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# LIFE-CYCLE COST COMPARISON OF ELECTRIC BOOSTED AND NATURAL GAS BOOSTED SOLAR WATER HEATING SYSTEMS

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## ABSTRACT

*The use of solar water heating system is becoming more popular in Australia as the demand for it is raising. Also, the climatic conditions in Australia favour the SWH progress. But in most situations due to the influence of weather and SWH design parameters, the water temperature required by the households are not met. For this, supplying auxiliary fuel is one of the best options but the cost involved in it is to be assessed properly. This paper presents a study on the life cycle cost assessment and greenhouse gas emissions (GHG) produced from the two SWH systems boosted by the auxiliary energy supplies like electric energy and natural gas (namely EBS and NGBS). Results analysed for the Australia household having 3 members in a family (2 adults and 1 child) revels that, life cycle cost (LCC) for electric boosted solar (EBS) water heater, and natural gas boosted solar (NGBS) are AU$ 4468, and AU$ 6315 respectively. GHG emissions produced for EBS and NGBS are 843 tons of CO2 and 386 tons of CO2. The study articulated here would the hot water consumers to select the best options as per their preference.*

**Keywords:** Solar energy; solar water heater; LCC of solar heater; auxiliary heating for solar; natural gas heating; electric heating.

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## NOMENCLATURE

| | |
|---|---|
| ARC | annual running cost |
| AU $ | Australia dollar |
| EBS | electric boosted solar water heater |
| GHG | greenhouse gas |
| LCC | life cycle cost |
| MC | maintenance cost |
| NGBS | natural gas boosted solar water heater |
| RC | running cost |
| SWH | solar water heater |
| TRC | total running cost |
| UC | upfront cost |
| WHT | water heater type |

## 1. INTRODUCTION

Among all the solar thermal applications, water heating is the one that is accepted widely in many nations. Even in Australia, most of the renewable energy schemes from the government endorses solar water heating projects [1]. Solar water heating systems have proven to be one of the cost efficient and effective ones when installation procedures, upfront cost involved in it, and operation and maintenance are considered [2].

In the present scenarios, hot water is an essential for the domestic and industrial applications. Based on the application and consumption criteria, the solar water heater system design and complexity increases. When the residential solar water heating systems alone considered, the design is based on the household water consumption patterns, location weather conditions, available auxiliary resources [3]. If we consider for typical Australian locations, is the domestic solar water heating is one of the most promising technology started adopting many years ago. In fact, the domestic water heater types are widely available and government support in making their availability to people is very high [4]. But the decision is left for the users to select which type of solar water heater they require. On the other hand, solar water heaters alone may not deliver the hot water at required temperature. Hence, in this situation, auxiliary fuel integrated solar water heaters are adopted. In most cases, the solar water heaters alone would be cost intensive but serves the specific need and viable on long run. Research studies carried out on accessing the feasibilities and economic viabilities of solar water heating technologies are positive towards their implementation for domestic and industrial applications [5,6]. But when auxiliary fuel is added what could be its influence on the life cycle cost and greenhouse gas emission productions is big question. The reason for this is the distributed availability of auxiliary fuel source, and other reason is technology gap between location to location resulting in price variation for energy source. Hence, the need for estimating the life cycle cost involved in such auxiliary fuel boosted solar water heating systems.

Objective of this paper is to compare the life cycle cost and greenhouse gas emission productions from the solar water heating system with two auxiliary fuels in Australia. The considered two auxiliary fuels are grid electricity and the natural gas.

## 2. MATERIALS AND METHODS

Among the various types of solar thermal technologies, water heating is one of the mature technologies that has gained huge attention and markets [7]. In general, the solar water heating system consists of solar thermal collector, storage tank, pipelines for water flow replacing the fossil fuels that were traditionally used for heating applications [8]. Depending up on the water quantity and required temperatures, the system design and complexity is varied. In SWH, the used thermal collectors are two types namely, flat plate and evacuated tube type. However, the most common one is flat plate thermal collectors. Typically, these thermal collectors are in rectangle box shape sealed inside the transparent cover. Small hollow tubes that allow water to flow through it are run into the thermal collector rectangular box. Here, these small tubes were attached to the absorber plate where heat exchange takes place between the thermal collector to the water [9,10]. In most applications, these SWH are installed over the building roofs or in the terrace areas of the building.

In solar water heating systems, when the thermal collectors are exposed to sun, then the incident solar radiation is converted into the heat energy and this is typically transmitted to one of the heat transfer mediums. If the user requirement is the hot water, then water can be used medium of heat transfer.

