INVESTMENT COST ANALYSIS OF SOLAR HOT WATER COMBINED WITH AN ECONOMIZER FOR WATER PRE-HEATING

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has been approved by the Graduate School as partial fulfillment of the requirements for the Doctor of Philosophy Degree in Renewable Energy of Naresuan University

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Samnao Pansang

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ABSTRACT

A combination of solar hot water system with the economizer for heating the water that circulates in the hot water storage tank is presented with the objective to reduce and analyze the cost of investment. The solar collector area will be affected to the investment cost of the solar hot water system. A combined system can be reduced the cost of solar collector by using the waste heat from the economizer to produce the hot water for reaching the requirement of the industry. In this paper the economizer installs in the boiler stack of the industry and produces hot water at 60°C of 5,400 liter per day and the solar hot water system produces the hot water at the same temperature of 6,100 liter per day. The analysis is proposed by determining the solar collector plate area from the data and calculation. Investment cost of the system is 151,000 baht for the solar hot water system of 110,000 baht and the economizer of 410,000 baht for producing the total hot water of 15,000 liter per day

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CHAPTER I

INTRODUCTION

Background

The sun is a very large source of perennial source of energy and the earth intercepts about 1.7×10^{14} kW of power, which is several thousands of times larger than the total energy consumption rate on the earth. Hence, this energy consumption certainly meets the present and future needs on a continuing basis. Thus, it makes one of the most promising renewable source of energy [1]. It has been estimated that if the present rate of population growth and exploitation of readily available stored energy in fossil fuels continues, then the fossil fuels may be depleted completely in a century or so. Scientists all over the world are in search of new and renewable energy sources. Solar energy, which is abundant, clean and a safe source of energy, is more important to consider than stored energy in fossil fuels. The annual insolation of the surface of the earth amounts to 17×10^{17} kWh. In comparison, the present yield in energy gained from fossil fuels and waterpower amounts to about 70×10^{12} kWh [2]. However, use of solar energy presently poses technical problems, primarily because of inefficient collection and storage.

Solar Thermal energy (ST) is the simplest and most efficient form of renewable energy available today. When solar energy is used for on-site heat generation, the system efficiency is much greater than converting solar energy into electricity and then delivering through the power grid for the same end-use heating applications. Situated in a tropical zone, Thailand has favorable conditions and significant potential for utilizing solar water heater (SWH) compared with many other regions. Based on past studies, annual mean daily global solar radiation in Thailand is between 4.5 kWh/m^2/day in winter and 4.7 kWh/m^2/day in summer. Despite the significant potential, the overall solar water heater (SWH) market size small and under developed due to different obstacles and Thailand has not been able to capitalize this cost-efficient and reliable solar energy source, particularly in the commercial and industrial sector

Technical advances in solar water heater have been very rapid in the last 40 years. The obvious benefit to the house holders can no longer be overlooked, where the climate is ideally suited for the application of solar energy for water heating, particularly, in the present situation of acute energy shortage, Solar water heaters find wide application in large establishments like hostels, hotels, hospitals, industries such as textile, paper, and food processing, domestic uses and in heating swimming pools.

Solar hot water used in house hold, hotels and industrial are different for using in home and hotels that storage at night time to be effective because the energy time is small loss and load is needed to high consumption but for industrial use, it is advantages to use hot water at the time of production, which is one reason that makes more cost effective because the storage of the surplus energy is used again in less radiation time by no source

Rationale for the Study

Due to the rapid growth of hot water demands for industrial processes, the availability of solar power for solar hot water system in Thailand and the advantage of waste heat recovering system. These reasons can be consider as the main purpose, which is using the solar hot water system to pre-heat the circulated water for boilers by installation of the heat exchanger into system.

So, this research presents the performance analysis and investment cost hybrid solar hot water system with flat plate collector type combine with waste heat by heat exchange (called Economizer) to use the data for choosing and deciding solar hot water system that proper in technology and economic related to Thai government's investment support decision making.

Statement of the Problem

Many industries require hot water or stream system for their industrial processing purposes. Most of the industries use diesel or gas or coal boiler to produce required hot water or stream for industries processing. In such boiler large amount of heat energy is wasted through its stack. Such wasted heat can be recovered and reutilize to pre-heat we feed water to feed into the boiler. Similarly there is huge amount of energy earth gets from sun that can effectively be utilized for industrials water pre-heating by using solar hot water collector. Such solar hot water collector system can be combined with an economizer; which collects wasted heat can from stacks and can be used for pre- heating the feed water for boilers industries hence saving fuel and the cost.

Objectives of Study

1. To investigate the investment cost and evaluate energy saving from solar hot water system combined with economizer for industrial use.

2. To analyze the possibility of investing on flat plate solar hot water system combine with an economizer to the processing industries in Thailand based on the Thai government's investment support making rules.

Scope of the Study

1. This thesis need to apply on an industrial group that uses hybrid solar hot water system consisting of a flat-plate solar collector array that is combined with an economizer.

2. Evaluate the system performance and energy saving by hybrid hot water system with the help of Thai government's investment support decision making rules.

3. Collect data from the real system installation site of the hybrid solar hot water system and analyze the collected data to calculate real energy saving cost of saved energy for cleaning industry.

Benefit of the Study

1. Determination of the better energy saving by industrial hybrid solar hot water system comparing compared with the conventional systems based on economic benefit cost analysis.

2. This research help industrial companies to follow Thai government's investment decision making to install hybrid solar hot water system and would set a trend to select the appropriate system for different hot water requirement process industries in Thailand.

3. Pre-heating feed water to boiler applications in process industry.

CHAPTER II

REVIEW OF RELATED LITERATURE AND RESEARCH

Solar Water Heaters

Solar water heating technology has greatly improved in those 100 years. Modern solar water heaters will now work when the outside temperature is well below freezing and they are protected from overheating on hot, sunny days. Many models also have their own built-in, back-up heater, which can meet all of a consumer's hot water needs even when there is no sunshine. Solar water heaters can be classified as active or passive systems, direct or indirect systems.

1. Active Systems

An active system (Figure1) uses electric pumps, valves, and controllers to circulate water or other heat-transfer fluids through the collectors. They are usually more expansive than passive systems but are also more efficient. Active systems are usually easier to retrofit than passive systems because their storage tanks do not need to be installed above or close to the collectors. But because they use electricity, they will not function in a power outage. Some applications of active systems are as follows.

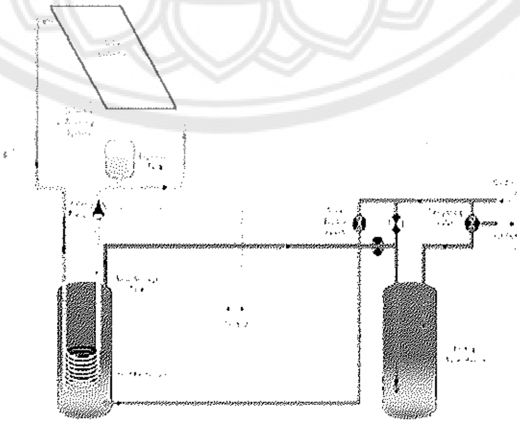


Figure 1 Active Systems [3]

1.1 Open-loop active systems

This system uses pumps to circulate household water through the collectors. This design is efficient and lowers operating costs but is not appropriate if your water is hard or acidic because scale and corrosion quickly disable the system. These open-loop systems are popular in nonfreezing climates such as Hawaii. They should never be installed in climates that experience freezing temperatures for sustained periods. You can install them in mild but occasionally freezing climates, but you must consider freeze protection. Recirculation system is a specific type of open-loop system that provides freeze protection. This design uses the system pump to circulate warm water from storage tanks through collectors and exposed piping when temperatures approach freezing. Consider recirculation systems only where mild freezes occur once or twice a year at most. Activating the freeze protection more frequently wastes electricity and stored heat. Of course. When the power is out, the pump will not work and the system will freeze. To guard against this, a freeze valve can be installed to provide additional protection in the event the pump does not operate. In freezing weather, the valve dribbles warmer water through the collector to prevent freezing. Consider recirculation systems only where mild freezes occur once or twice a year at most. Activating the freezes more frequency wastes electricity and storage heat.

1.2 Close-loop active systems

These system pump heat-transfer fluids (usually a glycol-water antifreezes mixture) through collectors. Heat exchangers transfer the heat from the fluid to the household water storage in the tanks. Double-walled heat exchangers prevent contamination of household water. Some codes require double walls when the heat-transfer fluid is anything other than household water. Closed-loop glycol systems in Figure 2.2 are popular in area subject to extended freezing temperature because they offer good freeze protection. However, glycol antifreeze systems are a bit more expensive to buy and install, and the glycol most be checked each year and changed every 3-10 years, depending on glycol quality and system temperature.

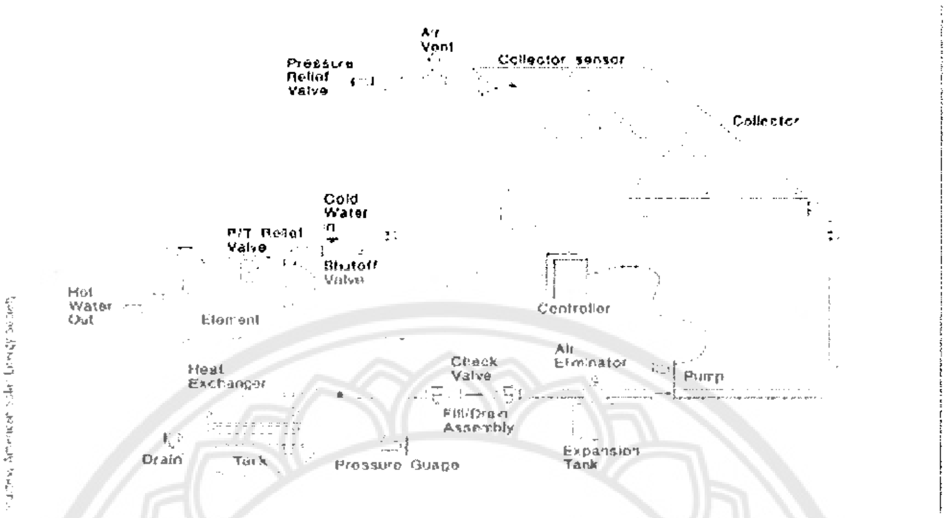


Figure 2 Glycol systems [4]

Drain back systems in Figure 3 uses water as the heat-transfer fluid in the collector loop. A pump circulates the water through the collectors. The water drains by gravity to the storage tank and heat exchanger; there are no valves to fail. When the pumps are off, the collectors are empty, which assures freeze protection and also allows the system to turn off if the water in the storage tank becomes too hot.

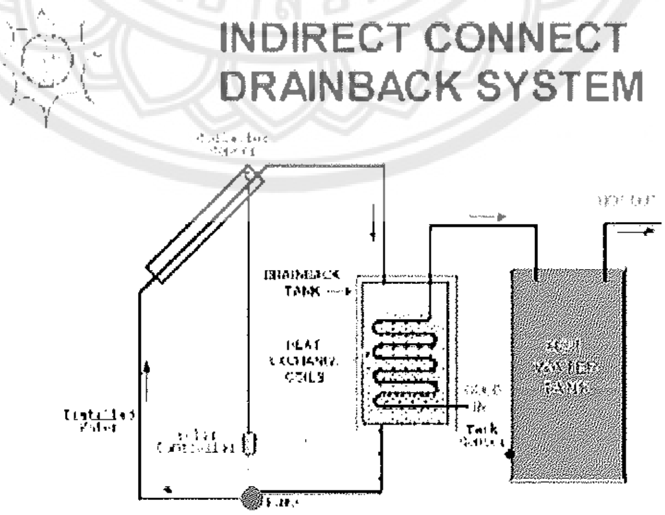


Figure 3 Drain back systems [5]

2. Passive Systems

A passive system relies on natural convection for fluid circulation.

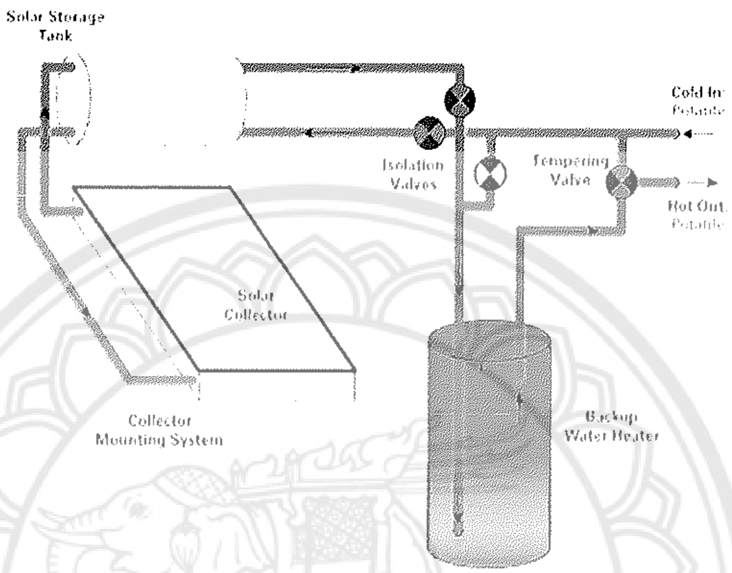


Figure 4 Passive Systems [6]

The amount of hot water a solar water heater produces depends on the type and size of the system, the amount of sun available at the site, proper installation, and the tilt angle and orientation of the collectors. Passive systems are feasible in warmer climates or for three season operation, but are generally not feasible for year-round operation in Pennsylvania. Some applications of passive systems as follows:

2.1 Batch heaters (also known as "bread box" or integral collector storage systems) This system are simple passive systems consisting of one or more storage tanks placed in and insulated box that has a glazed side facing the sun. Batch heaters are inexpensive and have few components-in other words, less maintenance and fewer failures. Batch heaters are mounted on the ground or on the roof (make sure your roof structure is strong enough to support it). Some batch heaters use "selective" surfaces on the tanks (S). These surfaces absorb sun well but inhibit radiative loss.

In climates where freezing occurs, batch heaters must either be protected from freezing or drained for the winter. In well-designed systems, the most vulnerable components for freezing are the pipes, if located in un-insulated areas that lead to the solar water heaters. If these pipes are well insulated, the warmth from the tank will prevent freezing. Certified systems clearly state the temperature level that can cause damage. In addition, you can install heat tape (electrical plug-in tape to wrap around the pipes to keep them from freezing), insulate exposed pipes, or both. Remember, heat tape requires electricity, so the combination of freezing weather and a power outage can lead to burst pipes. If you live in an area where freezing is infrequent. You can use plastic pipe that does not crack or burst when it freezes. Keep in mind, though, that some of these pipes can't withstand unlimited freeze/ thaw cycles before crack

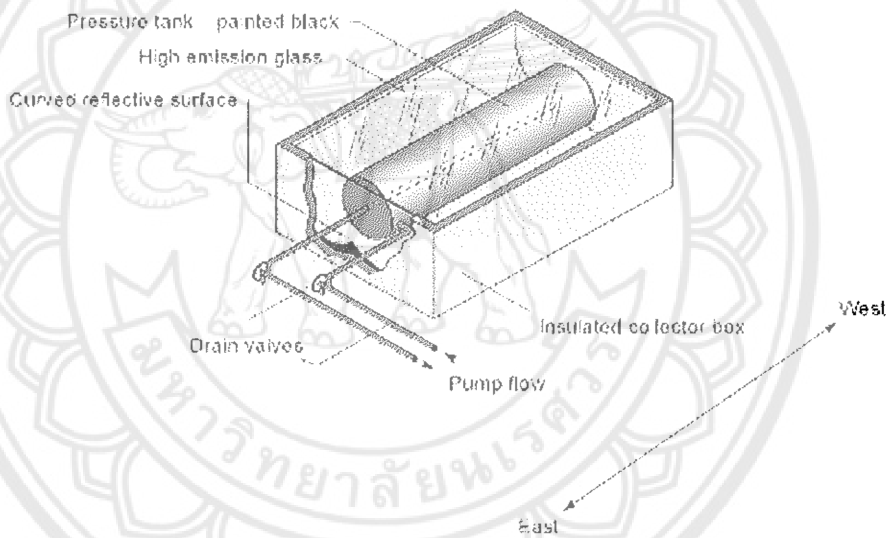


Figure 5 Batch heaters [7]

2.2 A thermosiphon system

A. relied on warm water rising, a phenomenon known as natural convection, to circulate water through the collectors and to the tank. In this type of installation, the tank must be above the collector. As water in the collector heats, it becomes lighter and rises naturally into the tank above. Meanwhile, cooler water in the tank flows down pipes to the bottom of the collector, causing circulation throughout the system. The storage tank is attached to the top of the collector so that thermosiphoning can occur. These systems are reliable and relatively inexpensive but require careful planning in new construction because the water tanks are heavy. They can be freeze proofed by circulating an antifreeze solution through a heat exchanger in a closed loop to heat the household water

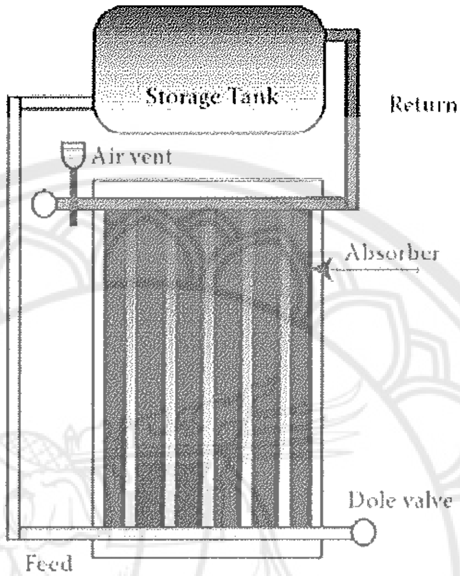


Figure 6 Thermosiphon system [8]

3. Direct Systems

A direct systems circulates household (potable) water through the collector loop. Direct water heating systems should not be used where the water is extremely hard or acidic to avoid scale deposits or corrosion.

