The Importance of Using Solar Water Heater as an Alternative Eco-Friendly Technology in Global Market: Some Lessons of Experiences for Bangladesh Economy

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Abstract

This research paper introduces alternative heating technology for Bangladesh in the form of solar water heater against conventional heating on the face of increasing demand for heating water. Solar water heater is that renewable technology which simply uses free sunlight to heat water. The main benefit of using this technology is that it is completely pollution free, unlike other non-renewable sources. However, from an economic point of view, it might not be a short term solution but will be economically viable in the long term. This technology also has the potential to ensure future energy security by diverting the energy load from non-renewable to renewable. This research paper gives a comparative analysis on the use of solar water heaters among different countries and Bangladesh. It also incorporates some useful measures that have attributed to the development of this industry. In this regard, many developed countries such as China, India, South Africa, Brazil, and Barbados along with small country like Tunisia have set up a remarkable example by patronizing this industry. This research paper has analyzed the factors and measures adopted for this technology in those countries and investigated the viability of solar water heating in the perspective of Bangladesh. It also aims to make a contribution to our energy sector by promoting this renewable technology with the lessons learned from those countries.

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1. Introduction

Water heaters have been around for a long time across the developed countries. However, it is becoming common now a day in the developing countries like Bangladesh too. In its early days, it might have been a luxury product, but now water heating accounts for one of the second largest segment of household energy use, after space heating and cooling. The higher energy usage for heating purpose is not only creating pressure on national grid for excess supply of electricity but also affecting electricity price badly. Moreover, traditional heaters such as geysers and boilers are harmful to the environment as this heating process involves burning of fossil fuels and emits greenhouse gas. In this regard, alternative technologies can be used to heat water without harming the environment. One such technology is solar water heating; which simply uses solar power to heat water.

Solar Water Heating (SWH) technology is used in many parts of the world including the China, India, Brazil and the Middle East countries. In fact, access to a low cost solar water heater would provide numerous benefits to households in developing communities. Many households could reduce their fuel costs by eliminating or reducing their need for wood, gas or electricity to heat water. Substituting traditional fuel sources with solar energy would reduce carbon emissions. For example, in Australia, domestic solar water heating systems can produce net greenhouse gas savings in 2.5 to 5 years. Furthermore, reducing biomass consumption would relieve stress on depleted forests.

From an economic point of view, SWH is simply an energy efficient technology which benefits the community in the long run. Generally, residential solar water heater systems cost between $1,500 and $3,500, compared to $150 to $450 for electric and gas heaters (Environment and Energy Study Institute, 2015).With savings in electricity or natural gas, solar water heaters pay

for themselves within four to eight years. And solar water heaters last between 15 and 40 years; the same as conventional systems. So, after that initial payback period is up, energy cost comes down to zero essentially means having free hot water for years to come.

Solar power is an integral and commonly used form of renewable energy which is derived from resources that are naturally regenerative or are practically inexhaustible with minimal environmental impacts. Renewable sources are clean sources of energy to power various things and will be cheaper over the long run. Application of it in the water heating industry is nothing new either, with many developed countries using solar power for water heating since the dawn of the century, however, a developing country like Bangladesh is still lagging behind in adopting it, even with its many advantages. But not all though, for instance, our neighboring country India is far ahead of Bangladesh in adapting to solar power to heat water, and it currently accounts for about 33% of India's primary energy consumptions (Kumar *et al*., 2010). This contrast in use of solar power for heating water between the two neighbouring developing countries needed to be investigated to understand the dynamics of the situation. There are various underlying factors (for example:cost, availability, awareness, environment etc.) which contributed to the low usage of renewable energy such as solar power for water heating in Bangladesh.The main goal of this research paper is to critically analyze these factors and determine the most significant issues which affect the SWH industry of Bangladesh.

Bangladesh being an advantageous position for harnessing solar power can utitilze this energy for water heating and divert the hot water demand from the national grid.In this way,Bangladesh can ensure its energy security by reducing presssure on our national grid.Besides, from an environmental aspect,this technology can also help Bangladesh to combat environmental challenges with minimal environmental impacts. However, even though solar water heating

comes with long term economic and environmental benefits, limited studies have found in the context of developing country like Bangladesh. Due to lack of research in this sector, strong knowledge gap persists in the diffusion of SWH technology. So, realizing the need for promoting this technology and in order to fill the research gap, prospect of using solar power for water heating has been analyzed thoroughly in this research paper. The most important aspect of this research paper is that it made the linkage between environmental benefits and economic viability of solar water heaters which will ensure energy sustainability in the future. The research paper overviewed the viability of solar water heaters in Bangladesh by reviewing some case studies from different countries and their implementation strategies. It also aims to make long-term contribution to the energy sector in Bangladesh by suggesting some policy recommendations regarding the benefits of SWH as an alternative to conventional sources.

For this research,case studies from different countries were used as one of the most important methods to critically analyze the viability of SWH technology in Bangladesh.Case studies are an important tool for research as it often tends to critically examine situations that may not be a part of other empirical research methods. In this case, if the prospects of SWH in Bangladesh can be identified, it would be helpful for future references and can also be used to propose efficient policies.The potential benefits (which may include economic or environmental benefits of alternative heating) need to be discovered so that it can be utilized to compare the costs and benefits.This would further assist the policymakers to estimate the net social gains from using this technology.

The rest of the research paper has been organized as follows.Chapter 2 contains the literature review where a detailed analysis of other relevant research work on similar topics, conducted in the past, has been briefly analyzed. Chapter 3 examines different case studies regarding the use

of solar water heaters. Chapter 4 examines the lessons learned from different countries. This is followed by the state of solar water heating market in Bangladesh in chapter 5. Then chapter 6 covers the recommendations of the policy followed by conclusions in chapter 7.

2.Literature Review

The potential of SWH was observed on several occasions, especially in the context of developed countries. For example, Gadgil (2007), West (2016) and Brown (2011) confirmed that SWH can be beneficial for the global environment as it can reduce pressure on the national grid and mitigate environmental change. Milton (2006) suggested some policy recommendations for SWH as an effective tool for sustainable development. Saxena and Srivastava (2012) and Brown (2011) analyzed the implementation of the solar water heater from a global perspective. Ramlow (2007), Kalogirou (2012), Özdemir *et al.* (2012) showed a positive relation between SWH and environmental efficiency. However, in the context of Bangladesh little research has been conducted so far especially in the case of households. Among others, Khan and Islam (2011), Arefin *et al*. (2011) confirmed that SWH system is more cost effective than conventional electric water heater such as geysers. This research paper makes a distinction by critically examining the crucial factors that attribute to the development of SWH and gives an analytical viewpoint on the viability of SWH in Bangladesh.

