Eco Campsite – Group 4

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# Introduction

The scenario chosen was to create a sustainable camp site. The campsite would have to be run entirely off grid while still being profitable enough to make it a reality. The problem of making the campsite entirely off grid is that often renewable energy is very unreliable; the amount of energy that can be generated is limited; and finally the initial investment is too high for it to be feasible. In this report through both existing methods and new solutions the problems at hand will be tackled with the final aim being a profitable business. The economic side will be discussed as well to present to the client the cost of starting up a sustainable camp site and the length of time it will take to pay back the initial investment.

In the campsite there are certain facilities which require energy, these being the resident’s house, electric hook up for the 12 caravans, a heated pool, a club house and a facilities block. These require electricity for an 8 month camping season between the beginning of March and the end of October.

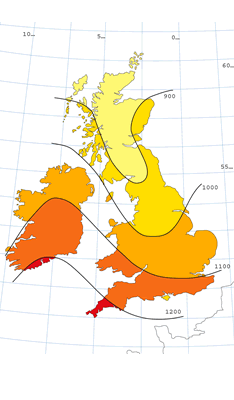


Figure - Solar Radiation in UK

# Location

The campsite is located in Cornwall; this is an ideal location as it has the highest solar radiation incident per unit area and is also located close to the coastline which means that the sea breeze can be taken advantage of in producing electricity using turbines. This is a location which is also attractive to campers, meaning that revenue will be higher as more people will require the campsite.

# Energy Requirements

## House

The resident’s house is a large source of energy consumption. Heating, lighting, hot water, and electricity are required all year round. The proposition for heating the house in the summer months is to use passive solar heating (Fosdick, 2012). This process uses heat from the sun to directly heat the house. For this to work house design is important; large windows are required facing south, whereas smaller windows are needed facing north (Fosdick, 2012). The sunlight enters through the south facing windows and heats the floor. For this design a dark surface floor is used to allow optimum heat absorption. This is usually stone floor slabs, as they have a high specific heat capacity and high density. An advantage to this is that it works in the summer and winter, and in the spring summer and autumn it can be used to heat the house on its own, meaning that the house has to be heated for approximately 4 months (Fosdick, 2012). In the scenario that it becomes too hot in the house an awning can be extended from the roof to block direct sunlight through the window. This can be achieved as shown in figure 2 (Fosdick, 2012). This design also means that during the night heat is still released into the house, as the high heat capacity of the floor means that it will remain warm, and then convection transfers the heat from the stone throughout the house. One example of this design working is shown in figure 3, large windows are facing south whereas small windows are facing north. During the months that the passive solar heating system cannot keep the house warm an electric boiler will be used, as no energy is required for the campsite during these months so more power can be used by the house, this will require around 17.5MWh of power assuming it is used 12 hours a day every day and is a 12W boiler.

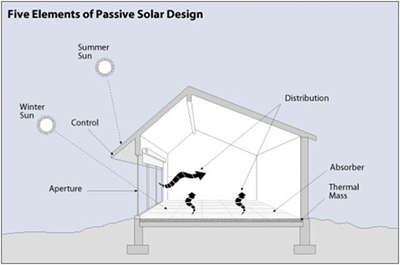


Figure 2 - Passive Solar Heating

Using this design for heating means that it is important that there is minimum heat loss through the roof and walls. To reduce the losses insulation can be implemented. This option is very economical and pays back for itself in only a couple of years. The installation cost of insulation in the roof is around £395 and in cavity walls is around £720 (Energy Saving Trust, 2014). Another design feature to reduce heat loss is draught proofing, this is important on doors and windows. Compression seals can be used on the frames of windows to stop any air getting through, and doors can be draught proofed by attaching a rubber stopper at the bottom (Thorpe, n.d.). Using all of these design features heat is kept in the house and therefore allows the passive solar heat to keep the house warm.



