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Energy Savings, Environmental Impacts and Monitoring Results of a Pumped Solar Water Heating System at Katutura Hospital Maternity Ward, Namibia

Helvi Ileka[1], Joseph Shigwedha[1], Rudolf Moschik[2], and Fenni Shidhika[1]

[1] Namibia Energy Institute (NEI), Namibia University of Science and Technology (NUST), Namibia

[2] Institute for Sustainable Technologies (AEE INTEC), Austria

*Correspondence: Helvi Ileka, hileka@nust.na

Abstract. The SADC region is endowed with solar radiation between 1800-2400 kWh/m^2 [1]. Nevertheless only 0.3 % of the worldwide solar thermal capacity is installed in the Sab-Saharan African Countries. Therefore, the main goal of the Southern African Solar Renewable Heating and Cooling Initiative (SOLTRAIN+) project funded by the Austrian Development Agency is to contribute to the transformation of the energy system to a sustainable, affordable and carbon-free system. This will be done by the implementation of Renewable, Heating and Cooling (RHC) systems in the targeted sectors: buildings, industry & commerce, tourism and hospitals, and enable this by a holistic capacity building. RHC technologies are solar thermal, heat pump and energy efficiency. This study therefore intends to evaluate and produce energy balance, based on real data recorded from January 2023 to December 2023 on a 120 m^2 collector area with 8000 litres storage tanks, and a 22 kW heat pump, installed at Katutura State Hospital maternity ward.

Keywords: Solar Water Heating, Monitoring, Heat Pump, Energy Efficiency

1. Introduction and background

The Namibia Energy Institute (NEI) is a national research Institute established by the Ministry of Mines and Energy (MME) and hosted at Namibia University of Science and Technology (NUST) to support the development and dissemination of knowledge, skills and good practices towards a safer, more secure and sustainable energy system in Namibia. Since 2009 the NEI has been implementing the Southern African Solar Thermal Training and Demonstration Initiative (SOLTRAIN) whose aim is to support the Namibian Government to implement the Cabinet Directive of 2007 on solar water heating, and the Solar Thermal Roadmap. By doing so, the institute build capacity in the field of solar thermal technologies, and promote the uptake of solar thermal systems and to ensure selection of quality products and workmanship in order to guarantee optimal performance during the lifetime of solar thermal systems. Additionally, SOLTRAIN supports the national policies on energy for sustainable development by creating new jobs in Small and Medium Enterprises (SMEs), through funding of flagship demonstration systems and strengthening the local support mechanisms for solar thermal systems.

The Namibia Government has shown a political will and commitment towards the roll-out of solar thermal technologies and other renewable energy technologies through well-artic-

ulated policy and strategy documents such as the 2007 Cabinet Directive on solar water heaters, the 2016 Solar Thermal Technology Roadmap, which has been adopted into the National Renewable Energy Policy, and the Nationally Determined Contribution (NDC). The Solar Thermal Technology (STT) Roadmap of Namibia outlines the country's path towards attaining 1.5 million m² of solar collector area with an average micro target of 0.5 m² installed per inhabitant by 2030 [2]. The Nationally Determined Contribution (NDC) aims to achieve a 91 % reduction of greenhouse gas (GHG) emissions by 2030 by increasing the share of renewable energy in the country's energy mix through various initiatives [3].

The Katutura Hospital complex consists of many buildings with the largest solar water heating system in the country, which is made up of 8 separate subsystems. These systems are Ground Floor East (200 m^2), Maternity and Tuberculosis Wards (100 m^2), Main Tower hospital (200 m^2), Operating Theatres (100 m^2), Ground Floor West (200 m^2), Kitchen (100 m^2), Nurses' quarters (100 m^2), and Doctors' block (100 m^2). The total systems were designed to provide over 50 000 liters of hot water per day. Currently only Maternity Ward System is functional. As a result of seven solar water heating systems not being functional, the departments have resorted to using various heating appliances using grid electricity, and thereby defeating the purpose of the installed solar water heating system.

2. Methodology

The study evaluated and analysed real data recorded from January 2023 to December 2023 on a 120 m^2 collector area with 8 000 litres tanks, 22 kW heat pump, as well as 6 kW electrical element used as back up installed in each of the two fresh water tanks for the system installed at Katutura State Hospital maternity ward. Heat meters are installed in the collector loop, to record data from the solar station, cold water inlet, hot water outlet, heat pump outlet as well at the circulation pump. Energy meters are not installed to measure electrical consumption of the electrical elements.