2.1 Definition and Classification of Solar Water Heating System

SWH is the conversion of sunlight into renewable energy for water heating using a solar thermal collector. 'Solar Water Heating' systems, or 'Solar Thermal' systems, use free heat from the sun to warm domestic hot water. There are two main types of solar water heating systems: active and passive. In an active solar water heating system, a collector that is installed on top of the roof collects solar energy. The collector is usually a box or a tube that contains air or liquid such as water or anti-freeze. As the collector collects solar energy, the medium, which is the air or the liquid, gets heated up. This heat is transferred to the different parts of the building using a pump and a venting mechanism. Active solar water heating systems are somewhat more reliable than

passive systems, but they still require some sort of backup for sunless days. These systems can be easily introduced into an existing building, unlike the passive systems that can only be implemented during the planning of a new building. However, active systems are very expensive as they integrate pumps and rotary elements and involve difficult engineering.

On the other hand, passive solar water heating systems use natural water circulation, gravity or pressurized water systems. Passive solar heating does not require the use of machinery or equipment to collect solar energy. On the contrary, passive solar water heating is achieved through planning and positioning of a building in such a way that it receives maximum sunlight. South facing windows are an important component of buildings that implement passive solar water heaters. Thermal mass is a heat-absorbing material such as water or concrete that is built into the walls or floors of the building. Throughout the day, as sunlight streams in and enters the building, the thermal mass absorbs the heat and retains it. After the sun sets, the temperature in the building starts to drop down. Now, the thermal mass begins to give up the heat it has collected during the course of the day and transfers it to the rest of the building.

Proper air flow is also essential in a passive solar water heater system because the heat must be delivered to all the parts of a building. A venting system or an air blower can come handy for the purpose of heat distribution. However, proper planning is also crucial. Passive solar water heating systems are much more cost efficient than the other one and involve low maintenance costs. Consequently, passive systems are more affordable for low-income communities and can meet their demands for heating water.

2.2 The Working Principles of Solar Water Heater

The main components of a solar water heating system include solar collectors, the hot water tank, and equipment such as a pump and controller. The whole heating process works by tapping energy from the sun in collector panels located on the rooftops.

Khan and Islam (2011) mentioned that the flat-plate collector is the most important type of solar collector because of its simple engineering and low maintenance cost. It can be used for a variety of applications in which temperatures ranging from 40˚C to about 100˚C are required. The principle mechanism of the solar collectors is to expose a dark surface to solar radiation so that the radiation is absorbed (Khan and Islam, 2011). A part of the absorbed radiation is then transferred to water stored in a hot water tank. At times especially in winter when there is limited solar energy to heat the water, 'booster' heating is used to keep the water in the tank at the right temperature. The booster heating can be provided by electricity, gas or a wetback.

Solar water heaters might differ in their mechanisms, but they all do the same basic things: gather heat in a solar collector; transfer the heat, directly or indirectly, to the water supply; and store the heated water until it's used.

2.3 Findings from Literature Review

From the analysis of different authors, the potential benefits and viability of solar water heating system have been summarized below.

2.3.1 Economic and Environmental Benefits of Solar Water Heater

Solar water heaters are such form of renewable technologies which can be used as alternatives to conventional water heaters such as electric geysers and fuel-fed boilers (Suhane and Pandey, 2013).As this technology takes advantage of sunlight as an energy source, SWH systems minimize dependence on conventional water heating fuels such as fuel wood or propane, or

fossil fuels that provide power for electric water heating systems (Milton, 2006).It can provide financial benefits along with environmental sustainability. It lowers the carbon footprint and is expected to reduce electricity bill since the fuel cost is free sunlight. As an energy conservative policy, it is easier to save one unit of electricity rather than producing one extra unit of electricity. SWH is simply an energy efficient technology which is economically viable in the long run and will reduce electricity generation from non-renewable resources needed for heating water.

An average solar water heater might incur huge fixed cost in the form of initial capital cost at first in comparison to electric heaters. However, due to low operating and maintenance cost, solar water heaters cover the huge initial fixed cost. So, in the long run it will be cost-effective as an average cost of SWH will eventually fall down. It is found that solar water heaters can reduce electricity bill up to 60-80% (SF Envionment, 2014). Not only in terms of cutting off energy bills, but also in terms of payback period SWH can be an effective long term solution. Generally, payback period means that the number of years required recovering the cost of the investment. When all costs for purchase, installation, maintenance and operation are taken into account, a solar water heater usually equals an electric heater after just eight and a half years and equals a gas heater in just less than 15 years. As the sunlight is free, the rest of the year is expected to provide hot water for free with bare maintenance cost and hence reduce pressure on the national grid.

Solar water heaters also come up with huge environmental impacts. Solar thermal is one of the ideal solutions to lower a building's carbon footprint and help protect the environment. For many businesses, water heating can account for over 50% of greenhouse gas emissions. It is estimated that, a typical residential solar water heater will offset greenhouse gas emissions by about 1,500

pounds of Carbon Dioxide (CO2) per year which is equivalent to the amount of CO2 released by an average vehicle every 1,685 miles (based on 19.6 pounds of CO2 per gallon at 22 mpg) (Ramlow, 2007).By reducing the need to extract and transport fossil fuels, this environmentally friendly technology can reduce greenhouse gas emissions. A 50-collector solar hot water system can offset over 50 tons of CO_2 per year, or 5,000 tons over the life of the system and a 100-collector pool-heating system can offset over 80 tons of CO_2 per year. Rather than burning fossil fuels such as natural gas or fuel oil to heat water, by tapping into the free, limitless energy of the sun to heat water will not only reduce electricity bills but also mitigate environmental pollution.

The introduction of SWH on a huge scale can benefit the global environment; since it can reduce environmental pollution by reducing consumption of fossil fuels. With so many advantages, the adaptation rate in developing countries is very low, where it can have the most benefits. Even though Bangladesh has a favorable location for harnessing solar energy to heat water limited literature regarding SWH has been conducted. Among the limited studies conducted so far it has been found that UNIDO (United Nations Industrial Development) has implemented solar thermal energy in tanneries of Bangladesh to heat water as a part of a Re-Tie-Bangladesh project (Reduction of Environmental Threats and Increase of Exportability of Bangladeshi Leather Products). The benefits of solar water heaters are acknowledged by tannery owners during the pilot demonstration by UNIDO and SWH system is being implemented in one tannery (UNIDO, 2014).Arefin *et al*.(2011) also confirmed that solar water heaters are more cost-effective than electric heaters in the long run.

3. Case studies

Single or multi-country case studies are desirable when an in-depth investigation or qualitative analysis is needed. Case studies involving single or multiple countries have been a popular technique to study the process and outcomes of energy sector reforms in many developing and developed countries. The following case studies are a detailed analysis of the key factors that has led to the development of SWH in the following countries.

