DOMESTIC HOT WATER, ALTERNATIVE ENERGY STUDY

NYC SCHOOL CONSTRUCTION AUTHORITY

OLA PROJECT NO.: NSCA1002.01

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TABLE OF CONTENTS

1.0 Executive Summary

OLA Consulting Engineers (OLA) was tasked with providing an alternative energy domestic hot water (DHW) study for the New York City School Construction Authority (SCA). The intent of this study is to determine the feasibility of removing the use of fossil fuels from DHW systems while considering maintenance and operational requirements.

Often domestic hot water systems are considered to be oversized. Conventions and code process establishes sizing methods that appear to far exceed consumption in schools given today's programming and usage. To better understand the actual domestic hot water consumption, four schools were visited and a water meter was installed on the domestic hot water piping to obtain an estimated daily consumption profile for each school. The approach for metering is found in the study and as suspected, the consumption was far less than the existing design anticipated. Although this testing was a sample of the types of schools, it informed the economics of the options considered. The metering data was utilized to generate a domestic hot water load profile and to determine a base daily consumption for each school. The meter was installed in four (4) NYC Public Schools with each school varying in size, number of occupants, and function (elementary vs. high school).

After initial review of options for an alternative energy domestic hot water system with the SCA, five (5) systems were selected to be further developed for study. The options are described as follows:

- Option 1: Solar Photovoltaic (PV) with electric heat pump (all electric)
- Option 2: Solar Thermal DHW with electric heat pump backup (auxiliary heat)
- Option 3: Solar Thermal DHW with gas fired backup (auxiliary heat)
- Option 4: Combination of Solar Thermal and Solar PV, with electric heat pump
- Option 5: Point of Use electric DHW

This study found that Option 1 appears to have the least first cost in most cases to get to a 100% renewable domestic hot water system. Note that these systems will be renewable in the sense that the local installed PV arrays offset the net energy consumed by the heat pumps. This approach eliminates the fossil fuel use for DHW onsite. Energy cost savings may or may not actually be realized with this option depending on the specific demand profile and demand rates at a particular school. Some control optimization to mitigate demand impacts would be needed for this and the other options.

Option 2 and 3 were explored extensively during this study, and it was found that the solar thermal systems are not able to cost effectively provide a 100% renewable solution. They can be effective at providing about 55% renewable DHW, and still generate some energy cost savings and avoided fossil fuel use onsite.

Option 4 combines the best features of both Option 1 and Option 2. By using the solar thermal installation, onsite fossil fuel use for DHW can be removed, while the electric auxiliary heat pump usage is minimized and offset by the PV system. This system can be said to be 100% renewable, again in a virtual sense due to the nature of the PV system. This option has the drawback of multiple technologies (i.e. thermal and PV along with backup electric) which can increase first costs and complicate maintenance and operations.

Option 5 was found to have some advantages and disadvantages. The primary advantage of the point-of-use system is that it eliminates the system losses associated with recirculating hot water systems and reduces energy consumption compared to the gas fired baseline or existing systems. The disadvantages are increased operational cost due to heavy electric demand increase, increase to electrical service, and energy performance not as high performing as the heat pump options. In addition, in order to be considered 100% renewable as Option 1 and 4 were, the PV system provided would have to be 3 times larger. Option 5 therefore would be expected to be the most expensive system to install.

This study includes more details of the investigated options for alternative energy domestic hot water to be implemented at NYC Public Schools including schematics, potential installation costs, and annual savings of each option. Options that have been considered are scalable for a variety of school types and resulting DHW demand.

2.0 Existing Schools: Conditions and Typical Operation

2.1 School A Domestic Hot Water Sub-Meter Analysis and Survey

School A is a three story (plus basement), 83,000 square foot elementary school serving grades pre-kindergarten – 5th grade. Typical school hours last from 8:00 am – 2:30 pm. After school activities such as YMCA programs begin after 2:30 pm and continue until approximately 5:00 pm. During this time cleaning crews are also actively cleaning throughout the school and continue to clean into the evening hours.

The domestic hot water loads throughout the building are served by one (1) gas-fired domestic hot water heater and one (1) 318 gallon storage tank (Photo 1). The domestic hot water system provides 140°F hot water to the kitchen, and provides tempered hot water to the rest of the hot water fixtures via a three-way mixing valve (Photo 2). Table 1 provides a summary of the existing domestic hot water equipment for this school. The domestic hot water loads throughout the building consist of lavatories, classroom sinks, janitor sinks, service sinks, and kitchen sinks (Photo 3 and Photo 4). The kitchen serves two meals a day beginning with breakfast from 8:00 am – 9:30 am and lunch from 11:05 am – 12:50 pm.

Table 1. School A Existing Domestic Hot Water Equipment Summary

School	Manufacturer	Heater Model	Tank Model	Heating Capacity (Btu)	Storage Capacity (gal)	Efficiency
School A	Lochinvar	CWN399PM	RGA0318	399,000	318	82%

Photo 1. School A DHW Storage Tank

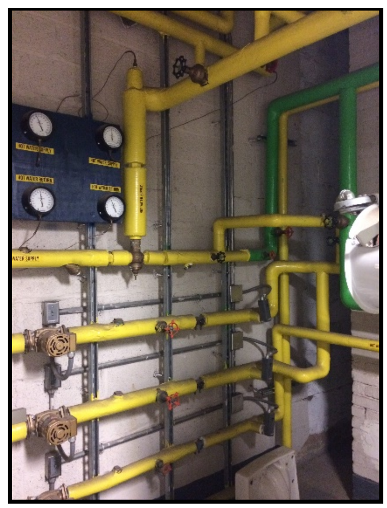


Photo 2. School A DHW Piping and Three-Way Mixing Valve

Photo 3. School A Typical Kitchen Sink

Photo 4. School A Typical Lavatory Sinks

The school's existing domestic hot water heater and storage tank is located in the basement boiler room. Domestic hot water is distributed throughout the building by three (3) recirculation pumps. One recirculation pump serves the kitchen hot water, another pump serves the tempered hot water, and the third pump serves a small tempered hot water line serving the basement bathrooms and janitor closets. The domestic hot water system is located in close proximity to an existing chimney that is currently not in operation. The school is currently using the chimney as a shaft to run conduit and other electrical items through it (Photo 5). The chimney penetrates through the roof, so it would be feasible to run conduit or piping from the roof and down into the boiler room (Photo 6). The roof of School A also has no roof-mounted mechanical equipment, which will make mounting any additional equipment on the roof feasible.

Photo 5. School A Inside Chimney Shaft

Photo 6. School A Chimney Shaft Through Roof

2.2 School B Domestic Hot Water Sub-Meter Analysis and Survey

School "B" is a four story, 180,000 square foot high school serving grades 9 – 12. Typical school hours last from 7:55 am – 2:10 pm. After school activities and after school sports programs begin after 2:10 pm and continue until approximately 5:00 pm. Cleaning crews are actively cleaning the building at 5:00 pm and continue into the evening hours.

The domestic hot water loads throughout the building are served by one (1) gas-fired domestic hot water heater and one (1) 700 gallon storage tank (Photo 7). The domestic hot water system provides 140°F hot water to the kitchen, and provides tempered hot water to the rest of the hot water fixtures via a three-way mixing valve (Photo 8). Table 2 provides a summary of the existing domestic hot water equipment for this school. The domestic hot water loads throughout the building consist of lavatories, classroom sinks, janitor sinks, service sinks, and kitchen sinks (Photo 9). The kitchen serves two meals a day beginning with breakfast from 7:30 am – 7:50 am and lunch from 11:03 am – 11:48 am.

Table 2. School B Existing Domestic Hot Water Equipment Summary

School	Manufacturer	Heater Model	Tank Model	Heating Capacity (Btu)	Storage Capacity (gal)	Efficiency
School B	Lochinvar	CWN0986PM	RGA0700H	986,000	700	81%

Photo 7. School B Existing Gas-Fired DHW Heater and Storage Tank

Photo 8. School B DHW Piping and Three-Way Mixing Valve

Photo 9. School B Typical Kitchen Sink

The school's existing domestic hot water heater and storage tank is located in a penthouse on the roof of the school. Two (2) recirculation pumps recirculate domestic hot water from the kitchen and the tempered hot water from the rest of the building. There are numerous air handlers, exhaust fans, and smoke hatches located on the roof.

2.3 School C Domestic Hot Water Sub-Meter Analysis and Survey

School C is a three story (plus basement), 45,000 square foot elementary school serves grades pre-kindergarten – 2^{nd} grade. Typical school hours last from 8:00 am – 2:30 pm.

The domestic hot water loads throughout the building are served by one (1) gas-fired domestic hot water heater (Photo 10). The domestic hot water system provides 140°F hot water to the kitchen, and provides tempered hot water to the rest of the hot water fixtures via a three-way mixing valve (Photo 11). Table 3 provides a summary of the existing domestic hot water equipment for this school. The domestic hot water loads throughout the building consist of lavatories, classroom sinks, janitor sinks, service sinks, and kitchen sinks (Photo 12). The kitchen serves two meals a day beginning with breakfast from 8:10 am – 8:30 am and lunch from 10:40 am – 12:34 pm.

Table 3. School C Existing Domestic Hot Water Equipment Summary

School	Manufacturer	Heater Model	Heating Capacity (Btu)	Storage Capacity (gal)	Efficiency
School C	AO Smith	BTR275118	275,000	100	80%

Photo 10. School C Existing Gas-Fired Domestic Water Heater

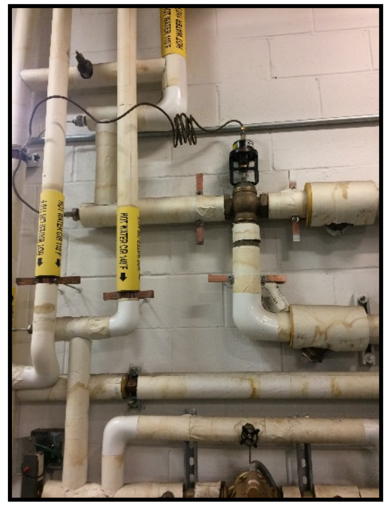


Photo 11. School C DHW Piping and Three-Way Mixing Valve

Photo 12. School C Typical Kitchen Sink

Photo 13. School C Decommissioned Water Heater

The school's existing domestic hot water heater is located in the basement boiler room. The original domestic hot water tank has been decommissioned and replaced with a new domestic hot water tank (Photo 13). The existing system capacity was sized for 600,000 Btu capacity. Two (2) recirculation pumps recirculate domestic hot water from the kitchen and the tempered hot water from the rest of the building. The roof of the school has roof mounted chillers, air handlers, and exhaust fans making roof space limited. There is a higher penthouse roof that may be the best location for mounting any additional roof mounted equipment. There is no direct path to run piping or conduit from the roof down to the basement boiler room. There is one shaft that runs from the roof to the basement but is located behind a wall.

2.4 School D Domestic Hot Water Sub-Meter Analysis and Survey

School D is a four story (plus basement), 373,000 square foot high school serving grades 9 – 12. Typical school hours last from 8:45 am – 3:35 pm. There are after school activities ongoing throughout the school after dismissal. There are also continuing education classes for adults from 5:30 pm – 8:30 pm. Cleaning crews are active in the building from 8:30 pm – midnight.

The domestic hot water loads throughout the building are served by one (1) gas-fired domestic hot water heater and one (1) 175 gallon storage tank (Photo 14). Unlike the other schools, there is no separate 140°F domestic hot water line serving the kitchen. The domestic hot water system provides tempered hot water to all hot water fixtures in the building including the kitchen via a three-way mixing valve (Photo 15). Table 4 provides a summary of the existing domestic hot water equipment for this school. The domestic hot water loads throughout the building consist of lavatories, classroom sinks, janitor sinks, service sinks, and kitchen sinks. The kitchen serves two meals a day beginning with breakfast from 7:30 am – 8:30 am and lunch from 10:30 am – 1:00 pm.

Table 4. School D Existing Domestic Hot Water Equipment Summary

School	Manufacturer	Heater Model	Tank Model	Heating Capacity (Btu)	Storage Capacity (gal)	Efficiency
School D	Lochinvar	CWN0497PM	ST175	495,000	175	81%

Photo 14. School D Existing Gas-Fired DHW Heater and Storage Tank

Photo 15. School D DHW Piping and Three-Way Mixing Valve

The school's existing domestic hot water heater and storage tank are located in the basement boiler room. The original design drawings show two large gas-fired domestic hot water heaters. These have since been replaced by one domestic hot water heater and storage tank. There are two (2) recirculation pumps serving the domestic hot water system. These pumps are piped in parallel and both were operating simultaneously during the site visit. The roof of the school is relatively open and has various small roof-mounted equipment such as exhaust fans. There is a relatively straight run from the roof down to the boiler room along the side of the building next to the adjacent courtyard. This location appears to be feasible for running piping into the boiler room.

3.0 Metering Domestic Hot Water Daily Consumption

3.1 Metering Approach

The meter that was used for the analysis was a Fuji Portaflow-C FSC-2 ultrasonic flow meter. This is a clamp-on flow meter that attaches to the outside of the pipe that is being metered (Photo 16). Once the flow meter is securely attached to the pipe, it generates ultrasonic waves that travel through the inside of the pipe that determine the amount of flow inside the pipe. The flow meter is able to record data such as flow rate, fluid velocity and total consumption (Photo 17).

Photo 16. Clamp-On Ultrasonic Meter Attached to Domestic Water Inlet Piping

Photo 17. Data Logger Recording Metering Data

For each school studied, the goal was to meter the domestic hot water consumption for the duration of a typical school day. The meter was installed at each school in the early morning hours before the building was occupied. Having the meter installed early in the morning would show any early morning kitchen consumption in the data collected. The meter continued to record data for the entirety of the school day encompassing lunch periods, after lunch kitchen clean-up, and any other domestic hot water usage such as washing of hands or gym showers. The meter continued to record data after dismissal to capture the domestic hot water consumption during after school activities and any cleaning crew water consumption.

3.2 Metering Results

3.2.1 School A Metering Results

The peak hot water demand for school School A was found to be during the lunch hours of 11:35 am – 12:19 pm consuming a total of approximately 43 gallons. There was also a peak hot water demand around the time of dismissal from 1:27 pm – 2:04 pm consuming a total of approximately 41 gallons. The total daily consumption of domestic hot water was found to be approximately 162 gallons metered from 7:05 am – 4:30 pm. Refer to Appendix A for the metering data for this school.

3.2.2 School B Metering Results

School B showed a relatively constant demand of hot water consumption throughout the school day. There was not one specific period of large peak domestic hot water consumption; however, the data shows five (5) shorter peaks of domestic hot water consumption throughout the day. The largest peak occurred around the time of dismissal from 1:09 pm – 1:48 pm and then again at 2:06 pm – 2:28 pm. This peak period consumed a total of approximately 129 gallons. The total daily consumption of domestic hot water was found to be approximately 436 gallons metered from 6:55 am – 4:44 pm. Refer to Appendix A for the metering data for this school.

3.2.3 School C Metering Results

School C had a relatively low domestic hot water load throughout the day. Nearly all of the domestic hot water load of this school was used by the kitchen during lunch hours. The peak hot water demand for the school was found to be during the lunch hours of 11:10 am – 1:24 pm consuming a total of approximately 214 gallons. Roughly 84% of the total domestic hot water consumption was used during this lunch period. The total daily consumption of domestic hot water was found to be approximately 255 gallons metered from 6:45 am – 4:27 pm. Refer to Appendix A for the metering data for this school.

3.2.4 Summary of Domestic Hot Water Metering Results

Table 5 summarizes the domestic hot water metering results for the schools included in this study. Table 5 shows that school School C had the highest gal/student ratio with 0.73 gal/student/day, and that school School B had the most daily hot water consumption with 436 gal/day. According to published ASHRAE values, the average domestic hot water consumption for a typical school is 0.60 gal/student/day (ASHRAE HVAC Applications 2015). For these three schools, the average daily domestic hot water consumption equates to 0.44 gal/student/day. On average, the metered schools consume approximately 27% less domestic hot water per day when compared to ASHRAE values.

Table 5. Domestic Hot Water Metering Results

School	Area (ft^2)	Number of Students	Peak GPM	gal/day	Average gal/student/day
School A	83,000	718	6.8	162	0.23
School B	180,000	1,244	12.8	436	0.35
School C	45,000	350	10.4	255	0.73
School D*	373,000	2,492	20.8	1,404*	0.56*
				Average*	0.44
				ASHRAE Average Value**	0.60

*The metering data for school “D” was disregarded for the purposes of this study due to the excessive water usage observed, caused by operational issue noted on the day of the survey. The average gal/student/day excludes School D.
**ASHRAE HVAC Applications 2015, Chapter 50, page 50.10 table 6

From the above metering results, it can be inferred that the typical NYC school is likely using less than the average ASHRAE expected value. This seems reasonable considering that the schools surveyed did not appear to have heavily active cooking kitchens. It did not appear that the showers were in use much during a normal day (which has become more typical for schools).

4.0 Domestic Hot Water Alternatives

4.1 Summary of Domestic Hot Water Alternatives Considered

4.1.1 Option 1: Solar Photovoltaic System with Electric Heat Pump

This option includes replacing (or supplementing) the existing gas-fired domestic hot water heater with an electric heat pump water heater, coupled with solar photovoltaic panels. The electric heat pump (sometimes called hybrid water heaters), would be sized to provide 100% of the daily domestic hot water consumption used at the schools. Since most of the daily hot water usage of the schools occurs during a 1 to 2 hour peak period, providing an adequate amount of storage is necessary.

There are generally two styles of heat pump water heaters on the market currently: The integral tank hybrid type, and commercial style heat pump water heaters. An example hybrid-style heat pump is shown in Figure 1. There are many manufacturer's currently of this type of water heater.

Figure 1. Hybrid Style Electric Heat Pump Domestic Hot Water Heater

The hybrid-style heat pumps reviewed were able to produce high hot water temperatures suitable for kitchen needs. This style of heat pump water heater provides its own storage capacity. These heat pump water heaters provide relatively low recovery rates while in heat pump mode (the most energy efficient mode). This would require multiple heat pump water heaters to be installed so the domestic hot water system can recover the storage tank without using the electric resistance mode during the building unoccupied hours.

The commercial-style heat pump water heater operates similar to the hybrid-style heat pump, but with increased water heating capacities, slightly better efficiencies, and more sophisticated controls. (These units do not have an electric resistance heating mode).

One main difference between the commercial and hybrid-style heat pump water heater is the commercial heat pump does not offer any storage capacity. The commercial heat pump must be paired with a storage tank capable of meeting the hot water load of the building during peak periods.

In schools where existing storage tanks exist, the commercial heat pump may be a more logical option than the hybrid-style. In addition, only one commercial-style heat pump water heater would need to be installed to satisfy the domestic hot water heating loads in the schools included in this report (since the commercial heat pump can satisfy larger water heating demands). Example commercial-style heat pump water heaters are shown in Figure 2 and Figure 3 below.

Figure 2. Commercial Electric Heat Pump Domestic Hot Water Heater

Figure 3. Commercial Electric Heat Pump Domestic Hot Water Heater

In addition to the above two types of heat pump water heaters, a third technology available are chiller-heater air-source heat pumps. These are heat pumps usually intended for HVAC applications but with an added heat exchanger, can be easily adapted to make domestic hot water. These type of heat pumps are similar to the commercial heat pumps described above and can make hot water up to 145 ºF. Example chiller-heater air source heat pump water heaters are shown in Figure 4 and Figure 5 below.

Figure 4. Commercial Electric Chiller-Heater Air Source Heat Pump Water Heater

Figure 5. Commercial Electric Chiller-Heater Air Source Heat Pump Water Heater

In both heat pump water heater scenarios, it is desirable to locate these heat pump water heaters in areas of the building where either "free" space heat is available (i.e. boiler rooms or kitchens), and/or where spot cooling is needed. This will increase the efficiency of the heat pumps. The heat loss generated by the boiler casing losses or the heat generated from the cooking and refrigeration equipment would be able to be absorbed by the heat pump water heater. Figure 6 shows a representation how the heat from the surrounding space would be absorbed from the heat pump water heater, in the example of a boiler room.

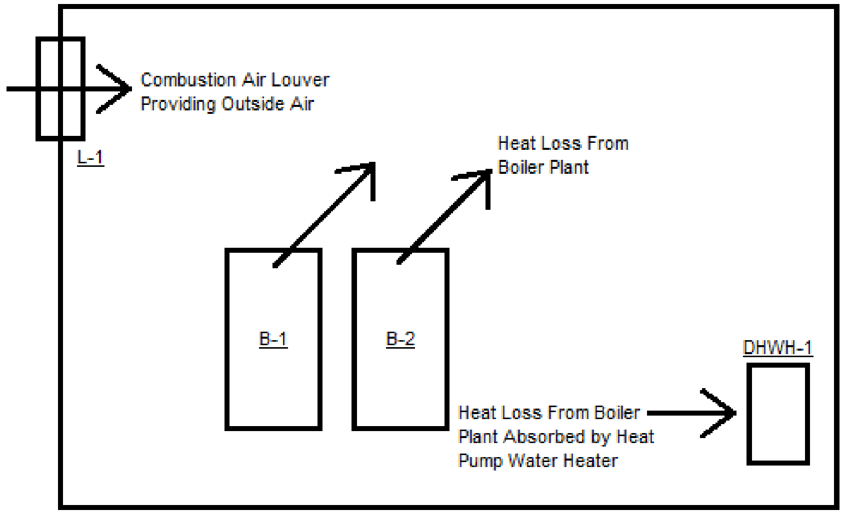


Figure 6. Example Boiler Plant and Heat Pump Water Heater Heat Absorption Diagram

In the above example, heat losses from the boilers typically range about 0.5% to 2% of their rated input. During most of the year, losses from the boilers would provide a suitable heat source for the heat pumps. During shoulder seasons when the boilers are off (May to September), outside air can be introduced to the boiler rooms to avoid overcooling of the space.

Both commercial and hybrid-style heat pump water heater options are capable of serving cooling needs to nearby spaces. During periods of recovery, the heat pump water heaters absorb heat from the surrounding spaces and reject cool air. Ideally, the heat pump water heaters should be installed in boiler rooms, kitchens, or in close proximity to MDF/IDF closets and other spaces where cooling is needed. The cooling air is also capable of being ducted into adjacent spaces if the heat pump water heaters are installed in close proximity to spaces that require cooling. This would reduce the consumption of HVAC cooling equipment in these spaces and would further decrease the overall energy usage of the building.

Note that in some existing schools, (or schools that do not have a boiler room) the configuration of such spaces may not allow for this optimal placement of heat pumps. In such cases, an outdoor rated commercial heat pump water heater could be considered. Refer to specific recommendations for the sample schools studied in this report for more information on this option.

The heat pump technology would be used in conjunction with the solar photovoltaic (PV) system, which would be sized to offset the projected energy usage of the electric heat pump, resulting in a net energy cost of $0 (assuming demand charges are not increased), and net-zero energy use for domestic water production. An example PV panel is shown in Figure 7. Note that with any of the heat pump water heater options described in this report, it may be necessary to consider exhaust and/or intake air ducts depending on the size of the room where the heat pumps are located and to optimize the unit efficiency. The intake or exhaust would be configured to avoid over-cooling the space containing the heat pump. In addition, it has been assumed that demand limiting strategies would be employed to avoid incurring increased electrical demand charges. Based on the load profiles observed at the schools, we expect this should be achievable.

Heat pump operation would be limited to times when it will not increase the building's peak electric demand. Typically, the schools have at least 12 hours of unoccupied periods during which hot water demand is limited and recovery of the storage tank can take place.

Figure 7. Photovoltaic (PV) Panels

Refer to Schematic #1 in the Appendix G for a diagram of this option.

This option is easily scalable by adding additional heat pump water heaters as needed to meet the hot water demand of a larger school, increasing the size of the storage tank, and/or adding PV panels accordingly subject to available roof space.

Option 1 Pros:

- 100% renewable
- Lowest incremental costs compared to other options
- Heat pump is able to cool adjacent spaces and potentially reduce overall building energy usage

Option 1 Cons:

- Requires roof area for PV panels
- Demolition/replacement of existing water heaters must be coordinated
- Floor space required for installing new heat pump water heaters

4.1.2 Option 2: Solar Thermal System with Electric Heat Pump Backup

This option would utilize roof-mounted solar thermal collectors as the renewable energy source, coupled with adequate solar thermal storage tanks. The tanks would serve as 'preheat' for the domestic hot water. The system would be coupled with electric heat pumps as auxiliary heating. As explained below, serving the domestic hot water load with 100% solar thermal is neither practical nor cost effective.

During our research for this study, it was determined that the most desirable configuration for a solar thermal collection system is to provide 100% of a given energy load on the 'best day' of the year, not 100% for the entire year. The reasoning to design for 100% on the 'best day' is to not oversize the system during that period and avoid overheating of the system fluid and possible damage to it and the panels. This reasoning will also make the annual operation of the system most efficient in the energy conversion. This approach results in there being less contribution to the hot water load (lower solar fraction) for all the other days of the year. During the winter, the contribution will be low and during the summer the solar fraction will be high. This is a natural function of the conditions that exist during the different seasons.

During the course of this study, we analyzed several configurations of solar thermal collectors and storage tanks. The conclusion reached is that it is neither practical nor economical to design a solar collection system that will provide 100% of the annual hot water load for a northern climate. Increasing the collector area will in fact increase the solar fraction (to a point), yet at the same time reduce system efficiency. Maximizing size to address the full consumption creates a trend of diminishing returns with respect to adding more collectors. This relationship is illustrated in Figure 8 below. This figure was extracted from "Viessmann" literature.

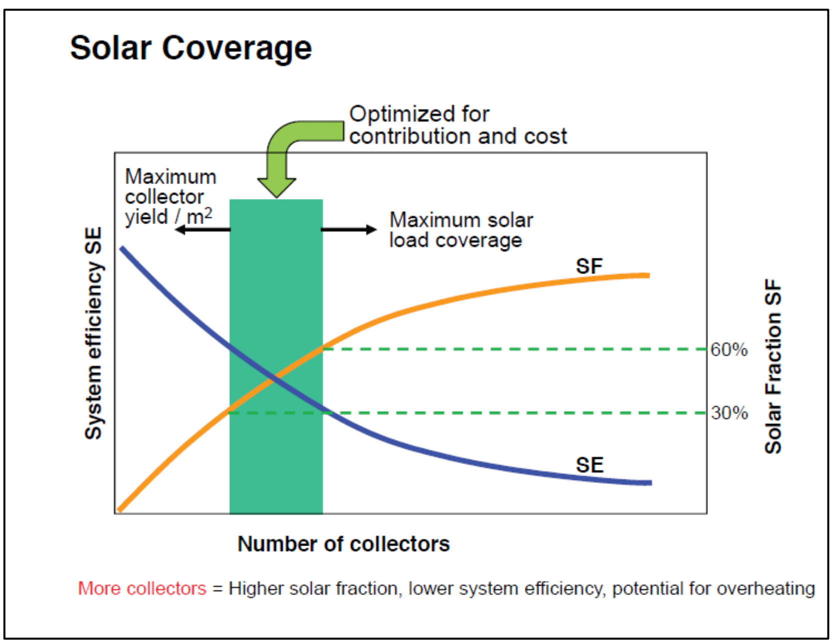


Figure 8. Solar Thermal System Efficiency

For a properly designed solar thermal system, it is necessary to provide adequate storage volume of hot water, which is a function of the area of collectors. The more collectors, the more the solar storage volume is required. In the New York region that ratio is most commonly between 1.25 to 1.5 gallons of storage for each square foot of collector. This strategy provides for best efficiencies and is necessary to protect the panels from overheating.

The prototype designs in this study utilize several pre-heat storage tanks with integral solar heating coils (Figure 9). For larger buildings, a separate preheat heat exchanger and storage tank may be used. The existing gas-fired domestic hot water heaters would be replaced by a high efficient electric heat pump acting as auxiliary heat to supplement the solar thermal system.

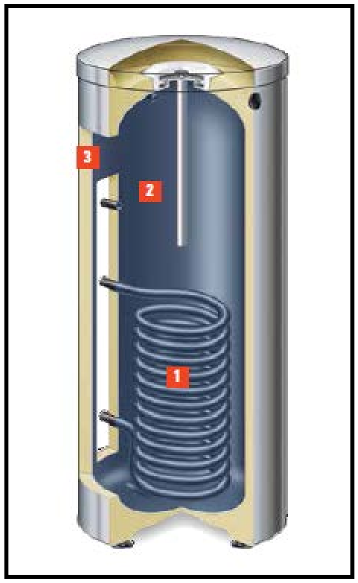


Figure 9. Solar Thermal Preheat Tank

Refer to Schematic #2 in the Appendix G for a diagram of this option. This option cannot provide a practical, 100% renewable solution.

<u>Option 2 Pros:</u>

- Reduces annual DHW heating costs
- Heat pump is able to cool adjacent spaces and potentially reduce overall building energy usage

<u>Option 2 Cons:</u>

- Not a 100% renewable system
- Requires roof area for solar thermal collectors
- Solar thermal panels are relatively expensive compared to PV.
- Glycol must be used to prevent freezing
- Additional solar thermal preheat tanks may be required
- Demolition/replacement of existing water heaters must be coordinated

4.1.3 Option 3: Solar Thermal System with Gas-Fired Backup

This option is essentially equivalent to Option 2 previously described and all the same considerations still apply. In this option, the existing gas-fired domestic hot water heaters would remain and would act as the auxiliary heat to supplement the solar thermal system.

Refer to Schematic #3 in the Appendix G for a diagram of this option. This option cannot provide a practical, 100% renewable solution.

Option 3 Pros:

- Reduces annual DHW heating costs
- Existing gas-fired water heaters will be utilized. No coordinating needed with installing new water heaters
- Incremental costs could be lower in some cases when utilizing existing water heaters

Option 3 Cons:

- Not a 100% renewable system
- Requires roof area for solar thermal collectors
- Solar thermal panels are relatively expensive compared to PV.
- Glycol must be used to prevent freezing
- Additional solar thermal preheat tanks may be required

4.1.4 Option 4: Hybrid Solar Thermal and PV System with Electric Heat Pump Backup

This option would use a combination of both a PV system and a solar thermal system. This option incorporates the features of Option 1 and Option 2 together allowing a smaller PV system to be used. Since some of the domestic hot water load will be provided by the solar thermal system, the electric energy used by the heat pump will be reduced, and therefore a smaller PV system can offset its consumption.

By merging the solar thermal with the electric heat pump and PV system, this option can provide a 100% renewable solution. Refer to Schematic #4 in the Appendix G for a diagram of this option.

Option 4 Pros:

- 100% renewable system
- Reduces annual DHW heating costs to $0
- Heat pump is able to cool adjacent spaces and reduce overall building energy usage

Option 4 Cons:

- Highest incremental costs since utilizing both PV and solar thermal
- Requires additional roof area for PV and solar thermal collectors
- Glycol must be used to prevent freezing during the winter months
- Additional solar thermal preheat tanks may be required in addition to electric heat pump water heaters
- Demolition/replacement of existing water heaters must be coordinated

4.1.5 Option 5: Point of Use Electric

This option is to utilize "point of use" electric hot water heaters installed close to the end uses, such as under the lavatories and sinks, or near to a group of bathroom lavatories, or in the kitchen to serve each sink. This type of electric heater is also referred to as a "tankless" electric water heater. The point of use heaters are only active when a sink demand for hot water exists. Point of use heaters, since they are located near the end use, do not require a circulating hot water system and storage tank, which is their prime advantage.

The prime disadvantage of the point of use heater is that the peak electrical demand of the building would be increased significantly, and in some cases the building's electric service would be affected as well. This option is not well suited for a school with large kitchen use. Storage tanks are typically going to be required to serve the kitchens in order to avoid large peak demand costs. The point of use heaters do have the potential to reduce site energy consumption however, and were therefore included in this study.

In order to quantify the potential energy use benefits, a high level energy analysis was performed for School B in order to verify the increase in energy costs and decrease in energy use. School B was selected since reliable metering was collected, and it represents an average size SCA School At 180,000 square feet.

Table 6 below summarizes the energy usage and costs of the point of use electric hot water heaters as compared to the existing gas-fired domestic hot water system for school School B. Note that the heat losses associated with the existing domestic hot water recirculation piping, storage tank, and recirculating pumps are factored into the annual heating energy usage and cost for the purposes of this evaluation. The results highlight that although consumption is less for point of use heaters compared to a gas-fired system, the penalty associated with demand charges is significant.

One benefit of point of use electric heaters is the reduced CO_2 emissions when compared to the SCA current standard gas fired DHW recirculating system. It was estimated that the annual heating energy associated with the additional piping losses and storage tank for School B is approximately 36% of the total domestic water system heating energy input. A similar study by another SCA consultant found that for PS 2Q (a smaller school), the recirculating system losses were about 20%. In general, it can be extrapolated that the larger the size the recirculation system, the larger system heat losses and the greater potential benefit of point of use heaters.

Elimination of the recirculation system and pump results in substantial energy savings and associated GHG emissions, however will increase the building's source energy input in most cases do the fuel switching and associated site-to-source conversions. In addition, point of use heaters will not save as much energy when compared to electric heat pump water heaters. This is primarily due to the significantly higher efficiencies achieved by heat pumps. The results of this analysis are summarized below.

Option 5 Pros:

- May be acceptable for schools with small kitchens
- High Thermal Efficiencies
- Eliminates recirculation system losses.
- Lower building site energy and CO_2 emissions compared to DHW recirculating system

Option 5 Cons:

- Significantly increases electrical demand and operating costs
- Will likely impact building electrical service
- Large kitchens will be very costly to operate.
- Higher site energy and CO_2 emissions when compared to electric heat pumps.
- Increased building source energy.
- Increased electric consumption compared to heat pumps would require larger PV array to offset
- Likely higher first cost than heat pump systems for retrofit projects.

Table 6. Option 5 Energy Usage and Cost Summary for School B with Point of Use Heaters

School	Option	Approximate System Cost ($)	Annual Water Heating Energy (therms)	Annual Electric Energy Input (kWh)	Annual Water Heating Energy (kBtu)	Annual Energy Cost ($)	Annual Demand Penalty (Cost) ($)	Annual CO_2 Emissions Avoided (lbs/year)
School B	Existing Gas-Fired DHW Heater	-	1,059	2,902[1]	133,127	$1,982	-	0
	Point of Use Electric Hot Water Heaters	$450,000	-	25,406	85,817	$1,385	$8,946	4,908

Notes:
1. Electric energy associated with DHW recirculation pumps.

4.2 School A Domestic Hot Water Alternatives

The sections below summarize the specifics of the Options and how they could be applied for School A.

4.2.1 Option 1: Solar Photovoltaic System with Electric Heat Pump

Two (2) new electric domestic hot water heat pumps would be located in the basement boiler room in close proximity to the existing gas-fired domestic hot water heater. Power would be distributed to the heat pumps from an existing electric panel. The PV panels would be roof-mounted in a South inclined orientation on the roof of the school. This school did not have much roof-mounted equipment located on the roof, so there will be ample space for mounting PV panels in an optimal orientation (Photo 18). Power can be routed from the roof and down through the existing chimney to a suitable tie-in location to be determined.

Photo 18. School A Roof

Table 7 shows the requirements for this option. A 3 kW solar PV system would need to be installed to offset the annual kWh usage of the heat pump. The total roof area required for this option is 190 ft^2 with nine (9) PV panels in total. The PV system would generate 3,720 kWh annually.

Table 7. School A Option 1 Requirements				
Size of PV array	Number of Panels	Roof Area Required (ft^2)	Annual kWh Generated by PV	Number of Electric Heat Pump Water Heaters
3 kW	9	190	3,720	2

4.2.2 Option 2 or 3: Thermal DHW Closed Loop Drainback System with Gas Fired or Electric Heat Pump Auxiliary heat.

Solar thermal collectors would be mounted on the roof of the school and a closed loop piping system would be routed through the chimney and into the basement boiler room. The closed loop solar thermal system would recirculate a heat transfer fluid, heated by solar energy, using a pump. The heat transfer fluid will flow to a heat exchanger, where it will heat the domestic hot water. The solar heated domestic water would be stored in a preheat tank. Depending on site specific conditions, an external heat exchanger could be used or the heat exchanger could be located inside the preheat tank (as shown in Figure 2).

Table 8 shows the requirements for this option. A 36,000 Btu/hr solar thermal collector array would need to be installed to efficiently contribute to the domestic hot water heating system. This would require six (6) solar thermal collectors to be installed on the roof totaling 162 ft^2 of collector area.

Table 8. School A Option 2 and 3 Requirements				
Installed Collector Power (kBtu/hr)	Number of Collectors	Roof Area Required (ft^2)	Annual Solar Contribution to DHW System (MBtu)	Solar Thermal Fraction %
36	6	162	17	53.4%

4.2.3 Option 4: Hybrid Solar Thermal and PV System with Electric Heat Pump Backup

Solar thermal collectors would be mounted on the roof of the school and a closed loop piping system would be routed through the chimney and into the basement boiler room. The PV panels would be roof-mounted in a South inclined orientation on the roof of the school. Two (2) new electric domestic hot water heat pumps would be located in the basement boiler room in close proximity to the existing gas-fired domestic hot water heater. This option would require the same amount of solar thermal collectors as in Option 2 and 3, but would require a 2 kW PV system to cover the rest of the domestic hot water load. Table 9 summarizes the PV requirements for this option.

Table 9. School A Option 4 Requirements

Size of PV array	Number of Panels	Roof Area Required (ft^2)	Annual kWh Generated by PV	Number of Electric Heat Pump Water Heaters	Solar Thermal Fraction %
2 kW	6	126	1,456	2	53.4%

4.3 School B Domestic Hot Water Alternatives

The sections below summarize the specifics of the Options and how they could be applied for School B.

4.3.1 Option 1: Solar Photovoltaic System with Electric Heat Pump Backup

Four (4) new electric domestic hot water heat pumps would be located in the roof penthouse where the existing gas-fired domestic hot water heater is currently located. Finding a location for this heat pump may be difficult since there is limited space inside of the penthouse. There are electric panels located inside the penthouse where power could be drawn from to power the new electric heat pumps. The PV panels would be roof-mounted in a South-West orientation on the roof of the school. This school has a number of air handlers, exhaust fans, sanitary vents, and smoke hatches located on the roof (Photo 19). The PV panels would need to be mounted such that clearance requirements are maintained with the existing roof-mounted equipment.

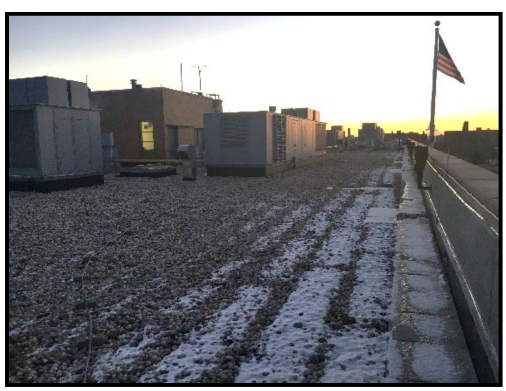


Photo 19. School B Roof

Table 10 shows the requirements for this option. An 8 kW solar PV system would be required to offset the annual kWh usage of the heat pumps. The total roof area required for this option is 484 ft^2 with twenty-three (23) PV panels in total. The PV system would generate 9,920 kWh annually.

Due to the small size of the penthouse, this installation may require additional intake and exhaust ductwork to allow the heat pumps to operate without overcooling the space.

Table 10. School B Option 1 Requirements

Size of PV array	Number of Panels	Roof Area Required (ft^2)	Annual kWh Generated by PV	Number of Electric Heat Pump Water Heaters
8 kW	23	484	9,920	4

4.3.2 Option 2 or 3: Thermal DHW Closed Loop Glycol System with Gas Fired Backup

Solar thermal collectors would be mounted on the roof of the school and a closed loop piping system would be routed from the collectors and into the roof penthouse. The closed loop solar thermal system would recirculate a heat transfer fluid, heated by solar energy, using a pump. The heat transfer fluid will flow to a heat exchanger, where it will heat the domestic hot water. The solar heated domestic water would be stored in a preheat tank. Depending on site specific conditions, an external heat exchanger could be used or the heat exchanger could be located inside the preheat tank (as shown in Figure 2). Since the existing water heater is located in the roof penthouse, it would not be possible for the system to drain down during the winter months. Therefore, this school would need to use a closed-loop pressurized system. The closed loop solar thermal system would need to be filled with a glycol mixture to prevent freezing in the collectors during the winter months.

Table 11 shows the requirements for this option. A 72,000 Btu/hr solar thermal collector array would need to be installed to efficiently contribute to the domestic hot water heating system. This would require twelve (12) solar thermal collectors to be installed on the roof totaling 324 ft^2 of collector area.

Table 11. School B Option 2 and 3 Requirements

Installed Collector Power (kBtu/hr)	Number of Collectors	Roof Area Required (ft^2)	Annual Solar Contribution to DHW Heating System (MBtu)	Solar Thermal Fraction %
72	12	324	45	52.3%

4.3.3 Option 4: Hybrid Solar Thermal and PV System with Electric Heat Pump Backup

Solar thermal collectors would be mounted on the roof of the school and a closed loop piping system would be routed from the collectors and into the roof penthouse. The PV panels would be roof-mounted in a South-West inclined orientation on the roof of the school. Four (4) new electric domestic hot water heat pumps would be located in the roof penthouse where the existing gas-fired domestic hot water heater is currently located. This option would require the same amount of solar thermal collectors as in Option 2 and 3, but would require a 4 kW PV system to cover the rest of the domestic hot water load. Table 12 summarizes the PV requirements for this option.

Table 12. School B Option 4 Requirements

Size of PV array	Number of Panels	Roof Area Required (ft^2)	Annual kWh Generated by PV	Number of Electric Heat Pump Water Heaters	Solar Thermal Fraction %
4 kW	12	253	3,999	4	52.3%

4.4 School C Domestic Hot Water Alternatives

The sections below summarize the specifics of the Options and how they could be applied for School C.

4.4.1 Option 1: Solar Photovoltaic System with Electric Heat Pump Backup

The new electric domestic hot water heat pump could be located in the basement boiler room in close proximity to the existing gas-fired domestic hot water heater. Power would be distributed to the heat pump from an existing electric panel located in the basement electrical room. The PV panels would be roof-mounted in a nearly South inclined orientation on the roof of the school. This school has numerous mechanical equipment, exhaust fans, and smoke hatches located on the roof (Photo 20).

Photo 20. School C Roof

13 shows the requirements for this option. A 5 kW solar PV system would need to be installed to offset the annual kWh usage of the heat pump. The total roof area required for this option is 316 ft^2 with fifteen (15) PV panels in total. The PV system would generate 6,200 kWh annually.

Table 13. School C Option 1 Requirements				
Size of PV array	Number of Panels	Roof Area Required (ft^2)	Annual kWh Generated by PV	Number of Electric Heat Pump Water Heaters
5 kW	15	316	6,200	2

4.4.2 Option 2 or 3: Thermal DHW Closed Loop Drainback System with Gas Fired Backup

Solar thermal collectors would be mounted on the roof of the school and a closed loop piping system would be routed from the roof and into the basement boiler room. There is no easily accessible shaft located in the school to route this piping. There is one main shaft that runs from the roof to the basement; however, gaining access to this shaft would require demolition of walls. The closed loop solar thermal system would recirculate a heat transfer fluid, heated by solar energy, using a pump. The heat transfer fluid will flow to a heat exchanger to where it will heat the domestic hot water. The solar heated domestic water would be stored in a preheat tank. Depending on site specific conditions, an external heat exchanger would be used or the heat exchanger could be located inside the preheat tank (as shown in Figure 2). A drainback tank would be installed somewhere inside the building to prevent heat transfer fluid (water) from freezing inside the solar collectors during the winter months.

Table 14 shows the requirements for this option. A 48,000 Btu/hr solar thermal collector array would be installed to efficiently contribute to the domestic hot water heating system. This would require eight (8) solar thermal collectors to be installed on the roof totaling 216 ft^2 of collector area.

