02	Parking	–	–	–
Parking Structure	W-27	Parking	198,000	–	–
Police Addition	S-18	Classroom – Vav	24,840	–	–
Southeast Recreational Facility	S-31	Gym – Rec Facility – Pool	253,000	5,465	–
Veterinary Medicine Building	W-17	Lab – Light	138,911	5,526	
Walnut Greenhouse II	W-12	Agricultural/ Greenhouse	24,000	760	–
		Removed	568,220	11,190	–
		Added	2,303,001	48,816	4,950
		Net	1,734,781	37,626	4,950
		Post Phase 1	27,418,706	731,166	141,454

Table 2-4 Future Heating Load Estimate By Building (Phase 2)

Building Name	Bldg. No.	Building Type	Gross Square Feet	HPS Peak Demand (PPH)	LPS Peak Demand (PPH)
Removed					
Engineering Drive 1410	486	Lab – Medium	63,561	3,695	–
Psychology Building, W J Brogden	470	Classroom – Cav	115,071	–	2,983
Schuman Shelter	116	Outdoor Services	960	5	5
Service Building	530	Service/ Grounds Facility	51,066	–	463
Service Building Annex (H)	534	Service/ Grounds Facility	38,356	–	3,220
Stovall Building, William D-Hygiene Lab	476	Lab – Light	80,939	–	–
Added					
Engineering Dr 1410 – Replacement	S-02	Lab – Light	169,091	6,726	–
Nielsen Tennis Stadium Expansion	W-28	Gym – W/ Spectators	47,075	415	–
		Removed	349,953	3,700	6,670
		Added	216,166	7,141	–
		Net	-133,787	3,441	(6,670)
		Post Phase 2	27,284,919	734,607	134,784

Table 2-5 Future Heating Load Estimate By Building (Phase 3)

Building Name	Bldg. No.	Building Type	Gross Square Feet	HPS Peak Demand (PPH)	LPS Peak Demand (PPH)
Removed					
Bardeen Medical Laboratories	451B	Lab – Heavy	69,344	–	5,617
Bradley Memorial Building	452	Lab – Light	23,363	–	929
Engineering Research Building	762	Lab – Light – Old	157,510	8,868	–
Extension Building G (432 N. Lake St.)	500	Office – Cav	76,318	1,648	–
Henry Rust/David Schreiner Hall	158	Residence Hall	21,098	–	–
Humanities Building, Mosse George L	469	Classroom – Cav	333,363	8,641	–
Livestock Laboratory	115	Animal/Vet.	35,129	683	–
McArdle Cancer Research Building	468	Lab – Heavy	96,657	7,829	–
Medical Sciences	451C	Lab – Extra Heavy	72,499	3,471	3,471
Middleton Building, W S	455	Library – Standard	45,217	–	684
Poultry Research Laboratory	110	Animal/Vet.	24,013	467	–
Service Memorial Institute	451A	Lab – Heavy	122,474	9,920	–
Added					
Academic/ Research (Mosse site south)	N-12A	Classroom – Vav	135,000	2,916	–
Academic/ Research – Humanities	N-11A	Lab – Light	84,000	3,342	–
Academic/ Research	S-08A	Lab – Medium	22,000	1,279	–
Academic/ Research (Stovall site)	N-04	Classroom – Vav	82,200	1,776	–
Academic/ Research (SMI Bardeen Med Sciences)	N-06A	Lab – Light	144,000	5,728	–
Engineering Research Building Replacement	S-01	Library – Standard	271,667	4,108	–
Academic/ Research (Meiklejohn Site)	S-28	Classroom – Vav	84,470	1,836	–
Music Phase 3	N-13C	Broadcast Facility	75,000	1,701	–
Parking Structure	N-05C	Parking	–	–	–
Parking Structure Under N-06A	N-06B	Parking	–	–	–
Parking Structure Under N-11A And N-11B	N-11B	Parking	–	–	–
Poultry Research Building	W-20	Animal/Vet.	52,965	1,030	–
Preserve Outreach Center	W-29	Service/Support	8,700	–	–
WID, Phase 2	S-03B	Lab – Medium	392,000	22,791	–
Wisconsin Institutes for Medical Research Ph3	W-01	Lab – Medium	308,000	17,907	–
		Removed	1,076,985	41,528	10,701
		Added	1,660,002	64,413	–
		Net	583,017	22,884	(10,701)
		Post Phase 3	27,867,936	757,491	124,083

Table 2-6 Future Heating Load Estimate By Building (Phase 4)

Building Name	Bldg. No.	Building Type	Gross Square Feet	HPS Peak Demand (PPH)	LPS Peak Demand (PPH)
Removed					
Agricultural Engineering Laboratory	99	Service/Grounds Facility	32,654	296	–
Biotron Laboratory	45	Lab – Medium	106,907	6,216	–
Charter St N 45	504	Office – Cav	22,110	478	–
Engineering Hall	408	Classroom – Cav	464,768	12,047	–
Greenhouse-King Hall	75	Agricultural/ Greenhouse	15,051	–	477
Hanson Biomedical Sciences Building	94	Lab – Light	43,519	1,731	–
Henry Mall 445	102	Lab – Light	54,750	–	2,178
Herrick Dr 505	108	Lab – Light	1,139	–	–
Herrick Dr 509	109	Lab – Light	–	–	–
Herrick Dr 525 – Electrical Storage	222	Service/Grounds Facility	3,630	–	–
Linden Dr 2105	465	Service/Grounds Facility	1,860	–	–
Linden Dr 2115	128	Academic	8,756	–	–
Meat Science And Muscle Biology Lab	123	Lab – Light	30,190	1,201	–
Noland Zoology Building, Lowell E	402	Lab – Light	92,818	3,692	–
Nutritional Sciences	449	Classroom – Cav	56,502	–	1,465
Physical Plant – Grounds Storage	125	Plant	2,560	–	–
Physical Plant – Grounds Storage 2	223	Plant	480	–	–
Primate Lab, Harlow	527	Lab – Heavy	36,944	2,992	–
Primate Center, Wisconsin	526	Lab – Extra Heavy	31,606	3,027	–
School Of Social Work Building	453	Classroom – Cav	41,344	–	1,072
Soils And King Hall – King Hall	74A	Lab – Medium	21,478	–	1,249
Van Hise Hall	482	Classroom – Cav	226,940	–	5,882
Wendt Library, Kurt F	404	Library – Standard	74,459	1,126	–
Zoology Research Building	401	Lab – Medium	44,256	2,573	–
Added					
Academic/Research (Van Hise)	N-03A	Classroom – Vav	114,000	2,462	–
Academic/Research (Van Hise)	N-03B	Classroom – Vav	48,000	1,037	–
Academic/Research	N-05A	Lab – Light	180,000	7,160	–
Academic/Research	N-05B	Lab – Light	165,000	6,564	–
Academic/Research	N-07	Lab – Light	30,000	1,193	–
Academic/Research (Spring St)	S-08C	Lab – Light	150,000	5,967	–
Academic/Research (Lot 45 Site)	S-11A	Classroom – Vav	30,000	648	–
Social/Dining/ Mtg Rooms/Health Sciences	W-06	Residence Hall – Food Service	127,000	2,875	–
Plant Sciences	W-24	Lab – Light	100,000	3,978	–
Art Building	S-16A	Classroom – Vav	162,000	3,499	–
Biological Systems Engineering	W-19	Classroom – Vav	246,000	5,314	–
Cooper Hall Addition	W-08	Classroom – Vav	30,000	648	–
Fluno Addition	S-20	Unknown Building Type	43,200	336	–

Table 2-6 Future Heating Load Estimate By Building (Phase 4), continued

Building Name	Bldg. No.	Building Type	Gross Square Feet	HPS Peak Demand (PPH)	LPS Peak Demand (PPH)
Grounds Storage A – Controlled Temp	W-31	Service/Grounds Facility	3,000	27	–
Grounds Storage B – Covered	W-30	Service/Grounds Facility	–	–	–
Grounds Storage C – Salt	W-33	Service/Grounds Facility	3,500	–	–
Grounds Office / Administration	W-34	Service/Grounds Facility	3,000	27	–
Grounds Greenhouse	W-32	Service/Grounds Facility	6,000	54	–
Health Sciences Research	W-07	Lab – Medium	122,000	7,093	–
Health Sciences Research	W-09B	Lab – Medium	233,250	13,561	–
Health Sciences Research	W-09C	Lab – Medium	231,000	13,430	–
Health Sciences Research	W-13	Classroom – Vav	65,674	1,419	–
Health Sciences Expansion	W-04A	Hospital	60,500	2,875	–
King Hall Greenhouse	N-15	Agricultural/ Greenhouse	7,500	238	–
McClimon Track / Soccer Grandstand	W-5	Sports – Outdoor	78,000	–	–
New Engineering	S-23	Classroom – Vav	204,000	4,406	–
New Engineering	S-24	Classroom – Vav	236,583	5,119	–
New Engineering	S-25	Classroom – Vav	274,986	5,940	–
New Engineering	S-26	Classroom – Vav	169,506	3,672	–
Parking Structure	S-27	Parking	345,600	–	–
Parking Structure	S-10A	Parking	–	–	–
Parking Structure	S-16C	Parking	–	–	–
Parking Structure	W-09A	Parking	–	–	–

Building Name	Bldg. No.	Building Type	Gross Square Feet	HPS Peak Demand (PPH)	LPS Peak Demand (PPH)
Animal Sciences (AHABS)	W-22	Lab – Light	85,000	3,381	–
Primate Center & Harlow Expansion	S-09A	Lab – Heavy	49,000	3,969	–
Primate Center & Harlow Expansion	S-09C	Lab – Heavy	60,000	4,860	–
Primate Center & Harlow Expansion	S-09D	Lab – Heavy	96,000	7,776	–
WARF Addition	W-11	Office – Vav	192,000	4,977	–
Weeks Hall Addition	S-08B	Lab – Medium	5,000	291	–
Zoology Research And Noland Hall	S-07	Lab – Medium	420,000	24,419	–
		Removed	1,414,721	35,379	12,322
		Added	4,376,299	149,216	0
		Net	2,961,578	113,837	(12,322)
		Post Phase 4	30,829,514	871,329	111,761

Steam Growth Analysis

As can be seen from Tables 2-3 through 2-6, a net steam load increase of 153,000 PPH will be added over the next 30 years resulting in a future steam load estimate of approximately 983,000 PPH. Figure 2-1 illustrates that the present boiler firm capacity of 2,000,000 PPH will not be exceeded in any phase, meaning that no additional boiler capacity will be required during the next 30 years. The graph also indicates the preferred order of dispatch for each plant and respective installed capacity.

Figure 2-1 Heating Load Growth Graph

Existing Distribution System

Typically, steam is distributed at 175 PSIG, then reduced at the buildings to an intermediate pressure of 60 PSIG for "process loads" and then to 10 PSIG for building heating loads. Due to increased backpressure steam driven equipment (175 PSIG to 10 PSIG), UW–Madison desires to increase the low pressure steam usage near the Charter Street Heating Plant (CSHP). Piping is either run in tunnels, boxed conduit, direct buried or within building basements.

The steam and condensate distribution system is composed of:

- High pressure steam piping is standard weight carbon steel ranging in size from 1" to 20".
- Low pressure steam piping is standard weight carbon steel ranging in size from 1-½" to 20".
- Condensate piping is extra strong carbon steel ranging in size from 1" to 12".

Refer to Appendix A for drawings of the high pressure steam (HPS AGE), and low pressure steam (LPS AGE), depicting piping age in 10 year bands. This information was obtained from the 2005 Utilities Master Plan and was revised based on steam piping replacement projects that occurred between 2005 and 2015. The majority of the piping is over 20 years old for the western portions of campus, over 50 years old for the central portions of campus, and over 30 years old for the eastern portions of campus.

Steam Hydraulic Calculations

Hydraulic Analysis Input and Assumptions

Arrow 6.0 by Advanced Flow Technologies (AFT) was the hydraulic modeling software used for this project. AFT Arrow 6.0 analyzes compressible fluid flow in piping systems and employs a robust solver using proven matrix methods to solve the governing equations of pipe flow and calculate a true and rigorous compressible flow solution. The model was revised based on our current understanding of pipe and building additions along with the following assumptions:

- Building peak loads indicated in Table 2-2,
- Future building peak loads indicated in Tables 4-3 through 4-6,
- Steam supply pressure of 175 PSIG saturated steam in the street outside the plants.
- Maximum steam velocities of 15,000 FPM,
- High to low pressure booster stations and discharge from CSHP for the low pressure steam system is assumed to be at 12 PSIG,
- Minimum low pressure steam pressure required at buildings is 5 PSIG,
- All systems were modeled as flat, and
- AFT uses the Darcy-Wiesbach equation "ε" for new steel (0.00015 feet) and it was increased by 10% to account for pipe aging = 0.000165 feet.

Analysis Results – Existing

Refer to Appendix B – Steam System Hydraulic Calculations for the output report and velocity map results for each phase. Refer to Appendix B for velocity gradient drawings of existing system as well as future phases. The existing scenario included all projects that were currently under design or construction that would be operational in 2016.

The existing HPS system is adequate to serve the existing loads and the resultant lowest pressure modeled at a building service entry was 166 PSIG at the Athletic Operations Building. Direction from UW–Madison indicated that the plants be set up as follows; 219,000 PPH from Walnut Street Heating Plant (WSHP), 180,000 PPH from the West Campus Cogeneration Facility, and the remainder of the load for each phase would be served from the Charter Street Heating Plant (CSHP).

Analysis Results – Phase 1

Low pressure steam usage will slightly increase during this phase, however there are no major piping efforts since this phase basically extends piping laterals to new buildings from existing piping mains.

The highest velocity occurs in a connecting pipe interior to the UW Hospitals and Clinics (Clinical Science Center) (hereafter shortened to CSC). The velocity is below the maximum allowable at 15,000 FPM, but is still higher than the rest of the campus distribution piping. UW–Madison, however, was not able to confirm the actual size of this pipe, and UW–Madison believes the pipe is most likely a larger size resulting in a lower velocity.

Analysis Results – Phase 2

No major piping efforts as this phase includes mostly removal of existing buildings.

The highest velocity occurs in a connecting pipe interior to the CSC. The velocity is below the maximum allowable at 15,000 FPM, but is still higher than the rest of the campus distribution piping. UW–Madison, however, was not able to confirm the actual size of this pipe, and UW–Madison believes the pipe is most likely a larger size resulting in a lower velocity.

Analysis Results – Phase 3

Low pressure steam usage across campus continues to be reduced. Piping efforts during this phase will be limited to new building piping laterals from existing piping mains.

The highest velocity occurs in a connecting pipe interior to the CSC. The velocity is below the maximum allowable at 15,000 FPM, but is still higher than the rest of the campus distribution piping. UW–Madison, however, was not able to confirm the actual size of this pipe, and UW–Madison believes the pipe is most likely a larger size resulting in a lower velocity.

Analysis Results – Phase 4

Growth on the south and west portions of campus will drive the Charter Street Heating Plant (CSHP) to supply more steam to the west portion of campus if Walnut Street Heating Plant (WSHP) and the West Campus Cogeneration Facility continue to hold production firm at 219,000 PPH and 180,000 PPH respectively. Velocities begin to increase in the mains heading north up N. Charter Street as well as the mains heading from the Charter Street Heating Plant (CSHP) to Engineering Drive. Velocities do not exceed 10,000 FPM but consideration should be given to upsizing the mains heading to Engineering Drive, particularly as 4 new Engineering buildings are slated for construction during this phase.

The highest velocity occurs in a connecting pipe interior to the CSC. The velocity is below the maximum allowable at 15,000 FPM, but is still higher than the rest of the campus distribution piping. UW–Madison, however, was not able to confirm the actual size of this pipe, and UW–Madison believes the pipe is most likely a larger size resulting in a lower velocity.

Firm capacity will at no point be reached over the next 30-35 years, therefore apart from replacement of old equipment there will be no need for additional capacity.

Table 2-7 summarizes the modeled load growth and the impact to flow and pressure drop at each plant during each phase. The total capacity shown for each phase accounts for only HPS other than 3 booster stations totaling 30,000 PPH. As seen in Figure 2-1, due the minimal growth in the heating load over the next 30 years, piping will not be greatly affected. For all cases the “Existing” case is for year 2016 estimated loads.

Analysis Conclusions – Overall

The existing pipe sizes and routing are adequate for the existing loads and future campus growth to maintain steam velocities below 10,000 FPM for normal operating conditions. The one exception to this is a short segment of connecting piping interior to CSC as indicated previously in each phase of the Analysis Results and in Table 2.7.

Table 2-7 Steam Hydraulic Summary

Plant	High Pressure Steam				
	Existing	Phase 1	Phase 2	Phase 3	Phase 4
Max Velocity (FPM) & Location	11,348 @ CSC	11,388 @ CSC	11,415 @ CSC	11,571 @ CSC	12,137 @ CSC
Min. Pressure (PSIG) at Critical Node	166 @ Athletic Op.	166 @ Athletic Op.	165 @ Athletic Op.	163 @ Waisman	155 @ Waisman
WSHP Capacity (PPH)	219,000	219,000	219,000	219,000	219,000
CSHP Capacity (PPH)	328,577	371,153	375,286	398,173	510,843
WCCF Capacity (PPH)	180,000	180,000	180,000	180,000	180,000
Booster Stations Assigned Output (PPH)	30,000	30,000	30,000	30,000	30,000
Total Capacity	757,577	800,153	804,286	827,173	939,843

CSC = UW Hospitals and Clinics (Clinical Science Center)

Recommended Steam and Condensate System Project List

Table 2-8 is a summary of the steam projects that are also included in the overall utility project list in Table 1-1 Project Summary List. Refer to the Project Improvements List portion of Section 1 Introduction for a description of the project naming convention. Table 2-8 includes projects identified as regional campus issues (RCI) or building specific issues (BSI). These projects are not included in Table 1-1. Timing for these projects is not defined and is to be determined by the university.

Table 2-8 Steam Project List

Project Number	Master Phased Project No.	Description
STM-E-02-P1-4	RCI	Add 200-300 kW induction type steam turbine generator to larger usage buildings where the base steam load would exceed 10,000 PPH for at least 6,000 hours per year
STM-E-04-P1-4	RCI	Building interconnection upgrades: Add steam and condensate meters to all existing buildings. Communicate data to campus historian database Add steam and condensate supply pressure transmitters at each building. Communicate data to campus historian database
STM-E-07-P1-2	RCI	Add steam meters at the two HPS to LPS booster stations
STM-O-03-P1	BSI	Replace condensate transfer pump CP-3 at WSHP
STM –O-06-P1	1M	Portion of distribution system (2" HPS, 1-1/2" CR, 1-1/4" CA) replacement from Helen C.. White Hall to Limnology about 290 feet
STM-O-07-P1 STM-O-13-P1 STM-O-20-P1	1L	• Direct buried piping (6" HPS, 10" LPS, 4" CR, 1½"CA) replacement from Pit 49/12 to Pit 44/12 • Replace brick-well steam tunnels (Bascom Hill) that are in poor condition
STM-O-09-P1	1E	Relocate central utility line (10" HPS, 4" CR, 2" CA) repair/upgrade from Pit 51/9 to Pit 58/10
STM-O-10-P3	3B	Replace central utility line (10" to 16" HPS, 1" to 10" LPS, 4" CR, 2" CA) and steam tunnel from Pit 59.1/10 to Pit 177/10
STM-O-14-P1	1K	Replace direct buried 14" HPS and 8" CR distribution piping in W. Dayton St. due to age Replace 20" HPS with two (20") HPS exiting CSHP due to age and future capacity. One 20" HPS installed, one 20" HPS remains be installed
STM-O-15-P2	BSI	Repair B-1 and B-2 at WSHP due to age of Gas Boilers
STM-O-21-P1	1B	Replace existing 8" HPS, 10" LPS and 4" CR in University Avenue due to age from Pit 134/10 to Pit 164/10
STM-O-22-P1	1N	Replace existing 16" HPS and 8" CR in Charter Street due to age. Replace 16" LPS with 18" LPS and 2" CA with 3" CA due to age
STM-O-23-P1	1C	Replace existing 18" HPS, 20" LPS and 10" CR in Charter Street from University Avenue to W. Johnson Street due to age
STM-R-01-P4	4A & 4B	Extend Piping south of Charter Street to Primate Center for redundant loop (8" HPS, 4" CR, 3" CA) and connect (20" HPS, 6" CR, 4" CA) into mains in W. Dayton Street to reduce velocity of plant. Extension from Pit 29/11 to Pit 44/11
STM-X-03-P1	1H	Relocate central utility line (6" HPS, 2" LPS, 6" CR, 1½"CA) from underneath the future footprint of Ingraham Hall addition to the adjacent street from Pit 99.1/10 to Pit 93/10
STM –X-05-P1	1D	Replace lateral lines (HPS, CR and CA) from mains in Kronshage Drive to Showerman, Turner, Mack, Gilman, Jorns and Humphrey Houses.
STM-X-06-P4	4H	Extend 6" HPS and 3" CR to Arts Block down W. Dayton Street

Table 2-8 Steam Project List, continued

Project Number	Master Phased Project No.	Description
STM-X-08-P4	4C	Extend 10" HPS and 4" CR to future West campus buildings in the Street due West of Walnut
STM-O-26-P1	1Z	Replace existing central utility line (pipe sizes) and steam tunnel from Pit 41/10 (west of Ag Hall) to Pit 35/10 (west of Ag Bulletin)
STM-O-27-P3	3B	Replace existing box conduit from Pit 177/10 (Charter St Tunnel) to the southwest corner of Sterling Hall
STM-O-28-P2	2C	Replace existing central utility line (HPS, CR, CA) and box conduit to Materials Science and Engineering
STM-O-29-P1	1E	Replace existing central utility line (HPS, CR, CA) and box conduit from Pit 42/9 to Pit 44/9
STM-O-30-P1	1W	Replace box conduit between Pit 16/8 and 18/8 west of Dejope Hall.
STM–O-31-P1	1X	Replace box conduit from Pit 19/11 to Educational Sciences
STM-O-32-P4	4J	Connect steam, condensate and air to Environmental Health and Safety Building
STM-O-33-P1	1Y	Replace box conduit from Pit 121/10 to Enzyme Institute, including Pit 121/10, Pit 91/9 and Pit 89/9
STM-O-34-P2	2C	Replace central utility piping (HPS, CR, CA) and box conduit and Steam Pits in Engineering Drive from Pit 4/11 to Pit 6/11 and from Pit 5.5/11 to Engineering Hall
STM-E-08-P4	BSI	Remove old boiler in Ag Bulletin and abate basement
STM-O-35-P1	1E	Replace box conduit from Pit 56/10 to Babcock Hall
STM-O-38-P1	RCI	Replace flanged valves with weld-in valves in the box conduit from Pit 86/9 to Pit 120/10
STM-O-36-P1	1E	Replace box conduit serving Russell Laboratory
STM-O-37-P2	2B	Replace existing piping (HPS, CR, and CA) and tunnel near WARF, from Pit 2.5/9 to Pit 3/9

Project Number	Master Phased Project No.	Description
STM-X-09-P1	1T	Replace box conduit piping in Linden Drive to accommodate new pedestrian corridor connections to Vet Med Addition.
STM-O-24-P4	BSI	Charter Street Heating and Cooling Plant • Replace Switchgear located underneath the cooling towers • Provide black start 4160V generator • Cross connect north deaerator to south boiler feedwater pumps • Install desuperheating pump • Inspection and overhaul of murray turbine generator • Replace pipe insulation in boilers: 201, 200L, 200M, 200P, 203-ACM • Install south deaerator Delta V and ARC valves on BFPs #2 and #3 • Replace combustion turbine emission monitoring system (CEMS) with predictive (PEMS) system. • Install DA vent silencer
STM-O-25-P4	BSI	Walnut Street Heating and Cooling Plant • Replace steam boxes in deaerator domes • Replace boiler feed pumps # 1 and #2, and install VFDs for new pumps • Install condensate polisher system • Replace brine reclamation controls • Reinsulate boilers #1 and #2

Opportunities to Enhance Energy Efficiency/ Operational Flexibility

Backpressure Steam Turbine Generator Building Pressure Reducer

The viability of including a backpressure steam turbine generator in future buildings should be investigated as part every building conceptual design, for future campus buildings/additions. The backpressure steam turbine generator would be utilized, in conjunction with steam pressure reducing valves, to reduce the incoming steam pressure from the campus system (175 psi) to low pressure steam (12 psi). The low pressure steam is typically utilized for generating building heating water, generating domestic how water, building humidification, and meeting any other low pressure steam requirements.

The steam turbine generator would generate electricity that would be utilized in the building/campus.

The steam turbine generator would be installed in parallel with typical pilot operated steam pressure reducing valves.

The size of the steam turbine generator would be based on the minimum constant steam demand of the building. An optimum sizing and economic analysis should be performed to determine if the inclusion of a backpressure steam turbine generator is financially viable.