Figure 3- Example of Passive Solar Heating Design

In a house one of the most energy dependent rooms is the kitchen. Therefore energy saving design is particularly important in this room. An energy efficient cooker can be implemented; an A+ energy rated cooker will require around 40% less energy than a B rated cooker (Energy Saving Trust, 2014). If it is assumed that a B rating is average then it will require around 4000W (Frequency Cast, 2011). Therefore the A+ cooker will require 1314kWh per annum assuming it is used for 1.5 hours a day. Microwaves are fairly efficient for cooking food as they only heat up the food. A standard microwave is 800W, and so if it is used for 0.25 hours per day it will require 73kWh per annum. Also to decrease the energy required all dishes are hand cleaned so that a dishwasher is not required. An eco-kettle can also save energy, as it does not boil more water than is needed, and has much lower power requirement, at 2.2kW (Nigel's, 2015). If this is used for 0.25 hours per day then the total yearly power requirement is 200.75kWh per annum. The last main appliances in the kitchen are the fridge and freezer, which will require around 70W, therefore needing 25.6 kWh per annum (Frequency Cast, 2011).

Other miscellaneous power saving options are using laptops instead of desktops as these can use up to 85% less energy than a desktop (Energy Saving Trust, 2014). An average desktop requires 90W of power, therefore around 790kWh per annum, using a laptop can reduce this to 118kWh per annum (Frequency Cast, 2011). Also lighting is a large use of energy, LEDs are the most efficient lighting however are very expensive at around £4 each, however these can produce the same amount of light as a traditional lightbulb, while only requiring 4W (Energy Saving Trust, 2014), if there are 30 lightbulbs in the house this is 120W, say that lighting is not used during the day in the summer due to the windows in the passive solar design, then they are on for 4 hours a day for 6 months of the year, and on 16 hours a day in the winter months the total power requirement for lighting is 438 kWh per annum.

This means that the total power requirement for these appliances per year is about 2170kWh. However there will be other miscellaneous devices which require power in the house, although these are not as large and so it is assumed these will add another 1000kWh per annum to the energy requirements, making the total energy requirement of the house around 3200kWh per annum. Another consideration is the peak power requirement that the house will need. This will probably be during the evening when food is being cooked as the cooker requires the largest amount of power, at this time the peak power requirement will be around 10kW, however in the winter this could be as high at 22kW when the electric boiler is running.

The last consideration in the energy required in the house is hot water. The water will be heated by a solar thermal panel in the summer and by an electric boiler in the winter. In the house there is one bathroom with a shower. A shower requires 7.5kW, if used for 30 minutes a day the total power requirements will be 1,369 kWh per year, along with other uses for hot water it is assumed that the total power requirement for hot water will be 2000 kWh.

# Caravans

For the caravans we worked out our power requirements by resorting back to first principle electronics. For each caravan we assumed that they would only has a single main circuit, this will follow the UK standard of 13A. So using the equation below we worked out that each caravan requires a maximum of 2,990W giving us a total of 35,880W for all 12 caravans.

# Facilities block

The facilities block contains 20 cubical shower units, 10 sinks, and 5 washer dryers that would be placed in a utility room at the club house, and a large freezer. A 7.5kW shower, if used for about 30 minutes a day will require about 960kWh for the season, 20 of these showers will require about 19.2MWh of power for the season (Mira Showers, 2015). A sink will require about 0.677kWh per day, making the total requirement for all the sinks to be about 160kWh for the season (Energy Monitoring Company, 2008). Then the 5 washers and dryers require 0.62 kWh and 2.5kWh per load respectively. If they are used 20 times a day then the total seasonal energy requirement will be 14.976 MWh (Carbon Footprint, n.d.). Lastly a large freezer needs to be added, this will be similar to the one used in the club house and will require about 138kWh per season (Carbon Footprint, n.d.). The peak power requirement will probably be around 100kW at peak times, this could last for about an hour. The total initial cost for the building the facilities will be around £20,000, this will build the shower and sink facilities and install the washers and dryers.

