EXPLORATION OF THE FEASIBILITY, BENEFITS AND CHALLENGES OF SOLAR WATER HEATERS FOR HOUSEHOLDS

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ABSTRACT

South Africa's abundant coal resources have historically kept electricity costs low, encouraging widespread use of electric appliances, especially electric geysers, which account for 25% to 40% of household electricity bills. However, rising energy prices and increasing strain on the national grid are eroding this advantage. Solar Water Heaters (SWHs) offer a cost-effective alternative, particularly given the country's high solar radiation levels. Despite this, there is limited research on the cost-benefit of SWHs in rural areas. This study examines their use in Thulamela Municipality, Limpopo Province, and finds that SWHs are a viable and sustainable solution for household energy needs. They reduce electricity consumption, require minimal maintenance, and have long lifespans. Although the initial cost of SWHs is higher than electrical geysers, they offer short payback periods, especially as electricity tariffs increase. The study recommends that the government actively promote solar energy by providing financial support and increasing public awareness to encourage wider adoption.

Keywords: Benefits, Challenges, Solar Water Heaters, Households, Thulamela Municipality, Limpopo Province, South Africa.

1. INTRODUCTION

Access to energy and water heating is closely linked to quality of life and sustainable devel-opment (Mohammed et al., 2017; Thobejane et al., 2023). However, dependence on fossil fuels has contributed to environmental degradation and climate change (IEA, 2021; IPCC, 2022). With rising populations and energy demands, the United Nations established the Sus-tainable Development Goals in 2015, including Goal 7, which promotes "affordable, reliable, sustainable and modern energy for all" (UN, 2015; IRENA, 2023). In this context, solar ener-gy, particularly solar water heating (SWH), is viewed as a viable alternative due to its renew-able, decentralized nature and potential to reduce household electricity use by up to 70% (DoE, 2020; Swanepoel et al., 2020).

South Africa remains heavily reliant on Eskom, which generates about 95% of electricity from coal, contributing significantly to carbon emissions and frequent power shortages due to ageing infrastructure and rising operational costs (StatsSA, 2022; Eskom, 2021; McKenzie, 2023). Recognizing these challenges, government initiatives such as the 2009 target to install one million SWHs sought to diversify the energy mix (Peters, 2009). Despite the benefits of SWHs, lower energy bills, reduced demand on the grid, and environmental gains, barriers such as high upfront costs, intermittent supply, and the need for auxiliary heating persist (Chen et al., 2019; Li et al., 2021; Peter et al., 2022).

While studies have examined technical performance and social dimensions of SWHs in South Africa (Thobejane et al., 2023; Peter et al., 2022), little is known about their cost-benefit dy-namics, particularly at the household level in Thulamela Municipality, Limpopo Province. Existing research in the broader Vhembe District (Chidembo et al., 2020) highlights adoption perceptions, but there is limited empirical evidence on the direct benefits and challenges ex-perienced by households in this local context. This study, therefore, seeks to fill this gap by exploring the benefits and challenges of solar water heaters on households in Thulamela Mu-nicipality.

The study addresses 2 research questions:

- What are the benefits of using solar water heating systems for domestic purposes in Thu-lamela Municipality?
- What are the challenges of using solar water heating systems for domestic purposes in Thu-lamela Municipality?

2. RESEARCH METHODOLOGY

Research Paradigm

A research paradigm provides a philosophical lens through which researchers understand re-ality (ontology), acquire knowledge (epistemology), choose methods (methodology), and re-flect on values (axiology) during the research process (Creswell and Poth, 2018). Four com-mon paradigms, positivism, realism, critical theory, and interpretivism, guide different re-search approaches (Alharahshah and Pius, 2020). This study is informed by the interpretivist paradigm, which posits that reality is socially constructed and best understood through partic-ipants' lived experiences. It acknowledges the researcher's subjectivity and embraces contex-tual interpretation as a means of generating meaning (Pham, 2018). Within this paradigm, the researcher plays an active role in the inquiry, contributing to the co-construction of knowledge (Irshaidat, 2019).

