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Risk/Return Profile and Input/Output Variables of Solar Water Heating (SWH) System and Policy Frame Work in India

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Abstract

In this paper, the present and future energy consumption, electricity demand, potential of renewable energy sources, risk/return, input & output variables and national energy policy in India are presented. India is a net energy importing country, with almost 96% of its annual needs relying on imported crude oil and refined products from neighboring Arab countries apart from our own exploration at different parts of India. Due to increasing fossil fuel combustion to meet growing national energy demand, especially electricity generation. A great deal more could be done to improve energy efficiency, and new and renewable energy schemes particularly Solar Water Heating systems should be advocated on different levels. To achieve this, all obstacles including institutional barriers to investment in renewable technologies (SWH) and national energy plan need to be addressed urgently. Thus, the government is invited to create a Sustainable Energy Unit, which will coordinate government cross-departmental thinking and provide adequate information to the public and to private investors. So, that we can avoid the utility cost on generation.

Introduction

The economic value of a domestic SWH system is in the amount of electrical energy it saves and a certain degree of independence from conventional energy supply it creates. The same amount of electrical energy would otherwise be used to heat sanitary water, which is a cost that can be avoided by using solar resource for water heating. Saved energy depends on the size of the system, its operation by the consumer, solar radiation levels and, most significantly, the cost of displaced conventional energy. As conventional fuel prices are unstable and liberalized electricity markets sensitive to variations in fuel supply, reducing dependency on outside electricity sources can be considered a risk mitigation action. Environmental concerns have made household SWH systems a positive status symbol. A solar thermal system has certain external benefits, like CO2 and other air polluting emissions savings, reducing dependency on energy imports, reducing further external costs related to the use of fossil fuels or nuclear power and reducing peak electricity demand if solar thermal displaces electrical heating [2]. Benefits have to be balanced with costs of a solar thermal system, consisting of funds needed to buy and install the system, operation and maintenance costs, costs of repairs, costs of decommissioning and all other costs linked with the decision to invest. Implementing domestic SWH, just like any other project, has its risks. Household owners as investors and financial institutions as loaners are naturally reluctant to accept risks that could create unexpected negative fluctuations in cash flows or value of a project. To ensure financing is feasible, there is a fundamental requirement to manage associated risks, in a way that minimizes the probability of occurrence that could give rise to a negative financial impact on the project. Using risk analysis for investment planning of SWH is a domain not explored in the available literature.

Solar Water Heating Systems

We are blessed with Solar Energy in abundance at no cost. The solar radiation incident on the surface of the earth can be conveniently utilized for the benefit of human society. One of the popular devices that harness the solar energy is solar hot water system (SHWS).A solar water heater consists of a collector to collect solar energy and an insulated storage tank to store hot water. The solar energy incident on the absorber panel coated with selected coating transfers the heat to the riser pipes underneath the absorber panel. The water passing through the risers get heated up and are delivered the storage tank. The re-circulation of the same water through absorber panel in the collector raises the temperature to 80 C (Maximum) in a good sunny day. The total system with solar collector, storage tank and pipelines is called solar hot water system.

Broadly, the solar water heating systems are of two categories. They are: closed loop system and open loop system. In the first one, heat exchangers are installed to protect the system from hard water obtained from bore wells or from freezing temperatures in the cold regions. In the other type, either thermosyphon or forced circulation system, the water in the system is open to the atmosphere at one point or other. The thermosyphon systems are simple and relatively inexpensive. They are suitable for domestic and small institutional systems, provided the water is treated and potable in quality. The forced circulation systems employ electrical pumps to circulate the water through collectors and storage tanks. The choice of system depends on heat requirement, weather conditions, heat transfer fluid quality, space availability, annual solar radiation, etc. The SHW systems are economical, pollution free and easy for operation in warm countries like ours. Based on the collector system, solar water heaters can be of two types.

