Investment Opportunities in Solar-Powered Lighting for Small Rural Shops in Zanzibar

Alexander Cheston
SIT Study Abroad

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Alexander Cheston

Advisor: Brenda Kazimili
AD: Helen Peeks
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Abstract

Small shop-owners in rural Zanzibar, Tanzania were surveyed on their shops lighting fixtures and requirements to determine whether using a solar home system to power the shops lights would be a profitable investment. The shops surveyed in 4 grid-connected rural villages in Zanzibar had very similar requirements, and a high-quality, affordable solar home system was designed to meet the requirements of the majority of these shops. Potential savings were calculated for each shop that replaced its current lighting fixture with a solar home system. 20% of the shops surveyed were found to potentially profit from investing in the solar home system, while 80% would lose money on the investment. However, the 20% that would profit from the investment represent an even larger demographic in Zanzibar than those surveyed: those who spend over 20,840/= per year lighting their shops, and who would benefit from an investment. The analysis was also found to be applicable to homes that use a solar home system to power their lights. This represents an enormous market opportunity for solar suppliers in Zanzibar. Recommendations were made for further studies addressing why diffusion of solar home systems in Zanzibar has been slow, despite its potential.

Introduction

The Future of Energy

The global community is presently facing an increasingly serious energy crisis. Current energy generation methods are causing climate change, and a growing population, with its growing demand for energy, will put additional stress on this problem. Because of this growing demand for energy, investments in new energy production will be in the tens of trillions (USD) over the next few decades (Seba 1281). Meanwhile, 1.6 billion people do not yet have access to electricity (Summary of Models for the Implementation of Solar Home Systems in Developing Countries 1). More than 70% of Sub-Saharan Africa, for instance, does not have access to electricity (Case Study Summary: Rural Energy Foundation (REF), Sub-Saharan Africa 1). The infrastructure to meet the growing demand for energy is still yet to be built. Whether this new energy will come from renewable sources or not is still to be seen. However, of all renewable energy technology, solar photovoltaic is the fastest growing in the world. Global annual production capacity has grown forty times over in the past decade alone (Review of Solar PV Market Development in East Africa 3). It is increasingly seen as a (if not *the*) solution to the world's growing demand for energy.

Solar photovoltaic is, without question, the best method of electrifying rural Africa. Tony Seba, an American solar entrepreneur, boasts about the benefits of solar: "Grid independence. Ruggedness. Scalability. Ability to work under any light condition... for the billions of people who aren't on the grid at all, solar PV may well be the only real choice for electricity at this point" (2142). Solar PV is, in most cases, independent of the main electrical grid. It is decentralized and distributed. This potential to bring modern energy to anyone, regardless of his or her remoteness, is unique to solar (Seba 2056). Additionally, the distributed nature of solar PV means that it requires local installation and maintenance, which creates local employment opportunities (Summary of Models for the Implementation of Solar Home Systems in Developing Countries 1). The scalability of solar PV can be attributed to its modularity. That is, a system can be built to meet the initial needs of the end-user, and then built larger to meet increasing demand or as money becomes available (Summary of Models for the Implementation of Solar Home Systems in Developing Countries 1). It can be as simple as adding more panels and batteries to the existing system. This characteristic makes it affordable to even some of the poorest demographics in rural Africa.

Despite its promise, the global solar PV market is not nearly as developed as it could be. In the U.S., subsidies for coal, oil and gas make solar more expensive, even though it would provide energy more cheaply if no energy was subsidized. However, this is soon to change. By 2020, unsubsidized solar will be cheaper than subsidized coal in the U.S. (Seba 1580). At this point, solar PV will reach grid parity, the point at which solar PV is equal in price to grid electricity (Seba 1973). This is sure to result in tremendous growth for the solar PV market. It is merely a matter of waiting for the price of grid electricity to rise and the price of solar to decline. Although it has yet to reach grid parity, solar PV still makes financial sense in many cases. The U.S. Air Force saves $1 million *every day* using its 72,000 solar panels at its Air Force base in Nevada. In most of rural Africa, reaching grid parity doesn't matter because there is no grid available. However, solar PV is still far cheaper than using kerosene to light homes (Seba 1753). As the technology becomes cheaper and more desirable, solar PV technology has the potential to be very lucrative for those who use or supply it.

The Tanzanian PV Market

Tanzania first became interested in solar photovoltaic in 1973 after the first oil crisis (Ondraczek 3). The country initially started using solar PV for the government-financed electrification of rural institutions like schools, churches and health centers. A consumer market began to emerge in the 1990s, mainly as a result of the expansion of the well-developed solar PV market in Kenya into Tanzania (Review of Solar PV Market Development in East Africa 8). Demand for solar home systems (SHS) was initially driven by the spread of broadcasting signals and the subsequent demand for TV and radio. Today, the primary needs from a solar home system are charging phones and powering lights (Ondraczek 3). Regardless of the consumer's needs, the Tanzanian solar photovoltaic market is encouraged by the abundance of available sunshine (Tanzania Power Report 10).

In spite of the lack of help from the government and national utility, TANESCO, the Tanzanian solar photovoltaic market is growing rapidly. The cumulative solar PV capacity increased 50 times over to 5MW between 2005 and 2012. The largest share of the market consists of off-grid solar home systems and over-the-counter, kit-type Pico systems, most of which come from low quality Chinese manufacturers (Target Market Study Tanzania 3). Tanzania's population is poor, meaning many homes cannot afford grid electricity, which is significantly higher than the African average (Tanzania Power Report 9). In many cases, PV is the only affordable way for Tanzanians to access electricity. PV solar home systems are purchased primarily by high-end consumers with higher income and education levels (Ikwaba 8). These are often wealthier farmers and urban-based consumers (Tanzania's Solar Home Systems Market 1). For the wealthier consumers, cost, energy independence, the capability to survive power cuts, and being environmentally friendly are all factors that contribute to the demand for solar PV (Tanzania's Solar Home Systems Market 3). It is also seen as a cheaper alternative to small back-up generators, which are becoming increasingly expensive to run as the price for oil rises (Tanzania's Solar Home Systems Market 2). For the poorer Tanzanian consumers, solar PV can be seen as a cheaper method of lighting, as opposed to kerosene, which is rapidly increasing in price (Browne 1). Depending on the size of the system, a $25-$250 solar system can typically be paid back over 1-3 years through savings in kerosene (Case Study Summary: Rural Energy Foundation (REF) 1). Not to mention, an LED light with a solar system is far brighter than a kerosene light, and does not cause dangerous indoor pollution (Seba 1753). Solar PV is increasingly seen as a good alternative to kerosene lighting for the average off-grid Tanzanian family, who spends 20% of income on fuel (Browne 1).

