Sunken Gardens Geothermal Study

College of William and Mary

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CMTA

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Contents

Table of Tables

Table of Figures

Executive Summary

The College of William and Mary engaged CMTA to study the possibility of adding a geothermal wellfield within the Sunken Gardens on the Old Campus. Geothermal systems present a valuable opportunity for substantial HVAC cost reductions, particularly with incentives available under the Inflation Reduction Act (IRA). Geothermal systems are highly durable, with extended lifespans for both equipment and well fields, resulting in reduced replacement frequency. Their consistent operating rates contribute to more predictable energy billing, enhancing financial planning.

Though various utilities are located within this area (steam and chilled water, domestic, storm, sanitary, electrical, and IT), approximately 380 geothermal wells can be located on the site with careful coordination, translating to around 475 Tons of cooling, and 5,700 MBH of heating.

Based on CMTA’s understanding of the current demands of each building, this amount of thermal energy can offset nearly 50% of the heating and cooling demands of the (7) buildings encircling the Sunken Gardens – James Blair Hall, Tyler Hall, Tucker Hall, Wren Building, Ewell Hall, Washington Hall, and McGothlin Hall. If additional Energy Conservation Measures (ECMs) are implemented across these facilities, the wellfield could offset 100% of the heating and cooling demands and completely decarbonize these facilities.

This report outlines the approximate scope and parameters of the geothermal wellfield, pumping strategies to connect each facility, space needs to accomplish the installation of this system, ECMs that can be implemented at each building to fully decarbonize, a cost opinion, and an analysis of the application of the IRA.

Geothermal Wellfield

See **Figures 1 and 2** for a potential wellfield layout within the Sunken Gardens. The storm, electric, IT, and domestic water lines require the greatest coordination to achieve the proposed wellfield. The proposed wellfield, to be installed by a certified water well driller, would include 450’ deep wells, spaced on 20’ centers. Each well includes a 1-1/4” SDR-9 polyethylene piping loop, backfilled with thermally enhanced grout. Prior to any work being performed, a full site survey should be done to confirm exact utility locations.

An estimated 380 wells can be located within this site, based on the average of (3) recent conductivity tests performed at the West Woods, Jamestown East, and Monroe sites. The quantity of wells possible to be located within each section of the Gardens is listed below. The total quantity of circuits, and wells per circuit, will depend on final location and quantity of wells.