3.1 China

China is one of the leading countries in adoption of SWH industries. Currently, it is estimated that there are about 3,000 solar water firms in China, of which about 1,800 are solar water heater manufacturers and the remaining 1,200 are component suppliers. Of these 3,000 firms, the top 10 account for more than a quarter of the Chinese SWH industry and about 30 firms are relatively large in terms of sales volume and production. Among these firms, 4 firms have an annual sales volume of approximately around US$326 million, 2 have an annual sales volume of approximately US$81–$162 million and more than 20 firms have an annual sales volume of approximately US$16–$81 million.

However, behind this industry's huge success, some key factors have played great roles. It is found that China's industrial policy was not so strong to support the growth of the SWH industry rather there was strong support at the local level for solar water heaters which led to the development of this industry. In China, solar water heaters have been developed mainly at the local level after their commercialization without much Central Government support (Li *et al.,* 2011 and Annini, 2014). These are mainly supply-side policies and subsidies which worked as strong economic incentives for the development of this industry.

Most importantly, it is observed that since the introduction of the Renewable Energy Law in 2006 there has been a rapid expansion of solar water heater installations across China. This is mainly due to two policy incentives. First, since 2007, some provincial and municipal governments have introduced a mandatory requirement to install solar water heaters as a part of every new building. Second, the payment of subsidies for solar water heaters under a 2009 policy on 'household appliances going to the countryside', which aims to increase the availability and use of solar water heaters in rural areas with a subsidy equivalent to a reduction of 13% of the wholesale price (Hu *et al*., 2012).

Another issue related to politics and the political economy is the career opportunities for provincial bureaucrats who have contributed to building up a successful SWH industry at the provincial level. Local bureaucrats who manage to attract solar energy firms to their province and municipality and contribute to the success of the firms may be likely to have improved chances for promotion. This is because successful local firms can lead to local employment, tax revenues, economic growth and increased competitiveness for the province and municipality.

Interestingly, neither the SWH firms nor the industry as a whole enjoys fiscal or taxation incentives in China, yet solar water heater installations and sales have nevertheless increased rapidly in recent years, driven only by a large and rapidly expanding demand, particularly in the rural areas and in smaller towns. Hu *et al.* (2012) argue that solar water heaters meet the demand of millions of Chinese customers by offering good quality, high performance, but at a low cost. Li *et al*. (2011) add that solar water heaters are also based on China's natural endowments for solar energy. It reduces pressure during peak load and thereby contributes to energy security and opportunities for economic growth at the local and provincial level. At the grassroots level it is also suggested that end-users in China generally have a very positive attitude and there are high

levels of public acceptance towards low carbon energy due to the general awareness of China's resource scarcity and the fact that solar energy provides employment in many regions in China (Li *et al*., 2011). Another reason that is mentioned for China's rapid rise in solar water heaters is its relaxed building codes that enable setting up solar water heaters on roofs, without planning permission or other bureaucratic rules. However, experts suggest that the most important argument for solar water heaters is their low cost. As socio technical preferences have changed in the last decade with regards to hot water provision, an observed change from the conventional high carbon pathway to the alternative low carbon pathway seems possible.

So, it can be concluded that China did not develop this industry at once, rather there are some economic and political factors mentioned above played significant roles in the emergence of this industry. It is clearly understood that to adopt SWH in Bangladesh cost is a major issue like it was for China. However, the investment scenario for solar heating in China was very competitive unlike in Bangladesh. The most interesting fact is found that most of the people of China were very environmentally conscious that led to the greatest innovation in the form of solar water heater. Economic incentives such as employment opportunities geared up the progress as well the renewable energy policy worked as a great factor in huge adoption of SWH in China (Urban and Geall, 2014).

The following table summarizes the whole market scenario of solar water heating industry in China and its underlying factors for the development of this industry.

Table 1: Summary of SWH Market Scenario in China

Background	One of the leading countries in adoption of SWH industries
Economic factors	Subsidies Low cost Competitive business environment Huge demand generation for solar water heaters especially at rural level and small towns
Policy	Supply-Side policies
Barriers	Weak industrial policy
Environmental/Social Factors	Strong support at the local level for SWH Environmental awareness
Political factors	Incentivize local bureaucrats to adopt SWH through promotion and career opportunities
Results	Ensures energy security Creates opportunities for economic growth at the local and provincial level

3.2 Georgia

Even though Georgia is far ahead in terms of development, industrial environment, governance, infrastructure from Bangladesh, the initiatives for installing SWH in the rural areas of Georgia can be a learning case for Bangladesh. The background of the rural areas of Georgia has some similarity with the rural areas of Bangladesh. The population of Georgia, especially in rural areas, suffers from a lack of access to safe and sustainable energy. Moreover, in countries with cold winters, where heating is a necessity, "energy poverty" is also an important dimension of overall poverty. Factors contributing to energy poverty in those areas are mainly: a poorly maintained infrastructure, rising fuel costs, extreme weather conditions, and the increasing unpredictability of the climate. In order to ensure energy security for those regions, a project was implemented by WECF (Women in Europe for a Common Future) to launch SWH technologies adapted to local needs and capacities. That year WECF also started piloting the implementation

of low-cost solar water heaters based on local production with the involvement of both women and men.

The main reason for choosing this case study is that it has adopted some innovative initiatives that have attributed to the adoption of affordable low cost SWH in those rural areas which can be adopted similarly in Bangladesh. As a part of the project "Building local capacity for domestic solar water heating, hot water and insulation for rural and remote areas in the EEC region", 400 solar warm water heaters have been installed since 2009 and monitored by locally trained men and women, using local materials. The programme has resulted in socio-economic benefits for the regions by reducing energy poverty (easy access to sustainable energy and fewer costs for fuel), environmental degradation (less resources need, e.g. wood) and mitigating climate change (less CO2 emissions). In terms of social aspect, the programme has also strengthened local capacity in regard to knowledge, gender equality and created business opportunities for women and men. The economic rationale behind the successful implementation of project was the incorporation of such designs which involved local workmen and women and local materials. In this way, the solar water heaters remain affordable for low-income households. The solar collector implementation program is also aimed at rural domestic usage, combined with accessible local credit, to allow replication of these systems which also worked as an important economic factor. Not only in terms of economic incentives, the programme has also become successful for socio factors such as the training concept developed by WECF and partners. This training programme aims to link the social context and the technology, i.e. the training courses consisting of participatory community learning, construction, operation, maintenance and monitoring of the technology. Local awareness about SWH systems has also been raised on different levels with positive results. Local project partners are working continuously on

information campaigns with press releases, radio shows, TV broadcasts and newspaper articles. This has proven to be an effective way to reach rural populations as well as decision-making authorities and different stakeholders. In the target villages, where solar collectors already are installed, the programme is well known and the interest amongst local population is increasing steadily.