Types of solar collectors are used for residential applications

Flat Plate Collectors (FPC) based Solar Water Heaters

The solar radiation is absorbed by Flat Plate Collectors which consist of an insulated outer metallic box covered on the top with glass sheet. Inside there are blackened metallic absorber (selectively coated) sheets with built in channels or riser tubes to carry water. The absorber absorbs the solar radiation and transfers the heat to the flowing water. There are around 60 BIS approved manufacturers of Solar Flat Plate Collectors.

Figure 2: FPC based SWH System.

Integral collector-storage(ITS) systems

Also known as ICS or *batch* systems, they feature one or more black tanks or tubes in an insulated, glazed box. Cold water first passes through the solar collector, which preheats the water. The water then continues on to the conventional backup water heater, providing a reliable source of hot water. They should be installed only in mild-freeze climates because the outdoor pipes could freeze in severe, cold weather.

Evacuated Tube Collectors (ETC) based Solar Water Heaters

Evacuated Tube Collector is made of double layer borosilicate glass tubes evacuated for providing insulation. The outer wall of the inner tube is coated with selective absorbing material. This helps absorption of solar radiation and transfers the heat to the water which flows through the inner tube. There are around 44 MNRE approved ETC based solar water heating suppliers. Solar water heating is now a mature technology. Wide spread utilization of solar water heaters can reduce a significant portion of the conventional energy being used for heating water in homes, factories and other commercial and institutional establishments. Internationally the market for solar water heaters has expanded significantly during the last decade.

Figure 3: ETC based SWH System.

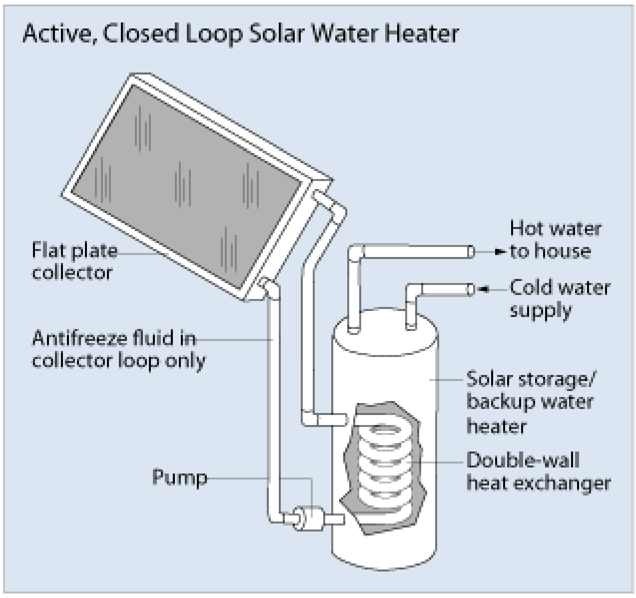
Types of active solar water heating systems

Direct Circulation Systems (DCS)

Pumps circulate household water through the collectors and into the home. They work well in climates where it rarely freezes.

Indirect circulation systems

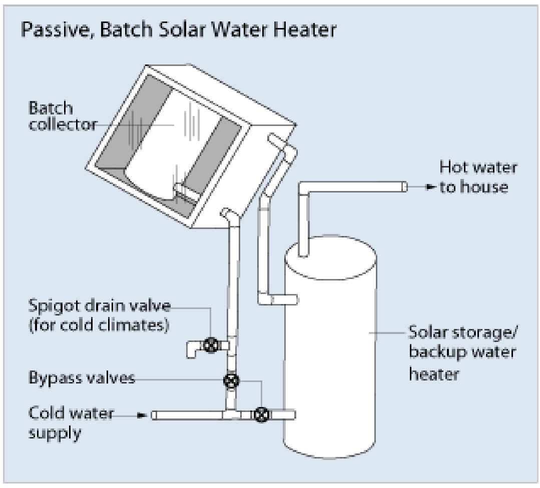
Pumps circulate a non-freezing, heat-transfer fluid through the collectors and a heat exchanger. This heats the water that then flows into the home. They are popular in climates prone to freezing temperatures.



