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Causes of Failure of the South African Solar Water Heating Programme and the Forgone Social Benefits

Edzisani Ellen Netshiozwi[1]

ABSTRACT

Access to energy is fundamental to meeting the economic and environmental needs of a country as well as the basic social needs for households. The study aimed at assessing the causes of failure of the South African Solar Water Heating Programme (SWHP) and the effect they had on the intended social, economic and environmental benefits. In 2009, the South African Government pronounced the national SWHP, which was meant to provide one million Solar Water Heaters (SWHs) by 2014 and four (4) million SWHs by 2030 across the country. The programme, however, experienced institutional, social and technical challenges which led to the non-achievement of the set targets. The study presents findings drawn from interviews conducted with households from two communities in the Gauteng Province (i.e. Soshanguve and Alexandra) and officials from the Department of Energy (DoE), the Gauteng Department of Economic Development (GDED) and two municipalities (i.e. City Power on behalf of the City of Johannesburg and the City of Tshwane). The study found that the programme failed due to the subsidisation of imported products, poor quality installations leading to non-functioning SWHs, lack of training and poor planning by the involved institutions as well as unreliable verification of the number and location of installed heaters as a result of lack of systematic reporting and independent verification. For the programme to contribute to the reduction of electricity load, reduction of Green House Gas (GHG) emissions and improving the livelihood of the poor, there is a need for better ecological governance systems which include improved institutional arrangements, improved capacity for the technology and scaling up the roll-out of the SWHs as intended.

Keywords: Solar Water Heaters, social benefits, renewable energy, climate change.
JEL Classification: Q01, Q20, Q28, Q42, Q48.

1. Introduction

Access to energy is fundamental to meeting the economic and environmental needs of a country as well as the basic social needs for households. South Africa experienced inequality in energy provision during the apartheid period, characterised by differentiation in the provision of infrastructure (for formal dwellings and electricity grid). There was also visible separation between the lower, middle and upper classes, with the benefits focusing on the minority (Azimoh, 2016). In order to address this inequality, one of the country's goals, as entrenched in the energy policy, is to

[1] Corresponding author, Department of Anthropology and Development Studies, University of Johannesburg, Auckland Park, South Africa. Email: edzisanie@yahoo.com, phone number: +27619597991

reach universal access to household electricity, which has resulted in the increase in energy consumption resultant from an increase in households' electricity connections (Wentzel, 2005). However, the country has been rated the 14th largest Green House Gas (GHG) emitter globally and the most carbon-intensive developing economy in the world due to its reliance on coal to generate electricity (Parr, Swilling and Henry, 2018). This challenge can be addressed through the use of low carbon-intensive energy sources. The use of Solar Water Heaters (SWHs), therefore, provides equal opportunities for households to receive clean and reliable energy that is affordable.

According to Feron (2016), the notion of social justice is the primary driver to energy access, which determines the fairness or inequality between different groups, with the poor being the most affected by the inequality. In addition, with the country experiencing load shedding which the State Utility (Eskom) claims that it is unable to keep up with the supply of electricity due to the shortage of coal, and continuous increase in the prices of electricity, it is vital that alternative and renewable energy sources are promoted in the energy mix for the benefit of the country's economy and social enhancements of the poor. For example, the price of electricity has drastically increased by 378.76 percent between 2007 and 2018, from 19.59 c/kWh in 2007 to 93.79 c/kWh in 2018 (Organisation Undoing Tax Abuse, 2019).

In 2009, the South African Government pronounced the Solar Water Heating Programme (SWHP), which was meant to provide one million SWHs by 2014 and four (4) million SWHs by 2030 across the country. The programme was informed by the White Paper on Renewable Energy policy (2008) which aimed at contributing 10 000GWh of energy through the use of renewable energy sources. The SWHP was meant to contribute 23 percent of the 10 000 GWh, translating to saving 620 megawatts (MW) of coal-based electricity, equivalent to about 12 percent of the generating capacity of Eskom's 4 800MW Medupi power station (Department of Energy, 2009). SWHs were identified as one of the most attractive demand-side interventions with the potential to reduce consumers' electricity costs between 30 and 50 percent and help to reduce South Africa's carbon emissions. The programme was also intended to provide poor or low-income households with 100 litres of hot water per day at no cost, saving them electricity that they would have used to heat water through a kettle or other sources. Rennkamp (2012) argues that a mass rollout of SWHs in the country would save energy equivalent to a large coal power station, create jobs, reduce carbon emissions and be financially beneficial to the end-users.

The programme objectives as outlined by the Department of Energy (DoE) were to contribute towards reducing electricity usage for heating water, contribute towards the reduction of Green House Gas (GHG) emissions and to protect the poor from the rising electricity prices. Also, the programme was intended to increase residential access to hot water through SWH, to facilitate the manufacturing of large-scale SWH equipment, improvement of local skills creation and contribute to the job creation agenda within communities (DoE, 2014). This programme entailed different sub-projects which included the social programme (providing fully subsidised SWHs to identified residential areas) and the rebate programme which provided a portion of the SWH cost as a partial subsidy to private users and businesses (i.e. for those who do not qualify to benefit from the social programme). The rebate programme entailed a subsidy of 50 percent per unit as the cost of one SWH unit was perceived as unaffordable with the estimated cost between R7,000 and R20,000 (Wentworth, 2014).