The Tanzanian government is beginning to follow in Kenya's footsteps regarding policy incentives to increase the use of solar PV. Kenya has a well-developed market for solar photovoltaic, and the government has some indirect policy measures to encourage the implementation of solar home systems. This includes exemptions from VAT (value-added tax) and no duties on imported PV products, which have been in place since 1986. Since the 1990s, Kenya's solar PV market has been driven mainly by the private sector (Review of Solar PV Market Development in East Africa 6). Tanzania, on the other hand, waited until 2005 to exempt solar home systems from VAT and reduce the import duties on solar PV products to 5% (Review of Solar PV Market Development in East Africa 8). Tanzania is still in the process of handing over the responsibility of diffusing solar photovoltaic to the private sector (Review of Solar PV Market Development in East Africa 3). More recently, the Tanzania Energy Development and Access Project (TEDAP), a World Bank-funded program implemented by Tanzania's Rural Energy Agency to promote SHS uptake in Tanzania, reduced consumer costs by providing a subsidy of $2/W per sold system for systems below 100W (for some suppliers). The total budget for this project was US $22.5 million (Review of Solar PV Market Development in East Africa 9). Despite these promising steps forward, the solar photovoltaic market in Tanzania still faces serious obstacles.

Obstacles in the Tanzanian solar PV market include high costs, poor local installation capacity, lack of maintenance and ultimate failure of the system, which makes people distrust the technology (Summary of Models for the Implementation of Solar Home Systems in Developing Countries 1). Many suppliers who install the systems are not qualified to install or repair the technology. In addition, Tanzanians often are not trained in simple maintenance like refilling batteries with water or dusting panels (Ikwaba 17). Many people also do not have knowledge of the product or market, and will purchase the cheapest option, which has led many suppliers to offer low quality, poorly functioning equipment (Solar Photovoltaic (PV) Clusters Project in Tanzania 2). In a Tanzanian study, 75% of solar home system owners report purchasing a given system because of its low price rather than its reputation (Ikwaba 8). In the same study, 88% of systems owned by rural off-grid SHS owners had low-quality amorphous panels that looked similar to those from well-known brands. These modules often fail early, and make people distrust solar technology (Ikwaba 10). Several established solar PV suppliers in Tanzania claim to have escaped the solar home system market because of the amount of competition and lack of margins in the sector (Target Market Study Tanzania 17). This intense competition for sales has led many dealers to make false claims about products, which mislead consumers (Tanzania's Solar Home Systems Market 2). The consumer PV market has been characterized by a "poorly developed and inconsistent offering across sales and installation" (Tanzania's Solar Home Systems Market 2). That is, the relationships between wholesalers and retailers are not well established, which leads to many mark-ups along the supply chain that ultimately reach the consumer (Tanzania's Solar Home Systems Market 1). Meanwhile, most problems with solar home systems are battery related. About 19% of rural, off-grid Tanzanians in a certain study did not have charge controllers, which had resulted in deep discharge in the batteries, which greatly decreases their lifespan (Ikwaba 10). Additionally, theft can be an issue in rural and urban areas. Some methods that have been used are special mounts that make the panels challenging to remove, as well as "basking," or taking the panel inside at night. Alarms are the best option, but they are expensive (Ikwaba 14). Some additional disadvantages noted by off-grid rural Tanzanians are how the system does not work during prolonged rainfall, and how the system shuts off unexpectedly because there is no meter that shows charge (Ikwaba 16). All of these problems contribute to a negative attitude toward solar electricity technology, which is sometimes seen as the greatest obstacle in the market (Ikwaba 3).

Despite its many barriers, the Tanzanian solar PV market shows promise in the coming years. The country's population and economy are growing, ensuring a steady increase in the demand for electricity (Tanzania Power Report 9). Tanzanian power consumption is expected to increase from 5TWh to 10TWh by 2023 (Tanzania Power Report 7). In 2013, the reputable US-based company SolarCity announced plans to invest US $7 million in off-grid solar power in Tanzania (Tanzania Power Report 8). Not to mention, grid parity is forecasted to come soon, especially when solar PV is compared to the cost of running off-grid diesel generators (Target Market Study Tanzania 35).

The Tanzanian Government and Solar PV

Tanzania's national utility, the Tanzania Electric Supply Company (TANESCO), which retains a "privileged and dominant position in the generation, transmission and distribution of electricity," will face problems as population and demand for energy in Tanzania rise (Tanzania Power Report 9). The national population is expected to grow from 50 million in 2014 to over 65 million in 2023 (Tanzania Power Report 24). To meet this growing demand for electricity, the Tanzanian government plans to double its energy production from 5TWh to 10TWh over the next 4 years (Tanzania Power Report 9). Meanwhile, the country relies on costly natural gas imports and unreliable hydropower, which have forced the country to repeatedly rely on expensive emergency power generation, usually during droughts (Tanzania Power Report 16). Tanzania is therefore attempting to diversify its energy supply by tapping into the country's large natural gas, coal, hydropower and renewables potential (Tanzania Power Report 17).

TANESCO's development of solar and other non-hydropower renewables is, unfortunately, very limited. The percentage of non-hydroelectric renewables as a percent of total electricity generation was only 0.002% in 2013 (Tanzania Power Report 13). Meanwhile, there are no signs that the government intends to include solar PV in the national energy mix in any way, and is focused exclusively on hydropower, gas and coal (Review of Solar PV Market Development in East Africa 10). Grid-tied PV, solar PV that contributes to the main grid's electricity, is out of the question for Tanzania, whose electricity prices are currently to low to encourage investment in grid-tied solar PV (Target Market Study Tanzania 3). This is mostly due to TANESCO's faulty electricity subsidies, which do not reflect the actual cost of electricity generation (Tanzania Power Report 51). As a result, the market for solar home systems is highly sensitive to TANESCO's electricity tariffs (Target Market Study Tanzania 3). The Tanzanian government's dedication to solar PV can be characterized by its national Solar Programme, "an open-ended attempt through broad partnerships and cooperation of governments and NGO organizations to promote the wider utilization of renewable energy sources" (Tanzania Power Report 23). Regardless of the future of this program, Tanzania's low electrification rates, rapidly increasing electricity costs and poor utility performance will continue to encourage the development of the off-grid solar PV market (Target Market Study Tanzania 4).