Passive solar water heating systems are typically less expensive than active systems, but they're usually not as efficient. However, passive systems can be more reliable and may last longer. There are two basic types of passive systems:

Integral collector-storage passive systems
These work best in areas where temperatures rarely fall below freezing. They also work well in households with significant daytime and evening hot-water needs.

Thermosyphon systems
Water flows through the system when warm water rises as cooler water sinks. The collector must be installed below the storage tank so that warm water will rise into the tank. These systems are reliable, but contractors must pay careful attention to the roof design because of the heavy storage tank. They are usually more expensive than integral collector-storage passive systems.



Solar water heating systems almost always require a backup system for cloudy days and times of increased demand. Conventional storage water heaters usually provide backup and may already be part of the solar system package. A backup system may also be part of the solar collector, such as rooftop tanks with thermosyphon systems. Since an integral-collector storage system already stores hot water in addition to collecting solar heat, it may be packaged with a demand (tankless or instantaneous) water heater for backup.

Salient Features of Solar Water Heating System

Solar Hot Water System turns cold water into hot water with the help of sun's rays.

- Around 60^oC. – 80^oC temperature can be attained depending on solar radiation, weather conditions and solar collector system efficiency.
- Hot water for homes, hostels, hotels, hospitals, restaurants, dairies, industries etc.
- Can be installed on roof-tops, building terrace and open ground where there is no shading, south orientation of collectors and over-head tank above SWH system.
- SWH system generates hot water on clear sunny days (maximum), partially

clouded (moderate) but not in rainy or heavy overcast day.

- Only soft and potable water can be used
- Stainless Steel is used for small tanks whereas Mild Steel tanks with anticorrosion coating inside are used for large tanks
- Solar water heaters of 100-300 litres capacity are suited for domestic application.
- Larger systems can be used in restaurants, guest houses, hotels, hospitals, industries etc.

Though the initial investment for a solar water heater is high compared to available conventional alternatives, the return on investment has become increasingly attractive with the increase in prices of conventional energy. The payback period depends on the site of installation, utilization pattern and fuel replaced.

Selecting a Solar Water Heater

Before you purchase and install a solar water heating system, you want to do the following:

- Consider the economics of a solar water heating system.
- Evaluate your site's solar resource.
- Determine the correct system size.
- Determine the system's energy efficiency.
- Estimate and compare system costs.
- Investigate local codes, covenants, and regulations.

SWH Project Risk Identification

Household owners make energy investment decisions based on their estimation of both, the risks and returns of a project.

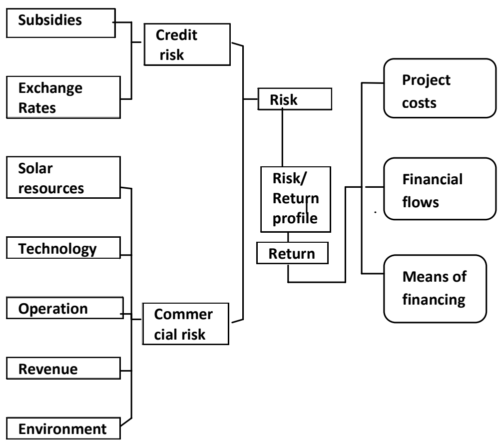


Figure 3: Risk / return profile parameters.

In considering a project, an owner should assess all the parameters of a risk/return profile, as shown Fig. 3. Risk / return profile parameters Countrywide Positioning of Domestic Solar Water Heating Systems using Risk Analysis. Each risk should be assessed to determine ways of reducing its potential impact on the project. Evaluating returns involves verifying the cost and revenue projections and then comparing the financials of the project with the cost of financing to be used. Risks can be categorized in wide ranges by dividing them into project risks, political/institutional risks and market risks. Project risks include:

- *Lead time risks* - associated with estimating the time and costs involved in the planning stage.
- *Construction risks* - associated with the construction phase and risks that may impact the project not being completed and operating on schedule.
- *Performance risk* – the possibility that the project does not perform or operate as expected.