# Swimming Pool

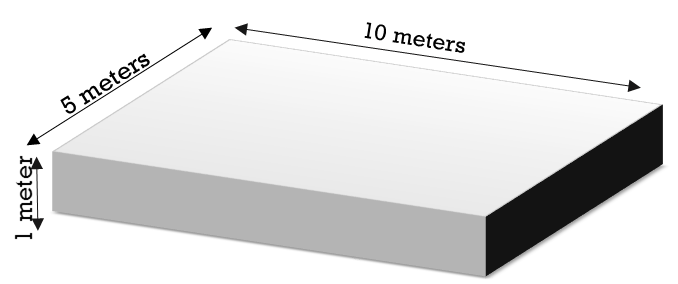
The pool we are going to have has a length of 10 meters and a width of 5 meters. The depth of pool will be 1 meter. Due to pool being a children’s pool there will be shallow areas for safety sake, this will not be taken into account in the calculation resulting in the energy needs being overestimated which is good as it allows a margin of error in our calculations. The volume of the pool with these dimensions is 50 m^3. The temperature in Cornwall on average in the summer months was set at 20 degrees Celsius with the required temperature for the pool being 25 degrees Celsius. Using calculations with these dimensions the energy needed to heat the pool is 1000 MJ (Engineering Toolbox, n.d.). This is a massive energy drain hence is important to use different methods to lower this energy usage. The first of which is air source heat pumping an inexpensive method of heat exchanging energy from the air straight into our pool. The result of air source heat pumping was that we could make savings around 50% (Azure Pools, n.d.), dropping the energy we need to supply to 500 MJ. The second important measure used is to place a transparent insulating material over the pool when not in use the result of this being a 5% decrease in the solar energy absorption but a massive decrease in the surface heat loss. Thirdly after the 5% decrease in solar energy absorption the efficiency of absorption is 80% (National Renewable Energy Laboratory, 2000) and since 100 W/m2 (MacKay, 2009) strikes each square meter of flat land the absorption we have is 4 kW. Over the heating period of 1 day the amount of solar energy that will be absorbed by the swimming pool is 260 MJ. The remaining 240 MJ or 70 kWh will be supplied by the combined energy input of the generation methods a week prior to the campsite opening. The large amount of energy needed means that it is much easier to sustain this temperature than it is to heat it again hence the air source heat pump will keep running throughout the entire time the campsite will be open. Wind breakers will be employed around the sides of the pool to further decrease the rate of evaporation. The running cost for the swimming pool is around £150 a year for the water treatment (Homebuilding & Renovating, 2007). The energy requirement for the season is around 46 MWh. This value is halved using the air source heat pump to 23 MWh. The price of the outdoor in-ground pool is around £20,000. The price of a top class air source heat pumping system around £10,000 (Wolseley, n.d.). The average power required for the pool is 4kW, this maintains the temperature of the pool, and this is using the air source heat pump.

Figure 4- Dimensions of Swimming Pool

# Club House

## The Restaurant

The kitchen area consumes around 2 and a half times more energy per square foot than any other commercial space and so it is crucial that, whilst energy cannot be produced from processes, energy is conserved and not wasted in preventable loss. The staff should also be trained in energy efficient ways of operating in the kitchen.

With regards to cooking, alternate methods can be used in order to reduce energy loss and possibly reuse/recycle energy that has passed through the appliance. The first method is using induction hob cooking as this method can be up to 50% more efficient than an electric hob because an induction hob applies the heat directly to the cooking appliances whereas electrical hobs have the heat source originate from somewhere else then to the hob, this results in more heat loss than in an induction heater. Induction hobs will also only turn on when the pan is in contact with the electro-magnetic field created by its electrical coil. Staff will also be trained to use the correct size pans when cooking, a lot energy is wasted in using pans smaller than the hob. Flat bottomed pans should be used to ensure maximum contact with the hob to reduce heat loss. It also prevents the hob heating the room up which reduces consumption of the extractor fans and air con. Whilst these induction hobs provide a high energy saving the cheapest induction stove is around $1300 (or £900). Due to this price, it will take 3 ¾ years to pay for itself. If you use all four burners for 4 hours a day on medium, seven days a week. (Green Hotelier, 2010)

Other methods of cooking include microwave ovens which can be 70 to 90% more efficient than a conventional oven and will not need to time to heat up / cool down which wastes heat. Grills can be designed to detect when food is placed underneath it and will heat up in seconds with infra-red elements maximising the heat applied to the food and not the surroundings.

With dish washing it is best to wash the pots by hand with low customer numbers however if a dishwasher is needed due to a large number of diners in the restaurant, the machine should incorporate a heat recovery condenser device to reuse waste hot water to heat the incoming supply of water.