3. Monitoring

3.1 System description

The solar water heating system was installed during May 2022 as a demonstration system under the SOLTRAIN project. The system operates on forced circulation pump system whereby the primary source is solar with an external heat exchanger through buffer tanks followed by heat pump which kicks in if temperature in the buffer tanks drops below 55 °C. The 6 kW elements back-up are the last priority and are set to switch on if temperature in the freshwater tanks drops below 40°C. The flat plates collectors are manufactured by GREENoneTEC from Austria (GK3002 large scale thermal solar panels 10 m^2 with gross area of 10.05 m^2 and aperture area of 9.28 m^2). In total 12 collectors are installed with expected power of 84.00 kW_{th} and 120m^2 total collector area. The collectors are installed at 35° angle of tilt to provide hot water as primary energy service to the maternity ward of Katutura hospital.

3.2 Energy Balance

Figure 1 illustrates the energy balance of the solar water heating system measured and logged during the year 2023. Figure 1 presented that there was no electricity meters installed to measure the contribution of electrical element back-up to the energy balance. The data only shows solar yield, contribution of heat pump as well as the ring main circulation of hot water to the taps. In total 53 MWh_{th} was used for hot water consumption for the period of 12 months while the ring circulation consumed 39 MWh_{th}. In the month April and May the solar fraction was low because there was air in the system and the heat meter could not pick up the measurements, therefore invalid measurements were recorded. The system was flushed again in November

hence a specific solar yield of 70 kWh_{th}/m^2 in December 2023. The total solar yield recorded during the year 2023 was 6 477 kWh_{th}.

Furthermore, it is evident from Figure 1 that the maternity ward of the Katutura State Hospital had the highest hot water consumption during mid-year during winter and the start of summer and the lowest during the first quarter of the year when winter was about to begin. It further shows that the heat pump seldom operates, and it has generated the most thermal energy during the month April. It is evident that the heat pump did not operate optimally especially in the month June, July to August when the consumption was higher than the solar generated.

