

Golden Energize Engineering

## 17.5 - Wastewater Heat Recovery

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### Final Design Report

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# Project Review

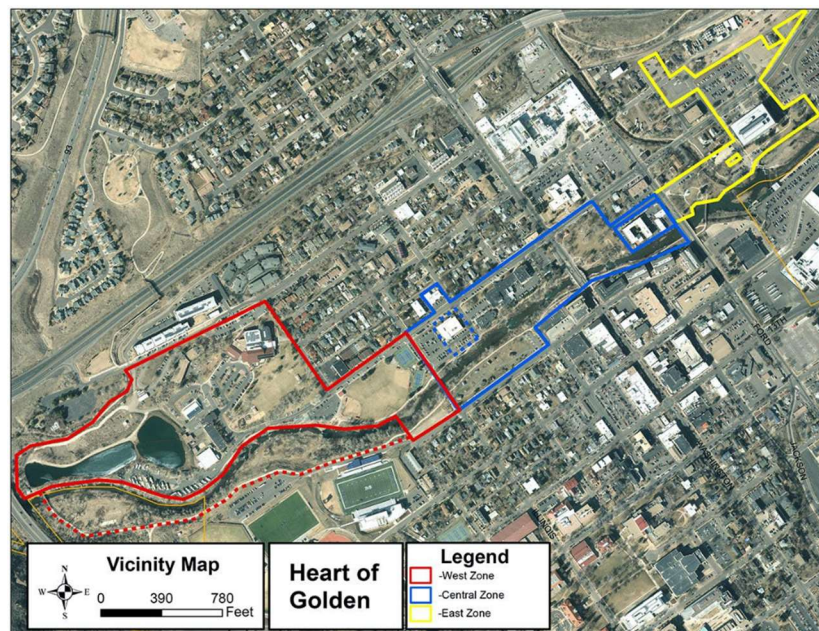
## Project Description

This project aims to design a system for wastewater heat recovery to be used as an energy resource for the buildings that will be built as part of the Heart of Golden initiative. The City of Golden plans to utilize approximately 10-acres of land near the Coors facility to build new city buildings which could include, but is not limited to, a city administration building, a cultural center, a fire station, and a mixed-use commercial-residential building. The city hopes to make these new buildings with net-zero emissions and implementing a wastewater heat recovery system could help achieve that goal.

## Scope & Deliverables Statement

While working with The City of Golden, Golden Energize Engineering shall develop a preliminary plan to determine whether wastewater heat recovery in the Heart of Golden will be a feasible addition.

The Heart of Golden is a 50-acre piece of land along Clear Creek that the city recently purchased (**Figure 1**) [1]. The focus of this project will be the East zone, outlined in yellow. In this, the City of Golden has multiple ideas of what could be implemented, and the team's job will be to determine what the possibilities for wastewater heat recovery will be, along with their environmental impacts, cost, and overall improvement regarding energy. This work shall be completed by late spring of 2022 in order to present it to the City of Golden Sustainability Board. With this, there will be a life cycle assessment, return on investment analysis, and greenhouse gas emission comparison. These will help determine the benefit of moving forward with this initiative. If it is deemed feasible, the team will outline the next steps to continue moving forward. If it is not deemed feasible, the team shall suggest other routes to explore to reach the City's sustainability goals.



*Figure 1: Heart of Golden Boundary [1]*

### Restrictions, Exclusions, and Assumptions

Based on initial client meetings and the project prompt, the following restrictions, exclusions, and assumptions will be used to limit the scope of the project. The team will only be providing data for a mixed use residential and commercial building. The building is estimated to be 75,000 square feet with commercial spaces on the first floor and 50 apartments on the top two. In addition, a new set of regulations have been passed regarding wastewater dumping temperatures in Clear Creek. The team will ensure any designs that discharge into Clear Creek will abide by the new regulation, Colorado Department of Public Health and Safety's Regulation 38 [2]. Though this does not pertain to the current direction the team pursued, it related to one direction that was explored towards the beginning of the project. One reason the discharge to Clear Creek was not explored further is the limitations with Coors. The team had difficulty contacting Coors, so substantial work could not be completed due to the lack of data. In addition, Coors treats the water for the City of Golden, but the facility is outside of the city's jurisdiction, so Golden would not be able to implement the heat recovery technology within Coors.

## Application of Design Methodology

### Concept Exploration

To begin, the team researched all possible solutions within wastewater heat recovery that were already in use. It was found that, in existing systems, there are four methods of implementing this technology. These methods include implementing the technology at the component level, building level, sewer level, and wastewater treatment level [3].

#### *Component Level*

At the component level, hot water from drains flows down a pipe with coiled conductive piping containing water wrapped around it (**Figure 2**) [4]. The water in the pipe transfers its heat to the water in the coiled piping which then flows to a hot water heater as pre-heated water. This pre-heating of the water reduces energy use in the water heater and provides hot water more quickly than if the water were to be heated from its original temperature [3].

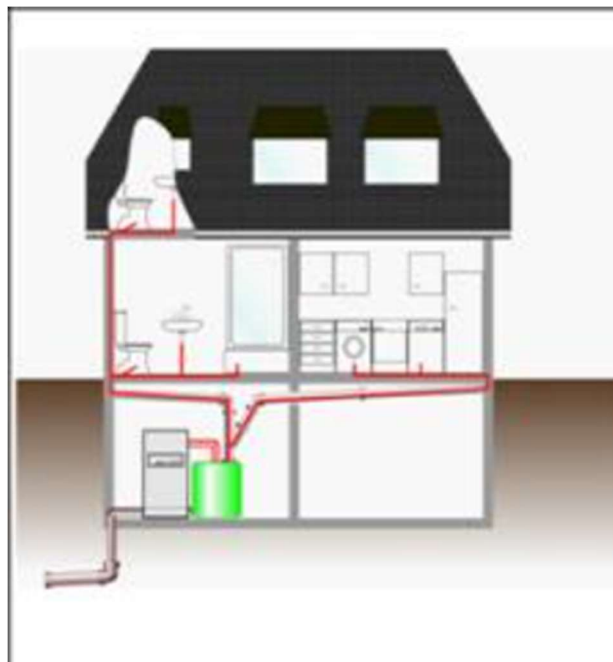


**Figure 2:** Wastewater heat recovery of components [4]

### *Building Level*

The building level is the next solution to the wastewater heat recovery problem. In this case, heat is used from all the wastewater in a building to then help heat or power the building it is attached to **Figure 3**. This solution was expressed by the client as an area of interest, so the team focused efforts on this concept.

The common uses for wastewater heat recovery for a building focus on reducing the energy consumption of water heaters and HVAC systems [3]. Components within a building that can be affected by wastewater heat recovery include dishwashers, laundry machines, showers, sinks, furnaces, and air conditioners. The goal at the building level is to take warm wastewater from the sewers and harness the natural heat it possesses using mechanical devices such as heat pumps and heat exchangers. These devices are compatible with the main heating and cooling mechanisms that are used in buildings and residential spaces, so it is quite simple to connect them to the existing system structure and provide value. Some concepts utilize untreated wastewater to achieve this goal, while others will include a screening process or minor filtration process to remove unwanted debris or solids to ease stress on the machinery and reduce backups and clogging [3]. These filtration methods were briefly analyzed by the team to understand if this method held any benefit to the solution. The team's findings indicated that removing debris is beneficial for the health and performance of the system as well as removing solids that are common in wastewater. Removing the solids and debris can increase the thermal potential that wastewater possesses. Removing these solids would create a smaller gap in temperature between the starting temperature and the desired temperature for operation resulting in a greater performance of the entire system. The dilemma with this proposal is that additional equipment that requires additional energy inputs is needed to filter the wastewater. This would incur an additional financial investment to the system that would increase the time frame of the return on investment of the entire system. With this addition, the system would provide a significant financial saving to the residents/building owner immediately, making it more desirable in the short run.



