DRAFT REPORT ON THE DYNAMICS OF HOUSEHOLD APPLIANCES AND ENERGY CONSUMPTION AND USE

Household Socio Economic and Energy Use Baseline Survey, Bartica, Guyana

Prepared for Caribbean Community Climate Change Centre

The Consultancy Group Inc.

263 Earl’s Avenue, Subryanville

Georgetown

Guyana

+592-225 8771, -225 8773

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Acronyms

CFL	Compact fluorescent lamps
CRT	Cathode Ray Tube
CO_2	Carbon Dioxide
DHW	Domestic Hot Water
HVAC	Heating, Ventilation, Air Conditioning
kWh	Kilowatt Hour
LED	Light Emitting Diode
LHV	Lower Heating Value
LPG	Liquefied Petroleum Gas
OLED	Organic Light Emitting Diode

Image 1 Aerial View of Bartica

Limitations

The Consultancy Group Inc. (TCGI) has prepared this report for the sole use of the **Caribbean Community Climate Change Centre** ("Client") in accordance with the agreement under which our services were performed. No other warranty, expressed or implied, is made as to the professional advice included in this report or any other services provided by TCGI.

The conclusions and recommendations contained in this report are based upon information provided by others and upon the assumption that all relevant information has been provided by those parties from whom it has been requested and that such information is accurate.

The methodology adopted and the sources of information used by TCG in providing its services are outlined in this report. The work described in this report was undertaken in **July to August 2018** and is based on the conditions encountered and the information available during the said period of time. The scope of this report and the services are accordingly factually limited by these circumstances.

Where assessments of works or costs identified in this report are made, such assessments are based upon the information available at the time and where appropriate are subject to further investigations or information which may become available.

Project Overview

Objectives

The objectives of this report are:

- To understand the energy use by inspecting the building envelope and energy consuming equipment.
- To identify the areas where energy is being wasted through equipment and systems and to also identify the energy saving opportunities.
- To prioritize the actions through an action plan and schedule and provide recommendations with regards to reducing the energy consumption.
- To provide a financial report for costs and savings along with breakeven charts for every quantifiable recommendation.

Energy Audit Criteria

Data was collected by a survey of households and small businesses in Bartica conducted from July 16, 2018 to July 27, 2018. A total number of 361 surveys were completed with 339 being from households and 22 from small businesses.

It should be noted that actual electricity, gas and water bills of survey respondents were not requested.

Methodology

In order to determine energy consumption in the Bartica Township the methodology employed is comparison, where the data gathered on all appliances and energy consuming equipment is listed and their annual energy consumption is calculated. Once the energy saving opportunities are identified, their impact on the consumption is calculated and compared against the existing situation. This is specifically done by:

1. Establishing where energy is consumed/wasted within the buildings.
2. Establishing practical energy saving schemes and budget costs for implementation.
3. Identifying strategies for the lighting and power and circuitry system and put forward recommendations for review.
4. Identifying strategies for the heating, ventilation, air conditioning (HVAC) and domestic hot water (DHW) systems and put forward recommendations for review.
5. Identifying strategies for the building envelope and put forward recommendations for review.
6. Identifying strategies for the occupants' behaviour and habits and put forward recommendations for review.
7. Making recommendations and feasibility cases for energy saving strategies.
8. Advising on any energy/building compliance items that are applicable for the property.

Deliverables

Draft report prepared containing energy survey findings and costed recommendations, where feasible, for energy savings.

Energy Consumption Analysis

Electricity Consumption

For the purpose of this report the baseline energy use for the developments are calculated with methodologies based on the analysis of three sections:

1. Electric Appliances and machines in Bartica´s sample
2. Lighting used in every room.
3. Domestic hot water.

To determine the electrical consumption of the properties, calculations of Average Consumption were made using:

- The age, power and an approximate weekly usage of electrical appliances in the households
- Lighting: use of every lamp, type, number and power
- Any electrical consumption for heating, cooling or domestic hot water.

Energy consumption due to electric appliance and machines

The main source of electricity in Bartica is the Guyana Power and Light Inc. (GPL) grid as identified by approximately 96.17% of the households surveyed as the majority of the appliances except for stoves are electric.

Analysing the number of houses, each appliance, average of the units, power (mode) and daily use will allow us to determine the total cost of each energy unit kWh (day and night).

Appliance in the household	Total households with this appliance	Number (mode)	Power per unit (W)	Daily use per unit (h/day)	Energy per unit (KWh/day)
Air-conditioning unit	27	1	1500	5	7.5
Others	36	1	NA	0.5	NA
Ceiling Fan	38	1	80	7	0.56
Video game	46	1	200	1	0.2
Freezer	58	1	200	8	1.6
Water pump	71	1	750	0.2	0.15
Tablet devices	108	1	50	3	0.15
Computer or laptop	123	1	70	4	0.28
Stereo	165	1	50	5	0.25
Washing machine	189	1	1200*	0.57	0.23
Microwave oven	190	1	1000	0.3	0.3
Refrigerator	292	1	150	8	1.2
Portable Fan	294	1	40	7	0.28
Iron	312	1	1000	0.2	0.2
Television	322	1	150	6	0.9
Mobile phone	323	2	5	2	0.01

*Washing machine power: 1200W maximum with spin working. 400W average

Table 1: Electricity consumption in appliances

According to *Washing machine power: 1200W maximum with spin working. 400W average

Table 1: Electricity consumption in appliances

, the most typical **electrical** appliance in the dwellings studied is the mobile phone (323) followed by the television (322), iron (312), and refrigerator (292) and less frequent being the air conditioning unit (27).

Given its power and daily use, the most powerful appliance is the air conditioning, most of which are split units. Although the refrigerator and freezer are on for 24 hours, the compressor in these machines operates for only 8 hours a day.

Mobile phones operate at full power at an average of 2 hours per day. By contrast, this is the less powerful device and less energy consumption is required. For this reason, it is important to create a comparison between the most popular devices in our sample and the energy consumption for this appliance. (Figure 1)

