A Field Guide to Solar Hot Water Systems for Multifamily Buildings

BY FRAN HERETH | Kango Development

Introduction

This article provides practical information on installing Solar Hot Water (SHW) systems in multifamily buildings, including:

- An overview of system types and features
- Descriptions of financing options
- Case studies and lessons learned
- Checklists for feasibility, maintenance, and installation

This guide is designed to help facility managers, property managers, construction managers, operations and maintenance staff, and asset managers make more informed decisions to prevent SHW projects from being unduly solely vendor-driven.

Pros and Cons of Solar Domestic Hot Water (DHW)

Pros:

- Rebate programs are available for a limited time in some states to help reduce the system cost. The California Solar Initiative Tier 1 rebates will pay for 30% to 40% of the system in participating utility territories.
- Solar DHW is highly efficient. Only about 12% to 18% of the solar radiation that strikes a Photovoltaic (PV) panel is converted to electricity while the rest ends up as wasted heat.
- Solar DHW provides three times the energy per square foot as PV.
- PV requires almost six times as much area to produce the equivalent power.

Cons:

- Low natural gas prices can make it difficult for Solar DHW to pencil out, especially if the property is receiving subsidized utility rates.
- Solar PV overproduction can be exported to the grid, while excess thermal heat that exceeds water storage tank capacity is wasted.
- Monitoring the performance of Solar DHW is more complicated than Solar PV. It requires a more complicated, costly monitoring system.

Solar DHW Components

The key components of any solar thermal system include:

1. A solar collector, most frequently panels
2. Heat transfer liquid, usually water or a glycol mixture
3. Water storage tank system
4. Pumps
5. Heat exchanger that shifts heat from the solar collector/heat transfer liquid to the potable water in the tank
6. Expansion tanks and safety devices
7. Controller (with temperature sensors in collector and in storage tank) that regulates the pumps on and off

While the Solar DHW preheats water, it must be paired with a conventional water heater, which covers periods of high demand and increases the preheated water temperature to the delivery temperature as needed.

Solar DHW Types of Systems

Types of systems can be broken down by following classifications:

- Direct vs. indirect
- Active vs. passive
- Low-, medium-, and high-temperature systems
- Freeze protection
- Overheat protection
  - Pressure
  - Drainback
  - Steamback
  - Dissipation
- Collector types
  - Integral
  - Batch
  - Flat plate
  - Evacuated tube
    - Direct-flow
    - Heat-pipe
    - Annealed glass plate
    - Coke glass plate

Direct vs. Indirect

Direct (open) vs. indirect (closed). Direct systems are simple, inexpensive, and ideal for warmer climates. Potable water flows through a collector, directly absorbs the sun's heat, and then returns to the storage tank.

Indirect (closed). Instead of running the water directly through the heat collector on the roof, an indirect system passes a heat-transfer fluid, e.g., propylene glycol (antifreeze), through the panels. This fluid picks up the heat, which is transferred to the potable water through a heat exchanger located inside or outside the storage tank. Indirect systems work in all but the most extremely cold climates, but they require more maintenance.

Active vs. Passive

In a passive system, the system's water pressure or temperature differences cause heat-transfer fluids to circulate. A passive system does not have pumps or other moving parts. An active system uses

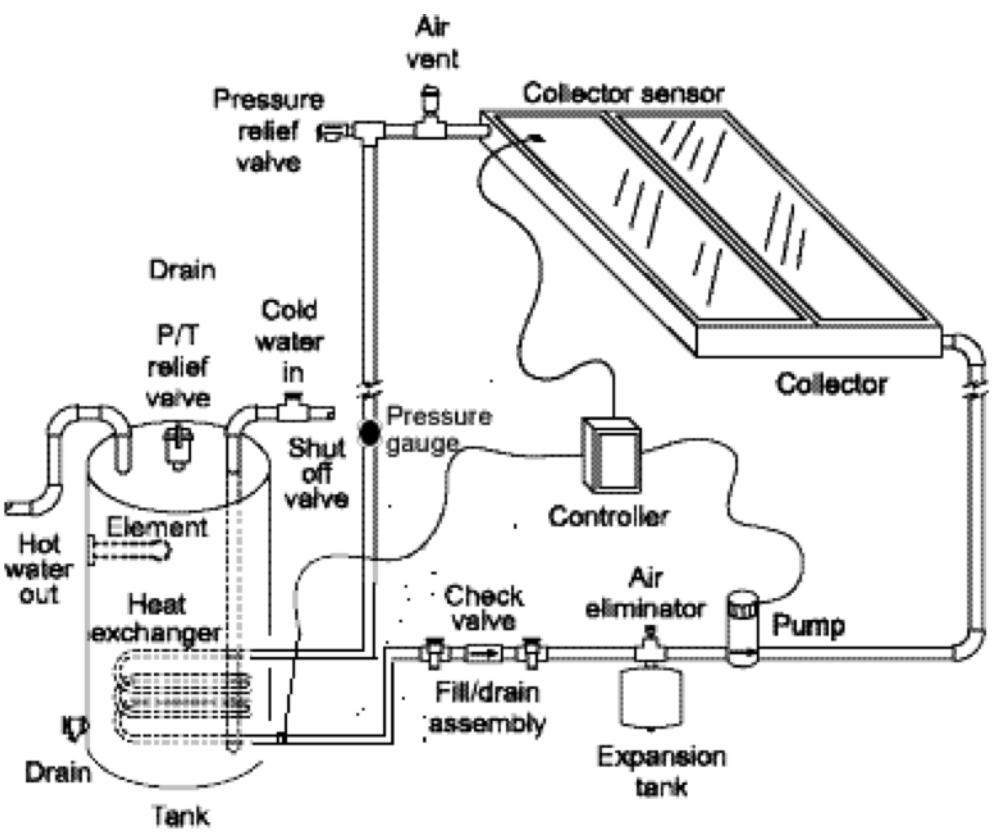
Passive, direct thermosiphon solar water heaters on a rooftop.
Credit: Wikipedia

