The Butler Sun Solutions, Inc. Solar PV Wand™ water heating system is a state-of-the-art solar water heating system that augments your existing water heater. This system can save over 2,400 pounds of CO₂ production per year compared to a conventional water heater, making hot water from clean sunlight. It is like having an oil well on your roof producing 2.5 barrels of oil per year (but without the pollution from burning the oil!).

The Solar PV Wand™ system has been designed for easy installation by either a professional contractor or a do-it-yourselfer. This guide is designed to lead you through the installation of the system in a simplified manner. It includes a pictorial summary of the installation steps, followed by explanations of each step. We hope you enjoy bathing and washing with hot water provided by the sun!

Dr. Barry Butler, CEO of Butler Sun Solutions, Inc.
Contents

PICTORIAL SUMMARY OF INSTALLATION STEPS ............................................................. 3
STEP 1. FAMILIARIZE AND PLAN .................................................................................. 5
STEP 2. SOLAR PANEL MOUNTING ............................................................................... 7
STEP 3. POWER WIRE ROUTING, CONDUIT, & ROOF PENETRATION ......................... 8
STEP 4. CONNECT CONDUIT FROM PV ARRAY BOX TO OVER-TEMPERATURE BOX ............................................................................................................................. 8
STEP 5. INSTALL PV WAND™ INTO HOT WATER TANK .............................................. 9
STEP 6. INSTALL MIXING VALVE (IF REQUIRED BY LOCAL CODE) ......................... 13
STEP 7. CONNECT POWER CABLE & TANK-TOP OVER-SENSOR ............................ 15
STEP 8. CONNECT POWER, VERIFY OPERATION & CLEAN UP ................................. 16
APPENDIX 1. TOOLS OF THE TRADE .......................................................................... 17
PICTORIAL SUMMARY OF INSTALLATION STEPS

1. FAMILIARIZE YOURSELF WITH THE SOLAR PV WAND™ PARTS & PLAN YOUR SOLAR WATER HEATER INSTALLATION

2. SOLAR PANEL MOUNTS WITH FLASHING FOR NO RAIN LEAKS

3. ROUTING POWER CABLE, CONDUIT & ROOF PENETRATION

4. CONNECT CONDUIT FROM PV ARRAY BOX TO OVER-THERMOPERATURE BOX

5. INSTALL PV WAND™ IN TANK: SEE INSTRUCTIONS FOR ANODE UNDER PORT TANKS

6. INSTALL MIXING VALVE (IF CODE REQUIRES)
Over-Temperature Protection

7. CONNECT POWER CABLE & INSTALL TANK TOP SENSOR

8. CLEAN UP ALL WORK AREAS & VERIFY OPERATION

Pictorial Installation Guide: PV Wand™ Hybrid Water Heating System
STEP 1. FAMILIARIZE AND PLAN

Step 1A: Open the boxes, lay out all of the parts, and be sure that you can identify them all. Look over the packing list to verify everything is included. The actual appearance of the parts may be different from the diagram below, but will have the same functionality.

Step 1B: Determine where you intend to put the solar collectors on the roof. The ideal orientation of the solar panels for maximum annual energy delivery is tilted at your latitude angle towards true South, with no shading of the collectors. Also, plan how you will route the power wires from the collectors to the top of the existing hot water tank. The power wires (in conduit) end near the PV panels at the PV array NEMA Disconnect Box. This NEMA box has connections to the PV panels and should be placed near the array where the pigtail wires will reach all of the panels. It should also be located where the cover can be raised and the disconnect pullout can be reached to shut off the PV array. The polarized connectors provided should be used to connect each panel. The roof cables should be protected from direct sunlight. Plan for the components needed for this conduit at this time. Finally, plan where the over-temperature protection NEMA Disconnect Box will be mounted near the water heater tank, allowing for ease of access to the disconnect pullout, which disconnects the Wand from the PV array.

The electrical schematic showing all of the parts is shown below. The yellow shaded area is the PV panel array which we provide or has been purchased separately. The green shaded area is what is normally provided with the kit. The 2-#6 THHN and 1#18 THHN wire and conduit to house the wire are not provided with the standard kit and must be purchased at a local hardware store.