According to EDF energy, 50% of the cost of a meal bought in a restaurant can be contributed to the cost of energy, 30% of this energy cost is taken up by kitchen ventilation alone so cutting energy bills in this area is also necessary for an eco-campsite. (Green Hotelier, 2010)

Variable speed drive ventilation (VSDV’s) is an efficient alternative as the output speed of the fans will match the requirements at different demands. This technology can be fitted to both the exhaust air and combustion air intakes. Combining this equipment and heat recovery ventilation systems recover the heat from the outgoing warm air using it to heat the incoming air or water supply via a heat exchanger. The variable speed drive cost will be around £25-50 and the ventilation unit will cost around £500. (Cater-kwik, n.d)

Regarding refrigeration, the most important thing would be to separate the freezers and refrigerators as far away from the ovens as possible to avoid the ovens from heating the freezers and vice versa. The freezers should also not be overfilled to allow sufficient airflow so the food freezes and the freezer is not overworked. Staff could be trained so they are aware of this. Alternatively alarms could be placed on the freezer doors so that the staff will know if they’ve left the door open. Correct maintenance of all equipment will ensure that door seals are air tight and all equipment is performing correctly. Routine checks should be carried out every month within the open season. For our refrigeration we will be using 3 fridges and two freezers

## The bar and games room

2 large TV’s would be used for watching as they use far less energy than a projector and are normally cheaper as well. A high energy rating TV will also waste less energy as heat when compared to a projector. The lighting will be provided by 4W LED bulbs like the kitchen. Each room will require 8 bulbs to sufficiently light the room. To ensure lights are not on when not needed, modern sensors, including PIR (passive infra-red), would be used to detect movement over a range of 12 metres and will switch only when someone is in the bar.

For heating of these rooms, heating the games room seemed unnecessary so only the bar was considered. Instead of conventional radiators, a new technology called ThermaSkirt could be incorporated which had a 50% higher heat transfer coefficient of 12.6 W/m² °C compared with the 8.4 W/m² °C of conventional panel radiators so a room would be heated more efficiently. However this technology is still in testing so these figures are not definitive and there are no available costs are available.

For entertainment in the games room there will be no powered games but instead games tables like pool/snooker tables, air hockey tables with a smooth laminate instead of an air pocket and pig pong tables so the energy requirements would be zero.

The following table lists all energy requirements:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Appliance | Appliance Power usage | Energy saving % | New feasible power usage | Seasonal power usage |
| Hobs | 1.00kW (per plate) | Up to 50% | 0.50kW (per plate) | 1920kWh |
| Oven | 3.00kW | Up to 50% | 1.50kW | 1440kWh |
| Grill | 1.54kW | Up to 79% | 0.32kW | 307.2kWh |
| Air con ( 1 ton) | 1.90kW | - | - | >1824kWh |
| Dishwasher | 1.21kW | Up to 20% | 0.97kW | 931.2kWh |
| Walk in fridge | 0.58kW | - | - | 3340kWh |
| Walk in freezer | 1.63kW | - | - | 9389kWh |
| ventillation | 20.7kW | Up to 80% | 4.6kW | 13.2 MWh |
|  |  |  |  |  |
| TV | 93 W (50 inch)  186W (for 2 TV’s) | - | - | 535kWh |
| Lights | 4W  (8 per room)  96W (3 rooms) | - | - | >275kWh |
| total |  |  | 11.869kW | 33.3 MWh |

The total value listed under the appliance power usage column is the peak demand as all values have been taken as an upper estimate. The total estimated cost for this build will be around £100,000, this builds the club house and installs all of the appliances.

# Energy Production

In the end we chose to generate all of our electricity power through a combination of solar and wind power by using a ‘SMA off grid system’ this is a product that will both generate and store electricity. We are also using solar thermal panels to heat most of the water required for the pool and the showers and then using electricity to heat them further when the panels can’t achieve the desired temperature. Solar thermal panels are affected by several factors and so are very unreliable, they are also not compatible with electric showers, and so their usefulness will be limited, therefore the main source of energy production will be an SMA system. Each SMA system produces 12kW of power so we are proposing having up to 10 of them to feed our campsite. With all 10 running at full power we will produce 120kW (Solar Energy Experts, 2015)and will take up 700m2 of space on top of our fixed buildings and on the ground around the campsite. This would be the area taken up by the panels and the turbines, however this does not take into consideration the distance between each system, however; this is not a huge concern as 12 acres is almost 50,000m2. To maintain the entire combined systems it will cost roughly £10,000 a year and will cost £45,000 for one so will be a total of £450,000 for the total system. These systems can surge up to 22kW however this is not expected as it shortens the life of the system and increases maintenance costs so we are trying to limit this by using the stored power to help supply the required power during the peak times. The peak power requirements will be around 150kW, however at during the rest of the day there will be excess power which can be stored. In addition to the SMA system we are going to install a generator which will serve as an emergency source of power in case something fails on our SMA systems. The generator will cost £5,644 and can produce 28kW of power at peak; the maintenance of the generator will be roughly £250 for an annual service. (Generator Warehouse, 2015) However to run this is very expensive, and is avoided where possible, the total cost per hour is about £10 (Anon., 2015).

