CLEAN ENERGY MASTER PLAN

VISION

The University at Buffalo understands the existential threat that climate change poses to our institution, our region, state, country and planet. That is why we have doubled down on our commitment to become climate neutral. To achieve this, we are standing on the shoulders of five decades of environmental leadership and focusing our climate action work on a holistic solutions-orientated approach.

Over the past five years, the University at Buffalo has reduced its carbon footprint by an average of 33% (as measured in metric tons of carbon dioxide equivalents) by replacing our annual electricity load to 100% renewable sources. This leadership was recognized by the Times Higher Education Impact Rankings, which rated UB #1 in the world among U.S. universities in taking urgent action to combat climate change. This progress has been made possible through a series of innovative renewable energy projects that now provide 100% clean electricity to our campus. From our early on campus work with the creation of the most publicly accessible renewable energy landscape in the country (the UB Solar Strand) to our new arrays across the university which make us one of the largest producers of on-campus renewable energy, we have methodically learned, continue to build upon our experiences and advance climate action across New York State and the nation. However, we recognize that these success stories are not the end, rather the foundation to build upon as we progress to a carbon neutral future.

UB's *10 in 10* is our roadmap of 10 innovative, engaging and digestible steps we are advancing to increase climate action throughout the University and put us on a path to net zero emissions by 2030. The strategy is holistic, inclusive, engages our broader community and leverages both a triple bottom line approach as well as the Sustainable Development Goals.

MISSION

This Clean Energy Master Plan focused on a key strategy of UB's *10 in 10 Climate Action Plan* at the University at Buffalo's South Campus. The South Campus, or Main Street Campus, is a Western New York landmark dating back to the 1920s. Situated in a residential neighborhood in North Buffalo, the 153-acre parcel is home to classic ivy-covered buildings, as well as residence halls and cutting-edge research and teaching facilities. The schools of Architecture and Planning, Dental Medicine, Public Health and Health Professions, and Nursing are located here. In addition, the campus is heated centrally and is the largest central source of Scope 1 Greenhouse Gas (GHG)(1) emissions at UB. South Campus comprises of 46 Buildings totaling more than 2.8 million square feet. Like all entities seeking to achieve long-term regenerative impacts on our environment, our desire for sustainable results is balanced by the scarcity of capital funding. This plan seeks to develop a strategy that will maximize the amount of construction that can be done by cost effectively implementing sustainable improvements, aligned with campus planning, that maximize the life cycle cost value to the University.

GOAL

We entered into this Clean Energy Master Plan with the goal of developing a strategy that will:

1. Provide a solution for a carbon neutral campus to meet UB goals and New York State law[1].
2. Lead to near term energy savings.
3. Provide a solution for electrification of heating systems on the South Campus.
4. Provide a solution for a 30% reduction in energy usage for the South Campus.

Note

[1] *New York State Laws impacting this plan are SUNY 1B-2 and Executive Order 22*

WHAT WE HAVE

The development of the Clean Energy Master Plan starts by assessing our current status. This takes three primary forms:

1. How we use energy and from what source. (Utility)
2. What infrastructure is used to transform and transport energy through our campus. (Plant)
3. How we consume energy within our buildings. (Load)

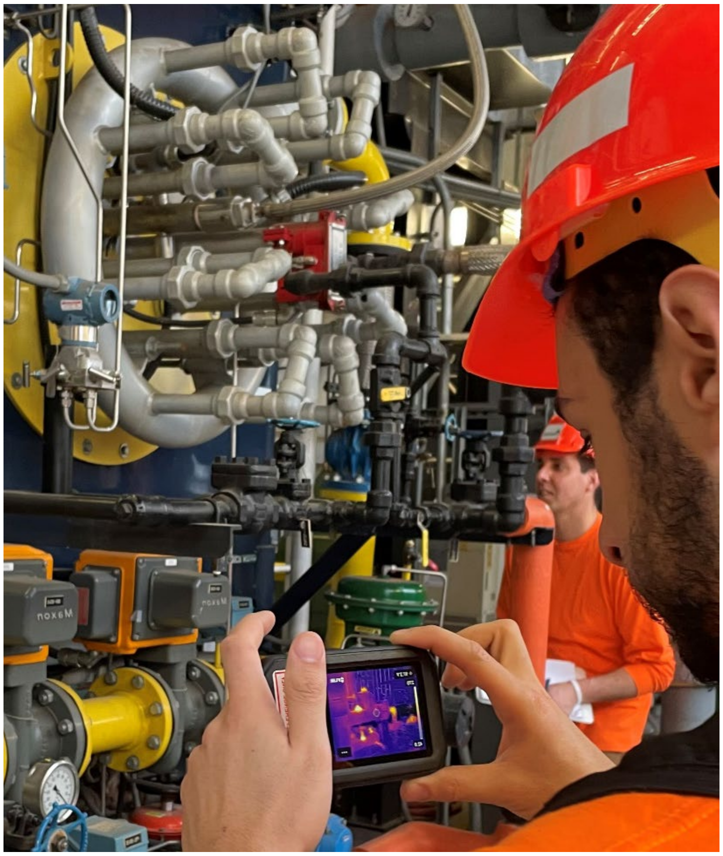

Figure 1: Assessment of Natural Gas Boilers

How We Use Energy

UB's South Campus has two primary energy sources, electricity provided by National Grid and natural gas provided by National Fuel.

