Design and Installation of Solar Water Heater Applications in Pakistan

Training Manual

REAP Renewable & Alternative Energies Association Pakistan

In cooperation with

AEDB Alternative Energy Development Board Pakistan

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Design and Installation of
Solar Water Heater Applications
in Pakistan

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Contents

Introduction

1. Training concept

- **Target groups:**

  Staff who is already taking responsibility, or who is expected to take responsibility in the near future, as:

  - SWH sales advisers / application planners
  - SWH installation supervisors

- **Criteria for the identification of participants**

  SWH sales advisers / application planners:

  - Technical skills.
  - Sound understanding of SWH technologies.
  - Customer orientation.
  - Awareness of quality issues.
  - Company spirit.

  SWH installation supervisors:

  - Trained plumber.
  - Technical understanding.
  - Practical experience.
  - Team leadership skills.
  - Awareness of quality issues.
  - Company spirit.

- **Nr. of participants: ~ 20**

- **Duration of the training seminar:**

  - SWH sales advisers / SWH application planners: **2 days**
  - SWH installation supervisors: **2+2 = 4 days**

- **Training targets**

  SWH sales advisers / application planners shall at the end of the training:

  - Know the major planning criteria for SWH installations.
  - Understand the comparative advantages of alternative solutions.
  - Be able to …
    - Evaluate customer needs and demands.
    - Recommend SWH applications fitting customer needs and demands.
    - Design recommended SWH applications to the customer needs by means of a standard calculation model (excel sheet).

  SWH installation supervisors shall at the end of the training:

  - Understand the principles and the technology of SWH.
  - Know how to integrate SWH applications into house installations.
  - Be able to …
    - Perform a qualified pre-inspection of installation sites.
    - Prepare the installation site, including tools and equipment.
    - Install SWH on site and instruct co-workers.
    - Perform functional tests and take corrective measures.
    - Ensure a proper maintenance of installed SWH.

- **Debriefings, exams & certification**

  De-briefings will be held at the end of each seminar day. Exams will be held at the end of the second and fourth day of the training seminar. A REAP/AEDB certificate will be issued to the successful participants of the seminar.

2. Training programme

<table>
<tr><th>1st Day</th><th>2nd Day</th><th>3rd Day</th><th>4th Day</th></tr>
<tr>
<td>Classroom lessons
All participants

<u>Module 1:</u>
SWH systems and components

<u>Module 2:</u>
Integration of SWH into house installations</td>
<td>Classroom lessons
All participants

<u>Module 3 (cont.):</u>
De-briefing of the pre-installation check of on-site conditions

<u>Module 4:</u>
Design parameters

<u>Module 5:</u>
Plumbing techniques

<u>Module 6:</u>
After Sales Service & Maintenance</td>
<td rowspan="2">Practical training
Installation supervisors

Installation of SWH on site</td>
<td>Practical Training
Installation supervisors

Installation of SWH on site</td>
</tr>
<tr>
<td>Practical demonstration
All participants

<u>Module 3:</u>
Pre-installation check of on-site conditions

(On-site inspection of Installation sites for practical training.)</td>
<td>Workshops for practical demonstration

<table><tr><td>Sales advisers & Application planners

<u>Module 7:</u>
Planning Tool</td><td>Installation supervisors

Assembling & dismantling of SHW units</td></tr></table>
Intermediate test</td>
<td>Workshop
All participants

De-Briefing
Final test
Participants feedback
Certificates</td>
</tr>
</table>

Please switch off your mobile during the whole seminar. Thanks!

Module 1: SWH Systems and Components

1. Different types of SWH systems

Due to the conditions of local water supply, most of the SWH systems installed in Pakistan will be **non-pressurized systems**. The following chapters are differentiating between the various types of SWH systems:

- **Thermosiphon systems ⇔ Forced circulation systems.**
- **Open loop systems ⇔ Closed loop systems.**
- **Batch heating systems ⇔ Continuous flow systems.**

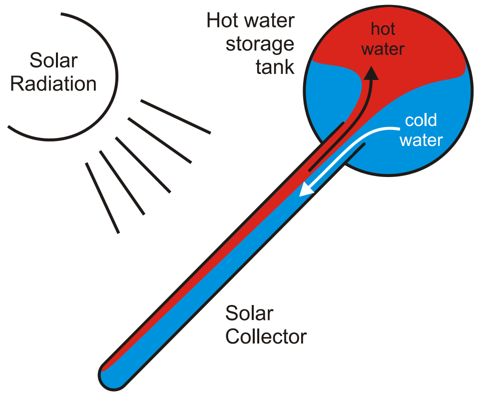
The different system types and their characteristics are presented on the following pages.

1.1 Thermosiphon systems ⇔ Forced circulation systems

a) Thermosiphon systems

Thermosiphon systems may be applied if the hot water storage tank can be installed above the collector as it is the case in most of the standard systems applied in Pakistan and if there is no strong frost in winter.

Picture: www.aguasolve.com/thermosiphon.jpg



Thermosiphon principle in an open-loop SWH with evacuated tube collector.

Thermosiphon systems are using **<u>natural convection</u>**:

- Solar radiation is heating the water in the collector.
- **Hot water** in the collector has a lower specific density than the cold water in the storage tank and is **ascending**.
- **Cold** water from the storage tank has a higher specific density than the hot water in the collector. It is **descending.**

No circulation pump or control is needed.

Advantages: Low investment cost / high reliability / little maintenance required.

DANGER: In thermosiphon systems the maximum temperature of water in the hot water storage tank may reach up to <u>99°C</u>!

b) Forced circulation systems

Forced circulation SWH systems have to be applied whenever the solar collector cannot be installed below the hot water storage tank. It is further recommended to install forced circulation systems for large scale SWH systems as well as in conditions requiring freeze protection.

www.solarireland.ie/images/set/6.jpg

Forced circulation is ensured by means of an electrical pump. Collector and storage tank can be installed independent from each other, height difference between tank and collector does not matter.

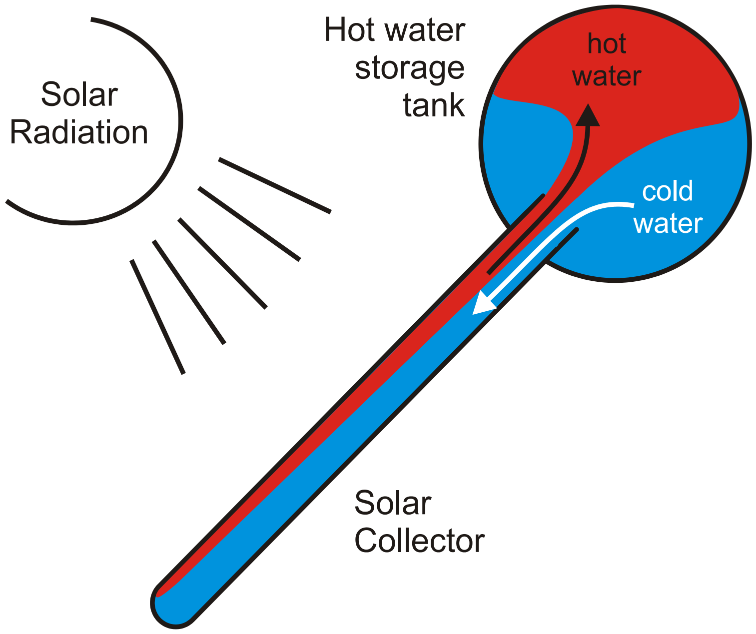
Forced circulation systems are operating economically in particular in large-scale applications.

✸ **Pumps and controls require maintenance!**

1.2 Open loop systems ⇔ Closed loop systems

a) Open-loop systems

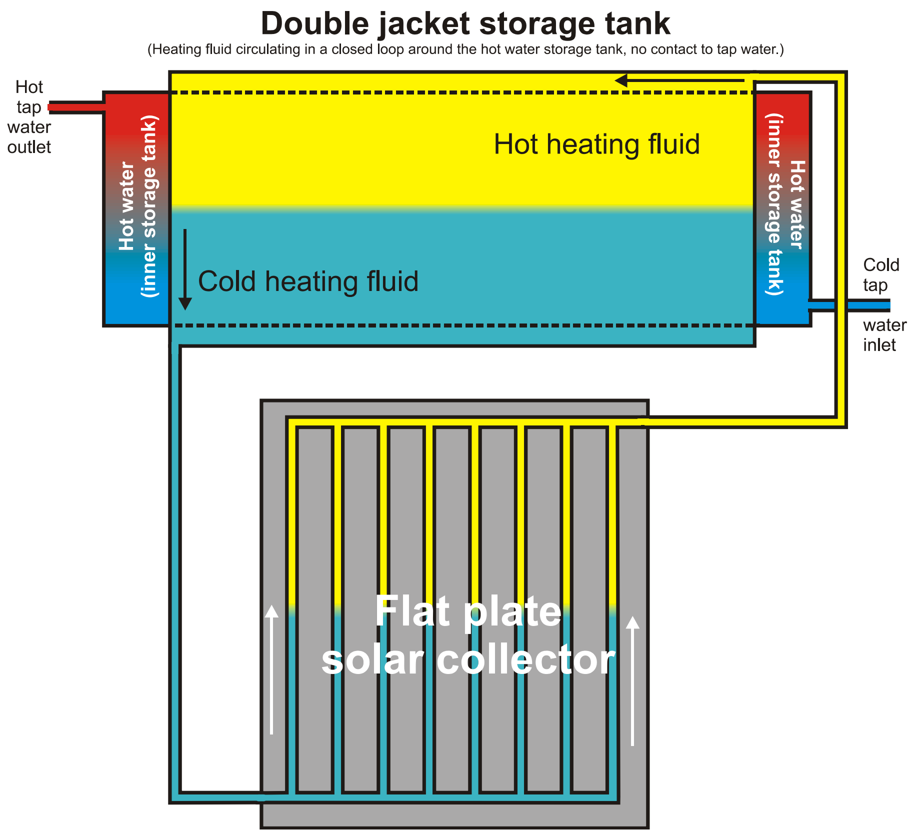
Tap water is circulating as heating fluid through the collector.



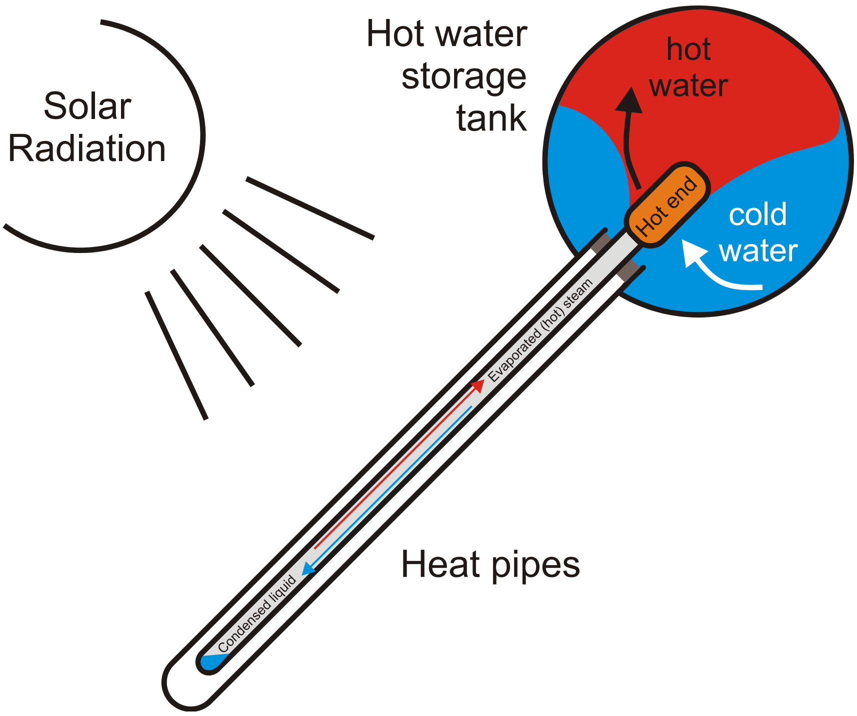
Thermosiphon principle in an open-loop SWH with evacuated tube collector.

b) Closed-loop systems

The heating fluid is circulated in a closed loop and is separated from the tap water. Heat transfer from the heating fluid to the hot water is performed through a heat exchanger.



Closed loop thermosiphon system with flat plate collector.



Closed loop thermosiphon SWH heater with heat pipes collector.

1.3 Batch heating systems ⇔ Continuous flow systems

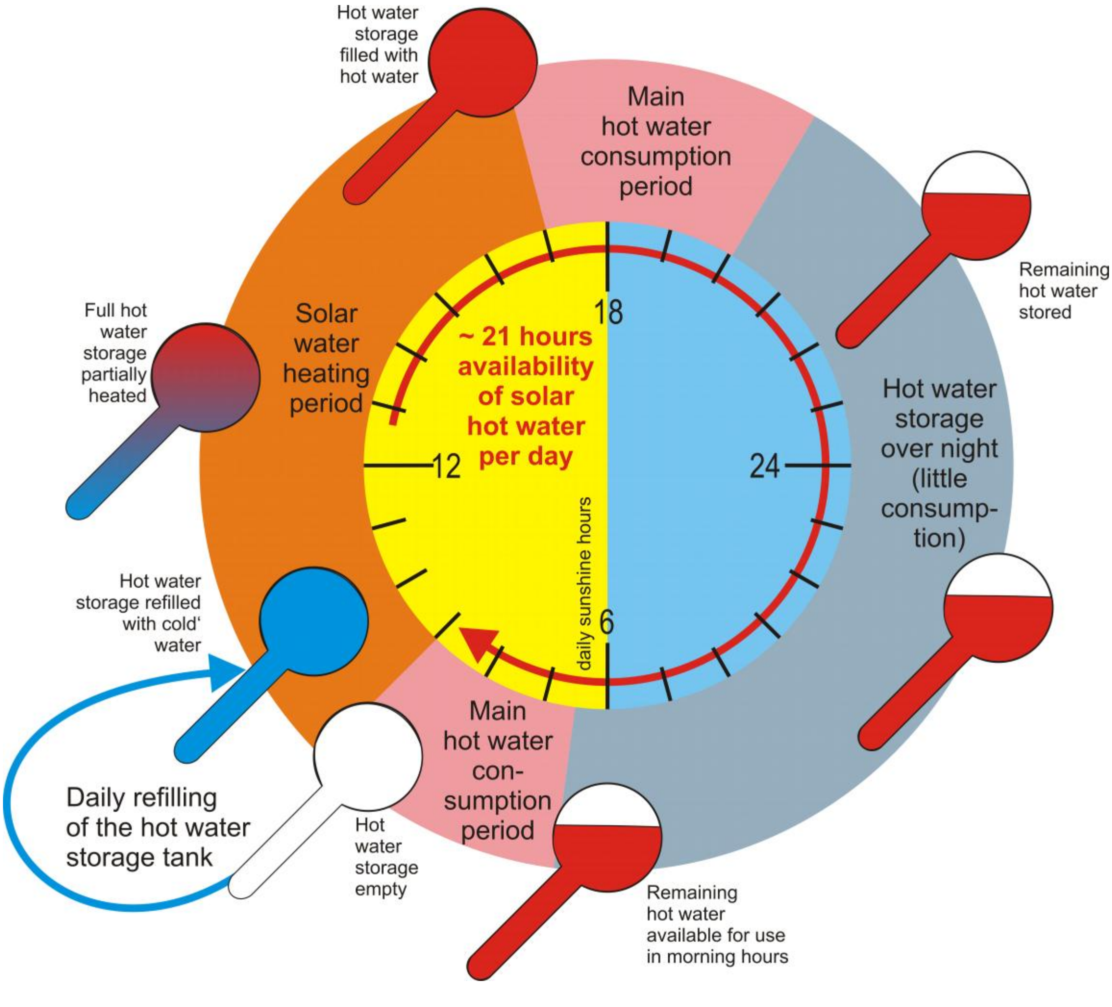
a) Batch heating systems

Batch heating systems are mainly applied in Pakistan in those cases where the SWH cannot be installed below the outlet level of the tap water overhead tank of a house.

In these cases, the hot water storage tank of the SWH is refilled e.g. once a day in the morning hours. Hot water is available after a few hours until the hot water storage tank is emptied.