**Figure 3:** Wastewater heat recovery of building [5]

In researching the building level in depth, there were two real world examples that were discovered that are currently implementing wastewater heat recovery solutions. These two case studies are the Wall Centre Central Park Phase 2 in Vancouver, Canada and the Bullitt Center in Seattle, Washington, USA.

The Wall Centre Central Park is a two-phase real estate development. The first phase supports more than 600 residential units while the second phase supports 332 residential units. Phase two of the park is LEED Gold certified, which indicates a high sustainability achievement. The Wall Centre Central Park Phase Two has implemented a wastewater heat recovery system that collects the wastewater from the 332 residential units and uses the energy it possesses to implement back into the air conditioning, heating, and water heating systems within the building. This system has been calculated to reduce carbon dioxide emissions by 130 US tons per year. This is all achievable by a wastewater heat recovery system that is implemented by Sharc Energy and is covered in greater detail in the drawings section [6].

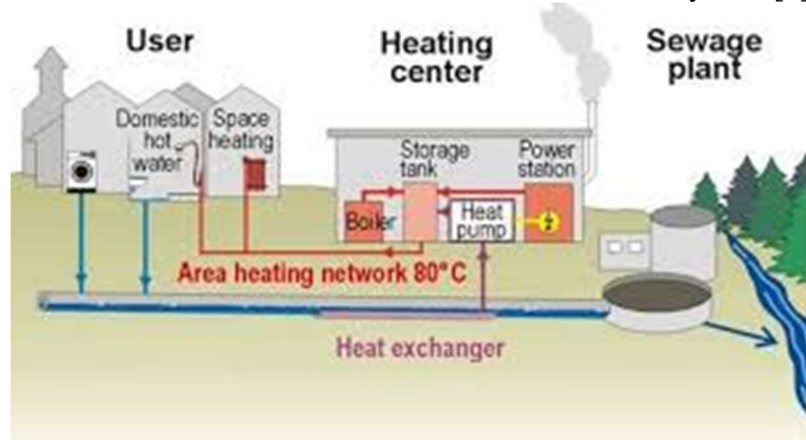
The Bullitt Center is a commercial office building that highlights fourteen sustainable initiatives that are possible today that demonstrate sustainability that can be incorporated into buildings to reduce energy usage. These initiatives are radiant heating, walkability, solar panels, building neurology, composting toilets, greywater system, rainwater harvesting, regenerative elevators, heat pumps, “irresistible” stairs, structural materials, windows and shades, bicycle services, and heat recovery ventilation. The Bullitt Center is located in a densely populated area of Capitol Hill in Seattle where it has access to bus routes, light rails, Zipcars and Car2Go. The increase in bike space and incorporating a bike repair area in the building paired with the building's location help individuals refrain from driving to work and use mass transit or biking. To combat water usage, the building's design uses a greywater system with composting toilets and rainwater harvesting, which allows the building to have reduced water costs. The energy to heat this water comes from the heat pumps that are used, which draw from some of the building's solar energy that is generated by the solar panels installed. For heating and cooling of the building, the radiant heat system uses a mixture of water and glycol that circulates through tubes in concrete floor plates acting as veins through the building like in a human's body. The building also utilizes a heat recovery ventilation system that targets used tempered exhaust air from the building to pre-heat incoming air, which increases heat transfer and reduces the amount of energy needed to heat incoming air. The windows in the building are triple pane to reduce heat loss from the building. The operable windows and automated blinds maximize daylight and adjust accordingly to inside temperatures. The windows can open automatically to maximize ventilation, when necessary. Together, these initiatives allow the building to operate energy independently and occasionally the Bullitt Center produces more energy than it needs to operate daily [7].

These two examples display a wide range of current solutions to wastewater heat recovery that will be considered in the design of this project.

### *Sewer Level*

In this solution, there are two options already in use. One is attaching a heat exchanger to the sewer line itself. This presents a few problems with general maintenance and repair since it would be underground. In addition, when maintenance is necessary, the sewer line must be shut down until the work is complete. However, its use would be more efficient than the other current solution at

this level: an above-ground heat exchanger (Figure 4). In this solution, maintenance is easier, and the water would be screened before entering the system. Without solid waste, the system would be more efficient and consistent. However, it takes more energy to move the wastewater aboveground, and it would take more land and resources to build the system [3].

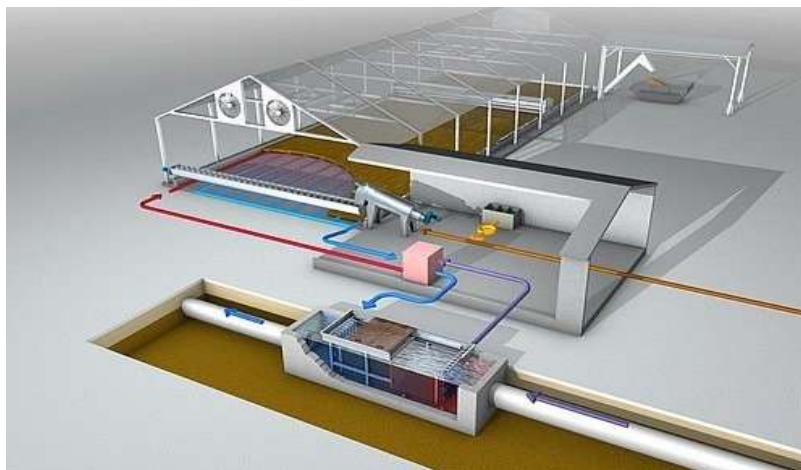


**Figure 4:** Wastewater heat recovery of sewer [8]

#### *Wastewater Treatment Plant Level*

The wastewater treatment plant level operates after all other wastewater treatment is completed, so the contents of the water are better known than at other levels, making the specific heat number easily calculable. Knowing the specific heat of the water allows for adjustment of the system in order to operate the most efficiently. Recovering wastewater heat at the end of the process means that discharge temperature can be readily controlled, making it easier for Coors to meet discharge requirements. An example of a company that utilizes this method is Huber RoWin Heat Exchanger [9]. This is implemented after the water has been treated, and it is used to help power the wastewater treatment plant as seen in Figure 5.

However, due to the fact that Coors is not within Golden's jurisdiction, the concept was not explored further since it was outside of the client's influence at this time. If Coors was able to be persuaded to move forward with this technology, it is the team's belief that it would benefit the company both environmentally and economically.



**Figure 5:** Wastewater heat recovery of wastewater treatment plant [9]



## Concept Critique

### *Component Level*

The component level is logical for existing buildings, especially single-family residences since there are multiple options for systems to be added to components such as showers. However, more energy can be harnessed through a larger scale system where it can draw energy from all components within a building, or even multiple buildings. At the component level, each component would need its own system which would take more time and money. Also, these systems generally only benefit the component it is attached to.

### *Building Level*

The building level has some of the benefits that the component level does not, such as being able to draw heat and energy from all systems within a building and contributing to the building as a whole. There are also many solutions already being implemented at this level. These are explained in more detail in the Drawings and Engineering Analysis sections. One downside is that the water must travel further from the source at which it was heated. This results in more heat being lost in the process than the component level would have.

### *Sewer Level*

This brings the same benefits as the building level where it allows for heat and energy to be derived from multiple sources with only one system. However, it presents more logistical downsides with space taken and maintenance issues. In addition, it loses more heat than the two previous solutions since the water will travel further than either.

### *Wastewater Treatment Plant Level*

The wastewater treatment plant level helps to reach goals regarding the regulations with the temperature of water being discharged into natural streams and rivers. However, it does not help to reach the goals of net-zero buildings that the City of Golden is looking to build. In addition, all water treatment for Golden happens through the Coors Brewery, but they are not within the city of Golden's jurisdiction.

## Concept Selection

After preliminary research, the team determined that the building level and sewer level were the most feasible options given the scope of the project and the professional relationships available. The component level was found to not be as effective, and the wastewater treatment plant level is outside of the scope for this project. However, though the wastewater treatment plant is not within the goals for this project, it could still be discussed in the context of discharge water temperatures since they will become more relevant with new laws being passed in the near future.

