Solar Hot Water System: The Nepalese Prospect

Jagan Nath Shrestha *, Raju Rimal **,
Sheekar Pradhan *, and Shree Raj Shakya *
* Center for Energy Studies, Institute of Engineering
Tribhuvan University, Kirtipur, Kathmandu
** Association of Solar Thermal Energy Development (ASTED) Nepal
NEPAL

ABSTRACT

Solar Water Heater (SWH) is one of the most successful solar thermal technology applications in Nepal. About 30,000 sets of SWHs have already been installed throughout the country. In a study conducted in 1998, it was estimated that more than 10,000 m² of SWHs had been installed with a capacity of around 200,000 liters/day. However, until now, locally manufactured solar water heaters are still under very poor condition. Thermo siphon is the only technology manufactured and sold at commercial stage. The performance standard of solar water heaters is very low. Although the technology is popular in the country, there is an urgent need to take measures on improving the current technology. The existing technology has not been assessed so far in terms of efficiency, low-cost design and extended lifetime measures. The use of SWHs in rural and in high altitude areas still lack attention. Government policy, standardization of the manufacturing technology, and lack of awareness among the public and the beneficiaries, are other vital issues which should be addressed.

1. INTRODUCTION

After the worldwide energy crisis in 1973-74, increasing emphasis was placed upon direct and indirect use of solar energy. Solar energy seems to be the most attractive and promising alternative energy source for the future, since it is non-polluting, inexhaustible, and a large energy resource.

The development of solar thermal conversion devices started in Nepal in early 1960s. A locally made solar water heater (SWH) installed in the premises of the Department of Mines and Geology was the first in Nepal. Based from other reports, the first prototype SWH was manufactured in 1968 by the late Rev. B.R. Saubolle and the Asha brothers in Kathmandu. Further records showed that Plumbing Division of Balaju Yantra Shala (BYS) paid their effort of developing SWH only after 1974. After considerable experiment and development, improved SWH systems were supplied by BYS to the hostel of a Budhanilkantha School in 1975. This was the first unit installed for public use, which brought favorable response among public and initiated the market attracting a number of manufacturers for the manufacturing and installation of solar water heaters for domestic and commercial applications. The development of SWHs received further support at the then newly established Sanitary Section of the Mechanical Training Center in Balaju with support from Helvetas of Switzerland. Through continuous improvements in design, fabrication and installation as well as through a combination of the efforts of private companies and technical institutions, the efficiency and performance of SWHs were greatly improved. The market of SWHs increased in such a way that more and more SWH manufacturers are emerging in the streets of Kathmandu.

Until 1992 there was a record of 35 solar water heater manufacturers registered with the Department of Cottage and Small Industries. There were 90 unregistered manufacturers in Kathmandu valley alone. It is estimated that presently there are more than 200 workshops making solar water heaters in Nepal.

Likewise, more than 30,000 households in Nepal have already installed solar water heaters in their homes and out of them 80% are said to be installed in Kathmandu valley alone. Every year more than 2000 solar water heaters are installed in the country, according to a 1997 study carried out by the Water and Energy Commission Secretariat (WECS) [1, 5].

2. IMPORTANCE OF SOLAR ENERGY

The potential of solar energy as an alternative energy resource has been recognized since long time ago. The gain in momentum to develop solar energy technologies, in recent years, has primarily been a result of increasing costs of conventional sources of energy and an increasing recognition of environmental problems resulting from its over exploitation.

Table 1 Average temperature distribution and sunshine hours in different development regions of Nepal during the months of June and December [2]

Region	June			December		
Tarai	Temp Max. (°C)	Temp Min. (°C)	Sunshine hours (Hrs)	Temp Max. (°C)	Temp Min. (°C)	Sunshine hours (Hrs)
Far Western Development Region	33	22.5	7	21	7.5	7
Mid Western Development Region	33	22.5	7	19.5	7.5	7
Western Development Region	30	21	7	22.5	7.5	7.25
Central Development Region	30	21	6.25	22.5	7.5	7.5
Eastern Development Region	30	21	5.25	21	7.5	7.75
Mid Hill						
Far Western Region	30	15	7	16.5	3	7.25
Mid Western Region	24	13.5	6.5	12	4.5	7.5
Western Region	16.5	9	7	10.5	4.5	6.75
Central Development Region	16.5	10.5	4.5	10.5	4.5	7.5
Eastern Development Region	15	15	4.75	15	4.5	7.75
Mountain						
Far Western Region	19.5	9	6.75	9	1.5	7.5
Mid Western Region	16.5	9	7	10.5	3	7
Western Region	15	10.5	6.5	10.5	3	6.75
Central Development Region	15	9	4.25	10.5	3	7
Eastern Development Region	15	10.5	4	10.5	3	6.75