The Tanzanian Energy Infrastructure

The energy infrastructure in Tanzania suffers from low installed capacity, weak electrification rates, limited diversification and aging transmission infrastructure

(Tanzania Power Report 40). The World Bank rated the quality of electricity supply in Tanzania 1.9/7, taking into account that only 18% of the population has access to electricity (Tanzania Power Report 11). This is also a problem for Zanzibar Island, which receives 220kV high-voltage electricity from the mainland through a 41km submarine cable (Tanzania Power Report 27). The lack of adequate infrastructure is a primary barrier to social and economic development in Tanzania (Tanzania Power Report 41). Transmission losses, the electricity lost during its transport, in Tanzania are some of the highest in the world as a result of outdated systems and the distribution of generation centers (about half of non-hydroelectric power is generated in the southern part of Tanzania, while most of the energy is consumed in the northern part) (Tanzania Power Report 27). This poor infrastructure, as well as vulnerability to droughts and volatile gas imports, results in frequent power outages and overproduction (Tanzania Power Report 41). This poor infrastructure ultimately leads to high consumer costs, even though the quality of power delivered is low (Ondraczek 4). The state of the grid also poses problems for increasing electricity-generating capacity (Tanzania Power Report 9). This all contributes to demand for solar photovoltaic, which is independent of the grid.

Financing Solar Home Systems

There are 5 popular models for financing solar home systems to make them more accessible to the public. In the Cash Sales model, the consumer pays for the entire system upfront. While it is very common, it is also prone to the high initial cost barrier, and often results in the purchase of cheaper, low-quality systems (Summary of Models for the Implementation of Solar Home Systems in Developing Countries 3). Other problems with this model include a lack of control over how the systems are installed and maintained, and the lack of risks for the dealer or manufacturer beyond the warranty (Summary of Models for the Implementation of Solar Home Systems in Developing Countries 5). The Credit Sales model reduces the high initial cost barrier by allowing the consumer to pay in short installments, usually over 6-12 months. The Credit Sales model usually consists of a high down payment (often up to 50%), and high interest rates, which are often as high as 25% (Summary of Models for the Implementation of Solar Home Systems in Developing Countries 7). The Credit Sales model is widely understood because in most countries there is experience with consumer credit systems to buy luxury goods (Summary of Models for the Implementation of Solar Home Systems in Developing Countries 8). However, the model still excludes some of the poorest households because of the high down payment, and a credit record is often required (Summary of Models for the Implementation of Solar Home Systems in Developing Countries 9). The End-User Credit model is similar to the Credit Sales model, but the credit scheme is outsourced to a separate company that lends directly to the consumer (Summary of Models for the Implementation of Solar Home Systems in Developing Countries 11). The End-User Credit model often has smaller down payments and installments over a longer time period (Summary of Models for the Implementation of Solar Home Systems in Developing Countries 13). In the Lease/Hire Purchase model, the consumer pays a regular fee for a limited time, and receives ownership of the system at the end of this term (Summary of Models for the Implementation of Solar Home Systems in Developing Countries 15). This model usually encourages the purchase of higher quality systems (Summary of Models for the Implementation of Solar Home Systems in Developing

Countries 16). Finally, in the Fee for Service model, an energy service company maintains ownership of the system, pays for all operations and management, and charges a fee for energy use (Summary of Models for the Implementation of Solar Home Systems in Developing Countries 18). An advantage of the Fee for Service model is its centralized nature, which encourages the purchase of higher quality systems and allows for the proper recycling of old systems (Summary of Models for the Implementation of Solar Home Systems in Developing Countries 19).

Tanzania has a handful of financial projects aimed at increasing the diffusion of solar home systems and electrifying rural areas. One program is the Clusters Solar PV Project, which is funded by the World Bank. It organizes groups, or clusters, of at least 1000 people, usually farmers, who buy solar home systems at wholesale. Local and international SHS suppliers bid to become providers for the project, and technicians are trained in installation, which ensures good price and quality (Solar Photovoltaic (PV) Clusters Project in Tanzania 1). In the Clusters Project, consumers receive a 20% subsidy on their system, paying 20% upfront and 60% in installments. This provides solar home systems to thousands of homes that are the hardest to provide electricity for (Solar Photovoltaic (PV) Clusters Project in Tanzania 2). It also prevents Tanzanians from paying too much for systems, as suppliers often sell at up to 50% above wholesale prices to compensate for the low number of sales (Solar Photovoltaic (PV) Clusters Project in Tanzania 1). In addition to the Clusters Project, the UN led a program from 2004-2009 entitled Transformation of the Rural Photovoltaic Market in Tanzania, which focused on using the private sector to diffuse solar home systems throughout the country. The program included the training of private-sector suppliers in business and technical skills and the establishment of financing mechanisms to help consumers purchase solar home systems (Review of Solar PV Market Development in East Africa 9).

Solar Photovoltaic Technology: How it Works

Solar photovoltaic panels turn photons, light energy from sunlight, directly into electricity. The photons strike atoms in a conducting element like copper, causing the atoms to shed electrons. These high-energy electrons bump into adjacent atoms, resulting in a cascade of high-energy electrons, also known as electric current (Seba 1075). The cheapest type of solar panel is the amorphous solar panel. These are the least efficient, converting only 6-8% of available sunlight into electricity (Boxwell 2383). Polycrystalline solar panels are made from multiple wafers of silicon crystals, with efficiency levels of 13-18% (Boxwell 2413). However, they often cost 20-30% more than amorphous panels (Boxwell 2420). Monocrystalline panels, which are made from a single layer of silicon crystals, are the most efficient panels on the market today, with efficiency levels of 15-24% (Boxwell 2427). In addition to the solar panel, a home solar system must include batteries, a controller, and sometimes an inverter, which converts DC electricity (that the panel produces naturally) into AC current that can run traditional appliances. The controller uses the solar panel to charge the batteries, preventing them from overcharging or becoming totally drained (deep discharge). The controller also provides power to devices, using either the batteries or the panel as the source of electricity (Boxwell 1032).