We established the calendar year 2019 as the baseline period for the plan. This period would not be impacted by the pandemic and would reflect anticipated energy used once the campus is back to normal operation. We also assessed the energy usage from the 2021 period. This provided us with insight into changes during the pandemic but also changes in energy rates which impact operational cost. Finally, we referenced The Environmental Protection Agency's eGRID 2021 data set to determine emission rates for electric utilities in Upstate New York.

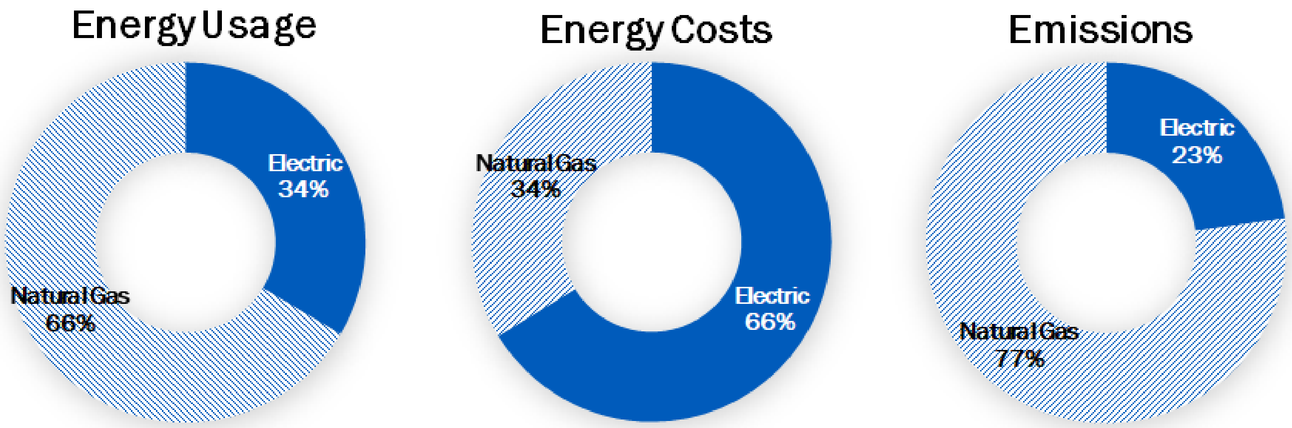

Figure 2: Baseline energy consumption, cost and emissions for UB South Campus

How We Transform Energy

UB’s South Campus has two major systems for transforming energy and transporting it to the buildings. The first is the **STEAM SYSTEM**.

Natural gas is provided to the central heating plant. This building has three (3) boilers which extract energy from natural gas through a combustion process and transfer that energy to the steam distribution system. The steam system distributes energy to most of the buildings on campus through a series of piping and tunnels.

Once in the building, steam is used in a variety of ways. The primary use is for space heating. This takes several forms including radiators, heat exchangers, and air handling units. Steam is also used for humidification, domestic hot water heating and sterilization.

The other energy transformation is the production of chilled water which affects the campus’s electrical utility. Chillers and direct expansion **COOLING SYSTEMS** use electrical energy to power compressors which facilitate the extraction of energy from the building. This happens either through the chilled water system or via air conditioning units.

How We Consume Energy

Buildings primarily consume electricity, steam, chilled water, and natural gas.

1. Electricity is used by lighting, computers, fans, pumps and air conditioning units.
2. Natural gas is used by labs and small, packaged boilers.
3. Steam is used by heating systems, humidification, sterilization and domestic hot water.
4. Chilled water is used by cooling systems.

A reduction in the energy consumed by the building systems outlined above will directly affect the overall energy consumption of the campus. Currently most of the systems within our campus are not able to respond to changes in occupancy or usage patterns.

