Final Report

Assessment for the Implementation of Solar Water Heaters to Hotels, Hospitals and Other Commercial Buildings in Addis Ababa



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DANAS Electrical Engineering

Addis Ababa, Jemo 01 near glass factory

danasrat@yahoo.com

+251911203050/ +251920717137

+251118120376

Addis Ababa, Ethiopia

EXECUTIVE SUMMARY

Addis Ababa, the nation's capital city, consumes significant portion of the electrical energy and power demand of the country owing to its population, large number of residential houses, commercial and public buildings, industrial premises and presence of national and international organization's offices and buildings. There exists a high electric energy consumption and power demand for water heating purposes at these premises, the prominent ones being Hotels, Hospitals and Commercial buildings, due to the hot water demand and large concentration of electric water heaters in these premises. The power demand and consumption of the electric water heaters affected the electric power supply infrastructure in the city by demanding high power and overloading the network.

The purpose of the study is to assess the existing conditions of electric water heating technologies at Hotels, Hospitals and Commercial buildings in Addis Ababa, conduct the feasibility of solar water heating systems and propose implementation measures. The study was conducted through collecting data at sample Solar Water Heater users and non-user hotels, hospitals and big buildings, importers/Installers and government institutions. Data analysis was done using SPSS version 26, and techno-economic feasibility was carried out using RETScreen Version 8 software. Review of existing legalizations, international experiences on Solar Water Heater implementations, and market barriers assessment have been conducted to establish proposed implementation measures.

Existing water heating technologies used at the premises in the city comprise of electric water heaters - 83.4%, Solar Water Heaters - 7.0%, Heat Pumps - 5.7%, Fossil fuel burner - 0.8 %, Fossil fuel burner and Heat pump - 0.2%, non-users - 2.9%. The installed capacity of electrical water heaters and energy demand for water heating is estimated to be 41.1 MW ad 18.7 GWh/year, respectively. The total installed gross collector area is estimated to be 1,358.9 square meter having equivalent thermal energy of 714 kW_{th}.

The lack of solar water heaters regulation and product standard, building mandates, and quality control on imported and locally manufactured products are determined to be the major reasons for the very small solar water heater market and its low adoption. Improper installations, absence of certification for designers and installers, shorter warranty period, poor after sales service, and lack of financial incentives, financing mechanisms, and awareness are additional reasons for the low adoption of solar water heaters.

The feasibility analysis of the flat plate and evacuated tube type SWH system for small scale water heating indicated that FPC type SWH system has shorter Equity Payback period of 7.1 years and higher pre-tax IRR-equity 17.5%. For large scale water heating, the Flat plate Collector has lowest Equity Payback period of 9.3 years and highest pre-tax IRR-equity 19.6%, compared to the Evacuated tube Collector and the Heat Pump system. The Flat Plate Collector is the most economically attractive water heating technology followed by the Evacuated Tube Collector and the Heat Pumps for large scale water heating.

Replacing the existing Electric water heaters in the premises by solar water heaters could bring an estimated energy consumption saving of 11.2 GWh/year equivalent to saving of birr 23.8 million Birr/year if consumed locally or USD 0.784 million/ year if the energy is exported. The implementation of solar water heaters would save power demand of 29.7 MW having monetized cost of power generation value of 35.7 million USD. The total solar water heaters collector area which could be installed at the hotels, hospitals, and big buildings in the city is estimated to be 14,926 square-meter which will equate to 171,649 woman/man - days of job creation over the 20 years life time of solar water heaters.

An eight-year solar water heaters implementation schedule has been proposed covering: awareness creation; development of standard and regulation, training manual, training for installers; implementation of Pre-Export Verification of Conformity, building mandates and Utility mandates, financing and financial incentives; and targeted replacement of instant, stand-alone and centralized electric water heaters at all premises by cascaded collector or centralized solar water heaters. It is proposed that Financing of the SWHs implementation could be based on upfront capital incentives at the beginning and followed by performance-based financing with revolving fund business model along with Partial Credit Guarantee (PCG) at the early stage and the Energy performance contracts-shared and guaranteed saving models (ESCOs) thereafter. The target implementation proposed and the suitability of trending renewable technologies of Heat Pump, Heat pump assisted SWHs, PVT water heaters and PV assisted Heat Pump shall take place on a case-by-case study basis.

Based on the assessment made replacing the existing EWHs by SWHs would save significant power demand and energy consumption for water heating in the city. The existing SWHs market is quite low, unregulated and there is a strong need for the proper regulatory framework, financing and awareness creation for the implementation of SWHs at the premises in the city.

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ABBREVIATION AND ACRONYMS

BoS	Balance of System
CIF	Cost, Insurance, and Freight
CoP	Coefficient of Performance
CSA	Central Statistical Agency of Ethiopia
CTE	Codigo Tecnico de la Edificacion
DAS	Data Acquisition Systems
EBC	Ethiopian Building Code
EC	Ethiopian Calendar
ECC	Ethiopian Customs Commission
EEA	Ethiopian Energy Authority
EEP	Ethiopian Electric Power
EEU	Ethiopian Electric Utility
EPP	Equity Payback Period
ES	Ethiopian Standard
ESA	Ethiopian Standards Agency
ESCOs	Energy Service Companies
ETB	Ethiopian Birr
ETC	Evacuated Tube Collector
ETSAP	Energy Technology Systems Analysis Program
EU	European Union
EWH	Electric Water Heater
FDRE	Federal Democratic Republic of Ethiopia
FFB	Fossil Fuel Boiler
FPC	Flat Plate Collector
GHI	Global Horizontal Irradiation
GIZ	Gesellschaft für Internationale Zusammenarbeit
GSWHP	Global Solar Water Heating Project
GTP	Growth and Transformation Plan
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit
GWh	Gigawatt Hours
HP	Heat Pump

HS	Harmonized Commodity Description and Coding Systems
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
IRR	Internal Rate of Return
ISO	International Organization for Standardization
kW	Kilowatt
kWh	Kilowatt hours
MENA	Middle East and North Africa
MoWIE	Ministry of Water, Irrigation and Energy
MW	Megawatt
MWh	Megawatt hour
NASA	National Aeronautics and Space Administration
NERD	National Engineering Research and Development
NGO	Non-Governmental Organization
NMA	National Metrology Agency
NPV	Net Present Value
OECD	Organization for Economic Co-operation and Development
OR	Occupancy Rate
PCG	Partial Credit Guarantee
PV	Photovoltaics
PVoC	Pre-export Verification of Conformity
RCREEE	Regional Center for Renewable Energy and Energy Efficiency
ROHS	Restriction of Hazardous Substance
SCoP	Seasonal Coefficient of Performance
SF	Solar Fraction
SHS	Solar Home System
SMEs	Small and Medium-Sized Enterprises
SPP	Simple Payback Period
SWH	Solar Water Heater
TÜV	Technischer Überwachungsverein
TVET	Technical and Vocational Education and Training
UK	United Kingdom
UN	United Nations

UNDP	United Nations Development Program
UNE	Asociación Española de Normalización
UNEP	United Nations Environment Program
USA	United States of America
USD	United States Dollar
UV	Ultraviolet
VAT	Value-Added Tax
WH	Water Heater

1. INTRODUCTION

1.1. Background

The demand for electricity in the world, especially in urban areas, is growing rapidly as it can be used for a variety of applications, such as cooking, water heating, lighting, refrigeration, etc. However, enormous amounts of scarce capital are being invested in its generation, transmission and distribution (Tamerat and Nasir, 2020).

Solar energy is considered as a key renewable energy source in future sustainable energy systems to replace electricity generated from other sources because it is abundantly available and can be transformed into other energy without causing much environmental pollution or emitting greenhouse gases. Solar thermal, solar photovoltaic and solar chemical technologies are among the technologies developed to harness solar power. Within the solar thermal, the solar water heater (SWH) has the longest history, and is the most widely deployed (Li, Rubin and Onyina, 2013).

In Ethiopia, the major energy sources of hot water production are electricity, imported oils, and firewood, and heavy dependence on these resources has several implications for Ethiopia (Alemnew, 2018). Addis Ababa, the nation's capital city, consumes significant portion of the electrical energy and power demand of the country owing to its population of 3.7 million (projected in 2021, (CSA, 2013)), large number of residential houses, commercial and public buildings, industrial premises and presence of national and international organization's offices and buildings. The city consumed 29% of national energy consumption in 2019/2020 (computation from EEU 2019/20 data). There exists a significant electric energy consumption and power demand for water heating purposes to serve the premises in Addis Ababa. The Hotels, Hospitals and other Commercial buildings in the city are believed to consume and demand larger portion of electrical energy and power for water heating as there is high concentration of electric water heaters in these premises.

The high peak power and energy consumption of electric water heaters and the increase in the price of electricity in Addis Ababa makes the search for an alternative source of thermal energy for water heaters to be critical.

The use of fossil fuel and biomass for water heating is not possible considering the present scarcity of these fuels, and relatively high initial cost of such heaters and their health and environmental impacts. Solar Water heating systems can be considered as a viable alternative under these circumstances to partially offset the impacts due to electric water heaters (Abebayehu and Demiss, 1992). SWHs could serve as a support for the reduction of peak demand and peak loads (GTZ and EEA, 2010) and represent an untapped renewable energy resource and market opportunity for many cities in developing countries (UNEP, 2015).

The annual average radiation in Addis Ababa is estimated to be 5.0 $kWh/m^2/day$ and the monthly Average Solar Global Irradiance (GHI varies from a minimum of 3.73 $kWh/m^2/day$ to a maximum value of 5.65 $kWh/m^2/day$ (Bole International Airport Synopsis center/NASA ground climate data source). This amount of radiation could be used for solar water heating in the commercial premises of Addis Ababa effectively if a proper SWH technology is selected and implemented effectively.

This study assesses the existing condition of water heating systems at Hotels, Hospitals and other Commercial buildings in Addis Ababa, reviews water heating technologies and the current policy, legal and institutional framework regarding SWHs, global experiences, conduct feasibility and proposes measures for the implementation of SWHs in the city.

1.2. Objective and Scope of the Study

1.2.1. Objectives of the study

The objective of the study is to conduct assessment for the implementation of SWH systems in Hotels, Hospitals and Big Commercial buildings in Addis Ababa.

The specific objectives to be undertaken include:

a) Assess the existing condition of EWH and SWH in use.
b) Assess best practices and possible approaches that could be adopted for the implementation of SWH
c) Feasibility study of replacing existing electric energized water heaters by solar water heaters
d) Assess the institutional, financial, financial mechanism, technical and environmental issues of implementation of SWH
e) Identify the key constraints facing the implementation of SWH projects

1.2.2. Scopes of the study

The scopes of the study are:

a) Review of SWH best practice installation programs that have taken place so far internationally and proven successful.

b) The assessment of the existing condition will include the type and total number of electric water boilers in the city, estimate the electricity consumption share of electric water heaters in the city, compare the electric water boiler with a solar water heater based on energy saving aspects, and identify immediate factors and potential type of customers where the investment is reliable with cost benefit.

c) Compare the electric energized water heaters with solar water heater based on energy saving aspects and indicate the investment cost and payback period if new solar water heater is installed in Hotels, Hospitals and Other Commercial Buildings in Addis Ababa.

d) The assessment for the implementation of SWH will include:

- Survey of the key participants and/or stakeholders associated with SWH installation programs.
- Detailed report that SWH is in line with Regulatory laws and regulations.
- Assess opportunities for sustainable local job creation as a result of the identified implementation projects and propose options for their realization. The expected number and types of jobs, as well as the detailed skills development requirements.
- The review and survey should also indicate the key issues related to the following: (i) pre-installation processes/procedures that have typically been followed; (ii) installation processes to test for conformance to some standard; (iii) the post-installation phase, including SWH system performance, maintenance and related customer support. As part of this activity factors that include, but are not limited to, capacity, implementation arrangements, marketing, technical and finance.
- Assessment and analysis of details testing protocols of the SWH
- Make suggestions on financial structuring and financing.

2. OVERVIEW OF WATER HEATING SYSTEMS

2.1. Hot Water Energy Consumption

As shown in Figure 2-1, about 60% of the global electricity consumed in building is used for heating and cooling application. Water heating in buildings consumed around 17 EJ, 18% (3.06 EJ) of which was from electricity (IRENA, OECD and IEA, 2020). The energy requirement for domestic hot water is responsible for around 22%, 16% and 23% of the total household energy requirement in the UK, European Union (EU) and Australia respectively (Nair et al., 2018). In Africa, water heating and cooking consume relatively high levels of electricity (Figure 2-2).

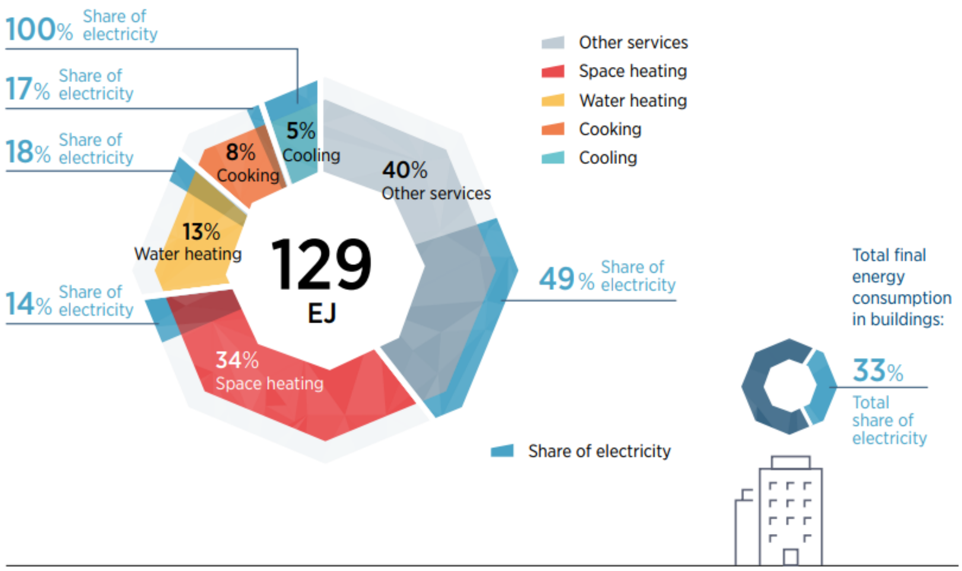


Figure 2-1: Global share of electricity in buildings by service, 2019 (IRENA, OECD and IEA, 2020)

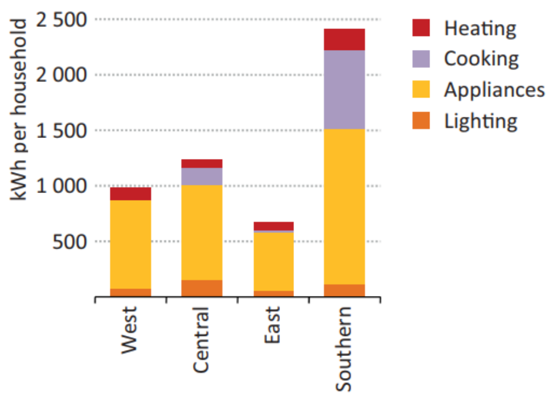


Figure 2-2: Average electricity consumption per household in Africa, 2012 (IEA, 2014)

2.2. Hot Water Generating Approaches

Hot water can be generated using solar energy, electricity, gas, a wetback system, or a heat pump water heater. These energy sources are used to raise the temperature of cold water from the water system before use.

2.2.1. Electric storage tank water heater (ESTWH)

The ESTWH has two functions: to heat water using electrical energy and storing the hot water the time it is required. Electrical energy is supplied to electrical resistive elements within the storage tank. Current flows through the elements in order to create heat and this thermal energy is exchanged to the surrounding water. The process gradually increases the thermal level of the entire water mass within the storage tank water heater. A thermostat maintains a certain thermal level set by the user.

2.2.2. Heat pump water heater (HPWH)

The HPWH extracts ambient energy from the surrounding air in order to heat water. This method of water heating is more efficient than any other electrical source water heater. Other electricity-based water heaters convert electrical energy into thermal energy, whereas the heat pump water heater solely transfers the thermal energy from one place to another. HP has low energy consumption approximately two thirds less than resistive element water heaters, due to the coefficient of performance (COP). The COP describes the ratio of useful heating (or cooling) provided to the work required. If work was to be converted to heat, the COP would be equal to one, assuming 100% efficiency. Rather, the HPWH transfers additional heat from external sources, to increase operating efficiency (Hohne, Kusakana and Numbi, 2019).

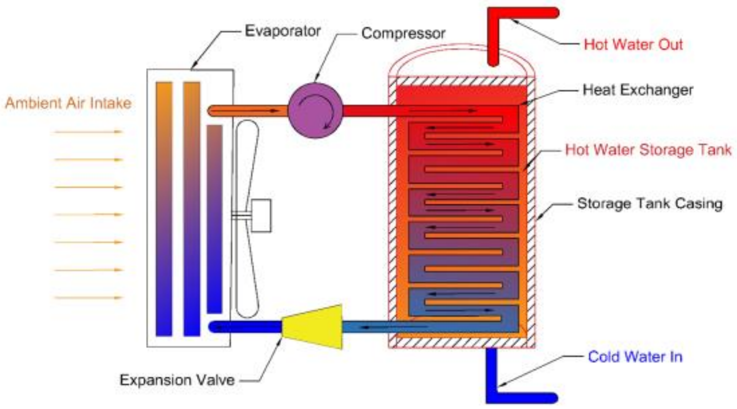


Figure 2-3: Heat pump water heater (Hohne, Kusakana and Numbi, 2019)

2.2.3. Oil-fired water heater (OFWH)

Oil-fired water heater ignites oil/diesel in order to initiate combustion. Oil is forced under pressure through a nozzle to the combustion chamber, so that a fine spray, or atomization, may take place. The major component of this system consists of a converter and a motorized fan. The motorized fan is attached to the converter system which contains an ignition transformer. The transformer creates a spark to ignite the atomized oil, while air is supplied by the fan system at the end of a blast tube or combustion chamber. The air and oil mixture are carefully regulated in order to heat the water to a specified level. Heat from the combustion chamber travels to the heat capturing fins. Cold water is supplied to the oil-fired water heating system and the heating fins transfer thermal energy to the water. The heated water is subsequently fed to the storage tank and ready for use by the hot water consumer (Hohne, Kusakana and Numbi, 2019).

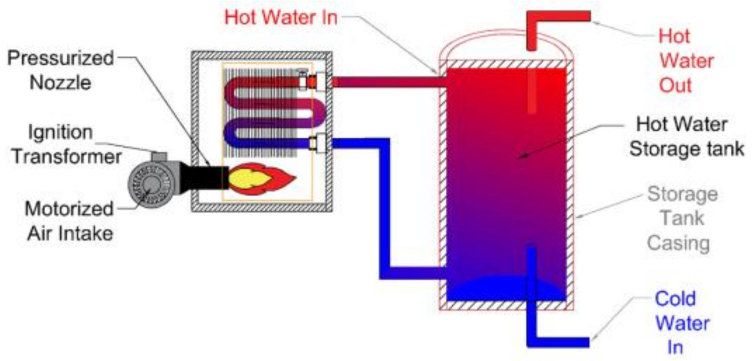


Figure 2-4: Oil-fired water heater (Hohne, Kusakana and Numbi, 2019)

2.2.4. Biomass water heater (BWH)

Biomass consists of any material of organic origin. Burning organic material may release energy used in water heating applications. The organic material is usually processed from wood sources and formed into equally sized pellets. These pellets are carbon neutral as a renewable energy source, meaning that the amount of CO_2 released while burning the pellets are equal to the amount that was absorbed during the growth or development of the tree/plant, from which the organic material was extracted. The biomass is supplied to a furnace through a pellet feeder system, the pellets are thereafter burned in the furnace, which is surrounded by the water that should be heated. Therefore, the area adjacent to the furnace acts as a heat exchanger, which heats water directly. The heated water travels to the storage tank to be consumed by the hot water user.

Some of the more common energy sources for water heating are listed in Table 2-1. Solar water heater will be discussed in detail in later in the section below.

Table 2-1: Comparison of some hot water generation approaches (Deevela and Kandpal, 2021)

Attribute	Water heating approach based on					
	ESTWH	OFWH	SWHs	Waste heat recovery water heaters	HPWH	BWH
Storage of water	Optional	Essential	Essential	Optional	Essential	Essential
Capital cost	Low	Medium	High	Medium	Very high	Medium
O&M cost	High	High	Low	Medium	Low	High
Useful life (Years)	10-15	10	20	10-15	10-15	10
Efficiency (%)/ CoP	90-95	70-85	40-60	60-70	3.0-4.5[a]	60-75

[a] COP (Coefficient of Performance)

2.3. Solar Water Heating Systems and Technologies

Solar water heaters (SWHs) collect solar radiation from the sun and convert that radiation to thermal energy and store it for future use. Because hot water demand is typically greater in the morning or late evening and does not coincide with times of maximum solar radiation, a SWH system is normally supplemented with a conventional system that provides additional heating as needed and when solar is not available. A solar water heater system contains five essential components (Hudon, 2013):

1. Solar thermal collector: typically, flat plate or evacuated tube;
2. Heat transfer system: piping and valves for liquids, pumps and heat exchangers, if necessary;
3. Storage system to store the thermal energy produced by the collectors;
4. Control system to manage the collection, storage and distribution of thermal energy;
5. Auxiliary hot water heating system to provide supplemental heat when solar energy is not sufficient to meet the demand. This is typically a conventional electric resistance or natural gas storage tank water heater, but tankless water heaters are also being used more frequently.

Figure 2-5 presents a schematic of typical solar water heater system.

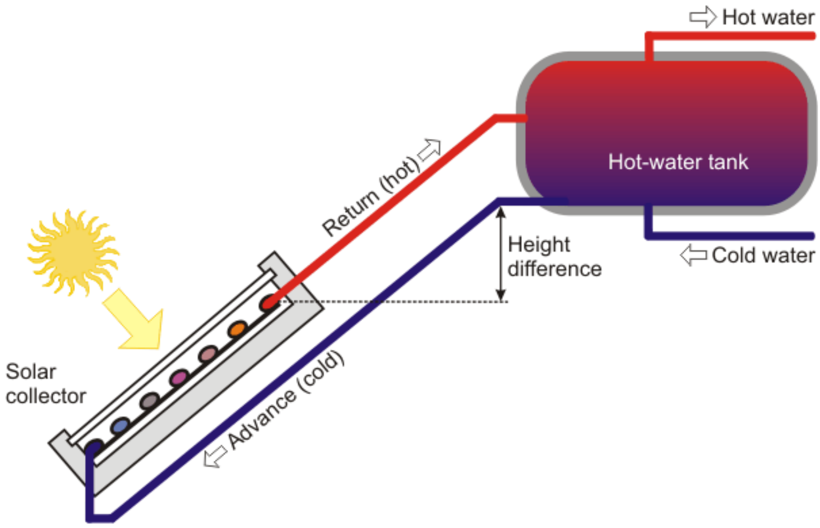


Figure 2-5: Schematic of typical solar water heater system (Luo et al., 2018)

2.3.1. Solar water heating collector

The collector is the heart of the solar water heating system. There are many different types of collectors, but all of them shared a common construction feature. The most common and simplest of these devices uses a black material and surrounding pipes that water flows through. The black material absorbs the solar radiation very well, and as the material heats up the water inside the pipes gets heated. This is a very simple design, but collectors can get very complex. Solar collectors, depending on their design features, can generate temperatures of more than 400°C using mirrors, lenses and trackers, but for domestic hot water applications, mainly low- to low-medium temperature collectors (below 150°C) are used. Currently, there is a large variety of designs and different types of solar collectors on the market, which can be classified in two main categories (IEA-ETSAP, 2015): Flat plate collector and Evacuated tube collector.

a) Flat plate collector (FPC)

A typical flat-plate solar collector is shown in Figure 2-6. It consists of tubes carrying a fluid running through an insulated, weatherproof box with a dark absorber material and thermal insulation material on the backside that also prevents heat loss. The simplest collector is an unglazed collector without backside insulation, typically used for low-temperature applications, while glazed flat plate collectors have higher efficiencies, lower heat loss, high working temperatures, and higher initial cost.

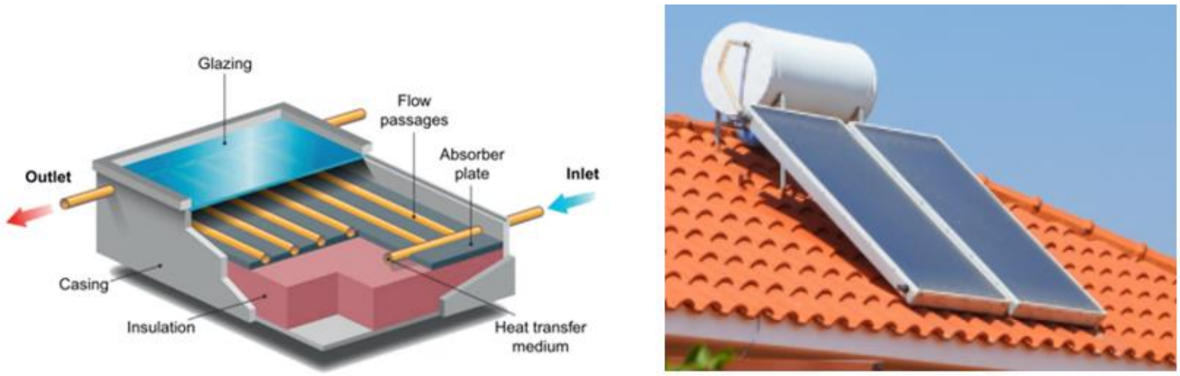


Figure 2-6: Typical flat-plate collector (Hudon, 2013)

b) Evacuated tube collector (ETC)

A typical evacuated tube collector is shown in Figure 2-9. ETC use parallel rows of glass tubes, each of which contains either a heat pipe or another type of absorber, surrounded by a vacuum. The vacuum between the tubes reduces to minimum the heat losses by convection and conduction, thus allowing obtaining superior performances (Sarbu and Adam, 2011; IEA-ETSAP, 2015). Currently, the solar thermal industry manufactures a large variety of evacuated tube collector concepts. But they have similar technical attributes (Weiss and Rommel, 2008):

- A collector consists of a row of parallel glass tube.
- A vacuum (10^{-2} pa) inside every single tube extremely reduces conduction losses and eliminates convection losses.
- The form of the glass is always a tube to withstand the stress of the vacuum.
- The upper end of the tubes is connected to a header pipe.

Evacuated tube collectors can be classified in two main groups:

i. **Direct flow tubes (non-pressurized)**

The traditional type is a collector with separated tubes for fluid inlet and fluid outlet. Besides this type, also collectors with concentric inlet and outlet pipes are manufactured. This means, that only the fluid outlet pipe is connected to the absorber. The pipe for fluid inlet is located inside the outlet pipe. The fluid flows back between the outer surface of the inner pipe and the inner surface of the outer pipe. A new type of concentric pipe configuration is the Lenz tube shown in Figure 2-7.

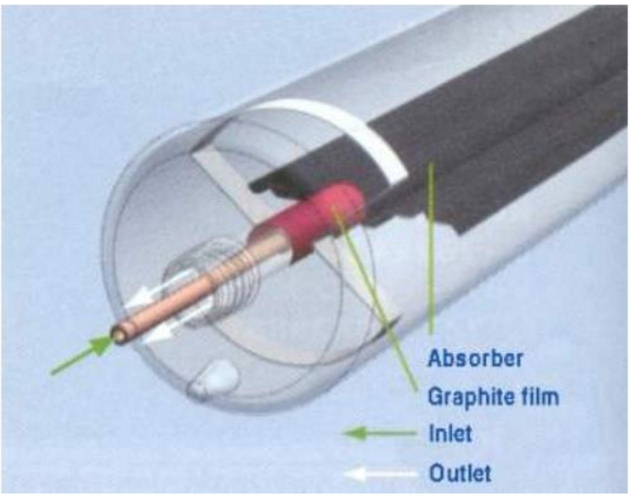


Figure 2-7: Function and design of the Lenz tube (AEE-INTEC, 2009)

Currently the most common type is the Sydney tube collector shown in Figure 2-8. It consists of two glass tubes fused together. The vacuum is located between the two tubes. The outside of the inner tube is usually coated with a sputtered cylindrical selective absorber (Al-N/Al). Inside of the inner pipe, the heat is removed by copper u-tubes, which are embedded in a cylindrical (aluminum) heat transfer fin.

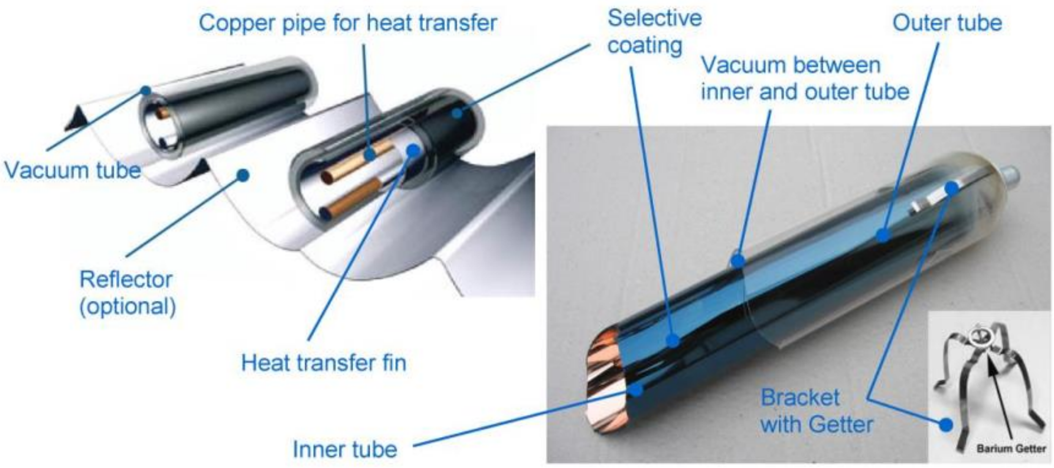


Figure 2-8: Basic elements of a Sydney tube collector (Weiss and Rommel, 2008)

ii. Heat pipe tubes (pressurized)

In heat-pipe collectors, collector pipes and solar loop are hydraulically disconnected. A working fluid evaporates within the collector pipes at low temperatures and condenses at the top of the pipe. The condensers are thermally connected to the header pipe, either dipping into the solar fluid (referred to as wet connection) or clamped to the header pipe and using heat conduction paste (dry connection).

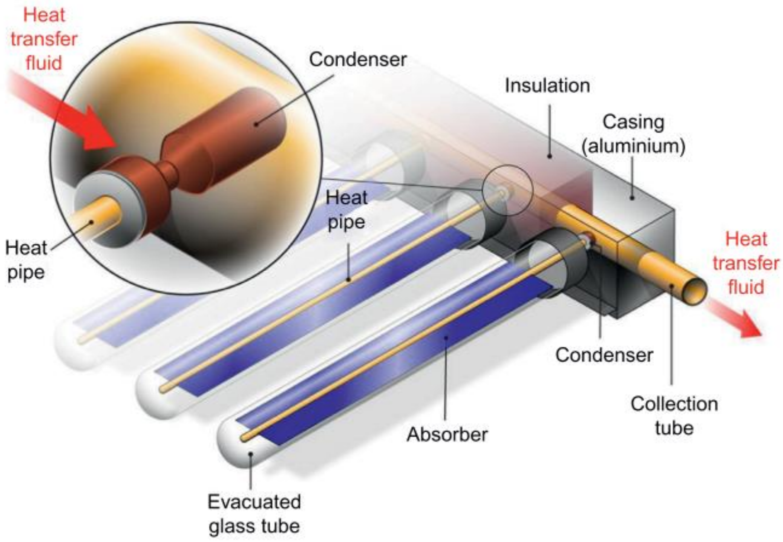


Figure 2-9: Typical evacuated tube collector (Hudon, 2013)

2.3.2. Comparison between ETCs and FPCs

ETCs perform better in colder and/or cloudier conditions than FPCs. This is because the vacuum in the glass tube allows to retain a high percentage of collected heat. ETCs are best for areas where winter temperatures frequently drop in the 4°C range or below. They work well in freezing conditions, where FPCs will not work. Generally, FPCs will not reliably perform above 55-60 °C while ETCs can produce hot water up to 90°C. ETC are typically less sensitive to sun angle and orientation than FPC.

The shape of ETCs ensures that the solar radiation is always perpendicular to the surface of the outer glass tube. ETCs capture sunlight better as they have a greater surface area exposed to the sun at any time. ETCs take more time to assemble while FPCs take more effort to hoist onto the roof (Ahmed, 2016; NITA, 2017; Chèze *et al.*, 2020).

Table 2-2: Comparison between ETCs and FPCs (Ahmed, 2016; NITA, 2017)

Evacuated tube	Flat plate
• The collector is hermetically sealed inside an evacuated glass tube, eliminating convection and conduction heat losses and isolating the collector from adverse ambient conditions. • Uses a heat-pipe for super-efficient heat conduction. No water enters into the collector. • The heat-pipe has a self-limitation of maximum working temperature through the physical properties of its special fluid resulting in safeguarding the system and system fluid. • Thermal diode operation principle. The heat pipe's thermal flows one way only; form the collector to the water and never in the reverse. • Easy installation and no maintenance. Lightweight individual collector tubes are assembled into the system at the point of installation. Each tube is an independently sealed unit requiring no maintenance. • Relatively insensitive to placement angle, allowing architectural and aesthetic freedom. • Corrosion and freeze free; there is nothing within the evacuated tube to freeze and the hermetic sealing of each tube eliminates corrosion.	• The air gap between absorber and cover pane allows heat losses to occur, especially during cold and windy days. • Circulates water inside insulated areas. Prone to leakage, corrosion and restriction of flow due to possible air lock. • FPCs have no internal method of limiting heat buildup and have to use outside tempering devices. When these safety or control devices fail the system and/or system-fluid can be destroyed. • Flat-plates can actually rob the water of built-up heat if the collector becomes colder than the water temperature. • Installation is difficult. Entire panels have to be hoisted onto the roof and installed. If one tube has a leak, the entire collector has to be shut down and removed. • Requires accurate southern exposure and elevation placement. • FPCs contain water and unless well protected can burst upon freezing. Corrosion can become a major problem reducing performance.

2.3.3. Direct and indirect solar water heating system

Table 2-3: Fluid circulation systems (EED, 2017)

Type	Direct (open) System	Indirect (closed loop) system
Key components and working principle	Portable water or the heat transfer fluid moves from the collector to storage by natural convention due to density differences of cold and hot water (thermosiphon effect).	Have a pump and a controller to drive portable water or a heat transfer fluid through the system
Advantage	• Do not rely on pumps or electrical controls therefore do not need electrical supply to operate. • Simpler design; hence, relatively cheaper. • Easier to maintain and have a longer lifespan.	• Typically, in indirect system the heat transfer fluid is freeze resistant. Ideal for areas with cold climates. • Greater flexibility in location of system components due to circulation pumps
Disadvantage	• Comparatively tall and heavy units that require larger and stronger mounting roof space. • Collector must be located at lower level from the storage tank; hence, system layout is rigid. • Normally in direct system hard water can cause scale deposits to clog passages.	• Additional components such as pumps and controllers make the system more expensive. • Needs electricity supply to operate.

2.3.4. Decentralized and centralized solar thermal systems

Solar heating systems may distinguish between a decentralized and a centralized approach. In a decentralized approach, the storage and collectors are placed within the individual demand like in an ordinary active solar heating system but of a larger size. In the centralized concepts, these components are centrally situated, i.e. all solar heat is collected in one storage unit, from which the heat is distributed to the hot water outlets. The major advantage of having a centralized system is the reduced unit costs and heat losses from the storage. In general, a centralized system may make better use of the economy of scale (unit prices drop with the size) than a decentralized one (Faninger, 2010).

2.4. Economic, Environmental, Social and Political Benefit of Using SWH

The benefits of solar water heating systems cover different aspects such as economic, environmental and social. Environmental benefits stem from the capacity to reduce harmful emissions. The reduction of CO_2 emissions depends on the quantity of fossil fuels replaced directly or indirectly, for instance, when the system replaces the use of carbon-based electricity used for water heating. Depending on the location, a system of 14 kW_{th} (20 m^2), could generate the equivalent of 11 MWh_{th} /year, a saving of around 1.75 Mt CO_2 (UNEP-GSWHP, 2015). Figure 2-10 presents the contribution of CO_2 reduction by solar water heating systems in 2018. The breakdown shows that China accounted for 90 million tons of CO_2 equivalent, Europe 17 million tons of CO_2 equivalent, and the rest of World 26.6 million tons of CO_2 equivalent.

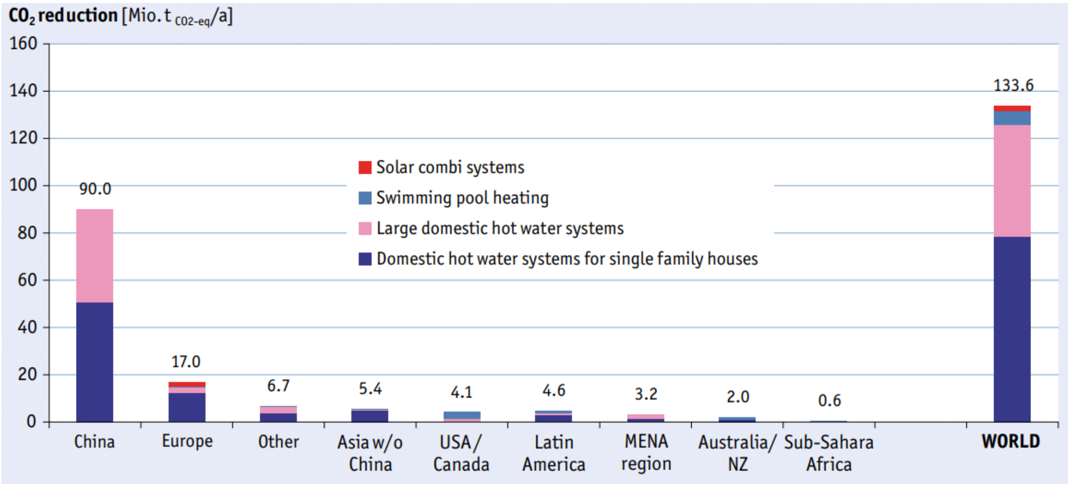


Figure 2-10: Contribution to CO_2 reduction by solar water heating systems in 2018 (IEA-SHC, 2019)

Economic, political and social benefits are associated with the potential savings in energy costs and the possibility of improving energy security by reducing energy imports, while creating local jobs related to the manufacturing, commercialization, installation and maintenance of solar thermal systems. According to (IEA-SHC, 2021), the number of jobs in the fields of production, installation and maintenance of solar thermal systems is estimated to be 400,000 worldwide in 2019.

The estimated worldwide turnover of the solar thermal industry in 2019 is 16.1 billion USD. Regarding energy costs and potential savings, there are three main aspects to consider that have a bigger impact on the comparable costs of the energy produced by a solar thermal system. These are the initial cost of the system, the lifetime of the system and the system performance.

In general, the benefits of SWH systems include (Berrill and Blair, 2007):

- Money is saved on conventional energy use that in effect creates manufacturing and installation jobs.
- Money is saved by the user. This is a tax-free earning that can be spent on other products and services or invested.
- Pollution and climate change costs are reduced
- Costs to upgrade the electricity and gas generation and supply systems are deferred.

According to (NITA, 2017), solar water heating are best suited in hospitals, hotels, laundries, military bases, prisons, restaurants, etc. There are certain situations that make good solar water heating applications in these establishments. These include:

a) Building that use hot water 7 days per week;
b) Building that are open 12 months of the year;
c) High cost of avoided fuel (electricity or fossil fuel)
d) Available roof or ground area to mount the collectors (unshaded);
e) Large hot water usage to justify installation of solar thermal system;
f) Temperature requirements that are within the range of solar thermal systems (lower temperature applications are better)
g) Uniform load; hot water used at all times of the day or more at noon/afternoon; diversity of loads

2.5. Global Status of Solar Water Heaters

According to IEA-SHC (IEA-SHC, 2021), the total installed capacity in operation of glazed and unglazed water and air collectors in 2019 was 479 GW_{th}, corresponding to a total of 684 million m^2 of collector area. The vast majority of the total capacity in operation was installed in China (346.5 GW_{th}) and Europe (58.9 GW_{th}), which accounted for 84.6% of the total installed capacity. The remaining installed capacity was shared between the United States and Canada (19.1 GW_{th}), Latin America (16.1 GW_{th}), Asia excluding China (15.7 GW_{th}), the MENA (Middle East and North Africa) countries Israel, Jordan, Lebanon, Morocco, the Palestinian Territories and Tunisia (7.3 GW_{th}), Australia and New Zealand (6.9 GW_{th}), and the Sub-Sahara African countries Botswana, Burkina Faso, Cape Verde, Ghana, Lesotho, Mauritius, Mozambique, Namibia, Nigeria, Senegal, South Africa and Zimbabwe (1.9 GW_{th}). The market volume of “all other countries” is estimated to amount to 5% (6.6 GW_{th}) of the installations, excluding China.

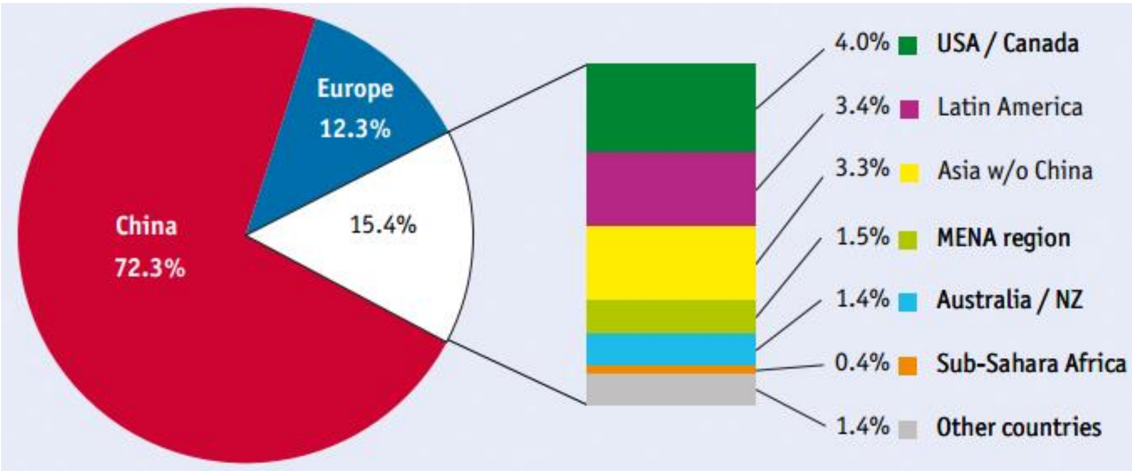


Figure 2-11: Share of the total installed capacity in operation (glazed and unglazed water and air collectors) by economic region in 2019 (IEA-SHC, 2021)

The total installed capacity in operation in 2019 was divided into flat plate collectors: 118.1 GW_{th} (168.8 million m^2), evacuated tube collectors: 329.4 GW_{th} (470.6 million m^2), unglazed water collectors: 30.4 GW_{th} (43.4 million m^2), and glazed and unglazed air collectors: 1 GW_{th} (1.5 million m^2). The global share of evacuated tube, flat plate and unglazed water solar thermal collector technologies are 68.8%, 24.7% and 6.3%, respectively. Solar air collectors play only a minor role in the total numbers.