However we did not start of using solar and wind power to power the campsite. One of our initial ideas was to use nuclear technology to power the site. To run the campsite on nuclear power we would have required a small scale reactor, this is available as they are designed for use in submarines and other maritime applications which can produce around 70MW in the case of the Trafalgar class submarine. This option was quickly ruled out due to legal and potential ethical issues with having a nuclear reactor so close to humans. This is where we decided to move towards more conventional methods of generation such as an anaerobic digester. The sources we found suggested that we could produce up to 300MW depending on what was fed into the digester and in what quantise, with slurry and food waste we could produce 30MW however this came at a cost of £750,000 which was deemed too great for a small business. For this reason we eventually ended up at solar and wind power for our campsite, although this did mean that we then had to store energy as we were relying on natural factors which varied with time and season.

# Energy Storage

Due to the sporadic nature of the power generation we will have to work out methods of storing the energy. The SMA system come preinstalled with a lead acid battery system which can store up to 120kWh of power. These lead acid batteries should be deep cycle batteries, this means that they can be charged and discharged thousands of times without effecting the performance of the battery. The most efficient method of charging deep cycle lead acid batteries are 98% efficient, so we are assuming that ours will be somewhere around 80% efficient.

However like the energy generation we didn’t arrive at batteries straight away. Our first idea for storing energy was too use molten salt to store heat energy which we will then convert into electrical energy when needed. This initial idea came from the molten salt power stations in southern Europe and Africa, however instead of using mirrors and the power for the sun to heat the salt we would use electric heaters to melt the salt where we would store it in its liquid form and use it to super heat water to produce steam which would run a turbine. One of the main advantages of doing this is that we would have an abundance of ‘waste’ steam which we could use to satisfy all the heating needs of the campsite. On the other hand the salt melts around 500oCand has an operating temperature of 1050oC. With a running temperature of 1050oC we decided that molten salt was not a viable source of storing energy, this is when we looked into using water as a form of storage.

To use water as a form of energy storage is not a new idea, in fact it’s being done on an industrial scale in Wales. For our application we decided to use a bucket of water suspended in a tower which is being hoisted by a DC motor/dynamo, we decided to take this approach rather than having a conventional dual reservoir where you pump water to a top of the hill and then running it down a hill at an angle. The advantage to our approach is that we aren’t using a slope so we don’t waste energy moving a mass up an incline. The mass will be suspended at a height of 10 metres above the ground, we settled on this height as having a large mass of around 3000Kg will create quite a large amount of wind resistance which could be dangerous in heavy winds. We decided to use a mass of 3000Kg as we intend to use water, as it’s cheap and readily available, so finding a container much bigger could be difficult and costly. The motor we are intend to use is a 1.5 tonne DC motor which can also operate as a dynamo, the motor will be coupled with a 3:1 block which should reduce the stress on the motor. Our reasons for choosing this in addition of our battery storage is for long term storage of power as once you have winched the mass to the maximum height you can apply a simple break or ratchet mechanism to hold the it in place and no energy will be lost over time. The reason that we are using the battery storage as the main reserve and the water tower as a reserve system is that the water tower can only store 4kWh at maximum height which is a fraction of the battery storage. Although as far as efficiencies go the motor/inductor has an efficiency around 60% and I estimate a loss of around 5% on the windings and gearing mechanism, giving an efficiency of 55%. With an efficiency of 55% it will require 7.27kW to hoist the mass to the top of the tower, this is not as high as an efficiency as the batteries however the advantage of this is that you can store the energy long term with our any losses.