However, the project has also faced some barriers in the implementation process. It has been found that in few cases, solar water heaters did not work properly because of construction flaws. Another common problem; lack of financial resources amongst rural population has also been observed. Even though the project aims to reduce rural energy poverty, with a subsidy of 100 Euro, the solar collector is still not affordable to the poorest segment of the population of that region. Technology transfer to a new region is always a challenge and needs time. Adaptation to different local conditions and constraints, as well as building the capacity of well-skilled local experts, can take several years.

So, considering the following obstacles some of which are similar in Bangladesh, some recommendations from this case study have been suggested to make solar collectors available for the lowest-income families. For instance, access to financial resources for capital investments has to be created first. These include loans via community-based mechanisms such as revolving funds or savings-groups as well as micro-finance. Other options are the provision of subsidies via national mechanisms or the international carbon market, like the Microscale Gold Standard and the concept of Nationally Appropriate Mitigation Action (NAMA). In order to properly maintain the installed solar water heaters, basic maintenance training should be an obligatory part for constructors, and all women and men from households who apply to install a solar water heater should be encouraged to take a basic course in maintenance as well. Most importantly, on

the policy level, the programme strives for a better convergence of legislative and regulatory frameworks by elaborating concrete policy recommendations. Local partners are working closely together with local authorities and representatives of the Ministry of Environment and Natural Resources Protection of Georgia.

Nevertheless, this project has resulted in numerous economic and environmental benefits for the community which again gives a strong motive to adopt SWH against traditional water heaters. According to monitoring results (2011-2014), after the installation of a solar collector consumption of wood as traditional fuel for heating water for households has been reduced by 10% during the cold season and 70% during the warm season resulting less deforestation. Combined with reduced gas and electricity use, this has resulted in 42% reduction of energy costs, savings on average each household more than 150 EUR per year. Generally, a solar collector costs up to 375 EUR, therefore the payback time is 2-3 years. So ,there is no doubt about the potential prospects of SWH as a viable long term solution and analyzing the whole case scenario, similar approaches can be taken in Bangladesh too.

The following table briefly summarizes the solar water heating market scenario in Georgia and its key factors.

Table 2: Summary of SWH Market Scenario in Georgia

Background	The population of Georgia, especially in rural areas, suffers from, "energy poverty" In 2008, WECF and its partners launched a programme to adopt SWH Since 2011, in the framework of the project "Building local capacity for domestic solar water heating, hot water and insulation for rural and remote areas in the EEC region" funded by the European Commission, more than 400 solar collectors have been constructed in Georgia by locally trained technicians, using local materials
Economic Factors	Lowering cost by using locally used materials Access to credit
Barriers	Construction flaws Lack of financial resources
Social factors	Training courses consisting of participatory community learning, construction, operation, maintenance and monitoring of the technology Raising local awareness about solar systems through information campaigns with press releases, radio spots, TV broadcasts and newspaper articles
Results	42% reduction of energy costs, which meant an overall 35% improvement of the household budget Less deforestation
Recommendations	Access to financial resources for capital investments including loans via community-based mechanisms such as revolving funds or savings-groups as well as micro-finance must be created first Provision of subsidies via national mechanisms or the international carbon market, like the Micro scale Gold Standard and the concept of a Nationally Appropriate Mitigation Action (NAMA) Basic maintenance training should be an obligatory part for constructors Capacity building of the technical staff of national and local partner NGOs, so that they are aware what is required to solve problems Strengthening of policy regarding SWH involving local community and stakeholders

3.3 Brazil

Brazil offers one of the advantageous locations for harnessing solar power and SWH can be very promising technology for this country. However, even though with financial benefits and shorter pay back periods, SWH industry has little development against traditional water heating sources in Brazil. Nevertheless, the Government of Brazil and the Ministry of Mines and Energy (MME) have realized the importance of renewable energy and targeted a 6400 MW (mega-watt) reduction in additional capacity through energy efficiency by the year of 2030. To achieve this target, various measures are proposed, including the use of solar water heaters to replace the typical electric shower heaters present in nearly every household in Brazil.

Some initiatives and projects have been undertaken by the ministry for the development of this industry. Even though the government does not offer direct subsidies to the SWH industry, but it does offer some tax incentives to those that purchase and install renewable energy technologies. In addition, a small number of private lenders offer financing opportunities for SWH system purchases.

Besides, a law has been approved by the state government of Rio de Janeiro which makes the installation of SWH systems mandatory for public buildings. Under state law, solar thermal systems are mandatory for new and refurbished public buildings in Rio de Janeiro. Solar energy must cover 40% of the annual hot water demand. However, an exemption is made for public buildings in which it is technically impossible to install a solar thermal system. Another project titled “1,000 Roofs Project” has also been commissioned by: German Federal Ministry for the Environment, Nature Conservation to promote renewable energy. The project supports the introduction of solar thermal installations for water heating in the context of existing promotion and funding programmes, e.g. in the social housing sector. National quality standards are being

introduced. Training has been provided to the technicians in the planning, installation, servicing and maintenance of solar thermal installations in this project. Similar approaches can be taken in Bangladesh for the newly built houses. Moreover, on the policy level in 2010, a working group headed by the Brazilian Ministry of Environment (MMA) drew up a strategy for disseminating solar thermal energy as a contribution to the national climate policy. It is proposed to double the installed solar collector capacity to 15 million square meters by 2015 which is a great initiative for the development of SWH technology (GIZ, 2010).

To summarize, it has again been proved that solar water heating is a long term potential solution with environmental and economic benefits. It has been found that solar thermal systems can reduce gas consumption by up to 50% in multi-family housing units, and that system can pay-back in less than 4 years.

The following table summarizes the solar water heating market scenario in Brazil and its key findings.

Table 3: Summary SWH Market Scenario in Brazil

Background	The SWH sector has been growing steadily since the Brazilian energy crisis in 2001, but the growth is modest to create market transformations considering the country's solar potential Installing SWH for 1,000,000 new houses has created huge impact in their SWH industry
Economic factors	Tax incentives Public-private partnership
Policy	Disseminating solar thermal energy as a contribution to the national climate policy
Barriers	Higher initial investment costs The government does not offer direct subsidies to the SWH industry
Social factors	Enabling training programmes for technicians
Results	Solar thermal systems can reduce gas consumption by up to 50% in multi-family housing units Improvement of household's budget by 35% Payback time has been calculated as 3.3 years Greenhouse gas reduction

3.4 India

Households and businesses across India often depend on grid electricity for heating purpose. According to Shah (2011), water is commonly heated using electricity from the grid, powered largely by coal, which is dirty and harmful to the environment. Most of the middle-income and poor households cannot afford to use hot water for their domestic uses. SWH can be an alternative solution to traditional heating to the hot water demand of households in India.

