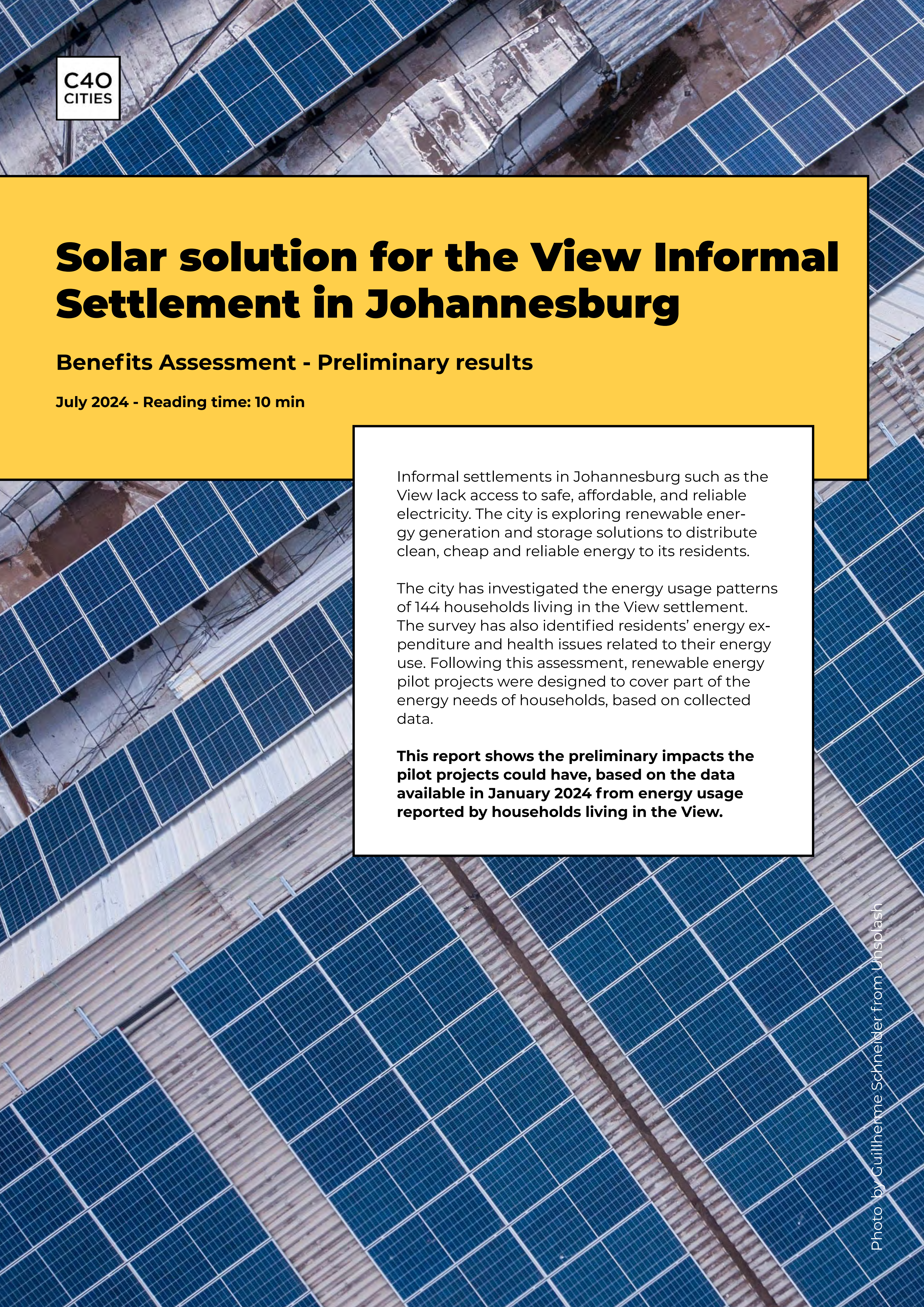


C40 CITIES

Solar solution for the View Informal Settlement in Johannesburg

Benefits Assessment - Preliminary results

July 2024 - Reading time: 10 min

Informal settlements in Johannesburg such as the View lack access to safe, affordable, and reliable electricity. The city is exploring renewable energy generation and storage solutions to distribute clean, cheap and reliable energy to its residents.