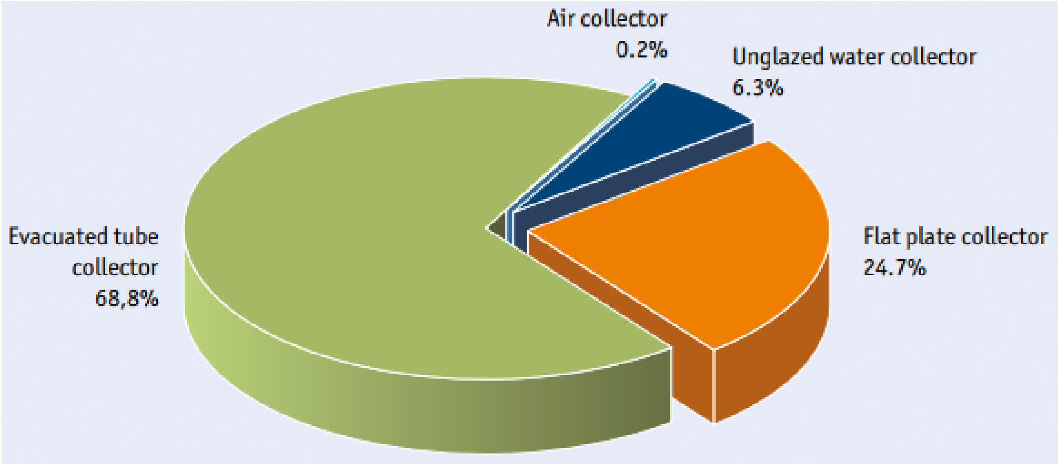


Figure 2-12: Distribution of the total installed capacity in operation by collector type in 2019 (IEA-SHC, 2021)

Figure 2-13 presents the top ten countries of cumulated SWH collector installations in 2019. China remained the world leader in total capacity and a market dominated by evacuated tube collectors.

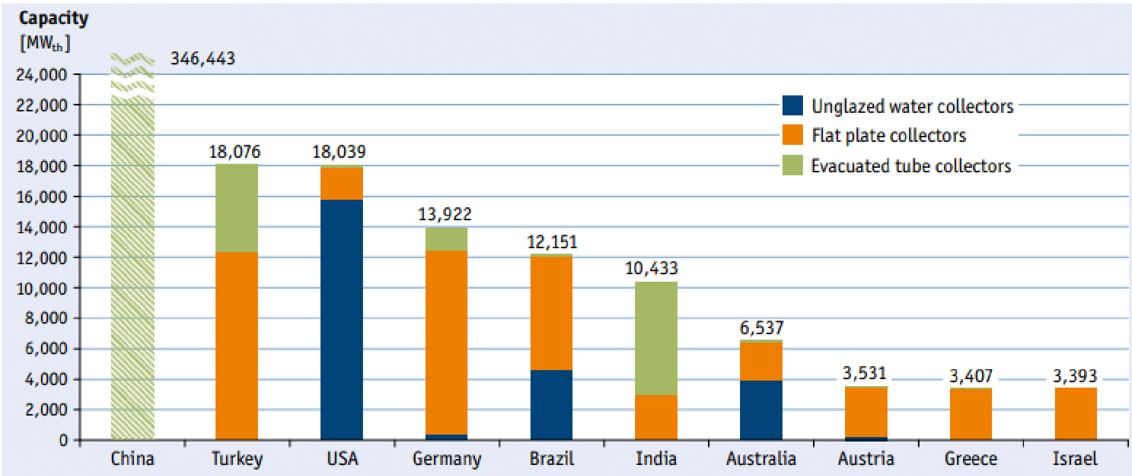


Figure 2-13: Top ten countries of cumulated SWH collector installations in 2019 (IEA-SHC, 2021)

The global solar thermal market is experiencing challenging times. For instance, in China and Europe, the traditional mass markets for small-scale SWHs for single-family houses and apartment buildings are outcompeted by the market pressure from heat pumps and Solar PV systems (IEA-SHC, 2020). This resulting in a market decrease of 4% in 2020 compared to 2019 (IEA-SHC, 2021).

However, there are some countries which experienced a positive market growth. In 2019, the growth was recorded in Denmark (170%), Cyprus (24%), South Africa (20%), Greece (10%), Tunisia (7%), Brazil (6%) and India (2%) (IEA-SHC, 2020). These countries experienced this market growth due to government support programs.

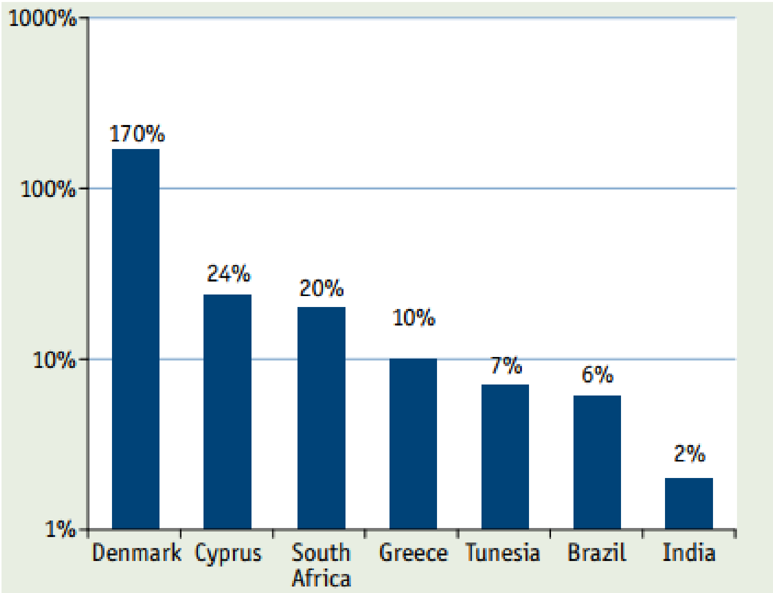


Figure 2-14: Growth rates of the most successful countries 2019 (IEA-SHC, 2020)

3. METHODOLOGY

3.1. Methodology for Assessment of Existing Conditions

3.1.1. Types of relevant data collected

The following relevant information have been collected from all the entities of the survey.

- Establishment's information: capacity, average facility occupancy rate, operating hours per day, types of water heaters used, average daily hot water requirement, hot water use areas, usage pattern, available SWH installation area, roof type and roof orientation.
- Electric energized water heater: Type, capacity (litters), power (kW), water heating arrangement (centralized or decentralized), maximum working temperature (℃) and efficiency.
- Solar water heater: Type, solar tracking mode, slope, azimuth, gross area per solar collector, number of collector, aperture area, storage (centralized/standalone) and back-up technology (power of auxiliary heating system).
- Market: SWH and EWH market size, growth, country of origin and market share etc.
- Solar and climate data: solar radiation and other metrological data.

The relevant data to be collected from different premises is indicated in Table 3-1.

Table 3-1: Relevant data to be collected from establishments

<table>
<tr><td colspan="2">Facility level observation
• Year of Establishment
• Number of patient beds/hotel rooms/guest rooms
• Daily hot water requirement of bathroom/kitchen/laundry etc.
• Total electric consumption and costs</td></tr>
<tr><td>Electric water heater
• Capacity (liter)
• Power rating (kW)
• Voltage (V)
• Heating time
• Maximum working temperature etc.</td><td>SWH data
• Capacity (litter)
• Collector efficiency
• Gross surface area and aperture area
• Number of tubes (for ET)
• Back-up technology</td></tr>
</table>

3.1.2. Sampling methodology

a) Study area description

Addis Ababa is found between 8°50′ N to 9°5′ N and 38°38′ E to 38°54′ E. It is the capital and the largest city of Ethiopia, covering a total area of 51,957.82 sq.km (Assaye *et al.*, 2017) with a total projected population of 3.78 million people in 2021 (CSA, 2013). The city is the central economic zone of Ethiopia. At present, the city is administratively divided in to 11 sub-cities and 116 woredas.

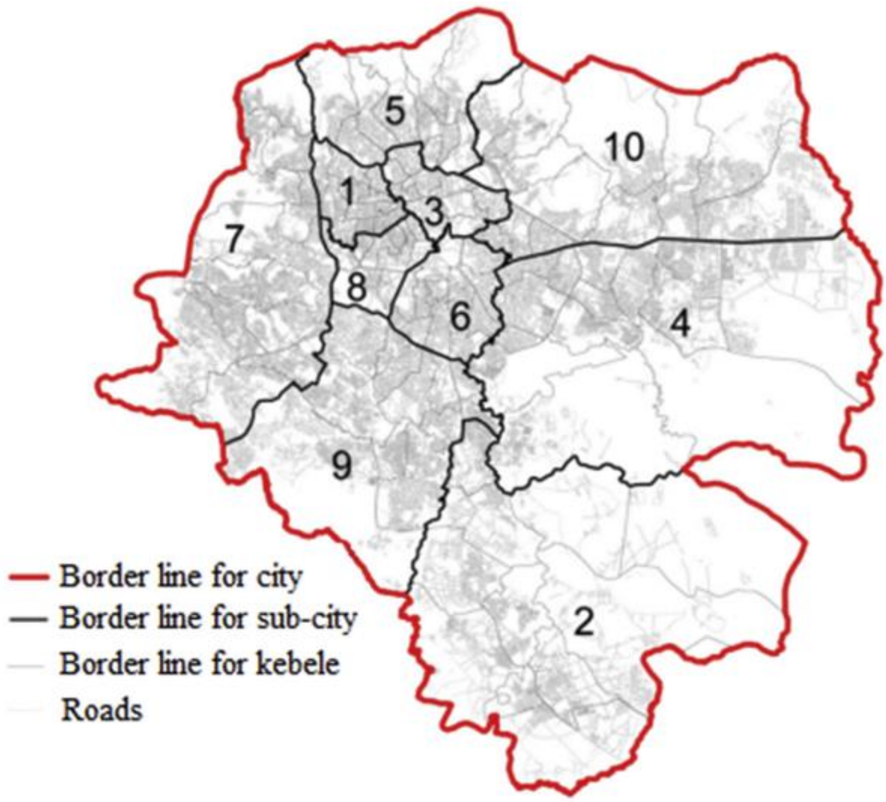


Figure 3-1: Addis Ababa city map (Teklemariam and Shen, 2020)

b) Target population

The target population to assess the type, total number and installed capacity of electric energized water heaters and solar water heaters; and to study and assess the implementation of solar water heater will comprise: end-users such as hotels, hospitals and big commercial buildings, importers, manufacturers, installer/assemblers of water heating technologies.

c) Sampling frame

The sampling frame for the study was constructed based on the pieces of information collected from

- Addis Ababa Trade Bureau
- Addis Ababa Culture and Tourism Bureau
- Addis Ababa City Administration Health Bureau
- Addis Ababa City Government Food, Medicine and Health Care Administration and Control Authority

Based on the above sampling frames, about one thousand three hundred fifty-nine establishments were considered and identified as a sampling frame for conducting the assessment for the implementation of solar water heaters in the city.

d) Sampling technique

The study employed a stratified systematic random sampling technique to select representative samples of the target population. The sampling technique was used to ensure that all hot water end-users in the targeted population have an equal and independent chance of selection in the sample. To do such a sampling scheme, the target population is grouped into four categories, namely hotels, hospitals, guest houses, and other commercial buildings.

e) Sampling Size

The sample size is defined as a total sum of a sampling unit accessible and in a position to be incorporated in the sample under study. The basic idea of sampling is, selecting some of the elements in a population, so that the same conclusions can be drawn about the entire population. In this study, the consulting firm decided to take 30% to 50% sample for each group mentioned above.

f) The sample for the study

The objectives of the study are to assess for the implementation of solar water in Hotels, Hospitals and other commercial buildings in Addis Ababa. To meet this objective, the consulting firm collected relevant data from the following entities and end-users in Addis Ababa: hotels, hospitals, guest houses and other commercial buildings; importers, manufacturer, installer; and maintenance service providers.

i. End-users

The consulting firm covered five hundred fifty-six end-users throughout the study area. The distribution of sample end-users in each group mentioned above is given in Table 3-2.

Table 3-2: Number of sampled establishments by categories of end-users

No.	Establishment	Population	Sample establishment
1	Hotels	336	138
2	Hospital and specialty centers	91	68
3	Guest houses	432	157
4	Other commercial buildings	500	193
Total		**1,359**	**556**

ii. Importers/assemblers and distributors of water heating technologies

The consulting firm surveyed all solar water heaters importers/assemblers and distributors and fifteen major electric water heater importers in the country. This survey included the types, country of origin, power rating, cost, market share, and growth rate of imported SWH and electric energized water heaters.

3.1.3. Data collection approach

The survey collected both primary and secondary data sources to study and assess the implementation of solar water heater in hotels, hospitals and other commercial buildings in Addis Ababa.

a) Primary data

The primary data for this study was collected through on facility field assessment, interview and questionnaires at end-users; questionnaires and interviews with key stakeholders such as importers, distributors, wholesalers of SWH and electric energized water heaters.

b) Secondary data

The secondary data sources were collected from Ethiopian Custom Commission, relevant literature, scientific articles, official policy documents, reports and proceeding of development organizations, previous studies, study reports, and development strategy.

3.1.4. Data processing

a) Editing, Coding and Verification

Different quality control steps were taken to ensure the quality of the data collected. The data entry by data collectors was monitored, edited, and coded. During the data collection stage, all the necessary precautions were taken to make sure that the respondents filled in all the items in the questionnaire. Finally, the edited, coded and verified data were ready for further analysis.

b) Data Entry, Cleaning and Tabulation

The data entry was done on laptop computer using SPSS software version 26.0. The quality of the data entered into SPSS were critically examined to make it ready for statistical analysis. The dataset was rechecked to ensure the accuracy of the data entry. Finally, the analysis result was extracted and ready for further discussion.

3.1.5. Technical approach

a) Annual thermal energy demand

There are basically two technical approaches that could be used to determine water heating energy demand for the establishments. These approaches are: a top-down approach and a bottom-up approach. The consultancy firm used bottom-up approach to estimate electric energy demand based on daily hot water requirements per person, per hotel room and per patient bed etc.

The water heating energy demand for hotel sector can be estimated by analyzing the water heating demand per hotel room, as there is an established standard for hot water consumption demand in all star rating hotels.

The water heating energy demand for the hotel sector $E_{Ele,hotel}$ is give as:

$$E_{Ele,hotel} = \sum_{k} \left(HR_k\ \beta\ C_p\ \rho\ V_k\ \Delta T\ CF\right)/\eta_k$$

Where HR_k is the number of hotel rooms in the city; β the average annual room occupancy; C_p is the specific heat capacity of water (4.19 kJ/(kg K)); ρ density of water (1 kg/L); V_k the required amount of hot water per hotel room per heating appliance/equipment; ΔT temperature difference between cold and hot water, CF conversion factor (1 MJ = 0.278 kWh) and η_k is efficiency of water heating appliance/equipment, i.e. 90% and 300% for the efficiency of electric water heater and air to water heat pump respectively.

The analysis is based on the existing electric energized water heaters used in hotels, hospital and health specialty centers and guest houses. The estimation of the water heating energy demand in hospital and health spatiality centers and guest houses is determined using same equation for $E_{Ele,hotel}$ above, but replacing HR_k by PB_k and GR_k, where PB_k is the number of patient beds in the city and GR_k is the number of guest rooms in the city.

Based on the above the total annual water heating energy demand for the three sectors E_{Ele} is given as

$$E_{Ele} = E_{Ele,hotel} + E_{Ele,health} + E_{Ele,guest}$$

b) Equivalent SWH capacity

RETScreen software has been used to estimate the equivalent solar water heating capacity which are equivalent collector area and energy collected per unit collector area. The estimation is based on the thermal energy demand for the sectors, the equivalent SWH capacity required to meet this demand was assessed using (Natural Resources Canada, 2004)

$$A_c = \frac{1}{F_R\ (\overline{\tau\alpha})\ H_T\ \overline{\phi}} \sum_{i} Q_{load,i}$$

Where $Q_{load,i}$ is the required water heating thermal load, A_c the collector area, F_R is the collector's heat removal factor, τ is the transmittance of the cover, α is the shortwave absorptivity of the absorber, H_T is the monthly average daily irradiance in the plane of the collector and $\overline{\phi}$ the monthly average daily utilisability.

The energy collected per unit collector area per unit time is represented as

$$\dot{Q}_{coll} = F_R(\tau\alpha)G - F_R U_L \Delta T$$

The mathematical modeling of SWHs system is discussed on section 3.2.4 (d) of this chapter.

The technical specification of the selected SWH collector for estimation of equivalent SWH capacity is presented in Table 3-3.

Table 3-3: The technical specification of selected SWH collector

No.	Parameters	Evacuated Tube Collector
1	Gross area per solar collector (m^2)	4.278
2	Aperture area per solar collector (m^2)	3.225
3	Fr (tau alpha) coefficient	0.563
4	Fr UL coefficient (W/m^2)/℃	1.438
5	Temperature coefficient for Fr UL	0

3.2. Methodology for Feasibility Study

3.2.1. Metrological data

The climate conditions at the site considered include air temperature, relative humidity, precipitation, daily solar radiation, wind speed and earth temperature. The ground climate data locations are found at Tikur Anbesa (National Meteorology Agency Head Quarter), which is 9° 1' 8.076" north and a longitude of 38° 44' 51" and at Bole International Airport, which is 8° 58' 51.8916" north and a longitude of 38° 47' 55.32". The climate data is made up of ground measurements and found in areas where study establishments are densely located. Figure 3-2 presents the ground climate data locations.

The Bole International Airport is international synopsis climate data center where different international organization have access to the raw data. The ground climate data outputs are sent by National Metrology Agency of Ethiopia to the organizations. Among this international organization, NASA is one which summarizes the raw data and makes it available for RETScreen Software analysis. NASA's data were checked against National Meteorology Agency data and were found to be consistent. Hence, both data have been used in this study. From the data collected, the daily average solar radiation, air temperature and sunshine hours are 5.0 kWh/m^2/day, 17.53 °C and 6.86 hours respectively.

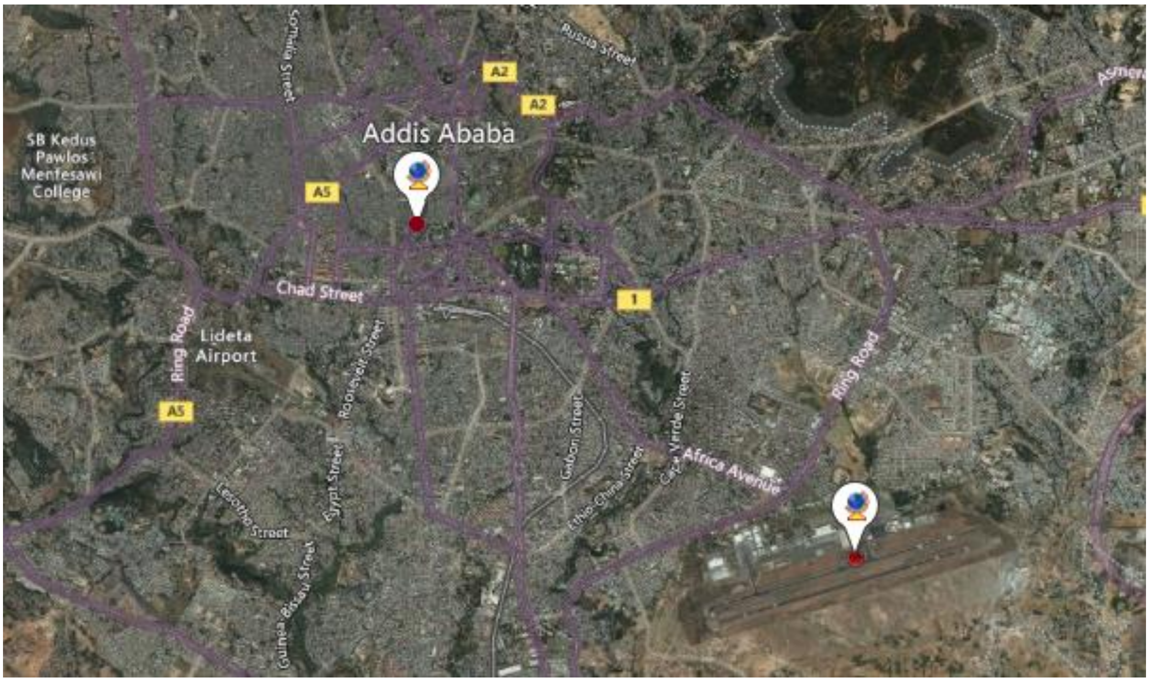


Figure 3-2: Ground climate data locations

Table 3-4: Addis Ababa city climate data

Month	Air Temperature (°C)	Relative Humidity (%)	Daily Average Solar Radiation-Horizontal (kWh/m²/day)	Wind speed @ 2m (m/s)	Earth Temperature (°C)
January	16.5	47.7	5.48	0.75	18.0
February	17.9	46.3	5.47	0.85	20.4
March	19.0	47.1	5.64	0.95	21.8
April	19.1	52.9	5.27	0.73	21.0
May	19.3	57.1	5.17	0.68	20.5
June	18.3	62.8	4.47	0.70	19.4
July	16.8	75.5	3.77	0.58	17.9
August	16.6	77.1	3.73	0.43	17.9
September	17.1	71.0	4.50	0.53	18.2
October	17.2	52.1	5.47	0.73	18.8
November	16.6	52.7	5.65	0.78	18.4
December	15.9	49.9	5.27	0.70	17.4
Average	**17.5**	**57.7**	**5.0**	**0.7**	**19.1**

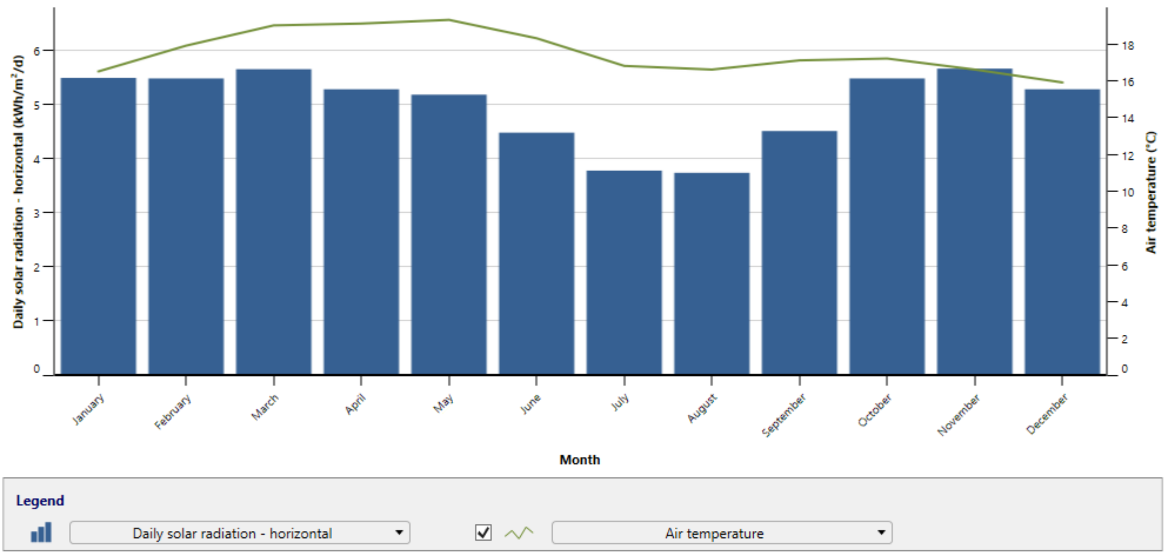


Figure 3-3: Daily Average Solar Radiation- on Horizontal Plane Vs Air Temperature

3.2.2. Types of relevant data collected

The relevant data collected for feasibility analysis are:

1. Capacity of establishments: (a) Hotel, number of rooms, average room occupancy (%) and operating hours per day; (b) Hospital, number of patient-bed, average bed occupancy (%) and operating hours per day; (c) Commercial buildings, number of dwellings/shops/rooms and operating hours per day.
2. Average daily hot water requirement: the average amount of hot water in liters and average hot water temperature for a shower, kitchen, laundry, etc.

3.2.3. Overview of RETScreen software

The simulation of SWH in hotels, hospitals, and other buildings was done using RETScreen Expert Clean Energy Management Software (version 8). The software is developed by the Ministry of Natural Resources Canada. It is a tool for evaluating the feasibility of various renewable energy projects around the globe. RETScreen is popular software for the evaluation of the feasibility of projects around the globe.

a) Solar Water Heating simulation model

The simulation of Solar Water Heating (SWH) project model contains six worksheets namely Energy Model, Solar Resource and Heating Load Calculation, Cost Analysis, Greenhouse Gas Emission Reduction Analysis, Financial Analysis, and Sensitivity and Risk Analysis as shown in Figure 3-4.

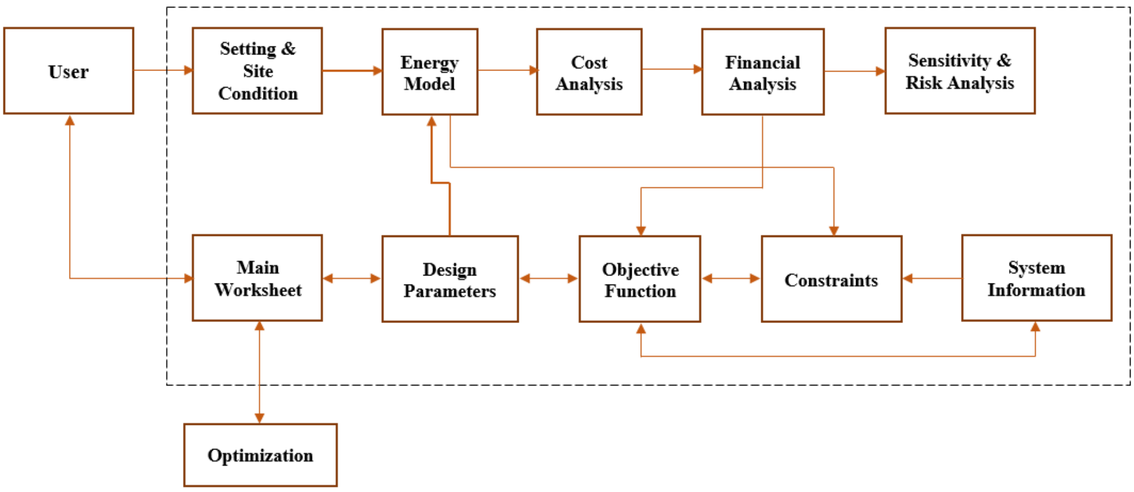


Figure 3-4: Simulation model flow chart, adopted from (Singh *et al.*, 2020)

The analysis begins with specifying the location of the establishment and the type of energy facility required at that place. After completing this worksheet, the energy worksheet comes which has Input parameters such as Fuels and Schedules, Equipment, End-use, Optimize supply, and summary. The monthly energy load required to heat up the water to the desired temperature is calculated by the Solar Resource and Heating Load Calculation (SRHLC) worksheet. The SRHLC worksheet also calculates the annual solar radiation on the tilted collector array for any orientation, using monthly values of solar radiation on a horizontal surface. The cost analysis includes initial costs, annual costs, and savings based on input parameters such as type of unit, number of collectors, storage, etc.

The gross annual Green House Gas (GHG) emission reduction potential in terms of tCO2 is analyzed by the worksheet of GHG analysis. The financial analysis worksheet performs the financial viability in terms of Internal Rate Return (IRR), simple payback period, and equity payback using input parameters such as inflation rate, project life, and debt ratio etc. The sensitivity and risk analysis worksheet evaluate the risk associated with the project based on constraints such as equity payback and IRR with a range of sensitivity.

3.2.4. Mathematical model

a) Tilted irradiance

The monthly average radiation in the plane of the collector ($\overline{H}_T$) is computed by using Liu and Jordan's isotropic diffuse algorithm for the SWH project model (Duffie, Beckman and Blair, 2020).

$$\overline{H}_T = \overline{H}_b\overline{R}_b + \overline{H}_d\left(\frac{1+\cos\beta}{2}\right) + H\rho_g\left(\frac{1-\cos\beta}{2}\right)$$

The first term represents direct/beam solar radiation and depends only on collector orientation, site latitude, and time of year. It is a product of monthly average beam radiation ($\overline{H}_b$) and geometrical factor ($\overline{R}_b$). The second term represents the contribution of monthly average diffuse radiation ($\overline{H}_d$) which depends on the slope of the collector β. The third term represents the reflection of radiation on the ground in front of the collector and depends on the slope of the collector (β) and on-ground reflectivity (ρ_g). The monthly average daily diffuse radiation ($\overline{H}_d$) is calculated from global radiation ($\overline{H}$) through the following equations.

When, W_s (sunset hour angle) less than 81.4°

$$\frac{\overline{H}_d}{\overline{H}} = 1.391 - 3.560\overline{K}_T + 4.189\overline{K}_T^2 - 2.137\overline{K}_T^3$$

Where $\overline{K}_T$ is the monthly average clearness index, its values depend on the location and the time of year considered; they are usually between 0.3 (for very overcast climates) and 0.8 (for very sunny locations).

When, W_s (sunset hour angle) greater than 81.4°

$$\frac{\overline{H}_d}{\overline{H}} = 1.311 - 3.022\overline{K}_T + 3.427\overline{K}_T^2 - 1.821\overline{K}_T^3$$

The monthly average daily beam radiation ($\overline{H}_b$) is computed as

$$\overline{H}_b = \overline{H} - \overline{H}_d$$

b) Sky temperature

It is required to quantify radiative transfer exchange between a solar collector and the sky. The sky long-wave radiation is radiation originating from the sky at wavelength greater than 3μm. An alternative variable intimately related to sky radiation is the sky temperature T_{sky}, which is the temperature of an ideal blackbody emitting the same amount of radiation. Its value in ℃ is computed from sky radiation L_{sky} as

$$L_{sky} = \sigma(T_{sky} + 273.2)^4$$

Where σ is the Stefan-Boltzmann constant ($5.669 \times 10^{-8}\ w/m^2K^4$)

c) Estimated load calculation

The actual thermal load is calculated as the energy required heating the water to the temperature of the specified hot water, is given as

$$Q_{load} = C_P \rho V_l (T_h - T_c)$$

Where V_l is the required amount of water, T_h is the required hot water temperature, C_P is the heat capacitance of water (4.2 $(kJ/kg)/°C$), ρ is the density of water (1 kg/L), and T_c is the cold (mains) water temperature.

d) Glazed or evacuated tube solar collectors

The energy collected per unit collector area per unit time is represented as

$$\dot{Q}_{coll} = F_R(\tau\alpha)G - F_R U_L \Delta T$$

Where F_R is the collector heat removal factor, τ is the transmittance of the cover, α is the shortwave absorptivity of the absorber, G is the global incident solar radiation on the collector, U_L is the overall heat loss coefficient of the collector, and ΔT is the temperature difference between the working fluid entering the collectors and the ambient. The values of $F_R(\tau\alpha)$ and $F_R U_L$ are set by selecting a solar collector type the database of RETScreen software.

e) Solar fraction

The solar fraction (SF) is the percentage of hot water load that can be met by solar energy on an annual basis compared to the original source of heating the water. For service hot water applications, the annual energy needs covered by a solar water heater are typically between 10 to 70% of the annual water heating use, depending on climate, system size and load (Natural Resources Canada, 2004). The solar fraction is given by

$$SF = \frac{Q_{solar,a}}{Q_{other,a} + Q_{solar,a}}$$

Where $Q_{solar,a}$ is the annual energy from solar (kWh/year) and $Q_{other,a}$ is the annual energy from other sources (kWh/year).

3.2.5. Cost analysis

The project total cost includes capital cost and operation and maintenance costs. Capital cost includes the cost of preliminary studies, the solar collectors, pipes, pumps, accessories, labor, spare parts, and contingencies.

a) Preliminary study

The initial studies include the feasibility, development, and engineering studies. Each of which is expected to cost an average of 2.5% of the total equipment and construction cost (Anees *et al.*, 2018).

b) Equipment cost

The price of SWHs and HPs in the local market varies as the market is not regulated. The price of the products also depends on the country of origin. Hence, the price of FPC or ETC type SWHs or air to water HP type water heaters was collected from Chinese's market, which is the major supplier of water heating systems in Ethiopia.

c) Piping, accessories, and installation

The piping, accessories and installation costs are assumed to be 30% of the equipment cost. The installation cost includes civil, plumping and erection works.

d) Spare parts and contingencies

The spare part item represents an inventory required which actually depends on the reliability of the system, warranty, complexity of equipment at the site, transportation difficulty and availability of off-the-shelf components (Natural Resources Canada, 2004). The spare parts cost is estimated to be 10% of the equipment cost. Contingency costs are considered for unexpected events during construction phase and are set to 10% of the total facility cost (Anees *et al.*, 2018).

e) Operation and Maintenance

Solar water heaters are characterized as low maintenance water heating technologies. After installation, only little maintenance is required, and solar water heater can run for up to 20 years. Heat pumps have a compressor and moving parts and they need a regular maintenance and a service check every 2–3 years. The maintenance cost of SWH and HP can be approximated to 0.5% and 2% of the equipment cost respectively.

3.2.6. Financial analysis

a) Simple payback period

The Simple Payback Period (SPP) is the number of years it takes for the cash flow (excluding debt payments) to equal the total investment (which is equal to the sum of the debt and equity), is calculated as

$$\mathrm{SPP} = \frac{\mathrm{C} - \mathrm{IG}}{\left(\mathrm{C_{ener}} + \mathrm{C_{capa}} + \mathrm{C_{RE}} + \mathrm{C_{GHG}}\right) - \left(\mathrm{C_{O\&M}} + \mathrm{C_{fuel}}\right)}$$

Where C is the total initial cost of the project, IG is the incentives and grants, $\mathrm{C_{ener}}$ is the annual energy savings or income, $\mathrm{C_{capa}}$ is annual capacity savings or income, $\mathrm{C_{RE}}$ is an annual renewable energy production credit income, $\mathrm{C_{GHG}}$ is a GHG reduction income, $\mathrm{C_{O\&M}}$ is a yearly operation and maintenance costs incurred by the project, and $\mathrm{C_{fuel}}$ is an annual cost of fuel or electricity.

b) Equity payback period

The Equity Payback Period (EPP) is also termed as a year to positive cash flow $\mathrm{N_{PCF}}$, it is the first year that the cumulative cash flows for the project are positive. It is calculated by solving the following equation for $\mathrm{N_{PCF}}$

$$0 = \sum_{\mathrm{n}=0}^{\mathrm{N_{PCF}}} \mathrm{C_n}$$

Where $\mathrm{C_n}$ is the after-tax cash flow in year n.

c) Internal rate of return

The Internal Rate of Return (IRR) is the discount rate that causes the Net Present Value (NPV) of the project to be zero. It is calculated by solving the following formula for IRR as

$$0 = \sum_{\mathrm{n}=0}^{\mathrm{N}} \frac{\mathrm{C_n}}{(1 + \mathrm{IRR})^{\mathrm{n}}}$$

Where N is the project life in years, and $\mathrm{C_n}$ is the cash flows for year n (i.e. $\mathrm{C_0}$ is the equity of the project minus incentives and grants, this is the cash flow for year zero). The pre-tax IRR is calculated using pre-tax cash flows, while the after-tax IRR is calculated using the after-tax cash flows.

3.2.7. Hot water consumption estimation

The feasibility study considers scenario studies of three models of Solar Water Heating (SWH) systems: hotels, hospitals and other buildings in Addis Ababa. The existing CES 161 Plumbing services of buildings, 2015 and other Ethiopian Standards do not specify hot water requirements for different establishments such as Hotels, Hospitals, and other buildings. To cope with this situation, different international standards on solar thermal installations for the production of sanitary hot water were reviewed. Table 3-5, presents the hot water consumption in hotels per day and person in liter. The standard values of UNE94002 standard, which are closer to the Accor Hotels and other brand hotels standards have been used.

Table 3-5: Average hot water demand per room in litters at a temperature of 60 °C according to different standards by category

Normative	1 Star	2 Stars	3 Stars	4 Stars	5 Stars
UNE94002 (Hiller and Russell, 2017)	40	50	60	80	100
CTE 2006 (Pérez *et al.*, 2019)	35	40	55	70	70
CTE 2017 (Pérez *et al.*, 2019)	28	34	41	55	69
(Accor Hotels, 2016)*	--	--	--	60 - 80	100 - 120
(GIZ and RCREEE, 2017)	--	55	55	115	115

*Accor Hotels is a French multinational hospitality company that owns, manages and franchises hotels, resorts and vacation properties.

Table 3-6: Hot water demand in other buildings, adopted from (GIZ and RCREEE, 2017)

Consumption type	Average daily hot water requirement per day and per person in liter at temperature of 60°C
Guest house, inn	40
Hospital	90
Sport facilities with showers	25
Sauna – public/private	70 / 35
Kitchen - breakfast	2
Kitchen – noon/evening	5

The hot water demand in hotel and hospitals is assumed to include demand at kitchen and any additional hot water tap connections.

a) Hotel Hot Water Consumption

According to the survey of (HVC, 2016), Ethiopia has the highest room occupancy rate (OR) of up to 80 percent in the content. One major factor that attributed for increase in hotel occupancy rate in Addis Ababa is conference tourism.

Table 3-7 presents the daily room occupancy rate of Hotels in Addis Ababa. The figures represent the average occupancy rate during the time of data collection.

Table 3-7: Average daily room occupancy (OR) (%) of Hotels in Addis Ababa

	Star Rating				
	=< One	Two	Three	Four	Five
Average low season daily room OR (%)	51	38	57	45	54
Average peak season daily room OR (%)	76	78	79	73	77

In hotel hot water consumption case, all star rating hotels with electric water heaters (EWHs) were considered for feasibility analysis. The minimum and maximum number of rooms and average hot water demand are indicated in Table 3-8 below.

Table 3-8: Hot water case for hotels

Star Rating	Scenario no.	Number of rooms	Average peak season daily OR (%)	Average hot water demand per room (L/day)	Daily hot water usage estimate (L/day)
1	1.1	12	76	50	456
	1.2	129			4,902
2	2.1	12	78	60	562
	2.2	87			4,072
3	3.1	18	79	70	996
	3.2	360			19,908
4	4.1	24	73	90	1,577
	4.2	160			10,512
5	5.1	90	77	110	7,623
	5.2	373			31,593

b) Hospital hot water consumption

Table 3-9 presents the daily room occupancy rate of hospital and health spciality centers in Addis Ababa. The table represents the average occupancy rate during the time of data collection.

Table 3-9: Average daily patient bed occupancy (%) of hospital and health specialty centers

	Hospital and Health Spciality centers
Average low season daily OR (%)	55
Average peak season daily OR (%)	78

In hospital hot water case, hospitals and health specialty centers with electric water heaters (EWHs) were considered for feasibility analysis. The minimum and maximum number of patient-beds and average hot water demand are indicated in Table 3-10 below.

Table 3-10: Hot water case for hospitals

Scenario no.	Number of patient beds	Average peak season daily OR (%)	Average hot water demand per room (L/day)	Daily hot water usage estimate (L/day)
1.1	10	78	90	702
1.2	300			21,060
1.3	623			43,735

c) Guest house hot water consumption

Table 3-11 presents the daily room occupancy rate of guest houses in Addis Ababa. The figures represent the average occupancy rate during the time of data collection.

Table 3-11: Average daily room occupancy (%) of guest houses

	Guest House
Average low season daily OR (%)	43
Average peak season daily OR (%)	70

In guest house hot water case, guest house with electric water heaters (EWHs) were considered for feasibility analysis. The minimum and maximum number of rooms and average hot water demand are indicated in Table 3-12 below.

Table 3-12: Hot water case for guest houses

Scenario no.	Number of rooms	Average peak season daily OR (%)	Average hot water demand per room (L/day)	Daily hot water usage estimate (L/day)
1.1	8	70	50	280
1.2	49			1715

3.2.8. SWH system design approaches

a) Design approach one: less than 2,000L SWH system

- For the daily hot water consumption less than 2,000L, the centralized SWH design solution can be pressurized tank (https://1stsunflower.com/SFBH-Solar-Heating-For-Hotel-pd74221277.html). The system is designed with pressurized water tank, due to the high cost of pressurized water tank and is suitable for small water heating projects.

b) Design approach two: 1,000L-2,000L SWH system

- The design uses a solar heat pipe collector and an unpressurized storage hot water tank, with 2 heat exchanger unit inside.
- The bottom coil is used for the solar collector circulation heating system and the top coil is used for the hot water supply.
- The water tank uses a float ball to replenish water.
- The top coil can be used to directly supply high pressure hot water, reduce equipment and operating costs for hot water supply.

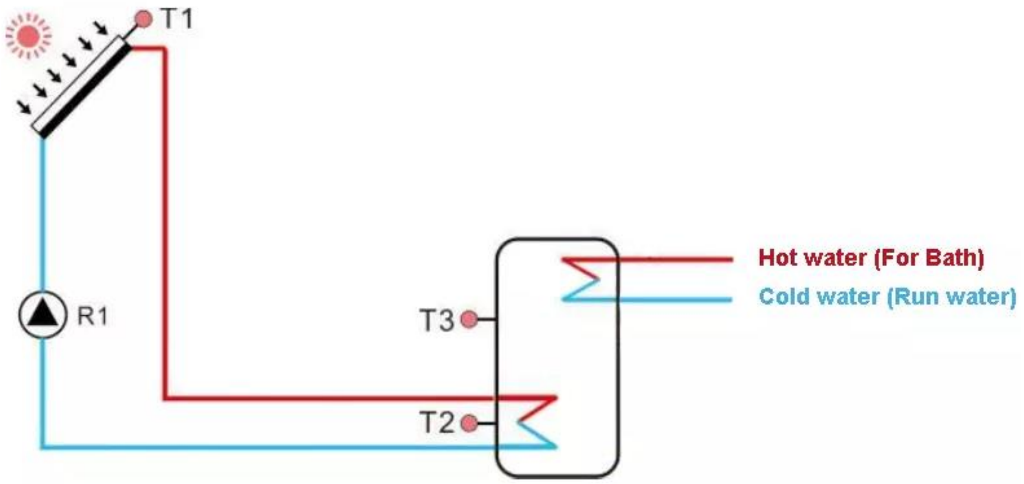


Figure 3-5: Design approach two: 1,000L-2,000L SWH system

c) Design approach three: 3,000L-5,000L SWH system

- The design uses a solar heat pipe collector and an unpressurized storage hot water tank with 1 heat exchanger unit at the bottom.
- The bottom coil is used for the solar collector circulation heating system.
- The solenoid valve in the tank help feed-water.
- Generally, a booster pump needs to be added into system hot water supply.

