Economic Analysis of Solar Water Heaters in GuangZhou

Ying Wang LiHua Zhao
Graduated Student Associate Professor
School of Architecture, South China University of Technology
Guangzhou China
onwing@163.com

Abstract: As a mature applied technology, the largest obstacle to the promotion of the solar water heater is the high initial investment that makes an impact on consumers' choices. The initial investment and maintenance cost of the solar water heater，gas water heater and electrical water heater in Guangzhou was compared and the Annual Cost Calculation Method (ACCM）was introduced to explain the remarkable economic benefits. The social benefits of the solar water heater were introduced from a scientific view.

Key words：renewable energy; solar water heater; economic analysis; Annual Cost Calculating Method (ACCM)

1 INTRODUCTION

Since last century, solar application has become an important part of new energy and renewable energy. The research on solar heat application, such as solar collector, solar greenhouse, solar air-conditioning and so on, is more than before. After 20 years of development, the manufacturing of solar water heater has become a relatively mature industry. As some data shown, the annual capacity of solar water heaters in China is 2 times that of in Europe and 4 times of that North America. China has become one of the largest manufacturing countries and application markets in the world. At the same time, the increasing rate is continuing upward from 20% to 30% per year[1].

At present, the primary holdback of the promotion of solar water heater is the higher initial investment rather than technology. As a kind of renewable energy which exists extensively, delivers equally and can be used freely, some investments on collector, exchange, storage and utilizing are essential. Comparing conventional water heaters, solar water heater has the advantage in lower run cost in its lifecycle though the initial investment is relative high. Basing on the economic guideline in Guangzhou, ACCM was used in this paper to take a lifecycle economic analysis comparing gas water heater and electricity water heater.

2 METHODOLOGY

2.1 Required Heat for Hot Water in Guangzhou

Basing on investigation, the local inhabitants in Guangzhou have the habit of taking bath almost everyday. Take an ordinary family with 3 persons for example, due to the present criterion which prescribes that every person in each family uses 30 kg in 45℃ hot water for bath, we can get annual water dosage. Then basing on the equation(1), we can get overall required heat with which tap water can be heated up to domestic hot water. The heat values of each family per month are shown in the following Table 1.

$$Q = C_p M (T_2 - T_1) \quad (1)$$

Where

Q—total heat （kJ）;

M —water consumption （kg）;

C_p —specific heat capacity at constant pressure gets 4.18 kJ/kg.□;

T_1—original temperature of water , here is tap water temperature;

T_2 —final temperature of hot water, here is 45□

Tab. 1 Required heat for family hot water

month		1	2	3	4	5	6
bath hot water consumption	kg/day	90	90	90	90	90	90
living hot water consumption	kg/day	30	30	30	20	20	10
daily total hot water consumption	kg/day	120	120	120	110	110	100
monthly total hot water consumption	kg/month	3720	3360	3720	3300	3410	3000
monthly average tap water temperature	□	15.2	15.2	20.6	20.6	29.3	29.3
required heat	MJ	463.4	418.5	379.4	336.6	223.8	196.9
month		7	8	9	10	11	12
bath hot water consumption	kg/day	90	90	90	90	90	90
living hot water consumption	kg/day	10	10	10	20	30	30
daily total hot water consumption	kg/day	100	100	100	110	120	120
monthly total hot water consumption	kg/month	3100	3100	3000	3410	3600	3720
monthly average tap water temperature	□	29.3	29.3	29.3	20.6	20.6	15.2
required heat	MJ	203.4	203.4	196.9	347.8	367.2	463.4

2.2 Solar Radiation in Guangzhou

Basing on the principle that the best angle of solar collector should be equal to local geographical latitudinal angle under the condition of being used year-round, a slope of 23°from the horizontal is being taken. With this angle the gross radiation getting by solar collectors locating southward has been listed in Table 2[2].

2.3 Effective Heat Gain by Solar Water Heater

Basing on the method introduced in Reference 3 and 4, we can get the average heat efficiency of evacuated tube solar water heater under the condition using heat water year-round with 1.5 m^2 collector area. Then the efficient heat values can be calculated listing in table 3. Basing on the above dates, the surplus or shortage heat in Guangzhou are shown in table 4.

From the above table we can conclude that there are 6 months requiring supplementary heating with a slope of 23°from the horizontal in Guangzhou.

3 ECONOMIC ANALYSIS OF THREE KINDS OF WATER HEATER

Basing on required heat, three kinds of water heater including solar water heater, gas water heater and electrical water heater are compared by ACCM.

The technical-economic effect embodied the proportion of heat gain and heat usage. If heat gain in comparing projects is equal, the one with the least heat usage will be the most efficient project. The two parts including initial investment and maintaining costs of heat usage in technological project could not be added together simply due to their different quality.