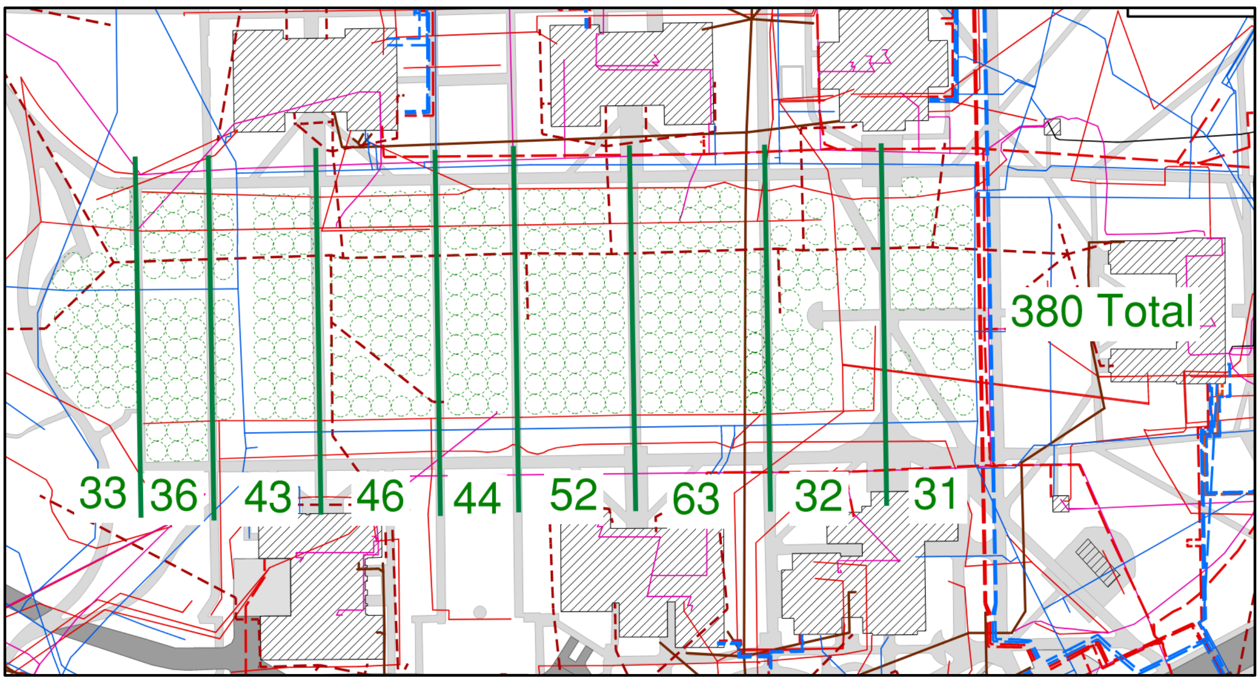

Figure 1 – Sunken Garden potential wellfield

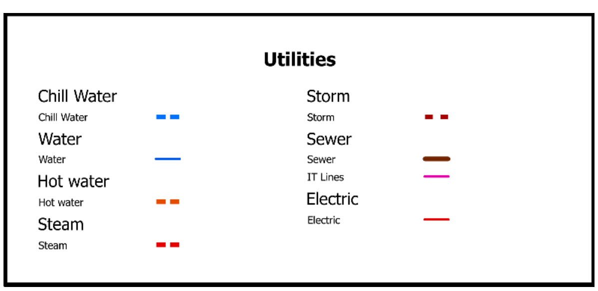

Figure 2 – Site Utilities Key

Central Pumping Station

The geothermal wellfield will require a central pumping location to distribute to the buildings. This can be a new, standalone feature building to be used as a showcase/education tool of the new geothermal system and highlight the College's commitment to carbon and energy reduction. This building could also function as a restroom, concession building, or provide some other public use, and be located anywhere in the near vicinity of the gardens. The pumping room may also have to be located within one of the surrounding buildings where there may be available space. In either case, approximately 800 square feet is needed to house all pumps, filtration system, etc.

A primary-secondary pumping strategy would be implemented. Three variable speed base-mounted pumps, sized for 50%-50%-50% redundancy, would serve the wellfield, while (3) additional variable speed pumps would serve the buildings. A total of (6) pumps is required.

Building-Level Geothermal Tie-In

A 2013 infrastructure upgrade project removed any local chilled or hot water sources, in favor of connecting to the central plant. Each of the (7) buildings are now provided with new chilled supply and return connections, tertiary pumps, system decoupler, and modulating plant control valve. Each building is also connected to campus high pressure steam system, with local pressure reducing stations that supply steam to end devices directly or converted to hot water via shell and tube heat exchangers.

There are a few ways that geothermal can be tied into each building. Cost, electrical capacity, and available space will all need consideration to determine the best path. In each approach, the most cost-effective way to minimize disruption to existing 4-pipe systems is to utilize a 6-pipe heat pump chiller (HPC). These chillers create both hot and chilled water, utilizing the geothermal system as the heat rejection and injection source. During times when there is simultaneous heating and cooling, these devices can achieve a coefficient of performance (COP) of 8 – more than 8 times the efficiency when compared to steam. The HPC can either be centralized or decentralized. In all options, the central plant will remain a backup source of chilled water or steam if issues with the HPC ever arise.