3. CHILLED WATER SYSTEM

Existing Facilities

UW–Madison has a long history with chilled water on campus. There are three existing operating chilled water plants. The operating plants at Charter Street Heating Plant (CSHP), Walnut Street Heating Plant (WSHP), and West Campus Cogeneration Facility (WCCF) total 75,700 tons of installed capacity. Chilled water is supplied at 39°F to 40°F to the campus loop. Typically the plants will see a temperature rise of 9°F to 10°F on peak cooling days. This is basically the average of newer buildings having differential temperatures (Delta Ts) of 12°F or higher and older buildings with Delta Ts of 8°F or lower. During non-peak load conditions the system Delta T drops off to 7°F. The exported chilled water is metered at each plant and several buildings have chilled water meters for billing purposes. Refer to Table 3-1 Chiller Type/Size for information on chillers installed in each plant.

Table 3-1 Chiller Type/Size per Plan

Plant	Electric Driven Chillers/Sizes (each)	Steam Driven Chillers/Sizes (each)	Steam Absorption Chillers/Sizes (each)
Charter Street Heating Plant	**None**	**2 @ 8,500 tons 2 @ 4,000 tons**	**1 @ 1,000 tons**
Walnut Street Heating Plant	**1 @ 5,500 tons 1 @ 5,000 tons**	**1 @ 5,000 tons 1 @ 3,500 tons**	**None**
West Campus Cogeneration Facility (Original Plant)	**4 @ 5,000 tons**	**None**	**None**
West Campus Cogeneration Facility (2014 Addition)	**2 @ 5,000 tons**	**None**	**None**

Over the years the campus distribution pumping system has been modified from the initial constant volume primary only configuration to primary-secondary-tertiary and finally to the primary-secondary pumping configuration with building booster pumps. The current campus design premise is to distribute flow to building air handling units without the use of the building booster pumps – a true primary/secondary distribution system.

CSHP, WSHP, and WCCF-South have constant speed primary (chiller pumps) and variable secondary (distribution) pumping configuration. WCCF-North has a variable-primary pumping configuration. The secondary/variable primary pumps are controlled to maintain a differential pressure control setpoint of approximately 20psi-25psi as it leaves the plant. This typically results in available differential pressures of approximately 10psi at Memorial Library and 8psi at Waisman Center. This pressure control strategy results in more efficient pump operation and avoids over-pumping at buildings located in closer proximity to the plants.

Most buildings connected to the campus system have their own booster chilled water pumps but only about a dozen are required to operate in peak periods to avoid having to increase the distribution system differential pressure. Many building pumps have been either bypassed or allow the secondary pump pressure to flow water through the de-energized pump impellers.

The estimated peak cooling load (as of June 2016) is 57,000 tons. There is a base cooling load of 2,500 to 3,000 tons year-round as a result of process loads across the campus.

Estimation Methodology

UW–Madison traditionally provides meters for chilled water in buildings that are revenue producing as well as all new buildings added to the campus distribution network. There are presently 13 such buildings on campus. Of the 13 meters, most are trended for energy usage as a cumulative daily total. This method is acceptable for the purposes of billing of thermal energy use, but has no value in determining the actual hourly peak load of the building[1]. Since all buildings are not metered on campus for energy use, a methodology was required to estimate the buildings' chilled water loads.

The load estimation methodology used the load densities and diversities provided in the 2005 Utilities Master Plan. The peak loads were divided by building gross square footage (GSF) resulting in load density values per building function (classroom, dormitory, office, research lab, hospital, etc.).

These diversification factors were then applied across the entire campus and then the loads and diversification factors were adjusted proportionally to the overall campus peak load which is known to be approximately 57,000 tons in 2015. Table 3-2 indicates the load densities and diversities selected for use on the campus based on building function. These values were applied to each campus building to develop the values illustrated in Table 3-3.

Existing Building Estimated Cooling Load

The estimated peak cooling load (as of June, 2016) is 56,360 tons. The load consists of 133 buildings connected to the campus loop totaling over 15,500,000 square feet or ~80% of the campus building area is connected to the chilled water loop.

Table 3-3 lists all of the campus buildings that in one way or another are connected to campus utilities (i.e., they may not be connected to chilled water, but are to steam). If they are not connected to the chilled water system currently the peak demand is zero tons.

1 Several of the meters are not installed per manufacturer's recommendations with adequate straight runs so the metered data is questionable.

Table 3-2 Cooling Load Density & Diversity Estimate

Building Type	Cooling Load Density (sf/Ton)	Assumed Diversity
Agricultural Greenhouse	450	0.60
Animal/Veterinary	400	0.70
Broadcast Facility	250	0.75
Child Care Facility	425	0.75
Classroom – VAV	350	0.70
Classroom – CAV	400	0.65
Computer Facility	100	0.95
Computer Lab	150	0.90
Food Service Facility	200	0.70
Gym – Recreation Facility	550	0.70
Gym – Recreation Facility – Pool	600	0.70
Gym – Arena	300	0.70
Hospital	225	0.83
Lab – Extra Heavy	110	0.95
Lab – Heavy	150	0.90
Lab – Heavy – Old	150	0.90
Lab – Medium	200	0.90

Building Type	Cooling Load Density (sf/Ton)	Assumed Diversity
Lab – Medium – Old	225	0.90
Lab – Light	325	0.90
Lab – Light – Old	375	0.90
Library	450	0.65
Museum	425	0.60
Office – CAV	375	0.70
Office – VAV	425	0.70
Outdoor Services	0	N/A
Residence Hall – Food Service	325	0.70
Residence Hall	350	0.70
Service/Grounds Facility	400	0.70
Sports Arena	200	0.25
Sports Outdoor	0	N/A
Sports – Training Facility	200	0.70
Storage Facility	0	N/A
Unknown Building Type	400	0.70
Vehicle Service Facility	200	0.75

Table 3-3 Campus Building Cooling Load Estimate

Building Name	No.	Building Type	Square Feet	(Tons)
1800 University Ave (Survey Center)	113	Lab – Light	5,101	-
1848 University Ave (UW Foundation)	493		-	-
30 North Mills	124	Office – Vav	62,906	-
Adams Hall	564	Residence Hall	89,821	-
Agricultural Bulletin Building	78	Classroom – Cav	7,353	14
Agricultural Dean'S Residence	72	Unknown Building Type	8,965	-
Agricultural Engineering Building	80	Classroom – Cav	23,909	45
Agricultural Engineering Laboratory	99	Service/Grounds Facility	32,654	54
Agricultural Hall	70	Classroom – Cav	77,385	145
American Family Childrens Hospital (Phase 1)	1426	Hospital	309,847	1,068
Animal Science Building	118	Lab – Light	127,626	332
Armory & Gymnasium	20	Office – Cav	77,688	136
Art Lofts	220	Classroom – Cav	78,974	-
Athletic Operations Bldg	584	Gym – Rec Facility	19,488	23
Atmospheric Oceanic & Space Sciences Bldg	156	Lab – Light	144,147	375
Babcock Hall	106	Lab – Light	136,071	354
Bardeen Medical Laboratories	451B	Lab – Heavy	69,344	413
Barnard Hall	560	Residence Hall	58,451	10
Bascom Hall	50	Office – Cav	178,329	313
Below Alumni Center	489	Office – Vav	23,417	36
Biotron Laboratory	45	Lab – Medium	106,907	452
Birge Hall	54	Lab – Light	171,883	447
Bock Laboratories, Robert M	33	Lab – Heavy	73,739	439
Bradley Hall, Harold C	506	Residence Hall	56,270	-
Bradley Memorial Building	452	Lab – Light	23,363	-
Camp Randall Stadium	22	Broadcast Facility	97,990	276
Camp Randall Sports Center (Shell)	25	Gym – Rec Facility	107,372	128
Capitol Ct 1220	782	Lab – Light	85,988	224
Carillon Tower	487	Unknown Building Type	1,694	-
Carson Gulley Commons	565	Residence Hall – Food Service	30,245	61
Central Kitchen-Chadbourne And Barnard	562	Food Service Facility	31,459	104
Cereal Crops Research Unit	121	Lab – Heavy	34,000	202
Chadbourne Hall	557	Residence Hall	145,365	273
Chamberlin Hall, Thomas C	55	Lab – Light	339,672	884
Chamberlin House	571	Residence Hall	16,453	-
Charter St N 45	504	Office – Cav	22,110	39
Chazen Museum Of Art	524	Museum	94,778	126
Chemistry Bldg, F Daniels & J H Mathews	47	Lab – Medium	409,067	1,730
Clinical Science Center	1400	Hospital	1,897,439	6,540
Cole Hall	555	Residence Hall	49,839	-
Computer Sciences And Statistics	155	Lab – Medium	244,096	1,033
Conover House	574C	Residence Hall	16,552	-
Dairy Barn	105	Unknown Building Type	40,782	-
Dairy Cattle Center	92	Animal/Vet.	34,049	-
Dairy Forage Research Center-Us	96	Animal/Vet.	58,898	97

Table 3-3 Campus Building Cooling Load Estimate, continued

Building Name	No.	Building Type	Square Feet	(Tons)
Dejope Residence Hall	567	Residence Hall – Food Service	229,420	464
Deluca Biochemical Sciences	204	Lab – Medium	224,078	948
Deluca Biochemistry Building	84	Lab – Medium	82,100	347
Deluca Biochemistry Laboratories	205	Lab – Heavy	219,524	1,307
East Campus Mall 333	467	Residence Hall	237,277	-
East Campus Mall 432	515	Food Service Facility	34,075	112
Education Building	400	Classroom – Vav	120,889	185
Educational Sciences	154	Classroom – Cav	178,004	335
Elizabeth Waters Hall	559	Residence Hall	143,626	270
Elvehjem Building, Conrad A.	544	Museum	94,262	125
Engineering Centers Building	481	Lab – Light	251,334	654
Engineering Drive 1410	486	Lab – Medium	63,561	269
Engineering Hall	408	Classroom – Cav	464,768	874
Engineering Mall	766	Outdoor Services	2,018	-
Engineering Research Building	762	Lab – Light – Old	157,510	355
Environmental Health And Safety Building	549	Service/Grounds Facility	79,675	-
Enzyme Institute	479	Lab – Medium	69,684	-
Extension Building G (432 N. Lake St.)	500	Office – Cav	76,318	-
Field House	29	Gym – Rec Facility	123,830	-
Fleet And Service Garage	1077	Vehicle Service Facility	16,142	57
Fluno Center For Executive Education	139	Office – Vav		-
Forest Products Laboratory	36	Lab – Light	-	586
Genetics-Biotechnology Center Building	82	Lab – Heavy	247,746	1,475
Gilman House	569	Residence Hall	16,470	-
Goodman Softball Complex	175	Sports – Training Facility	8,007	-
Goodnight Hall, Scott H	508	Residence Hall	55,386	-
Gordon Dining And Event Center	1249	Residence Hall – Food Service	111,644	226
Grainger Hall	140	Classroom – Vav	439,491	671
Greenhouse-King Hall	75	Agricultural/Greenhouse	15,051	19
Greenhouse-Walnut Street	122	Agricultural/Greenhouse	47,007	59
Gymnasium-Natatorium	31	Gym – Rec Facility	249,579	73
Hanson Biomedical Sciences Building	94	Lab – Light	43,519	113
Hasler Laboratory Of Limnology	483	Lab – Light	15,245	40
Health Science Learning Center (Hslc)	1480	Classroom – Vav	284,436	434
Heating And Cooling Plant-Charter St	529	Central Plants	111,532	-
Heating And Cooling Plant-Walnut St	49	Central Plants	37,423	-
Henry Mall 445	102	Lab – Light	54,750	143
Henry Rust/David Schreiner Hall	158	Residence Hall	21,098	-
Herrick Dr 502	111	Office – Cav	8,617	-
Herrick Dr 505	108	Service/Grounds Facility	1,139	-
Herrick Dr 525 – Electrical Storage	222	Service/Grounds Facility	3,630	-
Herrick Dr 550 – Incinerator	127	Service/Grounds Facility	2,163	-
Holt Center	574H	Classroom – Cav	20,143	-
Horse Barn	95	Unknown Building Type	19,808	-

Table 3-3 Campus Building Cooling Load Estimate, continued

Building Name	No.	Building Type	Square Feet	(Tons)
Horticulture	87B	Lab – Light	25,276	66
Humanities Building, Mosse George L	469	Classroom – Cav	333,363	627
Humphrey Hall	136	Residence Hall	16,523	-
Ingraham Hall, Mark H	56	Classroom – Cav	97,603	183
Jones House	572	Residence Hall	16,537	-
Jorns Hall	137	Residence Hall	16,820	-
Kellner Hall	460	Office – Vav	85,297	132
Kohl Center, The	225	Gym – W/ Spectators	472,906	1,037
Kronshage Hall	574	Residence Hall	17,249	-
LaBahn Arena	227	Sports – Arena	107,266	126
Lathrop Hall	32	Classroom – Cav	105,256	198
Law Building	430	Classroom – Cav	236,081	444
Leopold Residence Hall	576	Residence Hall	64,719	122
Lift Station – Lot 76	1714	Unknown Building Type	-	-
Linden Dr 1645	91	Service/Grounds Facility	3,210	-
Linden Dr 1910	103	Classroom – Cav	11,267	-
Linden Dr 2105	465	Unknown Building Type	1,860	-
Linden Dr 2115	128	Service/Grounds Facility	8,756	-
Livestock Laboratory	115	Animal/Vet.	35,129	58
Lowell Center	502	Classroom – Vav	136,010	-
Mack House	570	Residence Hall	16,986	-
Materials Science And Engineering Bldg	520	Classroom – Cav	45,759	86
Mcardle Cancer Research Building	468	Lab – Heavy	96,657	575
Mcclain Athletic Facility	21	Gym – Rec Facility – Pool	169,320	186
Meat Science And Muscle Biology Lab	123	Lab – Light	30,190	-
Mechanical Engineering Building	407	Classroom – Cav	297,993	560

Building Name	No.	Building Type	Square Feet	(Tons)
Medical Sciences	451C	Lab – Extra Heavy	72,499	620
Medical Sciences Center	450	Lab – Light	443,530	1,155
Memorial Library	15	Library – Standard	573,454	779
Memorial Union	8	Residence Hall – Food Service	220,475	446
Merit House	575	Residence Hall	19,662	37
Microbial Science Building	60	Lab – Heavy	440,846	2,625
Middleton Building, W S	455	Library – Standard	45,217	61
Moore Hall-Agronomy	87A	Lab – Light – Old	34,609	78
Morgridge Institute For Research	211	Lab – Medium	226,752	959
Music Hall	485	Classroom – Cav	38,131	72
Nancy Nicholas Hall	85	Classroom – Cav	198,915	374
Newell J. Smith Residence Hall	1079	Residence Hall	158,733	298
Nicholas-Johnson Pavilion And Plaza	226	Sports – Arena	27,847	33
Nielsen Tennis Stadium	38	Gym – Rec Facility	140,673	-
Noland Zoology Building, Lowell E	402	Lab – Light	92,818	242
North Hall	52	Office – Cav	22,447	39
Nutritional Sciences	449	Classroom – Cav	56,502	106
Observatory Hill Office Building	512	Unknown Building Type	6,964	-
Observatory, Washburn	510	Unknown Building Type	11,166	-
Ogg Hall	1243	Residence Hall	218,377	411
N. Park Street, 21 North	1078	Office – Vav	138,640	215
Parking Garage 6 – Helen C. White	9507	Parking	96,881	-
Parking Garage 7 – Grainger	9508	Parking	191,769	-

Table 3-3 Campus Building Cooling Load Estimate, continued

Building Name	No.	Building Type	Square Feet	(Tons)
Parking Garage 23 – Van Hise	9522	Parking	-	-
Parking Garage 38 – Microbial	9537	Parking	66,704	-
Parking Garage 83 – Fluno Center	9577	Parking	120,582	-
Parking Garage 95 – Hslc	9585	Parking	71,360	-
Parking Ramp 17 – Engineering Dr	536	Parking	264,321	-
Parking Ramp 20 – University Ave	142	Parking	94,111	-
Parking Ramp 29 – 21 N. Park St	9530	Parking	-	-
Parking Ramp 36 – Observatory Dr	104	Parking	147,883	-
Parking Ramp 46 – Lake & W. Johnson	152	Parking	254,841	-
Parking Ramp 75 – CSC	751	Parking	443,766	-
Parking Ramp 76 – University Bay Dr	9573	Parking	409,650	-
Phillips Residence Hall	507	Residence Hall	54,983	103
Physical Plant – Grounds Storage	125	Plant	2,560	-
Physical Plant – Grounds Storage 2	223	Plant	480	-
Plant Sciences	87C	Lab – Light	62,173	162
Police And Security	550	Classroom – Vav	17,323	-
Porter Boathouse	172	Gym – Rec Facility	49,996	-
Poultry Research Laboratory	110	Animal/Vet.	24,013	40
Primate Center, Wisconsin	526	Lab – Extra Heavy	31,606	-
Primate Lab, Harlow	527	Lab – Heavy	36,944	-

Building Name	No.	Building Type	Square Feet	(Tons)
Psychology Building, W J Brogden	470	Classroom – Cav	115,071	216
Pyle Center	6	Classroom – Cav	148,235	279
Radio Hall	405	Classroom – Cav	21,397	40
Rennebohm Hall	34	Lab – Heavy – Old	222,517	747
Residence Halls Garage	566	Vehicle Service Facility	1,361	-
Russell Laboratories	114	Lab – Light – Old	154,675	349
School Of Social Work Building	453	Classroom – Cav	41,344	-
Schuman Shelter	116	Outdoor Services	960	-
Science Hall	53	Classroom – Vav	101,646	155
Seed Building	119	Classroom – Cav	17,744	-
Sellery Hall	1245	Residence Hall	230,408	-
Service Building	530	Service/Grounds Facility	51,066	-
Service Building Annex (H)	534	Service/Grounds Facility	38,356	-
Service Memorial Institute	451A	Lab – Heavy	122,474	729
Showerman House	574S	Residence Hall	16,497	-
Signe Skott Cooper Hall	44	Classroom – Vav	169,924	260
Slichter Hall	558	Residence Hall	63,180	-
Smith Annex (H), Hiram	77	Classroom – Cav	12,755	24
Smith Greenhouse, D C	206	Agricultural/Greenhouse	13,057	16
Smith Hall, Hiram	76	Classroom – Cav	19,833	37
Social Science Building	46	Classroom – Vav	204,205	312
Soils And King Hall – Soils	74B	Lab – Medium	26,696	113
Soils And King Hall – King Hall	74A	Lab – Medium	21,478	91
South Hall	51	Office – Cav	22,522	40
Southeast Recreational Facility	28	Gym – Rec Facility – Pool	191,254	210

Table 3-3 Campus Building Cooling Load Estimate, continued

Building Name	No.	Building Type	Square Feet	(Tons)
State Historical Society	16	Office – Vav	237,700	368
Steenbock Memorial Library	79	Library – Standard	113,343	154
Sterling Hall	57	Classroom – Cav	170,190	320
Stock Pavilion	90	Unknown Building Type	94,775	156
Stovall Building, William D-Hygiene Lab	476	Lab – Light	80,939	211
Sullivan Hall	556	Residence Hall	49,023	-
Susan B. Davis Residence Hall	578	Residence Hall	11,967	-
Swenson House	573	Residence Hall	16,558	-
Taylor Hall, Henry	464	Classroom – Cav	34,504	65
Teacher Education	153	Classroom – Cav	97,103	183
Tripp Hall	563	Residence Hall	90,770	-
Turner House	568	Residence Hall	16,552	-
Union South	88	Residence Hall – Food Service	307,098	622
University Ave 1610	129	Classroom – Cav	24,589	-
University Club	515B	Gym – Rec Facility	15,969	19
UW Medical Foundation Centennial Building	1435	Lab – Light	136,060	354
Van Hise Hall	482	Classroom – Cav	226,940	427
Van Vleck Hall, E B	48	Classroom – Cav	109,914	207
Veterans Administration Hospital	1055	Hospital	618,517	2,132
Veterinary Diagnostic Lab	126	Lab – Heavy	81,777	487
Veterinary Medicine Building	93	Lab – Light	248,852	648
Vilas Communication Hall	545	Broadcast Facility	253,043	714
Waisman Center	459	Lab – Light – Old	166,143	375
WARF Office Building	39	Office – Cav	155,085	272

Building Name	No.	Building Type	Square Feet	(Tons)
Water Science And Engineering Laboratory	403	Lab – Light	41,947	109
Weeks Hall For Geological Sciences, Lewis G	521	Lab – Medium	146,474	620
Wendt Library, Kurt F	404	Library – Standard	74,459	101
West Campus Cogeneration Facility	120	Central Plants	120,000	-
White Hall, Helen C	18	Library – Standard	245,710	334
Wisconsin Energy Institute	752	Lab – Medium	110,636	468
Wisconsin Institute For Discovery	212	Lab – Medium	88,931	376
Wisconsin Institutes For Medical Research	1485	Lab – Medium	701,343	2,967
Witte Hall	1246	Residence Hall	230,799	-
Zoe Bayliss Co-Op	577	Residence Hall	11,603	-
Zoology Research Building	401	Lab – Medium	44,256	187
		TOTAL COOLING LOAD	25,683,925	56,360

Projected Future Loads

The following list of buildings, areas, functions, and phasing is based on the May 17, 2016, phasing spreadsheet developed by SmithGroupJJR for the 2015 Campus Master Plan Update. The loads were estimated using the identical density factors used for the existing buildings in Table 3-2. The future phases are divided into individual tables, staring with Table 3-4 for Phase 1. Each table summarizes both the construction and removal of buildings for that phase, noted in green and red respectively. All phases have six year durations. Buildings shown without an increase or decrease in load are not currently connected to the campus chilled water loop, nor will they be in the future.

In addition to the university campus buildings, steam is also provided to the Forest Products Laboratory, UW Hospital and Clinics-Clinical Science Center, and the Veterans Administration Hospital. Analysis of future expansion of these facilities was not part of the scope of the 2015 Utility Master Plan, therefore no future chilled water loads were estimated for these facilities. Existing chilled water loads for these facilities were included in Table 3-3 Campus Building Cooling Load Estimate.