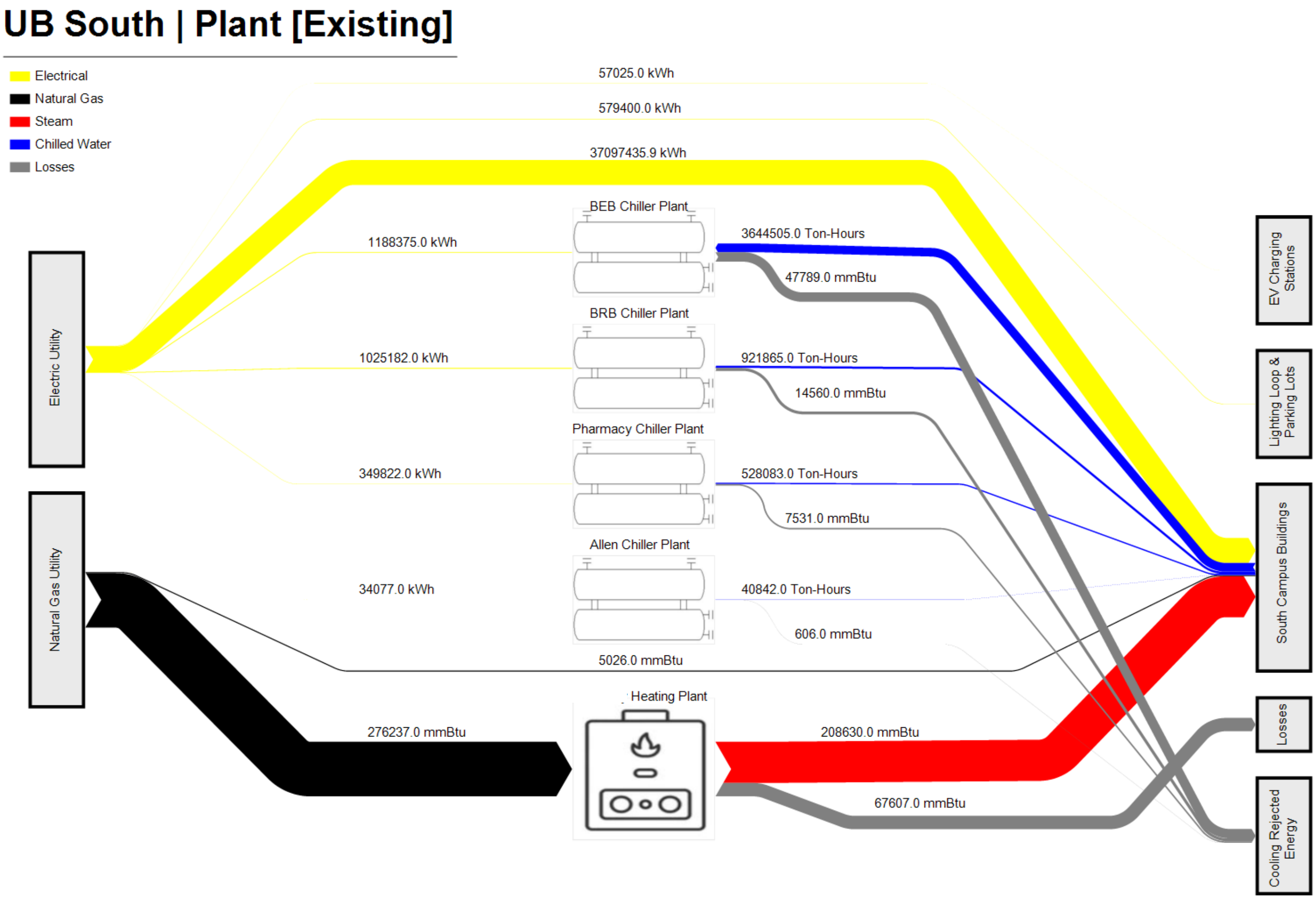

Figure 3: Sankey Chart showing energy flow (left to right) across South Campus

CHALLENGES

Achieving our vision will require us to overcome several challenges.

1. Steam infrastructure that is dependent on fossil fuel-based energy sources.
2. Limited electrical utiltiy capacity.
3. Managing operating costs - energy, operations and maintenance (O&M)
4. Maintaining a fully functional campus while upgrades are being made.

Steam Infrastructure

Steam systems operate at high temperatures and pressures limiting the type of systems and utilities that can be used to provide heat to the campus. As steam systems age, the reliability of the boilers, piping, heat exchangers and condensate return systems decrease. The result will be a consistent increase in maintenance costs. In addition, there is an industry wide decline in the number of technicians with expertise in steam systems.

Within the building, key systems such as sterilizers (autoclaves), humidification systems and domestic hot water systems all use steam at end-use equipment. These systems must be considered when making changes to the steam infrastructure.

As steam is released in the tunnel system, either at leaks, relief valves or traps, hot water vapor is released into the tunnel. The warm and moist environment present in steam tunnels also provides a hospitable habitat for pests.

Electrical Capacity

The campus has a current electrical peak demand of around 9 MW. The campus is designed for a peak electrical capacity of 14 MW. National Grid reports that there are several options to upgrade the service to the campus to 17 MW at 23 kV. Larger service upgrades would require upgrading the service to 115kV. National Grid also noted that due to increases in development in the area, capacity on the 23 kV system may be limited in the future. The cost associated with an upgrade to the electric utility service to the University, would be at the University's expense.