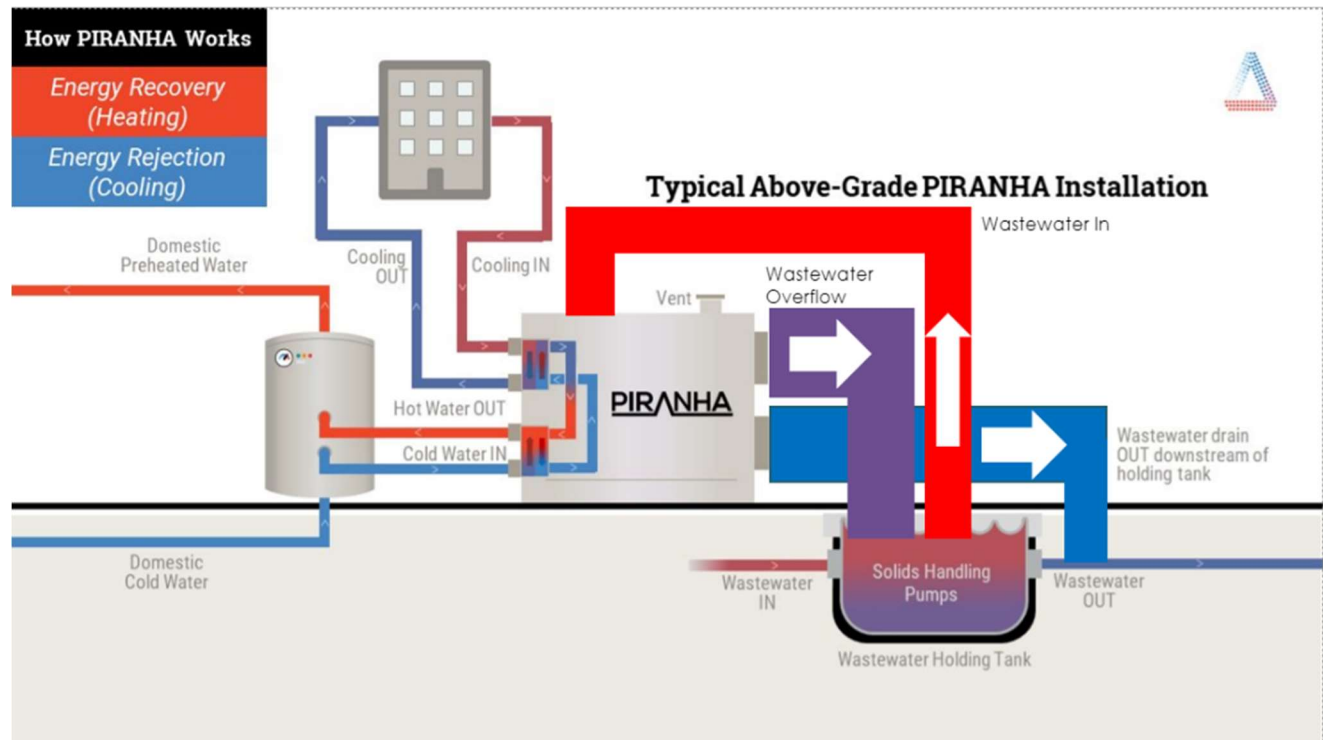
Between the sewer and building levels, the building level was deemed more beneficial in this project due to the shorter distance traveled by the heated water. In addition, with the uncertainty of what buildings will be constructed and where at this stage in the Heart of Golden development, it is more logical to design a system that can go with multiple types of buildings without the need to interact with existing infrastructure.

After discussing with the client, the building level was agreed upon as the direction for the project.



### Drawings

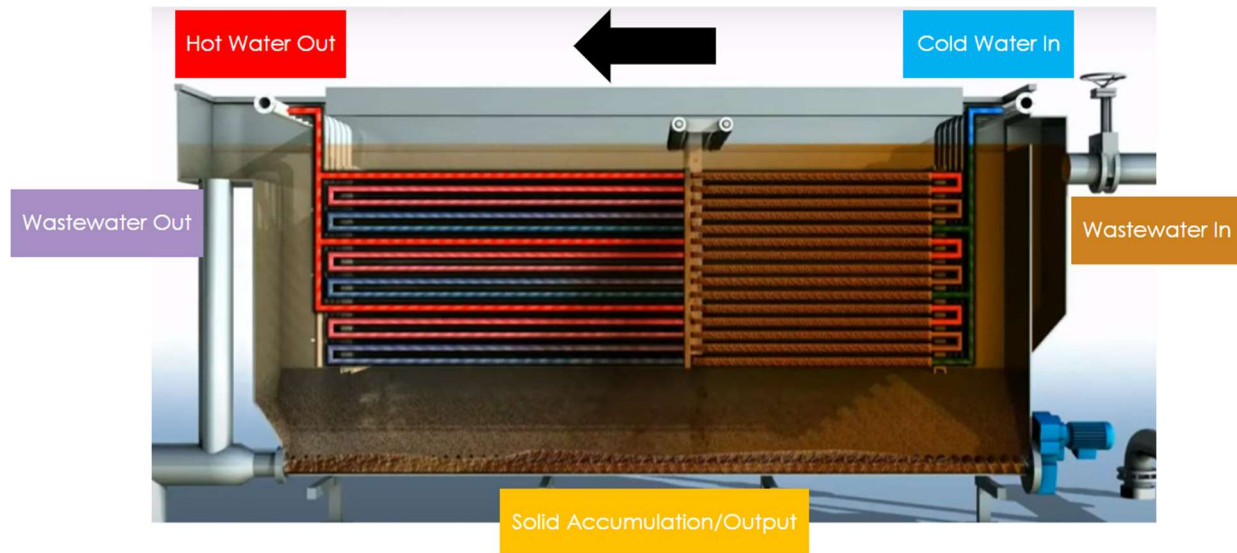
Below are design schematics at the building level for wastewater heat recovery. The two concepts below are from two current manufacturers who are involved in the wastewater heat recovery industry. The first concept depicted in **Figure 6** is designed by Sharc Energy. Their product, the Piranha HC Model, looks to use wastewater heat recovery to improve the heating and cooling of residential buildings.



**Figure 6:** Illustration of Piranha T10 heating and cooling system [6]

In the system, there are two cycles taking place: a refrigeration cycle and a heat exchange cycle. In the heat exchange cycle, the system takes wastewater from the sewer and stores it in a holding tank. From this tank the wastewater is then pumped into the Piranha. The Piranha's heat exchanger and heat pumps can transfer the heat from the wastewater to the potable water that is meant for the residential building, which is stored in a domestic hot water tank. Any overflow wastewater in this process is sent back to the wastewater holding tank and any used wastewater is sent back to the sewer. The left side of the drawing depicts the refrigeration cycle that is used to provide air conditioning to the building. The cold water is stored in a holding tank where it is then pumped and interacts with the condenser of the refrigeration cycle. In the condenser, the water takes on heat from the used refrigerant. The refrigerant is what cycles to the evaporator and cools supplied air that is forced into the building. The hot water now is sent back to the Piranha system where it interacts with an evaporator that adds energy from the water back into the refrigeration cycle. This water also flows through a condenser that will transfer this energy into the potable water. There is a second evaporator that exists within the Piranha that interacts directly with the wastewater and adds energy into the refrigeration cycle [10].

The second design schematic pictured in **Figure 7** is manufactured by Huber Technology. Below is a picture of the Huber RoWin, a modern heat exchanger that is designed specifically for wastewater heat recovery.