Table 3-4 Future Cooling Load Estimate By Building (Phase 1)

Building Name	Bldg. No.	Building Type	Gross Square Feet	Diversified Peak Demand (Tons)
Removed				
Greenhouse-Walnut Street	122	Agricultural/ Greenhouse	47,007	59
Gymnasium-Natatorium	31	Gym – Rec Facility	249,579	73
Linden Dr 1645	91	Service/Grounds Facility	3,210	-
Linden Dr 1910	103	Classroom – Cav	11,267	-
Seed Building	119	Classroom – Cav	17,744	-
Southeast Recreational Facility	28	Gym – Rec Facility – Pool	191,254	210
Susan B. Davis Residence Hall	578	Residence Hall	11,967	-
University Ave 1610	129	Classroom – Cav	24,589	-
Zoe Bayliss Co-Op	577	Residence Hall	11,603	-
Added				
Babcock Hall Center for Dairy Research Addition	W-25	Classroom – Vav	31,300	48
Chemistry Bldg Expansion	S-29	Classroom – Vav	173,169	264
College of Engineering Research Building	S-21	Lab – Medium	156,364	661
Gymnasium-Natatorium Replacement	W-16	Gym – Rec Facility	471,417	564
Hamel Music Center P1&2	N-13B	Broadcast Facility	135,000	381
Ingraham Hall Additions	N-14	Classroom – Vav	56,000	86
Academic/Research (W. Johnson/N. Park Site)	S-13A	Classroom – Vav	348,000	532
Meat Science And Muscle Biology Lab	W-18	Lab – Light	228,000	594
Officer Education Facility	S-30	Classroom – Vav	65,000	-
Parking Structure	S-13	Parking	-	-
Parking Structure	W-02	Parking	-	-
Parking Structure	W-27	Parking	198,000	-
Police Addition	S-18	Classroom – Vav	24,840	-
Southeast Recreational Facility	S-31	Gym – Rec Facility – Pool	253,000	277
Veterinary Medicine Building	W-17	Lab – Light	138,911	362
Walnut Greenhouse II	W-12	Agricultural/ Greenhouse	24,000	30
		Removed	568,220	342
		Added	2,303,001	3,798
		Net	1,734,781	3,456
		Post Phase 1	27,418,706	59,816

Table 3-5 Future Cooling Load Estimate By Building (Phase 2)

Building Name	Bldg. No.	Building Type	Gross Square Feet	Diversified Peak Demand (Tons)
Removed				
Engineering Drive 1410	486	Lab – Medium	63,561	269
Psychology Building, W J Brogden	470	Classroom – Cav	115,071	216
Schuman Shelter	116	Outdoor Services	960	-
Service Building	530	Service/Grounds Facility	51,066	-
Service Building Annex (H)	534	Service/Grounds Facility	38,356	-
Stovall Building, William D-Hygiene Lab	476	Lab – Light	80,939	211
Added				
Engineering Dr 1410 – Replacement	S-02	Lab – Light	169,091	440
Nielsen Tennis Stadium Expansion	W-28	Gym – W/ Spectators	47,075	103
		Removed	349,953	696
		Added	216,166	543
		Net	(133,787)	(152)
		Post Phase 2	27,284,919	59,664

Table 3-6 Future Cooling Load Estimate By Building (Phase 3)

Building Name	Bldg. No.	Building Type	Gross Square Feet	Diversified Peak Demand (Tons)
Removed				
Bardeen Medical Laboratories	451B	Lab – Heavy	69,344	413
Bradley Memorial Building	452	Lab – Light	23,363	-
Engineering Research Building	762	Lab – Light – Old	157,510	355
Extension Building G (432 N. Lake St.)	500	Office – Cav	76,318	-
Henry Rust/David Schreiner Hall	158	Residence Hall	21,098	-
Humanities Building, Mosse George L	469	Classroom – Cav	333,363	627
Livestock Laboratory	115	Animal/Vet.	35,129	58
McArdle Cancer Research Building	468	Lab – Heavy	96,657	575
Medical Sciences	451C	Lab – Extra Heavy	72,499	620
Middleton Building, W S	455	Library – Standard	45,217	61
Poultry Research Laboratory	110	Animal/Vet.	24,013	40
Service Memorial Institute	451A	Lab – Heavy	122,474	729
Added				
Academic/Research (Mosse site south)	N-12A	Classroom – Vav	135,000	206
Academic/Research – Humanities	N-11A	Lab – Light	84,000	219
Academic / Research	S-08A	Lab – Medium	22,000	93
Academic/Research (Stovall site)	N-04	Classroom – Vav	82,200	126
Academic/Research (SMI Bardeen Med Sciences)	N-06A	Lab – Light	144,000	375
Engineering Research Building Replacement	S-01	Library – Standard	271,667	369
Academic/Research (Meiklejohn Site)	S-28	Classroom – Vav	84,470	129
Music Phase 3	N-13C	Broadcast Facility	75,000	212
Parking Structure	N-05C	Parking	-	-
Parking Structure Under N-06A	N-06B	Parking	-	-
Parking Structure Under N-11A And N-11B	N-11B	Parking	-	-
Poultry Research Building	W-20	Animal/Vet.	52,965	87
Preserve Outreach Center	W-29	Service/Support	8,700	-
Wid, Phase 2	S-03B	Lab – Medium	392,000	1,658
Wisconsin Institutes for Medical Research Ph3	W-01	Lab – Medium	308,000	1,303
		Removed	1,076,985	3,478
		Added	1,660,002	4,776
		Net	583,017	1,298
		Post Phase 3	27,867,936	60,962

Table 3-7 Future Cooling Load Estimate By Building (Phase 4)

Building Name	Bldg. No.	Building Type	Gross Square Feet	Diversified Peak Demand (Tons)
Removed				
Agricultural Engineering Laboratory	99	Service/Grounds Facility	32,654	54
Biotron Laboratory	45	Lab – Medium	106,907	452
Charter St N 45	504	Office – Cav	22,110	39
Engineering Hall	408	Classroom – Cav	464,768	874
Greenhouse-King Hall	75	Agricultural/ Greenhouse	15,051	19
Hanson Biomedical Sciences Building	94	Lab – Light	43,519	113
Henry Mall 445	102	Lab – Light	54,750	152
Herrick Dr 505	108	Lab – Light	1,139	-
Herrick Dr 509	109	Lab – Light	-	-
Herrick Dr 525 – Electrical Storage	222	Service/Grounds Facility	3,630	-
Linden Dr 2105	465	Service/Grounds Facility	1,860	-
Linden Dr 2115	128	Academic	8,756	-
Meat Science And Muscle Biology Lab	123	Lab – Light	30,190	-
Noland Zoology Building, Lowell E	402	Lab – Light	92,818	242
Nutritional Sciences	449	Classroom – Cav	56,502	106
Physical Plant – Grounds Storage	125	Plant	2,560	-
Physical Plant – Grounds Storage 2	223	Plant	480	-
Primate Lab, Harlow	527	Lab – Heavy	36,944	-
Primate Center, Wisconsin	526	Lab – Extra Heavy	31,606	-
School Of Social Work Building	453	Classroom – Cav	41,344	-
Soils And King Hall – King Hall	74A	Lab – Medium	21,478	91
Van Hise Hall	482	Classroom – Cav	226,940	427
Wendt Library, Kurt F	404	Library – Standard	74,459	101
Zoology Research Building	401	Lab – Medium	44,256	187
Added				
Academic/Research (Van Hise)	N-03A	Classroom – Vav	114,000	174
Academic/Research (Van Hise)	N-03B	Classroom – Vav	48,000	73
Academic/Research	N-05A	Lab – Light	180,000	468
Academic/Research	N-05B	Lab – Light	165,000	430
Academic/Research	N-07	Lab – Light	30,000	78
Academic/Research (Spring St)	S-08C	Lab – Light	150,000	390
Academic/Research (Lot 45 Site)	S-11A	Classroom – Vav	30,000	46
Social/Dining/ Mtg Rooms/Health Sciences	W-06	Residence Hall – Food Service	127,000	258
Plant Sciences	W-24	Lab – Light	100,000	260
Art Building	S-16A	Classroom – Vav	162,000	247
Biological Systems Engineering	W-19	Classroom – Vav	246,000	376
Cooper Hall Addition	W-08	Classroom – Vav	30,000	46
Fluno Addition	S-20	Unknown Building Type	43,200	71

Table 3-7 Future Cooling Load Estimate By Building (Phase 4), continued

Building Name	Bldg. No.	Building Type	Gross Square Feet	Diversified Peak Demand (Tons)
Grounds Storage A – Controlled Temp	W-31	Service/Grounds Facility	3,000	5
Grounds Storage B – Covered	W-20	Service/Grounds Facility	-	-
Grounds Storage C – Salt	W-33	Service/Grounds Facility	3,500	-
Grounds Office / Administration	W-34	Service/Grounds Facility	3,000	5
Grounds Greenhouse	W-32	Service/Grounds Facility	6,000	10
Health Sciences Research	W-07	Lab – Medium	122,000	516
Health Sciences Research	W-09B	Lab – Medium	233,250	987
Health Sciences Research	W-09C	Lab – Medium	231,000	977
Health Sciences Research	W-13	Classroom – Vav	65,674	101
Health Sciences Expansion	W-04A	Hospital	60,500	209
King Hall Greenhouse	N-15	Agricultural/ Greenhouse	7,500	9
McClimon Track / Soccer Grandstand	W-5	Sports – Outdoor	78,000	-
New Engineering	S-23	Classroom – Vav	204,000	303
New Engineering	S-24	Classroom – Vav	236,583	362
New Engineering	S-25	Classroom – Vav	274,986	420
New Engineering	S-26	Classroom – Vav	169,506	259
Parking Structure	S-27	Parking	345,600	-
Parking Structure	S-10A	Parking	-	-
Parking Structure	S-16C	Parking	-	-
Parking Structure	W-09A	Parking	-	-
Animal Sciences (AHABS)	W-22	Lab – Light	85,000	221
Primate Center & Harlow Expansion	S-09A	Lab – Heavy	49,000	291
Primate Center & Harlow Expansion	S-09C	Lab – Heavy	60,000	357
Primate Center & Harlow Expansion	S-09D	Lab – Heavy	96,000	572
WARF Addition	W-11	Office – Vav	192,000	297
Weeks Hall Addition	S-08B	Lab – Medium	5,000	21
Zoology Research And Noland Hall	S-07	Lab – Medium	420,000	1,777
		Removed	1,414,721	2,856
		Added	4,376,299	10,617
		Net	2,961,578	7,761
		Post Phase 4	30,829,514	68,723

Chilled Water Growth Analysis

As can be seen from Tables 3-4 through 3-7, approximately 12,360 tons will be added to the current campus cooling load through development recommended in the 2015 Campus Master Plan Update. Ultimate cooling load is estimated to be 68,722 tons. This does not exceed the current installed capacity of 75,700 tons. It does exceed the currently installed firm capacity (67,200 tons) so an additional chiller will need to be installed during Phase 4 in order to maintain firm capacity. This chiller could be added at West Campus Cogeneration Facility (WCCF) as noted in Figure 3-1 or could be added as part of the proposed East Cooling Plant. Figure 3-1 indicates the total installed campus chilled water capacity as well as the installed capacity at each plant. The red line indicates the estimated chilled water demand. As noted in Figure 1-3, additional chilled water capacity will need to be installed in Phase 3 to maintain firm capacity for the campus.

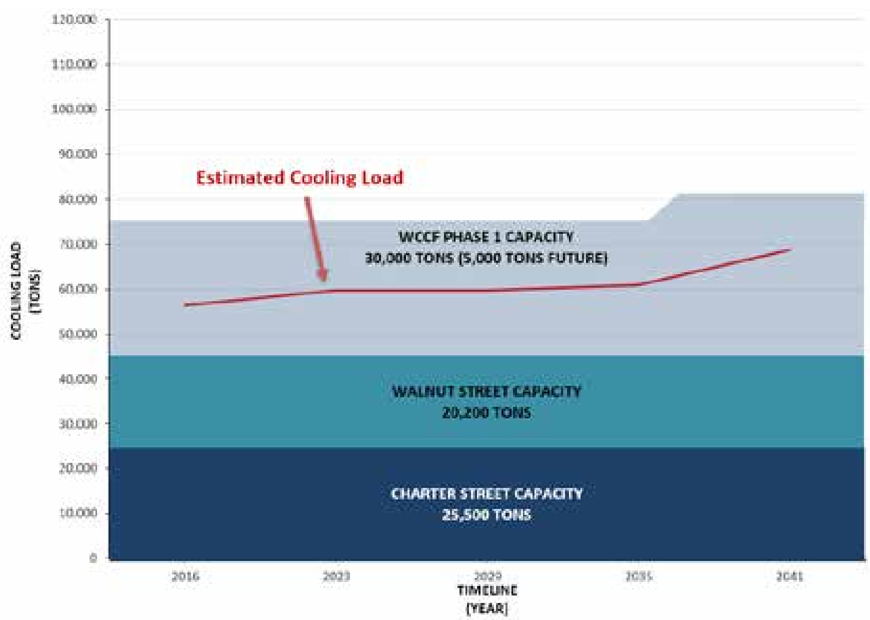


Figure 3-1 Cooling Load Growth Graph

Existing Distribution System Piping Materials

Refer to Appendix A for drawings of the chilled water piping (CHW AGE) drawings depicting piping age in 10 year bands. As can be seen from CHW AGE, there is a great deal of piping from the GIS system that does not have size or age information listed and there is a great deal of chilled water distribution pipes dating back to 1966. Existing system has 15,520 lineal feet of piping ranging in size from 4" to 54" with a material of welded carbon steel, cast iron, ductile, iron, and pre-cast concrete piping. The majority of buried chilled water piping is pre-stressed cylindrical concrete pipe (PCCP) which ranges in sizes from 16" to 48". There is also Class 51 ductile iron pipe (DIP) ranging in size from 3" to 48". Finally, welded carbon steel pipe is used ranging in size from 5" to 16".

Also in Appendix A is a summary of the TURN projects and a map showing locations of TURN projects. This summary and map provide additional information regarding age of distribution system components. TURN projects are projects that have been completed directly by UW–Madison

Chilled Water Hydraulic Calculations

Hydraulic Analysis Input and Assumptions

The estimated existing and future loads were input into the hydraulic model. Fathom 9.0 by Advanced Flow Technologies (AFT) was used as the hydraulic modeling software. AFT Fathom 9.0 analyzes incompressible pipe flow addressing open and closed loop systems. AFT Fathom includes a built-in library of fluids and fittings, variable model configurations, pump and control valve modeling. The model was revised based on our current understanding of pipe and building additions along with the following assumptions:

- Chilled water temperature differential of 10°F,
- Existing building peak loads indicated in Table 3-3,
- Future building peak loads indicated in Tables 3-4 through 3-7,
- All systems were modeled as flat[1],
- 14 PSID was set as the minimum pressure drop maintained across the most critical building (critical node). Any required pressure differential above this amount requires the building booster pumps to operate,
- AFT uses the Darcy-Wiesbach equation "ε" for new steel (0.00015 feet) and ductile iron piping (0.004 feet) which were increased by 10% to account for pipe aging:
  - Aged Steel = 0.000165 feet
  - Aged DIP = 0.0044 feet
- The Hazen-Williams equation "C" factor for concrete piping was also increased by 10% to account for pipe aging, resulting in a C-factor of 132.

The hydraulic calculations were also used to analyze the proper sizing of all building service entrance piping resulting in the conclusion that no existing piping is undersized.

1 Modeling a system as flat does not take into account the topography of the distribution system or the static pressure induced by the heights of all buildings.

Hydraulic Analysis Results – Existing

Refer to Appendix B – Chilled Water System Hydraulic Calculations for the output report and velocity profile results of each phase. The existing scenario is used as the base scenario and adds in buildings that are currently under design or construction as being existing. The model was set up using 3 pumps at WCCF, 2 pumps at CSHP and 1 pump at WSHP to pick up the additional load. For the most part, all buildings can be served from the secondary/variable primary pumping control strategy. (Refer to Existing Facilities portion of this section for description of secondary/variable primary pump control based on system pressure.) There are a few buildings however, that have a low available differential pressure which would necessitate the operation of building booster pumps. These buildings are UW Hospitals and Clinics (Clinical Science Center) (CSC), Helen C. White, Waisman Center, Veterans Administration Hospital, Water Science, Health Science Learning Center and IRC Phase I. Refer to Appendix B for nodal drawings of existing system as well as future phases. The existing scenario included all projects that were currently under design or construction that would be operational in 2016. The Veterans Administration Hospital was the critical node of this specific model.

Analysis Results – Phase 1

The growth in this phase includes large facilities such as the new Meat Science and Muscle Lab, the College of Engineering Research Building, and the Gymnasium-Natatorium Replacement. The net estimated load growth was calculated to be approximately 3,500 tons. Construction in this phase is split evenly between replacements or additions and new stand-alone buildings. The 16" mains serving WEI, among others, are adequate to pick up the new addition. The Veterans Administration Hospital was again the critical node, however CSC, Helen C. White, Waisman Center, Water Science, Health Science Learning Center and IRC Phase I also continued to see low available differential pressure. This is based on the distribution system pressure control strategy and not deficiencies in the distribution piping system as described in the Existing Facilities portion of this section. Therefore no consideration was given to increasing the pipe size of mains in the system. New laterals were sized for no more than 6 FPS, to consider future growth.

Analysis Results – Phase 2

Phase 2 saw an overall decrease in campus cooling load by approximately 150 tons. The Veterans Administration Hospital remains the critical node with the lowest available pressure. A second pump was operated as part of the analysis of this phase.

Analysis Results – Phase 3

The main point of growth in this phase happens along Linden Drive, increasing the velocity in the 30" mains in N. Charter Street as well as increasing the system pressure differential. Despite a net addition of only 1,300 tons issues begin to become apparent near the Charter Street Heating Plant (CSHP). As velocities approach 12 FPS thought should be given to the increase of main sizes in N. Charter Street as well as the mains serving Engineering Drive. The critical node for this phase remains the Veterans Administration Hospital, although predicted differential pressure on the east side of campus is beginning to drop as well.

Analysis Results – Phase 4

This phase has the largest increase in chilled water demand among all 4 phases and adds nearly 8,000 tons from Phase 3. Large additions in the central and south portions of campus resulted in high velocities in the 30" mains in N. Charter Street. Increasing the size of these mains between W. Dayton Street and University Avenue should be considered to reduce the system pressure drop. The critical node during this phase is the largest of the new Primate Center Expansion Buildings.

During this phase a fourth pump was turned on at WCCF, while the WSHP was used to cover additional load beyond what WCCF and CSHP could provide. Firm capacity was not maintained during this phase, however an additional 5,000 ton chiller, identified in the recommended chilled water project list, will need to be installed at WCCF in order to maintain firm capacity.

Table 3-8 summarizes the load growth and the impact to flow and pressure drop at each plant for each phase.

Table 3-8 Chilled Water Hydraulic Summary

Plant	Existing				Phase 1			
	Flow (Gpm)	Load (Tons)	Head (PSID)	Critical Node	Flow (GPM)	Load (Tons)	Head (PSID)	Critical Node
WSHP	4,000	1,667	25	Veterans Administration Hospital	10,000	4,167	25.7	Veterans Administration Hospital
CSHP	60,655	25,273	27.0		63,684	26,535	27.0	
WCCF	75,400	19,050	26.6		75,400	31,417	27.1	
Total/ Max	140,055	58,356	27.0		149,084	62,188	27.1	

Plant	Phase 2				Phase 3			
	Flow (Gpm)	Load (Tons)	Head (PSID)	Critical Node	Flow (GPM)	Load (Tons)	Head (PSID)	Critical Node
WSHP	10,000	4,167	26.6	Veterans Administration Hospital	14,000	5,833	28.6	Veterans Administration Hospital
CSHP	63,317	26,382	28.0		62,210	25,921	28.0	
WCCF	75,400	31,417	28.1		75,400	31,417	30.0	
Total/ Max	148,717	61,965	28.1		207,130	63,171	30.0	

Plant	Phase 4			
	Flow (GPM)	Load (Tons)	Head (PSID)	Critical Node
WSHP	7,000	2,917	36.1	S-09D Primate Expansion
CSHP	62,837	26,182	30.0	
WCCF	100,400	41,822	37.7	
Total/ Max	250,050	61,965	28.1	

Recommended Chilled Water Project List

Table 3-9 is a summary of the chilled water projects that are also included in the utility projects lists for Phases 1 through 4, as summarized in Tables 1-4 through 1-7. Refer to the Project Improvements List portion of Section 1 Introduction for description of project naming convention. Table 3-9 includes projects defined as regional campus issues (RCI) or building specified issues (BSI). These projects are not included in Tables 1-4 through 1-7. Timing for these projects is not defined and is to be determined by the university.

Table 3-9 Chilled Water Project List

Project Number	Master Phased Project No.	Description
CHW-E-01-P1	BSI	Control the plant distribution pumps based on the remote monitored differential pressure transmitters in lieu of the transmitters across the supply and return pipes of the plant
CHW-E-02-P1-2	RCI	Instrument each building with the following devices for billing, troubleshooting and energy managing purposes to optimize energy consumption: • Campus Chilled Water Supply & Return temperature and pressure • Campus Chilled Water Supply flow meter
CHW-E-04-P1-2	RCI	Increase Building Delta T – Selected AHU Component Replacement • AHU and/or cooling coils in poor condition (older than 25 years) • Increase AHU filtration efficiency
CHW-E-05-P1-2	RCI	Building Booster Pumps • A consistent DFD method should be employed to bypass the building booster pumps so as not to flow water through inactive pumps, etc and creating needless additional pressure drop • Add full line sized building booster pump by-pass pipes around building booster pumps • Remove building interface control valves and replace with line sized spool pieces
CHW-E-06-P1	BSI	Add chilled water sidestream filtration systems at each plant
CHW-E-08-P1-4	RCI	Increase Building Chilled Water Delta T – Maintenance • Clean AHU coils annually • Blowdown Coils periodically to check water quality
CHW-O-03-P1	1L	Replace existing 12" Cast Iron piping by Birge Hall with DIP
CHW-O-11-P1	BSI	Replace existing 100HP lake water pump in Helen C. White with 250 HP pump with VFD due to age of existing pump

Table 3-9 Chilled Water Project List, continued

Project Number	Master Phased Project No.	Description
CHW-X-05-P4	4H	• Add East Cooling Plant (6,000 tons). Located on the lower level of the Art Building, S-16A, the plant will include P/S chilled water pumps, condenser water pumps and cooling towers • New 30" CHW lines will extend from plant north and connect to 24" existing mains in W. Dayton Street.
CHW-X-06-P4	RCI	Extend 8" lake water pipe from Helen C. White pump room through the East Campus Utility Tunnel to W. Dayton Street.
CHW-X-07-P4	BSI	West Campus Cogen Plant – add 5,000 tons
CHW-X-10-P1	1H	Replace 14" CHW under footprint of future Ingraham Hall expansion.
CHW-X-13-P4	4H	Extend 8" lake water from Helen C. White to the Langdon St. Tunnel in N. Park Street and from W. Dayton Street and N. Park to new Arts Complex.
CHW-X-14-P4	4C	Extend 20" CHW to new West campus buildings in the Street West of Walnut Street
CHW-X-15-P2	2A	Extend 24" CHW to N. Park Street from existing 18" CHW in University Avenue and east campus utility tunnel
CHW-X-16-P4	4E	Extend 8" CHW to existing dorms along lakeshore
CHW-O-12-P2	2B	Replace existing piping (CHW) and tunnel near WARF, from Pit 2.5/9 to Pit 3/9
CHW-O-13-P1	1Y	Extend CHW piping near Pit 121.1/10 west to Enzyme Institute
CHW-O-14-P4	4J	Connect CHW piping to Environmental Health and Safety Building
		(Included in CHW-X-14-P4)
CHW-O-15-P1	RCI	Replace 3 sets of main CHW valves near Charter Street Heating and Cooling Plant
CHW-O-16-P2	2F	Replace CHW piping from east end of Engineering Drive to Charter Street heating and cooling plant.
CHW-O-17-P2	2C	Replace CHW piping in Engineering Drive.

Project Number	Master Phased Project No.	Description
CHW-R-01-P4	4K	Extend CHW piping in Engineering Drive to CHW main near WEI
CHW-X-17-P1	1T	Replace CHW piping in Linden Drive to accommodate new pedestrian corridor connections to Vet Med Addition. Install Manholes over CHW valve air vents near 2115 Linden Drive
CHW-O-19-P1	1T	Replace 10" CHW lateral piping serving Livestock Laboratory
CHW-O-20-P4	BSI	Charter Street Heating and Cooling Plant • Install two 4160V feedwater pump VFDs • Install two 4160V condenser feedwater pump VFDs • Replace condensate hotwell lining • Replace top section of cooling tower #5 • Remove Absorption chiller and associated cooling tower • R22 refrigerant phase-out • Remove and replace Chiller #3 surface condenser, outlet valve, inlet valve • Replace T&T valves on Chillers #1, #2, #3, and #4 • Overhaul steam turbines on chillers #1, #2, and #4 • Install Variable Frequency Drive (VFD) on the Charter Street Cooling Tower Pumps
CHW-O-21-P4	BSI	Walnut Street Heating and Cooling Plant • Install reduced voltage starter on Chiller #4 • Replace carbon steel condenser water piping with stainless steel piping • Replace water softener • Replace T&T valve on chiller #2 • Overhaul steam turbine on chiller #2 • System upgrades to the lake water inlet • Replace MCC-C3 and MCC-C4 – knife switches

Opportunities to Enhance Energy Efficiency/ Operational Flexibility

Chilled Water Thermal Storage

The viability of adding a chilled water thermal storage tank to the campus chilled water system should be studied as the electrical utility rate structure continues to evolve. The inclusion of a thermal storage tank would allow the campus to generate chilled water during electrical off-peak hours, to avoid demand charges, which would charge the tank with 42°F for use during the on-peak hours. This would allow the campus to meet the campus cooling load requirements during the on-peak hours utilizing a combination of chiller operation and discharge of the available chilled water in the thermal storage tank, thereby reducing the number of chillers required to operate during on-peak hours.

Preliminary analysis performed by Facilities Planning & Management personnel estimated that the thermal storage tank would be sized for between 5,000,000 and 8,000,000 gallons.

Current rate structure yields an attractive payback for tanks of this size.

While the tank can be of any shape, the most efficient and cost effective shape is round. A pump building may also be required in addition to the tank. A couple of tank sizes that would be capable of storing 8 million gallon are:

- 150 feet in diameter and 64 feet high
- 120 feet in diameter and 100 feet high

Proposed siting options for the thermal tank will also need further study. Options include the surface parking lot just east of the Charter Street Heating Plant, along the west side of N. Mills Street; or the surface parking lot east of N. Mills Street, also east of the plant in the same block. The second option would displace a proposed new academic/research facility and be separated from the main distribution plant by a roadway. Due to the size of the tank needed, an underground option appears not to be feasible at this time.

Future East Chiller Plant

The 2015 Campus Master Plan Update includes a location for a future east chiller plant at the south east corner of campus (Future Parking Structure S-16C). This plant is envisioned to provide 6,000 tons of chilled water. This additional chilled water capacity would allow the campus to provide firm chilled water capacity for the proposed ultimate build-out of the campus. This location was selected as having chilled water generation capability on the east side of campus provides operational flexibility and potential increased energy efficiency when dispatched in conjunction with the chillers in the Charter Street Plant.

4. ELECTRICAL POWER SYSTEM

Existing Facilities Analysis

The primary electrical system now serving the UW–Madison campus was originally planned and constructed using a radial 4.16 kilovolt (kV) distribution system supplied by Madison Gas and Electric Company (MGE). The UW–Madison system presently receives power from MGE at 4.16 kV at the East Campus and West Campus Substations, and serves 4.16 kV load from the N. Charter Street, East Campus, West Campus, Bacteriology, and Radio Hall Substations as well as Engineering Vault. The 4.16 kV distribution system consists of 5 kV feeder cables primarily installed in an underground concrete encased duct bank and manhole system.