Operating Costs

A variety of market conditions contribute to consistent escalation in energy costs. To accomplish UB's Energy Vision and climate goals, a strategy must consider managing these costs and escalation risks.

Labor shortages, with specific technical skillsets, are impacting operating and maintenance costs. Additionally, the application of new technology into a constrained workforce will create disruptions and technicians needing to learn new systems. Proactive workforce development coupled with modernization of state job descriptions is necessary to create the labor force needed by the University to operate this system.

Fully Functional Campus

The primary mission of the University is to research and education. A strategy to achieve UB's Energy Vision should complement this primary mission. As such, the campus will need to remain fully functionable. The solution should be implementable in stages and adaptable to changing priorities, needs and technology over time.

Figure 4: Existing steam infrastructure

SOLUTIONS

The electrification of the heating system is the primary hurdle to overcome on the path to a zero carbon energy system. There are two fundamental ways to achieve this an enable the university and state to achieve its climate goals.

1. Replacement of heating equipment with electric resistance heating.
2. Replacement of heating equipment with heat pumps connected to various thermal energy sources.

Electric Resistance Heating

An electric resistance heating solution would require replacing the existing boilers with electric resistance boilers. This approach would be able to reuse much of the existing HVAC infrastructure and steam distribution system.

However, the new electric boilers would require a significant amount of electrical power. The current capacity limit for the campus is 14 MW. The new boilers would require this to increase to 50 MW. This would require a new 115 kV electrical service from National Grid, a new substation on campus, a new boiler building and switchgear.

The operation of the system will increase annual electrical consumption by 300 to 400%. This will have a significant increase in annual operation cost (~$3.4M more annually), as well as require the University to further invest in renewable energy projects to offset the large increase in electrical usage.

This approach would also not address aging or end of life HVAC equipment within the buildings. This would require additional investment from the University over time to maintain efficient building operation.

Heat Pump Systems

A heat pump is designed to transfer energy between an energy source to an energy sink. By transferring energy, **heat pumps will use 3 to 4 times less energy from an electrical utility than a comparable electrical resistance system.** This will facilitate a system that is more efficient, cost effective and able to operate within existing electrical utility capacity.

However, a heat pump system will not be able to achieve these efficiencies while operating at temperatures required to produce steam or high temperature hot water. As such, the existing steam distribution system will need to be replaced and a new low temperature hot water system will need to be installed. This will also require the replacement or enhancement of HVAC equipment located within the buildings. The replacement of HVAC equipment within the buildings will likely be necessary over the timeline covered in this plan. By aligning these upgrades with this plan the University will achieve a win-win solution.

The results of these upgraded systems and controls will be a dynamic and efficient building level HVAC system that can respond quickly to changes in occupancy and load.

Discussion

By comparing both solution options, a Heat Pump System is far better aligned with the vision and goals of the University. The Heat Pump solution would:

1. Provide heating within the existing electrical capacity of the campus's electrical service.
2. Replace aging equipment that would require upgrades over the next 20 years independent of this transition.
3. Use far less overall energy compared to an electric resistance system and operate at a lower energy cost.
4. Require less renewable energy to offset the electrical energy uasge of the system.

Additionally, it is likely that if the University selected an Electric Resistance heating solution, the electrical utility will incur significant costs to upgrade the electrical service to South Campus. This cost is unknown at this time, however what is known is that this cost would be passed on to the University.