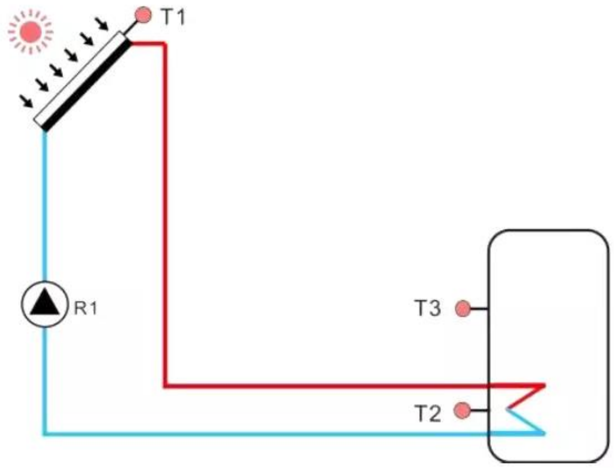


Figure 3-6: Design approach three: 3,000L-5,000L SWH system

d) Design approach four: 6,000L-12,000L SWH system

- The design uses a solar heat pipe collector and an unpressurized storage hot water tank without coils.
- Plate heat exchanger, transport heat energy absorbed by solar collectors to the tank.
- The solenoid valve in the tank help feed-water.
- The system can be equipped with a booster pump or a variable frequency booster pump.

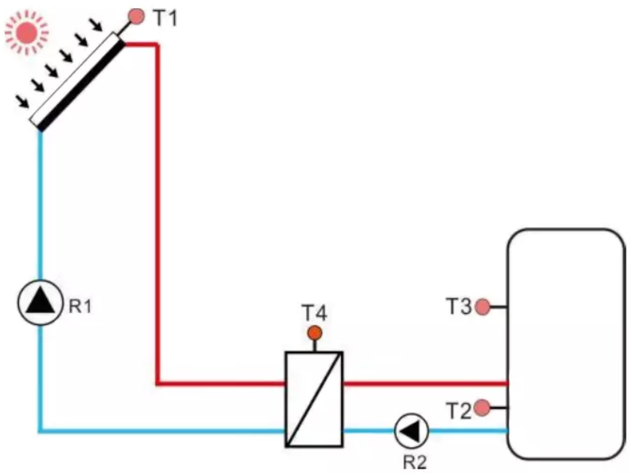


Figure 3-7: Design approach four: 6,000L-12,000L SWH system

Generally, the savings from SWH and initial cost of the SWH systems is expected to increase proportionally. Hence, 1000-liter hot water usage is considered for small scale pressurized systems whereas 10,000 liters is considered for large scale non-pressurized systems for the daily hot water usage estimates under section 3.2.7 and SWH system design approaches under section 3.2.8 above.

4. RESULTS AND FINDINGS OF EXISTING CONDITION ASSESSMENT

4.1. Existing Water Heating Technologies

Electric energized water heaters identified during the survey included the 50/80litre standalone EWH, Instant type EWH, the centralized EWH and the HPs. The 50/80-liter heaters are storage type heaters with power rating of 1.5 kW. The instant heater is a water flow pressure operated type and is rated at 5.5 kW whereas the central EWH is higher capacity storage heater and its rating depends on the storage capacity. The Heat Pump water heater rating depends on its heating capacity and CoP of the equipment.

The water heating technologies used at Hotels, Hospitals and big buildings in Addis Ababa constitute electric water heaters (including instant, stand alone and centralized) - 83.4%, Solar Water Heaters - 7.0%, Heat Pumps - 5.7%, Fossil fuel burner - 0.8 %, Fossil fuel burner and Heat pump - 0.2%, non-users - 2.9%. The installed capacity of electrical energy using water heating appliances/equipment at the premises in the city is estimated to be 41.1 MW whereas the electrical energy demand for water heating is 18.7 GWh. The aggregate total installed gross collector area at hotels, hospitals and big buildings is estimated to be 1,358.9 square meter which is equivalent to thermal energy of 714 kW_{th} indicating a very low SWHs installations in the city.

During the interruption of electricity, the hotels, hospitals and guest houses mostly use Diesel Generators to supply the loads including EWHs. Details of existing water heating technologies are presented in the following sections.

4.1.1. Hotel sector

Figure 4-1 shows the type of water heating technologies used at Hotels in Addis Ababa. Three hundred ten hotels use electric energized water heating appliances/equipment. Of these, two hundred twenty-five employed standalone 50/80-liter electric water heaters (EWH), forty-seven have centralized electric water heater (EWH), and thirty-eight installed centralized air to water heat pumps (HP). Only nineteen hotels use solar water heaters (SWH) and the remaining seven hotels make use of fossil fuel boilers (FFB).

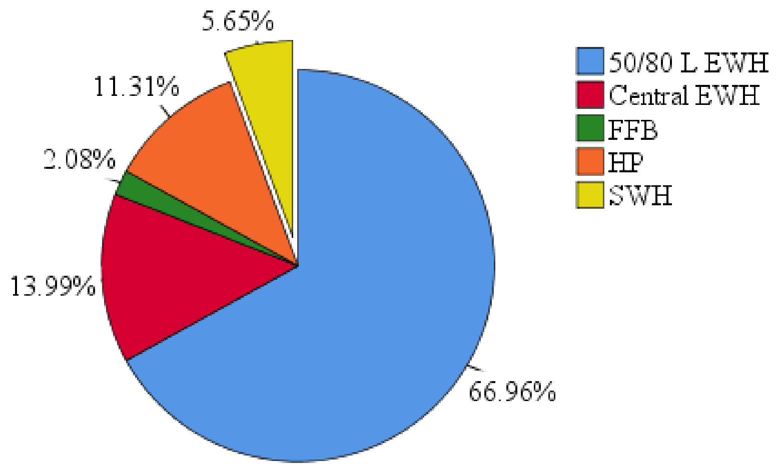


Figure 4-1: Water heating technologies used in Hotels

Figure 4-2 presents the water heating technologies used in different star rating hotels. Statistically, standalone 50/80-liter electric water heaters dominate in one- and two-star hotels. In four-star hotels the centralized HP is the dominant water heating technology. Fossil fuel boiler are the dominant service water heating technology in the five-star hotels.

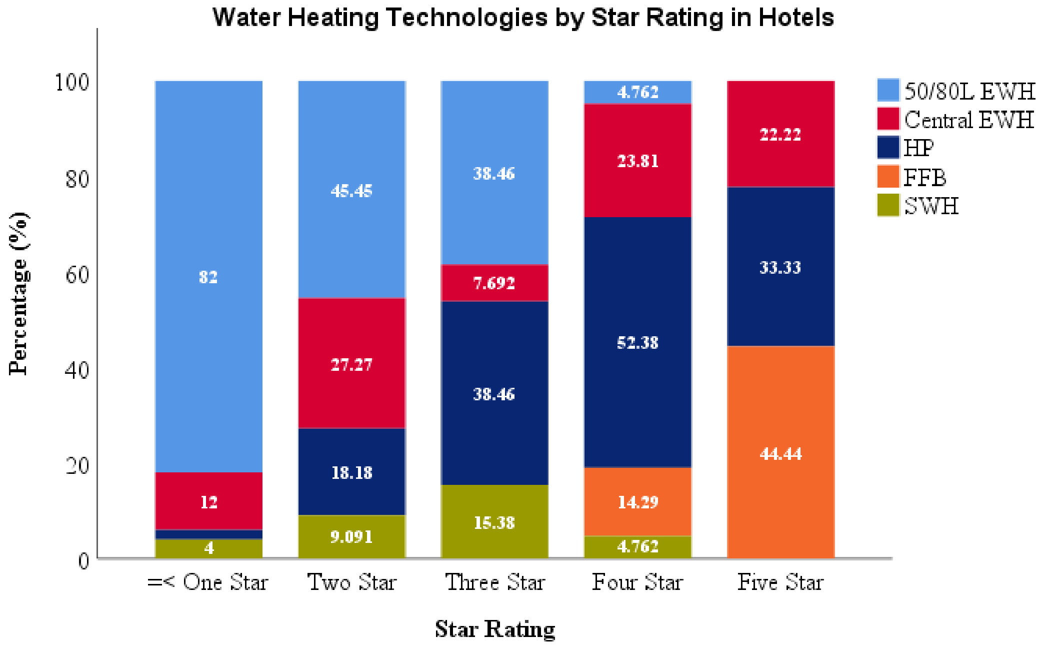


Figure 4-2: Water heating technologies by star rating in hotels

Figure 4-3 to Figure 4-8 show some of water heaters that were found in hotels during on site field assessment.

Figure 4-3: Collectors of some of centralized SWH systems in hotels

Figure 4-4: Collectors of some of cascaded SWH system in hotels

Figure 4-5: Storage Tanks of some of centralized electric water heating system in hotels

Figure 4-6: Some of centralized air to water HP system in hotels

Figure 4-7: Some of decentralized electric water heaters in hotels

Figure 4-8: Some of centralized fossil fuel boilers in hotels

4.1.2. Hospital and health specialty center

Figure 4-9 shows the type of water heating technologies used at hospitals and health specialty centers in Addis Ababa. Fifty-four hospitals and health specialty centers use standalone 50/80-litre electric water heaters and eight installed centralized air to water heat pumps (HP). Only seven hospitals and health specialty centers use SWHs as a means of energy for water heating. Eight hospitals and health specialty centers were found non-hot water users due to obsolescence of their former water heating system and some do not use hot water for their day-to-day activities.

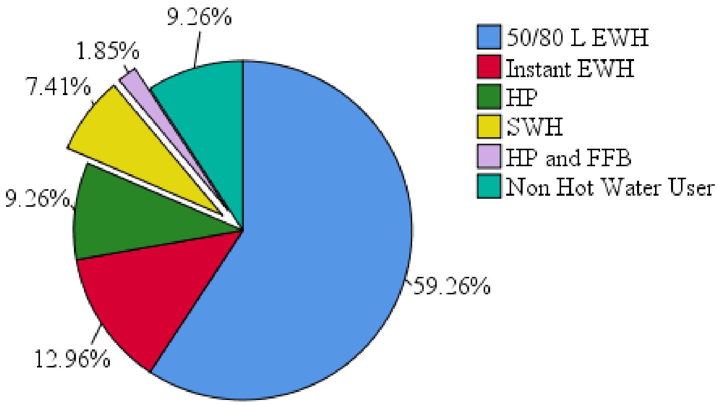


Figure 4-9: Water heating technologies used in hospital and health spatiality centers

Figure 4-10 to Figure 4-14 show some of the water heaters that were found in hospital and other health specialty centers during on site field assessment.

Figure 4-10: Some of the SWHs systems in hospital and health specialty centers

Figure 4-11: Some of decentralized EWHs in hospital and health specialty centers

Figure 4-12: Some of instant EWHs in hospital and health specialty centers

Figure 4-13: Some of centralized air to water HP system in hospital and health specialty centers

Figure 4-14: Some of centralized fossil fuel boilers in hospital and health specialty centers

4.1.3. Gust house

Figure 4-15 shows the type of water heating technologies used at guest houses in Addis Ababa. Three hundred eighty-one guest houses use electric energized water heating appliances/equipment. Of these, two hundred fifty-four employed standalone 50/80-liter EWHs and one hundred nineteen use instant electric water heaters. In contrast to other establishments, a significant thirty-four guest houses use solar water heaters (SWH) and the remaining establishments are non-hot water users.

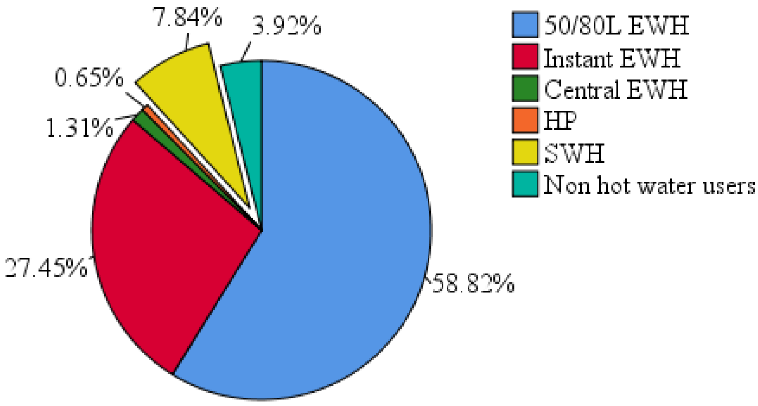


Figure 4-15: Water heating technologies used in guest houses

Figure 4-16 shows some of solar water heaters that were found in guest houses during on site field assessment.

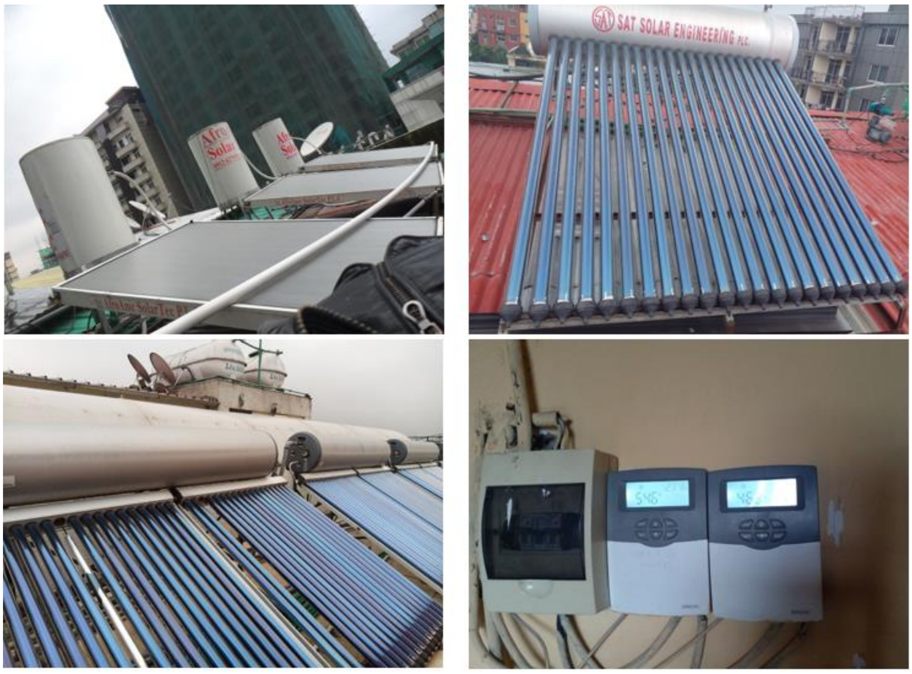


Figure 4-16: Some of SWH systems in guest houses

4.2. Types and Quantity of Electric Energized Water Heaters Used

4.2.1. Hotel sectors

Table 4-1 presents summary of estimated quantity of electric energized water heaters at star rating hotels in Addis Ababa. Based on the survey made, the quantity of electric energized water heaters is assessed to be 7,677.

Table 4-1: Quantity of electric energized water heaters in hotels

Water Heating Technologies	Quantity					
	=< One star	Two star	Three star	Four star	Five star	Total
50/80 Liter EWH	5,839	634	958	55	0	7,485
Central EWH	29	10	14	15	8	76
Heat Pump	10	15	31	34	27	116
Total						**7,677**

The installed capacity of standalone 50/80-litre EWH, centralized EWH and centralized air to water HPs at the hotels is estimated 11,228 kW, 2,778 kW and 1,847 kW respectively. The total installed capacity is estimated to be 15,853 kW.

Table 4-2: Installed power capacity of electric energized water heaters in hotels

Water Heating Technologies	Installed Power in kW					
	=< One star	Two star	Three star	Four star	Five star	Total
50/80 L EWH	8,759	950	1,437	82	0	11,228
Central EWH	696	435	440	607	600	2,778
Heat Pump	76	112	250	489	919	1,847
Total						**15,853**

Among non-solar water heater users, 29.46% have centralized EWH systems and the remaining 70.54% have decentralized EWH. Figure 4-17 show the non-solar water heating arrangement for hotels in Addis Ababa.

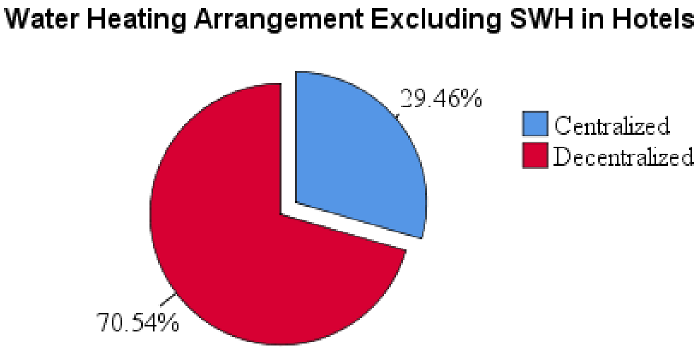


Figure 4-17: Water heating arrangement excluding SWH in Hotels

Figure 4-18 show the non-solar water heating arrangement in different star rating hotels in Addis Ababa.

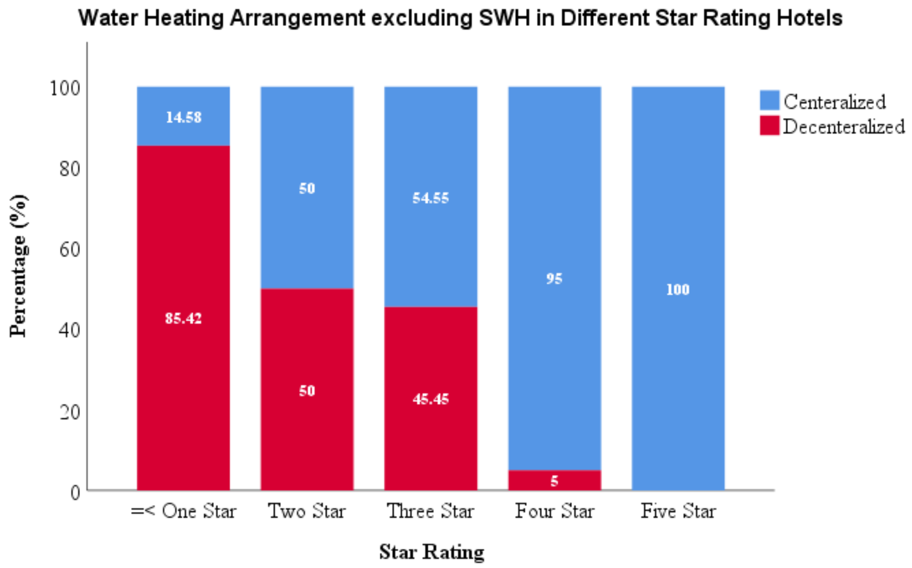


Figure 4-18: Water heating arrangement excluding SWH in different star rating hotels

4.2.2. Hospital and health specialty centers

As shown in Table 4-3, the quantity of electric energized water heaters in hospitals and health specialty centers is estimated to be 4,797. Among this quantity, 50/80-liter EWH is the dominant water heating technology and assessed to be 4,090 in quantity.

Table 4-3: Quantity of electric energized water heaters in hospital and health specialty centers

Water Heating Technologies	Quantity
50/80 Liter EWH	4,090
Instant EWH	693
Heat Pump	14
Total	**4,797**

Table 4-4 below indicates the installed power capacity of electric energized water heaters in hospital and health specialty centers. Based on this, the installed capacities of 50/80 liter electric water heaters, centralized electric water heaters and centralized air to water heat pumps are estimated to be 6,135 kW, 3,812 kW and 568 kW respectively, the total being 10,515 kW. Even though the percentage of instant EWH in hospital and health specialty center is 12.96%, the installed power capacity of instant EWH is very high.

Table 4-4: Installed power capacity of electric energized water heaters in hospital and health specialty centers

Water Heating Technologies	Installed Power in kW
50/80 Liter EWH	6,135
Instant EWH	3,812
Heat Pump	568
Total	**10,515**

Among non SWH users, only 15.22% have centralized EWH systems and the remaining 84.78% have decentralized EWH. Figure 4-19 shows the present water heating arrangement in hospital and health specialty centers.

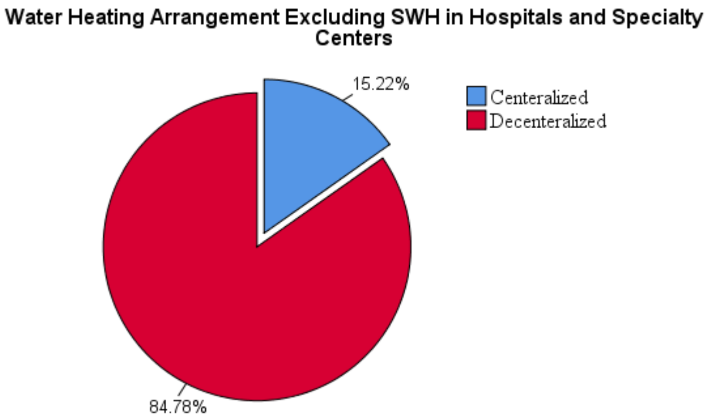


Figure 4-19: Water heating arrangement in Hospitals and health specialty centers

4.2.3. Guest houses

As shown in Table 4-5, the quantity of electric energized water heaters in guest houses is found to be 5,517. Among this quantity, 50/80 Liter EWH is the dominant water heating technology and assessed to be 3,923.

Table 4-5: Quantity of electric energized water heaters in guest houses

Water Heating Technologies	Quantity
50/80 Liter EWH	3,923
Instant EWH	1,576
Central EWH	12
Heat Pump	6
Total	**5,517**

The installed capacity of standalone 50/80-liter EWH, instant EWH and centralized EWH and centralized HPs is 5,884 kW, 8,667 kW, 156 kW and 48 kW respectively. The total installed capacity of electric energized water heating appliances/equipment in guest houses is 14,756 kW. Even though the percentage of instant EWH in Guest houses is less in quantity as compared to standalone 50/80-liter EWH, its installed power capacity is very high.

Table 4-6: Installed power capacity of electric energized water heaters in guest houses

Water Heating Technologies	Installed Power in kW
50/80 Liter EWH	5,884
Instant EWH	8,667
Central EWH	156
Heat Pump	48
Total	**14,756**

Among non SWH users, 2.59% have centralized EWH systems. The remaining 97.41% have decentralized EWH systems. Figure 4-20 shows the present water heating arrangement in guest houses in Addis Ababa.

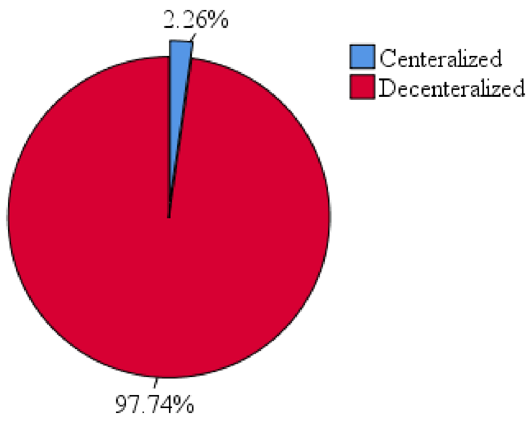


Figure 4-20: Water heating arrangement in Guest houses

4.3. Usage and Performance of Installed SWHs

The data on usage and performance of installed SWHs collected using questionnaire is summarized below. Questionnaire is attached as Annex 2.

4.3.1. Hotel sector

Base on the survey made nineteen hotels have installed SWHs in the city. The installed collector gross area ranges from 17.0 square meter to 98.7 square meter equating to a total gross area of 803.2 square meter and 442 kW_{th} indicating a very low penetration of the system at the hotels in the city. The number of rooms in the SWHs user hotels ranges from 25 to 120 and hot water is mainly used for rooms and kitchen. The SWHs in the premises have 5 to 16 years of service.

Majority of the SWHs installations, 68%, are Evacuated Tube types of 150 to 300 liters capacity and 32% are the glazed flat plate type, both with cascaded installations. The evacuated tubes are mostly pressurized types. Three hotels use central hot water storage tanks 2000 to 3000 liters capacity while others get hot water from stand-alone storage tanks detached from collector. It has been noticed at a hotel that a fully installed SWHs is not functional due to contractual problems and in another hotel, EWHs is operational while hot water is available from the SWHs due to closure of bypass valves on the SWHs line. Backups employed are: auxiliary electric heaters used in the solar collector storage tank and /or in centralized storage tanks, EWH and Heat pumps. Due to frequent interruptions majority of the hotels use standby diesel generators.

All SWHs are procured through self-financing except one who secured commercial loan from a bank. Most installations have been done by the two to three local importers in the country who are engaged also in the supply and installation of the products. The SWHs provide adequate hot water from 10:00 AM to 4:00 PM from October to May and at lower temperature in the months of July and August. Maintenance service is provided at all hotels with fulltime technicians/plumbers who cover other plumbing and maintenance works. These technicians have no formal training on SWHs.

Regarding the recourse to other than SWHs, all except one hotel use in-built auxiliary electric heaters in the SWHs central storage tanks. However, all hotels do not have the means to know how much the recourse costs in a month or year, and hence their savings from using SWHs. Some speculate that during rainy seasons' electricity bills are higher as compared to the summer seasons, and hence think the SWHs contribute to reduced bills in the summer time. It has been noticed that one of the hotels uses manual switching method of auxiliary heaters during periods of lower solar radiations.

All Hotels responded their main reason for installing SWHs are due to cost saving, load shedding and electricity interruption problems, and to reduce environmental problems.

Two third of the respondents expressed they are fully satisfied with their SWHs and one third are partially satisfied. Regarding the full satisfactions, all feel that cost of provision of hot water has reduced. One hotel's monthly electricity bill has reduced from average monthly birr 7,500 to birr 4,000 after installation of SWHs and the other hotel pays up to birr 20,000 monthly during Ethiopian winter and birr 12,000/month during the summer time. Most are satisfied in meeting hot water demand continuously in 24 hours and maintenance requirement. The partial satisfactions are due to shortage of accessories and fake replacement parts like auxiliary heater and thermostats in the market. The dissatisfactions are due to the overflow of significant amount of hot water during non-use, the shortage of accessories, and frequent failure of accessories. During the survey it was noticed at one hotel that there is a lot of dirt on the glazing of flat plates and solar radiation is almost obstructed. This shows that there is no cleaning and collector maintenance works on the SWHs and the lack of awareness on the basic operation of the system.

Figure 4-21: Flat plate collector type SWH under poor working condition

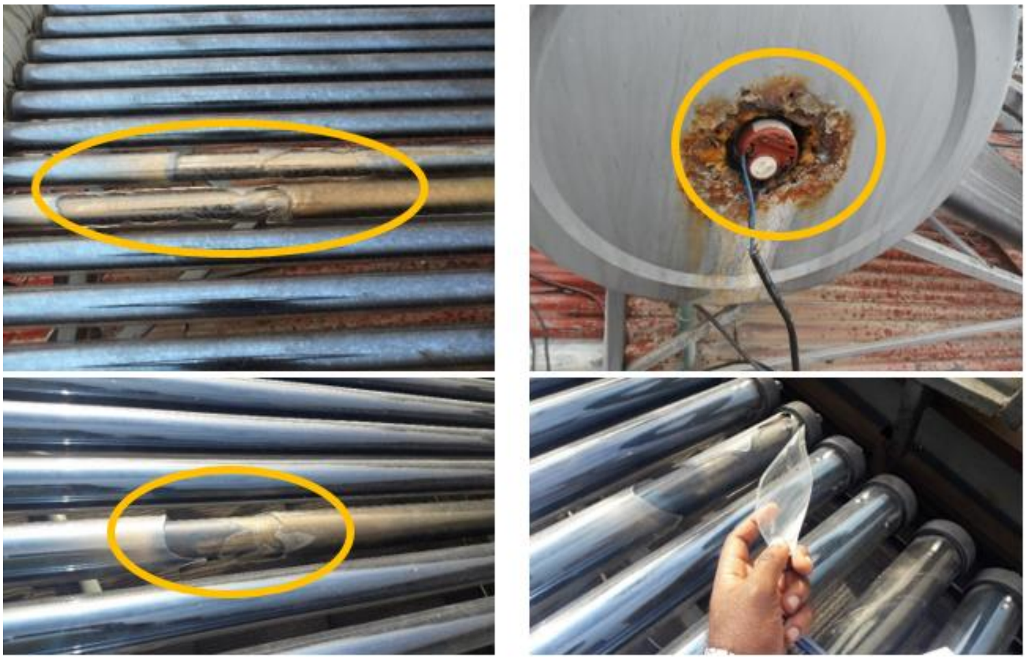


Figure 4-22: Evacuated tube collector type SWH under poor working condition

Concerning problems on the SWHs, some mentioned there are shortages of skilled solar technicians, braking of evacuated tubes during high temperature, hot water temperature getting low during high consumptions periods, loss of hot water due to overflow and warranty issues. A hotel which had installed SWHs has to add three Heat pumps due to the low temperature of hot water indicating design problems in the SWHs.

Regarding incentives on the acquisitions of the SWHs all hotels responded that there are no incentives at all except for the duty-free importation of the product along with hotel equipment. The hotels selected SWHs suppliers through reference from previous installations and the suppliers have determined the SWH capacity based on the number of rooms at the hotels.

In their comments and suggestions most hotels expressed that:

- The SWHs have proved to be important for their business in view of the electricity shortage and fluctuations they encounter.
- There shall be skilled and professional Solar technicians.
- Accessories in the market shall be of good quality at fair price and there shall be more suppliers to get reasonable price.
- The government has to take initiatives to promote the use of SWHs and incentivize through subsidy, tax reduction and rebate financing.

4.3.2. Hospitals and health specialty centers

Out of the ninety-one health facilities (fifteen government hospitals, twenty-two private hospitals and fifty-four specialty hospitals) in Addis Ababa, only 7.41% have installed SWHs. The total installed collector gross area is about 117.4 square meter being equivalent to installed capacity of 60.4 kW_{th}, representing a very small installation. SWHs related survey result is presented as below.

The number of patient beds rooms in the SWHs user hotels range from 12 to 70 and hot water is mainly used for patient bed rooms and kitchen. The SWHs in the premises have 10 to 11 of service years. Majority of the SWHs installations, 71%, are the Flat Plate type of 100 to 300 liters capacity and 29% are Evacuated Tube types, both with cascaded installations. The evacuated tubes are pressurized types. One of the big hospitals responded that they had installed SWHs and used ground water to supplement existing water supply system. However, the SWHs couldn’t continue functioning because of scaling problem in the heat exchanger unit due to hardness of the ground water and they reverted to ground hot spring water for their hot water demand indicating problem of design, maintenance and operation. Backups employed are: auxiliary electric heaters used in the solar collector storage tank and instant water heaters.

Figure 4-23: Damaged SWH heat exchanger due to scale and fouling formation caused by the hardness of inlet ground source water

Figure 4-24: Broken glazing of flat plate collector type SWH

There is no much information on the use and operation of the SWHs at the hospitals. The systems are not working at some of the hospitals due to increase in demand and problems of spare part availability, and as a result the instant and storage EWHs have been installed. The SWHs are procured through self-financing and donations.

In their comments and suggestions, the hospitals expressed that:

- Spare parts for the SWHs shall be available.
- The quality of spare parts shall be improved.

It was learned that there are problems of SWHs maintenance and operation and supply of quality spare parts at the hospitals. Most health specialty centers are not interested to install SWHs as they operate in rented buildings.

4.3.3. Guest houses

SWHs has been installed at thirty-four guest houses in the city. This amount represents 7.8% of total guest houses in the city. The installed collector gross area ranges from 6.1 square meter to 29.2 square meter, the total being 438.2 square meter and equivalent to 211.2 kW_{th}. The guest houses have number of rooms ranging from 14 to 49 and hot water is used for rooms, kitchen, and laundry services. The SWHs are in operation for 1 to 13 years. Evacuated tubes constitute 67% whereas flat plates have a share of 33%. Capacity of the SWHs ranges from 150 to 300 liters.

Auxiliary heater in the SWH tanks and instant and storage EWH are used as backup systems. The guest houses use the SWHs from 10:00 AM to 4:00 PM during the day from October to June in a year.

Figure 4-25 show samples of evacuated tube SWHs installed at Guest houses in the city. It can be seen in Figure 4-25 (a) that the collectors face opposing cardinal direction (orientation), which is not acceptable for optimum positioning.

(a) (b)

Figure 4-25: (a) Evacuated Tube SWHs installations and (b) Broken glass tube

SWHs are acquired through self-finance and the main reason to have it is for cost saving and avoid loss of service during electricity interruptions. All most all of the SWHs users are satisfied with the system because, cost of hot water especially during the summer seasons is reduced, water is very hot, hot water requirement is met and maintenance requirements are low. One guest house expressed that their electricity bill in the Ethiopian winter time is about Birr 10,000.00 whereas in the summer time it reduces to Birr 5,000.00 as they us SWHs.

Regarding problems while using SWH the respondents indicated that it takes a while to get hot water at the points of use, there are water consumption during waiting for hot water, lack of qualified technicians, customer dissatisfaction, and unavailability of spare parts.

In their comments and suggestions, the Guest house SWHs users expressed that:

- New buildings shall be built with SWHs
- SWHs have to promoted
- If there are companies who can supply quality products and warranty on the installation, they would recommend the SWHs.
- One user responded that he doesn't recommend SWHs as it didn't satisfy his customer's demand.

4.4. Hot Water Thermal Energy Demand of EWHs in the City

Besides bathing and showering purpose most hotels used heated water for different application such as cooking and cloth washing. About 35% of hotels used heated water for bathroom, cooking and laundry activities. The distributions of heated water use in hotels are shown in Figure 4-26.

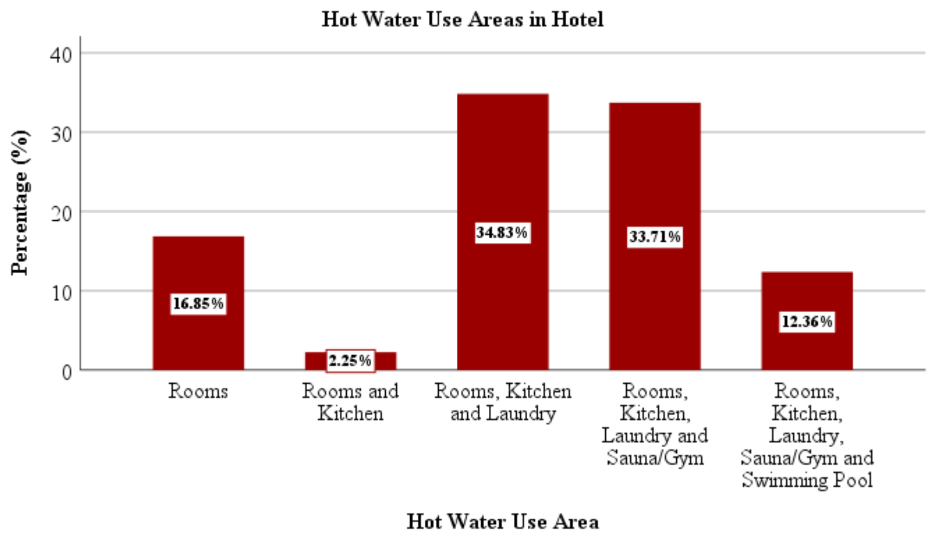


Figure 4-26: Hot water use areas in hotel

About 70% of hospitals and health specialty centers used heated water for the purpose of bathroom, kitchen and laundry. The remaining 26% used heated water for bathroom and kitchen and 4% used for bathrooms only.

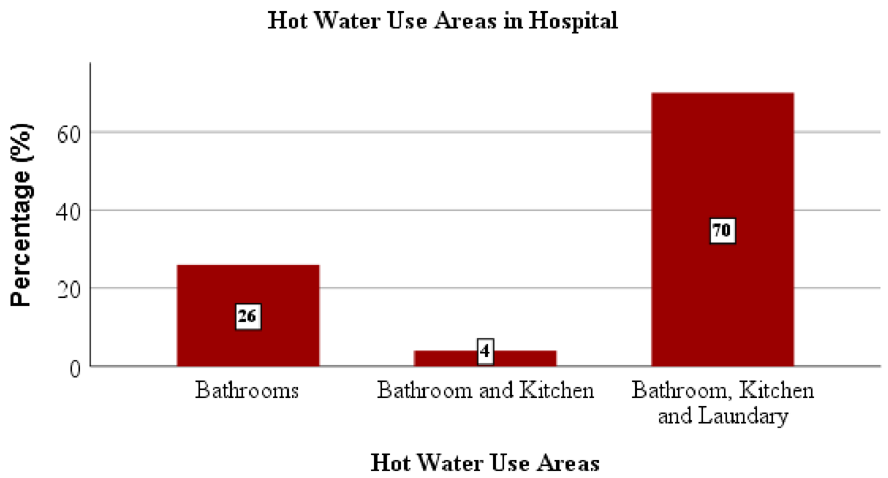


Figure 4-27: Hot water use areas in hospitals and health specialty centers

Majority (79.13%) of guest houses used heated water for bathroom service only. But there are some guest houses (9.48%) who have kitchens attached to the living rooms.

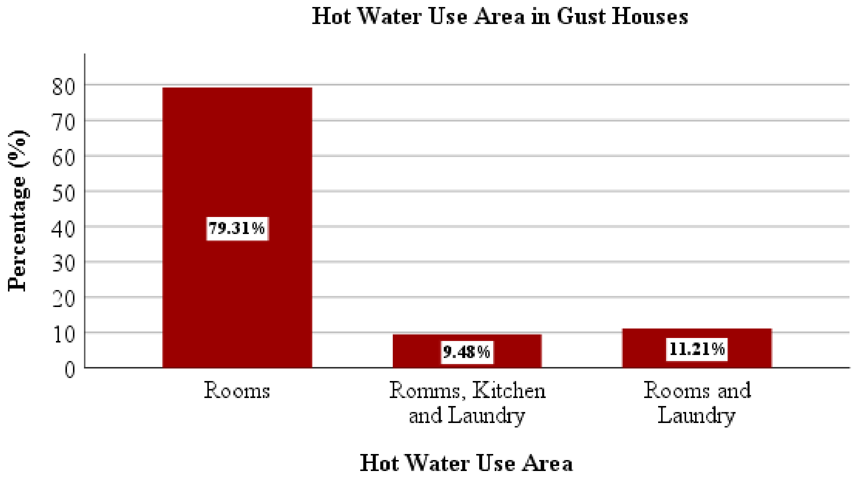


Figure 4-28: Hot water use areas in guest houses

The analysis is based on the existing electric energized water heaters used in hotels, hospital and health specialty centers and guest houses. The percentage shares of these technologies are presented in Figure 4-2, Figure 4-9 and Figure 4-15. Based on section 3.1.5, the thermal energy demand for the premises is estimated as in Table 4-7 and Table 4-9 below.

Table 4-7: Breakdown of annual energy consumption of EWHs in hotels

Type of WH	Total Thermal Energy (kWh)	Total Electric Energy (kWh)	Total Electric Energy (GWh)
50/80L EWH	4,779,219	5,310,244	5.31
Central EWH	2,276,964	2,529,959	2.53
Total	**7,056,183**	**7,840,203**	**7.84**

Table 4-8: Breakdown of annual energy consumption of EWHs in hospitals and health specialty centers

Type of WH	Total Thermal Energy (kWh)	Total Electric Energy (kWh)	Total Electric Energy (GWh)
50/80L EWH	4,890,577	5,433,974	5.43
Instant EWH	828,648	920,720	0.92
Total	**5,719,225**	**6,354,694**	**6.35**

Table 4-9: Breakdown of annual energy consumption of EWHs in guest houses

Type of WH	Total Thermal Energy (kWh)	Total Electric Energy (kWh)	Total Electric Energy (GWh)
50/80L EWH	2,717,924	3,019,916	3.02
Instant EWH	1,203,064	1,336,738	1.34
Central EWH	153,215	170,239	0.17
Total	**4,074,203**	**4,526,893**	**4.53**

Table 4-10: Total annual energy consumption of EWHs

Sectors	Total Thermal Energy (kWh)	Total Electric Energy (kWh)	Total Electric Energy (GWh)
Hotels	7,056,183	7,840,203	7.84
Hospitals & specialty centers	5,719,225	6,354,694	6.35
Guest house	4,074,203	4,526,892	4.53
Total	**16,849,611**	**18,721,789**	**18.72**

4.5. Solar Heating Capacity

RETScreen software has been used to estimate the equivalent solar water heating capacity. The mathematical equations for this analysis are presented on section 3.1.5 (b) and section 3.2.4 (d). The Electric Water heating base case resulted in aggregate collector area required of about 14,926-meter square, 7.9 MW_{th} capacity and energy saving of 11.2 GWh. Table 4-11, shows base cases and results.

Table 4-11: The equivalent solar heating capacity and energy saving

Sectors	Base Case Electric Energy Demand (kWh)	Solar collector area (m2)	Solar Heating Capacity (kW_{th})	Energy Saved (kWh)
Hotels	7,840,203	6,250	3,298	4,691,441
Hospitals/health specialty centers	6,354,694	5,065	2,673	3,802,100
Guest house	4,526,892	3,611	1,905	2,709,867
Total	**18,721,789**	**14,926**	**7,876**	**11,203,408**

4.6. Suitability of existing facilities for SWH installation

4.6.1. Available SWH installation area

There is an aggregate total of 61,440 square meters area available for SWHs installation at hotels, hospitals and guest houses in the city. Details are presented in the sections below.

As can be seen in Figure 4-29, about 87% of hotels in Addis Ababa have available SWH installation areas on their rooftops. The remaining hotels do not have suitable installation areas as the available area is occupied by other hotel-related activities. The total available roof area for SWH installation is 19,862 meters square. Among these, 12,056-meter square SWH installation area belongs to hotels with centralized water heating systems and 7,806-meter square SWH installation area belongs to hotels with decentralized water heating systems.

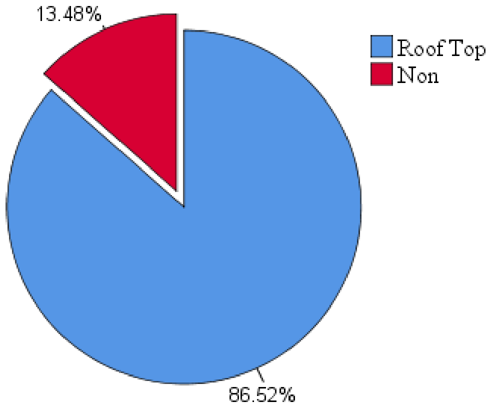
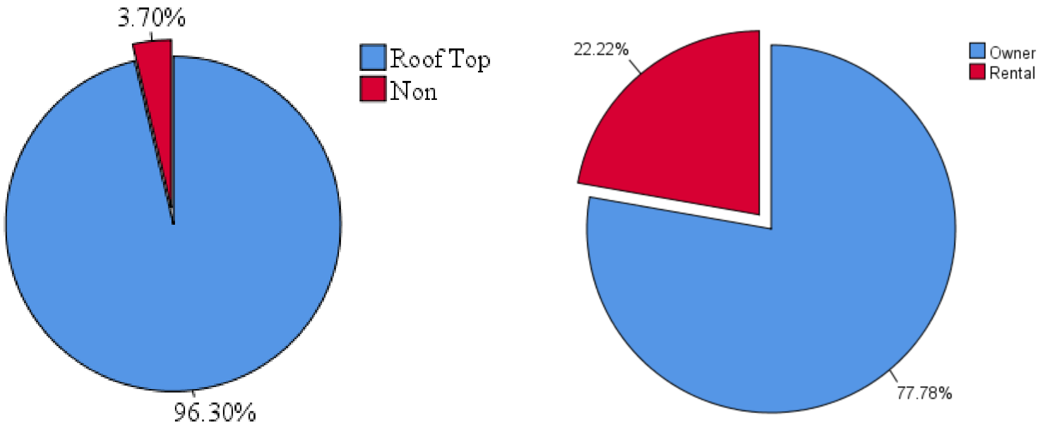


Figure 4-29: Suitable SWH installation area in hotels

Majority (96.3%) of hospital and health specialty centers have available SWH installation areas on their rooftops. The total available roof area for SWH installation is 16,718 meters square. Among these, 2,545-meter square SWH installation area belongs to hospitals and health specialty centers with centralized water heating systems and the remaining 14,173-meter square SWH installation area belongs to hospitals and health specialty centers with decentralized water heating systems. As shown in Figure 4-30 (b), about 78% of hospitals and health specialty centers are the owners of the premises. However, the remaining establishments are rented and this makes them not suitable for permanent SWH installation.