Despite the incredible power of sunlight, only so much of that energy can be converted by a solar system into electricity, and the efficiency of the system is compromised by all of its components. To start, solar energy is a combination of the amount of sunlight that hits a certain spot and the strength of that sunlight. This varies a lot depending on the location, time of day, and time of year. This measurement of the strength of the sunlight is called the solar insolation, or solar irradiance, and can be used to calculate how much energy a given solar system can produce (Boxwell 1396). Most power is generated between 9am and 3pm, but this also varies depending on the location and time of year (Boxwell 2255). There are several other factors that affect the efficiency of a solar system. For instance, photovoltaic panels can generate up to 40% more power if they track the sun throughout the day and year (Seba 3841). Additionally, batteries, inverters and any other components in the circuit reduce the efficiency of the system (Boxwell 1314). So running components directly from the panel through DC supply, and in doing so bypassing the inverter, increases the efficiency of the system (Boxwell 1012). Shading of the solar panel is also problematic. Even if only 5% of a PV panel is in the shade, 50-80% of power production from the entire solar array can be lost (Boxwell 1786). Shading also results in incomplete battery charging, which results in premature battery failure (Ikwaba 12).

Determining the Profitability of Solar Home Systems in Zanzibar

It is clear that the market potential for off-grid solar home systems is huge. Experience in Kenya has shown that the private sector can make great advancements in diffusing solar technology, and in doing so electrify rural Africa sustainably. Despite its small size, Zanzibar Island might also present a decent market opportunity. It has a large population, exorbitant electricity prices, and many people do not have electricity at all.

For the rural poor, a solar home system has the potential to save money. This study aims to determine the savings that can be made by lighting a rural shop with a solar system instead of using grid electricity, and in doing so determine the market potential for rural Zanzibari shop-owners, which should be significant.

Study Area

Zanzibar is a Tanzanian archipelago located 40km off the coast of mainland Tanzania. It has above average electricity prices and receives unreliable electricity from its underperforming utility, ZECO (Tanzania Power Report 9). Four rural villages in Zanzibar were selected for this study because they satisfied the demographic requirements for this study, which were rural poor who use grid electricity. The four villages surveyed were Bumbwini, Mangapwani, and Zingwe-Zingwe (all in the top left square on the map below) and Kizimkazi (bottom left square). Interviews of solar suppliers were all conducted in Stone Town. As the main urban area in Zanzibar, Stone Town is home to the majority of the island's solar suppliers. Interviews with ZECO took place at its headquarters in Kinazini in the outskirts of Stone Town.

Methodology

A survey of small shops in 4 rural villages was conducted to determine how much shop-owners pay to light their shops, as well as the lighting requirements of the shops. This required identifying the number of lights in the shop, their wattages, the hours per day they are used, and how much the shop-owners pay for electricity each month. The survey also consisted of scoping the shop to determine its suitability for a solar home system. This involved approximating the area and height of the shop, as well as the width of the outdoor area, to determine its lighting requirements. It also involved examining the rooftop space for potential obstacles that could shade a rooftop solar system.

Once the shops lighting requirements and suitability for a solar home system was determined, a solar home system could be designed to meet the needs of the majority of the shops surveyed. Designing this home solar system for rural Zanzibari shops involved collecting price quotes from 5 solar suppliers in Stone Town. The designed system had to accommodate the lighting requirements of the standard rural shop using the cheapest good-quality components. After the system had been designed, and its price determined, an analysis of savings could be made for the shop that replaces its lighting fixtures with a solar home system.

The information collected in the survey can be used to determine the amount each shop pays for its lighting. For example, one shop in Mangapwani uses 2 17W fluorescent bulbs, one inside and one outside. The outside light is used for 12 hours each day, while the inside light is used for 3 hours each day. This information can be used to calculate the daily energy requirement for each bulb:

$$17\text{W} \times 12 \text{ hrs} = 204 \text{ Wh/day}$$

$$17\text{W} \times 3 \text{ hrs} = 51 \text{ Wh/day}$$

The daily requirement to light the entire shop is 204 + 51 = 255 Wh per day. However, we need the requirement in the more useful measurement of kWh per month:

$$\frac{255 \text{ Wh/day} \times 30}{1000} = 7.65 \text{ kWh/month}$$

It was also determined through the survey that this shop pays 100,000/= per month for electricity (for the shop and home), placing it in ZECO's Z1 tariff group. This means that the shop pays 222/= per unit, or kWh. From here, the price paid per month to light the shop can be calculated:

$$7.65 \text{ x } 222 = 1698.3/\text{= per month}$$

Using this base price, the monthly VAT (value-added tax), which is 18%, can be calculated:

$$1698.3 \text{ x } .18 = 305.694$$

Therefore, the final price that shows how much the shop pays for the two lights in its shop is the base price plus the VAT:

$$1698.3 + 305.694 = 2004/\text{= per month, or } 24{,}048/\text{= per year}$$

Now that the price paid per year to light the entire shop has been calculated, and the price of the solar system to replace the lights has been determined, the savings from making the switch can be calculated. If the solar system has a one-time cost of 390,741/=, and the shop currently pays 24,048/= per year, then the time it takes for the system to pay for itself can be easily calculated:

$$\frac{390{,}741}{24{,}048} = 16.25 \text{ years}$$

Once the system has paid for itself in savings, it begins to make profit. The profit that accumulates over the life of the system (18.75 years) can then be calculated:

$$(18.75 - 16.25)(24{,}048) = 60{,}158/\text{=}$$

Therefore, by the time the system expires, if all goes well, the shop-owner will have made 60,158/= in profit.

Results

The survey results show that the majority of the shops have similar, standardized lighting fixtures. The sizes of the shops were also similar, with the median shop area being 120ft, the median height 10ft, and the median width of the outdoor area 20ft. The median number of lights used in shops was two for all villages surveyed (one inside and one outside). They were almost exclusively fluorescent, of various brands and wattages, but some shop-owners still used incandescent bulbs. Most shops used their outdoor lights as security lights 11-13 hours each day, while most indoor lights were used 2-4 hours each day. Only 13% of households were in ZECO's Z1 tariff group, Zanzibar's most populous tariff group, while the rest were in Z0, the group that uses the least electricity (Osman 2014). Those in the Z0 tariff group use less than 51 units per month and pay 66/= per unit (kWh), while those in the Z1 tariff group use 51-1500 units per month pay 222/= per unit. The average amount of energy used per month to light each of the 30 shops was 11.4kWh. The price paid to light each shop with the potential savings from using a solar home system to light each shop can be seen in figure 1.