In the course of the development of the present system, an additional higher voltage 13.8 kV distribution system was established and supplied by MGE. The UW–Madison system presently receives power from MGE at 13.8 kV at the N. Charter Street and Walnut Street Substations, and at the LaBahn and Athletic Operations Switching Stations. The 13.8 kV distribution system consists of 15 kV feeder cables installed in an underground concrete encased duct bank and manhole system. The Walnut Street Substation and the LaBahn and Athletic Operations Switching Station supply various campus building transformers at 13.8 kV, the Dayton Street and the Rennebohm Switching Station and Engineering Vault directly at 13.8 kV, as well as 13.8 to 4.16 kV transformers in the Bacteriology and Radio Hall Substations.

These systems have evolved into a reliable looped network of 4.16 and 13.8 kV radial feeder circuits supplied from the various substations and switching stations, that through various switching methods provide a backup supply to most campus building transformers. Figure 4-1 Major Primary Electrical Facilities identifies major primary electric facilities. The stations that are joint-use facilities are indicated as MGE/UW stations, in comparison to the stations that are owned and operated solely by UW–Madison. Drawing E-1 in Appendix C is the One-Line Diagram of the existing primary electric system, including substations, switching stations, 4.16 kV distribution system, and 13.8 kV distribution system.

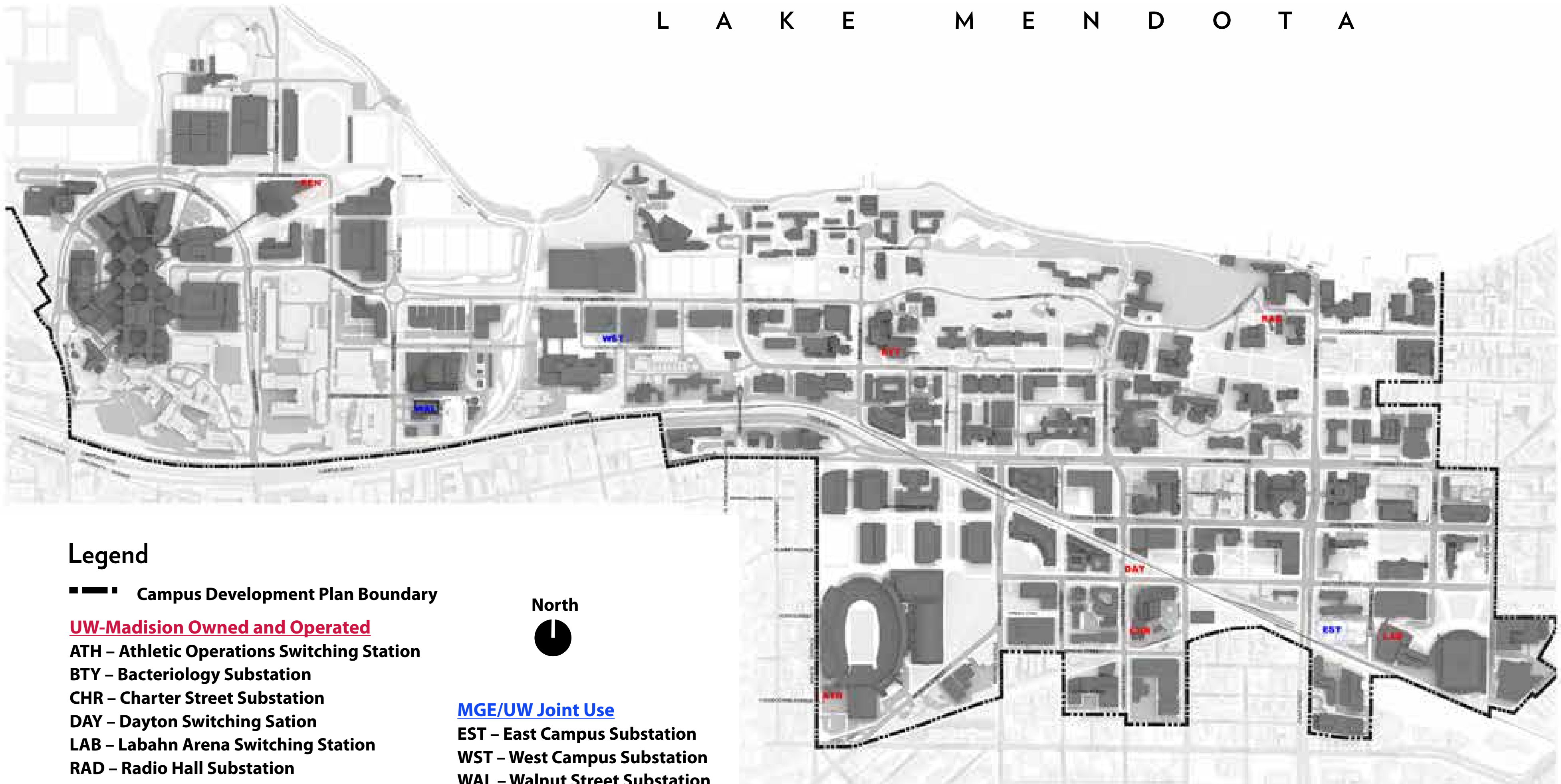
For the 2013-2014 year, the university system reported peak demand of approximately 72,628 kilowatts (kW) at a reported power factor of 0.85 (resulting in a net load of 85,445 kilovolt-amps (kVA)) and a load diversity factor of 0.70. Of this peak, 65,624 kW was purchased from MGE and 7,004 kW was supplied from the N. Charter Street Generator. There are a number of buildings in construction that aren't reflected in the 2013-2014 peak data, but which for study purposes are being treated as being in-place prior to the start of the 2015 Campus Master Plan Update's Phase 1.

This Utility Master Plan utilized a load diversity factor of 0.70 for substation loading and 1.0 for cable loading. All analysis will utilize the reported power factor of 0.85 lagging. Considering these factors, and adding estimates for the major buildings that are in construction, the projected electric system load at the start of Phase 1 is approximately 88.4 megavolt-amps (MVA).

Source

Each of the supplies from MGE has the ability to import power into the university electric system, which is described here as the capacity of the supply point. The amount of power that could be imported through each supply point would normally be limited by equipment sizes on the MGE system such as substation transformers or conductor sizes. MGE has provided data for these capacities, which are listed in Table 4-1 as the Maximum Available MGE Capacity.

The MGE distribution system that supports these supply points also serves electric customers other than UW–Madison. As a result, the amount of power available to serve university load at any particular point in time is something less than the maximum amount permitted by existing equipment sizes. In some locations, the amount of power available to serve UW–Madison load has been identified by MGE such as at Walnut Street Substation, where MGE indicates the total capacity available to serve the university's load is 87 MVA. In most cases the exact capacity is not known and the capacities, which reflect likely limitations due to MGE balancing load between UW–Madison and other MGE



Legend

▪▬▪ Campus Development Plan Boundary

<u>UW-Madision Owned and Operated</u>

ATH – Athletic Operations Switching Station
BTY – Bacteriology Substation
CHR – Charter Street Substation
DAY – Dayton Switching Sation
LAB – Labahn Arena Switching Station
RAD – Radio Hall Substation
REN – Rennebohm Switching Station

North

<u>MGE/UW Joint Use</u>

EST – East Campus Substation
WST – West Campus Substation
WAL – Walnut Street Substation

Figure 4-1 Major Primary Electrical Facilities

Table 4-1 Existing Supply Capacity Schedule

Supply Location	MGE Meter Number	Voltage (kV)	Maximum Available MGE Capacity [1] (MVA)	Estimated Available MGE Capacity[2] (MVA)	2015 UW Load at the MGE Coincident Peak (MVA)	UW–Madison Equipment Bus Capacity (MVA)
Athletic Office Switching Station – MGE 1313	E305942	13.8	10.3	4.1	2.1	47.8
Athletic Office Switching Station – MGE 1314	E323610	13.8	10.3	3.8	0.8	47.8
N. Charter Street Substation – MGE Blount	E309837	13.8	19.0	9.6	0.0	28.7
N. Charter Street Substation – MGE East Campus	E309836	13.8	10.3	3.8	2.1	28.7
East Campus Substation – MGE 1305	E312964	4.16	7.0	6.0	1.0	14.4
East Campus Substation – MGE 1306	E312966	4.16	7.0	6.0	5.1	14.4
LaBahn Arena Switching Station – East Campus 2307	E312889	13.8	17.2	34.0	3.4	47.8
LaBahn Arena Switching Station – East Campus 2308	E312976	13.8	17.2		6.2	47.8
Walnut Street Substation – MGE 2391	E308867	13.8	56.0	87.0	22.8	47.8
Walnut Street Substation – MGE 2392	E308859	13.8	56.0		13.3	47.8
Walnut Street Substation – MGE 2393	E314476	13.8	56.0		3.1	47.8
West Campus Substation – MGE 1321	E312963	4.16	7.0	4.0	2.2	14.4
West Campus Substation – MGE 1322	E312886	4.16	7.0	4.0	1.2	14.4

Notes:
(1) Maximum available capacity is determined by the limiting factor of equipment at the service (e.g. MGE owned transformer, equipment, cable size).
(2) Estimated available capacity is for all MGE load growth including UW–Madison

customers, were estimated and are also listed in Table 4-1 as the Estimated Available MGE Capacity.

Since MGE has an obligation under Wisconsin state law to serve the electric needs of their customers, MGE must install whatever facilities are necessary to serve UW–Madison if the loads grow in excess of MGE's existing capacity. As a result, from the university's perspective the amount of power that can be brought into UW–Madison from MGE is limited only by the ratings of the university equipment at the point of interconnection with MGE. These capacities are also listed in Table 4-1 as UW–Madison Equipment Bus Capacity.

Neglecting the influence of MGE serving customers other than UW–Madison, when used together to import power from MGE into the UW–Madison system these supply points have a net maximum available capacity of 280.3 MVA. Considering the likely effect of MGE serving other customers from some of the same equipment that supplies power into the university system, these supply points have a net estimated available capacity of 162.3 MVA. Assuming that UW–Madison would employ the right to draw maximum power from the MGE system using the existing supply points, the net import capacity of the university owned equipment is 449.6 MVA. Planning for a demand of 88.4 MVA on the entire UW–Madison system at the start of Phase 1, and considering that MGE has other customers to serve in addition to UW–Madison, this leaves 73.9 MVA of excess capacity to serve the existing university load with all supply points operational.

Table 4-2 Existing Campus 13.8 kV to 4.16 kV Transformer Schedule

Supply Location	Capacity (MVA)
Bacteriology Substation North East	7.5/10.5
Bacteriology Substation North West	7.5/10.5
Bacteriology Substation South	7.5/10.5
N. Charter Street Substation East	5
N. Charter Street Substation North	5/6.25
N. Charter Street Substation South	5/7
Engineering Vault	3
Engineering Vault	3
Radio Hall Substation North	7.5/10.5
Radio Hall Substation South	7.5/10.5

For planning purposes, it is not adequate to just look at the ability to serve loads under normal conditions, with all equipment operating properly. The mark of a well-designed system is the ability to serve all loads even with critical equipment out of service, a condition referred to as a "single contingency outage". Assuming the largest MGE supply point is out of service (one transformer out at Walnut Street Substation) the remaining import capabilities into the university system from MGE would still be as follows: maximum 224.3 MVA available from the existing MGE system; estimated 133.3 MVA from the existing MGE system when considering the effect of MGE serving other loads; and a maximum of 401.8 MVA with university system operating at maximum capacity assuming MGE has upgraded their facilities to support maximum university equipment ratings. Under these single contingency outage conditions, the existing MGE system will still be able to serve all campus load, including additional load through Phase 4 of this master plan. The N. Charter Street Generator (owned and operated by UW–Madison) will be able to continue providing additional redundant capacity.

In addition to the considerations regarding overall supply capacity into the system from MGE, the ability to supply power into the university 4.16 kV system must be examined. Supplementing the 4.16 kV supplies from MGE are UW–Madison transformers that convert power from 13.8 kV to 4.16 kV distribution voltage. Each of these transformation points capacity is limited by size of transformers and switchgear buses and potentially by conductor sizes on the university 13.8 kV system. Table 4-2 lists the capacity of each of these 13.8 to 4.16 kV transformation points.

When used in conjunction with the 4.16 kV supply points from MGE detailed in Table 4-1, these transformation points allow a net import into the university 4.16 kV system of 109.25 MVA. Under single contingency outage conditions (the largest 4.16 kV supply point is unavailable to serve the university load), the remaining supply capability into the university 4.16 kV system would still be 94.85 MVA. Based on 2013-2014 building load data the 4.16 kV system had a maximum demand of approximately 44.7 MVA, so there was approximately 40.15 MVA of reserve capacity to serve the existing 4.16 kV load under single contingency outage conditions.

As detailed above, the UW–Madison system receives power at 4.16 kV and 13.8 kV from MGE. This power is provided to MGE across the electric transmission system owned and operated by the American Transmission Company (ATC).

ATC is a regional transmission utility that owns and operates portions of the electric power transmission grid, including the transmission facilities in the Madison area. The transmission grid brings electric power to the Madison area from various electric generation plants, such as the West Campus Cogeneration Facility and the Blount, Fitchburg, Nine Springs, and Sycamore power plants located in the Madison area, and from other power plants located remote from the Madison area such as the Columbia Power Plant located near Portage, Wisconsin.

The portion of the transmission grid that supplies the Madison area currently consists of a 138 kV backbone system that interconnects to a lower voltage of 69 kV system through various transmission substations. The transmission systems also supply electric power to various MGE substations. Thus UW–Madison is supplied for the most part from the ATC 69 kV transmission grid through the MGE 69 kV facilities at East Campus, Walnut Street, and Blount Substations.

ATC has a formal system in place to review existing loads and to plan for accommodating future loads. Working with the utilities connected to the transmission system, ATC's planners evaluate the ability of their existing system to serve existing and projected future loads. ATC proposes new projects, tests them via planning and modeling software, and implements the least-cost projects that will accommodate the anticipated loads.

There are a number of governmental agencies regulating and overseeing the operation of ATC and the other utilities connected onto the transmission system, including the Public Service Commission of Wisconsin (PSCW) and the Federal Energy Regulatory Commission (FERC). Unless there are concerns raised by the PSCW or FERC regarding ATC's management of the transmission system, UW–Madison can assume there will be sufficient, reliable capacity on the transmission system to import power into the Madison area to support the university electric system loads. In order to support the efforts of both MGE and ATC, UW–Madison should provide accurate, timely estimates of their existing and projected future loads. The estimated load information contained within this master plan has been shared and reviewed by MGE.

Distribution System

The existing university underground distribution system consists of a variety of cable types and sizes. These cables are installed in an underground duct bank and manhole system.

Cable types include: 3 conductor lead jacketed; 3 conductor PVC jacketed; single conductor EPR insulated CSPE jacketed; and single conductor EPR insulated PVC jacketed, in copper cable sizes: 1/0 AWG; 4/0 AWG; 350 kcmil and 500 kcmil.

Nearly all of the 4.16 kV distribution feeders are loop fed with two or more sources available. Half of the feeders are loop fed from different substations, and just under half are loop fed from different buses within the same substation. A small portion of the feeders are radially fed with only one source available. The radially fed feeders could experience an extended outage to the buildings on the feeder if there is an outage at the supplying substation (due to a transformer failure, switchgear failure or failure of the substation battery), a problem with the feeder cables (such as a dig-in), or a major building fire requiring all power to the building to be shut down. An extended outage could also occur to the buildings on a loop fed feeder if the feeder is loop fed from different buses within the same substation and a station-wide outage occurs (due to a failure of the bus-tie breaker, failure of the substation battery, or other equipment failure or malfunction affecting more than one switchgear bus). Although the preferred location for backup to 4.16 kV feeders is from a different substation than the normal source, backup onto a different bus within the normal substation is considered acceptable for 4.16 kV circuits. Table E-1 in Appendix D is a table listing the existing distribution feeders. The table details the feeder voltage, normal and maximum loading (both in kVA and Amps), and the backup feeder if one exists.

All of the 13.8 kV distribution feeders are loop fed with two or more sources available. Some of the feeders are loop fed from different substations or switching stations, but most are loop fed from different buses within the same substation or switching station. The feeders that are looped back to the same facility could experience an extended outage to the buildings on the feeder if there is a large-scale outage at the supplying facility (due to a catastrophic equipment failure, or a failure of equipment tying two or more electrical buses together). A large portion of the university 4.16 kV system is fed through the university 13.8 kV system, so an outage on the 13.8 kV system would have a cascading effect on the 4.16 kV system. Table E-1 in Appendix D also lists the 13.8 kV feeders, and contains the same information as detailed above for the 4.16 kV feeders.

In the event of an outage or equipment failure occur, UW–Madison Electric Shop personnel can operate the appropriate loop switches and restore power to buildings from the backup source. This limits electric outages to mere hours, compared to outages of days or weeks if power couldn't be restored until the problem was resolved and failed equipment was repaired or replaced.

Cable age has been analyzed based upon existing facilities records. These records indicate the following distribution of cable ages across the 4.16 and 13.8 kV distribution systems:

- Over 50 Years Old 5%
- 40 to 50 Years Old 9%
- 30 to 40 Years Old 21%
- 10 to 30 Years Old 18%
- Less than 10 Years Old 33%
- Undetermined Age 14%

Table E-2 in Appendix D is a tabulation of the feeder cables and it includes information on the size, operating voltage, and age of each cable segment, if the information is known. Drawing E-3 in Appendix C is a diagram based on the system One-Line, with cable age represented by colored lines.

The older cables are generally located in the Central and East portions of campus and almost exclusively part of the 4.16 kV distribution system.

It is commonly accepted that cables are designed for a 40-year life expectancy and if correctly designed, installed, and operated can last over 60 years. Factors such as overloading (overheating), over voltage, ground or support movement, vibration, mechanical abuse, or damage, water immersion etc., all have a deleterious effect, which will shorten this expected cable life.

The lead jacketed cables are generally the older cables on campus and nearest the end of their life expectancies. They are expensive to repair and potentially an environmental hazard. However, industry experience has shown that lead cables tend to be some of the most reliable and longest-life cables in use in primary electric systems.

Table 4-3 Maximum Cable Size Vs. Minimum Conduit Size

Cable Size	Minimum Conduit Size for 5 kV Cables (inches)	Minimum Conduit Size for 15 kV Cables (inches)
1/0	3	3
4/0	3	3.5
350	3.5	4
500	4	5

An analysis of the existing system using the reported building loads and cable ampacities per NEC Table 310.60(C)(77), 5001-35,00 Volts, Type MV-90, Three Circuits (Figure 310.60, Detail 2), shows that approximately 2% of the existing cables are marginally sized and could become overloaded during normal operating conditions and over 20% of the existing cables are undersized and not capable of operating for a prolonged period under maximum loading conditions (loop feeder being fed from one end only).

Drawing E-3 in Appendix C is another diagram based on the system One-Line, with colored lines used to indicate cables that are potentially overloaded under normal or maximum loading conditions based on total feeder loads at points leaving respective substation or switching station feeder breakers.

Duct Capacity and Limitations

The existing 4.16 and 13.8 kV distribution systems consist of cables installed in an underground duct bank and manhole system. The underground duct bank system is comprised of several different types and sizes of conduit.

Most of the duct banks on campus are comprised of concrete encased schedule 40 PVC conduits with small sections of steel conduit installed at building walls and manholes. The oldest sections of the system are concrete encased transite or fiber duct.

Conduits in the duct bank occur in several different sizes. The majority of the system contains 4" conduit with all new primary duct banks being constructed with 5" conduit. A small portion of campus has 3" conduit installed, which limits the size of cable that can be installed.

Table 4-3 represents the limiting effect of conduit size on cable size and therefore current carrying capacity for both 5 kV and 15 kV cables.

Geographical Separation

The existing looped network of 4.16 and 13.8 kV feeder circuits generally has been built with the primary and backup circuits installed in ductbanks that are physically separated from each other except where they need to enter a building to the associated switchgear.

There are several areas on campus where both the primary and backup feeders are installed for a considerable distance in the same ductbank and manholes. In the event of a fault or fire in the manhole or accidental excavation of the ductbank, both feeders could be affected resulting in significant long duration outages of portions of the campus.

Existing Loads

4.16 kV Distribution System

The 4.16 kV distribution system serving UW–Madison is supplied from the N. Charter Street, East Campus, West Campus, Bacteriology, and Radio Hall Substations as well as Engineering Vault. The system consists of 5 kV feeder cables primarily installed in an underground concrete encased duct bank and manhole system, connected through various switching methods to provide a backup supply to most campus building transformers.

The typical connections on the 4.16 kV distribution system are such that a feeder is supplied from a substation bus, leaves the substation, and travels to a building that is equipped with in and out loop switches at the building. The feeder then travels to the next building, which is also equipped with in and out loop switches. After connecting to a small number of buildings, the feeder is connected back onto another substation bus. In practice the system is operated with one of the loop switches open out on the feeder, such that approximately half of the feeder load is actively supplied from one substation and the other half supplied from the other substation. This represents "normal operating conditions". The open point on the feeder can be moved from one building to another to balance load on the feeders or substations, or to allow equipment to be deenergized for maintenance or replacement. In this manner, load is transferred from one feeder to another.

If the open point on a feeder is moved beyond the last building on the feeder, the entire load for that particular feeder would be transferred off one substation and onto another. Under this condition the feeder that is serving the entire load is under its "maximum load" scenario and should be adequately sized and have sufficient capacity to supply power to the feeder when called upon to back up failed facilities or maintenance shutdowns. If all feeders from a particular substation bus are in their "maximum load" scenario, the substation will experience its "maximum possible load". Table E-3 in Appendix D lists the normal operating conditions and the maximum possible load for each substation serving existing 4.16 kV load on the university system (based on 2013-2014 building load data) and future calculations.

13.8 kV Distribution System

The existing 13.8 kV distribution system serving UW–Madison is supplied from the N. Charter Street and Walnut Street Substations, and from the LaBahn, Athletic Operations and Rennebohm Switching Stations. Limited 13.8 kV switching equipment is available at the Bacteriology Substation to aid the transfer and distribution of load on the 13.8 kV system. The system consists of 15 kV feeder cables installed in an underground concrete encased duct bank and manhole system, connected through various switching methods to provide a backup supply to campus building transformers and 13.8 to 4.16 kV substation transformers.

The typical connections on the 13.8 kV distribution system are such that a feeder is supplied from a substation or switching station bus, leaves the station, and travels to a building that is equipped with in and out loop switches at the building. The feeder then travels to the next building, which is also equipped with in and out loop switches. After connecting to a small number of buildings, the feeder is connected back onto another substation or switching station bus. In practice, the system is operated with one of the loop switches open out on the feeder, such that approximately half of the feeder load is actively supplied from one station and the other half supplied from the other station. This represents "normal operating conditions". The open point on the feeder can be moved from one building to another to balance load on the feeders or stations, or to allow equipment to be deenergized for maintenance or replacement. In this manner, load is transferred from one feeder to another.

If the open point on a feeder is moved beyond the last building on the feeder, the entire load for that particular feeder would be transferred off one station and onto another. Under this condition the feeder that is serving the entire load is under its "maximum load" scenario and should be adequately sized and have sufficient capacity to supply power to the feeder when called upon to back up failed facilities or maintenance shutdowns. If all feeders from a particular station bus are in their "maximum load" scenario, the station will experience its "maximum possible load". Table E-4 in Appendix D lists the normal operating conditions and the maximum possible load for each substation and switching station serving existing 13.8 kV load on the university system (based on 2013-2014 building load data) and future calculations.

Building Loads

Information from UW–Madison Annual Electrical Distribution Reports was used to determine existing peak load usage and demand values indicated in Table 4-4.