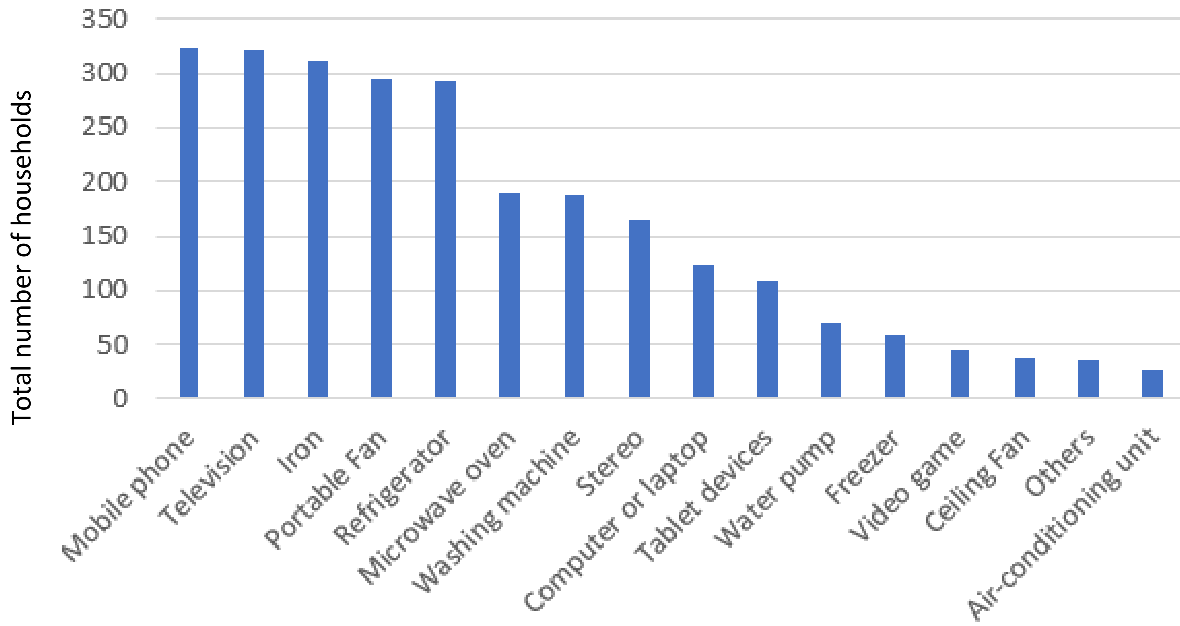

Figure 1: Number of houses owning each appliance

Energy consumption per day per appliance is represented in *Figure 2*. Televisions, refrigerators and air conditioning units are the appliances that consume the most energy and any modification in its use will result in the biggest energy savings in electricity.

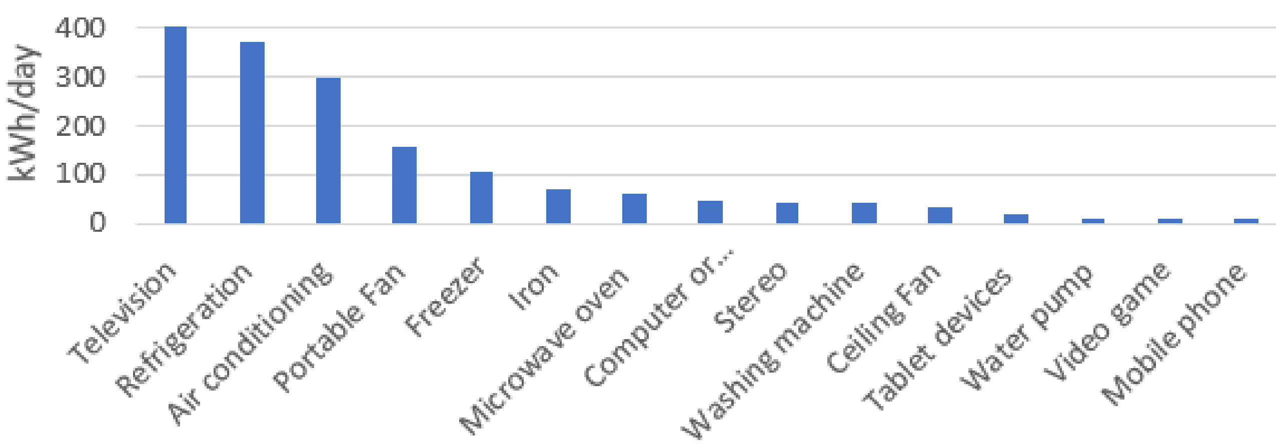

Figure 2: Energy Consumption per day of appliances

Mobile phones, video games, water pumps or even tablet devices are lower power i.e. they use a small amount of energy per day and any modification in use of these will not provide substantial energy savings.

Taking an example of a typical house from the survey as a case study where video games, air conditioning, water pump or freezer are not present, typical appliances (refrigerator, TV, microwave, fan, laptop, stereo, washing machine, iron and mobile) and the most popular kWh/day calculated (mode), the highest consumption is by the refrigerator (1.2kWh) and television (0.9kWh). (F*igure 3)*

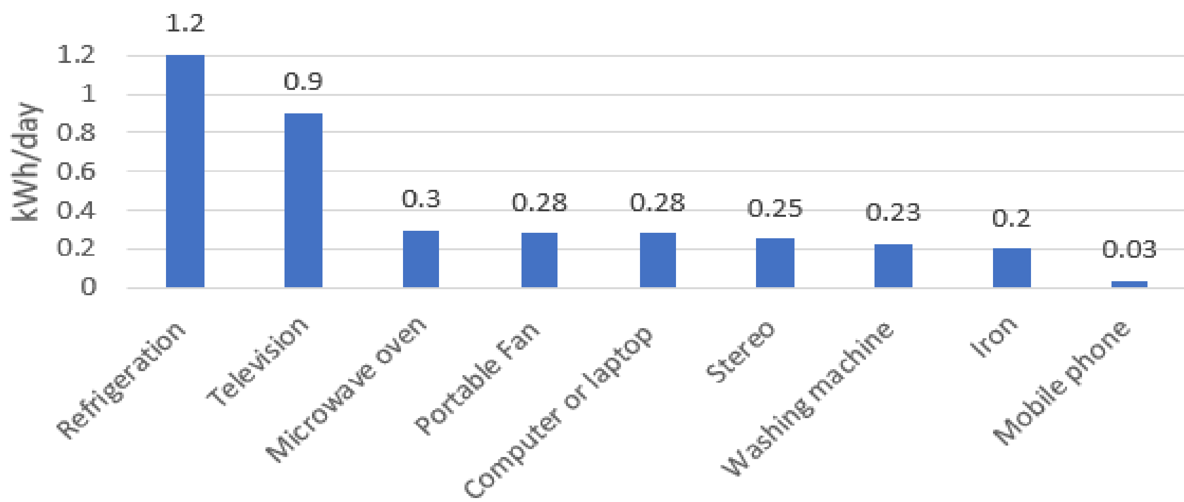

Figure 3: Energy consumption per day in typical Bartica households

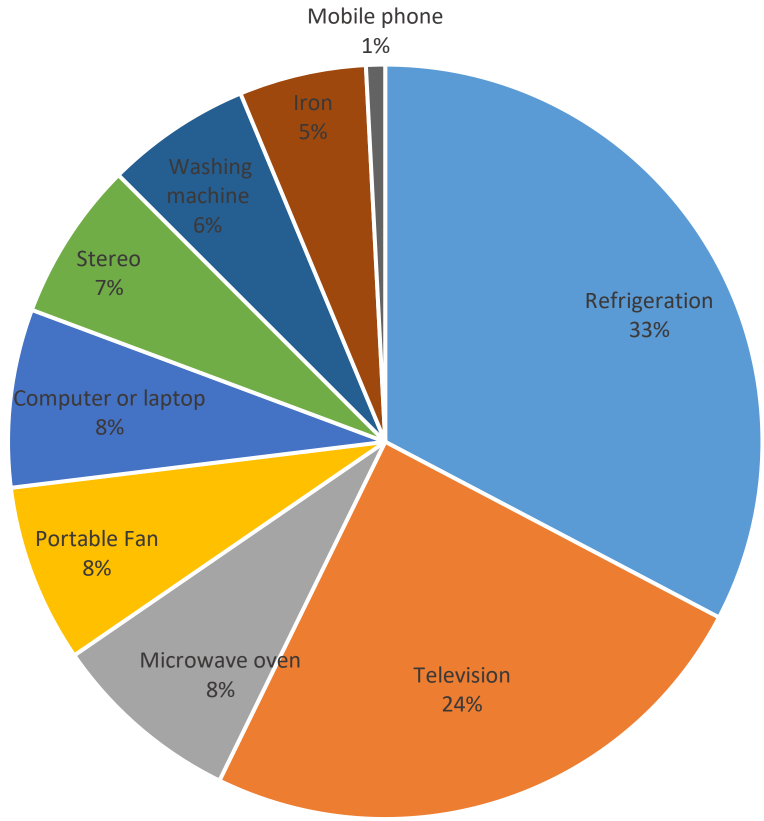

Figure 4: Percentage of Energy consumption per day in the most common Bartica´s households

The main consumers of energy in the Bartica households are refrigerators (33%) and televisions (24%), as illustrated in Figure 4.