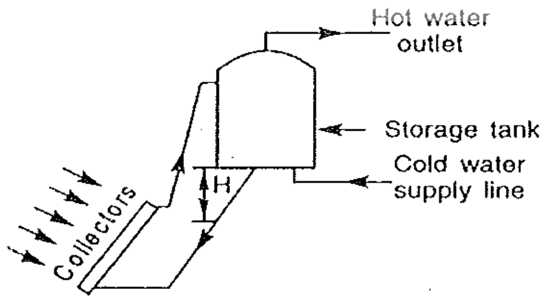


Figure 7 Direct natural circulation solar water heater

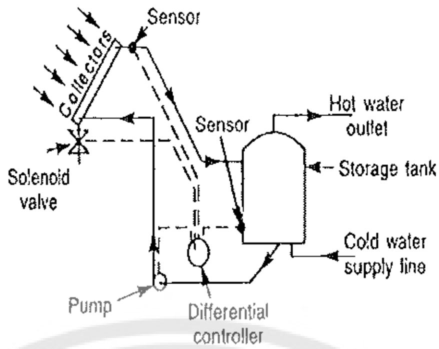


Figure 8 Direct forced circulation solar water heater with frost protection arrangement [9]

4. Indirect Systems

An indirect (closed-loop) systems uses a heat-transfer fluid (water or diluted antifreeze for example) to collect heat and a heat exchanger to transfer the heat to household water. There are basically three types of collectors: flat-plate, evacuated-tube, and concentrating.

A flat-plate collector is one of many possible types of solar collectors. It is the most efficient types of collector for use with temperatures between the freezing and boiling points of water and up to about 176.67° C when used with air as the working medium. Flat plate collectors are normally used with the flat surface facing south and tilted to an angle appropriate to the intended use.

Evacuate-tube collectors are made up of rows of parallel, transparent glass tubes. Each tube consist of a glass outer tube and inner tube, or absorber, covered with a selective coating that absorbs solar energy well but inhibits radiate heat loss. The air is withdrawn ("evacuated") from the space between the tubes to from a vacuum, which eliminates conductive and convective heat loss.

Concentrating collectors use a specially shaped surface to concentrate radiation to an area smaller than the reflector, thus producing a higher temperature. Concentrating collectors must track the sun for higher efficiency and can collect more solar energy compared to a flat plate collector with the same area.

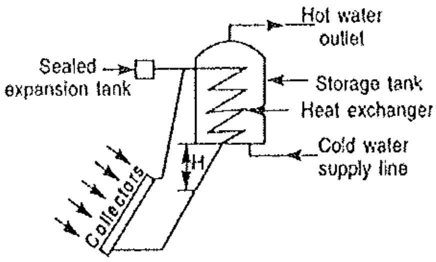


Figure 9 Indirect natural circulation solar water heater [9]

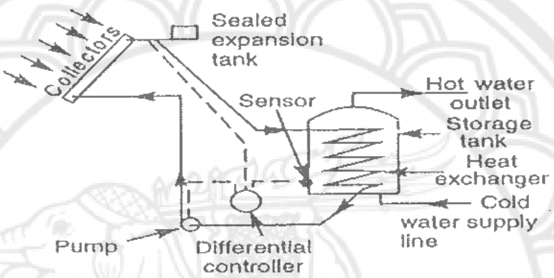


Figure 10 Indirect forced circulation solar water heater [9]

The use of hot water is also important in developing countries, even with their generally warmer climates. In many rural and poor urban areas, use of hot water remains modest today but will generally increase in the future. There are many technical approaches to water heating that greatly reduce fuel consumption and from the societal perspective, can reduce capital cost and life cycle operating cost. The most simple, and perhaps the most readily applicable in developing countries, is the use of solar water heaters. These can range from simple devices that hold the water in a container exposed to the sun, to complex devices that actively monitor water temperature and move it into large storage tanks until it is needed. The fuel demands of these systems are generally quite low. A variety of solar water heating technologies is now well developed. Solar water heating systems for developing countries can, in principle, be lower in cost and more efficient than those in industrial countries. Complicated and expensive protection mechanisms used in cold climates to keep the water from freezing the system are largely unnecessary in the warm developing countries. Solar water heater efficiencies are generally higher in the developing countries because of the warm outside temperatures.

Solar water heaters have been put into widespread use in some countries. There are more than two million solar water heaters in Japan and 600,000 in Israel. More than 50 firms manufacture or market solar water heaters in Turkey, a total area of 19,000 square meters of collectors were installed in 1982. China has an installed collector area of 150,000 square meters. Kenya has about 19,000 residential solar hot water heaters. Papua New Guinea has about 8,000. The initial capital cost to the individual consumer is substantially higher for solar water heaters than for electric heaters. Kunming, China is the number one city in the world when it comes to using solar water heaters Kunming is located on a high plateau with an altitude of about 1900m. The solar radiation is very strong there and there are about 280 clear days per year. So there is a richness of solar energy. The people in Kunming are not so wealthy, but they are able to buy one solar water heater for their family. This saves electricity and gas allowing them to save money.

There are many private companies making solar water heater in Yunnan Province. The quality of these companies is low. The cast of their product is low. Therefore, the general price is low. These private companies have well after sales service as the installation and maintenance are convenient. All the customer needs to do is just make a phone call to the company, everything is very convenient.

Although some organizations in Kunming, such as ISTIY, provide some support to people buying solar water heaters, most people have to pay all costs as there is no general government subsidy for purchasing or installing solar water heaters. The reason for purchasing is to save energy and because they have been well publicized and are popular.

At the beginning (10 years ago) there were few people using solar water heaters because few people knew the benefits of solar water heaters and the quality of solar water heater equipment was not so good then.

Chiang Mai has similar geography and technology, so there it will probably be successful in the future likes Kunming. They have good technology now but people do not know about solar water heating. It will be important for the common people to learn the benefits of solar water heaters. There is also a very interesting phenomenon: if a family uses a solar water heater, then the neighbors will use it very soon because of their desire to keep up, so if we can get a few people started using solar water heaters then more will follow.

An active solar hot water system consists with the solar collector, the electric circulate pump, the hot water storage tank, and economizer for using waste heat that installs at the top of the exhaust stack of the boiler. The economizer is a heat exchanger of the boiler exhaust gas that transfers heat to the water for producing hot water to add the hot water in the system. The solar hot water system (SHW) combines to the economizer by the connection of the piping in closed loop system to the storage tank. Conventional solar collector for hot water is flat plate collector, a type of flat plate collector, which composes of cover glass, thermal insulator frame and bottom and the copper absorber tube for heating water that circulates in the tube as shown in figure 11 [3].

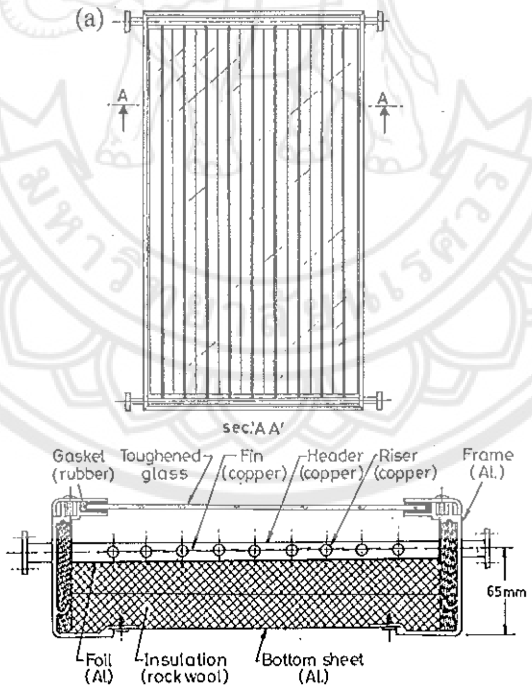


Figure 11 A solar collector structure

The hot water flow rate is produced by the solar radiation that converse to heat by the solar collector which install at the proper tilt angle and orientation of the collectors [4]. The flow rate of solar hot water system is calculated by the principle of energy balance of the radiation and the energy transform to heat the water in the collector by the equation (1)

$$q_u = A_c\left[G_t(\tau\alpha) - U_L\left(T_p - T_a\right)\right] = \dot{m}c_p\left(T_o - T_i\right) \qquad (1)$$

where q_u is the energy rate of heat from the collector

A_c is the area of the solar collector

G_t is the solar radiation impact on the collector

$\tau\alpha$ is the transmittance and absorptance respectively

U_L is the overall loss coefficient

T_p is the collector flat plate temperature

T_a is the ambient temperature

$\dot{m}$ is the water flow rate in the solar collector

c_p is the water heat capacity

T_o, T_i are the inlet and outlet water temperature respectively

5. Solar Energy Potential in Thailand

Thailand is blessed with its global positioning at high solar insolation zone, i.e. close to the equator; there is almost always a constant exposure of Thailand to the radiation from the sun during sunrise and sunset throughout the year. The average solar insolation in Thailand is about 5kWh/m^2.day, which is 923.58 × 10^6 GWh/year when multiplied by the land area of Thailand. In 2003, the energy demand of Thailand was 65,520,396 GWh, and it is just 7 % of the available solar energy potential in the country. However, the current area available for the exploitation of solar energy is 5.6x10^9 m^2 [SERT, 2005], making the available solar energy being 10,220 × 10^3 GWh, which is 15.6 % of the energy total demand of the country in year 2003.

Research on Solar Water Heating

1. China

A variety of solar water a heater have been produced in China for twenty years and now is at commercialization stage with a gradual increase of annual output, although its technology has to be improved. At present, there are more than a hundred small factories and workshops manufacturing solar water heaters with a yearly output of 400,000 m^{2}. The total amount of installed solar water heaters with a yearly output of domestic hot water supply while a few for public bath rooms and other commercial uses in rural as well as urban area for saving conventional energy and improving hygienic condition.

The Solar water heaters developed in China could be classified into integrated and separated systems. For integrated water heaters, a solar collector and hot water tank are integrated into the same unit, simple to install, and cheaper price. So they are of interest to the domestic sectors, of which around 15% of solar water heaters produced in China belong to the integrated type. Separated systems, with collector and storage tank, can be operated either on pumped or natural circulation. In China most of them are of Thermosyphon type.

The newly formed solar hot water industry in China, which started in 1980's, receives the encouraging support from Central Government as well as the technological support from the research institutions and universities and has got positive results on improving cost-effectiveness of the products.

As for the issue of how China should develop its solar energy industry, experts have raised two proposals. First, the government should make some policies to support the industry and encourage enterprises to produce better products. Second the government should devote more effort to the popularization of solar products. For instance, the government could mandate some buildings to use solar energy. If 5 to 10 percent of the buildings used solar water heaters, China's solar industry would gain unusual momentum.

2. Japan

In 1980 the Japanese government implemented a program to promote solar energy systems. This involved compilation of performance standards, development of performance evaluation tests, low interest loans to manufacturers to promote cost reduction, training of engineers and technicians, low interest for installation of solar systems on private homes, and promotion of solar installations in government and public buildings

The history of the solar water heater in Japan goes back to the 1940's after II World War. The solar water heaters then available were of either the breadbox type or cylindrical storage type. In the 1960's such as solar water were mass-produced. But with the availability of cheap oil, they lost popularity. The first oil shock of 1973 again raised the popularity of such heaters. And new types of solar water were beginning to be developed by many manufactures. Most of the solar water heaters currently available in the market are of the thermo siphon type where hot water produced during the day can be kept at night with little reduction in temperature. A typical solar water heater consists of 3 to 6 m^2 of collectors and a storage tank of 200-300 liters. No more than two hot water heaters can be placed on the roof many Japanese housed, which are not designed for the weight of a heavy storage tank. Those wanting a large quantity of hot water select an active solar energy system in which a large storage tank is placed on the ground, the solar collector on the roof, and a circulation pump used. But the cost and installation is more expensive than the Thermosiphon solar water heaters and the installation takes longer, so sales of active solar systems are much lower than Thermosiphon solar water heaters.

3. USA

One of the largest barriers to the adoption of SHW is builder and buyer satisfaction with existing gas water heaters; they provide the desired recovery time and are perceived as reliable. Past state and Federal incentive programs, where a number of contractors entered the market just to save money, created negative perceptions of SHW which must be overcome. Architects noted eliminating the term 'solar' would change negative associations with the historic product. Builders considered themselves the primary decision-makers for water heating systems. They will react to market demand and will build what their customers want; they do not perceive the market demand now. Architects were influential in the high-end custom market; they were relatively knowledgeable and open to SHW Plumbers wanted to be the trade responsible for SWH installations since they have many of the necessary skills.

First costs and payback period were the most important economic attributes to builders. The money saved through SHW does not appear to be enough to create consumer demand; a combination of buying movies is necessary. Mortgage lenders and energy efficient mortgages were not identified as being influential to the SHW decision making process. Incorporating SHW into the construction process was not generally viewed as an issue. The need for redundant water heating systems was seen as a negative. Builders felt a conventional water heating system would always be needed to account for extended cloudy periods. There was widespread ignorance among builders and architects about SWH incentives tax breaks, and laws in reference. Most builders reacted favorably to the concept of direct incentive programs.

Most people know about solar water heating, but are not familiar with current technology. Many have negative impressions based upon the early rush to solar.

Early applications were ugly.

Consumers are insecure about system reliability

Builders and consumers believe solar systems are expensive to install and maintain.

If a consumer is attracted to solar water heating, the major advantage considered is lower energy costs. Although using solar energy has some environmental appeal, the utility industry has done a good job convincing the consumers that gas and electricity are "clean" alternatives. After learning about current technology and product options, consumers were more likely to consider purchasing a solar water heating system.

4. Thailand

The opportunities for Large Scale Flat Plate Solar Water Heating in Thailand report of Mr. Martijn Vis on May 2000 says, this report is an assessment of the possibilities to utilize solar water heaters in commercial and industrial sectors in Thailand, which was carried out in cooperation with the International Institute for Energy Conservation (IIEC), Asia Office in Bangkok. From the Asia Office the field research was carried out in the period March until October 1999, mainly in the Greater Bangkok region.

The Research is split into three partial studies. In study one; an assessment is made of the most appropriate solar collection technology and the most appropriate design for application in Thailand. In study two, the most promising industrial and commercial sectors for the application of solar water heaters are selected. Then the applicability of solar water heaters in the selected sectors is assessed with help of six key factors: 1) energy saving, 2) financial feasibility, 3) environmental soundness, 4) locations conditions, 5) system reliability and 6) needed operation and maintenance attention. In study three the market potential in the selected economic sectors is determined, followed by an overview of barriers to the dissemination of solar water heaters. Finally measures to remove the barriers are assessed and evaluated.

The commercial sector (hotels and hospitals) and industrial sector demand payback periods lower than seven and five years respectively. Solar water heaters are attractive for the commercial sector mainly at lower temperature levels where solar water heaters are more efficient. In industry, solar water heaters are not attractive because conventional water heaters are often fired by low cost fuel oil. Moreover the five-year requirement for the payback period can not be reached even when savings are expressed in reduced electricity consumption at current electricity rates.

A major problem with the systems investigated was that piping with the collector panels was leaking. An unnoticed small leak will cause oxidation, and finally the inside of the collector plate has to be replaced. This kind of leaking is perhaps a technical failure that is specific for this collector brand name. Regular maintenance checks can, however, help to notice failures in an early stage. The supplier offered a six monthly maintenance check during the first five years after installation.

Secondly, it often happens that an uninstructed technician supposes the system is working well while the electrical back up heats all the water. The technician gets no complaints because hot water is available at the tap points, but actually no savages on the electricity bill are made. This happens often when the technician who was involved at the investment stage stops working at the site and is replaced by an untrained technician.

Thirdly, cleaning of the collector surface has not been carried out. Dust on the collector surface reduces the solar irradiation up to 30 percent. Further, because most systems are older than seven years, the insulation material wrapped around the piping is sometimes decayed. Further, sometimes, though not frequently, the glass covers of a collector plate broke.

Solar water heaters need maintenance attention during their entire lifetime. If there is a lot of dust on the collector glazing, then it should be washed, and a check of the whole system should be done once every two months. For this reason a maintenance program for the entire lifetime of the solar hot water system should be available, possibly exceeding the guarantee period [10].

The financial analysis explained that solar water heaters are attractive only when they save electricity. Table 1 presents an estimation of the market potential I Thailand based on the outcome of the financial analysis.