In most cases, to meet the user requirements, the auxiliary heaters are equipped or integrated with solar water heaters [11], see in Fig. 1. These are typically installed either at the hot water storage tank or at the point where water delivery points available.

Two types of auxiliary heater coupled with solar water heater are considered in this study, they are given below:

- Electric boosted solar water heating system
- Natural gas boosted solar water heating system

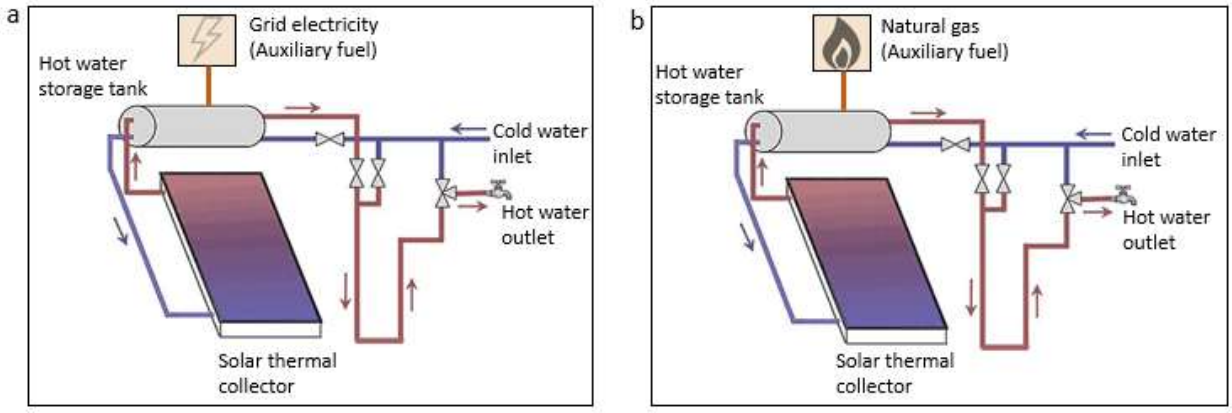


**Figure 1** a) Electric boosted solar water heater; b) Natural gas boosted solar water heater.

### 2.1. Electric boosted solar water heating system

Electricity is an auxiliary energy sources used for heating the water along with the solar energy, as shown in Fig. 1. a). Here, the cold water is passed through inlet pipe, when the water reaches the solar thermal collector energy from the sun is transferred to the water. Then the thermally rich water is stored in the storage tank. Here, an auxiliary source i.e., electrical energy is used to boost the performance of solar water heating system.

## 2.2. Natural gas boosted solar water heating system

Natural gas is an auxiliary energy sources used for heating the water along with the solar energy, as shown in Fig. 1. b). Here, the cold water is passed through inlet pipe, when the water reaches the solar thermal collector energy from the sun is transferred to the water. Then the thermally rich water is stored in the storage tank. Here, an auxiliary source i.e., natural gas is used to boost the performance of solar water heating system.

## 2.3. Data collection

For the evaluating the economics of solar water heater system, the design considerations are mandatory. These design considerations are directly depending on the household type, household water consumption patterns.

Hence, in this study, data related to the number of people use the hot water in a small size domestic house are collected and tabulated in Table 1. Similarly, the data related to the hot water consumption for shower, shower flow rate, kitchen usage, washing usage etc., are collected and tabulated in Table 2. As discussed in the section-2.1, and 2.2, electric and natural gas boosted solar water heater types were used for producing hot water. The upfront costs involved in EBS and NGBS are tabulated in Table 3.

**Table 1** Household details

| Description | Value or name |
|---|---|
| Location | Alice Springs, Australia |
| Size of the family | Small |
| No. of adults | 2 |
| No. of children | 1 |
| Is the house connected to natural gas network | Yes (direct house connection) |

**Table 2** Hot water usage facilities in the house.

| Description | Value or name |
|---|---|
| No. of showers per week in the family | 42 (including 2 adults and 1 child) |
| Length of each shower | 7 minutes |
| No. of bathrooms that has hot water facility | 1 |
| Flowrate of shower head | 9 liters/min |
| Kitchen tap water consumption in sinks | 10 sinks/week (medium size sink) |
| No. of hot water laundry tubs | 0.5 tub (medium size laundry tub) |
| Washing machine type used | Top loader |
| Washing machine capacity or size | Medium (approximately 6 kg) |
| No. of hot water washes using washing machine | 3 per week |
| Household daily water use capacity | >95 liters/person |

**Table 3** Water heater types and its upfront costs.

| Solar water heater type as per the auxiliary fuel | Upfront cost (AU $) |
|---|---|
| Electric boosted solar water heater (EBS) | 2324 |
| Natural gas boosted solar water heater (NGBS) | 3303 |

## 2.4. Life cycle cost and GHG calculation methodology

Cost involved in the solar water heating system differs as per the type of the thermal collectors and its materials adopted. Apart from this absorbent plate, water storage tank, pipelines, valves and regulators, insulating materials, and the auxiliary energy source. Evaluation of life cycle cost (LCC) is done using the tool developed by the South Australian Government (SAG) [12]. Here, upfront cost, running cost on annual basis and the total running cost, maintenance cost is considered for each time.