(a) (b)

Figure 4-30: (a) Suitable SWH installation area and (b) Building ownership in hospitals and health specialty centers

As can be seen in Figure 4-31, majority (93.3%) of guest houses have available SWH installation areas on their rooftops. The total available roof area for SWH installation is 24,860-meters square. Among these, 644-meter square SWH installation area belongs to guest houses with centralized water heating systems.

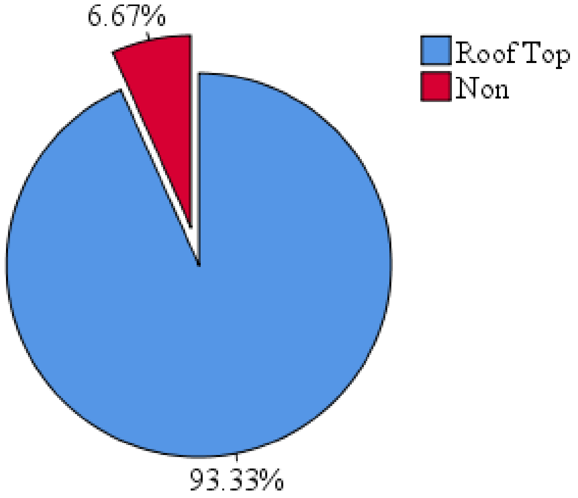


Figure 4-31: (a) Suitable SWH installation area in guest houses

4.6.2. Roof type and slope

About 55% of hotels in Addis Ababa are constructed with mixed corrugated sheet and concrete roofs. 23% of hotels are covered with concrete roofs and the reaming hotels have corrugated sheet roofs. The majority of hotels, about 60%, have mixed flat and inclined roof shape. The remaining 20.22% are flat roof, 12.36% are gable and 7.87% are inclined roofs. In contrast to hotels, 50% of hospitals and health specialty centers are constructed with mixed corrugated sheet and concrete roofs. The remaining 26% are covered with concrete roofs and 24% with corrugated sheet roofs. The roof slope in hospitals and health specialty centers is 40% gable roof, 26% flat roof, 24% mixed flat and inclined roof and the remaining 10% is inclined roof. Majority (63.64%) of guest houses are constructed with corrugated sheet roofs. About 21.2% are covered with concrete roofs and the reaming with mixed corrugated sheet and concrete roofs. A significant 54.55% of guest houses have inclined roof shape, 21.21% flat roof, 9.09% gable and 15.15% mixed flat and inclined roofs.

4.7. Awareness on Pros and Cons of Solar Water Heaters

SWHs non-users were asked a series of questions to better understand their awareness. Questionnaire is attached as Annex 3. Their feedback is represented as below.

a) Do you know how much money your establishment pays for water heating energy costs in a month?

Almost all (93.94%) hotel respondents do not know how much they pay for water heating energy. Only 6.06% of hotels measure their energy consumption for water heating. Amongst hospital and health center respondents, only 2.0% measure their consumption. All guest house respondents do not know how much they pay for water heating energy.

b) Have you heard about SWH?

Majority of respondents (91%) heard about solar water heating technologies. The most common sources of information are advertisements (45.16%), books/magazines (40.32%), and first-hand SWH observation on other premises (37.10%). In contrast to hotel respondents, about 88% of hospital and health center respondents are aware of SWH systems. Similar to hotel respondents the most common source of information is first-hand SWH observation on other premises (55.32), books/magazines (38.30%) and advertisements (36.17%). A Significant (72.7%) amount of guest house respondents heard about solar water heating technologies. The most common sources of information are first hand observation on other premises (51.28%), advertisement (30.77%), and first-hand observation on similar establishments (20.51%). Figure 4-32 to Figure 4-34 present sources of SWH information.

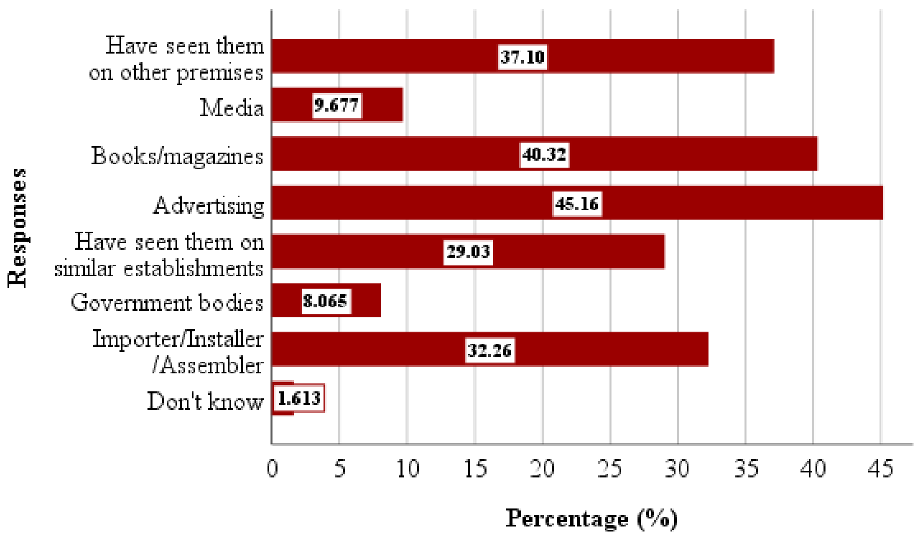


Figure 4-32: Sources of SWH information: hotel respondents

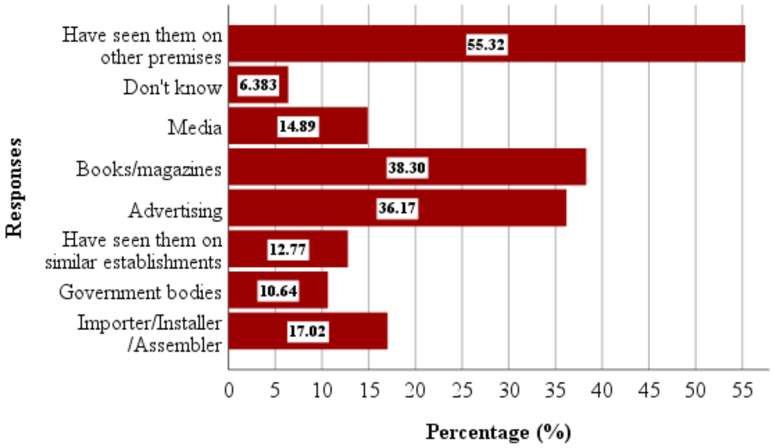


Figure 4-33: Sources of SWH information: hospital and health specialty center respondents

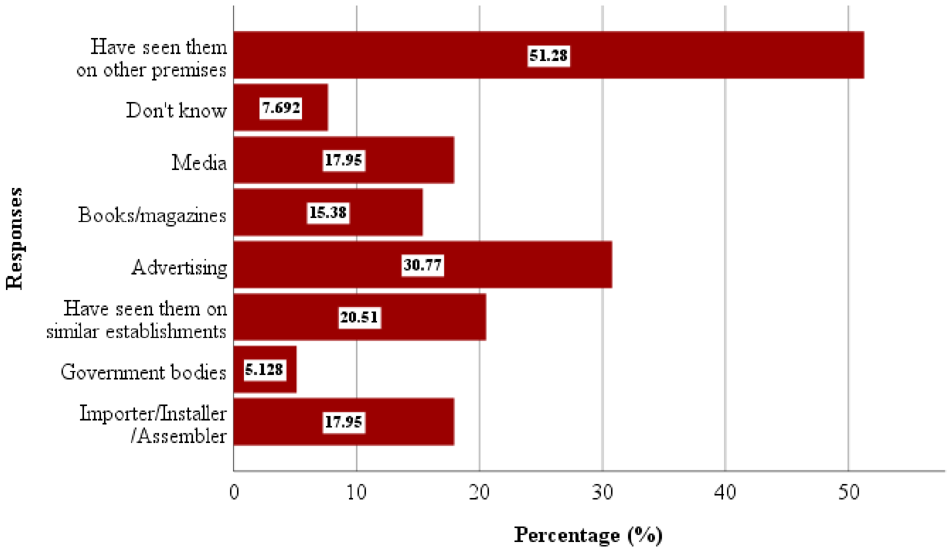
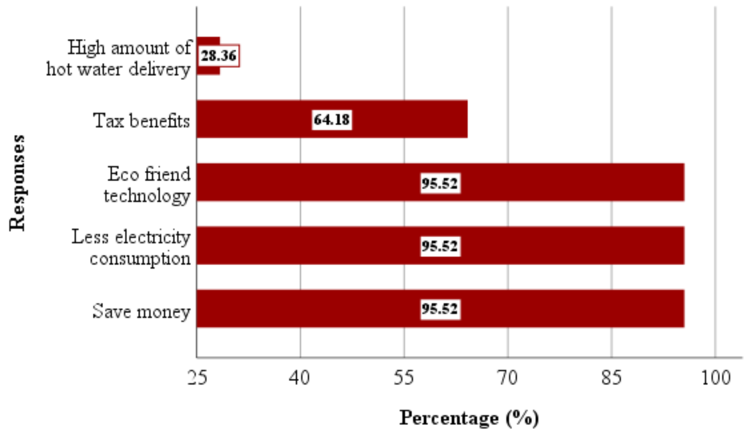


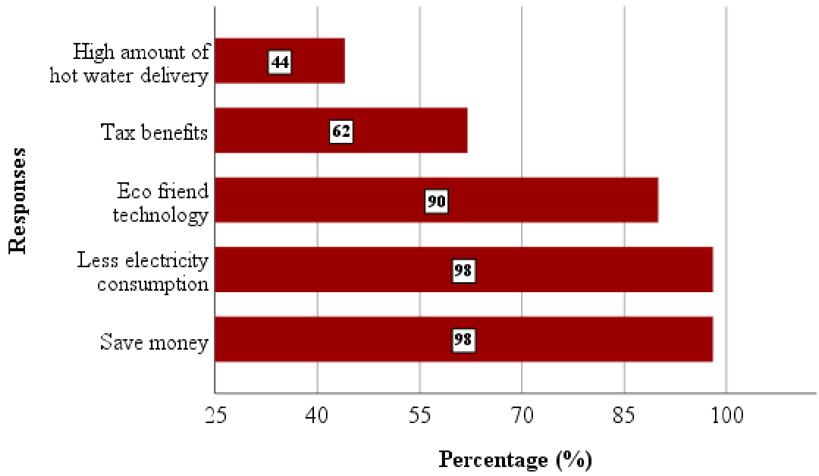
Figure 4-34: Sources of SWH information: guest house respondents

c) **What do you think the advantage of using SWH to heat the water in your establishment would be?**

An overwhelming majority of 95.52% respondents believed that solar water heaters are eco friendly technology, consume less electricity and save monthly electric water heating bills. Only 28.36% of the respondents believed that solar water heaters have high amount of hot water delivery capacity. As compared to hotel respondents, majority of hospital and health specialty center respondents (98%) feel that solar water heaters have high amount of hot water delivery capacity. Majority (95.74%) guest house respondent believed that solar water heaters consume less electricity, (82.98%) are eco friend technology, and (76.6%) save monthly electric water heating bills. Figure 4-35 presents responses on the advantage of solar water heating system.



(a)



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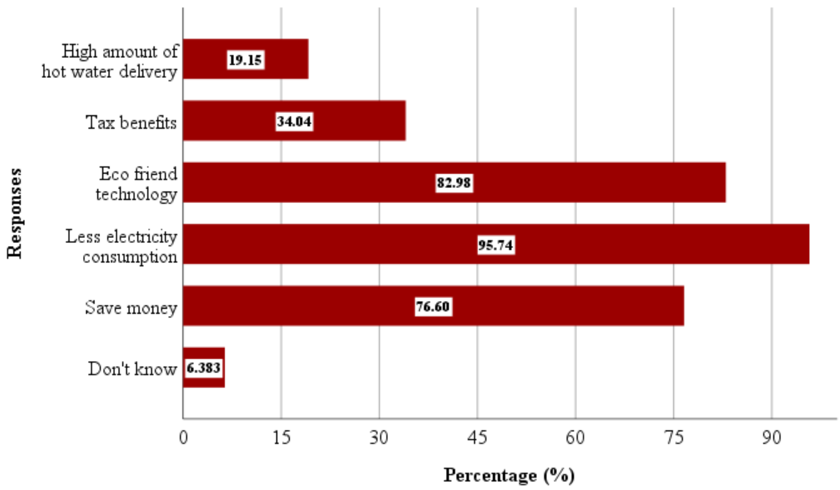


(c)

Figure 4-35: Advantage of solar water heating system: (a) hotel and (b) hospital and health specialty center and (c) guest house respondents

d) What do you think the disadvantages of using solar energy would be to heat the water in your establishment?

A significant, 71.43%, of hotel respondents believed that solar water heaters take a longer time to get hot water. The other two most responded disadvantages are that solar water heaters are "too expensive to install" and "do not have as much hot water delivery capacity". Only one fourth of the respondents feel that solar water heaters negatively affect the aesthetics of the buildings. In contrast to this, only 5% of hospital and health specialty centers respondents feel that solar water heaters negatively affect the aesthetic of the building. About 62.79% of guest house respondents revealed that solar water heaters are too expensive to install, 41.86% feel that solar water heaters take longer time to deliver hot water. Figure 4-36 and Figure 4-37 present responses on the disadvantage of solar water heating system.

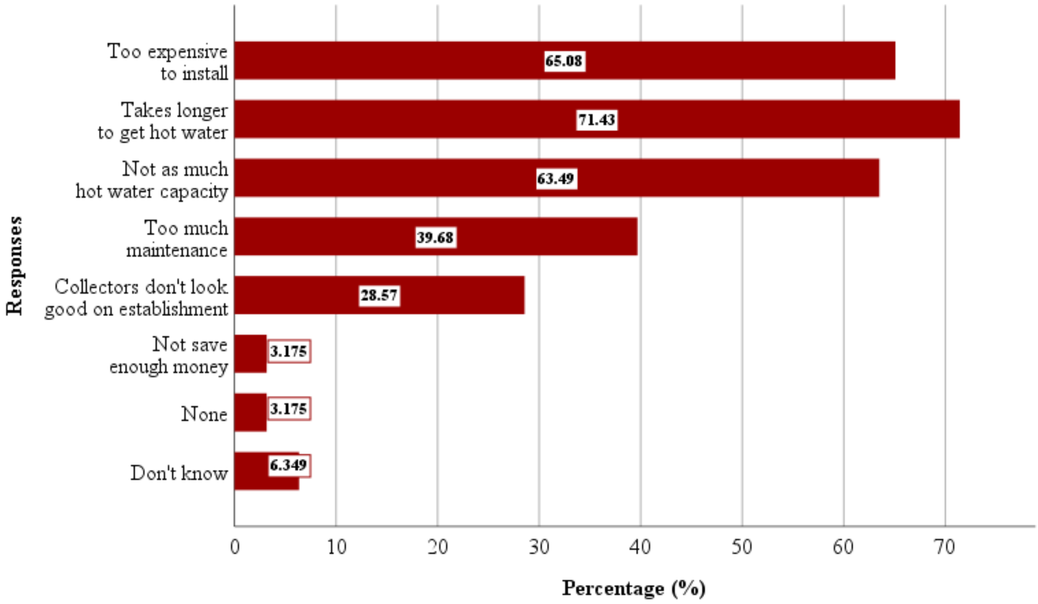
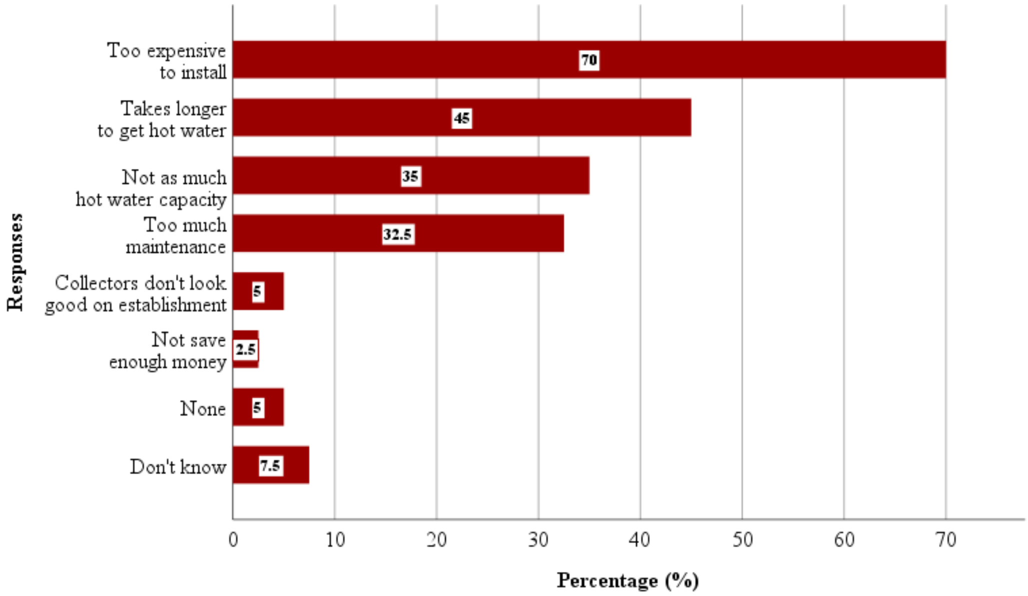
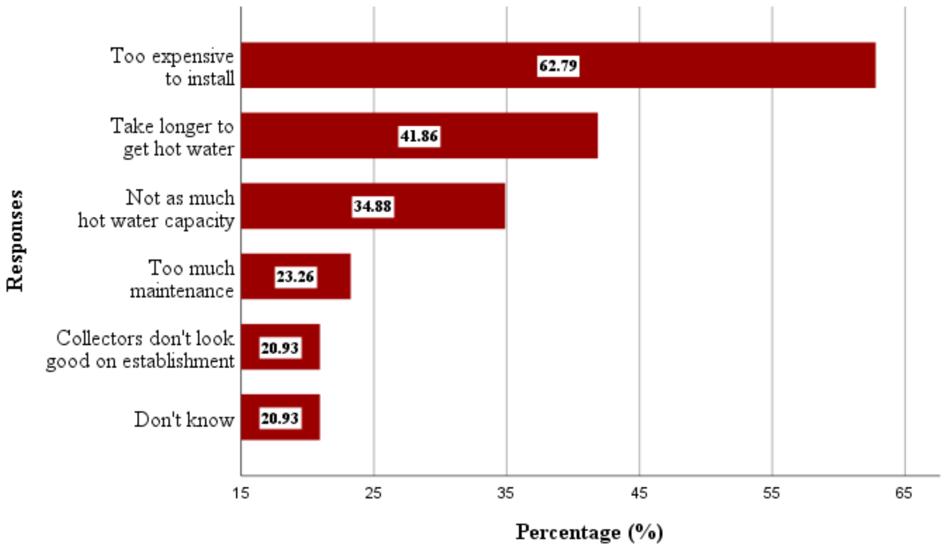


Figure 4-36: Disadvantages of solar water heaters: hotel respondents



(a)



(b)

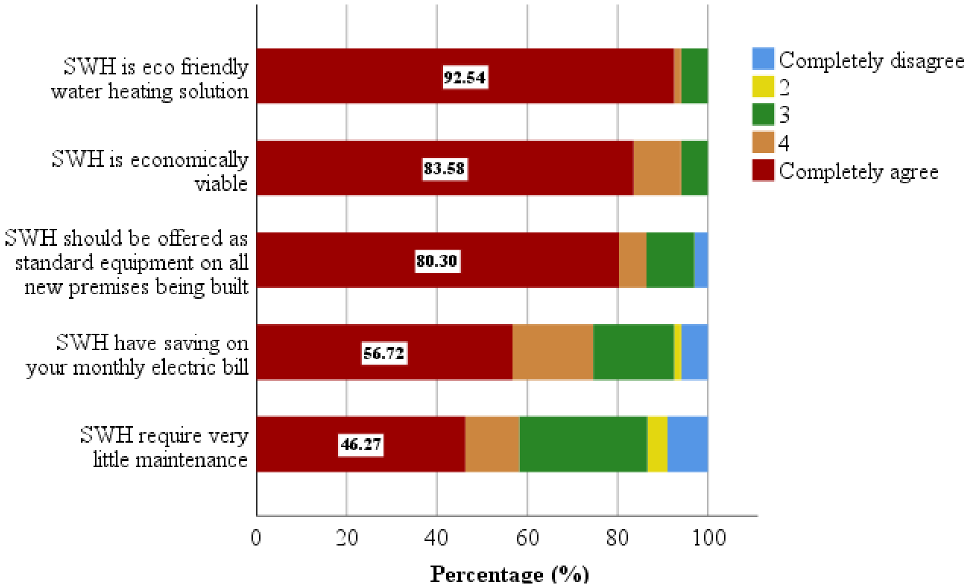
Figure 4-37: Disadvantages of solar water heaters:(a) hospital and health specialty center and (b) guest house respondents

e) How much do you think that a typical SWH system costs, fully installed?

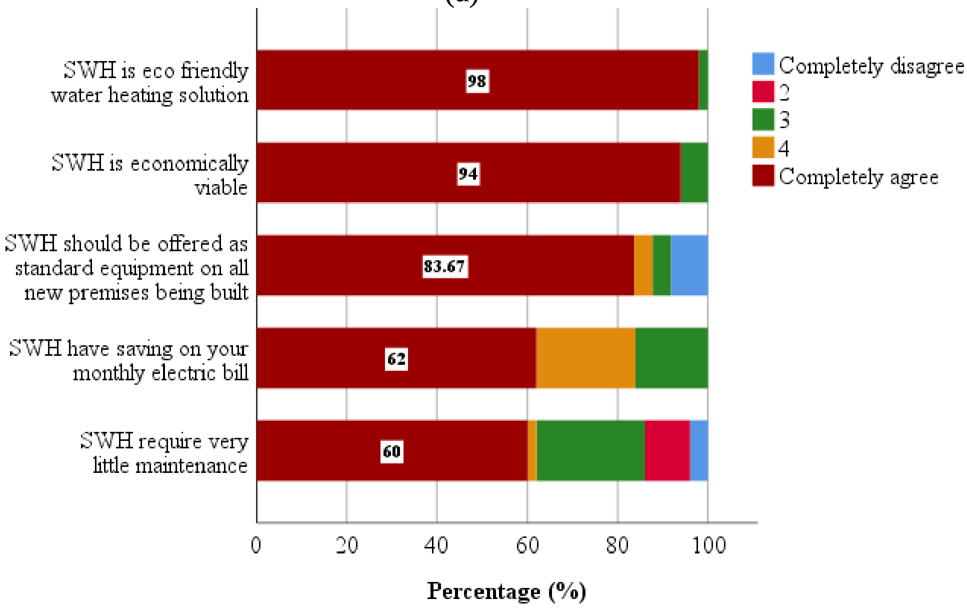
About 90% of hotel, 94% of hospital and health spatiality center and 95.7% of guest house respondents do not have any information about the cost of a typical SWH system.

f) How much do you agree or disagree with each of the following statements?

A significant, 92.54%, of hotel, 98% of hospital and health specialty center and 97.87% of guest house respondents completely agree that SWH systems are ecofriendly water heating solution. About 83.58% of hotel, 94% of hospital and health specialty center and 72.34% of guest house respondents also completely agree that SWH systems are economically viable water heating technology. Figure 4-38 and Figure 4-39 presents responses on the awareness of SWH.



(a)



(b)

Figure 4-38: Awareness on SWH: (a) hotel and (b) hospital and health center respondents

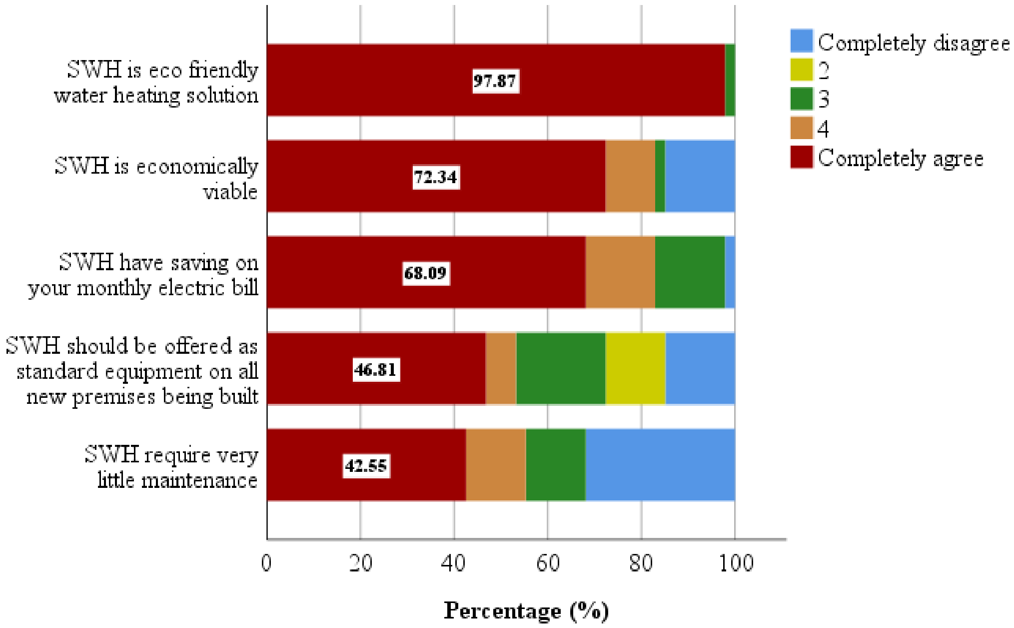


Figure 4-39: Awareness on SWH: guest house respondents

4.8. Adoption and Interest in SWHs

The attitudes and perceptions of non-users on the adoption of SWHs collected using questionnaire is summarized below. Questionnaire is attached as Annex 3.

a) Have you ever considered SWH for your premises?

Half of hotel respondents did not consider solar water heating systems for their establishments. About 63.4% of respondents admitted that they did not think about solar water heaters during the construction of the premises. The other most common responses are lack of information and lack of consultant/contractor advice about solar water heating systems. A significant 58% of hospital and health specialty center respondents did not consider solar water heating system for their establishment. Majority of respondents (83.33%) disclosed that they did not know enough about solar water heaters during their establishment. About 74.74% of guest house respondents did not consider solar water heating systems for their establishments. 90% of respondents admitted that they did not know enough about solar water heaters during the establishment of their firms. Figure 4-40 and Figure 4-41 present responses on consideration of solar water heating system.

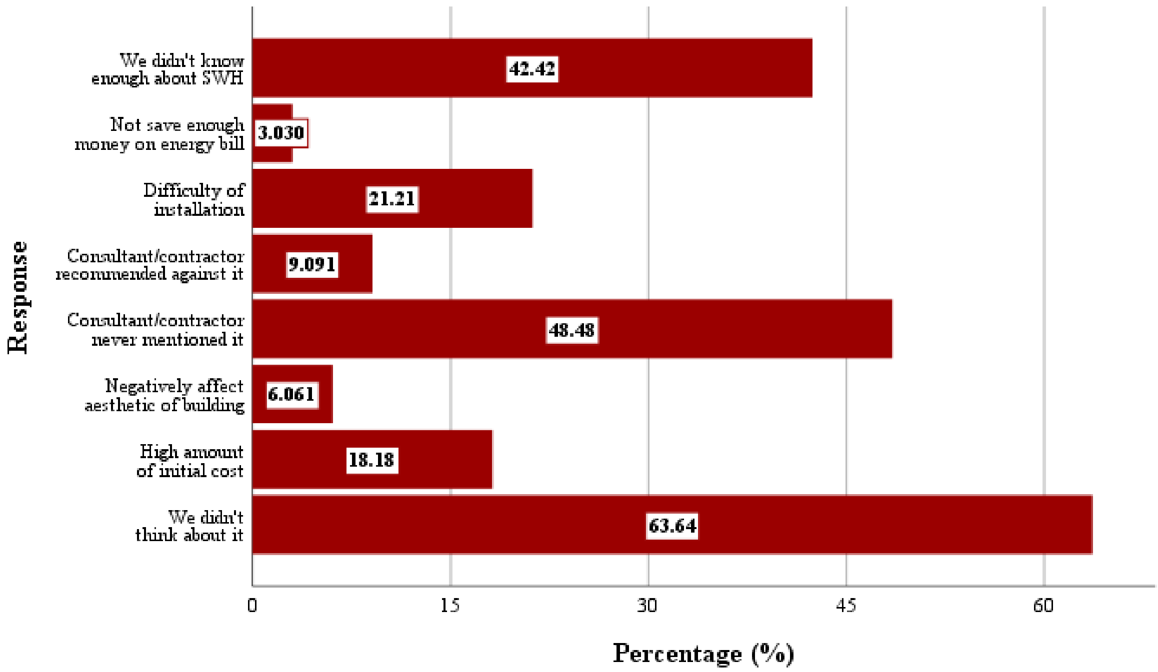


Figure 4-40: Reasons for not considering SWH during establishment: hotel respondents

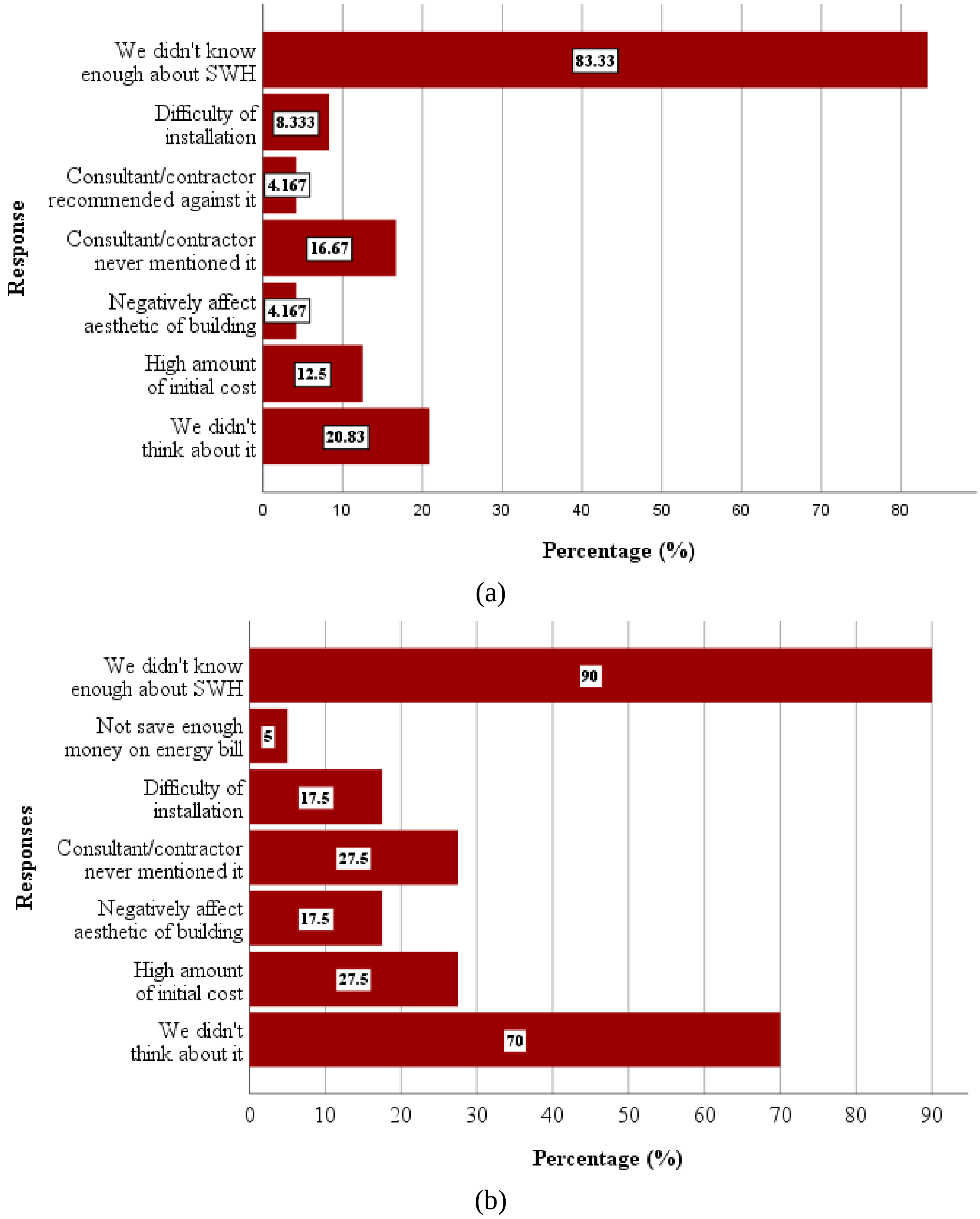


Figure 4-41: Reasons for not considering SWH during establishment: (a) hospital and health specialty center and (b) guest house respondents

b) Which of the following statement is most accurate? If my consultant/contractor had mentioned that solar water heaters were available…

More than 85% of hotel respondents revealed that a consultant or contractor's recommendation has a positive impact on their SWH installation decision during their establishment. About 15% of respondents indicated the consultant or contractor recommendation has nothing to do with their installation decision. In contrast to hotel respondents, majority (92%) of hospital and health specialty center respondents disclosed that a consultant or contractor’s recommendation has a positive impact on their SWH installation decision during their establishment. Majority (97.87%) of guest house respondents revealed that a consultant or contractor's recommendation has a positive impact on their SWH installation decision during their establishment. Figure 4-42 and Figure 4-43 presents responses on the consultant/contractor recommendation.

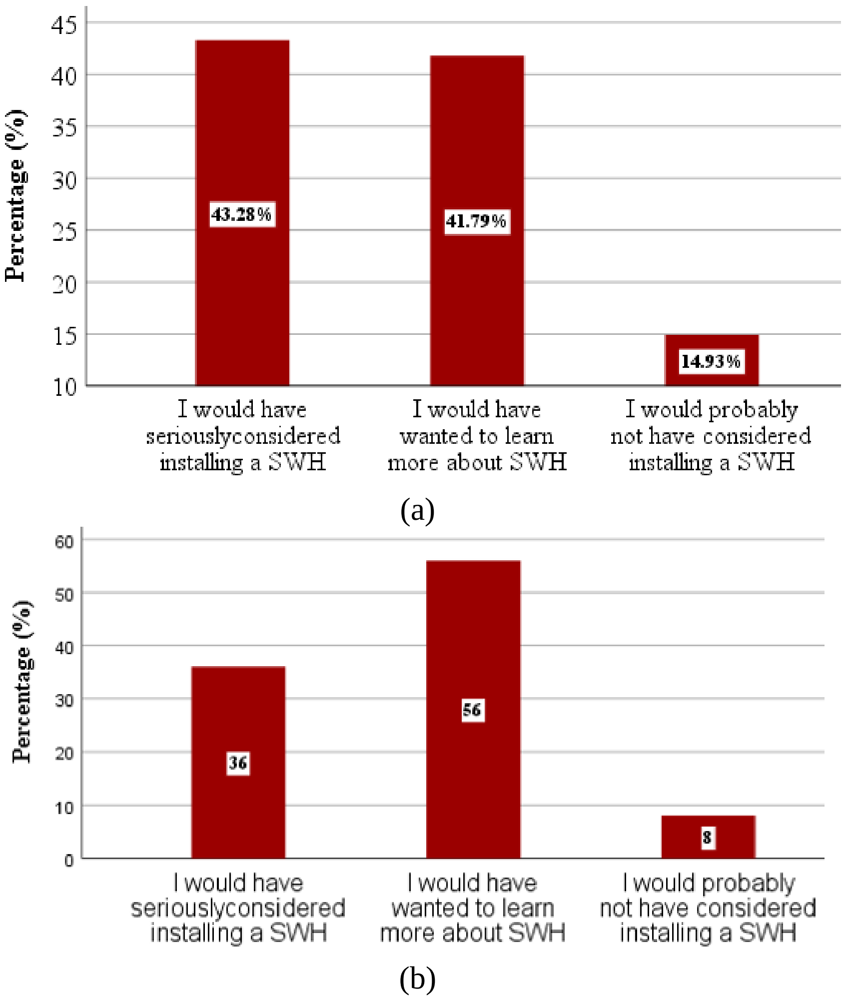


Figure 4-42: Consultant/contractor recommendation on SWH: (a) hotel and (b) hospital and health specialty center respondents

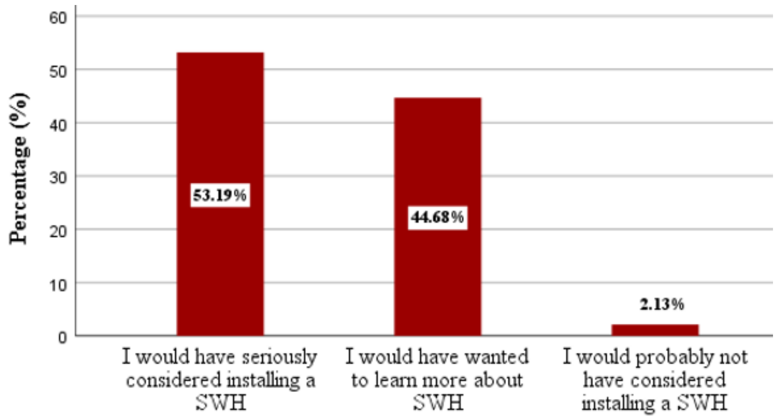


Figure 4-43: Consultant/contractor recommendation on SWH: guest house respondents

c) If a solar water heater had been voluntary standard in your premises, how likely would you be to have the system installed?

About 85% (Extremely likely and Somewhat likely) of the respondents would install a solar water heating system if a SWH system had been voluntary standard. The percentage of respondents who "might or might not" and "extremely unlikely" to install a solar water heating if the solar water heater had been voluntary standard are 13.43% and 1.49% respectively. Similar to hotels respondents, majority (70.0%) (Extremely likely and Somewhat likely) of hospital and health specialty centers would install a solar water heating system, if a SWH system had been voluntary standard. About 82.95% (Extremely likely and Somewhat likely) of guest respondents would install a solar water heating system, if a SWH system had been voluntary standard. Figure 4-44 and Figure 4-45 present responses on the effect of voluntary standard on adoption of solar water heating system.

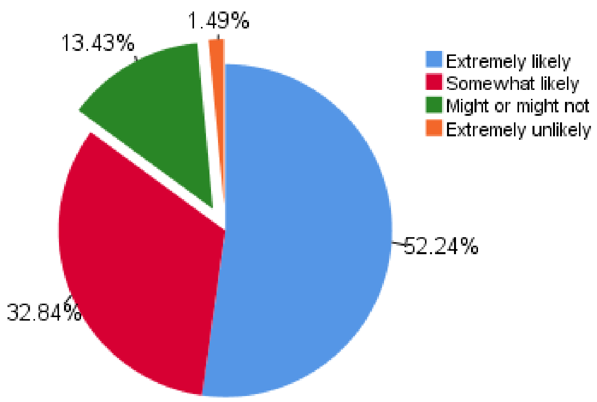


Figure 4-44: Effect of voluntary standard on adoption of SWH: hotel respondents

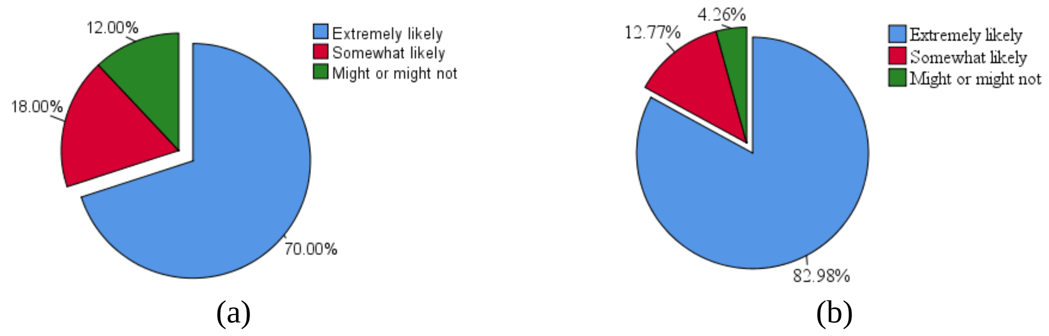


Figure 4-45: Effect of voluntary standard on adoption of SWH: (a) hospital and health specialty center and (b) guest house respondents

d) If you knew that the savings on your monthly utility bill would completely offset the monthly installment incurred for a SWH, how likely would you be to have the system installed?

An overwhelming majority (Extremely/Somewhat likely) of 71.64% of hotels, 82% of hospital and health specialty centers and 72.34% of guest house respondents would install SWH if they knew that the savings on monthly energy bill would completely offset the monthly fixed payment incurred for a SWH. Figure 4-46 presents responses on the effect of saving on the adoption of SWH.

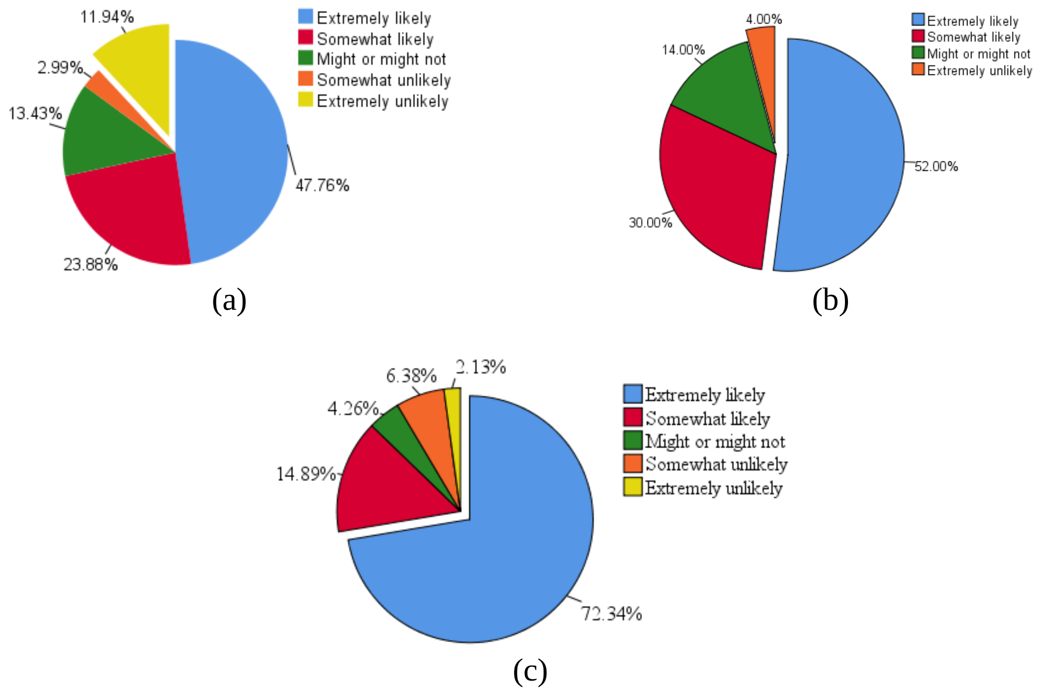


Figure 4-46: Effect of saving on adoption of SWH: (a) hotel, (b) hospital and health specialty center and (c) guest house respondents

e) How important would each of the following things be in your decision to install a SWH system for your premises if you had been interested in one?