- Refrigerators: Ratings for appliances that keep things cold work a little differently to other large domestic appliances. However, they are rated on how energy efficient they are in relation to their size, rather than their kWh consumption. This means the larger the fridge or freezer's internal volume, the more it will cost to operate.

- The television is possibly one of the most used electrical appliances in the home and one of the highest consumers apart from the refrigerator. Modern technologies such as LED (Light Emitting Diode) and OLED (Organic Light Emitting Diode) have brought television power usages down a fair margin, and long gone are the days of inefficient CRTs (Cathode Ray Tube) and plasma sets that could incur high electricity costs. CRT televisions are less efficient than plasma, LCD and LED televisions of similar size. For an accurate comparison, it is important to highlight that the size of CRTs usually are between 19-28” and Plasma average around 50-56” which means the size is more relevant than the type of devices in terms of electric consumption.

Table 2 below summarizes the most common power depending on the television screen size.

Type of television	Size (Inches)	Power (W)
CRT	29"	100
	19"	90
	14"	53
Plasma	50"	350
LCD	32"	156
	23"	50
	19"	30
LED	47"	80
	32"	60

Table 2: TV Power Examples by size

The most popular TV power in Bartica is up to 100 Watts with approximately 48% of television sets followed by 38% which are up to 200 Watts (Figure 5)

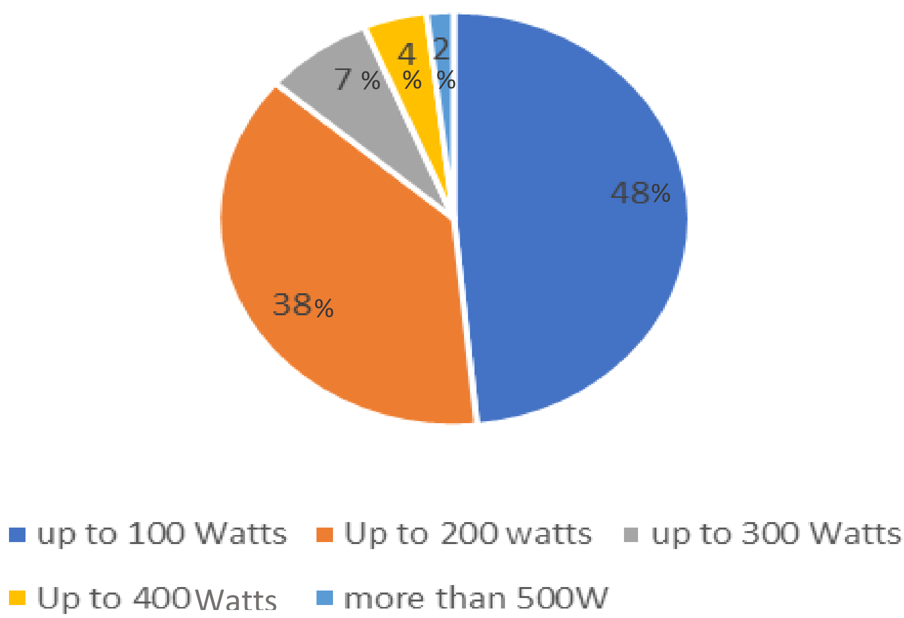

Figure 5: Percentage of Television Power in Bartica

Overall, the white goods and appliances in Bartica are fairly new and this is an important consideration for our assessment as more than 90% of the appliances are up to 10 years old which implies small losses in the efficiency of compressors or engines from the nominal energy performance values. Figure 6 summarizes the age of the most important technologies in terms of consumption. Other appliances, namely air conditioning, water pump and computers with 100% of the units below 10 years old are not included in the graph.

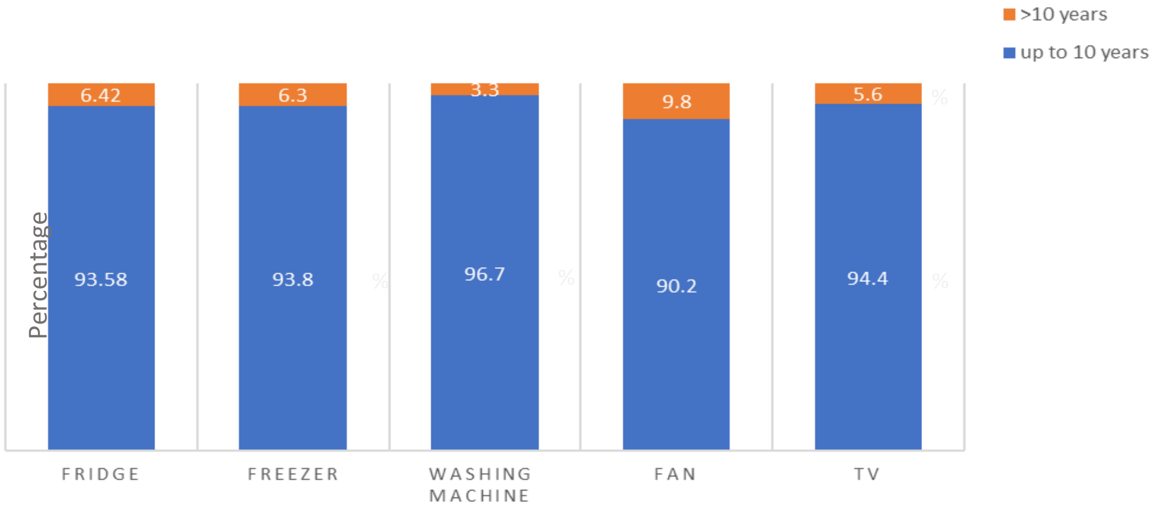

Figure 6: Age of electrical appliances

Table 3 demonstrates the common consumptions, with a majority of the households consuming between 3 and 5kWh per day. With all these figures assumed, the total average consumption of appliances and machines is approximately 4.98kWh/day.

kWh per day	Number of Houses per consumption (kWh/day)
Below 1kWh/day	5
Between 1-3kWh/day	82
Between 3-5kWh/day	157
Between 5-10kW/day	62
Between 10-20kWh/day	26
Between 20-50kWh/day	7
Above 50kWh/day	0
Total	339

Table 3: Number of houses -electric consumption by appliances

The Guyana Bureau of Statistics estimates the population of the Bartica township to be 8004 individuals distributed over 2219 households, assuming that 2000 households are grid connected and our sample of 339 dwellings has a total consumption of **1,688.6kWh/day** by appliances it is therefore possible to estimate a total consumption in Bartica at **9,962.2kWh/day** by white goods and other machines.