Nepal possesses an abundant amount of solar energy resource with the solar insolation ranging between 4 to 5 kWh per square meter per day and on an average of more than 6.5 hours of sunshine per day. Table 2 shows the solar radiation in different parts of Nepal.

3. Potential and Market of SWHs in Nepal

Nepal is largely relying on its traditional forest resources for most of domestic energy requirement. Most of commercial and industrial energy requirements are met by non-renewable fossil fuel with a very limited share from hydroelectric and solar. Since fossil fuels are not available in the country, expenditure on the import of petroleum products drains the country's limited foreign exchange reserves – about 40% of Nepal's total income from export is spent for fuel imports [3]. The prevailing pattern of energy use indicates many elements of unsustainability. The energy problem in Nepal arises not only from excessive reliance on non-renewable energy sources, but also from the excessive use of forest resources at an unsustainable rate creating environmental degradation. The vast potential of other forms of renewable energy, e.g., solar or hydro, remains virtually undeveloped.

An overview of the energy consumption pattern in the domestic, industrial and commercial sectors of Nepal suggests that a considerable quantity of the energy consumed is for water heating purposes. Using solar water heaters in household sector, on average, saves 20% unit monthly, while in commercial sector 42% and in public sector 40% unit in the current electricity consumption (for water heating) per month as reported by WECS [9]. This entire scenario indicates that the use of SWHs can bring economical benefits to the users in the long run as electricity tariff are quite high in the country. The current government tariff for the country is NRs. 9.95/kWh. This tariff is for each unit after 250 units of consumption in each month.

The use of SWHs is currently limited to domestic activities like hot shower, cloth washing and kitchen use, but there is great prospect to use solar water heaters to supply hot water to various industries like dairy, dying, distilleries, and brewery. Likewise SWH is equally important to supply hot water to commercial complexes like hotels, resorts, schools and college hostels, hospitals, and nursing homes. Similarly, besides water heating, SWHs are significant for other applications like solar floor/wall heating in cold areas and solar refrigeration in other areas.

At present, Nepal's SWH market is growing steadily mostly in urban regions. More than 30,000 conventional SWHs and 850 evacuated tube SWH systems have been installed throughout the country. Taking the size of the population into account, with 5 m^2 to 6 m^2 of collector surface per 1000 inhabitants, Nepal can be counted in the top five countries in the world in terms of solar market penetration. It is estimated that only 10% of total residential sector, 60% of commercial sector (hotels and lodges), 20% of schools and less than 1% of industrial sector in Kathmandu are currently using SWHs. No SWHs are found to be used for industrial purpose except for residential use in the industries. Only a few local distilleries (lickers producer) are using SWH for water heating purpose.

The size of SWHs installed in Nepal is mostly of 200-liter capacity. The overview on the size of the installed SWH can be seen from the study conducted by WECS [1] as shown in Table 3.

The total SWH collector area installed sector-wise in Nepal is said to be 126,000 m^2 and further potential for 1,400,000 m^2 is envisaged in a separate study report. The installation and future potential of SWH are shown in Table 4.

4. SOLAR WATER HEATING TECHNOLOGY

It is proven that the easiest and most practical application of solar energy is for water heating for domestic, commercial and industrial purposes. Although in Nepal, solar water heating started in the late 1970s, it has been proven a feasible technology to heat household water using solar energy only since 1930. Solar water heaters for hot water supply and other heating purposes for domestic, commercial and