Research Design

The study employs a qualitative descriptive research design, which focuses on providing rich, straightforward descriptions of participant perspectives without deep theoretical abstraction (Lambert and Lambert, 2012). Data were collected using semi-structured interviews, a meth-od that offers structure while allowing flexibility to probe participant responses (Kallio, Pie-tilä, Johnson and Kangasniemi, 2016).

Research Strategy

A research strategy serves as the blueprint linking the study's objectives with appropriate methods of inquiry and data collection (Saunders, Lewis and Thornhill, 2019). This study adopts a case study strategy, which is appropriate for exploring complex phenomena in their real-life context, such as the adoption of solar water heaters in a specific locality (Yin, 2018). While quantitative studies often employ experimental or correlational strategies (Hassan, 2023), qualitative case studies allow researchers to explore, describe, and explain real-world issues without manipulating variables (Crowe et al., 2011).

Population and Sampling

Purposive sampling was used in this study to deliberately select participants with relevant knowledge or experience of solar water heater usage in Thulamela Local Municipality. This non-probability sampling method is widely employed in qualitative research for its capacity to yield rich, detailed data (Etikan, Musa and Alkassim, 2016). It allows researchers to select information-rich cases that directly contribute to the research objectives.

As Palinkas et al. (2015) argue, purposive sampling is ideal when the goal is depth of under-standing rather than statistical generalization. The study initially targeted a minimum of 15 participants, with the final sample size determined by the point of data saturation, where no new insights emerged from additional interviews (Guest, Bunce and Johnson, 2006).

Data Collection Methods

Semi-structured interviews were the primary data collection method, consistent with the study's qualitative orientation. These interviews balance flexibility with structure, allowing researchers to follow up on emerging themes while maintaining consistency across participants (DiCicco-Bloom and Crabtree, 2006). This method is particularly effective in eliciting participants' experiences, opinions, and perceptions related to solar water heater use (Kallio et al., 2016). An interview guide was used to ensure coverage of key themes, and interviews were audio-recorded with participants' permission to preserve data integrity and facilitate ac-curate transcription. Interviews were conducted both in person and virtually, depending on participant availability, and were audio-recorded with consent. The data were analyzed using inductive thematic analysis, a method that

facilitates the emergence of themes directly from participants' narratives, aligning with the qualitative descriptive approach (Braun and Clarke, 2021).

Data Analysis

Thematic analysis was applied to the qualitative data following Braun and Clarke's (2006) six-phase framework: familiarization with data, generating initial codes, searching for themes, reviewing themes, defining and naming themes, and writing up the findings. This method is favored for its flexibility and its ability to provide a rich, detailed account of data across a range of paradigms (Nowell, Norris, White and Moules, 2017).

The data were organized and coded using Atlas.ti software, which facilitated the identifica-tion and visualization of key themes related to the benefits and challenges of solar water heaters. As emphasized by Vaismoradi, Jones, Turunen and Snelgrove (2016), thematic anal-ysis enhances the trustworthiness and transferability of qualitative findings when rigorously applied.

3. RESULTS

Introduction

The study reveals various factors influencing this technology application, focusing on its benefits and the obstacles households encounter in utilizing solar water heaters. These results are visually represented through ATLAS.Ti.23 network diagrams; this enabled the capturing of participants' insights into the research's key themes. The diagrams provide a visual summary of how solar water heaters affect the daily lives of households, illustrating both the potential of this technology to improve energy sustainability and the practical challenges that need to be addressed. This practical approach has ensured that the study's results are relevant to policymakers, researchers, and individuals interested in adopting sustainable energy solutions. P on quotations represents participant number.

Benefits of solar water heaters

The first objective of this study was to explore the benefits of solar water heaters as experienced by households in Thulamela Local Municipality. The ATLAS.Ti network diagrams were utilized to visually depict the interconnected themes and insights from the participants' feedback. These diagrams capture key aspects such as cost savings, energy efficiency, reliability, environmental benefits, and long-term affordability, thereby offering a clear representation of how solar water heaters can positively impact households. (The ATLAS.Ti network diagram is in the appendix).