The city has investigated the energy usage patterns of 144 households living in the View settlement. The survey has also identified residents' energy expenditure and health issues related to their energy use. Following this assessment, renewable energy pilot projects were designed to cover part of the energy needs of households, based on collected data.

This report shows the preliminary impacts the pilot projects could have, based on the data available in January 2024 from energy usage reported by households living in the View.

Photo by Guillherme Schneider from Unsplash

Informal settlements in Johannesburg lack access to safe, reliable, and affordable energy

With a combination of a a coal-dependant grid, and households using solid fuels, the stationary sector is responsible for more than half of Johannesburg's greenhouse gas (GHG) emissions.[1]

In addition, housing shortages, limited access to affordable housing, and increasing migration rates, have resulted in many individuals to live in informal settlements in Johannesburg, characterised by makeshift structures and poor access to city services. Although access to electricity is essential to empower communities and support their daily living, most informal settlements lack of access to the grid, and many residents have to use illegal connections. However, such connections can endanger lives, with health risks including electrocution and fires.

Households may also turn to other polluting fuels such as paraffin and wood for their cooking and heating needs, but these also have major health consequences: in 2019, 4,600 deaths in South Africa were due to household air pollution from solid fuels.[2]

54%
of Johannesburg GHG emissions are from the building, energy, and industrial sector

4,600
Deaths in South Africa attributable to household air pollution from solid fuels

Biomass fuels are estimated to contribute 17% of the city's PM2.5 concentrations.[3] High concentrations of air pollution, which consistently exceed the WHO recommended guidelines, has been found to lower life expectancy in Johannesburg by 3.2 years.[4]

Johannesburg's Climate Action Plan prioritises affordable clean energy for its residents and aims to address energy poverty through renewable energy generation and storage solutions.[5] This report explores how a solar photo-voltaic (PV) plus storage solution may benefit an informal community by replacing their solid fuel use.

Energy sources used in the View settlement are costly, polluting, and pose significant health risks for the community

30-65%
of residents reported fire risks when using paraffin, gas, wood, or candles

20%
of residents reported electrocution and shocks as risks when using illegal connections

110 tonnes CO2eq/year
emitted across the settlement, and 0.78 tonnes per household

25%
Report respiratory illness symptoms (e.g., coughing, asthma). This was highest among paraffin users.

55%
Report smoke inhalation from burning their energy sources. This was highest among wood users.

PM2.5 **0.25 tonnes PM2.5/year**
emitted across the settlement, harmful for human health

Photo by Sticky Situations

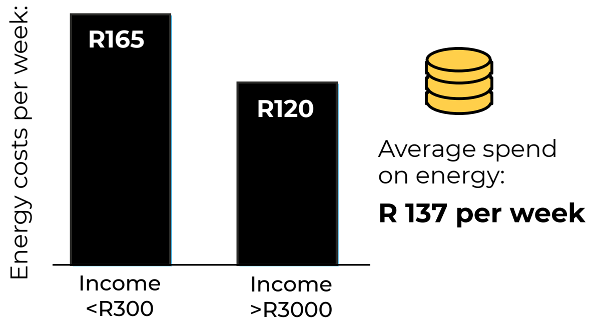
Zooming in on: The View Settlement

The View informal settlement offers an opportunity to pilot a clean and affordable energy intervention for a low-resource community. The View, established in 2008 in Ophirton, houses 142 mainly wooden and iron informal dwellings. While the settlement is not electrified, there are some illegal electrical connections. Located in an active industrial area, it attracts residents seeking employment.

In December 2023, a survey was conducted among the residents of the View informal settlement.[6] A total of 144 households participated in the survey and shared their insights on household demographics, dwelling characteristics, daily domestic activities, current energy usage, and expenditure. This information can be used to inform a tailored energy solution that replaces their use of harmful solid fuels.