Decentralized Approach

The first approach is to decentralize the heat pump chillers. Two pipes, geothermal supply and return, would exit the central pumping station and serve each building. Each building would house a new HPC in the basement mechanical room, near the steam and chilled water entries. The local HPC would connect to the buildings chilled and hot water loops, just before connecting back to the central plant, in a side steam arrangement. This would require around 100 square feet per building. See **Figures 3 and 4.**

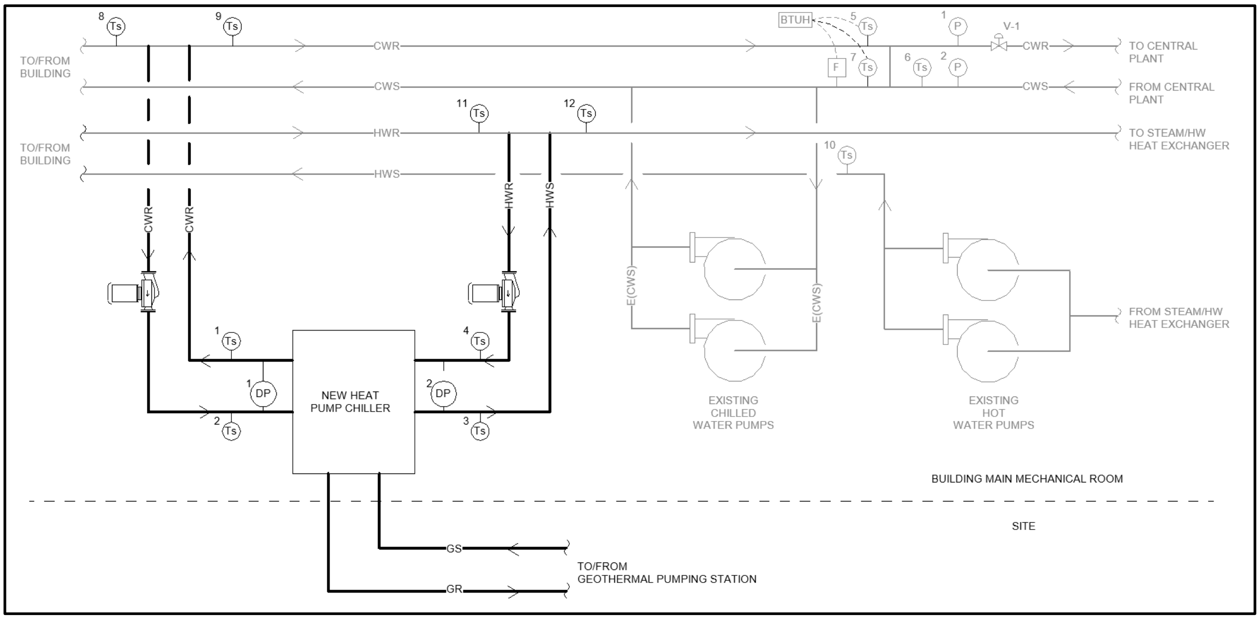

Figure 3 – Decentralized Approach Building Tie-In.