The programme, however, experienced challenges which led to the non-achievement of the set targets. The challenges were mainly related to institutional arrangements, regulatory environment and implementation strategies. According to the DoE (2018), implementation of the programme experienced challenges of installations that were dominated by imported products which affected performance of the systems, installations of poor quality SWHs resulting in reputational damage. Also, there was unreliable verification of the number and location of installed systems due to lack of systematic reporting and independent verification coupled with poor alignment of the programme with the objective of reducing electricity demand as a result of only focusing installations in low electricity consumption areas. When the programme was established, Eskom was playing a role of procuring the systems, installing and managing sustainability, including the appointment of installers, maintenance of the systems and reporting on the installations to the relevant government stakeholders. However, in 2015, Eskom handed over the responsibility to the DoE, as it failed to reach the set targets (DoE, 2015a). Since the programme was handed over to the DoE, the rebates were put on hold, with no clear indication of when they would continue. This has negatively affected the programme and suppliers since households' demand for SWHs declined due to prices that were deemed unaffordable.

As at 30 September 2014, only 417 000 SWHs were installed, and this was said to have emanated from the challenges outlined above. The installed SWHs included 38 000 high-pressure systems and 84 000 low-pressure systems, which resulted in energy savings of approximately 60GWh/annum (DoE, 2015a). Some municipalities are still implementing the social programme, while the rebate programme is still on hold. Funding for the programme was sourced through the environmental levy, of which one cent per kilowatt-hour increase was announced by the Minister of Finance in 2012 to fund energy efficiency initiatives. The anticipated revenue to be collected through the levy increase over three years (i.e. 2012/13 – 2014/15) was approximately R4.7 billion (DoE, 2015a). The overall objectives of the programme as outlined by the DoE (DoE, 2015a) were to:

- Reduce the demand for electricity by transferring the water heating load from the coal-based electricity to solar energy which is renewable;
- Mitigate climate change by using clean and renewable energy technology;
- Protecting poor households from the ever-increasing electricity prices; and
- Contribute to job creation through the local manufacturing of SWHs locally.

The advantage to South Africa is that it has greater potential to deploy solar energy into its energy mix, because of its high solar radiation levels. The Department of Energy (2015b) postulates that compared to other energy sources, solar energy is the most readily available and accessible renewable energy source in South Africa.

This study aims to unearth the causes of failure of the South African SWHP and recommend ways in which the programme can be revived in order to contribute to the social, environmental and economic benefits they were intended to achieve.

2. Literature review

South Africa, like any other country, has acknowledged the potential of solar energy to address household and business energy needs while reducing electricity demand and contributing to the reduction of global GHG emissions. This can be seen through the commitments in the country's National Development Plan (NDP) and energy policies which promote the increased use of renewable energy. Solar energy provides environmentally-friendly electricity for households and businesses as it collects energy from the sun as articulated in several studies, one of which is the study conducted by the Deutsche Gesellschaft für Internationale Zusammenarbeit - GIZ (2015).

The literature reviewed in this study provides a discussion of the urgent need to pursue alternative development trajectories by articulating the challenges facing the entire World and South Africa in implementing renewable energy initiatives, with more focus on SWHs. According to various sources, solar energy technologies have become a focus of many academic discussions as they are considered one of the most developing, attractive and preferred energy supply interventions in South Africa, with a potential to reduce consumers' electricity costs meanwhile reducing the emissions of GHG emissions (Winkler, Alfstad and Howells, 2005; Banks and Schäffler, 2006; Winkler and Van Es, 2007).

Sustainability of the solar energy initiatives is dependent on fundamental factors such as; the legislative framework, investment, finance and technology. Pervaz and Rahman (2012) contends that these factors impact on the results of the programme which include among others the quality of electricity provided by the system, satisfaction by those who use the system and affordability factors linked to the cost of the system after taking into consideration the subsidies that are offered by the government. According to Özdemir, Marathe, Tomaschek, Dobbins and Eltrop (2012), the utilisation of solar energy sources such as the SWHs can help with the reduction of the peak electricity demand of a household by up to 70 percent and reducing GHG emissions by up to 60 percent.

Pervaz and Rahman (2012) discuss the critical success factors for renewable energy programmes using South Asian countries as an example, which include the availability of proper legislative framework for the renewable energy sector, availability of reliable resource assessment data, well-established and efficient institutional arrangements for planning and implementation of renewable energy programmes. In addition, financial support through incentives and feed-in tariffs, community involvement/ participation and locally available capability are considered good success factors. Some renewable energy programmes that were implemented in South Asia did not succeed as a result of lack of proper ecological governance systems which include a lack of technical know-how for the installation of photovoltaic (PV) systems, a non-sustainable methodology for the programme and high cost. The ecological governance areas of focus in this study include the purpose of different institutions in managing the SWHP, assessing whether the programme design was done in an ecosystem friendly manner and if decision-making process was conducted in a democratic, participatory and consensus-based manner.

One of the important topics in solar energy relates to its reliability in generating sustainable energy and contributing to the green economy agenda. Lofthouse, Simmons and Yonk (2015) discuss that the roll-out of solar energy initiatives must ensure they are able to consistently meet the energy demands of consumers, which are referred to as physical reliability. According to Lofthouse et al. (2015), the reliability of solar energy depends on the availability of sunlight or good solar radiation. If the sunlight is inconsistent, solar power would have a low capacity factor, leading to its struggling to meet the demand relative to traditional energy sources.