Price Paid/Year (TZS)	Payoff Period (Years)
82,423	4.7
42,279	9.2
29,158	13.4
24,048	16.2
22,633	17.3
22,429	17.4
19,993	19.5
19,009	20.6
15,701	24.9
15,476	25.2
13,794	28.3
11,103	35.2
11,046	35.4
9,981	39.1
9,589	40.8
8,579	45.5
7,850	50
7,233	54
6,729	58.1
6,280	62.2
5,327	73.4
3,813	102.8
3,589	108.9
3,364	116.1
2,804	139.4
1,682	232.3
505	774.3
378	1,032.30

Figure 1: Duration of payoff period for 30 shops

It can be seen that the more a shop pays for its lights, the more it can save by using this solar system to power those lights. With the selected system, which lasts 18.75 years, a shop would have to be paying at least 20,840/= annually to see returns on an investment in a solar home system. Only 6 of the 30 shops surveyed could profit from using a solar home system exclusively for the lights in their shop, while the remainder of the shops surveyed do not spend enough on lighting their shop to make the investment. The savings from switching to solar for the 6 high-paying shops can be seen in figure 2.

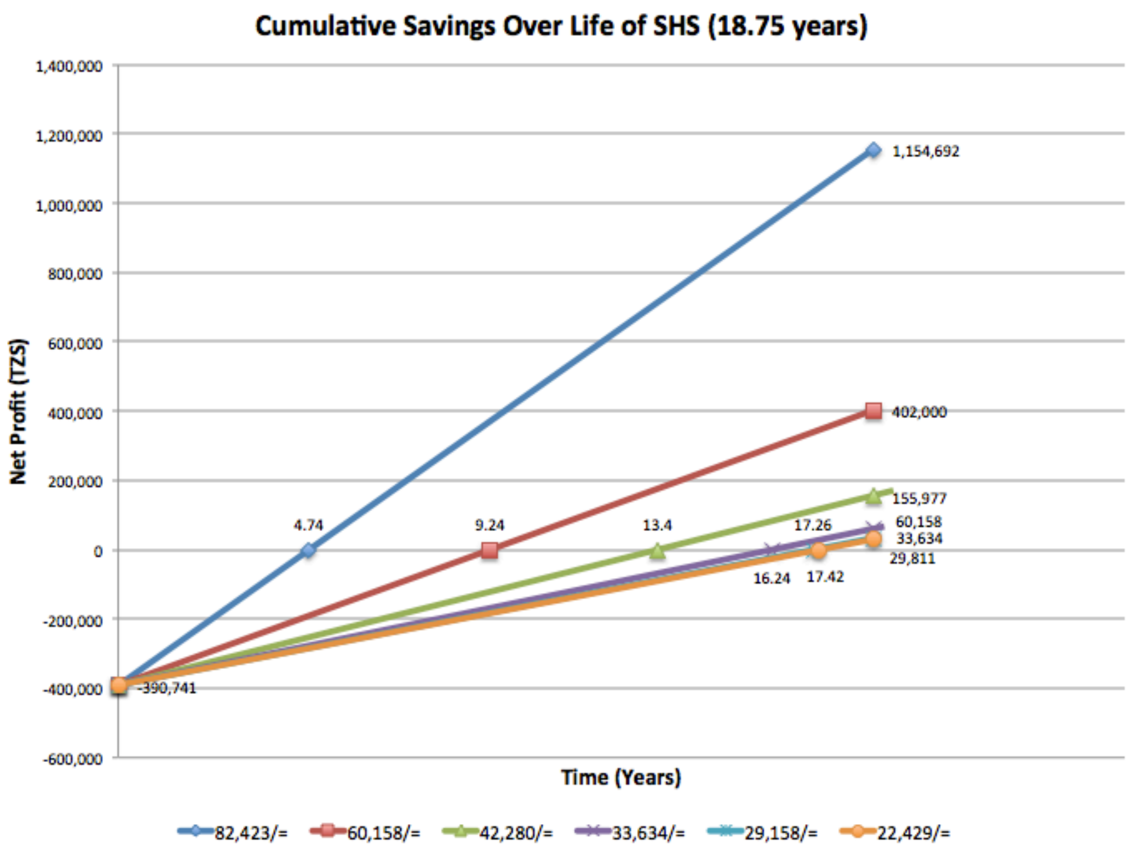


Figure 2: Cumulative savings for 6 shops

For each shop, the x-intercept is the time it takes for the solar system to pay for itself. Beyond that point, the shop receives free electricity, and profit accumulates. Out of all the shops surveyed, the shop that pays the most for its lighting pays 82,423/= per year. If this shop purchases the solar home system to power its lights, it would make more than 1mn TZS (US $689) by the time the system expires after 18.75 years.

Designing a Solar Home System

The first step in designing this solar system was determining the energy requirement for the shop's lighting.

Device	Voltage	Power (W)	Hours of use per day	Energy (Wh)
LED bulb (inside)	12V	7W	3	21
LED bulb (outside)	12V	7W	12	84
Energy requirement per day:				**105**

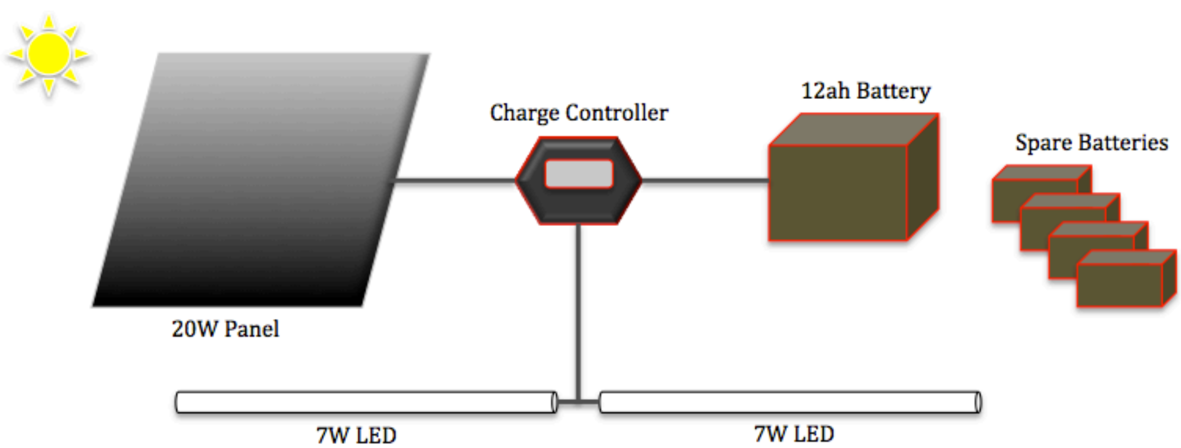
Using the value for Zanzibar's annual average solar irradiance, we can calculate the energy that the can be produced by a 20W panel.