Elements include the operational risk like machinery breakdown and property damage; the resource risk like a lack of sunlight; the technology risk like the quality of solar collectors and natural hazard risks. Political and institutional risks include a wide range of risks relating to the political, regulatory or institutional environment in which the project is operating. In case of household SWH systems these risks are secondary and will not be discussed. Broadly, they include legislative and political changes, administrative risks, risks associated with participating in Kyoto markets and any possible ownership problems. Market risks include:

- *Financial risk* – relating to the capital structure of the project and its ability to generate cash flows sufficient to fund a planned investment, operations and maintenance expenditures, service debt, and providing reasonable returns to the owner.
- *Economic risk* – relating to interest rates, exchange rates and product prices risk.
- *Subsidy risk* – risk of not getting subsidized from the Fund for Environmental Protection and Energy Efficiency, and the risk of payment delays.

Categories since some risks have been completely eliminated. For example, no permits are needed in India to install a solar thermal system in buildings which are not registered as historically important, and the focus is on households which do not belong in this category. In addition, no direct legislation defining the status of solar thermal systems exists. Consequently, variables to which risks could be associated are not defined by the legislator. Household SWH systems are generally small-scale projects, so most usual risks associated with renewable energy sources are considered irrelevant, such as roadwork, land ownership or public opinion (project being done on private property of the owner).

Project Input and Output Variables

Project income is equal to displaced energy that would otherwise be used to heat unitary water. Savings can be well above 60%. The most common way of heating water in India is by using electrical energy, therefore, the project income is considered to be equal to the amount of saved electrical energy priced according to current tariff systems. Project costs for SWH systems can generally be divided into:

- Solar collector costs,
- Storage tank costs,
- Other equipment costs (piping, etc.),
- Consultation costs,
- Installation costs.

The manufacturing price of solar collectors and other equipment are dependent on the prices of western manufacturers since there are no adequate factories producing solar equipment in India.

This creates a certain uncertainty over prices, especially taking into account that the projected domestic SWH systems are planned to be built in the near future when different prices might apply. Stainless steel storage tanks with efficient insulation and spiral heat exchangers, including outside measurement devices are not a large investment in the EU countries, which is contrary to India due to import policies and taxation. Summed with the prices of collectors, other equipment includes automation devices, heat exchangers, pumps, expansion tank, security devices, valves, pipes, pipe insulation, temperature sensors and mounting gear. Customizing systems according to the owner's needs brings costs to a minimum, however, the final price cannot be set until the system is operational, and hence it can be concluded there is an amount of uncertainty when assessing total system cost. Operation and maintenance costs are minimal for SWH systems and are usually only comprised of regular check-ups during annual or bi-annual maintenance.

All uncertain input variables are associated with risks and will have an impact on the project in the future. Risks are converted into monetary units so that their influence can be illustrated by changes of project financial indicators.

The chosen input variables are

- System parameters: persons in household – the fixed number of 4, the amount of hot water (60 °C) needed per person - given as 50 l for this model and the length of needed piping – given as 3 m horizontal and 2 floors 2.7 m high between collector and storage tank.
- *Initial costs:* Development and consulting, solar collector price, storage tank price, solar loop piping materials, construction equipment price, additional equipment price of pumps and automation electronics and installation costs.
- *Periodic and annual costs:* The cost of operation and maintenance every 2 years and the cost of repairs every 5 years.
- *Annual production:* solar radiation to horizontal surface and system efficiency.
- Annual savings: The price of electrical energy.

All input variables have been simulated according to probability distributions.

Selected output variables are the total cost of SWH system, electricity savings, payback time, net present value (*NPV*) and internal rate of return (*IRR*).

The total cost of the SWH system is the sum of individual expense categories. Electricity savings are the product of electricity price and produced energy from the SWH system. The produced energy is the product of total annual solar irradiation to all collectors and overall system efficiency.

NPV is calculated using (2):

$$\mathrm{NPV}(C,t,d) = \sum_{i=0}^{N} \frac{Ci}{(1+d)} \quad (2)$$

Where Ci is the i^{th} cash flow, d is the assumed discount rate, t_i is the time between the first cash flow and the i^{th}.