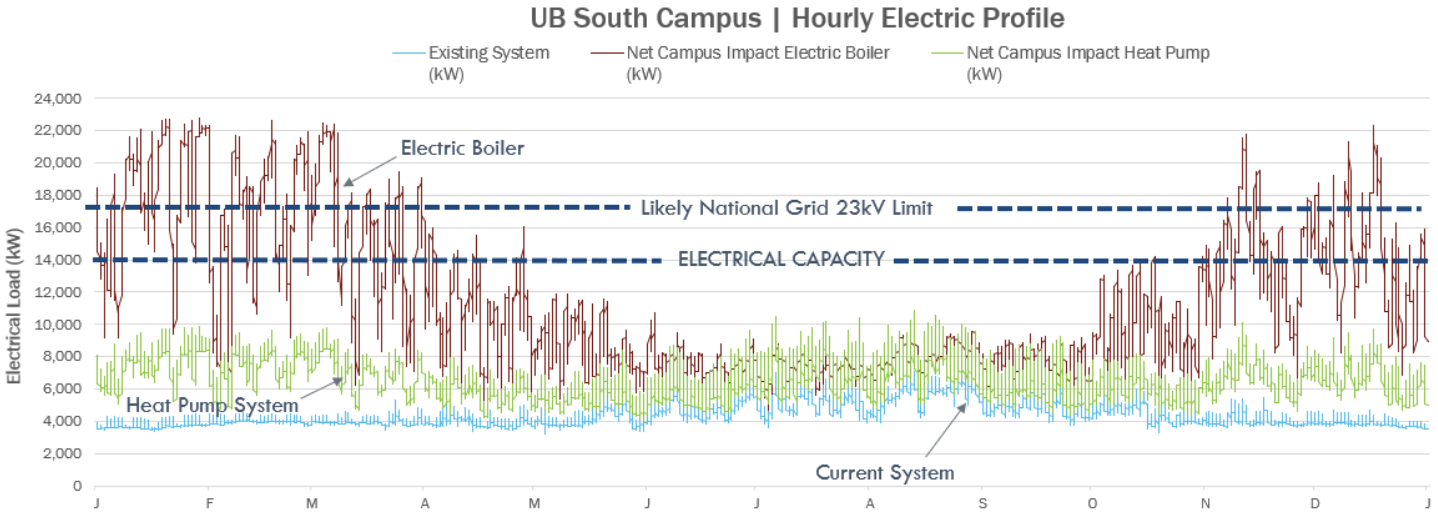

Figure 5: Hourly Electrical demand for an electric boiler comparted to the current campus electrical demand

STRATEGY

The strategy to transition to a zero-carbon energy system will focus on three elements:

1. Reduce energy usage within buildings through energy conservation strategies.
2. Convert the main heating system from a steam based system to a low temperature hot water system.
3. Transition the campus's primary energy utility from natural gas to electricity.

Submetering

Realtime data and a graphical user interface will allow the campus to better monitor and manage energy usage across the campus. As this happens, operators will be able to direct resources and capital to maintain efficient campus operation.

Energy Conservation

The efficient use of energy within the buildings—and between them--enables the transition to a carbon neutral energy system. To achieve that, upgrades to controls systems, incorporation of advance energy conservation sequences and the use of analytic tools will ensure systems operate at their peak efficiencies.

Over time, older system HVAC systems will need to be upgraded. Through this process, steam heating can be replaced with hot water, and air flow can be managed with advance control systems that will dynamically adjust airflow to match the usage of the space.

The results of these upgraded systems and controls will be a dynamic and efficient building level HVAC system which can respond quickly to changes in occupancy and load.

Electrification Make Ready Work

Removal of the steam distribution system and replacement with a campus-wide low temperature hot water distribution system is an important step to the electrification of the heating system. To enable this, end-use equipment that is dependent on a steam utility will need to be replaced. These items include steam heating coils, autoclaves, humidification systems, and domestic hot water heaters.

District Heat Pump Plants

Transitioning from a centralized boiler plant to district heat pump plants will allow the University to electrify the heating system while remaining within the current electric utility