Table 1 Market potential for large flat plate solar water heating in Thailand

Sector	Collector surface [m^2]
Hotels	180,000
Hospitals – private	10,400
Hospitals – government	43,800
Apartment – luxurious	60,000
Apartment – upper middle	160,000
Total	454,200

Present markets for solar water heaters are mainly in private hospitals and hotels, possibly because one person can make the investment decisions. It will be harder to market central solar water heating installations in apartment buildings especially if at present no central water heating installation has been used. It is better to install solar water heaters in the design and construction phase of apartment buildings because then optimal systems can be designed. Further, in this case one doesn't cause inconvenience to the residents.

Thailand government has been to promote and supported to use solar water heating in commercial and industrial scale because price of fuel has in cress feasibility the government to promote and push solar water heating in commercial and industrial scale in the primary stage higher than house hole system because house hole system that are not as popular same foreign countries same China or Europe or America or Australia in the cold countries zone so DEDE to promote and subsidy for solar water heating combine with waste heat system for school, hotel, hospitals and industries so heat exchange or economizer to help to saving.

Marketing Background

The American Marketing Association defines marketing as the "function which links the customer and public to the marketer through information whereby the information is used to identify and define marketing opportunities and problem; generate, refine and evaluate marketing actions; monitor marketing performance; and improve understanding of marketing as a process. Marketing research specifies the information required to address these issues; design the method for collecting information; manages and implements the data collection process; analyzes the results; and communications the finding and their implications".

Marketing and Planning

For many reviewers of business plans, the marketing plan is the heart of the business plan considered as on par with the financial plan and decision of management. The marketing plan occupies this position of importance because, in most cases, it is the quality and depth of the firms marketing programs and the marketing skills of its management team that determine a company's success.

Developing a good marketing plan is a disciplined, sequential process of information gathering, decision marking, action and evaluation of results. It is an evaluation and dynamic process. Markets change constantly and companies must change with them to harvest the fruits they offer. The marketing plan written today must be constantly evaluated for effectiveness and modified as often as necessary to achieve the goals of the company.

Solar Thermal Market in Thailand

1. History

Solar thermal water heaters has been introduced to Thailand since the Department of Alternative Energy Development and Efficiency (DEDE), formerly known as Department of Energy Development and Promotion (DEDP), implemented a pilot project in which 352m^2 of collector surface was installed in 6 hospitals, 1 hotel and 1 small industry. It might be interesting to know that only one local producer and one importer sold solar water heaters before 1990.

In the early 90s imported products from Australia, Germany and Israel dominated the market. The market grew and during the program more than 10 solar water heater suppliers were active. The solar thermal promotion program by DEDE, which had the focus on technical support and capacity building for end-users particularly in the commercial sector, might have caused this. Furthermore DEDE estimated that there were already about 50,000 m^2 of flat plate collectors installed in Thailand until 1996. DEDE figured out as well that alone in 1996 4,150m^2 were installed.

In the late 90's the SWH market declined because of two reasons. First reason was the Asian economic crisis, which hampered new investments in the residential as well as in the commercial sector. Second reason was the quality and durability of solar water heater systems were tarnished by incorrect design and poor workmanship during installation and maintenance. Due to this the diffusion of solar water heaters in 2000 was still at the same stage as in 1995.

After 2000 the market fall into a kind of stagnation until the government approved the first subsidy program for commercial customers in 2007. Supporting from the government and with several public awareness campaigns the market awoke again in 2007. 11,000 m^2 has been installed in 2007, which is approximately a flat 10% growth from 1996, as shown in the formula below; the expected forecast is now 20% growth for the next 10 years from 2008 to 2018. One significant change is the shift from residential market to commercial market. In 1996 70% of the market was residential, but in 2007 the market was 50% residential, 40% commercial and 10% industrial. Subsidy program from DEDE (2008 onwards)

2. Subsidy provide in 4 round program

2.1 First round

This program supported the investor with 3000 or 4500 Bath/m^2 installed collector area, depending on the energy collection per square meter. A subsidy spends 3000 Bath/m^2 for solar collectors with average energy collection lower than 800 kWh/m^2 per year, but higher than 500 kWh/m^2 per year and 4500 Bath/m^2 for solar collectors with average energy collection higher than 800 kWh/m^2 per year. To get the subsidies the solar system needs to be a hybrid system. That means the use of waste heat, e.g. from an air-conditioning system, has to be used as well and start supposed installed collectors area of 40 m^2 to be limited 500 m^2 for one investor installed the system.

This first round of subsidies was distributed in September 2008 and brought an installed collector s area of 3,972.52 m^2 in total, among them 9 hotels, 5 factories, 2 hospitals and 1 school.

2.2 Second round

With the success of the first round the government approved a second round for 2009, which was limited to 3000 m^2 of installed collector area. All those systems had to be built in 2009. According to this second round 12 hotels, 2 factories, 1 animal farm 1 hospital and 2 schools were supplied with solar water heater systems.

2.3 Third round

There is success of the second round the third round start in April 2010 and it is supposed to be limited to 10,000 m^2. The installed collector area total of 8,596.84 m^2 among them 18 hotels, 10 factories, 2 hospitals 4 schools 3 animal farm and 1 business building

2.4 Fourth round

Fourth round start in April 2011 this program supported the investor with 3000 or 3500 Bath/m^2 collectors start supposed the area of 40 m^2 to be limited 1000 m^2 for one investor installed the system. Depending on the energy collection per square meter. A subsidy spends 3000 bath/m^2 solar collectors with average energy collection lower than 800 kWh/m^2 per year, but higher than 500 kWh/m^2 per year and 3500 bath/m^2 for solar collectors with average energy collection higher than 800 kWh/m^2 per year. There are supposed to be limited to 10,000 m^2. by installed collectors area of 9,878.89 m^2 in total, among them 7 hotels, 16 factories, 5 hospitals 4 university 1 animal farm 1 business building and 1 residential building

3. Long term planning

In the end of 2007 the government developed a long-term alternative energy plan for the period from 2007-2022. This plan promotes all kind of renewable energies and solar thermal has become a part of the governmental long-term energy plan. The government plan is shown below.

Table 2 The governmental long-term energy plan in Thailand

<table>
<tr><th colspan="2">Short Term 2008-2011</th><th>Medium Term 2012-2016</th><th>Long Term 2017-2022</th></tr>
<tr><td colspan="2">Promote the use of hybrid SWH 1.Subsidy
2. Funding for study</td><td>Promote the use of small SWH systems</td><td rowspan="5">Building code for SWH</td></tr>
<tr><td colspan="2">Demonstration of hybrid SWH in 100 government offices</td><td>Demonstration small SWH</td></tr>
<tr><td colspan="2">R & D for small SWH</td><td rowspan="3">Technology transfer</td></tr>
<tr><td colspan="2">R & D to reduce cost of SWH components</td></tr>
<tr><td colspan="2">Testing facility</td></tr>
<tr><td colspan="4">Labeling program</td></tr>
<tr><td colspan="4">Low interest loan/ Taxes measure</td></tr>
<tr><td>R & D</td><td>Promote local production</td><td>Promote use of SWH</td><td>Promote SWH</td></tr>
</table>

Note: Solar Thermal Association (STA)

The STA was founded in January 2008 and is approved from the government since 2009. The purpose of the STA is to promote solar thermal system in Thailand, improve the quality, do joint marketing and coordinate with the government on subsidy programs for further promotion.

Market potential

1. Current market

The current market is still in the residential sector, even if there is a huge potential in the industrial and commercial sector as well. One of the main reasons for this is the lack of companies that have enough experience and are capable to design and install larger solar systems. In 2007 there were less than 5 companies able to build those systems. However, there has been a rapid increase of solar systems in the commercial and industrial since 2008 due to the DEDE subsidy program.

2. Market growth

Beside the oil price, the growth of the solar water heater market in Thailand depends on the economic situation of the country as well. This means that solar water heater systems are not attractive during an economic downturn, even if they have a possibility for energy cost saving and suitable payback period.

In other countries there are several policies to stimulate the solar thermal market, such as financial incentives, subsidy, and grants for demonstration, regulation and awareness campaign. In addition the solar thermal market in Thailand has suffered from the reputation of early installations. Awareness campaigns can have a wide spread impact on the market development if the quality of installed systems is appropriate, while a financial incentive policy can bring down the payback period and make the systems attractive for potential users and investors.

There are different growth scenarios existing for Thailand. If it would implement an extensive awareness campaign, the solar thermal market could reach 400,000 m^2 in the next 10 years. However, to achieve the target of 1,500,000 m^2, a stronger policy support, such as financial incentives in combination with an awareness campaign is necessary.

In 1997 there is 11 solar hot water companies in Thailand that first meeting at SERT and then there were several meeting promoted use solar water system to construction solar hot water exhibition hall to provide knowledge and information on the company's products after that there were invited many sectors to visit to seminar many companies at that time have been successful one of them Heritage International Development Co., Ltd. more experience of installation the solar hot water system that combine with an economizer many projects in Thailand and was successful.

3. Potential of solar water heater

3.1 Commercial sector

There are several services requiring hot water and have a potential to use solar water heaters. Hotels and hospitals alone are identified as having the highest potential for their continuous and large daily hot water demand. The main reason for this is that the hotels and hospitals are responsible for their energy costs as a whole, while most condominiums and apartments in Thailand have individual electric meters for their residences to be responsible for their electricity bill. Therefore owners of condominiums or apartments have less interest of installing a solar water heater system.

For hotels the cost for hot water generation is estimated with 5-10% of the energy cost, if using a LPG heater, which in turn is estimated to be 10-30% of the total operating cost. If using electrical heater to generate hot water the cost are estimated with 10-15% of the energy cost. The hot water demand for hospitals is similar to the one of hotels, which leads to an estimated hot water demand in these two commercial sectors of around 9 Mio Liters/day. The annual energy demand for hot water generation is approximately therefore around 18.5 ktoe, which are approximately 215,2 GWh/a.

3.2 Residential sector

The most common water heater in the residential sector in Thailand is the electric water heater. The low price of the products has led to a market expansion with an annual sale of approximately 200,000 units. All over the country are approximately 1,500,000 electric heaters in use. In average a dwelling in Thailand has 3.4 inhabitants. Assuming each water heater is 4.5 kW and operates 1.5 hours/ day, the annual electric consumption would be around 314 ktoe.

The total demand of the three sectors is estimated at 1206 ktoe per year, 1.9% of the total final energy consumption in Thailand in 2005.

3.3 Industrial Sector

Due to the industrialization in Thailand the energy demand in the manufacturing sector slightly increases, while the energy demand in the commercial and residential sector remain relatively constant. There are four sectors in the industry: Food and Beverage, Textile, Paper and the Chemical, which are suited to use solar water heater system with low-medium temperatures. These 4 sectors cover approximately 50% of the total energy consumption in the industrial sector. Recent studies in several countries estimated that about 50% of the industrial heat demand is located in the temperature range of 60-250°C. Assuming that 50% of fuel oil is used to generate heat at a low-medium temperature, the annual heat demand for the 4 sectors is estimated with 874 ktoe at this temperature level, which is approximately 10.2 TWh/a. Industrial process heat is the thermal energy used directly in the preparation or treatment of materials and items manufactured by an industry. Presently, the heat required by the industry is obtained by oil, natural gas, coal or electricity, but a large portion of industrial process heat is at sufficiently low temperatures which can easily be supplied by solar energy. The year round need for energy in industries allows a maximum utilization of solar equipment [1]. Some advantages and disadvantages of using solar energy for providing process heat 2 are listed in Table 3

Table 3 Characteristics of solar industrial process heat

1. Advantages
It can replace scare and environmentally hazardous fossil fuels like oil and gas.
Many processes are in temperature range well suited for solar technologies.
Year-round loads give good utilization of solar equipment.
Many end uses are possible without thermal storage requirements.
Large installations many give economics of scale.
Experts and field maintenances staff are available in industry.
Industry is accustomed to life cycle costing and long-term financing.
No heat engine required and therefore, higher efficiencies are obtained.

Table 3 (cont.)

2. Disadvantages
Industry generally gets favorable rates from utilities.
Process requirements, such as temperature control, may make integration with solar system difficult.
Variable nature of insolation requires solar system to have auxiliary backup or long term storage.
Lack of familiarity with solar equipment and solar system operation.
Size of system may be limited by land availability and maintenance.
Solar industrial process heat is a new and still an unproven technology.
Industry expects rapid pay back of investment (3 to 5 years).
Lower temperature operation gives lower overall efficiency.
Industrial environment affects the life of the system due to surface contamination.
Unfavorable economic criteria, taxes and high initial investments.

Various industrial surveys show [2, 3, 4, 5, 6] that up to 24 per cent of all industrial heat directly used in different process is at temperatures below 180 °C. In the remaining 76 per cent also, where higher temperatures are required, considerable amount of heat can be supplied to pre-heat it up to 180°C. Thus about 40 per cent of all process heat needed is found to be in the temperature range from ambient to 180°C. In several industries 100 per cent process heat required is below 180°C which can easily and economically be supplied by flat-plate collectors, solar ponds, evacuated tube collectors, and linear concentrators for which the technology is sufficiently advanced. Thus, this low temperature process heat requirement in industries makes the solar system quiet attractive.

Table 4 Temperature industrial process

Industry/Process	Working fluid	Temperature range (°C)
Food Industry		
cooking	stream	120 – 1185
drying	air, steam	120 – 230
canning	water, steam	80 – 130
Textile Industry		
mercerizing	water, steam	up to 100
drying	steam	60 – 135
finishing	steam	60 – 15
Chemical Industry		
drying	air	60 – 125
dissolving, distillation		
thickening, leaching, etc.	steam	85 – 170
Pulp and paper Industry		
kraft pulping	steam	185
kraft bleaching	steam	140
drying	steam	180
Stone –glass-clay-Industry		
brick curing	steam	75 – 180
gypsum calcining	air	160
gypsum curing	steam	300
glass fiber drying	air	100 – 180

Industrial Process Heat (IPH) system

The detailed knowledge of the way heat is supplied and used in industrial processes is required for economic use of solar energy. It is essential to know, how the heat is supplied to each process, the quantity of daily heat required, the temperature at which the heat is required, the fuel used and the heat transfer fluid required for transferring the heat. Generally, this type of information required for the design of process heat system is not available. The economic and technical feasibility of any solar industrial process heat system depends on four factors, namely: (i) heat must be supplied in sufficient quantity, (ii) heat must be of adequate quality i.e. at an appropriate temperature, (iii) heat must be transferred directly from the solar collector to the process where it is to be used and (iv) solar energy must be used profitably [9].

Each industrial plant has unique requirement and hence the SIPH system should be carefully designed. Because of the specific intermittent nature of solar radiation, SIPH must be backed up with alternate fossil-fuel systems so that the industry gets uninterrupted supply of process heat. Generally, SIPH has one of the following three possible modes:

(i) Solar augmentation without energy storage.

(ii) Solar augmentation with energy storage.

(iii) Solar pre-heating with and without storage.

The first system appears to be quite attractive because the cost of storage is eliminated but can work only during the day time and can save only up to 30 per cent of the total process heat load. If more fraction of the total process heat load by solar energy is required then the second alternative is preferred but it will be a costly system. The third alternative can universally and profitably be used in many industries to supply pre-heat boiler hot water or hot air. The pre-heat possibilities exist practically for all process applications. The process heat in various industries is supplied generally in the following three modes:

(i) Process hot water

(ii) Hot air

(iii) Process steam

In process hot water heating systems, both the direct solar water heating system (once through type) where the heated water from the solar collector is directly supplied as process heat an indirect solar hot water system where a heat exchanger is used between the collector loop and delivery loop are used. In cold climates, an indirect water system is used with some antifreeze mixtures in the collector and storage loop. Direct system, although works at higher efficiency are preferred only in hot climates or during the day time or in special process industry or with some precautionary measures for protecting it against damage due to freezing.

Hot air systems are employed for drying or dehydration processed in industries and such systems are safe from damage due to freezing. The hot air if sufficiently heated by solar energy can be directly supplied for drying/dehydration or can be further heated by an auxiliary heater before it goes to the process load. An additional advantage of hot air system is the use of rock bed storage system which can simultaneously be used for charging and discharging of heat. An alternative to the direct hot air system is the use of liquid collectors (since they are better than air collectors) and a liquid-to-air heat exchanger (which reduce the efficiency) and finally hot air can be supplied to the process load.

In process industries, steam is most common commodity particularly low pressure steam. The steam can easily be produced using solar energy collectors and directly fed into the industrial steam distribution system without any change in the existing processing practices. All the three options, the flash-steam system, unfired-oiler system, and direct steam generation system can be employed to meet the requirement of process heat in industries. Some of the systems using the above modes are discussed here in brief.

1. Hot Water Industrial Process Heat System

In industries, large amounts of hot water in the temperature range of 50-100°C is required for applications like cooking, washing, bleaching, anodizing, etc. The solar pre-heated water can also be used as feed water to boilers. For cleaning or curing purposes, large amounts of hot water is required in food processing and building material industries, and recycling of hot water is not preferred because of contaminations picked up by the water during the process. Hence, for such applications, once-through industrial solar water heating systems are used. This once-through system which is simple in operation can be used with or without any intermediate storage system.