For hotel respondents, the three most common SWH system installation decision factors are "warranty" (89.55%), "price of SWH" (80.60%) and "brand of SWH" (79.1%). Surprisingly, the availability of loan and money saving from SWH system were found less important for SWH system installation decision factors. Majority (91.84%) of hospital and health specialty center respondents revealed that their priority decision factor is the price of SWH system. The monthly energy saving value of SWH would not affect their purchasing decision for 64% of hospitals and health spatiality centers. For guest house respondents, the four most common SWH system installation decision factors are "price of SWH" (95.74%), "brand of SWH" (95.74%), "maintenance of SWH" (91.49%) and "warranty" (91.49%). Figure 4-47 and Figure 4-49 present responses on decision factor for installing SWH.

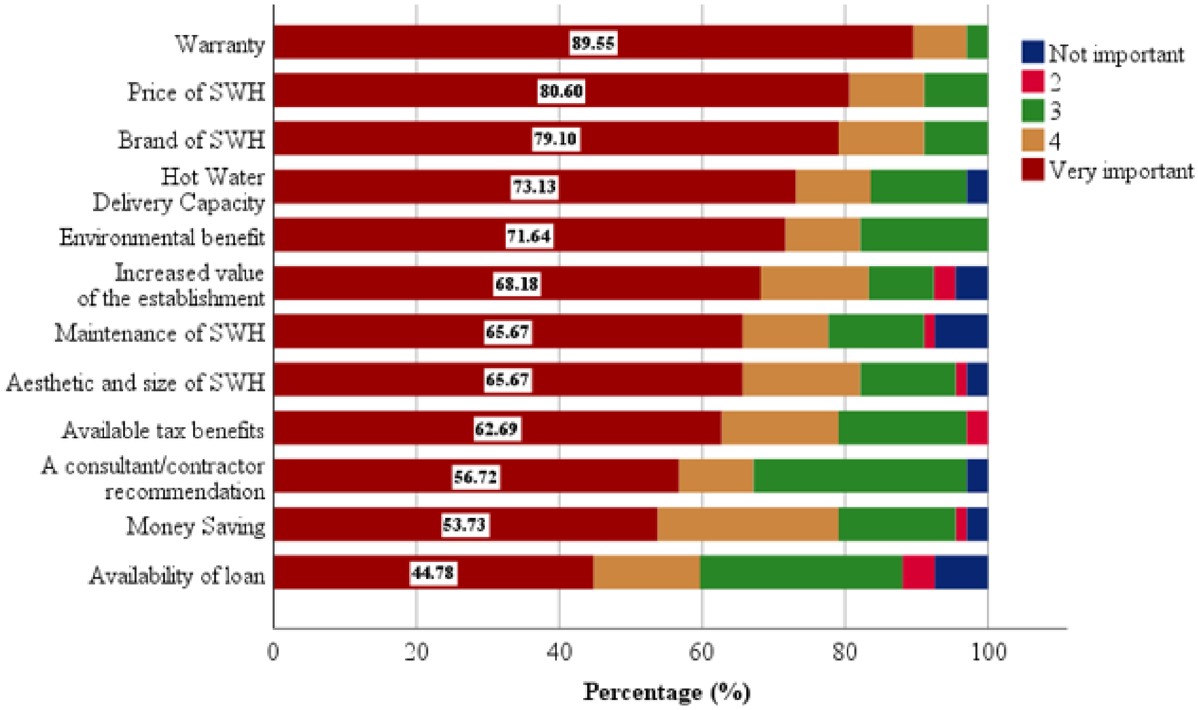


Figure 4-47: Decision factor for installing of SWH system: hotel

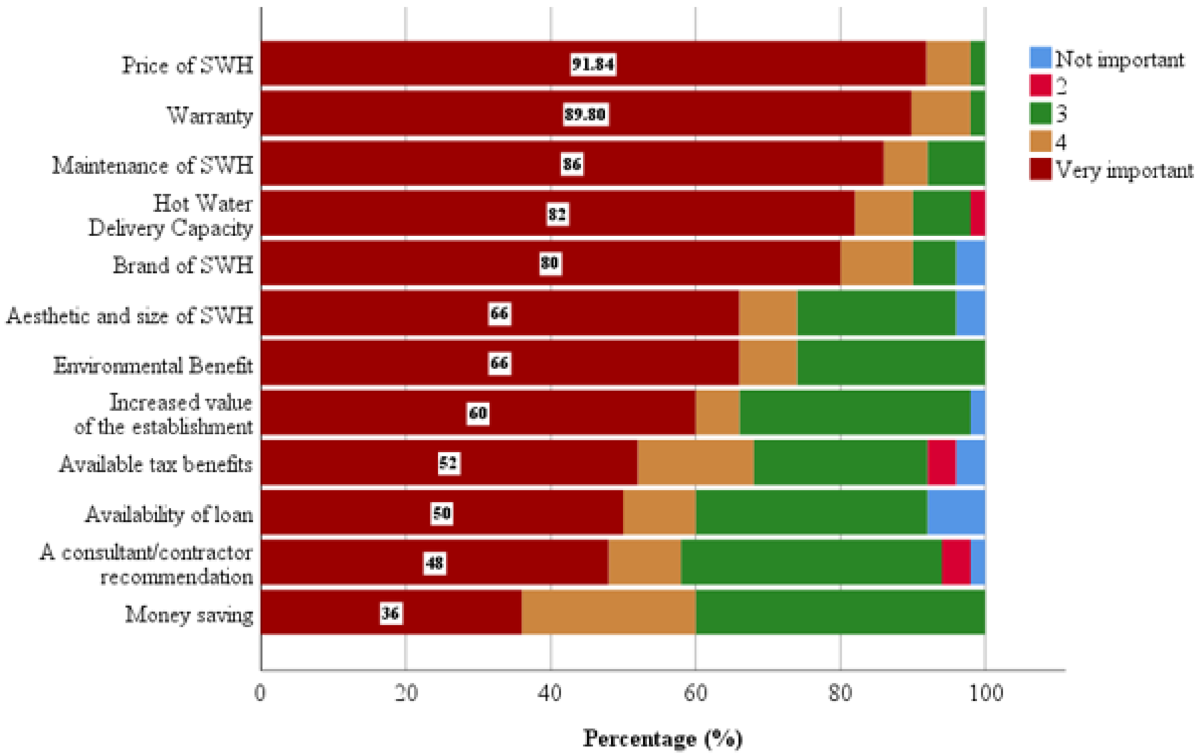


Figure 4-48: Decision factor for installing of SWH system: hospitals and health specialty center

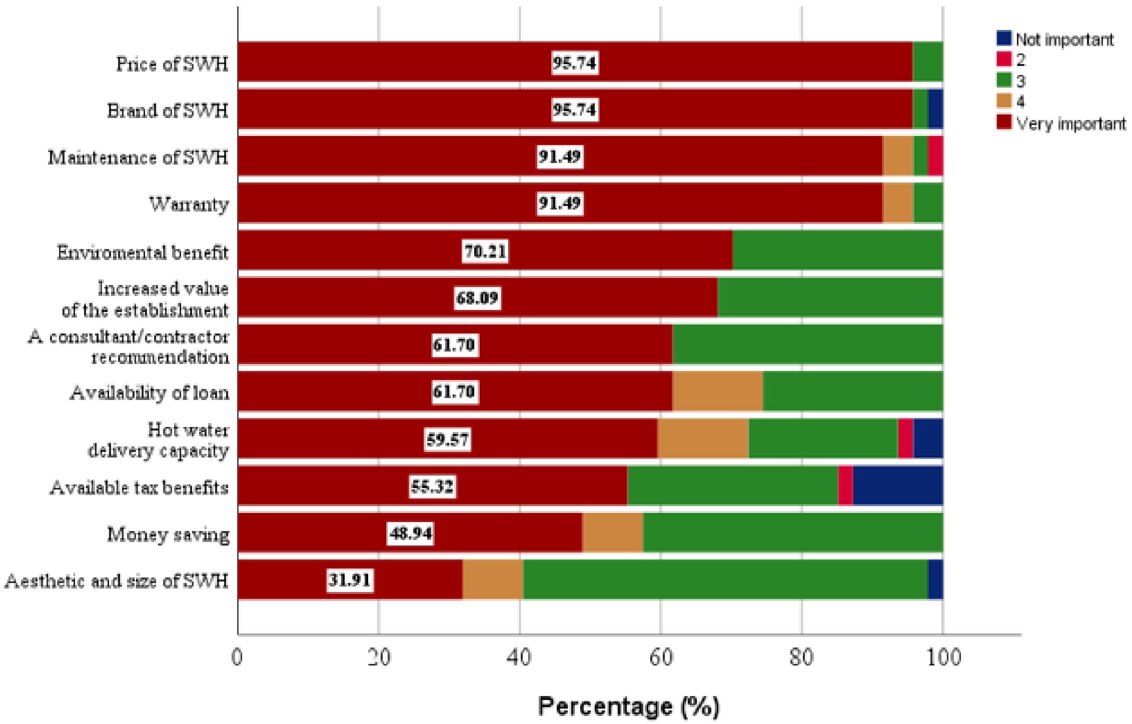


Figure 4-49: Decision factor for installing of SWH system: guest house

4.9. Other Commercial Buildings

In addition to Hotels, Hospitals and Guest houses; commercial buildings including malls, shopping centers and real estates apartments have been observed. Commercial buildings have no need of hot water as most of the functions of the rooms in the buildings are for offices, shops, banks etc. And the functions of the rooms change as per the tenant. Furthermore, building owners are not interested to make the necessary investment in SWH because the benefit associated with any savings will accrue to the tenant.

Real estates have been contacted to assess the technologies they use for water heating. The real estates develop houses and buildings ranging from ground villa houses to 19 story residential apartment and commercial purpose buildings. There are up to 25 flats in one building. Water heating systems are designed and built for EWHs and SWHs are not provisioned. As the real estate developers put it, provisions for SWHs are not made because it needs separate metering for the hot water produced, hot water installations are required, central systems serving the residents in common are not accepted by the users, and it takes up the top most floor of the building which could be used for various activities. However, water supply (including ground water), sewerage, CCTV and HVAC installations, are used in common for a building and costs are shared among occupants. Based on the experience of other countries, centralized SWHs could be installed in big apartment and commercial buildings provided it is included in the initial design and construction of the buildings. As an example, a real estate in Addis Ababa having 13 floors has 25 flats each fitted with 2 to 3 EWHs. The top terrace of the real estate building has about 320 square meter which can accommodate SWHs. However, the real estate has not thus far considered SWHs or any renewable energy water heating systems.

4.10. Other Potential Hot Water User Businesses

Potential hot water businesses in the city including wellness centers/ gyms and shower houses have been observed.

Almost all wellness centers/ gyms in the city use EWHs for showers and bathes except one which uses centralized SWHs of 2000-liter capacity with auxiliary heater installed by local company. The SWHs supplies hot water to 38 shower stands and 13 Spa positions. The users are satisfied with the hot water supply except for the shortage during peak demand. However, they couldn't know the reduction in electricity consumption due to the usage of the SWHs. The center plans to expand the installation once the contribution of the SWHs is determined.

Figure 4-50: SWH in one of the biggest wellness center/gym in Addis Ababa

Shower houses have been surveyed to get information on hot water use and demand. There are many small shower houses in the city having shower stalls ranging from one to thirty-five using mostly fire wood, instant and storage EWHs. The shower houses provide service from six to twenty-four hours per day and almost all electricity users employ the 5.5 kW, 220 V instant electric heaters per shower stall. Shower service costs Birr 30-40/person for hot shower and 20-25 for cold on the average.

A shower house having 33 shower stalls indicated their monthly expense for wood including labor is about Birr 42,000.00 per month. Figure 4-51 and Figure 4-52 show fire wood shower and storage and instant shower stalls respectively.

Figure 4-51: Fire wood water boiler at shower houses

Figure 4-52: Storage and instant type electric water heaters at shower houses

The following are summarized responses from shower stall owners.

- A fire wood hot shower service of eight shower stalls incurs birr 8000 per month for cost of wood to run for 12 hours per day.
- There is a strong perception that SWHs cannot provide the hot water flow rate their customers need based on their experiences from previously installed systems and couldn't be good enough as using instant EWHs and fire wood.
- Cost of SWHs is high and is not affordable for small and short life time business, most services are provided at rented houses and SWHs is not movable,
- SWHs are not easily maintainable, costly to maintain, qualified technicians are not available and the system is complex. The Evacuated Tubes installed at shower houses break often.
- Some enquired, "How much does the SWHs serve and what is the warranty? New technology comes with cost and we are not interested."
- Many have planned to expand their business but couldn't as hot shower service need three phase electric power and that is not available, not feasible on rented houses, and cost is beyond their financial capacity.
- Many are interested to know what SWHs could provide, its cost benefit, and whether it can give support at least to preheat water before it heated using wood fire or electric water heaters.

4.11. Water Heaters in the Market

a) Electric water heaters in the market

There are two types of EWHs in the market for Hotels, Hospitals and guest houses in Addis Ababa - Instant and Storage type. The instant types are for showerhead mounting or wall mounting having power ratings about 5500W, at 220V and their price ranging from 1500 to 3,000.00 Birr. Brands like Lorenzetti and Sterling are common.

Figure 4-53: Instant and storage electric water heaters in Addis Ababa market

Most of the storage electric water heaters in the market are imported and have capacities ranging from 30 to 100 liters. Prices range from 8,500 to 25,000 Birr. The most common type is the 50-liter having power rating of 1.5 kW. Common brands include: Ariston, Milano, Soresa, and Jaguar. There is a local firm manufacturing the storage Electric water Heaters with 80-liter capacity, its price being 16,000.00 Birr.

b) Heat pumps in the market

There are few heat pump suppliers in the market. Hotels, Hospitals and commercial buildings are supplied Heat pumps during building construction by specialized HVAC contractors or Solar thermal equipment importers/installers based on custom design.

c) SWH in the market

The solar water heater (SWH) market was started in Ethiopia with imported products and is currently mainly based on imported products. There is a locally manufactured FPC type product in the local market.

The Flat plate and pressurized and non-pressurized Evacuated Tube type SWHs are in the market with limited choice of storage capacity. Most of imports are from China. Other countries of origin include: Germany, Greece, Italy, UK, and UAE. The markets for the SWHs are mainly residential households and commercial premises in Addis Ababa and the regional capitals in the country. In July 2021, the different types of SWH have been surveyed. The price of the locally manufactured Flat plate SWH of 80 liters capacity is about birr 42,000. Imported EU standard flat plate of 160 liters cost birr 63,755. Non-pressurized SWHs of 150 (ETC) liters costs birr 28,000 whereas 200-300 liters capacity pressurized ETC SWHs imported from China cost Birr 40,000-78,000 indicating variation in price based on volume and brand. Market delivery is full payment upon installation of the system only as there are no credit through banks or from the system suppliers.

4.12. Importers/Manufacturers/Installers

Importers/installers were requested to fill in the questionnaire attached as Annex 1 regarding SWHs. There are about four major importers/installers of SWHs in the country who are also engaged in the design, installation and maintenance of the systems on top of their major line of business-like solar PV systems, solar lanterns, solar pumps, solar fridges etc. These importers/installers operate with few technical staffs of two to seven. There is one manufacturer who produces FPC, EWHs and two types of Solar boilers, i.e. thermosiphon and heat exchanger, since 2017.

a) General responses of Importers/installers on SWHs

- Importers/Installers have been in the business from four to fourteen years.
- The market for SWHs in commercial businesses has slowed down for various reasons. After sales service of SWHs demands resources and importers/installers prefer other short time paying businesses instead, consumers awareness on SWH is low, rate of electricity created favorable condition for the consumers not to look for alternative water heating energy source.
- There are no policy incentives, regulations or programs that provide credit on SWHs in the country which interests consumers.
- Most of their customers are domestic households.

- Regarding sustainability of SWHs business, the demand for SWHs is increasing because new townships are developing every day with multiple bathroom which is favorable to use SWH instead of one boiler in every room, its life time is more than 20 years, nearly maintenance free, big factories are being built and consumption of hot water is increasing in every aspect, the rate for electricity is increasing, power interruption is most common, and there is abundant solar radiation.
- Both the ETC and FPC are suitable for commercial and residential applications and installations are based on client need and interest. ETC are most common due to weight, ease of installation, ease of maintenance, and aesthetic.
- The pressurized stand alone and pressurized /non-pressurized centralized and de centralized systems are appropriate for the SWHs users
- Major import Country of origin is China.
- The motivations for acquisition of SWH by customers: no need to install EWH in every bathroom or room, cheaper on electricity usage, almost maintenance free, it is eco-friendly, longer life time.
- SWHs post installation system performance test is not carried out.
- Some importers issue warranties both for manufacturing and workmanship defect while others issue for manufacturing only.

b) Regarding adoption of SWHs by users

- Most agree that SWHs are cost effective compared to EWHs.
- If every hotel, hospital and other buildings in the city that consumes hot water installs a solar water heating system there will be positive impact on base load demand of electricity, customer satisfaction, and job growth,
- Most strongly disagree that there is adequate financial incentive currently in place to promote SWH technology in commercial and public sector.
- Most agree that rebate financing is an effective means of incentivizing the adoption of SWH. Most disagree that the benefits associated with SWH are well understood by the public, and existing loan programs from the government or other financial institution offer competitive rates and terms on SWHs
- Most of the Importers/installers believe that installation of SWH systems shall be mandatory for Hotels, Hospitals, and other commercial buildings in Addis Ababa.

c) Concerning barriers to the adoption of SWHs.

- Social/cultural/behavioral barriers: most important issues expressed are that users are not familiar with solar water heating.
- Economic/ financial barriers: The initial cost of a SWH system is too high, it takes too long to pay back the cost of the system, there is a lack of competitive financing options and, incentives for SWH are not big enough.
- Institutional/ regulatory barriers: Most important barriers include lack of institutions to disseminate information/ raise awareness about solar water heating systems, and lack of involvement by key stakeholders when making decisions.
- Market distortion/ failure barriers: Favor (such as larger subsides) given to other renewable energy technologies, unprofessional installations, and misinformation to customers.
- Policy barriers: Lack of incentives and other technologies (such as Solar PV) receive greater share of incentives as compared to solar thermal.

The only local manufacturer responded that:

- They operate with 12 technical staffs and provide a five-year warranty on their products.
- Shortage of raw materials mainly due to shortage of foreign currency, the financing bureaucracy of the local banks & other funding sources that used to flow through government organizations have prevented them from fulfilling the production demand
- There is almost the same percentage of demand level between residential and hotels end-users
- The energy saving potentials of the use of natural energy for heating water is not seriously recognized by concerned authorities.
- Import of other country's commodities are encouraged instead of manufacturing firms that produce the same or even higher quality products locally.
- Standard/Compliance is not set in the country. But they follow Israeli standard requirements in their production process.
- They install water tanks of various sizes due to the problem of water and shortage of water pressure.

4.13. Import Data from Ethiopian Customs Commission (ECC)

Import data of Electric water heaters from 2016/17 to 2020/21 collected from the Ethiopian Customs Commission (ECC) registered under the HS 85161000 is presented in Table 4-12 and Figure 4-54 below. However, it is noted that other electric water heater related appliances have been included under the HS code.

Table 4-12: Import data of electric instantaneous or storage water heaters and immersion heaters

Year	Quantity	CIF Value (ETB)	Tax (ETB)	Total Value (ETB)
2016-2017	170,127	90,494,965	48,535,607	139,030,572
2017-2018	138,917	105,010,063	59,758,845	164,768,908
2018-2019	212,561	118,808,073	72,513,766	191,321,839
2019-2020	241,010	162,629,094	101,420,601	264,049,695
2020-2021	344,970	169,136,745	98,709,204	267,845,949

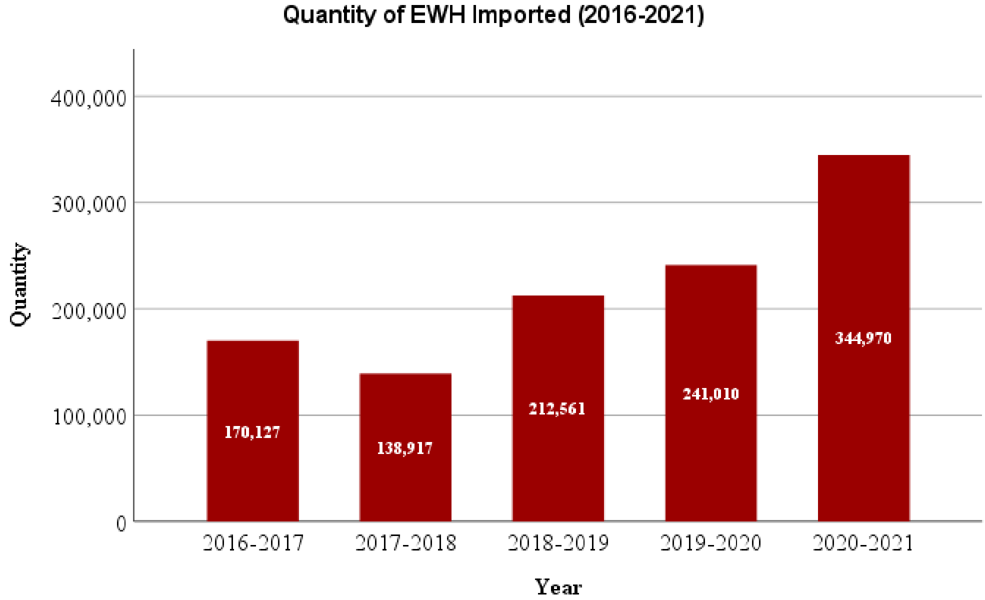


Figure 4-54: Quantity of EWH imported (2016-2021)

Solar Water Heaters imported from 2016/17 to 2020/21 under the HS code 84191910 and the corresponding values are shown in

Table 4-13 and Figure 4-55. The quantity and total value of imported items increased significantly in the year 2018/19. It is noted also that other Solar related appliances like rechargeable solar, solar refrigerator, solar panel, and basic solar tool kit have been registered under this HS code, which should have been treated under different HS code.

Table 4-13: Import data of solar water heaters

Year	Quantity	CIF Value (ETB)	Tax (ETB)	Total Value (ETB)
2016-2017	583	6,677,140	610,839	7,287,979
2017-2018	1,804	5,317,219	821,848	6,139,066
2018-2019	452	6,071,648	963,028	7,034,676
2019-2020	698	9,480,459	1,461,448	10,941,907
2020-2021	296	9,075,402	1,368,715	10,444,117

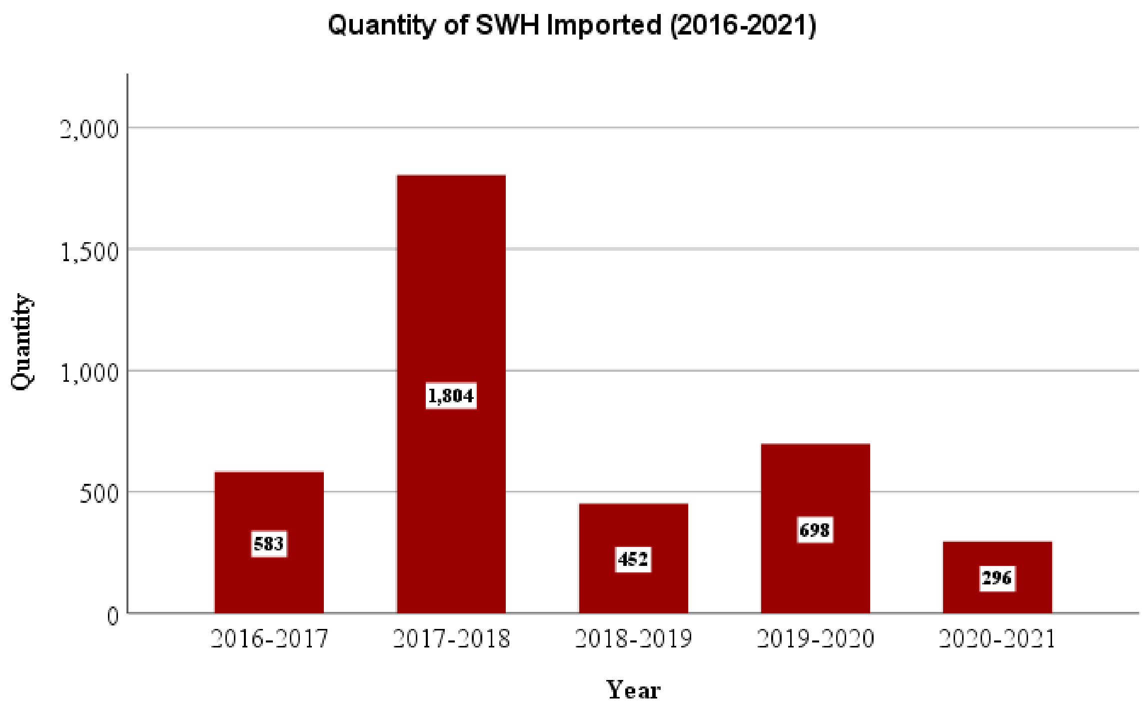


Figure 4-55: Quantity of SWH imported (2016-2021)

5. FEASIBILITY STUDY OF REPLACING EWHS WITH SWHS

5.1. RETScreen Energy Model and SWH Performance

5.1.1. Comparison of FPC and ETC type SWH for small scale water heating

RETScreen simulations were conducted for pressurized SWH system using flat plate and evacuated tube collectors and the input data has been listed in Table 5-1. For this scenario, SWH analysis was done for an average daily hot water consumption of 1000 L/day to represent smaller hot water consumption in the premises. Evaluation and comparisons in terms of performance and economic viability have been conducted for both FPC and ETC collector types.

Table 5-1: The energy model input parameters for small scale water heating

S.No.	Input Parameter	FPC	ETC
1	Daily peak hot water usage (L/day)	1000 L/day	1000 L/day
2	Hot water temperature (°C)	60	60
3	Occupancy rate: low season/ peak season (%)	51/76	51/76
4	Solar tracking mode	Fixed	Fixed
5	Slope	15°	15°
6	Azimuth	0°	0°
7	Operating days per week	7	7
8	Miscellaneous losses for collector (%)	3	2
9	Miscellaneous losses for BoS (%)	5	5
10	Conventional fuel type	Electricity	Electricity
11	Seasonal efficiency (%)	90	90
12	Electricity rate (ETB/kWh)	2.124	2.124
13	Inflation rate (%) *	8	8
14	Discount rate (%) **	10.5	10.5
15	Fuel cost escalation rate (%)	10	10
16	Project life (years)	20	20
17	Debt ratio (% of the initial cost)	0	0
18	Initial grant (% of the initial cost)	0	0
19	Annual O&M costs (% of initial cost)	0.5	0.5

* (Ethiopian Economics Association, 2021) ** (National Bank of Ethiopia, 2021)

The technical specification of the selected SWH system for this particular analysis is presented in Table 5-2.

Table 5-2: The technical specification of selected SWH

No.	Parameters	FPC	ETC
1	Gross area per solar collector (m^2)	2.721	4.278
2	Aperture area per solar collector (m^2)	2.571	3.225
3	Fr (tau alpha) coefficient	0.739	0.563
4	Fr UL coefficient (W/m^2)/°C	3.982	1.438
5	Temperature coefficient for Fr UL	0	0

The solar collector area, number of collectors, capacity, and solar fraction (SF) of the SWH system are presented in Table 5-3. The performance of the system is evaluated by the SF. The SF is the percentage of the hot water demand that can be covered by the SWH systems. The auxiliary system will cover the remaining fraction. Natural Resources Canada (2004) and Singh et al. (2020) assessed that the value of a solar fraction of SWH systems having storage capacity is between 10 to 70% of annual water heating use, depending on climate, system size and load.

Table 5-3: RETScreen results for small-scale FPC and ETC SWHs

Parameters	FPC	ETC
Energy required for WH ($kWh_{thermal}$)	17,653	17,653
Number of collectors	5.0	4.0
Solar collector area (m2)	13.6	17.1
Capacity (kW)	9.0	9.0
Solar fraction (%)	56.9	63.0
Energy Saved ($kWh_{Electric}$)	11,153	12,364
Initial cost (ETB)	245,526	333,109

As it can be seen in above table, the desired hot water temperature can be achieved by using five collectors of flat plate type or four collectors of evacuated tube type collectors. The results indicate that the maximum solar fraction is 63.0% in the case of ETCs. The value of the solar fraction can be increased by increasing the number of collectors. However, increasing the number of collectors would increase the initial cost of the system which could make the system unaffordable. Another evaluating term for a SHW technology is the electricity saving potential per year, which is the amount of energy that will be saved after using a solar water heating system and directly proportional to the solar fraction. The maximum value of energy-saving is 12.36 MWh which is again for the case of ETC. The reaming 5.29 MWh energy will be covered by conventional heating system such as electricity.

The financial feasibility of adopting SWH systems is analyzed by financial parameters such as Simple Payback Period (SPP), Equity Payback Period (EPP) and Internal Rate of Return-equity (IRR-equity). The SPP indicates the length of time that it takes to recoup the initial investment of the SWH system, out of the revenue or savings it generates. The EPP indicates the length of time that it takes for the owner of a facility to recoup its initial investment (equity) out of the project cash flows generated. The EPP considers project cash flows from its inception as well as the leverage (level of debt) of the project, which makes it a better time indicator of the project merits than the simple payback. The IRR-equity indicates the true interest yield provided by the project assets over its life before income tax. It is calculated using the pre-tax yearly cash flows and the project life and by finding the discount rate that causes the Net Present Value (NPV) of the assets to be equal to zero. NPV is the difference between the present value of cash inflows and the present value of cash outflows over a period of time. Positive NPV value is indicator of a potentially feasible investment. The net benefit-cost (B-C) ratio is the ratio of the net benefits to costs of the project. Ratios greater than 1 are indicative of profitable projects. The initial cost, annual net savings, IRR, SPP, EPP and other financial parameters results are presented in Table 5-4.

Table 5-4: Financial comparison of FPC and ETC SWHs

Parameters	FPC	ETC
Pre-tax IRR-equity (%)	17.5	14.7
Simple payback period (yr)	10.8	13.3
Equity payback period (yr)	7.1	8.3
(B-C) ratio	1.8	1.4
NPV (ETB)	191,686	147,935
Annual life cycle savings (ETB/yr)	23,289	17,973

As it can be seen in the above table, adopting FPC reveal better economic option because it recoups its initial cost faster than ETC. The maximum value of IRR is found to be 17.5% and it corresponds to the FPC based solar water heater.

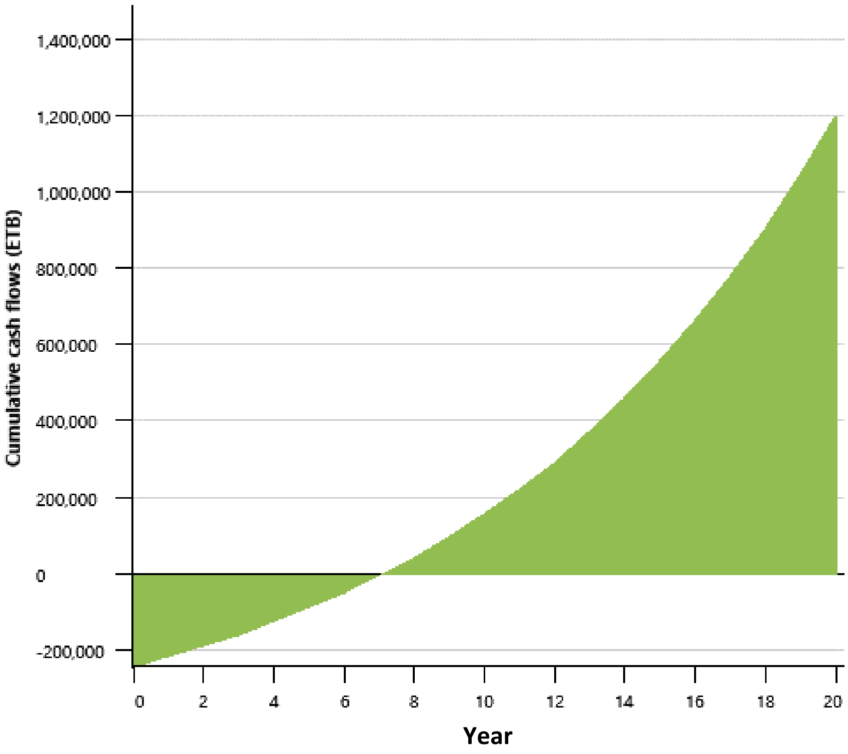


Figure 5-1: Cash flow diagram: FBC based SWH, extracted from RETScreen

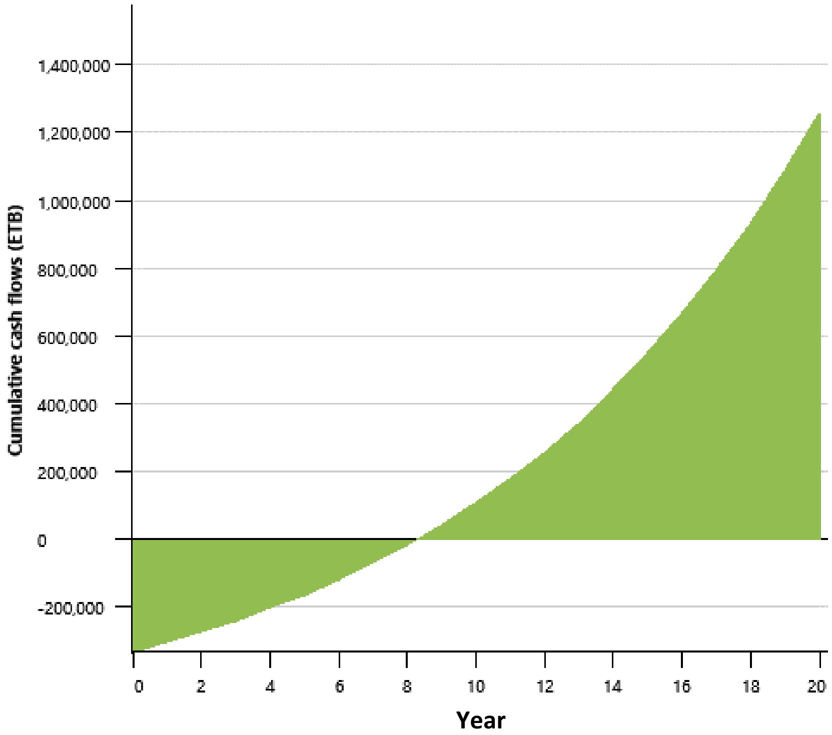


Figure 5-2: Cash flow diagram: ETC based SWH, extracted from RETScreen

5.2. Comparison of FPC, ETC and Air to Water Heat Pump for Large Scale Water Heating

5.2.1. Technical specification of FPC, ETC, Air to Water HPs and RETScreen results

Currently, there are two commonly used optimized large water heating technologies. These are SWHs (FPCs and ETCs) and air to water HP water heaters. The water heating systems were compared for the delivery of 10,000 L/day hot water at 60°C representing large scale water heating. The technical specification of flat plate and evacuated tube collectors employed and the resulting RETScreen output is listed in Table 5-5 and Table 5-6.

Table 5-5: Specification and RETScreen result of FPC and ETC SWHs

No.	Parameters	FPC	ETC
1	Gross area per solar collector (m^2)	2.721	4.278
2	Aperture area per solar collector (m^2)	2.571	3.225
3	Fr (tau alpha) coefficient	0.739	0.563
4	Fr UL coefficient (W/m^2)/℃	3.982	1.438
5	Temperature coefficient for Fr UL (W/m^2)/$℃^2$	0	0
6	Solar tracking mode	Fixed	Fixed
7	Slope	15°	15°
8	Azimuth	0°	0°
9	Collector loss (%)	3	2
10	BoS loss (%)	5	5
11	Energy required for WH ($kWh_{thermal}$)	172,022	172,022
12	Number of collectors	48	40
13	Capacity (kW)	86.4	90.3
14	Solar collector area (m^2)	131	171
15	Solar fraction (%)	56.0	63.8
16	Energy saved ($kWh_{Electric}$)	105,522	119,721
17	Initial cost (ETB)	2,016,032	2,918,023
18	Equipment life (years)	20	20

An air to water HP system was sized to provide 10,000 L/day hot water at 60 °C. The sizing approach is that the hot water system shall provide 50% of the daily demand in 2 hours which requires a heating capacity of 122.64 kW. This can be achieved by installing 3 x MG 120KFXRS-45 kW air to water HPs. The average annual seasonal CoP (SCoP) of the air to water heat pump employed is 3.09. This value is generally lower than the steady state CoP (Tangwe and Kusakana, 2021).

Table 5-6: The technical specification and RETScreen results of Air to water HP

No.	Parameters	Air to Water Heat Pump
1	Heating capacity (kW)	45
2	Input power (kW)	10.95
3	CoP/SCoP	4.11/3.09
4	Hot water supply (L/h)	967
5	Energy required for WH ($kWh_{thermal}$)	172,022
6	Energy saved ($kWh_{Electric}$)	133,795
7	Initial cost (ETB)	2,778,388
8	Annual O&M costs (% of HP and BoS cost)	2
9	Equipment life (years)	10
10	Heat pump replacement cost (ETB)	1,249,785

5.2.2. Financial comparison of FPC, ETC, HP and RETScreen results

The life cycle cost analysis of these water heating system includes the initial costs, annual operation and maintenance costs and the heat pump replacement cost on the 10^{th} year. The operation and maintenance costs for SWH and heat pump is estimated to be 0.5 and 2% of equipment cost respectively. RETScreen financial comparison result is presented in Table 5-7.

Table 5-7: Financial comparison of FPC, ETC and HP water heating systems

No.	Parameters	FPC	ETC	HP
1	Pre-tax IRR-equity (%)	19.6	16.1	14.1
2	Simple payback period (yr)	9.3	12.0	11.5
3	Equity Payback period (yr)	6.4	7.7	11.8
4	(B-C) ratio	2.1	1.6	1.4
5	NPV (ETB)	2,124,894	1,755,683	996,322
6	Annual life cycle savings (ETB/yr)	258,160	213,304	121,046

The range of EPP for large scale water heating is 6.4–11.8 years. The minimum value of EPP is found to be 6.4 years and it corresponds to the FPC based solar water heater. The maximum value of IRR is 19.6% for FPC type SWH.

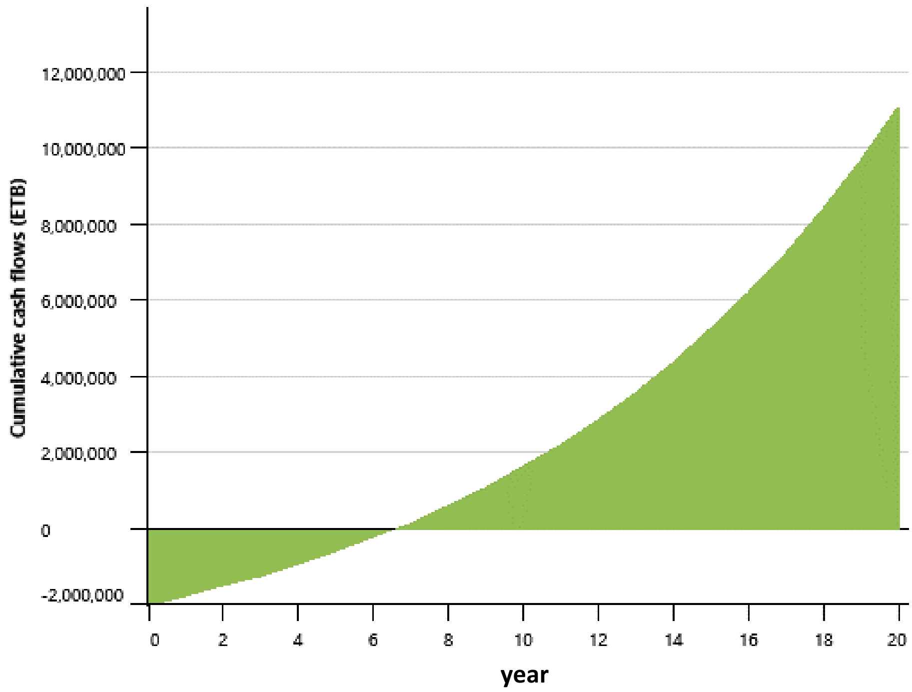


Figure 5-3: Cash flow diagram: Hot water system with FPC, extracted from RETScreen

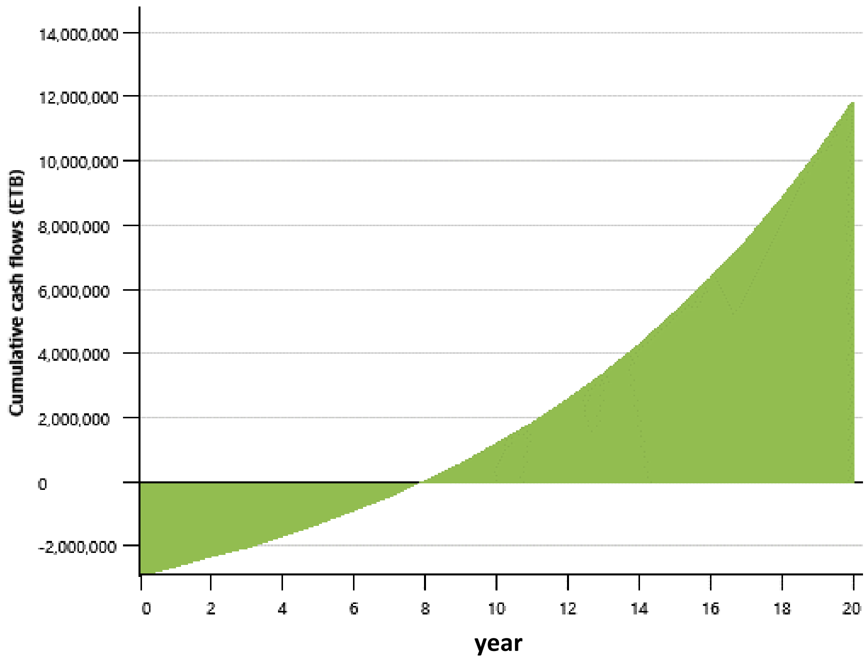


Figure 5-4: Cash flow diagram: Hot water system with ETC, extracted from RETScreen

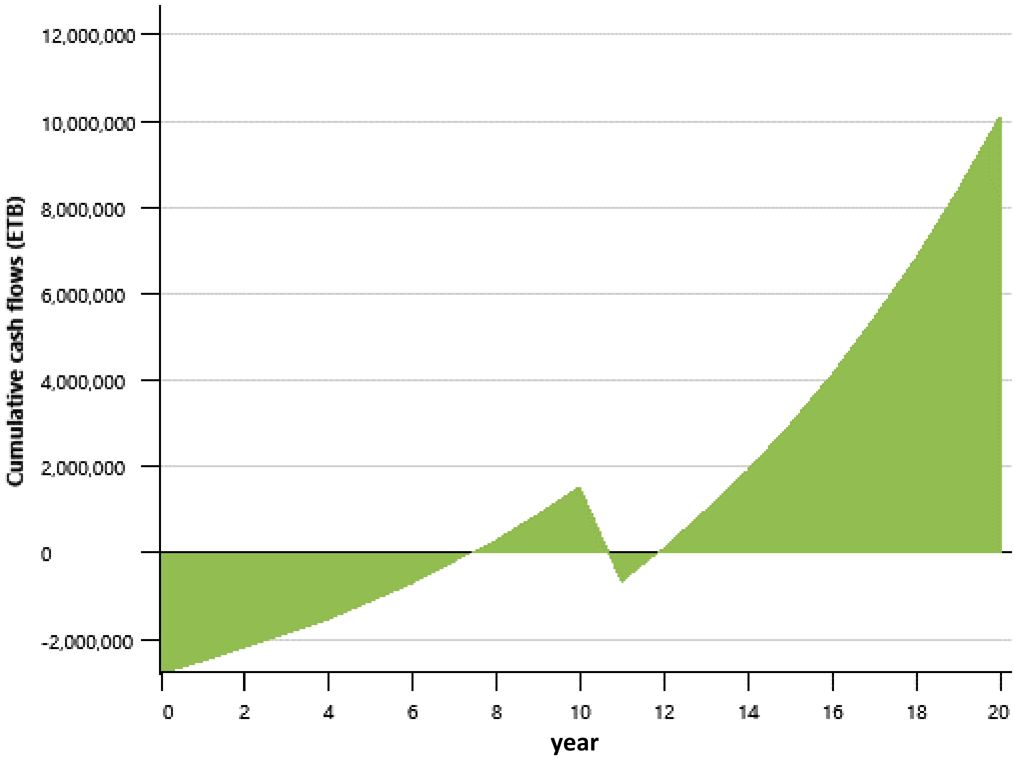


Figure 5-5: Cash flow diagram: Hot water system with Air to Water Heat Pump, extracted from RETScreen

5.3.Sensitivity Analysis

The level of uncertainty associated with the SWH investment during analysis is a measure of the level of uncertainty of the inputted variables which has an impact on the level of uncertainty on the calculated financial variables. The sensitivity analysis shows what happens to the selected financial indicator (e.g. NPV) when two key parameters (e.g. initial cost and O&M) are varied by the indicated percentage. The sensitivity analysis would reduce the level of uncertainty of the feasibility analysis (Natural Resources Canada, 2005). The sensitivity analysis was done for the NPV of the investment by varying the initial cost and the fuel cost-base case against each other by ± 100% for scenario one. Scenario two, the initial cost and fuel proposed-case varied against each other by ± 100%. The result of sensitivity analysis is presented in Table 5-8 and Table 5-9. This analysis is done only for small scale-water heating.