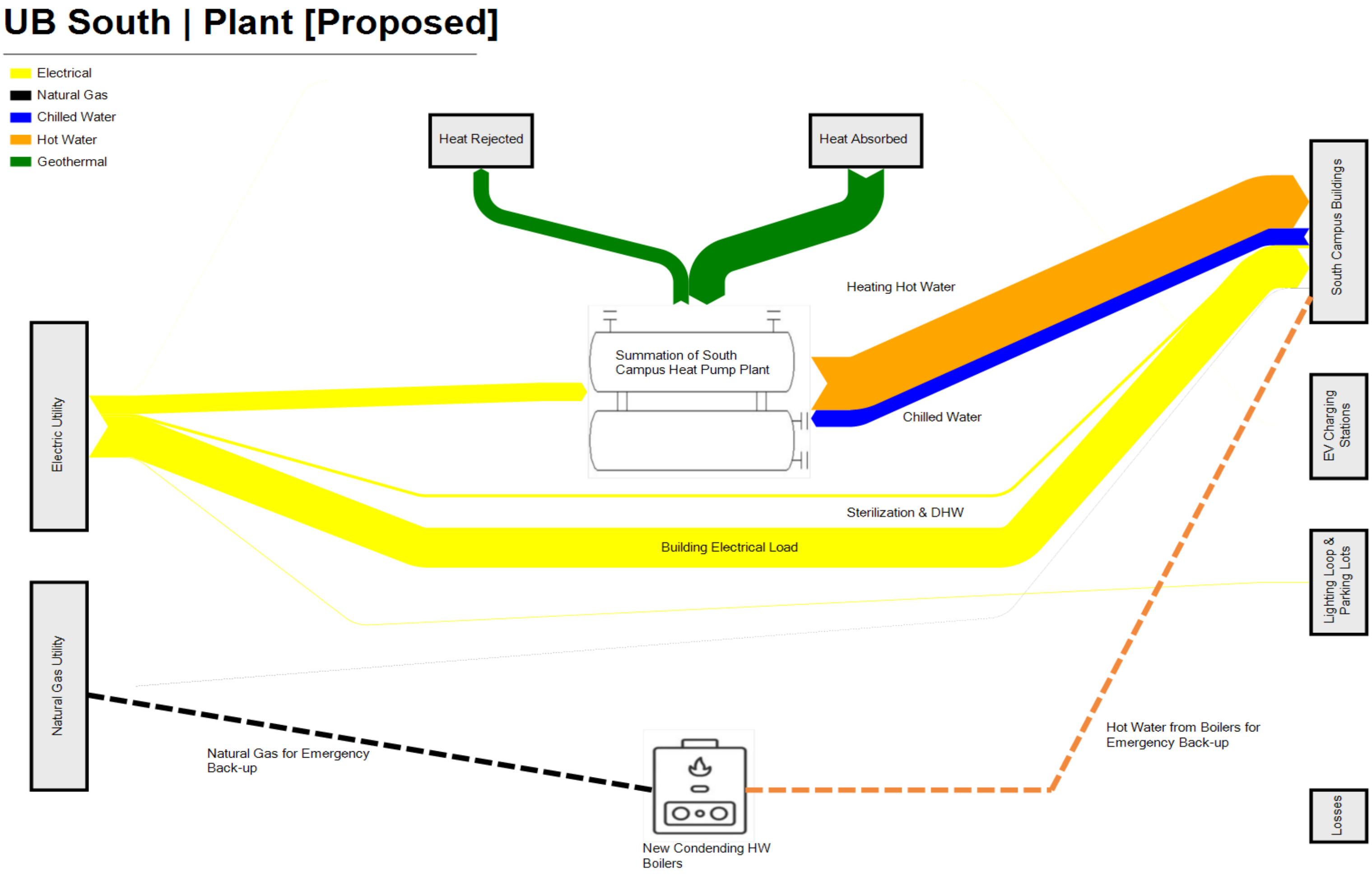

Figure 6: Sankey Chart showing energy flow (left to right) across South Campus with a heat pump plant

capacity constraints. Also, by utilizing centralized heat pump plants rather than terminal heat pump equipment, the University will be able to better manage and maintain resilient energy systems. The district heat pump plants will be connected to both a new low temperature hot water distribution system and the existing / expanded chilled water distribution system. By connecting these two loops via a heat pump plant, energy can now be recovered during simultaneous heating and cooling periods.

The heat pump plants will also be connected to a series of geothermal wellfields. These wellfields will be a thermal energy source for the heat pump system. They will allow the heat pumps to provide heating to the campus in the winter and will absorb energy from the campus during the summer.

The geothermal wellfields will be laid out and installed in a manner that will limit the impact on the campus's current aesthetics and future growth. In the image below, the driller is using angular boring to get 21 wells in the area shown in black. This allows for a building to be built near these wells without interference.

Figure 7: Minimally invasive geothermal well drilling

Figure 8: Field assessment of pipe routing

Resiliency / Redundancy

The heat pump system will be designed with N+1 redundancy on key equipment including, heat pumps, pumps and heat exchangers. Ground loops of static piping require little maintenance, however excess capacity has been built into the system concept along with zone isolation valves to cover unforeseen issues.

In the event of a power failure, the heat pump system will cycle off and emergency natural gas fired condensing hot water boilers will cycle on. In compliance with NYS Executive Order #22 these boilers will only service the campus during an emergency. Critical pumps will be backed up by an emergency generator.

Future Technology Ready

As immerging technologies accelerate into the market, the new low temperature hot water infrastructure system will be able to incorporate these technologies easier than an aging steam system.

As the plan is put into action, accommodations can be made to incorporate thermal energy storage in the system. This system would leverage large tanks of chilled or hot water and can be used to balance load across buildings and limit peak demand.

Another enhancement may be the use of hydrogen fuel cells or boilers. This system, once market viable, could be incorporated into the low temperature hot water network and provide emergency back-up and/or peak load mitigation.

PLAN

The plan will be to execute this strategy in phases. The strategy is also flexible, tools developed during this process will allow University leaders to adjust the timing and grouping of projects, as necessary. The plan outlined here is a strong framework that allows for adaption as the University evolves over the next 10 to 15 years.

Another key element to the Plan is the use of "Heat Pump Clusters". Rather than trying to push heat pumps into each building (which will increase maintenance costs) or have one central plant (which will require a larger one-time capital investment), the team selected an approach to build smaller heat pump plants that will service a cluster of buildings. This cluster approach will allow the University to reuse existing infrastructure, phase these projects in over time, and ensure that the campus will remain operational throughout the process.

Part 1 *Submetering & Efficiency*

The first phase of the project will be to upgrade and expand submetering across South Campus. These improvements would be in alignment with the requirements of NYS Executive Order #22. In addition, there are a handful of "low hanging fruit" energy conservation projects that will yield a favorable near-term return on investment. We would undertake these projects to improve energy efficiency.

Part 2 *Heat Recovery Heat Pump*

The second phase of the project will be to install a heat recovery heat pump in a demonstration building. This heat pump will recover energy from the chilled water and exhaust coils and use that energy to reduce the steam consumption of the building. This project will allow the campus to gain experience with water-to-water heat pumps, while keeping the capital costs manageable and realizing significant energy savings and carbon reductions at the Pharmacy Building.

