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Services of the San Francisco Public Utilities Commission

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MEMORANDUM

Executive Summary

In accordance with Ordinance 237-20 that amends the Building Code to require new construction utilize only electric power, the San Francisco Public Utilities Commission (SFPUC) drafted the following report evaluating opportunities for the expansion of non-potable onsite water treatment systems, graywater heat recovery systems, solar thermal water heating, and on-demand hot water heaters.

Through an ongoing evaluation of the SFPUC's existing water programs, SFPUC staff analyzed the City and County of San Francisco's Non-potable Water Ordinance to identify opportunities to increase potable water savings from new development projects and improve system implementation. Staff examined the three potential modifications to the ordinance for new development projects of 250,000 gross square feet (gsf) or greater and are recommending San Francisco move forward with the following:

- Requiring blackwater reuse in commercial buildings;
- Requiring graywater reuse for toilet and urinal flushing, clothes washing, and irrigation in multi-family and mixed-use residential buildings; and
- Requiring district-scale water reuse systems in development projects with more than one building.

Staff also examined the potential for lowering the 250,000 gsf threshold for compliance with the Non-potable Ordinance to 100,000 gsf. Staff analyzed the result this would have on achieving additional potable water savings. By lowering the threshold, this would only realize an additional 0.02 mgd of potable water savings which represents just 2% of the total savings anticipated for the developments projects that are required to comply with the Non-potable Ordinance by 2040.

In the report, SFPUC staff also included an extensive review of wastewater heat recovery systems, including a description of how the technology works, benefits that could be achieved in buildings with onsite water reuse systems, energy savings potential, and the applicability for San Francisco. For the single-family home scale, staff are not recommending to require the installation of drain-heat recovery systems in new single-family homes due to the fact that there is a limited market for single family home development opportunities in San Francisco and the technical challenges with applying this technology in existing homes. In new, larger development projects that are installing onsite water reuse systems, staff are recommending to continue encouraging wastewater heat recovery systems via the Onsite Water Reuse Grant Program because

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wastewater heat recovery systems have the potential to significantly offset the energy consumption of onsite water reuse systems. Voluntary use of the technology will allow staff to gather more information about the potential benefits and implementation.

The next section of the report evaluates the potential implementation of solar thermal water heating systems in San Francisco. SFPUC staff reviewed a description of how the technology works, example system costs, and considerations for evaluating the technology in San Francisco. Solar thermal systems are very well suited for rooftop installation and have a proven track record of meeting commercial and residential water heating needed. Therefore, it is recommended that residential properties and commercial businesses that use a lot of hot water in their operations should consider a solar thermal installation. With the high temperatures that can be achieved, the systems can offer value to a wide range of businesses, particularly hotels, restaurants, and laundromats. Consideration should also be given to the fact that qualified solar professionals are needed for the installation, but are in limited supply in the Bay Area.

Lastly, SFPUC staff included a brief overview of a new proposal to launch a pilot program in Fiscal Year 2021-2022 to rebate a portion off the purchase price of installed on-demand recirculating hot water heater pumps and to evaluate their water-savings potential. The target market for the pilot rebate program and study is residential single-family and small multi-family properties in which each dwelling unit has its own hot water tank.

1. SFPUC Water and Power Enterprises

The SFPUC is committed to an innovative approach to water and energy resources management. The SFPUC is implementing several programs and projects that are diversifying the City's water supply portfolio and ensuring resilient water sources for the future. The SFPUC's water conservation program includes many efforts to help residences and business save water. One example is the Plumbing Fixture Replacement Program, a toilet and urinal direct installation program that connects residences and businesses to plumbers for retrofitting inefficient fixtures. Another example is the Leak Alert Program, which notifies customers of a potential leak by sending an email, text, letter, and phone call and advises to contact a plumber. In addition, the SFPUC is committed to developing local groundwater to enhance the City's drinking water supply. The SFPUC also promotes the use of recycled water, as construction continues on the Westside Enhanced Water Recycling Project that will provide recycled water for irrigating Golden Gate Park, Lincoln Park Golf Course, and the San Francisco Zoo. Also underway is a satellite treatment facility feasibility study to evaluate options to deliver recycled water to dual-plumbed buildings on the eastside of San Francisco. In addition, the SFPUC implements the City's mandatory requirement for onsite water reuse in new large buildings. The SFPUC provides grant funding to encourage retail water users to install onsite water reuse systems, as well as encourage the installation of onsite treatment and reuse of brewery process water.

Additionally, the SFPUC's Power Enterprise provides numerous customer programs to both Hetch Hetchy Power and CleanPowerSF customers. Through rebates, specially designed rates and services, and other incentive structures, these programs help customers use energy as efficiently as possible, save money, and participate in San Francisco's clean energy future.

2. Non-potable Water Ordinance

Recognizing an opportunity in new and large redevelopment projects for onsite use of alternate water supplies in September 2012, the City and County of San Francisco adopted the Non-potable Water Ordinance (NPO). It added Article 12C to the San Francisco Health Code allowing for the collection, treatment, and use of alternate water sources such as graywater, rainwater, stormwater, blackwater, and foundation drainage for non-potable applications such as toilet flushing and irrigation. The following alternate water sources are defined as:

- Graywater: untreated wastewater that includes, but is not limited to, wastewater from bathtubs, showers, bathroom sinks, clothes washing machines, and laundry tubs, but does not include wastewater from kitchen sinks or dishwashers.
- Blackwater: includes graywater and is defined as wastewater containing bodily or other biological wastes, as from toilets, dishwashers, kitchen sinks and utility sinks.
- Rainwater: precipitation collected from roof surfaces or other manmade, above ground collection surfaces.
- Stormwater: precipitation collected from at-grade or below grade surfaces or from any surface where hydrocarbon-based fuels, hazardous materials, or fertilizers are stored or used.
- Foundation drainage: nuisance groundwater that is extracted to maintain a building's or facility's structural integrity and would otherwise be discharged to the sanitary or combined sewer system.