The refilling has to be controlled, either manually, mechanically or electronically.

An example for typical service cycle of a domestic SWH system with batch heating is presented in the following picture.



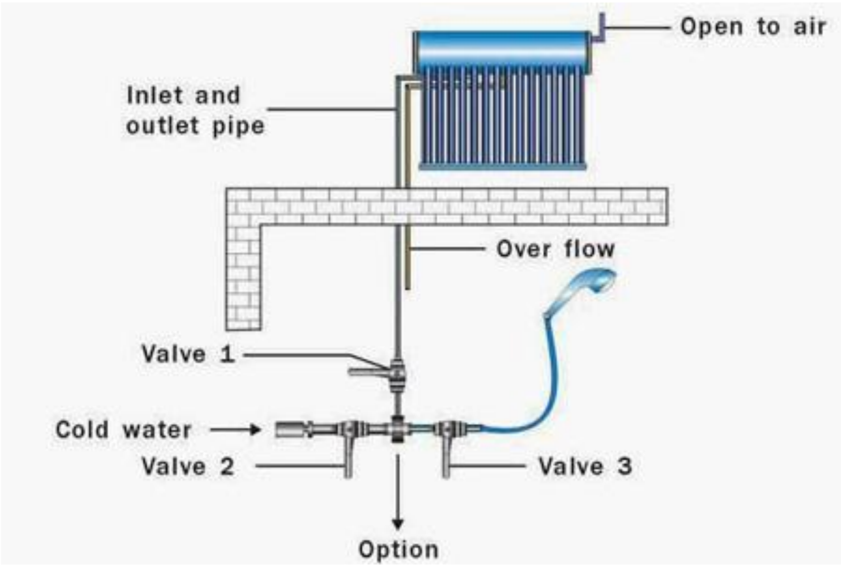
Typical daily service cycle of a batch heating SWH.

✷ **Inconvenience may occur to the customer as hot water is available only a few sunshine hours after refilling.**

a.1 Manually controlled batch heating SWH systems

The least sophisticated design for a SWH with batch heating is a one-pipe-system.

- One pipe for the inlet of cold water as well as for the outlet of hot water on the lower side of the storage tank.
- One-pipe systems without pumps are possible if the water pressure in the system is high enough to fill the hot water storage tank (e.g. if the outlet level of the overhead tap water storage tank is much higher than the water level of the full hot water storage tank).



Manually controlled one-pipe SWH system without extra pump and automatic control.
(Very basic design. Source: Rjin Sola, CN)

Most simple, manually controlled versions have an overflow pipe to indicate the complete filling of the hot water storage tank.

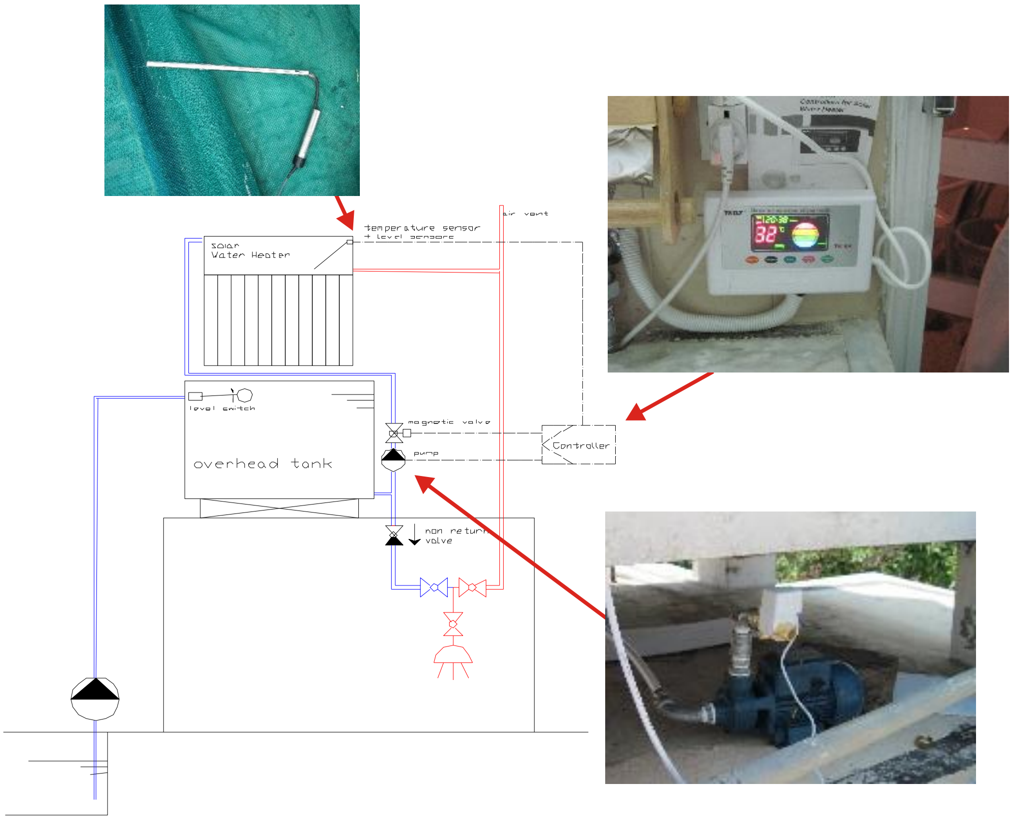
The size of the hot water storage tank of the SWH should be designed to allow for the batch heating and storage of a hot water volume which is equivalent to the household's average hot water consumption per day (e.g. 35-50 litres per person).

a.2 Automatically controlled batch heating SWH systems

Batch heating SWH solutions with electronically controlled filling pumps are standard on the market in Pakistan. They are useful where the SWH can only be installed above the overhead tank.

- Advantages:
  - High level of convenience when the system is properly working.
  - Efficient use of solar energy.
  - Flexible in SWH position on the roof with respect to water level of overhead tank.
- Disadvantages´:
  - High investment cost.
  - Complex installation requirements.
  - Additional risks of failure.
  - Maintenance requirements.

A typical configuration of a batch heating SWH installed in Pakistan with automatically controlled filling pump is presented in the following picture.



Typical configuration of a batch heating SWH with automatically controlled filling pump.

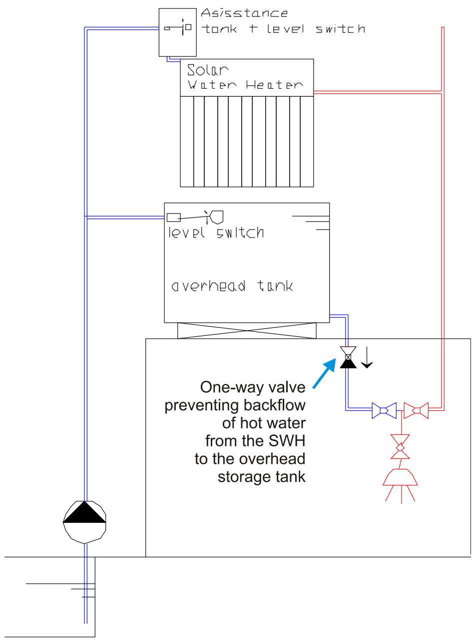
a.3 Batch heating SWH with level-controlled assistance tank

In order to reduce investment cost as well as risks of technical failure, many producers are now offering SWH for batch heating equipped with an assistance tank providing a level-switch for mechanical control of the filling of the SWH hot water storage tank.

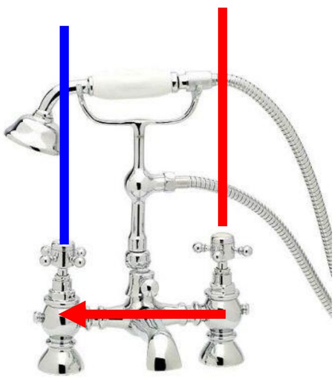
The concept is to use the already existing pump which is filling the standard roof-top tap water tank also for the filling of the hot water storage tank of the SWH.

- No extra pump required.
- No electronic control unit required.

A sample configuration is shown in the chart on the right side



SWH with level-controlled assistance tank

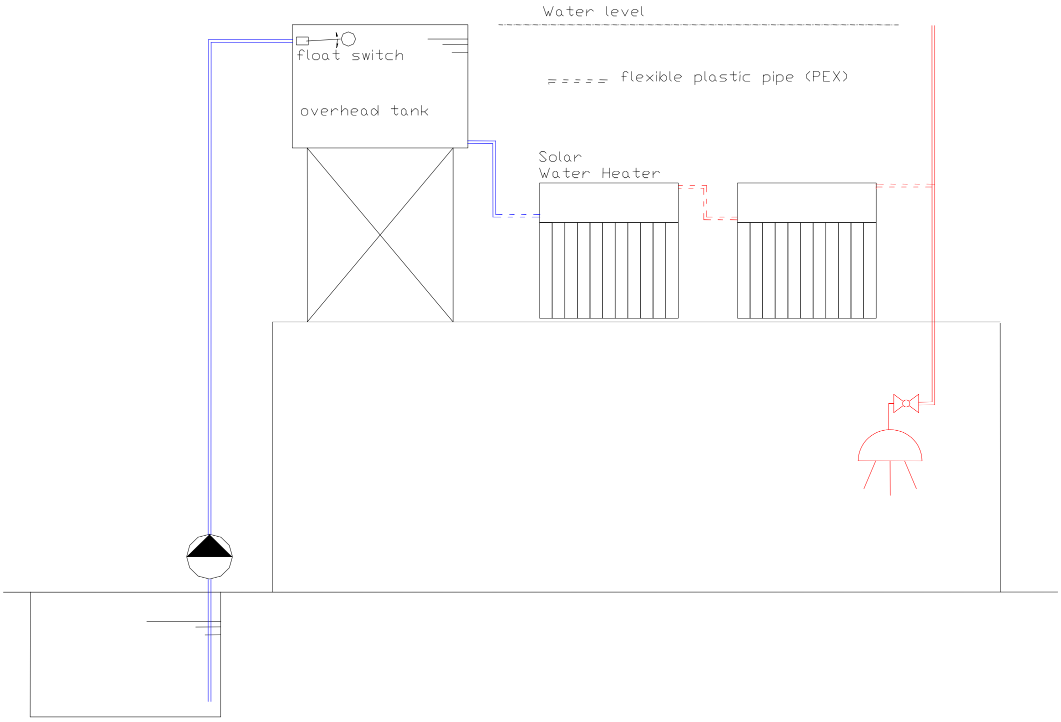


This configuration is providing an additional non-return valve to prevent the back-flow of hot water from the SWH to the overhead tank. Such a back-flow may e.g. happen if a modern mixer in the shower or bath-tube is in stand-by with open valves.

b) Continuous flow systems (two-pipes system)

In private houses, if the outlet of the overhead water tank is above the level of the hot water storage of the SWH, two-pipe systems with a separate cold water inlet and a separate hot water outlet are the most common SWH design.

In continuous flow systems the hot water in the storage tank can mix with inflowing cold water as soon as hot water is extracted. This can lead to a reduced hot water temperature at the outlet, especially during morning hours.



Most recommended installation scheme of a two-pipe thermosiphon SWH system
connected to an existing overhead tank (overhead tank at higher level than the SWH)
providing continuous refilling of the hot water storage tank
without any specific control or pump.

2. Major components

2.1 Solar collector types

Two collector types are available for SWH systems:

- Evacuated tube collectors.
- Flat plate collectors.

In Pakistan, evacuated tube collectors are the most commonly used collector type.

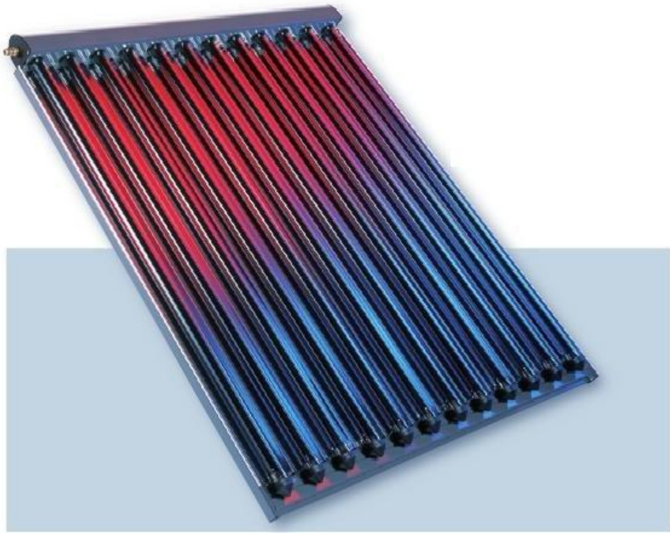
Main arguments which are often used **in favour of evacuated tube collectors** in small-scale SWH systems for domestic applications in Pakistan are the following:

- Simple systems design with minimum number of pipes and fittings.
- Little corrosion and low maintenance cost.
- Easy replacement of broken tubes.
- 10-20% higher heat production (per square meter of collector surface).

A special type of evacuated tube collectors are **heat pipes** supporting closed-loop systems e.g. in areas with strong frost.

Flat-plate collector systems have their advantages in large-scale applications (closed-loop systems) as e.g. the risk of overheating is lower for flat-plate collectors than for evacuated tube collectors.

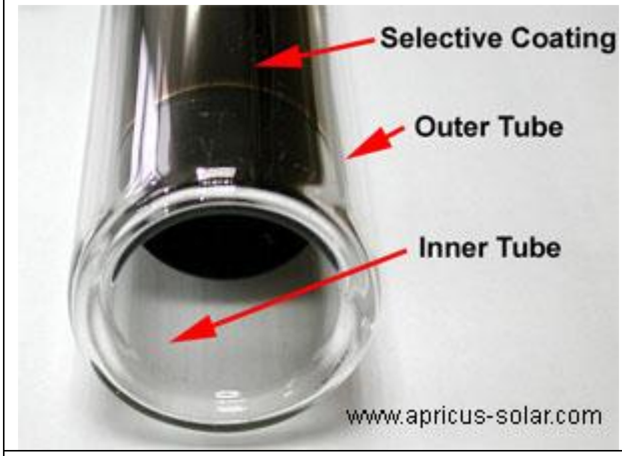
Evacuated tube collector



Flat plate collector

a) Evacuated tube collectors

Vacuum tubes



Left tube: Vacuum present
Right tube: Faulty

Vacuum tube collector

Picture: image.made-in-china.com/2f0j00UMSQZcEnfHkJ/Heat-Pipe-Evacuated-Tube-SSA-47-1-5-.jpg

Integrated vacuum tube SWH

Picture: image.made-in-china.com/2f0j00RBsQuyvFrDcM/Integrative-Vacuum-Tube-Solar-Water-Heater-Non-Pressure-Type-.jpg

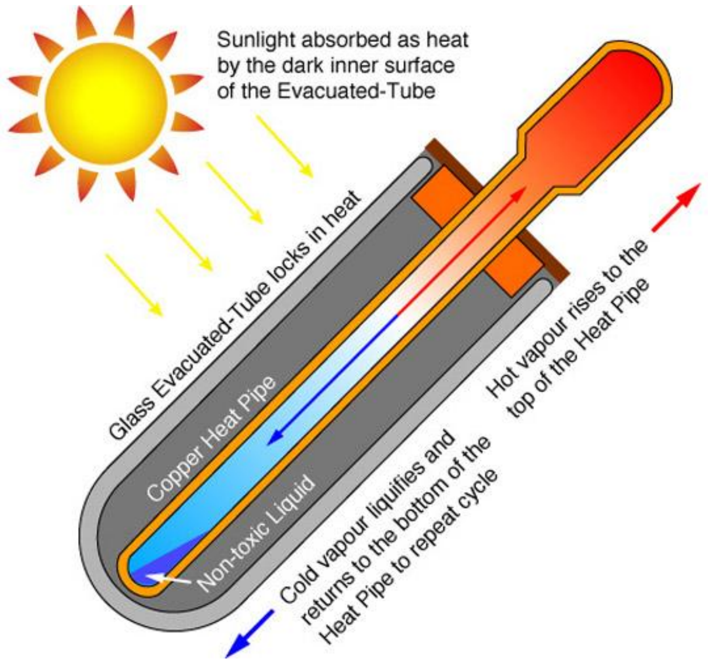
Vacuum tubes can be applied for:

- Small scale systems up to 10 square meters of collector surface.
- Family homes and dwellings with roof-top tank.
- Thermosiphon systems.
- Open loop systems.
- SHW in areas with no sustainable frost periods.