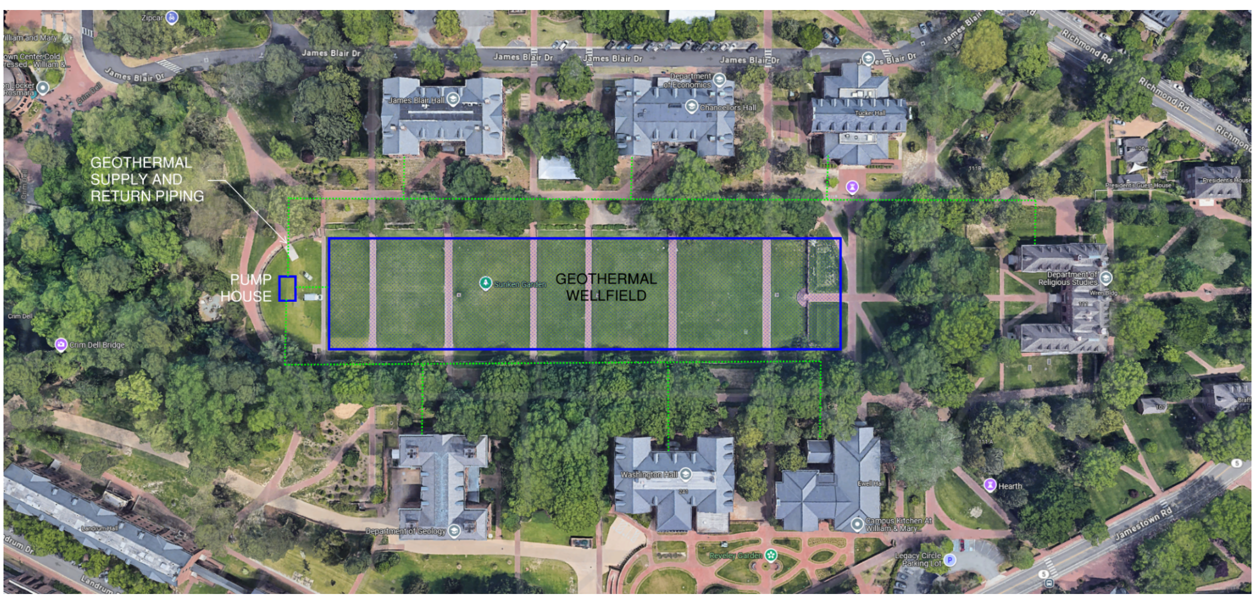

Figure 4 – Overall Decentralized Layout

Centralized Approach

If existing space conditions, electrical infrastructure, or other constraints do not allow a decentralized approach, then a centralized design could be utilized. One large bank of modular HPCs, sized for the entire wellfield, would be located within the central pumping station – which could either be in a new central building, or within one of the existing spaces. This would require an additional 400 square feet of space. Four pipes would distribute from this central location to each building: chilled water supply/return, and hot water supply/return. See **Figures 5 and 6.**