As a result of solar power failing to meet its demands, expensive new transmission infrastructure and grid management techniques would be needed. The solar power capacity factor referred to above is a measurement that compares the amount of energy which can be produced by a plant to the energy that would be produced by solar if it is operating at full capacity for the same amount of time. In countries and geographical areas where there is a high number of sunny days such as South Africa, solar energy production is more efficient. In provinces like Limpopo, for example, the average daily solar radiation is of 5.43 kWh/m2/day, which makes solar energy more favourable than other energy sources (Energy Information Administration, 2016). Achieving a sustainable energy future does not only require putting initiatives together but also effective and strong governance systems at all levels of the energy value chain (Karlsson-Vinkhuyzen, Nigel, and Lawrence, 2012). According to Roehrkasten (2015), the current energy market structures are still geared towards conventional forms of energy, which pose many challenges for renewable energy. This is mainly because fossil fuel energy relies on technologies that have been fully developed with established industries and stable existing structures.

3. Methodology

The study findings are drawn from the findings of interviews conducted with households from two communities in the Gauteng Province, officials from the DoE and the GDED as well as two municipalities (i.e. City Power on behalf of the City of Johannesburg and the City of Tshwane). The findings from the fieldwork/ interviews are also complemented by information from available published reports and literature on climate change, renewable energy and electricity generation from different sources. This study answers the question "what contributed to the failure of the South African SWHP and what social benefits have been compromised by this failure”.

The study adopts a critical theory paradigm and challenges the status quo of the energy sector regarding the use of alternative energy, as well as the design, plan and implementation of initiatives. The critical theory explains what is wrong with the current social reality, identifies the actors to change it and provides clear norms for criticism and achievable, practical goals for social transformation (Thomas, 2010). The study aims to contribute to an academic discussion about the preconditions for the success and sustainability of the SWHP and how they can contribute to bringing change on the current status of the effects of current dominating electricity generation sources in South Africa. The critical theory assists with identifying the challenges with the planning, design and implementation of the SWHP in South Africa and also provides an understanding of the status quo on the initiative by combining theory and practice. This study, therefore, contributes to both the social, economic and ecological change that would benefit and contribute to theoretical and policy development.

3.1 Population and sample

The criterion sampling method was used to select the population and sample for households. In each of the two case study areas, 20 households were selected according to the criteria that they use SWHs. The use of this sampling method was on the basis that households who use these technologies were able to provide rich information regarding their experiences and perceptions with regards to renewable energy. Criterion sampling is a purposive sampling that allows for the selection of information-rich cases, which works well when those who are interviewed understand the processes and weaknesses of the systems (Suri, 2011). As part of the criteria set, interviews were conducted with one adult per household regardless of gender. In addition to the households', four (4) officials were also selected using criterion purposive sampling. The criterion purposive sampling, in this case, allowed the researcher to identify individuals who are knowledgeable and experienced about renewable energy initiatives and the roles of different institutions.

A qualitative research approach was utilised to collect data with key informants (households) and major government stakeholders involved in the SWHP, either at a policy or implementation level. A qualitative research approach is used to answer questions that relate to the experience, the meaning and perspective of the participants on a certain subject, most often from the standpoint of the participant (Hammarberg, Kirkman and de Lacey, 2016). The qualitative approach was used to reveal, for example, potential problems in implementing the SWHP, where individual respondents were able to explain their views on the implementation. Interviews were conducted face to face with all the identified respondents. The interviews were recorded with the consent of the respondents, together with the use of a field diary for writing notes from the interview.

The establishment of rigour was ensured through triangulation by interviewing a wide range of informants, and also reviewing supporting documents, literature and reports. This ensured that findings were more dependable when they were confirmed from several independent sources, thereby enhancing rigour. Reflexivity was applied to achieve trustworthiness by using a field diary and materials to reflect on how the research was being conducted as well as reflecting on own actions, feelings and conflicts experienced during the study. The researcher continuously reflected on the values, pre-conceptions and behaviour of respondents which may affect the interpretation of responses. Reflexivity, which is basically a way of making the interview process open and transparent is essential because qualitative studies have some level of subjectivity as the interpretation of the respondents' behaviour, and the collected data is influenced by the values, beliefs, experience and the researcher's interest (Jootun, McGhee, and Marland, 2009).

3.2 Data analysis

The approach to analyse data was inductive, which required reading of field material based on the interviews conducted and listening as well as transcription of the tape recorded interviews. The main aim of inductive data analysis method is to allow the research findings to occur from the frequent and dominant themes that are inherent in the collected raw data (Thomas, 2003). The inductive data analysis, therefore, ensures that extensive and different raw data can be summarised into a brief format as well as establishing the clear links between the research objectives and the summary of findings that are derived from raw data (Thomas, 2003).

During the analysis of data, raw data from the interviews was reorganised through re-checking the interview guide as well as identifying and differentiating between the questions that the study seeks to answer and those that were simply included in the interview guide as necessary, but not essential. The ideas and concepts were organised from the data by finding meaning in the language that was used by respondents. This ensured an understanding of perceptions, attitudes and feelings of respondents about renewable energy initiatives. The way in which informants express themselves through words can reflect their attitudes or behaviours (O'Connor and Gibson, 2003). This was crucial, as household perceptions about renewable energy were one of the themes of the study, which made it essential to reflect on the attitudes and behaviours of interviewed households. After finding meaning from the language, all the ideas and concepts were organised into different categories. The categories used focused on experience, feelings, opinions, knowledge and inputs.

It was ensured that each of the response categories has one or more associated themes that offered a deeper meaning in order to build overarching themes in the data. Different categories were then collapsed under main overarching themes. Possible and plausible explanations for findings were then found by providing a summary of findings in line with the themes. This included the review of whether the findings are related to expectations of the study based on the literature reviewed. In addition, significant surprises in the findings were checked through assessing whether there were any differences or similarities regarding what was stated in the literature. This required reading of the field diary and listening to the recorded interviews several times to avoid eliminating essential aspects of the responses. Lastly, the information was organised into a final report by summarising the research findings, including the implications of the findings and strategies.