Table 4-4 Existing Electrical Load by Building

Building Name	Bldg. No.	Building Type	Gross Square Feet	Peak Demand (kW)
1800 University Ave (Survey Center)	113	Lab – Light	5,101	(1)
1848 University Ave (UW Foundation)	493		-	(1)
30 North Mills	124	Office – Vav	62,906	160.00
Adams Hall	564	Residence Hall	89,821	99.00
Agricultural Bulletin Building	78	Classroom – Cav	7,353	16.00
Agricultural Dean's Residence	72	Unknown Building Type	8,965	18.00
Agricultural Engineering Building	80	Classroom – Cav	23,909	52.80
Agricultural Engineering Laboratory	99	Service/ Grounds Facility	32,654	100.00
Agricultural Hall	70	Classroom – Cav	77,385	128.00
American Family Children's Hospital (Phase 1)	1426	Hospital	309,847	1067.00
Animal Science Building	118	Lab – Light	127,626	658.00
Armory & Gymnasium	20	Office – Cav	77,688	119.00
Art Lofts	220		78,974	(1)
Athletic Operations Bldg	584	Gym – Rec Facility	19,488	100.20
Atmospheric Oceanic & Space Sciences Bldg	156	Lab – Light	144,147	548.00
Babcock Hall	106	Lab – Light	136,071	377.00
Bardeen Medical Laboratories	451B	Lab – Heavy	69,344	732.00
Barnard Hall	560	Residence Hall	58,451	64.00
Bascom Hall	50	Office – Cav	178,329	192.00

Table 4-4 Existing Electrical Load by Building, continued

Building Name	Bldg. No.	Building Type	Gross Square Feet	Peak Demand (kW)
Below Alumni Center	489	Office – Vav	23,417	67.76
Biotron Laboratory	45	Lab – Medium – Old	106,907	900.00
Birge Hall	54	Lab – Light	171,883	418.00
Bock Laboratories, Robert M	33	Lab – Heavy	73,739	381.20
Bradley Hall, Harold C	506	Residence Hall	56,270	106.00
Bradley Memorial Building	452	Lab – Light	23,363	30.00
Camp Randall Sports Center (Shell)	25	Gym – Recreation Facility	107,372	245.60
Camp Randall Stadium	22	Sports – Outdoor	97,990	1956.00
Capitol Court 1220	782	Lab – Light	85,988	403.06
Carillon Tower	487	Unknown Building Type	1,694	(2)
Carson Gulley Commons	565	Residence Hall – Food Service	30,245	7460.00
Central Kitchen-Chadbourne And Barnard	562	Food Service Facility	31,459	(3)
Cereal Crops Research Unit	121	Lab – Heavy	34,000	(1)
Chadbourne Hall	557	Food Service Facility	145,365	302.00
Chamberlin Hall, Thomas C	55	Lab – Light	339,672	1109.80
Chamberlin House	571	Residence Hall	16,453	49.40
N. Charter Street N 45	504	Office – Cav	22,110	32.00
Chazen Museum Of Art	524	Museum	94,778	153.00
Chemistry Bldg, F Daniels & J H Mathews	47	Lab – Medium	409,067	1592.60
Clinical Science Center	1400	Hospital	1,897,439	6900.00
Cole Hall	555	Residence Hall	49,839	96.00
Computer Sciences And Statistics	155	Lab – Medium	244,096	1600.00
Conover House	574C	Residence Hall	16,552	(4)
Dairy Barn	105	Unknown Building Type	40,782	(5)
Dairy Cattle Center	92	Animal/Vet.	34,049	22.00
Dairy Forage Research Center-US	96	Animal/Vet.	58,898	375.00
Dejope Residence Hall	567	Residence Hall – Food Service	229,420	392.00
Deluca Biochemical Sciences	204	Lab Medium	224,078	899.00
Deluca Biochemistry Building	84	Lab Medium	82,100	588.00
Deluca Biochemistry Laboratories	205	Lab Heavy	219,524	984.10
East Campus Mall 333	467	Residence Hall	237,277	(1)
East Campus Mall 432	515	Food Service Facility	34,075	(6)
Education Building	400	Classroom – Vav	120,889	213.00
Education Sciences	154	Classroom – Cav	178,004	462.00
Elizabeth Waters Hall	559	Residence Hall	143,626	208.00
Elvehjem Building, Conrad A.	544	Museum	94,262	426.80
Engineering Centers Building	481	Lab – Light	251,334	1129.20
Engineering Drive 1410	486	Lab – Medium	63,561	197.00

Table 4-4 Existing Electrical Load by Building, continued

Building Name	Bldg. No.	Building Type	Gross Square Feet	Peak Demand (kW)
Engineering Hall	408	Classroom – Cav	464,768	1188.90
Engineering Mall	766	Outdoor Services	2,018	(7)
Engineering Research Building	762	Lab – Light – Old	157,510	560.00
Environmental Health And Safety Building	549	Service Facility	79,675	(1)
Enzyme Institute	479	Lab – Medium	69,684	527.66
Extension Building G (432 N. Lake St.)	500	Office – Cav	76,318	400.00
Field House	29	Gym – Rec Facility	123,830	112.00
Fleet And Service Garage	1077	Vehicle Service Facility	16,142	-
Fluno Center For Executive Education	139	Office – Vav	-	(1)
Forest Products Laboratory	36	Lab – Light	-	(1)
Genetics-Biotechnology Center Building	82	Lab – Heavy	247,746	1042.00
Gilman House	569	Residence Hall	16,470	32.00
Goodman Softball Complex	175	Sports – Training Facility	8,007	(8)
Goodnight Hall, Scott H	508	Residence Hall	55,386	88.00
Gordon Dining And Event Center	1249	Residence Hall – Food Service	111,644	292.00
Grainger Hall	140	Classroom – Vav	439,491	880.00
Greenhouse-King Hall	75	Agricultural/ Greenhouse	15,051	(9)

Building Name	Bldg. No.	Building Type	Gross Square Feet	Peak Demand (kW)
Greenhouse-Walnut Street	122	Agricultural/ Greenhouse	47,007	666.00
Gymnasium-Natatorium	31	Gym – Rec Facility	249,579	315.00
Hanson Biomedical Sciences Building	94	Lab – Light	43,519	164.35
Hasler Laboratory Of Limnology	483	Lab – Light	15,245	25.00
Health Science Learning Center (HSLC)	1480	Classroom – Vav	284,436	688.40
Heating And Cooling Plant –Walnut St	49	Central Plants	37,423	12594.00
Heating And Cooling Plant-Charter St	529	Central Plants	111,532	8008.01
Henry Mall 445	102	Lab – Light	54,750	105.00
Henry Rust/David Schreiner Hall	158	Residence Hall	21,098	(1)
Herrick Dr 550 Incinerator	127	Service/ Grounds Facility	2,163	(10)
Herrick Drive 502	111	Office	8,617	25.60
Herrick Drive 505	108	Service/ Grounds Facility	1,139	12.00
Herrick Drive 525 – Electrical Storage	222	Service/ Grounds Facility	3,630	(11)
Holt Center	574H	Classrooms – Cav	20,143	24.00
Horse Barn	95	Unknown Building Type	19,808	4.00
Horticulture	87B	Lab – Light	25,276	519.60
Humanities Building, Mosse George L	469	Classroom – Cav	333,363	465.70

Table 4-4 Existing Electrical Load by Building, continued

Building Name	Bldg. No.	Building Type	Gross Square Feet	Peak Demand (kW)
Humphrey Hall	136	Residence Hall	16,523	(12)
Ingraham Hall, Mark H	56	Classroom – Cav	97,603	168.00
Jones House	572	Residence Hall	16,537	72.60
Jorns Hall	137	Residence Hall	16,820	52.80
Kellner Hall	460	Offices – Vav	85,297	543.00
Kohl Center, The	225	Gym – W/ Spectators	472,906	1831.20
Kronshage Hall	574	Residence Hall	17,249	78.20
LaBahn Arena	227	Sports Arena	107,266	376.00
Lathrop Hall	32	Classroom – Cav	105,256	131.00
Law Building	430	Classroom – Cav	236,081	353.12
Leopold Residence Hall	576	Residence Hall	64,719	120.11
Lift Station-Lot 76	1714	Physical Plant	-	37.50
Linden Dr 1645	91	Service/ Grounds Facility	3,210	(10)
Linden Dr 1910	103	Classroom – Cav	11,267	42.00
Linden Dr 2105	465	Gym – Rec Facility	1,860	(10)
Linden Dr 2115	128	Unknown Building Type	8,756	24.00
Livestock Laboratory	115	Animal/Vet.	35,129	160.00

Building Name	Bldg. No.	Building Type	Gross Square Feet	Peak Demand (kW)
Lowell Center	502	Classrooms – Vav	136,010	(1)
Mack House	570	Residence Hall	16,986	30.00
Materials Science And Engineering Bldg	520	Classroom – Cav	45,759	306.00
McArdle Cancer Research Building	468	Lab – Heavy	96,657	400.00
McClain Athletic Facility	21	Gym – Rec Facility – Pool	169,320	429.00
Meat Science And Muscle Biology Lab	123	Lab – Light	30,190	142.00
Mechanical Engineering Building	407	Classroom – Cav	297,993	712.00
Medical Sciences	451C	Lab-Extra Heavy	72,499	(13)
Medical Sciences Center	450	Lab – Light	443,530	1064.00
Memorial Library	15	Library – Standard	573,454	730.00
Memorial Union	8	Residence Hall – Food Service	220,475	460.00
Merit House	575	Residence Hall	19,662	(1)
Microbial Science Building	60	Lab – Heavy	440,846	1030.70
Middleton Building, W S	455	Library – Standard	45,217	116.00
Moore Hall-Agronomy	87A	Lab – Light – Old	34,609	(14)
Morgridge Institute For Research	211	Lab – Medium	226,752	(15)
Music Hall	485	Classroom – Cav	38,131	80.00

Table 4-4 Existing Electrical Load by Building, continued

Building Name	Bldg. No.	Building Type	Gross Square Feet	Peak Demand (kW)
Nancy Nicholas Hall	85	Classroom – Vav	198,915	314.00
Newell J. Smith Residence Hall	1079	Residence Hall	158,733	286.80
Nicholas-Johnson Pavilion and Plaza	226	Sports – Arena	27,847	(16)
Nielsen Tennis Stadium	38	Gym – Rec Facility	140,673	744.00
Noland Zoology Building, Lowell E	402	Lab – Light	92,818	227.00
North Hall	52	Office – Cav	22,447	26.00
Nutritional Sciences	449	Classroom – Cav	56,502	144.00
Observatory Hill Office Building	512	Unknown Building Type	6,964	21.10
Observatory, Washburn	510	Unknown Building Type	11,166	21.00
Ogg Hall	1243	Residence Hall	218,377	277.10
N. Park Street, 21 North	1078	Office – Vav	138,640	368.00
Parking Garage 23-Van Hise	9522	Parking	-	(17)
Parking Garage 38-Microbial	9537	Parking	66,704	(18)
Parking Garage 6-Helen C. White	9507	Parking	96,881	(19)
Parking Garage 7-Grainger	9508	Parking	191,769	(20)
Parking Garage 83-Fluno Center	9577	Parking	120,582	(1)
Parking Garage 95-HSLC	9585	Parking	71,360	(21)
Parking Ramp 17-Engineering Dr	536	Parking	264,321	125.00
Parking Ramp 20-University Ave	142	Parking	94,111	45.00
Parking Ramp 29-21 N. Park St	9530	Parking	-	(22)
Parking Ramp 36-Observatory Dr	104	Parking	147,883	41.10
Parking Ramp 46-Lake & W. Johnson	152	Parking	254,841	56.00

Building Name	Bldg. No.	Building Type	Gross Square Feet	Peak Demand (kW)
Parking Ramp 75-CSC	751	Parking	443,766	165.00
Parking Ramp 76-University Bay Dr	9573	Parking	409,650	83.00
Phillips Residence Hall	507	Residence Hall	54,983	152.00
Physical Plant-Grounds Storage	125	Plant	2,560	(1)
Physical Plant-Grounds Storage 2	223	Parking	480	(1)
Plant Sciences	87C		62,173	(23)
Police And Security	550	Offices – Vav	17,323	(1)
Porter Boathouse	172	Gym – Recreation Facility	49,996	176.00
Poultry Research Laboratory	110	Animal/Vet.	24,013	24.40
Primate Center, Wisconsin	526	Lab – Extra Heavy	31,606	403.00
Primate Lab, Harlow	527	Lab – Heavy	36,944	314.40
Psychology Building, W J Brogden	470	Classroom – Cav	115,071	245.00
Pyle Center	6	Classroom – Cav	148,235	426.30
Radio Hall	405	Classroom – Cav	21,397	20.00
Rennebohm Hall	34	Lab – Heavy – Old	222,517	660.80
Residence Halls Garage	566	Vehicle Service Facility	1,361	(1)
Russell Laboratories	114	Lab – Light – Old	154,675	667.20
School Of Social Work Building	453	Classroom – Cav	41,344	47.60
Schuman Shelter, Carl	116	Outdoor Services	960	(24)

Table 4-4 Existing Electrical Load by Building, continued

Building Name	Bldg. No.	Building Type	Gross Square Feet	Peak Demand (kW)
Science Hall	53	Classroom – Vav	101,646	156.80
Seed Building	119	Classroom – Cav	17,744	(25)
Sellery Hall	1245	Residence Hall	230,408	383.00
Service Building	530	Service/ Grounds Facility	51,066	168.00
Service Building Annex (H)	534	Service/ Grounds Facility	38,356	27.00
Service Memorial Institute	451A	Lab – Heavy	122,474	400.00
Showerman House	574S	Residence Hall	16,497	(4)
Signe Skott Cooper Hall	44	Classrooms – Vav	169,924	450.00
Slichter Hall	558	Residence Hall	63,180	136.10
Smith Annex (H), Hiram	77	Classroom – Cav	12,755	670.00
Smith Greenhouse, D C	206	Agricultural/ Greenhouse	13,057	-
Smith Hall, Hiram	76	Classroom – Cav	19,833	20.20
Social Science Building	46	Classroom – Vav	204,205	336.00
Soils And King Hall – King Hall	74B	Lab – Medium	21,478	(9)
Soils And King Hall – Soils	74A	Lab – Medium	26,696	127.20
South Hall	51	Office – Cav	22,522	35.20

Building Name	Bldg. No.	Building Type	Gross Square Feet	Peak Demand (kW)
Southeast Recreational Facility	28	Gym – Rec Facility – Pool	191,254	347.00
State Historical Society	16	Library / Office-Vav	237,700	253.00
Steenbock Memorial Library	79	Library – Standard	113,343	197.00
Sterling Hall	57	Classroom – Cav	170,190	251.00
Stock Pavilion	90	Unknown Building Type	94,775	61.46
Stovall Building, William D-Hygiene Lab	476	Lab – Light	80,939	153.00
Sullivan Hall	556	Residence Hall	49,023	69.60
Susan B. Davis Residence Hall	578	Residence Hall	11,967	(1)
Swenson House	573	Residence Hall	16,558	88.40
Taylor Hall, Henry	464	Classroom – Cav	34,504	(25)
Teacher Education	153	Classroom – Cav	97,103	240.00
Tripp Hall	563	Residence Hall	90,770	132.00
Turner House	568	Residence Hall	16,552	44.00
Union South	88	Residence Hall – Food Service	307,098	601.00
University Ave 1610	129	Classroom	24,589	20.83
University Club	515B	Gym – Rec Facility	15,969	90.00

Table 4-4 Existing Electrical Load by Building, continued

Building Name	Bldg. No.	Building Type	Gross Square Feet	Peak Demand (kW)
UW Medical Foundation Centennial Building	1435	Lab – Light	136,060	376.00
Van Hise Hall	482	Classroom – Cav	226,940	490.00
Van Vleck Hall, E B	48	Classroom – Cav	109,914	468.00
Veterans Administration Hospital	1055	Hospital	618,517	(1)
Veterinary Diagnostic Lab	126	Lab – Heavy	81,777	386.00
Veterinary Medicine Building	93	Lab – Light	248,852	1000.00
Vilas Communication Hall	545	Broadcast Facility	253,043	1650.00
Waisman Center	459	Lab – Light – Old	166,143	900.00
WARF Office Building	39	Office – Cav	155,085	466.56
Water Science And Engineering Laboratory	403	Lab – Light	41,947	86.40
Weeks Hall For Geological Sciences, Lewis G	521	Lab – Medium	146,474	365.00
Wendt Library, Kurt F	404	Library – Standard	74,459	180.00
West Campus Cogeneration Facility	120	Central Plants	120,000	(1)
White Hall, Helen C	18	Library – Standard	245,710	693.00
Wisconsin Energy Institute	752	Lab – Medium	110,636	435.00
Wisconsin Institute For Discovery	212	Lab – Medium	88,931	1450.00
Wisconsin Institutes For Medical Research	1485	Lab – Medium	701,343	2455.00
Witte Hall	1246	Residence Hall	230,799	380.00
Zoe Bayliss Co-Op	577	Residence Hall	11,603	(1)
Zoology Research Building	401	Lab – Medium	44,256	192.00
Total Electrical Load			**25,683,925**	**95,870**

Notes:
(1) Fed from MGE
(2) Load included with Ingraham Hall, Mark H
(3) Load included with Chadbourne Hall
(4) Load included with Kronshage Hall
(5) Load included with Dairy Forage Research Center-US
(6) Load included with Humanities Building, Mosse George L
(7) Load included with Engineering Hall
(8) Load included with Nielsen Tennis Stadium
(9) Load included with Soils and King Hall – Soils
(10) Load included with Linden Dr 2115
(11) Load included with Herrick Dr 505
(12) Load included with Jorns Hall
(13) Load included with Bardeen Medical Laboratories
(14) Load included with Horticulture
(15) Load included with Wisconsin Institute For Discovery
(16) Load included with Kohl Center, The
(17) Load included with Van Hise Hall
(18) Load included with Microbial Science Building
(19) Load included with White Hall, Helen C
(20) Load included with Grainger Hall
(21) Load included with Health Science Learning Center (HSLC)
(22) Load included with Smith Hall, Hiram
(23) Load included with Livestock Laboratory
(24) Load included with Phillips Residence Hall
(25) Load included with Genetics-Biotechnology Center Building

Projected Future Loads

Building Additions and Removals

Tables 4-5 through 4-8 show the future loads that have been projected for planned building additions and removals based on load density factors as well as the 2015 Master Plan phasing spreadsheet developed by SmithGroupJJR for the Campus Master Plan. The growth is broken into four distinct phases. The first three phases have seven year durations and the last phase has a nine year duration to round-out the 30-year 2015 Utility Master Plan study period.

In order to support planned building additions, certain existing buildings will be removed. Removing these buildings has an impact on the configuration of the future electric distribution system, in that the existing load represented by these buildings will no longer need to be served. In addition, removing these buildings from the electric system provides opportunities for existing circuits to be condensed and reconfigured.

Table 4-5 Future Electrical Load Estimate By Building (Phase 1)

Building Name	Bldg. No.	Building Type	Gross Square Feet	Peak Demand (kW)
Removed				
Greenhouse-Walnut Street	122	Agricultural/ Greenhouse	47,007	666.00
Gymnasium-Natatorium	31	Gym – Rec Facility	249,579	315.00
Linden Dr 1645	91	Service/Grounds Facility	3,210	
Linden Dr 1910	103	Classroom – Cav	11,267	42.00
Seed Building	119	Classroom – Cav	17,744	
Southeast Recreational Facility	28	Gym – Rec Facility – Pool	191,254	347.00
Susan B. Davis Residence Hall	578	Residence Hall	11,967	MGE
University Ave 1610	129	Classroom – Cav	24,589	20.83
Zoe Bayliss Co-Op	577	Residence Hall	11,603	MGE

Building Name	Bldg. No.	Building Type	Gross Square Feet	Peak Demand (kW)
Added				
Babcock Hall Center for Dairy Research Addition	W-25	Classroom – Vav	31,300	60.72
Chemistry Bldg Expansion	S-29	Classroom – Vav	173,169	675.36
College of Engineering Research Building	S-21	Lab – Medium	156,364	609.82
Gymnasium-Natatorium Replacement	W-16	Gym – Rec Facility	471,417	612.84
Hamel Music Center P1&2	N-13B	Broadcast Facility	135,000	189.00
Ingraham Hall Additions	N-14	Classroom – Vav	56,000	108.64
Academic/Research (W. Johnson/N. Park Site)	S-13A	Classroom – Vav	348,000	675.12
Meat Science and Muscle Biology Lab	W-18	Lab – Light	228,000	1,071.60
Officer Education Facility	S-30	Classroom – Vav	65,000	-
Parking Structure	S-13	Parking		
Parking Structure	W-02	Parking		-
Parking Structure	W-27	Parking	198,000	65.34
Police Addition	S-18	Classroom – Vav	24,840	-
Southeast Recreational Facility	S-31	Gym – Rec Facility – Pool	253,000	455.40
Veterinary Medicine Building	W-17	Lab – Light	138,911	555.64
Walnut Greenhouse II	W-12	Agricultural/ Greenhouse	24,000	340.80
		Removed	568,220	1390.83
		Added	2,303,001	5420.29
		Net	1,734,781	4029.46
		Post Phase 1	27,418,706	9,899

Table 4-6 Future Electrical Load Estimate By Building (Phase 2)

Building Name	Bldg. No.	Building Type	Gross Square Feet	Peak Demand (kW
Removed				
Engineering Drive 1410	486	Lab – Medium	63,561	197.00
Psychology Building, W J Brogden	470	Classroom – Cav	115,071	245.00
Schuman Shelter	116	Outdoor Services	960	0.00
Service Building	530	Service/ Grounds Facility	51,066	168.00
Service Building Annex (H)	534	Service/ Grounds Facility	38,356	27.00
Stovall Building, William D-Hygiene Lab	476	Lab – Light	80,939	153.00
Added				
Engineering Dr 1410 – Replacement	S-02	Lab – Light	169,091	524.18
Nielsen Tennis Stadium Expansion	W-28	Gym – W/ Spectators	47,075	249.03
		Removed	349,953	790.00
		Added	216,166	773.21
		Net	(133,787)	-16.79
		Post Phase 2	27,284,919	99,882

Table 4-7 Future Electrical Load Estimate By Building (Phase 3)

Building Name	Bldg. No.	Building Type	Gross Sqare Feet	Peak Demand (kW)
Removed				
Bardeen Medical Laboratories	451B	Lab – Heavy	69,344	732.00
Bradley Memorial Building	452	Lab – Light	23,363	30.00
Engineering Research Building	762	Lab – Light – Old	157,510	560.00
Extension Building G (432 N. Lake St.)	500	Office – Cav	76,318	400.00
Henry Rust/David Schreiner Hall	158	Residence Hall	21,098	MGE
Humanities Building, Mosse George L	469	Classroom – Cav	333,363	465.70
Livestock Laboratory	115	Animal/Vet.	35,129	160.00
McArdle Cancer Research Building	468	Lab – Heavy	96,657	400.00
Medical Sciences	451C	Lab – Extra Heavy	72,499	0.00
Middleton Building, W S	455	Library – Standard	45,217	116.00
Poultry Research Laboratory	110	Animal/Vet.	24,013	24.40
Service Memorial Institute	451A	Lab – Heavy	122,474	400.00

Building Name	Bldg. No.	Building Type	Gross Sqare Feet	Peak Demand (kW)
Added				
Academic/Research (Mosse site south)	N-12A	Classroom – Vav	135,000	261.90
Academic/Research – Humanities	N-11A	Lab – Light	84,000	117.60
Academic / Research	S-08A	Lab – Medium	22,000	77.00
Academic/Research (Stovall site)	N-04	Classroom – Vav	82,200	159.47
Academic/Research (SMI Bardeen Med Sciences)	N-06A	Lab – Light	144,000	432.00
Engineering Research Building Replacement	S-01	Library – Standard	271,667	964.42
Academic/Research (Meiklejohn Site)	S-28	Classroom – Vav	84,470	163.87
Music Phase 3	N-13C	Broadcast Facility	75,000	105.00
Parking Structure	N-05C	Parking	-	-
Parking Structure Under N-06A	N-06B	Parking		0.00
Parking Structure Under N-11A and N-12A	N-11B	Parking		0.00
Poultry Research Building	W-20	Animal/Vet.	51,600	51.60
Preserve Outreach Center	W-29	Service/ Support	8,700	MGE
WID, Phase 2	S-03B	Lab – Medium	392,000	6,389.60
Wisconsin Institutes for Medical Research Ph3	W-01	Lab – Medium	308,000	1,078.00
		Removed	1,076,985	3288.10
		Added	1,658,637	9,800.46
		Net	581,652	6512.4
		Post Phase 3	27,866,571	106,395

Table 4-8 Future Electrical Load Estimate By Building (Phase 4)

Building Name	Bldg. No.	Building Types	Gross Square Feet	Peak Demand (kW)
Removed				
Agricultural Engineering Laboratory	99	Service/ Grounds Facility	32,654	100.00
Biotron Laboratory	45	Lab – Medium	106,907	900.00
Charter St N 45	504	Office – Cav	22,110	32.00
Engineering Hall	408	Classroom – Cav	464,768	1188.90
Greenhouse-King Hall	75	Agricultural/ Greenhouse	15,051	40.6
Hanson Biomedical Sciences Building	94	Lab – Light	43,519	164.35
Henry Mall 445	102	Lab – Light	54,750	105.00
Herrick Dr 505	108	Lab – Light	1,139	12.00
Herrick Dr 509	109	Lab – Light		
Herrick Dr 525 – Electrical Storage	222	Service/ Grounds Facility	3,630	
Linden Dr 2105	465	Service/ Grounds Facility	1,860	0.00
Linden Dr 2115	128	Academic	8,756	113.00
Meat Science And Muscle Biology Lab	123	Lab – Light	30,190	142.00
Noland Zoology Building, Lowell E	402	Lab – Light	92,818	227.00
Nutritional Sciences	449	Classroom – Cav	56,502	144.00
Physical Plant – Grounds Storage	125	Plant	2,560	MGE
Physical Plant – Grounds Storage 2	223	Plant	480	MGE
Primate Lab, Harlow	527	Lab – Heavy	36,944	314.40
Primate Center, Wisconsin	526	Lab – Extra Heavy	31,606	403.00
School Of Social Work Building	453	Classroom – Cav	41,344	47.60
Soils And King Hall – King Hall	74A	Lab – Medium	21,478	55.84
Van Hise Hall	482	Classroom – Cav	226,940	490.00
Wendt Library, Kurt F	404	Library – Standard	74,459	180.00
Zoology Research Building	401	Lab – Medium	44,256	192.00

Table 4-8 Future Electrical Load Estimate By Building (Phase 4), continued

Building Name	Bldg. No.	Building Types	Gross Square Feet	Peak Demand (kW)
Added				
Academic/Research (Van Hise)	N-03A	Classroom – Vav	114,000	221.16
Academic/Research (Van Hise)	N-03B	Classroom – Vav	48,000	93.12
Academic/Research	N-05A	Lab – Light	180,000	540.00
Academic/Research	N-05B	Lab – Light	165,000	495.00
Academic/Research	N-07	Lab – Light	30,000	90.00
Academic/Research (Spring St)	S-08C	Lab – Light	150,000	450.00
Academic/Research (Lot 45 Site)	S-11A	Classroom – Vav	30,000	58.20
Social/Dining/Meeting Rooms/ Health Science	W-06	Residence Hall – Food Service	127,000	317.50
Plant Sciences	W-24	Lab – Light	100,000	300.00
Art Building	S-16A	Classroom – Vav	162,000	5,414.28
Biological Systems Engineering	W-19	Classroom – Vav	246,000	477.24
Cooper Hall Addition	W-08	Classroom – Vav	30,000	58.20
Fluno Addition	S-20	Unknown Building Type	43,200	-
Grounds Storage A – Controlled Temp	W-31	Service/ Grounds Facility	3,000	0.99
Grounds Storage B – Covered	W-30	Service/ Grounds Facility		-
Grounds Storage C – Salt	W-33	Service/ Grounds Facility	3,500	1.16
Grounds Office / Administration	W-34	Service/ Grounds Facility	3,000	4.95
Grounds Greenhouse	W-32	Service/ Grounds Facility	6,000	85.20
Health Sciences Research	W-07	Lab – Medium	122,000	427.00
Health Sciences Research	W-09B	Lab – Medium	233,250	816.38
Health Sciences Research	W-09C	Lab – Medium	231,000	808.50
Health Sciences Research	W-13	Classroom – Vav	65,674	127.41
Health Sciences Expansion	W-04A	Hospital	60,500	220.22
King Hall Greenhouse	N-15	Agricultural/ Greenhouse	7,500	106.50
McClimon Track / Soccer Grandstand	W-5	Sports – Outdoor	78,000	269.88
New Engineering	S-23	Classroom – Vav	204,000	395.76
New Engineering	S-24	Classroom – Vav	236,583	458.97
New Engineering	S-25	Classroom – Vav	274,986	533.47
New Engineering	S-26	Classroom – Vav	169,506	328.84
Parking Structure	S-27	Parking	345,600	114.05
Parking Structure	S-10A	Parking		-
Parking Structure	S-16C	Parking		-
Parking Structure	W-09A	Parking	-	-

Table 4-8 Future Electrical Load Estimate By Building (Phase 4), continued

Building Name	Bldg. No.	Building Types	Gross Square Feet	Peak Demand (kW)
Animal Sciences (AHABS)	W-22	Lab – Light	85,000	255.00
Primate Center & Harlow Expansion	S-09A	Lab – Heavy	49,000	514.50
Primate Center & Harlow Expansion	S-09C	Lab – Heavy	60,000	630.00
Primate Center & Harlow Expansion	S-09D	Lab – Heavy	96,000	1,008.00
WARF Addition	W-11	Office – Vav	192,000	576.00
Weeks Hall Addition	S-08B	Lab – Medium	5,000	12.50
Zoology Research And Noland Hall	S-07	Lab – Medium	420,000	1,822.80
		Removed	1,414,721	4,852
		Added	4,376,299	18032.77
		Net	2,961,578	13,181.08
		Post Phase 4	30,828,149	119,576

Combined Building Load Analysis

Over the past ten years, the electric system peak has grown at an average rate of nearly 1.8% per year. Part of this growth is due to construction of new buildings and building additions, and part of the growth is due to increased electricity demand in existing buildings as building usage changes.