The majority of residents live alone (62%) and 25 families have children, with an average of 2 children. **Households spend on average R 137 per week on energy, but poorer households spend a third more on energy than wealthier households.** This may be due to them being unable to afford sources that are cheaper but require large upfront costs to use (e.g., gas cylinders, electricity infrastructure).

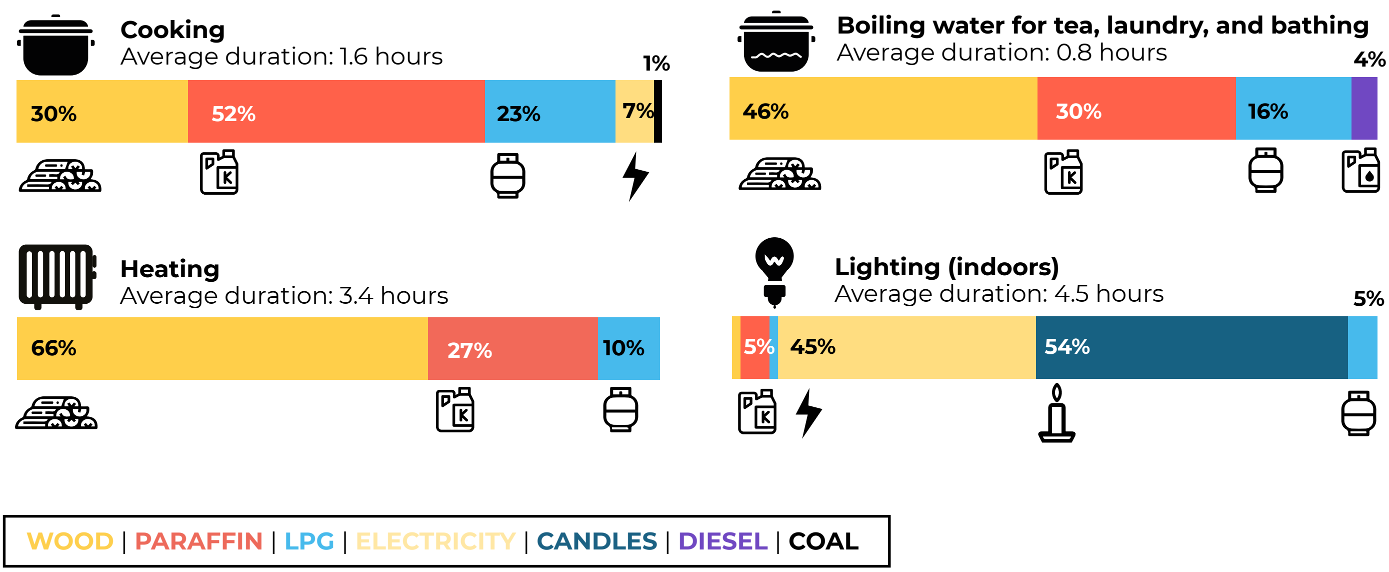
Poorer households spend a third more on energy than wealthier ones



The majority of residents (57%) are male and live in small to medium-sized shacks with a small cooking space. These cooking spaces are often in the same location as where residents sleep, as 69% of residents responded that they live in one room. Because air pollutants take time to disperse, this means that many residents are exposed to air pollutants both when they are cooking and when resting at night.

Households in the View are diverse and use a variety of fuel sources

Although most residents are illegally connected to the grid (52%), other commonly used energy types include wood (63%), paraffin (55%), candles (51%), and gas (26%). Households use various fuels in different daily activities, as shown in the figure below.