Energy consumption due to lighting

An average household dedicates approximately 5% of its energy budget to lighting. In order to ascertain energy consumption by lighting it is important identify the type of bulb, power and average hours of use daily. (*Table 4)*

Site	Type of luminaires	Number of lamps	Power per unit (W)	Daily use per unit (h/day)
Living room	**Incandescent**	**78**	**40**	**8**
	Fluorescent compact	287	40	6
	Halogen	4	30	7
	LED	47	20	3
	Fluorescent tubes	139	40	6
Kitchen	**Incandescent**	**68**	**40**	**10**
	Fluorescent compact	218	20	6
	LED	9	20	4
	Fluorescent tubes	76	20	3
Bedroom	**Incandescent**	**101**	**30**	**8**
	Fluorescent compact	431	20	5
	Halogen	1	15	5
	LED	39	15	1
	Fluorescent tubes	103	20	1
WC	**Incandescent**	**39**	**40**	**5**
	Fluorescent compact	127	20	1
	Halogen	1	15	4
	LED	9	20	4
	Fluorescent tubes	37	20	4
Garage	**Incandescent**	**2**	**100**	**12**
Hall	**Incandescent**	**4**	**45**	**3**
	Fluorescent compact	13	40	5
	Fluorescent tubes	5	20	5
Security	**Incandescent**	**94**	**60**	**12**
	Fluorescent compact	245	30	12
	Halogen	6	60	12
	LED	20	35	12
	Fluorescent tubes	129	90	12

Table 4: Lighting by rooms

In the Bartica Township approximately more than 50% of the total lamps are fluorescent compact, followed by fluorescent tubes (21%) and incandescent (17%), while LED and halogen are least popular. (Figure *7.)*

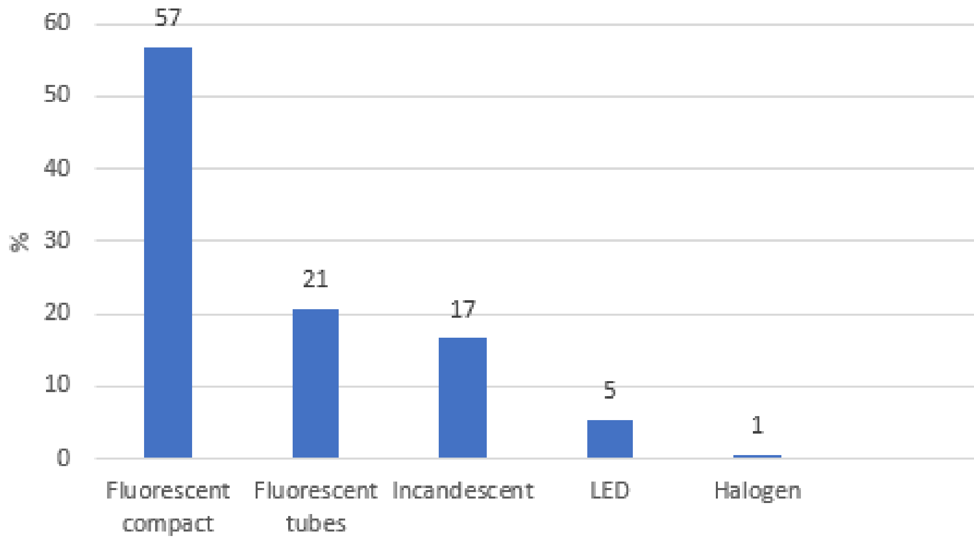

Figure 7: Common Type of Lamps

To assess the significance of lighting in the total energy consumption it is necessary to highlight the energy consumption due to lighting in a typical household in Bartica. For this calculation, the power and number of lamps as well as the type and working hours of the lamps are considered**.**

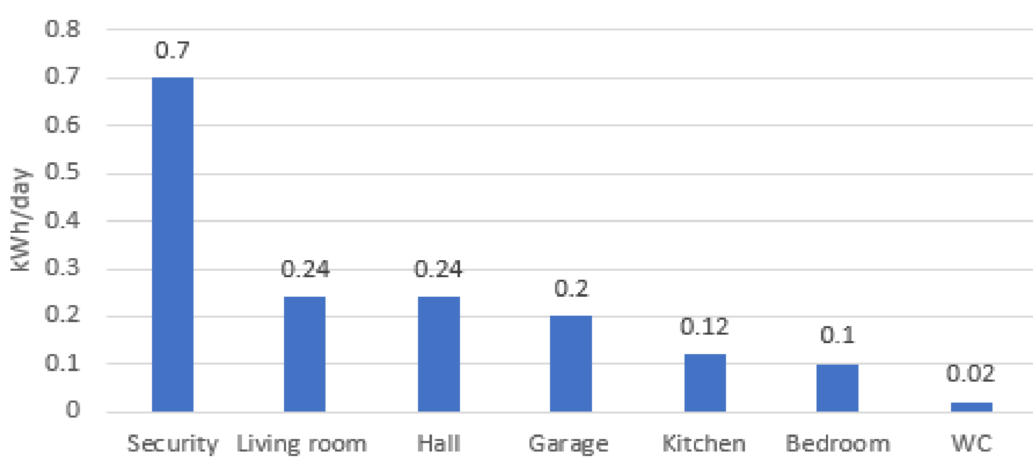

Figure 8: KWh /day per room in a typical house in Bartica

Figure 8 shows security lighting to be most demanding with high power in every luminaire and an average of 9-10 hours of use. The next popular areas are the living room and hall with a consumption of 0.24kWh, followed by the garage (0.2kWh), kitchen (0.12kWh), bedroom (0.1kWh) and finally toilet (0.02kWh).

With all these figures assumed, the total average consumption in lighting in the sample is **1.4kWh/day**.

The majority of households in Bartica consume below 1kWh per day due to lighting. (Table 5)

kWh per day	Number of Houses per consumption (kWh/day)
Below 1kWh/day	163
Between 1-2kW/day	107
Between 2-5kW/day	59
Between 5-12kW/day	10
Above 12kWh/day	0
Total	**339**

Table 5: Number of houses -electric consumption by appliances

With the population of the Bartica township estimated to be 8004 individuals distributed over 2219 households, assuming that 2000 households are grid connected, our sample of 339 dwellings have a total consumption of **447.7kWh/day** caused by lighting. Furthermore, it is possible to estimate a total consumption in Bartica of **2,800.6kWh/day** by lighting.

Energy consumption due to Domestic Hot Water

Bartica does not appear to have a demand for domestic hot water for personal hygiene, food preparation or drinking. Only 6 households have an instant water heater and, one household has an electric heater with deposit while 3 dwellings have solar thermal heaters.

- Instant Electric heater: The most typical system is the instant heater also known as tank less water heaters or demand-water heater, as it provides hot water only as it is needed. This kind of water heater heats water directly without the use of a storage tank. When a hot water tap is turned on, cold water travels through a pipe into the unit. In this case, an electric element heats the water. As a result, tank less water heaters deliver a constant supply of hot water and wait for a storage tank to fill up is not needed. However, an instant water heater's output limits the flow rate. The calculation for energy consumption based on this technology will assume a 200 W power and 0.1 working hours.