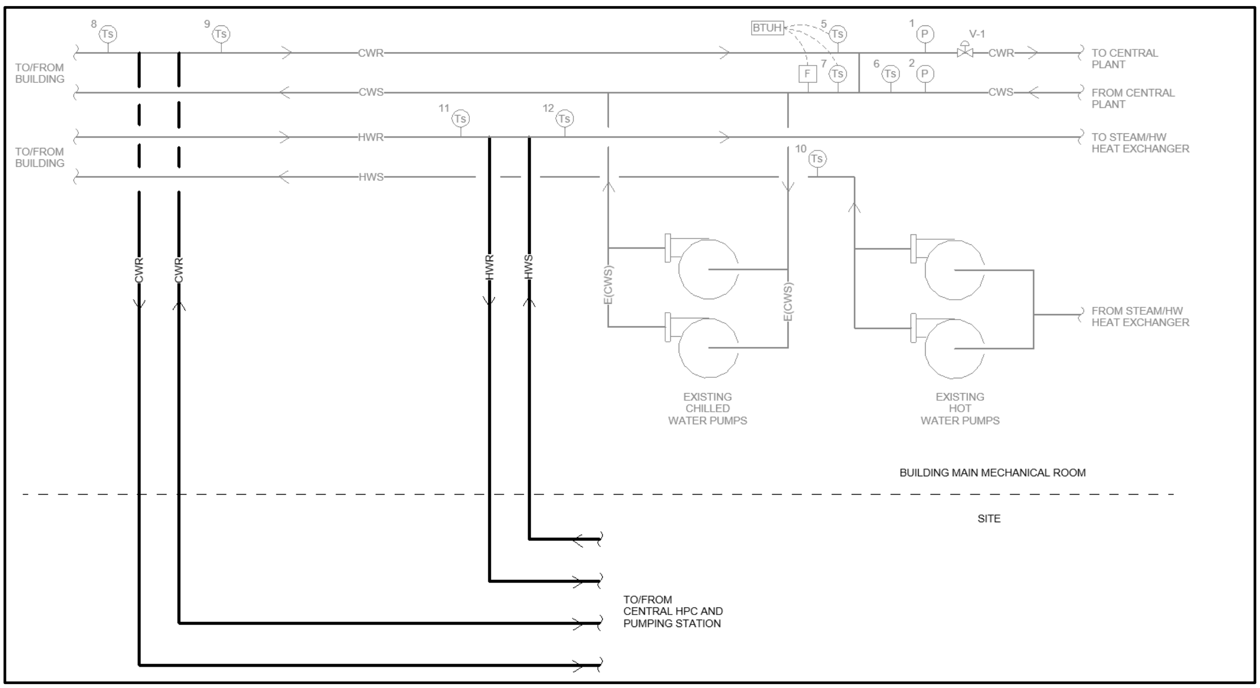

Figure 5 – Centralized Approach Building Tie-In

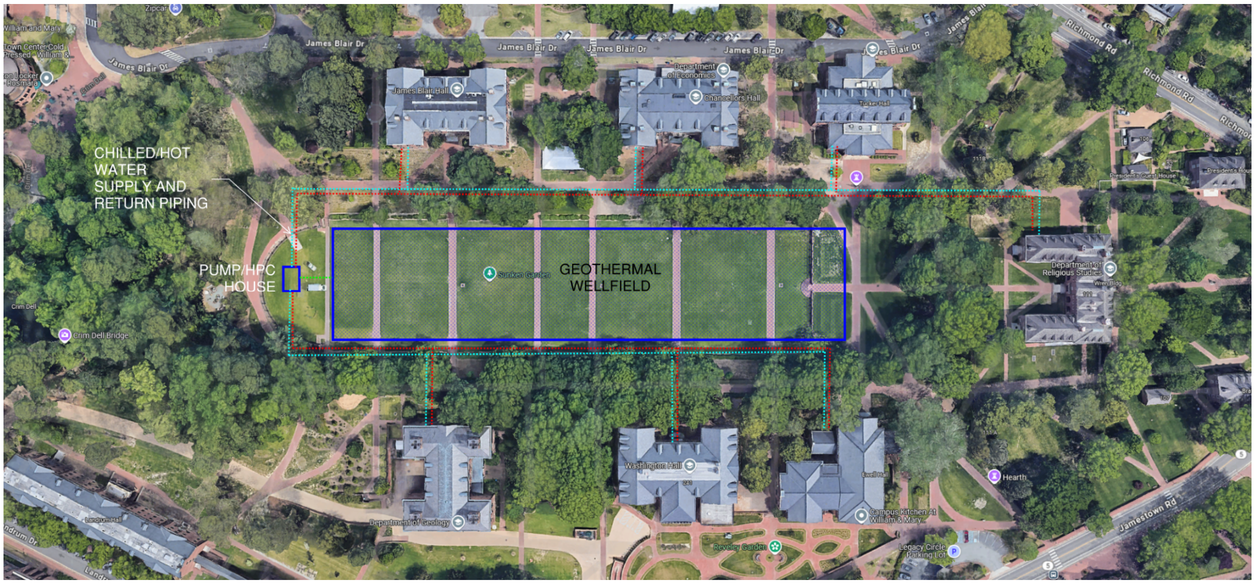

Figure 6 – Overall Centralized Layout.

Existing Building Analysis

There are (7) buildings that could be incorporated into the Sunken Gardens geothermal wellfield - James Blair Hall, Tyler Hall, Tucker Hall, Wren Building, Ewell Hall, Washington Hall, and McGlothlin Hall.

The new potential wellfield block size is fixed at a 475 Tons in cooling – approximately 45% of the current connected tonnage – and 5,700 MBH in heating – 57% of the current connected heating load. See **Table 1** for a summary of each building's existing energy demands on the chilled and steam plant.

The new wellfield goes a long way to reducing overall energy and partially decarbonizing these facilities. However, the overall chilled and hot water demand is very high and can be drastically reduced using ECMs. The overall peak demand can be drastically reduced at each building, and while each building will vary on a case-by-case basis, a target peak demand for cooling should be 500 SF/Ton, and 20 BTU/SF in heating.

It is possible to fully decarbonize this portion of campus, with 100% of the heating and cooling demands coming from the geothermal wellfield, by utilizing ECMs at each building to drastically reduce energy usage.

Building	SF	Tonnage	SF/Ton	MBH	BTU/SF
James Blair Hall	35600	185	192.4	2219.5	62.3
Tyler Hall	48000	133	360.9	1829.7	38.1
Tucker Hall	30100	94	320.2	900.0	29.9
Wren Building	25300	60	421.7	1598.5	63.2
Ewell Hall	29000	96	302.1	935.7	32.3
Washington Hall	41700	131	318.3	1600.9	38.4
McGlothlin Hall	45300	372	121.8	836.0	18.5
TOTAL	255000	1071	238.1	9920.3	282.7