circulation pumps and controllers to regulate the water temperature. The active system provides more control and creates more efficiency, but it increases the electrical load.

A drainback system is an active, indirect system that typically uses water as the heat-transfer fluid. When the temperature limit is reached at the collector, the pump to the panels shuts off and the fluid drains back into the storage tank to prevent overheating or freezing in the collector.

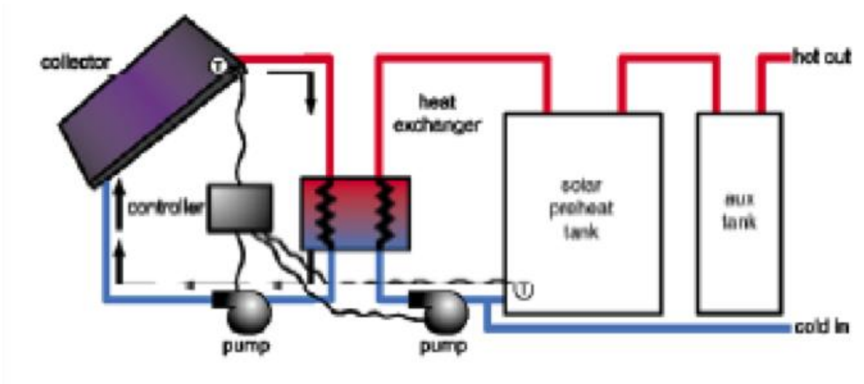
Passive, direct thermosiphon systems have a storage tank above the collector. As the hot water rises into the storage tank, cooler water settles back down into the collector. The tank and collector can be detached, but they are most often a single unit. This is the most common system throughout the world.

The active, direct system below has a loop containing a glycol mixture circulation from the panels into a storage tank, where it will shed the heat and then return to the panels.



Active, indirect system with internal *heat exchanger*.
Credit: Florida Solar Energy Center (FSEC)

The active, indirect system shown below has two circulating heat transfer loops. One loop contains antifreeze, i.e., glycol mixture, and circulates through the solar collectors. A heat exchanger transfers the heat from the glycol mixture to the potable water via an external plate heat exchanger.



Active, indirect system with external plate heat exchanger.

Credit: U.S. Army Central Solar Hot Water Systems Design Guide.

Large SHW systems must use such a two-loop system with an external heat exchanger to ensure that the potable water is not contaminated by chemicals and that the components are not corroded by high-mineral-content water.

Freeze Protection

Freeze protection for direct systems can be achieved by manually draining the water from the collectors based on weather predictions. Other direct systems use freeze-tolerant collectors made with flexible polymers such as silicone rubber, which allow frozen water to expand while still in the collectors.

Indirect systems that circulate a heat-exchange fluid such as glycol are generally immune to below-freezing temperatures.

Overheat Protection

Solar DHW systems can overheat in the summer, causing the heat transfer loop pumps to shut down to protect the pumps, tanks, and other components of the system. In this system shutdown, known as stagnation, there is no flow through the system but the panels still absorb the sun's thermal energy.

There are four primary methods to protect the system from stagnation:

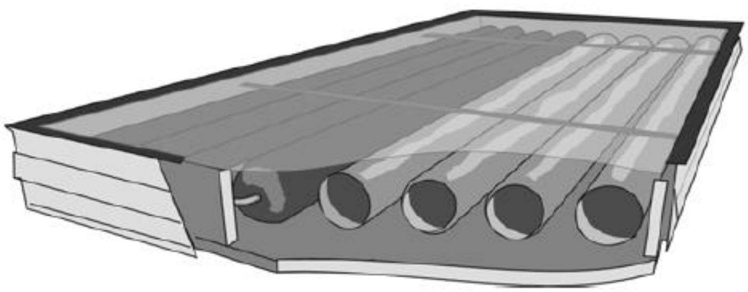
> **1. Pressure**. The system is pressurized to increase the boiling temperature of the heat-exchange fluid. This increased pressurization triggers added costs to the overall system, including a higher grade of glycol, upgraded system components, a pressurized storage tank, and a secondary pump.
>
> **2. Drainback**. This solution requires sufficient tilt to the panels to allow the water in the collectors to drain to an insulated tank. The drainback method is usually limited to panel water circulation systems with parallel risers and perpendicular piping rather than serpentine piping.