- Storage water heater: operates by releasing hot water from the top of the tank when the hot water tap is turned on. To replace that hot water, cold water enters the bottom of the tank, ensuring that the tank is always full. The storage water heater’s fuel source in this case is electricity. Since the water is constantly heated in the tank, energy can be wasted even when a hot water tap isn't running. For this reason, the calculation for energy consumption based on this technology will assume a 220W power, 20W more than an instant electric heater and 0.1 working hours.

Given these estimates and only 7 households utilising a DHW electric system the average currently is **0.77 kWh/day** and a **5.42kWh/day**. While it is not an important factor to be considered at this time, the prevalence of DWHs may see an increase in the future in parallel with the improvement of standard of living in Bartica.

Gas, diesel, LPG, kerosene and other fossil fuel consumption

The baseline energy use in Bartica using fossil fuel sources are LPG for cooking, diesel and gas for generators (mostly back up), kerosene and firewood for cooking. Approximately 94.6% of households indicate that LPG is used mainly for cooking on stoves and in ovens while a small percentage use kerosene (4.74%) and even less use electricity (0.3%) and firewood (0.3%) for cooking. (Table 6)

Fuel	Number of households	% Household
Electricity	1	0.3
LPG	319	94.6
Kerosene	16	4.74
Wood	1	0.3

Table 6: Main source of fuel for cooking in Bartica

An analysis of LPG given its lower heating value (LHV) and the annual consumption in 10, 20, 50 and 100 lbs cylinders for cooking indicate an average consumption in households of 1419 kWh per year (Table 7).

LPG	Average	Mode
Pounds/year	229	240
kWh/year	1419	1488
kWh /day	3.9	4.1

Table 7: Energy consumption during cooking in a typical dwelling

A total amount of 90 households have a fossil fuel generator, 85 of which are used as backup and 5 as a main source of electricity, giving a total of 26.5% of the total sample. The average power for the generator is 4377 Watts and the most frequent figure is 2000 Watts. The data collected for gas and diesel consumption gives an average estimation of 6.2 kWh/day as indicated in T*able 8*:

Diesel-Gas consumption	**Average**	**Mode**
Gallon /month	5.2	NA
kWh/day	6.2	1.27

Table 8: Energy consumption for the diesel and gas generator

Overall, the energy consumed by cooking devices and gas and diesel generators in the households is **707 kWh/day** for cooking and **319kWh/day** for generating electricity. This provides an estimation of 4,628kWh/day consumed in the 95% of the 2,219 households in Bartica and 2,088kWh/day consumed by fossil fuel generator present in the 25% of the households in Bartica.

Total Energy consumptions

From the figures it is evident that the electrical appliances (53%) and gas cooking (22%) are the highest energy consumers in Bartica. (*Table 9*)

Category	**kWh/day in a typical house**	**kWh/day in sample**	**%**
Appliances	4.98	1,688.6	53
Lighting	1.4	477.7	15
DHW	0.77	5.42	0
Gas and diesel generator	6.65	319	10
Gas cooking	7.68	707	22
TOTAL	**21.48**	**3197.7**	**100**

Table 9: Total Energy consumption

POTENTIAL SAVINGS

In this section several options and alternatives are presented and examined quantitatively. Correspondingly the potential savings for each option are identified and the costs for alterations and upgrades are provided, while the return on investment is calculated for quantitative options.

Savings on Electricity Consumption

Savings via a Lighting System Upgrade

Incandescent bulbs are the most inefficient of the luminaires as 90% of the energy is heat and only 10% light (Table 10). Although they cost much less than their energy-efficient alternatives -mainly CFLs (compact fluorescent lamps) and LEDs (light emitting diodes), there will ultimately be savings in energy consumption by replacing inefficient lamps for LED technology.

Type of Bulb	kW
Incandescent	60
Halogen	54
LED	7

Table 10: Power equivalence

Furthermore, with 17% of the total type of luminaires in Bartica being incandescent an upgrade to LED lamps can result in reduced carbon emissions. Considering an emission factor of 181 g CO_2/kW and the residential tariff of electricity in Guyana to be GYD43.43/kWh [1] *Table 11* shows total current and prospective consumptions by replacing luminaires.

Current scenario		**Proposed improvement**		**Difference**			
KWh/day	CO_2 **emissions (kg)**	**KWh/day**	CO_2 **emissions (kg)**	**KWh/day**	CO_2 **emissions (kg)**	**GYD/day**	**USD/day**
477.6	86	338.676	61	138.9	25	6,033.5	28.70
KWh/year	CO_2 **emissions (kg)**	**KWh/year**	CO_2 **emissions (kg)**	**KWh/year**	CO_2 **emissions (kg)**	**GYD/year**	**USD/year**
174,324	31,390	123,616.74	22,374.62994	**50,698**	**9,178**	2,202,216	10,486.74

Table 11: Potential kWh, CO_2 and energy bill savings by replacing incandescent bulbs

[1] http://www.gplinc.net/domestic/rates

The current situation in Bartica indicates an energy consumption of 447kWh/day or 174,324kWh/year, which has an environmental cost of 86 kg of CO_2 emitted daily or 31.5 tonnes of CO_2 annually. The proposed upgrade will achieve a total savings of **50,698kWh/year**, and a CO_2 reduction of **9,178 kg/year**. As it relates to the economic aspect, a total saving of approximately USD 10,500 can be achieved.

Additionally, Table 12 illustrates the number of hours of daily use for lamp with incandescent lamps functioning for longer periods in comparison to other lamps.

Site	Type of luminaires	Number lamps	Daily use per unit (h/day)
Living room	**Incandescent**	**78**	**8**
	Fluorescent compact	287	6
	Halogen	4	7
	LED	47	3
	Fluorescent tubes	130	6
Kitchen	**Incandescent**	**68**	**10**
	Fluorescent compact	218	6
	LED	9	4
	Fluorescent tubes	76	3
Bedroom	**Incandescent**	**101**	**8**
	Fluorescent compact	431	5
	Halogen	1	5
	LED	39	1
	Fluorescent tubes	103	1
WC	**Incandescent**	**39**	**5**
	Fluorescent compact	127	1
	Halogen	1	4
	LED	9	4
	Fluorescent tubes	37	4
Garage	**Incandescent**	**2**	**12**
HALL	**Incandescent**	**4**	**3**
	Fluorescent compact	13	5
	Fluorescent tubes	5	5
Security	**Incandescent**	**94**	**12**
	Fluorescent compact	245	12
	Halogen	6	12
	LED	20	12
	Fluorescent tubes	129	12

Table 12: Number of functioning hours of lamps

Best practices for lighting which can result in energy savings, would be to:

- turn off lighting when not in use
- use natural light when possible,
- use task lights
- turn off ceiling lights and use table lamps,
- Install track lighting and under-counter lights in work and hobby areas as well as in kitchens.