Table 14. School C Option 3 Requirements				
Installed Collector Power (kBtu/hr)	Number of Collectors	Roof Area Required (ft^2)	Annual Solar Contribution to DHW Heating System (MBtu)	Solar Thermal Fraction %
48	8	216	26	51.4%

4.4.3 Option 4: Hybrid Solar Thermal and PV System with Electric Heat Pump Backup

Solar thermal collectors would be mounted on the roof of the school and a closed loop piping system would be routed from the collectors and into the basement boiler room. The PV panels would be roof-mounted in a South-West inclined orientation on the roof of the school. Two (2) new electric domestic hot water heat pumps would be located in the basement boiler room where the existing gas-fired domestic hot water heater is currently located. This option would require the same amount of solar thermal collectors as in Option 2 and 3, but would require a 3 kW PV system to cover the rest of the domestic hot water load. Table 15 summarizes the PV requirements for this option.

Table 15. School C Option 4 Requirements

Size of PV array	Number of Panels	Roof Area Required (ft^2)	Annual kWh Generated by PV	Number of Electric Heat Pump Water Heaters	Solar Thermal Fraction %
3 kW	9	190	2,386	2	51.4%

5.0 Results

Table 16 provides a summary of the incremental costs and energy cost saving potential of each of the investigated options.

Table 16. Incremental Costs and Summary of Options

School	Option	Approximate Incremental Costs[3,4] ($)	$/ft^2 Incremental Costs	Annual Energy Cost Savings[1,2] ($/year)	Percent of Renewable Energy (%)	Annual CO_2 Emissions Avoided[5,6] (lbs/year)	$/lbs CO_2 Emissions Avoided
School A	Option 1: PV System with Electric Heat Pump	$80,000	$0.96	$488	100%	4,558	$17.6
	Option 2: Solar Thermal System with Electric Heat Pump	$145,000	$1.75	$94	53.4%	3,632	$39.9
	Option 3: Solar Thermal System with Gas-Fired Heater	$100,000	$1.20	$260	53.4%	2,434	$41.1
	Option 4: Hybrid Solar Thermal System and PV System with Electric Heat Pump	$170,000	$2.05	$488	100%	4,558	$37.3
School B	Option 1: PV System with Electric Heat Pump[7]	$140,000	$0.75	$1,324	100%	12,379	$11.3
	Option 2: Solar Thermal System with Electric Heat Pump	$155,000	$0.86	$245	52.3%	9,837	$15.8
	Option 3: Solar Thermal System with Gas-Fired Heater	$120,000	$0.67	$693	52.3%	6,474	$18.5
	Option 4: Hybrid Solar Thermal System and PV System with Electric Heat Pump	$230,000	$1.28	$1,324	100%	12,379	$18.6
School C	Option 1: PV System with Electric Heat Pump	$80,000	$1.78	$785	100%	7,340	$10.9
	Option 2: Solar Thermal System with Electric Heat Pump	$150,000	$3.33	$141	51.4%	5,823	$25.8
	Option 3: Solar Thermal System with Gas-Fired Heater	$110,000	$2.44	$404	51.4%	3,773	$29.2
	Option 4: Hybrid Solar Thermal System and PV System with Electric Heat Pump	$175,000	$3.89	$785	100%	7,340	$23.8

Notes:
1. Energy cost savings stated are order of magnitude only.
2. For electric heat pump options, it is assumed that controls and sufficient water storage will be provided to mitigate increased demand charges for electric heat pump systems.
3. Costing is for order of magnitude values only and is not intended to be used for construction costs.
4. Costing is developed for the existing buildings in this study. If these options are to be implemented in new buildings, the expectation is that the construction costs will be less.
5. 11.7 lbs CO_2/therm from EPA.
6. 635.8 lbs CO2/MWh from EPA eGrid 2016 data. Options 1 and 4 are both intended to be 100% renewable, and therefore have the same CO2 avoided emissions.
7. Oversized outdoor rated heat pump was used in the analysis to keep Option 1 100% renewable.

The above results summary in Table 16 indicates that Option 1, heat pumps coupled with PV arrays, will likely be the most cost effective alternative energy solution for typical NYC schools. The expected cost for these systems is between $1.00 to $1.80 per square foot, and would depend on the size of the school (smaller schools having a higher cost per square foot). The specific heat pump type (commercial or hybrid type) and installation location at a given school would have to be evaluated on a case by case basis. As described in Section 4.0, placement of heat pumps in or near ‘free’ heat sources such as boiler rooms, kitchen refrigerators, or IDF rooms would optimize their performance, and in some cases offset other cooling needs. Some existing schools may not have this opportunity, but could use outdoor rated heat pumps instead.

In general new schools could benefit from the cost effective hybrid style heat pumps with integral storage, as long as the sizing takes into account the need for enough storage to cover the peak period usage. Larger schools would necessarily benefit from using commercial grade heat pumps and large storage tanks (see below Sample Design School #1 as an example). For the two larger schools studied (School A and School B) the peak period usage accounted for 50-60% of the daily usage, and lasted about 1.5 hours. A smaller school is expected to have a higher percentage of usage during the peak period. As an example, School C used 80% of the daily hot water during the peak period of 2.5 hours. The peak period usage should be carefully estimated for schools using integral tank-hybrid type heat pump water heaters, since the recovery rates are lower than conventional water heaters of similar tank size, and the goal is to avoid using the electric resistance mode. Existing schools with enough storage capacity could use a commercial style (no integral storage) heat pump to take advantage of the existing storage.

The following section includes some design recommendations specific to the schools surveyed during this study, as wells as some additional school currently being developed, and these concepts could be applied to similar schools.

6.0 Specific Recommendations for Example Schools

6.1 School A

Option 1: PV System with Electric Heat Pump is recommended for School A. This school already utilizes a 318 gallon storage tank located in the boiler room, which provides a surplus of hot water storage capacity. Pairing a commercial heat pump water heater with the existing storage tank would be a viable option and locating the heat pump(s) in the boiler room is feasible. The boiler heat losses would provide enough energy to be absorbed by the commercial heat pump most of the year, thus maximizing its efficiency. The school would also benefit from the increased recovery rate and efficiency provided by the commercial heat pump over the hybrid heat pump water heaters. The roof of this school has no equipment on the roof which will allow ample space for a PV array to be installed.

6.2 School B

Option 1: PV System with Electric Heat Pump is recommended for School B. This school already utilizes a 700-gallon storage tank located in the penthouse MER, which provides a surplus of hot water storage capacity. Pairing a commercial heat pump water heater with the existing storage tank would be a viable option.

Unfortunately, there is no “free” waste heat source in the room. If a heat pump water heater were to be installed inside the penthouse, the temperature within the penthouse could drop below freezing conditions at times, if the heat pump was not ducted to the outdoors. In this situation, we recommend locating the commercial heat pump outdoors to avoid any ductwork modifications within the penthouse, avoid overcooling the space, and ultimately save on installation costs.

The results shown above in Table 15 were based on using an oversized commercial heat pump that could provide 140ºF hot water under all outdoor conditions. An alternate option is to use a hybrid system and a smaller outdoor rated heat pump. The results of this option are shown below in Table 17. The smaller sized commercial heat pump output would not be able to generate 140°F water during sub-freezing winter temperatures. The existing gas fired water heater would be utilized during some winter hours to supplement the hot water temperature. This arrangement would make the system less than 100% renewable, but reduce first cost. It is estimated that the gas-fired water heater would have to provide about 14% of the hot water heating throughout the year in this scenario. Table 17 provides a summary of the incremental costs and energy cost saving potential of this situation. The large roof of this school provides ample space for a PV array to be installed.

Table 17. School B Incremental Costs and Summary of Outdoor Rated Heat Pump Water Heater and Gas-Fired Supplemental Water Heater

School	Option	Approximate Incremental Costs[3,4] ($)	$/ft^2 Incremental Costs	Annual Energy Cost Savings[1,2] ($/year)	Percent of Renewable Energy (%)	Annual CO_2 Emissions Avoided[5,6] (lbs/year)	$/lbs CO_2 Emissions Avoided
School B	PV System with Electric Heat Pump and Gas-Fired Heater	$120,000	$0.67	$1,139	86%	10,646	$11.3

6.3 School C

Option 1: PV System with Electric Heat Pump is recommended for School C. This school only utilizes a 100 gallon storage tank located in the boiler room, which does not provide enough storage to be paired with a commercial heat pump. Utilizing the storage of two (2) hybrid-style heat pump water heaters in addition to the 100 gallon storage tank would be a viable option. The boiler heat losses would provide enough energy to be absorbed by the hybrid-style heat pumps most of the year, thus maximizing their efficiency. The heat pumps would have enough recovery capacity with two (2) hybrid heat pumps operating during off-hours to heat the storage for the following school day. The roof of this school has various mechanical equipment, exhaust fans, and smoke hatches on the roof, but a roof-mounted PV array would still be feasible.

6.4 Sample Design School #1

As part of a separate project, an electric heat pump water heater design for a new large high school was completed for SCA. This design has been designated as Sample Design School #1. Sample Design School #1 is approximately 308,000 square feet and will serve 3,870 students. The design scheme is included in this report for reference. The recommendation for Sample Design School #1 is primarily based on Option 1: Electric Heat Pumps, but with some modifications to the study concept. The proposed design for this school features two (2) commercial-style electric heat pump water heaters and one (1) 500 gallon storage tank to serve the domestic hot water system. (The PV system was not part of the project). Ideally, a larger storage tank would have been provided, however due to space constraints in the proposed boiler room, the 500 gallon tank was size was utilized. The heat pump water heaters were selected to provide equivalent recovery rate as the standard gas-fired system (roughly 287,000 Btu/hr for both, or 190 gph recovery rate).

The heat pump hot water heaters are proposed to be located outdoors on the roof of the building, as there was no allotted space in the boiler room. The storage tank is to be installed in the boiler room. In addition, one (1) plate and frame heat exchanger was included in the design to separate the heat pump circulating glycol loop from the domestic hot water. This accomplishes freeze protection for the heat pumps without relying on electrical heat trace for the small amount of domestic water piping that would be outdoors. Proposed DHW system schematics for Sample Design School #1 have been included in Appendix H of this report.

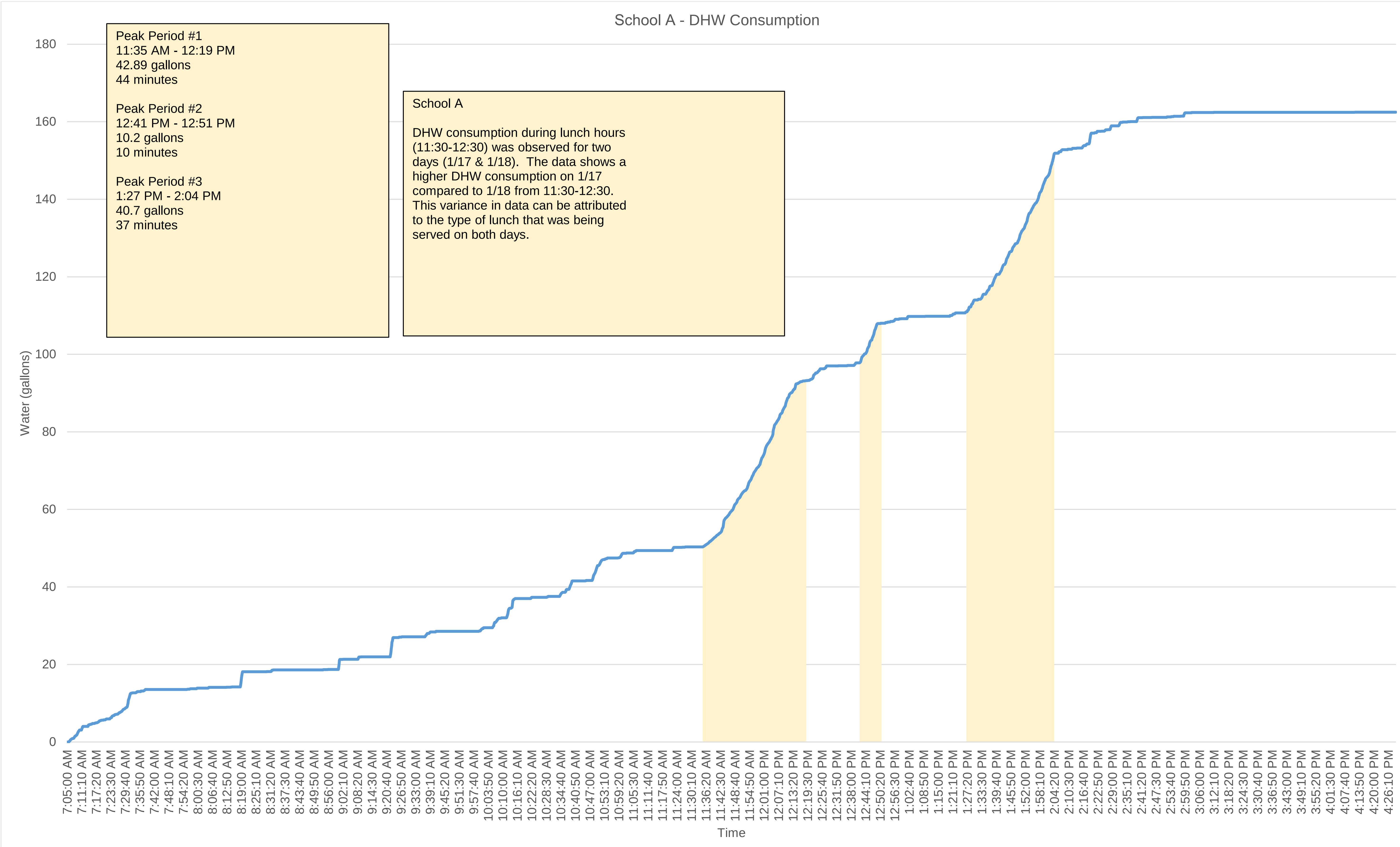
6.5 Sample Design School #2

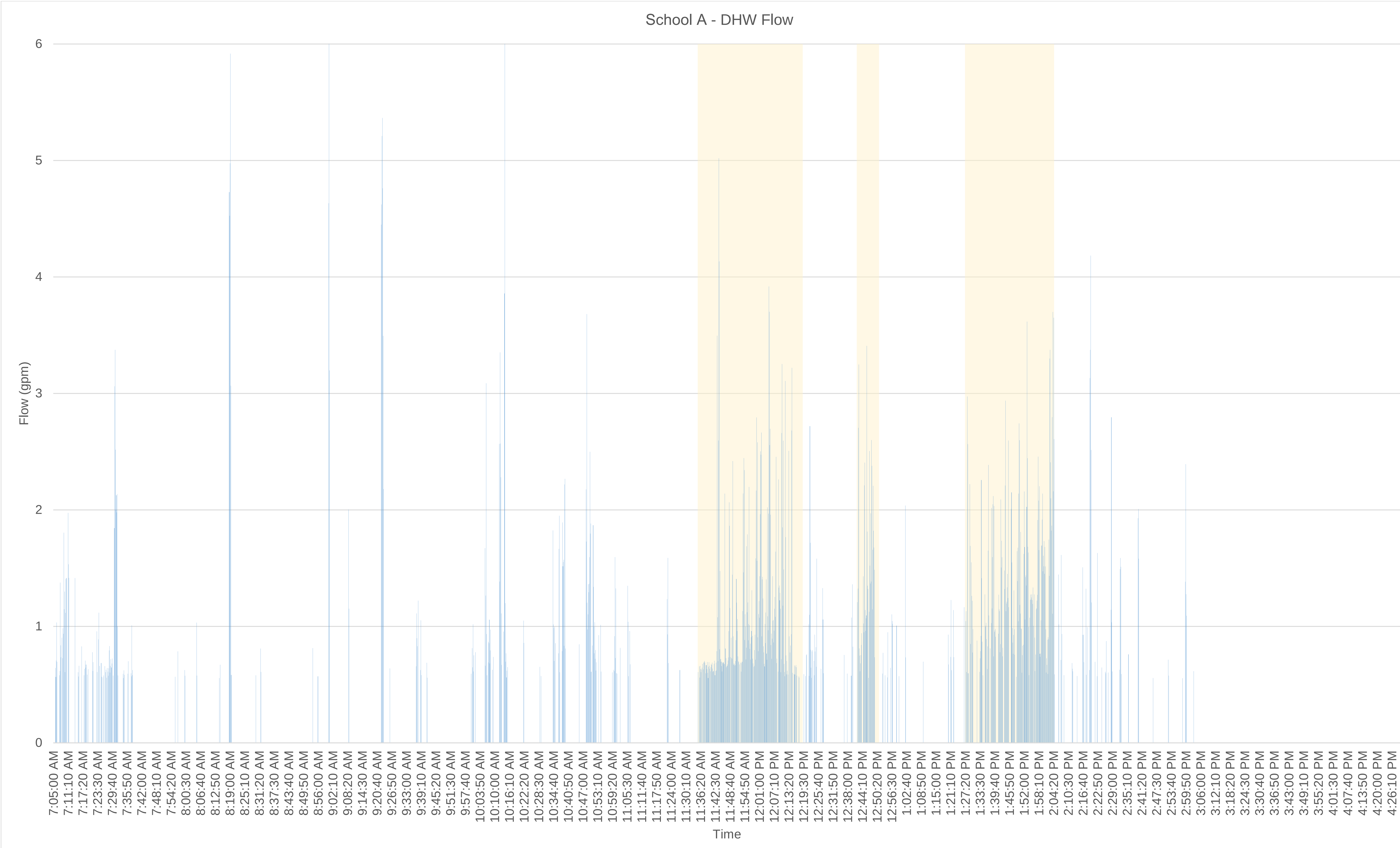
Another school for which heat pump water heaters are currently being designed has been included in this report as an example, and has been designated Sample Design School #2. Sample Design School #2 is about 50,000 square feet. Domestic hot water for this proposed school is to be provided by two (2) electric heat pump hot water heaters, each with peak outputs of 151 MBH and 222 MBH respectively. Domestic water is stored in one (1) 200 gallon DHW storage tank. The storage tank is equipped with a 72kW electrical resistance coil to provide supplemental heat when required. The heat pump water heaters and storage tank are all located in the rooftop MER of the building with heat pumps supply and exhaust air ducted to the outdoors. This design eliminates the need for the heat exchanger and glycol loop since the heat pumps are entirely inside the building. A floor plan layout and schematic diagram for this design has been included in Appendix I of this report.

7.0 Appendices

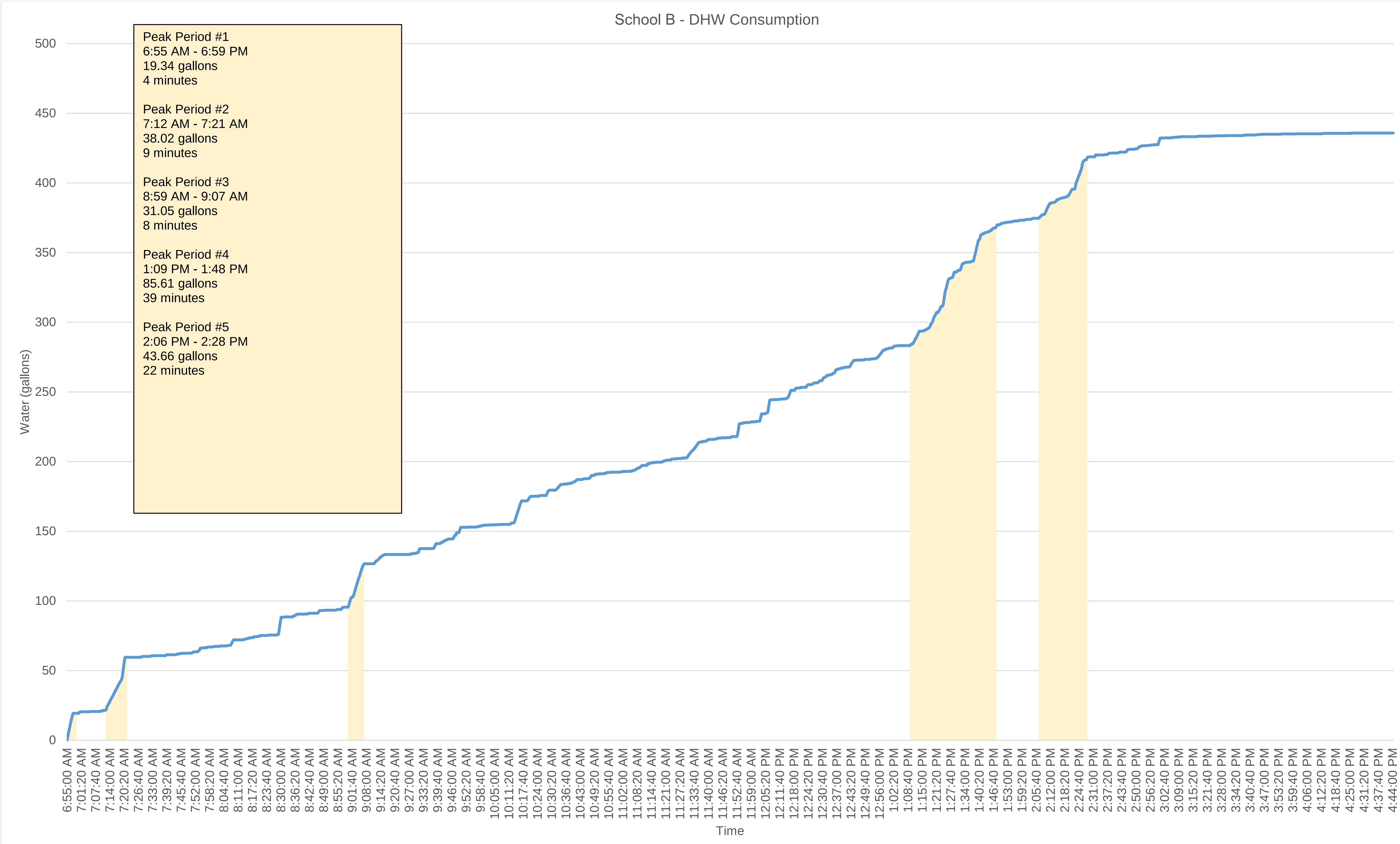
Appendix A:

Metering Data

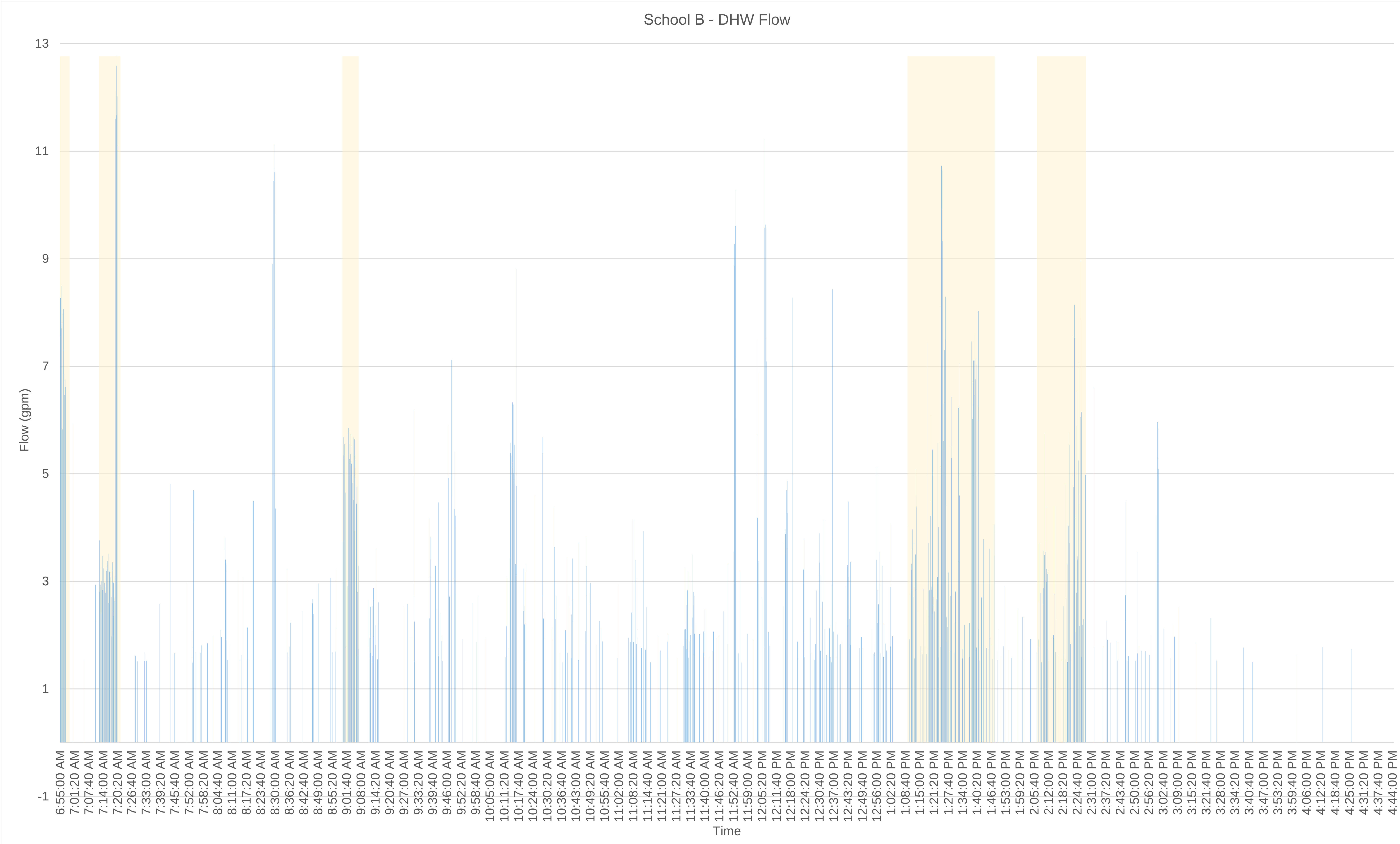

School A - DHW Consumption
Peak Period #1
11:35 AM - 12:19 PM
42.89 gallons
44 minutes
Peak Period #2
12:41 PM - 12:51 PM
10.2 gallons
10 minutes
Peak Period #3
1:27 PM - 2:04 PM
40.7 gallons
37 minutes
School A
DHW consumption during lunch hours (11:30-12:30) was observed for two days (1/17 & 1/18). The data shows a higher DHW consumption on 1/17 compared to 1/18 from 11:30-12:30. This variance in data can be attributed to the type of lunch that was being served on both days.
Water (gallons)
Time

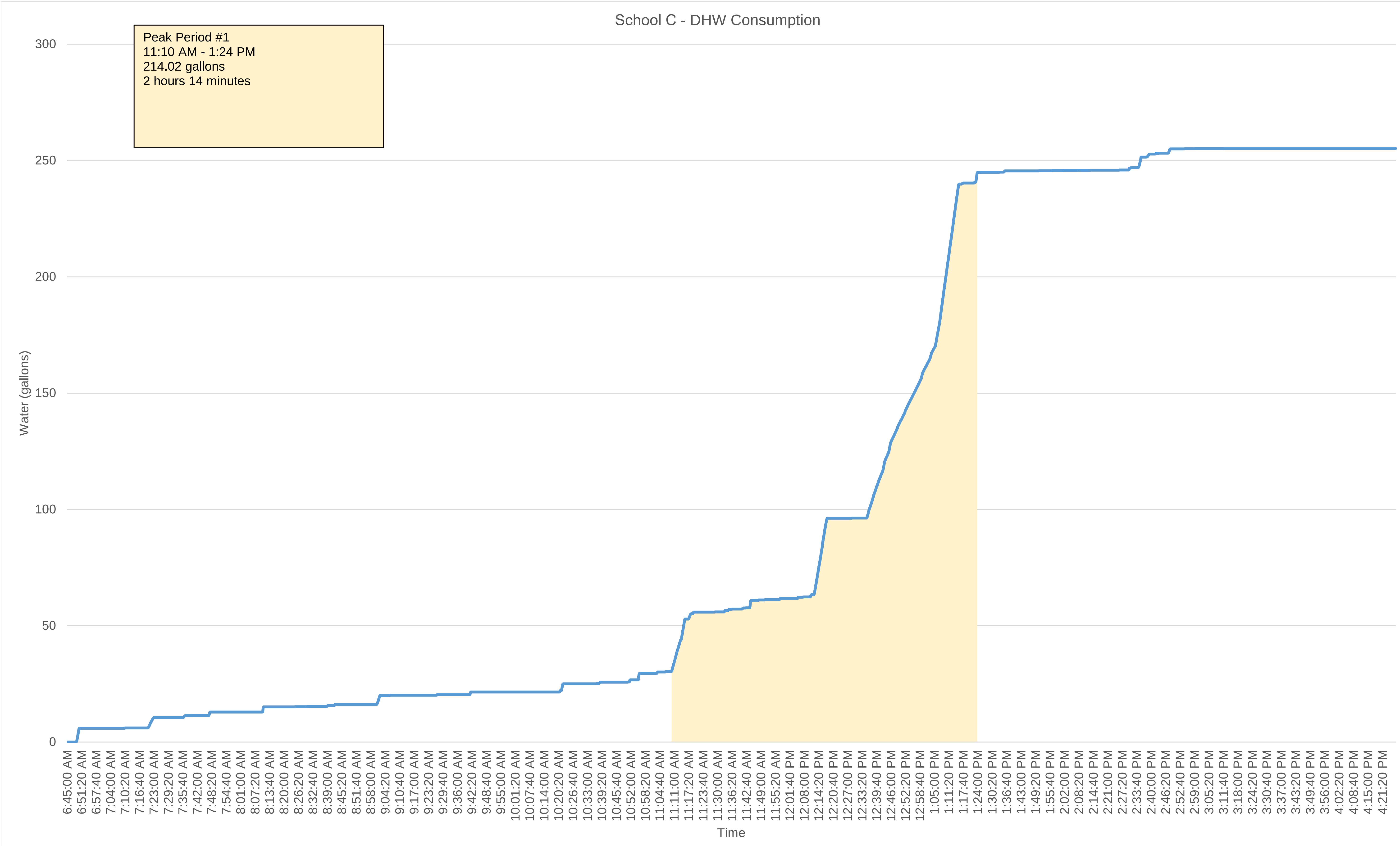


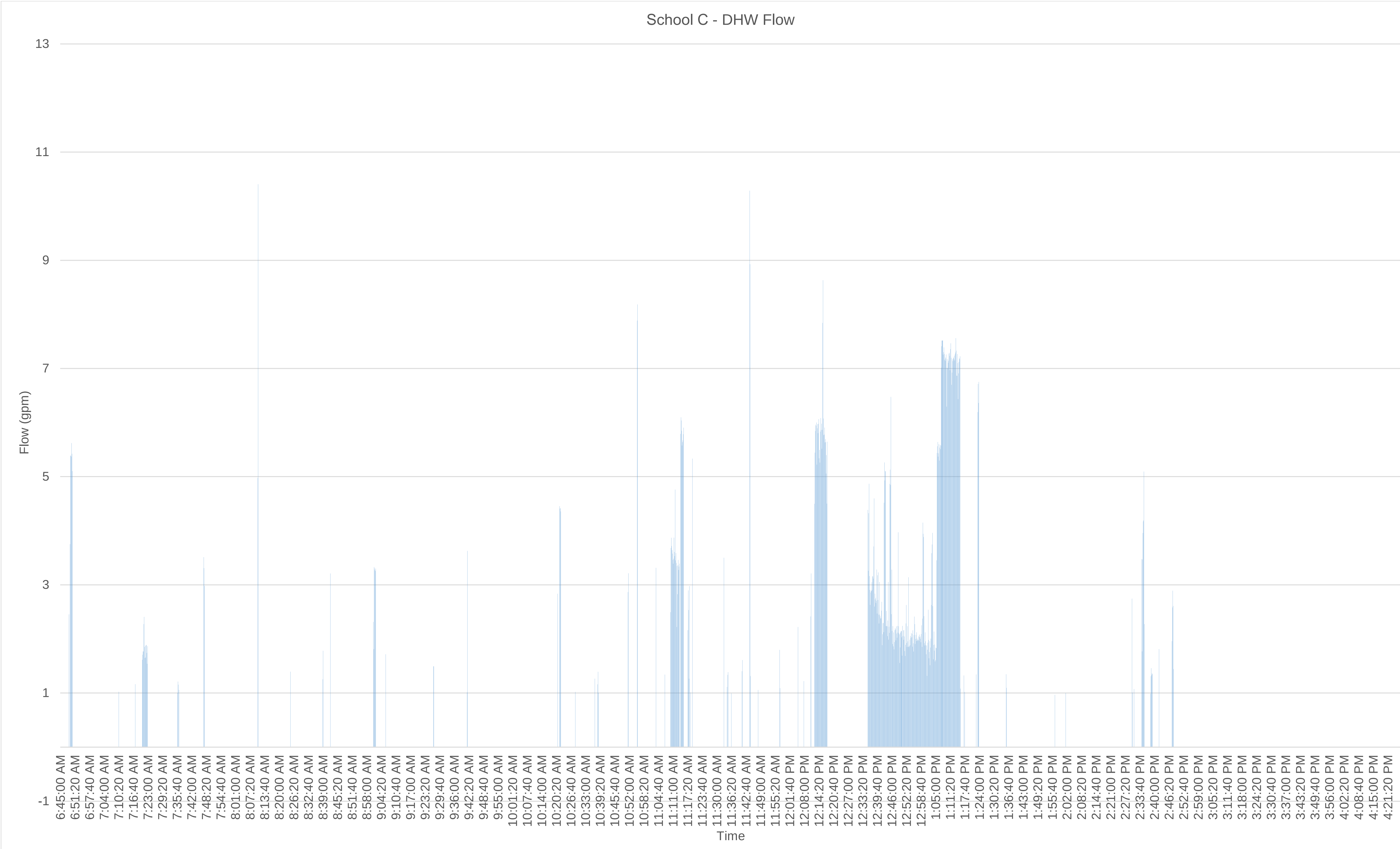
School A - DHW Flow
Flow (gpm)
Time

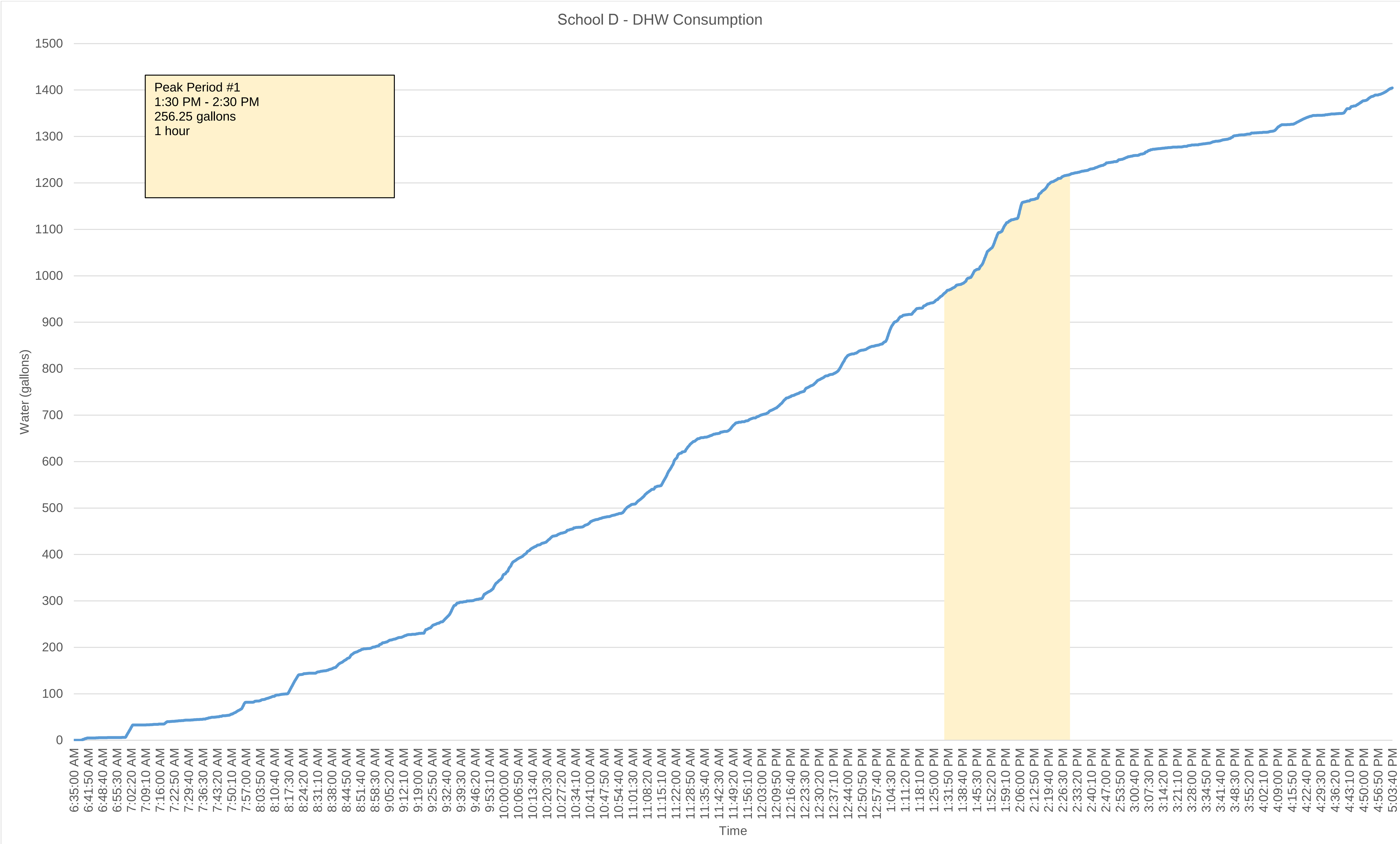


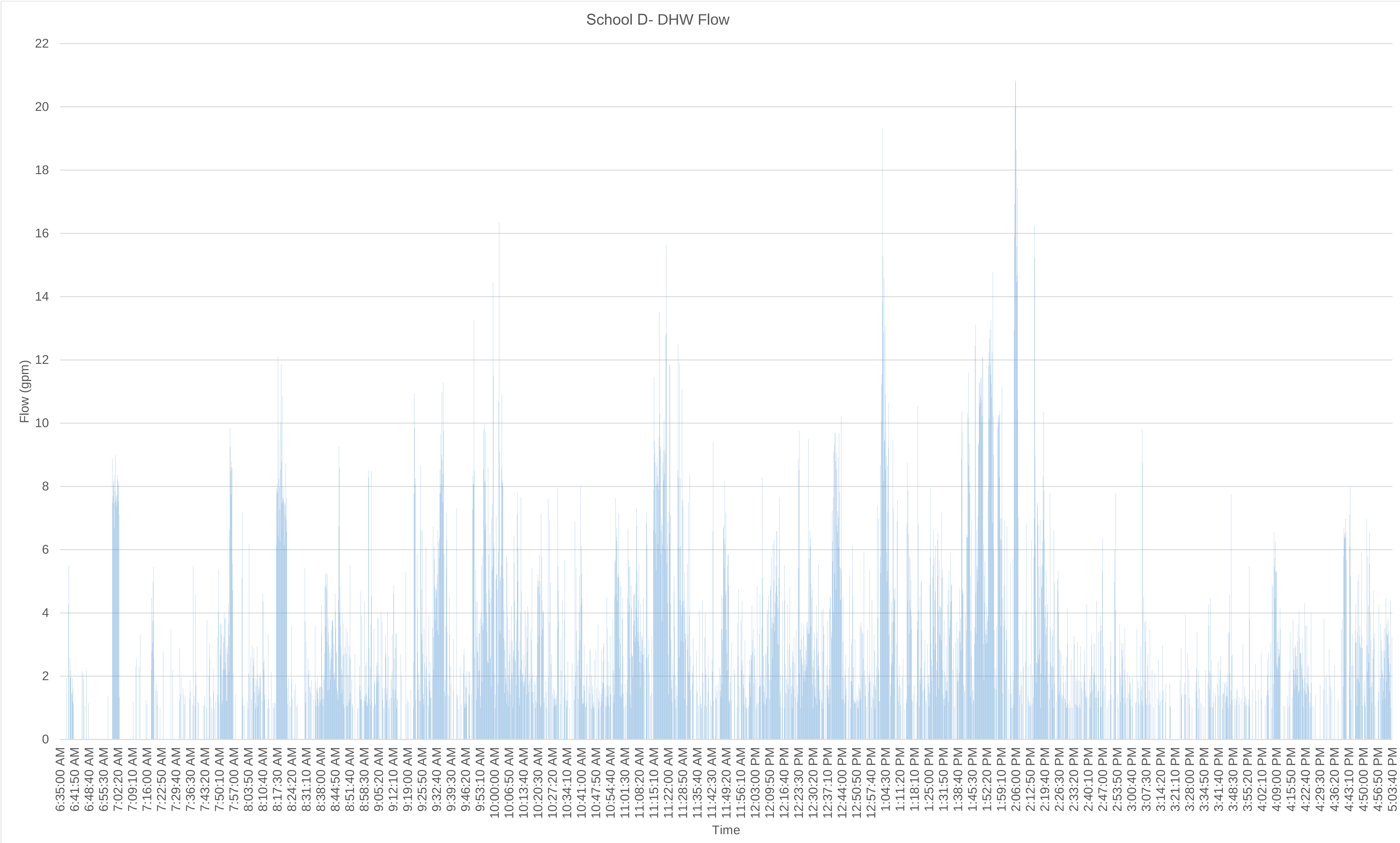
School B - DHW Consumption
Peak Period #1
6:55 AM - 6:59 PM
19.34 gallons
4 minutes
Peak Period #2
7:12 AM - 7:21 AM
38.02 gallons
9 minutes
Peak Period #3
8:59 AM - 9:07 AM
31.05 gallons
8 minutes
Peak Period #4
1:09 PM - 1:48 PM
85.61 gallons
39 minutes
Peak Period #5
2:06 PM - 2:28 PM
43.66 gallons
22 minutes
Water (gallons)
Time


School B - DHW Flow
Flow (gpm)
Time
13
11
9
7
5
3
1
-1
6:55:00 AM
4:44:00 PM


School C - DHW Consumption
Peak Period #1
11:10 AM - 1:24 PM
214.02 gallons
2 hours 14 minutes
Water (gallons)
Time
0
50
100
150
200
250
300


School C - DHW Flow
Flow (gpm)
Time


School D - DHW Consumption
Peak Period #1
1:30 PM - 2:30 PM
256.25 gallons
1 hour
Water (gallons)
Time



School D- DHW Flow
Flow (gpm)
Time

Appendix B:

PV System Analysis

Caution: Photovoltaic system performance predictions calculated by PVWatts® include many inherent assumptions and uncertainties and do not reflect variations between PV technologies nor site-specific characteristics except as represented by PVWatts® inputs. For example, PV modules with better performance are not differentiated within PVWatts® from lesser performing modules. Both NREL and private companies provide more sophisticated PV modeling tools (such as the System Advisor Model at http://sam.nrel.gov) that allow for more precise and complex modeling of PV systems.

The expected range is based on 30 years of actual weather data at the given location and is intended to provide an indication of the variation you might see. For more information, please refer to this NREL report: The Error Report.

The energy output range is based on analysis of 30 years of historical weather data for nearby , and is intended to provide an indication of the possible interannual variability in generation for a Fixed (open rack) PV system at this location.

RESULTS

3,720 kWh/Year*

System output may range from 3,571 to 3,845kWh per year near this location.

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)	Energy Value ($)
January	2.80	219	25
February	3.40	242	28
March	3.92	299	35
April	4.90	355	41
May	5.50	407	47
June	5.19	362	42
July	5.26	375	43
August	5.49	392	45
September	4.70	329	38
October	4.54	336	39
November	2.74	202	23
December	2.63	204	24
Annual	**4.26**	**3,722**	**$ 430**

Location and Station Identification

Requested Location	School A Address
Weather Data Source	(TMY3) NEW YORK LAGUARDIA ARPT, NY 6.5 mi
Latitude	40.78° N
Longitude	73.88° W

PV System Specifications *(Commercial)*

DC System Size	3 kW
Module Type	Premium
Array Type	Fixed (roof mount)
Array Tilt	41°
Array Azimuth	225°
System Losses	14.08%
Inverter Efficiency	96%
DC to AC Size Ratio	1.1

Economics

Average Cost of Electricity Purchased from Utility	0.12 $/kWh

Performance Metrics

Capacity Factor	14.2%

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Caution: Photovoltaic system performance predictions calculated by PVWatts® include many inherent assumptions and uncertainties and do not reflect variations between PV technologies nor site-specific characteristics except as represented by PVWatts® inputs. For example, PV modules with better performance are not differentiated within PVWatts® from lesser performing modules. Both NREL and private companies provide more sophisticated PV modeling tools (such as the System Advisor Model at http://sam.nrel.gov) that allow for more precise and complex modeling of PV systems.