Cost savings

One of the noticeable benefits of installing a solar water heater is the drastic reduction in electricity bills. participants across the board reported significant financial savings after switching to solar energy. Participant 1 shared that the household's monthly electricity expenditure had been reduced by over R1000 since adopting a solar water geyser:

"I've been using solar water geysers for five years now, and it's honestly a relief. I get hot water on time, and my electricity bill is very low! Before, I was buying electricity for R2500, but now I am buying electricity for R1500, which means I have saved R1000".

This reduction in utility bills has provided households with more financial flexibility, allowing them to allocate resources more efficiently. Another participant expressed astonishment at the continued reliance on traditional electric geysers, noting that solar energy provides a more cost-effective and rational solution:

"Oh, for sure, it saves a ton on electricity! I don't know why people are still holding on to electric geysers, to be honest. Solar is just smarter".

For many households, this decision to switch to solar was described as "life-changing," with participants recognizing the long-term economic benefits that go beyond the immediate savings as shown in the following quotation:

"We were paying so much for electricity, and now? We barely buy units since we installed the solar geyser. It's such a life-changing decision."

In summary, solar water heaters allow users to cut down on one of the largest household expenses - electricity - making energy consumption more sustainable and manageable.

Energy efficiency

The results revealed that energy efficiency is one of the primary motivations for individuals adopting solar water heaters. Unlike conventional electric geysers, which rely entirely on electricity, solar geysers harness natural sunlight, reducing the demand on the electrical grid and lowering overall energy consumption. One participant emphasized the versatility and efficiency of solar water heaters, particularly those with dual functionality:

"Yah, it uses way less electricity. Mine is dual; it uses both electricity and the sun, which means that if there is rain, it switches to electricity, and it will not use a lot of electricity. I've been using solar for over four years now, plus, we've hot water 24/7 without having to worry about Eskom".

The dual functionality of solar water heaters, which allows households to switch to electric power only when sunlight is insufficient, makes them highly adaptable to different weather conditions, ensuring continuous access to hot water while minimizing electricity usage. Another participant echoed these sentiments, appreciating how solar geysers take advantage of natural, renewable resources:

"Honestly, it's way better than the electric one because solar geysers use the sun's radiation. I mean, why not use what's naturally there?".

This sub-theme illustrates that solar water heaters are not only an environmentally friendly conscious choice but also an energy-efficient one. By relying on the sun's radiation, households reduce the strain on the electricity grid, contributing to a more sustainable energy system.

Reliability and convenience

The reliability of solar water heating is one of its standout benefits, particularly in regions prone to power outages or load shedding. Many participants noted that they no longer have to worry about any hot water supply interruptions, even when electricity is unavailable. One respondent explained:

"It's been so convenient! I don't have to deal with any inconvenience, even when there's load shedding. Unlike with the electric geyser, where you must switch it on and off, I always have hot water. With solar water heaters, we never run out of hot water as long as there is natural light.

This reliability brings immense convenience to users, eliminating the need for constant monitoring or manual intervention. Electric geysers are often cumbersome and susceptible to breakdowns; however, solar water heaters ensure a steady hot water supply if natural sunlight is available. As noted by the same participant, this convenience extends beyond just a hot water supply to a broader lifestyle improvement:

"No need to stress about electricity cuts or high bills; it makes life easier".

Having access to hot water regardless of electricity grid power disruptions is a significant advantage for households, offering them peace of mind and reducing the daily stress associated with electricity outages.

Reduction of environmental impact

The participants' views were that solar water heaters also contribute positively to environmental sustainability, making them an eco-friendly alternative to traditional electric geysers. By using solar energy, households can significantly reduce their reliance on non-renewable energy sources, such as fossil fuels. One participant pointed out the detrimental environmental effects of using other traditional energy sources, particularly wood:

"Using wood to boil water affects the environment. Cutting down trees for wood leads to deforestation and affects climate change. That's where we will find ourselves not able to differentiate if it is summer or winter, and smoke affects the ozone layer".

Beyond the financial and personal benefits, solar water heaters allow households to actively participate in environmental conservation. One participant remarked on the dual benefits of solar water heaters, highlighting how they not only save money but also support ecological well-being:

"These solar heaters really help cut down on energy use, and you're not just saving money; you're doing your part for the environment too!".