A streamlined permitting process was developed through a joint collaboration with the SFPUC, San Francisco Department of Public Health (SFDPH), San Francisco Department of Building Inspection (SFDBI), and San Francisco Department of Public Works (SFPW). Water quality, monitoring, and reporting requirements were established, giving regulatory oversight and management over onsite non-potable water systems to the Department of Public Health.

In 2013, the Board of Supervisors amended the NPO to allow district-scale non-potable water systems consisting of two or more buildings sharing non-potable water. Subsequently, the Ordinance was amended in July 2015 to mandate the installation of onsite water systems in new developments of 250,000 gross square feet or more. And the Ordinance was amended again in 2016 to clarify implementation requirements for district-scale systems.

3. Onsite Water Reuse Grant Program

The SFPUC's Onsite Water Reuse Grant Program provides grant funding to encourage retail water users to reduce SFPUC water supply usage by collecting, treating, and using alternate water sources including rainwater, stormwater, graywater, foundation drainage, air conditioning condensate, and blackwater for non-potable uses such as toilet flushing, irrigation, and cooling tower makeup. Projects must demonstrate the ability to achieve at least one of the following thresholds to eligible for grant funding:

- Projects that replace at least 450,000 gallons of SFPUC water per year are eligible for grant funding up to $200,000; or
- Projects that replace at least 1,000,000 gallons of SFPUC water per year are eligible for grant funding up to $500,000; or
- Projects that replace at least 3,000,000 gallons of SFPUC water per year are eligible for grant funding up to $1,000,000.

The SFPUC lowered the threshold of eligibility to 450,000 gallons of water per year offset to incentivize existing dual-plumbed buildings with no current recycled water source to install onsite water reuse systems. Recognizing that these buildings would likely otherwise not install onsite water reuse systems, the SFPUC is offering financial assistance to encourage additional potable water savings.

4. Potential Amendments to Non-potable Water Ordinance

Evaluating Impacts to Future Development Projects

Through an ongoing effort to evaluate the SFPUC's existing water programs, SFPUC staff analyzed the Non-potable Water Ordinance to identify opportunities to increase potable water savings from new development projects and improve system implementation. Several potential amendments were identified, which are discussed further below. During the spring of 2020, SFPUC staff met with the city agencies including SFDPH, SFDBI, SFPW, and SFPUC Water Quality Division that are responsible for implementing the ordinance. The city agencies were given opportunities to comment on the proposed amendments and provide suggestions to further streamline compliance with the ordinance.

To understand the impacts on future multi-family, mixed-use, and commercial development projects and anticipated potable water offsets, SFPUC staff reviewed the San Francisco Planning Department's Pipeline Report published with 2020 Quarter 1 data and internal databases used for tracking future developments' compliance with the ordinance. SFPUC staff, in consultation with other city agencies, determined that the most streamlined way to apply future potential amendments was to make them applicable to only planned development projects that have not yet filed a site permit. Therefore, SFPUC staff analyzed only planned development projects that have not yet filed for a site permit. Appendix A contains more information on these developments and Table 4 summarizes the number of future development projects and anticipated potable water offsets if the square footage threshold were lowered to 100,000 gsf. In Appendix A, any building marked with a Y in the 'Site Permit Filed or Issued' column was not included in the potable offset analysis for the above stated reason. The buildings with an 'N' were included, and the total number of buildings with an 'N' matches the numbers in Table 4.

Blackwater Reuse in Commercial Buildings of 250,000 Gross Square Feet (gsf) or Greater

SFPUC staff evaluated modifying the ordinance to require commercial buildings to reuse blackwater for toilet and urinal flushing to achieve additional potable water savings. Currently, the ordinance requires projects to capture available graywater, rainwater, and foundation drainage. Blackwater can be treated and reused on a voluntary basis. Analysis has shown that blackwater reuse in a commercial office building can offset 100% of the building's toilet and urinal flushing demands, which can represent up to 75% of the building's total indoor potable water demands. This increased water savings is substantial when compared to commercial buildings reusing graywater onsite, which can offset only about 15% of total building indoor potable water demands. Additionally, SFDPH's regulations for onsite water reuse systems contain water quality requirements for the treatment and reuse of blackwater that would result in water quality that is protective of public health. Furthermore, the SFPUC's Headquarters building serves as a successful example of a blackwater treatment system in operation in a commercial setting.

Table 1. Considerations for requiring blackwater reuse in commercial buildings of 250,000 gsf or greater

Pros	Cons
• Reusing blackwater in an office building can offset 100% of toilet and urinal flushing demands, which can represent up to 75% of a building's total indoor potable water demands. • Increasing potable water offsets from new development projects can help build the resilience of the City's water supply. • In combined sewer areas, development projects that reuse	• Commercial buildings reusing graywater onsite can offset only about 15% of total building indoor potable water demands.

blackwater onsite can benefit the sewer system by diverting wastewater flows away from the sewer during storm events.	

Graywater Reuse for Toilet and Urinal Flushing, Clothes Washing, and Irrigation in Multi-Family and Mixed-Use Residential Buildings of 250,000 Gross Square Feet or Greater

SFPUC staff also evaluated modifying the ordinance to require multi-family and mixed-use residential buildings to reuse graywater to meet clothes washing as an end use, going beyond the current requirement for only toilet and urinal flushing and irrigation demands to be met. Analysis has shown that toilet and urinal flushing demands account for about 15% of total indoor water use in multi-family and mixed-use residential buildings. By reusing graywater to also meet clothes washing demands, these buildings can increase their potable water offset by an additional 15%, which can result in up to 30% offset of the building's total indoor potable water use, thereby maximizing the potential potable water offsets of an onsite water reuse system. Multi-family and mixed-use residential buildings often produce ample graywater, therefore it's not necessary to reuse blackwater to meet their non-potable water demands. Analysis has also shown that adding clothes washing as an end use would require a minor amount of additional plumbing. Additionally, SFDPH's regulations for onsite water reuse systems contain water quality requirements for the treatment and reuse of graywater that would result in a water quality for clothes washing that is protective of public health.