The parts list is as follows:
## Pictorial Installation Guide: PV Wand™ Hybrid Water Heating System

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Part Name</th>
<th>Number Supplied</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 X PV-250W</td>
<td>PV Panels With Mounting Hardware</td>
<td>6</td>
<td>PV Panels 250W with Pigtail Connectors</td>
</tr>
<tr>
<td>#278</td>
<td>PV Array Disconnect Box With 15W PV Panel</td>
<td>1</td>
<td>NEMA 3R Enclosure: Rainproof, 60A, 220V, Disconnect Panel Box &amp; Electrical Pigtails</td>
</tr>
<tr>
<td>#279</td>
<td>Over-Temperature Protection Box for PV Wand™</td>
<td>1</td>
<td>NEMA 3R Enclosure: Rainproof, 60A, 220V, Disconnect Panel Box, With Temperature Sensor, Pigtail to Wand Connector &amp; Controls</td>
</tr>
<tr>
<td>#277</td>
<td>PV Wand™</td>
<td>1</td>
<td>1,500 W (50A and 30VDC) Immersion Resistance heater with 50A Connector</td>
</tr>
</tbody>
</table>

**PV Wand™ Hybrid Water Heating System Schematic**
STEP 2. SOLAR PANEL MOUNTING

2. SOLAR PANEL MOUNTS
WITH FLASHING FOR NO RAIN LEAKS

**Step 2A:** Determine how the panels will be mounted, based on the type of roof you have: flat or pitched, composition shingle, wood shakes, concrete tile, or clay tile. For flat roofs you need a tilt kit. You should follow local codes for attaching the solar panels to the roof.

**Step 2B:** If you did not get a complete kit with PV mounting rails, you can get them from a number of manufacturers. Typical mounting systems for flat roof tilt mount and flush roof mounting are shown below. If you are including the PV panels for this solar hot water system with a grid-tied PV power system, you can just extend the existing racks to include the PV panels for this system.

Unirac System

The IronRidge PV mounting rail

The racking system must support the solar panels to meet Housing and Urban Development Guidelines, which include:
• **Gravity Loads** of 4 psf
• **Wind Loads** of 25 psf from 125mph wind
• **Snow Loads** of 4 psf from deep snow
• **Structural Ties** to roof to prevent wind lifting up the panels, with corrosion-resistant bolts and screws
• **Lightning Grounding** for both the rack and panels

**Step 2C:** As you install each PV panel, connect it to the power cable connectors. The connectors are polarized so they cannot be connected backwards. Ideally, cables and connectors should be tie-wrapped to the mounting frames to secure them and keep them out of the sun and off the roof surface. The circuit diagram for the system is shown below.

**STEP 3. POWER WIRE ROUTING, CONDUIT, & ROOF PENETRATION**

![Diagram of power wire routing and conduit](image)

**Step 2A:** The power wire conduit is often routed through an attic or crawl space. Typically, the conduit penetrates through the roof below the solar panels. In some cases it is possible to avoid a roof penetration by routing it around the eaves. If you must make a roof penetration, doing it properly will save costs in repairs later. Flashing found at your local building supply store will most likely meet local roofing codes. Commercial “Roof Jack” flashing is designed to prevent rain water from entering the house and vermin from using the penetration as a pathway. Make sure that the flashing is fitted and sealed to the roof properly with roof tar or other proper sealant.

**STEP 4. CONNECT CONDUIT FROM PV ARRAY BOX TO OVER-TEMPERATURE BOX**
Before any wiring is done, be sure that the disconnect pullouts are removed from both NEMA boxes. That way all wire connections will be isolated from the power source. Route the power wires 2-#6 THHN and 1-#18 THHN in conduit from the PV array disconnect box to the over-temperature protection box near the top of the water tank, installing the THHN wires in conduit to meet the NEC (National Electric Code). At the water tank, leave the 50A 30VDC connector disconnected at this time.

**STEP 5. INSTALL PV WAND™ INTO HOT WATER TANK**

**Step 5A:** The ideal way to install the PV Wand™ is into an unused port on the top of the hot water tank. On tanks with such an extra port, simply remove the existing plug and install the PV
If no extra port is available, you will have to see if the Wand will fit in the cold water outlet port.