Table 4-9 indicates the net effect of the building additions, removal of existing buildings, and annual growth in electricity usage in existing and new buildings.

Table 4-9 Total Campus Electrical Load Summary

Existing 2015	Phase 1 (2017-2023)	Phase 2 (2023-2029)	Phase 3 (2029-2035)	Phase 4 (2035+)
88.4 MVA	92.3 MVA	92.1 MVA	103.8 MVA	115.1 MVA

Existing Distribution System

Feeder Connections

As previously discussed, the UW–Madison electric system consists of networks of 4.16 and 13.8 kV distribution cables (feeders) installed in an underground ductbank and manhole system. Each of these feeders is connected through a circuit breaker to a lineup of switchgear at a substation or switching station.

All new buildings will be connected onto the 13.8 kV distribution system. The exceptions would be where building additions represent fairly small electric loads and are to be constructed in areas where 13.8 kV is not readily available. In these cases, the costs of bringing 13.8 kV into the area outweigh the benefits of connecting into the 13.8 kV system, and the 4.16 kV system will be utilized to serve the new buildings.

It is estimated that 9 additional 13.8 kV circuit breaker connections will be needed to serve future feeders that will be required to support the planned building additions. This exceeds the number of spare breakers that currently exist, and in some cases the spare breakers are not located in the facilities where additional breakers will be required. Although a number of 4.16 kV circuit breaker positions will be lost by removal of existing substations, it is anticipated that sufficient 4.16 kV circuit breakers will remain to support the number of 4.16 kV feeders that will remain in service.

Substation Equipment

In terms of physical construction, other than additional breakers noted previously the existing substations are suitable for continued use to serve university electric system loads.

Future Considerations

As previously discussed, MGE has an obligation under state law to provide adequate facilities to serve their customers' loads. MGE does not have an obligation to provide redundant facilities such as those needed to ensure that firm capacity is available. When a customer such as UW–Madison has specific needs with respect to increased reliability or redundancy, including a desire to maintain firm capacity available to serve their loads, that customer may be obligated to pay for the redundant facilities installed to meet their needs.

Fortunately, based upon the recent upgrades at Walnut Street Substation, MGE and the university are in good shape to provide firm capacity to the campus for the foreseeable future even if a major failure were to occur at a facility such as the Walnut Street Substation. While MGE was not obligated to provide enough capacity to maintain firm capacity as part of the Walnut Street Substation project, the university's interests benefited rather by a byproduct of the size of transformer selected.

The existing system is configured such that all buildings and loads west of Willow Creek are essentially supplied from the Walnut Street Substation. As a result, a major equipment failure at Walnut Street Substation will result in long duration outages to these buildings regardless of the status of firm capacity available to the overall campus. In order to ensure adequate firm capacity is available to serve UW–Madison loads across campus for the entire 30-year period of the 2015 Utility Master Plan, additional connections should be provided to these buildings and loads from some facility other than the Walnut Street Substation. Truly redundant, backup sources of power need to be established for facility certifications, to establish grant eligibility, and to meet the needs of research and associated building usage.

Installing additional substation capacity closer to the west end of the campus and independent from the Walnut Street Substation is one option to consider down the road. A new transmission connection and a new substation on the west end of campus would provide firm capacity and would establish truly redundant, backup sources of power. In the meantime, heavy-tie feeders connecting eastern campus distribution points to western distribution points such as Walnut Street Substation and Rennebohm Switching Station should be installed to help provide redundant capacity to these campus locations.

Existing System

As previously discussed, there are a number of deficiencies in the existing UW–Madison electric system. The following system upgrades are recommended to address these existing electrical system deficiencies:

- If UW–Madison loads are transferred from one MGE supply point to another, local overloading of the supply points could occur. MGE should be kept informed of load transfers from one supply point to another, to allow for modifications to the MGE system required to provide full capacity to each university supply point.
- All lead jacketed cables, although being some of the oldest cables on campus, appear to be in relatively good operating condition. It is recommended that these be replaced upon failure of the cable or as encountered in the normal reconfiguring and/or recabling process. However, it is not necessary to initiate a structured program to replace these cables simply because they are jacketed in lead.
- There are a number of areas on campus where there is not geographical separation between feeder loops feeding specific buildings or areas of campus. Where possible, projects in the areas of these feeders should add separation or otherwise dedicated projects to develop separation should be completed if the associated risk of no separation deems necessary.
- A consolidated, comprehensive listing of electrical equipment (manufacturer, rating, date in service, etc.) and cable data (manufacturer, cable type, size, age, etc.) and an updated map of all underground facilities should be compiled and maintained in order to facilitate future planning, construction and maintenance efforts.

Future System Development

As the UW–Madison electric system is expanded to accommodate future load growth and planned building additions, certain potential problems will need to be addressed. The following general guidelines are recommended to address these potential problems:

- The number of existing and spare 13.8 kV circuit breaker connections will not be adequate to support the planned building additions. Additional 13.8 kV circuit breaker connections will be needed.
- Planned building additions will be similar to existing loads, in that redundant sources of reliable power will be required to maintain certifications, to continue grant eligibility, and to meet the needs of research and associated building usage. New feeders must be developed and laid-out in such a manner that each building has a backup source of power available.
- Redundant, backup sources of power between major campus switching/service locations need to be established for support of existing loads and planned building additions. Several heavy tie feeders between key campus switching stations should be added.

Recommended Electrical System Project List

The following paragraphs summarize elements of the approach to transforming the electrical system, including a discussion of the justifications for constructing the facilities and the specific benefits that will be achieved.

- Consider planning for new Far West and Far East Substations, including new connections into the transmission grid. Potential sites for each substation have been identified within the Electrical Project List. The final arrangement and location of each substation will need to be confirmed. It is anticipated that the substations will be enclosed in architectural enclosures to screen them from view and to improve the aesthetic appearance. As planned, the substations would include new 69kV transmission connections from American Transmission Company (ATC) with associated transmission breakers and related equipment to be installed in the substation as required by ATC. It should be noted that ATC has a specific procedure in place to be followed to apply for (and study the effects of) any new transmission connections. This process can take a significant amount of time to complete. Therefore, timing of the new substation planning needs to allow for adequate time such that by the completion of these planning efforts, all affected parties should have received all approvals necessary to allow the substation projects to proceed as scheduled, and have agreed upon allocation of costs amongst the various parties. UW–Madison would own and operate the new substation transformers and related 13.8 kV switchgear. Additional ductbanks and 13.8 kV cables would be installed to connect the new substation into the existing university electric distribution system. Once the new substation and related improvements are installed and in service, UW–Madison will have established two new 69 kV supply points. These supply points will provide additional supply capacity to the university electric system, increasing the reliability to existing loads and providing alternate power sources to future buildings necessary to obtain certifications, to establish grant eligibility, and to meet the needs of research and associated building usage.
- Replace existing lead cables as failure occur, or as they are encountered in the normal reconfiguring and recabling process.
- Provide additional ductbanks from Walnut Street Substation to connect additional heavy tie feeders between switching stations and new buildings into the existing university electric distribution system.
- Working with the thermal, civil and information technology utilities, establish common utility corridors and install/complete new electrical ductbanks along Highland Avenue, Walnut Street, Observatory Drive, Linden Street, N. Charter Street, Engineering Drive and W. Dayton Street. Installing these ductbanks at this time, in common utility corridors with the other utilities, will alleviate the expense and inconvenience of tearing up the corridors multiple times as each utility needs to install underground facilities in the area.
- Install new ductbanks and cabling as required to service existing loads and planned building additions. Together with the other planned system additions in Phase 1, these required upgrades will allow the university electric system to accommodate an additional 1,367,870 net gross square feet (GSF) of building space, representing approximately 2.8 MVA of additional net electric load.
- Install heavy tie feeders from Walnut Street Substation to the Athletic Operations Switching Station, and from the Athletic Operations Switching Station to Dayton Street Switching Station. These heavy tie feeders will provide two reliable sources to Athletic Operations Switching Station, improving the reliability, making the MG feed a backup and allowing additional planned building additions to be served from the facility.
- Construct a heavy tie feeder from LaBahn Switching Station to the Dayton Street Switching Station. This additional heavy tie feeder will provide ability to feed larger areas of campus from either of the two main MGE service points, which are located at Walnut Street Substation and LaBahn Switching Station as well as providing addition redundancy to feed the Charter Street Heating Plant.
- Install new ductbanks and cabling as required to service existing loads and planned building additions. Together with the other planned system additions in Phase 2, these required upgrades will allow the university

electric system to accommodate an additional 5,124 net GSF of building space, representing approximately 600 kVA of additional net electric load.

- Construct new circuits from the Dayton Street Switching Station, Walnut Street Substation, Bacteriology Substation and LaBahn Switching Station for increased feeder capacity and to provide redundant feeds to existing loads and planned building additions.
- Install an additional set of parallel conductors on the circuits supplying the hospital from Walnut Street Substation and the new Far West Substation. Increasing the capacity of these heavy feeders is required to keep pace with the load growth and planned additions occurring at the hospital and related medical buildings.
- Install new ductbanks and cabling as required to service existing loads and planned building additions. Together with the other planned system additions in Phase 3, these required upgrades will allow the university electric system to accommodate an additional 978,392 net GSF of building space, representing approximately 9.1 MVA of additional net electric load.
- Install new ductbanks and cabling as required to service existing loads and planned Phase 4 building additions. These required upgrades will allow the university electric system to accommodate an additional 2,781,578 net GSF of building space, representing approximately 15.3 MVA of additional net electric load.

Table 4-10 takes the deficiencies listed above and creates separate electrical system projects. The order in which projects within a particular Phase should be authorized and constructed will depend on the specific building addition projects, and will be affected by the growth of existing building loads and by the condition and operation of the existing electrical system as the new electric system additions are developed. Projects that are listed as regional campus issues (RCI) or building specific issues (BSI) are not priced and therefore, not reflected in construction estimates.

Table 4-10 Electrical Project Summary List

Project Number	Master Utility Project No.	Description
E-R-01-P1	1K	Extend existing 12-conduit underground electrical ductbank along W. Dayton Street from Dayton Street Switching Station to the southeast corner of N. Park Street. Install heavy tie feeder from LaBahn Switching Station to Dayton Street Switching Station. Refer to DFD Project 15K1F.
E-X-02-P1	1L	Install 12-conduit underground ductbank from Radio Hall Substation to Manhole 12P24. Replace existing ductbank and building loop feeders 5710/5720 along Lathrop Drive and Bascom Hill. Reroute feeder 5710 utilizing existing ductbank west along Observatory Drive to Charter Street and south on Charter Street to Lathrop Drive. Refer to DFD Project 13J2X.
E-X-06-P1	RCI	Extend existing 13.8 kV feeder from LaBahn Switching Station (1550/1580) to the Radio Hall Substation to feed Hamel Music Center P1&2, N-13B (Convert to 13.8kV) (Phase 1); Memorial Union, 8 (Phase 1); Academic – Humanities, N-11A (Phase 3); Academic (Mosse site south), N-12A (Phase 3); Music Phase 3, N-13C (Phase 3); Parking Structure Under N-11A and N-12A, N-11B (Phase 3); Chazen Museum Of Art, #0524 (Convert to 13.8kV) (Phase 3); Health and Safety Building, #0549 (Convert to 13.8kV) (Phase 3).
E-X-07-P1	1P	Install 16-conduit underground electrical ductbank from Walnut Street Substation to Observatory Drive. (UW Project 1895)
E-R-08-P1	RCI	Install 13.8 kV heavy tie feeder from Dayton Street Switching Station to the Athletic Operations Switching Station.

Project Number	Master Utility Project No.	Description
E-X-09-P1	1E, 1T, 1U	Install 16-conduit underground electrical ductbank along Linden Drive from Willow Creek to Bacteriology Substation. Requires project E-X-07-P1 to be completed to provide complete path between Walnut Street Substation and Bacteriology Substation to support new heavy tie feeders and building feeders.
E-X-10-P1	RCI	Install new 13.8 kV feeder from the Walnut Street Substation to the Bacteriology Substation to feed the Babcock Hall Center for Dairy Research Addition, W-25 (Refeed. Currently fed from 13.8 kV feeder 1420) (Phase 1); Gymnasium-Natatorium, W-16 (Phase 1); Meat Science and Muscle Biology Lab, W-18 (Phase 1); Parking Structure, W-27 (Phase 1); Poultry Research Building, W-20 (Phase 3); Animal Sciences (AHABS), W-24 (Phase 4); Biological Systems Engineering, W-19 (Phase 4); Plant Sciences, W-22 (Phase 4). Requires projects E-X-07-P1 and E-X-09-P1 to be completed.
E-X-12-P1	RCI	Extend existing 13.8 kV feeder from Rennebohm Pharmacy Switching Station (1270/1280) to feed Veterinary Medicine Building, W-17 (Phase 1); Walnut Greenhouse II, W-12 (Phase 1); Grounds Storage A – Controlled Temp, W-31 (Phase 4); Grounds Storage B – Covered, W-30 (Phase 4); Grounds Storage C – Salt, W-33 (Phase 4); Grounds Office / Administration, W-29 (Phase 4); Grounds Greenhouse, W-32 (Phase 4); Health Sciences Research, W-13 (Phase 4).
E-X-13-P1	RCI	Install new 13.8 kV feeder from the LaBahn Switching Station to Dayton Street Switching Station to feed new W. Johnson/N. Park Site, S-13A; Parking Structure, S-13. Requires project E-R-01-P1 to be completed.

Table 4-10 Electrical Project Summary List, continued

Project Number	Master Utility Project No.	Description
E-O-14-P1	1D	Install 4-conduit underground ductbank from Manhole 10P10 to Manhole 10P09. Replace existing ductbank and building loop feeders 4835/5320 serving Kronshage Residence Hall (East Houses).
E-X-15-P1	BSI	Install a new 13.8 kV loop switch for existing campus 13.8kV feeder currently tapped to WARF.
E-X-16-P1	1Q	Install additional (6) 15kV circuit breakers at Bacteriology Substation.
E-R-17-P1	1R	Install additional (3) 15kV circuit breakers at Radio Hall Substation.
E-R-18-P1	RCI	Install 3rd 13.8 kV heavy tie feeder from Walnut Street Substation to Bacteriology Substation. Requires projects E-X-07-P1, E-X-09-P1 and E-X-16-P1 to be completed.
E-R-19-P1	RCI	Install (2) 13.8 kV heavy tie feeders from Bacteriology Substation to Rennebohm Pharmacy Switching Station (UW Project 1558). Reconfigure existing feeder circuits at Rennebohm Switching Station to provide available breakers. Requires project E-X-16-P1 to be completed.
E-R-20-P1	RCI	Install 13.8 kV heavy tie feeder from Bacteriology Substation to Radio Hall Substation (UW Project 1897). Requires projects E-X-02-P1 and E-X-16-P1 to be completed.
E-R-21-P1	RCI	Install 13.8 kV heavy tie feeder from Bacteriology Substation to Dayton Street Switching Station (UW Project 1557). Requires project E-X-16-P1 to be completed.
E-X-23-P1	BSI	Connect Chemistry Bldg Expansion, S-29 to feeder 1613 off existing chemistry switch. Reconnect existing feeder from Grainger Hall switch and rename feeder.
E-X-24-P1	BSI	Connect Ingraham Hall Additions, N-14 to the existing building service.

Project Number	Master Utility Project No.	Description
E-X-25-P1	BSI	Connect Parking Structure, W-02 to the existing building service.
E-X-26-P1	BSI	Connect Southeast Recreational Facility, S-31 to the current Southeast Recreational Facility feeder from LaBahn Switching Station (1530/1540).
E-X-27-P1	BSI	Connect College of Engineering Research Building, S-21 to the existing building service.
E-X-28-P1	BSI	Electrical Service from MGE to feed new Officer Education, S-30; Police Addition, S-18.
E-X-01-P2	2C	Extend existing 12-conduit underground electrical ductbank along Engineering Drive from Engineering Mall to Manhole 6P33.
E-R-02-P2	RCI	Install 13.8 kV heavy tie feeder from Walnut Street Substation to the Athletic Operations Switching Station. Requires projects E-X-07-P1, E-X-09-P1 and E-X-01-P2 to be completed.
E-X-03-P2	RCI	Utilize existing 13.8 kV engineering vault feeder from Bacteriology Substation (1720) to the Athletic Operations Switching Station (1830) to feed new Engineering Dr 1410 – Replacement, S-02 (Phase 2); Engineering Research Building Replacement, S-01 (Phase 3); New Engineering, S-23 (Phase 4); New Engineering, S-24 (Phase 4); New Engineering, S-25 (Phase 4). Requires project E-X-01-P2 to be completed.
E-X-04-P2	BSI	Connect Nielsen Tennis Stadium Expansion, W-28 to the existing building service. Expand existing electrical room to add additional loop switch for feeder 1240.

Table 4-10 Electrical Project Summary List, continued

Project Number	Master Utility Project No.	Description
E-X-02-P3	RCI	Install new 13.8 kV feeder from Bacteriology Substation to Dayton Street Switching Station to feed new Academic/Research, N-05A (Phase 3); Academic/Research, N-05B; Academic/Research (Stovall site), N-04 (Phase 3); Academic/Research (SMI Bardeen Med Sciences), N-06A (Phase 3); Parking Structure, N-05C (Phase 3); Parking Structure Under N-06A, N-06B (Phase 3); Academic (Van Hise), N-03A (Phase 4); Academic (Van Hise), N-03B (Phase 4); Academic/Research, N-07 (Phase 4). Requires project E-X-16-P1 to be completed.
E-X-03-P3	RCI	Extend existing 13.8 kV feeder from LaBahn Switching Station (1560) to Charter Street Substation (1610) to feed Meiklejohn Site, S-28 (Phase 3); Zoology Research And Noland Hall, S-07 (Phase 4).
E-X-04-P3	BSI	Connect WID, Phase 2, S-03B to the current WID feeder from Athletic Operations Switching Station (1840) and Charter Street Substation (1620).
E-X-05-P3	BSI	Connect Wisconsin Institutes for Medical Research Ph3, W-01 to the current WIMR feeder from Rennebohm Pharmacy Switching Station (1200/1290).
E-R-06-P3	BSI	Install new (3) parallel sets of 500 kcmil conductors to CSC #1400 from Walnut Street Substation along alternate path (Feeder 1330). Repurpose (1) parallel set of existing feeder 1330 for 3rd parallel set of conductors for feeder 1310 to CSC #1400 from Walnut Street Substation. Requires project E-X-07-P1 to be completed.
E-X-01-P4	4H	Install 12-conduit underground electrical ductbank from an existing manhole at the intersection of East Campus Mall and W. Dayton Street to the Art Building/Southeaster Chiller Plant, S-16A.
E-X-02-P4	RCI	Install new feeder from LaBahn Switching Station to feed new Art Building, S-16A; Parking Structure, S-16C (Includes new East Chiller Plant). Requires project E-X-01-P4 to be completed.
E-X-03-P4	4A	Install 6-conduit underground electrical ductbank along Charter Street south from Dayton Street Switching Station. Extend east and west along Spring Street.
E-X-04-P4	RCI	Install a new 13.8 kV circuit from the Dayton Street Switching Station to feed new Academic / Research, S-08A; Academic Research (Spring St), S-08C (Phase 4); Academic (Lot 45 Site), S-11A; New Engineering, S-26 (Phase 4); Parking Structure, S-10A; Parking Structure, S-27 (Phase 4); Primate Center & Harlow Expansion, S-09A (Phase 4); Primate Center & Harlow Expansion, S-09C (Phase 4); Primate Center & Harlow Expansion, S-09D, (Phase 4); 30 North Mills , #0124, (Convert to 13.8kV) (Phase 4); Capitol Court 1220, #0782, (Convert to 13.8kV) (Phase 4); Fleet And Service Garage, #1077, (Convert to 13.8kV) (Phase 4). Requires project E-X-03-P4 to be completed.
E-X-05-P4	4C	Install 12-conduit underground electrical ductbank from the Rennebohm Pharmacy Switching Station along Walnut Street to Observatory Drive.
E-X-06-P4	RCI	Extend existing 13.8 kV circuit from Rennebohm Pharmacy Switching Station (1210/1220) to feed Academic/Union West/Child Care, W-06 (Phase 4); Health Sciences Research, W-09B (Phase 4); Health Sciences Research, W-09C (Phase 4); Parking Structure, W-09A (Phase 4). Requires project E-X-05-P4 to be completed.
E-X-07-P4	BSI	Extend existing 13.8 kV circuit from Rennebohm Pharmacy Switching Station (1250/1260) to feed Health Sciences Research, W-07.