ACCM is also named converting cost method. For the initial investments and maintaining costs being different costs which can not add together, a investment effective coefficient is used as the converting ratio. Then the annual calculating cost can be gotten by adding the converted expenses which is converted by initial investments during using period to maintaining costs. Finally the project with least annual calculating expenses will prove to be the best[3]. According to such conception, the calculating formula is as following, using a dynamic analysis method to make a technical-economic analysis:

Tab. 2 Monthly average daily radiation in Guangzhou with 23 tilt angle of collector

month		1	2	3	4	5	6
monthly average daily irradiation horizontal	MJ/m^2d^{-1}	8.9	7.6	7.4	8.7	11.2	12.8
monthly average daily irradiation with 23 degree angle	MJ/m^2d^{-1}	9.7	12.0	15.2	17.5	19.4	19.0
total monthly irradiation	MJ/m^2	302.1	335.1	470.9	523.6	600.9	571.3
month		7	8	9	10	11	12
monthly average daily irradiation horizontal	MJ/m^2d^{-1}	14.9	13.9	14.0	13.1	11.8	10.5
monthly average daily irradiation with 23 degree angle	MJ/m^2d^{-1}	16.1	15.5	15.4	13.2	10.0	9.2
total monthly irradiation	MJ/m^2	498.9	481.2	462.8	408.6	300.7	284.3

Tab. 3 Average heat efficiency of evacuated tube solar water heater with 1.5 m2 collector area

month		1	2	3	4	5	6
average heat efficiency		0.42	0.46	0.5	0.52	0.55	0.56
effective heat gain	MJ	190.3	231.2	353.2	408.4	495.7	479.9
month		7	8	9	10	11	12
average heat efficiency		0.56	0.56	0.56	0.54	0.51	0.46
effective heat gain	MJ	419.1	404.2	388.7	331.0	230.0	196.1

Tab. 4 Surplus or shortage heat values in Guangzhou

month		1	2	3	4	5	6
effective heat gain	MJ	190.3	231.2	353.2	408.4	495.7	479.9
required heat	MJ	463.4	418.5	379.4	336.6	223.8	196.9
surplus or shortage heat	MJ	-273.0	-187.3	-26.2	71.8	271.9	283.0
month		7	8	9	10	11	12
effective heat gain	MJ	419.1	404.2	388.7	331.0	230.0	196.1
required heat	MJ	203.4	203.4	196.9	347.8	367.2	463.4
surplus or shortage heat	MJ	215.6	200.8	191.9	-16.8	-137.1	-267.2

$$Z = \theta g \cdot K + C = \frac{i(1+i)^n}{(1+i)^n - 1} \times K + C \quad \text{RMB} \qquad (2)$$

Where

Z—annual calculating cost（RMB/year）

K—initial investment（RMB）

i —interest rate （%）

n —producing period , here take the lifecycle of solar water heater（RMB）

C—annual maintaining costs（RMB/year）

θ_g—fund reclaiming coefficient

For an evacuated tube solar water heater with $1.5m^2$ area , the annual converted cost of initial investments can be calculated with the assumption that Profit Margin is 1.8%. The initial investments of solar water heater are 2700 RMB, which lifecycle is 15 years. Supplementary energy can be used to make up the shortage. The result is as following:

$$Z_o = \frac{0.018 \times (1+0.018)^{15}}{(1+0.018)^{15} - 1} \times 2700 = 207.0 \quad \text{（RMB）}$$

Two additional heating ways by gas and electricity will be calculated in ACCM.

3.1 Assisting gas heating

The efficiency of gas supplementary heating is 80%. In Guangzhou the gas heat values are 6500kal/m^3 and the gas price is 2.5RMB/m^3. The gas usage per year which can be calculated according to total surplus and shortage heat is following:

$$\frac{819.2\times1000}{27209\times0.8}=37.6 \ \ m^3$$

Annual calculating cost are

$$Z = 207.0+37.6\times2.5=301.1 \quad （RMB）$$

3.2 Assisting electric heating

The efficiency of electric supplementary heating is 90% and the electric price is 0.699RMB/kWh. We can get the annual electricity usage is: $\frac{819.2}{3.6\times0.9}=284.4\,\mathrm{kWh}$

Annual calculating cost are

$$Z = 207.0+284.4\times0.699=405.8 \quad （RMB）$$

By the same way, the initial investment, lifecycle, and the efficiency of gas water heater and electricity water heater can be substituted to equation(2), so we can get annual calculating expenses of two types of water heaters. From Table 5 we can get a conclusion that for the same hot water demand, the annual calculating costs of solar water heater are the least, though its initial investment is more than the others. What is more, the gas assisting solar water heater proves more economic and has a highly economic

benefit which can respectively save 5000 to 10000 RMB comparing with gas water heater and electricity water heater under the condition of 15 years using period.

Tab. 5 Three kinds of water heaters contrasting in annual calculating expenses

Item		solar water heater (gas assisted)	solar water heater (electricity assisted)	gas water heater	electricity water heater
initial investment	RMB	2700	2700	1500	1200
bank ratio		0.018	0.018	0.018	0.018
water heater lifecycle	year	15	15	8	6
water heater efficiency		0.8	0.9	0.8	0.9
gas/electricity rice	RMB/m^3	2.5	0.699	2.5	0.699
gas heat values through city pipeline	kJ/m^3	27209		27209	
annual converted expenses of initial investment	RMB/year	207.0	207.0	203.0	212.8
annual gas consumption	m^3	37.6		174.6	
annual electricity consumption	kWh		284.4		1173.0
(assisted)gas cost	RMB	94.1		436.5	
(assisted) electricity cost	RMB		198.8		820.0
annual calculated cost	RMB	301.1	405.8	639.5	1032.7
annual calculated cost multiple basing on solar water heater		1.00	1.35	2.12	3.43

4 CONCLUSION

The distributing of solar source has obvious rationality and Guangzhou belongs to the third resource zone in China basing on the statistic on annual solar radiation. Due to the above analyses, the annual calculating expenses of electric assisting solar water heater, gas assisting solar water heater and electric water heater will respectively be 1.35 times, 2.12times and 3.43times as gas assisting solar water heater which has a relative competitive priority. Though enough roof areas are required to place the solar collectors, the meaning for choosing solar water heater is profound and lasting from a social benefit point of view in order to sustainable develop and

benefit our offspring.

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