The expected range is based on 30 years of actual weather data at the given location and is intended to provide an indication of the variation you might see. For more information, please refer to this NREL report: The Error Report.

The energy output range is based on analysis of 30 years of historical weather data for nearby , and is intended to provide an indication of the possible interannual variability in generation for a Fixed (open rack) PV system at this location.

RESULTS

9,920 kWh/Year*

System output may range from 9,522 to 10,252kWh per year near this location.

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)	Energy Value ($)
January	2.80	583	67
February	3.40	644	74
March	3.92	798	92
April	4.90	946	109
May	5.50	1,085	125
June	5.19	965	111
July	5.26	999	115
August	5.49	1,046	121
September	4.70	876	101
October	4.54	896	103
November	2.74	538	62
December	2.63	544	63
Annual	**4.26**	**9,920**	**$ 1,143**

Location and Station Identification

Requested Location	School B Address
Weather Data Source	(TMY3) NEW YORK LAGUARDIA ARPT, NY 7.4 mi
Latitude	40.78° N
Longitude	73.88° W

PV System Specifications *(Commercial)*

DC System Size	8 kW
Module Type	Premium
Array Type	Fixed (roof mount)
Array Tilt	41°
Array Azimuth	225°
System Losses	14.08%
Inverter Efficiency	96%
DC to AC Size Ratio	1.1

Economics

Average Cost of Electricity Purchased from Utility	0.12 $/kWh

Performance Metrics

Capacity Factor	14.2%

Caution: Photovoltaic system performance predictions calculated by PVWatts® include many inherent assumptions and uncertainties and do not reflect variations between PV technologies nor site-specific characteristics except as represented by PVWatts® inputs. For example, PV modules with better performance are not differentiated within PVWatts® from lesser performing modules. Both NREL and private companies provide more sophisticated PV modeling tools (such as the System Advisor Model at http://sam.nrel.gov) that allow for more precise and complex modeling of PV systems.

The expected range is based on 30 years of actual weather data at the given location and is intended to provide an indication of the variation you might see. For more information, please refer to this NREL report: The Error Report.

The energy output range is based on analysis of 30 years of historical weather data for nearby , and is intended to provide an indication of the possible interannual variability in generation for a Fixed (open rack) PV system at this location.

RESULTS

6,200 kWh/Year*

System output may range from 5,951 to 6,408kWh per year near this location.

Month	Solar Radiation (kWh / m^2 / day)	AC Energy (kWh)	Energy Value ($)
January	2.80	364	42
February	3.40	403	46
March	3.92	499	58
April	4.90	591	68
May	5.50	678	78
June	5.19	603	70
July	5.26	625	72
August	5.49	653	75
September	4.70	548	63
October	4.54	560	65
November	2.74	336	39
December	2.63	340	39
Annual	**4.26**	**6,200**	**$ 715**

Location and Station Identification

Requested Location	School C Address
Weather Data Source	(TMY3) NEW YORK LAGUARDIA ARPT, NY 1.8 mi
Latitude	40.78° N
Longitude	73.88° W

PV System Specifications *(Commercial)*

DC System Size	5 kW
Module Type	Premium
Array Type	Fixed (roof mount)
Array Tilt	41°
Array Azimuth	225°
System Losses	14.08%
Inverter Efficiency	96%
DC to AC Size Ratio	1.1

Economics

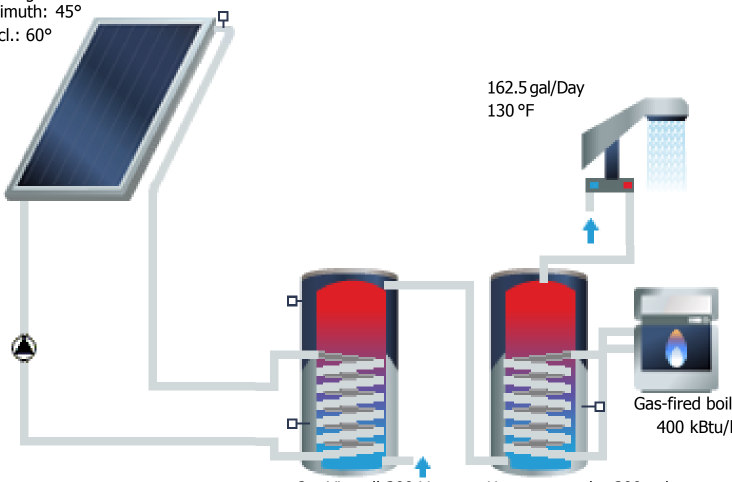
Average Cost of Electricity Purchased from Utility	0.12 $/kWh

Performance Metrics

Capacity Factor	14.2%

Appendix C:

Solar Thermal System Analysis



Results of annual simulation

Installed collector power:	35.97 kBtu/hr	
Installed solar surface area (gross):	162.12 ft²	
Irradiation on to collector surface (active):	66.17 MMBtu	439.73 kBtu/ft²
Energy delivered by collectors:	30.27 MMBtu	201.16 kBtu/ft²
Energy delivered by collector loop:	25.96 MMBtu	172.51 kBtu/ft²
DHW heating energy supply:	36.72 MMBtu	
Solar contribution to DHW:	22.26 MMBtu	
Energy from auxiliary heating:	19.4 MMBtu	
Natural gas (H) savings:		**332.0 therm**
CO2 emissions avoided:		**4,353.71 lbs**
DHW solar fraction:		**53.4 %**
System efficiency:		**33.6 %**

VIESSMANN
climate of innovation

Site data

Climate data

Location:	NEW YORK LAGUARDIA ARPT
Climate data record:	"NEW YORK LAGUARDIA ARPT"
Total annual global irradiation:	1436.389 kWh/m²
Latitude:	40.77 °
Longitude:	73.87 °

Domestic hot water

Average daily consumption:	162.5 gal
Desired temperature:	130 °F
Consumption profile:	High School
Cold water temperature:	February:50.9 °F / August:62.6 °F
Circulation:	No

System components

Collector loop

Manufacturer:	Viessmann Manufacturing Company (US) Inc.
Type:	200-FM, SV2F/SH2F
Number:	6.00
Total gross surface area:	162.12 ft²
Total active solar surface area:	150.48 ft²
Tilt angle:	60 °
Azimuth:	45 °

DHW standby tank

Manufacturer:	Existing
Type:	Hot water tank - 300 gal
Volume:	300 gal

Solar preheating tank

Manufacturer:	Viessmann Manufacturing US Inc
Type:	2 x Vitocell 300-V
Volume:	2 x 119 gal

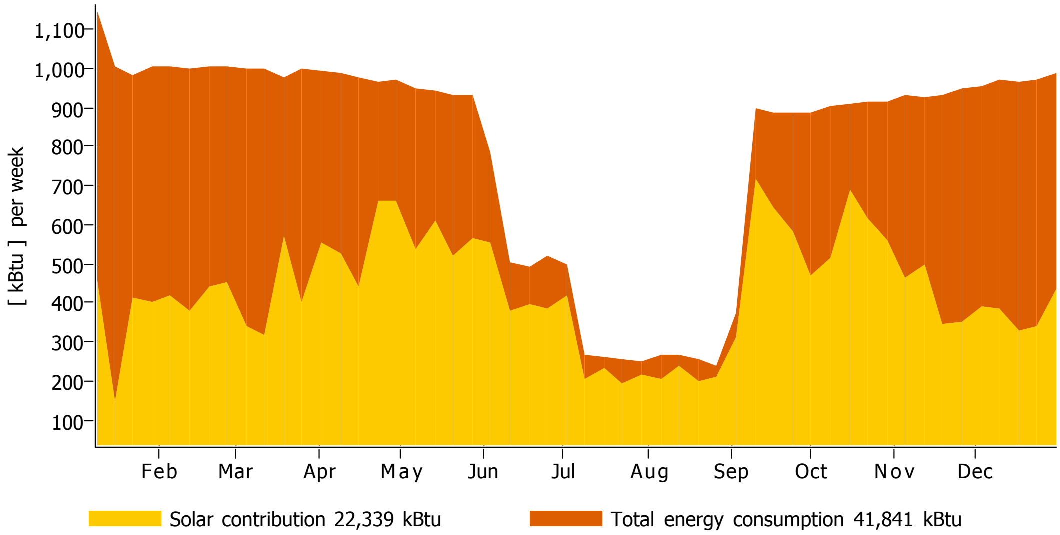
Auxiliary heating

Manufacturer:	Standard
Type:	Gas-fired boiler -400 kBtu/hr
Nominal output:	400 kBtu/hr

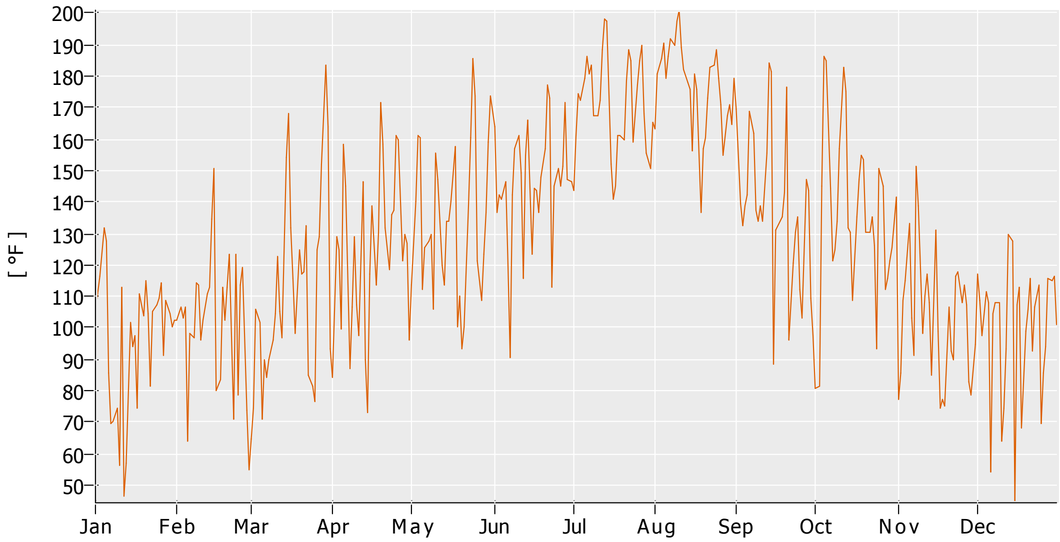
Legend

CERTIFIED With test report
Solar Keymark

Solar energy consumption as percentage of total consumption



Daily maximum collector temperature



These calculations were carried out by T*SOL Pro 5.0 - the simulation program for solar thermal heating systems. The results are determined from the computation of a mathematical model with variable time steps of up to 6 minutes. Actual yields can deviate from these values due to fluctuations in climate, consumption and other factors.The system schematic diagram above does not represent and cannot replace a full technical drawing of the solar system.

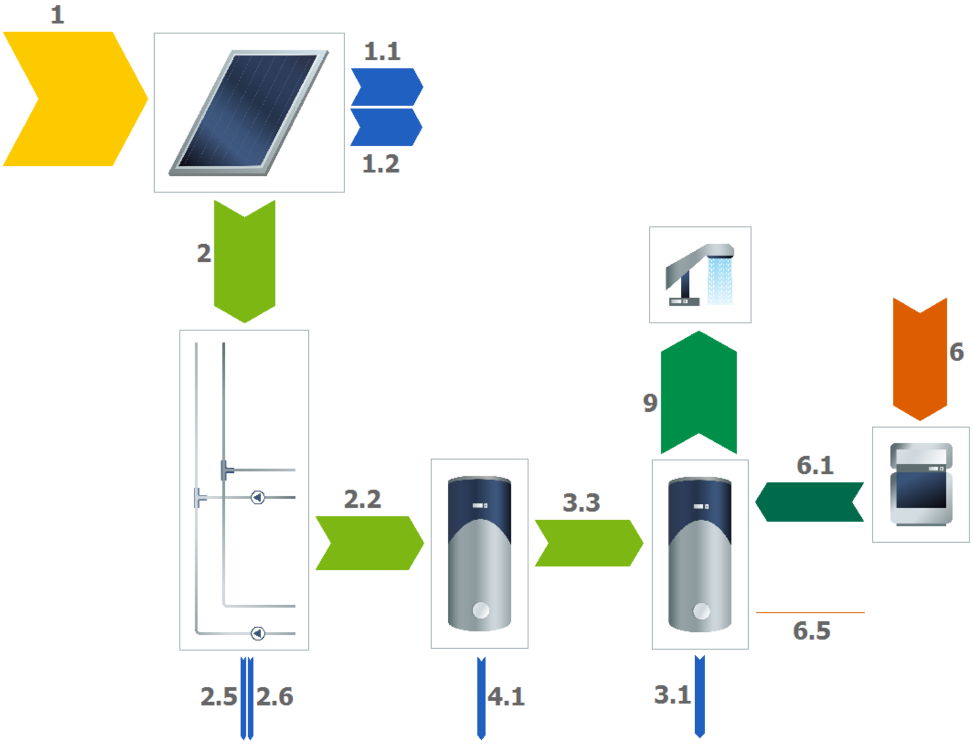
A Viessmann solar system will enjoy a significantly longer life if regular stagnation is not designed into the system. When a year-round use for the collected solar heat cannot be identified, then a small inexpensive heat dump is recommended. A heat dump should be installed for the following situations:

1. Oversized solar DHW systems and/or where extended periods of stagnation are anticipated.

2. If the T*SOL report shows numerous instances of maximum collector temperature over 200F.

*If a system falls under any of these categories, then a heat dump should be installed and sized based on 225 Btu / square foot of collector absorber area.

Energy balance schematic



Legend

1	Irradiation on to collector surface (active)	66 MMBtu
1.1	Optical collector losses	18 MMBtu
1.2	Thermal collector losses	18 MMBtu
2	Energy from collector array	30 MMBtu
2.2	Solar energy to preheating tank	26 MMBtu
2.5	Internal piping losses	2,172 kBtu
2.6	External piping losses	2,139 kBtu
3.1	Tank losses	5 MMBtu
3.3	Preheating tank to tank	22 MMBtu
4.1	Tank losses (S)	4 MMBtu
6	Final energy	26 MMBtu
6.1	Supplementary energy to tank	19 MMBtu
6.5	Electric element	0 kBtu
9	DHW energy from tank	37 MMBtu

Glossary

1 Irradiation on to collector surface (active)
Solar energy irradiated onto tilted collector area (active surface area)

1.1 Optical collector losses
Reflection and other losses

1.2 Thermal collector losses
Heat conduction and other losses

2 Energy from collector array
Energy output at collector array outlet (i.e. before piping)

2.2 Solar energy to preheating tank
Collector array energy minus piping losses

2.5 Internal piping losses
Internal piping losses

2.6 External piping losses
External piping losses

3.1 Tank losses
Heat losses via surface area

3.3 Preheating tank to tank
Heat from preheating tank to tank

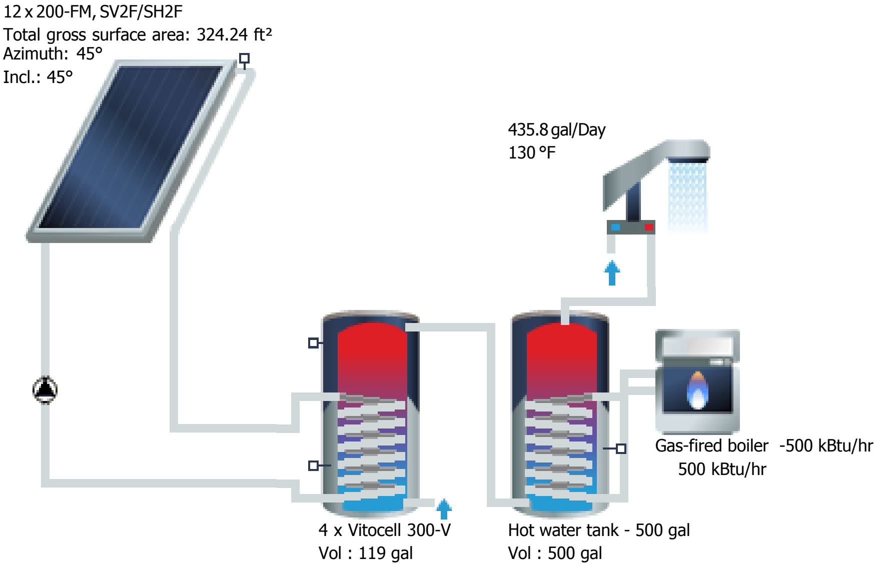
4.1 Tank losses (S)
Heat losses via surface area

6 Final energy
Final energy supply to system. This can be from natural gas, oil or electricity (not including solar energy) and takes efficiency into account.

6.1 Supplementary energy to tank
Supplementary energy (e.g. boiler) to tank

6.5 Electric element
Energy from electric water heater element

9 DHW energy from tank
Heat from tank (exluding circulation) for DHW consumption



Results of annual simulation

Installed collector power:	71.95 kBtu/hr	
Installed solar surface area (gross):	324.24 ft²	
Irradiation on to collector surface (active):	143.03 MMBtu	475.27 kBtu/ft²
Energy delivered by collectors:	65.28 MMBtu	216.91 kBtu/ft²
Energy delivered by collector loop:	62.52 MMBtu	207.73 kBtu/ft²
DHW heating energy supply:	98.47 MMBtu	
Solar contribution to DHW:	54.92 MMBtu	
Energy from auxiliary heating:	50.1 MMBtu	
Natural gas (H) savings:		**827.2 therm**
CO2 emissions avoided:		**10,847.50 lbs**
DHW solar fraction:		**52.3 %**
System efficiency:		**38.4 %**

Site data

Climate data

Location:	NEW YORK LAGUARDIA ARPT
Climate data record:	"NEW YORK LAGUARDIA ARPT"
Total annual global irradiation:	1436.389 kWh/m²
Latitude:	40.77 °
Longitude:	73.87 °

Domestic hot water

Average daily consumption:	435.8 gal
Desired temperature:	130 °F
Consumption profile:	High School
Cold water temperature:	February:50.9 °F / August:62.6 °F
Circulation:	No

System components

Collector loop

Manufacturer:	Viessmann Manufacturing Company (US) Inc.
Type:	200-FM, SV2F/SH2F
Number:	12.00
Total gross surface area:	324.24 ft²
Total active solar surface area:	300.96 ft²
Tilt angle:	45 °
Azimuth:	45 °

DHW standby tank

Manufacturer:	Existing
Type:	Hot water tank - 500 gal
Volume:	500 gal

Solar preheating tank

Manufacturer:	Viessmann Manufacturing US Inc
Type:	4 x Vitocell 300-V
Volume:	4 x 119 gal

Auxiliary heating

Manufacturer:	Standard
Type:	Gas-fired boiler -500 kBtu/hr
Nominal output:	500 kBtu/hr

Legend

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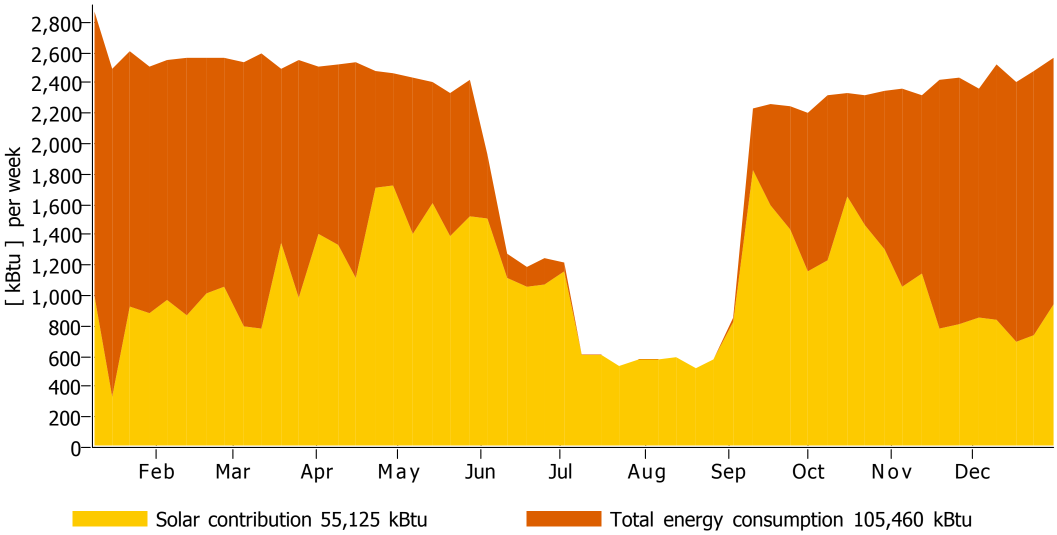
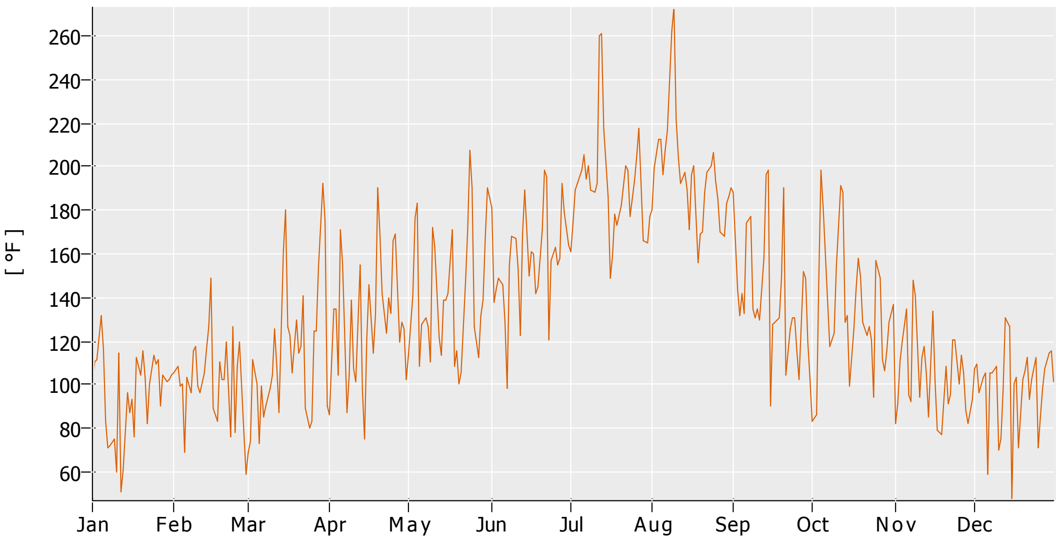
Solar Keymark

Solar energy consumption as percentage of total consumption



Daily maximum collector temperature



These calculations were carried out by T*SOL Pro 5.0 - the simulation program for solar thermal heating systems. The results are determined from the computation of a mathematical model with variable time steps of up to 6 minutes. Actual yields can deviate from these values due to fluctuations in climate, consumption and other factors.The system schematic diagram above does not represent and cannot replace a full technical drawing of the solar system.

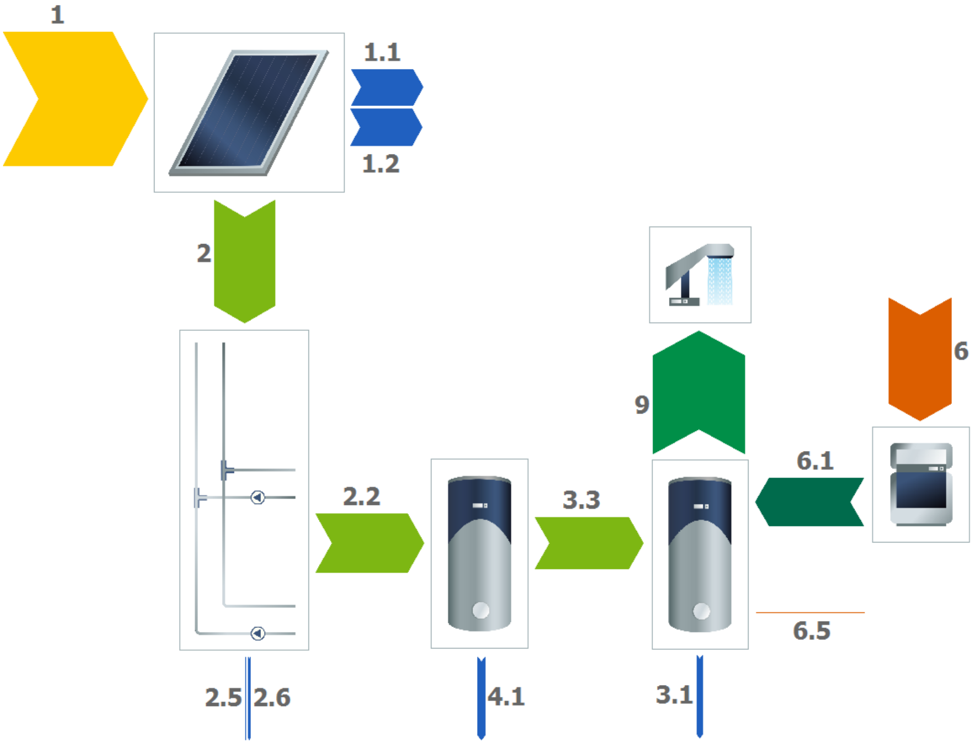
A Viessmann solar system will enjoy a significantly longer life if regular stagnation is not designed into the system. When a year-round use for the collected solar heat cannot be identified, then a small inexpensive heat dump is recommended. A heat dump should be installed for the following situations:

1. Oversized solar DHW systems and/or where extended periods of stagnation are anticipated.

2. If the T*SOL report shows numerous instances of maximum collector temperature over 200F.

*If a system falls under any of these categories, then a heat dump should be installed and sized based on 225 Btu / square foot of collector absorber area.

Energy balance schematic

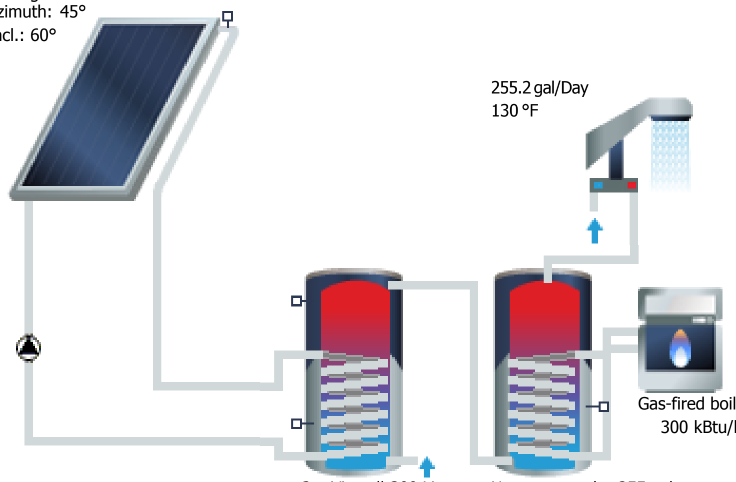


Legend

1	Irradiation on to collector surface (active)	143 MMBtu
1.1	Optical collector losses	39 MMBtu
1.2	Thermal collector losses	39 MMBtu
2	Energy from collector array	65 MMBtu
2.2	Solar energy to preheating tank	63 MMBtu
2.5	Internal piping losses	388 kBtu
2.6	External piping losses	2,374 kBtu
3.1	Tank losses	7 MMBtu
3.3	Preheating tank to tank	55 MMBtu
4.1	Tank losses (S)	8 MMBtu
6	Final energy	66 MMBtu
6.1	Supplementary energy to tank	50 MMBtu
6.5	Electric element	0 kBtu
9	DHW energy from tank	98 MMBtu

Glossary

1	Irradiation on to collector surface (active) Solar energy irradiated onto tilted collector area (active surface area)
1.1	Optical collector losses Reflection and other losses
1.2	Thermal collector losses Heat conduction and other losses
2	Energy from collector array Energy output at collector array outlet (i.e. before piping)
2.2	Solar energy to preheating tank Collector array energy minus piping losses
2.5	Internal piping losses Internal piping losses
2.6	External piping losses External piping losses
3.1	Tank losses Heat losses via surface area
3.3	Preheating tank to tank Heat from preheating tank to tank
4.1	Tank losses (S) Heat losses via surface area
6	Final energy Final energy supply to system. This can be from natural gas, oil or electricity (not including solar energy) and takes efficiency into account.
6.1	Supplementary energy to tank Supplementary energy (e.g. boiler) to tank
6.5	Electric element Energy from electric water heater element
9	DHW energy from tank Heat from tank (exluding circulation) for DHW consumption



Results of annual simulation

Installed collector power:	47.96 kBtu/hr	
Installed solar surface area (gross):	216.16 ft²	
Irradiation on to collector surface (active):	88.22 MMBtu	439.73 kBtu/ft²
Energy delivered by collectors:	41.07 MMBtu	204.71 kBtu/ft²
Energy delivered by collector loop:	37.15 MMBtu	185.18 kBtu/ft²
DHW heating energy supply:	57.66 MMBtu	
Solar contribution to DHW:	32.00 MMBtu	
Energy from auxiliary heating:	30.3 MMBtu	
Natural gas (H) savings:		**478.3 therm**
CO2 emissions avoided:		**6,272.02 lbs**
DHW solar fraction:		**51.4 %**
System efficiency:		**36.3 %**

Site data

Climate data

Location:	NEW YORK LAGUARDIA ARPT
Climate data record:	"NEW YORK LAGUARDIA ARPT"
Total annual global irradiation:	1436.389 kWh/m²
Latitude:	40.77 °
Longitude:	73.87 °

Domestic hot water

Average daily consumption:	255.2 gal
Desired temperature:	130 °F
Consumption profile:	High School
Cold water temperature:	February:50.9 °F / August:62.6 °F
Circulation:	No

System components

Collector loop

Manufacturer:	Viessmann Manufacturing Company (US) Inc.
Type:	200-FM, SV2F/SH2F
Number:	8.00
Total gross surface area:	216.16 ft²
Total active solar surface area:	200.64 ft²
Tilt angle:	60 °
Azimuth:	45 °

DHW standby tank

Manufacturer:	Existing
Type:	Hot water tank - 255 gal
Volume:	255 gal

Solar preheating tank

Manufacturer:	Viessmann Manufacturing US Inc
Type:	3 x Vitocell 300-V
Volume:	3 x 119 gal

Auxiliary heating

Manufacturer:	Standard
Type:	Gas-fired boiler -300 kBtu/hr
Nominal output:	300 kBtu/hr

Legend

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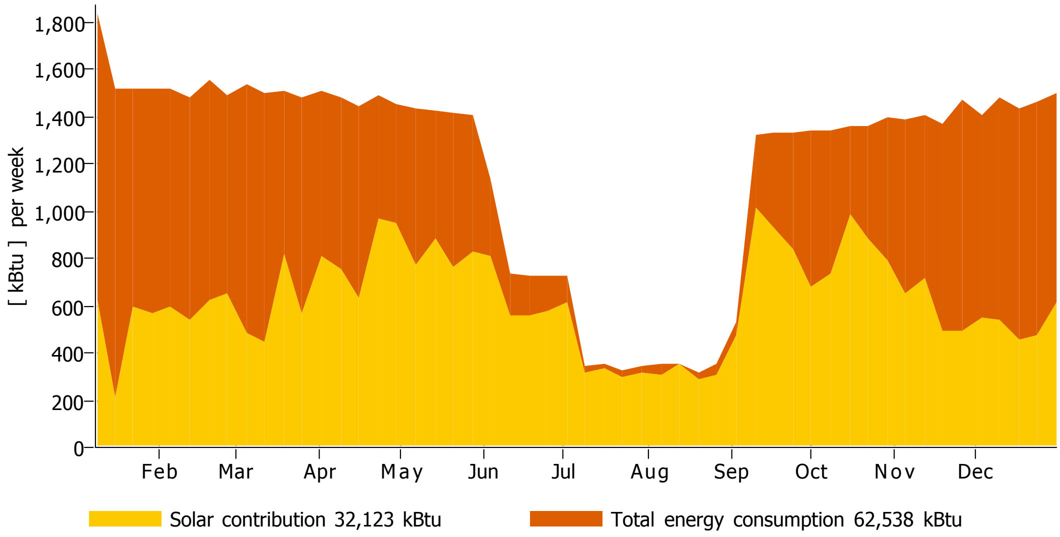
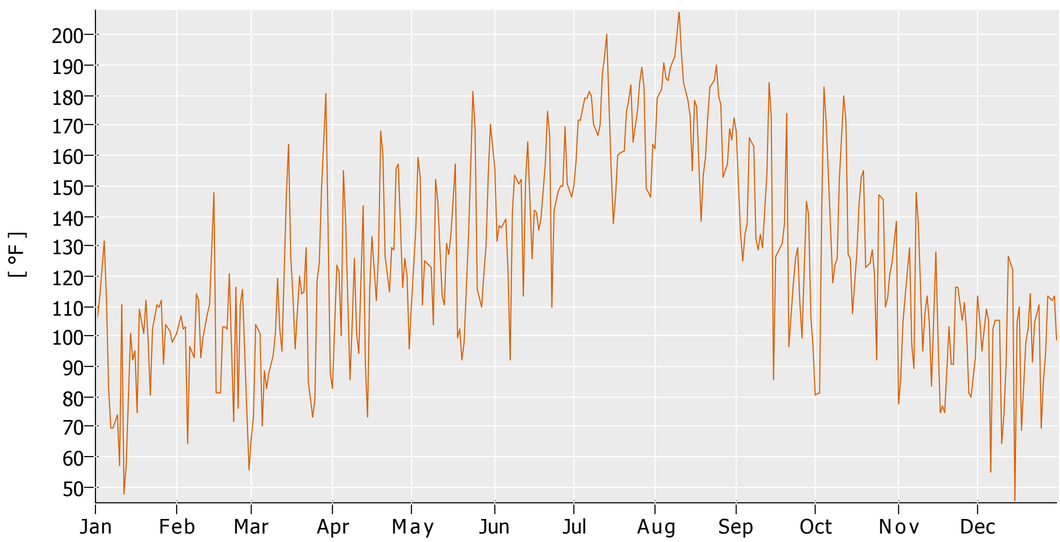
Solar Keymark

Solar energy consumption as percentage of total consumption



Daily maximum collector temperature



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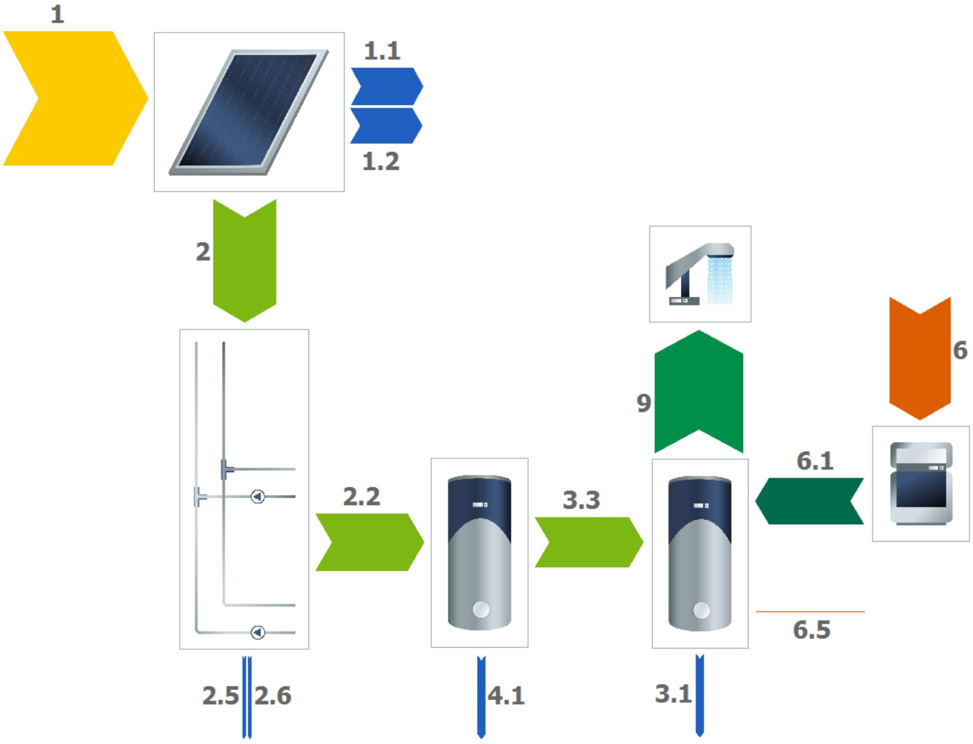
1. Oversized solar DHW systems and/or where extended periods of stagnation are anticipated.

2. If the T*SOL report shows numerous instances of maximum collector temperature over 200F.

*If a system falls under any of these categories, then a heat dump should be installed and sized based on 225 Btu / square foot of collector absorber area.

Energy balance schematic



Legend

1	Irradiation on to collector surface (active)	88 MMBtu
1.1	Optical collector losses	24 MMBtu
1.2	Thermal collector losses	23 MMBtu
2	Energy from collector array	41 MMBtu
2.2	Solar energy to preheating tank	37 MMBtu
2.5	Internal piping losses	1,952 kBtu
2.6	External piping losses	1,966 kBtu
3.1	Tank losses	5 MMBtu
3.3	Preheating tank to tank	32 MMBtu
4.1	Tank losses (S)	5 MMBtu
6	Final energy	40 MMBtu
6.1	Supplementary energy to tank	30 MMBtu
6.5	Electric element	0 kBtu
9	DHW energy from tank	58 MMBtu

Glossary

1 Irradiation on to collector surface (active)
Solar energy irradiated onto tilted collector area (active surface area)

1.1 Optical collector losses
Reflection and other losses

1.2 Thermal collector losses
Heat conduction and other losses

2 Energy from collector array
Energy output at collector array outlet (i.e. before piping)

2.2 Solar energy to preheating tank
Collector array energy minus piping losses

2.5 Internal piping losses
Internal piping losses

2.6 External piping losses
External piping losses

3.1 Tank losses
Heat losses via surface area

3.3 Preheating tank to tank
Heat from preheating tank to tank

4.1 Tank losses (S)
Heat losses via surface area

6 Final energy
Final energy supply to system. This can be from natural gas, oil or electricity (not including solar energy) and takes efficiency into account.

6.1 Supplementary energy to tank
Supplementary energy (e.g. boiler) to tank

6.5 Electric element
Energy from electric water heater element

9 DHW energy from tank
Heat from tank (exluding circulation) for DHW consumption

Appendix D:

Equipment Cutsheets

Technical Data Manual

Model Nos. and pricing: see Price List

Flat plate solar collectors for the harnessing of solar energy
Panels with 25 ft^2 (2.32 m^2) absorber surface

VITOSOL® 200-FM

Product may not be exactly as shown

VITOSOL 200-FM Model SV2F and SH2F

Flat plate solar collectors

For vertical (model SV) or horizontal (model SH) installation on sloped and flat roofs. For integration on walls (model SH only).

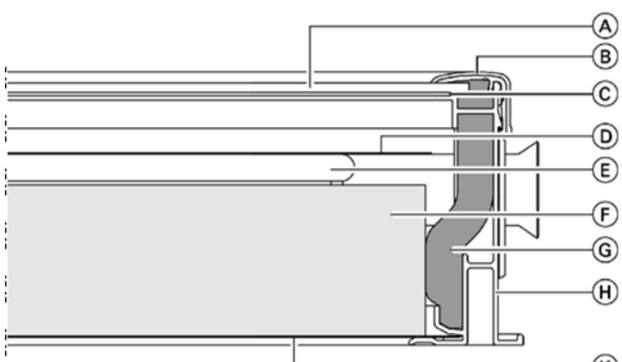
To produce domestic hot water, or to supplement low-temperature heating systems or swimming pools via a heat exchanger.

5786 602 - 01 10/2016

Product Description

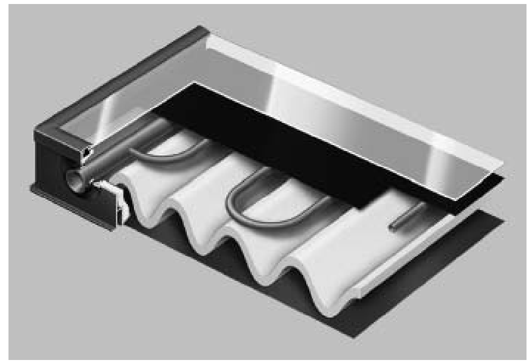
Benefits

- **High performance**, premium version flat plate collector, thanks to unique frame design and highly efficient ThermProtect coated aluminum absorbers.
- **Suitable for many residential or commercial applications** with vertical or horizontal versions available. Suitable for DHW or pool heating, space heating applications.
- **Attractive appearance** with powder coated dark blue frame, endless glass seal and minimal space between collectors. No screws or rivets used in frame for clean, neat finish.
- **Rugged, high-quality construction** using impact-resistant low-iron solar glass, copper piping, aluminum absorber and frame and non-degrading thermal insulation.
- **Permanently sealed and high stability** through all-around folded aluminum frame and endless glass seal.
- **Universal application** on flat, sloped roofs or freestanding, vertical (model SV) or horizontal (model SH) orientation. Model SH is suitable for installations on walls. Connect up to 12 collectors in one array for commercial or residential systems.
- **Fast installation** with flexible connection pipes and quick-connect fittings. Prefabricated collector mounting hardware ensures easy connection to roofs.
- **Maximum system performance and reliability** with a full range of solar system components designed to integrate seamlessly.
- **Quality tested** to Solar Keymark testing requirements.
- **Certified** to the Solar Rating and Certification Corporation (SRCC) OG-100 Standard.



Legend

Ⓐ Solar glass cover, 0.13″ (3.2 mm) thick
Ⓑ Aluminum cover strip in dark blue
Ⓒ Continuous flexible seal for solar glass cover
Ⓓ Aluminum absorber sheet with ThermProtect coating
Ⓔ Meander-shaped copper pipe
Ⓕ Melamine resin foam insulation
Ⓖ Melamine resin foam insulation
Ⓗ Aluminum frame in dark blue
Ⓚ Aluminum-zinc coated sheet steel back panel



Construction and function

The main component of the Vitosol 200-FM is the ThermProtect switching absorber. It ensures high absorption of solar radiation and low emission of thermal radiation. When the collector temperature becomes elevated >167°F (>75°C) the absorber will switch or transition to a higher rate of thermal emission. The net result is that the collector will operate at a reduced temperature as the absorber will be rejecting excess thermal radiation. The ThermProtect switching absorber limits the maximum or stagnation temperature of the collector 293°F (145°C). A meander-shaped copper pipe, through which the heat transfer medium flows, is permanently embedded into the absorber.

The heat transfer medium channels the absorber heat through the copper pipe. The absorber is encased in a highly insulated collector housing, which minimizes collector heat losses. The high quality thermal insulation provides temperature stability and is free from gas emissions.

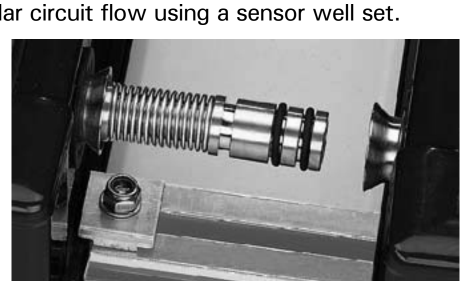
The cover consists of a solar glass panel with a very low iron content, thereby reducing reflection losses. The tempered solar glass is 3.2 mm thick, making it very resistant to weather influences.

The glass is set into the collector frame with a continuous profiled seal, preventing water from penetrating into the collector. This ensures a long and reliable service life for all internal components.

The collector housing consists of a one-piece powder-coated aluminum frame into which the solar glass is permanently sealed.

Up to twelve collectors can be joined quickly and easily to form a single collector array. For this, the standard equipment includes flexible connection pipes, sealed with O-rings (see picture below).

A connection kit with clamping ring fittings enables the collector array to be quickly connected to the pipes of the solar circuit. The collector temperature sensor is installed in the solar circuit flow using a sensor well set.