After China, India has advanced remarkably in the adoption of solar water heaters as alternatives to traditional water heaters. It is estimated that by installing solar water heaters in the house can save up to Rs 1000 per month on electricity and a person can attain a better quality of hot water as same as electric heating water. Maintenance cost is very low hence solar water heaters are very economical and affordable.

India's SWH has experienced a huge growth for the past 15 years with more than 20%CAGR (Compound Annual Growth Rate) especially in the last 4-5 years. The potentiality of this eco-friendly SWH market is estimated to be approximately 2.5 million square meters which is expected to reduce both economic and environmental costs of water heating in the long run. At present, more than 50% of the SWH Installations are concentrated in the states of Karnataka and Maharashtra. India being the advantageous location for receiving solar radiation, currently around 1 million households in India uses solar water heaters and the growth rate is around 20%. Assuming, an average solar water heater system costs around $650, the total market size would be around $130 million.

SWH is gaining popularity in India due to the subsidy scheme e.g. Jawaharlal Nehru National Solar Mission subsidy policy by Ministry of India which aims for SWH Installations at 7 million square meters in 2013 and 20 million in 2020. The payback period for solar heaters is quite short

in India and it substitutes the need for the electricity needed to run power guzzling water heaters in residential and commercial establishments. Another reason for the success of solar water heaters is that they are relatively easy to build and install making them quite popular. Moreover, the government of India through MNRE (Ministry of National and Renewable Energy) policy also provides subsidies to solar water heaters and grants to municipal corporations, solar heater installers and banks to promote the use of solar water heater. All these factors can be adopted in Bangladesh too with strong political will.

In spite of the commercial success of India's SWH industry, with a GNI (Gross National Income) of only $2,750, affordability remains an issue for vast segments of the population. Most SWH applications in India are in the commercial and industrial sector, and households only account for about 20% of SWH installations. Furthermore, low electricity tariffs impede the development of this industry.

The following table is a summarized version of the solar water heating market scenario in India and its underlying factors for the successful implementation of this industry.

Table 4: Summary of SWH Market Scenario in India

Background	After China, India has advanced remarkably in adoption of SWH as an alternative to traditional water heaters
Economic Factors	Subsidy schemes Shorter payback periods
Policy	Favorable policies for SWH users and installers
Barriers	Affordability Low Electricity Tariffs
Other Factors	Easy Engineering of SWH technology
Results	Savings up to Rs 1000 per month on electricity Low Maintenance cost

3.5 South Africa

The residential sector in South Africa consumes 17% of the country's electricity. The largest electricity consuming appliance in our houses is usually the electric geyser. It makes up typically 30% of the total electricity used in many households which translate to around 5% of the country's energy consumption. A solar water heater may reduce this energy consumption figure by more than half and can be a potential alternative solution for heating water. However, even though South Africa has one of the highest insulation (hours of sunshine) rates in the world, less than 1% of households across the country have solar water heaters. Nevertheless, the case study of South Africa can be a taken as a good example for its adoption of some incentive measures and subsidy schemes regarding solar water heater.

Solar Water Heater Bylaw

A city bylaw can enforce the installation of solar water heaters in, for example, i) all new buildings built in the city; ii) all additions to existing buildings in the city where extra water heating will be required and iii) all existing buildings (retrofit).

This is a potentially very effective mechanism to drive implementation and stimulate the SWH industry. This bylaw has been a major driver in adopting solar water heaters and Cape Town was the first city to implement this law.

A bylaw does hold particular challenges for a city: i) Building inspectors will need additional training so that they can approve installations and enforce the law correctly; ii) The tiered method of introduction should be carefully considered in order to make the bylaw practicable.

Fee For Service Mechanism

This is also an interesting mechanism which has popularized solar water heaters in South Africa. The main idea behind this scheme is that people buy a service, in this case hot water, from an Energy Services Company (ESCO), rather than energy to perform the service (e.g. purchasing electricity so it can be used to heat water). The ESCO buys and installs the solar water heaters at their own cost and retains ownership. They can then sell the hot water to the owners in the following ways: i) metering the hot water ; ii) a lease or purchase agreement over a fixed period for the SWH equipment; iii) a fixed monthly tariff - which is ideally comparable to the monthly electricity saving from a solar water heater.

This mechanism is attractive because the hot water user bears no capital costs and users need not worry about the maintenance of the system. Although in the long run users will pay more than if they bought and installed a system themselves, this mechanism works well as it avoids prohibitive capital costs and is relatively 'hassle free' (no maintenance, repair, responsibility etc).

Tradable Renewable Energy Certificates (TRECs)

TRECs (Tradable Renewable Energy Certificate System) can be applicable to anyone who uses 1 MWh (megawatt-hour) of clean electricity. TRECs have been traded in South Africa since 2002 and provides subsides for the capital cost of installing a solar water heater. This certificate is sold to those individuals or businesses who want to go for eco-friendly "green" energy consumption. The revenue generated from the sale of TRECs over the lifetime of solar water heaters is estimated to cover roughly 15% of the solar water heater's capital cost.

Despite offering some incentive mechanisms, SWH industry is still underdeveloped in South Africa. Generally, the up-front cost of typical residential SWH systems varies from $5.50 to $9

per liter of capacity in South Africa. Even though SWH prices in South Africa are competitive from a global perspective, they are still perceived as too expensive for many households. As a result, most residences receive their hot water services from conventional electric systems, as up-front equipment costs are cheaper and electricity tariffs are exceptionally low. Moreover, the institutional structure in South African government and society patronizes the dominance of electric water heating systems. Prevailing practices in government, energy utilities, building industries, and other institutions all contribute to the development of electric systems. For example, electricity utilities receive heavy government subsidies for their generating and distributing costs, including those associated with rural electrification programs. On the other hand, national and regional governments offer few incentives for people to adopt alternatives to electric water heaters.

Even though government support for SWH has generally been limited, markets for SWH and other small-scale renewable energy technologies have been developed in South Africa through the adoption of some incentive measures which can be adopted in Bangladesh too.

For instance, the city of Cape Town has recently launched a CDM (Clean Development Mechanism) project that involves the installation of SWH coupled with energy efficiency enhancements in low-income areas. Other municipalities have experimented with installing SWH systems in city-owned apartment buildings.

The following table is a brief summary of the solar water heating market analysis in South Africa and its key factors.