2. System Cost

This statement contradicts with usual market trends that is, when technology advances efficient system are produced at lower cost. When there is high demand of SHW system, more industries comes to market and compete for the market available market shares hence bringing down the price of the system

3. Flat plate collector

The flat plate collector forms the heart of any solar energy collection system designed for operation in the low temperature range, from ambition to 60°C, or the medium temperature range, from ambition to 100°C. A well-engineered flat plate collector delivers heat at a relatively low cost for a long duration. The flat plate collector is basically a heat exchanger which transfers the radiant energy of the incident sunlight to the sensible heat of a working fluid-liquid or air. The term 'Flat plate' is slightly misleading in the sense that the surface may not be truly flat – it may be a combination of flat, grooved or the other shapes as the absorbing surface, with some kind of heat removal device like tubes or channels. A quick glance at the available literature on the flat plate collectors gives an idea of the work done so far in this field. The invention of the liquid heating flat plate. Solar water heater is credited to H.B. Saussure, a Swiss scientist, during the second half of the seventeenth century, as reported by Ackermann[1]in the year 1915. However, the use of flat plate collector on a fairly large scale in the United States – in Illinois was resumed in the early 1900s and later in Needles, California. Water was heated in relatively shallow horizontal troughs made of asphalt, usually double glazed, with desert sand as an insulator, and the heat thus collected was used to generate sulphur-dioxide or ammonia for operating pumps. The most impressive array of the near – 1900 era was that of Frank Shuman of Philadelphia, who, in 1907, built a flat plate collector to produce hot water which in turn evaporated ether, and thus, powered a vertical single cylinder engine. During the last fifty years scientists all over the world have been trying to build and test different types of liquid flat plate collectors. This work has been carried out mainly in the United States [2, 3], United Kingdom [4], Australia [5], South Africa [6], Israel [7], and India [8, 9]. The main objective of these investigations has been to convert as much solar radiation as possible into heat at the highest attainable temperature, with the lowest possible investment in materials and labor.

Flat plate collectors have the following advantages over other types of solar energy collectors:

(i) Absorb direct, diffuse and reflected components of solar radiation,

(ii) Fixed in tilt and orientation and, thus, there is no need of tracking the sun,

(iii) Easy to make and are low in cost,

(iv) Comparatively low maintenance cost and long life,

(v) Operate at comparatively high efficiency.

The principle behind a flat plate collector is simple. If a metal sheet is exposed to the solar radiation, the temperature will rise until the rate at which energy is received is equal to the rate at which heat is lost from the plate; this temperature is termed as the 'equilibrium temperature'. If the back of the plate is protected by a heat insulating material, and the exposed surface of the plate is painted black and is covered by one or two glass sheets, then the equilibrium temperature will be much higher than that for the simple exposed sheet. This plate may be converted into a heat collector by adding a water circulating system, either by making it hollow or by soldering metal pipes to the surface, and transferring the heated Liquid to a tank for storage. For heat withdrawal from the system, the equilibrium temperature must decrease, since no useful heat can be extracted at the maximum equilibrium temperature at which the collection efficiency is zero. The other extreme condition is when the flow of liquid is so fast that the temperature rise is very small; in such a case, although the losses are small and the efficiency of heat collection approaches 100 per cent, yet no useful heat can be extracted. The optimum condition is approximately midway between the atmospheric temperature and the maximum equilibrium temperature, whereby an output of liquid at a useful temperature is obtained [9].

4. Economizer

Economizer is the name traditionally used to describe the gas-to-liquid heat exchanger used to preheat the feed water in boilers from waste heat in the exhaust-gas stream. These often take the form of loops, spiral or parallel arrays of finned tubing through which the feed water flows and over which the exhaust gases pass. They are available in modular form to be introduced into the exhaust stack or into the breeching. They can also be used in reverse to heat air or other gases with waste heat from liquid streams [11]. A more recent development is the use of condensing economizers which are placed in the exhaust stream following high-temperature economizers. They are capable of extracting an additional 6%-8% of the fuel input energy from the boiler exhaust gases. However, they are only used under certain restricted conditions. Obviously, the cooling fluid must be at a temperature below the dew point of the exhaust stream. This condition is often satisfied when boilers are operated with 100% make-up water. A second, less restrictive condition is that the flue gases be free of sulfur oxides. This is normally the case for natural gas-fired boilers. Otherwise the economizer tubes will be attacked by sulfurous and/or sulfuric acid. Acid corrosion can be slowed down markedly by the use of all-stainless steel construction, but the cost of the equipment is increased significantly.

Heat-pipe arrays are often used for air-to-air heat exchangers because of their compact size. Heat-transfer raters per unit area are quite high. A disadvantage is that a given heat pipe (that is, a given internal working substance) has a limited temperature range for efficient operation. The heat pipe transfers heat from the hot end by evaporative heating and at the cold end by condensing the vapor. Figure 2.12 is a sketch of an air pre-heater using an array of heat pipes.

Waste-heat boilers are water-tube boilers, usually prefabricated in all but the largest sizes, used to produce saturated steam from high-temperature waste heat in gas streams. The boiler tubes are often finned to keep the dimensions of the boiler smaller. They are often used to strip waste heat from diesel-engine exhausts, gas-turbine exhausts, and pollution-control incinerators or after burners.

Heats that wasted from the industrial combustion are released to atmosphere can be cause our world global warming. The idea to recover that kind of heat called "Wasted Heat Recovering System". The wasted heat recovering system is not only that save the heat lost, on the other hands also the social and economic impacts. Mostly the main part of wasted heat recovering system is mechanical equipment called "Heat Exchanger", which has the main function to transfer heat from one medium to others. The specific heat exchanger in case of boiler system is an *economizer* which always used in the air to water situation.

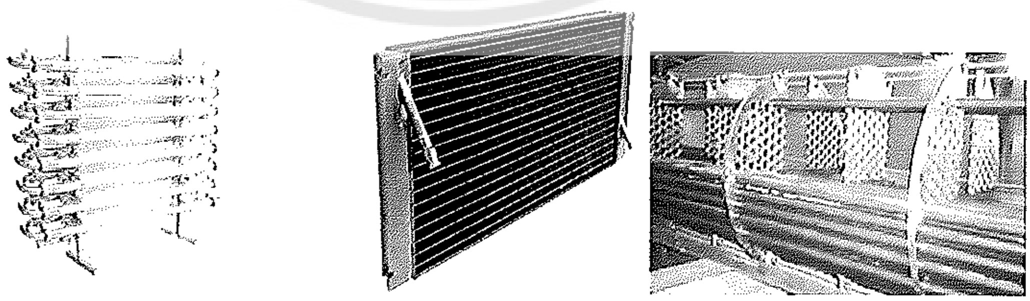
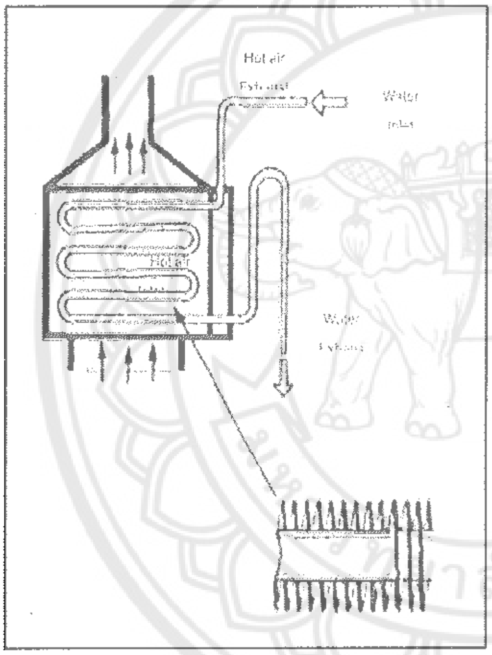


Figure 12 Varity types of Heat exchanger [11].

5. The energy saving for boiler system run as following rules:

Heated air that heat up water in boiler from fuel combustion flow through the economizer. Within the economizer is the large heat exchanging is that transfer heat from hot air to normal temperature water. Then the water temperature was increase but not reach the expected. This process called "Pre-Heating". After pre-heated, pre-heated water circulates to the boiler for heating up temperature to the expected one. During this process boiler need less energy to heating up the pre-heated water, thus this causes an energy saving.



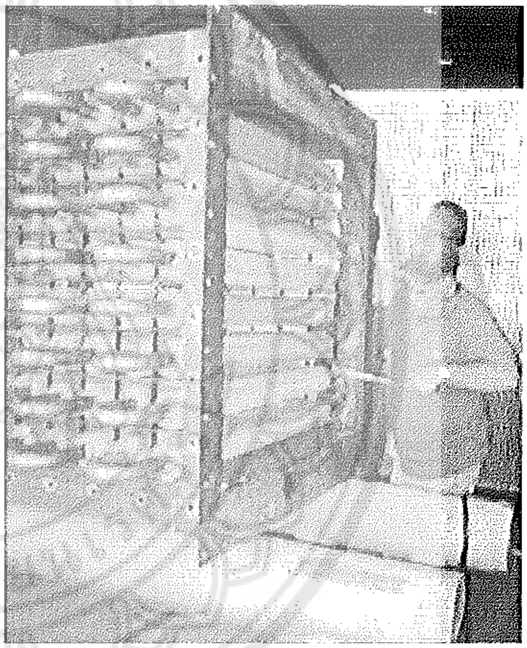


Figure 13 Economizer [11].

Energy and Economic Evaluation Method

Yordi [15] discovers from a fundamental research and technological development on PV devices and components reminds vitally important to develop lower cost PV modules with higher efficiencies and longer lifetime. However, it is equally important to move forward with the demonstration of PV energy services in the competitive energy markets of both the EU and developing countries. Further work based on the environmental integration of PV in urban and rural areas remains important, as do further demonstrations of sustainable schemes for supplying and financing PV energy services.

D. L., King, T. D., Hund, W. E., Boyson, & J. A., Kratochvil [16] disclosed that Stand-alone photovoltaic systems are deceptively complex. Optimizing the performance and reliability of these systems requires a complete understanding of their behavior as a function of site-dependent environmental conditions. Individual component specifications provide useful design information. However, to fully understand the interactions between components, it is necessary to simultaneously characterize the performance of the system and its components under actual operating conditions. The paper describes how a new 30-day outdoor testing procedure was coupled with our array performance model to accomplish this objective. The procedure determines battery capacity and appropriate set- points for charging, and based on daily intervals quantifies dc-energy available from the array, charge-controller efficiency, battery efficiency, inverter efficiency, system efficiency, days of autonomy, and ac-energy available by month.

The ISES, in co-operation with the Fraunhofer ISE [17] have released the survey on "Rural Energy Supply Models - RESuM". The result is a guideline for government, business entrepreneur, and financing organizations to providing energy to rural areas using renewable. The study collated and summarized information on the set-up of different dissemination methods as well as experiences made with them. The central question is: "How to get the product to the end user?" with special consideration of the business level – the level of interaction between the system or service provider and the customer. The product could either be an energy supply system for auto-generation, such as a pico-hydro system, or a service, such as electricity.

A characterization of the rural energy supply model was developed based on the existing experiences, consulted experts, and additional information generated through the consideration of practical examples. Regarded aspects include the contract between the system or service provider and the customer and project or business entrepreneur, like promotion and installation. The knowledge about indispensable requirements and certain obstacles to the dissemination models for rural energy supply permits to avoid mistakes in future actives and give preference to promising strategies

– adapted to the special conditions. Advantages and key barriers referring to the organization process of the different rural energy supply models were worked out. In addition, a catalogue of critical success factors within the models was developed to help the key players overcome model-specific problems. The study results in a structured presentation of different energy supply models, their characteristics, advantages and disadvantages, supported by project examples.

Reaching the rural customer, various ways exist for bringing the energy supply system or the service to the rural customer. The flow chart below gives an overview of the main categories and models – the Rural Energy Supply Models. This categorization is the result of the approach taken by ISES and Fraunhofer ISE.

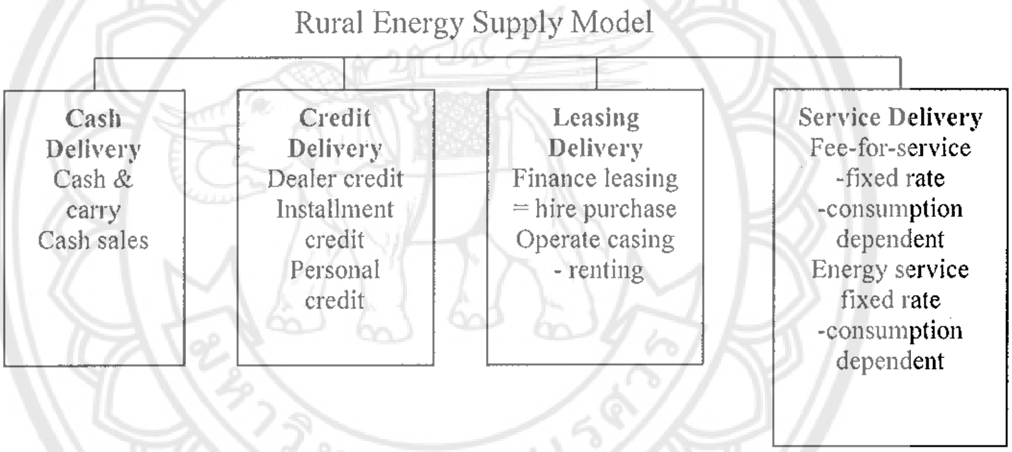


Figure 14 Rural Energy Supply Model

Some of these rural energy supply models have a higher practical relevance than others, and as a result of the practical examples considered, it was found that in the rural energy sector, often a mixture of these models were used. Econergy International Corporation [18] performed an economic evaluation of the market potential for a broad range of advanced end-use energy technologies. The analysis combined economic screening with a more detailed linear programming model to determine the optimal mix of each technology under different regional market growth scenarios. The analyses illustrated how variations in regional heating and cooling demand, as well as the price of electricity, are the principal drivers of the market for new end-use technologies. The results were used to guide EPRI R&D funding allocation decisions. Electric Power Research Institute, ECO Northwest staff evaluated the economic potential of alternative energy storage technologies for electric utility applications. Developed a linear programming model to determine the optimal mix of generation and storage technologies, based on anticipated system demand patterns, existing generation mix and the economics of alternative technologies. Using this decision framework, assessed the potential benefits of storage technologies under varying assumptions about future demand and technology costs. Benefits assessments were used to guide allocation of R&D funding for storage technologies at EPRI.

Energy-Economic Development Impact [19] analyzes the economic consequences of energy programs and policies. It estimates the magnitude of impacts on regional business growth over time, resulting from changes in energy prices and/or changes in investments in power generation and transmission facilities. It is applicable to assess impacts of alternative generation technologies, demand management programs and deregulation policies. The model provides a means for estimating the current pattern of spending on energy facilities & technologies, the allocation of spending benefits to area businesses, the allocation of costs to customers (for regulated activities) or to firms (for deregulated activities), impacts on the cost competitiveness of all types of local business activities and the long-term effects on economic growth of the affected area. The model provides a means for estimating the potential direct and indirect economic impacts on a state, county, community or service area. It can be used alone or in conjunction with a regional input-output or economic simulation model. capital and operations spending program for new power plants: coal, natural gas, biomass, wind, other; annual costs for energy services and demand-side management services; financing and allocation of long-term capital costs and short-term operating costs; differences in relative prices associated with differential loads; customer sizes & types (SIC group). Model Output impacts on the relative cost competitiveness of customers impacts on business revenues, output, employment and income in the affected area: by business type; short-term and long-term differences in impacts. Applications include: state policy impact and benefit-cost studies utility pricing and targeting studies. Energy Regional Impact Assessment (ERIA) has been applied in various forms for studies of energy programs and policies in Iowa, Wisconsin, and California.

Institute of Economic Research (IER) [20]. develops software name Strand Management Solutions, Inc. and DHL Associates, in the mid-1990's and modified in later years, delivers an economic evaluation that can be understood and applied by all participants in the decision-making process. For example, in deciding whether to replace a hydroelectric unit's generator cooling system, PEEM would weigh options in bringing the pump to the required performance level. Would it be best to replace, redesign, or rebuild the existing system? Should the current system be "band-aided" as a temporary solution? What is the net present value and cost of each option, the internal rate of return, and the payback period? How is the decision affected by the planned life of the entire generating unit? Once a decision to proceed with a project has been made, full documentation of the process that led to the decisions is available in the software. The PEEM software also provides for comparing the results of an evaluation of a specific capital improvement with any number of other proposed projects. This feature allows managers to rank capital projects within departments or within the full utility or corporation.