4. Findings and discussion

The discussion of findings is based on different themes which focus on accessibility, reliability, sustainability as well as social and environmental benefits. The summary of findings on the causes of failure of the SWHP and the forgone social benefits is provided in the table below.

Table 1.

Summary of findings

Theme	Summary of findings
Accessibility of SWHs	Access to solar energy technologies such as SWHs is affected by the high capital cost of the technology. Putting on hold the rebate programme which subsidised those who did not qualify for the social programme worsened the inability to access SWHs by households.
Reliability of SWHs	The SWHs provided through the social programme do not provide reliable access to hot water, meaning that they are not reliable.
Sustainability of SWHs	The SWHs provided through the social programme are not sustainable due to the poor quality of the installed technology. Sustainability is affected by the following: Incorrect installations Feasibility study/assessment not conducted Poor workmanship – no training conducted Damaged roof The use of imported products / no localisation Leakage of the installed geysers Installations only focused on low electricity consumption areas Failure to achieve electricity load reduction targets Lack of community awareness.
Social benefits of SWHs	Due to difficulties with accessing SWHs as well as their poor reliability and sustainability, the social benefits were not realised. Households continued to use electricity to heat water as the SWHs were not providing them with reliable and sustainable hot water as intended. Households who did not qualify to receive SWHs through the social programme could not afford to buy without the rebate as it was put on hold.
Environmental benefits of SWHs	The SWHP failed to contribute positively to the climate change agenda as the programme failed to reach the set target of load reduction due to the heaters not working properly and the target of one million heaters not reached. Thus, households continued to heat water using coal-based electricity.

4.1 Accessibility of SWHs

Literature indicates that access to solar energy technologies such as SWHs is affected by the high capital cost of the technology (Wentworth, 2014; Wlokas and Ellis, 2015; GIZ, 2015). In a country where almost half (49,2%) of the country's adult population were living below the upper-bound poverty line in 2014/15 (Statistics South Africa, 2018), access to SWHs would be difficult for this group of households taking into consideration the very high and unaffordable capital cost for the technology. The introduction of the rebate programme was meant to ensure the accessibility of SWHs as they were perceived to be unaffordable. Failure to manage the rebate programme by Eskom limited accessibility, especially from those who do not qualify for the social programme, thereby affecting the continuation and sustainability of the programme. During the interviews, Peter, an official from the Department of Energy confirming the termination of the rebate programme that was managed by Eskom. He said that:

"The DoE terminated the Eskom's mandate for the SWHP due to failure of the programme to achieve its intended objectives as a result of governance-related challenges".

By the end of September 2011, a total of 156,000 claims were received for systems installed nationally resulting in energy savings of approximately 60GWh per annum, which showed an interest by members of the public to participate in the programme (Eskom, 2012). According to Peter, the rebate programme has not yet been revived, and the DoE is currently focused on re-establishing the social programme that will be implemented by municipalities in line with the Memorandum of Agreements signed with the DoE.

4.2 Reliability of SWHs

Renewable energy provides sustainable and affordable energy to households, which make a positive economic, social and environmental impact if it is reliable. SWHs are reliable in that they provide hot water to households using a natural and renewable resource, which is the sun. According to households who were interviewed, SWHs provide them with reliable hot water for free without them having to plug the kettle. Sibusiso from Alexandra indicated that: “The SWH is reliable as I receive hot water without using electricity, meaning that even if there is load shedding, I still get hot water”.

The above statement by Sibusiso was supported by Portia, a household from Soshanguve who said that: “The SWH is reliable as the sun will always be there, meaning that I will always get hot water whether there is electricity or not”.

Even though households indicated that SWHs are a reliable renewable energy technology and energy source providing them with energy at a low cost, they highlighted that a challenge is when there is cold weather or when it rains as the water does not get hot. Mr Ncobo from Soshanguve said: “Even though I receive hot water for free, when it is cold or when there is rain, I do not get hot water”.

Other challenges which affect the reliability of SWHs is the lack of maintenance of the SWHs when required as said by Mr Johnson, a resident in Alexandra who said that: “My SWH has never been maintained even though it does not work properly”.

According to Peter from the DoE, SWHs are a reliable source of energy as solar energy is always available. The efficiency and reliability of SWHs are based on solar radiation, which is good in South Africa and Gauteng in particular. To ensure the efficiency and reliability of SWHs, the design must take into consideration the solar radiation intensity for that location. This includes ensuring that data related to hourly, daily and monthly average solar radiation that reaches the horizontal and tilted surfaces are known (Alboteanu, Bulucea and Degeratu, 2015). Peter said:

“The use of imported products affected the reliability of the installed SWHs as the design of the systems did not necessarily take into consideration the solar radiation of the provinces, which is why the emphasis is now given to local manufacturing”.

Tracy, an official from the City Power also indicated that: “to improve the reliability of the SWHs, there must be a consideration of manufacturing the tube system in the country to ensure that the glass utilised for the solar panel is of good quality and suitable for the weather of the country”.

The angle in which the SWH collector is installed against the sun is also vital in ensuring the reliability and efficiency of the SWH (Alboteanu et al., 2015). Precious from the City of Tshwane said that:

“Some of the SWHs were not installed in the right position as there was no feasibility assessment conducted before the systems were installed”.