IRR is the discount rate which sets the *NPV* of the given cash flows made at the given times to zero and is defined by (3),

$$NPV\,(C,t,IRR) = 0. \quad (3)$$

NPV and *IRR* are calculated using Excel's internal functions *NPV* and *IRR*, based on cash flow during 25 years, which is the systems assumed lifetime. SWH systems' typical lifetime is 30 years, so this can be considered a conservative estimate. *IRR* is calculated. Payback time is calculated using lookup function to determine where cumulative cash flow becomes positive. The model is scalable and allows determining any variable an output variable.

Solar Water Heater Energy Efficiency

For a solar water heating system, use the *solar energy factor* (SEF) *and solar fraction* (SF) to determine its energy efficiency.

The solar energy factor is defined as the energy delivered by the system divided by the electrical or gas energy put into the system. The higher the number, the more energy efficient. Solar energy factors range from 1.0 to 11. Systems with solar energy factors of 2 or 3 are the most common.

Another solar water heater performance metric is the solar fraction. The solar fraction is the portion of the total conventional hot water heating load (delivered energy and tank standby losses). The higher the solar fraction, the greater the solar contribution to water heating, which reduces the energy required by the backup water heater. The solar fraction varies from 0 to 1.0. Typical solar factors are 0.5–0.75. Don't choose a solar water heating system based solely on its energy efficiency.

The Economics of a Solar Water Heater

Solar water heating systems usually cost more to purchase and install than conventional water heating systems. However, a solar water heater can usually save you money in the long run.

How much money you save depends on the following:

- The amount of hot water you use.
- Your system's performance.

- Your geographic location and solar resource.
- Available financing and incentives
- The cost of conventional fuels (natural gas, oil, and electricity).
- The cost of the fuel you use for your backup water heating system, if you have one.

On average, if you install a solar water heater, your water heating bills should drop 50%–80%. Also, because the sun is free, you're protected from future fuel shortages and price hikes.

If you're building a new home or refinancing, the economics are even more attractive. Including the price of solar water heater in a new 30-year mortgage usually amounts to between Rs 600 and Rs 900 per month. The federal income tax deduction for mortgage interest attributable to the solar system reduces that by about Rs Rs 120–Rs 225 per month. So if your fuel savings are more than Rs 675 per month, the solar investment is profitable immediately. On a monthly basis, you're saving more than you're paying.

This paper reviews the current situation and the future prospects for the application of renewable energy (SWHS) in India. It shows that, in spite of the abundance of renewable energy resources, generation of electricity and other non-electric applications are minimal. Opportunities to use renew-able as part of the Indian energy mix are many, and could bring a number of benefits, social, economic, political and environmental, among others. Barriers to do so are also many and are outlined here.

Despite the immense solar energy potentials available, solar electricity generation is attractive only under severe CO_2 emissions mitigation of the nation's energy supply system. Similarly, the penetration of small-scale hydro power technology in the electricity supply mix is favored only under CO_2 emissions constraints. Due to economy of scale, large hydropower technology takes the lion share of the entire commercial renewable energy resources share for electricity generation under any CO_2emissions constraint. These analyses reveal that some barriers exist to the development and penetration of renewable energy resources electricity production in India's energy supply system. Barriers and possible strategies to overcome them are discussed. Intensive efforts and realistic approach towards energy supply system in the country will have to be adopted in order to adequately exploit renewable energy resources and technologies for economic growth and development.

The Vision and policy frame work

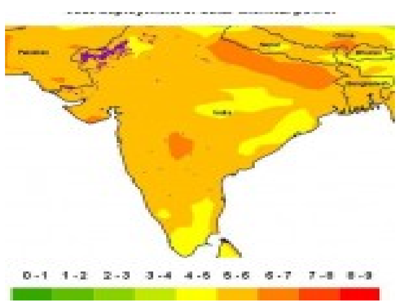
The broad vision behind the energy policy is to reliably meet the demand for energy services of all sectors including the lifeline energy needs of vulnerable households in all parts of the country with safe, clean and convenient energy at the least-cost. This must be done in a technically efficient, economically viable and environmentally sustainable manner using different fuels and forms of energy, conventional and non-conventional, as well as new and emerging energy sources to ensure supply at all times with a prescribed confidence level considering that shocks and disruption can be reasonably expected. In other words, the goal of the energy policy is to provide energy security to all.