Part 3 *District Heat Pump Clusters*

The next several phases of the project will be to install heat pump plants that will service a small cluster of buildings. The heat pumps will primarily replace existing chillers and reuse the existing electrical infrastructure serving these chiller plants. A couple of locations may require a buildout; however, this can be incorporated into a building renovation project.

Along with the heat pump plant, building infrastructure will be upgraded to include energy conservation improvements and electrification make-ready work. A new low temperature hot water distribution system will connect the plant to the buildings within the cluster. The plant will also be connected to a geothermal wellfield that will be installed at the same time.

As each cluster is built out over time, a common pipe will connect the heat pump plants together allowing them to share loads and thermally balance the geothermal wellfields located throughout the campus.

Condensing hot water boilers will be installed within some of the clusters to supply backup heating and allow portions of the steam system to be isolated and decommissioned over time.

Part 4 *Data Driven Operations*

To keep the campus running smoothly, the final phase of the project would be to enhance operations by phasing in with each heat pump cluster an analytics control system. These advance controls will allow operators to identify issues before they become problems. This will also allow building managers to prioritize the issues that have the greatest impact on energy, maintenance and indoor air quality first.

ECONOMICS

There are several factors to assessing the financial impact of this plan on the University. These are as follows:

1. Capital Cost
2. Operating Costs
3. Policy Requirements

Capital Cost

There are three components that will comprise a projects overall capital cost. The first is the actual cost of the project. This is inclusive of all material, labor, fees and contingencies. The next is the reallocation of deferred maintenance funds that would no longer be needed because of the new project. By upgrading systems that are nearing the end of their useful life, this project addresses aging and deferred maintenance items that would be incurred by the University over the next 10 to 15 years. This approach is more accurate and clarifies that the cost of doing nothing is not zero. We refer to these as reallocated capital costs. The final item are the incentives / grants and new tax credits (or direct pay) that can be used to offset the projects overall capital cost. The following summarizes all three of these costs and shows the net capital impact to the University.

Total Project Cost	$310,531,605	A
Reallocation of deferred maintenance	$182,145,551	B
Incentives / Grants	$96,483,845	C
NET CAPITAL IMPACT	**$31,902,208**	**D = A – B - C**

Operating Costs

The operation costs are defined as annual reoccurring costs to the University. This project will impact both energy costs as well as operation and maintenance (O&M) costs. While overall energy consumption will be 50% lower than current energy consumption, utility costs will increase as we shift from natural gas to electricity. Additionally, annual O&M costs will also increase as more pumps and heat pumps are needed and a new analytics system is put in place.

Annual Energy Cost	($228,809)	A
Avoided O&M Cost	($202,430)	B
OPERATIONAL IMPACT	**($431,239)**	**C = A + B**

Policy Requirements

To do our part to address climate change, New York State has issued Executive Order #22 which, among other items, drives state agencies to electrify their utility systems. As part of this order, New York State outlined the requirements for incorporating the social cost of carbon into the financial assessment of projects. That value is as follows:

Social Cost of Carbon: $1,117,694

Please note that this takes into consideration that all electrical energy for university is sourced from Renewable Energy Generating Sources.

Beyond state policy, the University's 2030 vision sets aggressive targets to reduce carbon emission. The combination of both State law and University policy projects a future where a business-as-usual energy system using fossil fuels will no longer be accepted.

The following is therefore a financial comparison between the two viable strategies: district heat pump plant and an electric steam boiler. The following is a side-by-side comparison between these two options.

	HEAT PUMP	ELECTRIC BOILER
CAPITAL COST	$310,531,605	$248,629,570
IRA INCENTIVE	Yes	No
ESTIMATED IRA VALUE	$96,483,845	$0
REPLACE AGING EQUIPMENT	Yes	No
AVOIDED CAPITAL COST	$182,145,551	$0
NET CAPITAL COST	$31,902,208	$248,629,570
UTILITY INCENTIVES	Yes	No
OPERATIONS COSTS	Increase	None
O&M COST	($202,430)	$0
ENERGY SAVINGS %	50.29%	4.59%
CO2e SAVINGS %	100.00%	100.00%
CHANGE IN ENERGY COST	($228,809)	($3,401,456)
SOCIAL COST OF CARBON	$1,117,694	$1,117,694
ELECTRICAL PEAK DEMAND	12.5 MW	25.5 MW
ELECTRICAL SERVICE IMPACT	None	Significant
RENEWABLE ENERGY IMPACT	Increase	Large Increase
ADDED ELECTRICAL ENERGY	20,317,871kWh	59,647,253kWh

CONCULSION

The Clean Energy Master Plan outlines a feasible, efficient and cost-effective approach to achieving our overarching goals of advancing the university's mission while achieving climate neutrality.

This approach will allow us to invest in our infrastructure today, using proven technology and the resources available to us.