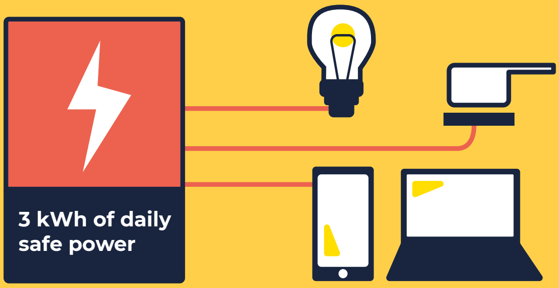


*Some percentages may not add to 100% as some households used more than one fuel type

Generating and distributing solar energy locally

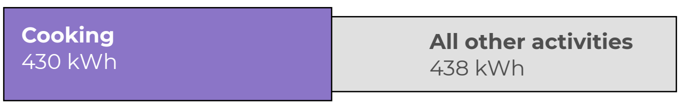
A solar microgrid energy solution has been proposed is to provide households with electricity that will be powered by solar panels on elevated towers and distributed throughout the neighbourhood using point of power delivery stations and the city grid. In addition, public lighting will be installed to improve public safety within the settlement.

The system is envisaged to be designed to provide safe, affordable, and reliable energy, as the switch from solid fuels to solar energy can decrease emissions, air pollution, and fire hazards. Each point of delivery station would be connected to 10 households and distribute 3 kWh of power per household per day. This means that across the 144 households surveyed in the View, a total of around 432 kWh will be supplied per day. These pods will also be secured with fencing to prevent unauthorized access.



Based on the current household energy demand in electricity-equivalents, and because the system is designed to allocate about 3 kWh of energy per household per day, which covers only part of the full household energy needs, there are two energy scenarios that may be considered. The first is replacing all current fuels used for cooking with solar energy, with the second scenario covering the remaining activities, which includes boiling water for tea, bathing, and laundry, and powering their current appliances and electronics (e.g., radios, TVs, charging cell phones), and lighting.

Scenario 1: Covering all cooking activities in the settlement



*Based on electricity equivalent of current activities

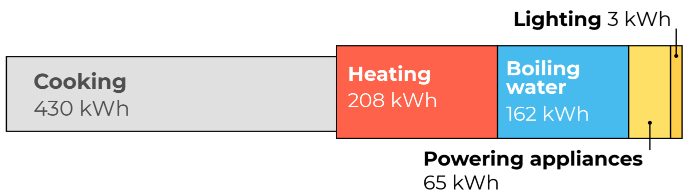
This means that for each year and each household:

0.42t of CO2eq emissions
would be saved

0.71kg PM 2.5 pollutants
would be avoided

R3,550
would be saved, allowing households to buy 350kg of pap or 100kg of chicken

Scenario 2: Covering all other activities (heating, lighting, boiling water, electronics) besides cooking



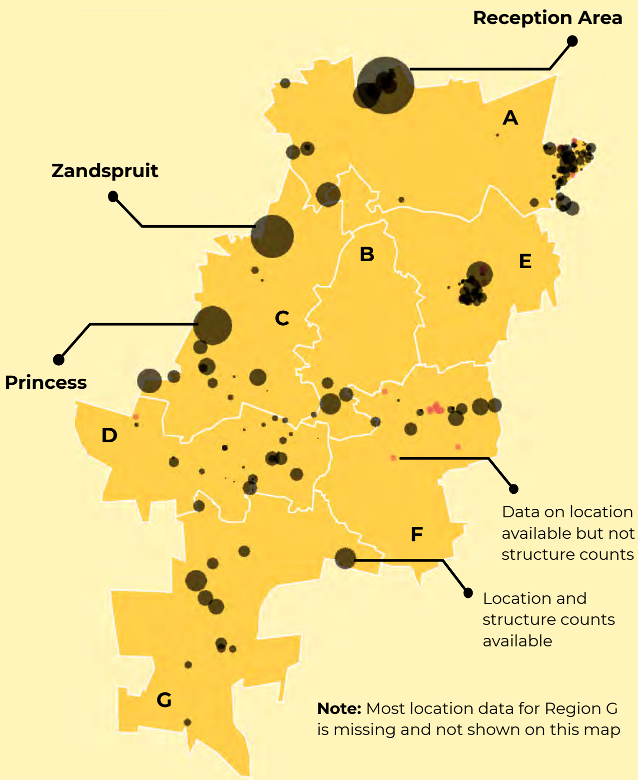
This means that for each year and each household:

0.35t of CO2eq emissions
would be saved

0.98kg PM 2.5 pollutants
would be avoided

R3,280
would be saved, allowing households to buy 320kg of pap or 92 kg of chicken

Scaling renewable energy infrastructure across all informal settlements



The View settlement is one of numerous informal settlements located around Johannesburg. As of 2023-2024, a total of 312 informal settlements, including the View settlement, representing 249,000 structures, were registered.