Klaus Weyerstrab, Hubert Reisinger, Norbert Wohlgemuth [21] was developed a governmental strategy for supporting the Slovenian economy and the rational use of energy in order to achieve a maximum of welfare. This is restricted by regulations on emissions and with certain strategies by EU regulations and a minimum amount of domestic coal to be consumed. Criteria for evaluating the investigated governmental strategies include gross domestic product, household income, sector value added, rate of unemployment, rate of inflation, current account of balance of payment, effects on the general government budget, emissions of SO_2 , NO_x dust and CO_2 , primary energy consumption and the total costs of the energy system. In order to show the effect of Integrated Resource Planning (IRP) strategies and to optimize these strategies not only with respect to the development of the energy system but also with respect to the development of the economy as a whole, the planning system developed in IRP- Slovenian has to be complemented by SMEEM, as well as a model which improves the "market valuation" of the goods and services produced in Slovenia, and a model for the market penetration of energy efficient technologies. Figure shows the outline of the whole modeling sequence.

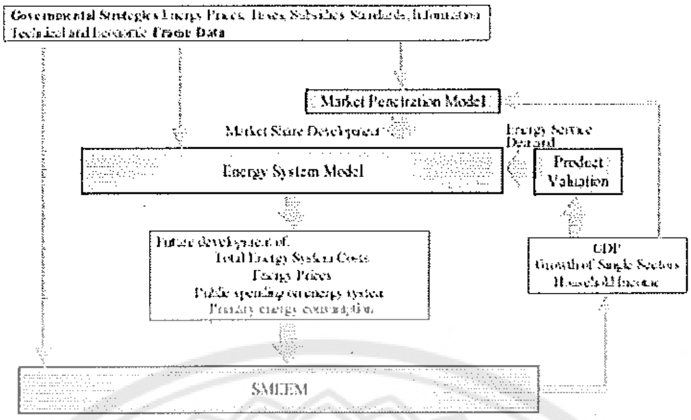


Figure 15 Energy System Model, Slovenian Macro Economic Energy Model (SMEEM) and other models necessary for a closed loop energy-economy investigation

In principal the two main models can operate independently. But to show the effect of governmental strategies on the energy system and the economy the results of one model are to be considered in the other model. The link between the models is that the output of one model is considered when defining the input of the other model. There is no hard link between the two models.

Cost-Benefit Analysis

Cost-benefit analysis (CBA) is a comparison of the estimated costs of an action with the estimated benefits it is likely or intended to produce. It is controversial when applied to policies intended to address potentially harmful or fatal risks, particularly environmental risks. Many critics argue that one cannot place a dollar value on human life. But that is not the intention. Rather, cost-benefit analysis permits comparison of various options, all of which may be beneficial but not all of which can be undertaken simultaneously. Researchers who study risks refer to "life-years saved," based on statistical probabilities.

1. Cost Benefit Analysis Involves a Particular Study Area

The impacts of a project are defined for a particular study area, be it a city, region, state, nation or the world. In the above example concerning cotton the impact of the project might be zero for the nation but still be a positive amount for Arizona. The nature of the study area is usually specified by the organization sponsoring the analysis. Many effects of a project may "net out" over one study area but not over a smaller one. The specification of the study area may be arbitrary but it may significantly affect the conclusions of the analysis.

2. Decision Criteria for Projects

2.1 The discounted present value of the benefits exceeds the discounted present value of the costs then the project is worthwhile. This is equivalent to the condition that the net benefit must be positive. Another equivalent condition is that the ratio of the present value of the benefits to the present value of the costs must be greater than one.

2.2 There are more than one mutually exclusive project that have positive net present value then there has to be further analysis. From the set of mutually exclusive project the one that should be selected is the one with the highest net present value.

2.3 The funds required carrying out all of the projects with positive net present value are less than the funds available this means the discount rate used in computing the present values is too low and does not reflect the true cost of capital. The present values must be recomputed using a higher discount rate. It may take some trial and error to find a discount rate such that the funds required for the projects with a positive net present value is no more than the funds available. Sometimes as an alternative to this procedure people try to select the best projects on the basis of some measure of goodness such as the internal rate of return or the benefit/cost ratio. This is not valid for several reasons.

The magnitude of the ratio of benefits to costs is to a degree arbitrary because some costs such as operating costs may be deducted from benefits and thus not be included in the cost figure. This may be done for some projects and not for others. This manipulation of the benefits and costs will not affect the net benefits and it will not raise the benefit cost ratio which is less than one to above one.

By reducing the positive and negative impacts of a project to their equivalent money value Cost-Benefit Analysis determines whether on balance the project is worthwhile. The equivalent money value are based upon information derived from consumer and producer market choices; i.e., the demand and supply schedules for the goods and services affected by the project. Care must be taken to properly allow for such things as inflation. When all this has been considered a worthwhile project is one for which the discounted value of the benefits exceeds the discounted value of the costs; i.e., the net benefits are positive. This is equivalent to the benefit/cost ratio being greater than one and the internal rate of return being greater than the cost of capital.

CHAPTER III

RESEARCH METHODOLOGY

Material and Equipment

In this study the data were collected at the installation site. The mathematic models were evaluated in term of energy balance for all parts of the systems as follows.

1. Flat-plate solar collector

The collector is used to test and has been certified by School of Renewable Energy Technology Naresuan University of testing standard ASHRAE STAND93-77 and was eligible for subsidies support program of the government (DEDE). The collectors were made and installed by Heritage International Development Ltd. The specification was: model HS.200 with the average solar radiation collection at 1,188 kWh/m^2/year, qualified for the top tier condition of the subsidy program and receiving subsidize money of 4,500 baht per m^2.

Detailed specification:

Heritage International Development Ltd. collector Model: HS: 200

Solar Absorber Panel

Dimension	: 1806 X 1090 X 80 mm.
Absorber Area	: 2 Sq.m.
Absorber	: Aluminum Black Coating
Absorber Material	: Copper-Aluminum
Number of Riser	: 8 x1/2”
Header Tube	: 2 x 7/8”
Casing Material	: Aluminum 2 mm. Thickness.
Insulation	: Micro fiber 50 mm. Thickness and Aluminum florid
Transparent Cover	: Temperate Glass
Weight (Empty)	: 38 kg.
Working Pressure	: 100 psi.
Test Pressure	: 200 psi (1,400kpa)

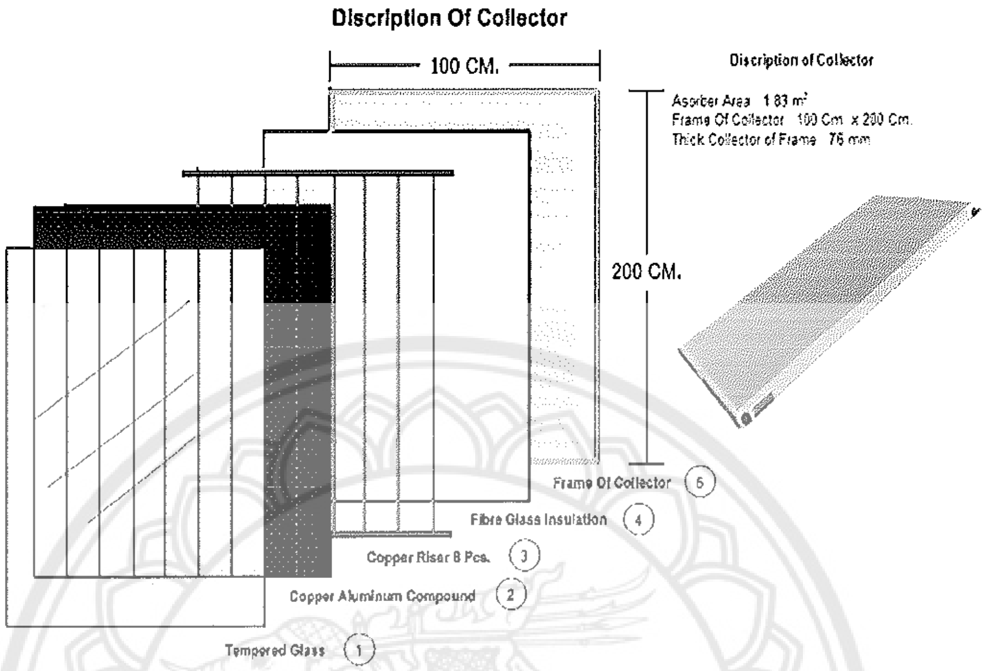


Figure 16 Description of heritage flat plate solar collector

2. Economizer

A heat exchange unit installed to complement the flat plate solar water heater to further help reduce the total water-preheating project cost. In this project, the economizer was obtained from Ntk workgroup Ltd.

Model: NTEMC-150-V

Heating capacity 18 kW.

Casing: steel SS: 400

Heat exchange: stand less still tube& stand less still fin

Air filter: flow rate 350 L./ Hr. water inlet 30°C

Hot water connection in/out ½

Figure 17 Economizer

3. Hot water storage tank

The storage tank in this study is a 5,000 liter closed system energy storage tank from Thai Sang Huad Co., Ltd. The double walled horizontal cylindrical tank was produced from black mild steel (SS400). The length of the tank is 230 centimeters with the diameter of 170 centimeters, with 1 centimeter thickness. The inside was sand blasted and epoxy-coated with Airless Spray technology. The tank can withstand pressure of at least 7kg/cm^2. The tank is insulated by 5 centimeters of fiberglass and aluminum foil. The outside wall of the tank is made of Stainless Steel (SS304) with 0.5 mm thickness.

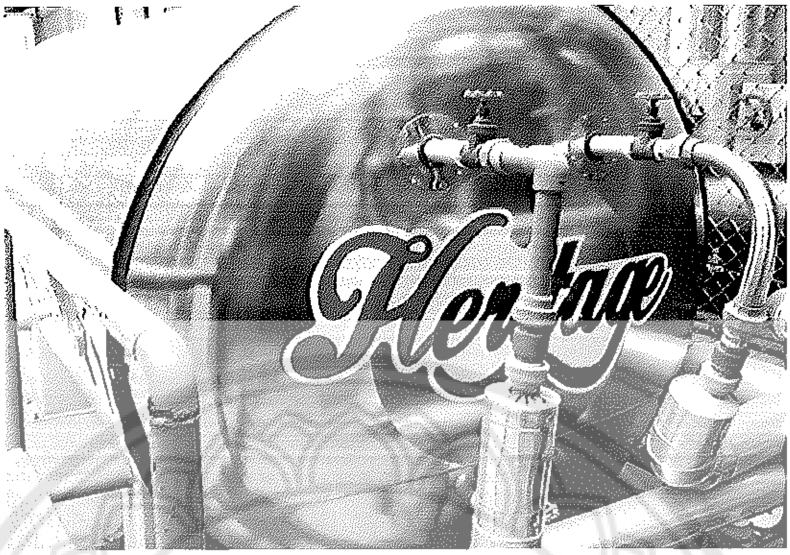


Figure 18 Hot Water Tank

4. Flow meter

Flow meter was installed to measure the amount of cold water passing through the hot water storage tank

Figure 19 Cold water meter

The flow meter was installed to measure the amount of cold water passing through the collector and meter is used to measure the amount of cold water going through the economizer

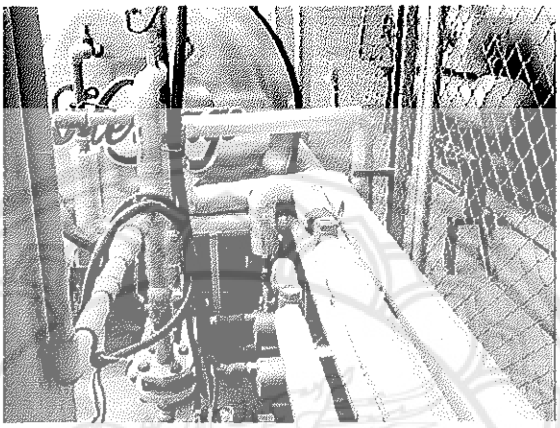


Figure 20 Cold water meter

5 Temperature gauge

This gauge is used to measure the temperature of outbound water going to economizer and solar panel.

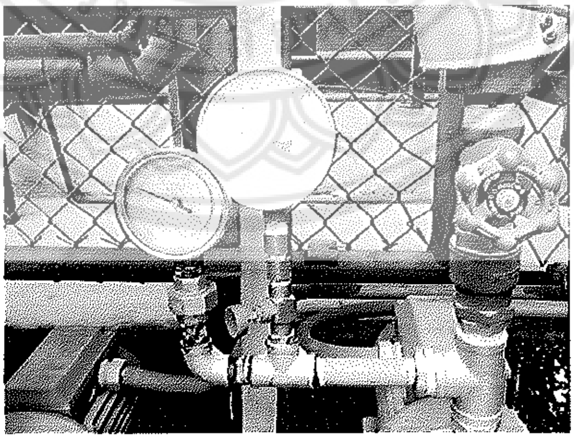


Figure 21 Temperature Gauge

6. Thermometer sensor

The sensor was installed at header of the collector panel to measure water temperature and passed the information to the control panel.

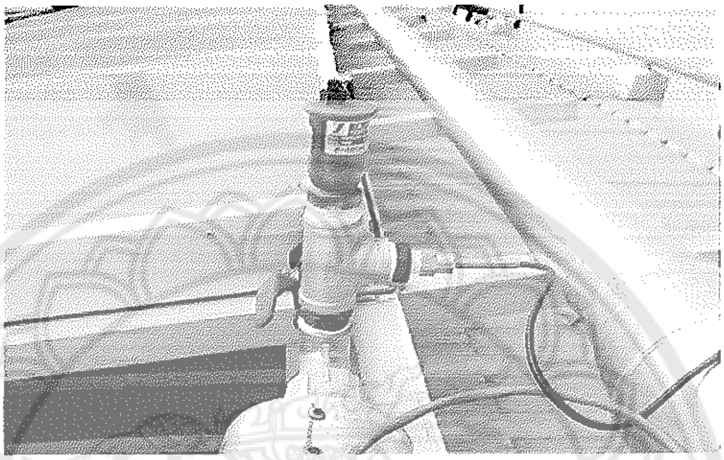


Figure 22 Thermometer sensor

Thermometer sensor is used to measure the temperature of hot water from economizer. The thermometer is attached to the upper part of economizer and when the batch of water reach reaches the preset temperature value, the water will be pumped out to storage tank, batch by batch. The temperature measured will be displayed on the control panel.

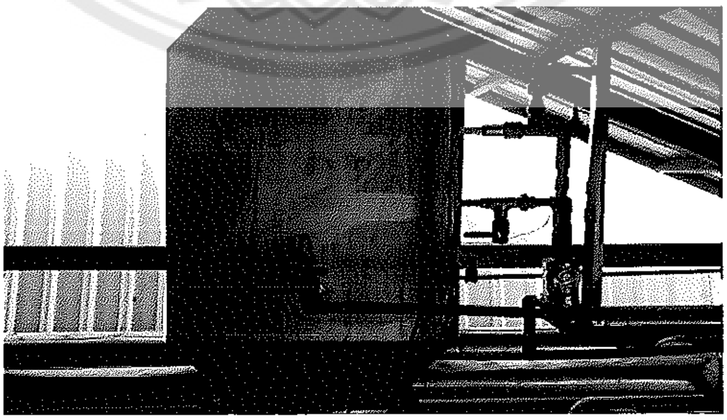


Figure 23 Thermometer sensor

7. Temperature of hot water storage tank control panel

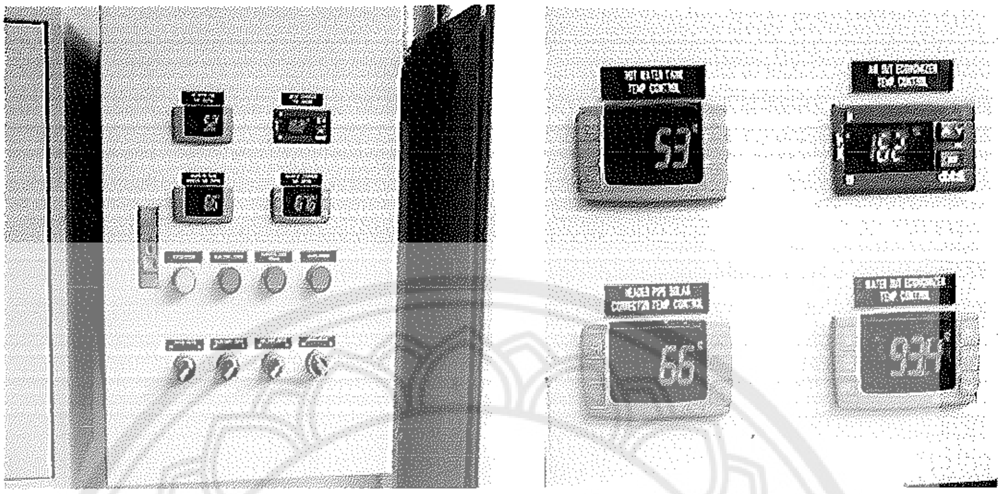


Figure 24 Control panel box to control hot water system

Another thermometer with temperature gauge is used to measure the temperature of water stored in the tank.