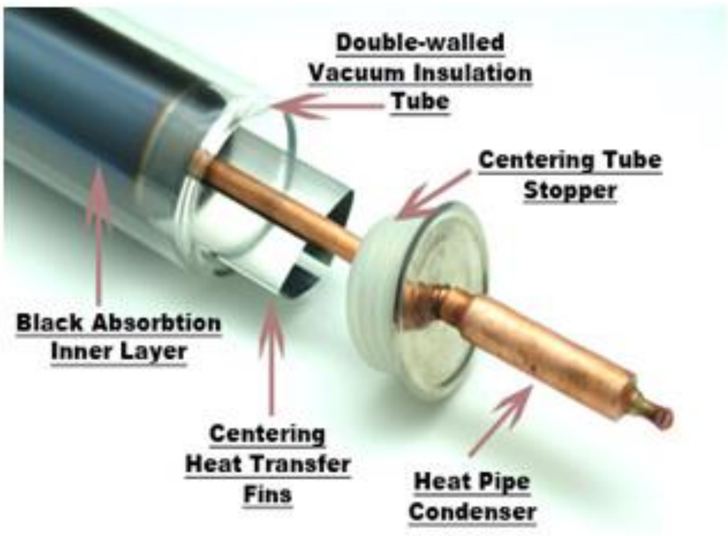
Specific advantages are:

- Low investment cost.
- Simple construction of the SWH device.
- No pumps and controls needed.
- Easy maintenance (replacement of broken tubes).

b) Heat pipes (special form of evacuated tube collector)



Picture: www.jinyi-solar.com/images/products/Heat_pipe_evacuated_collect.gif



Components of a standard Cu heat pipe
www.greensolargeyser.co.za/wp-content/heatpipes1.jpg

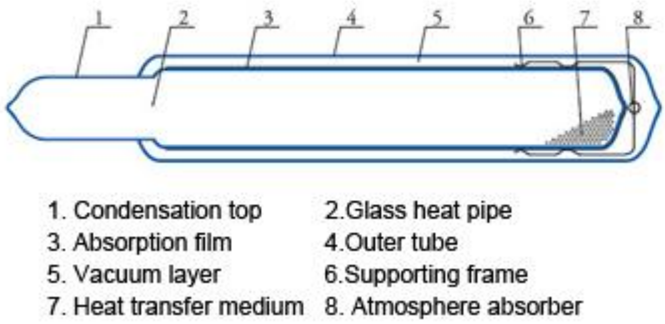
Heat pipe vacuum tubes give the heat directly to the storage tank without water flowing through the collector.

Advantages:

- Quick provision of hot water from the storage tank when the sun shines.
- High resistance to freezing.
- Applicable also for pressurized systems with sheet thickness of 1mm to 2 mm in the storage tank.
- No scaling of the vacuum tubes.

A new form of heat pipes is presented in the form of **all-glass heat pipe vacuum tubes.**

Condensation top of an all glass heat pipe
(Here: for demonstration purposes in top-down position in order to show the heating liquid).



All glass heat pipe (schematic)
Picture: www.solarheatercompany.com/userfiles/image/HY-GR%202007-P8-01.jpg

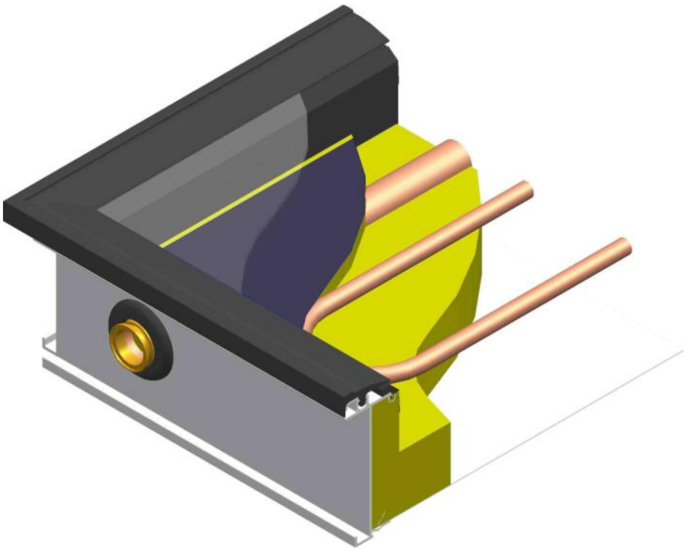
Advantages of all-glass heat pipes are:

- Economic alternative to common Cu-heat pipes.
- Better heat transfer performance.
- Better long term performance.
- Non-freezing of the tube (interesting for Northern Pakistan).

c) Flat plate collectors

Picture: www.greenterrafirma.com/images/flat_panel_collector.jpg

Picture: http://image.made-in-china.com/2f0j00sMkTBtrKZboV/Solar-Water-Heater-Flat-Plate.jpg



Picture: Consolar

Picture: http://www.insurgent49.com/FlatPlateSolarCollectors.jpg

✷ **Compared to vacuum tube collectors the flat plate collector provides 10-20% less solar heating efficiency.**

2.2 Hot water storage tanks

a.1 Standard tanks for non-pressurized systems

In most of the SWH systems which are sold for domestic application in Pakistan, the storage tank is directly linked to the collector.

www.made-in-china.com

These standard storage tanks which are made for non-pressurized systems usually have a steel thickness below 0.5 mm.

They are very sensitive for breaking e.g. in case of mechanical loads on the connections to and from house installation systems.

Flexible connections with house installation are a must!

At least 0.5 m flexible connection tube should be used between the SWH and the un-flexible piping of house installations.

The plastic tube should preferably be made from PEX (cross-linked polyethylene) which is suitable for hot water applications.

SWH installed in northern areas in Pakistan

a.2 Storage tanks for pressurized systems

Solar Water Heater with Integrated Pressurized Storage Tank
(3mm thickness stainless steel; withstands 6 bar pressure)
Picture: www.solar-heater.net

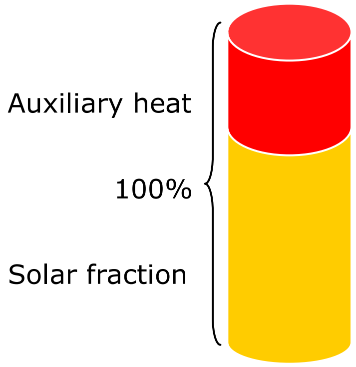
Pressurized Solar Hot Water Heater Storage Tank
with Enamel coating, Magnesium Bar and Heat Exchanger
Picture: Consolar

2.3 Backup heaters

For economic reasons, it is recommended to design SWH to provide at least 70% solar fraction.

"Solar Fraction" = Share of energy demand for water heating which is provided from solar energy every year.

"Solar Fraction 70%" means 70% of the annual energy demand for water heating is provided from solar energy.

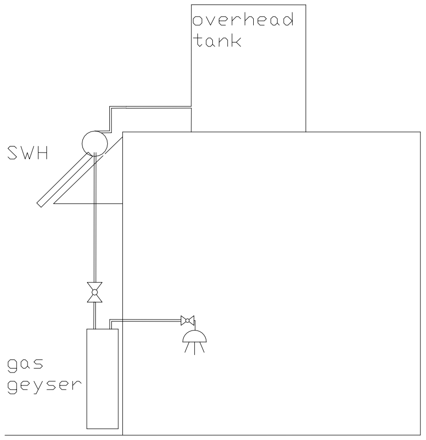


As the solar fraction will always be below 100%, there may be a need for backup heating during peak load or when the sun is not shining.

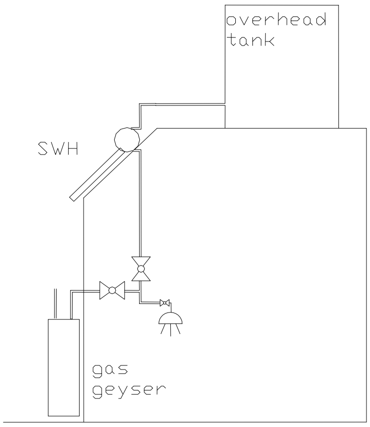
a) Gas geyser as backup heater

Although it is the least energy efficient and least economic option, it is still standard in Pakistan to maintain the existing gas geyser operating even when a SWH system is installed in a house.

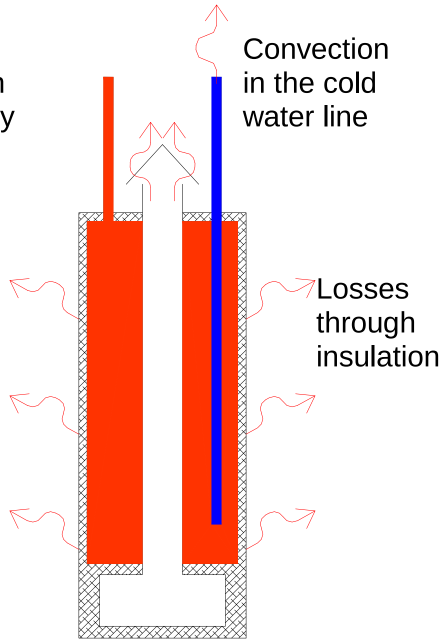
The common situation is in these cases that the SWH is connected to the water inlet of gas geyser and that it is feeding hot water only to the storage tank of the gas geyser.



Serial installation SWH – Gas geyser



Parallel installation SWH – Gas geyser



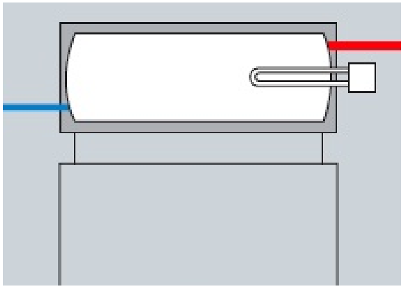
Thermal losses of a gas geyser

Such a system where the SWH is only used as a preheating for the gas geyser is leading to high losses of solar heat because of the high energy losses in standby modus of the gas geysers.

✸ **In terms of economic cost and energy savings, the utilization of a gas geyser in line and in combination with a SWH is the least efficient option.**

Nevertheless, this is the state-of-the art in Pakistan for the installation of SWH heaters where gas supply is available and where gas geysers are already installed in the houses, because it is the **customers' request** to maintain the high level of convenience of hot water supply which they have been experiencing from their gas geysers during many years.

b) Electric backup



Picture: www.viessmann.de

Currently the most recommended backup system will be an electric rod as this is requiring no extra piping or extra utilities and the electric rod can be operated without any losses in standby.

For economic reasons the SWH should provide the main share of hot water supply, covering at least 70% of the energy demand for hot water supply!

Relevant products are standard on the market and they are already used in Pakistan in those areas, where there is no gas but electricity supply available.

In order to minimise electric energy consumption the availability of the electric backup can be limited by means of a time switch e.g. to a maximum of 2 hours per day. The batch filling controller TK-8A (see also page 12) which is used in Pakistan is providing such a time switch function.

2.4 Piping & insulation

a) Pipe layout

The piping layout shall be designed to avoid unnecessary pipe length. The SWH shall be installed as close as possible to the overhead tank and the connection to the hot water mains.

✸ **20 m additional ½" steel pipe will reduce flow rate by approx. 2-3 litres/minute at the tap.**

b) Pipe material

Plastic pipes:

- Use only plastic material which is resistant to UV radiation and to temperatures up to 95 °C.
- In high altitude areas with very low temperatures piping should be made of flexible plastic in order to prevent bursting of pipes because of freezing.
- Plastic piping must **not be exposed to anti-freeze**.

Steel pipes:

- **No galvanized steel pipes** are to be installed after **copper** pipes or copper collectors in an **open loop** system.
- **Only galvanized steel, stainless steel or plastic pipes** are to be used in connection with **stainless steel storage** tanks.

✸ **Breaking these rules in the application of steel pipes may cause severe corrosion.**

c) Insulation

Insulation of the pipes connected to the SWH is in particular important in areas with heavy frost in order to reduce heat losses from the hot water mains and to protect the pipes against freezing.

Outdoor insulation should be covered with iron sheet as animals usually will destroy the soft insulation material within one year.

Picture: www.greengates.co.uk/images/pictures/insulation/pipe-insulation-(page-picture-large).jpg

2.5 Safety valves, air pipes, expansion vessels

Expansion of hot water may cause a risk of damage to the SWH and the house installation in two ways:

- Expansion of the **heating fluid** (water, probably mixed with anti-freeze) in **closed loop** SWH
- Expansion of hot water in the **storage tank** in both **closed loop** as well as in **open loop** SWH

a) Expansion of the heating fluid (water, probably mixed with anti-freeze) in closed loop SWH

Safety valve:

- Every closed circuit in the system shall contain a safety valve. This safety valve shall **withstand the highest temperature** that can be reached at its location and must **protect the SWH from high pressure** due to thermal expansion.
- If the SWH is equipped with a safety valve, this safety valve **must always be operational** and shall not be capable of being separated from the closed loop.

Solar Safety Group

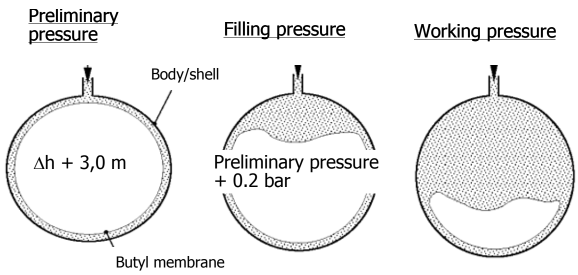
Diaphragm Safety Valve

Solar Expansion Vessel

www.wattsasia.com

Expansion vessel:

- Every closed loop must compensate thermal expansion without immediate reaction of a safety valve.
- Thermal expansion may be compensated by expansion vessels which are available on the market for this purpose, or, more simply, by an air volume which is enclosed in the loop and which is capable of compensating for thermal expansion.
- The **required air volume** is depending on the volume of the heating fluid circulating in the closed loop, the initially charged pressure and the maximum permissible installation pressure.



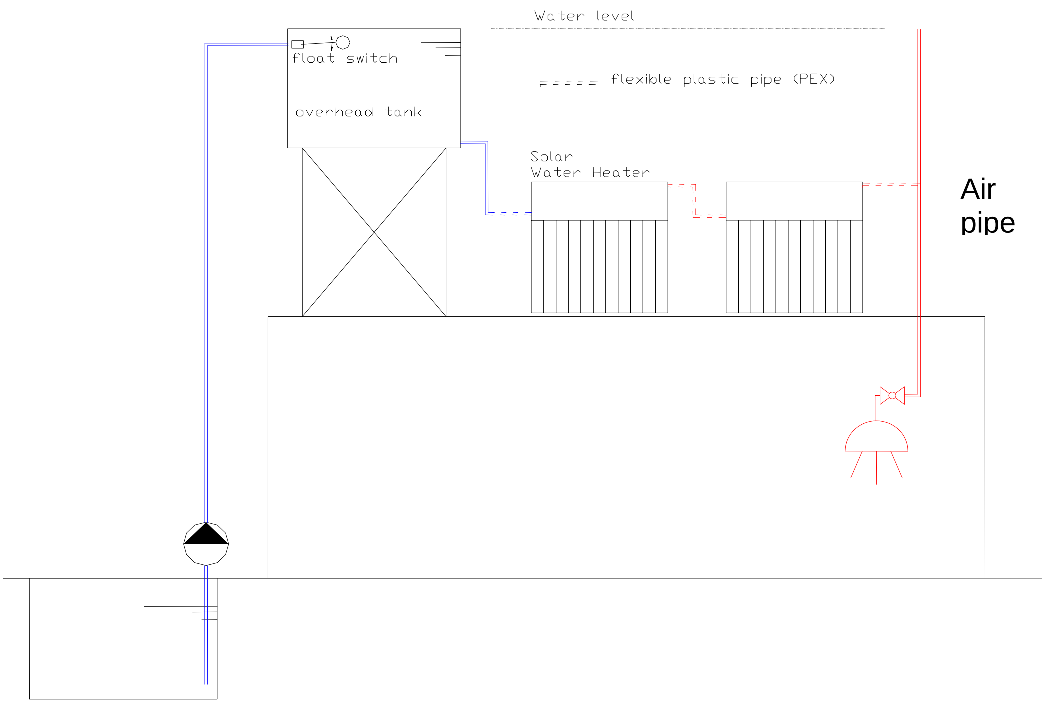
Operating principle of an expansion vessel.

b) Expansion of the hot water in the storage tank in both closed loop as well as in open loop SWH

b.1 Air relief pipes / venting pipes

In connection with an **external overhead tank**, air relief pipes are installed on the upper outlet of SWH. Outlet of the **air relief pipe** must be **equal to the maximum water level** of the overhead tank. One air pipe is sufficient for a SWH or a series of them.