Informal settlements are concentrated in Region A, with 113 settlements. Sizes vary widely, from 4 households (using structure count as a proxy) in Kliptown Market to 25,000 in the Diepsloot Reception Area. Other large settlements include Zandspruit (14,221 households) and Princess (12,065 households). Larger settlements may be prioritized for infrastructure improvements, potentially enabling local renewable energy generation.

If all cooking activities were replaced with solar-powered energy, and 67,840 households across 310 settlements (excluding those with existing microgrid infrastructure) were provided with infrastructure to be able to locally generate renewable energy, it is estimated that 95,400 tonnes of CO2eq/year and 172,450 kg of PM2.5 emissions/year could be avoided.

The scale-up could enable avoid greater amounts of GHG and air pollution emissions:

	Households impacted	CO_2eq emissions avoided	PM2.5 emissions avoided
Pilot: The View settlement	**144 households**	**55 tonnes/year**	**99 kg/year**
City-wide scale-up: All informal settlement households, except for settlements with infrastructure for local renewable energy generation	**249,162 households**	**95,400 tonnes/ year***	**172,450 kg/ year***

*** Based on consumption patters observed in the View Settlement.** This is likely an underestimate as household data is available for only 256/312 (82%) of settlements.

Amarasta Solar PV micro-grid

This case study highlights the benefits of shifting to a solar-PV powered microgrid system. This example also undescores the need to adapt energy solutions to local contexts and to consider unintended consequences on the most vulnerable community members.

Background

Amarasta is an informal settlement that is home to a Rastafarian community, consisting of approximately 185 households (500 individuals). The microgrid initiative involved the installation of 900 solar panels with batteries, resulting in a total maximum generated capacity of 2.65 MW and 1 MW of battery storage, sufficient for each household to receive about 3kWh of energy per day. This grid-tied solution is designed to act as a backup during periods of insufficient sunlight, reducing the risk of load-shedding and promoting smoother operations for local businesses. Furthermore, the microgrid can alleviate strain on the electricity grid by feeding energy back into the City Power grid, thereby enhancing existing electricity services.

Residents are billed for electricity usage at the same rate as formalized electricity, with provision for subsidies targeting low-income households, including free basic electricity coverage of up to 50 kWh per month (1.7kWh per day).

Enhancing employment and community development:

- The project created job opportunities for 80 community members, including a significant number of women. This not only provided income but also encouraged community engagement and support for the project.
- The project has resulted in increased community investment in permanent structures and infrastructure improvements, contributing to the development of the area.
- Based on high-level estimates, the project may avoid emitting 101 tCO_2eq/year of and 285 kgPM2.5/year.

Project Scope and Outcomes

The R60 million project involved installing security features, boundary walls, road paving to diminish dust interference, lights, poles, streetlights, cables, and smart meters. Preliminary calculations by City Authorities found that the project could pay for itself within 18 months. Early results include a reduction in complaints about illegal connections, indicating that surrounding communities have also benefited. Additionally, there has been progress in formalizing the settlement, as residents have shown increased investment in permanent structures and infrastructural improvements.

While the formalization process presents positive prospects, concerns regarding the potential displacement of vulnerable community members due to increased costs should be considered. This could potentially prompt the formation of new informal settlements without similar facilities, highlighting the need to expand such initiatives to ensure universal access to electricity services. It is imperative to engage surrounding municipalities to extend comparable provisions, as potential relocation of displaced individuals may lead to increased demand in their respective settlements.