Thus, solar water heaters align with broader goals of environmental preservation by reducing carbon footprints, minimizing deforestation, and contributing to the fight against climate change.

Accessibility and affordability

Despite the initial investment required for a solar water heater, participants generally agree that the long-term affordability of these systems makes them a worthwhile investment. Once installed, solar geysers eliminate the recurring costs associated with electricity for heating water, providing households with financial relief over time. As one participant noted:

"Once you've bought the solar heater, that's it, no more recurring electricity costs. It's affordable in the long run".

In addition, some respondents suggested that even those with limited financial resources could eventually afford solar water heaters, particularly with government support or by saving overtime:

"Nowadays, here in South Africa, we cannot say people are poor because there are various grants from the government. Even people who don't have a lot of money can benefit if they save".

The long-term cost savings make solar water heaters accessible to wider demographic groups as indicated by a participant.

"With solar, I don't need to worry about finding money for electricity every month. The water's always hot, and it doesn't break the bank!".

The perceived affordability of solar water heaters stems not only from immediate financial savings but also from their potential to provide long-term economic benefits, making them an attractive option for diverse households. Adopting solar water heaters, therefore, offers numerous benefits beyond financial savings. These heating systems provide energy efficiency, reliability, and significant environmental benefits, while also being accessible and affordable in the long term. Solar water heaters exemplify a sustainable and innovative solution to modern energy needs, making them an ideal choice for households aiming to reduce costs, conserve energy, and contribute positively to the environment. Their increasing adoption reflects a shift toward more sustainable and cost-effective energy solutions, highlighting the role of renewable energy technologies in shaping the future of household energy consumption.

Challenges of Solar Water Heaters

The second objective of this study was to explore the challenges of adopting and using solar water heaters, as perceived by households in Thulamela Local Municipality. ATLAS. Ti network diagrams were employed to visually represent the interconnected challenges identified during the interviews. Key challenges include dependence on weather conditions, occasional maintenance issues, limited hot water during extended cloudy or rainy periods, and infrastructure-related constraints, such as inconsistent water supply. The diagram provides a clear depiction of how these challenges affect the daily use of solar water heaters in the local context of Thulamela Municipality.

Weather dependence

One of the most prominent challenges of using solar water heaters is the system's reliance on favourable weather conditions, particularly sunny weather. Solar water heaters are designed to harness energy from the

sun, which means their efficiency drops during cloudy or rainy weather. Users understood that solar water heaters perform best on sunny days, hence, some participants admitted that during inclement weather, they switch to electricity to ensure they have access to hot water. As one participant noted:

"Yah, if it's raining, and in most cases during the winter season, I just switch to electricity. But you know, even if it's cloudy, the solar still absorbs some heat. So, I don't worry too much!".

This statement reflects the flexibility users have in managing their energy needs when the solar system cannot fully meet their hot water demands; when that happens, electricity becomes a reliable backup. A participant expressed a similar sentiment:

"Honestly, when it rains, I just use electricity. The water will still be a bit warm, but yah, I switch when I need to".

For most users, this weather dependence is not seen as a major inconvenience because of the adaptability of their solar water heaters. Alternating between solar energy and electricity offers a practical solution, allowing households to maintain access to hot water regardless of weather conditions. One participant explained:

"When the sun's not shining, I just plug in the electricity, and everything's fine."

Solar water heaters' weather dependence can be perceived as a drawback; however, most users accept it as a manageable limitation. The dual-functionality feature in many solar water heaters, which allows them to switch between solar energy and electricity, mitigates the inconvenience; thus, although users acknowledge this challenge, they view it as a minor trade-off for the overall benefits of solar energy.

Lack of significant challenges

Interestingly, many participants reported experiencing few to no major challenges after installing their solar water heaters. For these users, the transition to solar-powered water heating has been smooth, with minimal need for repairs or maintenance. This lack of technical issues underscores the reliability of solar water heaters, particularly over long periods of time.