Table 2 Solar radiation in different parts of Nepal

S. N.	Location	LAT (deg)	LON (deg)	ELV in meters	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Yearly Average in Langleys	Yearly Average in $kwh/m^2/day$
1	Dadeldhura	29.18	80.35	1865	288	356	420	500	519	398	344	335	347	366	326	282	373	6.08
2	Mahendra Nagar	29.02	80.13	176	320	395	475	530	529	435	392	390	392	378	346	304	407	6.64
3	Khajura	28.06	81.34	190	329	402	480	561	576	461	418	396	377	392	366	324	423	6.90
4	Gularia	28.10	81.21	215	325	402	480	561	576	461	418	396	377	391	366	321	423	6.90
5	Tulsipur	28.08	82.18	725	337	434	523	600	629	396	370	340	336	392	382	338	423	6.90
6	Surkhet	28.36	81.37	720	309	390	457	551	566	429	407	390	390	394	348	308	412	6.72
7	Jumla	29.17	82.10	2300	293	359	428	515	545	522	413	395	410	378	339	295	408	6.65
8	Dhungadhi	28.41	80.36	167	326	396	478	561	571	429	508	406	354	378	360	318	424	6.91
9	Lumia	28.18	83.48	1642	316	384	454	488	424	343	317	300	341	360	337	298	363	5.92
10	Pokhara Airport	28.13	84.00	827	305	373	437	478	429	375	359	335	350	357	338	299	370	6.03
11	Parwanipur	27.04	84.58	115	349	417	490	544	560	454	417	396	380	409	369	331	426	6.95
12	Taulihawa	27.33	83.04	94	347	422	501	573	571	454	449	416	397	415	379	337	438	7.14
13	Bhairawa Agri	27.32	83.28	120	353	429	510	578	586	454	443	416	384	408	379	337	440	7.18
14	Bhairawa	27.31	83.27	109	350	429	505	578	586	454	443	416	384	408	379	337	439	7.16
15	Simara Airport	27.10	84.59	137	349	420	485	534	534	422	464	416	357	393	372	333	423	6.90
16	Bhaktapur	27.40	85.26	1330	313	379	436	484	476	374	343	331	361	369	341	305	376	6.13
17	Kathmandu Airport	27.42	85.22	1367	319	386	445	494	487	379	343	331	370	376	347	310	382	6.23
18	Butwal	27.42	83.28	205	328	403	475	543	544	412	406	376	347	380	356	319	407	6.64
19	Tansen	27.52	83.32	1067	306	378	440	494	481	363	364	331	324	341	352	310	374	6.10
20	Okhaldhunga	27.18	86.3	1720	318	391	433	460	413	347	364	326	334	358	355	315	368	6.00
21	Bhojpur	27.11	87.03	1595	322	391	459	480	460	379	358	346	361	366	343	308	381	6.21
22	Khumaltar	27.39	85.20	1350	325	389	454	504	502	401	353	346	383	388	350	314	392	6.39
23	Rampur	27.37	84.25	256	335	404	488	538	523	422	444	436	356	380	360	331	418	6.82
24	Hetauda	27.26	85.03	466	338	408	476	529	539	422	390	371	352	396	361	320	409	6.67
25	Dhulikhel	27.37	85.33	1552	317	382	445	489	487	369	343	326	343	365	347	314	377	6.15
26	Taplejung	27.21	87.40	1732	318	373	416	465	465	347	343	331	334	346	339	307	365	5.95
27	Dhankuta	26.59	87.21	1445	335	395	466	500	507	410	374	432	417	377	356	318	407	6.64
28	Biratnagar	26.29	87.16	72	344	412	489	535	523	437	400	397	382	398	369	329	418	6.82
29	Tarahawa	26.42	87.16	200	349	414	488	545	533	464	400	391	386	397	368	328	422	6.88
30	Chandragadhi	26.34	88.03	120	349	415	489	535	528	431	389	391	400	394	368	329	418	6.82
31	Biraha	26.39	86.13	102	343	422	493	550	538	437	416	396	382	397	374	340	424	6.91
32	Dharan Bazar	26.49	87.17	444	345	410	479	525	502	416	395	371	349	370	364	327	404	6.59
33	Hardinath	26.46	85.59	93	358	436	506	574	559	453	448	412	390	405	387	345	439	7.16

Source: Agro - Climatic Data, FAO Headquarters, Rome, Italy

Table 3 Capacity of SWH installed in different sectors

	Percentage of Installation		
Capacity	Household Sector	Commercial Sector	Public Sector
Less than 100 liters	3.1 %	3.1 %	0.0 %
100 liters	10.42%	0.0 %	0.0 %
200 liters	51.0 %	56.2 %	75.0 %
300 liters	32.3 %	6.3 %	0.0 %
400 liters	3.1 %	0.0 %	0.0 %
500 liters or above	0.0 %	31.3 %	25.0 %
Not stated	0.0 %	3.12%	0.0 %
	100 %	100 %	100 %