Table 2. Considerations for requiring graywater reuse for toilet and urinal flushing, clothes washing, and irrigation in multi-family and mixed-use residential buildings of 250,000 gsf or greater

Pros	Cons
• Toilet and urinal flushing demands account for about 15% of total indoor water use in multi-family and mixed-use residential buildings. By reusing graywater to also meet clothes washing demands, these buildings can increase their potable water offset by an additional 15%, which can result in up to 30% offset of the building's total indoor potable water use, thereby maximizing the potential potable water offsets of an onsite water reuse	• Additional public education and outreach may be needed to encourage the safety and benefits of using graywater for clothes washing.

system.	

District-Scale Water Reuse Systems

Additionally, SFPUC staff analyzed modifying the ordinance to require development projects with more than one building to install a district-scale water reuse system. The modification would be applicable to development projects with a cumulative square footage of 250,000 gsf or greater, which could consist of multiple buildings that may be below 250,000 gsf individually. This requirement is consistent with the current ordinance and would not result in additional development projects being subject to the ordinance. Instead of development projects installing building-by-building graywater systems, the proposed modification would require development projects with more than one building to install a district-scale water reuse system. District-scale systems benefit from economies of scale compared to many individual building treatment systems, resulting in significantly lower capital costs, lower total energy consumption, and lower total footprint of treatment and storage equipment. A large development project in San Francisco has shown it could save over $10 million if a district-scale system was installed compared to individual building treatment systems. Furthermore, reducing the number of onsite water systems by requiring district-scale systems means that operators can spend more time ensuring the systems are working reliably. Any potential impacts on plumbing are site specific and dependent on the combination of commercial, residential, and mixed-use buildings.

Table 3. Considerations for requiring district-scale water reuse systems in development projects with more than one building

Pros	Cons
• District-scale systems benefit significantly from economies of scale compared to individual building-by-building systems. • A large development project in San Francisco has shown it could save over $10 million if a district-scale system was installed compared to individual building treatment systems. • Qualified operators of onsite water reuse systems are a limited resource in San Francisco. Reducing the number of onsite systems by requiring district-scale systems may result in operators being able to spend more time ensuring treatment	• District-scale systems require ownership and legal agreements among property owners. For example, establishing or designating one entity to be responsible for compliance with the Non-potable Ordinance may be challenging if there are multiple property owners. • District-scale systems require a higher initial capital investment. • The development project will have to balance the timing of construction of the district-scale system and the overall development project's phasing.

systems are working.	

Additional Alternate Water Sources and Non-potable End Uses

In an effort to evaluate the expansion of onsite water reuse systems, SFPUC staff considered expanding the required alternate water sources to include condensate and expanding the required non-potable end uses to include drain trap priming. Condensate is defined as water vapor that is converted to a liquid and collected, the most common source in buildings being equipment for air conditioning, refrigeration, and steam heating. A trap primer is a plumbing device or valve that adds water to traps. Per SFDPH's Rules and Regulations Regarding the Operation of Alternate Water Source Systems, non-potable water is suitable for drain trap priming. It was determined that these expansions are unlikely to result in significant cost impacts on development projects due to minimal additional infrastructure and treatment needed to add these alternate water sources and non-potable end uses to a system. These expansions may result in a small increase in potable water offsets.

SFPUC staff also considered requiring cooling tower make-up water as a non-potable use and do not recommend making this change. While cooling tower make-up water is currently allowed, it is likely to push designers toward reverse osmosis (RO) because that is currently the most reliable treatment to achieve the necessary water quality for cooling tower make-up. Because of the 75% recovery of RO systems, onsite water reuse systems may not achieve a significant additional potable offset beyond what is achieved with toilet flushing. Furthermore, requiring cooling as an end use may have significant cost impacts to a development project due to the need for a larger system size, additional treatment (i.e. RO), and the energy for operating an RO system that may be required.

Lowering the Square Footage Threshold for Compliance with the Non-potable Ordinance

As mentioned above, since 2015, new development projects of 250,000 gsf or more are required to install and operate an onsite water reuse system. It is estimated that by 2040, the development projects that are required to comply with the Non-potable Ordinance will offset approximately 1.1 mgd of potable water. When also factoring in the potable water savings from development projects voluntarily installing onsite water reuse systems, the total potable water offset increases to 1.3 mgd by 2040.

SFPUC staff analyzed the impact of lowering the 250,000 gsf threshold to 100,000 gsf. In this analysis, SFPUC also considered a volume-based threshold; however it was determined that using a single square footage threshold creates the simplest and most streamlined way for development projects to understand if they are required to comply with the ordinance.

To understand the number of planned multi-family, mixed-use, and commercial development projects that would be impacted by the potential amendments and anticipated potable water offsets, SFPUC staff reviewed the San Francisco Planning Department's Pipeline Report published with 2020 Quarter 1 data and internal databases used for tracking future developments' compliance with the ordinance. SFPUC staff, in consultation with other city agencies, determined that the most streamlined way to apply future potential amendments was to make them applicable to only planned development projects that have not yet filed a site permit. Therefore, SFPUC staff analyzed only planned development projects that have not yet filed for a site permit. Appendix A contains more information on these developments and Table 4 summarizes the number of future development projects and anticipated potable water offsets if the square footage threshold were lowered to 100,000 gsf. In Appendix A, any building marked with a Y in the 'Site Permit Filed or Issued' column was not included in the potable offset analysis for the above stated reason. The buildings with an 'N' were included, and the total number of buildings with an 'N' matches the numbers in Table 4.Table 4 shows that if the threshold were lowered to 100,000 gsf, approximately 0.02 mgd of additional potable water savings could be achieved. This constitutes only 2% of the total water savings estimated for developments projects that are required to comply with the Non-potable Ordinance.