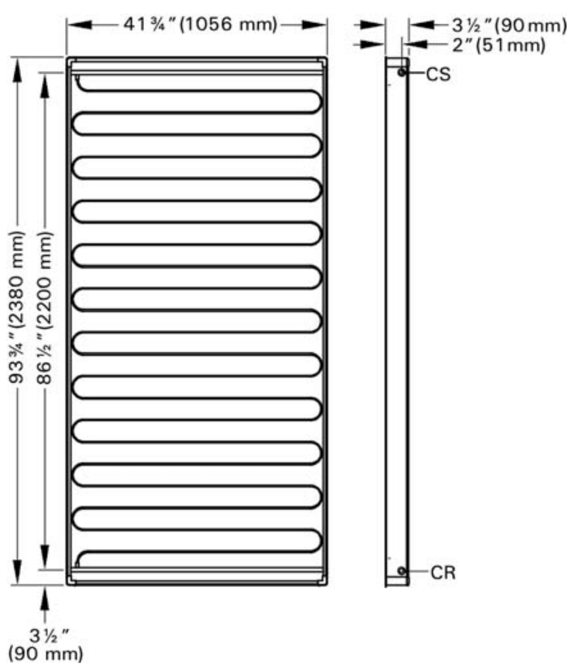
Flexible interconnection pipes

Specification

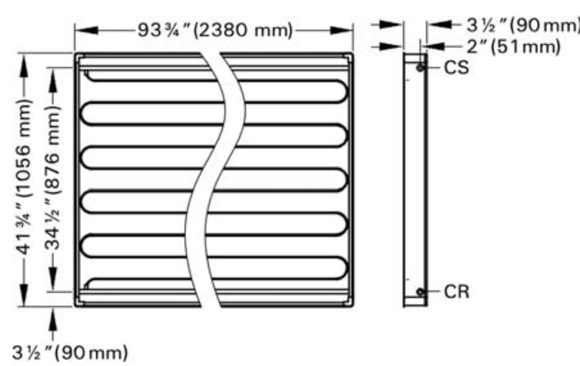
Vitosol 200-FM		SV2F	SH2F
Gross area	ft2 (m2)	27.0 (2.51)	27.0 (2.51)
Absorber area	ft2 (m2)	25.0 (2.32)	25.0 (2.32)
Aperture area **1*	ft2 (m2)	25.1 (2.33)	25.1 (2.33)
Spacing between collectors	in. (mm)	¾ (21)	¾ (21)
Dimensions*2*			
Width	in. (mm)	41¾ (1056)	93¾ (2380)
Height	in. (mm)	93¾ (2380)	41¾ (1056)
Depth	in. (mm)	3½ (90)	3½ (90)
Optical efficiency*3*	%	81.3	81.3
Heat loss coefficient U1	W/(m2 · K)	4.421	4.579
Heat loss coefficient U2	W/(m2 · K2)	0.0210	0.0239
Thermal capacity	kJ/(m2 · K)	4.9	5.97
Weight (dry)	lb (kg)	90.2 (40.9)	90.2 (40.9)
Fluid capacity (heat transfer medium)	USG (L)	0.48 (1.83)	0.63 (2.40)
Maximum working pressure*4*	psig (bar)	87 (6)	87 (6)
Maximum stagnation temperature*5*	°F (°C)	293 (145)	293 (145)
Connection	in. (mm)	¾ (22)	¾ (22)
Requirements for installation surface and anchorage		Roof construction with adequate load capacity for prevailing wind forces	
Mechanical test load			
Max. tested positive load	lb/ft2 (Pa)	73.1 (3500)	73.1 (3500)
Max. tested negative load	lb/ft2 (Pa)	62.7 (3000)	62.7 (3000)

**1* Important for system design considerations.
**2* Dimensions rounded to the nearest ¼ inch.
**3* Based on absorber area.
**4* In sealed systems, operating pressure of at least 44 psig + 0.45 psig x static head (ft.) (3.0 bar + 0.1 bar x static head (m) must be present in the collectors in cold condition.
**5* The stagnation temperature is the temperature which applies to the hottest point of the collector at a global radiation intensity of 3412 Btu/h / 1000 W when no heat is conducted by the heat transfer medium.

Model SV2F (Vertical mounting)



Model SH2F (Horizontal mounting)



Legend
CR Collector return (inlet)
CS Collector supply (outlet)

5786 602 - 01

Standard Equipment/Accessories

Standard equipment

Vitosol 200-FM, Models SH2F and SV2F come fully assembled in shrink-wrap packaging and ready to be connected.

Note: Viessmann offers complete solar heating system combi packages, as well as comprehensive design support in order to facilitate the component selection process.

Accessories

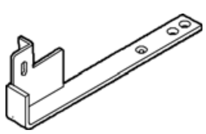
Accessories (individually packed, depending on order):
- Mounting hardware with technical literature
- Interconnection pipes with insulation
- General connection set
- Sensor well set
- Solar Divicon (pumping station for the collector circuit)
- Electronic differential temperature control
- Automatic air vent with air separator
- Fast air vent valve with tee and shutoff valve
- System filling manifold
- Solar hand pump
- Solar expansion tank
- Heat transfer medium

Mounting hardware

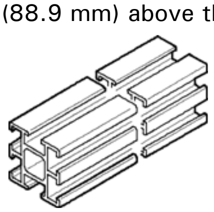
The mounting hardware consists of components required for the relevant method of installation, such as:
Roof brackets, mounting plates, mounting rails, connecting elements for mounting rails, clamping bolts, screws and nuts.

Sloped roof hardware

Required for mounting collector directly onto shingled roof. Raises collector 3½″ (88.9 mm) above the roof.



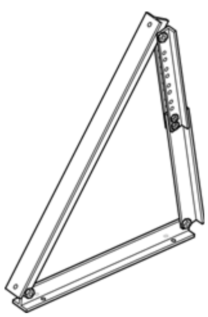
Roof bracket



Installation rail

Flat roof hardware

Required for freestanding, flat roof installations.

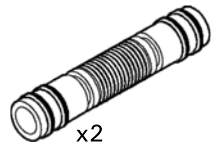


General connection set

Required to connect solar collector to system piping.
One set required per collector array - max. 269 ft^2 (25 m^2).

Pipe connection set

Required to connect multiple solar collectors.



SCU 124/224/345

Electronic differential temperature control for solar heating.

Solar Divicon

Preassembled pumping station for solar collector circuit. Includes: 3-speed pump (2 sizes), pressure gauge, 2 thermometers, 2 ball valves, pressure relief valve, flow meter, 2 flow check valves, air separator, system fill manifold, and foam insulation cover.

Heat transfer medium

Tyfocor non-toxic heating liquid for solar heating systems with active anti-corrosion and anti-ageing protection.

Frost protection:......................	to -31ºF (-35ºC)
Specific gravity at 68ºF (20ºC):...	1.032 to 1.035 g/cm^3 to ASTM D 1122
Viscosity at 68ºF (20ºC):..........	6.5 to 8.0 mm^2/s to DIN 51562
pH value:................................	7.5 to 8.5 to ASTM D 1287
Color:....................................	transparent, blue-green
Container:...............................	5.3 USG (20 L) in a disposable container

Flow Rate in the Collector Array

All Vitosol collectors have a minimum required flow rate (low flow) and maximum flow rate (high flow). The collectors must operate within this range and the system designer must choose a flow rate based on the specific parameters of the system. At the same collector output, a higher flow rate means a lower ΔT or temperature spread across the collector array. Inversely a lower flow rate will have a higher ΔT or temperature spread across the collector array. When the ΔT or temperature spread across the collector array becomes too large, the efficiency of the collectors will also decrease.

For larger solar installations, high flow is usually not recommended as this results in bigger pumps and larger pipe sizes. Typically low flow would be used as the decreased flow requirements result in smaller pumps which would use less energy, and small pipe sizes, reducing the overall installation and operating cost for the system.

Operating modes:
Low flow operation
Operation with flow rates up to approx. 0.014 USG/min/ft^2
0.010 - 0.0143 USG/min/ft^2 (25 - 35 L/h/m^2)

High flow operation
Operation with flow rates greater than 0.014 USG/min/ft^2
0.0143 - 0.0245 USG/min/ft^2 (35 - 60 L/h/m^2)

Flow Velocity

To minimize the pressure drop through the solar thermal system pipework, the flow velocity in the pipe should not exceed 3.3 ft/s (1 m/s). We recommend flow velocities of between 1.3 and 2.3 ft/s (0.4 and 0.7 m/s). At these flow velocities, a pressure drop of between 0.12 and 0.3 “w.c. (1 and 2.5 mbar) /m pipe length will result. For the installation of collectors, we recommend sizing the pipes as for a normal heating system according to flow rate and velocity.

Note: A higher flow velocity results in a higher pressure drop and potentially could erode the walls of the pipework. If the flow velocity is too low, the system will not capture or move the air trapped in the system.

Any residual air that has collected at the collector must be routed downwards through the solar return line to the air vent in the solar divicon. This will have to be manually vented.

Flow Rate - Vitosol 200-FM

High-flow mode

High-flow mode is best suited for small scale systems consisting of less than 8 collectors.

Medium and low-flow modes

Medium and low-flow modes are best suited for larger scale collector arrays consisting of greater than 8 collectors.

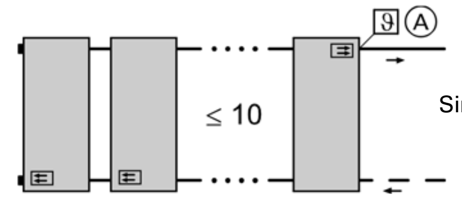
Vitosol 200-FM recommended flow rates per individual collector

Flow	**High flow mode** USG/min (L/min)	**Medium flow mode** USG/min (L/min)	**Low flow mode** USG/min (L/min)
SV and SH models	0.61 (2.32)	0.45 (1.74)	0.31 (1.16)

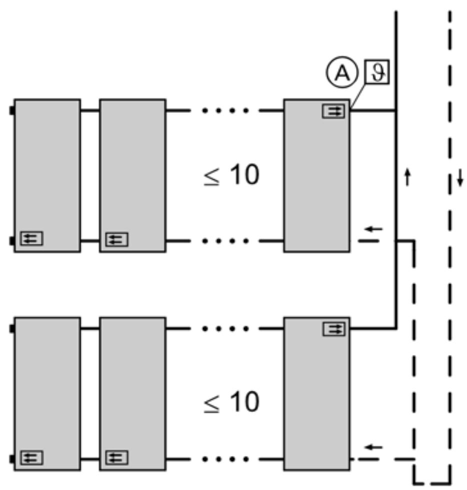
Collector array flow rates

Flow	**High flow mode** USG/min (L/min)	**Medium flow mode** USG/min (L/min)	**Low flow mode** USG/min (L/min)
2 collectors	1.22 (4.6)	--	--
3 collectors	1.83 (6.9)	--	--
4 collectors	2.44 (9.2)	--	--
5 collectors	3.05 (11.5)	--	--
6 collectors	3.66 (13.8)	--	--
8 collectors	--	3.6 (13.6)	2.48 (9.4)
10 collectors	--	4.5 (17.0)	3.1 (11.7)
12 collectors	--	5.4 (20.4)	3.72 (14.1)

Vitosol-FM, Type SV and SH High Flow Operation (single-sided connection)



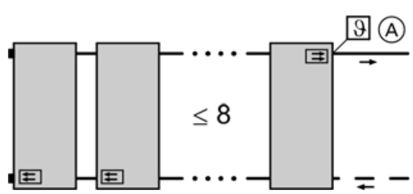
Single array less than or equal to (≤) 10x flat plate collectors



Multiple arrays less than or equal to (≤) 10x flat plate collectors per individual array

Legend
Ⓐ Collector temperature sensor (field installed)

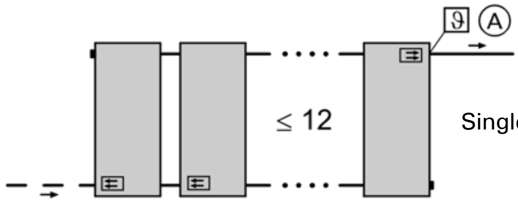
Vitosol-FM, Type SV and SH Low Flow Operation (single-sided connection)



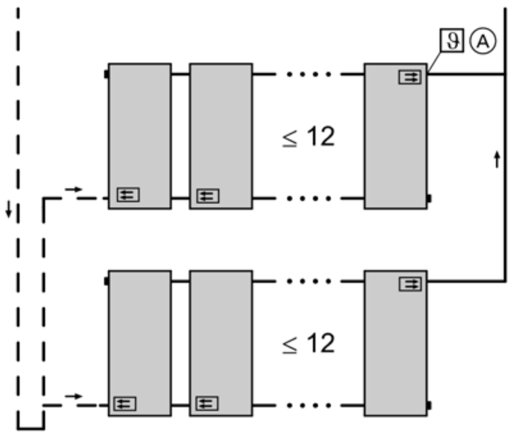
Single array less than or equal to (≤) 8x flat plate collectors

Legend
Ⓐ Collector temperature sensor (field installed)

Vitosol-FM, Type SV and SH High Flow Operation (connection on alternate sides)



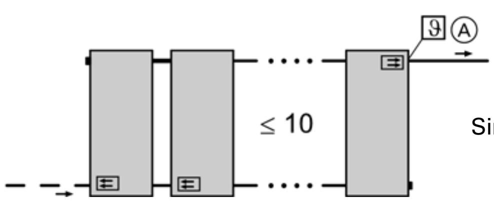
Single array less than or equal to (≤) 12x flat plate collectors



Multiple arrays less than or equal to (≤) 12x flat plate collectors per individual array

Legend
Ⓐ Collector temperature sensor (field installed)

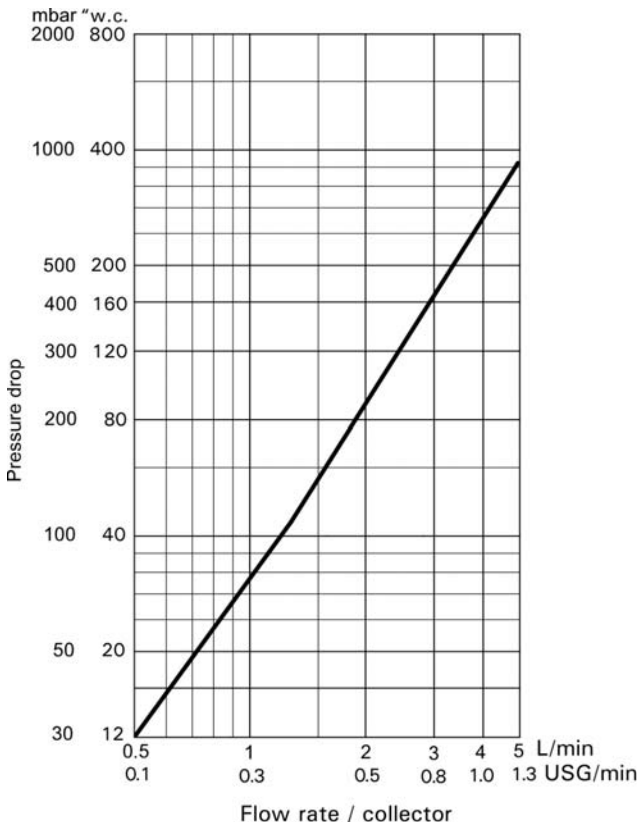
Vitosol-FM, Type SV and SH Low Flow Operation (connection on alternate sides)



Single array less than or equal to (≤) 10x flat plate collectors

Legend
Ⓐ Collector temperature sensor (field installed)

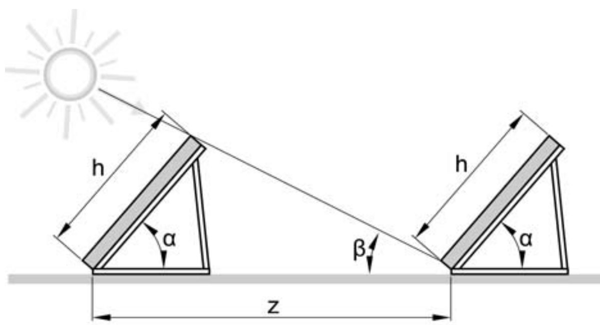
Pressure Drop of Vitosol-FM, Type SV and SH



Relative to water, corresponds to Tyfocor HTL at approx. 140°C (60°C).

Note: For multiple Vitosol-F collector arrays, use the flow rate per individual collector to calculate the pressure drop.

Determining the Collector Row Distance "z"



$$z = \frac{h \bullet \sin(180° - (\alpha + \beta))}{\sin \beta}$$

Legend:
z = Collector row distance
h = Collector height
200-FM model SV = 93¾ in. (2380 mm)
200-FM model SH = 41¾ in. (1056 mm)
α = Collector angle of inclination
200-FM model SV = 25° - 60°
200-FM model SH = 25° - 80°
β = Solar angle
$\beta = (90° - 23.5°)$ - Latitude

IMPORTANT

When installing several collectors in series, maintain a distance of "z".

Example:

Model SV
Toronto is located at approx. 43° latitude.

1. Determine the angle of the sun b. This should be chosen so that the midday sun December 21 falls on the second row of collectors without being obstructed by shadows.

   Solar angle β:
   $\beta = (90° - 23.5°)$ - latitude
   (23.5° should be accepted as constant value for northern latitudes)

   $\beta = (90° - 23.5°) - 43° = 23.5°$

2. Calculating dimension "z":
   h = 2380 mm
   α = 45°
   β = 23.5°

   $$z = \frac{2380 \text{ mm} \bullet \sin(180° - (45° + 23.5°))}{\sin 23.5°}$$

   $$z = \frac{2380 \text{ mm} \bullet \sin 111.5°}{\sin 23.5°}$$

   z = 218.6 in. (5553 mm)

Refer to Vitosol System Design Guide for more information on calculating "z".

Note: Contact Viessmann Solar Tech Support for assistance with calculating distance "z".

Solar System Design

When designing a solar thermal system, the engineer or installing contractor must carefully select system components to ensure efficient, trouble free operation. During the design phase it is recommended that the following details be addressed:

- Type of collector to be used and how it will be installed
- The recommended flow rate for each collector or collector array
- The supply/return pipe size, material and total length of run
- Recommended size of the solar storage/buffer tank
- The pressure drop of the solar collectors, piping, solar pumps, tanks, heat exchangers and other hydronic devices added to the system
- The size of the solar pump required based on flow and pressure drop of the system
- The size of the expansion tank required based on the height of the installation and the thermal expansion of the solar fluid. Since there is a potential for steam to be created, this will also need to be considered when sizing the expansion tank

Refer to Vitosol System Design Guide System sizing information which is available online.

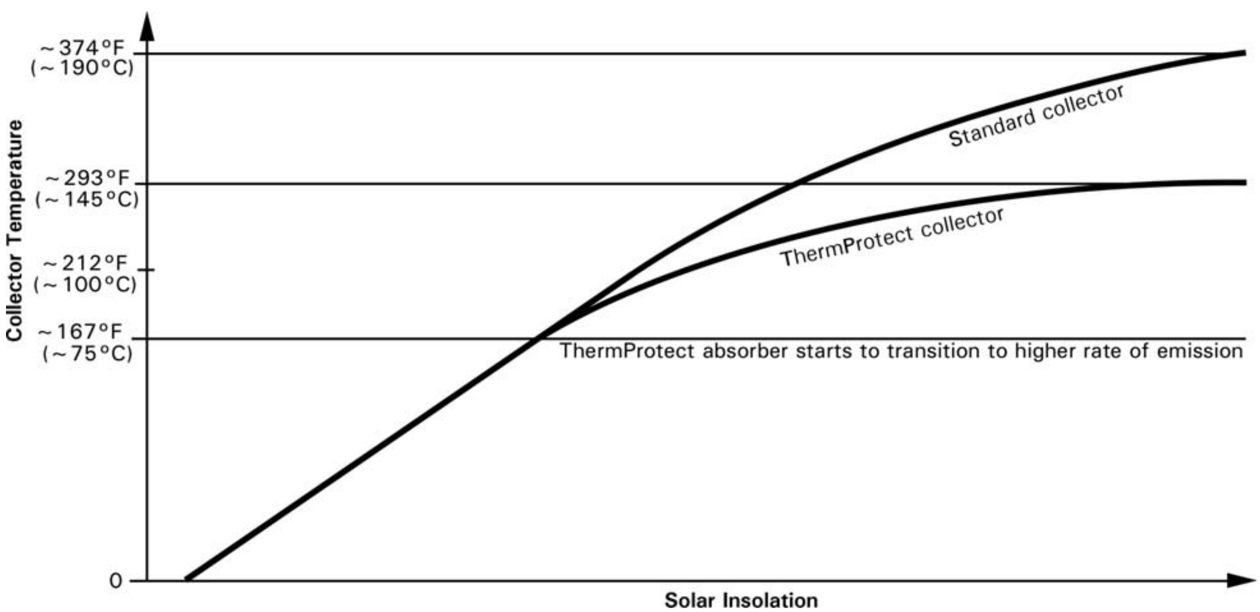
Note: Contact Viessmann Solar Tech Support for assistance with solar sizing.

ThermProtect Absorber Coating

ThermProtect temperature characteristics

Solar collector temperature	Solar tank operation	Emission ε
up to 167°F (75°C)	Solar storage tank being heated	~ 5%
from 167°F to 293°F (75°C to 145°C)	Solar storage tank at max. temperature	~ 5% increases to ~ 40%

- The absorber selective coating (ThermProtect), optical characteristics changes depending on operating temperature
- The rate of absorption α does not change
- The rate of emission ε automatically adapts to the system



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DHW storage tanks **VITOCELL**

Heating Systems ◄

Industrial Systems

Refrigeraation Systems

Vitocell domestic hot water storage tanks
42 to 119 USG / 160 to 450 ltr

Rediscover domestic hot water comfort

With a Vitocell tank from Viessmann, you increase your comfort level and your savings at the same time - the Vitocell line offers something for everyone.

With a new Vitocell tank from Viessmann, you increase your comfort level and your savings at the same time! Fast recovery rates, large water volume, low standby losses translate into comfort, convenience, efficiency and reliability. Choose Vitocell – choose peace of mind.

Something for everyone
Tanks are available in vertical and horizontal designs, for placement beside or underneath a boiler, from 42 to 119 USG / 160 to 450 liters. Also, with Viessmann Integrated System Technology, boiler, tank and control match perfectly. Everything fits together, installs quickly and arrives factory-adjusted - fast installation and maximum system performance are guaranteed. Find out on the following pages how you can improve your domestic hot water experience today.

Vitocell 300
Made of high-alloy stainless steel, the Vitocell 300 models are not only extremely hygienic, but are known for their operational reliability and long service life.

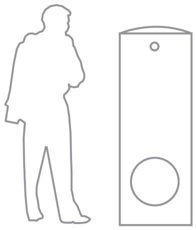
Vitocell 100
This series is an economical choice for convenient and efficient domestic hot water production.

The Vitocell 100 models are made of steel with a Ceraprotect two-coat enamel finish and a consumable anode to protect against corrosion.

Satisfaction guaranteed
The large heat exchanger surfaces of the Vitocell tanks extend right to the tank bottom and ensure an abundant supply of hot water and even water temperatures all day long. The heat exchanger coils are arranged for efficient venting and draining and facilitate start-up and smooth operation. HCFC-free insulation (foamed-in-place or wrap-around) reduces standby losses and increases operating efficiency.

Maximum System Performance
In contrast to most conventional direct-fired tanks, indirect-fired tanks from Viessmann, such as the Vitocell line, use the heating water from the boiler to heat the tank water. Space heating and domestic hot water production are integrated into one system - maximum system performance regulated by one control, powered by one burner!

Did you know?
You can save up to 50% in operating cost with Viessmann indirect-fired domestic hot water storage tanks.



VITOCELL 100-V

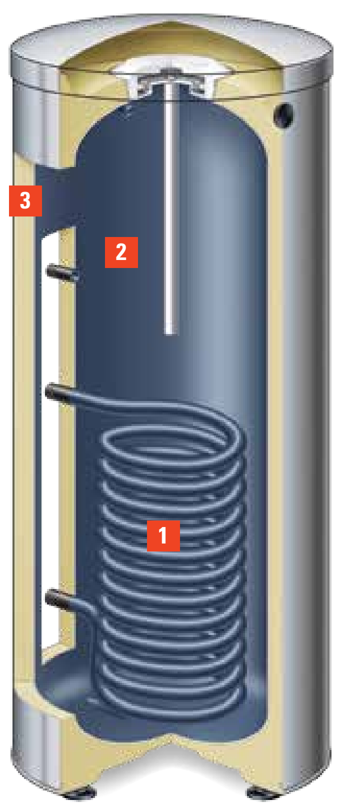
High performance and quality construction for economical domestic hot water
Vertical, indirect-fired domestic hot water tank, 42 to 119 USG

The Vitocell 100 tank series is the economical choice for reliable and efficient domestic hot water production. Single-coil tanks are available in 4 sizes from 42 to 119 USG / 160 to 450 ltr. Dual-coil tanks for use in solar thermal applications are available in 2 sizes, 79 and 119 USG / 300 and 450 ltr.

Quality construction
The steel construction of the Vitocell 100 tanks has a two-coat enamel finish which protects all interior surfaces from corrosion.

While the base layer provides a solid bond between the steel construction and the enamel finish, the second layer protects the tank from corrosion.

For additional protection each tank comes with a consumable anode.



Convenience
Fast recovery rates and the large heat exchanger surfaces of the tank coil ensure an abundant supply of hot water and even water temperatures at all times.

For more flexibility and to meet larger domestic hot water demands, take advantage of a multi-tank installation (Vitocell-V 100, 79 and 119 USG / 300 and 450 ltr only).

Economy
Extremely efficient domestic hot water production via boiler (indirect-fired). Save up to 50% in operating cost compared to most conventional (direct-fired) domestic hot water production.

Highly-effective HCFC-free foamed-in-place or wrap-around insulation reduces standby losses and operating cost.

Solar tank
Discover new ways of domestic hot water production! With the Vitocell-B 100 dual-coil tank you can have it two ways - via solar collector and/or the heating boiler. Find out more on pages 8/9.

Vitocell 100-V single-coil tank

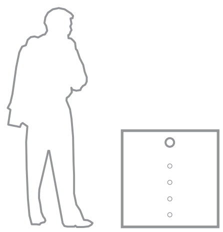
1. Heat exchanger coil : heat is transferred from the boiler to the tank water
2. Magnesium anode : provides additional active corrosion protection
3. HCFC-free, foamed-in-place insulation

Specifications

- Four single-coil tank sizes from 42 to 119 USG / 160 to 450 ltr
- Two dual-coil tank sizes from 79 and 119 USG / 300 and 450 ltr
- Vitocell 100-V, 119 USG / 450 ltr is supplied with removable soft polyester fiber (PET) insulation for easy handling.

Benefits at a glance

- Large heat exchanger surfaces for fast recovery rates and a constant and reliable DHW supply.
- Tank coil extends to tank bottom which guarantees even and consistent water temperatures at all times.
- Quality steel construction and Viessmann Ceraprotect permanent two-coat enamel finish for operational reliability and long service life.
- Magnesium anode provides additional active corrosion protection.
- Save up to 50% of your operating costs with extremely efficient indirect hot water production by a condensing boiler.
- Highly effective, HCFC-free insulation keeps standby losses and operating cost to a minimum.
- Ideal for small spaces with zero clearance to combustibles.
- Satisfy large DHW demands by connecting multiple Vitocell 100-V tanks (79 and 119 USG) to form a tank battery.



VITOCELL 300-V/-H

Comfort, convenience and reliability for abundant supply of domestic hot water
Vertical and horizontal, indirect-fired domestic hot water tank, 42 to 119 USG

The Vitocell 300 is the leading tank series in the Vitocell line of domestic hot water storage tanks. It's extremely durable, efficient, hygienic and provides all the hot water you need.

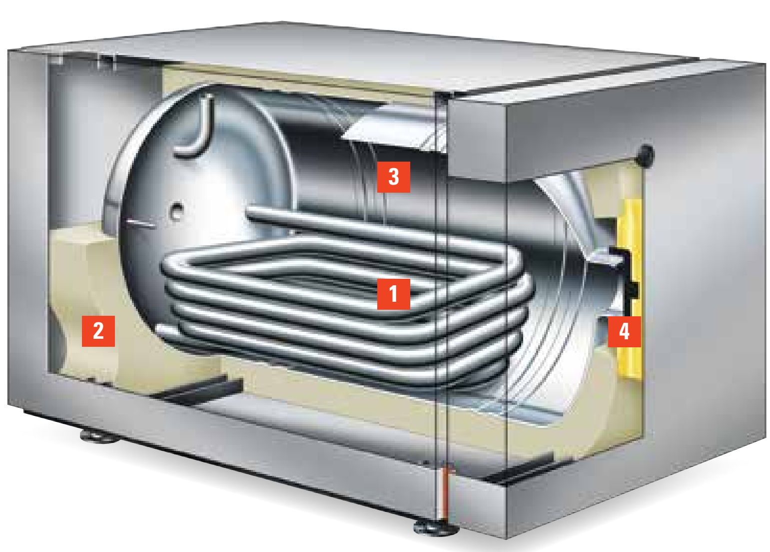
Available in vertical and horizontal designs, from 42 to 119 USG / 160 to 450 liters.

Long Service Life
Both tank and heat exchanger are made of SA240-316 Ti high-performance stainless steel, a material known for its durability, hygiene, acid resistance and aesthetic appearance. There is minimal wear - no corrosion protection is needed - and this maximizes your cost savings.

Comfort
Fast recovery rates due to large heat exchanger surfaces of the tank coil ensure an abundant supply of hot water and even water temperatures at all times. To meet the requirements of multiple-family housing you have the option of combining several Vitocell 300 tanks into 'tank batteries' - beside each other when room is available, or stacked (horizontal design) when space is at a premium.

Efficiency
Extremely efficient domestic hot water production via condensing boiler (indirect-fired). Save up to 50% in operating cost compared to most conventional (direct-fired) domestic hot water production. Highly effective HCFC-free foamed-in-place or wrap-around insulation reduces standby losses and operating cost.

Solar tank
Discover new ways of domestic hot water production! With the Vitocell-B 300 dual-coil tank you can have it two ways - via solar collector and/or the heating boiler. Find out more on pages 8/9.



Vitocell 300-H horizontal tank

1. Stainless steel heat exchanger coil extends to tank bottom to heat entire water volume
2. Foamed-in-place HCFC-free insulation
3. 316Ti Stainless steel construction
4. Clean-out opening

Specifications

- Three vertical single-coil tank sizes from 53 to 119 USG / 200 to 450 ltr
- Four horizontal single-coil tank sizes from 42 to 119 USG / 160 to 450 ltr
- Two vertical dual-coil tank sizes from 79 to 119 USG / 300 and 450 ltr
- Tank body and heat exchanger coil constructed of SA240-316 Ti stainless steel

Benefits at a glance

- Peace of mind with lifetime warranty for residential installations.
- Large heat exchanger surfaces for fast recovery rates and a constant and reliable DHW supply.
- Tank coil extends to tank bottom guaranteeing even and consistent water temperatures at all times.
- High alloy stainless steel construction provides operational reliability and a long service life.
- Scale and corrosion resistant, the Vitocell 300 is ideal for areas with poor water quality.
- Save up to 50% of your operating with extremely efficient indirect hot water production by a condensing boiler.
- Highly effective (HCFC-free) insulation keeps standby losses and operating cost at a minimum.
- Satisfy large DHW demands by connecting multiple Vitocell 300 DHW tanks to form a tank battery. Horizontal tanks can be stacked.
- Ideal for small spaces with zero clearance to combustibles.

VITOCELL 300-B/100-B

Solar thermal sytems are ideal for integration with your indirect-fired DHW tank
Vertical, indirect-fired dual-coil DHW tank, 79 to 120 USG

Vitosol 200-F flat plate
solar collectors

Integrating indirect-fired domestic hot water (DHW) heating with your gas-fired condensing boiler can save as much as 50% in operating costs when compared to conventional direct-fired hot water production.

Our complete line of DHW storage tanks offers high-quality construction and fast recovery rates for an abundant supply of DHW at all times. Plus, with thick thermal insulation, your DHW is guaranteed to stay hot. In addition to vertical and horizontal DHW storage tanks, choose from economical enamel-lined or premium stainless steel construction for a variety of applications.

Your economical choice

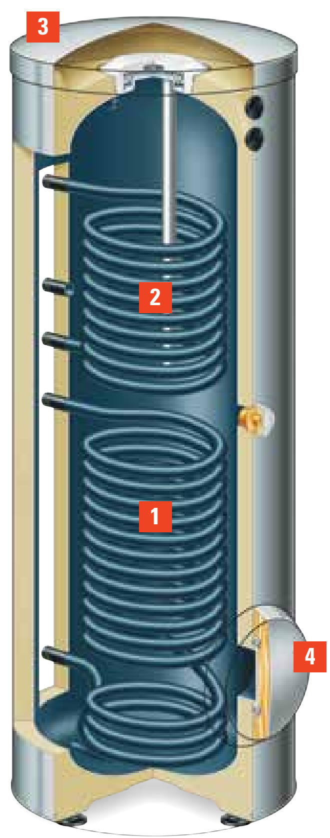
The Vitocell 100 Series meets all demands for comfortable and economical DHW heating. With steel construction, Ceraprotect enamel coating and a magnesium anode, the Vitocell 100 ensures operational reliability and a long service life. Single-coil tanks are available in 4 sizes from 42 to 119 USG. Dual-coil tanks for use in solar thermal applications are available in 2 sizes, 79 and 119 USG.

Your premium choice

Vitocell 300 tanks are made from corrosion-resistant, high-alloy stainless steel to satisfy the most stringent hygiene standards. With its premium-quality construction, the Vitocell 300 offers long-term, reliable operation and comes with a lifetime warranty. Vitocell 300 tanks meet the stringent standards required to carry the Environmental Choice logo. Single-coil tanks are available in 7 sizes from 42 to 119 USG. Dual-coil tanks are available in 2 sizes, 79 and 119 USG.

Solar hot water heating

Our dual-coil solar tank allows both the solar collectors and gas-fired condensing boiler to produce your home's DHW. Solar heat is transferred using the lower coil, while back-up heat is supplied by the heating boiler, as required, via the upper coil (see illustration). By using solar energy to help generate your home's DHW, you can lower your heating bill further without compromising your hot water supply.



Vitocell 100-B dual-coil solar tank

1 Lower coil : Heat is transferred from the solar collectors to the tank water

2 Upper coil : Additional heat supplied by the high-efficiency boiler

3 Stainless steel construction (Vitocell 300)

4 Clean-out opening

1. High-performance solar thermal collectors
2. Dual-coil storage tank
3. High-efficiency gas-fired condensing boiler
4. Reliable supply of domestic hot water
5. Hot water space heating system

How it works
The tank has two coils. Via the bottom coil, heat is transferred from the solar collectors to the tank water. On days when the heat transfer from the solar collectors is too low, the boiler uses the top coil to supply additional heat to the tank water.

Integration with an indirect-fired hot water tank
If your home uses a hot water based heating system, you have the option of an integrated single-tank system. Using a dual-coil storage tank, both the solar collectors and gas-fired condensing boiler contribute to DHW production.

High performance solar systems
Built on more than 30 years of experience, our high-performance flat plate and vacuum tube solar collectors and system components deliver superior year-round performance in a variety of applications. Plus, for residential installations, we offer complete solar system packages that simplify ordering and installation.

Technical Specifications

Vitocell 100-V and Vitocell 100-B indirect-fired vertical DHW storage tank

Model		CVA	CVA	CVA	CVA	CVB*	CVB*
Capacity	USG	42	53	79	119	79	119
	ltr	160	200	300	450	300	450
Dimensions (inches)	Width	23	23	25	33.5	25	33.5
	Depth	24	24	27.75	35.25	28	36
	Height	47	55.5	68.75	77	69	77
Weight	lbs	190	214	333	399	353	452

*Bivalent, dual-coil hot water production via solar collector and boiler.

Vitocell 300-V and Vitocell 300-B indirect-fired vertical DHW storage tank

Model		EVI	EVI	EVI	EVB*	EVB*
Capacity	USG	53	79	119	79	119
	ltr	200	300	450	300	450
Dimensions (inches)	Width	23	25	36	25	36.5
	Depth	25.5	27.75	38.5	27.75	38.5
	Height	56	70	69.5	70	68.5
Weight	lbs	168	220	245	251	275

*Bivalent, dual-coil hot water production via solar collector and boiler.

Vitocell 300-H indirect-fired horizontal DHW storage tank

Model		EHA	EHA	EHA	EHA
Capacity	USG	42	53	92	119
	ltr	160	200	350	450
Dimensions (inches)	Width	25.25	25.25	32.75	35.75
	Depth	42.25	48.25	62.5	65
	Height	25.75	25.75	31	35
Weight	lbs	168	185	379	421

Viessmann - The Company

Viessmann - climate of innovation
The Viessmann brand promise concisely expresses all that we hope to achieve. It is our key brand message and, together with our brand label, an identifying feature throughout the world. "Climate of innovation" is a promise on three levels: It is a commitment to a culture of innovation. It is a promise of high product utilization and, at the same time, an obligation to protect the environment.

Comprehensive range of products and services for all fuel types
Viessmann is one of the leading international manufacturers of heating systems and, with its comprehensive range of products and services, offers individual solutions of efficient systems for all applications and fuel types. As an environmental pioneer, the company has been supplying particularly efficient and clean heating systems for decades.

Acting in a sustainable manner
For Viessmann, to take responsibility, means a commitment to act in a sustainable way. This means bringing ecology, economy and social responsibility into harmony with each other, ensuring that current needs are satisfied without limiting the basis for life for the generations to come.

Efficiency program
With our efficiency program, Viessmann shows that the political goals set for 2020 with regard to climate and energy can already be achieved today with commercially available technology.

This project demonstrates:
- Environmental protection
- Efficiency with resources
- Securing manufacturing sites for the future

As a result, fossil fuels have been cut by 40 percent and CO_2 emissions reduced by a third.

Deutscher Nachhaltigkeitspreis
Deutschlands nachhaltigste Marke 2013

Viessmann won the German Sustainability Award 2013 for its commitment to climate protection and efficient use of resources.

For the particularly efficient utilization of energy through the innovative heat recovery center at the company's main site in Allendorf/Eder, Viessmann was rewarded with the Energy Efficiency Award 2010.

Viessmann Werke GmbH & Co. KG

Company details
- Established in: 1917
- Employees: 11,500
- Group turnover: 2.2 billion Euro
- Export share: 56 percent
- 22 factories in 11 countries
- Operating in 74 countries
- 120 sales offices worldwide

Performance spectrum
- Condensing technology for oil and gas
- Solar thermal systems
- Heat pumps
- Wood combustion systems
- CHP modules
- Biogas plants
- Services

VIESSMANN

climate of innovation

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BIOFerm™ Energy Systems
Verona, WI U.S.A.
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www.bioferm-es.com

Technical information subject to change without notice.
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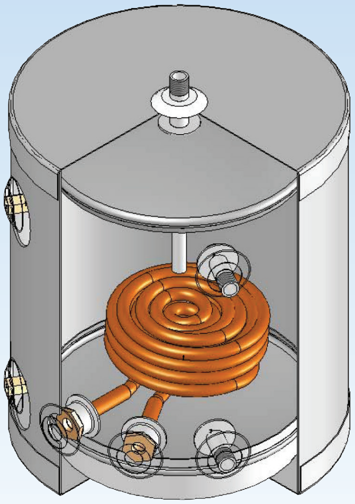
Advanced Heating & Hot Water Systems

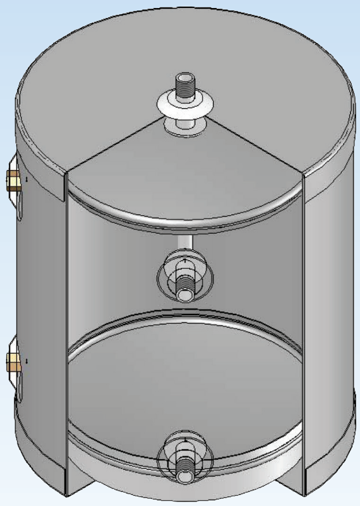
DRAIN BACK TANK

316L Stainless Steel Tank

The **Drain Back Tank** is designed to allow the solar collectors to drain all the water from collector and related pipe connections into the drain back tank reservoir to protect the system from both freezing and overheating. The Drain Back Tank comes with either an internal heat exchanger for use with a storage tank or without a heat exchanger to be connected to a tank with an internal heat exchanger or plate frame heat exchanger. Drain back systems are a smart choice when designing a solar thermal system to supplement central heating and domestic hot water heating when overheating during the warmer months is a problem. Drain back systems have less components, so maintenance is reduced, compared to a pressurized glycol system. Drain back systems also provide protection where water quality may be a problem.



SSU-DBX with Heat Exchanger



SSU-DB without Heat Exchanger

Drain Back Features

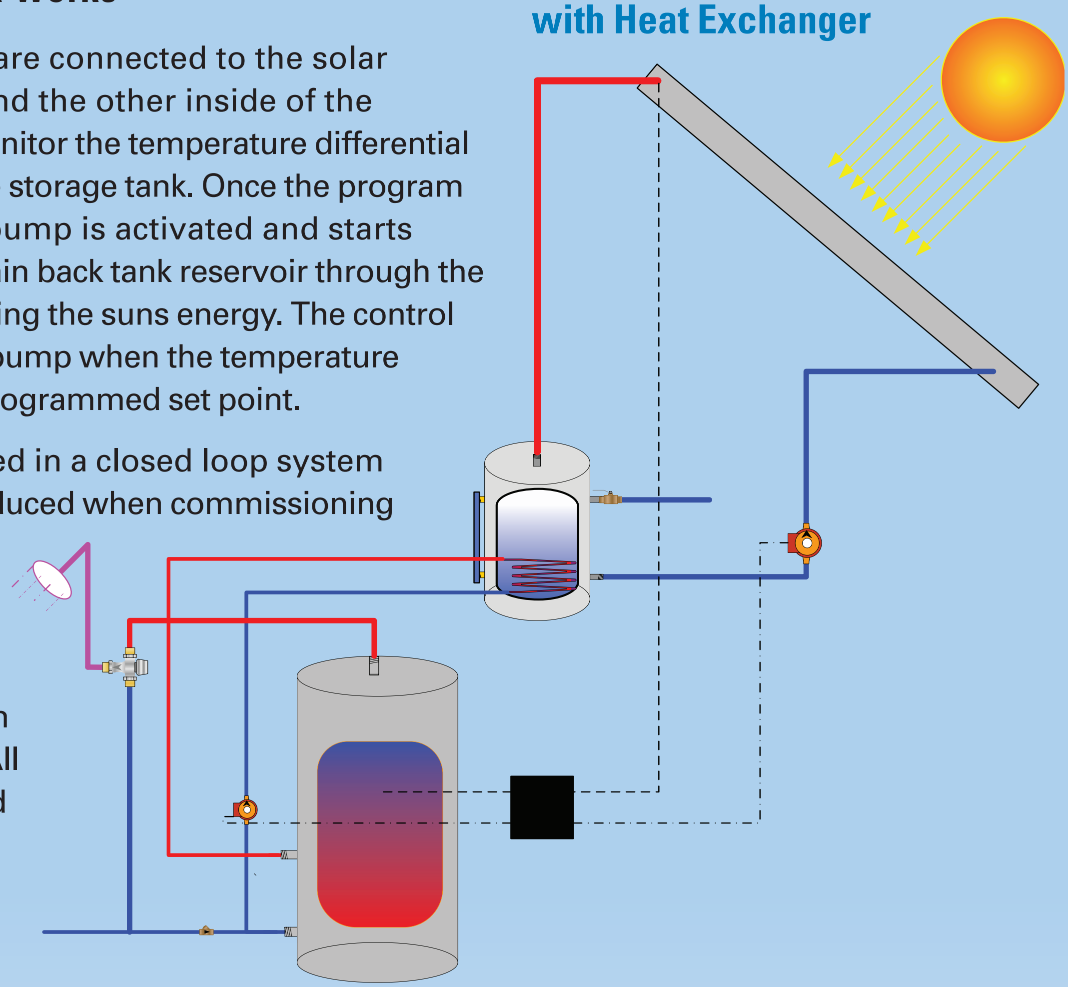
- Tank constructed of durable **316L stainless steel**
- Plastic Jacket will not dent
- Light weight construction
- Maintenance free operation
- 5 year warranty against leaks
- Available with or without heat exchanger
- Highly efficient Copper Heat Exchanger with large surface area
- Site Glass to monitor water level
- Internal dip tube enhance heat exchanger performance

How the Drain Back Tank works

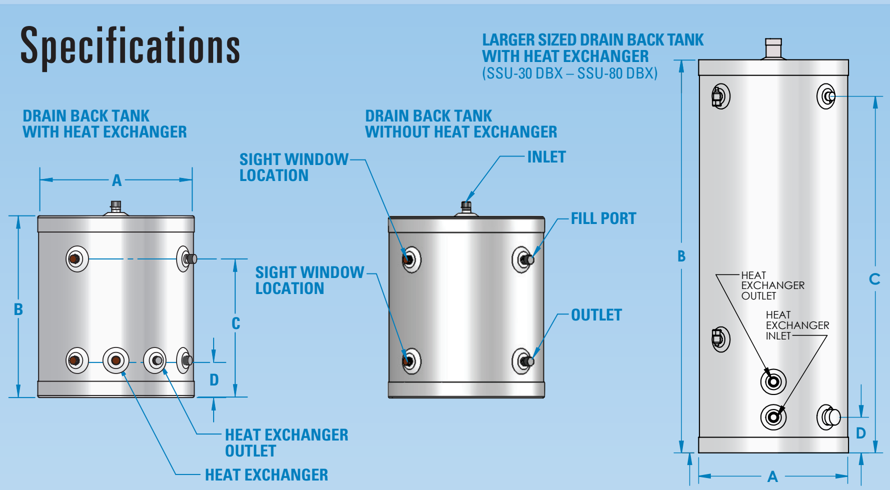
There are two sensors that are connected to the solar control – one on collector and the other inside of the storage tank. The sensors monitor the temperature differential between the collector and the storage tank. Once the program differential is reached, the pump is activated and starts circulating water from the drain back tank reservoir through the solar collector to start absorbing the suns energy. The control will deactivate the circulator pump when the temperature difference drops below the programmed set point.

