AJ's Technical Tips:
An Economic Comparison of Electric Torches

by Arne Jacobson

On a recent trip to Yala District in Nyanza Province, some friends and I were in a conversation with some people about the economics of different types of electric torches. The question that we were trying to resolve was whether it was better to buy an ordinary torch, one of the new types of high efficiency light emitting diode (LED) torches that are now so common in the market, or a more expensive solar powered torch. See Figure 1 for an image of ordinary and LED torches at a market stall. As we talked, we discussed issues ranging from the initial cost of buying a torch, the cost of operating it, and ways that the economics can change with different levels of use.

In the end, we chose one based on a comparison of the total cost of buying and operating each of the torches over a period of two years. We decided that we would buy the one that had the lowest total cost over this time period. I will present the results of this analysis at the end of the article.

Figure 1. Electric Torches for Sale in a Market in the town of Luanda, Nyanza Province, Kenya. Photo: Evan Mills

The economic analysis technique that we used to reach our conclusion was both simple and very useful. It is sometimes called life cycle cost analysis, and I will describe a basic approach for using this technique in this article. It can be very helpful for explaining the costs and benefits of different types of energy technologies, including energy efficient devices, solar PV, and other renewable energy systems, to customers.

The two green torches on the left have ordinary incandescent bulbs, while the others use the newer light emitting diode (LED) technology.

To make the economic comparison, let us consider four different types of torches.

Torch #1 (on the left in Figure 2) is an ordinary torch that uses an incandescent bulb and two D size dry cell batteries. According to my measurements, this torch can be used for approximately 15 hours on a single set of black Eveready batteries. The number of hours of use will, of course, be different if higher or lower quality batteries are used.

Torch #2 is similar in that it uses two D size dry cell batteries. The difference is that it has three LEDs instead of an incandescent bulb. The total power draw of the three LEDs in torch #2 is about one-third less than the incandescent bulb in torch #1. As a result of the lower power draw, this torch will stay lit for about 22 hours on a set of black Eveready batteries. See Figure 3 for images of the incandescent bulb in torch #1 and the three LEDs in torch #2.

Torch #3 in Figure 2 uses a set of three LEDs that are similar those in torch #2. The main difference here is that torch #3 uses a sealed lead acid battery (SLA) instead of dry cell batteries. This torch can be used for about 12 hours on a single charge, and it is re-charged by plugging it into the electric grid (that is, 240 volt AC electricity).

Torch #4 in Figure 2 uses six LEDs. It has three rechargeable nickel cadmium batteries inside (AA size). These batteries are charged using a small solar PV panel that is mounted on the outside of the torch. When it is fully charged, the torch can stay lit for about 10 hours. It generally takes one to two days in the sun to recharge the torch fully, although it can take longer if the weather is cloudy.

Now that I have introduced the torches, I will discuss the cost comparison. The first important cost is, of course, the cost to buy. I present purchase prices for each of the torches, including the cost to purchase the first set of batteries for torches #1 and #2, in Table 1.

Figure 2. Four types of electric torches sold in Kenya. Photo: Evan Mills

Figure 3. Incandescent (#1) and LED (#2) based electric torches. Photo: Evan Mills

It is important to keep in mind that for any given product, the purchase price can change from one town to another, from one vendor to another, and even from one buyer to another. For example, a customer who is skilled in bargaining can often get a better price from a market seller than one who has less experience or who does not know what the price for that product should be. In addition, prices in larger towns are often, though not always, lower than in market centers, and different vendors have different pricing schemes. When making an economic life cycle comparison, it is generally best to use the purchase prices that *most* customers in the situation you are analyzing will pay. We tried to achieve this by having one of our group (Maina Mumbi of Off-Grid Solar) purchase the torches from a market in the area where we were working. The prices given in Table 1 reflect prices that he obtained when purchasing the items. This is true except in the case of torch #4, which is not yet available widely in Kenya (see note under Table 1).

The next important cost is the cost to operate each torch. Here, the costs for replacing batteries or for charging are the most important, although there may be other costs associated with torch operation that should also be considered (e.g. replacing bulbs for the ordinary torch).

I will start by discussing the steps associated with determining the cost associated with replacing batteries or charging each torch. There are several factors that influence these costs. One factor is related to the number of hours per day that each torch is used. A second factor is linked to the number of hours that the batteries for each torch can provide light before they need to be replaced or recharged. A third factor is linked to the cost of replacing or recharging the batteries.

We began the process by making an *assumption* about the number of hours per day that each torch was used. Different people use their torches in different ways and for differing numbers of hours (minutes) per day. As a result, the cost of operating a torch will change from one person to another. For the purposes of making an analysis, though, it is useful to try to select a pattern of use for the torch that is common for the place you are working. In addition, in order to make a fair comparison, it is important to use the same assumption for all of the torches.

After some discussion with the people we were talking with in Yala, we decided that we would make the comparison based on an assumption that each torch was used one hour per day. This is approximately the same as saying that each torch is used 30 hours per month.

The second step involves determining the number of hours that each torch can be operated before it must be charged or have its batteries replaced. Perhaps the best way to get this number is to simply turn a torch with fully charged batteries on and wait for the batteries to drain completely. The time that it takes to drain the batteries is the time that the torch can last on a single charge or set of batteries. While this method is a good one, it can take some time. In the case of the torches with disposable batteries, this test also involves the use of a set of batteries.