Few cost considerations used in this study are given below:

- The natural gas supply charge is a fixed charge approximately 0.73 AU$ per day in South Australia.
- 12 years is considered as the running and maintenance period.
- Here, the considered upfront costs are included of capital cost of the equipment, installation costs with workforce charge.

## 3. RESULTS AND DISCUSSION

The outcome of this study reveals that, there exists a variation in the life cycle cost of solar water heaters used for meeting the hot water requirement of the households when two different auxiliary fuels are given as options. The auxiliary fuels are used for boosting the performance of solar water heaters and those fuels are grid electricity and natural gas. The life cycle cost is evaluated for the specific case by considering the upfront cost in AU $, running cost and maintenance cost for the period of 12 years in AU$.

In Fig. 2., the LCC of the two considered water heating systems were compared. The standard testing condition temperature is considered as 25°C, as our concentration is on the solar water heating systems for a location having moderate weather conditions. The upfront cost, running costs over the period of 12 years, and maintenance cost over the period of 12 years for electric boosted solar water heating system are 2324 AU$, 1522 AU$, and 622 AU$ respectively. Similarly, for the natural gas boosted solar water heating system, the upfront cost, running costs over the period of 12 years, and maintenance cost over the period of 12 years are 3303 AU$, 2431 AU$, and 581 AU$ respectively.