Table 5-8: Scenario 1, sensitivity analysis for NPV by varying initial cost and the fuel cost-base case

Initial cost (ETB)		Fuel cost-base case (ETB)						
		0	13,887	27,774	41,661	55,548	69,435	83,322
		-100.0%	-66.7%	-33.3%	0.0%	33.3%	66.7%	100.0%
0	-100%	NA*	NA*	NA*	NA*	NA*	NA*	NA*
81,842	-66.7%	NA*	-174,463	90,453	355,369	620,286	885,202	1,150,118
163,684	-33.3%	NA*	-256,305	8,611	273,527	538,444	803,360	1,068,276
245,526	0.0%	NA*	-338,147	-73,231	191,686	456,602	721,518	986,434
327,368	33.3%	NA*	-419,989	-155,073	109,844	374,760	639,676	904,593
409,210	66.7%	NA*	-501,831	-236,915	28,002	292,918	557,834	822,751
491,051	100.0%	NA*	-583,673	-318,757	-53,840	210,076	475,992	740,909

* NA= Not applicable

The RETScreen sensitivity analysis tool recalculates the NPV for the combination of initial cost and Fuel cost-base case holding all other parameters fixed. The Scenario 1, Table 5-8, sensitivity analysis shows that initial cost and the base case fuel cost could reach maximums of 491,051 ETB and 83,322 ETB respectively. The values of the NPV below the threshold of zero are indicated by green color. For example, with an increase of 100% of the initial cost and a decrease of 66.7% to the Fuel cost-base case, the investment will not be financially profitable because the NPV will be -583,673 ETB. For the case of Scenario 2, Table 5-9, investment would not be financially attractive in the green colored part, mostly where initial cost increases above 0% and Fuel cost -base case is above 0%.

Table 5-9: Scenario 2, sensitivity analysis for NPV by varying initial cost and the fuel cost-proposed case

Initial cost (ETB)		Fuel cost-proposed case (ETB)						
		0	5,991	11,981	17,972	23,963	29,954	35,944
		-100.0%	-66.7%	-33.3%	0.0%	33.3%	66.7%	100.0%
0	-100%	NA*	NA*	NA*	NA*	NA*	NA*	NA*
81,842	-66.7%	NA*	583,934	469,651	355,369	241,087	126,805	12,523
163,684	-33.3%	NA*	502,092	387,810	273,527	159,245	44,963	-69,319
245,526	0.0%	NA*	420,250	305,968	191,686	77,403	-36,879	-151,161
327,368	33.3%	NA*	338,408	224,126	109,844	-4,438	-118,721	-233,003
409,210	66.7%	NA*	256,566	142,284	28,002	-86,280	-200,563	-314,845
491,051	100.0%	NA*	174,724	60,442	-53,840	-168,122	-2824,04	-396,687

* NA= Not applicable

The impact of the changes in parameters is also presented in Figure 5-6. The parameter with the highest impact on the feasibility of the investment is the fuel cost-base case. The higher the electricity cost-base case, the higher the NPV would be. In contrast, the increasing in initial cost, fuel cost-proposed case and operation and maintenance cost have adverse impact on the NPV. Higher electricity base case cost manifests due to overestimation of electricity consumption of the base case, for example, estimating higher level of electricity consumption without metering, and increase of fuel cost of proposed case could be due to over sizing of auxiliary electric heater of the SWHs.

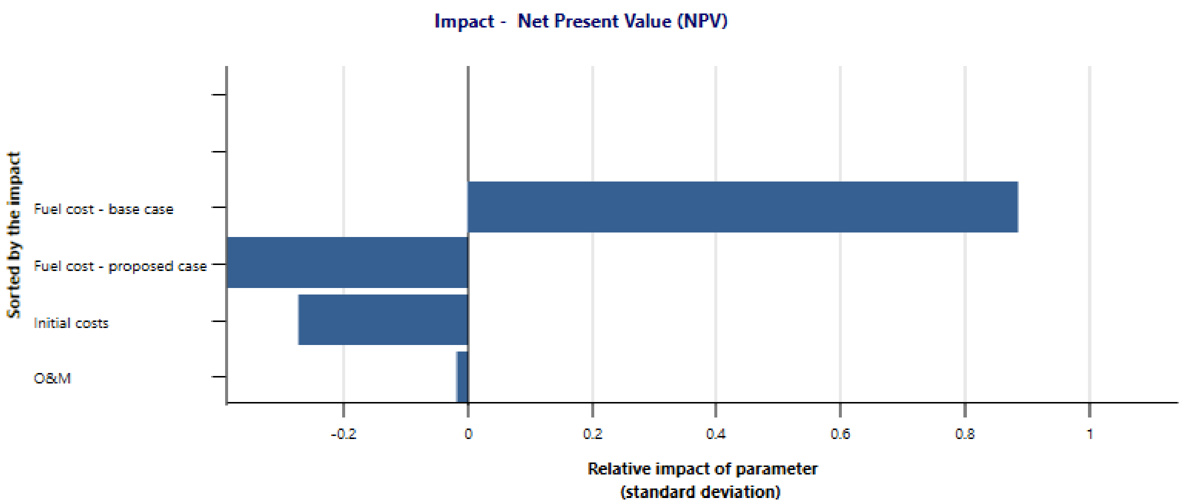


Figure 5-6: Tornado diagram, impact of the change of different parameters on NPV, extracted from RETScreen

6. EXISTING CONDITIONS RELATED TO SOLAR WATER HEATERS (SWH) REGULATIONS, REQUIREMENTS AND IMPLEMENTATION EFFORTS

Even though the existing policy documents, symposiums and national workshops proceeding indicated Solar water heaters are technologies that could have a large impact on energy consumption and conservation in Ethiopia, a regulatory framework governing the SWH industry has not been established so far and the same challenges hindering its growth are persisting. Following are existing policies, requirements and efforts being made.

6.1. Legalizations, Regulations, Government Targets and Studies on SWH

The policies and programs of the country establish the government's strategic direction and goals to be achieved by implementing bodies. These policies and programs are enforced in Addis Ababa city too as it is the major energy consumer of the country. The following are existing policies, regulations and programs set by the government related to renewable energy and solar water heating.

a) Proclamation on Energy No 810/2013

The proclamation entrusts to the EEA the power and duties to formulate long-term, medium-term, and short-term energy efficiency and conservation strategy. The proclamation further requires EEA to promote the programs at national and sectoral levels.

b) Energy regulation 227/2019

The energy regulation under the electrical equipment and appliance section states that no electrical equipment or appliance which do not comply with mandatory national standards of energy efficiency or do not have certificate of efficiency shall be put in use in the country. Under the methods for Energy efficiency and conservation in buildings, it is stated that Building codes shall take into account the energy efficiency and conservation measures to be achieved either during construction or maintenance period. The regulation stipulates that EEA may designate buildings based on their type, size, quantity of energy use, or method of energy utilization through directive to be issued to implement the regulation including standard for air conditioning, hot water generation and space heating systems of the building.

c) National Energy Policy (Revised 2018)

The revised National Energy Policy issued in October 2018 indicates the current electricity generation capacity of the country has reached 4,300 MW with hydropower resource accounting for 92% of electricity production.

Within the broad coverage of energy sector overview, key energy sector policy issues and energy sector objectives, goals and instruments, the policy states that solar energy use has grown over the past years for Telecommunications repeater stations, solar home systems mainly for lighting and small power demand such as water pumping, and heating. The policy recognizes the need to promote solar water heating for both domestic and institutional applications as one of the policy instruments under small scale renewable energy resources.

d) Energy Efficiency Program and activity plan, Ethiopian Energy Authority (2018)

The energy efficiency program presents overview of energy efficiency and conservation activity programs that are planned or underway. Technology acceleration program listed Solar water heaters as medium priority. The awareness creation campaign on solar water heaters aims to make the commercial and residential sectors aware of its energy saving potential. The program states Solar water heaters are technologies that could have a large impact on energy consumption and conservation in Ethiopia if rolled out at large scale, and are capable of being manufactured or assembled locally. Solar water heating systems are established technologies which are already widely available internationally, but which could be adapted for local manufacture to promote local development, import substitution and cost reduction.

e) EEA ten years strategic plan for 2013 to 2020 GC, 2012 EC (Amharic version)

The ten-year plan entails schedule of major objectives to be achieved. Even though many activities have been indicated under the demand side energy efficiency and conservation works, renewable energy programs like Solar water heating roll out are not included.

f) Energy Efficiency strategy for Industries, Buildings and appliances, EEA, Dec 2018

The strategy acknowledges that there exists significant potential for energy efficiency improvement in Industrial sectors, buildings and use of appliances. It indicates apart from PV Solar Home Systems (SHS) there is also a market for Solar Water Heating systems to heat up water which can significantly reduce fuel wood and electricity consumption.

Under the strategic energy efficiency framework for appliances, product selection criteria, it is indicated that the five most important appliance and equipment that use significant amounts of energy in the context of efficiency improvement are Injera Mitad, electric ovens and cooking plates, refrigeration, Hotel Air conditioning machines and cloth washing machines.

g) Growth and Transformation Plan II (GTP II) (2015/16-2019/20)

Under the GTP II, Expanding Energy Infrastructure and Ensuring its Quality, energy potentials of the country are prioritized in order of importance as: (i) Hydroelectric power generation, (ii) Geothermal energy, (iii) Wind Power and (iv) Solar energy. Major targets during GTP II with regard to solar energy technology is planned to produce 3,600,000 solar lanterns, 400,000 household solar PVs, 3600 institutional solar PVs, 500 solar thermals and 3,600 solar cookers to be achieved by 2019/20.

h) Scaling up- Renewable energy program, Ethiopia Investment Plan (2012)

The overall objective of the renewable energy investment plan is to support market development for clean, renewable energy-based products and services in the household and commercial segments, by providing targeted capacity building and financing to small and medium-sized enterprises (SMEs). The SMEs are, among others, companies selling efficient energy conversion systems for institutions (institutional cook stoves, solar water heaters, roof top solar systems).

i) Updated Rapid Assessment and Gap Analysis on Sustainable Energy for All (SE4All)

One of the sustainable Energy for All (SE4All) initiative aims stated is doubling of the share of renewable energy in the energy mix in the country. Renewable energy resources are playing and will continue to play a major role in providing clean energy both for electricity generation and for thermal applications. In the short-term government plan up to 2015 and the long-term directions described, it has been considered that 7000 SWHs installation as a base line in 2012/13 and forecasted installations of 15,500 SWHs units in 2015 (MoWIE, 2013).

6.2. Standards and Requirements

6.2.1. Available standards

a) The following standards have been adopted by Ethiopian Standards Agency for Solar Thermal Systems. The standards are test methods and requirements and do not cover product standards.

- ES ISO 9459-1: 2015: Solar Heating - Domestic Water Heating Systems - Part 1, Performance Rating Procedure Using Indoor Test Methods
- ES ISO 9459-2: 2015: Solar Heating - Domestic Water Heating Systems - Part 2, Outdoor Test Methods for System Performance Characterization and Yearly Performance Prediction of Solar--Only Systems
- ES ISO 9459-4: 2015: Solar Heating - Domestic Water Heating Systems - Part 4, System Performance Characterization by Means of Component Tests and Computer Simulation
- ES ISO 9459-5: 2015: Solar Heating - Domestic Water Heating Systems - Part 5, System Performance Characterization by Means of Whole-System Tests and Computer Simulation
- ES ISO 9806: 2015: Solar Energy - Solar Thermal Collectors - Test Methods
- ES ISO 10217: 2015: Solar Energy - Water Heating Systems - Guide to Material Selection with Regard to Internal Corrosion
- ES ISO 22975-3: 2015: Solar Energy - Collector Components and Materials - Part 3 Absorber Surface Durability

b) Ethiopian standards regarding the requirements and classifications of Hotels and Hospitals are indicate below.

i. Hotel star rating and grading

The Ethiopian standard ES 3808-1:2014, for Hotel: - rating requirements and classification, assign star rating to hotels considering various evaluation criteria. Under the Sustainability, Energy sub section, the evaluation assigns 10 points and 5 points for the availability of central boiler and Solar power /heating initiatives respectively out of total 1176 points.

ii. Hospital requirements

Ethiopian Standards ES3617:2012 and ES 3619:2012 specify requirements for Primary and Specialty centers respectively.

The standard ES3617:2012, Primary Hospital–Requirements, states Primary hospital shall mean a health facility at primary level of healthcare which provides promotive, preventive, curative and rehabilitative services with a minimum capacity of 35 beds. Section 7.3, Construction Requirements of the standard requires Plans and specifications for any hospital construction or remodeling shall comply with Ethiopian Building Code whereas Section 7.5, Building Systems, Water supply and plumbing, indicates the hospital shall have an approved method of supplying hot water for all hospital consumption. Water to lavatories and scrub sinks must be 37.8 - 54 °C. Water to mechanical dishwashers must be delivered at 82 °C for rinsing.

ES 3619:2012, Specialty Center, – Requirements, indicates that Specialty center shall have varying number of beds with a minimum of 10 beds for inpatient services per specialty. The construction of the centers shall comply with the Ethiopian Standard Building Code and plumbing system that fulfill an approved municipal water system and method of supplying hot water.

6.2.2. Product quality assurance

Even though the standards indicated under 6.2.1 above have been adopted, the standards thus far implemented are voluntary standards. Tests in the standards are not yet put into effect as there are no testing facilities and trained manpower for testing. Furthermore, no conformity assessment on SWH products is being carried out either in the form of Pre-export Verification of Conformity (PVoC) for imported products or domestically for locally manufactured ones.

6.2.3. Quality assurance in skill development

There are no regulatory frameworks that govern the SWH industry inclusive of all downstream activities to support the implementation of the system. Registration and certification of SWH installers is not in place. There are no skill development trainings offered on how to install and maintain the SWH systems except for the technical and vocational trainings in plumbing and the on-the-job trainings provided by the few Importers/installers.

6.2.4. Housing projects and building codes

Currently there are many housing projects for commercial activities, and residential purposes in Addis Ababa. There are no regulatory requirements of SWH on new and existing buildings to replace the installation of Electric Water heaters and wood or fuel-based water heating with SWH systems.

The Compulsory Ethiopian Standards (CES) do not fully specify solar thermal requirements in the Standard Technical Specification for Buildings. However, the CES 161, (Compulsory Ethiopian Standards (CES) 161, Plumbing services of buildings, Ministry of Construction), provides detail technical requirements of hot water supply in buildings. This includes: design considerations, storage temperature and capacity, rate of hot water flow, Materials, location and Installation of hot water storage tanks (Vessel), Types of System, Cold Feed and Hot Water Distribution Pipes, and Safety Devices. The design considerations further specify that:

- Hot water at the premises shall be designed to provide hot water in the quantities and at the temperatures required by the user at the least overall cost, taking account of installation, maintenance and energy costs.
- Electric water heating, the common practice for domestic purposes uses storage heaters. In modern hotels and apartment blocks and service apartments, centralized storage and distribution systems are adopted, where other energy sources such as oil, gas, heat pumps, solar panels, etc., may be used for the generation of hot water as these options prove more economical and convenient in heating large volumes of water for storage.
- When water supplied to the buildings contain hard water, measures such as installation of water softening plants etc. shall be taken to avoid formation of scales in the hot water installations.

6.3. Education and Awareness Creation on SWHs

6.3.1. Education

Theory based courses on Solar thermal systems, Solar PV and Renewable energy technologies are given in post graduate programs and a similar course on renewable energy is delivered to undergraduate programs in engineering streams at government universities in the country. The syllabus of primary, secondary and the curriculums of vocational/technical centers in the city and country do not entail trainings, demonstration units and laboratory facilities related to solar thermal or water heating systems.

6.3.2. Awareness creation

Various awareness creation activities have been conducted by the EEA on energy efficiency and conservation issues. Two major workshops were conducted on SWH and solar energy technologies topics thus far.

- The symposium, organized by EEA and GTZ on Solar Water Heating and attended by representatives from Ministry of Mines and Energy, EEPCO (EEU), Addis Ababa Institute of Technology, suppliers/importers and stakeholders was conducted in 2010 in Addis Ababa. The deliberations were on SWH technologies, SWH business, perspectives on SWH and conceptual notes on SWH in Ethiopia. The main discussion outcomes of the symposium regarding SWH implementation in the country were actions for:
    - Standardization, certification and quality management
    - Wider awareness creation
    - Promotion of local production
    - Integration of SWH program into national programs
    - Financing: Long term loans, incentive mechanisms,
    - Ratification of clear policy
    - Establishment of on-line forum

- The National Workshop: Dissemination of Solar Energy Technologies in Ethiopia; Successes, Challenges, and Opportunities, 2014, was conducted with the objectives to assess the current solar market in Ethiopia by reviewing successes and challenges of the stakeholders. The specific goals were to evaluate opportunities, challenges, and best practices in policies and regulatory frameworks, marketing and financing and existing technologies. The workshop was attended by representatives from the MoWIE, Regional Energy Bureaus, Horn of Africa Regional Environment Centre and Network (HoA-REC&N), The Energy and Resources Institute (TERI), non-governmental organizations (NGOs), bilateral agencies, solar energy businesses, microfinance institutions, universities, and research institutes. The stakeholders considered energy needs for basic lighting and off-grid communities should be priority for all and drew the following priority areas:
    - Creating a forum for the relevant actors in the solar market to meet and exchange knowledge on the solar industry (subsequently, The National Solar Forum was formed)
    - Initiating the structures through which relevant issues are identified and addressed by the relevant bodies.
    - Setting quality standards and control for products and services.
    - Market development through capacity building of retailers and technicians with value additions from local assembly. Installations, maintenance, and repairs should be supported by government, NGOs, and bilateral agencies.
    - Adopting installment payment schemes such as the revolving fund approach.
    - Disposal of BoS through proper waste management treatment systems should be discussed at the onset of dissemination and must be the responsibility of the supplier.

6.4. Import duties on SWHs

SWHs is identified under HS code 841919 and the equipment and its parts are free from duty tax on imports. However, 15% VAT is applicable. Parts for manufacturing of SWHs are also free from duty tax (Ethiopian Customs Commission, August, 2019].

6.5. Market barriers on SWHs implementation

Based on responses from interviewed non SWH users, the market barriers hindering the uptake of SWH can be grouped into technical, policy/regulatory and lack of awareness as described below.

6.5.1. Technical barrier

The Technical barrier includes the inadequate system design and technical skills of the installers. There are no trainings on SWHs design, installation and maintenance in the country. The few skilled installers have no installer certifications, and customers are not able to evaluate SWH system performance due to lack of simple, cheap and robust monitoring solutions. There are instances of much hot water spillage due to non-use of hot water, problems of hot water temperature getting low during high consumptions periods, it takes a while to get hot water at the points of use, water consumption during waiting for hot water, provision of spare parts and the warranties of one year indicating design and installation problems.

6.5.2. Policy/regulatory

There are no policy frameworks, regulations and building mandates in place regarding SWHs. In the absence of financial incentives and proper regulations the SWHs market couldn't be stimulated. Furthermore, most premises of specialty hospitals are not interested to install SWHs as they operate in rented buildings, requiring regulation in the owner occupier mismatch for the deployment of the products.

There are low cost SWHs products which have failed after few years in operation, frequent failures of controlling units and auxiliary heater, breaking of evacuated tubes etc. Currently there are no requirements on the Certification of Compliance on the products. The existing standards for SWHs are only testing standards and product standard is required including PVoC until local testing capability is developed.

6.5.3. Lack of awareness

Regarding the barriers related to awareness, it is perceived by non SWHs users that:

- SWHs are too expensive to install,
- It takes a longer time to provide hot water,
- SWHs do not have as much hot water delivery capacity.

Furthermore, non-users did not know enough about SWH during the establishment of their businesses. Consultant or contractor's recommendation has a positive impact on SWH installation decision during their establishment.

7. SOLAR WATER HEATER IMPLEMENTATIONS: EXPERIENCE OF OTHER COUNTRIES

7.1. Installed Capacity of Top Ten Countries

SWHs have been implemented successfully for over 30 years in several developed and developing countries. The following country experiences in implementing SWHs in residential households and commercial buildings (IRENA, 2021) are applicable to the SWHs for Hotels, Hospitals and commercial buildings in Addis Ababa.

Countries like Barbados, Cyprus and Israel have installed SWHs for 80-90% of their residential houses. In countries where the use of electric boilers may strain the electricity system or be unaffordable to many households, the installation of SWHs is needed. The skills in manufacturing, construction and plumbing could easily be transferred to the manufacturing, installation and maintenance of solar thermal systems. Local manufacturing capacities and economic development have been achieved in countries like Barbados, Brazil, China, Greece, Israel, South Africa, Tunisia and Turkey employing small to medium enterprise manufacturers.

Figure 7-1 shows ten top countries by installed capacity of SWHs for the year 2018. Figure 7-2 indicates newly installed SWHs per 1000 inhabitants in 2018, revealing the efforts of small countries and territories with smaller populations.

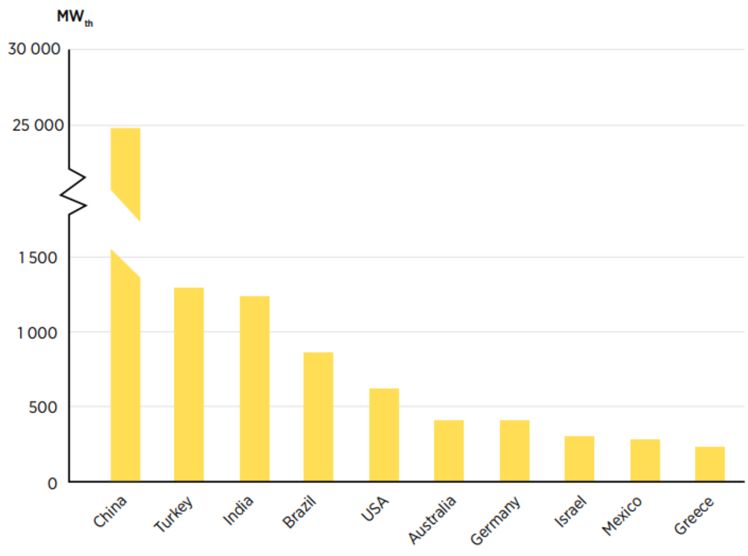


Figure 7-1: Installed capacity in the ten countries that installed the most new solar water heaters in 2018 (IRENA, 2021)

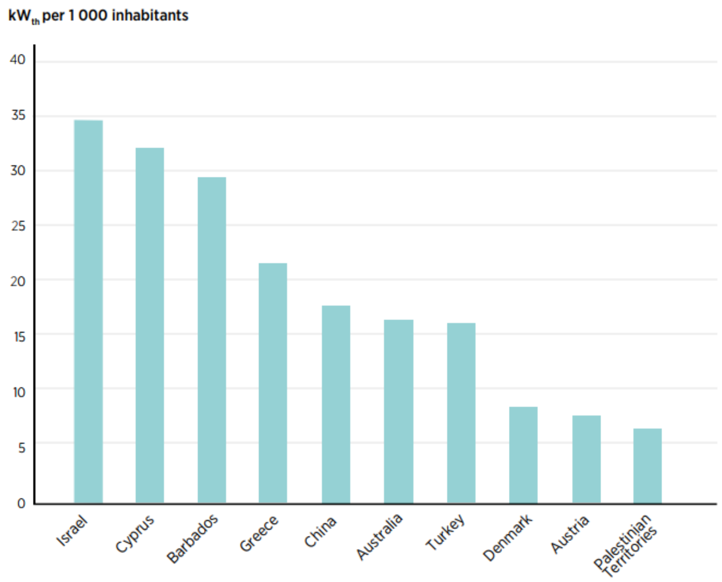


Figure 7-2: Ten countries and territories that installed the most solar water heaters per 1,000 inhabitants in 2018 (IRENA, 2021)

7.2. Policies Used in the Deployment of SWHs

A mix of policies have been used in the deployment of SWHs in many countries. These include direct policies such as targets, programs, obligations and mandates, and financial incentives. Furthermore, an enabling environment for the development of a SWHs sector have been established through enabling policies such as technical standards and certificates and training and retraining measures.

7.2.1. Targets

Targets define a clear indication of the intended deployment and schedule envisioned by the government. They often become key drivers of policy, investment and development and inform industries and consumers alike. Targets for solar water heaters are set in terms of the number of systems, collector surface or thermal capacity.

a) China

A target of cumulative SWH collector the surface of 400 million square meters was included in the 12th Five-Year Plan (2011-2015) of the country which have been exceeded by 10.5%. By 2020, the end of the 13th Five-Year Plan period, this number was expected to have doubled to 800 million m².

b) South Africa

In 2009 a target of one million SWH have been set to be installed within five years. However, only about 400,000 systems were installed. Although the program was supported by financial instruments. Between 2010 and 2015 solar thermal capacity still increased by more than 50%. South Africa has since updated its target to 1.75 million systems by 2019 and 5 million by 2030.

c) Lebanon

Financial mechanisms including favorable loans and cash-back applications supported the 2020 target of 1,054,000 m² in Lebanon. A surface area of 683,133 m² was installed by the end of 2015, and only around 150,000 m² had been added by the end of 2018. A national targets surface area of 1,716,835 m² has been set by 2030 by the government.

7.2.2. Obligations and mandates

Obligations and mandates have taken key roles in encouraging the deployment of solar water heaters in many countries. SWHs are most frequently installed in new or renovated buildings, often as mandated by building codes at the regional, national, subnational or municipal level. SWH mandates place an obligation on specific entities – like utilities, building owners, or building developers – to install SWH. They can be a powerful tool to drive development of SWH and have been implemented in jurisdictions across the globe. Utility obligations for SWH can be coupled with incentive programs to encourage contractors and other stakeholders to increase installation of systems.

Installing a solar system implies works on the roof, piping through walls and finding the place for the hot water tank inside the building, if it is not installed on the roof. All this is easier, cheaper and often more effective if the solar system is included from the earliest stage of planning of a new building. In existing buildings, there are short windows of opportunities when the installation of the system is usually most convenient.

Once these opportunities (new built, refurbishment) are missed, the installation of a solar thermal system is usually technically possible, but economically less interesting. One has to consider not only the direct financial cost of the works, but also the time and effort needed to commission them, as well as the disturbance caused to those living or working in the building.

It is most convenient to include solar at an early stage of planning in new buildings or when a new heating system is being installed in existing buildings. Solar mandates and obligations make sure that these convenient opportunities are not missed.

SWH mandates place an obligation on specific entities – like utilities, building owners, or building developers – to install SWH. They can be a powerful tool to drive development of SWH. Local policymakers can implement building mandates to address split incentive barriers, requiring the installation of SWH systems in new or existing buildings. Utility obligations for SWH can be coupled with incentive programs to encourage contractors and other stakeholders to increase installation of systems.

Solar building mandates (also known as solar ordinances) have been widely deployed to support SWH market development in new construction or building renovations. SWH mandates require building owners to source a minimum amount of their domestic hot water heating load from SWH systems. They are usually expressed as a percentage of the total hot water demand for a building sector and typically focus on new construction (e.g. SWH to provide 60% of hot water for all new residential construction). When designed for existing buildings, it is necessary to establish a trigger for compliance.

Triggers may include the sale or lease of a building, building renovation, replacement of the heating system, or energy commissioning or audits. Mandates also require cities or other implementing authorities to establish procedures for measuring and verifying compliance.

a) Israel

Israel became the first country to mandate the installation of solar water heaters in new buildings 1980s. The country now has among the highest penetration rates of solar water heaters in the world.

b) India

India proposes that 20-40% of the hot water demand in new hotels and hospitals across the country, as well as in new buildings in regions with cold winters, should be met by solar systems, by its Energy Conservation Building Code of 2017.

c) Germany

Germany set in 2009 an obligation for the use of renewable energy in buildings larger than 50 m². Renewable energies must cover Heating (or cooling) energy requirements, for instance, 15% for solar water heaters,

d) China.

New residential buildings with fewer than 12 floors have been required to install SWHs as of 2010.

e) Brazil

In Brazil, many cities have established solar mandates. São Paulo, for example (since 2007), mandates that 40% of the energy needed to heat water in newly constructed buildings, both residential and commercial, should be solar. At the state level, Rio de Janeiro implemented a mandate in 2008 that all new and refurbished public buildings meet at least 40% of their water heating needs with solar energy.

f) Rosario, Argentina

An ordinance mandating that all new and renovated public buildings within the municipality to derive at least 50% of hot water usage from SWH was approved. To ensure compliance, all installation designs must be submitted to the concerned authority for approval. Trainings to SWH installers for appropriate system sizing and installation, as well as other public outreach and education actions have been delivered.

7.2.3. Financial incentives

To raise the cost competitiveness of SWHs compared to other water heating systems, financial incentives are required. These include a range of grants, low-interest loans and tax incentives. The incentives are most widely used in low-income countries where support is needed for the initial investment and where the alternatives (e.g., electricity, gas or diesel) are low cost, most often due to subsidies.

a) Tunisia

Subsidies and concessional loans for solar water heaters have been provided by the government, supported by UN environment program, to counter the market barrier imposed by their high upfront costs. Funding mechanisms started in 2005 by Tunisia's solar program. The first phase, which focused on supplier lending, supported 20% of the capital costs of SWH, a temporary interest rate subsidy and credit repayable over five years. In this scheme, individual suppliers acted as indirect lenders and debt guarantors for consumers, while the Tunisian Electricity and Gas Company collected loan repayments through utility bills. The second phase focused on consumer lending, where it granted direct credit to households for SWH installation, relieving suppliers from debt liability. The electricity company serves as a guarantor for the repayment. Bonuses of Tunisian dinar (TD) 200-400 (USD 150-300) have replaced the 20% subsidy.

b) Lebanon

A national financing mechanism for SWH to achieve the 2030 target has been developed by the Ministry of Energy and Water and the Central Bank of Lebanon. A loan with no interest rate has been arranged with USD 200 subsidy for the first 7,500 SWH loan applications.

Under this schedule, more than USD 1,450,000 had been injected into the market at the end of 2017 and investments exceeding USD 135 million in solar water heaters has been generated.

c) Barbados

Financial incentives at times combined with mandates have been implemented. The government mandated SWH installation in new government housing developments in the late 1970s and introduced a tax exemption for the materials used to produce SWH in 1974. A tax benefit that deducts the full cost of installation of SWH up to USD 1,750 was introduced in 1980. There were around 45,000 solar water systems installed in Barbados covering 40% of households by 2009.

7.2.4. Standards for solar water heaters

To Support the creation of certifications and warranties, and to keep product quality by installers and for consumers, technical standards are required. Design requirements and testing methods should be applied to SWHs and the technical information such as product design details and service requirements must be provided.

a) USA

The solar energy industry and a national consortium of utilities, state energy offices and regulatory bodies came together to establish the basis for establishment of the Solar Rating and Certification Corporation to support the development of a uniform, national standard for testing and rating solar equipment. The Standards also apply to larger systems.

b) Lebanon

Technical standards which apply to local manufacturers of SWH in Lebanon include the Lebanese Norm NL EN 12975, NL EN 12976, NL EN 12977 and ISO 9806-1-2. Standards for imported panels and tanks include Lebanese Norm NL EN 12975, in addition to product certifications such as ISO, ROHS (Restriction of Hazardous Substances) and TÜV (Technischer Überwachungsverein).

7.2.5. Training and retraining

The deployment of SWHs critically require training and retraining programs for the proper, efficient and safe installation and maintenance of SWH. A wide range of occupations like sales, engineering and plumbing are needed for the installation and maintaining the SWH which could be fulfilled with proper training.

a) Mexico

A work group from the public and private convened to develop a standard installation process for solar water heaters in 2012. Using the Occupational Competency Standard EC0325 published in May 2013 training and certification of 200 installers in 11 Mexican states was conducted.

b) Australia

The Australian government has conducted train plumbers in installing and commissioning water heating systems since 2011.

7.2.6. Other successful experiences of thermosyphon SWHs implementations

The United Nations Environment Program (UNEP) had conducted Solar Water Heater Market Assessment in four Asian countries in 2011. Below are indicated UNEP and additional successful experiences of thermosyphon SWHs implementations in other countries (IEA-SHC, 2019).

a) Greece

Greece has become one of the leading countries in installed capacity per capita with 309 kWth/1,000 inhabitants with well-established market based on strong solar industry since 1980s. The solar thermal market mostly consists of individual thermosiphon type solar water heaters with typical systems of 150–300 liters hot water storage in combination with 2–4 m^2 highly selective flat plate collectors with antifreeze protection. A capacity of 253 MW_{th}, or 361,500 m^2 was installed in 2019 alone. The major factors for the achievement are: the favorable climatic condition, the development of local production capacity and government support programs. Mandatory requirements in like Energy Efficiency Building Regulation Code which requires the installation of a solar thermal system to cover at least 60% of hot water demand for every new building were in place and, the installation of a solar thermal system for hot water production is funded up to 70% by energy saving programs.

b) Namibia

The Government of Namibia for its plan to build 185,000 new residential buildings by 2030 envisaged the installation of thermal solar systems as there is shortage of power supply in Southern Africa. In studies conducted at Windhoek it was revealed that domestic hot water consumed 40–50%, about 1000 kWh/yr, of household electricity demand. Following this, a solar urban development concept of a new settlement with around 10,000 apartments was launched in 2019 having a requirement of equipping each residential building with a solar water heating system - a key to the implementation of the Namibian National Energy Policy.

c) Sri Lanka

The National Engineering Research and Development (NERD) Centre in Siri Lanka undertakes R&D and testing work for solar thermal technologies and successfully manufactured SWH from locally available materials by 1980s. In 20 years time about 80,000 SWH systems have been installed all over the country.

The popular sizes are between 150 to 300 L. The growth of SWH industry in Sri Lanka is mainly attributed to the efforts of manufacturers, research institutions in the country and though it is not the Government's priority.

d) Thailand

Solar water heating technologies began in Thailand in the early 1980s with installation of SWH systems having a total of 352 m^2 of collector area in 6 hospitals, a hotel and a small-scale industry. The industry grew slowly, with a greater portion of imported products and a small slice of local manufacturing.

The customers of SWHs lost faith in the longevity of the technology due to improper installations and maintenance activities and lack of efficient system design by service providers. After the Asian economic crisis hit the industry, SWH industry was severely affected, even after the Thai government introducing a financial incentive scheme for promotion of SWH systems in residential sector. The number of SWHs installations increased since 2000 due to the assistance of the government to the SWH industry through a combination of new quality standards, training programs for better quality installations, incentive programs and tax benefits. Milestone projects/initiatives for promotion of SWH systems in Thailand included:

- Establishment of Solar Thermal Research Unit working with the private and government with the aims to produce and develop the knowledge, and technology in the solar thermal field, publishes a journal, and provides academic services in this field in order to address the problems resulting from the energy crisis and leading to climate change thermal field, publishes a journal, and provides academic services in this field in order to address the problems resulting from the energy crisis and leading to climate change.
- Establishment of Thai Solar Thermal Association of local manufacturers in solar thermal business as founding members with the aim of the association to act as single point contact for government on solar thermal applications, public awareness on solar thermal technologies and manufacture of quality products.

e) Vietnam

Because of its proximity to China, SWH technology was introduced to Vietnam in the 1990s when a few affluent domestic consumers imported SWH from neighboring China. Renewable Energy Research Centre and universities were the pioneer institutions in conducting research on SWH applications in the country. Without any exclusive marketing for uptake of the technology, in span of 16 years the total installation in the country hit 3.8 million (70% of installations in South Vietnam). The annual sales during 2010 are approximately 40,000 units of which 85% have capacity between 150 and 200 Liters.

Vietnam aimed to harness solar energy and reduce the electrical water heating load by developing 1,760,000 m^2 of collector area for SWH by 2015 and 9,100,000 m^2 of collector area by 2025. Various projects are initiated for promotion of SWH systems in Vietnam to meet the country targets including:

- About 30,000 Evacuated Tube Collector type SWH systems were funded during August 2008 and July 2013 at a flat discount of USD 52 per system.
- Under Small Grants Program of UNDP, Women's Union of Hanoi City is implementing a demonstration project to introduce and develop demonstration model for use of solar water heaters in households and public service sector with appropriate design, installation and operation protocols.

8. PROPOSED IMPLEMENTATION MEASURES FOR SWH

Based on the base line assessment results and findings of the study, the existing policy, regulatory frameworks, and the SWHs experiences of other countries, the implementation measures indicated in this section are proposed.

8.1. Target SWH Installation in Addis Ababa

The current water heating systems in Addis Ababa are categorized into users of Instant water heater, Storage Electric Water heater (geysers), Centralized electric water heaters, Centralized HP, Decentralized SWHs and Centralized SWHs. As indicated in the result section, 14,926 square meters of SWH collector area can be installed in hotels, hospitals and guest houses in Addis Ababa.

Currently most guest houses and pensions use the 1.5 kW standalone EWH and the instant electric heater having power demand of 5.5 kW per shower stand or room. Due to the higher power capacity and prevalence of the EWHs, its power demand and energy consumption are high and it needs to be replaced by cascaded stand-alone SWHs in a short term. Existing centralized EWHs employ centralized storage tank and installed distribution pipes which are convenient for centralized SWHs installations. Hence the transition to SWHs could be planned in the short term also.

Existing standalone/storage EWH of 1.5 kW rating constitute the largest proportion of water heating arrangement in hospitals and health specialty centers and lower star rating hotels. The quantity of these appliances is significant thereby their power and energy demand. The shift from Stand-alone storage EWHs to Centralized SWHs requires retrofitting works on existing water supply intake, distribution and plumbing works. These works require expenditure in modifying existing water supply installations and disruption of business operations and shall be planned to be implemented with time. The experience gained on the short-term plans will be used to implement the shift from the decentralized EWHs to SWHs.

The feasibility of replacing EWHs by SWHs or HPs has been presented in the feasibility study section of this document. The techno economic assessment shows that the replacement of the EWHs by both SWHs and HPs is feasible. Per the study, SWHs have shorter payback period compared to HPs due to HPs replacement cost involved. Even though, the energy saving of HPs is higher. HP is more suitable for premises not having enough space for the installation of SWHs, the FPC is a better option to use compared to the ETC, and ETC is a better option for roof tops having less installation area and not having southern exposure, and water quality issues.

Existing installations constitute 58% ETCs collectors by gross area whereas FPCs cover 42%. The FPC technology has been used for over 50 years by manufacturers and has a well-established track record of reliability performance globally. As compared to ETC and HP technologies the manufacturing of the FPC could be feasible to establish locally as it has been experienced in Addis Ababa and could engage small to medium scale manufacturers.

The global experience indicates that ETC account for 93% of the solar thermal collector market in China. ETC are also the preferred technology option in: India (63% of the market) as they are cheaper than available FPC; South Africa (57% of market); and in a number of Eastern European countries (45%-67% of market). Other Asian countries, the Middle East, Latin America and Europe mostly use FPC. In the USA/Canada and Australia/ New Zealand, unglazed water collectors account for 89% and 71% of the market (IRENA, 2015). ETCs currently dominate the market in China and account for about 70% of the worldwide market, while FPCs dominate in Europe and elsewhere, and account for almost a quarter of the global market (IRENA, 2021).

The target installation is proposed to take place based on SWHs or HPs, or from SWHs on FPC or ETC on a case-by-case study basis. In view of strengthening and encouraging local manufacturing capability, local manufacturing of both FPC and ETCs has to be encouraged and supported.

Table 8-1: Implementation schedule of SWH

Base Case WH Arrangement	Specific Target	Transition to	Transitioning Schedule
Standalone storage EWHs and Instant water heaters	Lower star rating hotels, Guest houses and Hospitals and health specialty centers	Cascaded collector SWH	Short term
Centralized EWHs	Guest houses, Hotels,	Centralized SWHs	Short term
Stand-alone Storage EWHs	All premises requiring major retrofit works	Centralized SWHs	After implementation of short-term plan

8.2. Mandates, Regulations and Standards

8.2.1. Mandates

For the implementation of SWHs in hotels, Hospitals and commercial buildings in Addis Ababa, it is proposed to issue obligations for the provision of hot water demand by SWHs on newly constructed or renovated buildings. Apartment buildings shall be subjected to the requirement to install SWHs based on the top roof terrace area size and number of dwellers in the building because the roof top shall accommodate the number of required solar collectors and its access to the sun.