Table 1 – Existing Load Summary

Energy Conservation Measures

Energy Conservation Measures (ECMs) will focus on upgrading the building's HVAC systems, and range in scope, budget, and impact to occupants. Each building will need careful consideration as to which ECM can be selected, its impact, and its return on investment. Common issues included high steam use for inefficient reheat loads, antiquated controls and outdated control strategies, oversized HVAC systems, failing/aged equipment, and inefficient ventilation strategies. In several major facilities, ECMs such as retro-commissioning of HVAC controls, ductwork modifications to minimize reheat load and dehumidification, would significantly reduce energy use and peak demand of chilled water, steam, and electricity. These measures would also optimize ventilation rates, improve indoor air quality, and enhance overall system performance.

Additional HVAC efficiency measures include occupancy-based ventilation strategies and dedicated outdoor air systems (DOAS), real-time optimization of HVAC systems based on demand using enhanced building controls, and comprehensive retro-commissioning of existing systems. Collectively, these approaches would ensure that facilities operate efficiently under varying conditions, reducing both energy use and operational costs. Other common ECMs identified included upgrading building control systems, improving pressurization to minimize outdoor air infiltration, and envelope improvements such as air sealing and window replacements.

Energy Recovery Ventilator

New energy recovery ventilation (ERV) systems capture and reuse waste heat from code-required restroom exhaust and relief air, and pre-treat the code-required minimum outside air for each air handling unit. Ductwork modification and mechanical room/attic space is required for the equipment itself, but this ECM is achievable for all buildings. The minimum outside air required for each individual AHU should be re-analyzed based on the current usage of each space, and the latest codes. When decoupled outside air is commissioned correctly and the building is balanced positively, infiltration loads can drop to zero.

Retro Commissioning

Some of these buildings were last renovated over 30 years ago. It is recommended that all facilities are retro commissioned. A Commissioning agent would develop a retro-commissioning plan for each building which typically includes HVAC system equipment retro and controls point-to-point verification, sequence of operation optimization to maximize efficiency, trending, development of a deficiency log, and a report of all work performed and recommendations.

System Rightsizing and Rebalancing

Many of the buildings were sized for airflows far beyond what is required for the current space needs. A typical office and classroom building will average 0.7 CFM/SF, while many of these buildings have been sized for 1.5-1.75 CFM/SF – over twice what should be required, even for an older facility. The air handing unit itself, plus the coils and terminal boxes are mostly oversized. It is recommended that each building HVAC loads are re-analyzed based on a realistic understanding of loads (people count, equipment, infiltration, envelope). Each terminal box, grille, coil, etc. is to be completely re-balanced by an AABC certified test and balance contractor. This applies to all buildings.

Building Pressure Testing

Building pressure testing, adhering to ASTM E779 and E3158 standards, is recommended to assess airtightness through fan pressurization and depressurization tests. Using infrared (IR) thermography, potential infiltration/exfiltration points are recommended to be identified based on temperature differentials, aiding in precise envelope sealing.

Testing Parameters: Testing conditions, including a wind-free day, dry roof surfaces, and a significant indoor-outdoor temperature delta (optimally around 36°C), are recommended. Leakage Rate Standards: it is understood that these facilities range in age from 30 years old to nearly 325 years old, and modern leakage rates may be achievable. The purpose of the test is to locate opportunities to reduce building infiltration. That said, the target leakage rates below 0.40 cfm/ft^2 of wall area for typical buildings and 0.15 cfm/ft^2 for high-performance designs are advised, with exceptional performance at 0.06 cfm/ft^2. If the ERV ECM is incorporated, it is recommended that building pressure testing is performed after this work is completed.

Plumbing Systems

All but the two most recently renovated buildings, Blair and Tyler, utilize steam-to-DHW heat exchangers from the central plant. It is recommended that these are replaced with air or water source heat pumps specifically designed for domestic hot water heating. These heat pumps are highly efficient, drawing heat from ambient air or water to provide a reliable and energy-efficient hot water supply. Additionally, this system presents innovative opportunities for secondary benefits within the building: as it generates hot water, the heat pump also rejects cool air, which can be strategically used to pre-cool return air, support IT room cooling, or address other cooling needs within the facility.