Table 4-10 Electrical Project Summary List, continued

Project Number	Master Utility Project No.	Description
E-X-08-P4	BSI	Extend existing 13.8 kV circuit from Rennebohm Pharmacy Switching Station (1230/1240) to feed McClimon Track / Soccer Grandstand, W-5.
E-X-09-P4	BSI	Connect Cooper Hall Addition, W-08 to the existing building service.
E-X-10-P4	BSI	Connect Hospital Expansion, W-04A to the existing building service.
E-X-11-P4	BSI	Connect King Hall Greenhouse, N-15 to the existing building service.
E-X-12-P4	BSI	Connect WARF Addition, W-11 to the existing building service.
E-X-13-P4	BSI	Connect Weeks Hall Addition, S-08B to the existing building service.
E-X-14-P4	BSI	Electrical Service from MGE to feed new Fluno Addition, S-20.
E-R-15-P4	RCI	Install 3rd parallel conductor for two heavy tie feeders from Walnut Street Substation to Rennebohm Pharmacy Switching Station. (UW Project 1896). Requires projects E-X-07-P1 and E-X-05-P4 to be completed.
E-R-16-P4	4G & 4I	Commission the application process for the new Far West and Far East 69 kV substations.
E-R-17-P4	4G	Install new Far West 69/13.8 kV, 30-56 MVA substation and 13.8 kV switchgear with approximately (6) feeders. Extend the existing 12-conduit underground electrical duct bank along Highland Avenue from American Family Children's Hospital to the new Far West Substation (UW Project 1898). Install new 15 kV cabling from the Far West substation to CSC, #1400; WIMR; Waisman Center, #459 and the Rennebohm Pharmacy Switching Station. Requires project E-R-16-P4 to be completed.
E-R-18-P4	4I	Install new Far East 69/13.8 kV, 30-56 MVA substation and 13.8 kV switchgear with approximately (6) feeders. Install 15kV cabling from the Far East Substation to the new East Chiller Plant. Requires project E-R-16-P4 to be completed.

Opportunities to Enhance Energy Efficiency/ Operational Flexibility

Distribution Energy Storage

The application of "Smart Grid" energy technologies with combination of advanced battery technology plus building energy management system interface should be investigated. The university should evaluate economics of energy storage and controls for demand response with building automation systems that reduce costs and make building operations more reliable. Analysis should be performed to determine if the inclusion of modular energy storage systems, associated with the electrical power generation capability of the Charter Street Plant, would reduce costs and provide uninterrupted power supply or electrical backup for critical campus buildings.

5. RENEWABLE ENERGY

Solar Hot Water System, Moses H. Cone Memorial Hospital, Greensboro, NC

Introduction

This section examines renewable energy systems as a method to reduce campus energy use and cost. Opportunities for existing building retrofits as well as for new construction are considered along with multiple technologies for generating renewable energy. Multiple drivers, both internal and external, are driving interest and need for renewable energy systems. These include the university's own sustainable goals as stated in the 2010 Sustainability Initiative Task Force which identified the following:

- Reduce existing building energy use
- Maximize purchase and generation of sustainable alternative power
- Tracking consumption and emissions

In addition to the internal goals, external drivers include national and state level sustainability requirements. The State of Wisconsin's Sustainable Facilities Standards include minimum building energy performance compliance with ASHRAE/IESNA 90.1-2007 and recommends improved energy performance as well as generation of on-site renewable energy to reduce environmental impacts and fossil fuel use. The Governor's Executive Order #63 requires building energy performance 10% better than IECC 2009. In addition, the energy codes and standards used by the state are developed with support of the US Department of Energy and are continuously advancing building performance requirements. The ASHRAE 90.1 standard is developing toward a goal of achieving net zero building energy use by approximately 2030 for new construction and major renovations; and renewable energy strategies will become more important as building systems' energy efficiency reach physical limitations of existing technology.

The university has implemented multiple building energy conservation retrofits as well as completed new construction projects with improved energy performance consistent with the State's Sustainable Facilities Standards and the Governor's Executive Order #63. This section includes a survey of existing renewable energy systems, renewable energy system technology review, and estimates of potential renewable energy generation from each proposed strategy. The amount of energy input from existing renewable energy systems is estimated and the potential impact from a variety renewable energy systems is considered based on the opportunities identified by the 2015 Campus Master Plan Update.

Benchmarks

To consider the impact of renewable energy systems on campus energy use, current energy use data was collected and summarized as a method for benchmarking current performance and estimating the impact of potential strategies. The 2010 Big Ten Sustainability Report provides one benchmark comparison for campus energy use, with the university's building Energy Use Intensity (EUI) being reported as 222 kBtu/SF/yr. This EUI is very similar for UW–Madison's peer institutions as summarized in Table 5-1 with data from the Big Ten report.

Using 2014 campus utility meter data, the most recent annual building EUI is estimated at 220 kBtu/SF/yr and is summarized in Table 5-2 by primary utility and building area. The EUI has dropped slightly from that reported in 2010. Electricity use includes electricity necessary to generate chilled water used to cool most buildings on campus.

Building EUI is a good benchmark for providing estimates of how much impact building integrated renewable energy systems can have on reducing or offsetting energy use. For instance, 25 kBtu/SF/yr is often used as a metric for estimated maximum building integrated renewable energy generation potential. As an example, estimating the potential EUI generation capacity of photovoltaic (PV) panels for Madison, WI in relation to building area and levels, indicates a 2-level building with 60% roof utilization for fixed axis solar panels will offset the equivalent of 25 kBtu/SF/yr building energy which would be approximately 11% of the average UW–Madison building EUI. With taller buildings, this potential reduces as the roof area to total building area ratio decreases.

Table 5-3 illustrates the potential photovoltaic generation for different tracking technologies and varying building heights. This demonstrates the need to further reduce building EUI in order to increase the offset potential for renewables. Furthermore it points to the need for additional renewable energy strategies beyond roof mounted equipment, technology advancements, as well as potentially offsite generation.

Table 5-1 Big Ten Energy Consumption Comparison

University	Total Energy Use (MMBTU)	EUI (kBtu/SF/yr)
Illinois	5,730,016	285
Indiana	4,511,319	289
Iowa	3,516,320	214
Michigan	6,400,287	205
Michigan State	6,813,950	298
Ohio State	4,965,355	226
Pennsylvania State	3,233,368	168
Purdue	2,710,161	234
Wisconsin	4,440,000	222

Table 5-2 Current Campus Energy Consumption

Utility 2014)	Energy	Units
Steam	3,601,440	MMBtu
Electricity	376,293,602	kWh
Building Area	22,256,015	GSF
	220	kBtu/SF/yr

Table 5-3 Photovoltaic Generation Potential as a Function of Building Levels and Tracking Method

		Fixed		Single Axis		Two Axis	
		%	EUI	%	EUI	%	EUI
Number of Levels	10	2%	5	3%	6	3%	6
	9	3%	6	3%	7	3%	7
	8	3%	6	3%	8	4%	8
	7	3%	7	4%	9	4%	9
	6	4%	8	5%	10	5%	11
	5	5%	10	6%	12	6%	13
	4	6%	12	7%	15	7%	16
	3	8%	17	9%	21	10%	21
	2	11%	25	14%	31	15%	32
	1	23%	50	28%	62	29%	64

Existing Renewable Energy Systems

A survey of existing renewable energy systems on campus was completed to determine what types of systems are being used and what the impact is on current campus energy use. Multiple systems and system types are in place, some of which are off campus and some of which are no longer operational.

The existing photovoltaic and solar hot water installations are not currently metered, so data is not available on how much energy is being generated. In lieu of measured data, energy generation calculations were used to estimate the generated energy from these systems. System Advisor Model software along with TMY3 weather data for Madison, WI was used to estimate the renewable system generation. This was compared with campus total metered electricity and steam use. The off campus systems as well as those no longer operational are not included in the analysis of energy generation. In addition, the university purchases wind generated power through a contract with electrical utility. The systems, their operational status, and energy generation are summarized in Table 5-4 and locations are shown on Figure 5-1 Existing Renewable Energy Systems.

Table 5-4 Existing Renewable Energy Systems

	System		Energy	
Building Name	**Type**	**Status**	**Generated**	**Units**
Veterinary Medicine	Solar Hot Water	Removed 2016	N/A	
Leopold Residence	Solar Hot Water	Operating	23	MMBtu/yr
Dejope Residence	Solar Hot Water	Operating	41	MMBtu/yr
Wisconsin Energy Institute	Photovoltaic	Operating	27	MWh/yr
Wisconsin Institute for Discovery	Solar Hot Water Geoexchange	Operating Not Operational	12	MMBtu/yr
Arboretum McKay (off campus)	Solar Hot Water Photovoltaic	Operating Operating	N/A N/A	
Purchased Wind Contract	Wind	N/A	54,653	MWh/yr

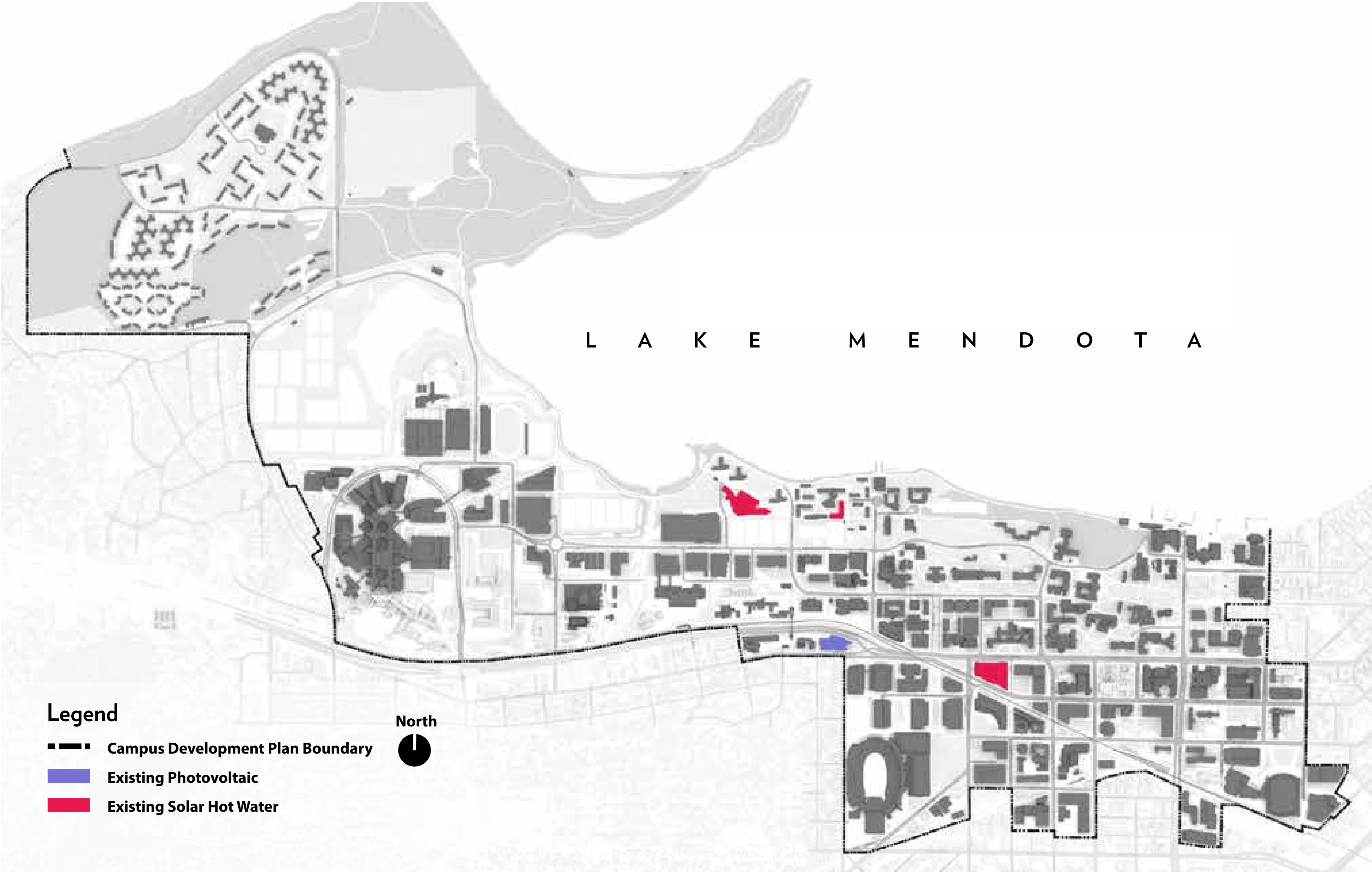


Figure 5-1 Existing Renewable Energy Systems

Renewable Energy Technologies

Renewable energy systems include technology capable of harvesting naturally replenishing sources of energy including solar, wind, moving water, organic plant and waste products, and geothermal. Some of these technologies are more appropriate for buildings and an urban campus than others, and some technologies are not suitable for this location due to lack of availability. Following is a summary of technologies and their potential application for the 2015 Campus Master Plan Update.

Figure 5-2 Transpired Solar Collector Installation, Montana State University Jake Jabs College of Business & Entrepreneurship

Photovoltaics

Photovoltaic cells generate electrical energy from solar energy. This energy can be supplied to the electrical distribution system and/or stored in a battery. Storage systems for large scale commercial applications are very expensive and cost prohibitive. The cost effectiveness of photovoltaic is improving due to panel costs dropping as well as familiarity and improved efficiency in the labor market resulting in reduced installation costs. Power purchase agreements, tax deductions and credits, and alternative financing arrangements also have a big effect on the cost effectiveness. Panel efficiency has improved from the 2005 plan time period with relatively standard panels achieving 19% efficiency. For these reasons photovoltaic is being investigated further.

Transpired Solar Collectors

A transpired solar collector is an unglazed, dark colored perforated collector that uses solar energy to preheat ventilation air. Outside air is drawn through the collector with a ventilation fan and is heated by the warm surface of the perforated metal panel. The collector can be bypassed during the cooling season. SOLARWALL® is one manufacturer of the system, and collection efficiency can exceed 70% at high air flow rates.

The transpired solar collector is relatively low cost as the construction is a metal panel and higher cost building skin materials may be eliminated where the collector is installed. There are costs associated with the bypass and controls. Limitations include the amount of surface area needed for the collector. Buildings with a high percentage of outdoor air flow may require more south facing exterior wall area than is available. This technology is recommended for consideration in the 2015 Campus Master Plan Update and is investigated further. Figure 5-2 shows an example transpired solar wall.

Solar Thermal

Another solar energy related technology is a solar thermal collector which is used to generate hot water for domestic or building space water heating. These collectors can either be a flat plate collector or an evacuated tube technology. The higher the hot water temperature required, the less effective these systems are, so retrofit applications where high temperature hot water is being used for building heat are not cost effective. For new or replacement systems where heating water temperature can be kept lower or for applications where lower temperature water can be used, these systems can be cost effective. This technology is investigated further for applications such as dining facilities and pools.

Wind

Wind turbines use wind to spin the turbine and generate electrical power. Based on the U.S. Department of Energy's National Renewable Energy Laboratory wind resource data, Madison, WI is not in a good zone for generating wind power. Figure 5-3, on the next page, depicts average wind speeds for the State of Wisconsin with Madison in the 5 to 5.5 meter per second (11 to 12 miles per hour) range. A minimum average wind speed of 6.5 meters per second (14.5 miles per hour) is recommended before considering a wind turbine system.

There may be very localized areas with better wind resource potential, but utility scale wind generation has limited opportunity as it also requires significant amounts of open land. Madison's urban environment is not conducive to this technology. In addition, building integrated wind technology has not proven yo be cost effective. For these reasons, it is not recommended to be considered within the 2015 Campus Master Plan Update. However, it should be noted that the cost of purchasing wind energy on the open market generated in areas has become very competitive as compared to self-generating with marginal wind resources.

Biomass

Biomass uses naturally replenishing organic material and waste products to fuel heating and power equipment. The university previously conducted an extensive study and proposal to convert the Charter Street Heating Plant to burn biomass products. This proposal was not funded and this renewable energy strategy is not recommended within the 2015 Campus Master Plan Update.

Geothermal

Geothermal energy can be considered in two ways. One being the use of high temperature thermal energy from underground heat sources to use for building heat and/or to generate power. This requires relatively close to the surface sources, otherwise extremely deep and cost prohibitive wells are required. No geothermal sources are known as a practical resource for Madison.

The second method is to use the massive source of heat stored relatively near to the ground surface (<500 feet) as a heat sink or source for heat pump conditioning units. This approach uses wells through which fluid is circulated to either pull heat out during winter or reject heat to during summer cooling. The campus currently has one small geothermal well installation at the Wisconsin Institute of Discovery, but this system has not been operating. A research project is currently in progress investigating why this system has not been operating properly. At this time no additional exploration of this technology is recommended until the research project has reached its conclusion.

Nuclear

Nuclear power has been cited as a potential renewable energy source due to the known relatively large quantities of potential nuclear fuel versus the amount of energy that humans will potentially be able to use. This argument is not widely accepted as a sustainable and renewable source of energy and current technology is not viable for a campus scale urban environment. This strategy is not recommended within the 2015 Campus Master Plan Update.

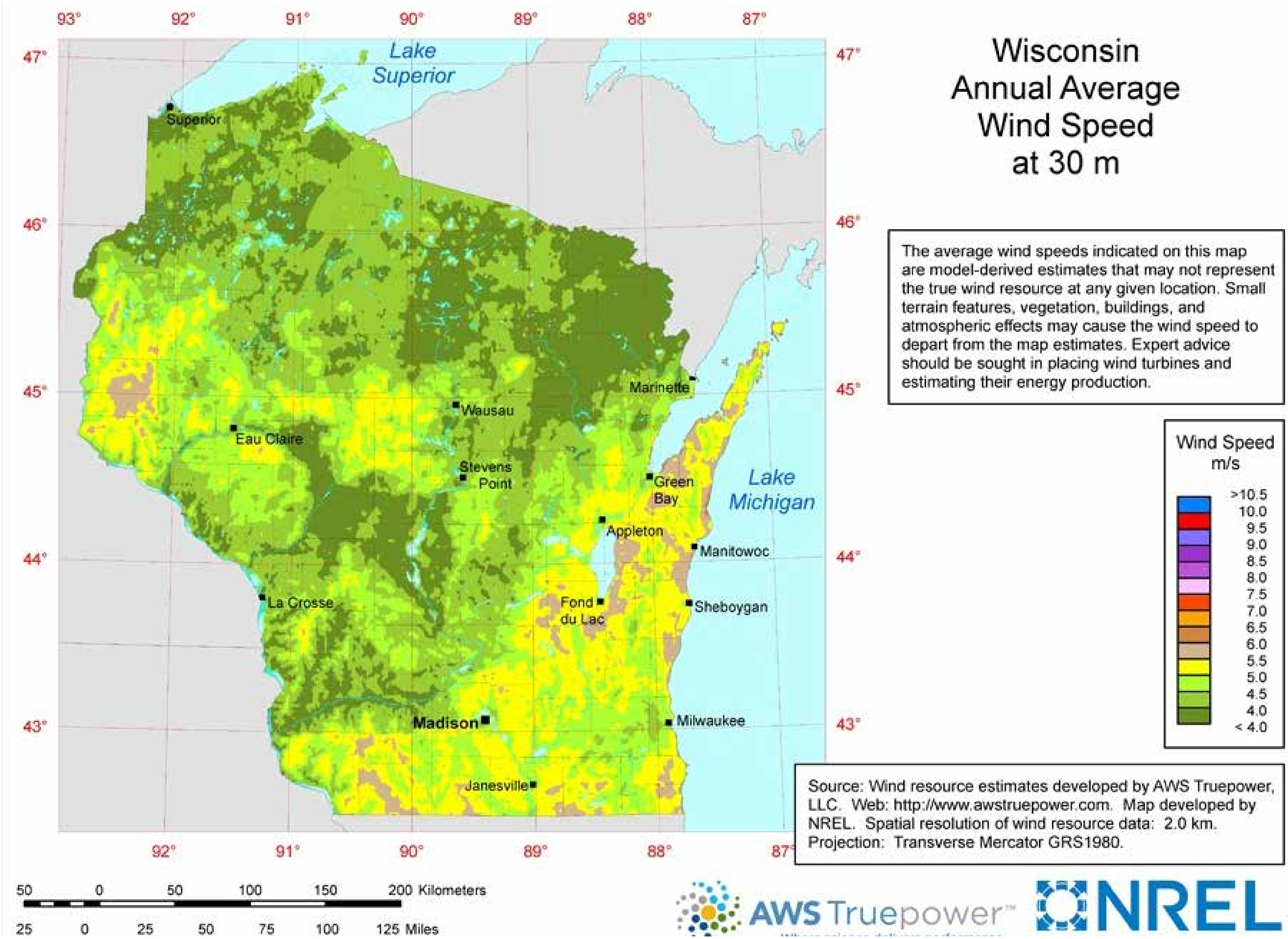


Figure 5-3 Wisconsin Wind Resource Map

Photovoltaics

Photovoltaic energy was investigated for parking structures and for the future building projects identified in the 2015 Campus Master Plan Update. An estimate of photovoltaic generation potential in kWh/kW installed capacity was calculated using System Advisor Model software. For parking structures, the upper level area is used to determine the installed photovoltaic capacity based on a 50% usable area factor. Figure 5-4 shows an example photovoltaic installation for a parking garage (not affiliated with UW–Madison).

Based on the estimated generation capacity and the available roof area, the total generation potential for new parking ramps is calculated. Table 5-5 summarizes the photovoltaic area, installed kW, and generated kWh/yr for the proposed parking structures. Figure 5-5 shows proposed photovoltaic installation locations.

Table 5-5 Photovoltaic New Parking Ramp Summary

Building Id		Type	Floor Area (SF)	Photovoltaic Area (SF)
W-09A	Parking Structure	Above	84,000	42,000
W-27	Parking Structure	Above	39,600	19,800
N-05C	Parking Structure	Above	28,800	14,400
S-10A	Parking Structure	Above	37,200	18,600
S-16C	Parking Structure	Above	54,000	27,000
A-27	Parking Structure	Above	57,600	28,800
		Total:	301,200	150,600
Installed PV (kW):				2,746
Energy Generated (kWh/yr):				3,654,995

Figure 5-4 Photovoltaic Installation on Parking Garage, St. Elizabeth Hospital, Affinity Health, Appleton, WI

Similarly for new buildings, the available roof area is used along with a usable area factor of 60% is used to calculate the generation potential. Table 5-6 summarizes the photovoltaic area, installed kW, and generated kWh/yr for the proposed new buildings.

Photovoltaic Sizing Method

Based on past project experience the minimum photovoltaic array size to be considered economic is 10 kW. This array size makes effective use of installer's time and provides sufficient electrical production to offset the first cost. Going forward cost effective array sizes will continue to shrink in size as economies of scale on the production side as well as ease of installation improve. This has been the trend for the last seven years as the installed price of photovoltaic has dropped from $9-10/Watt to $2-4/Watt.

A typical photovoltaic panel today (Kyocera 250 Watt panel, 15% efficient) has an area of 17.9 square feet. To generate 10 kW of electrical power, 40 panels are required for a panel area of 715 square feet. Using a conservative sizing approach with panels tilted at latitude of 45 degrees, or a packing factor of 2.4, a total array footprint of 1,716 square feet of roof area is required to fit the 10 kW array. Packing factor is defined as the ratio of the array footprint to the array panel area. Arrays larger than 20-40kW would likely reduce their angle in order to reduce wind loading and structural impacts on the building. Therefore the sizing method shown above is very conservative as larger arrays approach a packing factor of 1.4.

All of the buildings in Tables 5-5 and 5-6 meet this space threshold after the rooftop area reductions to account for roof top equipment with a conservative margin of error.