Annual Average Solar Irradiance: 5.58 5.58 x 20W = 111.6 Wh/day

The median range for hours of use per day for indoor lights was 2-4 hours, while the same range for outdoor lights was 11-13 hours. A store that uses its indoor light for 3 hours and its outdoor light for 12 hours each day would have an energy requirement of 105 Wh/day. Based on the average annual solar irradiation in Zanzibar, the selected system would be able to power its devices with 111.6Wh/day. While this would not always accommodate the given lights for the required time, it would usually come close. Solar irradiance varies throughout the year, meaning that during the rainy months, the lights would not be able to be used for as long. Additionally, panels will most likely be fixed, rather than adjusted each month to track the sun's path. This would also result in less energy from the panels. The household would have to compensate by reducing the amount of hours that the lights are kept on.

Of the 5 solar suppliers in Stone Town, the one selected to supply parts for this system was chosen based both on price and quality. Girish Zalera can provide a 20W system, enough to power 2 7W LEDs, for 390,741/= (US $233). The system designed consists of a 20W polycrystalline panel, 5 12ah batteries (each of which lasts 3.5-4 years, and only one is used at a time), 2 7W LED bulbs and a charge controller. All components, with the exception of the batteries, last at least 20 years. If the system owner replaces the batteries 4 times, or every 3.75 years, the system will last a total of 18.75 years.

Item	Price
20W panel	$44
5 12ah batteries	$150
2 7W LED bulbs	$18
Charge controller	$30
Total	$233



Discussion

Because only 20% of the shops surveyed would actually profit from investing in a solar home system, it is clear that the majority of the demographic surveyed was too poor for the type of solar home system recommended in this study. The 20% surveyed that could invest in solar were those that paid the most to light their shops. The majority of the shops that would profit from such an investment were also those in ZECO's Z1 tariff group, which represents 80% of grid-connected homes in Zanzibar (Mzee 2014). This means that although the demographic surveyed was not right for the system recommended, there is likely an even larger demographic that would profit from investing in this system. While this is not great news for the majority of those surveyed, who do not spend enough on electricity to make the investment worthwhile, it is great news for the large majority of grid-connected families in Zanzibar, as well as the solar system dealers in Zanzibar. If around 80% of the island's population would benefit from investing in a solar home system, this has the potential to be an extremely lucrative market opportunity.

The shop-owners on the higher end of the demographic surveyed, those who spend more on lighting their shops, are evidence of the savings that can be generated for most Zanzibari shop-owners who invest in solar home systems. While those that spend just enough on electricity to make solar a viable alternative would only save tens of thousands of shillings over the entire lifetime of the system, those that spend far more (almost 100,000 per year) on electricity would save over 1 million shillings. For these shop-owners, an investment in a solar home system would be highly lucrative. Although this study initially intended to show that an investment in a solar home system would be beneficial for any shop-owner and solar supplier in Zanzibar, it has instead shown that, for the majority of the people surveyed, it would not make financial sense to use a solar system that is 20W or larger only to power lights in a shop. However, it has proven that those who spend more on electricity would certainly benefit from investing in solar for their shop.

While this solar home system is designed to be a profitable investment for the shop, a closer look at the survey shows that it could also be a good investment for the home. Only 4 out of the 30 shops surveyed were in ZECO's Z1, tariff group, while the rest were in its lower-spending, "lifeline," group. Of those 4 Z1 shops, 3 would profit from investing in a solar system for their shop, and 1 would not (although at 19,993/= per year it comes very close). While 3 of the shops that could save from switching to solar were in ZECO's higher spending demographic, the other 3 were not. This is because, while the shop-owners do not spend much on electricity, a larger portion of the electricity they buy is used to light their shops (rather than their house, which shares the electricity bill). Indeed, two of these Z0 shops used more than 2 fluorescent lights for a greater than average time period per day, and 1 used only two lights for a short amount of time, but they were of the far less efficient incandescent variety. This shows that, in determining the profitability of an investment in solar, the distinction between shop and home is insignificant. Shops were chosen for this survey rather than shops and homes because shop-owners are easier to interview. However, because in every case the shop and home share an electricity bill, the fact that the lights are used in the shop is insignificant. While the demand for lighting a home might differ slightly from that for a shop (in brightness and hours needed), it is very possible that the solar system designed would work just as well inside the home as it would in the shop, with some minor adjustments (for example, using 3 small LED bulbs instead of 2 big ones).

An enormous portion of the savings generated by the shops that would benefit from investing in solar comes simply from using an LED light bulb instead of fluorescent or incandescent. LEDs have long been known to be brighter, more reliable, faster to turn on, and cheaper in the long run than other types of bulbs (Zalera 2014). They are also far more efficient, converting more energy into light rather than wasted heat (Heck 154). This study does not evaluate the portion of the savings that can be attributed from simply switching to an LED bulb versus the portion of the savings generated from switching to a solar system altogether. However, this would be an interesting additional study. Regardless, any home or shop using a fluorescent or incandescent bulb would save money and energy by replacing it with an LED. However, like the solar home system, an LED is an investment, and consumers are often discouraged by its high cost (around $25) despite the savings it generates in the long run (Heck 158).

Although this study has shown that the purchase of the designed system would not be a worthwhile investment for the given demographic, it is possible that there are other systems that would be worthy investments to the light the shops for the demographic surveyed. For instance, there are many cheaper, smaller, kit-type systems that are sold over-the-counter and do not require installation (Mkubwa 2014). However, these Pico systems have a poor track record, and are notorious for failing prematurely because they are often low quality. In fact, any panel smaller than 20W is widely regarded as poor quality (Zalera 2014). Because of this bad reputation and the damage to the attitudes toward solar electricity that could result from a failed system, this study recommends using the smallest available good-quality system (20W). While it is very likely that good quality small systems exist, this is not examined here.