Table 4 Sector-wise SWH collector area installation and future potential

S.N.	Usage	Installed	Potential
1	Residential Sector	100,000 m^2	1,000,000 m^2
2	Hotels and lodges	20,000 m^2	200,000 m^2
3	Schools	5,000 m^2	100,000 m^2
4	Hospitals and health centers	1,000 m^2	50,000 m^2
5	Industries	-	50,000 m^2
Total		126,000 m^2	1,400,000 m^2

industrial applications have been employed extensively in Australia, Israel, and Japan, and were quite popular in California and Florida prior to World War II. Currently, solar water heaters are being used extensively all over the world.

The most common design currently use in Nepal is an open-loop natural-circulation type developed in the 1970s [6] and hardly altered since then. The design consists of the flat plate collector made of galvanized iron (GI) pipe as riser pipe and with black coated (non-selective coating) aluminum sheet as absorber beneath and adjoined with the pipe, fixed in GI casing with top glass cover. A hot water storage tank (mostly 200-liter capacity) made of black mild steel sheet with a cover tank made with GI sheet after a layer of insulation rapped by glass wool blanket.

In an experiment, it was found that the efficiency of the flat plate collector of present design, during 8 hrs of current exposure, was around 22.24%. The experiment was carried out in two panel collectors, each having an effective area of 1.55 m^2 and 100-liter capacity storage tank. The fluid temperature at the inlet and outlet was found to be 34.63°C and 44.43°C, respectively with top panel temperature of 65.67°C. The efficiency reported is much lower in comparison to the theoretical efficiency [7].

The existing SWH system has deteriorated life expectancy. There is hardly any similarity among manufacturers about the system life expectancy which is believed to be 25 years but in reality it is found to be much lower. The life expectancy of existing system is believed to be approximately around 5 years or less than 25 years, which clearly shows that the quality of the system is deteriorating.

This device also has limitation; that it is not suitable for frost-prone areas and large-scale system [8, 9]. Besides it should always to be placed above the roof to maintain gravity flow. Few manufacturers have started working on force circulation system using the same category of solar hot water system but could not gain appreciable market due to high cost and poor marketing performance.

There is not any report that indicates any system manufactured with indirect heating using heat exchanger with anti-freeze liquid, which is very much essential for locations where the temperature goes down below 0°C temperature. There is also not any record of a single unit manufactured or installed solar hot water system for generating high heat for industrial large-scale application.

Since few years back, some trading houses imported the solar hot water system with indirect heating that used heat exchanger fluid and evacuated tube collector type of both direct and indirect heating. This system has reached significant market and filled the gap that was not covered by the present conventional system. However, these systems are quite expensive and most of the consumers could not afford them and have to rely on the existing local-made conventional device.

Although Nepal has had several decades of experience in the field of SHW system, the technology in application has been in the same state as it was developed in 1970s. No significant modification has been made to enhance the system efficiency. The unhealthy competition in this sector however gave rise to the increasing trend of developing cheap solar water heaters thereby leading to quantitative increase with compromise over quality. This scenario urges the set up of an immediate quality monitoring and controlling mechanism with minimum standardization.

There is an urgent need for R&D to improve the efficiency of the existing local SWH designs and introduce more effective and economical designs for large-scale industrial and commercial applications as well as for frost-prone regions. Institutions like the Center for Energy Studies (CES), Royal Nepal Academy of Science and Technology (RONAST), and Research Center for Applied Science and Technology (RECAST) could play an active role in the field of R&D.

All other renewable energy technologies like micro-hydro, solar photovoltaic, solar cookers, solar dryers, solar pumps and biogas are prioritized and given due importance for promotion, development and dissemination. The equipment for these technologies are not even required to pay for value-added tax (VAT), customs and other taxes [10]. But this is not the case with solar water heater technology. The manufacturers who are willing to import raw materials and manufacture a more efficient design of SWH are thus reluctant to promote the technology. The lack of priority given to SWHs is one of the main barriers of cost reduction.