These are economical and the main barrier to their adoption is the expense of retrofitting plumbing in households and industries. Building laws should be amended to ensure that all new buildings and factories have solar water heaters. Existing households, commercial establishments and factories should be encouraged to install solar water heaters through a DSM programme run by electricity utilities. Alternatively incentives may be given in the form of income tax rebates, property tax rebates, rebates in transfer fees and rebates in electricity charges. The government, including the defence and public sector, account for a Significant amount of new construction and installation. They can set the example by conforming to revised building laws.

Solar water heating is now a mature technology. Wide spread utilization of solar water heaters can reduce a significant portion of the conventional energy being used for heating water in homes, factories and other commercial & institutional establishments. Internationally the market for solar water heaters has expanded significantly during the last decade. It is estimated that over 107 million sq.m. of collector area has so far been installed worldwide for heating water. In the country, the collector area so far installed for water heating is over 1.00 million sq.m. Ministry has plans to add another 1.00 million sq. m. in next two years.Though the initial investment for a solar water heater is high compared to available conventional alternatives, the return on investment has become increasingly attractive with the increase in prices of conventional energy.

The payback period depends on the site of installation, size of equipment, subsidies, utilization pattern and fuel replaced. To offset the high initial investment for solar water heaters, the Ministry is currently implementing a soft loan scheme through seven designated banks and IREDA, which has now been extended to all kind of Financial Institutions.

India commits over $210 Million to Solar Thermal Projects totaling 1300 MW by 2013



According to a recent article written by the Press Trust of India, the Union Government of India has pledged Rs 1,000 crore ($ 210.5 million U.S) for subsidizing solar thermal power generation, it says is in line with its plan to boost utilization of renewable energy resources. Projections for Electricity Requirement by MoP

Table 1.0

Year	Billion kWh		Installed Capacity (GW)	
	8%	9%	8%	9%
2006-07	700	700	140	140
2011-12	1029	1077	206	215
2016-17	1511	1657	303	331
2021-22	2221	2550	445	510
2026-27	3263	3923	655	785
2031-32	4793	6036	962	1207

The announcement was made by Union Ministry of New and Renewable Energy (MNRE). The MNRE aims to produce 1,300 MW of power from the new energy sector within the next three years.

Renewable Energy Resources

Table 1.1 (Source: Respective Line Ministries).

Resources	UOM Year	Present	Potential	Basics of accessing potential
Solar				
PV	Mtoe	-	1,200	Expected by utilising 5 million hectare wasteland at an efficiency level of 15 % for Solar PV cells
Thermal	Mtoe	-	1’200	MWe scale power plants using 5 million hectare
Wind	Mtoe	<1	10	Onshore potential of 65,000 MWe at 20% LF
Small Hydropower	Mtoe	<1	5	
*The availability of land inputs for getting projected yields is a critical constraint. **based on 50 percent under use.				

The Government of India has proposed to declare Chandigarh, Amritsar and New Delhi as ‘solar cities’ under the National Solar Mission.

Use of solar water heating worldwide:

Top countries using solar thermal power, worldwide: GW_{th}

Table 1.2

SNo	Country	2005	2006	2007	2008	2009
1	China	55.5	67.9	84.0	105.0	134.0
2	European Union	11.2	13.5	15.5	20.0	22.8
3	Turkey	5.7	6.6	7.1	7.8	N/A
4	Japan	5.0	4.7	4.9	5.0	N/A
5	Israel	3.3	3.8	3.5	3.6	N/A
6	Brazil	1.6	2.2	2.5	2.4	2.9
7	United States	1.6	1.8	1.7	2.0	2.2
8	Australia	1.2	1.3	1.2	1.3	>1.3
9	India	1.1	1.2	1.5	1.7	>1.7
10	Germany	0.5	0.6	0.6	0.8	0.9
11	Mexico	?	?	?	0.7	N/A
World (GWth)		88	105	126	149	N/A