SFPUC staff also compared other potential impacts on factors such as cost and footprint to development projects under the existing 250,000 gsf threshold. Onsite water reuse systems benefit from economies of scale for both cost and footprint, and these factors do not scale on a 1:1 basis. The footprint needed for an onsite water reuse system in a smaller building would be smaller, but the ratio of system size to total building size likely goes up, meaning the system takes up a larger percentage of total building space. Similarly, the cost of a system in a smaller building would also be smaller, but again not on a 1:1 basis. For example, a major technology supplier in San Francisco indicated that the cost of a graywater treatment system would only be 15% different between a 250,000 gsf and 100,000 gsf building. Additionally, there are other costs associated with onsite water reuse systems that are more fixed, such as operations, maintenance, and water quality sampling. A smaller treatment system will still need a qualified operator and the same number of water quality samples as a larger system of the same type; therefore the fixed costs wouldn't be substantially less for smaller buildings. Although smaller buildings with onsite water reuse systems may have reduced water and sewer bills, they would face a relatively higher capital and operations and maintenance cost than larger buildings. There is not sufficient data at this time to say conclusively whether this would be a net benefit or cost to smaller buildings.

Some smaller buildings lower than 250,000 gsf will be required to comply with the Non-potable Ordinance if the individual buildings are part of a larger development project. In this case, these buildings can leverage the economies of scale of onsite reuse by connecting to a district-scale system serving the whole development.

Table 4. Estimated potable water offsets from multi-family, mixed-use, and commercial development projects required to comply with the NPO (i.e. >250,000 gsf) and from future development projects 100,000 gsf or greater

Size Range (gross square feet)	Number of Development Projects[1]	Estimated Potable Water Offsets in mgd[2]
≥250,000	50	1.1 mgd
200,000 – 250,000	0	0 mgd
150,000 – 200,000	2	0.003 mgd
100,000 – 150,000	5	0.012 mgd

[1] *Estimates of future development projects between 100,000 and 250,000 gsf taken from San Francisco Planning Department's Pipeline 2020 Q1 Report and SFPUC tracking databases.*
[2] *Potable offsets estimated using information provided by projects such as water budget applications, where available. For future projects, staff used the SFPUC Water Use Calculator to estimate future offsets.*

In summary, the Non-potable Ordinance amendments discussed above are estimated to achieve an additional potable water savings of approximately 0.2 mgd. The water savings of 0.2 mgd is equivalent to about 5,500 San Francisco residents daily water use. A breakdown of the estimated water savings can be found in Table 5 below.

Table 5. Additional Potable Water Savings Resulting from the Non-potable Ordinance Amendments

	Potable water savings by requiring blackwater reuse in commercial buildings (mgd)	Potable water savings by requiring graywater reuse for clothes washing in multi-family and mixed-used residential buildings (mgd)	Total potable water savings (mgd)
New development projects over 250,000 gross square foot (gsf) threshold	0.04	0.14	0.18
New development projects between 100,000 gsf and 250,000 gsf	0.001	0.014	0.02

Table 6. Considerations for requiring new development projects 100,000 gsf or greater to comply with the Non-potable Ordinance

Pros	Cons
• There is not a significant potable water offset that could be achieved by requiring new development projects below 250,000 gsf to comply with the ordinance.	• Minimal additional potable water savings could be achieved by requiring smaller buildings to comply with the ordinance. If the square footage threshold for compliance were lowered to 100,000 gsf, this would only realize an additional 0.02 mgd of potable water savings, representing just 2% of the total savings anticipated for the developments projects that are required to comply with the Non-potable Ordinance by 2040. • Compared to a 250,000 gsf building, the relative capital cost that a smaller building would face would be larger. For example, according to a major technology supplier in San Francisco, a graywater treatment system in a 100,000 gsf building would cost only 15% less than that for a 250,000 gsf building. • The ongoing operations and maintenance costs and water quality sampling costs are largely fixed for onsite treatment systems, and wouldn't be substantially less for smaller buildings.

Recommendations for Potential Non-potable Ordinance Amendments

- It is recommended to require commercial buildings to reuse blackwater to meet toilet and urinal flushing demands. Commercial buildings reusing blackwater can offset more potable water use as compared to graywater. For example, a commercial office building can offset 100% of toilet flushing demands with blackwater reuse compared to graywater reuse which can only offset about 20% of toilet flushing demands.
- It is recommended to require multi-family and mixed-use residential buildings to reuse graywater to meet toilet and urinal flushing, clothes washing, and irrigation demands. Residential buildings produce an excess of graywater and can achieve additional potable water savings by

going beyond the current requirement for only toilet and urinal flushing and irrigation demands to be met by adding clothes washing as an additional required end use.
- It is recommended to require new developments with more than one building to install a district-scale reuse system. District-scale water reuse systems have additional benefits compared to individual building treatment systems, as economies of scale can result in significantly lower capital costs, lower total energy consumption, and lower total footprint of treatment and storage equipment.
- To incorporate condensate and drain trap priming is a policy decision for the Board of Supervisors.
- To lower the threshold to 100,000 gsf is a policy decision for the Board of Supervisors.

5. Wastewater Heat Recovery Systems: Evaluating Implementation in San Francisco

Wastewater heat recovery refers to the extraction of thermal energy from warm wastewater, and subsequent beneficial use of this energy to offset existing energy requirements. Common components of wastewater heat recovery systems include:

- Wet Well or Equalization Tank: a tank used to collect raw wastewater upstream of a wastewater heat recovery system for the purpose of supplying a consistent flow.
- Solid-Liquid Separation: an initial process step whereby solids are removed from the liquid portion of the wastewater prior to the liquid being sent to the heat exchanger and/or heat pump.
- Heat Exchanger: a device for passively transferring heat between two or more fluids. The fluids may be separated by a solid wall to prevent mixing or they may be in direct contact. In a heat exchanger, heat will move spontaneously from the hotter fluid into the colder fluid.
- Heat Pump: a device that actively transfers heat from a colder fluid to a hotter fluid, i.e. in the opposite direction of spontaneous heat transfer. In a heat pump, an additional energy source is needed to facilitate the heat transfer. Heat pump efficiency is defined by a coefficient of performance (COP), which describes the ratio of energy recovered to external energy used. Generally, a COP above 3 is deemed fairly efficient.