*Figure 7: Illustration of Huber RoWin wastewater heat recovery system [7]*

The Huber RoWin has two inlet pipes and two outlet pipes. The inlet pipes bring in potable cold water and heated wastewater. The wastewater fills the heat exchanger and surrounds the parallel pipes. As cold-water flows through the parallel pipes the heat from the wastewater is transferred to the cold water and heats it up. By the time the water reaches the outlet pipe, the water is heated and sent to a heat pump for temperature regulation. The wastewater is collected at the other outlet pipe and sent back to the sewer. In this design, a biofilm can form on the outside of the parallel pipes and limit the heat transfer effectiveness of the heat exchanger. To address this issue, an automated arm will scrape the biofilm off the pipes. The solids from the wastewater and this process collect at the bottom of the heat exchanger and are removed by a corkscrew mechanism. In this system, pre-screening of the wastewater must take place before the wastewater can enter the heat exchanger. This is to eliminate debris from backing up the heat exchanger or reducing the thermal efficiency of the process [11]. Also, this system only takes into account using wastewater for heating. If air conditioning is an area where wastewater heat recovery wants to be used, then separate equipment is needed to be added to this to create a refrigeration cycle to address this.

## Engineering Analysis

### Life Cycle Assessment

To begin the LCA, material data were collected and converted into consistent units that would be used in the system input of SimaPro (**Tables 1&2**).

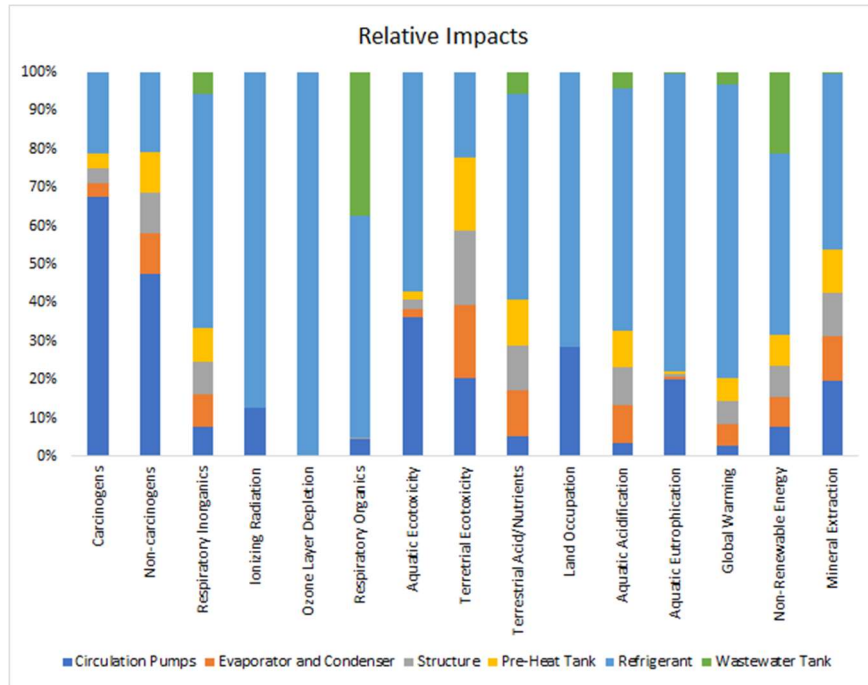
**Table 1: Quantities used for LCA**

<b>Structure</b>					
8835.84	in2	Small sides			
10030	in2	Top/bottom			
12729.6	in2	Large sides			
31595.44	in2	Total area			
219.4128	ft2	Total area			
438.8256	ft2	Total area for 2 units			
2.656	lb/ft2	Density of steel			
1165.521	lb	Weight of steel			
528.67	kg	Mass of steel			
2.281984	lb	Powder coating needed			
1.035	kg	Powder coating needed			
<b>Pre-Heat Tank</b>					
1000	gal	Stainless steel			
13.56	m2	Surface area			
0.02712	m3	Stainless steel needed (2 mm thick)			
7500	kg/m3	Density of stainless steel			
203.4	kg	Mass of stainless steel			
<b>Wastewater Tank</b>					
2250	gal	Minimum capacity			
23.13	m2	Surface area			
0.04626	m3	Polyethylene needed (2 mm thick)			
965	kg/m3	Density of polyethylene			
44.6409	kg	Mass of PE			

**Table 2: Quantities used for LCA**

<b>Circulation Pumps</b>					
3		Pumps needed			
7	lbs	Cast iron			
3.1745	kg	Cast iron needed			
<b>Evaporator</b>					
6240	gal	Evaporation capacity			
875	gal	Volume of evaporator			
202125	in3	Volume of evaporator			
22497	in2	Surface area			
14.51416	m2	Surafce area			
0.029028	m3	Stainless steel needed (2 mm thick)			
217.7125	kg	Mass of stainless steel			
<b>Condenser</b>					
Same as evaporator					
<b>Refrigerant</b>					
31	lbs	R-513a			
14.0585	kg				

Once the inputs were in the format needed for SimaPro, the system was created in the software and analyzed for impacts. The results provided by SimaPro were manipulated to be normalized to one another for relative comparison of components. Finally, the normalized results were put together graphically for simplistic comparison (**Figure 8**).



**Figure 8: LCA results**

### Financial Analysis

For the return on investment, the different line items have been estimated through several different means. For the energy, Sharc provided their estimate on the amount of energy to be saved and used. The energy saved was used to calculate the power saved, and these numbers were used with the 2021 Xcel Energy costs to find the total cost of energy being saved with this system [7]. Also considered is the amount of energy the system will use and the costs associated with this. For the installation, labor costs for plumbers, electricians, and HVAC technicians were researched, and an upper-middle cost per hour was used in conjunction with an estimate of an 8-hour day to install the unit [8,9,10]. The cost for a plumber was estimated to be \$75 per hour, \$100 for an electrician, and \$125 for an HVAC technician. For maintenance, it was estimated the plumber, electrician, and HVAC technician would need to come in twice a year to service the Piranha unit since the Sharc representative stated that it would take very little maintenance. The cost of shipping began with a general cost to ship a washer and dryer across the United States, \$600, and then it was rounded up to \$1,000 [11]. This was to account for the fact that the unit will be larger, and it will have to cross country borders. Commissioning was estimated at 2% per information contained in a paper released by Portland Energy Conservation, Inc., and the taxes were estimated at the standard sales tax in Golden, Colorado, 7.5% [12,13]. The summary of the cost and savings estimations can be seen in **Table 3**.

For the cost of the original system, a lot of similar information was used. The approximate cost of a water heater was found and that information was used [14]. The installation was estimated as an eight-hour day with a plumber and an electrician working using the same per hour estimates listed above. For maintenance, it was assumed that the two would need to come in for a total of six hours per year. The shipping was assumed to be the \$600 found in the research above since it would not have to be shipped across country borders.

*Table 3: Summary of costs and savings*

Cost of Piranha Unit		Cost of Water Heater (Original System)	
Item	Total Cost	Item	Total Cost
PIRAHNA T15 HC	\$73,000.00	Water Heater	\$2,000.00
Energy	\$3,931.05	Installation	\$1,400.00
Power	\$59.50	Taxes	\$150.00
Installation	\$2,400.00	Energy	\$13,177.45
Maintenance	\$600.00	Power	\$199.45
Shipping	\$1,000	Maintenance	\$1,050.00
Commissioning	\$1,460.00	Shipping	\$600
Taxes	\$5,475.00		
<b>Total Up-Front Cost</b>	<b>\$83,335.00</b>	<b>Total Up-Front Cost</b>	<b>\$4,150.00</b>
<b>Total per Year</b>	<b>\$4,590.55</b>	<b>Total per Year</b>	<b>\$14,426.90</b>

As seen above, both the up-front and yearly costs were included to ensure the yearly cost for energy used was not ignored. After these costs were found, the return on investment was calculated. To do this, the cost and savings of every year were added to find the overall cost saved per year. The time value of money and rate of return has not been included in the estimate shown in **Table 4**, but it is the next step for the return on investment to be calculated. The current numbers result in a return on investment in nine years, but this will likely increase once the time value has been included.