Experimental Observations

1. In SWH system the inclusion of energy losses through the side walls of a reasonable thickness reduces the efficiency of the system by about 5%. The integrated side energy losses for the whole day are not equal for the various segments of the wall. Hence, it will be economical to construct wedge shape walls, thickness decreasing downward, instead of usual rectangular walls.
2. A transparent honeycomb insulated ground integrated-collector-storage system has been investigated for the engineering design and solar thermal performance. The system consists of a network of pipes embedded in a concrete slab whose surface is blackened and covered with transparent insulation materials (TIM) and the bottom is insulated by the ground. Heat may be retrieved by the flow of fluid through the pipe. The pipe network depth of 10 cm and the TIM cover made of 5 cm compounded honeycomb seem suitable for the proposed system. Solar gain (solar collection efficiency of 30–50% corresponding to collection temperature of 40–60°C) and the diurnal heat storage characteristics of the system are found to be of the right order of magnitude for solar water cover.
3. A rectangular cavity used as a simplified geometry. With the aid of particle image velocimetry (PIV) the flow field in the centre-plane of the rectangular cavity has been visualized. Three-dimensional flow simulations were performed using a commercial CFD package. The impinging jet formed by the inlet flow directed towards the opposite wall was found to produce localised turbulence in the cavity, with an inlet Reynolds number as low as 360. This turbulence was found to affect the flow field and heat transfer in the cavity when the inlet Reynolds number was above 1200. It is shown that, with the boundary conditions used in this study, most of the heat transferred was in the bottom half of the cavity. This is not the ideal situation for optimization of

solar water heating systems. Some aspects concerning modeling the flow and heat transfer in horizontal mantle heat exchangers in solar water heaters.

4. The results obtained from laboratory testing of four liquid flat plate collectors. The collectors tested include a wavy fin collector, two flat plate heat pipe collectors, and a clip fin solar collector. The clip fin solar collector was tested, so as to compare this simple and inexpensive type of collector against the more costly wavy fin collector and the flat plate heat pipe collector. Using a similar basis of comparison, efficiency values have been formulated in order to compare the performance of the solar collectors. The experimental results show the clip fin solar collector to be promising, with experimental efficiencies approaching 86 per cent.

Conclusion

In many countries, the energy deficit is wide and levels of access to modern forms of energy are extremely low. Yet even a cursory glance at the country reports shows a wealth of untapped resources with a huge potential for development of Renewable Energy Technologies (RETs) that are suited to local conditions.

Many developing countries already have considerable experience with RETs, but that expected results have not been forthcoming. Some common causes for this failure can be identified. In almost every case attempts have been made to import sophisticated electricity-producing technologies in an *ad hoc* manner, with heavily subsidized or donor sponsored projects working well while support lasts but failing once it is withdrawn.

The initial costs of the SWHS on offer have been far beyond the ability of poor individuals and communities to purchase and maintain them. If communities are not consulted as to their real needs and capacities, there will be a mismatch between what is provided and what is actually required. Inappropriate technologies which local skills are not adequate to operate or maintain do not, generally, drive development. The lack of coherent policies has led to a lack of coordination between stakeholders that have not been conducive to efficient development. Furthermore, a concentration on SWHS for residential supply to low income households, rather than for productive uses, has made financial institutions shy of RETs, considering them as risky and of low profitability.

Sensitivity analysis shows that most influential risks are linked to available solar irradiation, overall system efficiency and displaced electricity price in the process of transforming solar energy to heating energy for water. Risks related to price differences can be reduced by narrowing input variable ranges just before the project is about to start.

It is concluded that India is lagging behind other countries of similar economic capacity with respect to the development of its renewable energy resources, and that a concerted action among different sectors of the economy is necessary to alter the present situation. Otherwise, the opportunity ahead will be lost and India will remain a net importer of new energy technologies.

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