3. Steamback. In this method, the water in the glycol solution boils into steam and pushes the liquid glycol out of the collector's back into a tank. This prevents glycol degradation; however, the saturated steam stresses other system components by overheating.

4. Heat dissipation. Added controllers can circulate fluid through the collectors at night or early in the morning to dissipate the surplus heat. This increases hardware and operations costs.

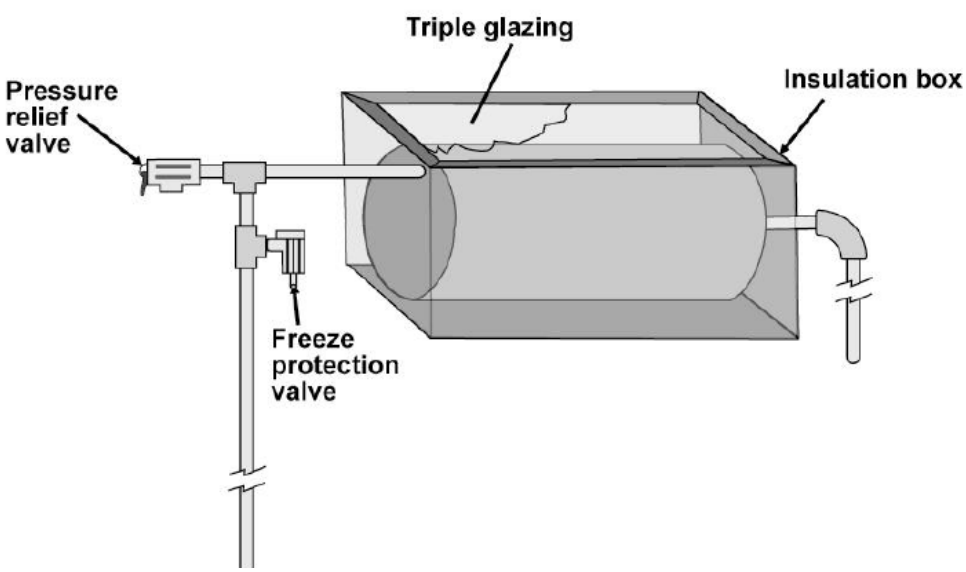
Types of Collectors

Integral Collector Storage (ICS), also called a batch system, is the most basic solar thermal system. It consists of a tank or a series of pipes inside a glass-covered, black, insulated box. The pipes absorb the heat and act as the storage tank.



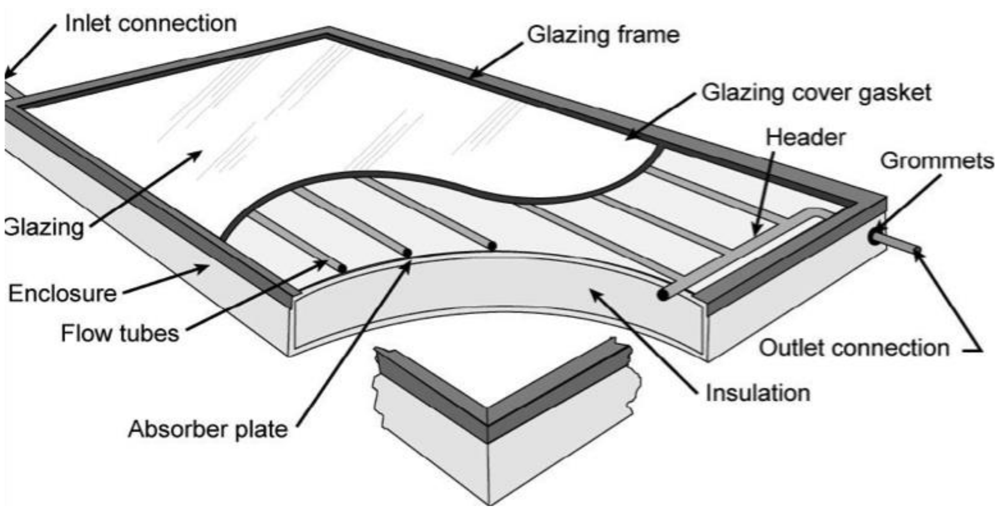
ICS System
Credit: "Solar Domestic Hot Water Heating Systems: Design Installation and Maintenance" by Christopher A. Homola

A **batch system** comprises one or several storage tanks lined with black material in an enclosure with glazing across the top and insulation around the sides. The tank absorbs the heat from the sun and transfers it to the water it contains.