*Table 4: Summary of return on investment*

Year	Cost	Yearly Savings	Total Remaining
0	\$83,335.00	\$8,786.35	\$74,548.65
1	\$74,548.65	\$8,786.35	\$65,762.30
2	\$65,762.30	\$8,786.35	\$56,975.95
3	\$56,975.95	\$8,786.35	\$48,189.61
4	\$48,189.61	\$8,786.35	\$39,403.26
5	\$39,403.26	\$8,786.35	\$30,616.91
6	\$30,616.91	\$8,786.35	\$21,830.56
7	\$21,830.56	\$8,786.35	\$13,044.21
8	\$13,044.21	\$8,786.35	\$4,257.86
9	\$4,257.86	\$8,786.35	\$(4,528.48)
10	\$(4,528.48)	\$8,786.35	\$(13,314.83)

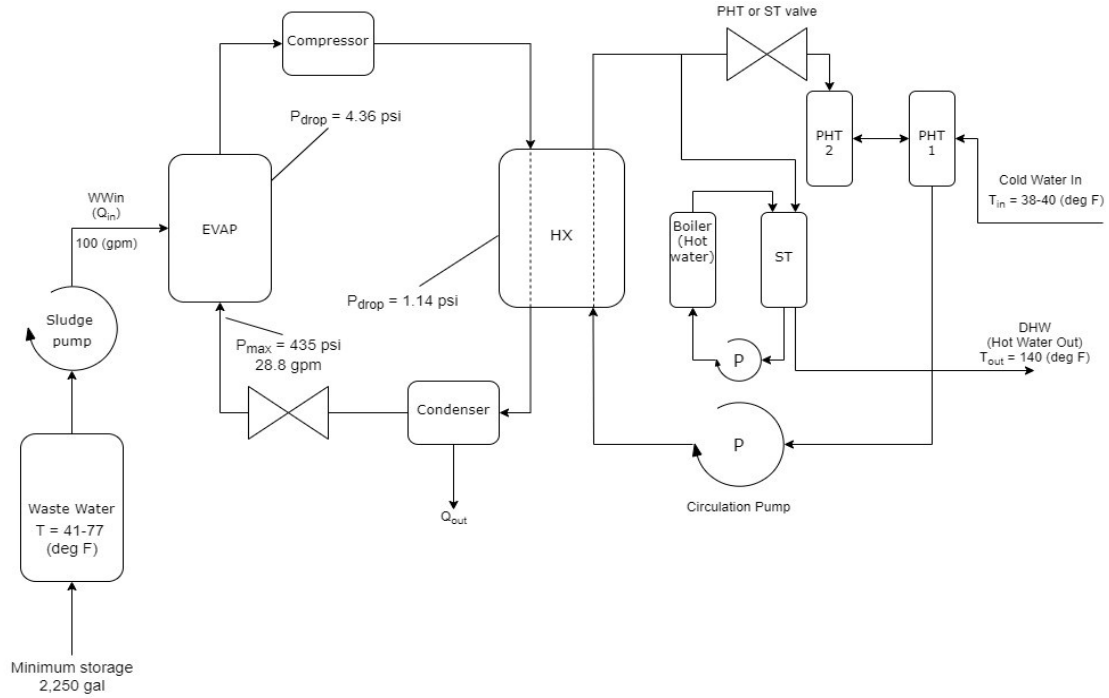
Finally, a rate of return analysis was conducted to find what the rate of return would be over a number of years. To do this, the cost for the original solution was subtracted from the cost for the Piranha unit, and the rate of return was conducted on the result. The overall rate of return for every five years can be seen in **Figure 9**.



**Figure 9:** Rate of return of the project over 5-year intervals

#### Thermal Analysis

To conduct a fair and accurate thermal analysis for this system, a few assumptions and constraints were established. First, it is important to establish that the analysis is comprised of two cycles: one being a heating cycle and the other being a refrigeration cycle (**Figure 10**). The refrigeration cycle resembles the components of the Piranha unit that will be used to extract heat from the wastewater, transfer this heat to the domestic water, and reject any remaining heat. To perform this task, the working fluid of the refrigeration cycle is R513a, a commercial grade refrigerant that is more environmentally friendly than the old industry leading refrigerant R22. The heating cycle's purpose is to bring in domestic cold water and produce domestic hot water. This cycle performs with only water being used in the cycle.



**Figure 10:** Thermal Analysis Diagram of the Wastewater Heat Recovery System

The major operating conditions were assumed for the thermal analysis based on the findings of preliminary research. These operating conditions include the temperatures and pressures of the domestic cold water and domestic hot water and the temperatures and pressures of the wastewater supplied. All components of this system were assumed to be adiabatic, meaning that they would experience no heat loss to the environment, unless specified by the manufacturer. The manufacturer also specified that specific components experience a decrease of pressure from the inlet to outlet of the component and this was considered in the analysis. The flow rates of the two cycles were determined by manufacturer specifications stating the limiting flow rates for components. The lowest limiting flow rate was selected for each cycle and was held constant throughout the entire cycle. For the refrigeration cycle, the efficiency of the cycle, also known as the coefficient of performance (COP), was assumed to be 3.0 based on research of refrigeration cycles for the region and discussions with industry experts. This portion of the analysis does not consider time and assumes steady state conditions for all tanks. A further analysis may be conducted to determine time dependencies between filling and discharging the tanks. Finally, this analysis was conducted using the phase change (PC) model. This model considers the working fluids of the cycles to be in a pure form and evaluates state changes of the fluid between solid, liquid, and gas. Using this model for the analysis governs further assumptions and equations used for calculations.

The major question that the thermal analysis is supposed to answer is: how efficient is this system? To determine this, the two cycles are analyzed individually and then combined. The equation for efficiency can be seen in **Equation 1** below.

Equation 1:

$$\eta_{tot} = \frac{\text{power produced}}{\text{energy consumed}}$$



Efficiency is determined by the ratio of the total amount of power produced by the system with the total amount of energy consumed by the system. For this analysis the energy being input into the system and consumed is done by the boiler in the heating cycle and the wastewater into the evaporator in the refrigeration cycle. The majority of the power consumption for both systems will come from the three pumps and the compressor. The evaporator and condenser do not produce any work and so they are left out of the analysis. With this knowledge, Equation 1 can be modified to represent **Equation 2**.

Equation 2:

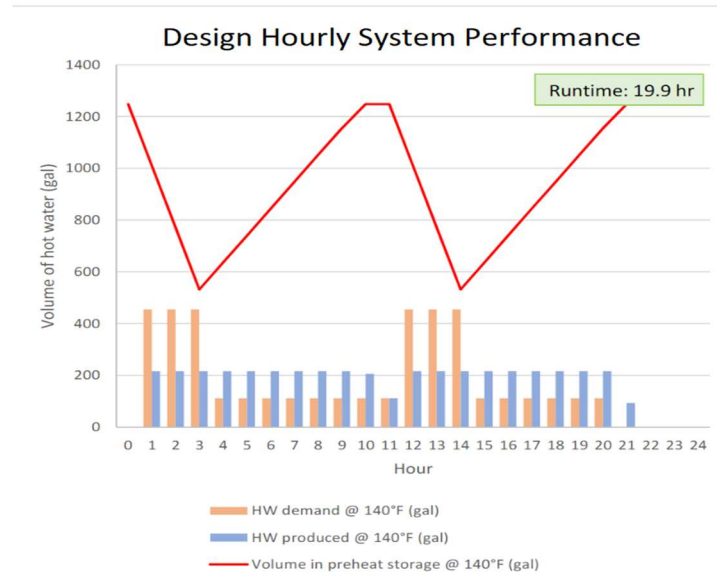
$$\eta_{tot} = \frac{Q_{in,waste} - W_{pum} - W_{pump2}}{W_{comp} + Q_{in,boiler}}$$

To determine how much energy a component in either cycle uses or produces can all be determined using the same equation. To measure this, determine the enthalpic difference across the component and multiply that difference by the mass flow rate of the fluid into the component. This relationship can be visualized in **Equation 3**.

Equation 3:

$$W_{component} = m \times (h_{in} - h_{out})$$

The results of the analysis are shown below in **Figure 11**. This figure displays the amount of hot water consumed for the building, the amount produced, and the storage amount. This graph is broken down by the hours of the day to show how the system is operating with time.