An identified risk of the project was the susceptibility of solar panels to theft. By actively engaging the community and gaining support from respected leaders, along with compensating community members and small businesses for their services during construction, community buy-in was maintained throughout and after the project. The employment of 80 community members, including a large proportion of women, was a notable benefit of the initiative.

Future Considerations

These lessons may be applied to formalizing and providing universal access to electricity in other informal settlements, including the View settlement. Additionally, strategies to prevent displacement and promote community resilience and sustainable development must be regularly reviewed and coordinated at the municipal level. Community engagement and buy-in are also key to the success of future projects.

Photo by Anil Reddy, Unsplash

Equity Impacts

The solar PV project in the View settlement offers significant potential benefits by reducing GHG emissions and harmful pollutants like PM2.5. By decreasing the reliance on costly and polluting fuels, this project can improve the health and wellbeing of households, particularly among women and children, and alleviate the financial burden among the most disadvantaged groups.

Lower-income households stand to benefit through:

Increasing disposable income: Introducing solar energy can mitigate the existing inequality where low-income households pay more for energy. It helps save a larger portion of their income previously spent on energy and improve their financial resilience.

Improving air quality: Reducing the use of fossil fuels for heating, cooking or bathing can reduce the emission of harmful pollutants locally, and improve both indoor and outdoor local air quality.

Women and children can have improved wellbeing:

Reducing exposure to pollutants: Women and children are typically more exposed to air pollutants due to their traditional domestic roles. Reducing reliance on polluting fuels used indoor minimizes their exposure to harmful pollutants. This is important as children are still developing their respiratory and cognitive systems.

Providing social benefits: By freeing time spent in domestic tasks such as collecting wood, preparation, and clean-up, the solar energy system can increase time spent for education, personal development, economic opportunities, and social engagement.

Solar PV considerations and recommendations

By decreasing the reliance on costly and polluting fuels, the solar PV project can improve the health and wellbeing of households. Training, maintenance support, and clear communication will be crucial for setting realistic expectations and achieving acceptance and long-term sustainability of the project among households.

While transitioning to solar PV is a positive shift, the current proposal may not fully meet all daily energy needs of residents, which risks them resorting to 'fuel stacking', or continuing to use traditional fuels or illegal connections to fill the gaps of the new energy system. Poorer households may take a longer time to transition to solar power, as electrical appliances can require a large upfront cost. To fully support a complete shift to solar energy, it is important to **provide not only resources for cooking and boiling water as cookstoves and cookware but also additional resources such as efficient electric space heaters, LEDs.** Improving electrical infrastructures can also support other household activities safely.

In designing an energy system, it is crucial to engage and support additional key stakeholders such as small business owners. Within the surveyed community, six small businesses were identified, typically in the food sector. These businesses depend on electric stoves for cooking and refrigerators for storing perishable goods and cold beverages, both of which are high-energy appliances. A scalable energy solution allowing traders to purchase additional power would support the economic activities in the community.

Successful implementation may also rely on the community's acceptance and adaptability to new technologies, particularly related to cooking. Experiences from similar contexts underscores the importance of addressing various factors such as cost, stove design, time efficiency, and the ability to prepare traditional dishes.[10] Educational initiatives can assist in the transition, with routinely delivered demonstrations on induction cooking. An additional approach might be to develop an 'eCookbook' with showing how traditional recipes may beadapted for induction cooking.[11] These efforts can help ensure that food taste are maintained as well as acceptability.

References & Methodology

This report shows the preliminary impacts, based on the data available in January 2024 from the survey conducted by Sticky Situations.

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Methodology

Data collected from the View household surveys in December 2023 was used to estimate daily energy consumption for each household. Households reported on the duration of time they engaged in domestic activities, such as cooking, boiling water for laundry, heating, and lighting. They also provided information on the energy sources they used for each activity.