Implementation Scales for Wastewater Heat Recovery Systems

In a single-family home application, graywater (also referred to as drain-water heat exchangers) recover heat from hot water used in showers, bathtubs, sinks, dishwashers, and clothes washers. They then typically store the recovered heat so it can be used to heat future home water needs. Drain-water heat recovery systems usually have a copper heat exchanger that replaces a vertical section of a main waste drain. As warm water flows down the waste drain, incoming cold water flows through a spiral copper tube wrapped tightly around the copper section of the waste drain. This preheats the incoming cold water that goes to the water heater or a fixture, such as a shower.

By preheating cold water, drain-water heat recovery systems help increase water heating capacity. This increased capacity may be of particular value in homes with undersized water heater. They also allow homes to lower their water heating temperature without affecting water heating capacity. From an economic standpoint, these systems offer a payback period of 3-7 years, depending on how often the system is used (Department of Energy).

At the individual, larger building scale, wastewater heat recovery systems could be configured as shown below in Figure 1. The heat recovered from a building's wastewater (blackwater or graywater) can be directly used for domestic hot water heating or space heating and/or cooling.

Alternatively, district scale wastewater heat recovery systems can provide domestic water heating, space heating, and space cooling to entire neighborhoods. The district-scale model is based around a centralized treatment facility, which acts as the energy and wastewater hub for a community and distinguishes district-scale systems from those installed in individual buildings. Incorporating wastewater heat recovery into district-scale water reuse system would require projects to include a district energy system that could be used to distribute the recovered heat to individual buildings. This would introduce a significant level of complexity, requiring a central energy plant, as well as additional infrastructure in the streets and likely in each building. The False Creek Energy Center in Vancouver is a prime example and more details can be found in Appendix B.

Wastewater Heat Recovery Benefits and Onsite Water Reuse Synergies

Wastewater heat recovery systems have the potential to significantly offset the energy consumption of onsite water reuse systems. In fact, integrating wastewater heat recovery with onsite water reuse offers several synergies:

- Tanks that collect raw wastewater for onsite water recycling can be leveraged for wastewater heat recovery. Onsite water reuse systems will already have such tanks available to provide a consistent flow to the wastewater heat recovery system.
- Using raw wastewater in a wastewater heat recovery system can present challenges for the equipment because of solids, oils, grease, hair, and other constituents; using treated blackwater or graywater from an onsite water reuse system as the heat source can enable heat recovery from a much cleaner stream.
- Wastewater heat recovery systems cool down the treated water being sent

to buildings for applications such as toilet flushing and cooling towers. Cooling down the treated water has several benefits, including improved efficiency in cooling towers and improved control of *Legionella* growth in premise plumbing.

Wastewater heat recovery systems can be integrated with onsite water reuse systems in multiple configurations. Two examples of potential integration are illustrated in Figure 1. In both examples, the heat is recovered from the treated blackwater or graywater storage tank and used in the domestic hot water heating system. In the top configuration, 'Hot Water Boiler Pre-Heating,' the recovered heat is used to pre-heat potable water that is then sent through a hot water boiler. In the bottom scenario, 'Hot Water Tank Temperature Control,' the recovered heat is used to maintain the temperature of water that has already been heated and is being stored in a hot water storage tank.

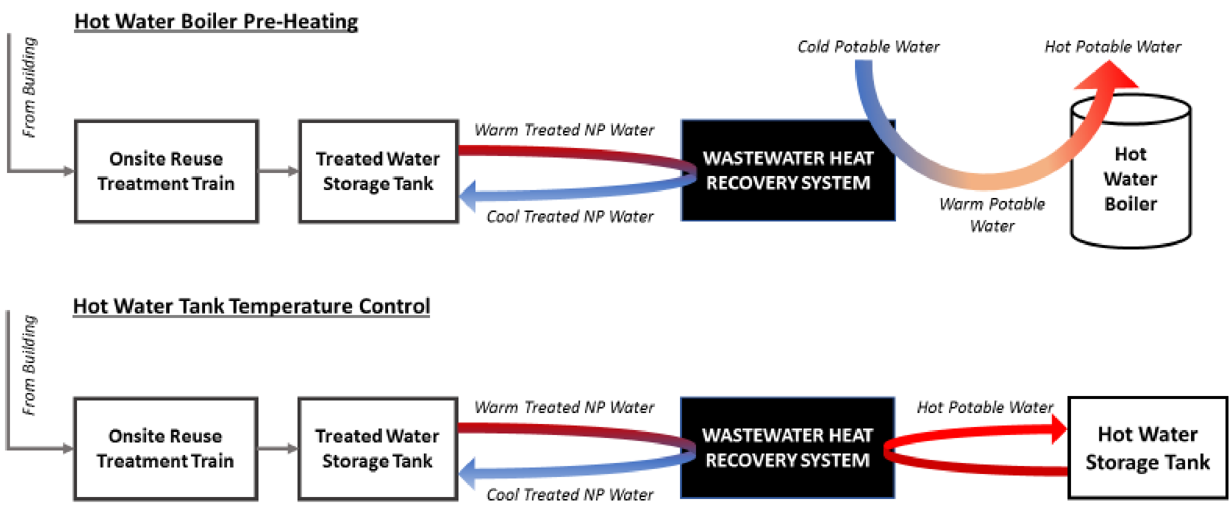

Figure 1. Example configurations for integration of wastewater heat recovery and onsite water reuse systems.