Although SWHs have similar significance with other clean energy technologies and have equal potential to contribute in supplying heat energy requirement for domestic, commercial and industrial sectors, SWHs are deprived of the support from governmental and non-governmental sectors as well as renewable energy stakeholders and donors. There is therefore an urgent need to achieve sequential growth on SWH technology and application in Nepal to catch up with the worldwide development pace of the sector.

5. RECENT DEVELOPMENT

Since the last few months, some RE professionals and few institutions have realized the significance of the sector and showed interest in its promotion. Thus some development practices have been undetaken and resulted to technology transfer and capacity building on the present trends in the developed countries. Training on large-scale solar hot water system recently conducted jointly by Renewable Energy Development Program/UNDP, Alternative Energy Promotion Center and European Union's Asia Ecobest Programme on large-scale solar hot water system is an example of such development. The Association of Solar Thermal Energy Development of Nepal (ASTED Nepal) in association with ESCO Nepal has initiated the prototype development jointly with Kathmandu University on copper fin solar water heater and organized an exhibition to share the experience with a number of manufacturers. The Ad-hoc Committee of ASTED Nepal is created among the manufacturers to initiate and access some development, quality control and monitoring activities.

These are the positive impact resulting from training, but the sector still needs due attention and support from governmental, non-governmental and other promoters to accelerate further research and development, technology transfer and training; education exposure to the manpower involved in the sector; together with some standardization, monitoring and quality control mechanisms.

Introduction of the copper fin collector in the market is still difficult because of the high cost involved for importing the fins, aluminum channels, and toughened glass with high transmittivity.

ESCO Nepal has also initiated the introduction of Stainless Steel Storage tank with polyurethane insulation, copper fin and evacuated tube collector to the market to enhance the efficiency of the present system, but these result in significant rise in cost. Polyurethane is a liquid prepared from the mix of two chemicals (polyol and isocynate). The liquid, when sprayed or poured with desired density, turns into foam which will ultimately turn into solid taking the shape of the container in SWH. Hence to get control, monitoring and implementation of minimum standardization on SWH manufacturing required subsidy or some sort of incentive mechanism.

Most of the SWH installations are concentrated in the capital city only and the rest of the country is deprived of using this technology, even though there is high potential of solar water heating. So far certain lodges and hotels along trekking routes in areas frequently used by tourist, have installed SWHs and have found to be beneficial and cost effective as the cost can be included in the service they pass on to their customers. Except for one or two, most of the SWH manufacturers are based in the capital. Thus the promotion of the SWHs is so far limited to the capital city only. There is high potential in the rural areas on the installation of SWHs, if the financial burden can be lowered for them. This can be achieved by providing subsidy and micro-credit loan schemes with the involvement of donor agencies and financial institutions.

6. PROBLEMS AND ISSUES

The following problems and issues are listed as a barrier in the promotion of solar water heater systems in Nepal:

- The inefficient and ineffective current technology has deteriorated quality,
- The expected lifetime of the systems is much lower than it should be theoretically,
- The current technology is not suitable for frost-prone areas at high altitude,
- Cost of the SHWs is high as there is no subsidy given to SWH systems in comparison to other renewable energy technologies (RETs),
- There is a lack of standardization in the manufacturing systems among the manufacturers,
- The financial institutions are inactive to support SWHs financially, and
- There is a lack of awareness among potential users on saving conventional loss while using the SWHs.

7. CONCLUSIONS

SWH applications have high prospects in the context of Nepal. Although it has been decades since Nepal started using the technology for water heating, further applications of the technology other than household use have not been explored yet. It will be a great achievement if the technology can be implemented in industrial process heating, which will surely contribute in reducing national energy demand in a significant amount. Lessons to be learned from renewable energy policies implemented in developed countries like USA and the European countries should be given due importance by all sectors based on their potential to contribute to national development [4, 11].

Research and development in these sectors is an important aspect in order to address the issues like efficient design, low-cost technology, and extended life span of the existing systems. The standardization of the manufacturing technology is another important need with which the existing deteriorating quality of the system can see an improvement. The financial aspect of the system is still in a niche in which the existing financial institutions are not able to pay any attention towards. The government should review its policy on SWHs and should be able to waive the add-up costs like VATs, customs and taxes levied on the system.

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