In addition to turning off lights manually, using passive infrared (PIR) sensors, timers, and other automatic lighting controls specifically for security lights or the garage should be considered. It will have a significant reduction in wasted lighting hours and a substantial decrease in the cost of running the security lighting

Calculations for lighting are assessed assuming the following working hours per day:

- Living room, Kitchen, bedroom: 4 hours
- WC, garage and hall: 2 hours
- Security: 4 working hours considering the installation of passive infrared sensor (PIR sensor)

Current scenario		**Proposed improvement**		**Difference**			
KWh/day	CO_2 **emissions (kg)**	**KWh/day**	CO_2 **emissions (kg)**	**KWh/day**	CO_2 **emissions (kg)**	**GYD/day**	**USD/day**
477.6	86	242.3	43.8	235.3	42	10,219	48
KWh/year	CO_2**emissions (kg)**	**KWh/year**	CO_2 **emissions (kg)**	**KWh/year**	CO_2**emissions (kg)**	**GYD/year**	**USD/year**
174,324	31,553	88,439.5	16,007	**85,885**	**15,330**	3,729,986	17,520

Table 13: Potential kWh, CO_2 and energy bill savings by reducing hours of luminaire use

Table 13 shows total current and prospective consumptions by reducing the hours of use in every luminaire. The current scenario in Bartica indicates energy consumption of 447kWh/day, 174,324kWh/year which has an environmental cost of 86 kg of CO_2 emitted every day or 31.5 tonne of CO_2 per year. The proposed upgrade will achieve a total saving of **85,885kWh/year**, and a CO_2 reduction of **15 tonnes/year** in Bartica and a savings of USD17, 520 in the electric bill due to reduced lighting use.

It is especially noteworthy that a reduction in the daily use of lighting can create a higher reduction in terms of energy used and money expended than a change in the type of lightings. While there can be a **29%** reduction in energy use and CO_2 emission by upgrading incandescent lamps to LED, a **49%** reduction in energy consumption and CO_2 emission can be realised by decreasing the number of hours lights are functioning.

Savings via Appliance Upgrade

As cited previously, more than 90% of the appliances in Bartica are less than 10 years old, which means upgrading to newer appliances is not an important consideration for our assessment. However, in the future switching older model televisions for LED televisions or purchasing a more energy efficient fridge will be a good practice for energy saving purposes. It is estimated a total saving of 40% for replacing a television of same size with LED technology.

Savings via DHW

As mentioned Bartica does not have a demand for domestic hot water for personal hygiene, food preparation or drinking with only a small percentage of households currently using DWH. However, an increase in demand for DWH in the future is assumed.

A solar thermal system will be a great solution in order to minimize the electric consumption. Solar systems can be used wherever moderately hot water is required. Off-the-shelf packages provide hot water to the bathroom and kitchen of a house; custom systems are designed for bigger loads, such as multi-unit apartments. The most common collector is called a flat-plate collector. Mounted on the roof, it consists of a thin, flat, rectangular box with a transparent cover that faces the sun. Small tubes run through the box and carry water– to be heated. The tubes are attached to an absorber plate, which is painted black to absorb the heat. As heat builds up in the collector, it heats the fluid passing through the tubes. Solar water heating can provide about a third of a typical dwelling or business hot water needs.

Technologies

There are two possible technologies recommended, Forced-circulation systems and Thermosiphon.

The most affordable system is the **thermosiphon**. For storing water overnight or on cloudy days, a storage tank is needed. A very simple way of doing this, is by making use of gravity as shown in *Figure 9*.

The principle of the thermosiphon system is that cold water has a higher specific density than warm water, and so being heavier will sink down. Therefore, the collector is always mounted below the water storage tank, so that cold water from the tank reaches the collector via a descending water pipe. If the collector heats up the water, the water rises again and reaches the tank through an ascending water pipe at the upper end of the collector. The cycle of tank–water pipe–collector ensures the water is heated up until it achieves an equilibrium temperature. The consumer can then make use of the hot water from the top of the tank, with any water used being replaced by cold water at the bottom. The collector then heats up the cold water again. Due to higher temperature differences at higher solar irradiances, warm water rises faster than it does at lower irradiances. Therefore, the circulation of water adapts itself almost perfectly to the level of solar irradiance.

Thermosiphon systems operate very economically as domestic water heating systems, and the principle is simple, needing neither a pump nor a control. However, thermosiphon systems are usually not suitable for large systems, that is, those with more than 10 m² of collector surface. Furthermore, it is difficult to place the tank above the collector in buildings with sloping roofs, and single-circuit thermosiphon systems are suitable for frost-free regions.

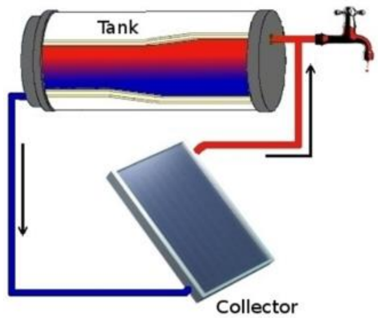

Figure 9: Thermosiphon system

Forced-circulation systems

In contrast to thermosiphon systems, an electrical pump can be used to move water through the solar cycle of a system by forced circulation. Collector and storage tanks can then be installed independently, and no height difference between tank and collector is necessary. *Figure 10* shows a system using forced circulation with a conventional boiler for back-up heating. Two temperature sensors monitor the temperatures in the solar collector and the storage tank. If the collector temperature is above the tank temperature by a certain amount, the control starts the pump, which moves the heat transfer fluid in the solar cycle; 'switch-on' temperature differences are normally between 5°C and 10°C. If the temperature difference decreases below a second threshold, the control switches off the pump again.

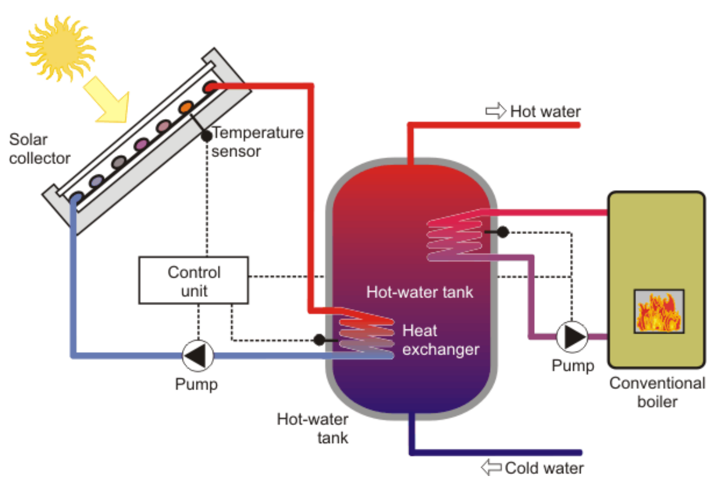

Figure 10 Solar thermal system

Maintenance SWH systems in general have a 5-10 year warranty and require little maintenance. A yearly check by the owner of the system and a more detailed maintenance check by an installer every 3-5 years should be adequate.

Savings on the Building Envelope

This section outlines energy efficient measures that can be implemented in order to minimise the building's energy demand in cooling and therefore reduce energy use and CO_2 emissions further than the baseline. While currently only 7.96% of households in Bartica have air conditioning (Figure 11) an increase is assumed in the future due to improvement in the standard of living.