The drain back system is used in a closed loop system where the water is only introduced when commissioning the system. When the circulator shuts down, all the water must drain back into the tank reservoir so any exposed piping or system components will not freeze. All drain back tanks are equipped with a site glass to determine water level inside the tank.

Drain Back Application with Heat Exchanger

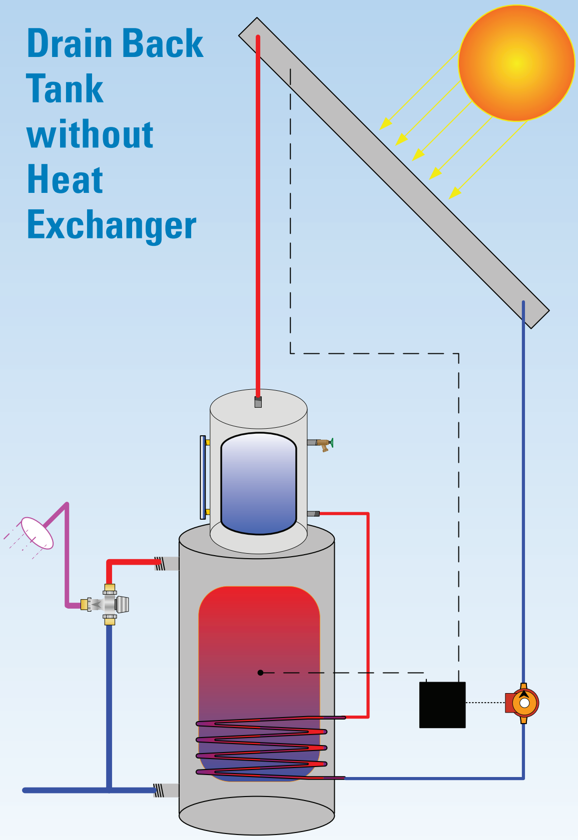


Specifications



Model	A	B	C	D	Inlet/Outlet	Capacity	Heat Hx	Ship. Weight	Total Tank Vol W / HX	Useable Tank Vol Above Internal HX
SSU-10 DB	19.25	20.00	15.00	4.50	3/4" NPT	10 Gal	N/A	31 lbs.	–	–
SSU-10 DBX	19.25	20.00	15.00	4.50	3/4" NPT	10 Gal	10 Sq. Ft.	39.7 lbs.	12 Gal	7.8 Gal
SSU-15 DB	19.25	22.00	17.00	4.50	3/4" NPT	15 Gal	N/A	33 lbs.	–	–
SSU-15 DBX	19.25	22.00	17.00	4.50	3/4" NPT	15 Gal	15 Sq. Ft.	47.5 lbs.	14.1 Gal	9.8 Gal
SSU-20 DB	19.25	27.00	21.75	4.50	1" NPT	20 Gal	N/A	37 lbs.	–	–
SSU-20 DBX	19.25	27.00	21.75	4.50	1" NPT	20 Gal	20 Sq. Ft.	54.1 lbs.	17.8 Gal	13.5 Gal
SSU-30 DB	19.25	39.50	33.75	4.50	1" NPT	30 Gal	N/A	49 lbs.	–	–
SSU-30 DBX	19.25	39.50	33.75	4.50	1" NPT	30 Gal	20 Sq. Ft.	75 lbs.	23.4 Gal	18.8 Gal
SSU-40 DB	19.25	51.875	46	4.50	1.5" NPT	40 Gal	N/A	61 lbs.	–	–
SSU-40 DBX	19.25	51.875	46	4.50	1.5" NPT	40 Gal	20 Sq. Ft.	84 lbs.	32.8 Gal	28.3 Gal
SSU-60 DB	23.25	52.125	46.25	4.50	1.5" NPT	60 Gal	N/A	90 lbs.	–	–
SSU-60 DBX	23.25	52.125	46.25	4.50	1.5" NPT	60 Gal	20 Sq. Ft.	116 lbs.	51.9 Gal	44.2 Gal
SSU-80 DB	23.25	71.5	65.5	4.50	1.5" NPT	80 Gal	N/A	125 lbs.	–	–
SSU-80 DBX	23.25	71.5	65.5	4.50	1.5" NPT	80 Gal	40 Sq. Ft.	151 lbs.	74.4 Gal	68 Gal

Drain Back Tank without Heat Exchanger



www.hhi-green.com/solar/en

Hyundai Solar Module

Hyundai Heavy Industries was founded in 1972 and is a Fortune 500 company. The company employs more than 48,000 people, and has a global leading 7 business divisions with sales of 51.3 Billion USD in 2013. As one of our core businesses of the company, Hyundai Heavy Industries is committed to develop and invest heavily in the field of renewable energy.

Hyundai Solar is the largest and the longest standing PV cell and module manufacturer in South Korea. We have 600 MW of module production capacity and provide high-quality solar PV products to more than 3,000 customers worldwide. We strive to achieve one of the most efficient PV modules by establishing an R&D laboratory and investing more than 20 Million USD on innovative technologies.

TI-Series

Multi-crystalline Type

HiS-M300TI | HiS-M305TI | HiS-M310TI | HiS-M315TI | HiS-M320TI | HiS-M325TI

Mono-crystalline Type

HiS-S325TI | HiS-S330TI | HiS-S335TI | HiS-S340TI | HiS-S345TI | HiS-S350TI

Mechanical Characteristics

※ Several models are under certification process.

Dimensions	998 mm (39.29")(W) × 1,960 mm (77.17")(L) × 50 mm (1.97")(H)
Weight	Approx. 23.2 kg (51.1 lbs)
Solar cells	72 cells in series (6 × 12 matrix) (Hyundai cell, Made in Korea)
Output cables	4 mm² (12AWG) cables with polarized weatherproof connectors, IEC certified (UL listed), Length 1.2 m (47.2")
Junction box	IP67, weatherproof, IEC certified (UL listed)
Bypass diodes	3 bypass diodes to prevent power decrease by partial shade
Construction	Front : High transmission low-iron tempered glass, 3.2 mm (0.126") Encapsulant : EVA Back Sheet : Weatherproof film
Frame	Clear anodized aluminum alloy type 6063

High Quality

- UL listed (UL 1703), Type 1 for Class A Fire Rating
- Output power tolerance +3/-0 %
- ISO 9001:2000 and ISO 14001:2004 Certified
- Advanced Mechanical Test (5,400 Pa) Passed (IEC) / Mechanical Load Test (40 lbs/ft²) Passed (UL)
- Ammonia Corrosion Resistance Test Passed
- IEC 61701 (Salt Mist Corrosion Test) Passed

Fast and Inexpensive Mounting

- Delivered ready for connection
- IEC (UL) certified and weatherproof connectors
- Integrated bypass diodes

Limited Warranty

- 10 years for product defect
- 10 years for 90 % of warranted min. power
- 25 years for 80 % of warranted min. power

※ **Important Notice on Warranty**

The warranties apply only to the PV modules with Hyundai Heavy Industries Co., Ltd.'s logo (shown below) and product serial number on it.

CE c UL us LISTED JET PV CYCLE

HYUNDAI HEAVY INDUSTRIES

Electrical Characteristics

| Multi-crystalline Type |

		HiS-M□□□TI					
		300	305	310	315	320	325
Nominal output (Pmpp)	W	300	305	310	315	320	325
Voltage at Pmax (Vmpp)	V	35.8	36.0	36.1	36.2	36.4	36.6
Current at Pmax (Impp)	A	8.4	8.5	8.6	8.7	8.8	8.8
Open circuit voltage (Voc)	V	44.9	45.1	45.3	45.5	45.7	45.9
Short circuit current (Isc)	A	8.7	8.8	8.9	9.0	9.0	9.1
Output tolerance	%	+3/-0					
No. of cells & connections	pcs	72 in series					
Cell type	-	6" Multi-crystalline silicon (Hyundai cell, Made in Korea)					
Module efficiency	%	15.3	15.6	15.8	16.1	16.4	16.6
Temperature coefficient of Pmpp	%/K	-0.41	-0.41	-0.41	-0.41	-0.41	-0.41
Temperature coefficient of Voc	%/K	-0.32	-0.32	-0.32	-0.32	-0.32	-0.32
Temperature coefficient of Isc	%/K	0.039	0.039	0.039	0.039	0.039	0.039

※All data at STC (Standard Test Conditions). Above data may be changed without prior notice.

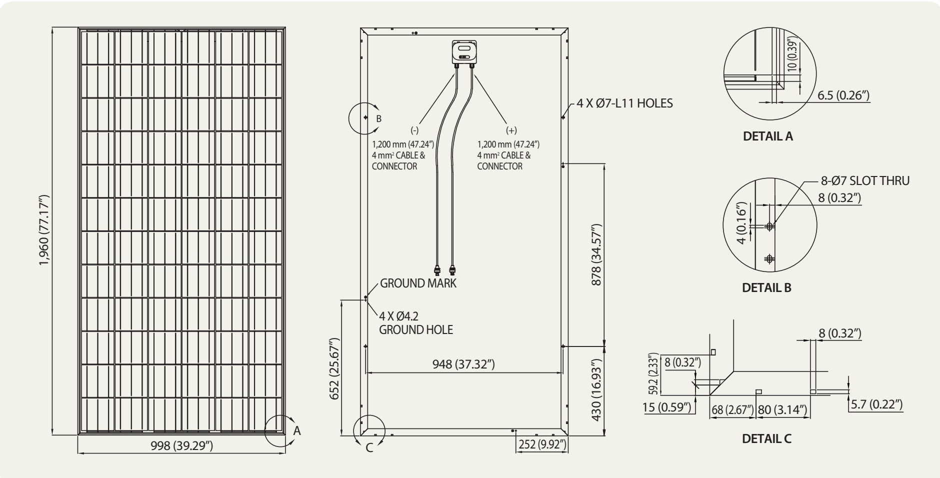
| Mono-crystalline Type |

		HiS-S□□□TI					
		325	330	335	340	345	350
Nominal output (Pmpp)	W	325	330	335	340	345	350
Voltage at Pmax (Vmpp)	V	37.8	38.0	38.2	38.4	38.6	38.7
Current at Pmax (Impp)	A	8.6	8.7	8.78	8.9	9.0	9.0
Open circuit voltage (Voc)	V	46.1	46.3	46.5	46.7	46.9	47.1
Short circuit current (Isc)	A	9.2	9.3	9.4	9.5	9.6	9.6
Output tolerance	%	+3/-0					
No. of cells & connections	pcs	72 in series					
Cell type	-	6" Mono-crystalline silicon (Hyundai cell, Made in Korea)					
Module efficiency	%	16.6	16.9	17.1	17.4	17.6	17.9
Temperature coefficient of Pmpp	%/K	-0.42	-0.42	-0.42	-0.42	-0.42	-0.42
Temperature coefficient of Voc	%/K	-0.30	-0.30	-0.30	-0.30	-0.30	-0.30
Temperature coefficient of Isc	%/K	0.047	0.047	0.047	0.047	0.047	0.047

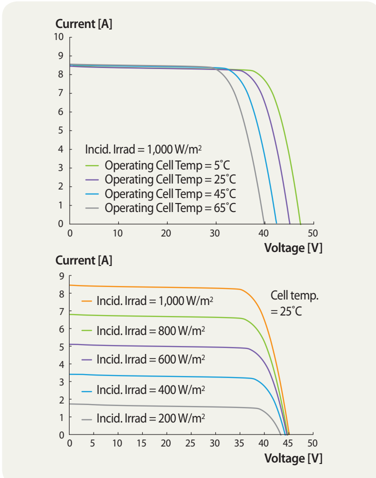
※All data at STC (Standard Test Conditions). Above data may be changed without prior notice.

| Module Diagram |

(unit : mm, inch)



| I-V Curves |



| Installation Safety Guide |

• Only qualified personnel should install or perform maintenance.
• Be aware of dangerous high DC voltage.
• Do not damage or scratch the rear surface of the module.
• Do not handle or install modules when they are wet.

Nominal Operating Cell Temperature	46˚C ± 2
Operating Temperature	-40 - 85˚C
Maximum System Voltage	DC 1,000 V (IEC) DC 1,000 V (UL)
Maximum Reverse Current	15 A

[Printed Date : December 2015]

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HYUNDAI HEAVY INDUSTRIES

Lochinvar®
HIGH EFFICIENCY BOILERS & WATER HEATERS

Heat Pump Residential Electric Water Heaters

Heat Pump Models

Lochinvar's Heat Pump residential electric models are available in 50, 66 and 80 gallon capacities and feature a heat pump operating with environmentally-friendly R134a refrigerant that will absorb ambient heat from the surrounding air reducing electrical consumption by up to 66%.

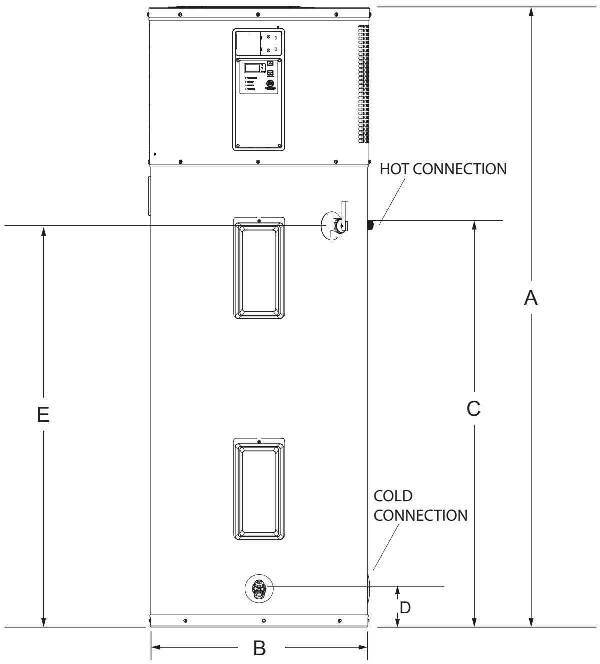
Standard Features

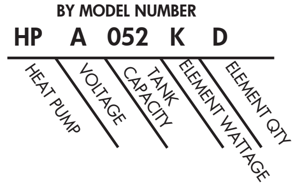
- **ENERGY STAR® -** The Heat Pump water heater meets the ENERGY STAR requirement with 3.06 to 3.24 Energy Factor in hybrid mode and are eligible for most utility rebate programs.
- **Code Compliance –** Complies with the Federal Energy Conservation Standards effective April 16, 2015, in accordance with the Energy Policy and Conservation Act, (EPCA), as amended.
- **Electronic Control –** The electronic control features an LED display and four operating modes to match the heating requirements of the environment. The LED display will also read-out current status, set point and fault codes.
- **Immersion Heating Elements –** Zinc-coated copper sheath design for longer life in hard, aggressive water. The elements screw in for easy service and replacement.
- **Glass-Lined Steel Tank –** The durable glass lining is fused to the steel tank at 1600°F to assure lasting protection against rust and corrosion while providing clear, clean hot water. 300 PSI test pressure; 150 PSI working pressure.
- **Non-CFC Foam Insulation –** A uniform coverage of thick closed-cell foam insulation minimizes standby heat loss, maximizes heat retention and delivers a high Energy Factor.
- **Tank Saver Anode –** A large diameter, high capacity anode inhibits corrosion of the tank interior for long, trouble-free service.
- **Heat Trap –** Heat traps are built into the inlet and outlet connections to eliminate heat migration and heat loss in the water piping.
- **Temperature & Pressure Relief Valve –** Factory installed for optimum safety.
- **Brass Drain Valve –** An enhanced ball valve design for effective drainage and positive shut-off.
- **10 Year Limited Tank & Parts Warranty* –** See warranty sheet for details.

** 1-year limited tank & parts warranty when installed in a commercial application.*

All models meet or exceed Federal and ASHRAE Energy Efficiency Standards

Dimensions and Specifications





This heater has a 10 year warranty. It is a heat pump model, has a 50 gallon capacity with a 240 volt 4500 watt upper element and 4500 watt lower element.

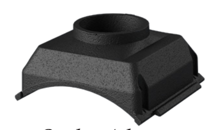
Model Number	Nominal Gallon Cap	Rated Storage Cap.	Input Watts	Standard Voltage	1st Hr. Rating	UEF	A	B	C	D	E	Ship. Wt.
HPA052KD	50	46	4500	208V/240V	66	3.42	63″	22″	40-1/2″	3-3/4″	40-1/2″	196
HPA068KD	66	67	4500	208V/240V	79	3.00	61″	27″	38″	4″	38″	289
HPA082KD	80	82	4500	208V/240V	84	2.73	69″	27″	46″	4″	46″	307

Water connections are 3/4” NPT.

Available Air Kits

- **Inlet & Outlet Outdoor Air Kit** – The Inlet & Outlet Air Kit adapts the Heat Pump water heater to work with outdoor air. This allows the Heat Pump to be installed in confined spaces and spaces with conditioned air. The kit works with standard 8” flexible duct (field supplied) up to 10 total feet.
- **Booster Fan Kit** – By adding the Booster Fan Kit to the Inlet & Outlet Air Kit, the flexible duct can extend to 25 total feet.

Inlet Adapter



Outlet Adapter

Part Number	Description	Shipping Weight
100234320	Inlet & Outlet Outdoor Air Kit	5
100131328	Booster Fan Kit	10

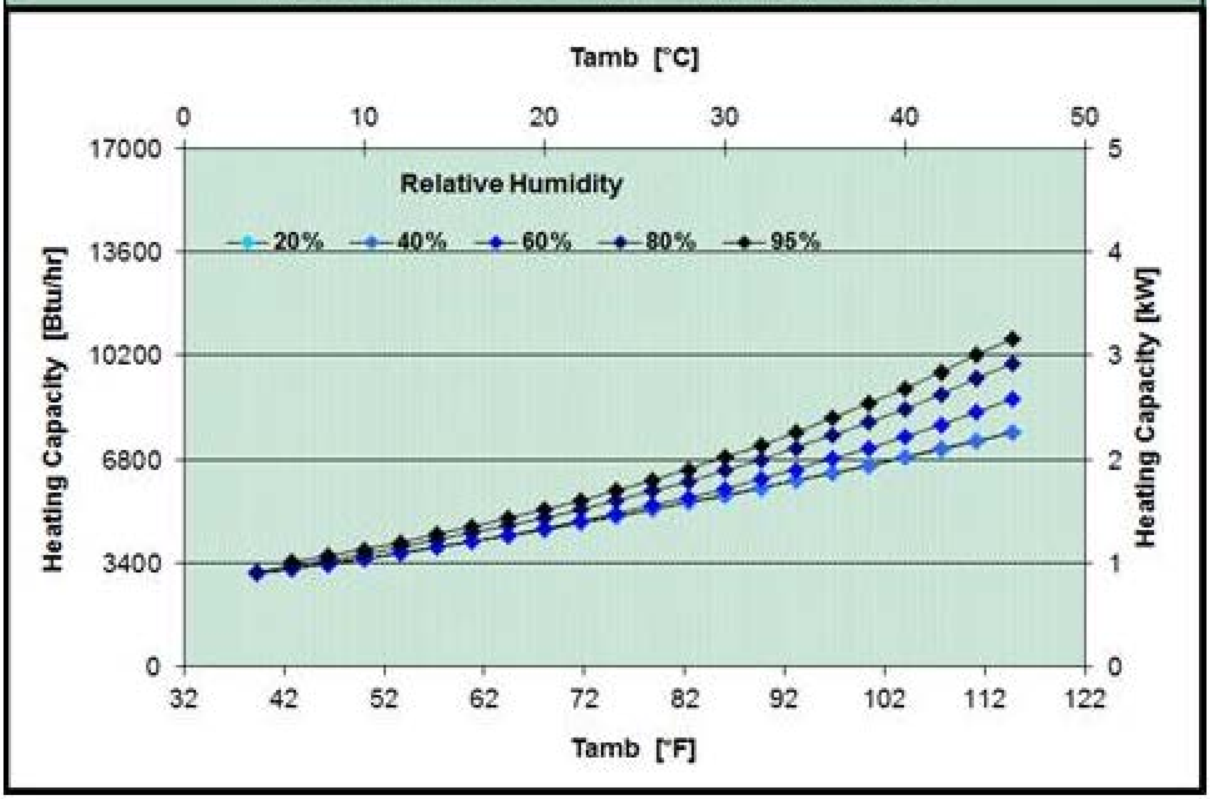
Certified for Potable Water and Space Heating Applications
This water heater is suitable for water heating and space heating. Toxic chemicals, such as those used for boiler water treatment shall NEVER be introduced into this system. This water heater may NEVER be connected to any existing heating system or components previously used with non-potable water heating appliances.

Lochinvar®
HIGH EFFICIENCY BOILERS & WATER HEATERS
Lochinvar, LLC
300 Maddox Simpson Parkway
Lebanon, Tennessee 37090
P: 615.889.8900 / F: 615.547.1000
Lochinvar.com

AHRI CERTIFIED™ www.ahridirectory.org
LOW LEAD CONTENT
DESIGN CERTIFIED

Lochinvar Hybrid Heat Pump Water Heater Specs:
Max Supply Water Temp: 150F
Recovery: 27 GPH @ 90F Rise
Storage: 80 Gallons
Cooling Capacity: 5,000 Btu/hr

DATA BELOW SHOWN FOR STORAGE TEMPERATURE OF 134.6°F



COMMERCIAL-GRADE
RESIDENTIAL ELECTRIC WATER HEATERS

VOLTEX® HYBRID ELECTRIC HEAT PUMP WATER HEATER

The Voltex Hybrid Electric heat pump water heater from A. O. Smith is the most cost effective energy-efficient option available for consumers who want to save money on their utility bills. Voltex can reduce water heating costs up to 73% and provide payback in 2-3 years. With annual savings of $305 or more, there is no better way to go green than Voltex.

HOW DO THEY WORK?

Absorb ambient heat from the surrounding air to heat water using a compressor and "Environmentally-Friendly" R134a refrigerant

- Self-contained heat pump unit is integrated into the top of the tank
- Multiple operating modes to maximize efficiency and performance

QUALIFIES FOR MANY STATE AND LOCAL UTILITY REBATES - CHECK WWW.DSIREUSA.ORG

INCREASED ENERGY EFFICIENCY

- Improved efficiency designed in, to ensure available hot water at the lowest possible cost. Up to a 3.52 Uniform Energy Factor (UEF) Rating conserves energy and meets ENERGY STAR® qualifications

CHOICE OF OPERATING MODES

- Select from Efficiency, Hybrid, or Electric modes to match heating requirements to environmental conditions.
- Hybrid mode automatically adjusts between compressor and element, depending upon heat requirements.
- Vacation mode reduces operating costs and provides freeze protection during extended absence

BACKUP ELECTRIC ELEMENTS

- Long-lasting backup heating elements help heat water according to environmental conditions, demand, and the chosen operating mode

COREGARD™ ANODE ROD

- Our anode rods have a stainless steel core that extends the life of the anode rod allowing superior tank protection far longer than standard anode rods
- 66 and 80 gallon models have dual anodes for added protection.

DRY FIRE PROTECTION

- Control system checks to ensure the tank is full of water during start up to prevent dry firing the heating elements

ELECTRONIC USER INTERFACE

- User-friendly electronic interface allows easy control of temperature setting, operating mode, and communicates diagnostics
- Easy to read temperature display (see back) shows temperature in °F or °C
- Advanced diagnostics convey error messages for service purposes. The last four error messages are saved in the control system memory.

OTHER FEATURES

- Ideal for basements or garage installations; the compressor transfers heat to the water while dehumidifying and cooling the ambient air
- Washable air filter is easily removed for routine cleaning

OPTIONAL AIR DUCT ADAPTER KIT

- Permits installation in confined spaces

SIX YEAR LIMITED WARRANTY

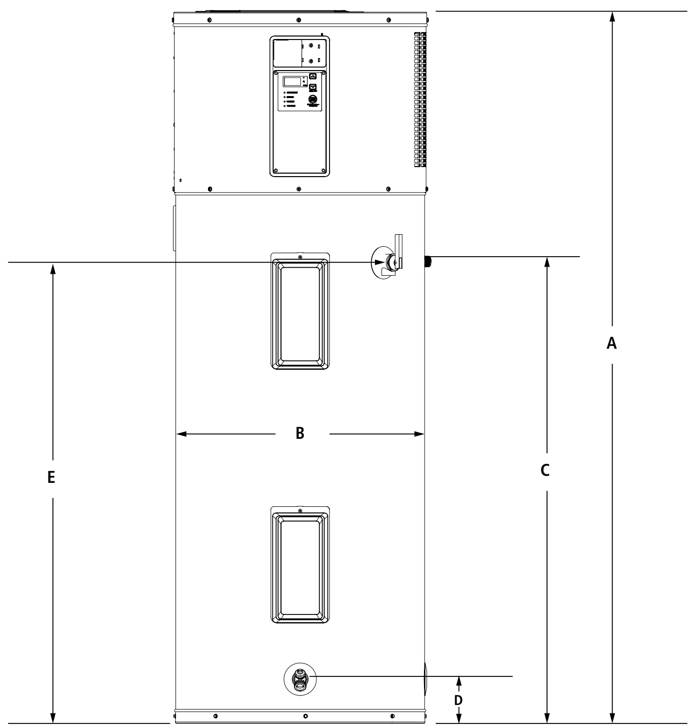
- For complete information, consult written warranty or go to hotwater.com

Low Lead Content
ENERGY STAR
LISTED
AHRI CERTIFIED®
www.ahridirectory.org

COMMERCIAL-GRADE
RESIDENTIAL ELECTRIC WATER HEATERS

Model Number	Nominal Capacity	Rated Storage Volume	UEF	First Hour Rating (Gallons)	Dimensions in Inches					Approx. Shipping Weight (lbs)	Warranty Term
					A	B	C	D	E		
FPTU-50	50	46	3.42	66	63	22	40-5/8	3-3/4	40-1/2	196	6
FPTU-66	66	67	3.52	66	61	27	38	4	38	289	6
FPTU-80	80	82	2.73	84	69	27	46	4	46	307	6

Requires 30 amp breaker.
Top T&P option not available.



ELECTRONIC USER INTERFACE

- User friendly, easy to read display.
- LEDs clearly indicate the current operating mode.
- Easily select operating mode:
  - Efficiency
  - Hybrid
  - Electric
  - Vacation
- Display communicates current status, mode and set point, and displays error messages when applicable.

EFFICIENCY MODE

- Utilizes the heat pump for all water heating.
- Automatically reverts to heating element if ambient air or water temperatures are outside optimal operating range for heat pump.

HYBRID MODE

- Utilizes the heat pump or heating element, depending on demand.

ELECTRIC MODE

- Standard electric water heater operation.

VACATION MODE

- One touch operation maintains tank temperature of 60°F (15.6°C) during vacation or extended absence to reduce operating costs and provide freeze protection.
- Programmable up to 99 days.

OTHER FEATURES:

- Sacrificial anode to protect against tank corrosion.
- Environmentally-friendly non-CFC foam insulation.
- Durable, enhanced-flow brass drain valve.
- CSA certified and ASME rated temperature & pressure relief valve.

OPERATING REQUIREMENTS:

- Requires provision for condensate draining; if a suitable drain is not available, a condensate pump is required.
- 208/240 VAC 60Hz single phase 30 amp power supply.

For Technical Information, call 800-527-1953. A. O. Smith Corporation reserves the right to make product changes or improvements without prior notice.

Air Source
Heat Pump Water Heaters

Standard Features

- 140°F - 160°F hot water temperatures to prevent and eradicate Legionella
- Single or multi-pass capability for easy integration into new or existing systems
- Vented double wall, stainless steel, heat exchanger ensuring safe, potable water
- Integrated stainless steel circulator pump
- Industrial electro-mechanical controls

	HPWH Model (60 Hz)	Heating Capacity (MBH)	Cooling Capacity (MBH)	Heating COP	Cooling COP	Combined COP	Hot Water Flow Rate (GPM)	Airflow (CFM)
Propeller Fan	HPA7	110	88	4.5	3.6	8.1	3.1	4000
	HPA9	131	104	4.5	3.6	8.1	3.7	4000
	HPA11	170	137	4.7	3.8	8.5	4.9	4000
	HPA12	209	169	4.9	4.0	8.9	6.0	4000
	HPA15	267	210	4.4	3.5	7.9	7.6	6000
Centrifugal Fan	HPA4	66	53	4.9	4.0	8.9	1.9	1200
	HPA7	110	88	3.7	3.0	6.7	3.1	4000
	HPA9	131	104	3.8	3.1	6.9	3.7	4000
	HPA11	170	137	4.2	3.3	7.5	4.9	4000
	HPA12	209	169	4.4	3.6	8.0	6.0	4000
	HPA15	267	210	3.9	3.1	7.0	7.6	6000

Based on 75°F entering air wet bulb temperature, 70°F entering potable water temperature and 140°F leaving potable water temperature.

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A division of Colmac Industries

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Air Source
Heat Pump Water Heaters

COLMAC WATERHEAT

Applications

- Hotels
- Apartments
- Offices
- Dormatories
- Laundries
- Hospitals
- Schools
- Industrial Process
- Pools
- Hydronic Heating

Optional Features

- High Temperature Circuit to produce up to 185°F water
- Compressor VFD for additional operational cost savings
- PLC control with BMS communication
- Electronic Expansion Valve (EEV) for improved performance over varying conditions
- Galvanized, aluminum, or stainless steel enclosure
- Copper, Polycoat, or Electroplate evaporator construction
- Coaxial condensers for poor water quality or pool heating applications
- Defrost and freeze protection
- Protective screen and rain hood for outdoor applications

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CUSTOMER NAME : **Highmark** **JOB NAME :** **SCA**

NUMBER OF UNITS : **1**

SALES CONTACT : Bart Ransom

HPA 2 PLC

CABINET CONSTRUCTION

CABINET MATERIAL :	304 STAINLESS STEEL (S)
FIN MATERIAL :	MICROCHANNEL
FAN TYPE :	PROP FAN

ELECTRICAL SPECIFICATIONS*

VOLTAGE :	230V / 60Hz / 1Ph
TOTAL PANEL AMPACITY (FLA) :	19.1 A
MINIMUM CIRCUIT AMPACITY (MCA) :	23.3 A
FEEDER WIRE GAUGE :	12 AWG
MAXIMUM OVERCURRENT PROTECTION (MOP) :	30 A

***APPROXIMATE VALUES, SUBJECT TO CHANGE**

OPERATING CONDITIONS

ENTERING AIR WET BULB TEMP :	42 °F
ENTERING POTABLE WATER TEMP :	50 °F
LEAVING POTABLE WATER TEMP :	140 °F
POTABLE FLOW RATE AT DESIGN CONDITION :	0.6 GPM
REQUIRED POTABLE FLOW FOR MINIMUM LIFT CONDITION :	3.1 GPM

PERFORMANCE SPECIFICATIONS**

HEATING CAPACITY:	30,506 BTU/hr
HEATING CAPACITY:	3 Tons
SUCTION TEMPERATURE:	24 °F
COOLING CAPACITY:	19,183 BTU/hr
HEATING COP:	2.5
COOLING COP:	1.5
COMBINED COP:	4.0

****APPROXIMATE VALUES, SUBJECT TO CHANGE. VALUES BASED ON CONDITIONS SPECIFIED ABOVE. IF ACTUAL CONDITIONS DIFFER, PERFORMACE WILL ALSO DIFFER.**

INCLUDED OPTIONS :
POLYESTER AIR FILTER, PLC

COMPRESSOR: COPELAND ZR34K5E-PFV-160
POTABLE PUMP: GRUNDFOS UPS 15-55 x 1

NOTES:

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CUSTOMER NAME : **Highmark** **JOB NAME :** **SCA**

NUMBER OF UNITS : **1**

SALES CONTACT : Bart Ransom

HPA 2 PLC

CABINET CONSTRUCTION

CABINET MATERIAL :	304 STAINLESS STEEL (S)
FIN MATERIAL :	MICROCHANNEL
FAN TYPE :	PROP FAN

ELECTRICAL SPECIFICATIONS*

VOLTAGE :	230V / 60Hz / 1Ph
TOTAL PANEL AMPACITY (FLA) :	19.1 A
MINIMUM CIRCUIT AMPACITY (MCA) :	23.3 A
FEEDER WIRE GAUGE :	12 AWG
MAXIMUM OVERCURRENT PROTECTION (MOP) :	30 A

***APPROXIMATE VALUES, SUBJECT TO CHANGE**

OPERATING CONDITIONS

ENTERING AIR WET BULB TEMP :	59 °F
ENTERING POTABLE WATER TEMP :	50 °F
LEAVING POTABLE WATER TEMP :	140 °F
POTABLE FLOW RATE AT DESIGN CONDITION :	0.8 GPM
REQUIRED POTABLE FLOW FOR MINIMUM LIFT CONDITION :	3.5 GPM

PERFORMANCE SPECIFICATIONS**

HEATING CAPACITY:	34,551 BTU/hr
HEATING CAPACITY:	3 Tons
SUCTION TEMPERATURE:	30 °F
COOLING CAPACITY:	23,275 BTU/hr
HEATING COP:	2.8
COOLING COP:	1.9
COMBINED COP:	4.7

****APPROXIMATE VALUES, SUBJECT TO CHANGE. VALUES BASED ON CONDITIONS SPECIFIED ABOVE. IF ACTUAL CONDITIONS DIFFER, PERFORMACE WILL ALSO DIFFER.**

INCLUDED OPTIONS :
POLYESTER AIR FILTER, PLC

COMPRESSOR: COPELAND ZR34K5E-PFV-160
POTABLE PUMP: GRUNDFOS UPS 15-55 x 1

NOTES:

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CUSTOMER NAME : **Highmark** **JOB NAME :** **SCA**

NUMBER OF UNITS : **1**

SALES CONTACT : Bart Ransom

HPA 2 PLC

CABINET CONSTRUCTION

CABINET MATERIAL :	304 STAINLESS STEEL (S)
FIN MATERIAL :	MICROCHANNEL
FAN TYPE :	PROP FAN

ELECTRICAL SPECIFICATIONS*

VOLTAGE :	230V / 60Hz / 1Ph
TOTAL PANEL AMPACITY (FLA) :	19.1 A
MINIMUM CIRCUIT AMPACITY (MCA) :	23.3 A
FEEDER WIRE GAUGE :	12 AWG
MAXIMUM OVERCURRENT PROTECTION (MOP) :	30 A

***APPROXIMATE VALUES, SUBJECT TO CHANGE**

OPERATING CONDITIONS

ENTERING AIR WET BULB TEMP :	78 °F
ENTERING POTABLE WATER TEMP :	50 °F
LEAVING POTABLE WATER TEMP :	140 °F
POTABLE FLOW RATE AT DESIGN CONDITION :	0.9 GPM
REQUIRED POTABLE FLOW FOR MINIMUM LIFT CONDITION :	4.2 GPM

PERFORMANCE SPECIFICATIONS**

HEATING CAPACITY:	42,334 BTU/hr
HEATING CAPACITY:	4 Tons
SUCTION TEMPERATURE:	42 °F
COOLING CAPACITY:	31,148 BTU/hr
HEATING COP:	3.5
COOLING COP:	2.5
COMBINED COP:	6.0

****APPROXIMATE VALUES, SUBJECT TO CHANGE. VALUES BASED ON CONDITIONS SPECIFIED ABOVE. IF ACTUAL CONDITIONS DIFFER, PERFORMACE WILL ALSO DIFFER.**

INCLUDED OPTIONS :
POLYESTER AIR FILTER, PLC

COMPRESSOR: COPELAND ZR34K5E-PFV-160
POTABLE PUMP: GRUNDFOS UPS 15-55 x 1

NOTES:

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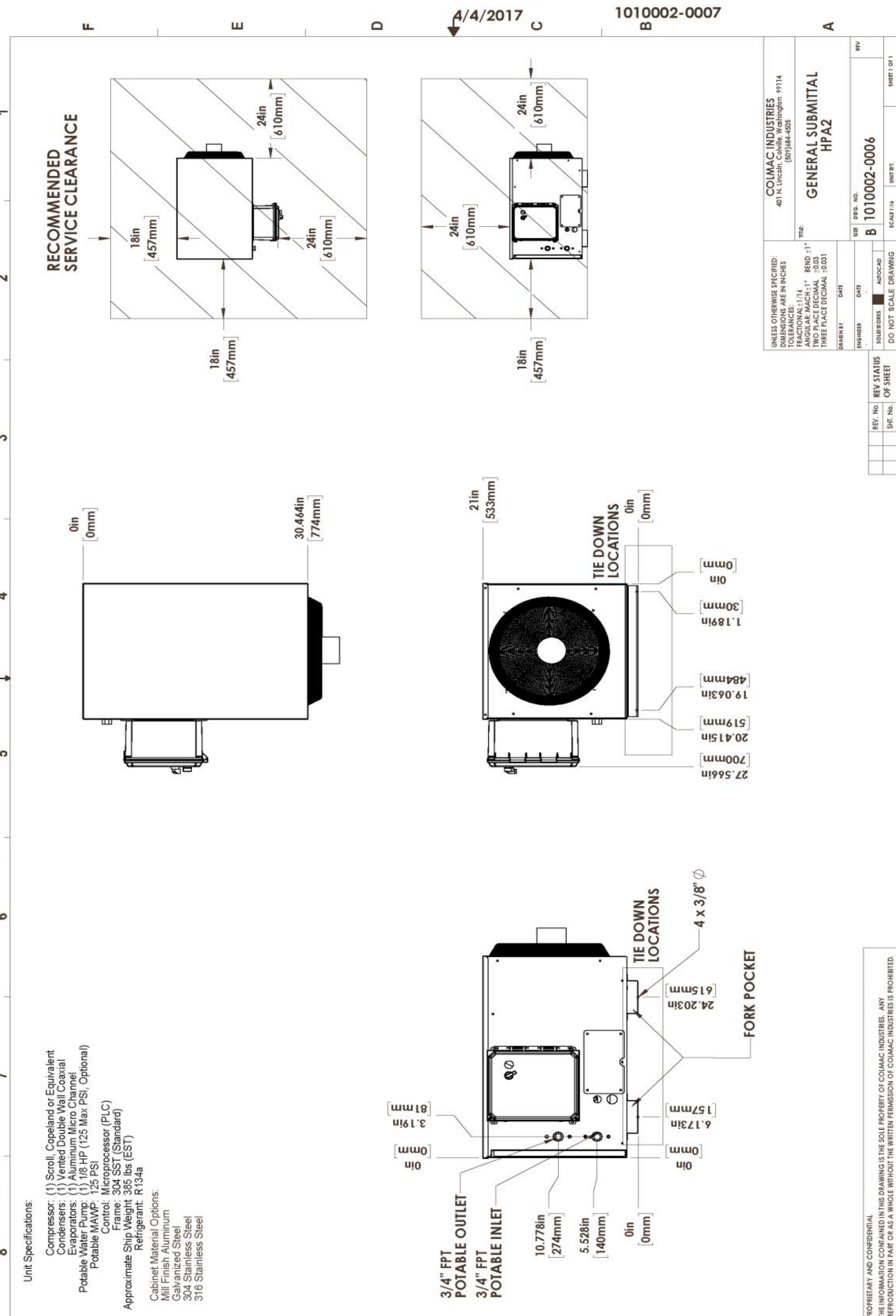

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CUSTOMER NAME : **Highmark** **JOB NAME :** **SCA**

NUMBER OF UNITS : **1**

SALES CONTACT : Bart Ransom

HPA4-PASP PLC (SINGLE PASS)

CONSTRUCTION:

CABINET MATERIAL :	304 STAINLESS STEEL (S)
FIN MATERIAL :	POLYCOAT (P)
FAN TYPE :	PROP FAN

ELECTRICAL SPECIFICATIONS*:

VOLTAGE :	230V / 60Hz / 1Ph
TOTAL PANEL AMPACITY (FLA) :	29.7 A
MINIMUM CIRCUIT AMPACITY (MCA) :	35.6 A
FEEDER WIRE GAUGE :	10 AWG
MAXIMUM OVERCURRENT PROTECTION (MOP) :	50 A

***APPROXIMATE VALUES, SUBJECT TO CHANGE**

OPERATING CONDITIONS:

	60 hz Operation:	Optional VFD at: 45 hz
ENTERING AIR WET BULB TEMP :	42 °F	
ENTERING POTABLE WATER TEMP :	50 °F	
LEAVING POTABLE WATER TEMP :	140 °F	
POTABLE FLOW RATE AT DESIGN CONDITION :	0.9 GPM	0.6 GPM
REQUIRED POTABLE FLOW AT MINIMUM LIFT CONDITION :	3.9 GPM	2.6 GPM

PERFORMANCE SPECIFICATIONS**:

HEATING CAPACITY:	39,359 BTU/hr	26,391 BTU/h
HEATING CAPACITY:	3 Tons	2.2 Tons
SUCTION TEMPERATURE:	27 °F	
COOLING CAPACITY:	28,197 BTU/hr	21,148 BTU/h
HEATING COP:	3.2	5.0
COOLING COP:	2.3	4.0
COMBINED COP:	5.4	9.1
POWER DRAW:	3.64 kW	1.54 kW

****APPROXIMATE VALUES, SUBJECT TO CHANGE. VALUES BASED ON CONDITIONS SPECIFIED ABOVE. IF ACTUAL CONDITIONS DIFFER, PERFORMACE WILL ALSO DIFFER.**

INCLUDED OPTIONS :
POLYESTER AIR FILTER, PLC

COMPRESSOR: COPELAND ZR61KCE-PFV-250
POTABLE PUMP: GRUNDFOS UPS 26-150 x 1

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CUSTOMER NAME : Highmark **JOB NAME :** SCA

NUMBER OF UNITS : 1

SALES CONTACT : Bart Ransom

HPA4-PASP PLC (SINGLE PASS)

CONSTRUCTION:

CABINET MATERIAL :	304 STAINLESS STEEL (S)
FIN MATERIAL :	POLYCOAT (P)
FAN TYPE :	PROP FAN

ELECTRICAL SPECIFICATIONS*:

VOLTAGE :	230V / 60Hz / 1Ph
TOTAL PANEL AMPACITY (FLA) :	29.7 A
MINIMUM CIRCUIT AMPACITY (MCA) :	35.6 A
FEEDER WIRE GAUGE :	10 AWG
MAXIMUM OVERCURRENT PROTECTION (MOP) :	50 A

***APPROXIMATE VALUES, SUBJECT TO CHANGE**

OPERATING CONDITIONS:

	60 hz Operation:	Optional VFD at: 45 hz
ENTERING AIR WET BULB TEMP :	59 °F	
ENTERING POTABLE WATER TEMP :	50 °F	
LEAVING POTABLE WATER TEMP :	140 °F	
POTABLE FLOW RATE AT DESIGN CONDITION :	1.1 GPM	0.8 GPM
REQUIRED POTABLE FLOW AT MINIMUM LIFT CONDITION :	5.2 GPM	3.5 GPM