As one user confidently stated:

"Nope, no other challenges here! Everything's been smooth since I installed it. I haven't had to fix anything at all. Ever since I installed it, I've had no issues, no repairs, nothing! I think in the long term, solar is the way to go. It's sustainable and cost-effective"

This participant's experience highlights not only the lack of challenges but also users' long-term confidence in the sustainability and cost-effectiveness of solar water heaters. For them, the absence of frequent repairs and malfunctions makes the system even more appealing. Another participant echoed similar feelings:

"Honestly, no challenges. I've been using it for a while, and it's all good. Life's just easier with solar!".

The study found that solar water heaters (SWHs) significantly reduce household electricity bills, with participants reporting monthly savings of up to R1000. Participants valued the energy efficiency and reliability of SWHs, which reduce dependence on grid electricity and perform well even during power outages. SWHs were also praised for being user-friendly and low maintenance.

Environmentally, participants appreciated reduced fossil fuel use and lower greenhouse gas emissions, supporting national sustainability goals. While initial costs are high, participants acknowledged long-term affordability, especially with government incentives or personal savings.

Challenges included weather dependence, requiring supplemental electric heating during cloudy or rainy periods, and rural infrastructure limitations such as inconsistent water supply and low pressure. Despite these issues, SWHs were considered low-maintenance, reliable, and a practical, sustainable energy solution.

The consensus among these users suggests that, while some minor adjustments may be necessary in dealing with the system's weather dependence, the absence of significant maintenance challenges makes solar

water heaters an attractive investment. The system's reliability, combined with low maintenance, contributes to the long-term appeal of solar water heating as a sustainable energy solution. This positive feedback from users reinforces the perception that solar water heaters offer more benefits than challenges.

Limited hot water during extended rain

Participants indicated that while solar water heaters are generally reliable, extended periods of rain or cloudy weather can limit the amount of hot water they can provide. Participants noted that, during prolonged rainy spells, the solar heater's efficiency drops, and they cannot generate enough hot water to meet their needs. One participant described how his system performs during extended rainy periods:

"Yah, so if it rains for like, five days straight, I won't get hot water from the solar heater. But that doesn't happen often, maybe two days max, because it can keep warm water from previous days, or if it rains and there is a bit of light, it will absorb the heat, and I will get warm water. I think it works from the light. But for two days of rain, I then just use electricity".

This response highlights that while solar water heaters can maintain warm water for short periods of rainy weather, they eventually require backup from electric sources if such weather conditions persist. The system is designed to retain some heat from sunlight, but it cannot fully meet the hot water demands during extended cloudy periods. Another participant shared a similar experience:

"If it rains, then we can't use the solar, obviously. So, we have to switch to electricity, but it's not that big of a deal".

For most users, this issue was not seen as a significant hindrance, since they could seamlessly switch to electricity during extended rain. While it is a limitation, the system's adaptability allows users to work around it. Another participant confirmed this:

"When it rains a lot, we just use electricity. It's okay though because it doesn't rain for too long."

Ultimately, while solar water heaters face limitations during extended rain, these situations are manageable for most users. The ability to switch to electricity ensures that hot water remains available, and since the frequency of extended rain is generally low, this makes this particular challenge more of a minor inconvenience than a significant issue.

Water supply issues

Some participants indicated that some of the challenges are not related to technology itself, but rather to the availability and pressure of the water supply. For users in rural or underdeveloped areas, the lack of a consistent water supply can affect the efficiency of the solar water heater. One participant from a village where water access is limited responded:

"Our village, ah, we lack water! If you don't have a pressure pump, the water's slow, and that's the challenge for me, not the solar itself".

This answer illustrates that the benefits of solar water heaters can be compromised in regions with poor water infrastructure. In such areas, even if the solar heater is functioning well, its effectiveness is limited by water unavailability. This issue, therefore, highlights a broader infrastructural challenge than a problem inherent to solar water heating systems, for while solar water heaters can be a sustainable solution for energy consumption, they still rely on a stable water supply to function optimally.