Table 5-6 Photovoltaic New Building Summary

Building ID	Building Name	Available Roof Area (SF)	Photovoltaic Footprint (SF)
W-29	Preserve Outreach Center	8,700	5,220
W-18	Meat Science and Muscle Biology Lab	114,000	68,400
W-19	Biological Systems Engineering	41,000	24,600
W-20	Poultry Research Building	35,310	21,186
W-22	Animal Sciences (AHABS)	17,000	10,200
W-24	Plant Sciences	20,000	12,000
W-16	Gymnasium-Natatorium Replacement	94,180	28,254
W-17	Veterinary Medicine Building	57,880	34,728
S-21	College of Engineering Research Building	22,338	13,403
N-03A	Academic/Research (Van Hise Site)	19,000	11,400
N-03B	Academic/Research (Van Hise Site)	6,000	3,600
N-04	Academic/Research (Stovall Site)	13,700	8,220
N-05A	Academic/Research (Nutritional Sciences site)	30,000	18,000
N-05B	Academic/Research (Middleton site)	27,500	16,500
N-06A	Academic/Research (SMI Bardeen Med Sciences site)	24,000	14,400
N-07	Academic/Research (445 Henry site)	10,000	6,000
N-11A	Academic/Research (Mosse site north)	21,000	12,600
N-12A	Academic/Research (Mosse site south)	27,000	16,200
N-13B	Hamel Music Center P1&2	45,000	27,000
N-13C	Music Phase 3	15,000	9,000
N-14	Ingraham Hall Additions	8,125	4,875
N-15	King Hall Greenhouse	7,500	4,500
S-01	Engineering Research Building Replacement	45,278	27,167

Table 5-6 Photovoltaic New Building Summary, continued

Building ID	Building Name	Available Roof Area (SF)	Photovoltaic Footprint (SF)
S-02	Engineering Dr 1410 – Replacement	28,182	16,909
S-03B	Wisconsin Institute of Discovery, Phase 2	65,333	39,200
S-07	Zoology Research and Noland Hall	52,486	31,492
S-08A	Academic/Research	11,000	6,600
S-08B	Weeks Hall Addition	5,000	3,000
S-08C	Academic/Research (Spring St)	25,000	15,000
S-09A	Primate Center & Harlow Expansion	8,137	4,882
S-09C	Primate Center & Harlow Expansion	10,000	6,000
S-09D	Primate Center & Harlow Expansion	16,000	9,600
S-11A	Academic/Research (Lot 45 Site)	15,000	9,000
S-13A	Academic/Research (W. Johnson/N. Park Site)	58,000	34,800
S-18	Police Addition	12,420	7,452
S-20	Fluno Addition	7,200	4,320
S-31	Southeast Recreational Facility	63,250	18,975
S-29	Chemistry Bldg Expansion	19,241	11,545
S-28	Academic/Research (Meiklejohn Site)	16,894	10,136
S-30	Officer Education Facility	16,250	9,750
S-23	New Engineering	45,333	27,200
S-24	New Engineering	52,574	31,544
S-25	New Engineering	61,108	36,665
S-26	New Engineering	37,668	22,601
W-01	Wisconsin Institutes for Medical Research Ph3	44,000	26,400
W-04A	Health Sciences Expansion	8,743	5,246
W-06	Social/Dining/Meeting Rooms/ Health Sciences	23,055	6,916
W-07	Nursing Building/Health Sciences Research	20,323	12,194
W-08	Cooper Hall Addition	10,000	6,000
W-09B	Health Sciences Research	46,650	27,990
W-09C	Health Sciences Research	38,500	23,100
W-11	WARF Addition	32,000	19,200
W-13	Health Sciences Research	82,093	49,256
W-28	Nielsen Tennis Stadium Expansion	23,538	14,123
W-05	McClimon Track Shelter-South	26,000	15,600
S-16A	Art Building	54,000	32,400
W-12	Walnut Greenhouse II	24,000	14,400
S-22	University Research Park (Lorch St)	8,500	5,100
	Total :	1,776,987	1,12,47
	Installed Photovoltaic (kW):		18,454
	Energy Generated (kWh/yr):		24,561,926

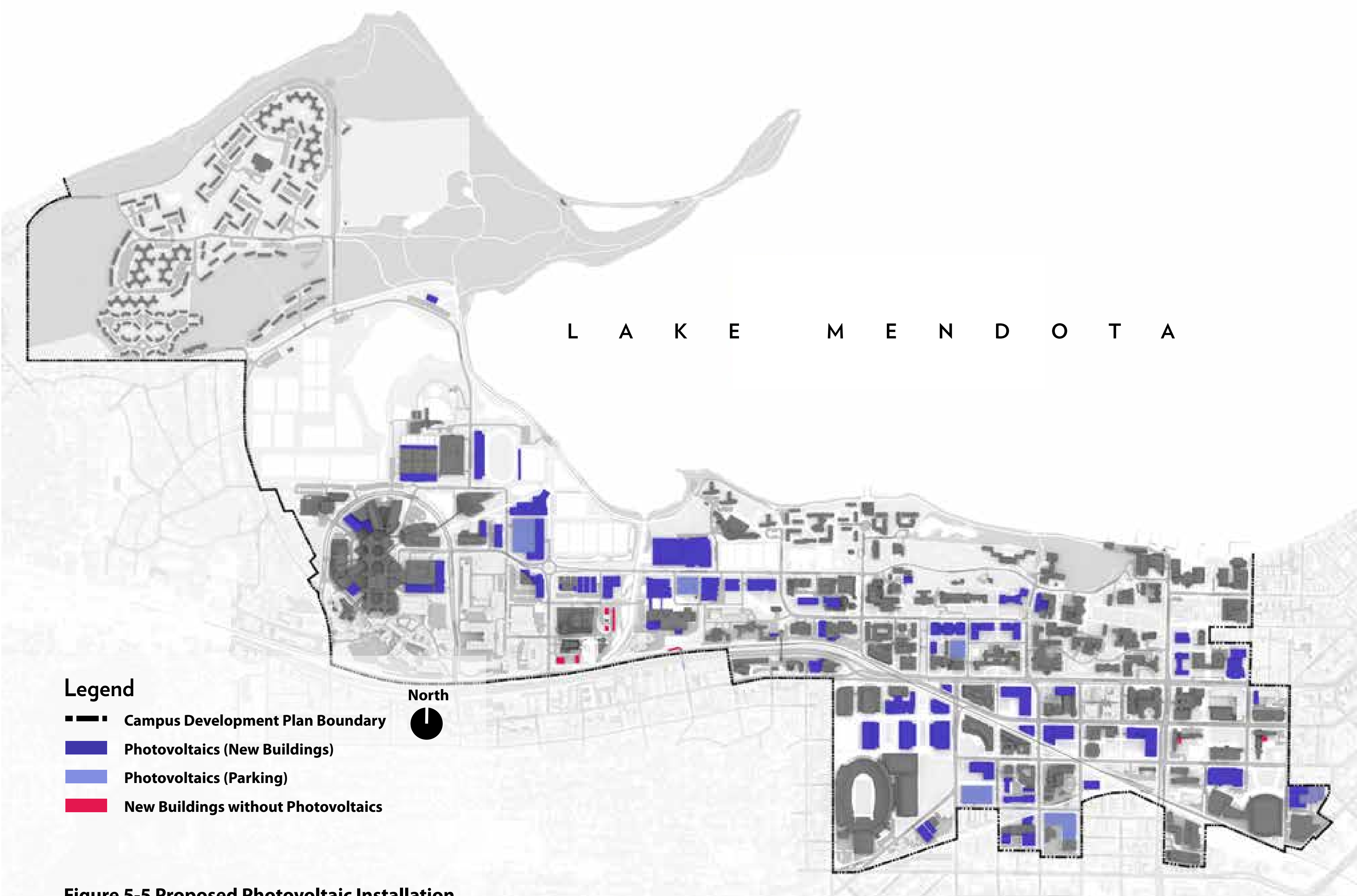


Figure 5-5 Proposed Photovoltaic Installation

Solar Thermal Hot Water

Solar thermal systems are recommended for new buildings identified in Table 5-7 that have large domestic hot water loads or low temperature process heating loads such as dining facilities or natatoriums. The buildings are located across campus as shown in Figure 5-6.

Solar Thermal Sizing

Based on typical TRNSYS solar thermal models a unit capacity of 5.28 SF/kWt, and a production of 1.37 MMBtu/yr/kWt is estimated.

Transpired Solar Collectors

Transpired solar collectors are recommended to preheat outside air for new buildings identified in Table 5-8. The buildings are located throughout campus as shown in Figure 5-7.

Transpired Solar Collector Sizing

The identified buildings were selected based on program areas that likely required fractions of outside air greater than 30 percent. The collector area was then sized based on the a typical cfm per square foot value multiplied by the total outside air. Next an EnergyPlus model was used to estimate average preheat energy savings based on a design air flow rate through the collector.

Table 5-7 Solar Thermal Summary

Building ID	Building Name	Available Roof Area (SF)	Solar Thermal Footprint (SF)
W-16	Gymnasium-Natatorium Replacement	95,800	9,580
S-31	Southeast Recreational Facility	63,250	6,325
W-06	Social/Dining/Meeting Rooms/ Health Sciences	23,055	2,305
	Total:	182,105	18,210
	Installed Photovoltaic (kW):		3,131
	Energy Generated (kWh/yr):		4,293

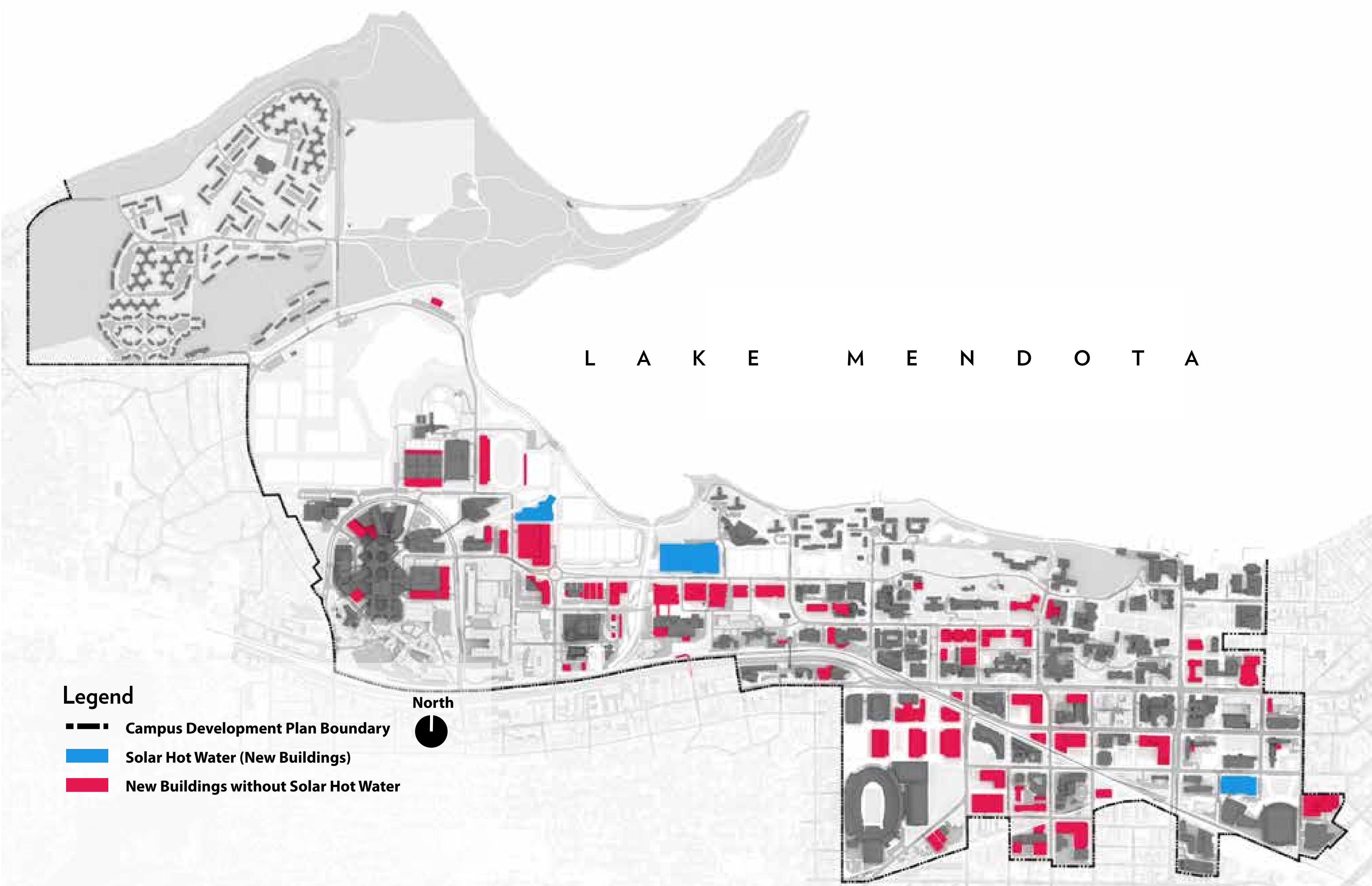


Figure 5-6 Proposed Solar Thermal Installation

Table 5-8 Transpired Solar Collector Summary

Building ID	Floor Area (SF)	% OA	Outside Airflow		TSC Area (SF)	Annual energy (MMBtu)
			(CFM/SF)	(CFM)		
W-29	8,700	0.3	0.9	2,349	810	41
W-18	114,000	1.0	1.2	136,800	47,172	2,387
W-19	40,830	0.7	1.0	28,581	9,856	499
W-20	35,310	1.0	1.2	42,372	14,611	739
W-22	16,977	1.0	1.2	20,372	7,025	355
W-24	17,671	1.0	1.2	21,205	7,312	370
W-16	179,867	0.6	1.0	107,920	37,214	1,883
W-17	27,782	1.0	1.2	33,339	11,496	582
S-21	23,355	1.0	1.2	28,026	9,664	489
N-03A	18,521	0.3	0.9	5,001	1,724	87
N-03B	6,427	0.3	0.9	1,735	598	30
N-04	12,000	0.5	1.0	6,000	2,069	105
N-05A	13,600	0.7	1.0	9,520	3,283	166
N-05B	13,600	0.7	1.0	9,520	3,283	166
N-06A	49,310	0.7	1.0	34,517	11,902	602
N-07	10,000	0.7	1.0	7,000	2,414	122
N-11A	21,000	0.3	0.9	5,670	1,955	99
N-12A	28,507	0.3	0.9	7,697	2,654	134
N-13B	37,793	0.3	0.9	10,204	3,519	178
N-13C	15,163	0.3	0.9	4,094	1,412	71
N-14	14,000	0.3	0.9	3,780	1,303	66
N-15	7,469	1.0	1.0	7,469	2,576	130
S-01	45,278	0.6	0.9	24,450	8,431	427
S-02	28,182	0.6	1.0	16,909	5,831	295
S-03B	227,647	0.7	1.2	191,223	65,939	3,337
S-07	52,486	1.0	1.2	62,983	21,718	1,099
S-08A	10,394	0.3	0.9	2,806	968	49
S-08B	5,221	0.3	0.9	1,410	486	25
S-08C	22,252	0.3	0.9	6,008	2,072	105

Building ID	Floor Area (SF)	% OA	Outside Airflow		TSC Area (SF)	Annual energy (MMBtu)
			(CFM/SF)	(CFM)		
S-09A	8,137	1.0	1.2	9,764	3,367	170
S-09C	10,600	1.0	1.2	12,720	4,386	222
S-09D	18,859	1.0	1.2	22,631	7,804	395
S-11A	15,671	0.3	0.9	4,231	1,459	74
S-13A	67,261	0.3	0.9	18,160	6,262	317
S-18	8,000	0.3	0.9	2,160	745	38
S-20	7,238	0.3	0.9	1,954	674	34
S-31	51,840	0.5	0.9	23,328	8,044	407
S-29	19,241	1.0	1.2	23,089	7,962	403
S-28	16,894	0.3	0.9	4,561	1,573	80
S-30	12,000	0.6	1.0	7,200	2,483	126
S-23	5,102	0.6	1.2	3,673	1,267	64
S-24	52,574	0.6	1.2	37,853	13,053	661
S-25	61,108	0.6	1.2	43,998	15,172	768
S-26	37,668	0.6	1.2	27,121	9,352	473
W-01	44,000	1.0	1.2	52,800	18,207	921
W-04A	8,743	0.3	0.9	2,361	814	41
W-06	23,069	0.3	1.2	8,305	2,864	145
W-07	20,323	0.7	1.2	17,071	5,887	298
W-08	10,000	0.7	1.2	8,400	2,897	147
W-09B	42,192	0.7	1.2	35,441	12,221	618
W-09C	42,000	0.7	1.2	35,280	12,166	616
W-11	32,000	0.7	1.2	26,880	9,269	469
W-13	32,837	0.7	1.2	27,583	9,511	481
W-28	23,538	0.3	1.2	8,474	2,922	148
W-05	26,000	0.3	0.9	7,020	2,421	122
S-16A	54,000	0.3	0.9	14,580	5,028	254
W-12	24,000	1.0	1.0	24,000	8,276	419
S-22	8,500	0.6	1.2	6,120	2,110	107
	1,886,736	Energy Generated (MMBtu/yr):				23,657

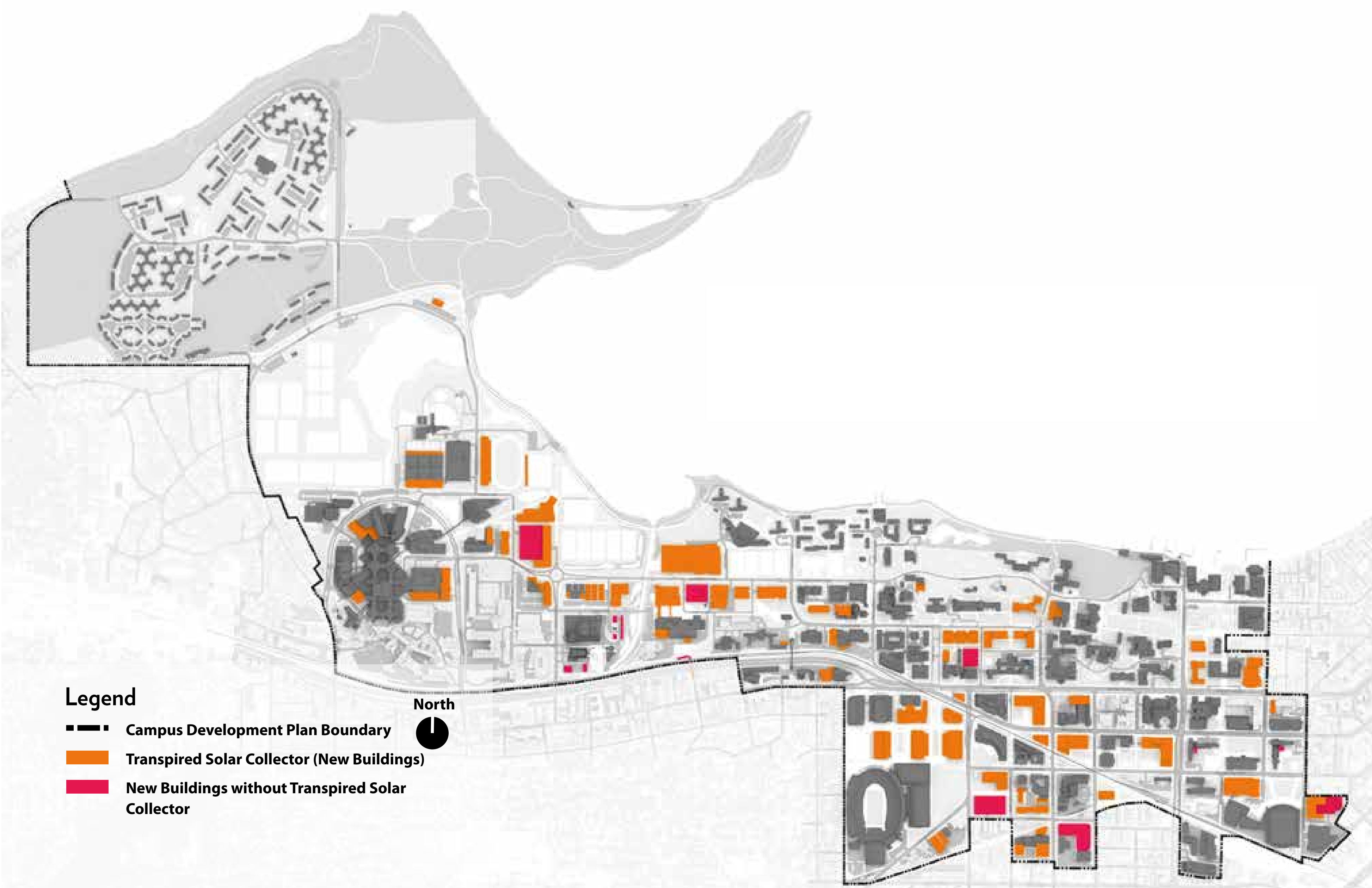


Figure 5-7 Proposed Transpired Solar Collector Installation

Renewable Energy Generation Potential

The total campus energy use based on the 2014 utility data was used to develop a monthly energy use summary. The existing campus energy use is scaled based on the future growth identified in the 2015 Campus Master Plan Update, and the renewable energy generation from photovoltaic (PV), solar thermal (ST), and transpired solar collectors (TSC) is compared to these future projections. Table 5-9 depicts the 2014 monthly energy demand as well as a projection of future monthly energy demand.

Figure 5-8 breaks out electricity from heating in a monthly chart showing the relative impact of each technology considered in the renewable energy analysis.

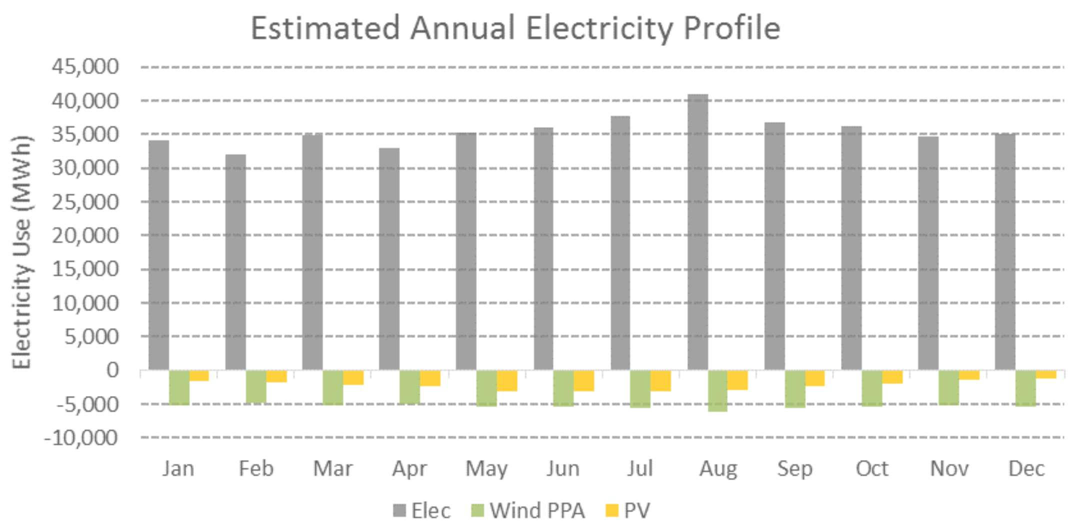
Based on the renewable energy analysis and the 2014 utility bills a combined energy impact of 2.3 percent savings on future energy consumption for on campus generation. When off-site wind energy is purchased for approximately 15 percent of future campus electricity the impact increases to 6.5 percent renewable energy in the future load scenario.

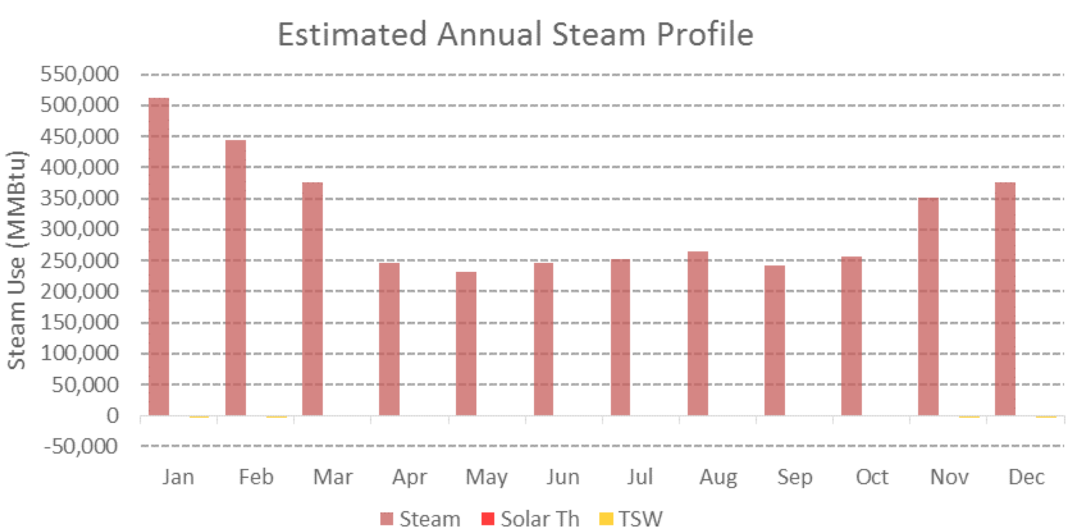
While impactful at a campus scale this reinforces the need for comprehensive improvements in energy efficiency and conservation in order to achieve greater levels of reduced energy consumption.

Table 5-9 Annual Campus Energy Summary

Month	Current Consumption		Future Consumption		Renewable Energy Generation			
	Electricity (MWh)	Steam (MMBtu)	Electricity (MWh)	Steam (MMBtu)	Wind PPA Elec (MWh)	PV Electricity (MWh)	ST Steam (MMBtu)	TSC Steam (MMBtu)
January	29,105	436,707	34,105	511,732	-5,116	-1,602	-319	-4,681
February	27,281	378,754	31,968	443,823	-4,795	-1,768	-371	-3,858
March	29,793	321,596	34,912	376,845	-5,237	-2,139	-529	-2,474
April	28,171	210,726	33,011	246,927	-4,952	-2,350	-580	-1,685
May	30,120	197,478	35,294	231,403	-5,294	-3,016	-664	-551
June	30,803	209,456	36,095	245,440	-5,414	-3,028	-693	-316
July	32,140	214,943	37,662	251,869	-5,649	-3,018	-673	-330
August	34,904	225,484	40,900	264,221	-6,135	-2,853	-640	-374
September	31,449	207,149	36,852	242,736	-5,528	-2,410	-567	-589
October	30,976	218,197	36,297	255,683	-5,445	-1,989	-439	-1,575
November	29,626	299,763	34,716	351,261	-5,207	-1,349	-313	-11,535
December	29,984	320,909	35,135	376,040	-5,270	-1,283	-246	-4,347
Totals	364,351	3,241,162	426,945	3,797,980	-64,042	-26,806	-6,034	-23,657
			Percent Reduction		15%	6%	0.2%	1%

Figure 5-8 Annual Campus Renewable Energy Generation Profiles





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