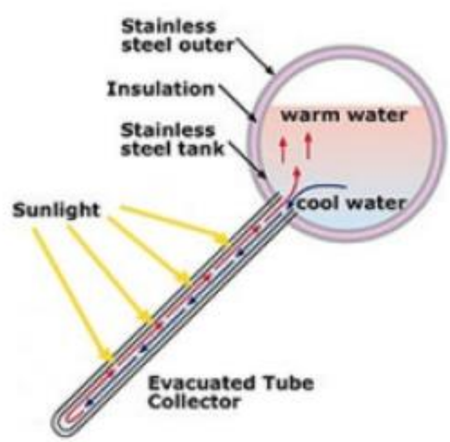
Batch System
Credit: "Solar Domestic Hot Water Heating Systems: Design Installation and Maintenance" by Christopher A. Homola

Flat plate collectors are the most common type in the United States. The four-inch-thick panels are typically four-by-eight feet, covered in tempered glass. Glazed systems are more efficient and have a layer of low-iron glass, which lets the light through and traps the heat. Unglazed systems are used to generate lower-temperature water for pools. Low-iron, tempered glass is usually used on flat plate collector panels, which are resistant even to strong hail. The pipes inside the collectors can be configured in a serpentine or jail-bar pattern. Panels with serpentine piping cannot be used in drainback systems.



Flat Plate Collectors
Credit: "Solar Domestic Hot Water Heating Systems; Design Installation and Maintenance" by Christopher A. Homola

Evacuated tube collectors (ETCs) work well in colder, cloudier locations. The tubes in the collectors are insulated inside a vacuum and contain an aluminum or copper fin that heats up in the sunlight and transfers the heat to the water or glycol inside the pipes. The vacuum reduces heat loss. Usually annealed glass, which is not resistant to strong hail barrage, covers the ETCs. ETCs made of "coke glass" which has a signature green tint, are resistant to breakage from hail but are less efficient.



Evacuated tube collectors
Credit: "Solar Domestic Hot Water Heating Systems: Design Installation and Maintenance" by Christopher A. Homola

Low-, Medium-, and High-temperature Systems

Low-temperature systems generate water less than 110° F and are used mostly for pool heating.

Medium-temperature systems produce water at 110–180° F and use either glazed flat plate or evacuated tube collectors.

High-temperature systems are indirect and use evacuated tube and concentrating solar collectors to heat water to above 180° for use in generating electricity, hot water, space heating, or powering absorption chillers.

Rating Systems

Solar water heaters can be rated based on three methods:

1. Performance of the collector (SRCC OG-100: RM-1)
2. Performance of the complete water heating system (SRCC OG-300)
3. Solar Fraction—the percentage of a building's hot water requirements that can be met by solar without generating any wasted hot water

Financing/Funding

There are several options to offset the upfront purchase of a SDHW system, including:

Rebates from the utility companies in some states can pay for a significant portion of the cost of a SDHW system. The California Solar Initiative (CSI-Thermal) Program, a solar rebate program for customers of the investor-owned utilities, offers Tier 1 rebates, which will pay 30% to 40% of the cost of a SDHW system. However, the CSI-Thermal Program offers rebates only for indirect active systems, not for passive or direct heating systems.

Federal Energy Tax Credits and Accelerated Depreciation. SDHW systems are eligible for a tax credit of 30% of the cost with no upper limit until December 31, 2013. Additionally, the owner of the panels is also entitled to Accelerated Depreciation-Five Year MACRS. Nonprofit affordable housing owners will have to set up an ownership structure for the system that includes a for-profit entity to take advantage of these financial benefits. The nonprofit can then enter into a lease or an Energy Services Agreement with the system owner. These agreements have an owner buy-out option usually in 7 to 10 years.

Lease structure rents the system to the customer and includes maintenance and repair services. Some leasing companies will guarantee the minimum production of the system and compensate the property owner for any shortfall. Leases generally range from 7 to 15 years with a buy-out option predefined in the contract.

Energy Services Agreement, offered by companies such as Skyline and Metrus, provide an alternative to using cash reserves or taking on additional debt. In an ESA, the property owner contracts for energy services paid through savings. ESAs overcome barriers to implementation of water system retrofits because they:

- Can be "off balance sheet"