**Figure 11:** Daily hot water usage and storage

The thermal analysis was able to confirm the performance metrics of the system that were provided by Sharc Energy. These metrics included that the Piranha unit will be adequate to provide all the daily demand for hot water for the building and will operate with an average coefficient of performance of three. The rest of these performance metrics can be seen in **Figure 12** below.

Main Selection Performance Stats	
Selection type	Primary selection
Selection	1 × PIRANHA T15
Nominal heating output (BTU/h)	180,000
Estimated % of daily demand provided by PIRANHA	100%
Estimated % of peak demand able to be provided by PIRANHA	100%
Average COP	3.0
Estimated runtime (hr/day)	19.9
System recovery rate, 140°F (US gal/hr)	216.0
Hot water production, 140°F (US gal/day)	4,300
Hot water production, 140°F (US gal/year)	1,569,500
Estimated heat output from PIRANHA (therm/year)	13,076.8
Estimated baseline fuel offset using PIRANHA (therm/year)	15,384.5
Estimated power consumption by PIRANHA (kWh/year)	127,748.1
Expected net DHW heating energy use reduction (therm/year)	11,025.6
Available space cooling (MBTU/h)	144.0
Estimated net GHG reduction (metric t CO2e/year)	3.9
Equivalent number of cars off road to offset GHG emissions	0.9
Equivalent number of trees needed to offset GHG emissions	179
Auxiliary Components	
Recommended total usable DHW storage, 140°F (US gal)	1,248
Recommended usable preheat storage (US gal)	1,248
Recommended usable top-up storage (US gal)	0
Recommended wastewater storage based on estimated peak flow (US gal)	3,334
Minimum recommended wastewater storage (US gal)	3,334
Recommended minimum top-up/redundancy (MBTU/h)	90.0
Recommended minimum top-up/redundancy (kW)	26.4
Estimated required top-up energy to meet demand (MBTU/h)	0.0

*Figure 12: Performance metrics of the wastewater heat recovery system*

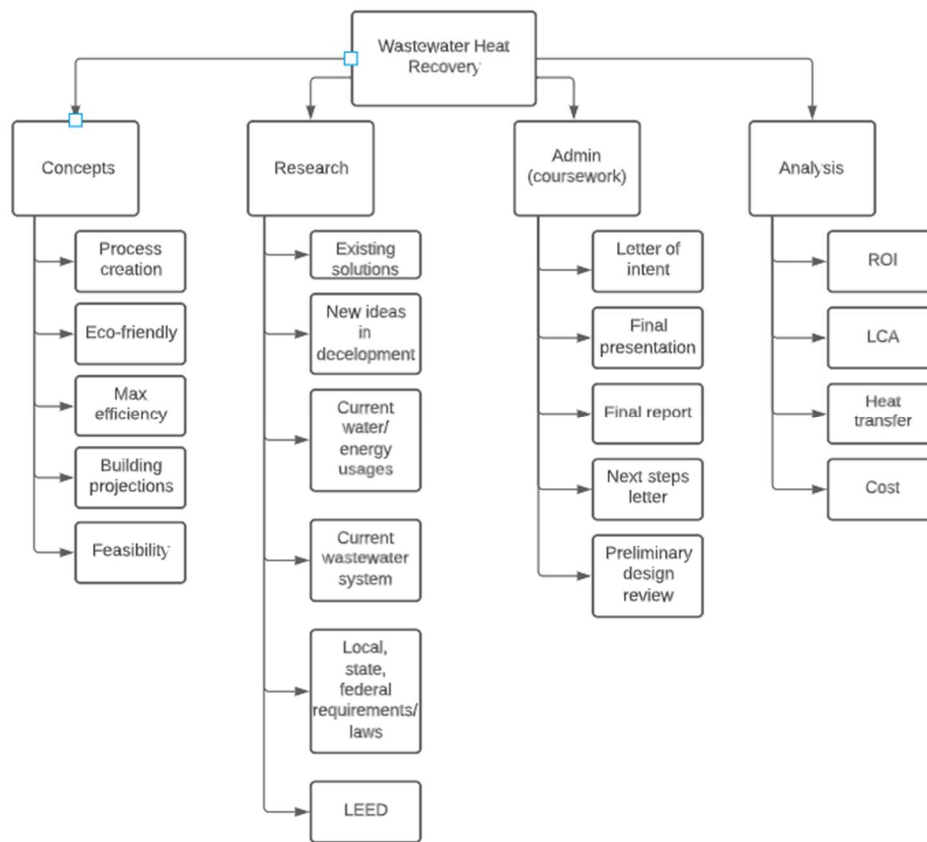
## Final Deliverables

Due to the nature of this project as a predominantly research-based and conceptual project, this final design report is the primary final deliverable submitted. Included in this report are all pertinent drawings, graphs, tables, equations, and ideas. The team will also submit an Excel file that can be used to predict the return-on-investment rates should there be changes to costs or savings at any point in the implementation process. Unfortunately, due to software restraints, the same cannot be done for the LCA nor the thermal analysis. The team also created an informational flyer to be used at community outreach events which can be found in the **Appendix**.

## Project Management

### Work Breakdown Structure

Throughout the project, the work breakdown structure remained relatively consistent in terms of who was responsible for what aspects of the project. Hanna was responsible for all things financial, Daniel and Sam oversaw the mechanical aspects, and Jo did the environmental analysis work. The breakdown of the work can be seen in **Figure 13** below.



**Figure 13:** Work Breakdown Structure for wastewater heat recovery project

### Schedule

The team did not follow a strict schedule over the course of the project aside from the deadlines on portions of the project assigned by the advisors. For weekly scheduling, the team operated with the agile method. This method consists of two-week intervals, known as sprints, where the team will organize a set amount of work to complete every sprints. The team meets twice every week to give an update on the progress of their work and can ask for assistance, if necessary.

### Budget

Since this project was largely conceptual, the team found that there was not a need for the budget during the development of this project.

### Next Steps

When the City of Golden begins to design the buildings that will be a part of the Heart of Golden initiative, they will be able to incorporate the Sharc Piranha Unit since the School of Mines team found it would help their goal of reaching net zero carbon emissions. Though the City does not have all the details, they will be able to contact Sharc through the representative the team had worked with during the project, Brock Trimble, and he will be able to provide more detailed information as the building is developed and the size and hot water need for the building is more concrete. In addition, an excel spreadsheet with cost information has been provided for the city to fine tune and add to once the prices are known as well. Further layout design and analysis will

need to be done on the HVAC design. Preliminary research suggests a rooftop HVAC design, but further research would need to be done before implementation.

Lastly, the team explored solar as a way to power the Piranha Unit instead of using the traditional city power, and this has also proved to be a viable way to both save money and reduce emissions. With the size of the proposed building there is a lot of roof space available. It would only take two thousand square feet to cover the top up capacity using a 16 square foot solar panel [15]. This equates to 100 panels and 40kW of power available. From our knowledge of the building design there would be room for at least 500 panels which could provide upwards of 200kW of power to the building. If the city of golden decides to continue to pursue the use of solar the buildings in the Heart of Golden will be even more sustainable. So, the team recommends exploring this further as the buildings are designed and developed.