PERFORMANCE SPECIFICATIONS**:

HEATING CAPACITY:	51,534 BTU/hr	35,427 BTU/h
HEATING CAPACITY:	4 Tons	3.0 Tons
SUCTION TEMPERATURE:	40 °F	
COOLING CAPACITY:	40,085 BTU/hr	30,063 BTU/h
HEATING COP:	4.1	6.6
COOLING COP:	3.2	5.6
COMBINED COP:	7.2	12.2
POWER DRAW:	3.73 kW	1.57 kW

****APPROXIMATE VALUES, SUBJECT TO CHANGE. VALUES BASED ON CONDITIONS SPECIFIED ABOVE. IF ACTUAL CONDITIONS DIFFER, PERFORMACE WILL ALSO DIFFER.**

INCLUDED OPTIONS :
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COMPRESSOR: COPELAND ZR61KCE-PFV-250
POTABLE PUMP: GRUNDFOS UPS 26-150 x 1

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CUSTOMER NAME : **Highmark** **JOB NAME :** **SCA**

NUMBER OF UNITS : **1**

SALES CONTACT : Bart Ransom

HPA4-PASP PLC (SINGLE PASS)

CONSTRUCTION:

CABINET MATERIAL :	304 STAINLESS STEEL (S)
FIN MATERIAL :	POLYCOAT (P)
FAN TYPE :	PROP FAN

ELECTRICAL SPECIFICATIONS*:

VOLTAGE :	230V / 60Hz / 1Ph
TOTAL PANEL AMPACITY (FLA) :	29.7 A
MINIMUM CIRCUIT AMPACITY (MCA) :	35.6 A
FEEDER WIRE GAUGE :	10 AWG
MAXIMUM OVERCURRENT PROTECTION (MOP) :	50 A

***APPROXIMATE VALUES, SUBJECT TO CHANGE**

OPERATING CONDITIONS:

	60 hz Operation:	Optional VFD at: 45 hz
ENTERING AIR WET BULB TEMP :	78 °F	
ENTERING POTABLE WATER TEMP :	50 °F	
LEAVING POTABLE WATER TEMP :	140 °F	
POTABLE FLOW RATE AT DESIGN CONDITION :	1.6 GPM	1.1 GPM
REQUIRED POTABLE FLOW AT MINIMUM LIFT CONDITION :	7.0 GPM	4.9 GPM

PERFORMANCE SPECIFICATIONS**:

	60 hz Operation	Optional VFD at 45 hz
HEATING CAPACITY:	69,991 BTU/hr	49,127 BTU/h
HEATING CAPACITY:	6 Tons	4.1 Tons
SUCTION TEMPERATURE:	59 °F	
COOLING CAPACITY:	58,106 BTU/hr	43,580 BTU/h
HEATING COP:	5.3	8.9
COOLING COP:	4.4	7.9
COMBINED COP:	9.7	16.7
POWER DRAW:	3.86 kW	1.63 kW

****APPROXIMATE VALUES, SUBJECT TO CHANGE. VALUES BASED ON CONDITIONS SPECIFIED ABOVE. IF ACTUAL CONDITIONS DIFFER, PERFORMACE WILL ALSO DIFFER.**

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COMPRESSOR: COPELAND ZR61KCE-PFV-250
POTABLE PUMP: GRUNDFOS UPS 26-150 x 1

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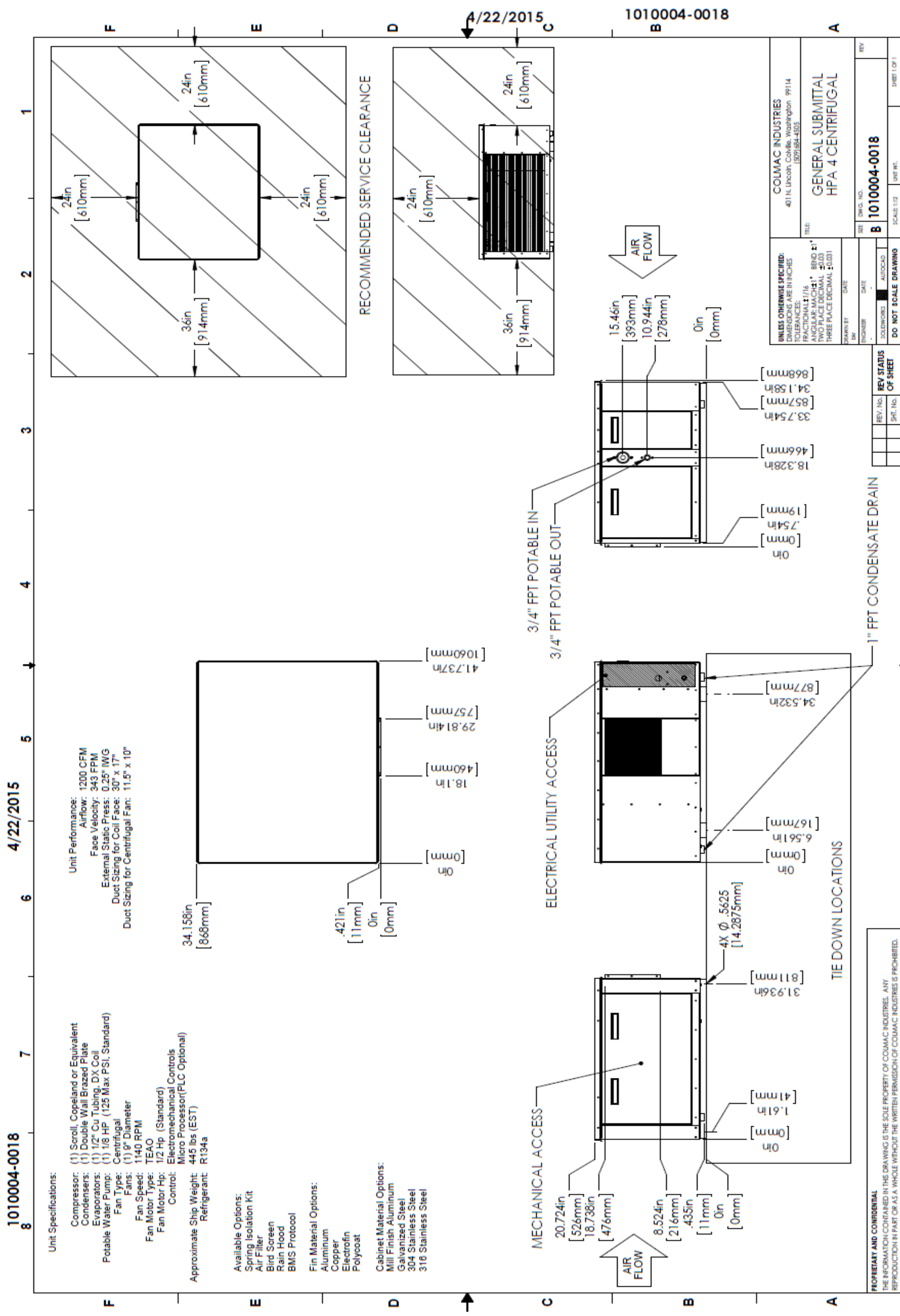

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World Class Comfort®

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Cold Climate Heat Pump Water Heater

ccHPWH Series

Ice Air's cold climate heat pump water heaters capture the free energy in the environment and convert it to hot water. These commercial water heater are designed to provide domestic hot water to large buildings on the coldest days.

- Industry leading performance
  - Lower cost of operation and maintenance compared to condensing gas-fired water heaters
  - 4x more efficient compared to electric resistance heaters
- Multiple independent circuits provide built-in redundancy
- Double wall heat exchangers ensure occupant safety
- Optional single wall heat exchangers (for glycol applications)
- Freeze protection standard
- Optional heat-trace powered by building emergency power
- Clean out ports to remove sediment or lime deposits

Model Numbers			ccHPWH275-S	ccHPWH275-D	ccHPWH550-S	ccHPWH550-D
Heat Exchanger Type			Single Wall Brazed Plate HXR	Double Wall Brazed Plate HXR	Single Wall Brazed Plate HXR	Double Wall Brazed Plate HXR
Performance Specifications	Input Power		208-230V/3PH/60Hz	208-230V/3PH/60Hz	208-230V/3PH/60Hz	208-230V/3PH/60Hz
	Refrigerant Circuits		2	2	4	4
	Refrigerant / Quantity		R410A (30.8 Lbs / 15.4 Lbs per circuit)	R410A (30.8 Lbs / 15.4 Lbs per circuit)	R410A (70.8 Lbs / 17.7 Lbs per circuit)	R410A (70.8 Lbs / 17.7 Lbs per circuit)
	Max H/W Temperature		140°F	140°F	140°F	140°F
	Dry Bulb Temperature (68°F) Wet Bulb Temperature (59°F) Inlet Water Temperature (59°F) Outlet Water Temperature (131°F)	Heating Capacity (Btu/H)	341,263	327,246	563,003	532,287
		Input Power (kW)	22.2	22.7	37	37.3
		COP	4.41	4.23	4.42	4.18
	Dry Bulb Temperature (45°F) Wet Bulb Temperature (43°F) Inlet Water Temperature (48°F) Outlet Water Temperature (131°F)	Heating Capacity (Btu/H)	270,645	262,360	495,600	470,820
		Input Power (kW)	18.6	21.7	39.2	44.8
		COP	3.70	3.54	3.71	3.48
	Dry Bulb Temperature (10°F) Wet Bulb Temperature (7°F) Inlet Water Temperature (43°F) Outlet Water Temperature (131°F)	Heating Capacity (Btu/H)	175,396	170,027	304,500	289,275
		Input Power (kW)	17.3	20.3	37.8	43.2
		COP	2.57	2.46	2.36	2.22
	Minimum Ambient Operating Temperature (°F)		-13	-13	-13	-13
	Max. Input Power (kW)		29.8	29.8	62	62
	FLA (A)		85.1	85.1	170.2	170.2
	MCA (A)		93.7	93.7	187.2	187.2
	MOCP (A)		127.7	127.7	255.4	255.4
	Sound Level (dBA)		≤71	≤71	≤76	≤76
Water Data	Water Side Pressure Loss (psig)		8.1	16.51	7.25	13.0
	Rated Water Flow (GPM)		73.4	58.9	129.6	122.5
	Single pass delta-T (F) (average)		9.30	10.60	9.36	9.36
	Max Working Pressure (psig)		230	230	230	230
	Piping Position (Refer to the electric box as front)		Rear	Rear	Right Hand	Right Hand
	Piping Sizes		2"	2"	3"	3"
Overall Dimensions [L x W x H] (inches)			81 x 39 x 89	81 x 39 x 89	95 x 51 x 89	95 x 51 x 89
Net Weight (Lbs)			1,500	1,555	2,850	2,950

Appendix E:

Deleted

Appendix F:

Energy Analysis Calculations

Energy Analysis Using Hybrid Heat Pumps

Existing Conditions						
School	Manufacturer	Heater Model	Tank Model	Heating Capacity (Btu)	Storage Capacity (gal)	Efficiency
A	Lochinvar	CWN399PM	RGA0318	399,000	318	82%
B	Lochinvar	CWN0986PM	RGA0700H	986,000	700	81%
C	AO Smith	BTR275118		275,000	100	80%
D	Lochinvar	CWN0497PM	ST175	495,000	175	81%

Existing Operation (Gas)							
School	Daily Consumption (gal)	Daily Water Heating Energy (kBtu)	Daily Water Heating Energy (therm)	Daily Gas Heating Energy Input (therm)	Annual Water Heating Energy (kBtu)	Annual Gas Heating Energy (therm)	Energy Cost ($/yr)
A	162	87.6	0.876	1.069	31,989	390	$487.63
B	436	235.1	2.351	2.903	85,817	1,059	$1,324.33
C	255	137.7	1.377	1.721	50,252	628	$785.18

Option 1: Electric Heat Pump Operation						
School	Daily Consumption (gal)	Daily Water Heating Energy (kBtu)	Daily Water Heating Energy (kWh)	Daily Electric Heating Energy Input (kWh) (Heat Pump WH)	Annual Water Heating Energy (kBtu)	Annual Electric Heating Energy (kWh)
A	162	87.6	25.686	8.562	31,989	3,125
B	436	235.1	68.908	22.969	85,817	8,384
C	255	137.7	40.351	13.450	50,252	4,909

COP = 3.0

Option 1: PV System									
School	Annual Electric Heating Energy (kWh)	Heating Energy Covered by PV System (kWh)	Size of PV System (kW)	Number of PV Panels	Roof Area Required (sqft)	$/kWh	Energy Cost ($/yr)	Energy Cost Savings @ 100% PV ($/yr)	Incremental Costs ($)	Annual CO2 Emissions Avoided (lbs)
A	3,125	3,125	3	9	189.50	$0.27	$0.00	$487.63	$66,750	4,558
B	8,384	8,384	8	23	484.27		$0.00	$1,324.33	$103,375	12,379
C	4,909	4,909	5	15	315.83		$0.00	$785.18	$80,250	7,340

From DOE	0.0053	Metric tons of CO2/therm
eGrid	635.8	lbs CO2/MW

Option 2: Solar Thermal System with Electric Heat Pump Auxiliary													
School	Annual Gas Heating Energy (therm)	Solar Fraction (%)	Heating Energy Covered by Solar Thermal System (therm)	Auxiliary Heating Energy Required (therm)	Auxiliary Heating Energy Required (kBtu)	Auxiliary Heating Energy Input, Elec Heat Pump (kWh)	Solar Thermal Number of Collectors	Roof Area Required (sqft)	$/kWh	Energy Cost ($/yr)	Energy Cost Savings ($/yr)	Incremental Costs ($)	Annual CO2 Emissions Avoided (lbs)
A	320	53.4%	171	149	14,907	1,456	6	162.12	$0.27	$393.20	$94.43	$127,753	3,632
B	858	52.3%	449	409	40,935	3,999	12	324.24		$1,079.75	$244.58	$153,253	9,837
C	503	51.4%	258	244	24,422	2,386	8	216.16		$644.20	$140.98	$146,265	5,823

Option 3: Solar Thermal System with Gas-Fired Heater Auxiliary													
School	Annual Gas Heating Energy (therm)	Solar Fraction (%)	Heating Energy Covered by Solar Thermal System (therm)	Auxiliary Heating Energy Required (therm)	Auxiliary Heating Energy Required (kBtu)	Auxiliary Heating Energy Covered by Gas Boiler (therm)	Solar Thermal Number of Collectors	Roof Area Required (sqft)	$/therm	Energy Cost ($/yr)	Energy Cost Savings ($/yr)	Incremental Costs ($)	Annual CO2 Emissions Avoided (lbs)
A	320	53.4%	171	149	14,907	182	6	162.12	$1.25	$227.24	$260.40	$96,253	2,434
B	858	52.3%	449	409	40,935	505	12	324.24		$631.71	$692.63	$112,503	6,474
C	503	51.4%	258	244	24,422	305	8	216.16		$381.60	$403.58	$107,265	3,773

Option 4: Hybrid Solar Thermal System and PV System with Electric Heat Pump																		
School	Annual Gas Heating Energy (therm)	Solar Fraction (%)	Heating Energy Covered by Solar Thermal System (therm)	Auxiliary Heating Energy Required (therm)	Auxiliary Heating Energy Required (kBtu)	Auxiliary Heating Energy Input, Elec Heat Pump (kWh)	Size of PV System (kW)	Number of PV Panels	PV Roof Area Required (sqft)	Solar Thermal Number of Collectors	Solar Thermal Roof Area Required (sqft)	Total Roof Area Required (sqft)	$/kWh	$/therm	Energy Cost ($)	Energy Cost Savings ($/yr)	Incremental Costs ($)	Annual CO2 Emissions Avoided (lbs)
A	320	53.4%	171	149	14,907	1,456	2	6	126.33	6	162.12	288.45	$0.27	$1.25	$0.00	$487.63	$153,003	4,558
B	858	52.3%	449	409	40,935	3,999	4	12	252.66	12	324.24	576.9			$0.00	$1,324.33	$225,578	12,379
C	503	51.4%	258	244	24,422	2,386	3	9	189.50	8	216.16	405.66			$0.00	$785.18	$172,515	7,340

Energy Analysis Using Commercial Heat Pumps for School A and B

Existing Conditions

School	Manufacturer	Heater Model	Tank Model	Heating Capacity (Btu)	Storage Capacity (gal)	Efficiency
A	Lochinvar	CWN399PM	RGA0318	399,000	318	82%
B	Lochinvar	CWN0986PM	RGA0700H	986,000	700	81%
C	AO Smith	BTR275118		275,000	100	80%
D	Lochinvar	CWN0497PM	ST175	495,000	175	81%

Existing Operation (Gas)

School	Daily Consumption (gal)	Daily Water Heating Energy (kBtu)	Daily Water Heating Energy (therm)	Daily Gas Heating Energy Input (therm)	Annual Water Heating Energy (kBtu)	Annual Gas Heating Energy (therm)	Energy Cost ($/yr)
A	162	87.6	0.876	1.069	31,989	390	$487.63
B	436	235.1	2.351	2.903	85,817	1,059	$1,324.33

Option 1: Electric Heat Pump Operation

School	Daily Consumption (gal)	Daily Water Heating Energy (kBtu)	Daily Water Heating Energy (kWh)	Daily Electric Heating Energy Input (kWh) (Heat Pump WH)	Annual Water Heating Energy (kBtu)	Annual Electric Heating Energy (kWh)
A	162	87.6	25.686	7.784	31,989	2,841
B	436	235.1	68.908	20.881	85,817	7,622

COP = 3.3

Option 1: PV System

School	Annual Electric Heating Energy (kWh)	Heating Energy Covered by PV System (kWh)	Size of PV System (kW)	Number of PV Panels	Roof Area Required (sqft)	$/kWh	Energy Cost ($/yr)	Energy Cost Savings @ 100% PV ($/yr)	Incremental Costs ($)	Annual CO2 Emissions Avoided (lbs)
A	2,841	2,841	3	9	189.50	$0.27	$0.00	$487.63	$80,250	4,558
B	7,622	7,622	8	23	484.27		$0.00	$1,324.33	$136,625	12,379

From DOE	0.0053	Metric tons of CO2/therm
eGrid	635.8	lbs CO2/MW

Option 2: Solar Thermal System with Electric Heat Pump Auxiliary

School	Annual Gas Heating Energy (therm)	Solar Fraction (%)	Heating Energy Covered by Solar Thermal System (therm)	Auxiliary Heating Energy Required (therm)	Auxiliary Heating Energy Required (kBtu)	Auxiliary Heating Energy Input, Elec Heat Pump (kWh)	Solar Thermal Number of Collectors	Roof Area Required (sqft)	$/kWh	Energy Cost ($/yr)	Energy Cost Savings ($/yr)	Incremental Costs ($)	Annual CO2 Emissions Avoided (lbs)
A	320	53.4%	171	149	14,907	1,324	6	162.12	$0.27	$357.46	$130.18	$141,253	3,716
B	858	52.3%	449	409	40,935	3,636	12	324.24		$981.59	$342.74	$153,253	10,068

Option 3: Solar Thermal System with Gas-Fired Heater Auxiliary

School	Annual Gas Heating Energy (therm)	Solar Fraction (%)	Heating Energy Covered by Solar Thermal System (therm)	Auxiliary Heating Energy Required (therm)	Auxiliary Heating Energy Required (kBtu)	Auxiliary Heating Energy Covered by Gas Boiler (therm)	Solar Thermal Number of Collectors	Roof Area Required (sqft)	$/therm	Energy Cost ($/yr)	Energy Cost Savings ($/yr)	Incremental Costs ($)	Annual CO2 Emissions Avoided (lbs)
A	320	53.4%	171	149	14,907	182	6	162.12	$1.25	$227.24	$260.40	$96,253	2,434
B	858	52.3%	449	409	40,935	505	12	324.24		$631.71	$692.63	$112,503	6,474

Option 4: Hybrid Solar Thermal System and PV System with Electric Heat Pump

School	Annual Gas Heating Energy (therm)	Solar Fraction (%)	Heating Energy Covered by Solar Thermal System (therm)	Auxiliary Heating Energy Required (therm)	Auxiliary Heating Energy Required (kBtu)	Auxiliary Heating Energy Input, Elec Heat Pump (kWh)	Size of PV System (kW)	Number of PV Panels	PV Roof Area Required (sqft)	Solar Thermal Number of Collectors	Solar Thermal Roof Area Required (sqft)	Total Roof Area Required (sqft)	$/kWh	$/therm	Energy Cost ($)	Energy Cost Savings ($/yr)	Incremental Costs ($)	Annual CO2 Emissions Avoided (lbs)
A	320	53.4%	171	149	14,907	1,324	2	6	126.33	6	162.12	288.45	$0.27	$1.25	$0.00	$487.63	$166,503	4,558
B	858	52.3%	449	409	40,935	3,636	4	12	252.66	12	324.24	576.9			$0.00	$1,324.33	$225,578	12,379

Energy Analysis Using Commercial Heat Pump and Gas-Fired Supplemental Heater for School B

Existing Conditions						
School	Manufacturer	Heater Model	Tank Model	Heating Capacity (Btu)	Storage Capacity (gal)	Efficiency
B	Lochinvar	CWN0986PM	RGA0700H	986,000	700	81%

Existing Operation (Gas)							
School	Daily Consumption (gal)	Daily Water Heating Energy (kBtu)	Daily Water Heating Energy (therm)	Daily Gas Heating Energy Input (therm)	Annual Water Heating Energy (kBtu)	Annual Gas Heating Energy (therm)	Energy Cost ($/yr)
B	436	235.1	2.351	2.903	85,817	1,059	$1,324.33

Option 1: Electric Heat Pump Operation							
School	Daily Consumption (gal)	Daily Water Heating Energy (kBtu)	Daily Water Heating Energy (kWh)	Daily Electric Heating Energy Input (kWh) (Heat Pump WH)	Annual Water Heating Energy (kBtu)	Annual Electric Heating Energy (kWh)
B	436	235.1	68.908	22.969	85,817	8,384

COP = 3.0

PV System with Gas-Fired Heater										
School	Annual Electric Heating Energy (kWh)	Heating Energy Covered by PV System (kWh)	Size of PV System (kW)	Number of PV Panels	Roof Area Required (sqft)	$/therm	Energy Cost ($/yr)	Energy Cost Savings @ 100% PV ($/yr)	Incremental Costs ($)	Annual CO2 Emissions Avoided (lbs)
B	8,384	8,384	8	23	484.27	$1.25	$185.41	$1,138.93	$117,875	10,646

From DOE	0.0053	Metric tons of CO2/therm
eGrid	635.8	lbs CO2/MW

School: B **Site Visits: 2/1/18**

Existing Conditions					
Manufacturer	Heater Model	Tank Model	Heating Capacity (Btu)	Storage Capacity (gal)	Efficiency
Lochinvar	CWN0986PM	RGA0700H	986,000	700	81.0%

Existing DHW System vs Option 1: Solar PV and Heat Pump vs Option 5: Point of Use Electric

System Component	**Consumption (gal)**	**Daily Energy Consumption / Load (kBtu)**	**Annual Energy Consumption / Load (kBtu)**	**Percent of Total Annual Heating Energy**	**Annualized Heating System Efficiency**	**Annual Gas Heating Energy @ 81% Eff (therm)**	**Annual Electric Energy Input (kWh)**	**Annual Energy Cost ($)**	**Annual CO_2 Emissions (lbs/year)**	**DHW Site kBtu/ft²**	**DHW Source kBtu/ft²**
DHW Heating Load	436	235.1	85,817	64%	52%	1,059	0	$ 1,176	12,379	0.59	0.62
DHWR Piping Losses	0	112.4	41,040	31%	-	507	0	$ 562	5,920	0.28	0.30
DHW Storage Tank	0	17.2	6,271	5%	-	77	0	$ 86	905	0.04	0.05
DHW Heating Total	**436**	**364.7**	**133,127**	**100%**	**-**	**1,644**	**0**	**$ 1,824**	**19,204**	**0.91**	**0.96**
DHW Recirculation Pumps	0	27.1	9,900	0	-	0	2,902	$ 158	1,848	0.05	0.14
Ex. DHW System Total	**436**	**392**	**143,027**	**100%**	**-**	**1,644**	**2,902**	**$ 1,982**	**21,052**	**0.97**	**1.10**
Chronomite Model M-20L/120 Electric Tankless Water Heater	436	235.1	85,817	100%	99%	0	25,406	$ 10,331	16,185	0.48	1.23
Savings	**0**	**156.7**	**57,210**	**-**	**-**	**1,644**	**-22,504**	**$ (8,349)**	**4,868**	**0.49**	**-0.13**
Option 1: Solar PV and Heat Pump	436	235.1	85,817	-	-	0	7,622	-	4,855	0.14	0.37
DHWR Piping Losses	0	112.4	41,040	-	-	0	3,645	-	2,322	0.07	0.18
DHW Storage Tank	0	17.2	6,271	-	-	0	557	-	355	0.01	0.03
DHW Recirculation Pumps	0	27.1	9,900	-	-	0	2,902	-	1,848	0.05	0.14
Option 1 System Total	**436**	**392**	**143,027**	**-**	**-**	**0**	**14,725**	**-**	**9,381**	**0.28**	**0.71**
Savings	**0**	**0**	**0**	**-**	**-**	**1,644**	**-11,823**	**-**	**11,672**	**0.69**	**0.39**
										0.69	

Demand Charges

3.07	peak gpm per 15 minute period
65	delta T
99,901	Btu/h
100.9	kBtu
29.6	peak kW
$ 8,946	annual demand charge
$ 1,385	annual energy charge
$ 10,331	annual electricity charge

DHW System Heat Loss Calcs

DHWR Piping

Floor	**Length (LF)**
First	1301
Second	168
Third	488
Fourth	28
Roof Penthouse	30
Total	2015
Btu/LF 3/4" pipe	4.7
Total BTU/h	9,370
Daily kBtu	112

1.9 gpm

DHW Storage Tank

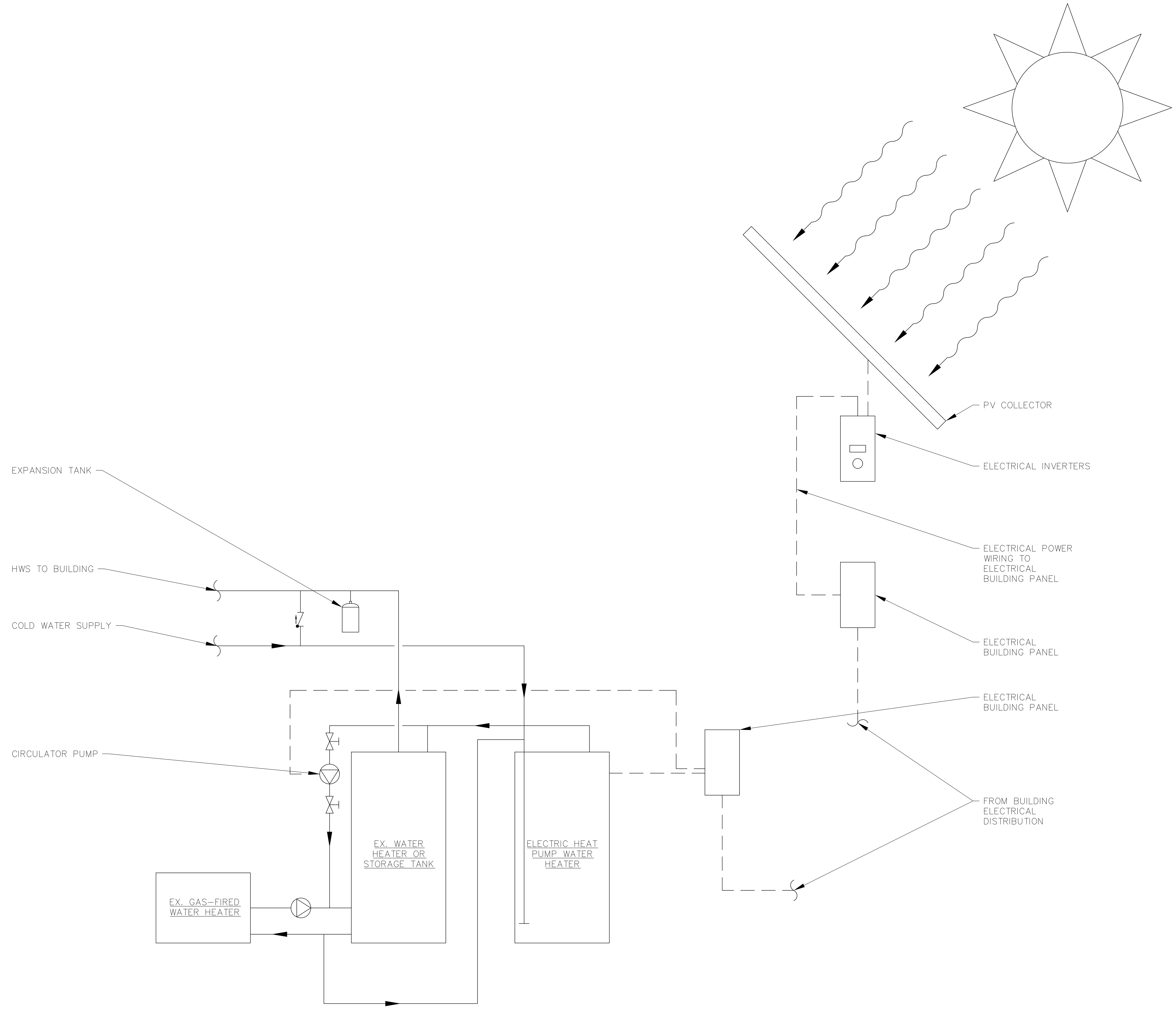
U-value	0.077
Surface Area (ft)	143.2
Delta T	65
Total Heat Loss (Btu	715.8
Daily kBtu	17.2
Annual kBtu	**6,271**
Annual Therms	62.7

DHW Recirculation Pumps

0.666	hp
0.497	kW output
0.662	kW input
4380	run hours
2,902	annual kWh input
9,900	annual kBtu input
$ 158.13	annual pump energy cost
27.1	daily kbtu

Appendix G:

Schematic Diagrams and Sketches



1 PV SYSTEM FLOW DIAGRAM
SCALE: NONE

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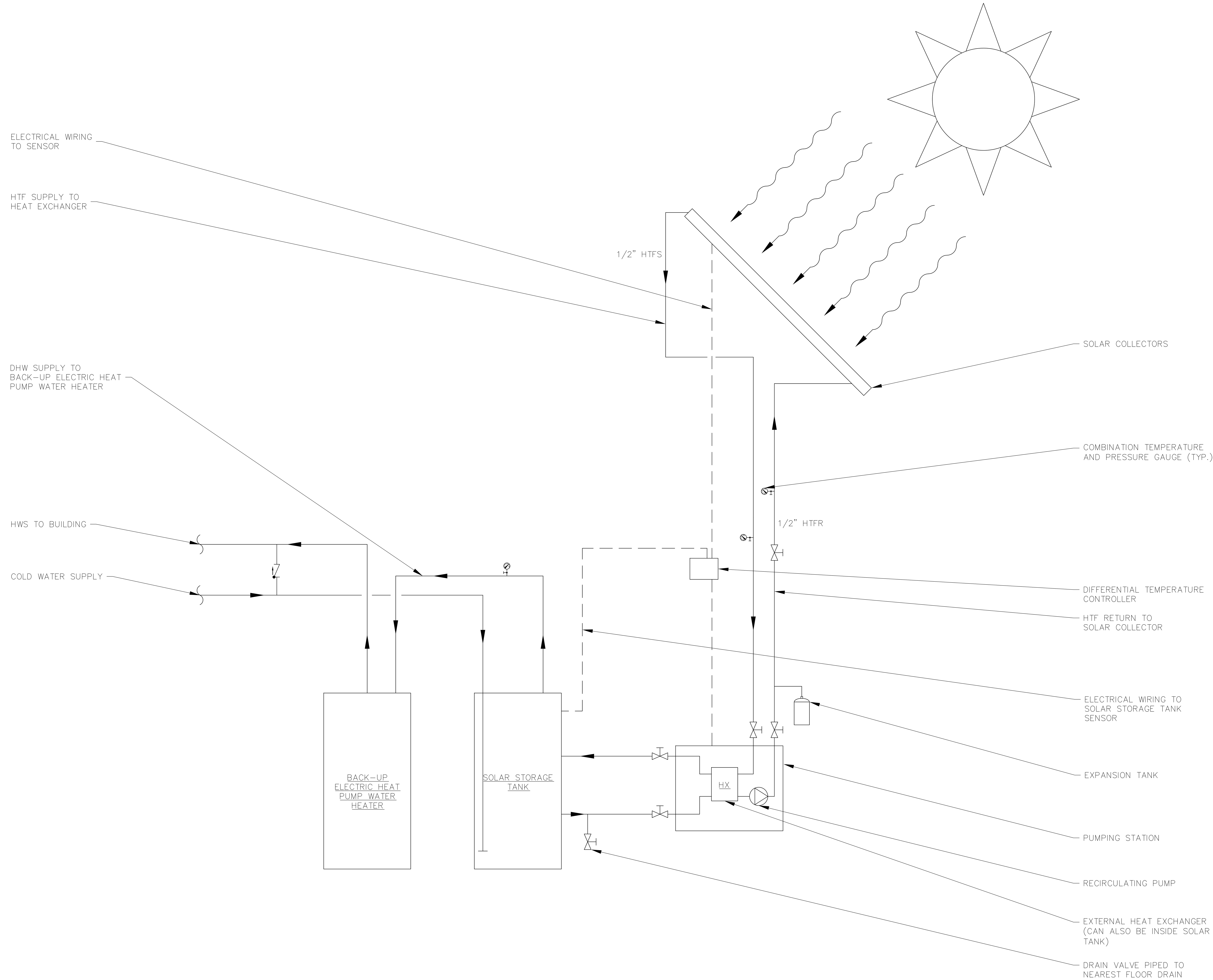
PROJECT TITLE

SOLAR DHW STUDY

DRAWING TITLE

OPTION 1 - PV SYSTEM FLOW DIAGRAM

SEAL	SCALE	PROJECT NO.
	AS NOTED	NSCA1002.00
	DRAWN BY: AP	DRAWING NO.
	CHECKED BY: KG	P5.1
	DATE: 12/14/17	



2 SOLAR THERMAL SYSTEM CLOSED LOOP WITH ELECTRIC HEAT PUMP FLOW DIAGRAM
SCALE: NONE

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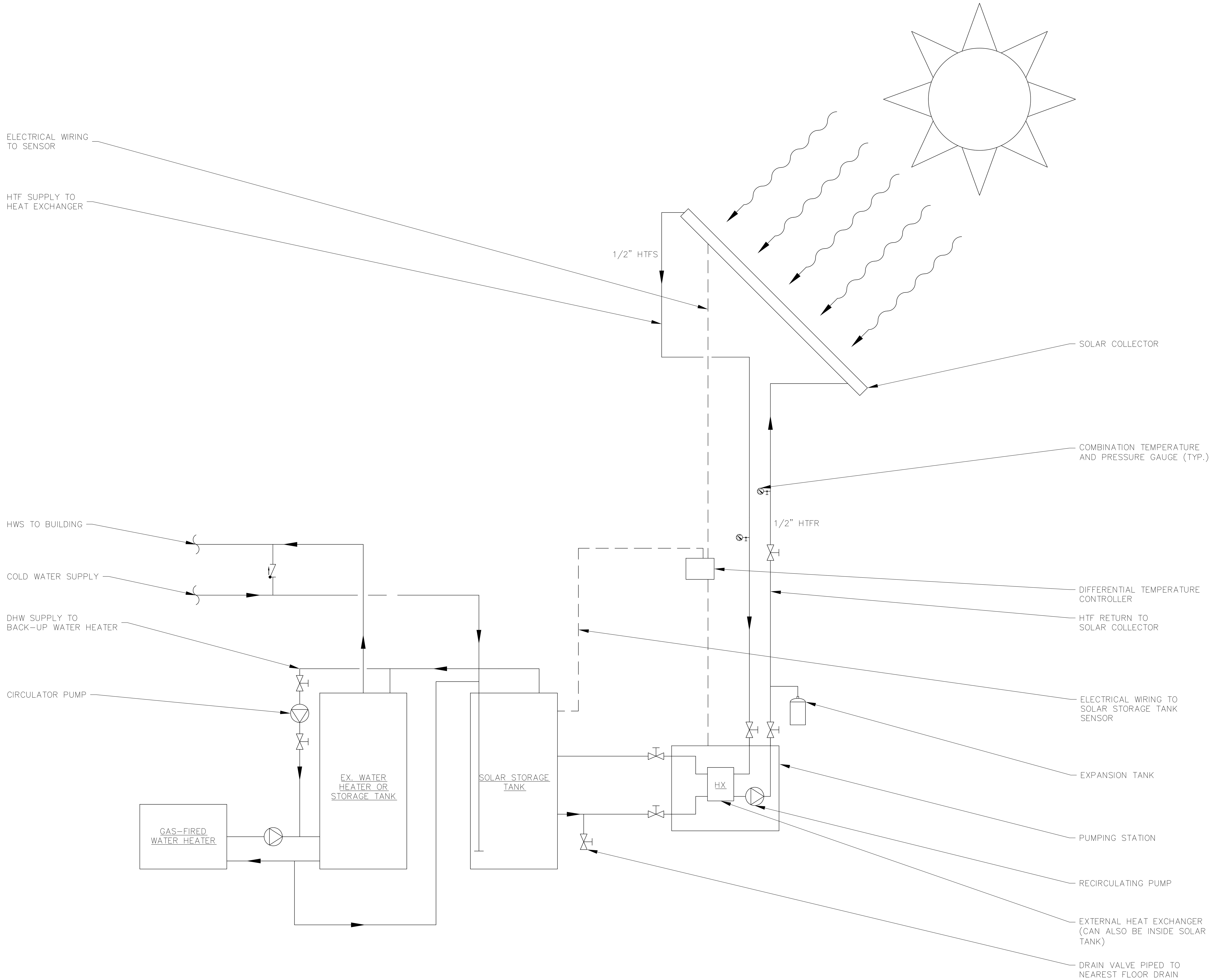
SOLAR DHW STUDY

DRAWING TITLE

OPTION 2 - SOLAR THERMAL SYSTEM WITH ELECTRIC HEAT PUMP FLOW DIAGRAM

SEAL		
	SCALE: AS NOTED	PROJECT NO.: NSCA1002.00
	DRAWN BY: AP	DRAWING NO.
	CHECKED BY: KG	P5.1
	DATE: 12/14/17	



3 SOLAR THERMAL SYSTEM CLOSED LOOP WITH GAS-FIRED WATER HEATER FLOW DIAGRAM
SCALE: NONE

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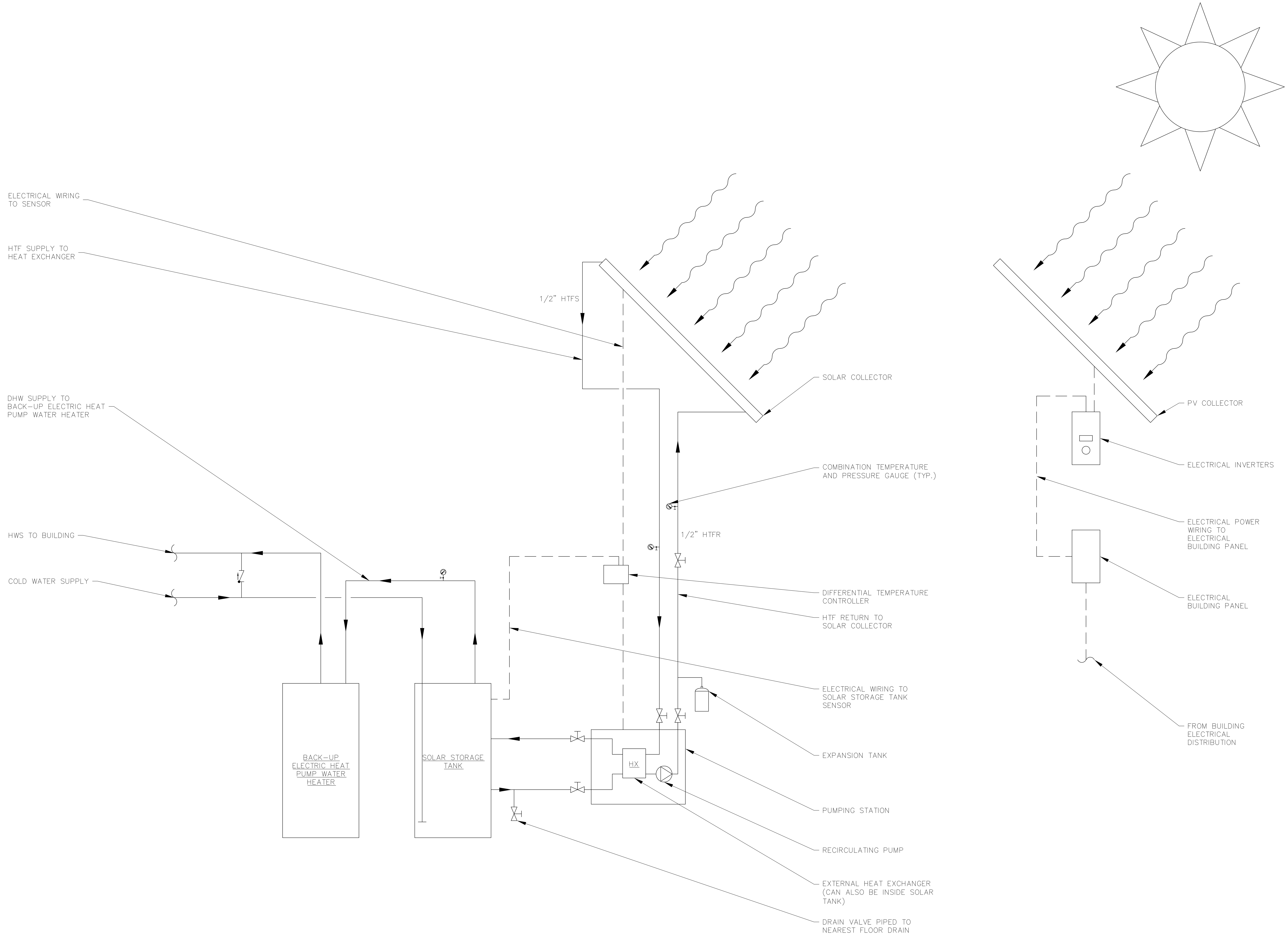
OPTION 3 - SOLAR THERMAL SYSTEM WITH GAS-FIRED WATER HEATER FLOW DIAGRAM