Table 5: Summary of SWH Scenario in South Africa

Background	The residential sector in South Africa consumes 17% of the country's electricity. The largest electricity consuming appliance in our houses is usually the electric geyser. It makes up typically 30% of the total electricity used in many households which translates to around 5% of the country's energy consumption. A solar water heater may reduce this energy consumption figure by more than half.
Economic factors	Tradable Renewable Energy Certificates (TRECs) Fee for service mechanism Clean Development Mechanism(CDM)
Policy	Solar Water heater bylaw
Barriers	Financing/low electricity prices Lack of awareness about solar water heating Limited government support
Results	The reduction in residential power use will improve the energy security of a city as it needs to draw down less power from the grid supply Jobs will be created in the SWH industry; both in manufacturing and system installation

3.6 Tunisia

Tunisia provides the example of a "small" country that has been attempting to develop a market for SWH for many years. It seems to be achieving success by combining a variety of measures to provide direct subsidies and loans in order to address the problem of financing.

From 2005 to 2011, SWH market went through a huge market transformation where the use of domestic solar water heaters reached from 7,400 households to 1, 33,340 households due to the introduction of financing mechanism in Tunisia. Understanding this transformation can be useful for other solar energy financing programs in developing countries such as Bangladesh.

Tunisia offers a promising location for harnessing solar power. Despite the obvious benefits of solar water heaters for households, the cost of purchasing a solar heater was too high for many

people in Tunisia. Therefore, in 2005, the government of Tunisia initiated the “Programme Solaire” (Prosol) to increase solar energy capacity. Starting with 1.7 million Euros in initial funding from the Italian Ministry for Environment, Land and Sea through the United Nations Environment Program (UNEP), Prosol provided a subsidy on the capital costs of solar water heaters and loans at a reduced interest rate by commercial banks to residential consumers. The loans were repaid via the State Electricity Utility (STEG) through the electricity bill. It also undertook awareness-raising campaigns targeted at consumers and commercial banks and provided capacity building to financial institutions and technology providers to develop long-term knowledge and expertise. Gradually the SWH market showed a dramatic increase when loans became available. By 2010, Prosol built a SWH market worth US$66 million.

To make it easier for Tunisians, several financing measures have been adopted by their government. First, a subsidy scheme was introduced to cover the initial capital cost of solar water heaters. Loan payments for the solar water heaters were paid back in a five-year term through the electricity bill. Moreover, banks were able to lower the interest rate from 14 to7; and during the first two years of Prosol, UNEP (United Nations Environment Programme) provided an interest rate subsidy to make the loan interest-free. As energy savings directly benefitted the end user, the water heater could pay for itself in four years.

Prosol programme has helped form policy changes that support a long-term, sustainable solar water-heater market. In 2005, the Tunisian government passed a law providing for a 20% capital cost subsidy for solar water heaters installed in the residential sector. Prosol entered a second phase in 2007 with $21.8 million in funding from the Tunisian government and $0.2 million from the Italian government.

The Tunisian government now encourages solar energy by allowing a subsidy that was previously provided only to LPG. Prosol has been so successful that after the first two years, the Tunisian Government decided to continue the project even if the funds from the Italian Ministry and UNEP phased out. The success of Prosol has incentivized private finance in Tunisia to flow. By the end of 2008, the Prosol programme reduced carbon emissions by 214,000 tones which again proved the environmental efficiency of solar water heater.

By 2010, annual deployment of solar water heater systems has been increased fivefold since the start of the initiative. Total public and private investment in the program amounted to an estimated $134 million, of which the public sector provided 18%, while 82% was provided by local private investors, a leverage rate of $5 of private capital for every $1 of public resources.

However, there are a number of barriers found to be exploiting renewable energy in Tunisia, including significant subsidies on fossil fuels and lack of financing availability, despite sophisticated financial and credit markets. Furthermore, lack of awareness among consumers regarding the use of solar water heaters as an alternative to LPG-fired boiler also has been identified similar to any other developing countries.

There is no doubt that all those financial incentives triggered the development of SWH industry in Tunisia. However, despite those economic measures; capacity building, readiness activities, the involvement of all stake holders, strong commitment from Tunisian government worked as important factors to promote this industry which are highly absent in Bangladesh. Access to finance is also a critical barrier that needed to be addressed in the case of Bangladesh unlike in Tunisia.

The following table briefly analyzes the whole solar water heating market scenario in Tunisia and its implementation strategies.

Table 6: Summary of SWH Market Scenario in Tunisia

Background	SWH reached from 7,400 households to 1,33,340 households from 2005 to 2011 in Tunisia specially undertaking the project "Program Solaire" (Prosol)
Economic factors	Subsidies to the capital cost Provision of loans at reduced rate Attracting donors to invest in SWH
Policy	Long term and sustainable SWH policy
Barriers	Significant subsidies on fossil fuels Lack of financing availability
Social factors	Awareness-raising campaigns Involvement of all stakeholders Strong political will
Results	By 2010, annual deployment of SWH systems has been increased fivefold since the start of the initiative.

3.7 Barbados

This Caribbean country is far developed from Bangladesh in terms of governance, infrastructure, and economic structure. However, some economic instruments adopted by their government can be an important learning tool for Bangladesh in the adoption of SWH. For instance; their favorable tax policies for SWH are one of the essential economic instruments to develop this industry. With per capita income of over $15,000, most of the Barbadians are relatively well equipped to pay the up-front costs of SWH systems.

So, affordability is not an issue for most of the buyers of SWH systems in Barbados. Moreover, they can take advantage of 100% income tax rebate. Besides, to keep costs down; the government offers preferential import tax treatment to local manufacturers for fabrication materials, in addition to the 100% income tax rebate to buyers of domestic SWH systems as a part of economic incentives. As a result of these very favorable tax policies, Barbados has one of

the world's highest per capita rates of SWH penetration; as of 2001, over 32,000 installed systems provided at least 39% of all households with SWH services. Apart from this tax rebates, the high rate of SWH adoption is attributed by several factors, including the country's relatively high rate of insulation, extremely high electricity tariffs, and very active government pro-SWH incentive programs. Despite the robust SWH market, electric systems are still the norm. Almost all of Barbados's 78,000 households are connected to the national grid, which is powered almost entirely by combustion of imported oil. Relative to the global average, electricity tariffs in Barbados are very high, with average rates of around 17.5 cents per KWh (kilowatt-hour); furthermore, electricity prices have been rising at record rates throughout the Caribbean region.

Nevertheless, the reason for choosing the case study of Barbados is their economic measures for widespread adoption of a renewable energy technology such as solar water heaters to help offset high energy cost. Similar approaches can be adopted and adapted with necessary changes in Bangladesh too in their journey of transition from non-renewable to renewable.

The table briefly summarizes the solar water heating market scenario in Barbados and its key implementation factors.