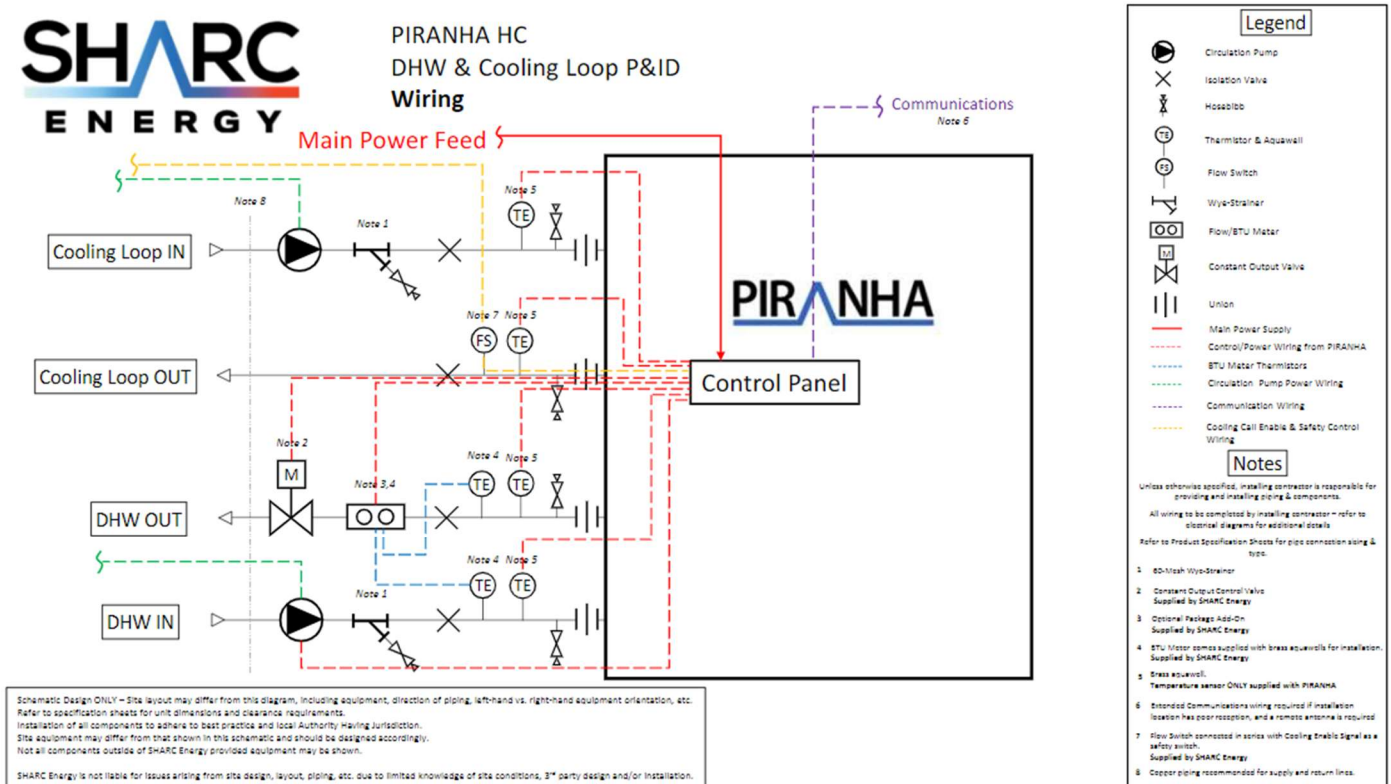
## **Lessons Learned**

One lesson learned from this project is how to manage the many facets of a project that requires work from multiple disciplines. Up to this point, many projects that team members have worked on have been projects specific to their respective majors in teams with other members of their majors. Because this project was interdisciplinary, there was opportunity for growth in learning how to work with and help with the design process outside of a given major.

Another lesson was how to prioritize the needs of clients. Towards the beginning of the project, an advisor recommended additional work to the team that would have taken the project in an entirely different direction. After thoughtful deliberation, the team decided to continue with the original project statement as laid out by the client. This taught the team to take advisors into account but hold the client's desires as the most important influencer of decisions.

# Appendix

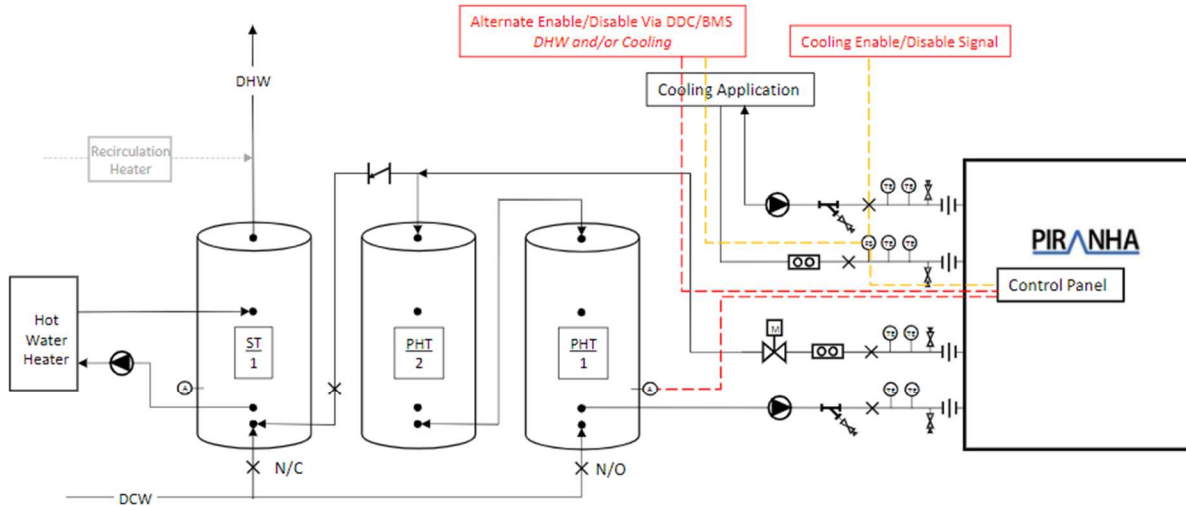
## Appendix A-1: Wiring diagram for P&ID DHW and cooling loops



## Appendix A-2: Wiring diagram for DHW and cooling loops with optional BTU meter



### PIRANHA HC DHW P&ID w/ Optional BTU Meter DHW System & Storage Tank Piping Demand Call Wiring



Schematic Design ONLY - Site layout may differ from this diagram, including equipment, direction of piping, left-hand vs. right-hand equipment orientation, etc. Refer to specification sheets for unit dimensions and clearance requirements.

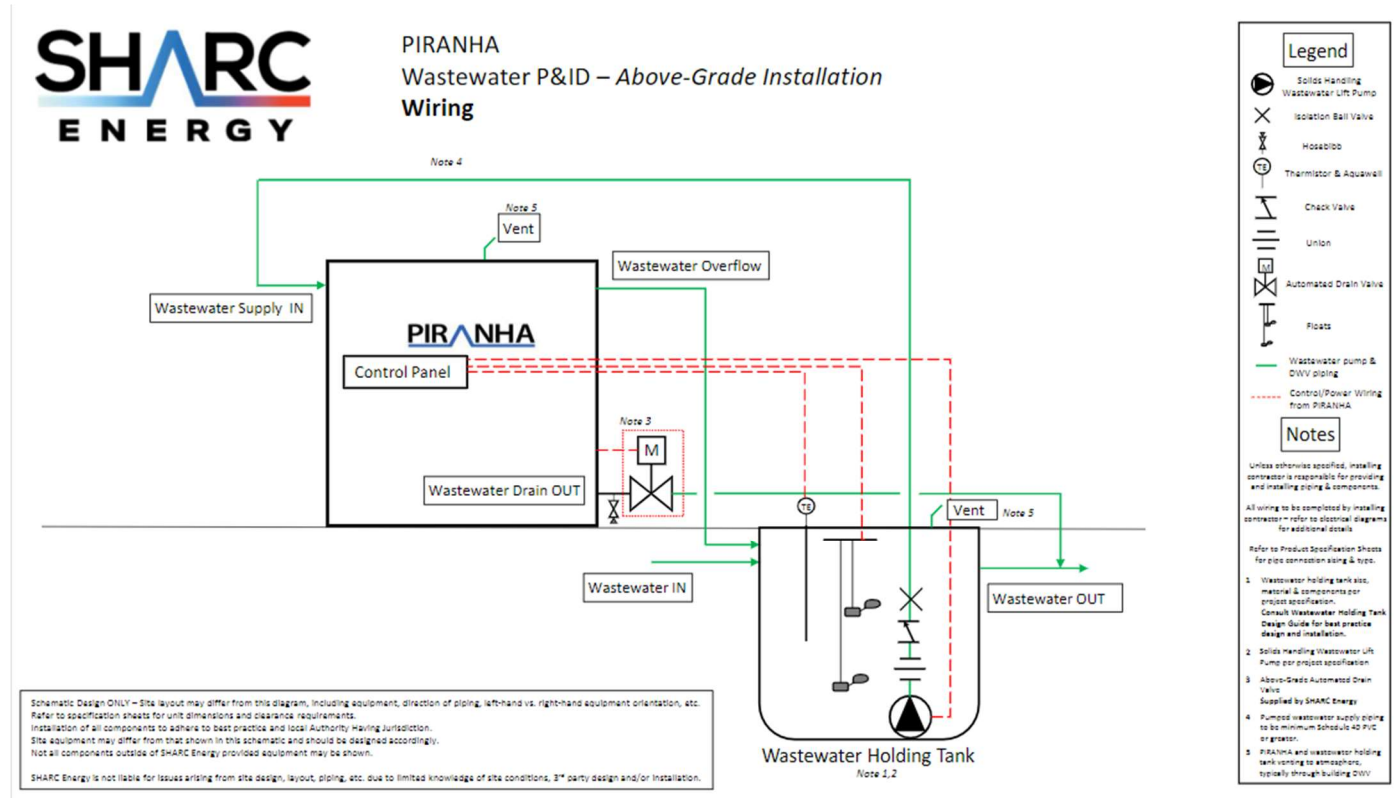
Installation of all components to adhere to best practice and local Authority Having Jurisdiction.