Types of Wastewater Heat Recovery Technology

Companies offer packaged wastewater heat recovery systems that can be compact and self-contained. For example, SHARC Energy Systems Inc. offers the Piranha packaged system, which is intended for use in buildings with 50 – 200 units (International Wastewater Systems, 2014). The system is designed to provide hot water heating or pre-heating. Another packaged system offering is the HUBER RoWin system, which can be used at the building scale. The system would integrate with a building's domestic hot water system or could be coupled to the HVAC system (HUBER Technology, 2018). In general, these types of systems experience the highest efficiency when the wastewater storage tank, the heat exchanger, and the hot water boiler are located in close proximity to one another.

Current Status of Wastewater Heat Recovery in San Francisco

In an effort to consider ways to reduce energy footprint of onsite water reuse systems, SFPUC updated its existing Onsite Water Reuse Grant Program in 2019 to incentivize the implementation of wastewater heat recovery systems within development projects installing onsite water reuse systems. The grant program requires all projects applying for a grant to estimate the potential energy offset that can be achieved with wastewater heat recovery. In addition, mixed-used and multi-family buildings that are grant recipients are required to implement wastewater heat recovery. Research shows that multi-family and mixed-use buildings present the best opportunity for wastewater heat recovery because they are most likely to have centralized hot water boilers. There can be a significant volume of graywater and thus more energy to recover via wastewater heat recovery. Commercial buildings are not optimal for the installation of wastewater heat recovery because they do not tend to have centralized hot water boilers, and so using the heat recovered from wastewater becomes more challenging.

SFPUC's goal in integrating wastewater heat recovery into the grant program is to gather more information about the potential benefits of these systems and understand how implementation could occur successfully in San Francisco.

More broadly, decentralized wastewater heat recovery systems implemented at the building or district scale are very limited in the U.S. Based on research and interviews with SFPUC staff and consultants, while wastewater heat recovery has been piloted at a few wastewater treatment plants in the U.S., these systems have been implemented as demonstration projects and haven't resulted in any formal regulatory processes being developed.

Energy Savings and Emissions Reduction from Wastewater Heat Recovery

The emissions reduction associated with wastewater heat recovery technology is dependent on the nature of the energy sources powering the relevant grid. A recent study conducted life cycle assessments of onsite water reuse systems with associated wastewater heat recovery systems; the findings in terms of global warming potential depended on the underlying energy sources (Arden et al., 2020). If buildings are fully powered by electricity, then wastewater heat recovery systems will result in a reduction in electricity usage. The resultant benefit in terms of emissions depends on the extent to which the electric grid relies on fossil fuels. For buildings powered entirely by renewables, as many are in San Francisco, there would be no net benefit to the building in terms of greenhouse gas emissions reduction. Additionally, there is typically a tradeoff between energy recovery and system efficiency. Recovering higher amounts of heat will require a higher input of energy via the heat pump, and thus the efficiency will go down.

The following example provides context for the potential energy savings that could be achieved in a multi-family residential building, based on the following assumptions:

- Assumed graywater as source water, as is required by the NPO
- Assumed 15 gpy/sf of graywater generation for primarily residential buildings, based on SFPUC's Water Use Calculator
- Assumed a 15°F drop in graywater temperature through the heat recovery system

Under these conditions, a theoretical 250,000 square foot residential building could recover 300 kWh/day using wastewater heat recovery. This type of building is likely to use in total somewhere in the range of 10,000 kWh/day (Energy Star Portfolio Manager, 2018). Although the recovered energy is a small percentage of the overall building energy demand, it is likely to be a significant portion of the energy used for onsite water reuse treatment.

Table 7. Summary of considerations for installing wastewater heat recovery systems in conjunction with an onsite water reuse system in San Francisco

Pros	Cons
• Wastewater heat recovery has the potential to lower the energy use associated with onsite water reuse treatment. The biggest opportunity is in multi-family residential and mixed-used buildings. • Wastewater heat recovery and onsite water reuse can have synergies when installed together, such as shared infrastructure.	• Adding wastewater heat recovery to a building will add cost and take up building footprint. • Including wastewater heat recovery in a district-scale system can be highly complex, as it would require a district energy system to recover and distribute the energy. • There are limited examples of the technology being successfully installed and operated in the United States. Therefore, SFPUC is incentivizing the voluntary installation of these systems to gather additional information.

Recommendations for Wastewater Heat Recovery Systems

- The best opportunity to install a drain-heat recovery system in a single-family home application would be during new construction or a major renovation, although this is a minimal market since there are limited single family home development opportunities in San Francisco. Application of this technology in existing homes would most likely be limited due to technical challenges around physical space constraints. It is not recommended to require installation of drain-heat recovery systems in new San Francisco single-family homes.

- It is recommended for the SFPUC to continue to encourage wastewater heat recovery systems in larger individual buildings with onsite water reuse systems and at the district-scale via the Onsite Water Reuse Grant Program because wastewater heat recovery systems have the potential to significantly offset the energy consumption of onsite water reuse systems. Voluntary use of the technology will allow staff to gather more information about the potential benefits and implementation.

6. Solar Thermal Water Heating Systems: Evaluating Implementation in San Francisco

Solar thermal technology is a well-established means of heating domestic hot water. Over the last 40 years the technology has been refined and improved upon. Today's solar thermal products follow established codes, certifications (Solar Rating and Certification Corporation (SRCC)), and make use of modern engineering practices.

For the purposes of this document, Flat Plate Collector (FPC) and Evacuated Tube collectors are considered. These two technologies are commercially available, have proven track records, and meet commercial and residential water heating needs. FPC and Evacuated Tube collectors rely on standard solar principles such as good sun exposure and southern orientation. These collectors are manufactured in various sizes; 4' x 10' is a common size for commercial installations. Both collector types are comprised of copper tubing (which contains the fluid that is heated by the sun) inside an insulated glass enclosure. These systems are very modular; collectors can be added together in groups to increase the system size depending on the energy production requirements for a given site. These characteristics make FPC and Evacuated Tube collectors ideal for roof top installations.