Table: 7 Summary of SWH Market Scenario in Barbados

Background	Barbados has one of the world's highest per capita rates of SWH penetration
Economic Factors	100% income tax rebate Preferential import tax treatment to local manufacturers Extremely high electricity tariffs
Policy	Favorable tax policies
Barriers	Huge acceptance for electric heaters
Results	Offsets High Energy Costs

4. Lessons Learned From these Case Studies

The case studies reviewed above have some success stories along with failures. It is commonly found that, adopting solar heaters have benefitted most of the countries environmentally and the transition towards solar water heating is attributed to some innovative financing mechanisms. One such mechanism is subsidy scheme which more or less has been adopted by most of the countries discussed earlier. Subsidies are intended to reduce the capital cost at the time of purchase and shorten the payback time. They can also be used to promote quality if they are granted on condition that the equipment or the contractors comply with certain quality criteria. Finally, subsidies provide the public authorities with the opportunity to show their interest in solar technologies. Combined with a clear and policy to develop solar technologies, this can help mobilize professionals in the sector and build consumer confidence in the reliability of solar water heating equipment. Countries like China, India and Brazil have mainly gained success in solar water heating industries because of this scheme.

Access to initial funding is also necessary to boost this industry. And in order to get access to those initial funds, creating a competitive investment environment is necessary to create interest among the donors to invest in this sector. For example, for a small country like Tunisia without initial funding from the Italian government, such progress in solar water heating industry was not possible. Tunisia also undertook pilot projects in this sector which gained huge success later. A similar case is with China where they created a local investment opportunity which works as a strong economic motive to develop this industry. Bangladesh, however, could not create such a competitive environment to attract donors to invest in solar heating in Bangladesh. Awareness about solar water heaters is also a strong factor in adopting this industry which is strongly present in China. However, most of the countries lack this factor along with Bangladesh which

hampers the growth of this industry. Affordability is a major issue in this regard where most of the countries faced barriers in implementing solar water heaters. In this case, Georgia's adoption of locally used materials to make solar water heaters more affordable, can be an effective economic measure and can be replicated in Bangladesh too.

South Africa has been successful in adopting solar water heaters by merging both economic and environmental factors such as solar water heating bylaw, a fee for service mechanism, tradable renewable energy certificates which triggered the growth of this industry. However, to adopt those approaches commitment from government is necessary which is quite unlikely for Bangladesh. On the policy level, our neighboring country India is far ahead in adopting stringent policy measures which is clearly absent in Bangladesh. Besides, apart from India's policy, China's favorable tax reduction policies for solar water heaters and Brazil's renewable energy policies are also recommendable.

From the analysis of the factors working in the implementation of this alternative heating technology; some key factors have been identified. Among them; strong political will, subsidy schemes, awareness programmes, tax rebate policies and the creation of employment opportunities can be considered as major drivers in bringing the change in SWH industries. There is no doubt that the transition towards non-renewable to renewable has always been difficult in almost every country and the cost has been found as the main constraint behind the wide scale implementation of this alternative heating technology. Nevertheless, the resulted economic and environmental benefits from the use of solar water heating cannot be denied and therefore, all the economic, environmental and policy instruments should be adopted simultaneously for the rigorous implementation of this clean solar water heating industry.

5. The Case of Bangladesh

This chapter summarizes the findings gathered from the limited literature found in SWH sector for the case of Bangladesh. This chapter also looks into the market growth of SWH in Bangladesh and analyzes its potential barriers.

5.1 Findings from the Literature regarding SWH for Bangladesh

There is no literature found regarding the use of SWH in the households of Bangladesh. Nevertheless, SWH has been installed in one of the Hazaribagh tanneries as a part of Pilot Project introduced by UNIDO (United Nations Industrial Development Organization). The project aims to reduce the use of non-renewable sources for water heating and expects to reduce CO2 emissions. From the project, it is found that, expected Payback period for SWH system is approximately 6 years, however, it is expected that it will be shorter as gas prices are expected to rise. Tannery owners have already recognized the usefulness of SWH and during the project; one tannery owner has already installed SWH system for their tannery consumption. Additional tanneries have made plans for their installations. So, ifthe tanning industries in Bangladesh can switch its hot water needs from non renewable to renewable sources; it not only can reduce pressure from national grid but also can mitigate environmental pollution.

Arefin *et al.* (2011) mentioned that 150 liters solar collector is used along with a 300 liters storage tank to store the water produced by the solar collector throughout the day. From the system, the optimum temperature of the water to be stored in the storage tank has been analyzed and a payback calculation has been done to determine the system's feasibility in terms of economical advantage. A cost-benefit analysis of the system has also been done against electric heaters.

From that one-week data, the main results of the study show that, the temperature of the hot water tank rose up to (on a full sunny day) 68 degree Celsius and in cloudy days, the maximum temperature was reached up to 56 degree Celsius with an average 4 degree temperature drop. Therefore, 50 degree Celsius temperature has been selected as the operating temperature of the solar hot water system.

The total cost of the alternative solar heating system is BDT 1,00,000 considering every component of this system and an average electric heater costs BDT 8567.67 per year (Arefin *et al*., 2011). Now, considering that the electric heater and the controller consume approximately 20% of the electricity bill, the amounts are saved: BDT 8,567.67 x 80% = BDT 6,854.136.

So, the payback for the solar heater is 14.5 years (1,00,000/6854.136) and the lifetime of a solar heater is 30 years. On the other hand, the lifetime of an average electric heater is 5 years and after 5 years, a new heater will bear the additional cost. Moreover, the maintenance cost of the electric heater is about BDT 1000 to 2000 whereas the maintenance cost for solar water heater is nearly zero. So, from the cost-benefit analysis it can be concluded that the using solar water heater instead of electric water heater is more beneficial for the users in the long run for it cost effectiveness.

(Khan and Islam, 2011) confirmed that solar water heaters can work uninterruptedly in Bangladesh. As a part of this study, two solar water heaters of 100 liters and 200 liters were installed on the rooftop of Electronics Engineering Department of BUET. Data of 12 months have been collected of these heaters and it is found that the incoming hot tap water is about 30˚C during day time in winter months and about 25˚C in afternoon hours. However, cost-benefit analysis of solar water heater has not been found in this study.

5.2 SWH Market Penetration in Bangladesh and Market Barriers

Solar water heating technology was first introduced in Bangladesh since the 1990s (International Institute for Energy Conservation, 2011). The initial efforts were targeted towards studies on suitability of SWH technology to the country's climatic conditions. Under the guidelines of Renewable Energy Policy, solar water heaters are exempted from custom duties and Value Added Tax (VAT).

Initially, the SWH systems were imported, mainly from China, but the system cost was very high and not at all affordable. Then, the research and academic organizations such as Renewable Energy Research Institute (RERC) of Bangladesh University and Institute of Fuel Research & Development (IFRD), Centre for Mass Education in Science (CMES), Local Government Engineering Department (LGED) strived to develop SWH systems using locally available materials. The systems were successfully manufactured and tested at their own facilities. In parallel, a few local manufacturers who were already involved in other solar energy businesses started manufacturing the SWH systems locally. However, the SWH market could not face much growth due to lower living standards in Bangladesh, high initial costs and cheaper competitive fuels. Most importantly, in a developing country like Bangladesh where issues of priority are basic needs to citizens (healthy food, secure living space, and health facilities), poverty, and electricity access to all for the Government, the market is not that developed to absorb such technologies which form the secondary needs to citizens.