Estimated Project Cost

Depending on the space available at each building, electrical capacity, etc. that may impact the direction where equipment could go, this base project will range in cost. The estimate below includes 25% contingency and 25% contractor markup, which includes general conditions, overhead, and profit. An A/E fee of 8% is also applied. The most expensive total cost (Option 3) is around **$19.4M**. See **Table 2** below for a cost opinion.

	Units	Qty	Unit Price	Cost
Wellfield				
450' Wells	EA	380	$ 20,000.0	$ 7,600,000.00
Pump Equipment				
Base Mounted Pumps	EA	6	$ 25,000.0	$ 150,000.00
VFDs	EA	6	$ 10,000.0	$ 60,000.00
Controls	LS	1	$ 100,000.0	$ 100,000.00
Electrical	LS	1	$ 200,000.0	$ 200,000.00
Pump Building (Pumps Only - Decentralized)	SF	800	$ 800.0	$ 640,000.00
Pump Building (Pumps and HPC - Centralized)	SF	1,200	$ 800.0	$ 960,000.00
Distribution Piping				
Geothermal Supply/Return - Decentralized	LF	4,000	$ 100.0	$ 400,000.00
Hot and Chilled Water Supply/Return - Centralized	LF	8,000	$ 100.0	$ 800,000.00
Buildling Side Equipment				
Heat Pump Chiller	EA	7	$ 150,000.0	$ 1,050,000.00
Inline Pumps	EA	14	$ 10,000.0	$ 140,000.00
Controls	LS	7	$ 20,000.0	$ 140,000.00
Electrical	LS	7	$ 50,000.0	$ 350,000.00
Misc. Hydronics	LS	7	$ 25,000.0	$ 175,000.00
Sub-Total A/E Cost (Includes 25% OH&P)				
Option 1 Subtotal				$ 13,756,250.00
Option 2 Subtotal				$ 13,956,250.00
Option 3 Subtotal				$ 14,656,250.00
Option 4 Subtotal				$ 13,456,250.00
Contingency (25%)*				$ 3,664,062.50
A/E Design Fees (8%)*				$ 1,172,500.00
Total Cost*				***$19,492,812.50***
Option 1: Decentralized With New Pump Building				
Option 2: Decentralized Without New Pump Building				
Option 3: Centralized With New Pump Building				
Option 4: Centralized Without New Pump Building				
* Total cost for Option 3				

Table 2 – Cost Opinion.

The total cost to completely decarbonize and apply ECMs to each building such that 100% of the wellfield will account for all load within the buildings, will vary depending on what ECMs are identified as achievable.

Impact of Inflation Reduction Act

The Inflation Reduction Act (IRA) is transformative legislation aimed at accelerating the adoption of clean energy, reducing greenhouse gas emissions, and promoting energy efficiency across industries, including the hospitality sector. By offering substantial tax credits, direct payments, and bonus incentives, the IRA significantly reduces financial barriers to implementing high-performance, sustainable technologies.

The IRA, signed into law in 2022, is one of the largest investments in clean energy and climate change mitigation in U.S. history, with over $350 billion allocated toward renewable energy incentives, sustainability projects, and infrastructure improvements. The act focuses on making clean energy technologies more affordable and accessible, while incentivizing businesses to transition toward sustainable operations. The IRA provides direct payment credits would be applied via the following:

- Investment Tax Credits (ITC): A base 30% ITC is available for renewable energy installations, such as solar and geothermal systems, covering both installation and equipment costs.
- Domestic Content Bonus: Projects that meet specific requirements for U.S.-manufactured materials, such as 100% domestic steel, can receive an additional 10% tax credit.

Nearly the entire cost of this project would be applicable to receive both the ITC credit of 30%, and likely the 10% bonus credit for a total of 40% of the cost back to the College in the form of a direct payment. The geothermal system, including all piping, pumping, controls, equipment, electrical connection, and labor, are applicable on this project, for an estimated credit back of **$5M**. this direct payment would be received after substantial completion, and could be funneled directly into other energy projects to improve the (7) buildings being served by the wellfield, making the entire wellfield even more energy efficient and closer to fully decarbonizing.