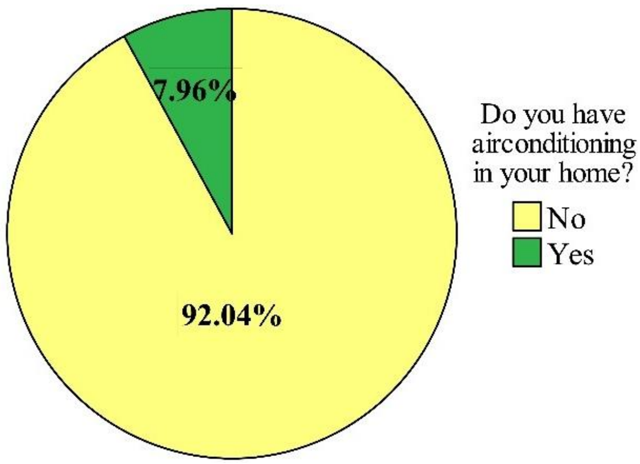

Figure 11: Air-conditioning in the Home

Solar shading is a spectrally-selective internal solar film with a high level of visible light transmission. It provides extraordinary solar energy rejection of Infra-Red Heat with higher visible light transmission than comparative neutral or reflective products. This allows for a luminous, interior with an improved colour rendition.

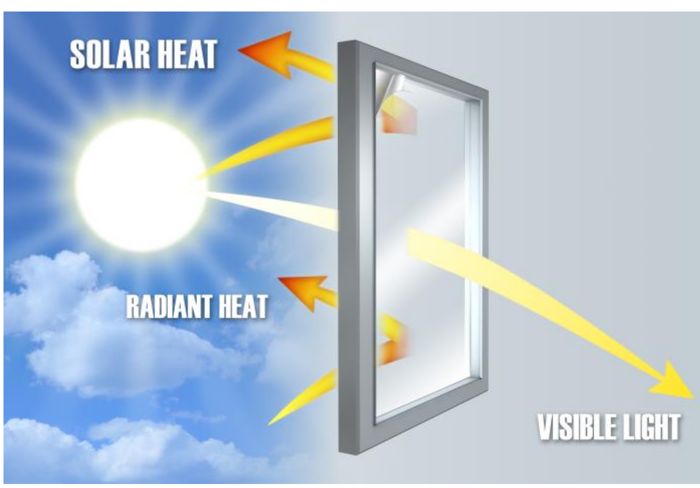

Figure 12: Heat gain is greatly reduced since the solar energy is being rejected

High Performance Insulation film lends itself to 'older glazing', where the insulation properties are poor. The film is virtually undetectable. **Error! Reference source not found.** indicates the technical specification of solar shading.

Performance Results	4mm Single Glazed	4mm Double Glazed
Summer Heat Gain Reduction	41%	31%
Visible Light Transmission	70% (90% w/o film)	62% (81% w/o film)
G Value	0.52	0.54
U Value	3.5 (5.8 w/o film)	2.1 (2.7 w/o film)
Light to Solar Heat Gain Factor	1.35	1.15
Ultra Violet Light Blocked	>99%	>99%
Manufacturers Limited Warranty	15 years	15 years

Table 14 Solar Shading - Technical Specification

Solar shading is a non-disruptive High Performance Insulation Film. The benefits of solar shading are as follows:

- Energy Savings from reduced air conditioning costs
- Up to 10 % savings on commercial building energy costs achievable
- Patent-pending, combined super-Low E (ε = 0,099) + solar control coating – directs solar and radiant heat back to its source for good energy savings; > 90 % reflection of radiant heat
- Suited to historic buildings where historic glazing must be retained, where appearance is important and also suited to historic buildings where improved energy efficiency of glazing is otherwise difficult or impossible to achieve
- Ultra-low iridescence (rainbow) makes it fully compatible with many types of lighting, including high efficiency lighting
- Glazing makes it safer if glass broken
- Improved aesthetics/cosmetics
- UV protection helps to reduce fading of textiles, furniture, and works of art
- Uniquely designed scratch resistant coating gives increased longevity & easy cleaning
- Interior installation
- Improved Comfort Levels for Occupants

The price for provision and installation of solar shading is approximately GYD 44,900 +VAT per square metre subject to size of windows.

Insulation Improvement

An improvement in the insulation of the building envelope will decrease energy consumption. This kind of measurement is more complex than a shading device as previously recommended

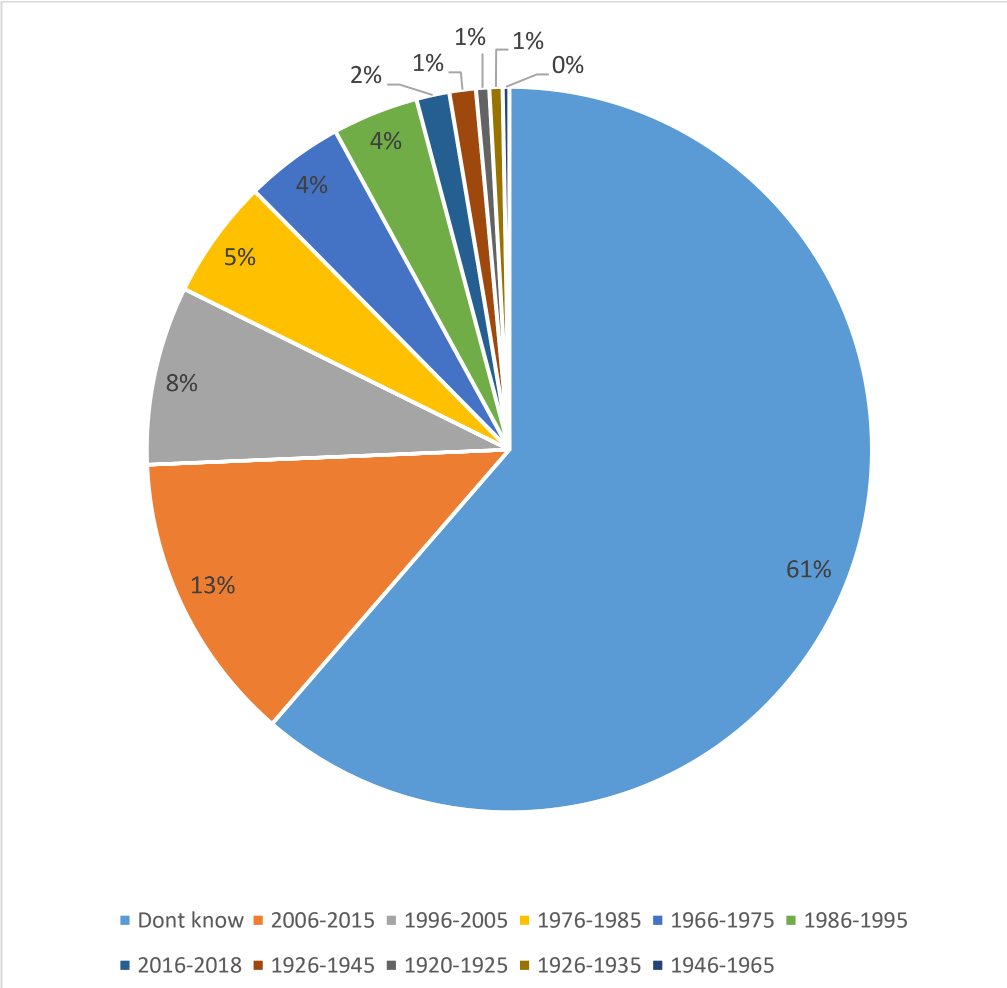

Figure 13: Year house was constructed

As Figure 13 illustrates the most typical year of construction is between 2006 -2015 (13%). For insulation calculation purposes an acceptable construction material is assumed and a poorly insulated two-storey house is compared with the same structure using three options for improvement of insulation:

1. a cavity wall
2. a cavity wall + reduced infiltration
3. improvement in the U values, infiltration and cavity wall

To further explain:

- **U-values** measure how effective a material is an insulator.
- A **cavity wall** is made up of two walls with a gap in between, known as the cavity; the outer leaf is usually made of brick, and the inner layer of brick or concrete block.