To determine if there is a sacrificial anode on the hot water outlet, follow these steps:

1. Remove the flexible pipe from the hot water outlet to the house
2. Look down into the hot water nipple on the tank (you may have to remove rubber heat trap parts)
3. Determine if the anode is below the nipple by probing with a wire or screwdriver as shown in the photo to the left
4. If you find that an anode is present, do not remove the nipple, as you may damage it. Just reconnect it

If you find the anode under the hot water outlet, you will need to put the PV Wand™ into the cold water inlet port. Proceed to Step 5B to verify that the sacrificial anode is good, then to Step 5E for cold water inlet port insertion instructions.

If you do not find any obstructions, clean the threads with a wire brush or a ¾” NPT (National Pipe Thread) tap. Once the threads are cleaned out you may be ready to put the PV Wand™ in place after you complete the Step 5B.

**Step 5B:** Check the sacrificial anode in the tank. If the tank is only a few years old this may not be necessary. If the tank is more than five years old, it is a must. Replacing a bad anode will add another five to seven years to your tank’s life. A good LED flashlight will allow you to see the anode condition within the tank. If you have one, it is handy to use an inspection scope such as the one shown in the following figure. The pictures to the left in the picture below show anodes in various states of usage. The one on the far left is new, the one in the center is well used but still providing protection to the tank, and the one on the right is down to just the central wire. If the anode is showing the central wire, it should be replaced. If it is down to just the wire, you might consider replacing the tank since the anode has stopped providing any protection and the tank may be compromised.
Step 5C: If you do not have enough head room over the tank to insert the PV Wand™, you have a couple of choices. One is to drain about half the water out of the tank, remove the earthquake straps and other connections and tilt the tank over to insert the PV Wand™. If yours is a gas-fired tank you can sometimes slide the PV Wand™ up the flue and then slide it down into the tank. Finally, if the ceiling surface is the only obstacle, you can drill a small hole in the ceiling, and slide the PV Wand™ up through the hole and then down into the tank. If the power conduit will be routed through the ceiling, you can use the same hole for the power conduit; otherwise, you can just patch the hole after installation of the Wand.

Step 5D: If there is an obstruction below the hot water outlet fitting, a round file can be used to remove some material from the bottom thread of the tank fitting. In a few water heaters there is a plate below the outlet opening that must be drilled out with a 15/16” drill or filed out with a round file or Dremel tool to accommodate the PV Wand™. Instructions on how to do this are provided in the Step 5 Figure. You can use a magnet to catch the filings, but if they fall to the bottom of the tank they will not hurt anything. When the PV Wand™ fits through, screw it in and tighten it into place.

Step 5E: If a sacrificial anode is attached to the hot water outlet, some additional plumbing may be needed. The anode is absolutely necessary to protect the steel in the glass lined tank from corroding. Therefore, first reconnect the hot water outlet nipple and anode (if it is still good) in the tank to the house hot water or mixing valve. If the tank has no extra top port, you must insert the PV Wand™ into the cold water inlet port. There will be a plate below the fitting to hold the plastic DIP tube that takes cold water to the bottom of the tank. Remove the DIP tube. Follow the procedure in the Step 5 Figure to get the PV Wand™ into the tank. Finally, plumb the cold water inlet into the bottom of the tank, using a Tee Adapter provided with the PV Wand™ where the tank drain valve is installed, as shown in the following figures.
Pictorial Installation Guide: PV Wand™ Hybrid Water Heating System

STEPS:

1. Remove brass tee and adapter from PV Wand™

2. Attach a garden hose to the drain and drain the tank, being careful not to be scalded by the hot water.

3. Remove drain valve & insert brass nipple & Tee Adapter removed from PV Wand™

4. Reroute cold water inlet from top of tank to drain valve Tee Adapter

5. Remove cold water inlet down inlet pipe (DIP) & discard

6. File out the cold water inlet DIP tube retainer

7. Add Teflon™ tape and screw the PV Wand™ into the cold water outlet port

8. Attach the mixing valve (if required by local Code) at the hot water outlet, either below it or with a heat trapping loop