It will also allow us to phase our investments over time balancing funding, impact to research and teaching and accommodations for University growth.

The strategy will offer us the opportunity to address differed maintenance items and end of life equipment.

We will avoid costly and impractical utility service upgrades.

The plan provides the foundation for the incorporation of future technologies such as thermal energy storage and hydrogen energy sources.

The work can be implemented using advanced drilling techniques that will limit the impact to green space and preserve areas for future growth.

This plan will also allow for adaptation over time. The phasing of projects or cluster can be adjusted based on changes to the campus planning cycle and capital investments. Additionally, as new technologies become market viable, this plan can allow for the integration of new systems while avoiding rework or underutilized equipment.

We are confident this plan outlines the best path forward to a clean energy future for our University. One that is both achievable and adaptable to our needs.

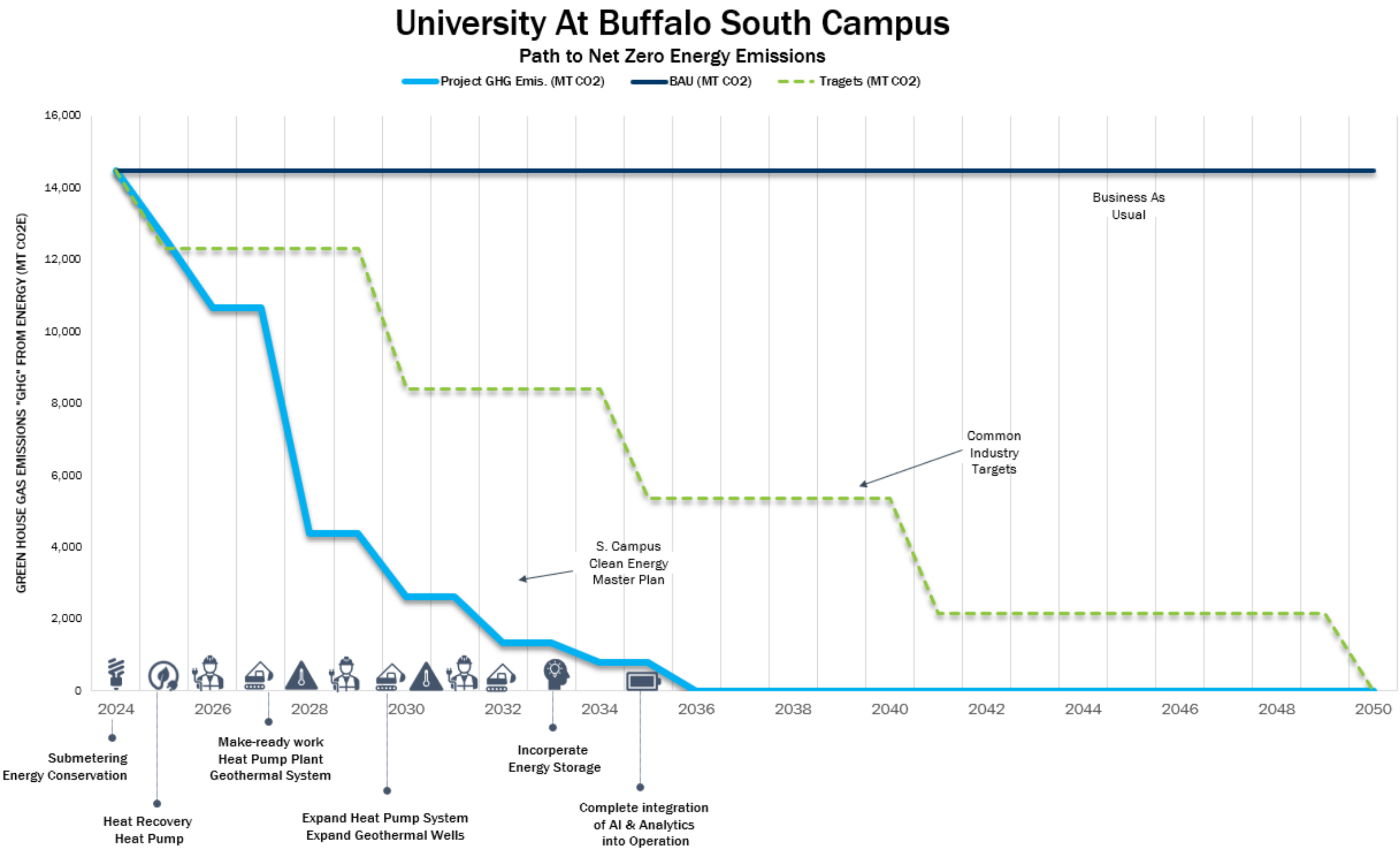

Figure 10: Projected emissions reduction over time as project are implemented.

ACKNOWLEDGEMENT

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Figure 11: Working session attended by UB Facility Directors and Wendel staff.