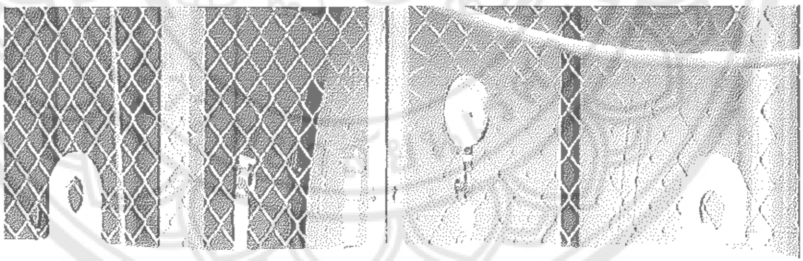


Figure 25 Temperature gauge and the storage tank

Experiment of industrial hot water system and the investment

Many industries use hot water for many activities to operate production in conventional from the electric heater or boiler but get the high cost in recent time. Presently the renewable energy is a better solution for producing the hot water for the industry by the solar and waste heat. A combination of renewable energy heat sources depends on the cost investment for optimum in cost and energy get from the design system. Hot water requirement of an example industry, Milott laboratories, Thailand with the amount of 11,500 liter per day is the research problem that needs to solve for the solar hot water system combine with the economizer. The input of the system is hot water requirement then the calculation is separated to optimum size of the solar hot water system and the investment cost for the waste heat. An economizer from the boiler is fixed by the size of the boiler installed in the industry which calculates the hot water by heat exchanger equation for producing hot water of 60°C. In this paper, the capacity of the economizer from installing of the boiler is 18 kW that produces hot water of 5,400 liter in 12.5 hours which the system investment cost of 410,000 baht. There is more utilization for backup the system after sunset and the investment is suitable for the capacity of the boiler. The investment cost in the other capacity is increased by the size of the economizer capacity. The solar hot water system would produce hot water of 6,100 liter for sufficient of the industrial requirement and this amount is used to find the area of the solar collector. A schematic diagram of the combined system is shown in Figure 21

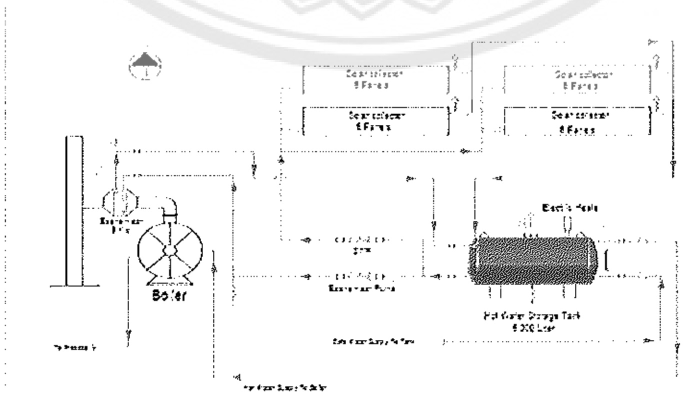


Figure 26 Schematic diagram of the solar hot water combined with economizer system

In figure 4, the economizer installs at the exhaust stack of the boiler in the industry for producing hot water parallel with the solar hot water system by the ratio of 1.13 respectively. The hot water system from the solar and economizer is used to collect the data and determine the investment cost analysis from the plate collector cost of the solar hot water system.

1. Solar hot water and economizer performance

The experiment for calculate the collector area is set up by the data from the real system there is installed in many area of hotel, hospital, and some building that needs to use the hot water. Firstly, the experimental and the calculation of the hot water production by the solar collector area is collected and secondly comparing to the calculation from the principle of energy balance for checking valid with the experiment. In average data of radiation in a year, therefore the hot water production can be calculated by the equation (1). The experiments are shown for calculation for finding out the satisfying of the experiment and calculation and determine the acceptable error. The classification of the experiments are set up by the hot water criteria of temperature difference form 30°C to 60°C that is the suitable temperature of hot water using in the conventional industry. [22] The requirement of the hot water is average of 5,800 liter per day that calculated by the equation from fitting curve is 85 m^2, but it could be reduced to 60 m^2 by increasing the collector efficiency from 50% to 70% since the collector decreases heat loss to the ambient with a good insulator. Cost of solar flat plate collector from surveying data is increased by the area and it can also determine with the same method of hot water as mention earlier. The cost equation from fitting curve of cost and area graph is shown in Figure 5. This equation is based on the criteria of flat plate collector which the efficiency between 50-70% and the hot water is produced by the principle of energy balance of the solar radiation transfer of to heat.

2. Investment cost analysis of the hot water system

The cost of the solar collector and the economizer is suitable with the hot water quantity that produce from the hybrid source of the solar energy and the economizer. For the financial section, this research determine the cost of installation, cost of energy saving and the payback period of installed system as the final results. All of the evaluations for system performance and financial mathematical model are according to government's investment decision making to support the solar hot water in Thailand. The initial data of cost estimation is started from the hot water quantity of the system around 6,000 L/d and the economizer will be selected the nearly size for producing hot water in the lowest cost but cheaper than the solar collector flat plate then the solar collector will be calculated by the fitting curve for determining the surplus hot water in this case around 2,000 L/d. The analysis of the investment cost is the evaluation on the hybrid system cost and calculated in the case of financial supporting and no supporting from the government sector.

The results of the surveying of the installation system

The solar hot water performance is surveyed from 6 hotel, 3 hospital and 7 factory for the solar radiation on the area and the hot water produced with the flat plate solar collector of various area. The data of each system is depended on the various solar collector area and the hot water consumption as shown in Table 5

Table 5 The various solar hot water system in hospitals of Thailand

	Nakornthon (A= 51m²)		Jaroenkrung (40 m²)		Klang (95 m²)	
Month	Radiation (MJ/m²d)	Hot water (L/d)	Radiation (MJ/m²d)	Hot water (L/d)	Radiation (MJ/m²d)	Hot water (L/d)
Jan	17.58	3,261	18.36	2,937	18.23	6,866
Feb	19.94	3,699	20.66	3,305	20.51	7,724
Mar	20.88	3,873	22.07	3,530	21.92	8,255
Apr	21.75	4,034	22.93	3,668	22.8	8,587
May	20.7	3,840	22.33	3,572	22.18	8,353
Jun	19.52	3,621	20.74	3,317	20.64	7,773
Jul	18.27	3,389	19.29	3,086	19.06	7,178
Aug	17.94	3,328	20.74	3,317	20.64	7,773
Sep	16.97	3,148	19.09	3,054	18.84	7,095
Oct	16.55	3,070	18.55	2,967	18.38	6,922
Nov	16.32	3,027	17.99	2,878	17.83	6,715
Dec	17.19	3,189	17.82	2,850	17.65	6,647
Average	18.63	3,457	20.05	3,206.75	19.89	7,490.67

The data in Table 5 is shown as the similarly of solar radiation that there is nearly in the same month. Hot water produced in Table 6 while the inlet and outlet is average of 30°C – 60°C. Average data from the six hospitals is shown in Table 6

Table 6 Average solar radiation and hot water production of various collector area in hospitals of Thailand

Area (m^2)	51	40	95	101	459	84
Radiation (MJ/m^2d)	18.63	20.05	19.89	19.91	20.10	19.95
Hot water (L/d)	3,457	3,206.75	7,490.67	8,036.17	55,058.3	6,703.67

These solar hot water data is used to calculate the solar collector area for design the area to produce hot water follow the requirement. The waste heat from the air condition or the boiler is used to produce hot water and combined to the solar collector. All hospitals, factories, and hotels are measured the waste heat for producing hot water in average of litres per day. The data is shown in Table 7 with the cost of heat exchanger in the economizer that install to the waste heat.

Table 7 Waste heat and hot water produced by the economizer from 30°C to 60°C

Waste heat (kJ)	Hot water from the Waste heat (L/d)	Cost of the economizer(baht)
300,730	2,281	25,000
1,706,400	12,000	200,000
426,736	3,403	25,000
62,700	5,000	50,000
1,805,760	14,400	200,000
853,347	6,805	150,000
1,354,320	10,800	200,000
2,896,740	21,000	200,000
1,053,360	6,000	150,000
1,565,620	12,485	200,000
82,969	863	25,000

Note: These data are modified to fit with the require temperature.

From Table 7, the cost of the equipment for transferring heat to water is depended on the amount of the heat and the hot water yield. The relation is not linear but there is discrete from 25,000 baht to 200,000 baht and this data is used to select the cost for making the heat exchanger or economizer. In the case of this research, the waste heat is measured of 640,000 kJ/d that produces the hot water of 5100 L/d by the installation cost of 50,000 baht. Financial survey of the collector cost is depended on the area size that shows in Table 8

Table 8 Cost of the solar collector at various area size

Collector area (m^2)	Cost of the system equipment (Baht)				Hot water production (L/d)
	Construction material	Storage tank	Economizer	Maintenance	
11	135,659	100,000	50,000	72,719	2,825
17	199,329	400,000	200,000	101,138	12,964
20	243,448	200,000	25,000	40,937	2,614
21	247,510	200,000	25,000	222,171	5,041
25	294,263	200,000	25,000	8,465	3,082
32	387,928	200,000	25,000	10,096	3,492
36	437,201	600,000	200,000	119,528	17,262
38	460,469	500,000	150,000	2,945,658	9,912
40	482,088	230,000	200,000	143,010	14,007
41	490,336	200,000	50,000	42,015	4,246
51	614,970	500,000	200,000	357,054	24,440
61	730,773	300,000	200,000	251,996	9,232
53	630,094	300,000	25,000	117,261	7,574
70	845,014	500,000	50,000	14,372	5,667
84	1,012,677	300,000	25,000	30,351	10,106
85	1,019,549	1,100,000	200,000	272,836	34,542
92	1,107,621	800,000	200,000	183,177	26,018

Note: Plate heat exchanger: Plate Hx

These survey data is used to analyse for the combination of an economizer and a solar collector for producing hot water according to the system for analysing the investment cost. The suitable system starts with the hot water requirement for the consumption data.

CHAPTER IV

RESULTS AND DISCUSSION

In this chapter, results of research are shown based on site survey, measurement and determination energy saving of solar hot water combined with an economizer system for water Pre-heating compared with the conventional systems based on economic benefit cost analysis economic calculation that were being made during this research work.

Analysis of solar hot water production investment

1. Solar hot water production combined with waste heat from an economizer

From the experimental setup, the data collection was provided from 16 hotel or industry and the comparison of solar collector area versus to the hot water production is shown in the Figure 27

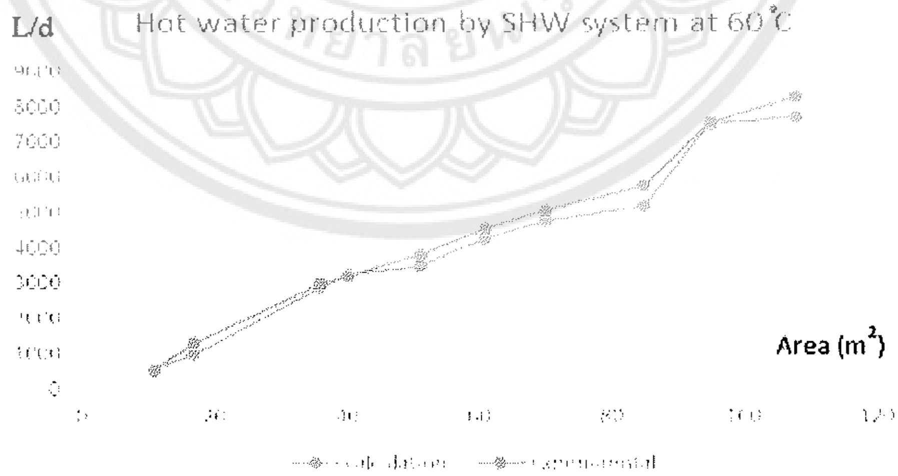


Figure 27 the comparison of the experimental and calculation of the SHW

2. Requirement and acceptance of the users on the hot water consumption

The result is validated for the principle of energy balance by small error and there is utilized to estimate hot water in the other collector area for finding the collector size that concerns to the material cost. Calculation result by fitting curve gives the equation for the case of annual solar radiation in Thailand as shown in Figure 28

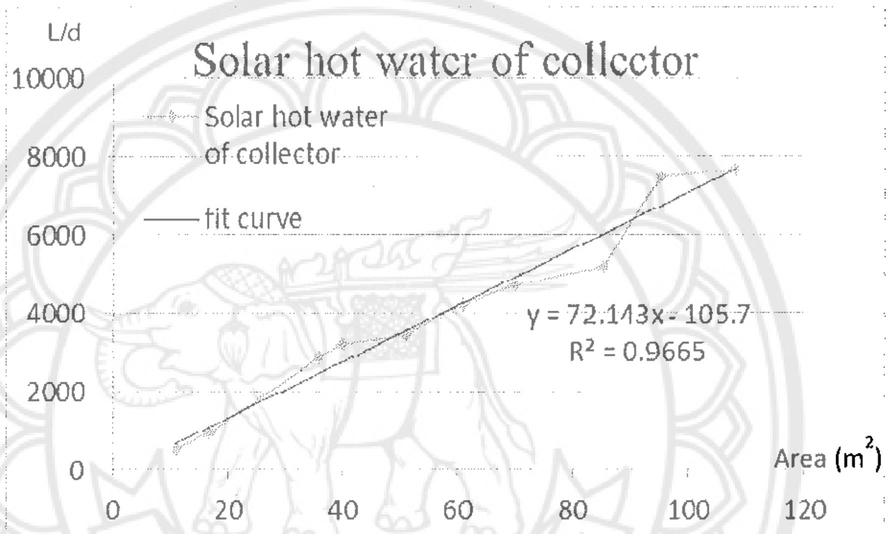


Figure 28 Data fitting curve of the collector area and the hot water from the SHW

For the industry and hospital and also hotel as suitable for installation the hybrid hot water system, there is around 6,000 L/d of hot water production for using and storage by investing the solar collector, piping work, storage tank and the economizer. The analysis is depended on the technology to increase the energy efficiency of the collector and the collector area will be reduced with the cost but the same capacity. The conventional solar collector is classified by the efficiency of around 50%, but the improvement collector with a new material and technology that increase the efficiency to 70% so the hot water is produced by the smaller area comparing to the lower efficiency. In this case the area of the collector is calculated of 60 m^2 with the efficiency of 70% as shown in Figure 29.

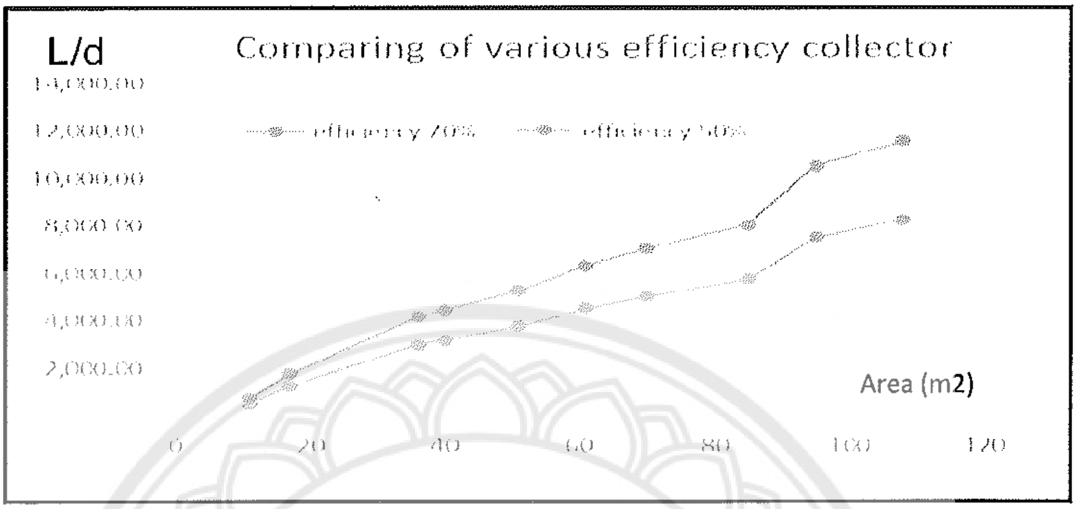


Figure 29 Comparing of various efficiency collector in area and hot water

The hot water increase due to the collector efficiency increase at the significant area of over than 40 m^2 and the improvement on the collector efficiency is mainly in the insulator for reducing heat loss. Cost analysis of the improvement collector efficiency is compared between the same hot water of larger collector as 80 m^2 and the collector insulator of 60 m^2. The result is shown that the high efficiency collector is cheaper than the bigger collector so this case indicates that the selection off the collector area is 60 m^2 with the hot water production of average 6,100 L/d.

Analysis of the equipment and installation of hybrid hot water production

Analysis of the solar hot water system and the economizer system from the waste heat supply is classified to solar thermal system and economizer heat system as following.

1. Solar collector and the storage tank system

The cost of the solar collector is increased when the area also increases due to the cost of the cover glass and material include with the insulator. The collector cost from the survey data in many system of solar hot water is shown in the Figure 30 and then the fitting curve is done by the linear equation for using to estimate the cost that gets from the first calculation input of 60m^2 and the output of 721,000 baht.