Electricity demand calculations

Surveyed residents responded to questions on appliance use duration (e.g., cellphones, radios, TVs), lighting their homes, cooking on weekdays/weekends, heating water for tea/bathing/laundry, and heating. Residents with fridges reported they powered them for the entire day (24 hours), followed by radios and TVs (about 4.4-4.9 hours per day), and lighting indoors (4.5 hours per day). Households spent the least amount of time boiling water for bathing (0.49 hours), laundry (0.22 hours), and tea (0.05 hours).

To establish a baseline of activity that may be replaced if solar PV were to be introduced, these activities were then converted to their electricity-equivalents in Watt-hours (Wh), or the amount of electricity that would be consumed if the activity were to be performed using an electricity-powered appliance for a duration of time. The following wattages for common electrical appliances were used:

Appliance	Watts
Induction hotplate	2000
Small electric heater	500
12 V fridge	100
55 inch plasma TV*	370
55 inch LED TV*	80
32 inch LED TV*	41
20 inch LED TV*	24
Small desk fan	70
Laptop	45
Cable TV	20
Radio	10
Smart phone charger	5
3W LED lightbulb	3

*The size and type of TVs were sampled from 10/31 households who reported needing to power a TV, as the wattages can vastly vary based on TV characteristics. The percentages of households using each TV type and size was then applied to the rest of the households using TVs to approximate TV characteristics across the settlement.

Based on the average duration that residents spent on various activities, the activities that required the most energy were cooking on weekends and weekdays (3,365Wh and 3,071Wh, respectively), powering

***Table 1:** Emission factors by energy source*

Emission factor	Wood solid fuel stove	Gas stove	Paraffin liquid fuel stove	Electricity	Coal solid fuel stove
kgCO2eq/unit	0.044/kg	1.623/litre	2.578/litre	1.044/kWh	2.687/kg
tSO2/GJ	2.50E-05		2.86E-06		6.04E-04
tNH3/GJ	8.20E-06	2.00E-07	2.00E-07		8.00E-06
tNOx/GJ	6.00E-05	5.28E-05	4.74E-05		7.00E-05
tPM2.5/GJ	2.05E-04	3.00E-07	2.89E-05		2.66E-04
tPM BC/GJ	7.13E-05	2.00E-08	1.67E-05		4.61E-05
tVOC/GJ	2.40E-04	3.00E-06	3.01E-07		4.44E-04

Abbreviations: kg, kilograms; CO2eq, carbon dioxide equivalent; kWh, kilowatt-hour; t, tonnes; GJ, gigajoules; PM, particulate matter; BC, black carbon; VOC, volatile organic compounds
Note: Although it is acknowledged there are air pollution emissions from electricity through power plants connected to the grid, the scope of the study only considers locally-generated air pollution.

a fridge (2,400Wh), and heating (1,701Wh). This was followed by boiling water for bathing (972Wh), powering a TV (493Wh), and boiling water for laundry (448Wh). Activities that required the least Wh included boiling water for tea (78kWh), powering a radio (49Wh), charging cellphones (17Wh), and lighting, either indoors (19Wh) or outdoors (5Wh).

Baseline GHG and air pollution modelling
Baseline emissions were calculated based on household energy expenditure data by first taking the cost midpoint and estimating the number of units purchased. It was assumed that, based on 2024 firewood prices from the Joburg Firewood Company, wood costs 4 ZAR/kg. The cost of coal was taken from Index Mundi's coal export price for South Africa. The costs for the remaining energy sources were based on those reported in the C40 and Sticky Situations report (2024). The cost of paraffin was taken to be 25 ZAR/litre, electricity to be 1.38 ZAR/kWh, the cost of candles to be 5 ZAR/candle stick, and the cost of LPG to be 14.55 ZAR/L.

To estimate the amount of emissions released, these quantites were then multiplied by the corresponding emissions factor (**Table 1**) for GHG emissions sourced from the 2021 Johannesburg CIRIS inventory, and air pollution emissions for South Africa sourced from C40's Healthy and Efficient Retroffited Buildings (HERB) tool and the Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS) model. Values for candle emissions are taken from a study by Salthammer et al., 2021, for which it was assumed that most households were using unscented paraffin candles for lighting, as these are the most common candles sold globally. Imputed values for wood collection were calculated using the average emissions of households who reported their wood consumption, given that nearly half of households reported collecting their wood for free.