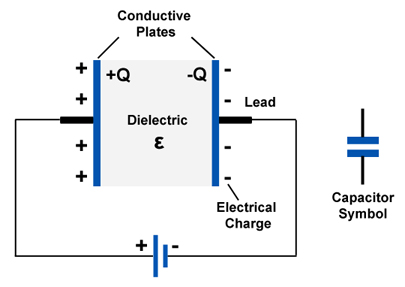
Along our journey of looking at different methods of storing energy we looked quite a lot in to super capacitors as they offer the greatest power density of all the storage methods as a back up to batteries one of our energy storage methods is to use a capacitor. A capacitor works by having two plates separated by a dielectric (insulating material). In theory the plates can be made from any material the conducts electricity well but are often made from metals. The dielectric on the other hand is an insulating material and is chosen because of its poor conducting ability. Typical dielectrics are ceramics, plastics, paper or air.

Figure 5- Capacitor

To charge a capacitor a voltage must be applied which results in one plate becoming charged and the other losing charge. The plate that becomes charged is the plate attached to the negative terminal of the battery. Once charged this charge can have the same voltage as the electromotive force. To release the energy charged up in a capacitor the battery is removed and replaced with wire. The built up charge on one side of the capacitor then moves towards the other.

A capacitor compared to a battery is able to release its voltage much faster which means it is useful for tasks that need instantaneous power. It also means that a capacitor is more appropriate as backup power rather than the main energy store. As capacitors only charge on the surface of the plates the energy density is lower than that of a battery. A capacitor can be cycled many times compared to a battery due to no chemical action meaning they are replaced much less than batteries usually are. Below the important equations related to the storage of energy in a capacitor are discussed.

Where E is the energy stored in a capacitor with capacitance C. The V is the potential difference across the two plates. The A in the capacitance equation is the area of the plate with the d being the distance between the two plates. Is the permittivity of free space, which is a constant. Finally Is the dielectric constant which changes with the material between the two plates.

The energy density of a typical super capacitor is around 6 Wh/Kg which is quite a bit lower than that of modern batteries. The main advantage is the much greater power density capacitors offer due to their fast speed of discharging. As mentioned earlier these factors make super capacitors very desirable as back-up power sources. Looking forward into super capacitors MIT are working on carbon nanotube enhanced super capacitors with energy densities of around 60 Wh/Kg.

# Monitoring System

The monitoring system is part of the SMA system, it can use the local weather report to predict how long the sun will shine for, and it also can be set to plan the best times to use certain appliances such as the washing machine. It charges the batteries at the ideal time and also automatically switches between the renewable energy sources and the energy stored in the batteries. This means that there will be limited problems with monitoring the energy usage. If this system runs out of power completely then the generator will have to be manually turned on to supply the power needed.

# Costs

The cost of the land and house in Cornwall comes to a sum total of £700,000 based on the location we are setting it in (Businesses for sale, 2015). This land contains 12 acres, and a house. The rest of the campsite components in total come to £600,000. The joint total upfront capital cost of the campsite hence comes to £1,300,000.

In terms of revenue the camp prices will be set at £15 a night for the tents and £30 a night for the caravans. Assuming half the caravans are booked out at all times and 120 of 200 tents are being used at any one night. The revenue from the camp site will be £1980 a night. This translates to around £475,000 for the entire season.

The outgoings of the campsite yearly include both taxes and wages of the workers. The tax is set at 40% of income hence being equal to £190,000. The number of workers we will have working at the campsite is 5 which will be paid £20,000 a year to work through the busy season and manage the campsite during the offseason. The total wages that will be paid out yearly works out to £100,000.

## Feed In Tariffs

Feed in tariffs can lead to a small amount of payback from excess energy, however at 11p per kWh this pay back will be very small, and so has not been included in payback time.

## Profits

This means that the profit each year works out to £185,000. Using these figures and our starting capital cost the business will break even in 7 years and then begin to be profitable. These figures show the campsite is feasible financially and a good business to invest into. However there may be added costs to this, as if there is not enough power produced the generator is very expensive to run and due to the unreliability of the renewable energy it is likely that this will need to be used.

# Conclusion

In conclusion it is very expensive to start off a business of this scale. The payback time on the initial investment means that there will be no profits for the first 7 years and so the site would require an initial financial backing. There are also problems with the reliability of the energy therefore meaning that there are added costs when using the generator. Overall the process of an eco-campsite is possible; however it is unlikely that it will feasible as it costs a lot compared to power from the grid, and there aren’t any benefits.

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