It was also observed that the majority of the SWHs installed in Alexandra were not facing north, which is the direction that would make the systems to work effectively. This affects the water heating ability of the SWH, which was also confirmed by Reyneke, a contractor who installed SWHs in Riverlea, Gauteng. He mentioned in a previous study conducted by Kings (2013) that: “south-facing geysers lose a third of their heating ability”.

4.3 Sustainability of SWHs

Sustainability areas of focus for the SWHP in this study relate to economic, social, ecological and environmental sustainability. According to Oberheitmann (2014), sustainability of the solar energy initiatives is dependent on fundamental factors such as; the legislative framework, investment, finance and technology. These factors impact on the results of the programme which include among others the quality of electricity provided by the system, satisfaction by those who use the system and affordability linked to the cost of the system after taking into consideration the subsidies that are offered by the government.

Mark, an official from the Gauteng Department of Economic Development has indicated that: “Solar energy is not sustainable on its own in Gauteng currently, as the storage is too expensive and would need to be complemented by other sources. However, in future when the storage capacity is increased and when there is enough land, solar energy would be sustainable”.

Mark further said that: "rooftop solar PVs are however at an advantage as they do not require land", making SWHs to be considered a sustainable source of energy. He added that: "Sustainability of solar energy is also impacted by the approval processes done by the DoE which tends to take too long, and sometimes projects are not approved if they are not part of the Independent Power Producers Programme, affecting the mass roll-out of solar energy".

The City Power implemented the SWHP on its own without participating in the DOE's national programme. Tracy also indicated that the reason the City Power embarked on its programme, and not participate in the DoE programme was because of the difficulties in obtaining funds from both Eskom and the DoE. These difficulties also affect the sustainability of the programme.

The above statements by Mark and Tracy relate to the role that ecological governance plays in the form of institutional arrangements to ensure success and sustainability of solar energy initiatives. In supporting the views of the GDED, the DoE said that solar energy, including SWHs, are a sustainable source of energy. Peter said: "Solar energy is a sustainable source of energy; if the initiatives are managed well, although they still need to be part of the energy mix, which means that they cannot ensure energy security on their own".

Peter further said that the use of SWHs is beneficial to the ecosystem as they use the sun, which is a renewable natural resource. He said: "The sun will always be there even with global warming, unlike coal which can be depleted at any time".

He said that governance, however, becomes crucial in ensuring that solar energy initiatives can be sustainable. Sustainability related challenges experienced with the SWHP, as explained by Peter, were as a result of lack of proper governance systems including the installation of systems which did not contribute to load reduction, meaning that they were not ecologically and socially sustainable. Factors which affected the sustainability of SWHs are discussed below.

4.3.1 Incorrect installations

(a) Feasibility study / assessment not conducted

A feasibility study is important as it provides information on whether or not the project implementation is feasible in the identified areas. Shen, Vivian, Tam and Ji (2010), describes feasibility study as the first and most vital step that is done before conducting any programme or project design. They contend that the success of programmes and projects is mostly determined by the effectiveness of the feasibility study.

Peter said: "The other reason the Eskom programme failed was because they implemented the programme without conducting feasibility studies and readiness assessments in the identified areas, which resulted in the SWHs being installed in houses that were not SWHs ready".

Peter explained that before installations can be done, feasibility assessment must be conducted confirming the state of readiness for houses in identified areas. He said: "This is a crucial step that will be conducted in the redesigned national SWHP which the DoE is managing. The assessment will include identifying the number of low-income and mid-high income households, a number of Reconstruction and Development Programme (RDP) and non-RDP houses, roof types and roof load-bearing capacity, water connections as well as the security of water supply in the identified areas of implementation".

(b) Poor workmanship – no training conducted

Literature has shown that the lack of expert know-how can affect the sustainability of renewable energy initiatives (Kariuki, 2018). According to the DoE (2015b), there was no proper training conducted for installers to ensure that they have knowledge and understanding of SWHs and their installations, which led to some of the SWHs not being operational in both study areas. Charmaine, a household from Alexandra, has said that her SWH does not work as it was not installed correctly.

In addition, Peter said: "One of the reasons the Eskom mandate for the programme was terminated was due to the poor quality of installations, as installers were not properly trained".

He further explained that to ensure that the SWHs can be sustainable, the DoE will work in conjunction with the Department of Higher Education and Training (DHET), Department of Labour (DoL), Energy and Water Sector Education and Training Authority (SETA) and accredited training institutions to ensure that service providers are appropriately trained. Furthermore, before installations can be done, the quality of potable water and water pressure would be tested so that a suitable type of SWH system (freeze on non-freeze resistant) is installed in each household.

Tracy also confirmed that in the City of Johannesburg (City Power), training of installers was not done. She said:

"Even though it was initially planned that the installers would be trained, the plan did not materialise, and the installations ended up being done without proper training provided".

Maintenance was also a challenge as households have indicated that their geysers were not maintained. Peter has also agreed that this was a challenge which the DoE is addressing through the re-designed programme. He indicated that: "In order to address the maintenance problem, the current SWH systems come with a 5-year warranty which is effective upon installation and this is done to ensure sustainability".

Both the City of Johannesburg (City Power) and City of Tshwane confirmed that the installed SWHs were not maintained, which affected sustainability. Tracy said:

"If there was proper maintenance done to the systems, they would provide a sustainable solution to hot water for households as they would still be working properly. However, even if the systems are still working, they will soon stop functioning as they need to be maintained every five years. The City Power currently does not have plans to maintain or refurbish the installed systems, and this will continue to be a challenge".