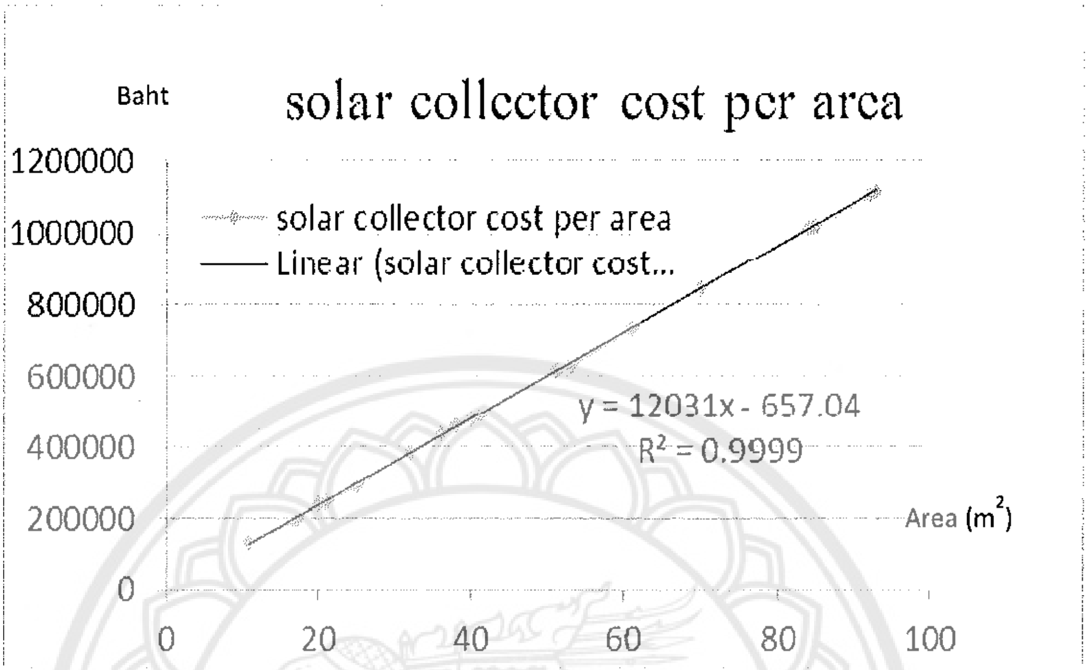


Figure 30 The cost of solar flat plate collector versus the plate area

The solar hot water is produced by the collector of 6,100 L/d reaching the requirement and the cost of the efficiency improvement collector with a storage tank and the piping system of 110,000 baht from the list of the equipment and the installation cost

High efficiency flat plate in the area of 60 m^2 of 720,000 baht.

Storage tank for the solar system volume of 6,000 L/d is 180,000 baht.

System installation cost of 200,000 baht.

2. **The economizer system**

This system is composed with the heat exchanger tube, water pumping, and the piping system which produces hot water of around 5,000 L/d. The evaluation cost of this system is classified to the composition of 2 main parts for the total cost of 410,000 baht from as the following:

The system material cost of 380,000 baht

The installation cost of 30,000 baht

Total cost in the system includes with the storage tank of 5,000 liter and installation cost of solar hot water system. The economizer cost is composed with the equipment material of 380,000 baht and the installation cost of 30,000 baht. The investment cost of two hot water system, solar and economizer is shown in the Figure 31

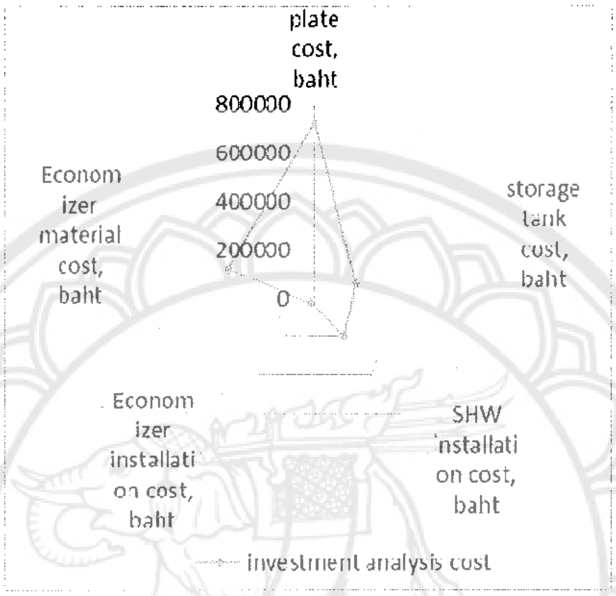


Figure 31 The investment cost analysis of solar hot water with economizer

From the figure 7 the major cost of investment is the solar hot water system which the highest of the solar collector cost. The important of the reduction cost by increasing the efficiency of the collector for producing the hot water in the requirement of the system. When comparing this system to the system of liquefied petroleum gas (LPG) using, It founds that the LPG fuel consumption of 43.70 kg per day which calculate to the cost of 473,044 baht per year. Playback period of the system is 3.19 years and the cost of solar hot water is 0.16 baht per liter and the cost of the economizer hot water is 0.07 baht per liter. The cost of outlet hot water production by the two systems is 0.11 baht per liter from the investment of 151,000 baht that is minimum cost from the context and the analysis for hot water of the industry.

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In Thailand, the renewable energy project as solar hot water is subsidized by Department of Alternative Energy Development and Efficiency (DEDE), Ministry of energy of Thailand, for saving energy project with the subsidy in this case of 4,500 baht per area. The investment cost is decreased by the subsidy to 1,240,000 baht and the playback period result is reduced from 3.19 years to 2.62 years. This project is promoted for encouraging the investor to install by the lower cost and stimulate people to use renewable energy by the policy of energy saving.

Validation of the analysis and experimental results

The combined system of solar hot water and waste heat production is set up the experiment to measure the hot water in average of 11,500 L/d from solar collector of 6,100 L/d and the economizer of 5,400 L/d with the error of 10% depend on the radiation and the loss of the system. From this result, it is found that the system could able to produce hot water at least of 10,000 L/d. The analysis of the investment cost, there is 2 main part of the investment, first is the solar collector and the storage tank investment cost of 72.8% and the hot water output of 53% respectively. Second is the economizer which composes of the equipment of heat exchanger and the installation cost of 27.2% and the hot water output of 47%. Although the solar hot water investment is higher than the economizer but the hot water production is nearly. For the other system, there is the difference of the requirement hot water and the waste heat that generates from the boiler or air condition. Analysis of the other system is used the same method by considering to the raw data and calculate the size of sources to meet the requirement of the target.

Subsidization of the government for promoting the renewable energy project

Background of subsidy for solar water hot water systems in Thailand for using of electricity in various activities such as agriculture, industries, commercial, fisheries, service and housing. For daily activities, there are many different styles and there is useless of electricity in some obvious ways. Electric power is produced directly into heat, such as hot water for washing, or cooking. Because the electricity is considered to be high-grade energy, it is unlikely that the electricity produced to be produced as low-energy then it would be suitable for the value of electricity produced. Therefore, the production of hot water to exploit is used of solar and waste heat from the air conditioning unit. It is one way to produce hot water instead of electricity. This will reduce some electrical power consumption. It also reduces pollution from clean energy. Various types of services such as hospitals, hotels, barber shops, restaurants, etc. are used to power many types of hot water or cold water for using LPG and electricity in production. More large as hospitals and hotels company use fuel oil or diesel fuel in a boiler. The solar water hot water can be used in combination with the hot water production system of the air conditioner. Most hospitals, hotels and industries use waste heat of refrigeration or so. The use of solar hot water production and hot water from waste heat. It may not be enough for both the volume and the temperature required to operate it, but it can reduce the depletion in hot water production until fuel consumption of the power consumption is reduced. The main thing is to bring the heat energy from the nature and heat energy left to use directly. From the concept the DEDE under the Ministry of Energy. The technology and form of the integrated solar water heater and waste heat recovery system have been implemented for commercial and industrial use to replace the use of electric power or other commercial energy.

Subsidy investment project to entrepreneurs who are attracted to install solar hot water systems. The establishment is needed to apply the letter confirming from the senior management who are authorized and participated in the project. The letter is applied to the Department of Alternative Energy Development and Efficiency (DEDE) under condition of these followings:

1. Provide support investment in solar hot water system

An integrated system to produce hot water using solar collector (solar collector) with a source of waste heat that can be used to produce hot water.

2. Provide support investment costs for the installation of the solar panels comprise the piping hot water storage tank. Control systems and other parts of the system which is not included in the waste heat recovery.

3. Funding investment as solar hot water system.

For devices with the average solar radiation was collected. Bachelors produced in the past year ranged from 800 kWh/m^2 up and store nutrients. Sun shade on a Flat Plate. Coated with a UV Absorber Type Properties (Selective Surface) or randomly large vacuum tube type Heat Pipe to 4,500 Baht per square meter store radiation of the Sun (By Flat Plate Solar Collector ideas. Areas Aperture-Aperture Area and Vacuum Tube Solar Collector area idea net-Gross Area).

For the average values of solar radiation at the store. Sunday in annual production is between 500-800 kWh/m2- year to 3,500 Baht per square meter store radiation of the Sun

Systems, solar hot water system can be integrated. Equipment already. Unable to obtain funding for this project which is a project to support both new and renovation projects. New Solar Collector substitution. Or increasing the size or capacity by a period not exceeding five years.

Material components used in solar hot water system. Be integrated with industry standards or international standards and new equipment never been used before all.

Glass of solar collector flat plate solar collector tempered glass vacuum solar collector must be of type borosilicate.

System design. And use of materials and equipment must have been received. design engineer licensed to practice engineering according to the council of engineers and under international standards certified installation.

Cases the support of installed systems ranging in size from 40 square meters to 500 square meters install system

CHAPTER V

CONCLUSION AND RECOMMENDATION

Conclusion

1. System production of the hot water

The analysis is composed with the data survey and the context in the industry about the waste heat and the method for transferring the waste heat to the water for combining to the system or even preheating in less radiation time. The cost of the solar collector is increased when the area also increases due to the cost of the cover glass and material include with the insulator. The solar hot water is produced by the collector of 6,100 L/d reaching the requirement and the total cost of the efficiency improvement collector with a storage tank and the piping system of 110,000 baht with the investment cost of 72.8% of the whole cost and the hot water output of 53% respectively while the economizer which composes of the equipment of heat exchanger and the installation cost of 27.2% of the whole cost and the hot water output of 47% respectively.

2. The investment cost analysis of solar hot water system

The system is calculated from the requirement based on the performance of the industry in this paper is 11,500 liter per day and capacity the economizer for producing hot water of 5,400 liter from the power of 18 kW and 6,100 liter from the solar collector. Estimation of the solar collector area is calculated by the fitting curve of the data and the result is 86 m^2 for the collector efficiency of 50%. The method of reduction the area for decreasing the cost by using high quality insulator and cover glass that decrease the heat loss and increase the efficiency of the collector to the area of 60 m^2 and the cost is around 721,000 baht. Total cost for the whole system is 151,000 baht including the supporting equipment that is storage tank, installed worker payment and the piping system. The playback period of the system is 3.19 years and the cost of solar hot water is 0.16 baht per liter and the cost of the economizer hot water is 0.07 baht per liter. The cost of outlet hot water production by the two systems is 0.11 baht per liter.

Recommendation

The investment analysis method of solar hot water and economizer is focuses on the investment cost analysis of hybrid solar hot water and economizer system for water pre-heating in industrial use. The system use both solar energy and waste heat recovered from boiler to preheat water before being fed into boiler. The analysis included investment cost, evaluation of economic cost, benefits returned on investment and feasibility analysis of the hybrid system with the subsidiary from Thai government.

Data collection was carried out by finding the usage of gas as boiler fuel before the installation of the hybrid system. The data from solar collector and economizer were collected by measuring the water temperature from the inlet and outlet in both systems. Calculation were used to find out the hot water producing capabilities and combined capability.

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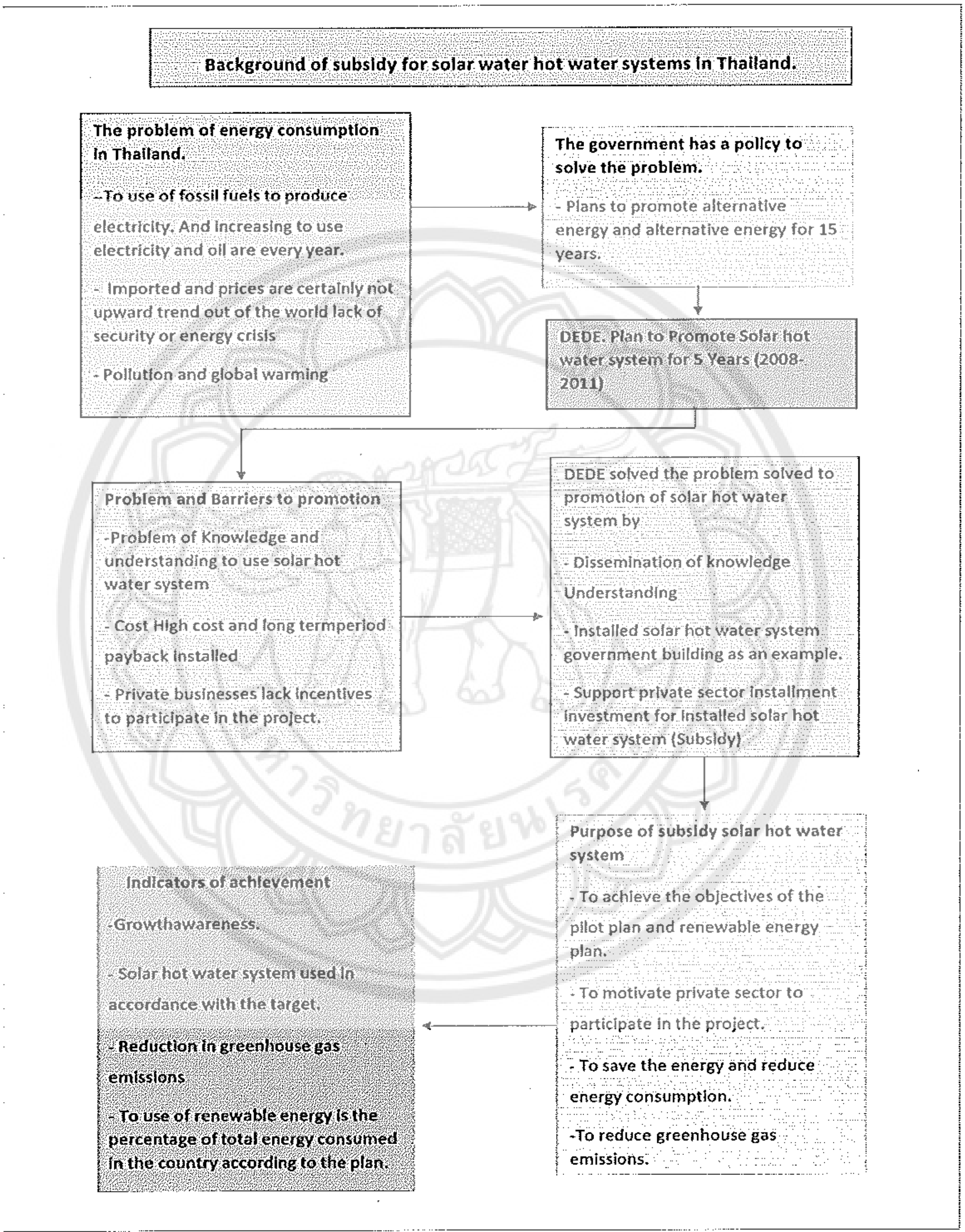
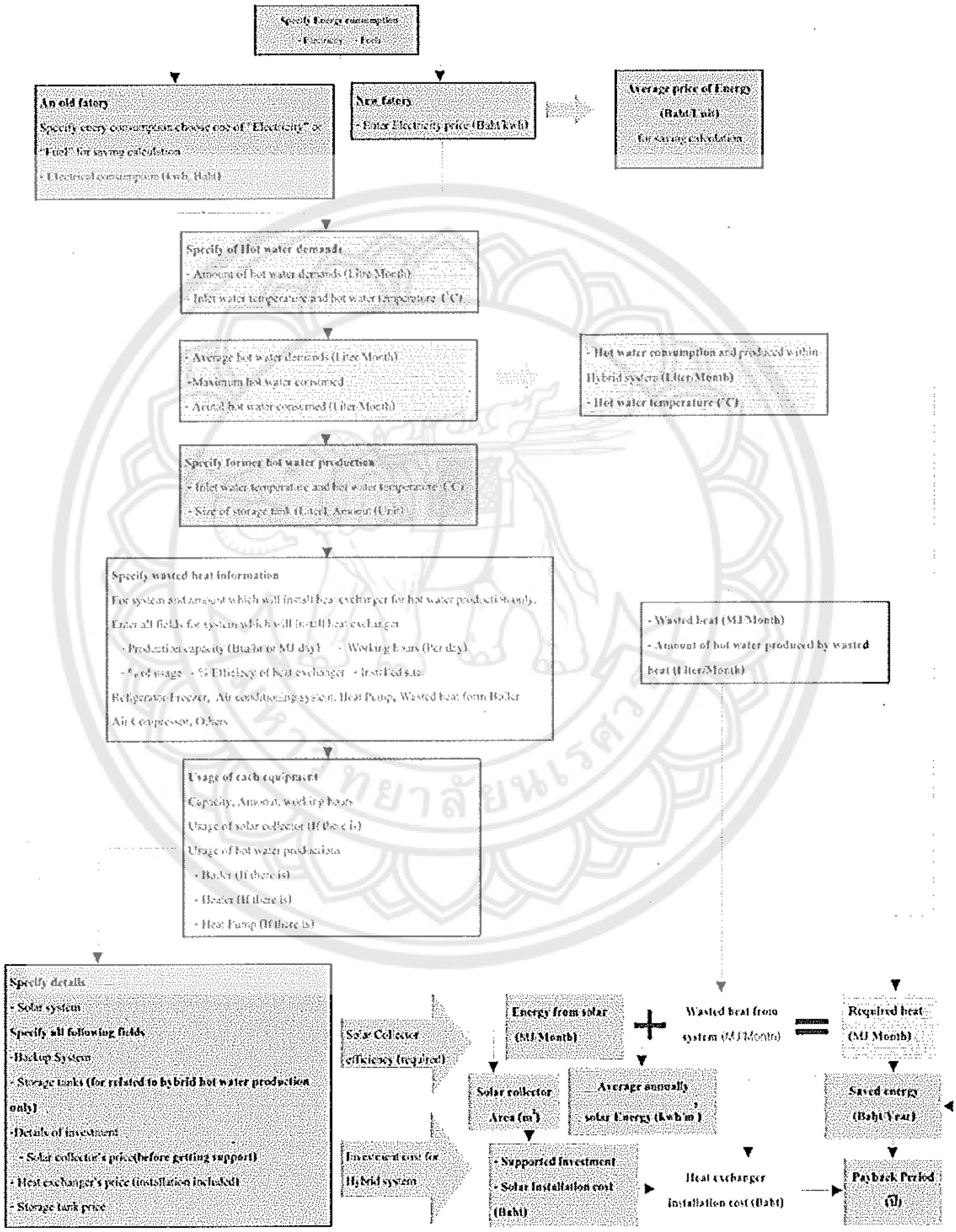
APPENDIX