The challenge, hence, is not with the solar heater system but the surrounding infrastructure in these cases. This suggests that, for solar water heaters to be fully effective, they must be implemented in areas with sufficient water access or accompanied by investments in water infrastructure, such as pressure pumps. These identified challenges associated with using solar water heaters, although notable, are generally manageable by most users. The system's sunny-weather dependence remains a key concern, particularly during prolonged periods of rain or cloud cover. However, users have adapted to this limitation by relying on electricity as a backup, which ensures they still have access to hot water. For many, this adaptability mitigates the potential

drawbacks; hence, most users reported no significant challenges; rather, they emphasized the low-maintenance and reliable nature of solar water heaters. Water unavailability poses a challenge in regions with poor water supply infrastructure, but this is not related to the solar technology itself.

Overall, the challenges faced by users of solar water heaters seem to be generally predictable and manageable as these systems provide a sustainable and energy-efficient solution, with minor limitations that users have learned to navigate. The ability to switch between solar energy and electricity, coupled with the absence of significant maintenance issues, reinforces the value of solar water heaters as a viable long-term investment. For many households, the benefits of solar water heaters far outweigh these challenges, making them a practical and eco-friendly alternative to traditional water heating systems.

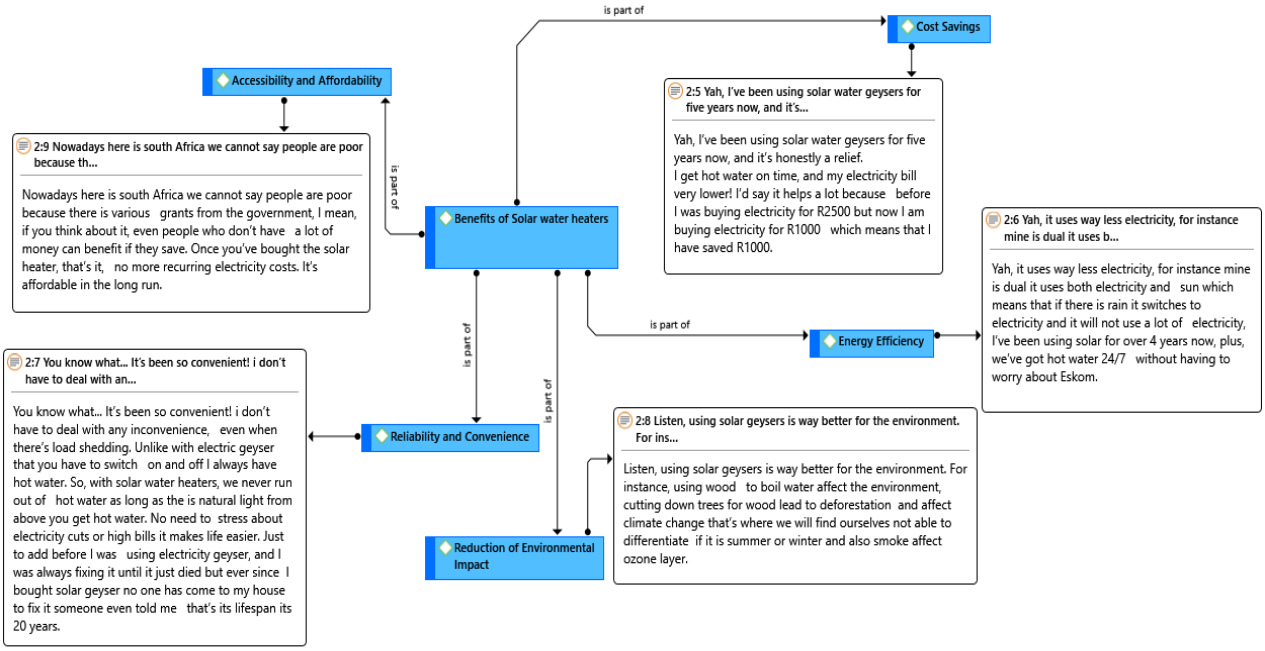
4. RECOMMENDATIONS

Based on the findings and conclusion, it is recommended that the government and local authorities implement targeted subsidy programs to offset the high upfront costs of solar water heaters (SWHs), particularly for low-income households. Additionally, public awareness campaigns should be launched to educate communities about the long-term financial and environmental benefits of SWHs. Technical support structures must be strengthened by training local technicians and ensuring accessible maintenance services. Furthermore, integrating SWH adoption into broader rural development and energy infrastructure plans—such as improving water pressure systems—can enhance their performance and sustainability, especially in under-resourced areas. These measures will support wider adoption and help meet South Africa’s clean energy goals.