So, from the above analysis, it can be easily deduced that Bangladesh has to come a long way to adopt SWH. The following chapter is a detailed account of some recommendations along with policy suggestions to tackle these market barriers.

6. Policy Recommendations

It is clearly evident that no competitive investment environment has been created yet for SWH in Bangladesh.SWH is still an unknown phenomenon for most of the citizens and strong literature gap persists for the diffusion of this technology. On the other hand, our neighboring country India is far ahead in patronizing SWH market through subsidy schemes and strong policies. Such schemes and policies are clearly not practiced in Bangladesh. Nevertheless, analyzing the case studies, it can be apprehended that, SWH has huge prospect for a country like Bangladesh. So, the potential prospects of this technology should be taken into consideration against conventional heating sources.

It is interesting to note that, Bangladesh has also long established renewable energy policy which envisions 5% of total generation from renewable sources by 2015 and 10% of the same by 2020.SWH is still at introductory phase under Energy Efficiency (EE) action plan by the Government of Bangladesh (GOB), with incentives like tax rebate policies for solar water heaters along with other financial schemes. However, the problem is that these economic measures are not practiced in Bangladesh due lack of awareness about this technology and most importantly, people of our country are not environmentally conscious of practicing sustainable method of water heating.

Nevertheless, considering the prospects, the transition should be followed by important economic measures along with strong policy recommendations to adopt this technology. It has been commonly found that lack of awareness about SWH widely persists in almost every countries reviewed above except in China. In order to fill this knowledge gap, a strategic long term plan has to be developed to promote SWH in Bangladesh. The plan should aim to implement capacity building, awareness, research and development of manufacturing programs

with planned policy and regulatory control for quality control of the systems. In this regard, the case of Georgia can be a very good example where local project partners have launched information campaigns with press releases, radio shows, TV broadcasts and newspaper articles. This has proven to be an effective way to reach more people including decision-making authorities and different stakeholders.

Capacity building of trainers, installers, and users of solar water heaters is also necessary to get used to this new technology. In this regard, training programmes about the engineering and mechanism of this technology should be conducted extensively involving both men and women like the ones of Georgia.

Access to initial funding is an important element for the development of any new technology. Projection of any successful campaign is necessary to attract donors to invest in this sector. Pilot programmes in this regard should be implemented at first to create a positive perception about this technology. The similar approach brought a huge revolution in countries like Tunisia and Brazil and created successful investment environment for SWH. Tunisia's Prosol (Programme Solaire) and Brazil's "1000 Roof's Project" can be considered as great examples in developing investment environment for solar water heaters.

Most importantly, strong political will along with community participation is the key tool to develop any industry. India has set up a great example in this regard by formulating a strong renewable energy policy regarding solar water heaters. India's JNNSM (Jawaharlal Nehru National Solar Mission) policy which aims for SWH installation at 7 million square meters in 2013 and 20 million by 2020 is a very remarkable example in this case and can be followed by Bangladesh.

Finally, it is commonly found that people mostly have preferences for low cost and shorter payback period times for solar water heaters against traditional electric heaters. In this case, instead of importing; locally made tools and capacity building of local installers and trainers can be considered as great economic measures to make SWH more affordable. Besides, research and development on this technology should be given more priority to make this technology cheaper for users. Moreover, the scattered and individual research activities of various academic institutions and government organizations of Bangladesh need to be assembled and assessed, which later can be the basis for the development of long-term plan or policy for SWH.

7. Conclusions

In this research paper, the prospect of solar water heating has been analyzed thoroughly against conventional sources. The potential environmental and economic benefits of this technology are also emphasized. This research paper also gives a comparative analysis of SWH among different countries and Bangladesh.

From the overall analysis presented in this research paper, it can be concluded that, SWH has the potential to reduce environmental pollution and is a long term investment in terms of economic point of view. However, even with numerous environmental and economic benefits, the adaption rate of this renewable technology is still very low in a developing country like Bangladesh. One of the main reasons behind this low adaption rate is strong knowledge gap persists widely in the diffusion of this technology in our country. Besides, Bangladesh also faces some market barriers for SWH like other countries mentioned above. That is why; this research paper has investigated the potential benefits and barriers of SWH by reviewing different works of literatures and case studies in order to fill this knowledge gap.

There is no doubt that, energy is the crucial factor for the development of any country and that's why energy security comes as a top priority for any country. Considering the increasing demand for heating purpose both in developed and developing nations, energy security is at stake due to the huge extraction of fossil fuels and natural gas for heating water. This high extraction rate creates pressure on the national grid and also pollutes the environment. So, it is high time for Bangladesh government and respective authorities to acknowledge this industry and create a competitive market for this industry. To reach a sustainable future, Bangladesh needs to ensure its energy security and environmental sustainability. SWH will undoubtedly help Bangladesh

toensure energy security by reducing pressure on the national grid and also maintain environmental sustainability.

Case studies of China, Brazil, India, Barbados, Tunisia, Georgia, and South Africa have been reviewed for this research paper to analyze the factors working behind the development of solar water heating. Factors such as economic measures, awareness, environment, low cost, strong policies etc have been identified as key factors which have led to the development of SWH industries.

There is no doubt that the transition towards non-renewable to renewable has always been constrained by lots of factors. So, in order to tackle those barriers, a strategic long term plan has to be developed to promote SWH in Bangladesh. Nevertheless, Bangladesh has a favorable location and climate to harness solar power. All need to be done is to adopt those factors along with strong policies to patronize this sector. Our neighboring country India is a great inspiration for Bangladesh to adopt SWH against conventional heating and has been strongly committed to reduce green house gas emissions. For that, awareness about the new technology and consciousness about the environment need to be created vigorously in our country. Finally, switching from electric heating to solar water heating is not an easy task and people in Bangladesh have been dependent on non-renewable sources of heating water for a long period of time. Nevertheless, every country reviewed above started from a scratch and with some innovative schemes; these countries are the pioneer of solar water heaters now. So, as soon as Bangladesh realizes the environmental and economic benefits of this sector, the greater for Bangladesh will be to ensure its energy sustainability.

This research has faced limitations due to unavailability of empirical data on the impact of using SWH in energy savings and consumption. That is why empirical study could not be conducted

for this research paper. Moreover, even though, SWH has been used in the tanneries of Bangladesh, no data has been found regarding the use of SWH in the households of Bangladesh. So, analyzing the scope and potentiality of SWH in Bangladesh, household surveys can be conducted in future to determine the viability of SWH in the households of Bangladesh.

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