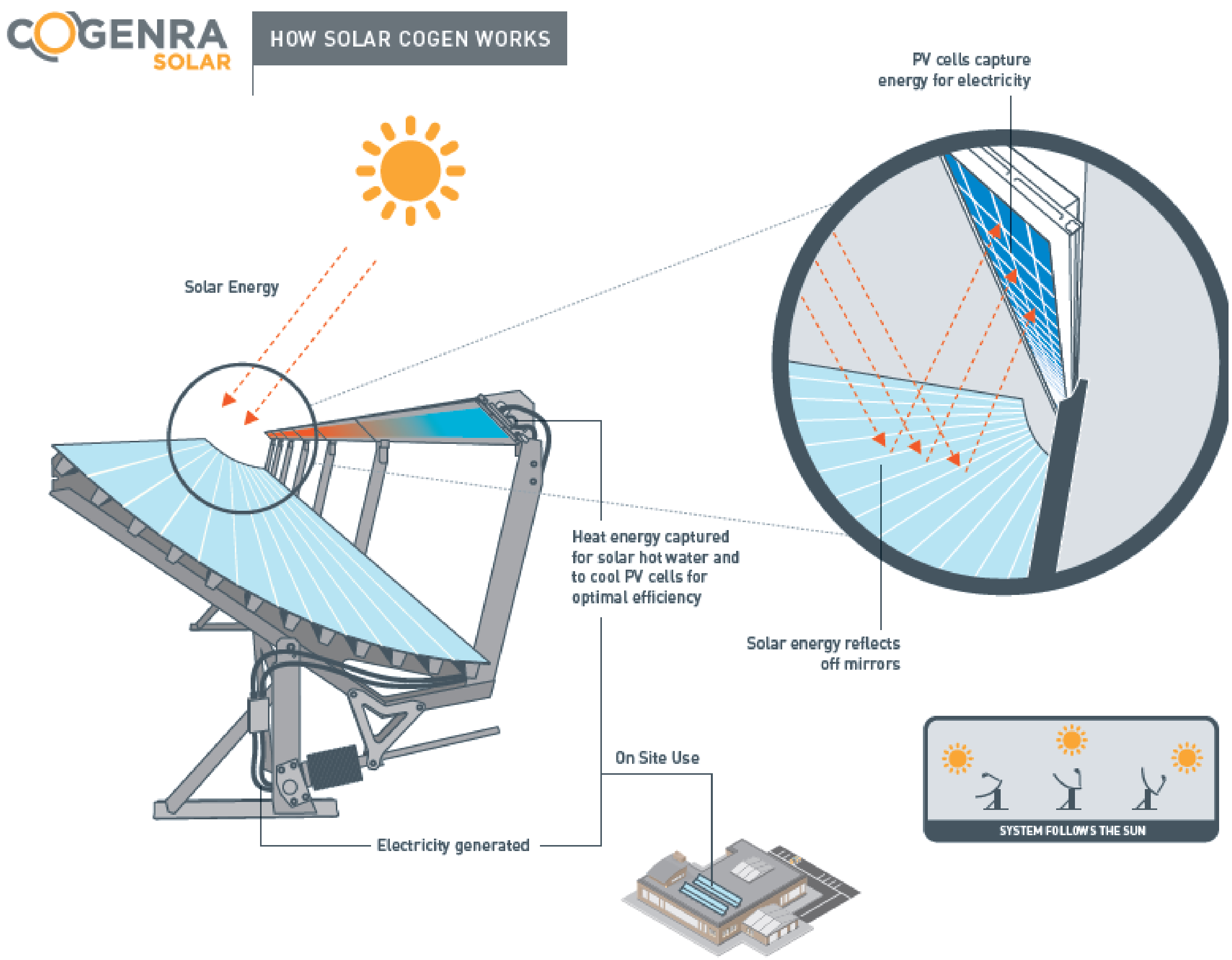
- Take on the risk that savings will be sufficient to pay for upfront costs and may offer savings performance guarantees or payments based on therms or kwh saved
- Provide financing
- Can be transferred to new owners
- Buffer against rising energy costs
- Provide monitoring and maintenance

Owner payments can be structured as 1) two payments, a reduced payment to the utility company and a separate payment to the ESA based on actual energy savings; or 2) one payment made to the ESA, which in turn is responsible for paying utility costs and financing on the retrofit measures.

Skyline Innovations Energy Services Agreement Model
Credit: Skyline Innovation

New Technology

The Cogenera system combines Solar PV and Solar DHW. Ordinary PV systems convert only 15% to 20% of the sun's energy into electricity with the remaining heat dissipating into the air. The Cogenera system captures this wasted heat and uses it to heat water. It uses mirrors to concentrate the sun's rays into a small-form solar panel rather than a flat plate collector. Concentration with mirrors saves money because fewer Solar PV cells are required and SHW thermal losses are reduced. The Cogenera system can also automatically track the sun's path throughout the day or it can adjust to face away from the sun to prevent overheating and stagnation.



Cogenera combination Solar DHW + PV System

Credit: Cogenera Solar, Technical Overview White Paper, "Solar Cogeneration in Context"

Practical Case Studies

The following two practical case studies describe Solar DHW installations at contrasting properties; an urban high-rise SRO and a suburban garden-style apartment complex. Each of the studies walks through some of the issues that arose when the Solar DHW was integrated into the existing DHW system. Hopefully these experiences will alert multifamily property owners to potential issues with Solar DHW retrofits and encourage a robust dialogue between designers, vendors, contractors, operations and maintenance staff, resident services, and property management during pre-construction.

Practical Case Study 1: San Francisco urban high-rise SRO

Building description:	Seven-story 1919 masonry building, 177 SRO units
(E) DHW plant:	660 MBH, natural gas-fired boiler with three 119-gallon storage tanks and a single in-line fractional horsepower recirculating pump
Solar DHW system:	40-panel indirect (closed) loop glycol system with 1,000-gallon storage tank in the basement

Problem #1: Property owner received a call on Thanksgiving that there was no hot water the day after new Solar DHW system had been hooked up to the existing DHW system.