Air relief pipes and hot water outlets shall not be carried by the SWH but shall be fixed with reinforcement on the ground so that no mechanical load will be on the sensitive connections of the storage tank.



b.2 Safety valve on the storage tank

Every critical thermal expansion volume must be blown off by the safety valve.

Safety valve
Picture: ecx.images-amazon.com/images/I/41VEr1-pKJL._SL500_AA300_.jpg

2.6 Mixing valves for user safety

- Tap water for direct human use (shower, bathing, washing) should not exceed a temperature of ~40°C.
- **More than 50 °C tap water temperature is dangerous.** It is causing severe damages to the body (burns) within 10 seconds of exposure and can kill children.
- **More than 60° C is killing your customer!**

Temperature of tap water must not exceed 60°C.

International Standard:

- For systems in which the temperature of domestic hot water at the tap can exceed 60 °C, a cold water mixing valve or any other device to limit the tapping temperature to at most 60 °C (+/- 5°C) shall be installed on the solar heating system or elsewhere in the domestic hot water installation (EN 12976-2).

An easy means to ensure the limitation of hot water temperature is the installation of a mixing valve. Mixing valves are on the market for prices of **50-150 USD**.

This extra investment saves your customers' lives!

Picture: www.wattsasia.com

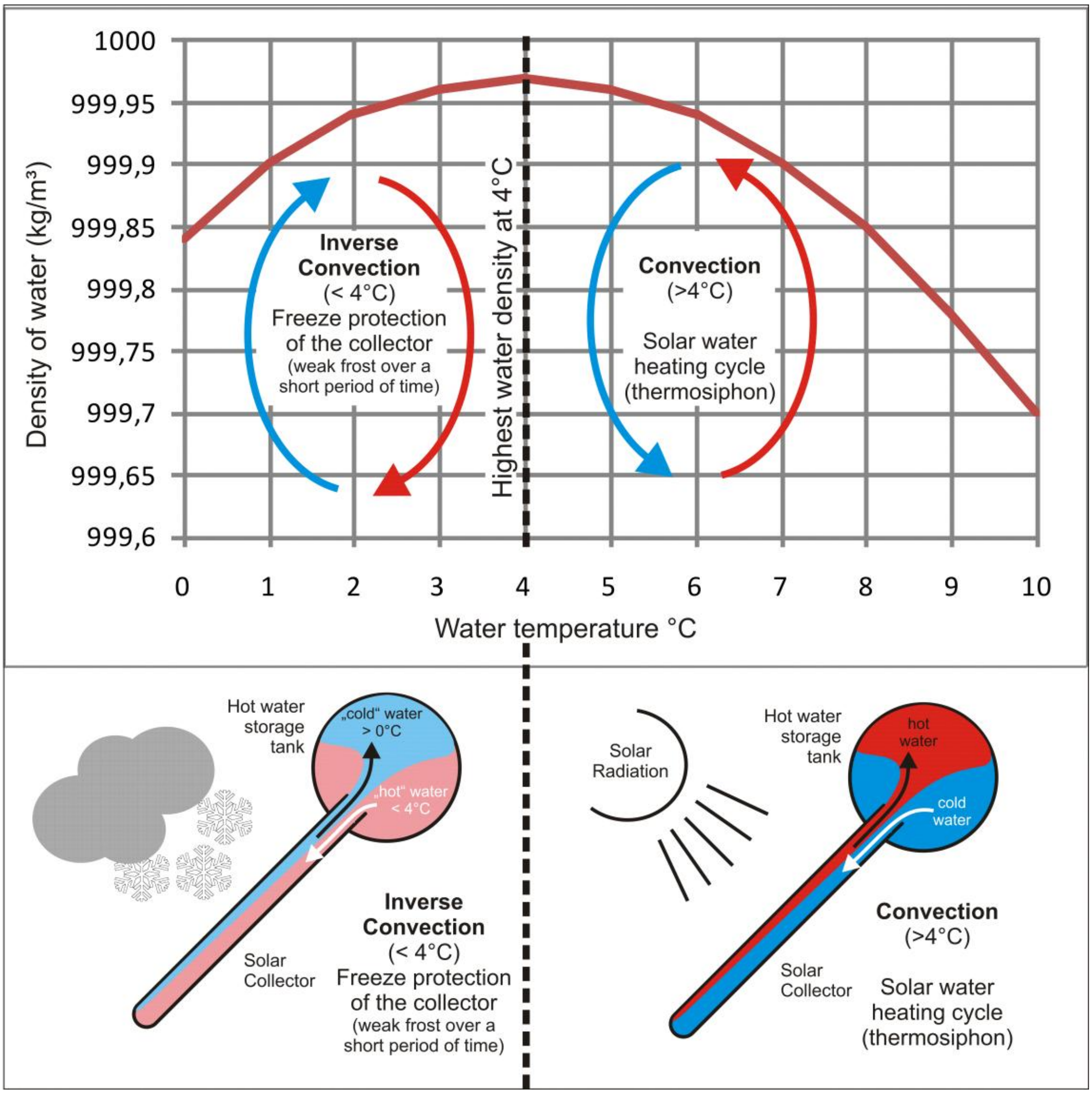
2.7 Freeze protection

a) No extra freeze protection required for thermosiphon SWH in the Potohar region and in western regions of Pakistan (< 1500 m altitude)

Freezing of SWH is most unlikely to happen in thermosiphon SWH systems in the Potohar region and in western areas of Pakistan.

As soon as the water temperature is decreasing to less than 4°C in the collector, the water in a thermosiphon system starts to circulate in the reverse direction (inverse convection) and heats the collector with water of higher temperatures from the storage tank.

This is because the density of water is the highest at a water temperature of 4°C.



Natural freeze protection of thermosiphon systems in areas without strong frost

Inverse convection stops and the freezing of collector starts, when the water temperature in the collector and in the storage tank is balanced at 4°C. <u>This is very unlikely to happen under the climatic conditions of Islamabad and the western areas of Pakistan.</u>

It is recommended that each SWH is fitted with an electric rod backup heater which provides additional freeze protection.

b) Freeze protection of SWH in northern areas of Pakistan (> 1500 m altitude)

Active freeze protection of SWH is required in the Northern areas of Pakistan.

In northern areas of Pakistan with heavy frost,

- Vacuum tube collectors should be of heat pipe type.
- Electric rod backup is needed to protect the storage tank.
- Pipe connections from and to the SWH must be of flexible plastic material in order to prevent damage caused by extreme ambient temperatures.
- Vertical pipe lines between the SWH and the non-freezing areas of the building are improving the water flow also at temperatures below 0°C.
- The heating water has to be mixed with **anti-freeze** in flat plate SWH and run in a **closed loop** in order to avoid freezing of the collector.

The appropriate volume of anti-freeze which is to be added to the heating fluid in a **closed loop system** with **flat plate collector** is depending on the climatic conditions on site:

Anti-Freeze added to the heating fluid	15%	25%	33%	37%	43%
Freezing point	**-5°C**	**-10°C**	**-15°C**	**-20°C**	**-25°C**

Data valid for Antifrogen L Source: Tyfocor

Anti-freeze liquids reduce the heat transfer characteristics of the heating fluid compared to pure water with regard to heat conductivity (W/mK) and specific heat (kJ/kgK).

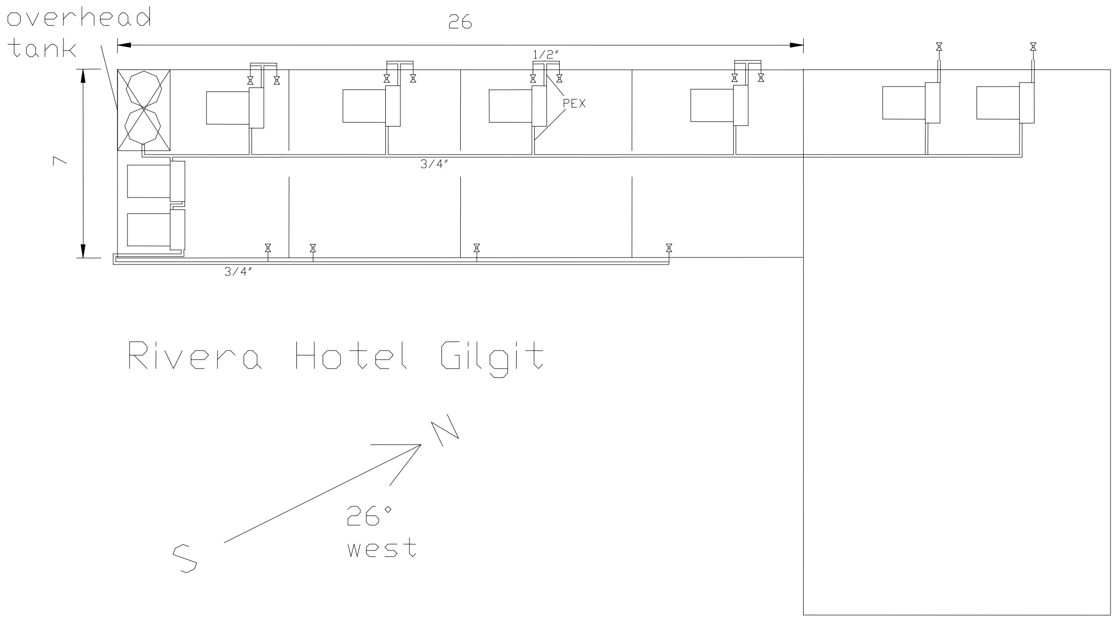
Therefore it is not recommended to use more anti-freeze than required for freeze-protection.

3. Large scale applications (design examples)

a) Decentralized installation of more than one SWH, with direct connection to the single hot water taps

Decentralized SWH installations may be applied in small hotels and apartment buildings with many hot water consumption points.

The following solution was designed for a Hotel in Gilgit-Baltistan



Cold Water supply is provided from one single overhead tank.

The connection between the SWH and the hot water tap is designed as short as possible in order to provide hot water quickly after opening the tap.

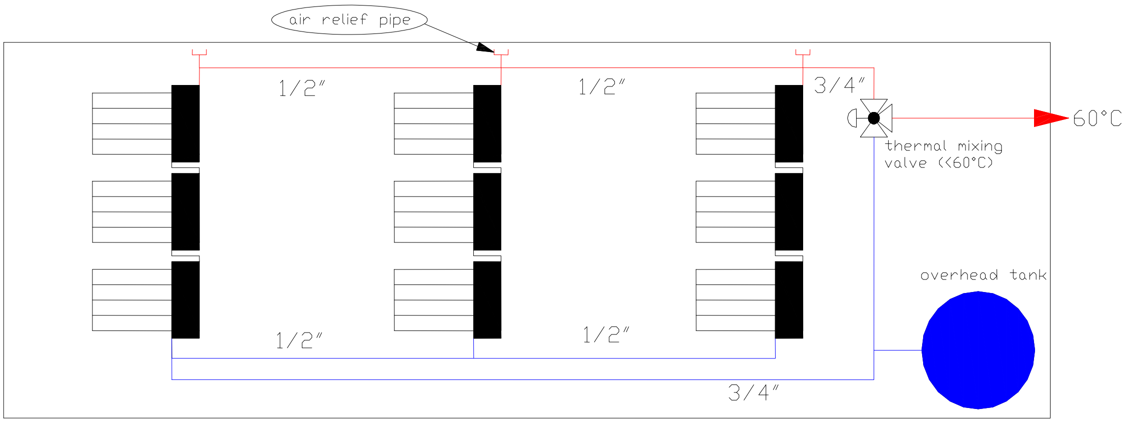
Advantage:

- With lifted overhead tank, no level control switch would be necessary in the SWH. There the investment cost as well as the maintenance requirements are.

Disadvantage:

- Thermal mixing valve is necessary for each single SWH in order to limit hot water temperature to 60°C.
- Separate cold water supply to each SWH will mix the cold water with the hot water in the tank and may reduce hot water temperature at the tap.

b) Centralized SWH installation of more SWH, with only one hot water supply pipe to the house



This installation is mainly used in combination with existing centralized hot water supply systems e.g. process heat for car wash.

Air relief pipes are required at the hot water outlet side of each row.

Diagonal connection of SWH area will ensure equal water flow through all single SWH.

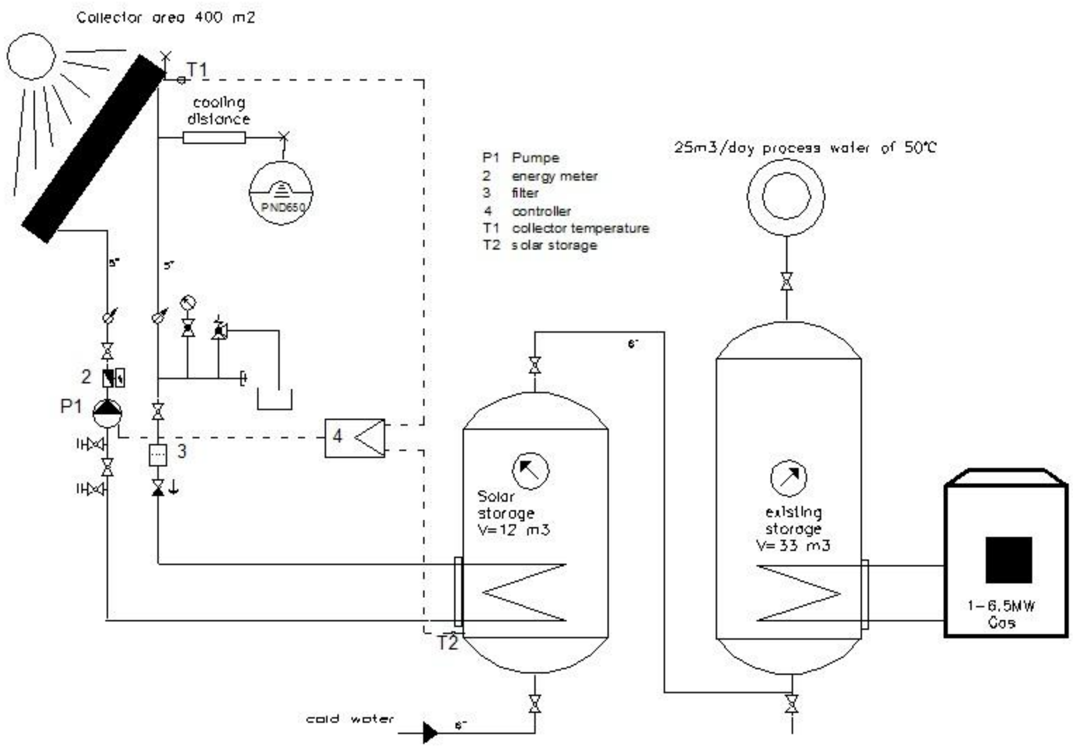
Advantage:

- Only one thermal mixing valve (limiting water temperature to 60°C) is necessary.
- Hot water temperature is more balanced than in systems with decentralised installation of SWH.
- Reduced pipe length within the SWH area.

Disadvantages:

- If many decentralised consumers are connected to the SWH the hot water pipe may become very long. This will lead to pressure drop, thermal losses and longer reaction times.

For SWH with collector areas of more than 30 m² **forced circulation systems with closed loop** are recommended.



Components of large scale SWH need individual design.

Advantages:

- Storage volume can be designed according to the real needs.
- Central storage tank with thermal stratification.
- Higher system efficiency, and reduced heat losses compared to decentralised storage tanks of multiple thermosiphon SWH.