Site equipment may differ from that shown in this schematic and should be designed accordingly.

Not all components outside of SHARC Energy provided equipment may be shown.

SHARC Energy is not liable for issues arising from site design, layout, piping, etc. due to limited knowledge of site conditions, 3<sup>rd</sup> party design and/or installation.

## Appendix A-3: Wiring diagram for wastewater P&ID loop





#### Appendix A-4: Theoretical building used for calculations



**CITY OF GOLDEN:  
HEART OF GOLDEN**

<https://www.guidinggolden.com/heart-of-golden>



**WASTEWATER  
HEAT  
RECOVERY**

Buildings may implement Piranha HC units for wastewater heat recovery.

**Energy Savings**

The amount of energy input required for heating and cooling building will be reduced compared to a regular HVAC system. The required energy inputs can be provided by solar.

**Cost Savings**

Due to reduced energy input required, return on investment is rapid and lends itself to monetary savings over time.

**Sustainability**

Environmental analyses show limited environmental impacts due to system creation and operation compared to regular HVAC systems.

**WHY HEAT RECOVERY?**

More than half of the energy demanded by a house is demanded for ambient heating and cooling. Hot water from showers, laundry, and other household activities hold heat that is wasted when the water is sent to the sewer. Wastewater heat recovery systems, like the Piranha HC, harness this rejected heat and turn it into ambient heating and cooling for the building.

**THEORETICAL BUILDING**

The analyses completed by the School of Mines team were performed using the values provided by a theoretical building. The building matches the description of an idealized multi-use structure to house 50 apartments and 25,000 square feet of retail space.

**More About Share**

<https://www.shareenergy.com/>

<https://www.shareenergy.com/products/piranha-wastewater-heat-recovery-system/>

## Works Cited

- [1] “Heart of Golden 2020 Map.” *City of Golden*. Golden, Colorado, USA. [Online]. Available: <https://www.guidinggolden.com/heart-of-golden-2020/widgets/13606/photos/5297>, [Accessed: 7-Sep-2021].
- [2] “REGULATION NO. 38 - CLASSIFICATIONS AND NUMERIC STANDARDS FOR SOUTH PLATTE RIVER BASIN, LARAMIE RIVER BASIN, REPUBLICAN RIVER BASIN, SMOKY HILL RIVER BASIN.” *Colorado Department of Public Health and Safety*. Colorado, USA. [Online]. Available: <https://www.sos.state.co.us/CCR/GenerateRulePdf.do?ruleVersionId=9588&fileName=5%20CCR%201002-38>
- [3] H. Nagpal, J. Spriet, M. K. Murali, and A. McNabola. “Heat Recovery from Wastewater— A Review of Available Resource.” *Water*, 2021, 13, 1274, April 2021. [Online]. Available: <https://www.mdpi.com/2073-4441/13/9/1274>. [Accessed: 23-Sep-2021].
- [4] A. Uk. “Diagram showing how a Waste Water Heat Recovery unit can be installed into a house.” *Wikipedia*. [Online]. Available: [https://en.wikipedia.org/wiki/Water\\_heat\\_recycling#/media/File:Waste\\_Water\\_Heat\\_Recovery\\_in\\_the\\_most\\_efficient\\_'equal\\_flow'\\_configuration.png](https://en.wikipedia.org/wiki/Water_heat_recycling#/media/File:Waste_Water_Heat_Recovery_in_the_most_efficient_'equal_flow'_configuration.png). [Accessed: 128-Oct-2021].
- [5] “Concepts of Wastewater Heat Recovery”. REHVA, 2013. [Online]. Available: <https://www.rehva.eu/rehva-journal/chapter/in-house-waste-water-heat-recovery>. [Accessed: 28-Oct-2021].
- [6] *Wall Center, Phase 2*. Sharc Energy, 2012. [Online]. Available: <https://www.sharcenergy.com/wall-centre-central-park-phase-2/>. [Accessed: 27-Oct-2021].
- [7] *Building Features*. Bullitt Center, 2013. [Online]. Available: <http://bullittcenter.dreamhosters.com/building/building-features/>. [Accessed: 5-Oct-2021]
- [8] S. Garmsiri, S. Koochi, and M. A. Rosen. “Heat recovery from sewage waste heat.” *Recovery of Sewer Waste Heat vs. Heat Pumps Using Borehole Geothermal Energy Storage for a Small Community Water Heating System: Comparison and Feasibility Analysis*. [Online]. Available: <https://sciforum.net/manuscripts/2680/manuscript.pdf>. [Accessed: 28-Oct-2021].
- [9] “HUBER Solution for Heat Recovery from the Wastewater Treatment Plant Effluent.” *Huber Technology Waste Water Solutions*, 2021. [Online]. Available: <https://www.huber-technology.com/solutions/heating-and-cooling-with-wastewater/heat-from-wwtp-effluent.html>. [Accessed: 3-Nov-2021].
- [10] “Piranha wastewater heat recovery system,” *SHARC Energy*, 21-Sep-2021. [Online]. Available: <https://www.sharcenergy.com/piranha-wastewater-heat-recovery-system/>. [Accessed: 15-Oct-2021].
- [11] “Huber Heat Exchanger Rowin,” *HUBER Heat Exchanger RoWin - HUBER SE*, 21-Oct-2021. [Online]. Available: <https://www.huber.de/products/energy-from-wastewater/huber-heat-exchanger-rowin.html>. [Accessed: 27-Oct-2021].
- [12] D. T. “Mixed use storefront building.” *3D Warehouse*, 2018. [Online]. Available: <https://3dwarehouse.sketchup.com/model/945b84d7-dd2d-486e-9928-2e01c2957fbd/Mixed-use-storefront-building>. [Accessed: 28-Oct-2021].

- [13]“U.S. Energy Information Administration - EIA - independent statistics and analysis,” *EIA*, Dec-2016. [Online]. Available: <https://www.eia.gov/consumption/commercial/reports/2012/water/>. [Accessed: 14-Oct-2021].
- [14] “How Much Does It Cost To Install A Water Heater?,” HomeAdvisor, 02-Mar-2022. [Online]. Available: <https://www.homeadvisor.com/cost/plumbing/install-a-water-heater/>. [Accessed: 31-Mar-2022].
- [15] “Sunpower Maxeon 5 AC Modules .” *Powerful Maxeon 5 AC Modules | Maxeon 5 | SunPower Global*, <https://sunpower.maxeon.com/int/solar-panel-products/ac-modules/maxeon-5-ac>. [Accessed: 16-Mar-2022].