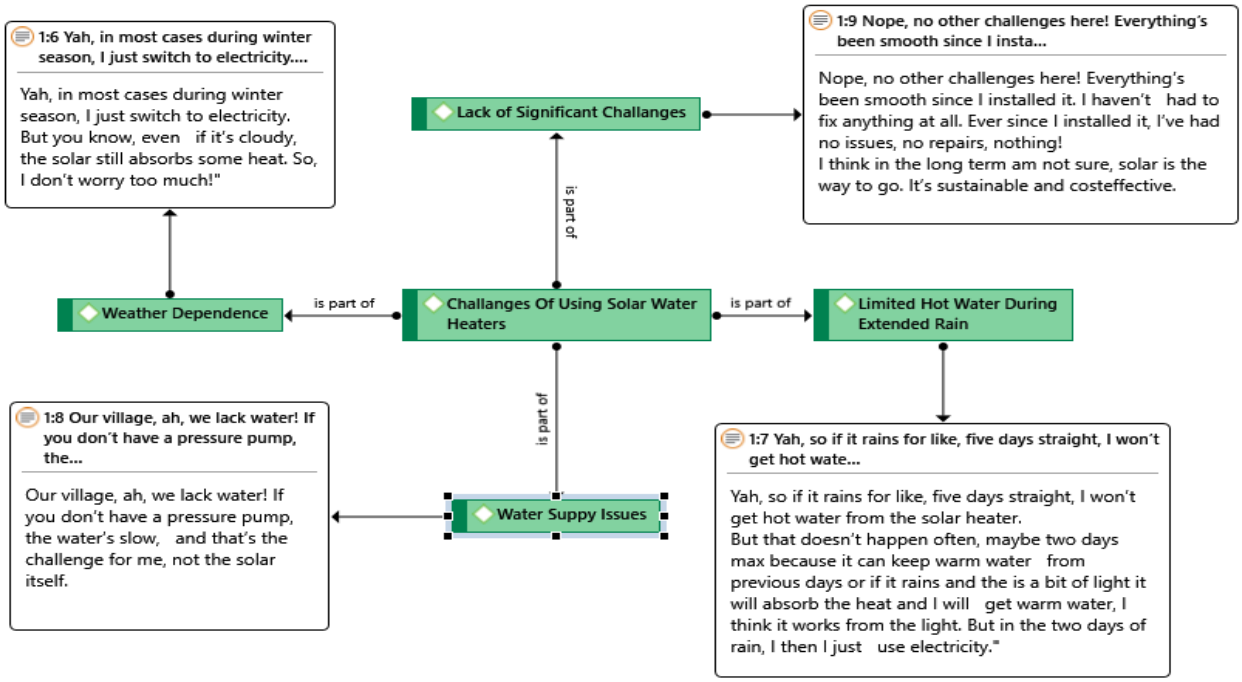
Contributions of the study to the body of knowledge

This study contributes to the existing literature by addressing the underexplored benefits and challenges of solar water heaters (SWHs) in rural settings, specifically within Thulamela Municipality. While previous research has largely focused on urban areas or national-level analyses, this study offers a localized perspective on the feasibility and practical impacts of SWHs in rural South Africa. By highlighting both the socioeconomic and environmental implications, the findings can inform future policy formulation and the design of targeted renewable energy programs, especially if accompanied by appropriate incentives and increased public awareness of solar energy's benefits.

APPENDICES



APPENDIX 1
ILLUSTRATES ANSWERS OF RESPONDENTS ON THE BENEFITS OF SOLAR WATER HEATERS



APPENDIX 2

ILLUSTRATES ANSWERS OF RESPONDENTS ON THE CHALLENGES OF SOLAR WATER HEATER

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