- **Air infiltration** is a type of ventilation (also referred to as leakage) where there is an uncontrolled and unintentional flow of fresh air through gaps and cracks in the building envelope.

Reducing U values, introducing a cavity wall and reducing air infiltration into a home will allow for more efficient use of the HVAC system, which may translate into energy savings if the strategy is properly implemented.

Baseline: The model will be a 2 storey house with the following area common to every household.

2 storey house		
Lenght (m)	15	
Width (m)	5	
Storey Height (m)	2.5	Each floor
Windows (%)	15%	respect the external wall area

A U value and temperatures are indicated in Table *15* below.

Element	U (W/m2·ºC)
Single Glazed window	**3.50**
External wall without insulation	**2.50**
Ground	**2.50**
Roof without insulation	**3.00**
	Tª for calculation
External	30
Interior	23
Soil	23
External Walls temperature	35
External Roof	40

Table 15: Temperature values for the average house

Total electrical demand for a poorly insulated house is calculated in the T*able 16* below.

Room	Element	Area (m2)	U(W/m2·ºC)	Tª exterior (ºC)	ΔT (ºC)	Qtr (W)	Ach	Total Area m2
Ground Floor	Windows	15	3.50	30.0	7.0	368	2.0	75
	External wall	85	2.50	35.0	12.0	2.550		
	Ground	75	2.50	23.0	0.0	0		
First Floor	Windows	15	3.50	30.0	7.0	368	2.0	75
	External wall	85	2.50	35.0	12.0	2.550		
	Roof	75	3.00	40.0	17.0	3.825		

Volume (m3)	Qtr total (local) (W)	Qv (W)	Qequipment (W)	Qpeople (W)	***Q totales (W)***
263	2.918	1.271	300	600	***5.088***
263	6.743	1.271	300	600	***8.913***
				TOTAL	*14.002*
				Total electrical demand (W)	***5.601***
				Total electrical demand (kWh/year)	***16.354***

Table 16: Energy demand for a poorly insulated house

A total electrical demand of **16,354kWh/year** is calculated with these assumptions.

Option 1: Ventilated cavity in wall and roof: As indicated in Table 17 U values are the same, and temperatures change due to the cavity.

Element	U (W/m2·ºC)
Single Glazed window	**3.50**
External wall without insulation	**2.50**
Ground	**2.50**
Roof without insulation	**3.00**
	Tª for calculation
External ambient temperature	30
Interior	23
Soil	23
External Walls temperature	30
External Roof	30

Table 17: Temperatures in a well ventilated house

Ventilated Cavity in wall and roof — Reduced temperature in the walls and roof

Room	Element	Area (m2)	U (W/m2·ºC)	Tª exterior (ºC)	ΔT (ºC)	Qtr (W)	Ach	Total Area m2
Ground Floor	Windows	15	3.50	30.0	7.0	368	2.0	75
	External wall	85	2.50	30.0	7.0	1.488		
	Ceiling	75	2.50	23.0	0.0	0		
First Floor	Windows	15	3.50	30.0	7.0	368	2.0	75
	External wall	85	2.50	30.0	7.0	1.488		
	Roof	75	3.00	30.0	7.0	1.575		

Volume (m3)	Qtr total (local) (W)	Qv (W)	Qequipment (W)	Qpeople (W)	***Q totales (W)***
263	1.855	1.271	300	600	***4.026***
263	3.430	1.271	300	600	***5.601***

TOTAL	***9.627***
Total electrical demand (W)	***3.851***
Total electrical demand (kWh/year)	***11.244***

Table 18: Energy demand in a well ventilated house

A total electrical demand of **11,244 kWh/year** is calculated with these assumptions (Table 18).

Option 2: Ventilated cavity in wall and roof + reduce infiltration

Vent Cavity + Reduce infiltration Reduced temperature in the walls and reduced infiltration

Room	Element	Area (m2)	K (W/m2·ºC)	Tª exterior (ºC)	ΔT (ºC)	Qtr (W)	Ach	Total Area m2
Ground Floor	Windows	15	3.50	30.0	7.0	368	1.0	75
	External wall	85	2.50	30.0	7.0	1.488		
	Ceiling	75	2.50	23.0	0.0	0		
First Floor	Windows	15	3.50	30.0	7.0	368	1.0	75
	External wall	85	2.50	30.0	7.0	1.488		
	Roof	75	3.00	30.0	7.0	1.575		

Volume (m3)	Qtr total (local) (W)	Qv (W)	Qequipment (W)	Qpeople (W)	***Q totales (W)***
263	1.855	635	300	600	***3.390***
263	3.430	635	300	600	***4.965***

TOTAL	*8.356*
Total electrical demand (W)	***3.342***
Total electrical demand (kWh/year)	***9.760***

Table 19: Energy demand of a well-insulated + reduced infiltration

A total electrical demand of **9,760 kWh/year** is calculated (Table 19) with these assumptions.

Option 3: Ventilated cavity in wall and roof + reduce infiltration

Element	K (W/m2·ºC)
Double window	**2.50**
External wall with insulation	**1.00**
Ground insulated	**2.50**
Roof with insulation	**0.50**
	Tª for calculation
External ambient temperature	30
Interior	23
Soil	23
External Walls temperature	30
External Roof	30

Table 20 Temperatures in a well ventilated house + reduced infiltration

Vent Cavity+Reduce infiltration+insultation Reduced temperature in the walls, reduced infiltration and improved insulation

Room	Element	Area (m2)	U (W/m2·ºC)	Tª exterior (ºC)	ΔT (ºC)	Qtr (W)	Ach	Total Area m2	Volume (m3)
Ground Floor	Windows	15	2.50	30.0	7.0	263	1.0	75	263
	External wall	85	1.00	30.0	7.0	595			
	Ceiling	75	2.50	23.0	0.0	0			
First Floor	Windows	15	2.50	30.0	7.0	263	1.0	75	263
	External wall	85	1.00	30.0	7.0	595			
	Roof	75	0.50	30.0	7.0	263			

Qtr total (local) (W)	Qv (W)	Qequipment (W)	Qpeople (W)	***Q totales (W)***
858	635	300	600	***2.393***
1.120	635	300	600	***2.655***

TOTAL	***5.048***
Total electrical demand (W)	***2.019***
Total electrical demand (kWh/year)	***5.897***

Table 21 Energy demand of a well-insulated house with proper insulation and reduced infiltration

A total electrical demand of **5,897 kWh/year** is calculated with these assumptions. (Table 21)

	Energy (kWh/year)	**% Energy savings**
Baseline	16.354	NA
Option 1	11.244	31%
Option 2	9.760	40%
Option 3	5.897	64%

Table 22 Comparison of energy savings

From the calculations approximately 64% of savings in electricity can be achieved by improving insulation, infiltration and adding a cavity wall, 40% by adding cavity wall and infiltration and approximately 31% by adding cavity wall. (Table 22)