Solutions:

1. Three new 119-gallon hot water storage tanks were installed. The old tanks had integral, double-wall heat exchangers that were plugged up with rust and sediment and could not be flushed and cleaned. The encrusted heat exchangers were impeding the heat exchange process.
2. The new storage tanks were re-piped in a reverse return configuration to insure equal draw-down from all three tanks, maximizing capacity and equalizing usage. The original piping configuration was parallel and dead-ended. That configuration resulted in most of the hot water entering the first tank and reduction in flow to the second and third tanks. It also resulted in boiler short-cycling. Elimination of short-cycling now allows the boiler burners to burn at peak, steady-state efficiency, which in turn will increase the boiler’s useful life and save energy.
3. The boiler controls were upgraded.
4. Once steps 1–3 were completed, if problems persisted, the contractor recommended assessing whether or not the return piping needed to be balanced.

Problem #2: Ongoing head pressure issues, which manifested as poor water pressure at the top floors.

Solution

Initially the Solar DHW vendor proposed re-piping the configuration and keeping the existing mixing valve. O&M staff did not agree with that solution and pushed for further analysis. Upon further research, the Solar DHW vendor agreed to install a new mixing valve. There were no further pressure head issues after the larger-diameter mixing valve was installed.

Practical Case Study 2:
Los Angeles suburban two-story garden-style family apartments on 11-acre campus

Building description:	Two-story garden-style apartments with 28 buildings and 274 units
(E) DHW plant:	7 DHW systems serving 3–4 buildings each; 12 total natural gas-fired boilers rated between 264,000 BTUH and 500,000 BTUH with 115-gallon storage tanks
Solar DHW Plant:	Indirect (closed) loop glycol, flat plate collector system with 500-gallon storage tanks

Problem: Residents complained of water temperature fluctuations after on-demand recirculation pumps were integrated into the DHW system at each boiler plant, which included a recently installed Solar DHW system.

Solar DHW systems had been installed at each of the DHW boiler plants. About six months later, on-demand recirculation pumps were installed. The on-demand recirculation pumps have several benefits, including:

1. Reduction in pump run time, resulting in electricity savings
2. Reduction in water heater run time, resulting in gas savings
3. Less wear and tear on DHW pipes and equipment
4. Less wear and tear on the pump; on-demand pumps last two to four times longer

But following the installation of the on-demand pumps, there were complaints in buildings being served by four of the seven boiler plants that there were water temperature fluctuation problems.

Solution

The immediate solution was to place the on-demand pumps on bypass and revert to the constant 24/7 recirculation pumping.

The resulting solution is still being worked out. The team is working under the assumption that the installation of the on-demand recirculation pumps exacerbated pre-existing conditions in the DHW system, including water crossover and unbalanced split loops. When these two common conditions are present, operation of 24/7 recirculation pumps will often mask the symptoms—but at a high cost because of wasted gas and electricity.

The team is working to address these underlying problems of crossover and balancing first. Once these issues are resolved, the team will activate the on-demand recirculation pumps and test their performance.

The following steps are being taken to isolate the problems and implement targeted, cost-effective fixes for the underlying crossover and balancing issues:

1. Work with the manufacturer of the on-demand recirculation pumps in a systematic research study funded by the gas company to systematically isolate issues related to pumps and mixing cartridges.
2. Conduct research to see if there are temperature fluctuations at units served by the other three boiler plants (ones with no expressed complaints) to determine if residents in those units are

just not reporting issues. Research tools include a) conducting resident interviews/surveys and b) taking temperature readings at a random sampling of units served by all boiler plants.

3. Replace mixing cartridges at all shower valves to prevent cold-water crossover, which could be the cause or one of the causes of the problem.

The work is still under way, so there are no definitive results at the time of writing this paper.

Lessons Learned from the Practical Case Studies

Prior to construction start and before design and specs are finalized, conduct meeting/s with the DHW system/boiler service contractor, operations & maintenance staff, the Solar DHW contractor, property management, resident services, the architect, and the mechanical engineer if applicable. Meeting agenda items should include:

- Review the design and operations of the existing systems, including controllers and recirculation pumps.
- Discuss any issues with the performance of the existing system as identified by a DHW system/boiler service contractor, property management, and residents.
- Assess the condition of the entire existing domestic hot water system, including the boiler, storage tanks, heat exchangers, and recirculation pumps by the service contractor and operations and maintenance staff. Make recommendations for any necessary replacements or upgrades.
- Schedule a presentation of the proposed design of the new Solar DHW system by the contractor, including piping configuration, and all components, including panels, storage tanks, expansion tanks, pumps, and mixing valves.
- If there is a mechanical engineer involved in the project, solicit his/her input regarding the proposed Solar DHW system and its interface with existing equipment and infrastructure, e.g., existing supply lines, pumps, etc.
- Establish submittal procedures and schedule team meetings to ensure adequate review and coordination between the mechanical engineer, the boiler service contractor, and the Solar DHW contractor through final design and installation.