Precious said: "The majority of the SWHs installed in the City of Tshwane through the social programme are no longer working, and they were never maintained. Majority of them were broken during the hail storms and they were not fixed. This affect sustainability as the systems only worked for a short period".

(c) Damaged roof

Some of the installed SWHs left the households with damage to their roofs. Xolani, a resident from Alexandra said: "My roof was left with big holes after the installation, and no one has taken responsibility to fix it".

Peter has supported claims that were made by households' regarding the damages that were left on their roofs. He said: "Some installations damaged the roof structures as no roof structure assessment was conducted before the systems were installed. For example, the strength of the roof must be considered before installation to ensure that the geyser is not heavier than the roof can carry". One of the criteria of the installation with the redesigned programme is to assess the roof strength, and this will address the challenges experienced with the previous programme".

Precious also commented on the issue of the SWHs installations leaving damaged roof by saying: "The qualifying criteria for the installation of SWHs was that a household must have an RDP house which has a gable roof type. The service providers then went to install the systems with the assumption that the roof would be of quality, only to find that the quality was compromised by those who build the house, leading to damaged roofs".

4.3.2 The use of imported products / no localisation

When the programme was established, the local content policy was not taken into consideration. Many geysers and panels that were installed (which were mostly imported or used imported components) created challenges with the quality and credibility of the programme. Peter said: "The use of imported systems affected the sustainability of the programme and the systems themselves, as the majority of them ended up not working".

Tracy alluded to the fact that one of the problems with the SWHP was the fact that a lot of the systems that were installed were imported and were of poor quality. This was also supported by Precious who indicated that in the City of Tshwane, the SWHs that were installed were imported and were of poor quality. Hence, the majority of the systems are not operational as they broke when there was hail because of poor quality. She said: "The quality of the SWHs plays an important role in ensuring reliability and sustainability, which would work better if the products are manufactured locally".

Tracy also supported the local content debate by saying: "If there has to be success and sustainability of the programme, the government must consider supporting local glass manufacturing companies so that they can manufacture the tubes for the solar panels. This would have greater benefits in terms of quality, cost, maintenance as well as the installation, which would be easy if the components were manufactured locally".

The DoE has indicated that to address the problem of using imported products, the Department of Trade and Industry (DTI) issued the SWH designation, which will assist with ensuring that the SWHs installed are manufactured locally. Peter indicated that this would assist in ensuring the sustainability of the programme.

4.3.3 Leakage of the installed geysers

According to households in both study areas, some installed SWHs leaks, which damages the ceiling and walls. The leaks also create water wastage leading to high water bill for households. Mahlodi, a resident from Alexandra said that his geyser has been leaking, damaging the ceiling and walls and no one has maintained the geyser since it was installed. Adding to the reliability and sustainability challenges of the SWH, Dineo, a household from Soshanguve said: “The valve of my SWH is unable to maintain the water pressure when the water is too hot, creating challenges with accessing hot water”.

Tracy said: “The problem is that when City Power installers started with the installations, copper piping was utilised which created problems with the leakage. This was, however, corrected by changing the piping material”.

It was also established during this study that in some areas such as Alexandra, the SWHs installed were not of the same quality as those that were presented during the bidding process. Companies submitted the good quality SWHs to South African Bureau of standards for certification, and once certification was received, they installed poor quality SWHs.

4.3.4 Installations only focused on low electricity consumption areas

The social programme, which is implemented by the DoE and municipalities focuses on low-cost housing areas, which are also low electricity consuming areas. Even though the programme is beneficial, an ecological rationale decision would be to also promote and support the use of SWHs in high electricity consumption areas in order to realise the electricity savings and reduction in greenhouse gas emissions, thereby ensuring sustainability. Peter said that: “One of the challenges with the programme was that the focus was on areas where electricity consumption is very low which led to the programmes not being able to make a noticeable impact on the load reduction objective”.

He also indicated that there are currently no plans with implementing the rebate programme which was stopped when the Eskom mandate was terminated, although this would be considered in future depending on the availability of funding.

Tracy also indicated that the City of Johannesburg focused the installations at the low-income areas as the grid electricity capacity in those areas was too low to accommodate the electric geyser. He further said: “If households had to use electric geysers in those areas, City Power would have a serious challenge with the power capacity which would always trip. If we could not use the SWHs, we would have had to replace the cables to put the ones that can allow for an increased load”.

One of the emerging finding relating to the accessibility of SWHs in Tshwane was the fact that housing developers are ahead of the government in terms of ensuring that the use of SWHs increases. In the area where households were interviewed in Soshanguve, it was found that all the households in that area received the SWHs from the housing developer. Those are the households who would not have qualified for the free SWH provided through the social programme. Housing developers have become innovative to make SWHs a standard for all new housing development and the government must consider promoting these initiatives.

4.3.5 Failure to achieve electricity load reduction targets

When the programme was established, the plan was to reduce electricity consumption by 3 000 MW by 2012, and a further 5 000 MW by 2025. The programme, however, failed to achieve this objective as the majority of the installed SWHs did not function correctly, and a few SWHs were installed against the set target (i.e. 400 000 SWHs were installed by 2014 against the target of one million). According to Peter, "the installed heaters failed to reduce the electricity load as planned, which is one of the reasons why the Eskom mandate for the programme was terminated”.

Precious indicated that the poor success of the programme in the City of Tshwane related to challenges with the non-contribution to the load reduction. She said: “The problem is that the majority of the SWHs installed in the City of Tshwane are not operating, which means that they are not contributing to the load reduction targets”.