9. Review diagram at left to be sure that you have all of the connections correct.
STEP 6. INSTALL MIXING VALVE (IF REQUIRED BY LOCAL CODE)

Mixing valves are used in solar hot water systems to limit the temperature of the hot water delivered from the system to the house. Water temperatures in solar storage tanks can reach 180°F (82°C) or more, but temperatures above 120°F (50°C) can cause scalding in sinks, showers or baths. The mixing valve senses the temperature of hot water being drawn from the tank and automatically mixes in cold water to reduce the temperature delivered to the house to a preset value below 120°F (50°C).

Mixing valves are not required in all jurisdictions; check your local building code to see if a mixing valve is required in your area. Also, be sure that the mixing valve you are using meets your local code requirements. You may not need mixing valves in newer homes that have shower valves with built-in scald control features.

The mixing valve is not a part of the standard PV Wand™ Kit, since mixing valves are not required in all jurisdictions. The standard kit does include a tank top temperature sensor and thermostat that turns the heater off if the tank top temperature gets to about 150°F. This is the same type of system used on conventional electric water heaters to prevent scalding water from reaching a faucet in the home.

For customers who need or want a mixing valve, the Butler Sun Solutions, Inc. (BSSI) mixing valve installation kit contains all the parts you need to install the mixing valve with its connections to the house and to your solar hot water tank. The kit is designed to simplify the installation and to minimize problems of heat losses, maintenance, and leakage from the mixing valve.

Mixing Valve Installation Kit
The mixing valve installation kit consists of the following parts (see figure to right):
• Mixing valve assembly, with the mixing valve and pre-attached soldered fittings
• One male ¾” pipe adapter in case the cold water supply plumbing to the hot water tank does not have a male pipe fitting coming out of the wall
• Three flex lines, two short and one long

Mixing Valve Installation Instructions

Refer to the Step 6 Figure above to see how the various parts fit together in both single-tank installations and two-tank installations. Note the isolation valves that are added in the two-tank installation that allow the solar tank to be bypassed if necessary without disconnecting any plumbing.

The mixing valve attaches to the cold and hot water lines leading to the house, and to the cold and hot water ports of the hot water tank. Step-by-step installation instructions follow:

1. Turn off the cold water supply to the hot water tank. If there is no valve at the tank for this purpose, you will need to turn off the house cold water supply, and this would be a good time to install a cold water valve at the tank. If the cold water supply does not have a ¾” male pipe fitting, solder the supplied fitting onto the end of the pipe.

2. Disconnect the existing hot water pipe between the tank and the wall.

3. Remove the open half of the ¾” copper union from the mixing valve, and solder it to the hot water pipe going to the house.

4. Attach the mixing valve assembly to the union and tighten by hand. Adjust the position so the mixing valve adjustment knob is easily reached and the dial can be seen.

5. Attach one of the flex lines from the cold water supply fitting (Step 1) to the mixing valve assembly Tee. Note that the flex lines have rubber seals and therefore do not use Teflon™ tape on their threads.

6. Attach the other flex line from the mixing valve assembly Tee to the cold water inlet of the hot water tank.

7. Apply Teflon™ tape to the bottom threads and install the PV Wand™ into the hot water outlet of the hot water tank, if it is not already in place.

8. Attach the hot water outlet flex from the hot water tank outlet to mixing valve. This line must arch upwards from the tank to a point 4-6” above the mixing valve before coming back down to the mixing valve. This upward arch provides a heat trap loop that prevents hot water from the tank from rising up to the valve, cooling and leaving deposits inside the mixing
9. Make a final adjustment of the flex hoses to ensure they have smooth curves and are not pinched, and a final adjustment of the mixing valve to orient it for easy access, then tighten all fittings. Don’t forget to tighten the union on the back of the mixing valve!

10. Turn on the cold water and verify all the joints are leak-free. Tighten the flex lines and other joints as needed to eliminate any leaks.

11. When done with the rest of the system installation, verify again that all joints remain leak-free. Then, insulate the hot water line coming from the tank. In California, you are required to insulate the last 1.5 m (5 feet) of the cold water line to the tank to limit heat losses by conduction from that line as well.