Risks:

- In the closed loop, air will stop water flow in the SWH and interrupt heating operation.
- If circulation pump stops e.g. because of power cut during daytime the SWH will go in stagnation (no circulation) for the rest of the day.
- Central thermal expansion of the water volume of SWH with more than 100 m² collector surface is high and requires an open expansion vessel (i.e. opening the loop). This is an additional source of system failures and requires additional maintenance.

In order to avoid excessive storage in multiple thermosiphon systems, the following recommendation should be considered.

- SWH up to 30 m²:
  Thermosiphon systems with de-centralized storage
- SWH with more than 30 m²:
  Forced circulation system with central storage

Module 2: Integration of SWH into house installations

1. Water levels in thermosiphon

- If the hot water storage tank of the SWH can be installed at a lower level than the outlet level of the overhead tap water storage …

  ➔ **continuous flow system without pump are possible.**

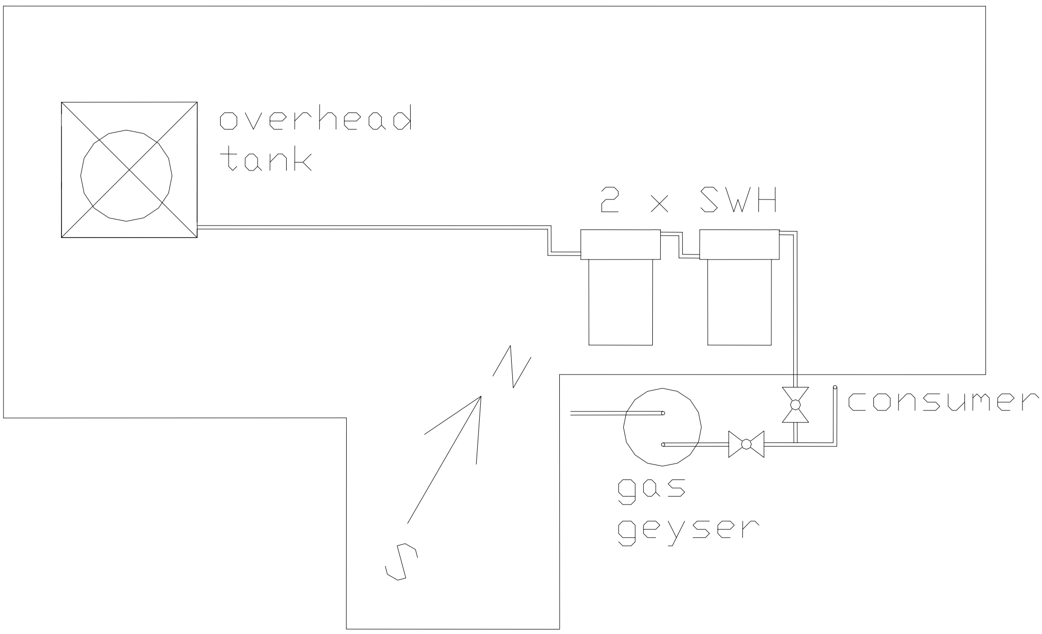
- If the hot water storage tank has to be installed at a higher level than the outlet level of the overhead tap water storage tank …

  ➔ **batch heating systems with pump filling are required**

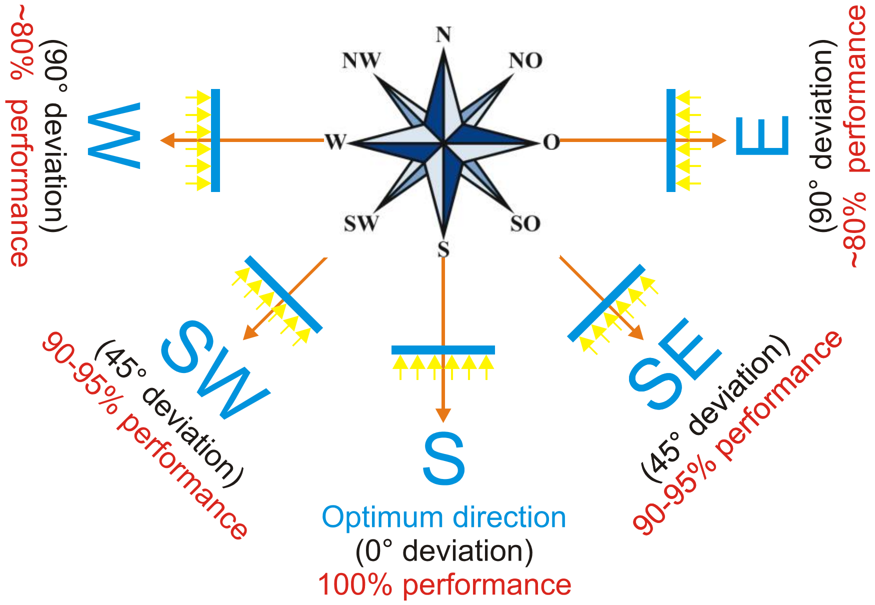
2. Location of the SWH on the roof

- Distance between hot water outlet of the SWH and the tap should be as short as possible.
- The piping layout should find the shortest possible way.
- If more than one SWH is to be installed, the SWHs should be placed next to each other in order to minimize pipe length and to ensure balanced water flow through all SWH units.

Compromises may be required e.g. in order to maintain optimum direction to the sun and to avoid shadow on the collector.

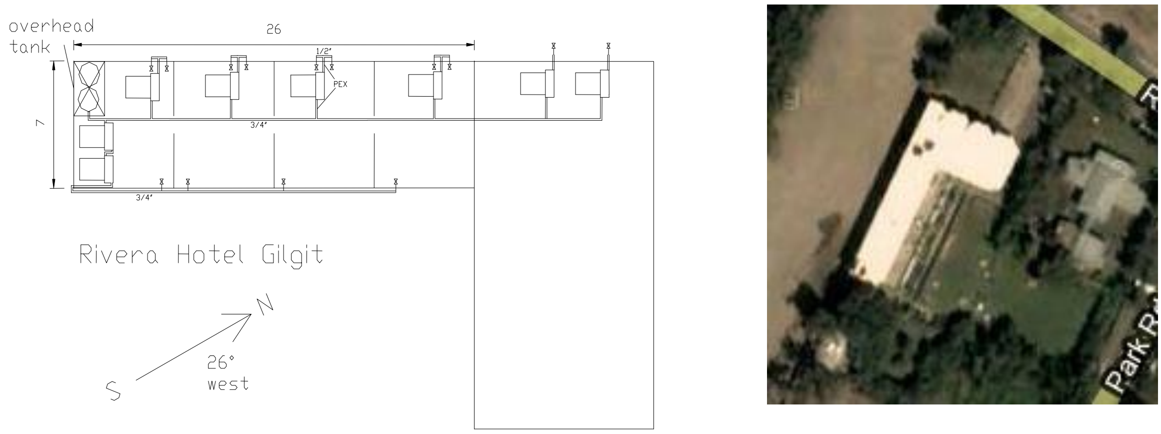


3. Direction of the SWH to the sun



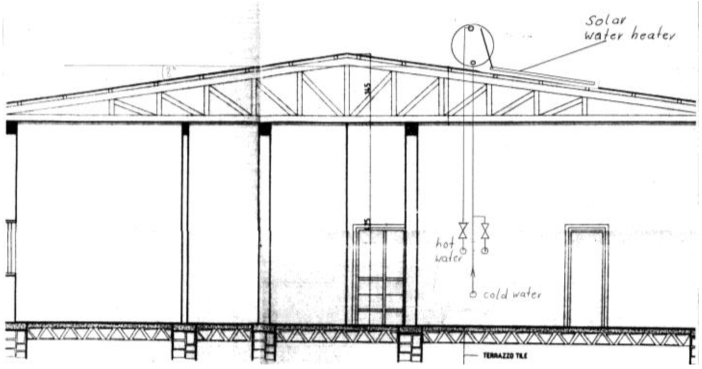
- 20% less solar heat generation if the Collector is directed to the East or West.
- Direction should be checked by means of compass.
- Collectors should not be in the shade at any time of the day.

Use a compass or www.earth.google.com to control of the SWH direction to the sun.



Example: Series of SWH planned on the roof of a Hotel in Gilgit.
Optimum direction of the SWH under the given conditions on site is South-West.

4. Roof stability



In most houses, in particular with concrete roofs, there is no need for a detailed static calculation ensuring roof stability required for the installation of a SWH.

- On roof constructions with corrugated sheet the SWH should be placed on top of the beam and not between two beams.
- If the roof construction is built of welded steel the structure will be strong enough.
- For wooden roof constructions enforcement needs to be considered in order to support the weight of the SWH.

More details on roof load been given in PS 2727-1989: Bases for design of structures - determination of snow loads on roof.

5. Sufficient water pressure after SWH installation

Under the conditions of water supply in Pakistan, integration of a SWH with additional piping into existing house installations will always reduce water pressure and flow rate at the tap.

- Static pressure provided by an overhead tank mounted on the roof of an 8 m (two-storey) building is ~ 0.8 bar.

For a more detailed calculation of the pressure you may refer to the diagrams and tables on page 70.

Flow rate in litres/minute can be simply determined by means of a measuring cup and a watch.

The minimum flow rate at the most remote tap in the building should not be less than 5 l/minute prior to the installation of a SWH system.

General rules for orientation:

- SWH installation will reduce flow rate by 2 – 3 l/minute.
- 20 m additional ½" steel pipe will reduce flow rate by further 2-3 l/minute

SWH shall be installed as close as possible to the overhead tank and the hot water mains in order to avoid excessive additional piping.

6. Integration of backup systems

Compare page 22.

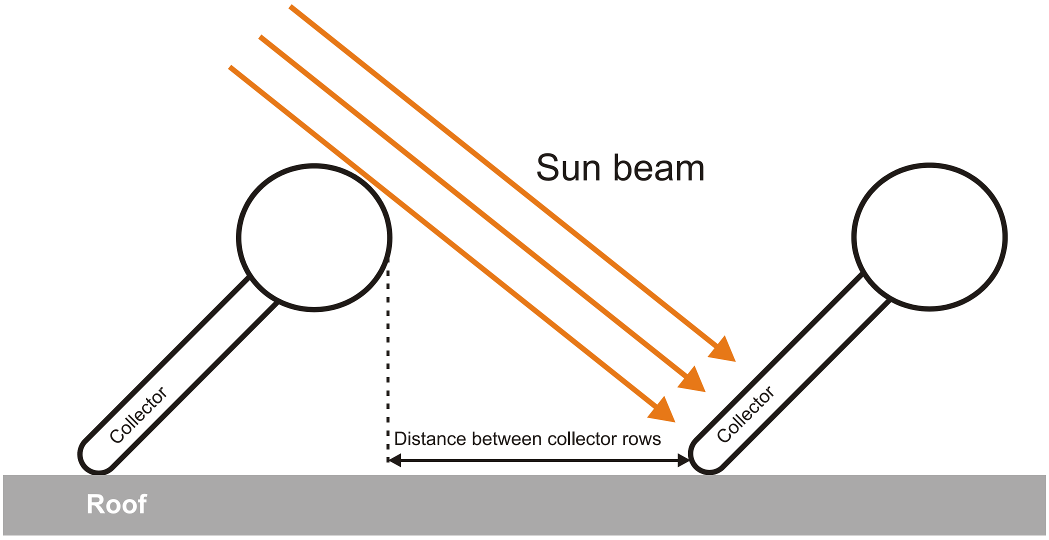
Module 3: Pre-installation check of on-site conditions

1st Step: Check and take corrective measures, if required:

- ☑ Roof is clear for installation.
- ☑ Roof is accessible with equipment and tools.
- ☑ Roof is stable.
- ☑ Roof space is sufficient.

- ☑ Water pressure is sufficient before installation of the SWH (8 l/minute at the most remote tap).

- ☑ Solar collector is directed to the South as far as possible.
- ☑ SWH location is free of shade at all time (no shade from other construction or trees throughout the year).
- ☑ In case of SWH being installed in rows, distance between the SWH rows must be wide enough to prevent SWH from shadowing each other.



- ☑ Overhead tank is above SWH level.
- ☑ Access to hot water mains is ensured.
- ☑ SWH location is placed as close as possible to the overhead storage tank and the hot water mains.
- ☑ Existing pipes are of the appropriate dimension (normally ½ ‘’) and still useable (no visible corrosion).
- ☑ New pipes and connections to existing pipes can be laid in the shortest way (no unnecessary detours).
- ☑ Check the required pipe length, fittings and armatures.

2nd Step: Complete the initial fact sheet (input to detailed application planning):

INITIAL FACT SHEET
Feasibility of Domestic Solar Water Heater (SWH)

Necessary tools:
Measuring meter;
Compass;
Camera;
Watch;
Measuring Jar.

☐ input cell ☐ automatic calculation

Location	Name of the application	picture of location
Street	Street	
City	City	
Owner contact	Owner	
Phone	Phone	
Fax	Fax Nr.	
Email	Email address	

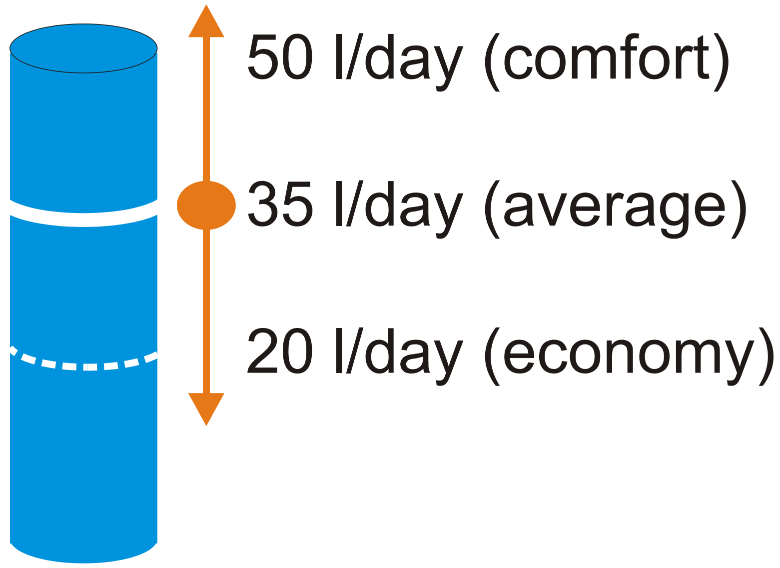
Type of building	single family	x	multi-flat		other:	
No. of floors	1					
No. of hot water lines	4					
Number of Persons	4					
Hot water consumption type	comfort	x	average	x	economic	
Hot water consumption per person per day	50	litre / day				
Calculated total consumption	200	litre / day				
Consumption for SWH design	200	litre / day				
Consumption profile (highest consumption)	morning	x	evening			
Present energy source	Gas					
Type of heater	geyser					
Estimated energy cost per year	30000	PKR per year				
Simplified standard design	2	m2 - collector				
specific collector area per person		m2 - collector per person (deault: 0.5m²)				

IMPORTANT CHECK LIST	ok? Y N	
Is the available roof size sufficient for the installation of the SWH?	Y	Measured: not given
Is the integration of the SWH between the existing overhead tank and the existing hot water lines possible (levels, location, piping) ?	Y	
Is installation of the SWH below the over head tank possible without reconstruction?	Y	
Is the roof construction stable enough to carry the SWH (question rises e.g. when corrugated iron sheet roof is used)?	Y	
Can the SWH be installed South orientation without shadow at any time of the day?	Y	Remarks and recommendations:
Renovation intended, which needs to remove the SWH again?	N	
Can the SWH be easy transported on the roof for installation?	Y	proper stairs lead to roof
Will the water pressure be high enough after installation? ATTENTION: Minimum accepted flow at tap is usually 5 Litr./min.. Installatin of a SWH will reduce flow by approx. 3 Litr./min. Therefore, you need min 8 Litr./min. before installing a SWH.	Y	Present water flow at tap (Please use watch and measuring cup for the measuring of water flow at the tap located on the lowest level in the builiding):

Layout sketch of present installation

Module 4: Design parameters

1. Hot water consumption per person in Pakistan



2. Sizing of collector and tank

Collector surface per person (average):