4.3.6 Lack of community awareness

When implementing renewable energy programmes, it is vital that there is social acceptance for the technology which can be achieved through community awareness campaigns before the programme can be implemented (Wustenhagen, Wolsink and Burer, 2007). Households have complained about the fact that the water is often cold during cold weather periods or when it rains, which shows that they have expectations of getting hot water always without interruption. Phumzile, a resident from Soshanguve said: “When it is cold, I do not get hot water, and if someone bathes at night, in the morning there will not be hot water”.

Expectations must be managed before the implementation of any programme to ensure sustainability through awareness campaigns, where the community must be told about the technology, how it works and its benefits thereof (Wustenhagen et al., 2007). Lack of consultation and involvement of municipalities in the rollout plans also led to municipalities not being able to address complaints and concerns raised by the households on faulty systems. The DoE indicated that in order to address this challenge, municipalities are now required to sign Framework Agreements with the DoE, which clearly outline the roles and responsibilities of all parties involved. Peter said: “Community awareness programmes are being conducted as part of the social support programme. By the time the programme roll-out commences, households will be aware of the installations and their benefits”.

Peter further alluded to the fact that for the programme to be sustainable, it is crucial how the beneficiary communities would be identified and selected, and this would require prior consultation with the communities and affected municipalities. Furthermore, before the installations can be done, there must be technical, and efficiency assessments that must be taken into consideration and would require that prior consultation or awareness is conducted. These considerations include, but not limited to, the availability of piped water in identified households, water quality, roof strength and location of households in order to consider the solar radiation.

One crucial element in ecological governance is participatory decision making, which contributes to the success and sustainability of initiatives. The DoE has taken a step in ensuring that social facilitation can be conducted in communities before the SWHs can be installed. Social facilitation promotes participation, ownership and active involvement of stakeholders including beneficiary communities throughout the life cycle of SWH projects as well as mobilising communities in order to make linkages and partnerships to expand the knowledge, skills and resources available in the communities. Peter indicated that service providers will be appointed by the DoE to conduct the Social Facilitation Support Programme.

Institutions play an essential role in ensuring the sustainability of initiatives. According to the DoE in its presentation on the "storage of procured baseline system” made on 31 May 2018 at the SWH inception workshop, among many responsibilities of the DOE regarding the implementation of the programme, the Department is also responsible for the procurement of the SWHs from suppliers. These are the SWHs that would be installed in participating municipalities that have signed the Municipal Framework Agreement (MFA). In this case, the DoE has already procured 87 206 SWHs between 2015/16 and 2017/18 financial years which are currently stored at the suppliers’ warehouses and would be moved to a central storage facility and then moved to respective municipalities when they are ready for installation. This may have an impact on the success and sustainability of the programme due to the following risk factors:

- By the time the systems are installed in houses, the supplier warranty may have been affected, thereby affecting sustainability should the system experience faults when installed;
- The systems may be damaged during storage in either the central storage or municipal storage where the supplier might not take responsibility;
- The systems may be damaged during transportation which may have financial implications or affect installations; and
- The procured systems, as they were procured between 2015/16 and 2017/18 may not be in line with the feasibility or social support programme results, which means that they may not be feasible for installation in identified areas or houses.

The above can imply that the procured SWHs might not contribute to the achievement of the programme objectives, especially load reduction, and may not be sustainable.

4.4 Social benefits of SWHs

Literature shows that SWHs benefit households as they reduce the cost of electricity (Winkler, Spalding-fecher, Tyani and Matibe, 2002). The Department of Energy (2014) suggests that water-heating accounts for a third to half of the energy consumption in an average household, which is derived mainly from electricity. The use of SWHs could therefore reduce household expenditure on electricity, which could lead to significant improvements in the disposable incomes of lower-income households. This was supported by Sustainable Energy Africa (2017), postulating that SWHs have the potential to help households to save resources by providing them with 100 litres of hot water and reduce water heating cost by 60 percent, resulting in a monthly savings of 25 to 30 percent to the household electricity bills.

The findings agree with literature as households indicated that SWHs have benefited them in many ways. Salome, a resident of Soshanguve, said: "SWHs provides me with hot water always at no cost, which means that I spend less on electricity".

In confirming the social benefits of the SWH, Mashudu said: "SWH has changed my life as I now spend less on electricity. Before I got a SWH, I used to plug the kettle five times to have hot water to bathe with, but now I just turn on the tap and hot water comes out, and this saves me time".

Households indicated that since SWHs were installed in their houses, they have saved between R150 to R500 every month, which is half of their previous electricity bill which can now be used for other household needs. Tshepo said that he now saves R300 on electricity while Ronald saves R400 per month. Thabang said: "SWH decreases my electricity bill, and even when there is no electricity, I still have hot water".

4.5 Environmental benefits of SWHs (Contribution to the climate change agenda)

The main aim of establishing the SWHP was to contribute to the increased use of renewable energy and reduce carbon emissions. According to the DoE (2009), the SWHP would lower the country's high carbon emissions and contribute to the Long-Term Mitigation Strategy (LTMS) to combat climate change. The Department has also indicated that the use of SWHs would have environmental benefits, as currently the equivalent of a large coal-fired power station (2 000MW+) is used to provide hot water on tap to the domestic sector alone. Literature (Maia, et al., 2011) also suggests that as water is heated mostly by the sun, a SWH that displaces electric geyser heating would reduce CO2 emissions by about 2 to 3 tons per household per year.

The above was also confirmed by households who said that SWHs are environmentally friendly and use the sun, which is a natural and renewable resource. Ronald from Soshanguve said, "The SWH is environmentally friendly as it does not produce any pollutions".