Inspirational Case Study

This paper closes with an inspirational case study about the Solar Thermal District Energy System in St. Paul, Minnesota. While the lessons from this case study are not immediately applicable, it does offer a large-scale, real-life example of the potential for Solar DHW. While this type of district solar thermal is common in Europe, the installation described below is the first system of this type in the United States.

The District Energy St. Paul was launched in 1983 and enhanced in 1993 with cooling service, and again in 2003 with the integration of an affiliated combined heat and power (CHP) plant. In 2011 the Solar DHW installation was added.

System Description:	District hot water heating system, servicing more than 191 buildings and 300 single-family homes, totaling more than 31.7 million square feet of building space
Solar DHW system:	144 roof-mounted, high-temperature (200 F) flat plate collectors with glycol mixture; special structural steel “exoskeleton” for mounting collectors, designed to withstand ice, wind, and snow loading; no conventional storage system as excess energy is pumped into the district heating network for other customers

The project was a collaboration between District Energy St. Paul, the City of St. Paul, Saint Paul RiverCentre, and the Department of Energy Solar America Cities program. The collectors are located on the roof of the RiverCentre convention center. The heat generated is used primarily by the convention center for space and water heating. Any excess solar heat is exported to the District Energy’s thermal grid. The excess heat is used to provide space heat, domestic water heating for restaurants, hotels, laundry and dishwashing facilities, as well as heat for snow-melt systems for other customers in the district.

The advantages of integrating a Solar DHW installation into a district energy system include:

- Efficiencies of scale with larger installations
- Optimizes installation efficiency, minimizing waste with varied demand from multiple users
- Reduces costs through centralizing boiler operations

Solar Feasibility Assessment Checklist

Installation	Install water conservation measures, including low-flow showerheads and aerators, before installing Solar DHW.
	Determine the type of domestic hot water system; central system is best.
	Meet with operations and maintenance staff and outside service vendors to get information about design, operations, and performance of the existing DHW system.
	Review work orders related to DHW issues.
	Assess if there is sufficient space on the roof for panels, factoring in building code and fire department requirements.
	Evaluate solar exposure. If it's not a south-facing building, additional panels and/or angled panels will be required.
	Factor in any shading from trees or surrounding buildings. Include future tree growth horizons.
	Inspect the age and condition of the roof. If installation will be done atop: • an existing roofing: Work with a Solar DHW contractor and a roofer for optimal stanchion installation to facilitate re-roofing. • a new roof: Require coordination between the roofer and the Solar DHW installer to ensure a leak-proof installation and to clarify assignment of liability. Obtain a warranty on the installation.
	Evaluate the roofing structure's capacity to withstand the weight of panels/racking and wind uplift. Cost out any required reinforcement.
	Research all building codes, historical designations, fire department regulations that affect design and layout, etc.
	Identify a location and sufficient space for storage tank/s.
	Document all options for a pipe to run from the collectors to the storage tank/s.
	Assess the mineral content in water supply; hard water increases scaling.

Finance	Obtain proposals from three contractors that include system size, cost, and projected annual savings.
	Compare projected savings to actual gas bills to see if they are realistic.
	Factor in an annual escalator for utility costs.
	Research local, state, and federal financing and funding sources for Solar DHW at www.dsireusa.org.
	Find out when, how, and to whom rebates are distributed. Will the Solar DHW contractor carry the rebates or will there be a need for bridge funding?
	Identify all performance and specification requirements from funders, including solar fraction and ratings for panels or other components.
	Calculate all operation and maintenance costs, including panel cleaning, and factor these into the financial payback analysis.

Solar DHW Maintenance Checklist

Corrosion	Sometimes heat-transfer liquid can be the medium for corrosion between two dissimilar metals.
Scaling	Check for scaling in the collector, piping, and the heat exchanger. Scale buildup is caused by the high mineral content in "hard" domestic water.
Shading	Trim back trees or bushes that are overgrown.
Dust and dirt	Clean panels periodically.
Glazing and seals	Check for cracks and broken seals.
Piping	Look for any fluid leaks at pipes and joints.
Wiring	Tighten and secure all loose wiring.
Insulation	Inspect for any damage to insulation on pipes and wiring.
Roof penetrations	Make sure flashing and sealant around roof penetrations are in good condition.
Support structures	Check that all nuts and bolts are tightened.
Pressure relief valve	Inspect to make sure it is not stuck in an open or closed position.
Pumps	• Confirm pumps are operating as designed. • Other required maintenance, e.g., lubrication.
Heat transfer fluids	Replace antifreeze solutions (i.e., water-glycol mixture) every three to five years. If hard water is circulated in the collectors, you may need to add anti-scalding or mild acidic solution periodically.
Storage tanks	Check that tanks are securely anchored with no cracks, leaks, or rust.
Glycol	• Test for freeze protection and pH annually or after a prolonged no-flow situation. • Pressure test per specifications.
Monitoring Software	Set up a monitoring system and schedule regular monthly inspections so that system issues or failure are quickly identified and fixed. Because the existing DHW system acts as a backup system, a problem can go undetected.
Owners Manual	Manual should contain: • Date of installation • Installation and service contractor contact information • System diagram and written description • Instructions for freeze protection • Monthly and annual maintenance information • Component warranty information • Glycol information (manufacturer, date of fill, concentration, volume, refractometer reading, etc.)