- Depending on hot water demand per person and on the percentage of energy needed for hot water supply which shall be provided by the SWH (solar fraction). A **rough orientation** may be given by the following figures:
  - Solar fraction 70% ➔ 0.5 m² collector surface per person
  - Solar fraction 100% ➔ 0.9 m² collector surface per person

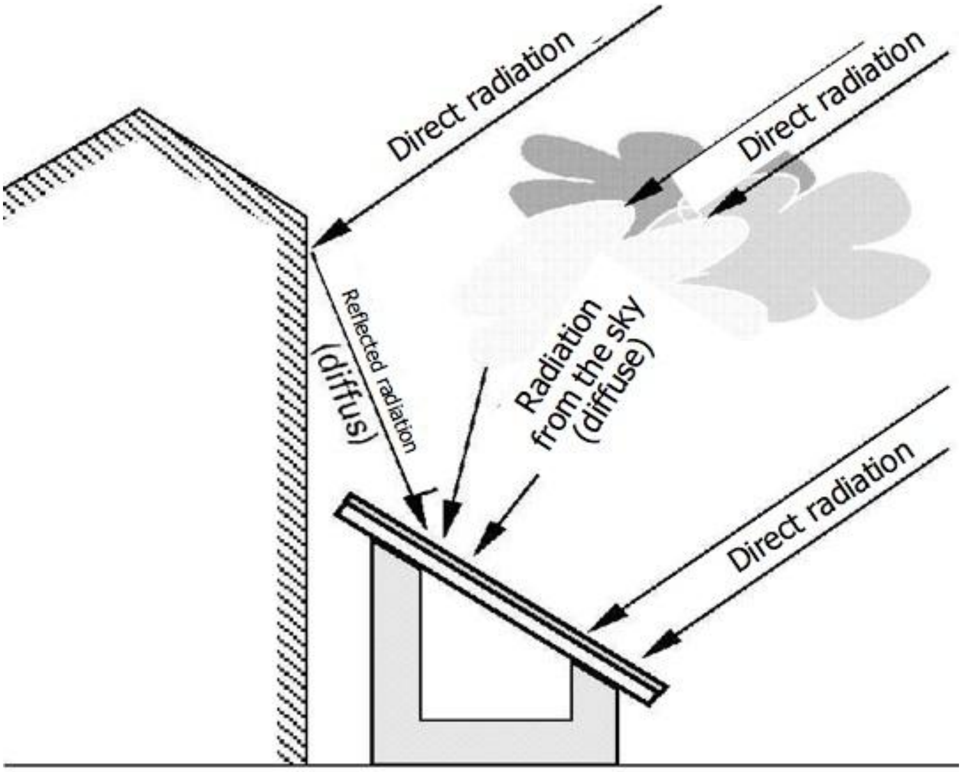
- Vacuum tube collectors do need more storage tank capacity compare to flat plate collectors because of their higher energy product.

  A **rough orientation** may be given by the following figures for thermosiphon SWH:
  - 1 m² vacuum tube collector ➔ **80 litres** storage
  - 1 m² flat plate collector ➔ **60 litres** storage

Excessive storage volume is increasing heat losses and slowing down the reaction time of the SWH (availability of hot water after the start sunshine on the collector).

3. Global radiation

SWH are mainly working with direct radiation from the sun. Vacuum tube collectors can also absorb limited diffuse radiation.

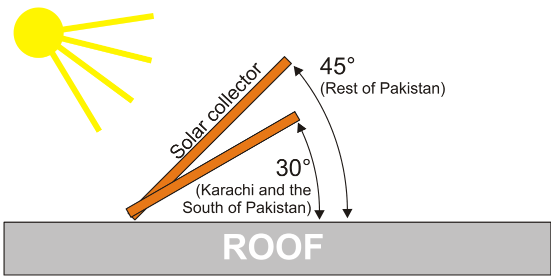


Global radiation includes direct and diffuse radiation. Global radiation varies slightly between different regions in Pakistan.

Islamabad	**2054** kWh/m² per year
Lahore	**1854** kWh/m² per year
Multan	**1920** kWh/m² per year
Karachi	**1985** kWh/m² per year
Peshawar	**2087** kWh/m² per year
Gilgit	**1537** kWh/m² per year

With a global radiation between 1.900 -2.100 kWh/year*m² in most areas, Pakistan is ideal for the use of SWH.

4. Optimum inclination of the collector

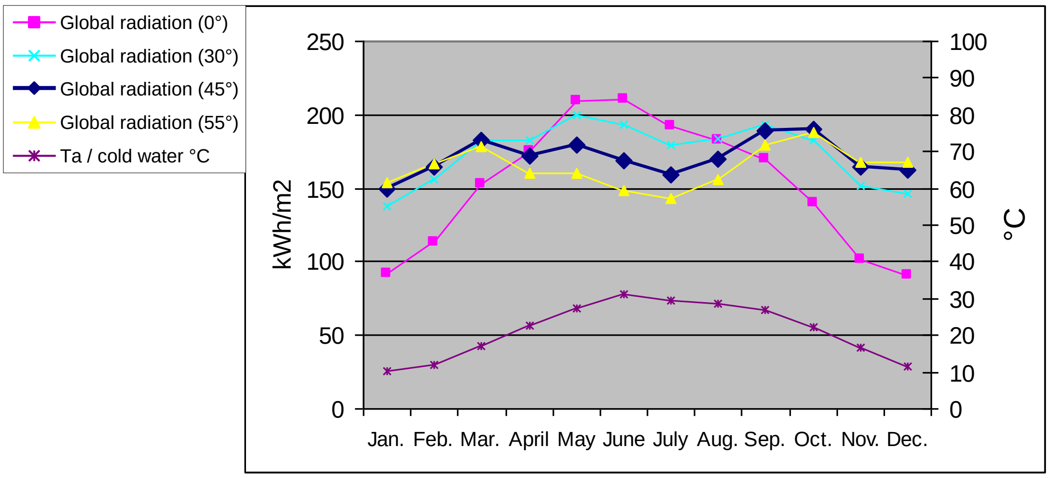


Optimum inclination of the collector is achieved if it the collector makes best use of global radiation in winter month.

Global radiation depending on the inclination of the collector.

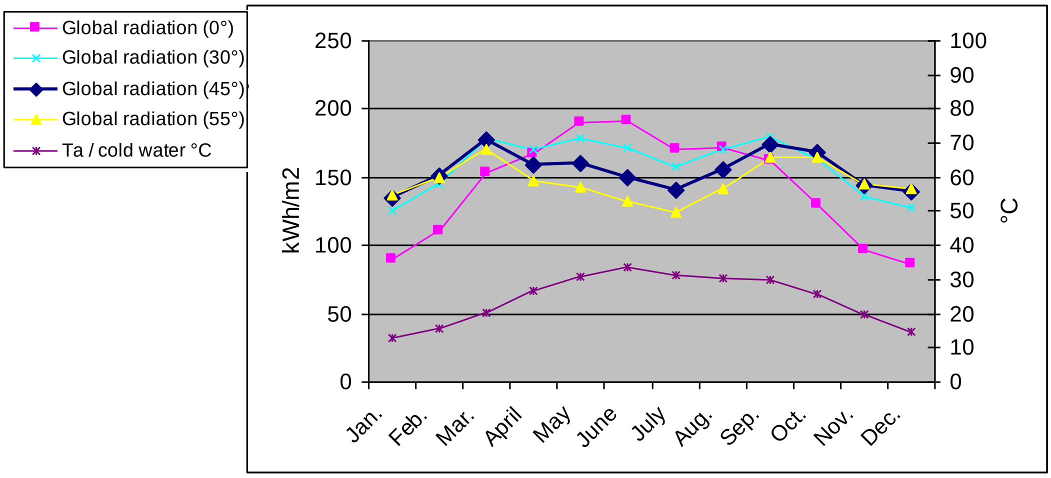
Islamabad

kWh/m2	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Global radiation (0°)	92.1	113	153	175	209	211	192	183	170	140	102	90.8	1831
Global radiation (30°)	138	156	183	183	200	193	179	184	193	183	152	146	2090
Global radiation (45°)	**150**	**165**	**183**	**172**	**179**	**169**	**159**	**170**	**189**	**190**	**165**	**162**	**2054**
Global radiation (55°)	154	167	178	160	160	149	143	156	180	188	168	168	1971
Ta / cold water °C	10.1	12.1	16.9	22.6	27.5	31.2	29.7	28.5	27	22.4	16.5	11.6	



Lahore

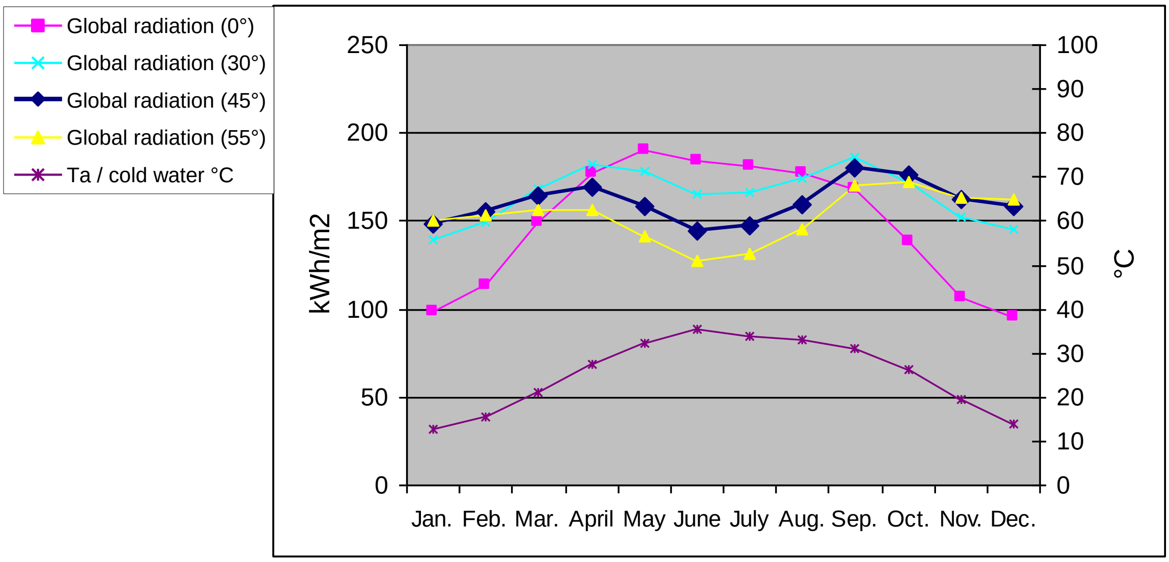
kWh/m2	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Global radiation (0°)	89.3	111	153	167	190	191	171	172	163	130	97.2	86.3	1721
Global radiation (30°)	126	145	179	171	179	172	158	170	180	164	136	128	1908
Global radiation (45°)	**135**	**151**	**177**	**159**	**160**	**150**	**140**	**156**	**174**	**168**	**144**	**139**	**1854**
Global radiation (55°)	137	150	171	147	143	132	125	142	165	165	145	142	1765
Ta / cold water °C	13.1	15.5	20.4	26.7	30.9	33.5	31.2	30.6	29.8	25.7	19.8	14.6	



Global radiation depending on the inclination of the collector.

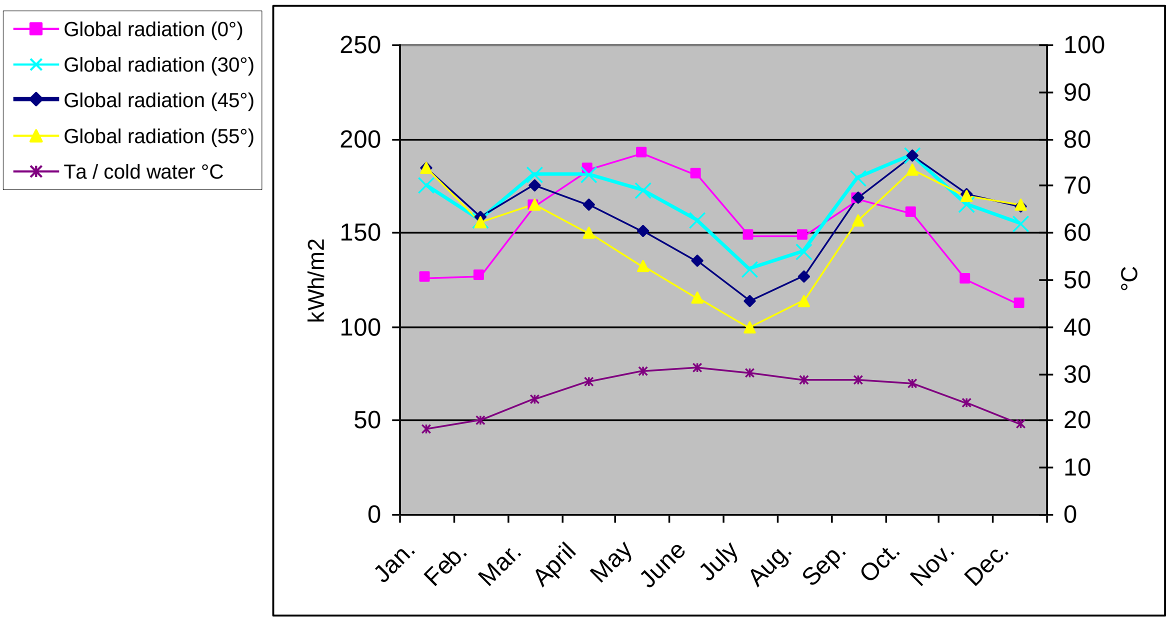
Multan

kWh/m2	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Global radiation (0°)	98.2	114	149	177	190	184	181	177	168	138	107	95.2	1780
Global radiation (30°)	139	149	168	182	178	165	166	174	186	172	152	145	1976
Global radiation (45°)	**148**	**155**	**164**	**169**	**158**	**144**	**147**	**159**	**180**	**176**	**162**	**158**	**1920**
Global radiation (55°)	150	153	156	156	141	127	131	145	170	172	163	162	1826
Ta / cold water °C	12.7	15.4	21	27.5	32.4	35.5	33.9	33	31	26.4	19.7	14.1	



Karachi

kWh/m2	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Global radiation (0°)	126	127	164	184	192	181	148	148	168	160	125	112	1836
Global radiation (30°)	**175**	**157**	**181**	**181**	**173**	**157**	**131**	**140**	**179**	**191**	**165**	**155**	**1985**
Global radiation (45°)	185	159	175	165	151	135	114	127	169	191	171	164	1905
Global radiation (55°)	185	156	165	150	132	116	100	114	157	184	170	165	1796
Ta / cold water °C	18.1	20.2	24.5	28.3	30.5	31.4	30.3	28.9	28.9	27.9	23.9	19.5	



5. Further design criteria

- Direction of the collector to the sun: Compare page 34.
- Water pressure after SWH installation: Compare page 35.

Module 5: Plumbing Techniques

1. Assembly of a standard SWH unit

1. Assemble the stand frame of the SWH on the ground.

2. Put stand frame in position and screw it on the ground to protect it against wind force. Screw storage tank on the stand frame.

3. Connect SWH with cold and hot water line and water lifting pump. Modify existing hot water supply in order to implement the SWH in the existing plumbing.

4. If SWH is going to be installed on a higher level as the overhead tank make sure that water from the SWH can not flow by gravity force in to the overhead tank and air vent pipes are high enough for the water level of the SWH.


5. Insert temperature and level sensor. Connect sensor, pump and magnetic valve with the controller.


6. Insert vacuum tubes in the tank. For simply installation without blocking put soap on the upper side of the tube. If necessary clean the holes from insulation foam with a knife.

Fill the vacuum tubes with water before installation. Without water the vacuum tubes will be heated heat up to 200°C by the sun. When filled with cold water during system start the overheated tubes would break because of temperature shock.

7. Clean the tubes from soap and close the sealing. And clean your installation side after finishing the work!

2. Basic plumbing techniques

- Never install copper pipes before galvanized steel pipes (in direction of water flow).
- Never install steel pipes for cold water piping before storage tanks made of stainless steel (corrosion!).
- Drill holes on corrugated roofs must be closed in a waterproof way (drilling on the crest of wave).