SEAL	SCALE	PROJECT NO.
	AS NOTED	NSCA1002.00
	DRAWN BY: AP	DRAWING NO.
	CHECKED BY: KG	P5.1
	DATE: 12/14/17	



4 HYBRID SOLAR THERMAL CLOSED LOOP AND PV SYSTEM WITH ELECTRIC HEAT PUMP FLOW DIAGRAM
SCALE: NONE

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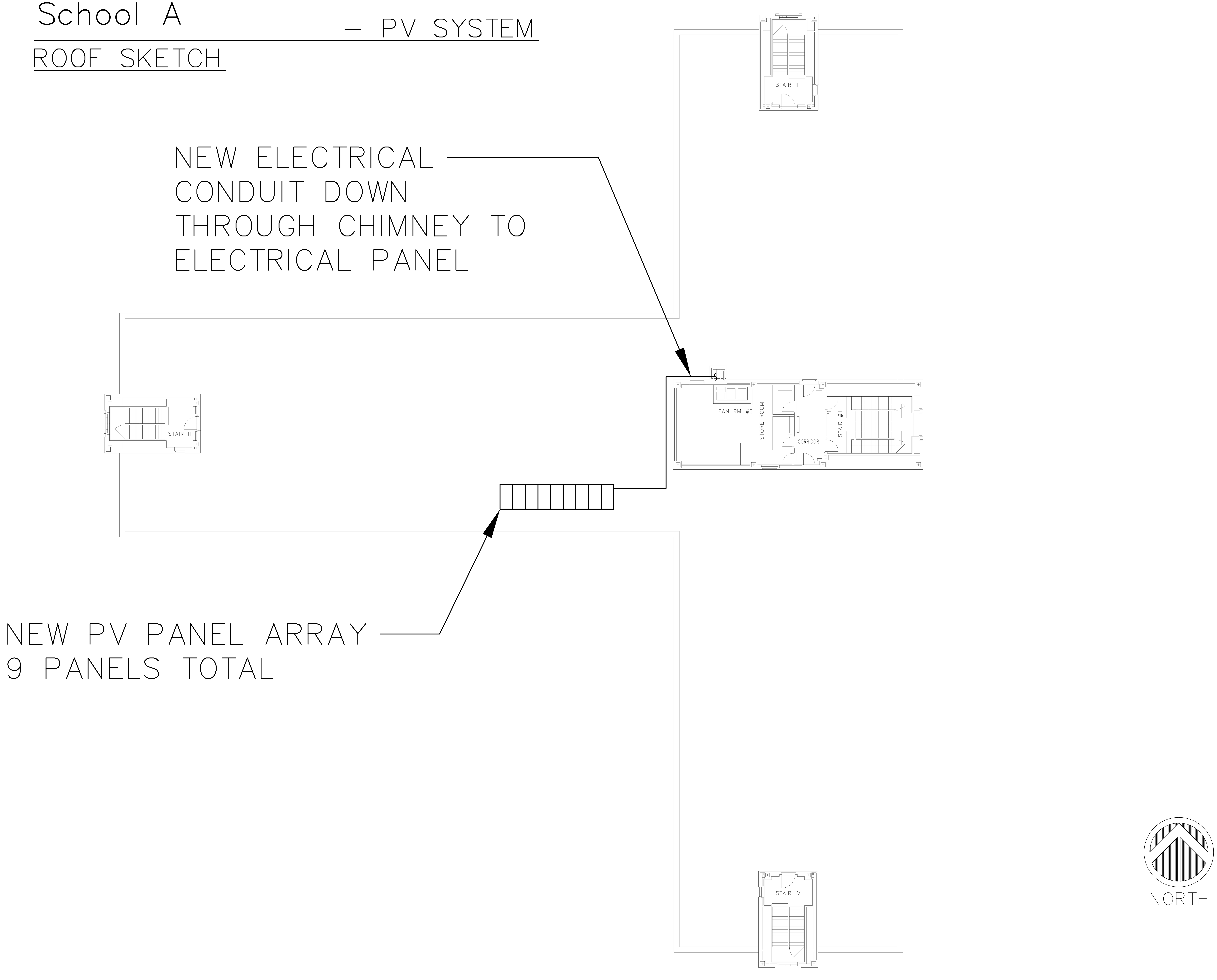
PROJECT TITLE
SOLAR DHW STUDY

DRAWING TITLE
OPTION 4 - HYBRID SOLAR THERMAL SYSTEM AND PV SYSTEM WITH ELECTRIC HEAT PUMP FLOW DIAGRAM

SEAL	SCALE: AS NOTED	PROJECT NO.: NSCA1002.00
	DRAWN BY: AP	DRAWING NO.
	CHECKED BY: KG	P5.1
	DATE: 12/14/17	

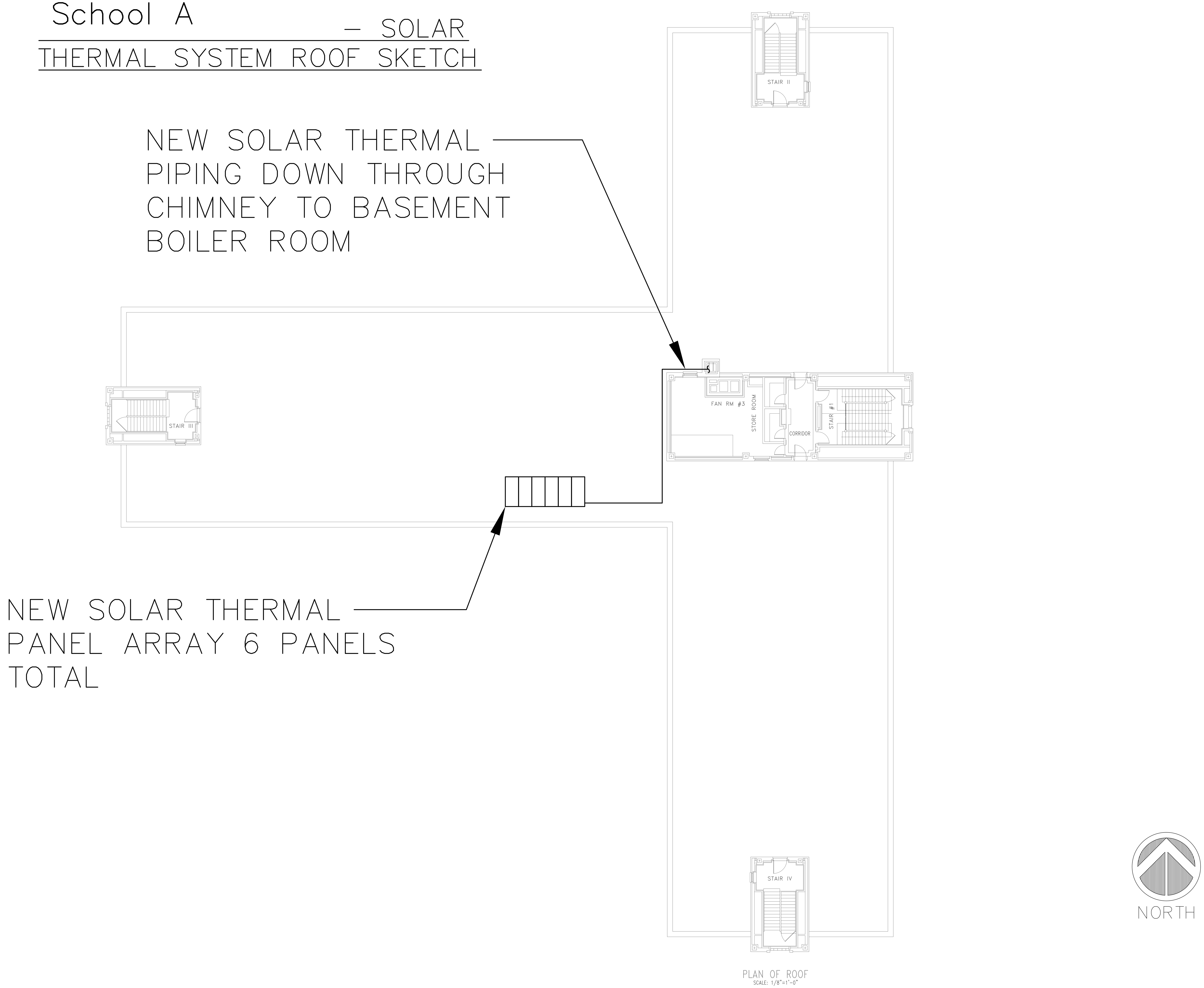
School A — PV SYSTEM

ROOF SKETCH

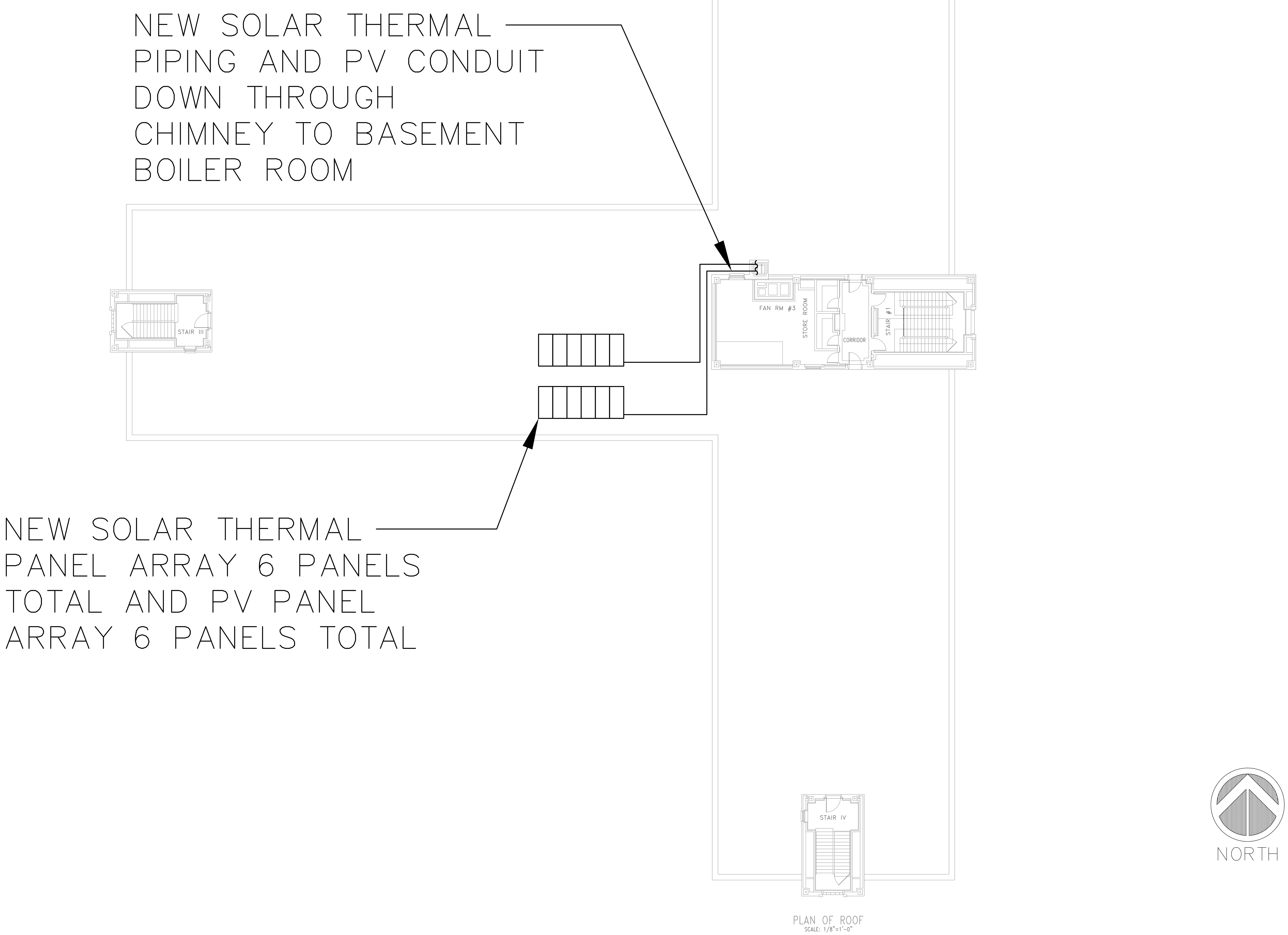


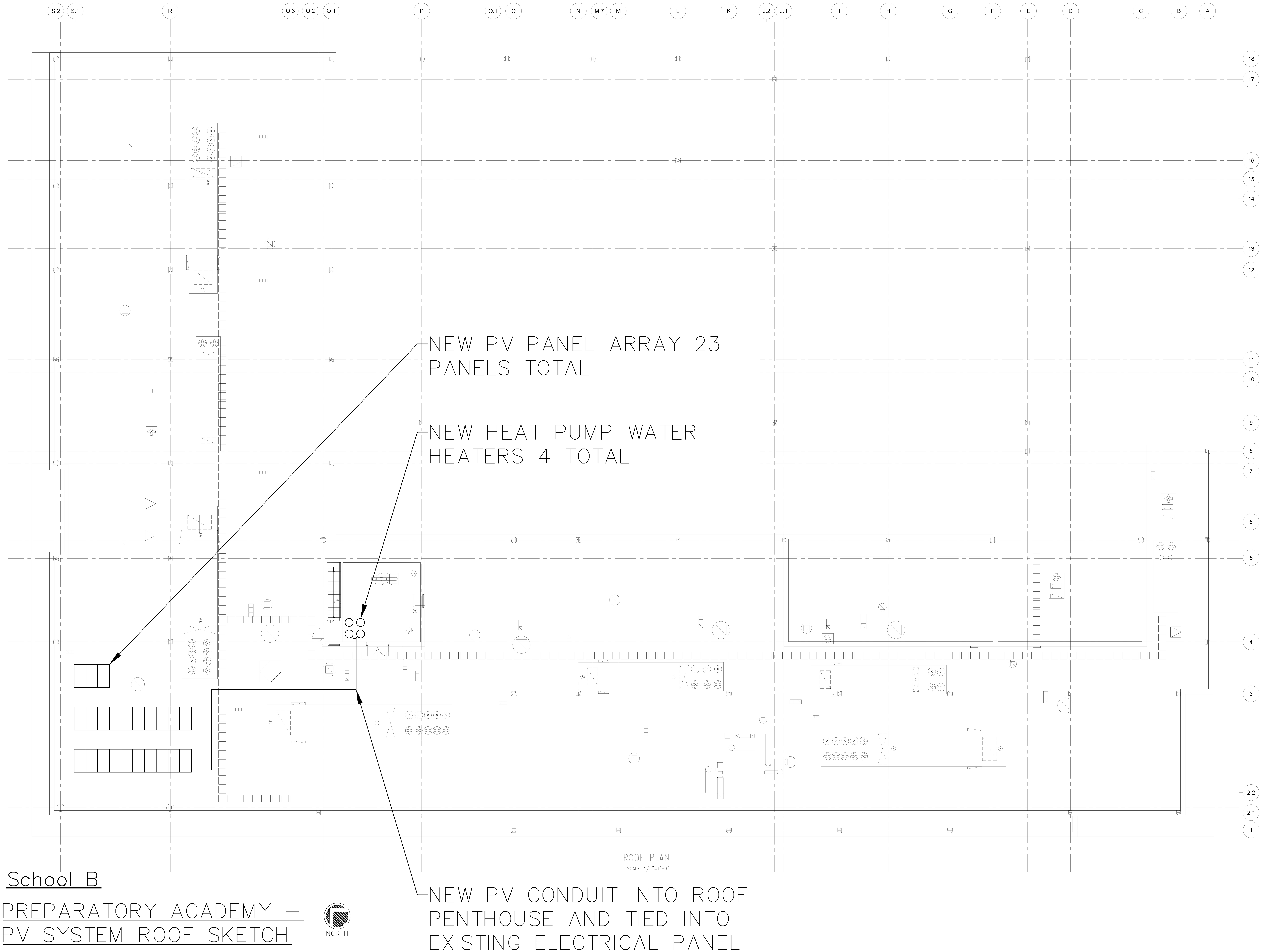
PLAN OF ROOF
SCALE: 1/8"=1'-0"

School A – SOLAR THERMAL SYSTEM ROOF SKETCH



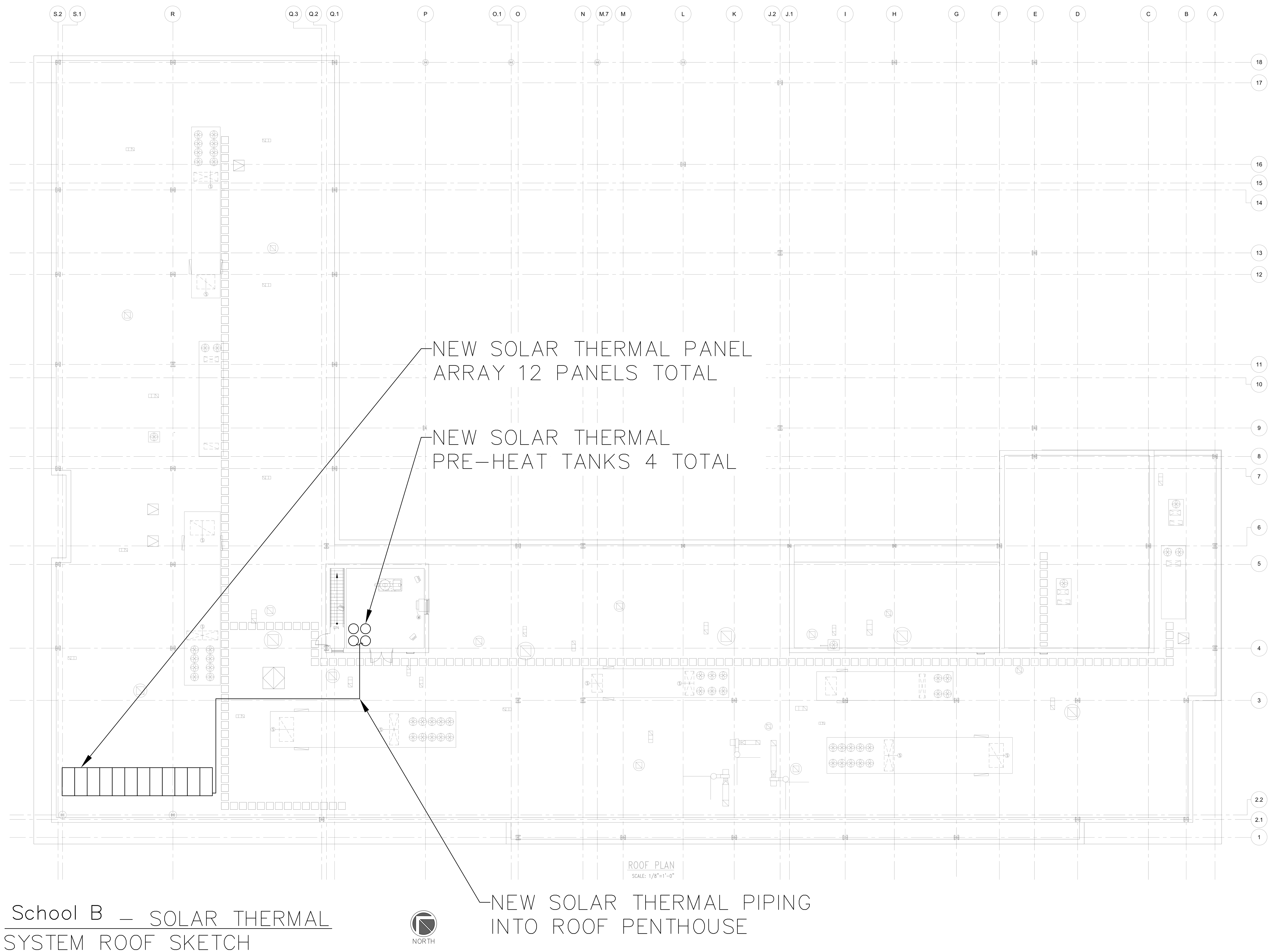
School A – HYBRID
SOLAR THERMAL AND PV SYSTEM ROOF SKETCH



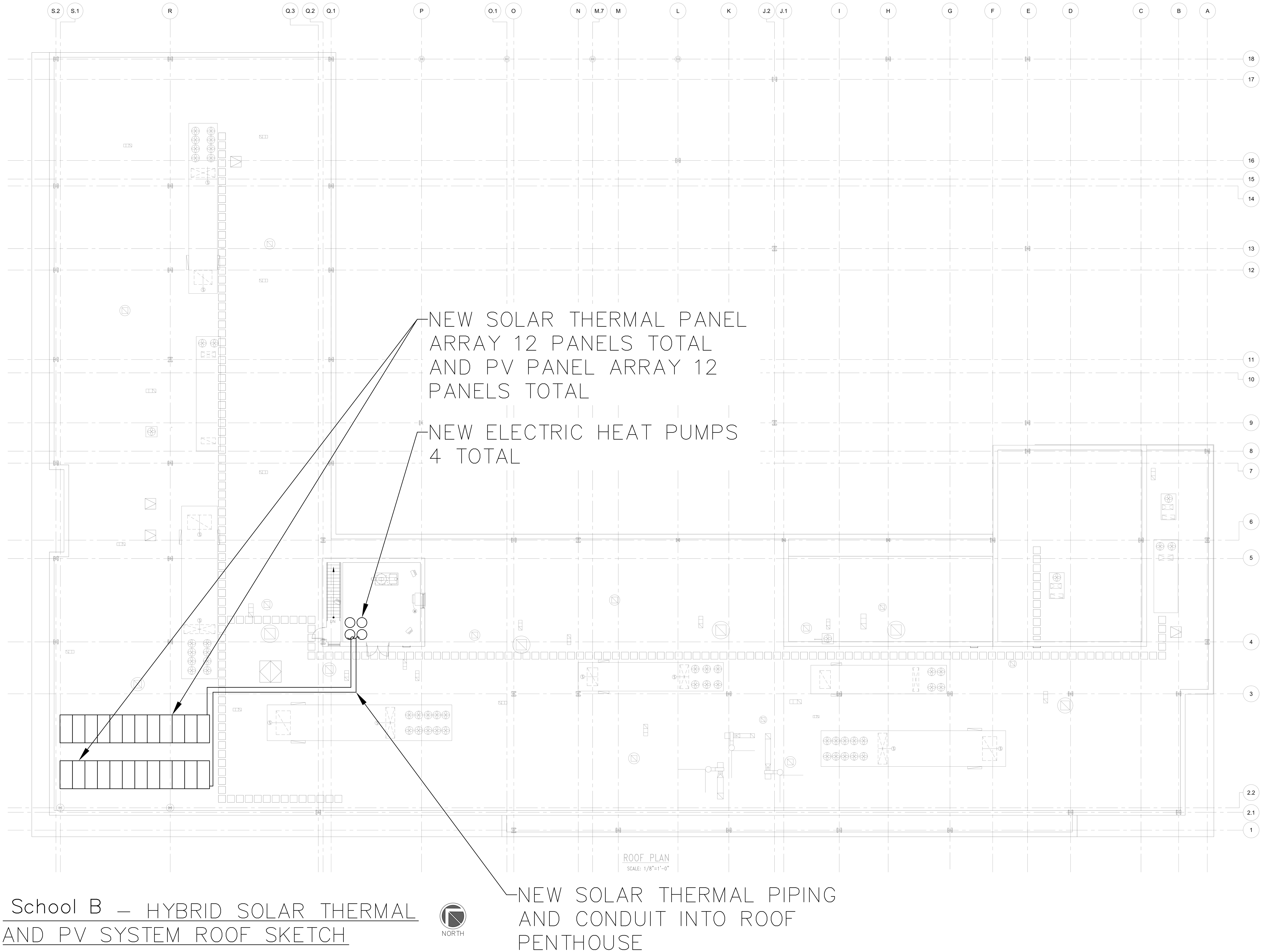


School B

PREPARATORY ACADEMY –
PV SYSTEM ROOF SKETCH

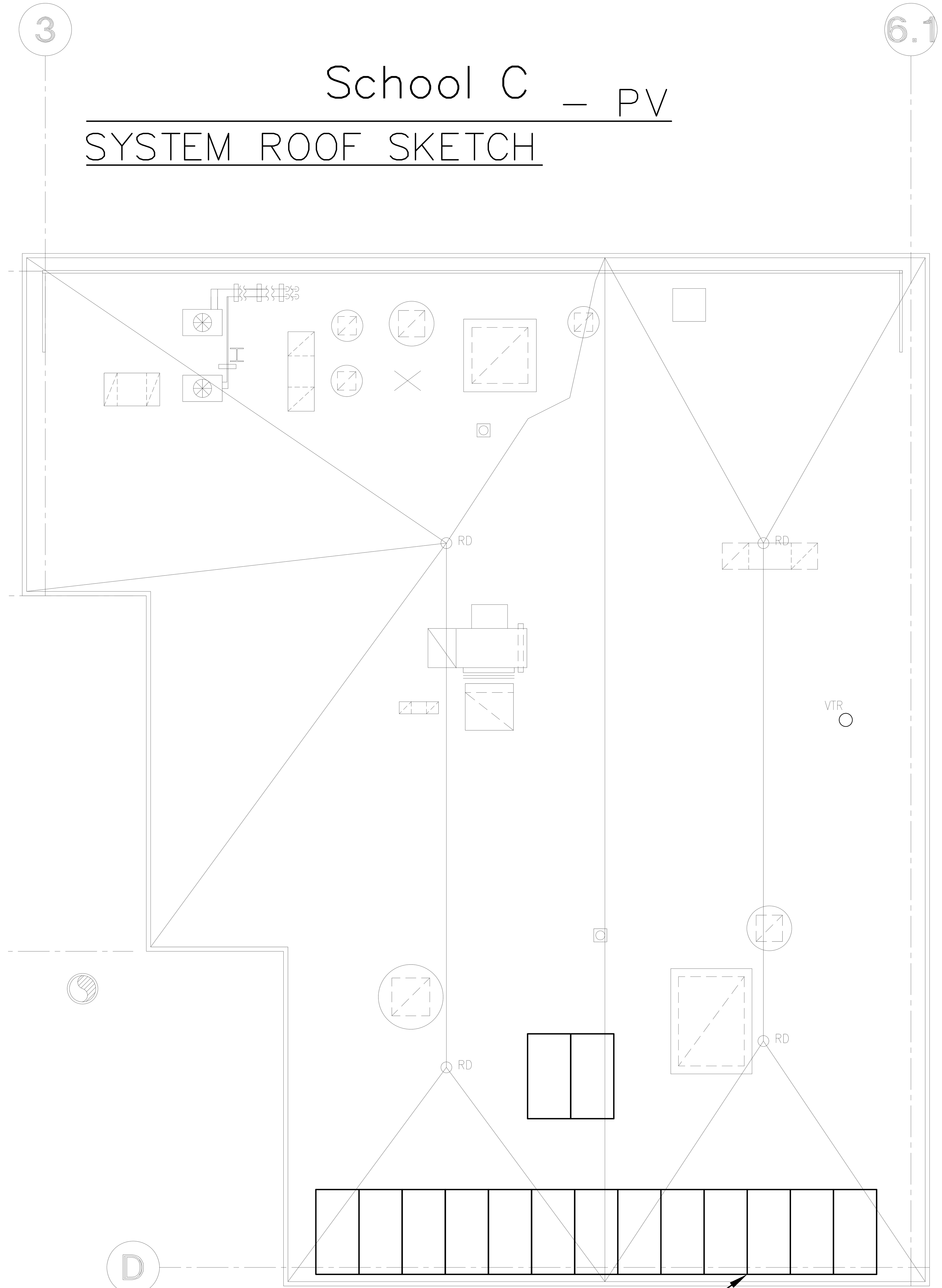


School B – SOLAR THERMAL SYSTEM ROOF SKETCH



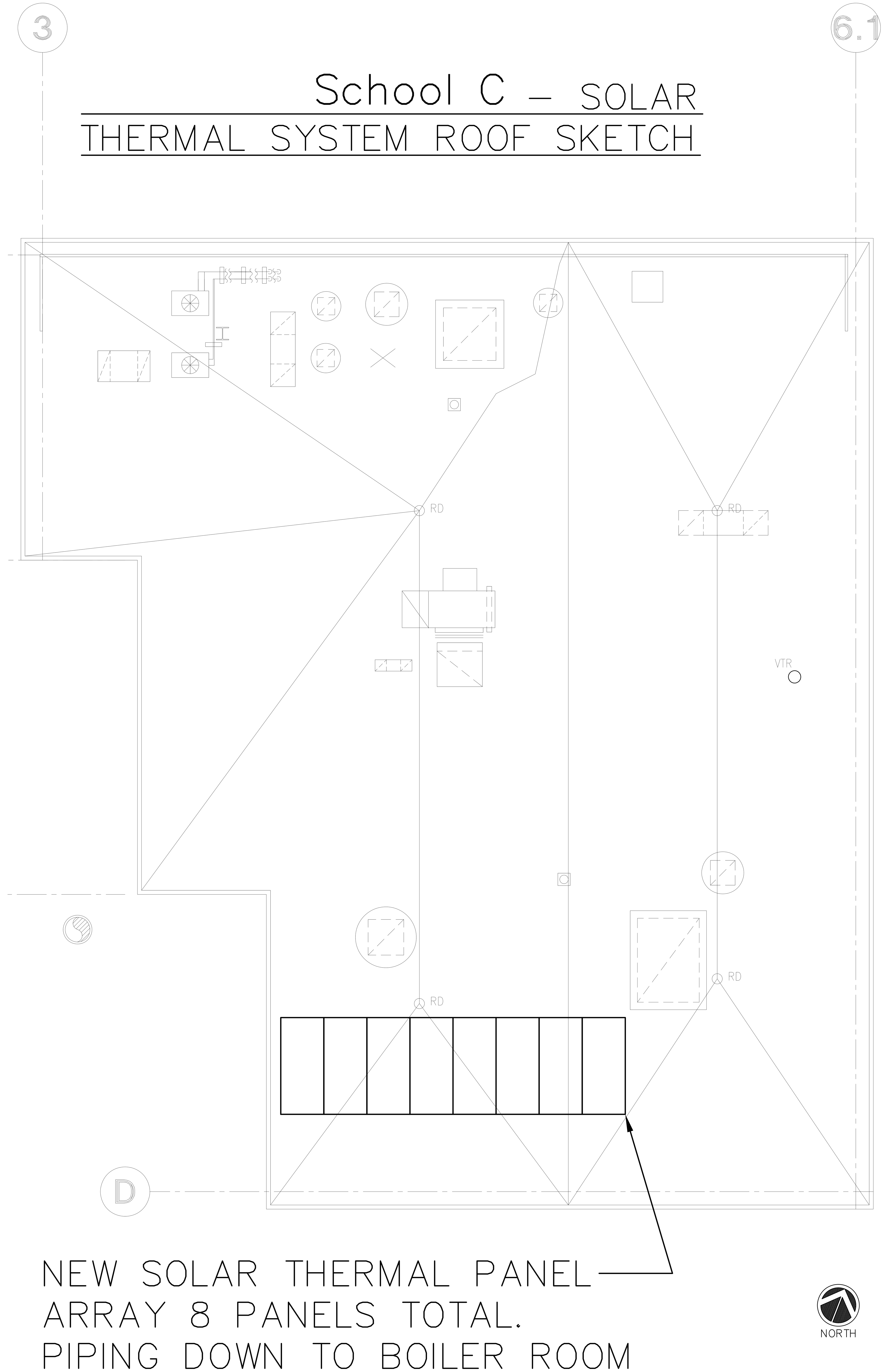
School B – HYBRID SOLAR THERMAL AND PV SYSTEM ROOF SKETCH

School C – PV
SYSTEM ROOF SKETCH

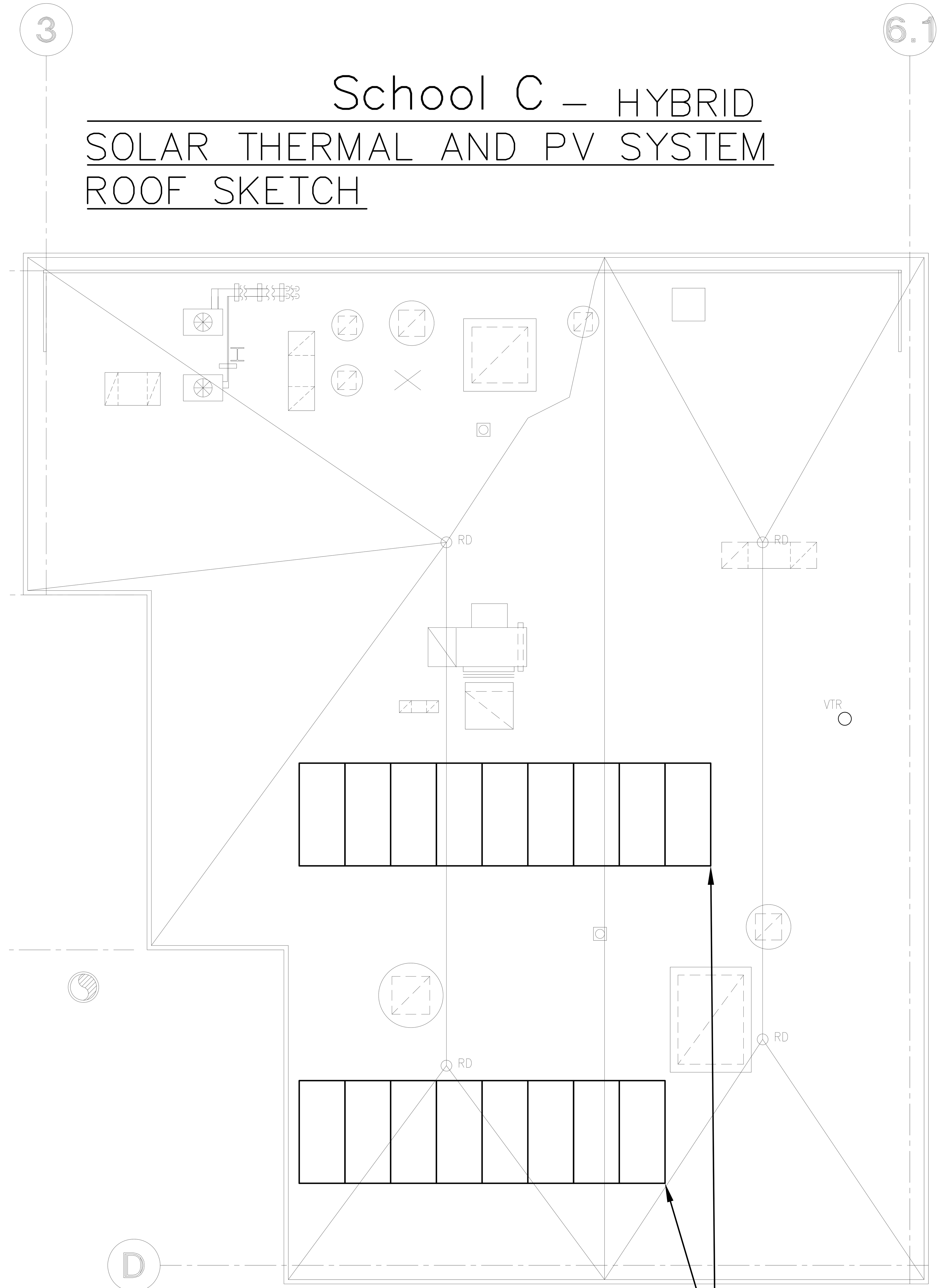


NEW PV PANEL ARRAY 15 PANELS TOTAL. ELECTRICAL CONDUIT DOWN THROUGH ROOF TO ELECTRICAL PANEL

School C – SOLAR THERMAL SYSTEM ROOF SKETCH



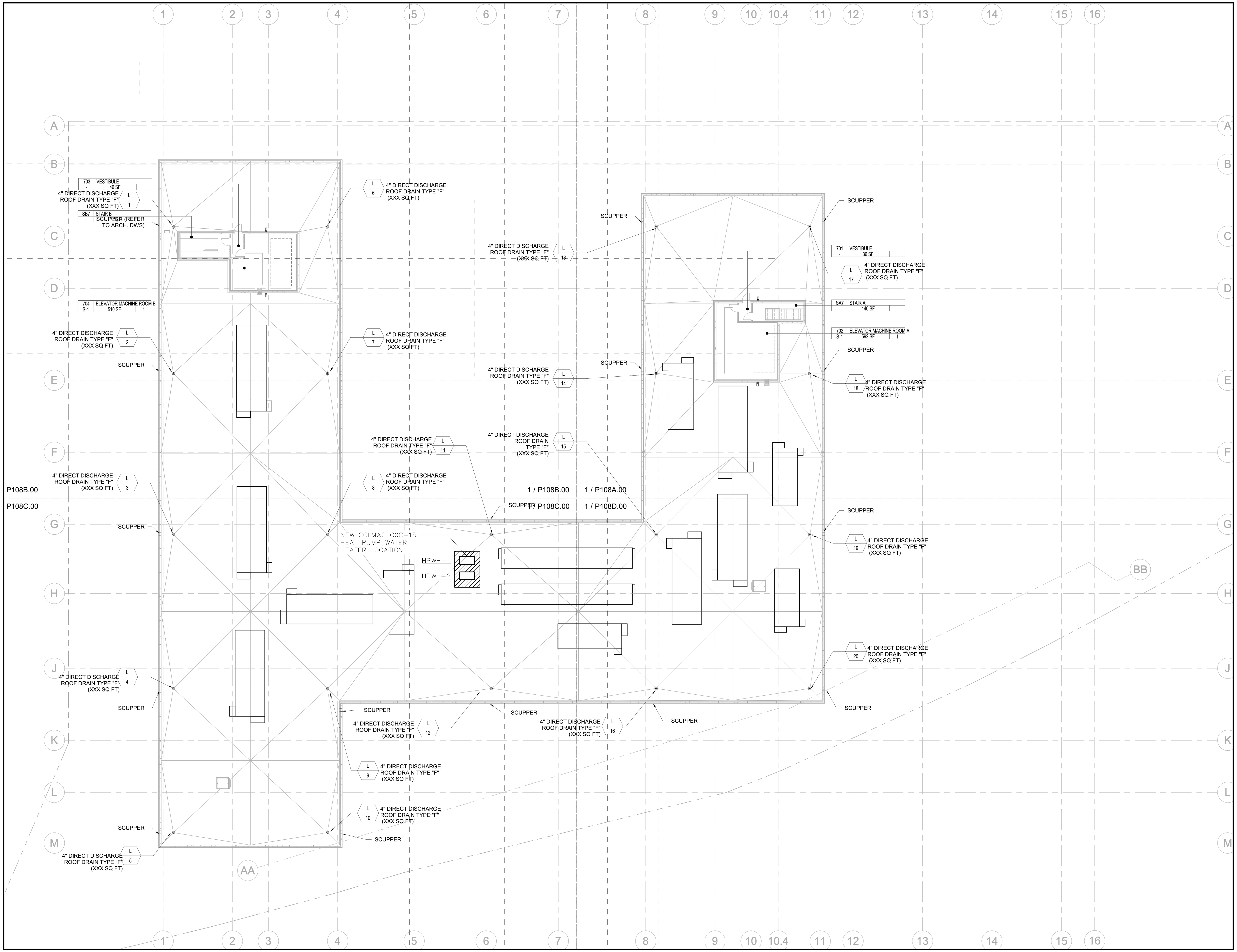
School C – HYBRID
SOLAR THERMAL AND PV SYSTEM
ROOF SKETCH



NEW SOLAR THERMAL PANEL
ARRAY 8 PANELS TOTAL AND
PV ARRAY. PIPING DOWN TO
BOILER ROOM AND CONDUIT
DOWN TO MECHANICAL ROOM

Appendix H:

Sample Design School #1 Schematic Diagrams



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3	FINAL ISSUE	5/29/19
2	ISSUED FOR REVIEW	5/6/19
1	ISSUED FOR REVIEW	4/23/19

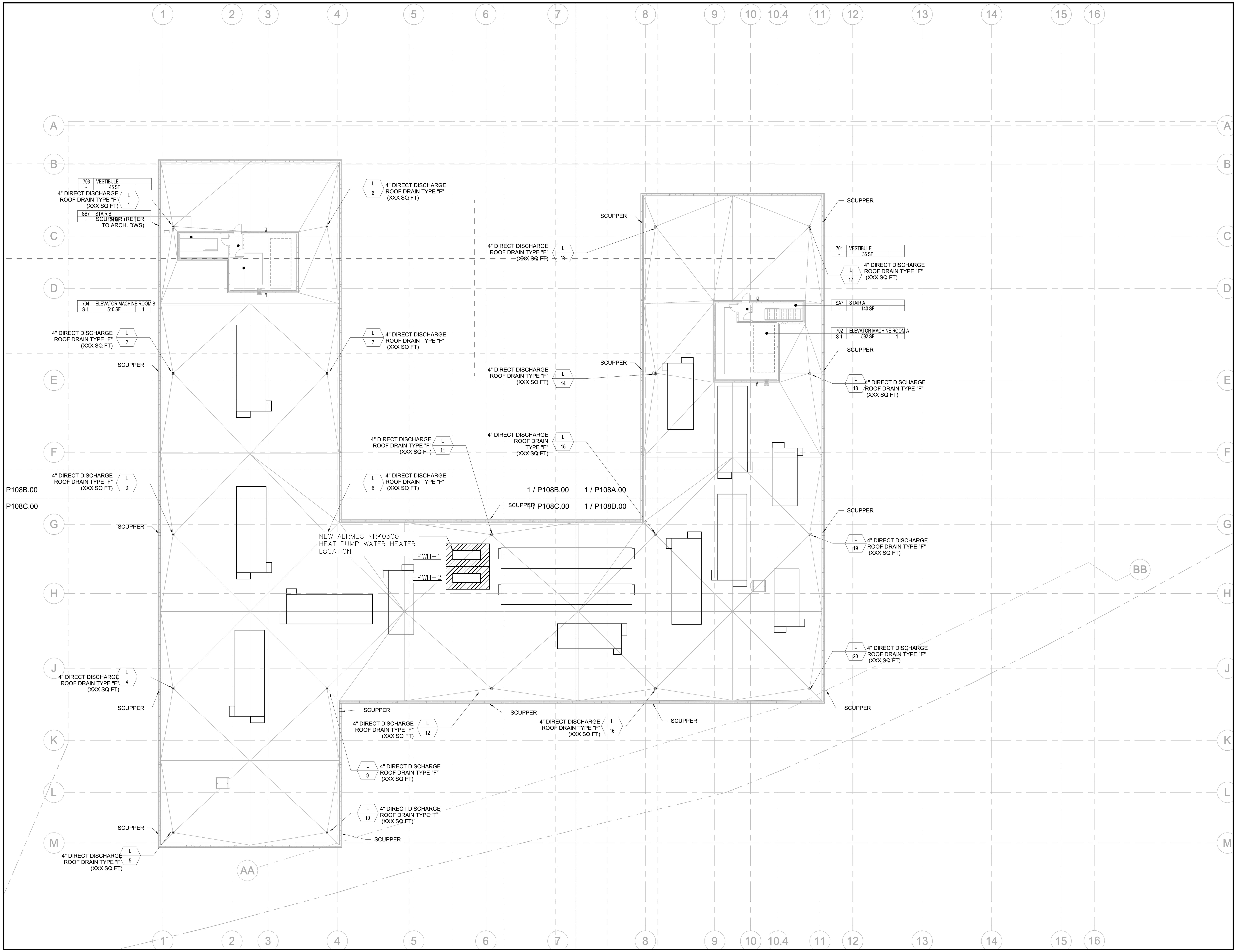
PROJECT TITLE

SCA [redacted] HEAT PUMP DHW DESIGN SUPPORT

DRAWING TITLE

PLUMBING ROOF PLAN
OPTION A: COLMAC CXC-15

SEAL	SCALE	PROJECT NO.
	AS NOTED	NSCA1008.00
	DRAWN BY: AP	DRAWING NO.
	CHECKED BY: JK	P2.1A
	DATE: 3/28/19	



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PROJECT TITLE

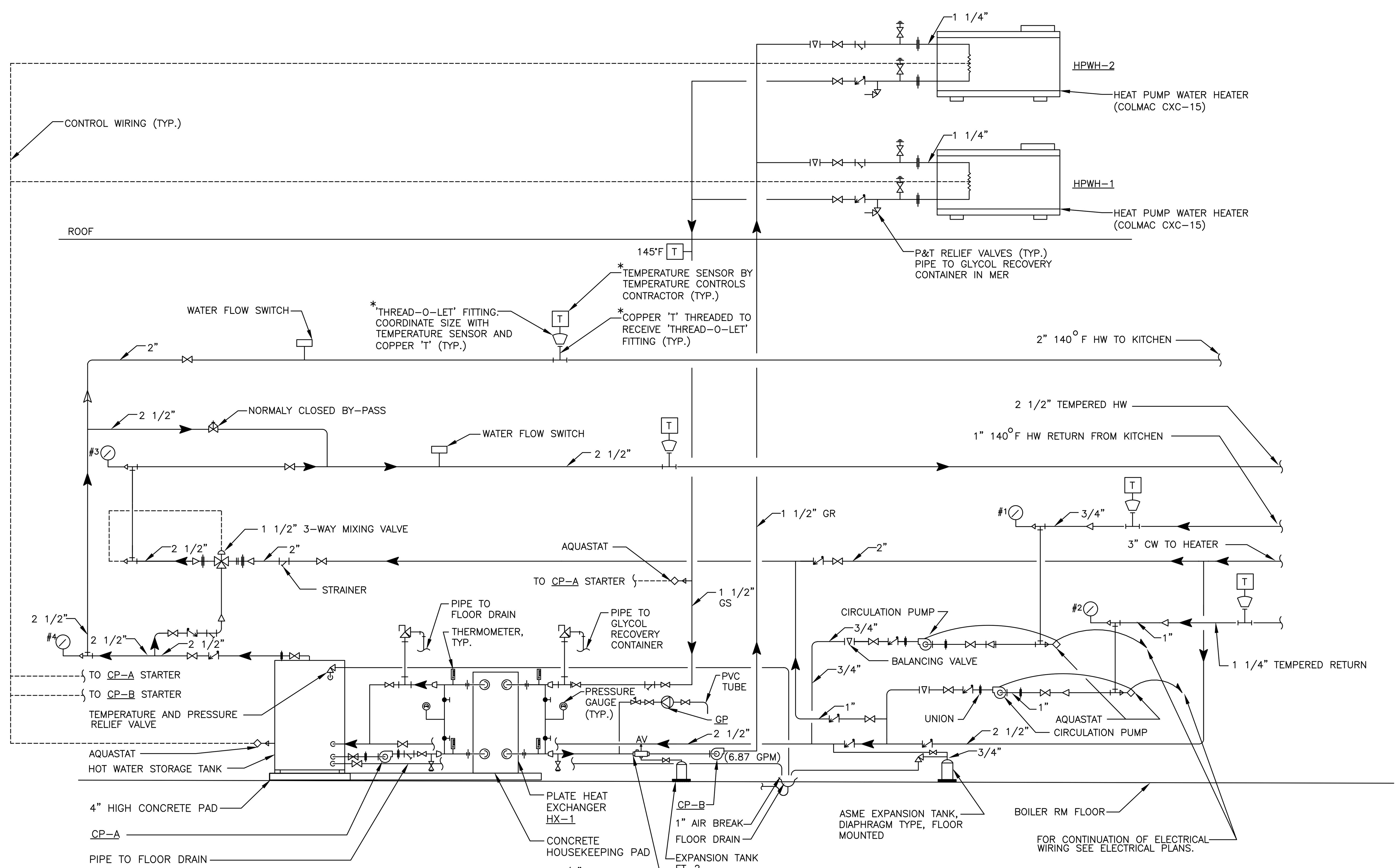
SCA [redacted] HEAT PUMP DHW DESIGN SUPPORT

DRAWING TITLE

PLUMBING ROOF PLAN
OPTION B: AERMEC NRK0300

SEAL

SCALE	AS NOTED
DRAWN BY	AP
CHECKED BY	JK
DATE	3/28/19
PROJECT NO.	NSCA1008.00
DRAWING NO.	P2.1B



DIAL THERMOMETERS:
1. KITCHEN CIRC
2. TEMPERED CIRC
3. TEMPERED HW
4. HW-TANK STORAGE TEMPERATURE

WATER HEATER PIPING SCHEMATIC

NOT TO SCALE

AQUASTATS:
1. SET POINT: KITCHEN CIRC – 130°F
2. SET POINT: TEMPERED/GENERAL CIRC – 104°F
3. AQUASTAT WIRED IN SERIES WITH THE CORRESPONDING FLOW SWITCH.
4. STORAGE TANK 140°F.
5. GLYCOL SUPPLY (GS) 140°F.