In San Francisco's climate, FPC and Evacuated Tube collectors are capable of heating water to 140 degrees Fahrenheit. Using industry standards, an estimate can be made of the energy production of a solar thermal system in San Francisco. A FPC and Evacuated Tube collector will generate about 1,000 BTU's per square foot of collector on a sunny day (850-1,000 watts/meter squared). Therefore, a standard sized 4' x 10' collector will produce about 40,000 BTU/day (which is equivalent to 12 kWh).

Pricing for commercial systems is based on a price per square foot of collector.[1] In San Francisco, prices range from $190 to $250 per square foot of collector, depending on site conditions and project complexity. For example, in 2020, a commercial solar thermal system (with 16 collectors) was installed at a low-income multifamily housing development. The total project cost was $152,885, or $237 per square foot of installed collector. The cost of a fully installed residential system in San Francisco is typically between $6,500 and $14,000.

System sizing and cost savings can be calculated based on the energy needs of a business or residence and current utility rates. There are several online calculation tools that are free to users. Links to two examples are shown below.

- https://www.eere.energy.gov/femp/solar_hotwater_system/
- http://www.freehotwater.com/solar-calculators/solar-thermal-calculator/

Below are some considerations for San Francisco businesses to factor into their evaluation process when looking into FPC and Evacuated Tube solar thermal systems.

Table 8. Considerations for evaluating solar thermal systems in San Francisco

Pros	Cons
• Solar thermal systems are very well suited for rooftop installation. • These systems generate high temperatures making them viable for many commercial and residential needs. • The products have a proven track record and are commercially available. • Energy production can be estimated with a high degree of certainty allowing businesses and home owners to better understand what their investment can do to reduce energy demand and increase savings.	• Solar thermal systems are affected by fog, so locations on the east side of San Francisco will be better suited for this technology. • Solar professionals that are qualified to work on solar thermal systems are limited in the Bay Area. Finding the right company to do the installation will take some research. • Solar Thermal systems will not eliminate 100% of the annual domestic hot water heating needs. These systems need a backup source of energy in times of the year when there is not enough sun to cover the water heating needs. • The proposed site for a solar thermal installation should have minimal shading and a southern

[1] Financial information in this section is based on a review of California Solar Thermal Statistics as reported by the California Solar Initiative (CSI)-Thermal Program. Data can be found at http://www.csithermalstats.org/

	exposure.

Recommendations for Solar Thermal Systems

- Residential properties and commercial businesses that use a lot of hot water in their operations should consider a solar thermal installation. With the high temperatures that can be achieved, the systems can offer value to a wide range of businesses, particularly hotels, restaurants, and laundromats.

7. On-Demand Hot Water Heaters

In FY 2021-2022, the SFPUC proposes to launch a pilot program to rebate a portion off the purchase price of installed on-demand recirculating hot water heater pumps and to evaluate their water-savings potential. Manufacturers claim that such pumps can save water by reducing the amount of time customers, particularly in older homes, have to wait for hot water to hit showers and taps. When the pump is activated, it begins recirculating cold water that has been sitting in the hot water line and sends it back to the water heater through the cold water line. When the water reaches a desired temperature, a control turns the pump off. This process is similar to turning on the shower and letting the water run until it gets hot, but instead of the water going down the drain, it is returned back to the water heater. The target market for the pilot rebate program and study is residential single-family and small multi-family properties in which each dwelling unit has its own hot water tank. Multi-family properties with central hot water boilers that serve all dwelling units would not qualify. Other site conditions would also have to be met.

8. Summary of Recommendations

SFPUC staff have identified the following recommendations for the modifications of the Non-potable Ordinance in order to increase potable water savings from new buildings and development projects and increase opportunities for cost-effective systems:

- It is recommended to require commercial buildings to reuse blackwater to meet toilet and urinal flushing demands. Commercial buildings reusing blackwater can offset more potable water use as compared to graywater. For example, a commercial office building can offset 100% of toilet flushing demands with blackwater reuse compared to graywater reuse which can only offset about 20% of toilet flushing demands.
- It is recommended to require multi-family and mixed-use residential buildings to reuse graywater to meet toilet and urinal flushing, clothes washing, and irrigation demands. Residential buildings produce an excess of graywater and can achieve additional potable water savings by

going beyond the current requirement for only toilet and urinal flushing and irrigation demands to be met by adding clothes washing as an additional required end use.

- It is recommended to require new developments with more than one building to install a district-scale reuse system. District-scale water reuse systems have additional benefits compared to individual building treatment systems, as economies of scale can result in significantly lower capital costs, lower total energy consumption, and lower total footprint of treatment and storage equipment.
- To incorporate condensate and drain trap priming is a policy decision for the Board of Supervisors.
- To lower the threshold to 100,000 gsf is a policy decision for the Board of Supervisors.

SFPUC staff have identified the following recommendations pertaining to wastewater heat recovery systems:

- The best opportunity to install a drain-heat recovery system in a single-family home application would be during new construction or a major renovation, although this is a minimal market since there are limited single family home development opportunities in San Francisco. Application of this technology in existing homes would most likely be limited due to technical challenges around physical space constraints. It is not recommended to require installation of drain-heat recovery systems in new San Francisco single-family homes.
- It is recommended for the SFPUC to continue to encourage wastewater heat recovery systems in larger individual buildings with onsite water reuse systems and at the district-scale via the Onsite Water Reuse Grant Program because wastewater heat recovery systems have the potential to significantly offset the energy consumption of onsite water reuse systems. Voluntary use of the technology will allow staff to gather more information about the potential benefits and implementation.

SFPUC staff have identified the following recommendations pertaining to solar thermal systems:

- Residential properties and commercial businesses that use a lot of hot water in their operations should consider a solar thermal installation. With the high temperatures that can be achieved, the systems can offer value to a wide range of businesses, particularly hotels, restaurants, and laundromats.