12. Adjust the knob on top of the mixing valve to obtain the desired hot water temperature in the house. Note that the adjustment at the mixing valve will take precedence over the set point of the tank, so if you increase the tank set point temperature, the water going to the house may not get hotter unless you also increase the setting of the mixing valve. NOTE: Many homeowners have never had mixing valves and are used to having their water much hotter. Most mixing valves will not deliver water over 120°F. If showers and faucets are a long way from the tank, the customer might blame the solar without realizing that it is really the mixing valve set too low.

**STEP 7. CONNECT POWER CABLE & TANK-TOP OVER-SENSOR**

Step 7A: Select a location on the wall near the hot water tank for the over-temperature protection NEMA disconnect box and mount it securely with self-tapping screws.
**Step 7B:** Route the tank-top temperature sensor wire from the over-temperature protection NEMA disconnect box to the hot water tank. The sensor should be placed on bare metal close to the top of the tank, but not on the PV Wand™. The temperature/pressure relief valve is one easy location to put it. It can also be placed against the tank between the tank and insulation. A screwdriver can be used to create a space between the insulation and the tank wall to place the sensor in, as shown below. After installation, the sensor must be covered with insulation so the sensor does not get cooled by air passing over it.

**STEP 8. CONNECT POWER, VERIFY OPERATION & CLEAN UP**

**Step 8A:** Connect the power cable from the PV Wand™ to over-temperature protection NEMA disconnect box. Next go to the PV array NEMA disconnect box and place the disconnect pullout into place in the ON position. Now go to the over-temperature protection NEMA disconnect box and place its disconnect pullout into place in the ON position.

**Step 7B:** If the sun is out, the panel meter on the over-temperature protection NEMA disconnect box will show the voltage being applied to heat the PV Wand™. If the wiring is correct, the voltage should be between 20 and 30 Volts. The connector is engraved with the correct polarity,
and the voltage should be 30-40VDC when disconnected from the over-temperature protection NEMA disconnect box. If the panel meter does not read properly, the wires may have been mixed up. If any wiring needs to be changed, it is safest to remove both pullout disconnects before changing any wires in the system, and the wires should only be disconnected one at a time and their ends taped or capped when they are loose. Although the voltage level of the system is intentionally below voltages where electrocution is a problem, shorting of the power conductors can cause large sparks.

**Step 7C:** Set the tank high limit temperature. This is an important step. Turn the knob to “Set Tank Limit” you should see the value of 180°F (82°C), the factory preset temperature. You can use a screwdriver to adjust this valve between 120°F (40°C) and 180°F (82°C). Turning the dial to “Tank Temperature” you can read the tank top temperature and watch it rise when the sun is out. If you are away and your tank reaches the set point, the “over limit” light will come on, de-energizing the PV Wand™ heating element until you use some hot water and cool off the tank.

**Step 7D:** Clean up the roof and the area around the water heater tank, making sure all wires are adequately protected from damage and well supported, and assuring that all water lines around the water heater are free of leaks and insulated as necessary.

**APPENDIX 1. TOOLS OF THE TRADE**

The following tools will allow you to collect information on your system operation and will be real time savers if you are installing multiple systems. A digital multimeter (inexpensive ones are available from hardware stores) with a thermocouple readout to measure temperatures will allow you to check system voltages and currents to determine if the PV panel is providing the proper power. The tools on the right in the following photo are the only specialty tools one should need in addition to simple drills and carpentry tools:
SAFETY TOOLS: In addition to the above tools you should have the following safety items:

- Safety Glasses
- Leather work gloves
  - Prevent hand cuts
  - Prevent scalding by hot water
- A safety harness and climbing ropes if you are on a pitched roof
- Closed-toe shoes with slip-resistant soles
- Rated ladder for access to roofs. Ladders slipping and related falls are all too common, and can be avoided with proper safety procedures such as anchoring ladders to roof and ground.

Of course, use of the above tools is not a replacement for Common Sense! Working on roofs is inherently dangerous. So, pay attention, be careful, and trust your gut – If it feels dangerous, it probably is!