Flow chart of subsidy solar hot water system



Flow chart System of Solar Hot Water System Installation



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An Investment Cost Analysis of Solar Hot Water System Combined with Economizer for Industry

Sammao Pansang and Sarayooth Vaivudh

School of Renewable Energy Technology, Naresuan University, Phitsanulok 65000, Thailand

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Abstract: A combination of solar hot water system with the economizer for heating the water that circulates in the hot water storage tank is presented with the objective to reduce and analyze the cost of investment. The solar collector area will be affected to the investment cost of the solar hot water system. A combined system can be reduced the cost of solar collector by using the waste heat from the economizer to produce the hot water for reaching the requirement of the industry. In this paper the economizer installs in the boiler stack of the industry and produces hot water at 60 °C of 5,400 liter per day and the solar hot water system produces the hot water at the same temperature of 6,100 liter per day. The analysis is purposed by determining the solar collector plate area from the data and calculation. Investment cost of the system is 151,000 baht for the solar hot water system of 110,000 baht and the economizer of 410,000 baht for producing the total hot water of 155,000 liter per day.

Key words: Investment cost analysis, solar hot water system, economizer.

1. Introduction

Hot water is used in many industry processes for multipurpose as cleaning, disinfection, and transform material in some products. The conventional fuel for producing hot water is petroleum or fossil fuel as heavy oil, diesel, natural gas, or coal that release more waste heat, gas pollution and greenhouse gas that is not saving for human health and environmental. From the region of Thailand that experience of high solar radiation, there is more capacity of solar hot water production for using in the industrial activities [1]. Recently, the industry process uses more energy for producing the products and running many systems by investing the energy system that spend money for the fuel or electricity. Fossil fuel or electricity is selected to be the main energy that is simply using by conventional equipment and get more consumption for energy or fuel. The new environmental friendly equipment is presented to the industrial energy system for reducing the fuel cost is solar energy, and waste heat energy that is available in every industry. Since of more and more area of solar collector can be installed in the industry, it will get more heat for using in the process. The hot water is very important of the industrial process in the production process and cleaning system, therefore the solar hot water system is selected for producing hot water for the industry without the energy cost due to free energy from the solar radiation. Hot water from the solar collector is transformed by the solar radiation that depends on the collector area and the loss in the system [2]. The hybrid source is a new technology to apply in present day to reduce the waste energy as shown in the case of solar hot water combined with the waste heat exchange from the economizer. An economizer is the heat exchanger of the waste heat gas to the water for preheating to the hot water system. These often take the form of loops, spiral or parallel arrays of finned tubing through which the feed water flows and over which the exhaust gases pass. They are available in modular form to be introduced into the exhaust stack or into the breeching [3].

Corresponding author: Sammao Pansang, M.Sc., research field: solar hot water system.

2. Solar Hot Water System Combined with the Economizer

An active solar hot water system consists with the solar collector, the electric circulate pump, the hot water storage tank, and economizer for using waste heat that installs at the top of the exhaust stack of the boiler. The economizer is a heat exchanger of the boiler exhaust gas that transfers heat to the water for producing hot water to add the hot water in the system. The SHW (solar hot water) system combines to the economizer by the connection of the piping in closed loop system to the storage tank. Conventional solar collector for hot water is flat plate collector, a type of flat plate collector, which composes of cover glass, thermal insulator frame and bottom and the copper absorber tube for heating water that circulates in the tube as shown in Fig. 1 [4].

The hot water flow rate is produced by the solar radiation that converse to heat by the solar collector which install at the proper tilt angle and orientation of the collectors [5]. The flow rate of solar hot water system is calculated by the principle of energy balance of the radiation and the energy transform to heat the water in the collector by Eq. (1)

$$q_u = A_c\left[G_t(\tau\alpha) - U_L(T_p - T_a)\right] = \dot{m}c_p(T_o - T_i) \tag{1}$$

where,

q_u is the energy rate of heat from the collector;

A_c is the area of the solar collector;

G_t is the solar radiation impact on the collector;

$\tau\alpha$ is the transmittance and absorptance respectively;

U_L is the overall loss coefficient;

T_p is the collector flat plate temperature;

T_a is the ambient temperature;

$\dot{m}$ is the water flow rate in the solar collector;

c_p is the water heat capacity;

T_o, T_i are the inlet and outlet water temperature, respectively.

A solar flat plate is impacted by the radiation and produces the hot water depending on the area of the

Fig. 1 A solar collector structure.

Fig. 2 The data of solar hot water system measuring and calculation.

collector and the radiation that varies by the time. The experiment result of the example solar collector flat plate area of 51 m^2 is measured and compared to the calculation by Eq. (1) as shown in Fig. 2.

From Fig. 2 the variation of solar hot water is followed by the radiation that increased to maximum in April and minimum in November. The average of the hot water is 3,546 liter per day. An average hot water is varied by the area of the collector that could be calculated to find out by the data fit curve as done in the experimental and calculation. In the figure is shown the solar radiation in one year that is not constant in every month but the same average over the year with small error.

An economizer is a device that removes waste heat from the stack gas of some equipment in industry such as boiler, refrigeration or air condition. Waste heat is free and return to be the utilizing energy for reduction the investment cost for hot water system by the economizer. By recovering industrial waste heat, energy efficiency can be increased, greenhouse gas emissions can be reduced and the cost of waste heat disposal can be lowered [6]. Economizer composes with heat exchanger for transferring heat from the exhaust stack of the boiler to the water by the jacket tube as shown in Fig. 3.

The hot water from the waste heat is recovered by the economizer with the capacity for preheating water or backup the system when the solar radiation is less by controlling the hot water temperature to set up at the same temperature of solar hot water [7].

3. Hot Water for the Industry and the Investment

Many industries use hot water for many activities to operate production in conventional from the electric heater or boiler but get the high cost in recent time. Presently the renewable energy is a better solution for producing the hot water for the industry by the solar and waste heat. A combination of renewable energy heat sources depends on the cost investment for optimum in cost and energy got from the design system. Hot water requirement of an example industry, Milott laboratories, Thailand with the amount of 11,500 liter per day is the research problem that needs to solve for the solar hot water system combined with the economizer. The input of the system is hot water requirement then the calculation is separated to optimum size of the solar hot water system and the investment cost for the waste heat. An economizer from the boiler is fixed by the size of the boiler

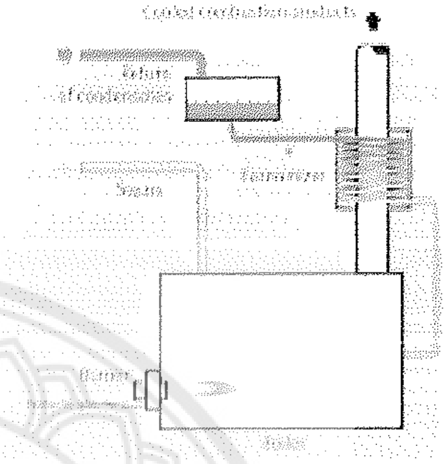

Fig. 3 The economizer diagram with the boiler stack of installation.

installed in the industry which calculates the hot water by heat exchanger equation for producing hot water of 60 °C. In this paper, the capacity of the economizer from installing of the boiler is 15 kW that produces hot water of 5,400 liter in 12.5 hours which the system investment cost is 410,000 baht. There is more utilization for backup the system after sunset and the investment is suitable for the capacity of the boiler. The investment cost in the other capacity is increased by the size of the economizer capacity. The solar hot water system would produce hot water of 6,100 liter for sufficient of the industrial requirement and this amount is used to find the area of the solar collector. A schematic diagram of the combined system is shown in Fig. 4.

In Fig. 4, the economizer installs at the exhaust stack of the boiler in the industry for producing hot water parallel with the solar hot water system by the ratio of 1.13 respectively. The hot water system from the solar and economizer is used to collect the data and determine the investment cost analysis from the plate collector cost of the solar hot water system [8].

Since the solar hot water system combined with waste heat from the economizer not only reduces the cost of collector by including waste heat to the system but also decreasing the ambient temperature due to the climate change and saving the boiler exhaust stack

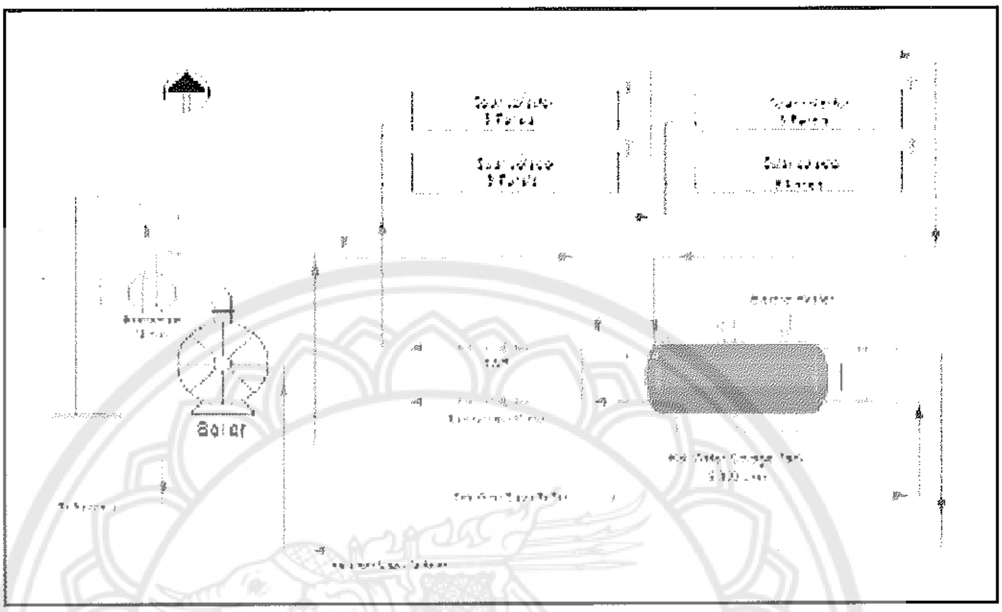

Fig. 4 Schematic diagram of the solar hot water combined with economizer system

from heat.

4. Experimental Setup

The experiment for calculating the collector area is set up by the data from the real system that is installed in many areas of hotel, hospital, and some building that needs to use the hot water. Firstly, the experimental and the calculation of the hot water production by the solar collector area is collecting the data from the experiment as shown in Fig. 3 and secondly comparing to the calculation from the principle of energy balance for checking valid with the experiment. In average data of radiation in a year, therefore the hot water production can be calculated by Eq. (1). Fig. 3 is shown the satisfying of the experiment and calculation by the error less than 10%.

This result is validated for the principle of energy balance by small error and there is utilized to estimate hot water in the other collector area for finding the collector size that concerns to the material cost. Calculation result by fitting curve gives the equation for the case of annual solar radiation in Thailand as shown in Fig. 5.

In Fig. 5 the hot water from the collector is calculated for the criteria of temperature difference from 30 °C to 60 °C that is the suitable temperature of hot water using in the conventional industry. The requirement of the hot water is average of 6,000 liter per day that calculated by the equation from fitting curve is 86 m^2, but it could be reduced to 60 m^2 by increasing the collector efficiency from 50% to 70% since the collector decreases heat loss to the ambient with a good insulator. Cost of solar flat plate collector from surveying data is increased by the area and it can also determine with the same method of hot water as mention earlier. The cost equation from fitting curve of cost and area graph is shown in Fig. 6. This equation is based on the criteria of flat plate collector which the efficiency between 50-70% and the hot water is produced by the principle of energy balance of the solar radiation transfer of to heat.

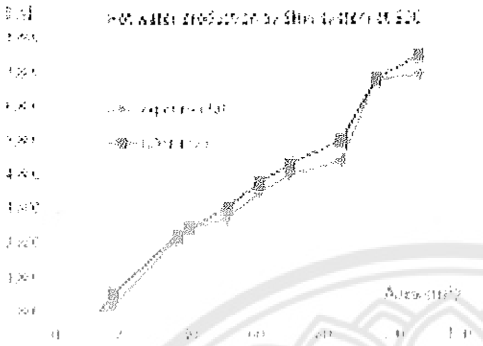

Fig. 5 The comparison of the experimental and calculation of the SHW.

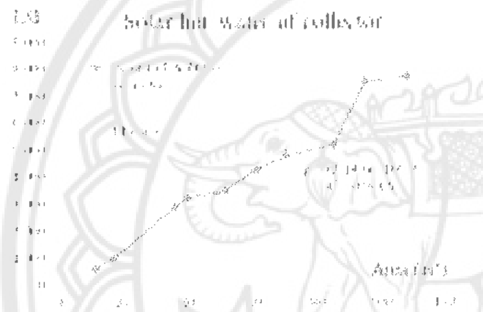

Fig. 6 Data fitting curve of the collector area and the hot water from the SHW.

Fig. 7 The cost of solar flat plate collector versus the plate area.

5. The Investment Analysis Method of Solar Hot Water and Economizer

The cost of the solar collector is increased when the area also increases due to the cost of the cover glass and material included with the insulator. The collector cost from the survey data in many system of solar hot water is shown in the Fig. 7 and then the fitting curve is done by the linear equation for using to estimate the cost that gets from the first calculation input of 60 m² and the output of 721,000 baht.

Total cost in the system includes with the storage tank of 5,000 liter and installation cost of solar hot water system. The economizer cost is composed with the equipment material of 330,000 baht and the installation cost of 30,000 baht. The investment cost of two hot water system, solar and economizer is shown in Fig. 8.

From Fig. 8 the major cost of investment is the solar hot water system which has the highest solar collector cost. The important is the reduction cost by increasing the efficiency of the collector for producing the hot water in the requirement of the system. When comparing this systems to the system of LPG (liquefied petroleum gas) using, it founds that the LPG fuel consumption of 43.70 kg per day is calculated to the cost of 473,044 baht per year. Playback period of the systems is 3.19 years and the cost of solar hot water is 0.16 baht per liter and the cost of the economizer hot water is 0.07 baht per liter. The cost of outlet hot water production by the two systems is 0.11 baht per liter from the investment of 151,000 baht that is minimum cost from the content and the analysis for hot water of the industry.

Fig. 8 The investment cost analysis of solar hot water with economizer.

In Thailand, the renewable energy project as solar hot water is subsidized by DEDE (Department of Alternative Energy Development and Efficiency), Ministry of energy of Thailand, for saving energy project with the subsidy in this case of 4,500 baht per area. The investment cost is decreased by the subsidy to 1,240,000 baht and the playback period result is reduced from 3.19 years to 2.62 years. This project is promoted for encouraging the investor to install by the lower cost and stimulate people to use renewable energy by the policy of energy saving.

6. Conclusions

The investment cost analysis of solar hot water system is compered with the data survey and the context in the industry about the waste heat and the method for transferring the waste heat to the water for combining to the system or even preheating in less radiation time. System production of the hot water which is calculated from the requirement based on the performance of the industry in this paper is 11,500 liter per day and capacity the economizer for producing hot water of 5,400 liter from the power of 18 kW and 6,100 liter from the solar collector. Estimation of the solar collector area is calculated by the fitting curve of the data and the result is 86 m² for the collector efficiency of 50%. The method of reduction the area for decreasing the cost by using high quality insulator and cover glass that decrease the heat loss and increase the efficiency of the collector to the area of 60 m² and the cost is around 721,000 baht. Total cost for the whole system is 151,000 baht including the supporting equipment that is storage tank, installed worker payment and the piping system.

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