Peter said that the use of SWHs would reduce energy consumption by about 55 GWh per month, which potentially can displace the use of expensive diesel to the extent of 12 percent every month.

5. Recommendations and policy implications

The study recommends the following:

- **Improved technology to ensure reliability and sustainability of SWHs**

The specifications and capabilities of the technology that is being utilised for SWHs seem to be limited as it does not have enough storage and battery capacity to heat the water during cold or rainy weathers. Both interviewed officials and households confirmed this. The solution would be to ensure that the specifications of the solar panels utilised are manufactured taking into consideration the theory of thermodynamics. With enough storage capacity, SWHs would be more reliable and sustainable, thereby contributing to the social benefits expected by households as well as achieving the government's objectives for the programme. With the current SWHs, households continue to use coal-based electricity to heat water as the technology does not always provide hot water as intended.

- **Improved institutional arrangements for the planning and implementation of solar energy initiatives**

In the current institutional arrangements, the DoE plays the majority of the roles in the planning, implementation and monitoring of the solar energy programmes. This has its own challenges as the department also has other priorities, which may lead to the SWHP being overlooked. The DoE must delegate some of the functions for this programme to a provincial department and municipalities to avoid centralisation of the programme implementation, which can negatively affect success and sustainability.

This study, therefore, proposes that a polycentric institutional model is utilised for the provision of SWHs across the country. A polycentric institutional model allows for multiple actors and mechanisms to share powers in dealing with energy problems at different spheres (Feron, 2016). Using the polycentric institutional model in the SWHP would allow for the provincial government to have powers on planning and setting targets for the SWHs to be installed in the province. The polycentric model would also bring an advantage for the programme to become a local initiative where there can be an exchange of knowledge and the control of measures by local representatives who know the area and its dynamics well, including the needs of the people. Another benefit of localising the programme would be the local facilitation of the programme implementation which would ensure easy acceptance as locals would easily identify with initiatives that are being led by the people that they know and live with. With this model, it can be easy for the national sphere of government to achieve its goals as each province would work towards ensuring that there is an improvement at its sphere, therefore, contributing towards the achievement of national goals. The provincial Department of Corporative Governance and Traditional Affairs (COGTA) would be the best institution to manage the programme at a provincial sphere, which would also make it easy for the municipalities to implement the programme. This is due to the fact that COGTA is responsible for monitoring the local government, making planning, implementation, management and monitoring of the programme easy.

- **Scaling up the roll-out of SWHs as intended**

For the SWHP to have a positive impact on social indicators and climate change mitigation, it is vital that the roll-out is scaled up as it was intended. Installing SWHs in small scales may affect the realisation of the intended change. Scaling up the rollout would enable the economies of scale required for the businesses involved in the manufacturing and installation of the technology and for the programme to succeed and be sustained. It is not possible for the government to achieve the intended electricity load reduction and energy efficiency targets if the SWHs are not installed where they matter most. The installation of the SWHs must be scaled up, in both low and middle-class areas.

6. Conclusion

Implementation of the SWHP has not been a success due to ecological governance-related challenges. A lot still needs to be done to ensure that the programme can also contribute to the green economy agenda. This study aimed to unearth the causes of failure of the South African SWHP as well as recommending ways in which the programme can be revived in order to contribute to the social, environmental and economic benefits they were intended to achieve.

Underlying causes of failure for the programme have been identified and would need to be corrected. The study found that the programme failed due to the subsidisation of imported products, poor quality installations leading to non-functioning SWHs, lack of training and poor planning by the involved institutions. There was also a problem of poor alignment of programme implementation with the objective of reducing electricity demand as installations were focused in low electricity consumption areas only. Also, lack of maintenance obligations by the suppliers which led to SWHs not being maintained when not functioning and poor workmanship which resulted in SWHs being dysfunctional also contributed to the failure of the programme.

The study also found that SWHs currently are only easily accessible to those who receive them through the social programme of the DoE because the prices of SWHs are still a bit high. Lastly, almost all of the SWHs that have been installed by the municipalities are not working or have faults, meaning that households are unable to enjoy access to free hot water.

There is a strong motivation for making the programme a success as it does not only provide benefits in terms of environmental protection and sustainability but also social benefits for households. Households have indicated that SWHs provide them with hot water with reduced spending on electricity as this leads to reduced electricity costs. In addition, the current levels of GHG emissions that cause climate change require urgent intervention to ensure ecological sustainability, which would require increased use of renewable energy. Moreover, there is a need for electricity load reduction if the country must reach its universal access targets as the current generation capacity from coal cannot be sustained as it will deplete over time.

Even though the DoE has re-designed the SWHP to focus on improved ecological governance so that the programme can be a success and sustainable, more focus has been on the delivery of the social programme, with a target of 1.5 million SWH by 2019. For the programme to contribute to the reduction of the load and GHG emissions as well as improving the livelihood of the poor, there is a need for better governance systems. The success of initiatives is seen through the data that is produced during the monitoring and verification of the programmes. The Monitoring and Verification (M&V) of solar energy initiatives must be improved to clarify and make transparent the impact made by those initiatives. Effective M&V can be achieved if a polycentric institutional model is applied. The SWHP failed because there was no monitoring and verification done to assure the quality of the installed SWHs. It was only realised when the systems started to fall apart that installed SWHs were of poor quality.

This study, therefore, concludes that the success and sustainability of the SWHP that would ensure the realisation of the economic, environmental and social benefits are dependent on ecological governance.

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