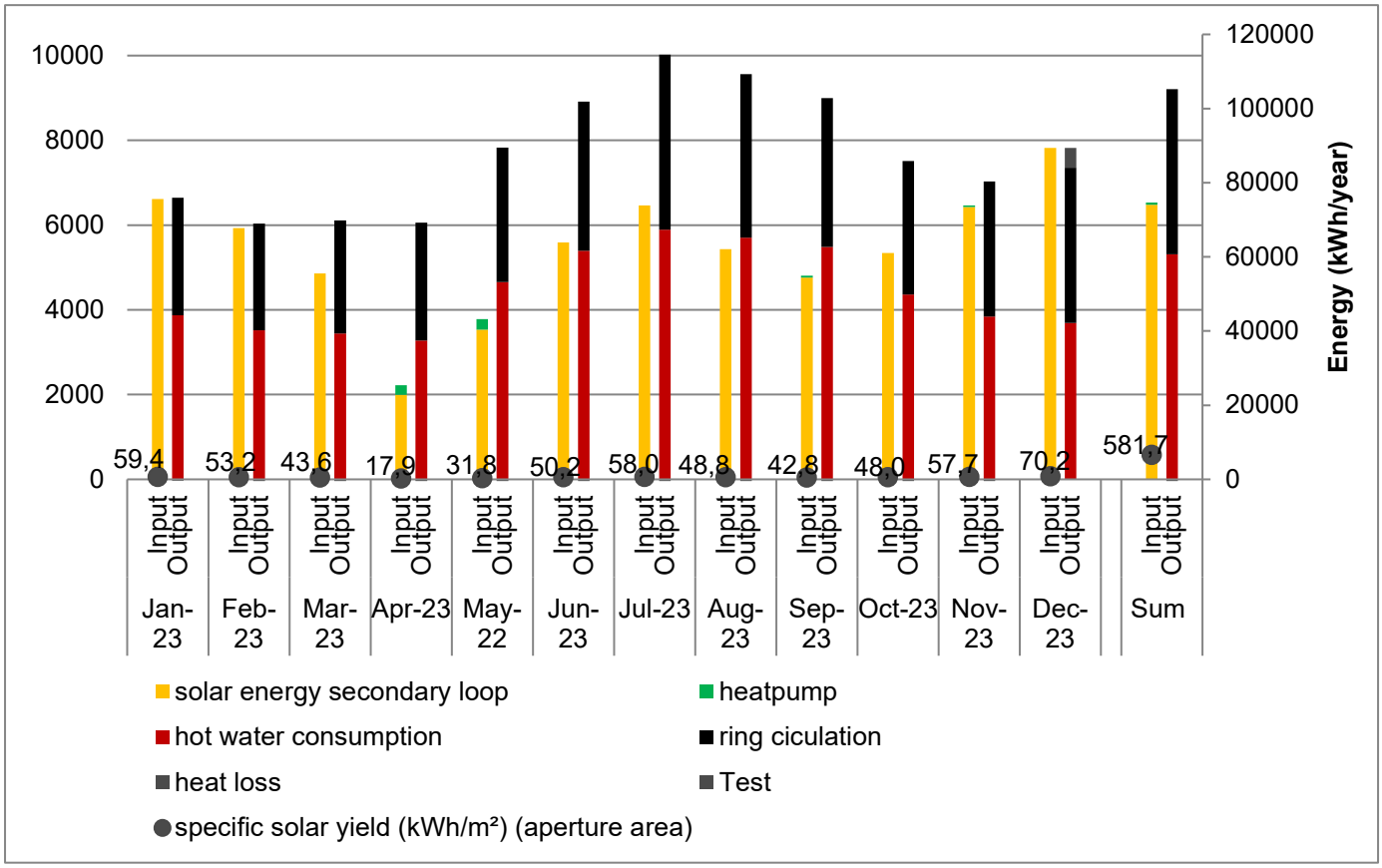

Figure 1. *Katutura State Hospital Maternity Ward solar water heating system's energy balance.*

3.3 Energy Yield

The specific energy yield remains almost uniform, at around 50 kWh_{th}/m^2 during the year 2023 except for the month April when the system was malfunctioning and underwent maintenance. During that period, the solar closed loop appeared to exhibit air. The system was then refilled with water-glycol mixture to restore nominal operation. The best month with highest solar yield is December with 70.2 kWh_{th}/m^2 but this was also because the system was flashed in November.

3.4 Electricity Savings

The total amount of hot water energy demand during the year 2023 amounts to 65 MWh_{th}, corresponding to "solar energy secondary loop" in Figure 1. This is the amount of energy avoided from the municipality's distribution network. This energy accounts for some losses of the ring circulation that guarantees hot water instantly at the consumption point, and thermal losses which are minimal since this system has good insulation.

3.5 Avoided electricity cost

During the year 2023, the electricity tariff of the municipality that the hospital would be subject to is at an average of 2.33 NAD/kWh_{el} including levies [4]. Therefore, the annual avoided electricity costs associated with the 65 MWh_{th} is approximately 151 000 NAD.

3.6 CO_2 emission avoided

When a grid emission factor of Namibia is considered to be 0.0007 metricTCO_2/kWh_{el} [5], a total of 455 metricTCO_2 was avoided during the year 2023 by the solar water heating system for the measured annual solar yield at Katutura State Hospital Maternity Ward.

4. Conclusion

In general we have reasonable results to provide on the performance of the water heating system which pointed out a number of parameters of the system such as the annual solar yield, the ring main circulation and the consumption of hot water of the Katutura State hospital, however due to air in the system during the month of April and May some of the values were incorrectly recorded. Additionally, the contribution of the electrical element could not be determine due to the fact the metre is not yet installed, therefore the energy balance for the hot water system is incomplete. It is important to install the electrical metre and compare the results obtained with another year‘s data to have a full balance on the performance of the system.

The study will contribute to NUST’s Green Vision of 2030, which aspires to contribute towards a future where all energy is consumed from sustainable sources and sustained by a public that understands and values the social, economic, and environmental benefits that green energy provides to our communities, our nation, and beyond through an integrated green energy creative value chain.

More than 50 % of the world’s energy demand is required by heat. Monitoring and measuring the operation of solar systems are proofing the benefit of the system. Solar thermal system are simple, are able to compete with other technologies, and are able to play significantly role to contribute to CO_2 reduction.

Data availability statement

The data is collected and supported by the SOLTRAIN project monitoring equipment with the aim to obtain performance of demonstration systems and to get a representatives of different designs and concepts, therefore the data acquisition was setup with technical assistance of AEE INTEC who also assisted with data organization.

Underlying and related material

There are no underlying and related material.

Author contributions

Helvi Ileka: Conceptualization, Investigation, Methodology, Project administration, Resources, Visualization, Data curation, Writing – original draft. **Joseph Shigwedha:** Conceptualization, Project administration, Data curation, Writing – review & editing. **Fenni Shidhika:** Writing – review & editing. **Rudi Moschik:** Conceptualization, Data curation, Funding acquisition, Investigation, Methodology and Supervision

Competing interests

The authors declare that they have no competing interests.

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