There are several sources of error that could have affected this study. For instance, the size of the shop (indoor area, height, and width of outdoor space), which was used to determine the lighting requirements, was approximated. Instead of measuring precisely, I "eyeballed" the size of the room. Additionally, many homes had electricity bills that varied from month to month. If they gave a range, the study used the middle of the range as the price paid for electricity per month. This could have resulted in inaccurate data on electricity use, and therefore an inaccurate calculation of savings.

Conclusion

This study has identified a large market opportunity for solar suppliers in Zanzibar. While the majority of the demographic surveyed may not be wealthy enough to make an investment in solar profitable, the upper end of the demographic surveyed is, and represents an even larger market for solar systems for the home and shop. Despite this proven profitability of investing in solar home systems for Zanzibari home and shop-owners, the diffusion of systems has been slow. While the prospective profit to be made is enticing, it is likely that there are more systemic reasons why solar home systems are not as ubiquitous as they should be. While this study does not seriously address the reasons for the lack of diffusion, it proves that it is not a result of their investment value.

Recommendations

Using the findings from this study, further studies could involve targeting the Z1 demographic more directly, which encompasses 80% of grid-connected homes in Zanzibar (Mzee 2014). The needs of this group could be evaluated and standardized so that several systems could be designed to meet the needs of many households. From there, the returns on the investment could be calculated. Another useful study would be an analysis of the energy and monetary savings that could be incurred by replacing incandescent and fluorescent bulbs with LEDs. Additionally, research on the market for Pico systems, as well as on their quality, would be beneficial. Further study could also focus on solving the problem of the lack of diffusion of solar home systems in Zanzibar, despite their potential profitability, through various disciplinary lenses:

The Technological Solution

There are several ways in which the diffusion of solar home systems could improve through technological advancements. Firstly, if the technology were to become cheaper, it would become more appealing to consumers, especially when it becomes so cheap that it reaches grid parity. Additionally, there are many problems with local installation and maintenance. If large solar home systems were designed so that they did not need to be installed and required very little or no maintenance, these would have higher success with the rural poor. There is also a current problem with the quality of Pico systems (smaller than 20W). If these become more durable and longer lasting, they too would have greater success in the market. Further study could aim to determine the solution that would most likely bring about a change in the market, and increase the number of solar home systems purchased in Zanzibar.

The Marketing Solution

Zanzibar's solar electricity market faces a serious marketing problem. Many of those who could benefit from an investment in a solar home system are weary because they have little money to pay upfront, live day-to-day, and do not have experience with investment. Despite the various financing schemes available, many rural Zanzibaris are reluctant to buy anything so expensive, regardless of how much they would profit in the long run (Zalera 2014). However, the first solar supplier in Zanzibar to successfully market to this demographic would be opening up a huge market opportunity. This marketing solution would most likely require education about the benefits of investment in general. Further studies could consider how to best address this marketing and awareness problem.

The Financial Solution

There are already a myriad of financial solutions for making solar home systems available to the rural poor in Tanzania. However, many families who could benefit from purchasing a solar system through one of the credit schemes examined here have yet to. Perhaps if the down payment was even smaller and installments spread out over an even longer period of time, they would become more appealing to the very poor. Further studies could analyze the market for long-term loans, to see if Zanzibaris would be interested in purchasing solar home systems through this type of credit scheme.

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Appendices

Survey Questions:

How many lights do you use inside and outside of your shop?

What is the wattage of each bulb?

When do you start and stop using each light each day?

How much do you pay for electricity per month for your home and shop?