On existing buildings, the use of solar collectors shall be mandated without the need of any special authorization as far as the structure and aesthetics allows, except for a precisely defined and limited number of buildings of special historical interest. In the case of split incentives, also referred to as landlord/tenant barriers, where the landlord is probably not inclined to make the necessary investment in SWH because the benefit associated with any savings will accrue to the tenant, the landlord shall be required to provide SWHs.

The EEU/EEP and private utility companies entering the electricity supply and distribution market in the country shall be required to invest nominal amount of their net revenue in electricity conservation programs. In such cases, regulatory agencies require utilities to finance SWH programs or derive a certain portion of their total energy load from SWH. Compliance by the utility is typically demonstrated through the creation and procurement of renewable energy certificates. Each energy certificate may represent certain Kilowatt-hour thermal (kWh_{th}) of useful thermal output. For the implementation of such obligations the federal government shall put in place a new law.

8.2.2. Regulations and standards

SWHs are being implemented in Ethiopia for over twenty years but the market for the products is still low. Regulations and standards for SWHs shall be in place for the long-term market development of the product. The current SWH Ethiopian standards are product testing standards and performance requirements. Standards regarding Product design, manufacturing installation, maintenance, repair and replacement of the SWHs shall be developed.

The building mandates described above shall be included in the building codes of the country updating the existing Ethiopian Building Code Standards. Furthermore, the engineering design of all new and renovated buildings shall address the provision of space, cardinal orientation, mounting, structural support, electrical power and plumbing requirements for either centralized or decentralized SWHs on such buildings. The designs shall also allow provisions for optimized renewable energy powered water heaters Heat pump and PV assisted SWHs. The construction of the buildings shall be such that SWHs, piping and connection points are installed.

The EEA shall prepare regulations on SWHs, EEA and Ethiopian standards Agency (ESA) jointly develop product standard for SWHs. The EEA and the Addis Ababa city administration and sub city administrations’ building design approval departments shall be the implementers of the mandates and obligations on buildings. The authorities in charge need to prepare regulations and procedures for measurement and verification for compliance to implement the mandates and obligations.

8.3. SWH Quality Control, Certification and Training

For the implementation of SWH in the city through enforcing mandates and other policy models, the proper infrastructure for SWH quality control shall be in place first. The quality concerns refer only to the functionality of the system, i.e. to their durability and the solar energy output. Quality assurance measures should cover the following areas:

- Components and system configurations
- Installation works, guarantee and after sale service
- Function control
- Third party monitoring of a sample of the systems installed

8.3.1. Quality control

Quality control is achieved through meeting standard and regulatory specifications and requirements. All equipment components furnished by the SWH importer/ manufacturer/installer shall be developed, designed, and/or fabricated using high quality design, materials, and workmanship meeting the requirements of the Purchaser-Owner and all applicable industry codes and Ethiopian standards. The installations shall comply with at least, but not limited to, the latest approved versions of the Ethiopian Building Codes and SWH standards and regulations, and all other local jurisdictions having authority.

a) Imported product quality

Product quality of imported items can be achieved through Pre-Verification of Conformity (PVoC) to standard on imported products as almost all SWHs installed and parts for assembly are imported. PVoC on SWHs could be developed jointly by EEA and ESA as have been done for other imported energy equipment.

b) Specifications and requirements of SWHs

The requirements to be met by SWHs include product design standards, Installation, Testing and commissioning, Operation and Maintenance, Troubleshooting and customer service, Major component maintenance and repair, Training to Purchaser-Owner, Training and certification (EPA, 2016).

i. Design standards

The design, products, and installation shall comply with at least, but not limited to, the relevant Ethiopian SWHs standards regarding:

- Solar collectors: Compliance with relevant Ethiopian standard product design requirements.
- Solar collector arrays: Array Layout, Piping for Solar Collector Array.
- Heat energy transport sub system: Heat Exchanger (if required by system design), Pumps (for active systems) and Heat Transfer Fluid.
- Piping system: Provide a piping system complete with pipe, pipe fittings, valves, strainers, expansion loops, pipe hangers, inserts, supports, anchors, guides, sleeves, and accessories with specification and the drawings.
- Electrical components: Provide electrical equipment and wiring in accordance with relevant Ethiopian standard.
- Mounting system: Mounting systems shall be designed and installed such that the panels may be fixed with reliable components proven in similar projects, and shall be designed to resist dead load, live load, corrosion, UV degradation, wind loads, and seismic loads appropriate to the geographic area over the expected 25-year lifetime.
- Corrosion control: Fasteners and hardware throughout the system shall be stainless steel or material of equivalent corrosion resistance.
- Roofing requirements: Proposed roof top mounted systems shall not exceed the ability of the existing structure to support the entire solar thermal system and withstand increased wind uplift and seismic loads, roof penetrations, if part of the mounting solution, shall be kept to a minimum, all penetrations shall be waterproofed and any damage to roofing material during installation of solar systems must be remedied by the supplier/installer.
- Monitoring system. Supplier/Installer shall design, build, activate and ensure proper functioning of the necessary Data Acquisition Systems (DAS) that enable the Purchaser-Owner to track the performance of the Solar Systems.

- Stagnation protection: Designing and installing a solar system that meets stagnation and overheat protection requirements, closed loop drain back systems must have a controller which will shut down a pump when the storage tank temperature limit has been reached.
- Shading: Supplier/Installers shall perform a shading analysis justifying the basis for their design explaining why shading does not create an adverse performance and/or economic impact.
- Warranties: Supplier/Installer shall provide a comprehensive ten (10) year warranty on all system components against defects in materials and workmanship under normal application, installation, and use and service conditions, and a 15% performance degradation. All systems must have a minimum 1-year warranty on installation labor and workmanship not otherwise covered by the manufacturer's performance warranty.

ii. Installation

SWH importer/manufacturer/installer shall provide all necessary labor, materials, equipment, and services required to install complete integrated turnkey solar thermal systems. The installer shall supply all solar collectors, mounting equipment, piping, pumps, controls, metering, related wiring, monitoring equipment, and all ancillary equipment necessary to install the solar system and interconnect it to the Purchaser-Owner hot water system. The solar system installations shall comply with all contract requirements, technical specifications, approved design documents, and applicable regulatory codes and requirements. As-Built drawings in hard copy and an electronic copy in DWG or other convenient format shall be submitted to the Purchaser-Owner after completion of the Proving Period for each system at the site.

The installation requirements shall cover:

- Materials and equipment incorporated in the work,
- Line location of utilities, conduits, piping, substructures, etc.
- Cleaning/Purging new piping and parts of existing water piping that have been altered, extended, or repaired.
- Removal of all construction spoils, utilities, construction equipment and other byproducts of installation.

iii. Testing and commissioning

Following completion of construction, the supplier/installer shall provide the following services related to startup and performance testing of the systems:

- Acceptance Testing: Component tests as well as other standard tests, inspections, safety and quality checks.
- System Startup: Following Purchaser-Owner approval of the Acceptance Test Report, supplier/installer shall conduct tests over twenty-four (24) hours and at a time resolution of fifteen (15) minutes, recording the following data:
    - Thermal output (kWh)
    - In-plane irradiance
    - Ambient temperature
    - Collector inlet temperature
    - Thermal energy storage temperatures
- Proving Period (30 Days): Upon completion of Acceptance Testing and System Startup, and approval by the Purchaser-Owner, supplier/installer shall monitor the system during a thirty (30) day Proving Period and submit a report for Purchaser - Owner review and approval prior to final acceptance. This includes monitoring system output and ensuring the correct functioning of system components over this time. The values for the following data shall be acquired every fifteen (15) minutes over thirty (30) days:
    - Date and Time of data points
    - Thermal output (kWh)
    - Total kWh delivered (per tank if system has multiple tanks)
    - In-plane irradiance
    - Ambient temperature
    - Collector inlet temperature
    - Thermal energy storage temperatures
    - Quantity of back-up fuel consumption
    - System availability

- Close out documentation requirements: Close-Out documents prepared by supplier/installer must include at minimum, but not limited to, the following items:
  - Final As-Built drawing Set, provided in hard copy and an electronic copy in DWG format (or as desired by Purchaser-Owner)
  - Owner's Manual and component warranties
  - Signed inspections cards by concerned authority.
  - O&M Manuals – Supplier/Installer shall provide O&M Manuals. Updated editions of O&M Manuals shall be sent electronically to the Purchaser-Owner as they become available

iv. Operation and Maintenance

- Preventive maintenance: Preventive maintenance shall be performed at least annually and include:
  - Test system performance vs. insolation and ambient temperature to verify continued performance at or near design levels
  - System level testing including tests of individual major components
  - System visual inspection to include but not be limited to the list below. All discovered issues shall be resolved as needed.
    - Inspect for stolen, broken or damaged collectors, record damage and location. Report to the Purchaser-Owner and wait for the Purchaser-Owner to authorize a course of action.
    - Check mechanical attachments of the collectors and racking system.
    - Inspect all metallic parts for corrosion.
    - Survey entire jobsite for debris or obstructions.
    - Inspect fasteners for proper torque and corrosion.
    - Check for proper operation and reporting of monitoring hardware.
    - Inspect pipe connections for leaks
    - Inspect piping and other hardware for signs of damage from vandalism or animal damage.
    - Inspect storage tank(s) for signs of damage
  - Routine system maintenance to include correction of loose water pipe connections, replacement if defective collectors found during testing, other minor maintenance repair work.

- Collector cleaning, at a frequency to be determined by the ongoing monitoring of the system such that effect on production is no more than 5%, but not less often than twice a year.
- Routine DAS maintenance to include sensor calibration and data integrity check

v. Trouble shooting and customer service

- Dispatch of field service resources within two business days of notification (via automated or manual means) for repairs as necessary to maintain system performance.
- Any corrective action required to restore the system to fully operational status shall be completed within 24 hours of the service resources arriving on-site.
- Support telephone line made available to Purchaser-Owner staff to answer questions or report issues.
- Support line shall be staffed during operational hours from 8 AM - 6 PM local time. During times outside of this operational period, an urgent call shall be able to be routed to a supervisor for immediate action.

vi. Major component maintenance and repair

- Pump repair and component replacement and refurbishment as required in the event of pump failure.
- Pump inspection and regular servicing as required under pump manufacturer's warranty specifications. Those include but are not limited to the following annually:
  - Check for corrosion on all fittings
  - Check all connections.
  - Perform a complete visual inspection of all connected systems including expansion tank and back-up water heater.
  - Record all inspections completed.
  - Inform pump manufacturer of all deficiencies identified.
  - Oversee pump manufacturer performance of In-Warranty replacement of failed pump components.
- Customer advocacy with vendors.

vii. Training to Purchaser-Owner

The Supplier/Installer shall provide four (4) hours of on-site training for Purchaser-Owner personnel in all aspects of operation. At a minimum, training topics shall include the following:

- System safety, including shut-down procedures
- Solar thermal collector maintenance and troubleshooting
- Calibration and adjustment procedures for flow meter, temperature sensors, pressure gauges
- DAS and monitoring solution, including standard and custom reporting
- Heat transfer fluid changing guide and schedule

viii. Training and Certification

Ethiopia has very few trained professionals in the SWH value chain (e.g. architects, engineers, contractors, installers) that are qualified to design and install SWH systems

Training on SWHs is required for designers, installers and maintenance service providers as there are no institutions delivering such service in the country today. Certification of SWH installers by EEA or a certification body is also necessary. The Addis Ababa TVET shall introduce certification for the skill of SWH installation as a technical occupation. Training manual on SWHs industry in the country shall be developed which shall be used by designers, architects, engineers and installers.

8.4. Financial Incentives

While solar hot water can offer significant savings to businesses, upfront costs can be prohibitive and remain a persistent barrier to deployment. As there are no many SWHs manufacturing firms in Addis Ababa, customers face higher costs from import tariffs. These combined factors can push many businesses that could benefit the most from energy savings from the market. As a result, financial incentives are often necessary to help the business overcome upfront investment costs and achieve attractive economic returns.

Three main types of incentive policies can be deployed or leveraged. These include: upfront capital incentives, performance-based incentives, and hybrid models based on expected performance. The Performance based and expected performance policies require measurement of the solar thermal energy generated and to justify if the generation is sufficient as it is dependent on on-site heating demand. Hence, only the upfront capital incentives policy option appears to be applicable at the moment.

8.4.1. Upfront capital incentives

Upfront incentives, including rebates and grants, are the most widely implemented SWH incentives. These are usually structured as direct, one-time payments and could be made by the government or Addis Ababa city administration to consumers at the time they purchase a SWH system. Capital incentives may be calculated based upon the total expenditure made for the system (e.g. 10% of the total system cost), the capacity of the system (e.g. Birr/m^2 of solar collector area), or a flat rate (e.g. An amount of Birr for the commercial premise SWH system). The total expenditure of the SWHs and collector area could be estimated after detail study of the specific site. Incentive programs can be administered by Addis Ababa revenue authorities, the EEU’s Addis Ababa bill collection offices, government agencies, or via non-governmental partner organizations.

8.5. Financing and Business Models

Even with capital incentives from governments, upfront costs for SWHs may still be too high for many consumers. Access to business financing is frequently lower in developing country cities like Addis Ababa, and high interest rates may deter many consumers from borrowing to finance a system where the option is available.

Banks in these markets are often hesitant to provide loans for unfamiliar technologies. In addition, SWH systems can seem complex, especially commercial installations, and many end-users will not want to deal with the hassle of managing the maintenance or operational issues that affect system performance.

Increasing access to SWH will in many cases require the development of low cost and innovative financing and business models to enable end-users to overcome high first costs. These include options such as low-interest lending programs, utility on-bill programs, as well as innovative contractor business models provided by energy service companies (ESCOs).

8.5.1. Low-interest lending programs

Under low-interest lending programs, the government (EEA/EEU) can implement programs that increase customer access to low-cost financing for SWH investment. These may include (i) direct loan programs, where the government acts as the loan underwriter and servicer; (ii) matching loan programs, where the government provides a certain share of a loan (often at a below market interest rate) and a commercial lender provides the balance of the loan; or (iii) interest rate buy-downs, in which case a government agency subsidizes the interest rate offered by a private lender.

8.5.2. Utility on-bill programs

Under this scheme, customers are able to repay the cost of installation via a surcharge on their utility bill. EEU or its financial partner will cover the cost associated with the purchase and installation of the SWH system. EEU recovers its cost by adding a charge to the consumer's utility bill until all costs are repaid. The on-bill utility programs provide customers with convenient access to financing for SWH or other energy efficiency investments. However, it needs regulation to be issued in this regard.

8.5.3. Innovative contractor business models

In addition to the high upfront costs, SWH technologies, especially commercial-scale installations, have to compete against other corporate or institutional priorities for scarce internal investment money. Many businesses or institutions will resist making large capital investments in projects like SWH that are not related to core business activities.

As a result, decision-makers will often determine that the opportunity costs associated with the time, energy, or capital required for investment in SWH is too great compared to potential returns.

Innovative SWH contractor business models mitigate the extra effort and cost associated with SWH by simplifying the design, development, operation, financing, and maintenance of systems. In this case, a separate entity, such as an energy service company (ESCO) or financial investor, assumes most of the operational risk for SWH and in some cases will also assume ownership of the system. Thus, in regions with good SWH economics, commercial hosts can potentially integrate SWH into their building for little or no money down, reduce the risk and complexity related to system operation and maintenance, and achieve immediate cost-savings.

The Energy regulation No 447/2019, chapter 6, provides for the establishment of Revolving fund, partial or full fund, partial or full credit guarantee or on cost sharing basis to energy efficiency and conservation activities in Ethiopia. The source of funds may include budget allocation from government, loans and grants from financial institutions, grants from non-governmental organizations. The EEA directive 006/2012, provides for the establishment of ESCOs. The energy efficiency strategy for industries, buildings, and appliances, directive No 005/2012, states that barriers in financing energy projects can be addressed by the development of financial products such as Partial Credit Guarantees (PCG). Under this scheme, EEA will use the fund from the revolving fund to provide partial credit guarantees for 50% of the project cost to the financial institution.

The revolving fund business model in conjunction with Partial Credit Guarantee (PCG) and guarantee fee raised either by the customer or ESCO can be used to reduce the perceived risk of financial institutions. After the implementation and maturing of the energy conservation financing of SWHs with the revolving fund & PCG model above, the EPC shared and guaranteed savings models (ESCOs) may be introduced without the revolving fund and PCG mechanisms. Currently there are no ESCOs in the country.

Figure 8-1 shows the revolving fund along with PCG business model while the EPC – shared and guaranteed savings models (ESCOs) are presented in Figure 8-2 and Figure 8-3 respectively.

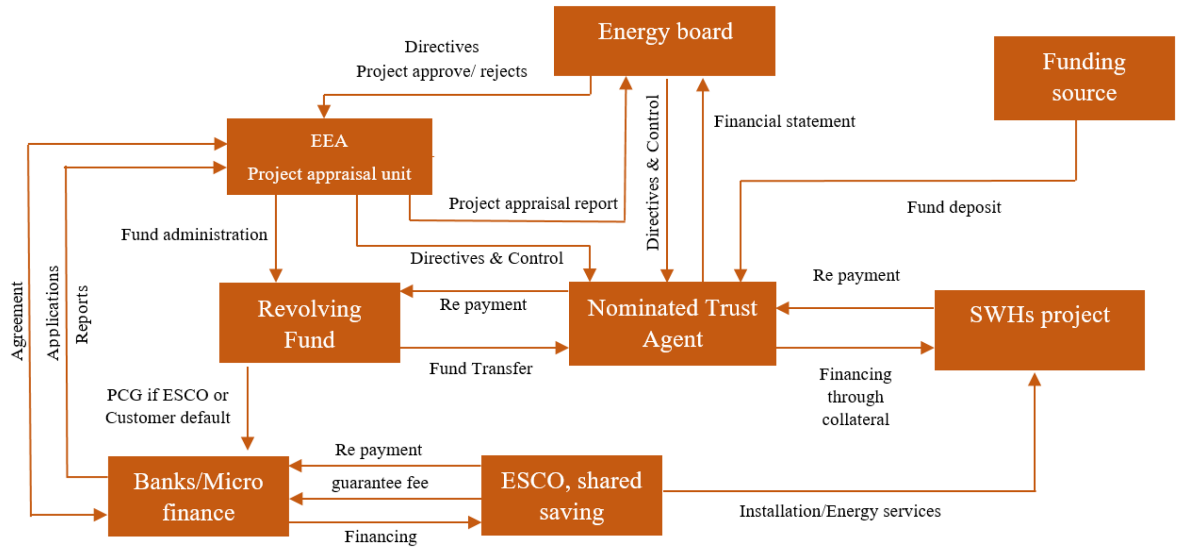


Figure 8-1: Revolving fund/PCG business model relationship

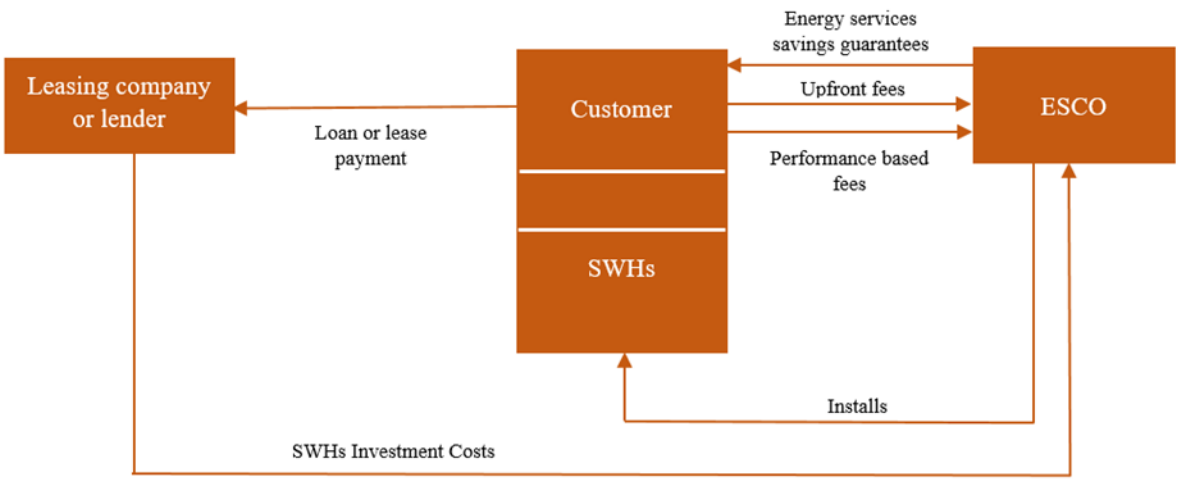


Figure 8-2: Energy Performance Contract business model: Guaranteed-Savings

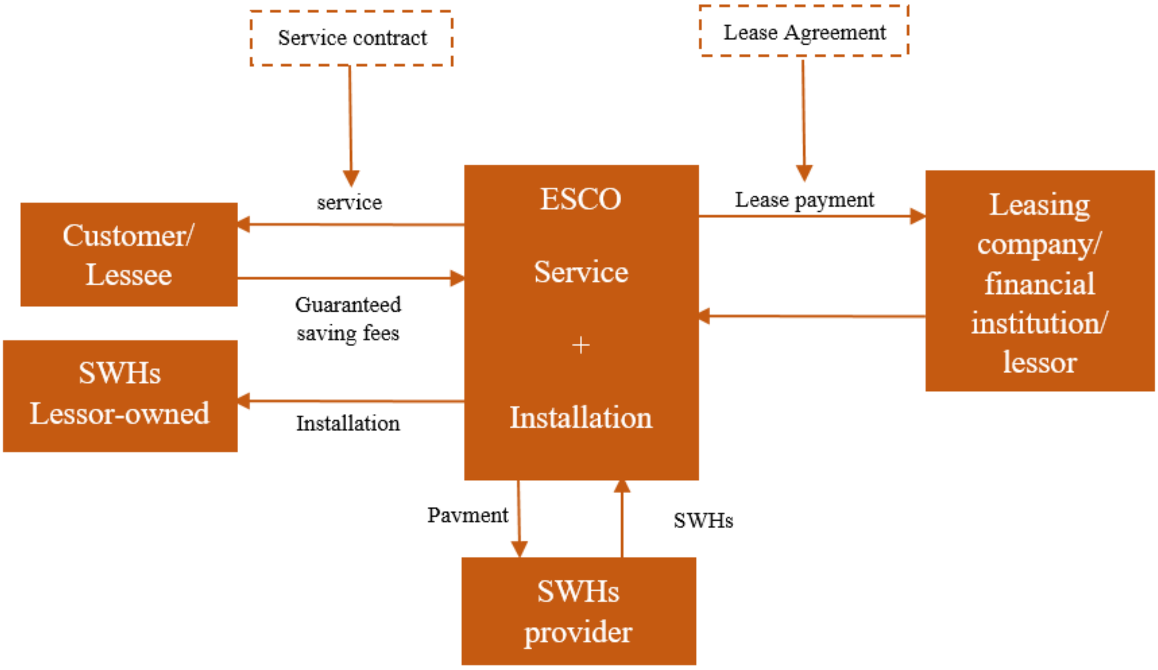


Figure 8-3: Energy Performance Contract business model: Shared Saving (Pay-as-You-Save)

8.6. Awareness Creation

As with any new or unfamiliar technology, consumers need to understand what SWH is and how it works if they are to make an investment in it. Based on the assessment made on Hotels, Hospitals and commercial buildings there is a huge lack of awareness on SWHs. As a result, many consumers are unfamiliar with the benefits that SWH can provide their business or where or how to install a system.

There are a wide variety of consumer education programs that can be implemented to support SWH market development. These include consumer advertising and awareness campaigns, group purchasing programs, and demonstration projects.

8.6.1. Public advertising campaigns

SWH public advertising campaigns help connect consumers with qualified installers and help contractors to better market the benefits of SWH to consumers. Consumer perceptions about SWH is important to overcome any negative or inaccurate perceptions. The public advertising campaigns may encompass a broad range of media and events, including workshops, pamphlets, online media, billboards, newspaper, radio, and TV.

8.6.2. Community demonstration projects

SWH demonstrations projects help increase local awareness of the technology and its uses. Exploring SWH firsthand at a public facility enables constituents to get a solid understanding of the technology. While demonstration projects may be small or large, they should be in highly visible locations that are easily accessible to the public. This could include, for example, an installation on a local school, city hall, park, conference center, or community center. Awareness creation shall also extend to policymakers, hotel, hospital and commercial building owners, building designers, and plumbers in Addis Ababa.

8.7. Stakeholder Engagement

Implementation of SWHs require cooperation between government offices like Ministry of construction, the EEA, the EEU, ESA, AA city administration, government banks and private sector entities such as business owners, banks, designers, importers and installers. The private sector entities can aid in program implementation and will often assume some of the financial risk and burden from the program. It is crucial to engage the private sector stakeholders early in the design and throughout the program implementation process to align stakeholder interests, mitigate market barriers, and create successful policies and programs to drive SWH market development. Table 8-2 presents stakeholders with their roles and potential project impacts.

Table 8-2: Stakeholders with their role and potential impacts

No	Stakeholder's Name	Role	Interest	Potential project Impact (+, _ , ?)	Relative priorities of interest (1 = high, 5 = low)
1	Primary				
1.1	SWH Importers/Manufacturer/Distributors /Installers/Maintenance service providers	Partners in the implementation program in providing SWHs equipment and services	- Better market opportunities	+	1
			- Additional cost to be incurred in the program	_	1
			- Import, Manufacturing, Distribution, Installation, Maintenance to continue as used to be.	+	1
1.2	Hotels, Hospitals, Commercial building owners	Partners in the implementation program in purchasing equipment and services	- Reduction on the cost of energy	+	1
			- Better provision of hot water	+	1
1.3	EEA/EEU/EEP/MoWIE, Ministry of urban development and construction, Addis Ababa city Energy bureau,	Implementers of the program	- -successfulness of the program	+	1
1.4	Ethiopian Customs Commission	Avail SWHs import Data	- successfulness of the program	+	1
2	Secondary		-		
2.1	Ministry of Health	Develop Hotel SWHs requirements	- successfulness of the program	+	2
2.2	Addis Ababa Environmental protection Commission	Coordinate program and report the achievements	- successfulness of the program	+	2

No	Stakeholder's Name	Role	Interest	Potential project Impact (+, _ , ?)	Relative priorities of interest (1 = high, 5 = low)
2.3	Addis Ababa trade and Industry	Coordinate project and report the achievements	- successfulness of the program	+	2
2.4	AA culture and tourism bureau	Coordinate SWHs program in hotels	- successfulness of the program	+	2
2.5	AA Health bureau	Coordinate SWHs program in Hospitals/Specialty centers	- successfulness of the program	+	2
2.6	Ethiopian Standard Agency	Develop Product Standard and enforcement of the standard	- successfulness of the program	+	2
3	External		-		
3.1	Ministry of Finance and Economic Development	Allocate budget for the program and secure fund	- successfulness of the program	+	2
3.2	Ethiopian Conformity Assessment Enterprise	Avail testing facility as per agreement with EEA, test samples and provide test report	- successfulness of the program	+	2
3.3	Donors	Supports the project financially	- successfulness of the program	+	3
3.4	Banks	Provide loan	- Successfulness of the program	+	2

8.8. Institutional Arrangement

EEA is the implementing authority for the SWHs. The organizational and institutional setting of EEA is assessed as follows.

8.8.1. Institutional setting and legal frame work

a) The EEA is mandated by the Proclamation on Energy, proclamation No. 810/2013, on EE regulation and conservation works in Ethiopia. Article 19, 2, of the proclamation states that Energy efficiency and conservation activity may be regulated through the application of, among many: a) mandatory energy saving; or b) mandatory installation of energy efficient and conserving equipment. The energy regulation 447/2019, Article 50.1 states that energy efficiency and conservation in buildings may be regulated through energy efficiency and conservation codes, standards or labels, or through a combination of any or all.

b) The implementation of the proposed SWHs program is within the mandate of EEA. However, the program necessarily needs the ratification of regulatory framework governing the SWH industry, development of product standard and implementation of PVoC.

8.8.2. Organizational capacity assessment

a) Organizational structure of EEA

EEA is established under Ministry of Water, irrigation and Energy and headed by a Director General. According to the current organizational structure there are fourteen directorates, one Support office and one Service unit. Figure 8-3, overleaf, shows the organizational structure of EEA.

Under the existing structure the EE and Conservation Directorate, being one of the core directorates, will be tasked with the responsibilities of regulating the SWHs implementation program in the city. There are a total of eight staffs. Currently there are two teams under the directorate: Energy audit and Licensing team with six staffs and EE Standards, labeling and promotion team with one staff. There are no organizational structures and dedicated staffs for demand side energy conservation works like SWHs and related.

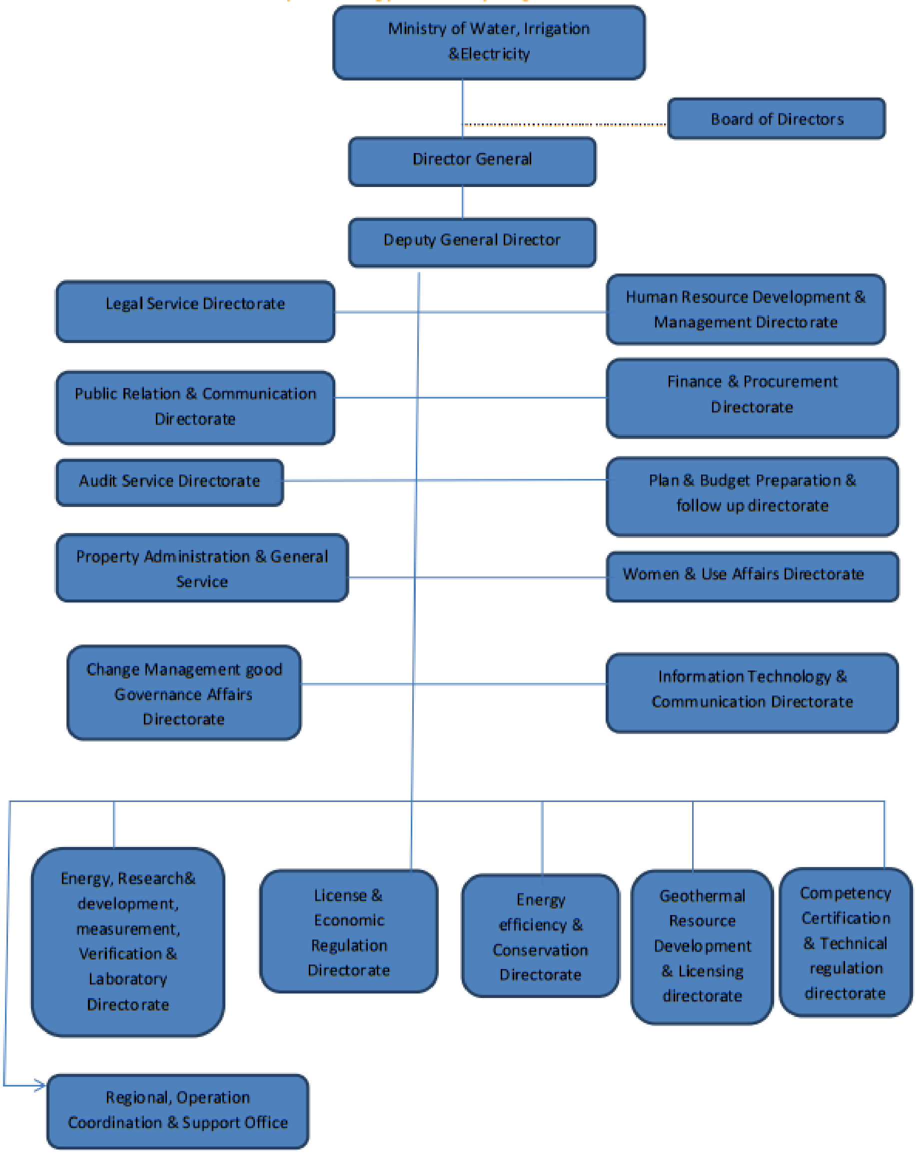


Table 8-3: Organizational structure of EEA

b) Proposed organization for the implementation of the SWHs.

As indicated in earlier sections, the SWHs program involves the development of SWHs regulatory framework and engages different types of stake holders including manufacturers, consumers, importers, and government institutions. Lots of activities are expected to be carried out with the stakeholders to achieve the desired goals of the program. Programs like SWHs implementations are Demand-Side Renewable technologies (DSR) technologies that utilize renewable energy to reduce the end-use load of a customer (as seen by the utility serving the load (Carlisle *et al.*, 1992). Hence, there is a strong need to establish a structure under the EEA EE and Conservation Directorate to handle the implementation of Demand side Renewable technologies including SWHs, Heat pumps, other solar thermal applications, PVs etc.

c) Capacity building activities.

The Energy conservation program on SWHs is proposed to be accomplished by hosting the program within the EEA structure. Training on Solar thermal and SWHs shall be given to the staffs of the EE and Conservation Directorate in order to enhance their capacity for the implementation of the program.

8.9. Implementation Schedule

Based on the existing water heating arrangement, hot water demand, and the energy and power demand saving potential in transitioning to SWHs, the implementation schedules in Table 8-4 have been identified.

Awareness creation on SWHs and stake holders' engagement shall commence at the beginning of the implementation. Development of SWHs regulation and product standard are necessary to enforce the implementation and proposed at the early stage in 2022. SWHs training manual and training of installers is scheduled at the beginning of 2023. Implementation of PVoC, mandates on buildings and Utilities, and financial incentives are proposed to commence after awareness creation and training in mid-2023. Replacement of existing EWHs is proposed to commence after all the awareness creation, standard and regulation development, PVoC and financial incentives have been applied, in 2024.

Table 8-4: Proposed implementation schedule

No.	Activity	Year								
		2021	2022	2023	2024	2025	2026	2027	2028	2029
1	Awareness creation and stake holders' engagement		■	■	■	■	■	■	■	■
2	Develop SWHs product standard and regulations		■							
3	Develop SWHs training manual and train installers			■	■	■	■	■	■	■
4	Implement PVoC			■						
5	Implement building mandates and Utility mandates			■						
6	Implement Financial incentives			■	■	■	■	■	■	■
7	Replace Standalone storage EWHs and Instant water heaters at lower star rating hotels, Guest houses, Hospitals and health specialty centers. Cascaded collector SWH by Cascaded collector SWH and centralized SWHs				■					
8	Replace centralized EWHs at Guest houses, Hotels, by centralized SWHs					■				
9	Replace Stand-alone Storage EWHs at all premises requiring major retrofit works by centralized SWH						■	■	■	■

9. BENEFITS OF APPLYING SWH IMPLEMENTATION MEASURES

The deployment of SWHs in the hotels, hospitals and other buildings leads to the reduction of electricity demand in the city and would create additional jobs. Major benefits include reduction of electric power demand and energy consumption that will improve the energy security of the city and job creation in the solar water heater industry - both in manufacturing and system installation. Employment creation is the city's priority.

9.1. Energy Consumption Saving and Electricity Tariff

9.1.1. Electricity tariffs

Figure 9-1 shows a simple comparison of electricity tariff of selected Africa countries. The tariff is for Business rates: Small firms (30,000 kWh annual consumption), medium-sized firms (150,000 kWh annual consumption), large firms (1,000,000 kWh annual consumption) and extra-large firms (7,500,000 kWh annual consumption). The average electricity tariff prices in Africa vary widely across the continent from 0.5 U.S. dollars per kilowatt hour in Burkina Faso to 0.02 U.S. dollars per kilowatt hour in Ethiopia.

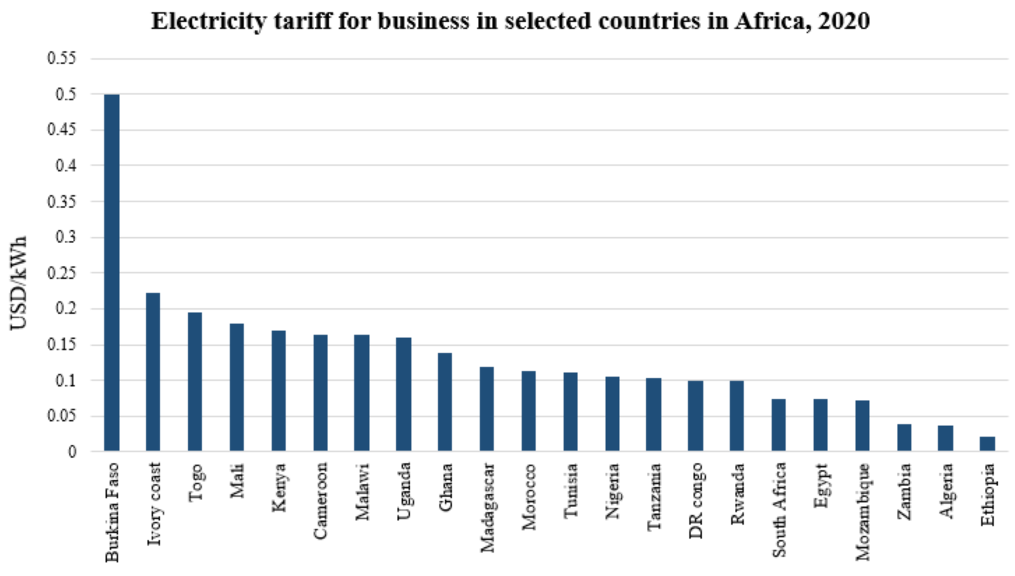


Figure 9-1: Electricity tariff of selected countries in Africa, 2020 (adopted from Global petrol prices, 2020)

The Ethiopian electricity tariffs are among the lowest in Africa, very cheap in energy saving value and insufficient to offset the additional capital cost of energy conservation efforts. Table 9-1 shows working Tariffs for the Tariff groups.

Table 9-1: Industrial and commercial electricity tariff in Ethiopia, 2018-2021

Tariff category	As of Dec, 2018 onwards (Birr/kWh)	As of Dec, 2019 onwards (Birr/kWh)	As of Dec, 2020 onwards (Birr/kWh)	As of Dec, 2021 onwards (Birr/kWh)
General (Commercial)	1.0352	1.3982	1.7611	2.124
Low voltage Industry	0.8161	1.0544	1.2927	1.531
Medium Voltage Industry	0.6047	0.8008	0.9969	1.193
High Voltage Industry	0.5174	0.654	0.7911	0.928

9.1.2. Energy consumption saving

From Table 4-10, the aggregate energy consumption of hot water production using Electrical energy is 18.72 GWh/year whereas the energy saved if SWHs are installed at the premises will be 11.2 GWh/year.

Table 9-2 and Figure 9-2 show the electricity consumption of A.A by tariff group in 2012 EC.

Table 9-2: A.A city energy consumption by tariff group, 2012 EC

Tariff group	Consumption (GWh)	Percentage
Domestic	2,159.2	66%
Commercial	879.8	27%
Industrial	253.7	8%
Total	3,292.7	100%

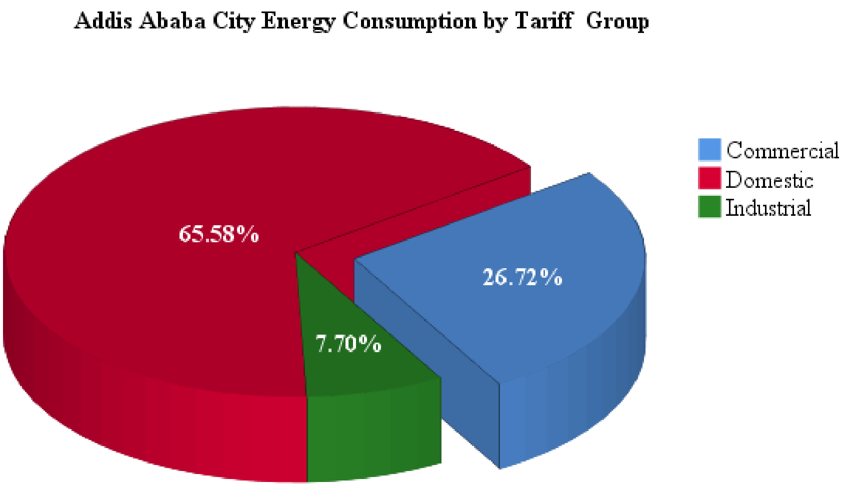


Figure 9-2: Electricity consumption of Addis Ababa by tariff group, 2012 EC

The aggregate energy consumption of hot water production will be 2.1% of the city's 2012 EC consumption. The energy saving of 11.2 GWh amounts to a saving of birr 23.8million Birr/year at the Commercial tariff rate of 2.124 birr/kWh rate as of December 2021, or USD 0.784 million/year at energy export rate of USD 0.07/kWh (MoWIE, 2019).

9.2. Power Demand Saving

As per Table 4-2, Table 4-4 and Table 4-6, the aggregate total installed capacity of existing electric energized water heaters excluding HPs is about 38.7 MW. Assuming a demand factor of 80% for buildings (Compulsory Ethiopian Standard (CES) 162, Electrical Work, 2015) the peak power demand imposed by the installed electric energized water heaters would be 30.9 MW.

From Table 4-16 the energy saving of 11.2 GWh is contributed by the SWHs during a year for an average sunshine hour of 6.9 hour per day (See section 3.2.1) whereas the balance 7.5 GWh is covered by the auxiliary electric power supply for 17.1 hours per day in a year. Hence, the actual power demand for hot water production using the auxiliary electric power will be 7.5 GWh per year/ (17.1 hrx365 days) or 1.8 MW. Thus, 30.9MW less 1.2 MW equal to 29.7MW will be the amount of installed power demand capacity reduced. Hence, the implementation of SWHs would bring power demand reduction of 29.7MW having monetized cost of power generation value of USD 35.7 Million USD at the rate of USD 1,200/kW (https://energypedia.info/wiki/Ethiopia_Energy_Situation).

9.3. Job Creation

Jobs will be created in the solar water heater industry both in manufacturing and system installation. Employment creation is a huge national and city priority in Addis Ababa. Job opportunities are generated in SWHs deployment from direct employment, which refers to employment that is generated directly by core activities, and indirect employment including upstream industries that supply and support core activities.

Employment that is generated directly by core activities in the value chain of solar water heaters include those in: procurement of materials and manufacturing of equipment, sales and distribution, installation, operation and maintenance, and decommissioning of solar water heaters.

According to experience of many countries, installation of SWHs at 10,000 households, 4 square meters per house generates employment opportunity of 11.5 man-days per square meters of collector installed over the 20 years of SWHs life time (IRENA, 2021). Based on this reference, the total collector area which could be installed at the hotels, hospitals, and big buildings is estimated to be 14,926 square meters, which will equate to 171,649 man- days over the 20 years life time.