- No mechanical load on the pipe connections of the SWH.
- Flexible pipe connections to and from the SWH are required.

www.dimplex.co.uk

www.uponor-usa.com

- All pipes must be fixed on the building construction (never fix pipes on the SWH structures).
- **No application of spanner force** during connection and sealing of in- and outlets of SWH (sensitive connections).

A plumbers' joke from Germany

- All sealing material used in the collector loop must withstand temperatures more than 150°C for flat plate collectors and 250°C if vacuum tube collectors are used.

3. Critical points

- No dry running of circulation pumps
  (damage of pump).
- No dry heating of electric rods
  (damage of electric rod).
- Compliance to national electric installation code
  (PS 3632-1995)
- Thermal expansion
  must be possible.
- Security installations
  (valves, air pipes, air vales …)
  must always work properly.
- Flexible connection
  between storage tank and pipe
  (protection of sensitive fittings on the SWH tank).
- No mechanical force on SWH connection
- No filling of SWH when vacuum tubs are hot
- DANGER: Hot water of 90°C can burn skin during maintenance work

4. System start-up

System start-up should be performed in the following steps:

(1) Ensure that there is no mechanical load on the fittings of the SWH tank.

(2) Check thermal expansion potential (functionality of security valves, air valves, air relief pipes, back-flow of water into the overhead tank, expansion vessel, as applicable).

(3) Check the vacuum of vacuum tubes.

> **If the low end of the tube changed its colour from silver to white, the vacuum is broken.**

(4) Make sure the vacuum tubes are not heated by the sun before filling. Fill the tubes before mounting or cover the collector area.

(5) Fill the SWH with water

(6) Check the SWH and all pipes and fittings for leakage.

(7) Check if air can exhaust from the SWH.

(8) Check if water pressure is sufficient at all taps (at least 5 litres/minute).

(9) Connect electric rod to the power supply and check proper function.

(10) Switch off backup heater and check if the SWH can heat the water by solar radiation.

> **With clear sky at noon the SWH should increase water temperature by 10°C after one hour.**

(11) Check if hot water is available on all hot water taps as expected by the customer.

5. Installation protocol

For example:

Solar Water Heater (SWH)

Installation protocol

Customer:					
Installation site:					
In charge of installations:					
Supplier:					
Installer:					
Location of Installations:					
Date of Installation:					
Type of System*:		Thermosyphon open loop			closed loop
Type of collector*:		vacuum tube			flat plate
Serial Nr					
Capacity storage tank:		Litre			
Collector area:		m2			
Antifreeze within the collector?		yes/no	Type of antifreeze		
The SWH provides hot water at clear sky, when electric heater / gas heater is switched off					yes
The hot water has the right pressure on the water tape?					yes
The SWH is without leakage?					yes
Installer certification					
I hereby certify that this installation have been installed, tested and approved to					
be in order and function.					
Signature:		Name:	Date:		
Customer acknowledgment					
I acknowledges the installation of this solar water heater and the receipt of the					
necessary instructions in words and writing.					
Signature:		Name:	Date:		
Original: to Owner cc to: Supplier, Installer, manual of owner					
* thick what ever is applicable			Date:		
Date of first maintenance inspection					

Module 6: After sales service & maintenance

1. General safety advice

HANDLE WITH CARE
Water with more than 60°C can burn skin and eyes.

Before checking SWH on unprotected roof construction,
make sure safety equipments are installed.

2. Maintenance schedule

Maintenance schedule	Recommended period of duty
Cleaning collector glass	**Every month and after each dust storm**
Check system operation	**Every 6 months**
Check for leakage	**Every 6 months**
Check scaling / descaling if required	**Every year, minimum**
Check tree growth	**Every 3 years, minimum**
Exchange of anti-freeze	**Every 5 years**

a) Cleaning of collector glass

In areas with high dust deposition efficiency will decrease by 10-30% and regular cleaning is required.

- Use water and a brush for cleaning the collector in order to prevent scratching the surface.
- Cleaning of collector glass will be possible within a general check of SWH function.
- Do not clean reflection mirrors in dry condition as it will destroy the surface and decrease reflection rate.
- Use water and flannel cloth for cleaning the collector (vacuum tube collector as well as flat-plate collectors).

b) Check system operation

SWH is not working properly under clear sky during sunshine hours (with backup heater in stand-by)

- Remove the socket of the electric rod and stop all backup heaters.
- Refill the storage tank with cold water by means of emptying the hot water tape.
- At clear sky at noon the SWH should be able to increase water temperature by 10°C after 1 hour.

c) Check for leakage

Check all fitting connections of the SWH especially after the first month following installation and than every year.

The open loop vacuum tube SWH must be checked for leakage at the connection sealing between storage tank and vacuum tube.

If leakage is detected on the SWH unit, call the supplier.

d) Check scaling and corrosion

Domestic water that is high in mineral content (or "hard water") may cause the build-up or scaling of mineral (calcium) deposits in SWH.

Scaling can occur in

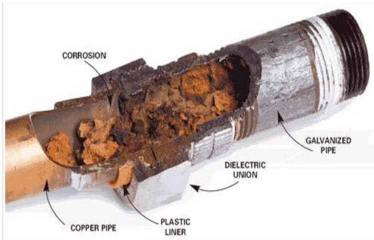
- the collector,
- the electric rod,
- distribution pipes, and
- the heat exchanger.

Scaling starts at water temperatures higher than 57°C in standing water (no flow).

Limestone scaling of pipes

Scaling of electric rod.

Rusted pipes



Galvanic corrosion

In open loop vacuum tube SWH (Design from China manufacturer) scaling is the most problematic inside the vacuum tubes.

The supplier can replace a tube or clean it mechanically or with formic acid or with similar anti-scaling fluids.

Special advice for de-scaling:

- **Lay empty vacuum tubes in the open sun with closed inlet.**
- **Cool down the tube carefully after one hour.**
- **Removed scaling by means of flushing (inserting a water tube) and/or with by means of bottle brush.**

Water hardness	**Period of maintenance (de-scaling)** in order to provide full efficiency
< 200 ppm	Every 5 years
200 to 300 ppm	Every 4 years
> 300 ppm	Every 2 years

Replacing sacrificial anode (only in enamelled storage tanks).

www.ersatzteilfachmann.de

www.bs-wiki.de

Inside enamelled storage tanks a sacrificial magnesium anode protect the tank from corrosion by corrosion first the magnesium. This needs to be replaced according to the condition of the anode.

✷ **In open loop systems electrochemical corrosion e.g. between copper and galvanized steel tubes may destroy the SWH.**

✷ **Oxygen entering into an open loop solar system may cause rust in any iron or steel component.**

e) Check tree growth

Trees and shrubbery can easily grow to shade a SWH within a few years. This will make SWH inefficient.

The trees need to be cut to the original height.

f) Check anti-freeze

(Only for closed loop SWH with flat plate collector).

The appropriate mixture of water and anti-freeze in the closed loop of SWH operating under harsh conditions is depending on the climatic conditions on site:

Anti-Freeze added to the heating fluid	15%	25%	33%	37%	43%
Freezing point	**-5°C**	**-10°C**	**-15°C**	**-20°C**	**-25°C**

Data valid for Antifrogen L Source: Tyfocor

Simple devices which are useful to check the freezing point of the applied mixture are available on the market at low cost.

www.solarplanet.de

www.allproducts.com

www.2kpaints.co.z

When the freezing point of the heating fluid is higher than the extreme winter temperature on site, anti-freeze must be added in a sufficient quantity.

Module 7: Planning Tool

1.1 Presentation of the tool

An excel file with 4 work sheets supporting the design and dimensioning of SWH is presented and its application demonstrated. All participants may receive copies of this Excel file for their personal use for free. The 5 work sheets are shown in the following charts.

- First Step: Collecting initial data during on-site pre-inspection.

INITIAL FACT SHEET
Feasibility of Domestic Solar Water Heater (SWH)

Necessary tools:
Measuring meter;
Compass;
Camera;
Watch;
Measuring Jar.

☐ input cell ☐ automatic calculation

Location	**Name of the application**		picture of location		
Street	**Street**				
City	**City**				
Owner contact	**Owner**				
Phone	**Phone**				
Fax	**Fax Nr.**				
Email	Email address				
Type of building	single family	x	multi-flat		other:
No. of floors	1				
No. of hot water lines	4				
Number of Persons	**4**				
Hot water consumption type	comfort	x	average	x	economic
Hot water consumption per person per day	50	litre / day			
Calculated total consumption	200	litre / day			
Consumption for SWH design	200	litre / day			
Consumption profile (highest consumption)	morning	x	evening		
Present energy source	Gas				
Type of heater	geyser				
Estimated energy cost per year	30000	PKR per year			
Simplified standard design	2	m2 - collector			
specific collector area per person		m2 - collector per person (deault: 0.5m²)			

IMPORTANT CHECK LIST	ok? Y N	
Is the available roof size sufficient for the installation of the SWH?	Y	Measured: not given
Is the integration of the SWH between the existing overhead tank and the existing hot water lines possible (levels, location, piping) ?	Y	
Is installation of the SWH below the over head tank possible without reconstruction?	Y	
Is the roof construction stable enough to carry the SWH (question rises e.g. when corrugated iron sheet roof is used)?	Y	
Can the SWH be installed South orientation without shadow at any time of the day?	Y	Remarks and recommendations:
Renovation intended, which needs to remove the SWH again?	N	
Can the SWH be easy transported on the roof for installation?	Y	proper stairs lead to roof
Will the water pressure be high enough after installation? ATTENTION: Minimum accepted flow at tap is usually 5 Litr./min.. Installatin of a SWH will reduce flow by approx. 3 Litr./min. Therefore, you need min 8 Litr./min. before installing a SWH.	Y	Present water flow at tap (Please use watch and measuring cup for the measuring of water flow at the tap located on the lowest level in the builiding):

Layout sketch of present installation

- Second step: Collecting customer's energy bills of the previous year, if available.

Owner
City
Street

ENERGY BILLS of the house without the new SWH
(per months - most recent available data)

	Power	Gas		
January				
February				
March				
April				
May				
June				
July				
August				
September				
October				
November				
December				

- Third Step: Develop an appropriate SWH layout (proposal) to the customer's needs.

SWH Layout

Owner
City
Street

(white box)	input cell
(shaded box)	automatic calculation

Basic design

	Calculated design	Chosen design	Remarks
Collector area [m²]	1,1	2,0	
No. of collectors	0,5	1	
Storage tank volume [l]	60	210	
Pipe diameter (inch)	1/2	1/2	
Solar gross heat gain	1265	2300	kWh/year
Solar fraction	38%	69%	
Backup heat requiree	2087	1052	kWh/year
Backup integrated in design		YES	

Reasons for deviation of the chosen design from calculated design

Economic

Calculation parameters

Hot water	**200**	**litre / day**	
Required hot water temperature	60	°C	
Meteorological region	Islamabad		
Target solar fraction	30%	-	
Orientation of SWH	30		(S: 0°; W: 90°; E:-90°)
Manufacturer data of SWH:			
Collector type	**Evacuated tube**		
Size of collector surface	**2,00**	m2	
Length of collector	**1,8**	m	
Requ. distance of collector rows	1,9	m	If various rows would have to installed behind each other.
Size of storage tank	**210**	Litres	
Collector efficiency	**0,7**		
System losses	**0,2**	(piping, storage tank)	
Backup			
Backup system	Gas geyser		
Efficiency backup system	0,3		

Settings

Temp. cold water	20	°C
optimal Inclination	30	°
Global radiation per day (Jan.)	4839	Wh/m2 per day
Global radiation per year	2054	kWh/m2 per year
Hot water withdrawal per day	9312	Wh/day
Hot water withdrawal per year	3352	kWh/year
heat capacity of water	1,164	Wh/ K kg
January temperature in the tank	60	°C

Product suggestion:

Manufacturer	NN
Product/Type	Thermosiphon Vacuum tube SWH

- Fourth step: Perform an economic calculation of the proposed SWH layout.

SWH cost and amortisation

Owner
City
Street

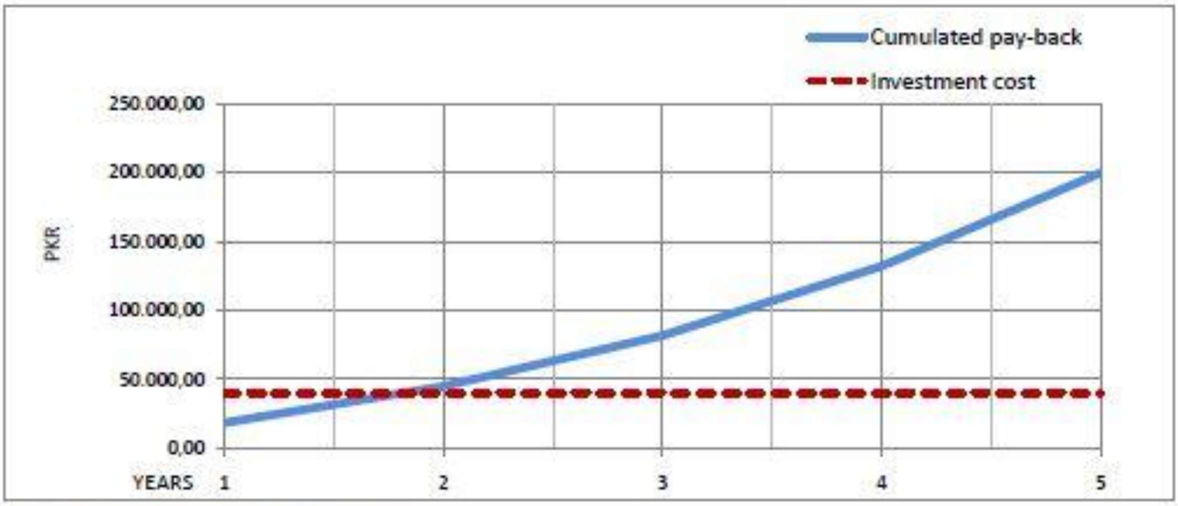
	input cell
	automatic calculation

Cost and Economic estimation

Cost estimation	[PKR]	Remarks
SWH including delivery	30.000	Total average cost
mounting on prepared roof surface with stand frame	included	
Lifting of overhead tank	N.A.	
Pressure pump	N.A.	
Piping including necessary fittings and valves	7.000	
Pipe insulation	2.000	
respective existing hot water pipes	N.A.	
Integration of backup	1.000	
etc.		
Total investment cost	40.000	

Annual savings per year over the life time of the SWH system

Life time of SWH	15	Years
Energy tariff of backup heater	1,02	PKR / kWh
Backup heat	3.507	kWh / year
Annual saving of energy cost	26.423	PKR / year
Interest rate on capital investment	15%	
Annuity of investment per year	6.841,00	PKR / year
Annual maintenance cost	1.000,00	PKR / year
Annual savings in the first year	18.582	PKR / year
Average increase of energy prices (estimated)	30%	per year
Net profit over the first 10 years	1.047.734	PKR / lifetime of SWH



Remarks & recommendations:

- Installation follow-up (if required): Monitoring of the SWH performance.