SOURCES: *Solar Domestic Hot Water Heating Systems: Design Installation and Maintenance* by Christopher A. Homola and www.energy.gov.

SOLAR DHW

Summary of System Types

	INDIRECT	DIRECT		HYBRID SOLAR DHW & PV
	Pressurized Steamback Glycol System	**Drainback**	**Thermosiphon**	**Cogenera**
Description	Pumps circulate an antifreeze heat-transfer fluid through the collectors. The antifreeze transfers heat to the domestic water via a heat exchanger. In the event of overheating, water in antifreeze solution boils into steam and pushes liquid glycol out of collectors back into the tank.	Systems use a controller to drain the collector loop automatically. Sensors on the collector and storage tank signal to controller when to: 1) turn off the circulation pump; 2) drain the collector piping; and 3) restart the pump.	The collector is installed below a storage tank. Warm water rises into the storage tank and cold water sinks.	Produces Solar PV electricity and Solar DHW.
Advantages	• Antifreeze fluid provides freeze protection • Collector piping not in direct contact with water, so less corrosion or scaling	• More efficient heat transfer using water; some utility programs reward these systems with a higher rebate • Simpler system • Long-term durability because there is less stagnation and pressure on system	• No need for circulating pump and controller. • No heat exchanger; more efficient heat transfer to storage • Simpler and less costly system	• Produces both hot water and electricity, extracting more energy per SF • Sun-tracking system can control optimal exposure • Eligible for both Solar DHW and Solar PV rebates • Concentration with mirrors saves money; fewer Solar PV Cells required

Disadvantages	• Heat exchanger reduces efficiency • Antifreeze heat exchange fluids degrade over time and should be replaced every three to five years • More complicated system results in additional costs • Most designs require added pumping costs • Saturated steam stresses other components	• Freeze protection temperature sensors must be located properly and checked periodically • Panels require .25-inch/foot tilt angle to ensure complete drainage • Hard water leads to corrosion and scaling; water treatment is a possible solution	• Limited in how much water volume it can handle • Collector must be installed below the storage tank; potential freezing issues, since water is stored on roof • Suitable only for individual buildings or a single heating demand, not for central systems serving several buildings • Thermosiphon systems, or any system that directly heats domestic water, are not eligible for California Solar Initiative Solar Thermal rebates	• Heavier weight; requires roof with more load-bearing capacity • Higher upfront costs • Sun-tracking system results in additional moving parts
Best Application	• Climates with freezing temperatures. • Piping is protected from hard water damage.	• Can be used in freezing climates if plumbed properly • May need to treat water that is too “hard” to avoid corrosion and scaling. • Best to have a simple and symmetrical panel layout to facilitate a balanced flow across panel array • Buildings of four or fewer stories	• Systems with individual water heaters • Flat roofs	• Ground installation unless roof can bear weight of heavy equipment

Common Problems	• Glycol has degraded lost freeze protection and pH • Expansion tank is too small	• Incorrect piping can cause freezing problems		

Resources

Articles

"Best Practices Manual for Solar How Water Systems"
http://arthaonline.com/Word%20Files/12.11BPmanual.pdf

"California Solar Initiative—Thermal Program Installation Inspection Checklist: Multifamily & Commercial Projects"
https://www.sce.com/NR/rdonlyres/C25CB305-E014-401E-A520-8D7E2D0E403D/0/CSI_InspectionProtocol_081707.pdf

"California Solar Initiative—Thermal Program Installation Inspection Checklist: Failure Items"
http://www.gosolarcalifornia.ca.gov/documents/CSI_Supporting_info/CSI_Thermal_Inspection_Checklist_Combined_SF_and_MF_Commercial.pdf

"Solar DHW Checklist from the US Department of Energy: Energy Efficiency and Renewable Energy"
http://www.eere.energy.gov

Software

Feasibility Analysis

- **Federal Renewable Energy Screening Assistant (FRESA)** Free Windows-based software tool that evaluates the economic feasibility of renewable technologies including Solar DHW, Solar PV, and wind
  https://www3.eere.energy.gov/femp/fresa/

- **Retscreen** A free, detailed screening tool developed by Natural Resources Canada
  http://www.retscreen.net/

Performance Analysis

- **FCHART** from the University of Wisconsin: http://www.fchart.com

- **TRNYS** from the University of Wisconsin: http://sel.me.wisc.edu/trnsys/

- Solar Ratings: http://www.solar-rating.org/ratings/ratings.htm

Funding

- http://www.dsireusa.org