Furthermore, the distribution of human resource along the value chain is estimated as:

- Operation and maintenance work - 33% or 56,644 man- days. Includes: Plumbers, Mechanical technicians and Electricians.
- Installation - 28% or 48,062 man- days. Includes: Plumbers, Mechanical technicians, Electricians, Masons.
- Decommissioning - 20% or 34,330 man- days. Includes: Includes: Plumbers, Mechanical technicians, Electricians and Civil workers.
- Sales and distribution- 10% or 17,165 man- days. Includes: Store personnel, Truck drivers, Administrative and accountant, Management, Commercial agents, Logistic experts, and Quality and safety experts.
- Procurement and manufacturing - 9%, or 15, 448 man- days. Includes: Factory workers and technicians, Logistic experts, Engineers, Quality and safety experts, Marketing and sales personnel, Administrative and accounting personnel, Management, Regulation and standardization experts.

9.4. Emissions Reduction

The emission reduction potential for the energy consumption saving due to the implementation of SWHs is computed assuming the energy saved may be exported to neighboring countries where it replaces oil-based power generation. The emission reduction is calculated based on the base line emission data of the Ethio-Kenya power interconnection project, which is 0.571 tCO2/MWh (CDM-PDD, 2012). Table 9-3 shows CO_2 savings of the water heating systems.

Table 9-3: Emission reduction due to implementation of SWHs

Annual Energy savings (MWh)	Project life (Years)	Project life Energy savings (MWh)	Emission Factor tCO2/MWh	Project life CO_2 savings (Metric Tons)
11,203.41	20	224,068	0.571	127,943

10. RISK AND MITIGATION MEASURES

Risks identified for the implementation of SWHs, their impact level and mitigation measures to be taken are presented in Table 10-1 below.

Table 10-1: Risk and mitigation measures

No.	Risks	Rating	Mitigation Measures	Responsibility
1	Lack of awareness in hotels, hospitals and guest houses on the significance of energy and power demand savings obtained from the implementation of proposed SWHs	High	▪ Guidebook and web-based application on the use and savings of SWHs and help in capacity building. Covering the following topics • Introduce SWHs • SWHs lifetime costs • SWHs benefits as compared to EWHS	EEA/EEU
2	Unwillingness of non SWHs users to buy SWHs due to high initial cost may lead to failure of proposed implementation.	High	▪ Encourage and assist non SWHs users to make real time and informed decision making when buying SWHs including Web site support. ▪ Awareness creation on available financing, incentives and government target implementation programs. ▪ Introduce a campaign in the city to encourage greater use of SWHs through television, radio and social media campaign.	EEA and stakeholders
3	Inadequate incentives and lack of financing set aside for importers and end-users purchasing SWHs.	High	▪ Establish and look for financing sources and mechanisms for the implementation of SWHs ▪ EEA, MoWIE, and MoF, and other stakeholders such as the development bank of Ethiopia and microfinance institution and revolving fund administration to secure medium to long term financing for the implementation program	EEA, MoWIE MoF, DBE and financial institutions

No.	Risks	Rating	Mitigation Measures	Responsibility
4	Low technical capacity and ineffective stakeholder coordination	High	▪ Series of capacity building activities, trainings, workshops on SWHs to help remove technical barriers to the implementation of SWHs and regular meetings with the stockholders to exchange implementation plans	EEA and stakeholders
5	Increase in Illegal trade/ contraband of substandard SWHs	Medium	▪ Monitoring illegal or contraband injection of substandard SWHs in the country through serious implementation of PVoC and labelling of SWHs	EEA, ECC
6	Delay in the implementation of SWHs	Low	▪ Include SWHs regulatory framework in national agenda papers ▪ Initiate round table discussions with stakeholders	EEA

11. CONCLUSION AND RECOMMENDATION

11.1. Conclusion

This study assessed the existing conditions of Water Heating systems in the hotels, hospitals and big commercia buildings in Addis Ababa, conducted feasibility assessment and proposed SWHs implementation measures.

The water heating technologies used at Hotels, Hospitals and big buildings in Addis Ababa constitute electric water heaters (including instant, stand alone and centralized) - 83.4%, Solar Water Heaters - 7.0%, Heat Pumps - 5.7%, Fossil fuel burner - 0.8 %, Fossil fuel burner and Heat pump - 0.2%, non-users - 2.9%. The installed capacity of electrical energy using water heating appliances/equipment at the premises in the city is estimated to be 41.1 MW whereas the electrical energy demand for water heating is 18.7 GWh. The aggregate total installed gross collector area at hotels, hospitals and big buildings is estimated to be 1,358.9 square meter which is equivalent to thermal capacity of 714 kW_{th} indicating a very low SWHs installations in the city.

The survey on the SWHs users showed that major reasons for the current very small SWH market and low adoption of SWHs in Addis Ababa are lack of building mandates, SWHs regulation and product standard, quality control on imported and locally manufactured products. Improper installations, absence of certification for designers and installers, shorter warranty, poor after sales service, and lack of financial incentives and financing mechanisms are other reasons for the low adoption of SWHs. For the non SWHs users, lack of awareness are the main causes for the perception that SWHs might take longer time to supply hot water, are too expensive, and may not have enough capacity to supply adequate hot water. The three most important decision factors to acquire SWHs are: warranty, price and brand. The above implicates there is a strong need for regulatory framework governing the SWH industry.

The feasibility analysis of the flat plate and evacuated tube type SWH system for small scale water heating, and SWH (FPC and ETC) and air to water HPs for large scale water heating has been done against the base cases of EWHs. The two alternatives, SWH system and air to water heat pump, are compared in terms of energy saving potential, capital cost, IRR, SPP, EPP, NPV, and benefit-cost ratio. The solar fractions (SF) for flat plate and evacuated tube type SWH system for small-scale water heating is determined to be 56.9% and 63.0%, respectively.

For FPC and ETC large scale type SWH system, SF is found to be 56.0% and 63.8%, respectively. The annual energy saving potentials for small-scale water heating system with FPC and ETC type SWH system are found to be 11.15 MWh and 12.36 MWh respectively. For large-scale water heating system with air to water heat pump, ETC and FPC type SWH system the savings are 133.8 MWh, 119.7 MWh and 105.5 MWh, respectively. The Equity Payback period and pre-tax IRR-equity for small-scale water heating system are 7.1 years and 17.5 percent, respectively for FPC; and 8.3 years and 14.7 percent, respectively for ETC. The Equity Payback period and pre-tax IRR-equity for large scale water heating system are 9.3 years and 19.6 percent, respectively for FPC; 12 years and 16.1 percent, respectively for ETC; and 11.5 years and 14.1 percent, respectively for HPs. Based on the feasibility analysis, FPC type SWH system is the most economically attractive water heating technology followed by ETC SWH system and HP water heating system.

ETC is a better option for roof tops having less installation area and not having southern exposure, and water quality issues. SWHs have shorter payback period compared to HPs. HP is more suitable for premises not having enough space for the installation of SWHs. The target installation proposed shall take place on a case-by-case study basis using SWHs or HPs, and from SWHs either using FPC or ETC. The suitability of trending renewable technologies of Heat Pump, Solar Thermal and Heat pump hybrid, PVT water heaters and PV assisted Heat Pump etc., for hotels, hospitals and other buildings in Addis Ababa shall be investigated and evaluated in a similar way.

Replacing the existing EWHs in the city by SWHs could bring an estimated energy consumption saving of 11,2GWh/year equivalent to saving of birr 23.8 million Birr/year if consumed locally or 0.784 million USD / year if the energy is exported. The implementation of SWHs would bring power demand saving of 29.7 MW having monetized cost of power generation value of USD 35.7 million USD.

The total SWHs collector area which could be installed at the hotels, hospitals, and big buildings in the city is estimated to be 14,926 square meter which will equate to 171,649 woman/man - days of job creation over the 20 years life time of SWHs.

An eight-year SWHs implementation schedule has been proposed for hotels, hospitals and buildings in Addis Ababa covering: awareness creation; development of standard and regulation, training manual, training of installers; Implementation of PVoC, building mandates and Utility mandates, financing and financial incentives; and replacement of instant, stand-alone and centralized EWHs at all premises by cascaded collector or centralized SWH. It is proposed that Financing of the SWHs implementation could be based on upfront capital incentives at the beginning and followed by performance-based financing with revolving fund business model along with Partial Credit Guarantee (PCG) at the early stage. After maturing of this financing model, the Energy performance contracts -shared and guaranteed saving models (ESCOs) may be introduced without the revolving fund and PCG mechanisms. One mechanism for example could be the EEU can bear the upfront cost of the purchase and installation of SWH, retaining ownership of the systems, while charging end users a fixed monthly fee lower than the cost incurred if an EWH device was used.

The existing SWHs market is quite low, unregulated, and there is a strong need for the proper regulatory framework, financing and awareness creation for the implementation of SWHs at the premises in the city.

11.2. Recommendation

The final delivery of the SWHs implementation should be a SWH market transformation initiative combining the measures that will address both the barriers and the placement of appropriate and supportive policy and regulatory environment that will forge market expansion and capacity development. Recommendations listed below are needed for the uptake of SWHs and stimulation of the market in the city.

a) A holistic regulatory framework governing the SWH industry shall be developed inclusive of all activities that support the industry covering the specification and requirements for design, installation, testing, commissioning, operation and maintenance, and trouble shooting and customer service.
b) Building mandates for SWHs shall be applied on newly constructed or renovated hotels, hospitals, apartment buildings built by real estates, condominium buildings for middle- and high-income owners like the 40/60 (Saving/Bank loan) type. However, the mandates presuppose that the premises shall have adequate water supply before compliance.
c) The EEU/EEP and private utility companies entering the electricity supply and distribution market in the country shall be required to invest nominal amount of their net revenue in electricity conservation programs such as SWHs for commercial premises. These mandates shall extend to institutional and industrial buildings in the future.
d) SWH product standard shall be developed jointly by the EEA and ESA.
e) The Compulsory Ethiopian Standard CES161, Plumbing Services of Buildings, and CES 162, Electric Work, 2015, shall be updated to accommodate SWHs design, specification and installation requirements as per the building mandates.
f) There shall be awareness creation programs on SWHs to Hotels, Hospitals, guest houses, shower houses, building developers, and other potential users and implementers in the city. Demonstration centers shall be established for such purposes. Information dissemination platforms for consumers and a free consultation on available SWH systems and technology shall be available including web-based means.
g) Training manual for SWHs design and installation shall be developed. Technical training on SWHs shall be delivered to technicians. The syllabus shall be prepared and training delivered by professionals in the field of SWHs design and installation.

h) An occupational standard and competency assessment certification shall be developed to certify the engineers and technicians working on the design, installation and maintenance of SWHs.

i) To avoid the importation of substandard products, import of SWHs shall be subjected to PVoC. The establishment of testing capability shall be planned for the future.

j) Government support is important for expansion of SWHs. Incentives and financing mechanisms have to be available for local production, assembly and acquisition of SWHs.

k) SWHs equipment under the HS code 84191910 shall be registered separately from other solar products.

l) Heat Pump, Solar Thermal and Heat pump hybrid, PVT water heaters, PV assisted Heat Pump and building integrated solar thermal etc., are optimized Renewable energy technology-based equipment and their use shall be encouraged by exempting duty tax on import similar to that of SWHs. Future water heating regulations shall include the use of these equipment.

m) In view of building national capacity in the sector, local manufacturing of all the renewable energy water heating systems has to be supported and encouraged.

n) It is recommended that SWHs implementation extended to residential buildings and factories in the city and country wide where there would be a big potential of electric energy saving.

o) In order to assess the saving from SWH installations, separate electric meters shall be installed at auxiliary electric heaters of storage water tanks of SWH users.

REFERENCE

Abebayehu, A. and Demiss, A. (1992) 'The Viability Of Solar Energy For Domestic', Zede Journal, 9.

Accor Hotels (2016) 'HVAC - Plumbing Plumbing Addendum Heating Mode - Design Temperature In Premises Technical Specifications Addendum Cooling Mode - Design Temperature In Premises'. Accor Hotels, pp. 1–4.

AEE-INTEC (2009) 'Thermal Use of Solar Energy', SOLTRAIN, pp. 119–136.

Ahmed, E. (2016) Design , Simulation and Experimental Analysis of a Solar Absorption Cooling System in Khartoum. University of Khartoum.

Alemnew, E. (2018) 'Analysis of Status, Potential and Economic Significance of Solar Water Heating System in Ethiopia', Renewable Energy.

Anees, M. et al. (2018) 'Solar Water Heating for Aquaculture Applications in Cold Climates: A Case Study of Finland', in The Role ofExergy in Energy and the Environment, Green Energy and Technology. Springer International Publishing.

Assaye, R. et al. (2017) 'Geo-Spatial Approach for Urban Green Space and Environmental Quality Assessment: A Case Study in Addis Ababa City', Journal of Geographic Information System, 09(02), pp. 191–206. doi: 10.4236/jgis.2017.92012.

Berrill, T. and Blair, A. (2007) Solar Water Heater Training Course, Installer and User Guide. SEIAA.

Carlisle, N. et al. (1992) The strategic use of renewables to achieve demand-side management impact. Available at: http://www.osti.gov/energycitations/product.biblio.jsp?osti_id= 10161658.

CDM-PDD (2012) Ethiopia-Kenya power Interconnection.

Chèze, D. et al. (2020) Heating and Cooling Technology Assessment Report, THERMOSS. Available at: https://online210.psych.wisc.edu/wp-content/uploads/PSY-210_Unit_Materials /PSY-210_Unit01_Materials/Frost_Blog_2020.pdf%0Ahttps://www.economist.com/special-report/2020/02/06/china-is-making-substantial-investment-in-ports-and-pipelines-worldwide%0A

CSA (2013) Population Projections for Ethiopia (2007-2037), Central Statistical Agency Population, Ethiopia.

Deevela, N. R. and Kandpal, T. C. (2021) 'Solar Energy for Meeting Service Hot Water Demand in Hotels: Potential and Economic Feasibility in India', in Proceedings of the 7th International Conference on Advances in Energy Research. Springer Proceedings in Energy, pp. 55–69. Available at: https://link.springer.com/book/10.1007%2F978-981-15-5955-6.

Duffie, J. A., Beckman, W. A. and Blair, N. (2020) Solar Engineering of Thermal Processes, Photovoltaics and Wind, John Wiley & Sons, Inc. doi: 10.1002/9781119540328.

EED (2017) Study of the Solar Water Heating Industry in Kenya. Available at: https://www.solarthermalworld.org/sites/default/files/news/file/2018-10-31/study_of_the_swh_industry_-_kenya_high_res_final.pdf.

EPA (2016) SOLAR HOT WATER SYSTEM SPECIFICATIONS AND REQUIREMENTS, EPA. Available at: https://www.epa.gov/sites/production/files/2016-01/documents/webinar_20140416_systemspecifications.pdf.

Ethiopian Economics Association (2021) State of the Ethiopian Economy: Economic Development, Population Dynamics, and Welfare, Discrete & Continuous Dynamical Systems - B. doi: 10.3934/dcdsb.2021178.

Faninger, G. (2010) 'The Potential of Solar Heat in the Future Energy System', pp. 1–20. Available at: https://www.aee-intec.at/0uploads/dateien868.pdf.

GIZ and RCREEE (2017) 'Technical Manual on Solar PV and Solar Thermal Applications for the Hotel Sector in the MENA Region'.

Global petrol prices (2020) Electricity prices. Available at: https://www.globalpetrolprices.com/electricity_prices/.

GTZ and EEA (2010) 'Symposium on Solar Water Heating'.

Hiller, C. and Russell, J. (2017) 'Hot Water Use in Hotels: Part 5--Updated Hotel Hot Water System Design Techniques'. ASHRAE Transactions.

Hohne, P. A., Kusakana, K. and Numbi, B. P. (2019) 'A review of water heating technologies: An application to the South African context', Energy Reports, 5, pp. 1–19. doi: 10.1016/j.egyr.2018.10.013.

Hudon, K. (2013) 'Solar Energy - Water Heating', in Future Energy: Improved, Sustainable and Clean Options for our Planet. Second, pp. 433–451. doi: 10.1016/B978-0-08-099424-6.00020-X.

HVC (2016) African Hotel Valuation Index.

IEA-ETSAP (2015) Solar Heating and Cooling for Residential Applications.

IEA-SHC (2019) Global Market Development and Trends in 2018, Solar Heat Worldwide Report. IEA-SHC. Available at: http://www.iea-shc.org/solar-heat-worldwide.

IEA-SHC (2020) Solar Heat Worldwide, Energy. IEA-SHC.

IEA-SHC (2021) Solar Heat Worldwide. IEA-SHC.

IEA (2014) 'Africa Energy Outlook'.

IRENA (2015) Solar Heating and Cooling for Residential Applications: Technology Brief. Available at: www.etsap.org-www.irena.org.

IRENA (2021) Renewable Energy Benefits: Leveraging Local Capacity for Solar Water Heaters. Abu Dhabi.

IRENA, OECD and IEA (2020) Renewable Energy Policies in a Time of Transition Heating and Cooling.

Li, W., Rubin, T. H. and Onyina, P. A. (2013) 'Comparing solar water heater popularization policies in China, Israel and Australia: The roles of governments in adopting green innovations', Sustainable Development, 21(3), pp. 160–170. doi: 10.1002/sd.1547.

Luo, X. et al. (2018) 'Solar water heating system', in Handbook of Energy Systems in Green Buildings. Second. Academic Press: Elsevier, pp. 145–194. doi: 10.1007/978-3-662-49120-1_32.

MoWIE (2013) 'Updated Rapid Assessment and Gap Analysis on Sustainable Energy for All (SE4All): The UN Secretary General Initiative', (December), p. 31. Available at: https://www.se4all-africa.org/fileadmin/uploads/se4all/Documents/Country_RAGAs/MWH_-_Updated-Rapid_Gap_Analysis.pdf.

MoWIE (2019) 'National Electrification Program 2 . 0: Integrated planning for universal access. Addis Abeba, Ethiopia.'

Nair, S. et al. (2018) 'End Use Level Water and Energy Interactions: A Large Non-Residential Building Case Study'. doi: 10.3390/w10060810.

National Bank of Ethiopia (2021) 'National Bank of Ethiopia Annual Report', NBE. Available at: www.nbe.gov.et.

Natural Resources Canada (2004) Solar Water Heating Project Analysis, Minister of Natural Resources Canada.

Natural Resources Canada (2005) Clean Energy Project Analysis, Development.

NITA (2017) Solar Water Heating Training Manual for the Kenyan Industry. Available at: https://www.undp.org/content/dam/kenya/docs/energy_and_environment/2018/Solar Water Heating Manual _Final.pdf.

Pérez, F. J. D. et al. (2019) 'Consumption and emissions analysis in domestic hot water hotels. Case study: Canary Islands', Sustainability (Switzerland), 11(3), pp. 1–17. doi: 10.3390/su11030599.

Sarbu, I. and Adam, M. (2011) 'Applications of solar energy for domestic hot–water and buildings heating/cooling', International Journal of Energy, 5(2).

Singh, S. et al. (2020) 'Technical , financial , and environmental feasibility of solar water heater for residential , commercial , and industrial application : A theoretical approach', Materials Science for Energy Technologies, 3, pp. 648–671. doi: 10.1016/j.mset.2020.07.001.

Tamerat, D. and Nasir, A. (2020) 'Technical and Lifetime Cost Benefit Analysis of RET Solar Water Heater a Way to Substitute Electrical Water Heaters for Domestic use: A Case Study in Addis Ababa-Ethiopia', International Journal of Engineering Research & Technology, 09(07). doi: 10.17577/ijertv9is070583.

Tangwe, S. and Kusakana, K. (2021) 'Evaluation of the coefficient of performance of an air source heat pump unit and an air to water heat pump', Journal of Energy in Southern Africa, 32(1), pp. 27–40. doi: 10.17159/2413-3051/2021/v32i1a7935.

Teklemariam, E. A. and Shen, Z. (2020) 'Determining transit nodes for potential transit-oriented development: Along the LRT corridor in Addis Ababa, Ethiopia', Frontiers of Architectural Research, 9(3), pp. 606–622. doi: 10.1016/j.foar.2020.03.005.

UNEP-GSWHP (2015) 'Domestic water heaters for multi-family houses: Fact Sheet'.

UNEP (2015) 'Solar Water Heating a Strategic Planning Guide for Cities in Developing'.

Weiss, W. and Rommel, M. (2008) Process Heat Collectors: State of the Art Within Task 33/IV. AEE INTEC, Gleisdorg.

Annex 1: **Data Collection Sheet for Importers/Distributors/Assemblers/Installers/Maintenance service providers**

Part 1: General Data

1. Name of the establishment: ________________________________ Year of establishment: ___________
2. Address: City_____________, Woreda__________, House No.___________, Tel. No________________
3. Contact person. _______________________________. Tel _____________________
4. (a) How did you get into SWH business? (b) What else does your company manufacture/import/install? (c) What other types and components of solar systems do you manufacture/import/assemble/install?

(a) (b) (c)

5. (a) How long have you been manufacturing/importing/assembling/installing SWH systems? (b)Who/where was the target market?

a) b)

6. How feasible/sustainable do you feel is the business of manufacturing/importing/assembling/installing SWH systems?

7. (a) What type of SWH technologies and components (Flat plate, Evacuated tube, Direct/Indirect, Passive /Active, Storage, heat exchanger, backup heater) does your company manufacture/import/assemble/install? (b) Where are they best suited regarding hot water load/end use, climate, building type,) - residential only, and/or commercial premises (hotels, commercial building, hospitals etc.)

1. Technologies
   i) Technology 1

   ii) Technology 2

   iii) Technology 3

   iv) Technology 4

   v) Technology 5

   vi) Technology 6

2. Where are they best suited?

8. What is the typical rated performance of the SWH system technologies your company provide?

Technology	Rated Performance
Technology 1	
Technology 2	
Technology 3	
Technology 4	
Technology 5	
Technology 6	

9. Country of origin of SWH systems in descending order for quantity of SWH manufactured/imported/assembled/installed.

10. Quantity of SWH manufactured/imported/assembled/installed in the last five years (2015-2020GC) in ascending order by SWH capacity and market share.

No.	SWH Technology	Quantity manufactured/imported/assembled/installed						Market Share by Technology (%)
		Capacity 1 ( )	Market Share (%)	Capacity 2 ( )	Market Share (%)	Capacity 3 ( )	Market Share (%)	
1	Technology 1							
2	Technology 2							
3	Technology 3							
4	Technology 4							
5	Technology 5							
6	Technology 6							

11. Price of SWH system by technology and capacity. Please attach price catalog, if any.

No.	SWH Technology	Price of SWH by Capacity (Birr)			Average annual O & M cost of SWH (Birr)
		Capacity 1	Capacity 2	Capacity 3	
1	Technology 1				
2	Technology 2				
3	Technology 3				
4	Technology 4				
5	Technology 5				
6	Technology 6				

12. (a) Which solar water heating technology is found suitable and appropriate for Addis Ababa? (b) Why?

(a)

(b)

13. Could you please provide the percentage of share of demand for SWH systems from residential, commercial and Industrial end users?

Tariff Group		**Percentage demand for SWH systems (%)**
Residential end-users		
Commercial end-users	Hotels	
	Hospitals	
	Commercial buildings	
	Others	
Industry end-users		
Total		**100%**

14. For which reason do you think that the above percentage demand occurs?

15. (a) What are the categories of end-users who are interested in installing SWH system? (hotels star, size of the end-users, types of the end-users). (b) What is their main motivation for acquiring SWH system installations?

a) Categories
   i) Hotels in Star rating or number of rooms:

   ii) Hospitals in capacity:

   iii) Commercial buildings in size and type:

b) Motivations

16. a) How many staffs are currently employed at your company? Please list their job title and roles. In table

No.	Job title	No of staffs	Roles	Educational level	SWH training

17. How many technical employees are directly involved in pre-installation, installation and post-installation phase in a typical SWH system?

18. What are the pre-installation processes/procedures that have typically been followed? As part of this question, specific attention should be given to factors that include, but are not limited to: (a) demand assessment (hot water requirement per person/ per service) including amount of current energy source being used for water heating, (b) resource assessment (solar energy potential, shading etc.), (c) orientation (slope/tilt angle, azimuth etc.), (d) structural integrity and (e) orientation of premises. Please attach the procedures document, checklist, if any.

(a)

(b)

(c)

(d)

(e)

19. What are: (a) the procedures and (b) the standards /compliance requirements followed is the design and installation process to test for conformance to some standard, and (c) Commissioning works. Please attach checklists and detail test protocols/ ISO standard, if any.

a)   b)   c)

20. What are the activities being accomplished in post-installation phase, including: (a) SWH system performance, (b)maintenance of the system periodic or scheduled, (c) Warranty and (d) related customer support? Please attach the procedures document, checklist, if any.

a)   b)   c)   (d)

21. What are the considerations you take for the provision of SWH systems regarding (a) structural integrity of premises, (b) Cardinal direction(orientation) of premises, (c) quality of and access to water, (d) reduction in electricity consumption and (e) reduction in carbon emission?

(a)   (b)   (c)   (d)   (e)

22. (a) At which specific location (roof top or ground level) have you installed SWH systems for Hotels, Hospitals and Commercial buildings in Addis Ababa? Percentage of Roof top or Ground level installations, and (b) why?

   a) Roof top = ______% and Ground level = ____%

   b) Why?

23. How do you evaluate the suitability of centralized and decentralized solar water heating system for hotels, hospitals and other commercial buildings in Addis Ababa?

(a) Centralized

(b) Decentralized

Part 2: Data on the adoption of SWH systems

1. Please rate your level of agreement with the following statements regarding solar water heating systems, with 1 being strongly disagree and 5 being strongly agree.

	Strongly disagree 1	Somewhat disagree 2	Neutral 3	Somewhat agree 4	Strongly agree 5
If there is a higher rate of adoption of SWHs in the city, there would be a positive environmental impact	☐	☐	☐	☐	☐
If there were a higher rate of adoption of SWHs in the city, there would be a positive economic impact	☐	☐	☐	☐	☐
SWHs are not cost effective compared to electric water heaters	☐	☐	☐	☐	☐
I am well informed about SWHs	☐	☐	☐	☐	☐

2. Please rate your level of agreement with the following statements, with 1 being strongly disagree and 5 being strongly agree.

	Strongly disagree 1	Somewhat disagree 2	Neutral 3	Somewhat agree 4	Strongly agree 5
It's easy to measure the economic impact of solar water heating	☐	☐	☐	☐	☐
There should be a higher level of involvement by the utilities and Energy authorities in solar water heating programs	☐	☐	☐	☐	☐

3. Assume a hypothetical scenario where every hotel, hospital and other buildings in the city that consumes hot water installs a solar water heating system. Please indicate whether you think there would be a positive or a negative impact on the following factors.

	Positive impact	Negative impact	Neither
The environment	☐	☐	☐
Base load demand for electricity and natural gas	☐	☐	☐
Utility company profits	☐	☐	☐
Customer satisfaction	☐	☐	☐
Public image of SWHs	☐	☐	☐
Job growth	☐	☐	☐
SWHs development	☐	☐	☐

4. Please rate your level of agreement with the following statements, with 1 being strongly disagree and 5 being strongly agree.

	Strongly disagree 1	Somewhat disagree 2	Neutral 3	Somewhat agree 4	Strongly agree 5
A consumer who purchases a solar PV system is significantly less likely to purchase a solar water heating system	☐	☐	☐	☐	☐

There is adequate financial incentive currently in place to promote SWH technology in commercial and public sector.	☐	☐	☐	☐	☐
Tax credits are an effective means of incentivizing the adoption of SWH	☐	☐	☐	☐	☐
Competitive loans are an effective means of incentivizing the adoption of SWH	☐	☐	☐	☐	☐
Leasing a SWH system through a third party, such as a utility company or a financial institution is an effective means of incentivizing the adoption of SWH	☐	☐	☐	☐	☐
Rebate financing are an effective means of incentivizing the adoption of SWH	☐	☐	☐	☐	☐
The benefits associated with SWH are well understood by the public	☐	☐	☐	☐	☐
The costs associated with SWH are well understood by the public	☐	☐	☐	☐	☐
Existing loan programs from the government or other financial institution offer competitive rates and terms on SWHs	☐	☐	☐	☐	☐

5. The following series of questions concern specific barriers to adoption that are faced by solar water heating in Addis Ababa. These barriers are divided into six categories:
   a) Social/cultural/behavioral barriers
   b) Economic/ financial barriers
   c) Technical barriers
   d) Institutional/ regulatory barriers
   e) Market distortion/ failure barriers
   f) Policy barriers

Please rate each barrier based on their importance for the adoption of SWH in hotels, hospitals and other building in Addis Ababa. Where 1 indicates the "least important" (removing barrier would have the least impact on the adoption of solar water heating) and 5 indicates the "most important" (removing barrier would have maximum impact on adoption of solar water heating). If you can think of any other social, cultural, or behavioral barriers, please list and rate them in the space provided.

a) Social/cultural/behavioral barriers

	Least important 1	2	3	4	Most important 5
Consumers are not familiar with solar water heating	☐	☐	☐	☐	☐
Consumer are not aware of incentives for solar water heating	☐	☐	☐	☐	☐
Consumer prefer conventional water heating systems (such as electricity or natural gas)	☐	☐	☐	☐	☐
Consumer prefer solar PV technologies that produce electricity over Solar thermal (heat) energy sources	☐	☐	☐	☐	☐
Other (please specify)	☐	☐	☐	☐	☐

	Least important 1	2	3	4	Most important 5
Other (please specify)	☐	☐	☐	☐	☐
Other (please specify)	☐	☐	☐	☐	☐

b) Economic/ financial barriers

	Least important 1	2	3	4	Most important 5
The initial cost of a SWH system is too high	☐	☐	☐	☐	☐
It takes too long to pay back the cost of the system	☐	☐	☐	☐	☐
There is a lack of competitive financing options (interest and term length)	☐	☐	☐	☐	☐
Incentives for SWH are not large enough	☐	☐	☐	☐	☐
Other (please specify)	☐	☐	☐	☐	☐
Other (please specify)	☐	☐	☐	☐	☐
Other (please specify)	☐	☐	☐	☐	☐

c) Technical barriers

	Least important 1	2	3	4	Most important 5
Solar water heating installation and maintenance is too complicated/ expensive	☐	☐	☐	☐	☐
Existing products are unreliable	☐	☐	☐	☐	☐
Physical space limitation on potential sites	☐	☐	☐	☐	☐
Other (please specify)	☐	☐	☐	☐	☐
Other (please specify)	☐	☐	☐	☐	☐
Other (please specify)	☐	☐	☐	☐	☐

d) Institutional/ regulatory barriers

	Least important 1	2	3	4	Most important 5
Lack of institutions to disseminate information/ raise awareness about solar water heating systems	☐	☐	☐	☐	☐
Lack of involvement by key stakeholders when making decisions	☐	☐	☐	☐	☐
Regulatory framework is too constricting	☐	☐	☐	☐	☐
Other (please specify)	☐	☐	☐	☐	☐
Other (please specify)	☐	☐	☐	☐	☐
Other (please specify)	☐	☐	☐	☐	☐

e) Market distortion/ failure barriers

	Least important 1	2	3	4	Most important 5
Favor (such as larger subsides) given to other renewable energy technologies	☐	☐	☐	☐	☐
Lack of competition in market for solar water heating products	☐	☐	☐	☐	☐
Too much competition in the market for solar water heating products	☐	☐	☐	☐	☐
Conventional energy sources (fossil fuels) are cheaper	☐	☐	☐	☐	☐
Other (please specify)	☐	☐	☐	☐	☐
Other (please specify)	☐	☐	☐	☐	☐
Other (please specify)	☐	☐	☐	☐	☐

f) Policy barriers

	Least important 1	2	3	4	Most important 5
Lack of incentives	☐	☐	☐	☐	☐
Consumers unable to take advantage of loan and seed money due to non-implementation of policies	☐	☐	☐	☐	☐
Incentive of policies to promote awareness or disseminate information	☐	☐	☐	☐	☐
Competing technologies (such as Solar PV) receive greater share of incentives as compared to solar thermal	☐	☐	☐	☐	☐
Other (please specify)	☐	☐	☐	☐	☐
Other (please specify)	☐	☐	☐	☐	☐
Other (please specify)	☐	☐	☐	☐	☐

g) Summary of barriers

	Least important 1	2	3	4	Most important 5
Social/ cultural/ behavioral	☐	☐	☐	☐	☐
Economic/ financial	☐	☐	☐	☐	☐
Technical	☐	☐	☐	☐	☐
Institutional/ regulatory	☐	☐	☐	☐	☐
Market distortion/ failure	☐	☐	☐	☐	☐

6. Do you think installation of SWH systems shall be mandatory for Hotels, Hospitals, and other commercial buildings in Addis Ababa?

Yes	No	Indifferent
☐	☐	☐

7. Why?

If you would like to offer any additional information regarding your perspective on barriers to the adoption of solar water heating in Hotels, Hospitals and other buildings in Addis Ababa, or if you have any additional information regarding your perspective on measures for overcoming these barriers, please indicate them in the space below.

Thank you so much for your participation in this questionnaire, it is greatly valued.

Annex 2: **<u>Data collection sheet for hotels/hospitals/other buildings (for installed SWH)</u>**

1.	**Establishment's Information**		
a.	Facility Name:	Facility location:	
b.	Contact person:	Address/Phone:	
c.	Available land area/SWH installation area:		
2.	**Capacity**		
a.	Number of patient-beds		
b.	Average bed occupancy (%)		
3.	**Average daily hot water requirement**		
a.	Bathroom (Yes/No)	Liters:	Temp (ºC):
b.	Kitchen (Yes/No)	Liters:	Temp (ºC):
c.	Laundry (Yes/No)	Liters:	Temp (ºC):
d.	Childbirth rooms (Yes/No)	Liters:	Temp (ºC):
e.	Other (specify)	Liters:	Temp (ºC):
4.	**SWH Installation**		
a.	Year of building construction		
b.	Year of Installation		
5.	**Type of SWH**		
a.	Evacuated Tube (Y/N)		
b.	Flat Plate (Y/N)	Glazed: ☐	Unglazed: ☐
c.	Fixed/ tracking		
d.	Slope:	Azimuth:	
e.	Gross area per solar collector (m^2)		
f.	Storage (Central/decentralized)		
6.	**SWH capacity**		
a.	Capacity in liter/day		
b.	Number of tubes for evacuated type		
c.	Number of collector module		
d.	Number of panels for flat plate type		
e.	Capacity in square meters for flat plate type		
f.	Storage capacity		
7.	**Back-up technology and fuel consumption for water heating**		
a.	Electric (kWh)		
b.	Fossil fuel (Litter)		
c.	Biomass (kg)		
d.	Other 1		
e.	Other 2		

8. Type and total number of electric water boiler (if any)					
	Capacity (Litters)	Power (W)	Type (e.g., instant heater, boiler etc.)	Quantity	Usage (hours/day)
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

9. SWH Supplier Details		
a.	Manufacturer	
b.	Dealer	
10. SWH Cost in Birr		
a.	System cost	
b.	Installation cost	
c.	Extra piping/plumbing cost	
d.	Total Cost (A+B+C)	
e.	Subsidy	
f.	Net cost (D-E)	
11. Net provision of SWH supply points		
a.	Bathroom (Yes/No)	
b.	Kitchen (Yes/No)	
c.	Laundry (Yes/No)	
d.	Childbirth room (Yes/No)	
e.	Other (specify)	
12. Usage Pattern		
a.	Number of days/years on which SWH water is used	
b.	Months of the year during which SWH water is used	
13. SWH Financing		
a.	Bank Loan (Y/N, amount, in Birr)	
b.	Self-Finance (Y/N, amount, in Birr)	
c.	Dealer Finance (Y/N, amount, in Birr)	
d.	Interest on bank loan (%)	
e.	Interest on dealer finance (%)	

14.	**SWH Repair and Maintenance**	
a.	Annual contract (Y/N)	
b.	Average annual expenditure on R&M (Birr)	
15.	**Recourse to other (than SWH) water-heating devices in a year (no of days/year)**	
a.	Electrical backup with SWH (Y/N)	
b.	Electric geyser (Y/N)	
c.	Gas geyser (Y/N)	
d.	Immersion Rod (Y/N)	
e.	LPG Stove (Y/N)	
f.	Other (Y/N)	
16.	**Main reasons for SWH installation**	
a.	Cost saving	
b.	Subsidy	
c.	Load shedding/shortage of electricity	
d.	Environmental concerns	
e.	Other (specify)	
17.	**Satisfaction with SWH**	
a.	Fully satisfied	
b.	Partial satisfied	
c.	Not satisfied	
18.	**Describe aspects of SWH with which you are satisfied or dissatisfied (1=satisfied, 2= so-so, 3= dissatisfied)**	
a.	Cost of hot water through SWH	
b.	Meeting hot water requirement	
c.	Maintenance requirement of SWH	
d.	After sale service for SWH	
e.	Structural integrity	
f.	Other (specify)	
g.	Other (specify)	
19.	**Other SWH associated benefits availed of**	
a.	Electricity rebate (Y/N, Amount in Birr per month)	
b.	Municipal property tax rebate (Y/N, Amount in Birr per year)	
c.	How did you go about selecting SWH supplier? Describe all you can recall	
d.	Details of problems, if any, while installing SWH. Share fully	

e.	How did you arrive at the SWH capacity?
f.	Details of problems, if any, while using SWH
g.	Describe aspects of SWH with which you are satisfied
h.	Describe aspects of SWH with which you are dissatisfied
i.	Explain how you calculate cost and benefit of SWH. Pl. use number and explain
j.	Comment/suggestion

Annex 3: Data collection sheet for hotels/ hospital/other buildings (SWH non-user)

Part 1: General Data

1.	**Establishment's Information**		
d.	Facility Name:	Facility location:	
e.	Contact person:	Address/Phone:	
f.	Available installation area:		
2.	**Capacity**		
c.	No of rooms		
d.	Average room occupancy (%)		
e.	Operating hours per day		
3.	**Average daily hot water requirement**		
f.	Rooms (Yes/No)	Liters:	Temp (ºC):
g.	Kitchen (Yes/No)	Liters:	Temp (ºC):
h.	Laundry (Yes/No)	Liters:	Temp (ºC):
i.	Swimming Pool (Yes/No)	Liters:	Temp (ºC):
j.	Other (specify)	Liters:	Temp (ºC):
k.	Average daily hot water required by the establishment	Liters:	Temp (ºC):
4.	**Present water heating arrangement**		
a.	Electric boiler (Distributed) (Yes/No)	Capacity:	
b.	Electric boiler (Centralized) (Yes/No)	Capacity:	
c.	LPG boiler (Yes/No)	Capacity:	
d.	Liquid fuel boiler/ hot water generator	Capacity:	
e.	Biomass boiler/ hot water generator (Yes/No)	Capacity:	

5. Type and total number of electric water boiler (if any)

	Capacity (Litters)	Power (W)	Type (e.g., instant heater, boiler etc.)	Quantity	Usage (hours/day)

Part 2: Data on the adoption of SWH systems

1. Do you know how much money your establishment is using water heating energy costs in a month?

   Yes ☐ No ☐

2. Have you heard anything solar water heaters?

   Yes ☐ No ☐

3. From what sources have you heard anything about solar water heaters? (Check all that are apply)

Importer/Installer/Assembler	☐
Government bodies	☐
Have seen them on similar establishments	☐
Advertising	☐
Books/magazines	☐
Other	☐
Don’t know	☐

4. Have You Seen SWH in an Establishment Similar as Yours?

   Yes ☐ No ☐

5. What do you think the advantages of using solar energy to help heat the water in your establishment would be? What other advantages would there be? (Check all that are apply)

Save money	☐
Use less fuel/electricity	☐
Better for the environment	☐
Tax benefits	☐
More hot water capacity	☐
None	☐
Don’t know	☐
Other (specify)	☐

6. What do you think the disadvantages of using solar energy to help heat the water in your establishment would be? What other disadvantages would there be? (Check all that are apply)

Units do not look on establishment/appearance	☐
Too much maintenance	☐
Not as much hot water capacity	☐
Takes longer to get hot water	☐
Too expensive to install	☐
Not save any/ enough money	☐
None	☐
Don’t know	☐

7. Have You Ever Considered SWH for Your premises?

Yes (Ask Q.7)	No (Skip to Q.8)
☐	☐

8. Why did you decide against purchasing a solar water heating unit?

9. Why did you not consider a solar water heater when you establish this facility? (Check all that are apply)

	Check here for Q.6 (No)
Just didn’t think about it	☐
Too expensive to purchase and install	☐
Not attractive/ unsightly	☐
Consultant/contractor never mentioned it	☐
Consultant/contractor recommended against it	☐
Too difficult to install	☐
Not save any/ enough money	☐
Do not know enough about it	☐
Other (specify)	☐

10. Which of the following statements is most accurate? If my consultant/ contractor had mentioned that solar water heaters were available… (Read list and check one)

	Check here for Q.6 (No**)**
I would have seriously considered installing a solar water heater, ...	☐
I would have wanted to learn more about solar water heating, or...........	☐
I would probably not have considered installing a solar water heater	☐

11. If a solar water heater had been voluntary standard in your premises, how likely would you be to have the system installed? (Read list and check one)

Extremely likely ……	☐
Somewhat likely	☐
Might or might not	☐
Somewhat unlikely	☐
Extremely unlikely ……	☐

12. Why is that?

13. If you knew that the savings on your monthly utility bill would completely offset the monthly installment incurred for a solar water heater, how likely would you be to have the system installed? (Read list and check one)

Extremely likely ……	☐
Somewhat likely	☐
Might or might not	☐
Somewhat unlikely	☐
Extremely unlikely ……	☐

14. How much do you think that a typical solar water heating system costs, fully installed?

Amount in Birr ________________________________

Not sure/ don’t know ☐

15. Using a scale of 1 to 5, where a 1 means "not at all important" and a 5 means "very important," how important would each of the following things be in your decision to install a solar water heating system for your premises if you had been interested in one? (Read each item, and check one box for each)

	Not important 1	2	3	4	Very important 5
The price of the system fully installed	☐	☐	☐	☐	☐
The amount of maintenance required	☐	☐	☐	☐	☐
Helping to clean the air	☐	☐	☐	☐	☐
A consultant/contractor recommendation	☐	☐	☐	☐	☐
Receiving tax benefits	☐	☐	☐	☐	☐
The size and appearance of the system	☐	☐	☐	☐	☐
Money saved on water heating bills each month	☐	☐	☐	☐	☐
The hot water delivery capacity of the system	☐	☐	☐	☐	☐
Availability of loan	☐	☐	☐	☐	☐
The brand name on the equipment	☐	☐	☐	☐	☐
The type of warranty provided	☐	☐	☐	☐	☐
Increased value of the premises	☐	☐	☐	☐	☐

16. Now let's use a scale of 1 to 5 again, 1 means "completely disagree" and 5 means "completely agree", how much do you agree or disagree with each of the following statements? (Read each item, and check one box for each)

	Not important 1	2	3	4	Very important 5
A solar water heating unit would make economic sense	☐	☐	☐	☐	☐
A solar water heating unit would require very little maintenance	☐	☐	☐	☐	☐
I like the idea of using clean energy and helping the environment	☐	☐	☐	☐	☐
The savings on my monthly energy bills would outweigh the cost of purchasing the solar unit	☐	☐	☐	☐	☐
Solar water heating systems should be offered as standard equipment on all new premises being built	☐	☐	☐	☐	☐