Monitoring Solar Water Heater (SWH)

Client	Owner
Location	Name of the application
Street	Street
City	City

Collector area	2	m2
No. of collectors	1	
Storage tank	210	Litre

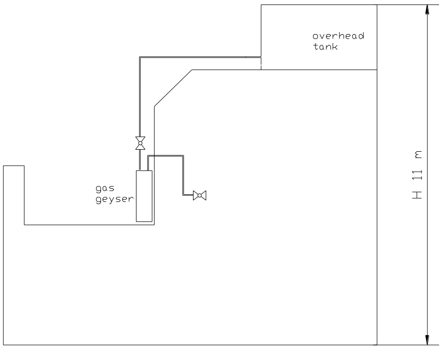
	Monthls	Cumulated annual data (meter readings)					Monthly data			
	expected solar	expected solar	hot water	electric backup	actual solar	actual solar % of expected solar	hot water	electric backup	actual solar	actual solar % of expected solar
Date	[kWh]	[kWh]	m3	[kWh]	[kWh]		m3	[kWh]	[kWh]	
01.01.2010	168	168				0%	0	0	0	0%
01.02.2010	185	353				0%	0	0	0	0%
01.03.2010	205	558				0%	0	0	0	0%
01.04.2010	193	750				0%	0	0	0	0%
01.05.2010	200	951				0%	0	0	0	0%
01.06.2010	189	1140				0%	0	0	0	0%
01.07.2010	178	1318				0%	0	0	0	0%
01.08.2010	190	1509				0%	0	0	0	0%
01.09.2010	212	1720				0%	0	0	0	0%
01.10.2010	213	1933				0%	0	0	0	0%
01.11.2010	185	2118				0%	0	0	0	0%
01.12.2010	181	2299				0%	0	0	0	0%

1.2 Practical demonstration

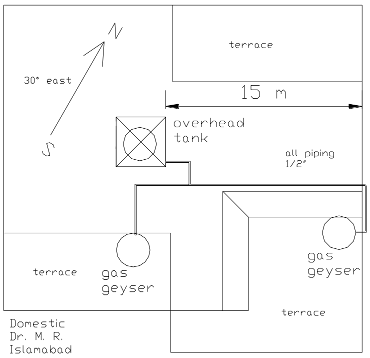
Solve the following planning tasks by means of the planning tool presented above.

a) Case Study: Single-family home in Islamabad

Side view



Top View



Satellite View

2 adults (35 litre per day)

2 children's (10 litre per day)

2 x 150 litre gas geyser

Flow rate at tap: 8 litre / min

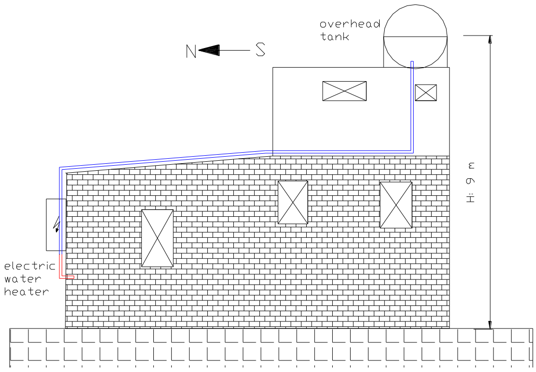
Energy cost per year: PKR30`000.-

Meteorological location: Islamabad

Results & remarks:

b) Case Study: Single-family home in Gilgit

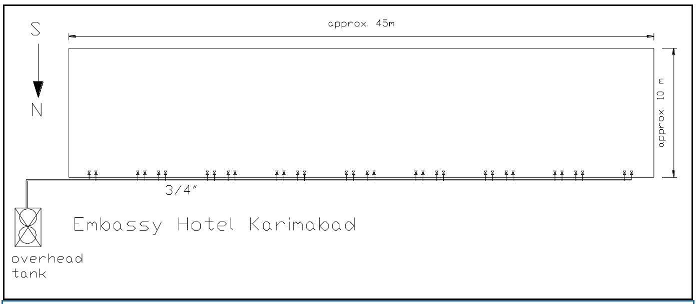


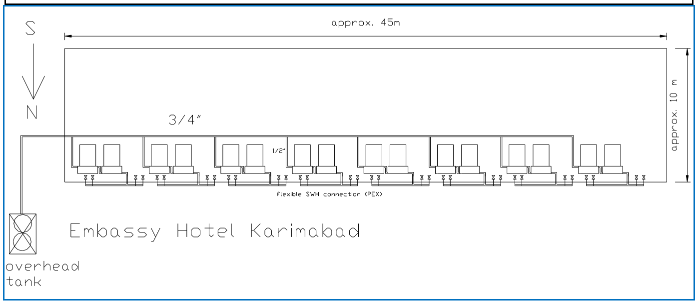



4 adults (25 litres per person)
4 children's (10 litre per child)
1 electric heater
Meteorological location: Gilgit
Flow rate at tap: 6 litre / min
Energy cost per year: PKR18`000.-

Results / remarks:

c) Case Study: Hotel Hunza Embassy





Number of rooms		40
Present		
present energy cost	Rs	424400
tot energy (hot water)	kWh	110067
wood fraction	%	90
Solar		
Expected collector area	m2	
expected SWH capacity	Litre	
tot investment	Rs	
expected energy cost	Rs	
pay back time	a	
running cost reduction	%	
energy reduction	%	

Present energy source:
1000 + 800 Litre wood boiler with electric backup.

Meteorological location:
Gilgit

Flow rate at tap:
8 Litres/min.

Static height:
12 m

Results & remarks:

Checklists and Protocols

1. Tool kits

1.1 Tool kit for pre-installation check:

- ☐ Measuring meter
- ☐ Compass
- ☐ Photo camera
- ☐ Watch
- ☐ Measuring Jar

1.2 Tool kit for SWH installation tool kit:

- ☐ Measuring meter
- ☐ Compass
- ☐ Level
- ☐ Watch
- ☐ Thermometer
- ☐ Measuring Jar
- ☐ Ladder
- ☐ Flexible spanner
- ☐ Drilling machine +
  - Screw driver with cross
  - Drill pit d: 5 to 12 mm
  - Screw driver with line
- ☐ Extension wire
- ☐ Hack saw
- ☐ Soap and pot
- ☐ Cleaning cloth
- ☐ Two pipe wrench
- ☐ Die ½" + ¾"
- ☐ Electric screw driver
- ☐ Cutting oil
- ☐ Knife
- ☐ Measuring meter
- ☐ Nipper
- ☐ Tape
- ☐ Universal pliers
- ☐ Sealing tape

2. Pre-installation check-list

- ☐ Roof is clear for installation.
- ☐ Roof is accessible with equipment and tools.
- ☐ Roof is stable.
- ☐ Roof space is sufficient.

- ☐ Water pressure is sufficient before installation of the SWH (8 l/minute at the most remote tap).

- ☐ Solar collector is directed to the South as far as possible.
- ☐ SWH location is free of shade at all time (no shade from other construction or trees <u>throughout the year</u>).
- ☐ In case of SWH being installed in rows, distance between the SWH rows must be wide enough to prevent SWH from shadowing each other.

- ☐ Overhead tank is above SWH level.
- ☐ Access to hot water mains is ensured.
- ☐ SWH location is placed as close as possible to the overhead storage tank and the hot water mains.
- ☐ Existing pipes are of the appropriate dimension (normally ½ ‘’) and still useable (no visible corrosion).
- ☐ New pipes and connections to existing pipes can be laid in the shortest way (no unnecessary detours).
- ☐ Check the required pipe length, fittings and armatures.

3. Initial fact sheet (result of pre-installation check)

INITIAL FACT SHEET

Feasibility of Domestic Solar Water Heater (SWH)

input cell | automatic calculation

Necessary tools:
Measuring meter;
Compass;
Camera;
Watch;
Measuring Jar.

Location	Name of the application		picture of location			
Street	Street					
City	City					
Owner contact	Owner					
Phone	Phone					
Fax	Fax Nr.					
Email	Email address					
Type of building	single family	x	multi-flat		other:	
No. of floors	1					
No. of hot water lines	4					
Number of Persons	4					
Hot water consumption type	comfort	x	average	x	economic	
Hot water consumption per person per day	50	litre / day				
Calculated total consumption	200	litre / day				
Consumption for SWH design	200	litre / day				
Consumption profile (highest consumption)	morning	x	evening			
Present energy source	Gas					
Type of heater	geyser					
Estimated energy cost per year	30000	PKR per year				
Simplified standard design	2	m2 - collector				
specific collector area per person		m2 - collector per person (deault: 0.5m²				

IMPORTANT CHECK LIST	ok? Y N	
Is the available roof size sufficient for the installation of the SWH?	Y	Measured: not given
Is the integration of the SWH between the existing overhead tank and the existing hot water lines possible (levels, location, piping) ?	Y	
Is installation of the SWH below the over head tank possible without reconstruction?	Y	
Is the roof construction stable enough to carry the SWH (question rises e.g. when corrugated iron sheet roof is used)?	Y	
Can the SWH be installed South orientation without shadow at any time of the day?	Y	Remarks and recommendations:
Renovation intended, which needs to remove the SWH again?	N	
Can the SWH be easy transported on the roof for installation?	Y	proper stairs lead to roof
Will the water pressure be high enough after installation? ATTENTION: Minimum accepted flow at tap is usually 5 Litr./min.. Installatin of a SWH will reduce flow by approx. 3 Litr./min. Therefore, you need min 8 Litr./min. before installing a SWH.	Y	Present water flow at tap (Please use watch and measuring cup for the measuring of water flow at the tap located on the lowest level in the builiding):

Layout sketch of present installation

4. Bill of material (results of pre-installation check)

Material	1/2"	3/4"	1"
GN pipe			
bend			
T-pice			
PEX pipe			
PEX adapter			
Pipe insulation			
Pipe clip			
Nonreturn valve			
Ball valve			
Connector			
Magnetic valve			
Pump			
Level switch			
220V wire (3 pole)			
Sensor wire (2 pole)			
Cable cannel			
Insulation tape			

5. Checklist for system start-up

System start-up should be performed in the following steps:

(1) Ensure that there is no mechanical load on the fittings of the SWH tank.

(2) Check thermal expansion potential (functionality of security valves, air valves, air relief pipes, back-flow of water into the overhead tank, expansion vessel, as applicable).

(3) Check the vacuum of vacuum tubes.

If the low end of the tube changed its colour from silver to white, the vacuum is broken.

(4) Make sure the vacuum tubes are not heated by the sun before filling. Fill the tubes before mounting or cover the collector area.

(5) Fill the SWH with water

(6) Check the SWH and all pipes and fittings for leakage.

(7) Check if air can exhaust from the SWH.

(8) Check if water pressure is sufficient at all taps (at least 5 litres/minute).

(9) Connect electric rod to the power supply and check proper function.

(10) Switch off backup heater and check if the SWH can heat the water by solar radiation.

With clear sky at noon the SWH should increase water temperature by 10°C after one hour.

(11) Check if hot water is available on all hot water taps as expected by the customer.

6. Installation protocol

Solar Water Heater (SWH)

Installation protocol

Customer:				
Installation site:				
In charge of installations:				
Supplier:				
Installer:				
Location of Installations:				
Date of Installation:				
Type of System*:		Thermosyphon open loop		closed loop
Type of collector*:		vacuum tube		flat plate
Serial Nr				
Capacity storage tank:		Litre		
Collector area:		m2		
Antifreeze within the collector?		yes/no	Type of antifreeze	

The SWH provides hot water at clear sky, when electric heater / gas heater is switched off		yes
The hot water has the right pressure on the water tape?		yes
The SWH is without leakage?		yes

Installer certification

I hereby certify that this installation have been installed, tested and approved to be in order and function.

Signature:	Name:	Date:

Customer acknowledgment

I acknowledges the installation of this solar water heater and the receipt of the necessary instructions in words and writing.

Signature:	Name:	Date:

Original: to Owner cc to: Supplier, Installer, manual of owner

* thick what ever is applicable — Date:

Date of first maintenance inspection

7. Maintenance protocol

Solar Water Heater (SWH)

Maintenance protocol

Customer:					
Installation site:					
In charge of installations:					
Supplier:					
Installer:					
Location of Installations:					
Date of Installation:					
Type of System*:		Thermosyphon open loop		closed loop	
Type of collector*:		vacuum tube		flate plate	
Serial Nr					
Capacity storage tank:		Litre			
Collector area:		m2			
Antifreeze within the collector?		yes/no	Type of antifreeze		
Check list of maintenance work to be done:					
The SWH provides hot water at clear sky, when electric heater / gas heater is switched off					yes
The backup is working properly only at cloudy weather					yes
The hot water pressure on the tape is in full satisfaction					yes
The SWH and the piping is without leakage, therefore no water get lost.					yes
Installer certification					
I hereby certify that this solar water heater have been checked, tested and approved to					
be in order and function.					
Signature:		Name:	Date:		
Customer acknowledgment					
I acknowledges that this solar water heater provides hot water to my full satisfaction.					
Signature:		Name:	Date:		
Original: to Owner cc to: Service provider					
* thick what ever is applicable			Date:		
Date of next maintenance inspection					

8. Calculation of pressure drop per pipe length

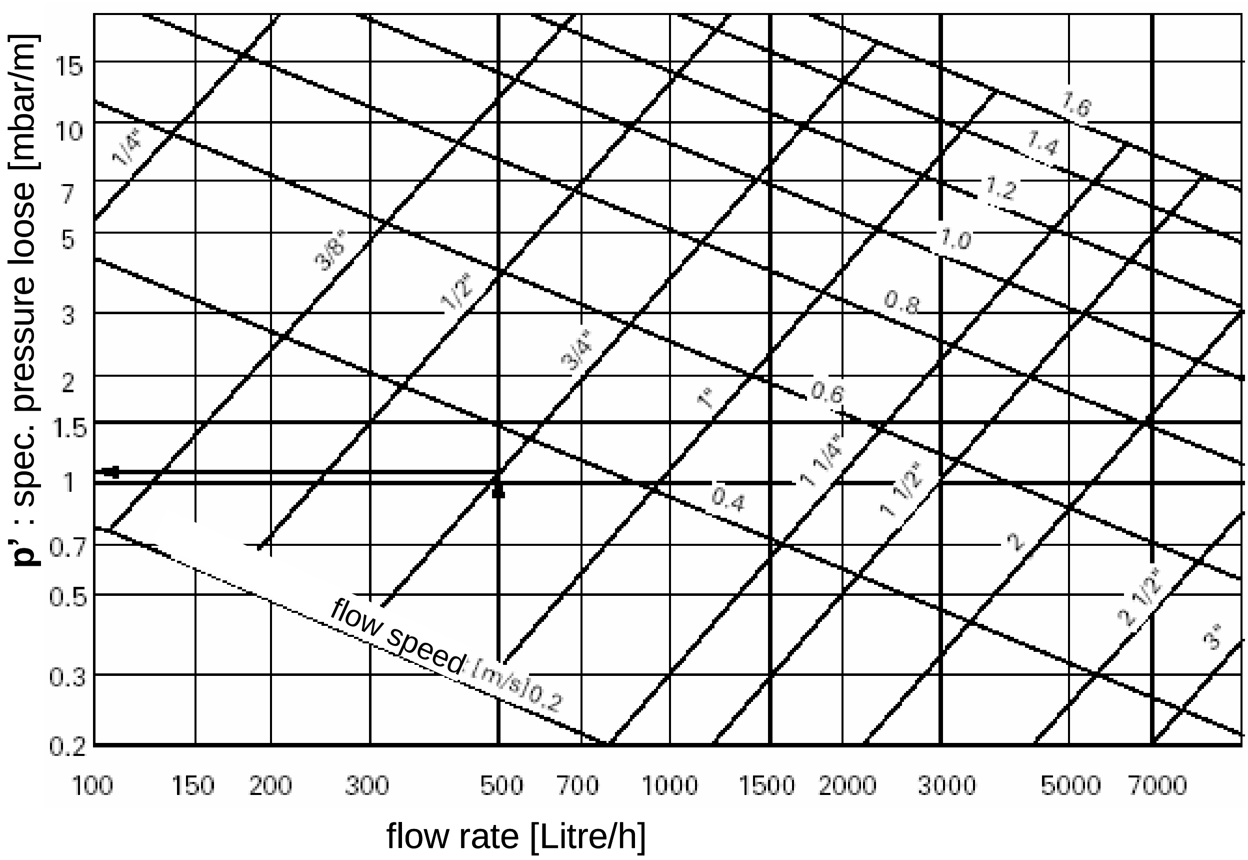


Diagram indication pressure loss per meter of steel pipe in correlation to water flow rate and pipe diameter.

type of fitting	diameter of pipe ½"	¾"	1"	5/4"	1½"	2"	2½"
		Ln: equal pipe length in m					
90° bend	0,3	0,4	0,4	0,5	0,6	0,7	0,9
90° angle	0,3	0,4	0,6	0,7	0,8	1,1	1,4
T-piece 90°	0,5	0,7	0,9	1,2	1,4	1,7	2,4
T-piece 90°	0,4	0,5	0,6	0,9	1,0	1,2	1,7
T-piece 90°	1,3	1,8	2,5	3,4	4,1	5,4	7,5
ball valve	3,5	6,0	8,0	10,9	13,0	16,0	23,0
water tap	1,5	1,5	1,5	2,0	2,5	3,5	4,5

Pipe length equivalents of additional fittings and bends with regard to pressure loss.