Changes to GHG and air pollution modelling
With the assumption that each household would receive 3kWh of electricity from the solar PV system per day, this would mean that in total, the settlement would receive 432,000 kWh per day. To assess which activities may be covered by this allocation of energy, for each activity performed, the total kWh-equivalent of energy was calculated by summing the Wh (watts of each activity if an electrical appliance were used) multiplied by the number of hours a household spent performing the activity. Once these totals were calculated for each activity, the sums were further divided by the number of households using a certain fuel type by activity, which was then scaled to the total amount of Wh across the settlement by activity as calculated in the first step. This is because some households reported more than one energy source per activity, but it is unknown how they distribute each energy source per activity by duration.

Once the total electricity-equivalent demand across the settlement by activity and fuel type was calculated for the baseline, a proportion was calculated over the total amount of fuel used as computed using the energy expenditure data (spend divided by price per unit of fuel). This proportion was then multiplied by the amount of emissions emitted and costs/fuel type, to arrive at the amount of emissions and potential costs saved associated with each fuel type and activity if they were completely replaced by solar PV.

Limitations
- Estimates for electricity consumption are underestimated as only 25% of households reported both electricity use and spending. Estimates for gas and paraffin are also underestimated, but less so, as 92% of those who reported using these sources also provided responses on the amount they spent on these energy sources.
- Estimates may be underreported due to self-report bias in participants misremembering the amount they spend per week. As energy usage and emissions are derived from the amount spent (taken as a mid-point between two values as represented by the questions in the survey), these values may not accurately or fully capture

the quantity of emissions released. In addition, wood emissions are also under-represented for this reason as many respondents reported spending 0 ZAR on wood as it is free to collect. As the survey question is categorical, with the upper limit being R300+, it is unknown what the highest amount that respondents spent. However, very few (<3-8%) of respondents reported spending greater than the maximum spend category for wood, gas, and paraffin. Although a few respondents reported using other energy sources such as coal and diesel, no cost data was available.

- However, one strong assumption that was taken is that there is the same amount of fuel being used for each activity (e.g., cooking and heating are the same) for each kWh being consumed, which may not be the case. Reliable efficiency data by types of heating or lighting appliances are not available, especially as it is not known what current technologies are being used at informal settlements. Thus, to not introduce an additional source of uncertainty and error, the assumption described above was made.
- Modelling was not performed for the business activities of the 6 households who reported owning a small business. This was because data was only available for the energy sources and overall energy spend, and no information was given about how the spending was allocated among the different sources or the duration for which each energy sources was used. As these activities were not accounted for, changes to emissions are likely to be underestimated.
- In addition, air pollution concentration and health modelling was also not conducted due to the lack of data to measure air pollution exposure at the household level. It is also worth noting that health symptoms are self-reported and a proxy for measure of disease prevalence.
- The scale-up scenario was based on data for 2023-2024, and thus may not include new settlements introduced since this period. It is also unknown which other settlements have received energy interventions (e.g., micro-grid infrastructure), which means results for the scale-up may be over-estimated. Structure counts were used as a proxy for the number of households and the amount of emissions avoided was based on those from the View and may thus be inaccurate. Values are likely to be underestimated, as modelling was not conducted for the 56 settlements where structure count data was unavailable.

Considering energy alternatives
Liquefied petroleum gas (LPG) is often used as a transitional energy source in areas where electricity supply is not reliable or stable. However, LPG is a relatively costly fuel that is less accessible for lower-income families, who would require continuous subsidization for LPG supplies. Moreover, LPG prices are influenced by volatile petroleum markets, making long-term affordability and reliability challenging for low-income users. There are also safety issues associated with LPG, as noted by the household survey, it can pose as a fire hazard. Improved biomass stoves, many of which use firewood as the primary fuel, are another alternative but frequently fail to reduce indoor air pollutant levels to WHO-recommended standards.

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