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Appendix A: Site Permit Status of Future Developments in San Francisco Between 250,000 and 100,000 Gross Square Feet

To understand the number of planned multi-family, mixed-use, and commercial development projects that would be impacted and anticipated potable water offsets, SFPUC staff reviewed the San Francisco Planning Department's Pipeline Report published with 2020 Quarter 1 data and internal databases used for tracking future developments' compliance with the ordinance. SFPUC staff, in consultation with other city agencies, determined that the most streamlined way to apply future potential amendments was to make them applicable to only planned development projects that have not yet filed a site permit. Therefore, SFPUC staff analyzed only planned development projects that have not yet filed for a site permit. Appendix A contains more information on these developments and Table 4 summarizes the number of future development projects and anticipated potable water offsets if the square footage threshold were lowered to 100,000 gsf. In Appendix A, any building marked with a Y in the 'Site Permit Filed or Issued' column was not included in the potable offset analysis for the above stated reason. The buildings with an 'N' were included, and the total number of buildings with an 'N' matches the numbers in Table 4.

Address	Type	Sq Ft	Site Permit Filed or Issued
145 Hooper St, 188 Hooper St	Residential	243,330	Y
625 Gilman	Residential	234,887	Y
2500-2698 Turk	Residential	234,450	Y
950 - 974 MARKET ST	Mixed-Use Residential	230,100	Y
1401 Illinois	Mixed-Use	228,869	Y
1401 - 1443, 1499 Illinois St	Mixed-Use	228,869	Y
1601 Mission	Residential	225,000	Y
555 HOWARD STREET	Mixed-Use Residential	210,906	Y
2201 Bay Shore Blvd	Residential	210,000	Y
MISSION BAY BLOCK 1 (VISITOR)	Hotel	207,000	Y
1550 Evans	Community Facility	203,775	Y
565 BRYANT ST	Hotel	193,045	N
600 Van Ness	Mixed-Use Residential	185,739	Y

Address	Type	Sq Ft	Site Permit Filed or Issued
302 silver	Residential	180,000	Y
1028 Market	Mixed-Use	178,308	Y
1064-1068 Mission	Residential	177,000	Y
1850 BRYANT ST	Office	175,333	Y
1995 Evans	Office	175,150	Y
2060 Folsom	Mixed-Use	165,350	Y
525 Harrison	Mixed-Use Residential	159,302	Y
1351 42nd Ave	Residential	159,000	Y
1990 Folsom	Residential	156,800	Y
1140 Folsom/99 Rausch St	Residential	153,675	Y
2130 3rd St	UCSF Child, Teen, Family Center and UCSF Dept of Psychiatry Building	150,000	N
1532 Harrison St	Mixed-Use Residential	144,487	Y
333 12th St	Residential	144,000	Y
150 HOOPER ST	Mixed-Use	142,784	Y
325 Fremont	Mixed-Use Residential	142,465	Y
1125 MARKET ST	Mixed-Use	139,852	Y
SEAWALL LOTS 323 & 324	Hotel	138,800	N
1546-1564 Market St	Mixed-Use Residential	138,000	N
1200 VAN NESS AV	Mixed-Use Residential	137,749	Y
360 5th Street	Mixed-Use Residential	132,560	Y
552 BERRY ST / 1 DE HARO ST	Mixed-Use	129,619	N
210 Taylor St	Mixed-Use	129,526	Y
2675 Folsom	Residential	127,082	Y
570 MARKET ST	Hotel	126,824	N
950 Gough	Mixed-Use Residential	125,000	Y
58 Kirkwood Ave	Residential	118,886	N
2800 Sloat	Residential	117,000	Y
1830 Alemany Blvd	Mixed-Use Residential	115,610	Y

Address	Type	Sq Ft	Site Permit Filed or Issued
424 Brannan ST	Hotel	105,989	Y

Appendix B: Wastewater Heat Recovery Case Studies

Solaire Building, Battery Park – Coupled Onsite Water Reuse and Wastewater Heat Recovery System

The Solaire building is a 27-story residential tower with 293 units located in New York City. Since 2003, Solaire has been operating an onsite blackwater treatment system that collects and treats 100 percent of the building's wastewater for use in toilet flushing, irrigation, and cooling. In 2017, Natural Systems Utilities retrofitted the system, adding a wastewater heat recovery system that transfers heat from the treated blackwater to the building's hot water boiler.

The heat recovery system consists of a heat pump and heat exchanger that serves to pre-heat water going to the building's hot water boiler. The heat source is the treated and disinfected wastewater, which exits the treatment train at about 75 °F, and drops to 55 °F after the heat recovery system. The heat recovery unit itself is smaller than a refrigerator, and the total cost of the retrofit was in the range of $100,000 - $150,000. The system has a capacity of 150,000 BTU/hr, or 44 kW, and operates at just under half of that capacity. The system can recover about 400 kWh/day, which is more than the energy consumption of the onsite reuse treatment train (~300 - 350 kWh/day), giving the onsite reuse system a net zero energy balance. Approximately 30% of water heating demands are offset by the wastewater heat recovery system.

The False Creek Neighborhood Energy Utility Wastewater Heat Recovery System

The False Creek Neighborhood Energy Utility (NEU) in Vancouver, Canada is a district-scale wastewater heat recovery system, the first of its kind in North America. The development contains multi-family residential, commercial, and community buildings and covers an area of over 4.2 million square feet. The NEU was implemented through a joint effort by the City of Vancouver and Metro Vancouver, the region's water and wastewater utility. The project cost roughly $31 million to construct and was financed by the city through a combination of city funds and government loans.

The NEU distributes heat to 27 buildings and over 4,000 residential suites within the South East False Creek development, meeting about 70% of the total heating demand for the community. The NEU contains a 3.2 MW wastewater heat recovery unit and 16 MW natural gas peaking boilers for backup. The system uses both heat pumps and heat exchangers to recover thermal energy from untreated wastewater and transfer it to distribution water. This heated water is then sent to buildings, each of which contains an energy transfer station that transfers the thermal energy from the heated water to the building's mechanical system, which then distributes heat and hot water to building occupants. The energy transfer stations also meter the building’s energy production and consumption for billing.