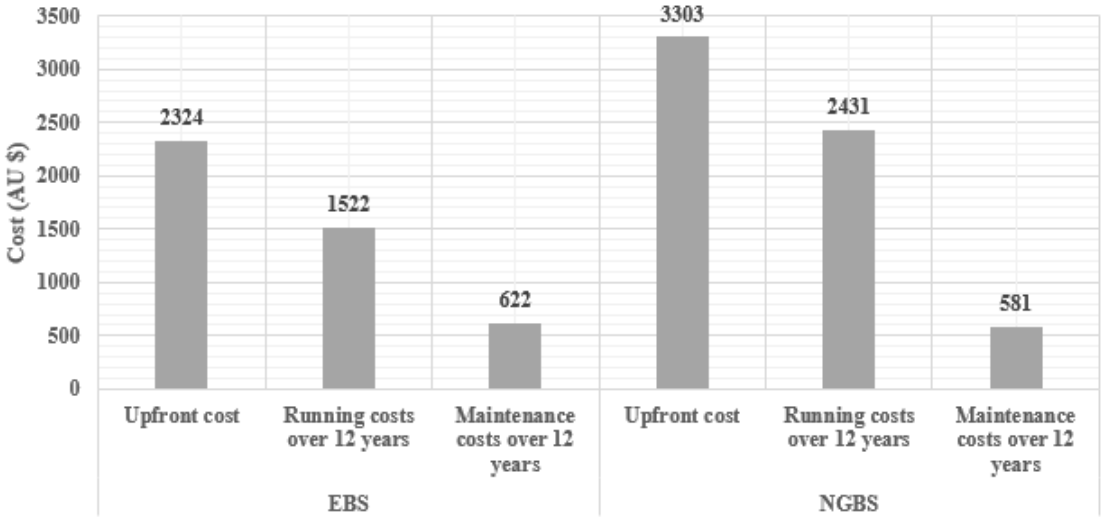


**Figure 2** Life cycle cost comparison of two solar water heater with auxiliary energy

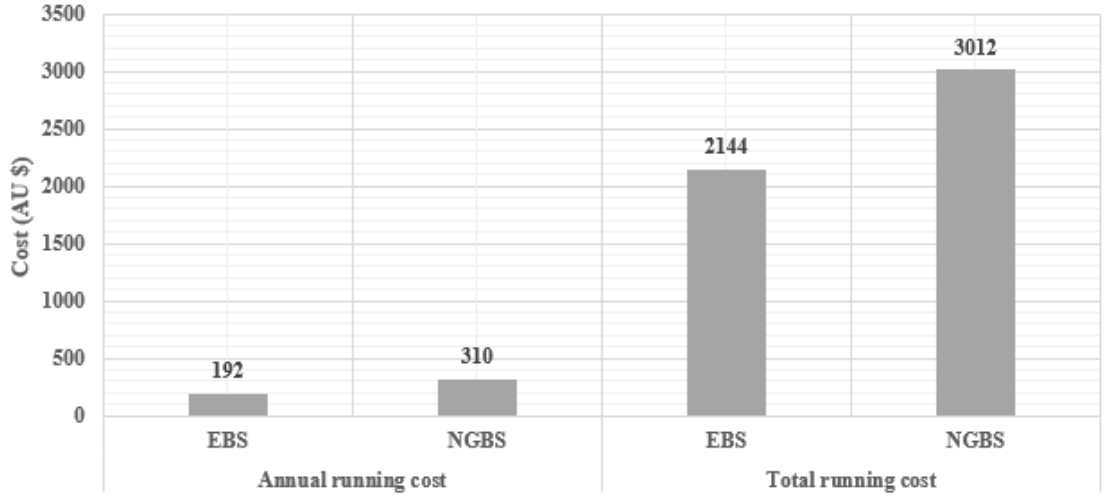


**Figure 3** Solar water heater type vs. running cost

The running cost on annual basis is observed as 192 AU$ for electric boosted solar water heating system, similarly for the natural gas boosted solar water heater is 310 AU$. The total running cost for the EBS and NGBS life time are estimated 2144 AU$, and 3012 AU$ respectively. The comparison of running costs for the EBS and NGBS are depicted in the Fig. 3.

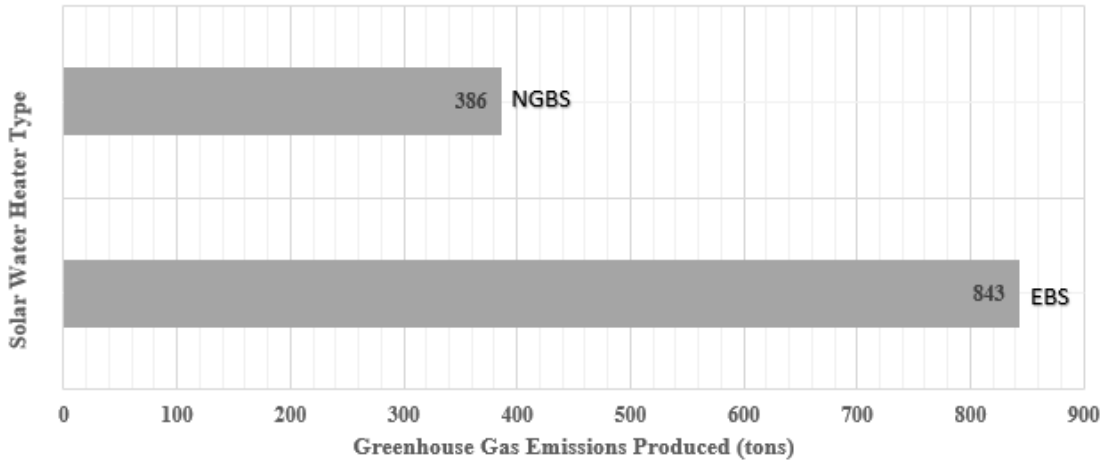


**Figure 4** Greenhouse gas emissions produced vs. solar water heater type.

Fig. 4, shows the greenhouse gas emission production details for the electric boosted solar water heater and natural gas boosted solar water heater. GHG emission production results for both EBS and NGBS for the studied region is compared. GHG emissions produced from the EBS, and NGBS are estimated as 843 tons of CO2 and 386 tons of CO2 respectively.

**Table 4** Life cycle cost comparison of EBS and NGBS.

| Solar water heater type as per the auxiliary fuel | Life cycle cost (AU $) |
|---|---|
| Electric boosted solar water heater (EBS) | 4468 |
| Natural gas boosted solar water heater (NGBS) | 6315 |

Life cycle cost of electric boosted solar water and natural gas boosted solar water heater is estimated as 4468 AU$, and 6315 AU$ respectively, and tabulated in Table 4.

## 4. CONCLUSION

In this paper, a study on life cycle cost assessment of solar water heater with two auxiliary energy sources like electricity and natural gas is carried out. This assessment evaluated the annual running cost, total running cost, greenhouse gas emissions for the electric and natural gas boosted solar water heaters. Also, the amounts of greenhouse gas productions in the two types of water heating systems are evaluated. This study gives an opportunity for the customers to select the preferred auxiliary energy source for boosting the performance of solar water heater. Users can have their choice on selecting the water heater either based on annual running cost, greenhouse gas emissions produced, maintenance cost.

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