List of Solar Suppliers Surveyed

Alsalman Shop

Girish Zalera

Kikwajuni Zanzibar Solar Shop

Naj Global Planning

ZASEA

Shop ID#	Device	Voltage	Power (W)	Hrs of use/day	Wh/day	Total Wh/day	kWh/month	Bill/month (=/)	Price/kWh	Base price	VAT	Price w/VAT	Price/year	Payoff (years) with 390741/= system	Total Savings
Mangapwani															
1	Powersaver fluorescent	240VAC	28W	4	112	224	6.72	5,000	66	443.52	79.8336	523.3536	6280.2432	62.217495	
	Powersaver fluorescent	240VAC	28W	4	112										
2	Oreva fluorescent	240VAC	17W	12	204	255	7.65	100,000	222	1698.3	305.694	2003.994	24047.928	16.2484269 *	2.50157311
	Oreva fluorescent	240VAC	17W	3	51										**60157.65**
3	Torch fluorescent	240VAC	40W	12	480	492	14.76	30,000	66	974.16	175.3488	1149.5088	13794.1056	28.3266644	
	Torch fluorescent	240VAC	40W	3	12										
4	Torch fluorescent	240VAC	40W	6	240	240	7.2	8,000	66	475.2	85.536	560.736	6728.832	58.069662	
5	Britania-Daylight striplight	240VAC	18W					50,000	66						
	Britania-Daylight striplight	240VAC	18W												
9	Incandescent	240VAC	40W	3	120	240	7.2	75,000	222	1598.4	287.712	1886.112	22633.344	17.2639536 *	1.48604643
	Incandescent	240VAC	40W	3	120										**33634.2**
10	Torch fluorescent	240VAC	40W	12	480	552	16.56	40,000	66	1092.96	196.7328	1289.6928	15476.3136	25.2476791	
	Torch fluorescent	240VAC	18W	4	72										
11	Oreva power saver fluoresc	240VAC	18W	12	216	356	10.68	25,000	66	704.88	126.8784	831.7584	9981.1008	39.1480868	
	Torch fluorescent	240VAC	40W	3.5	140										
12	Torch fluorescent	240VAC	18W	11	198	306	9.18	40,000	66	605.88	109.0584	714.9384	8579.2608	45.544833	
	Torch fluorescent	240VAC	18W	6	108										
13	Torch fluorescent	240VAC	18W	12	216	342	10.26	30,000	66	677.16	121.8888	799.0488	9588.5856	40.75064	
	Torch fluorescent	240VAC	18W	7	126										
Zingwe-Zingwe															
6	Torch fluorescent	240VAC	18W	11	198	258	7.74	10,000	66	510.84	91.9512	602.7912	7233.4944	54.0182902	
	CATA energy saving fluores	220VAC	20W	3	60										
7	Oreva power saver fluoresc	240VAC	8W	12	96	128	3.84	12,000	66	253.44	45.6192	299.0592	3588.7104	108.880616	
	Oreva power saver fluoresc	240VAC	8W	4	32										
8	Torch fluorescent	240VAC	18W	11.5	207	874	26.22	120,000	222	5820.84	1047.751	6868.5912	82423.0944	4.74067375 *	14.0093263
	Strip light fluorescent		18W	11.5	207										**1154692.02**
	Torch fluorescent	240VAC	40W	11.5	460										
Bumbwini															
16	Fluorescent	240VAC	18W	11	198	212	6.36	125,000		6.36	1.1448	7.5048	90.0576	4338.78984	
	Oreva fluorescent	240VAC	14W	1	14										
17	Torch fluorescent	240VAC	40W	12	480	560	16.8	20,000	66	1108.8	199.584	1308.384	15700.608	24.886998	
	Torch fluorescent	240VAC	40W	2	80										
18	Torch fluorescent	240VAC	40W	12	480	1040	31.2	10,000	66	2059.2	370.656	2429.856	29158.272	13.4006912 *	5.34930877
	Torch fluorescent	240VAC	40W	7	280										**155976.6**
	Torch fluorescent	240VAC	40W	7	280										
19	Torch fluorescent	240VAC	18W	13	234	394	11.82	20,000	66	780.12	140.4216	920.5416	11046.4992	35.372383	
	Fluorescent	240VAC	40W	4	160										
20	Oreva fluorescent	240VAC	14W	12	168	678	20.34	40,000	66	1342.44	241.6392	1584.0792	19008.9504	20.5556326	
	Crabtree fluorescent	240VAC	85W	6	510										
21	Incandescent	240VAC	40W	6	240	240	7.2	40,000	66	475.2	85.536	560.736	6728.832	58.069662	
Kizimkazi															
22	Torch fluorescent	240VAC	40W	13	520	1508	45.24	30,000	66	2985.84	537.4512	3523.2912	42279.4944	9.24185602 *	9.50814398
	Strip light fluorescent	240VAC	18W	13	234										**401999.52**
	Torch fluorescent	240VAC	40W	13	520										
	Torch fluorescent	240VAC	18W	13	234										
26	Oreva powersaver fluoresc	240VAC	8W	2	16	136	4.08	50,000	66	269.28	48.4704	317.7504	3813.0048	102.475874	
	Incandescent	240VAC	60W	2	120										
28	Fluorescent	240VAC	9W	1.5	13.5	13.5	0.405 ?		66	26.73	4.8114	31.5414	378.4968	1032.34955	
29	Fluorescent	240VAC	9W	2	18	18	0.54	50,000	66	35.64	6.4152	42.0552	504.6624	774.26216	
31	Palma fluorescent	220-240\	30W	2	60	60	1.8 ?		66	118.8	21.384	140.184	1682.208	232.278648	
32	Incandescent	220-240\	100W	1.5	150	190	5.7	2,000	66	376.2	67.716	443.916	5326.992	73.351152	
	Max CATA energy saving fl	220-240\	20W	2	40										
33	CATA fluoresecent	220-240\	20W	2	40	120	3.6	2,000	66	237.6	42.768	280.368	3364.416	116.139324	
	CATA fluoresecent	220-240\	20W	2	40										
	CATA fluoresecent	220-240\	20W	2	40										
34	Incandescent	220-240\	100W	4	400	800	24	40,000	66	1584	285.12	1869.12	22429.44	17.4208986 *	1.3291014
	Incandescent	220-240\	100W	4	400										**29811**
35	Incandescent	220-240\	40W	3	120	280	8.4	30,000	66	554.4	99.792	654.192	7850.304	49.773996	
	Torch fluorescent	240VAC	40W	4	160										
36	Incandescent	220-240\	100W	1	100	100	3	30,000	66	198	35.64	233.64	2803.68	139.367189	
40	Fluorescent	220-240\	18W	11	198	396	11.88	10,000	66	784.08	141.1344	925.2144	11102.5728	35.1937346	
	Fluorescent	220-240\	18W	11	198										

Raw Data and Savings Analysis

Shop ID#	Inside	Outside	Area	Height
1	10x8x10		80	10
2	10x10x10	20	100	10
3	10x12x12		120	12
4		20		
5	8x6x8	12	48	8
6	10x6x12	20	60	12
7	12x12x12	20	144	12
8	15x8x10	40	120	10
9	10x10x10	10	100	10
10	15x15x10	10	225	10
11	15x15x15	30	225	15
12	15x8x8	20	120	8
13	10x8x10	12	80	10
16	20x10x12	25	200	12
17	12x12x15	30	144	15
18	20x8x8	15	160	8
19	20x10x12	30	200	12
20	20x10x10	20	200	10
21	10x6x10		60	10
22	20x12x10	15	240	10
26	10x10x10	20	100	10
28	12x6x12		72	12
29	12x10x12		120	12
31	20x12x12		240	12
32	12x6x12		72	12
33	20x15x12		300	12
34	20x12x12		240	12
35	12x6x10		72	10
36	12x10x12		120	12
40	12x8x10	20	96	10
		Median Widt	Median Area	Median Height
		20	**120**	**10**

Raw Data and Lighting Requirements Analysis

ISP Review Sheet

1. Your topic - suitability, development, accessibility

Important research for Zanzibar - continued research as suggested in recommendations section would be very helpful. Also accessible.

2. Location of field study - where you conducted your field study, who helped set it up (who was helpful and who was not; include names, addresses, and phone numbers if possible), strengths and weaknesses of the site

Centered in Stone Town, Mangapwani and Kizimkazi. In Mangapwani, stayed at Creative Solutions. Girish Zalera in Stone Town, a local entrepreneur with experience with solar, was very helpful.

3. Nuts and bolts - where to get water & food, costs, where to stay, medical resources, other problems

Shemsha's in Lebanon for 10,000/= per night.

4. Other noteworthy comments

For future students interested in examining solar electricity in Zanzibar, I would suggest focusing on the Pico system market. These systems are easier to market to Zanzibaris (because they are cheaper) and there is a lot of room for improvement in the supply chain.

List your secondary sources and contacts, where they were found, and which were most helpful here:-

Salim Mchengo, ZECO
Girish Zalera, Stone Town