GS – GLYCOL SUPPLY
GR – GLYCOL RETURN

PLATE AND FRAME HEAT EXCHANGER SCHEDULE

DESIGNATION	HX-1
LOCATION	BOILER ROOM
SERVICE	DOMESTIC HOT WATER
MODEL	AT190X-IG1-120/96-DW
CAPACITY (MBH)	287.10
NUMBER OF PLATES	96
HEAT TRANSFER AREA (SF)	225.36
NUMBER OF PASSES	8
DIMENSIONS (LxWxH IN.)	31.08x15.6x37.2
WORKING PRESSURE (PSI)	150.0
WEIGHT (LBS)	782
COLD SIDE:	
FLUID	WATER
GPM	6.42
E.W.T./L.W.T. (°F)	50°/140°
WATER P.D. (PSI)	3.95
CONNECTION SIZE (IN.)	2.5
HOT SIDE:	
FLUID	40% PROPYLENE GLYCOL
GPM	6.87
E.W.T./L.W.T. (°F)	145°/55°
WATER P.D. (PSI)	4.81
CONNECTION SIZE (IN.)	2.5

NOTES:
1. POTABLE WATER HEAT EXCHANGER SHALL BE VENTED/DOUBLE WALL 0.4 MM AISI 316L, STAINLESS STEEL, PLATE AND FRAME, EPDM GASKET MATERIAL.
2. BASIS OF DESIGN BASED ON AIC.

HEAT PUMP WATER HEATER & STORAGE TANK SCHEDULE

WATER HEATER	LOCATION	PERFORMANCE DATA								ELECTRICAL DATA					APPROX. WEIGHT (LBS)	SOUND DATA (DBA)	STORAGE TANK DIMENSIONS/WEIGHT/CAPACITY	REMARKS
		EAT	FLUID	EWT	LWT	MIN/MAX FLOW (GPM)	HEATING CAPACITY (BTU/H)	MIN HEATING COP	MIN RECOVERY RATE (GPH) (50°F–140°F)	FLA	MOCP/MCA	PHASE	CYCLE	VOLTS				
HPWH-1/2	ROOF	7°F WB 7°F DB	40% PROPYLENE GLYCOL	55°F	145°F	3.18/6.87	143,552 (11.96 TONS)	2.0	190	55	50 / 68	3	60	460	TBD	90.0	DIA. 40" X 110" (H)/982 LBS/449 GAL. STORAGE (ST#1) BRADFORD WHITE MODEL NH449JG5A	COLMAC CXC-15 AS BASIS OF DESIGN.

NOTES:

1. PROVIDE ADJUSTABLE TXV, SIGHT GLASS, LIQUID LINE DRIER.
2. PROVIDE BRONZE DHW CIRCULATING PUMP 1/6 HP FOR POTABLE WATER. CP-A; 6.42 GPM, 25 FT. WC. BELL & GOSSETT MODEL PL-36B 115/1/60 OR EQUAL.
3. PROVIDE 40% PROPYLENE GLYCOL CIRCULATING PUMP 1/6 HP. CP-B; 6.87 GPM, 25 FT. WC. BELL & GOSSETT MODEL PL-36 115/1/60 OR EQUAL.
4. PROVIDE GLYCOL FILL PUMP GP; 50 WATT, 0.7 GPM, AXIOM MODEL MF300 DIAPHRAGM PUMP (PUMP ONLY) OR EQUAL. 115/1/60 PROVIDE 24 VDC 50 WATTS POWER SUPPLY.
5. PROVIDE UNIT MOUNTED MICROPROCESSOR CONTROLLER WITH BACNET INTERFACE.
6. SS 304 CABINET, ALUMINUM FINS.
7. ET-2; AMTROL AX-15(V) AS BASIS OF DESIGN.
8. PROVIDE INLINE AIR SEPARATOR IAS-1; BELL AND GOSSETT IAS-1½ AS BASIS OF DESIGN.
9. PROVIDE MOTOR STARTER AND DISCONNECT SWITCH FOR EACH PUMP.

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1	ISSUED FOR REVIEW	4/23/19

PROJECT TITLE

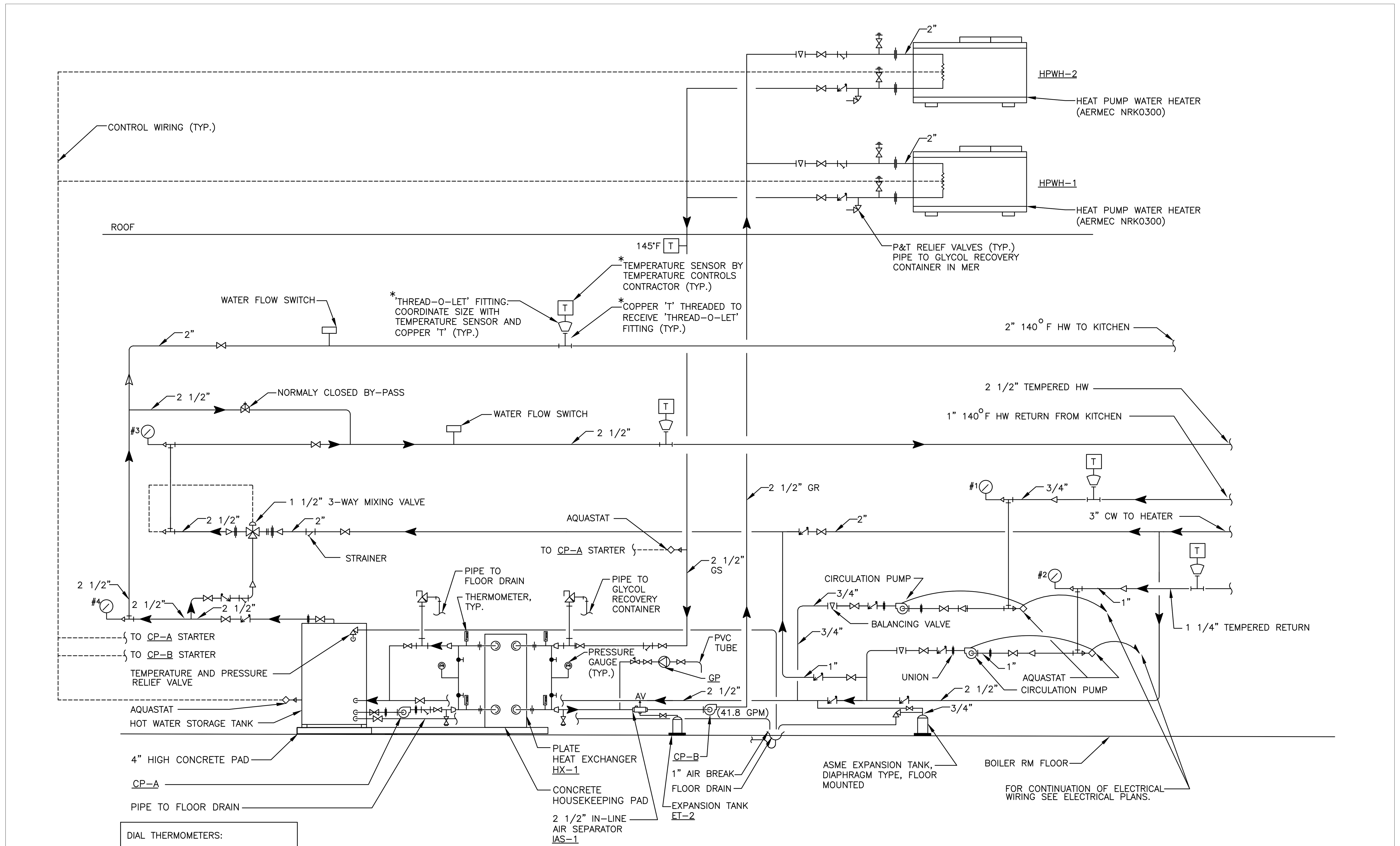
SCA [redacted]
DESIGN SUPPORT

DRAWING TITLE

PLUMBING DETAILS & SCHEDULE
OPTION A: COLMAC CXC-15
WITH SPLIT HEAT EXCHANGER

SEAL

SCALE: AS NOTED	PROJECT NO.: NSCA1008.00
DRAWN BY: AP	DRAWING NO.:
CHECKED BY: JK	P7.1A
DATE: 3/28/19	



DIAL THERMOMETERS:
1. KITCHEN CIRC
2. TEMPERED CIRC
3. TEMPERED HW
4. HW-TANK STORAGE TEMPERATURE

WATER HEATER PIPING SCHEMATIC

NOT TO SCALE

AQUASTATS:
1. SET POINT: KITCHEN CIRC - 130°F
2. SET POINT: TEMPERED/GENERAL CIRC - 104°F
3. AQUASTAT WIRED IN SERIES WITH THE CORRESPONDING FLOW SWITCH.
4. STORAGE TANK 140°F.
5. GLYCOL SUPPLY (GS) 140°F.

GS - GLYCOL SUPPLY
GR - GLYCOL RETURN

PLATE AND FRAME HEAT EXCHANGER SCHEDULE

DESIGNATION	HX-1
LOCATION	BOILER ROOM
SERVICE	DOMESTIC HOT WATER
MODEL	AT140X-IG1-47/26-DW
CAPACITY (MBH)	330.03
NUMBER OF PLATES	26
HEAT TRANSFER AREA (SF)	38.75
NUMBER OF PASSES	1
DIMENSIONS (LxWxH IN.)	17.64x11.80x39.10
WORKING PRESSURE (PSI)	150.0
WEIGHT (LBS)	413
COLD SIDE:	
FLUID	WATER
GPM	7.38
E.W.T/L.W.T. (°F)	50°/140°
WATER P.D. (PSI)	0.27
CONNECTION SIZE (IN.)	2.0
HOT SIDE:	
FLUID	40% PROPYLENE GLYCOL
GPM	41.71
E.W.T./L.W.T. (°F)	145°/128°
WATER P.D. (PSI)	5.79
CONNECTION SIZE (IN.)	2.0

NOTES:
1. POTABLE WATER HEAT EXCHANGER SHALL BE VENTED/DOUBLE WALL 0.4 MM AISI 316L, STAINLESS STEEL, PLATE AND FRAME, EPDM GASKET MATERIAL.
2. BASIS OF DESIGN BASED ON AIC.

HEAT PUMP WATER HEATER & STORAGE TANK SCHEDULE

WATER HEATER	LOCATION	PERFORMANCE DATA								ELECTRICAL DATA					APPROX. WEIGHT (LBS)	SOUND DATA (DBA)	STORAGE TANK DIMENSIONS/WEIGHT/CAPACITY	REMARKS
		EAT	FLUID	EWT	LWT	MIN/MAX FLOW (GPM)	HEATING CAPACITY (BTU/H)	MIN HEATING COP	MIN RECOVERY RATE (GPH) (50°F-140°F)	FLA	MOCP/MCA	PHASE	CYCLE	VOLTS				
HPWH-1/2	ROOF	8.1°F WB 9.9°F DB	40% PROPYLENE GLYCOL	128°F	145°F	20.9 / 41.8	165,015 (13.75 TONS)	1.66	220	34	76 / 59	3	60	460	1,741	85.4	DIA. 40" X 110" (H)/982 LBS/449 GAL. STORAGE (ST#1) BRADFORD WHITE MODEL NH449JG5A	AERMEC NRK0300 AS BASIS OF DESIGN

NOTES:
1. PROVIDE ADJUSTABLE TXV, SIGHT GLASS, LIQUID LINE DRIER.
2. PROVIDE BRONZE DHW CIRCULATING PUMP 1/6 HP FOR POTABLE WATER. CP-A: (7.38 GPM, 25 FT. WC.). BELL & GOSSETT MODEL PL-36B 115/1/60 OR EQUAL.
3. PROVIDE 40% PROPYLENE GLYCOL CIRCULATING PUMP 3/4 HP. CP-B: 41.8 GPM, 25 FT. WC. BELL & GOSSETT MODEL PD-37S 115/1/60 OR EQUAL.
4. PROVIDE GLYCOL FILL PUMP GP: 50 WATT, 0.7 GPM, AXIOM MODEL MF300 DIAPHRAGM PUMP (PUMP ONLY) OR EQUAL. 115/1/60 PROVIDE 24 VDC 50 WATTS POWER SUPPLY.
5. PROVIDE UNIT MOUNTED MICROPROCESSOR CONTROLLER WITH BACNET INTERFACE.
6. SS 304 CABINET, ALUMINUM FINS.
7. ET-2: AMTROL AX-15(V) AS BASIS OF DESIGN.
8. PROVIDE INLINE AIR SEPARATOR IAS-1: BELL AND GOSSETT IAS-2½ AS BASIS OF DESIGN.
9. PROVIDE MOTOR STARTER AND DISCONNECT SWITCH FOR EACH PUMP.

OLA CONSULTING ENGINEERS

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12 East 49th Street, 11th Flr. New York, NY 10017
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CLIENT

NEW YORK CITY
SCHOOL CONSTRUCTION AUTHORITY
3030 THOMPSON AVENUE
LONG ISLAND CITY, NY 11101

No.	ISSUE OR REVISION	DATE
3	FINAL ISSUE	5/29/19
2	ISSUED FOR REVIEW	5/6/19
1	ISSUED FOR REVIEW	4/23/19

PROJECT TITLE

SCA [redacted]
DESIGN SUPPORT

DRAWING TITLE

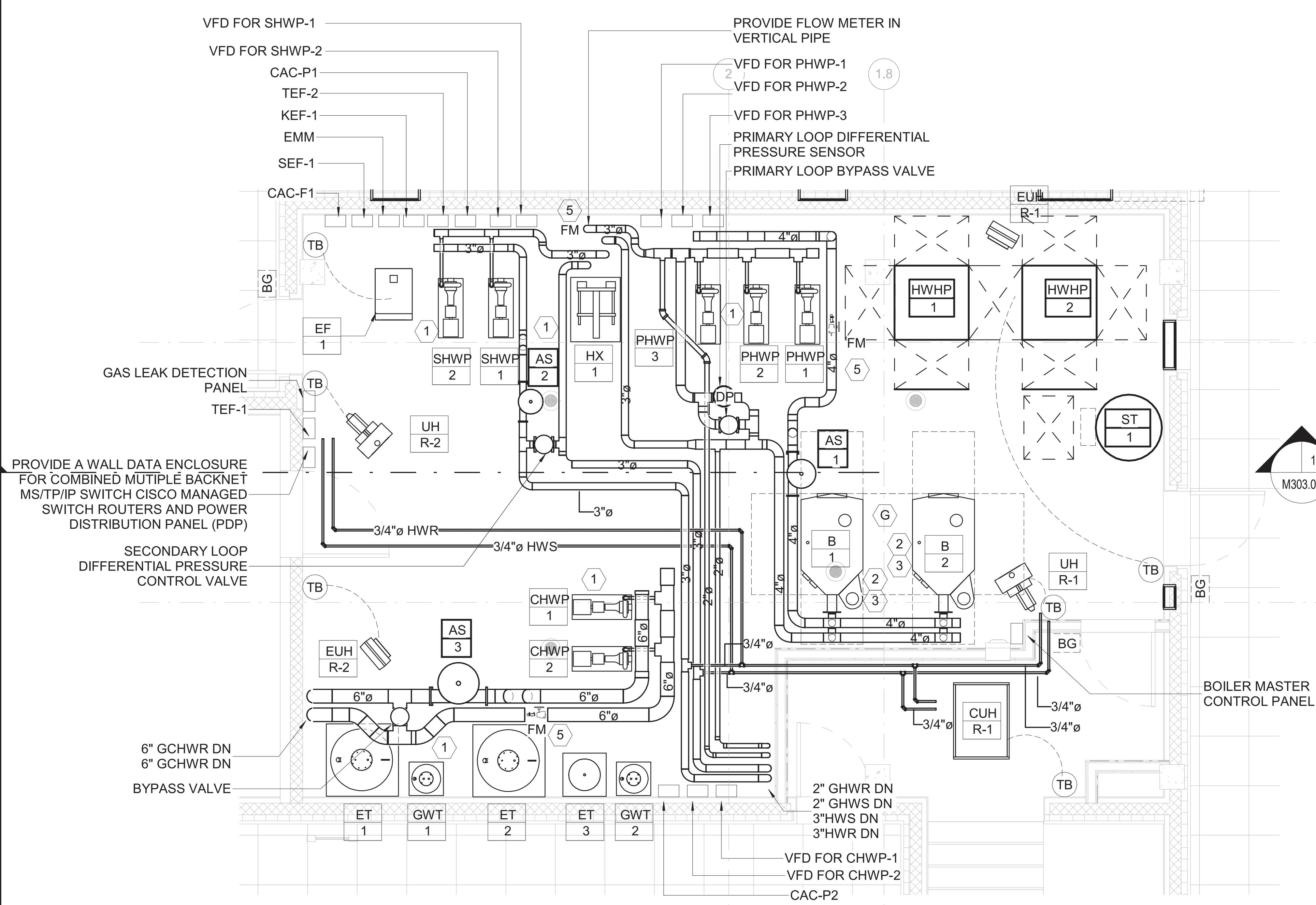
PLUMBING DETAILS & SCHEDULE
OPTION B: AERMEC NRK0300
WITH SPLIT HEAT EXCHANGER

SEAL

SCALE: AS NOTED	PROJECT NO.: NSCA1008.00
DRAWN BY: AP	DRAWING NO.: P7.1B
CHECKED BY: JK	
DATE: 3/28/19	

Appendix I:

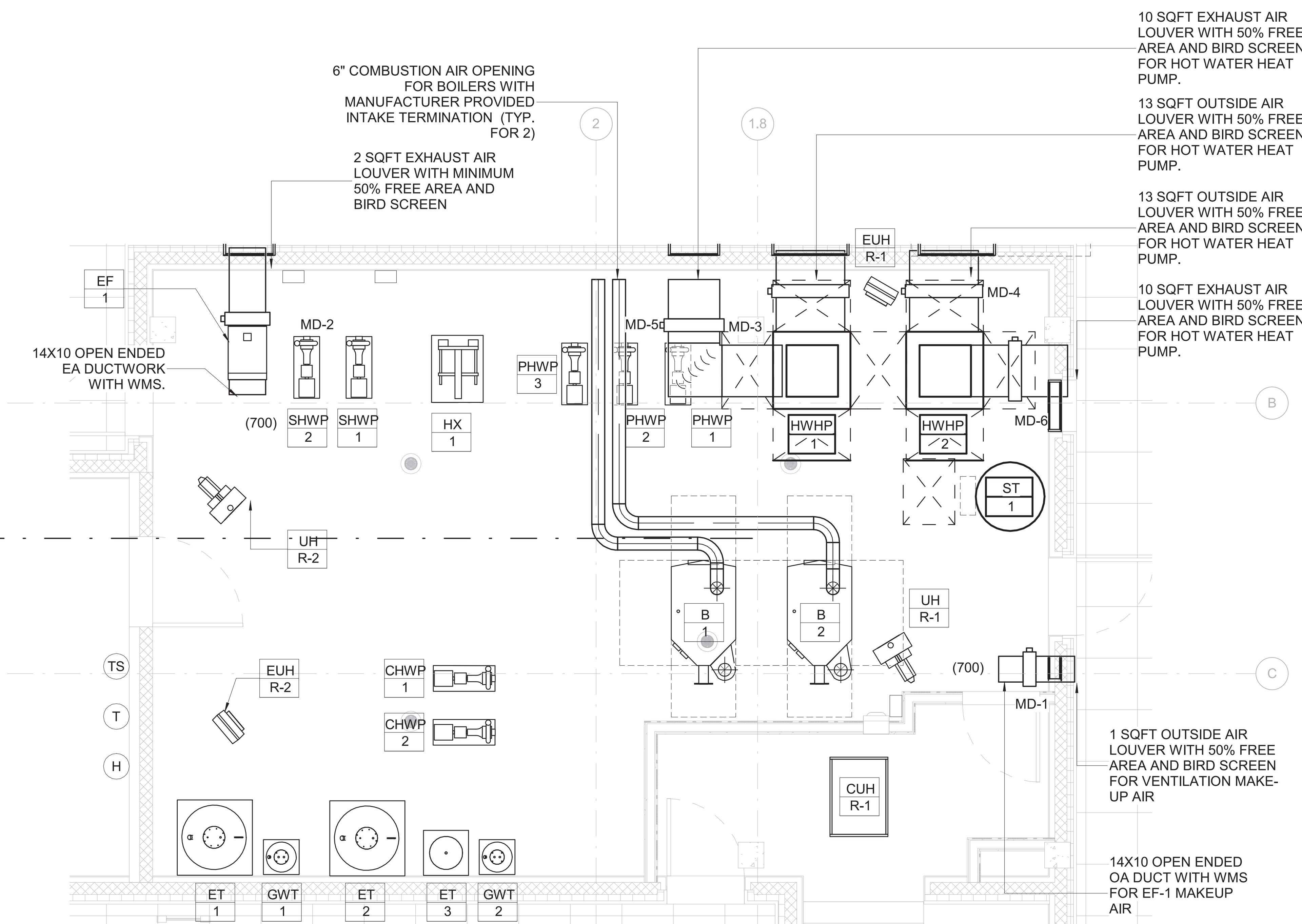
Sample Design School #2 Floor Plan and Schematic Diagram



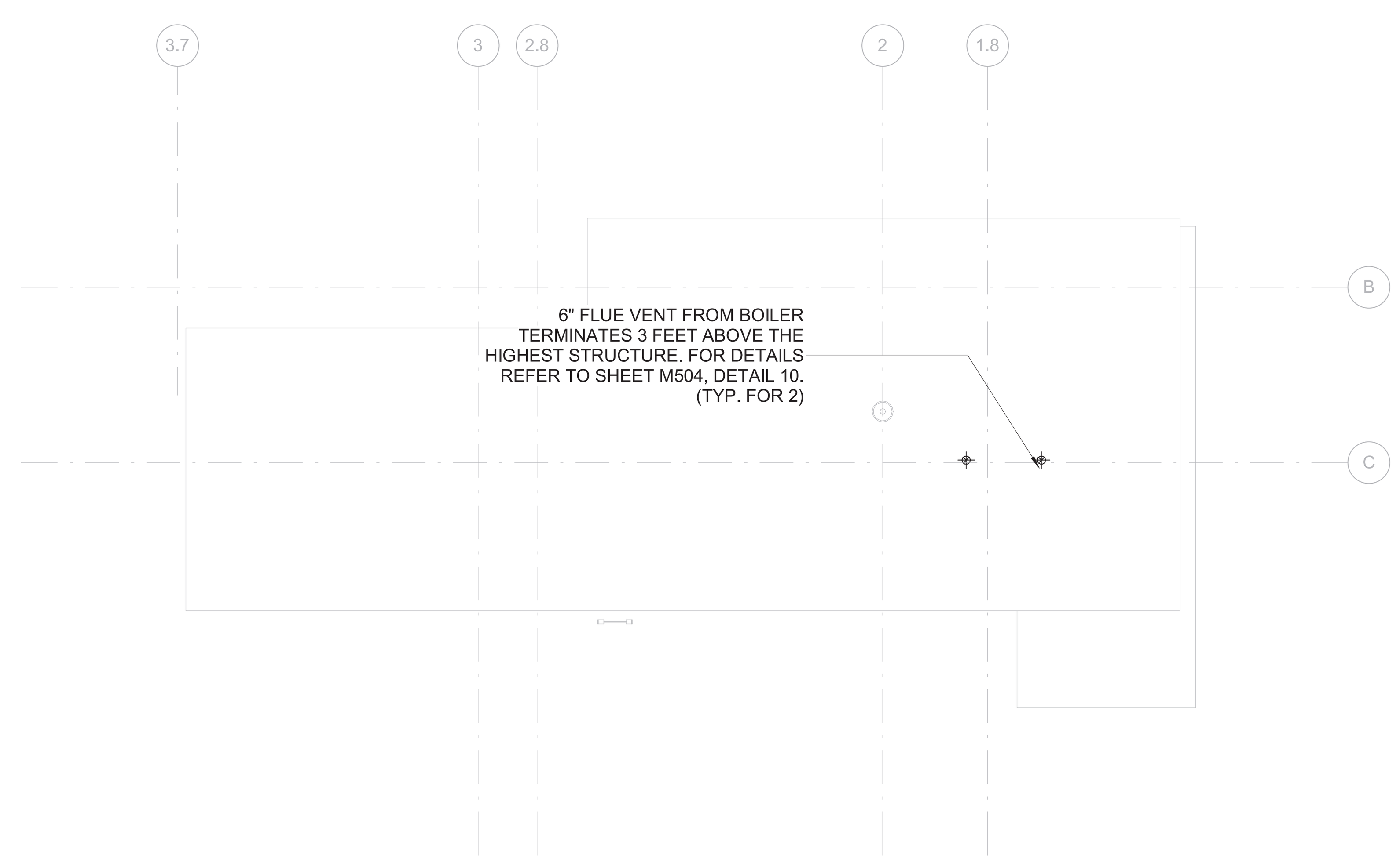
D 1 M301.00
MECHANICAL EQUIPMENT ROOM PIPING LAYOUT
SCALE: 1/4" = 1'-0"

SHEET NOTES:

1. PROVIDE 4" THICK CONCRETE PAD TO SUPPORT ALL PUMPS, EXPANSION TANKS, GLYCOL WATER TANK AND HEAT EXCHANGER. ALLOW A MINIMUM OF 4' WIDTH AROUND EACH EQUIPMENT.
2. PROVIDE 6" THICK CONCRETE PAD TO SUPPORT BOILER. ALLOW A MINIMUM OF 6" WIDTH AROUND EACH EQUIPMENT.
3. PROVIDE ACID NEUTRILIZATION KIT AS RECOMMENDED BY MANUFACTURER.FOR DETAILS REFER TO PLUMBING DRAWING P201.00/DETAIL 05.
4. BOILER VENT TERMINATES 3'-0" ABOVE HIGHEST STRUCTURE WITHIN 10 FEET RADIUS
5. PROVIDE 15 PIPE DIAMETERS OF STRAIGHT PIPE FOR UPSTREAM OF FLOW METER.
6. REMOTE CONTROL (SHUT DOWN) SHALL BE PROVIDED TO STOP THE FLOW OF GAS TO THE BOILER



D 2 M301.00
MECHANICAL EQUIPMENT ROOM DUCTWORK LAYOUT
SCALE: 1/4" = 1'-0"



D 3 M301.00
FP05_T.O. BULKHEAD DUCTWORK
SCALE: 1/8" = 1'-0"

SCA NYC School Construction Authority

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María A. Gómez, P.E., LEED A.P., Director, A&E In-House Design
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Geotechnical:
Langan Engineering
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Landscape Architect & Civil Engineer:
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Romano Gatland
1 Huntington Quadrangle, Melville, NY 11747
Acoustical Consultant:
Cerami Associates
404 Fifth Avenue, New York, NY 10018
Elevator Consultant:
Van Deusen & Associates
120 Eagle Rock Avenue, Suite 310, East Hanover, NJ 07936
Cost Estimating:
Slocum Construction Consulting
37 Pulver Road, Hudson, NY 12534

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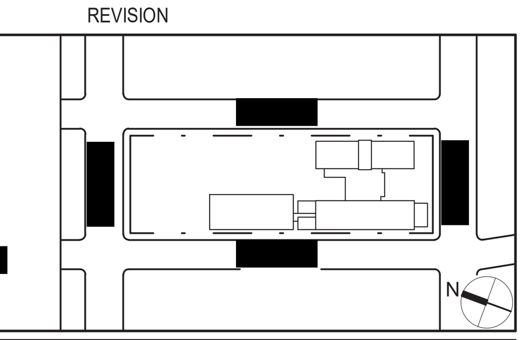
NO.	DATE	REVISION
2	07/11/2019	100% CD SUBMISSION
1	04/11/2019	60% CD SUBMISSION

KEY PLAN:



SCA DESIGN MANAGER: EMAD ASAAD, RA
PROJECT ARCHITECT/ENGINEER: JITENDRA K. AGARWAL, P.E.
DISCIPLINE LEAD: RAJ SRINIVAS
DESIGNER: UDAY GORRE
DRAWN BY: P.ROKAD/ W.SANCHEZ
CHECKED BY: RAJ SRINIVAS

LLW NO:	FACILITY CODE:	DATE:
[redacted]	[redacted]	9/19/2019

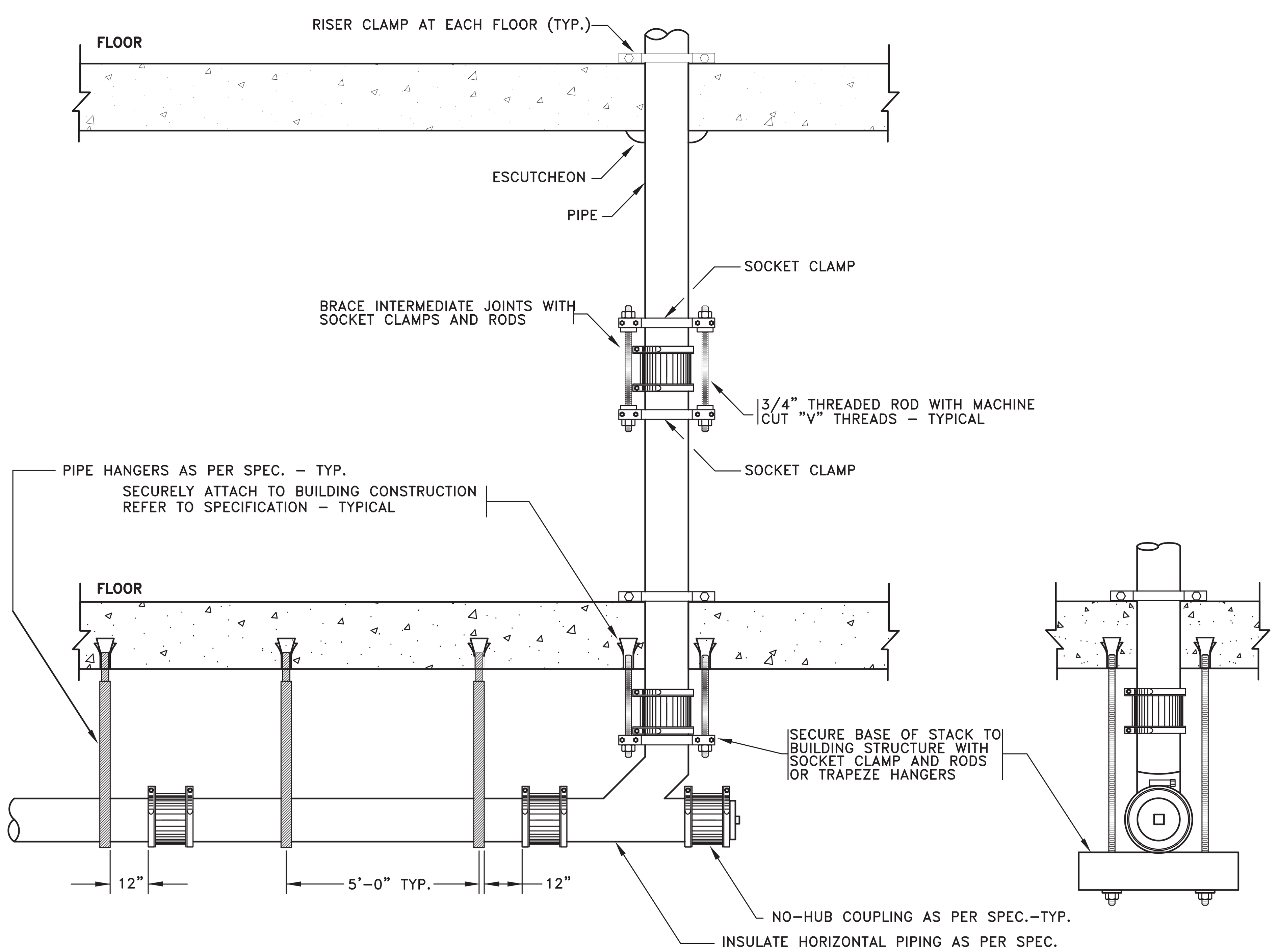
[redacted] - [redacted]
BUILDING ADDITION
ADDRESS: [redacted]

DRAWING TITLE:
MECHANICAL ENLARGED PART PLAN

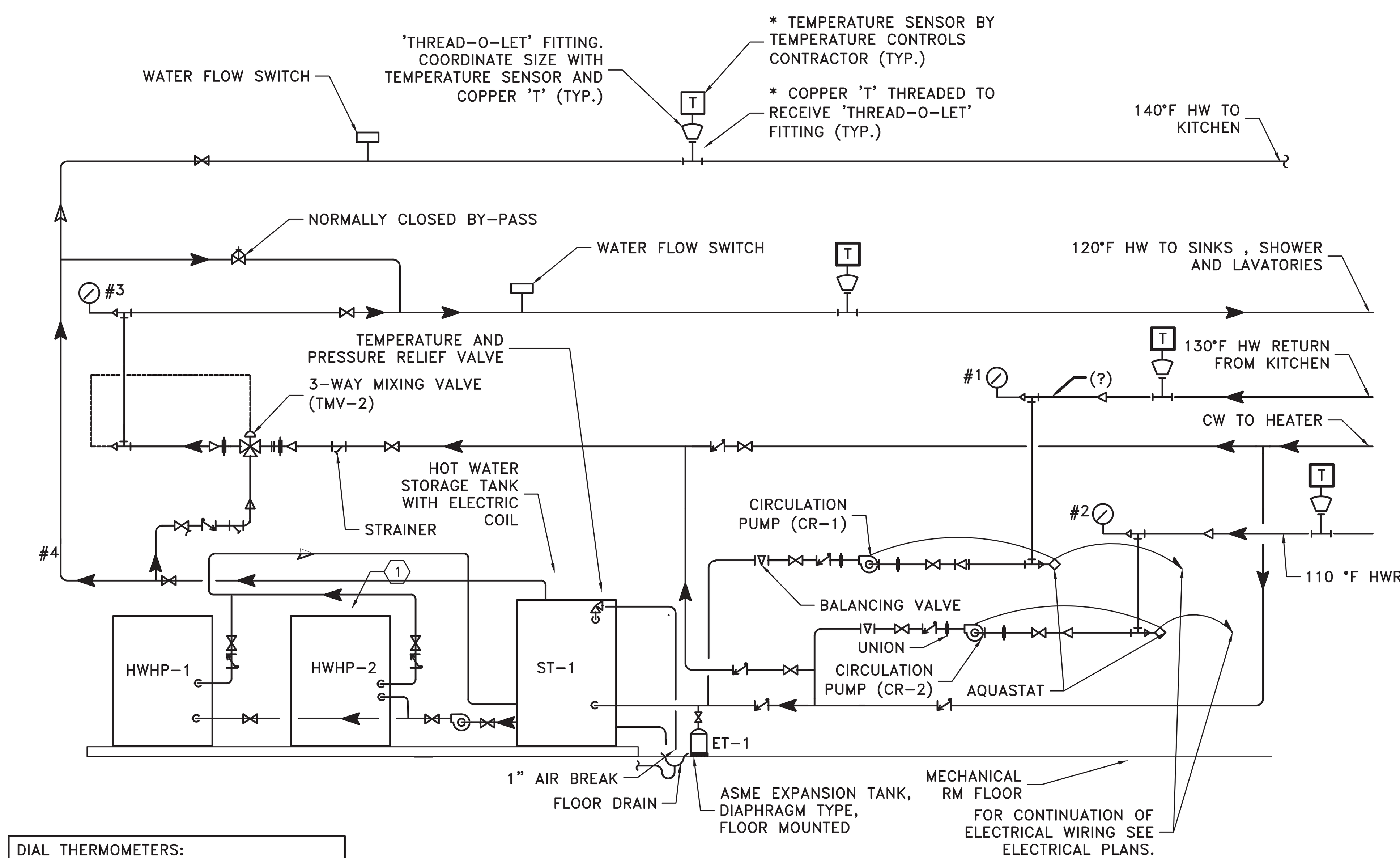
DRAWING NO.:
M301.00

SHEETS IN CONTRACT SET:
OF

SHEETS IN DOB SET:
OF



1
P404
NO-HUB PIPE BRACING FOR VERTICAL PIPING
N.T.S.



DIAL THERMOMETERS:

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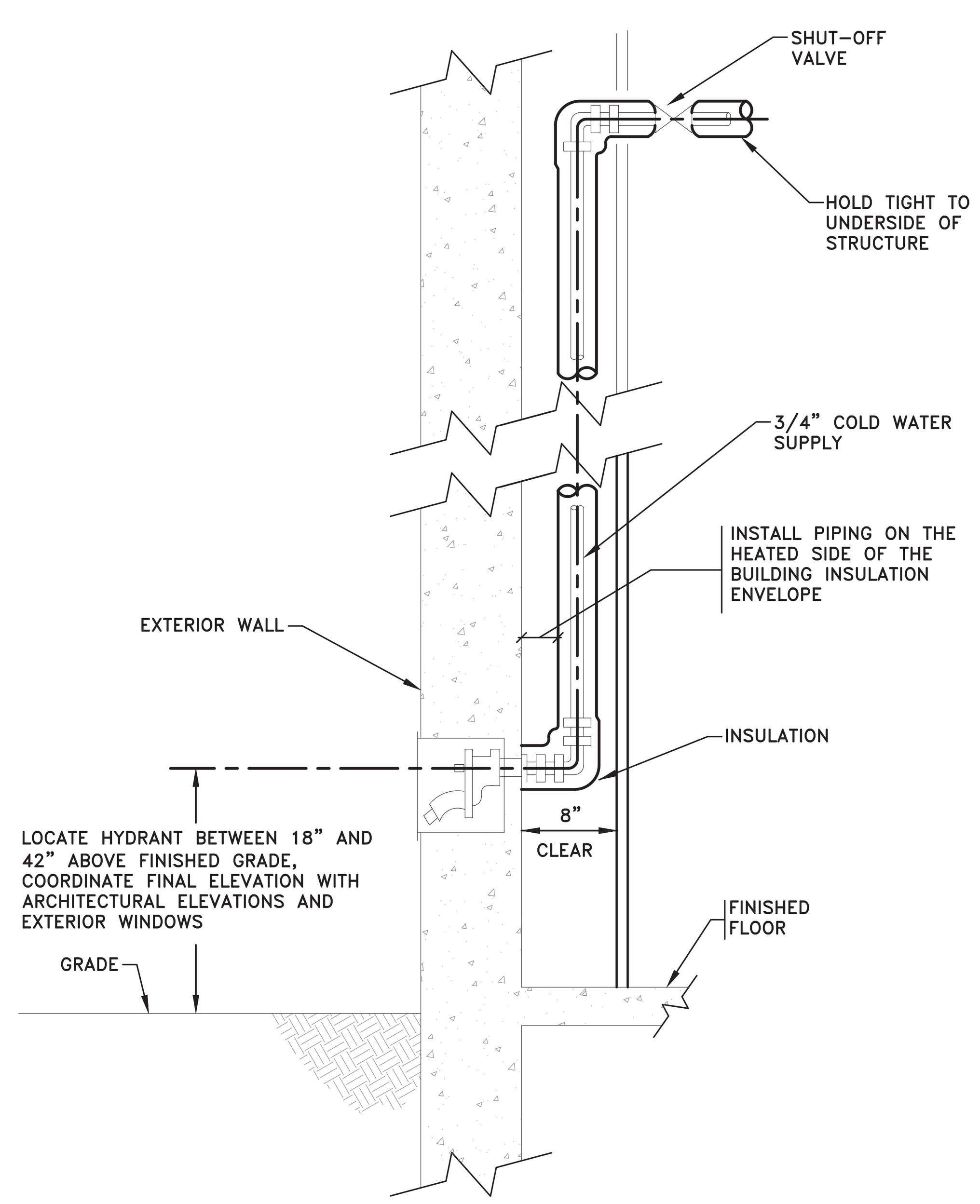
3. TEMPERED HW
4. HW-TANK STORAGE TEMPERATURE

AQUASTATS:

1. SET POINT: KITCHEN CIRC - 130°F
2. SET POINT: TEMPERED/GENERAL CIRC - 110°F
3. AQUASTAT WIRED IN SERIES WITH THE CORRESPONDING FLOW SWITCH.

2
P404
WATER HEATER HEAT PUMP PIPING SCHEMATIC
N.T.S.



3
P404
TYPICAL NON-FREEZE WALL HYDRANT DETAIL
N.T.S.

07/31/2019

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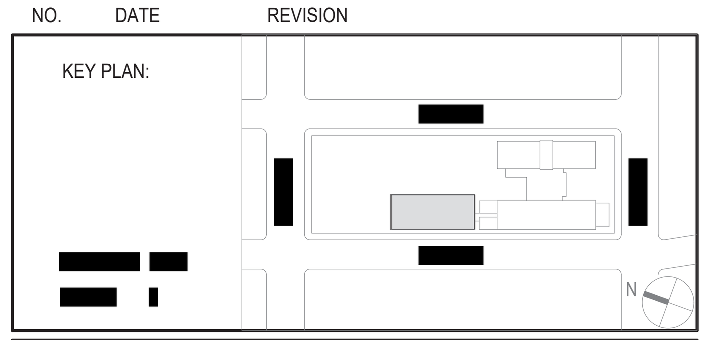
2	7/11/2019	100% CD SUBMISSION
1	4/11/2019	60% CD SUBMISSION

KEY PLAN:



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[redacted]	[redacted]	9/19/2019

PROJECT:
[redacted] - [redacted]
BUILDING ADDITION
ADDRESS:
[redacted]

DRAWING TITLE:
P&D TYPICAL DETAILS SHEET NO. 4

DRAWING NO.:
P404.00

SHEETS IN CONTRACT SET:
OF

SHEETS IN DOB SET:
OF

A & J PROJECT No. 2154