Another way to get the number is to use information about the capacity

Table 1. Initial Cost to Purchase Four Types of Electric Torches

#	Type	Purchase Price (KSh)
1	Ordinary Torch with Two D Cell Batteries*	200
2	LED Torch with Two D Cell Batteries*	230
3	LED Torch with SLA Battery and Grid Charging	180
4	LED Torch with Solar Charging**	1,000

* *The purchase prices listed here for torches #1 and #2 include Eveready "black" D size batteries at a cost of 70 Kenyan Shillings (KSh) for a two-pack.*

** *Torch #4 is not yet widely available in Kenya, though it should be coming soon. The purchase price listed here is an estimate based on its sale price in other countries.*

of the battery (often given in milliampere hours, which are abbreviated as mAh) and the current draw when the torch is on to estimate the amount of time the torch will operate on a single charge or set of batteries. The difficulty with this method is that it requires an accurate estimate of the capacity of the batteries, and this information can be difficult to obtain in the case of the dry cell batteries. I have made some preliminary laboratory measurements of the capacities of batteries commonly sold in Kenya, and I plan complete a more detailed set of measurements soon. I will include these results in a future issue of Solarnet.

At this point we have enough information to estimate the number of times that each torch must have its batteries charged or replaced in a month. This is done by dividing the number of hours of operation per month by the number of hours that the torch can operate on a fully charged set of batteries. The results of these calculations are given in Table 2 under the heading "**Number of Times Batteries are Replaced or Recharged per Month.**" This number can then be multiplied by the cost of recharging or replacing batteries to get the monthly operating cost associated with battery use. We obtained costs for buying D cell batteries and for recharging torches like #3 from the market. In general, we found that a pack of two Eveready black D cell batteries cost 70 KSh, while the cost to pay to have torches like torch #3 charged at a battery charging shop was 20 KSh. The monthly operating cost associated with battery charging or replacement is given in the final column of Table 2.

You will note that the solar torch (#4) does not involve any cost to charge, as the sun does this work for free. With the solar torch it is important, though, to have a secure place to leave the torch in the sun during the day so that it can get a good charge.

At this point, we now have the initial cost to buy and the monthly cost to operate each torch. There are a few other minor costs that can be added to complete the analysis. For example, the cost to replace the bulb in an ordinary torch is much smaller than the cost of replacing batteries, but it can still be significant. I have assumed that it will cost a total of 50 KSh to replace bulbs in torch #1 over a two year time period.

The LEDs used in the other three torches generally have a long life, so they should not need to be replaced within the two year period that we are using for this analysis.

Replacement of rechargeable batteries can be an issue for the torches that use sealed lead acid batteries like torch #3. These batteries might last the full two years, but they may not. I have assumed in this case that the battery in torch #3 will be replaced after one year at a cost of 100 KSh. The NiCd batteries in torch #4 should easily last two years if the torch is used for one hour per day. In other words, it should not be necessary to replace these batteries in the two year time period for our analysis.

At this point we are ready to combine all of these costs to make a simple estimate of the cost to buy and operate the torches over a two year time period. The summation starts with the initial cost. To this, we add the cost for battery charging or replacement over two years. This is calculated by multiplying the cost per month to use each torch by 24 months. We can then add any additional costs such as those associated with the replacement of bulbs or rechargeable batteries.

For example, the cost to operate torch #1 over two years can be calculated as shown in Table 3. A summary of the results from the analysis for all four torches is presented in Table 4. I encourage you to check my calculations for torches #2, #3, and #4 using the same approach that I show for torch #1 in Table 3 so that you can be sure you understand how I did them.

The overall costs after two years (presented in the far right column in Table 4) indicate that the solar torch (#4) is the best buy. It is followed by torch #3, which has an overall cost of 1,480 KSh to purchase and operate over the time period. The other two torches

Table 2. Information Used to Estimate Monthly Battery or Charging Costs for Torches

#	Type	Monthly Operation (hours)	Hours of Use per Charge or Battery Change	Number of Times Batteries are Replaced or Recharged per Month	Cost to Recharge or Replace Batteries (KSh)	Monthly Cost for Battery Use (KSh)
1	Ordinary Torch w/D Cells*	30	15	2	70	140
2	LED Torch w/D Cells*	30	22	1,4	70	100
3	LED Torch w/SLA Battery	30	12	2.5	20	50
4	LED Torch w/Solar	30	10	3	0	0

** I assume that the batteries for torches #1 and #2 are black Eveready D cells.*

Table 3. Total Estimated Cost to Operate Torch #1 for One Hour Per Day Over Two Years

Item	Calculation	Amount
Initial Cost w/ Batteries	200 KSh	200 KSh
Monthly Battery Replacement	140 KSh X 24 months	3,360 KSh
Additional Costs	50 KSh for bulbs	50 KSh
Total Cost Over 24 Months		**3,610 KSh**

have higher overall costs, with the ordinary torch being the most expensive to operate over a two year period due to high battery replacement costs.

While the solar torch is the best value according to this analysis, many people may not be able to purchase one because of the high initial cost. In addition, some people may not have a secure place to leave the solar torch for charging. People in these situations may prefer one of the rechargeable torches like #3. In fact, for those who are able to find a way to charge this torch without taking it to a battery charging shop, torches like #3 can be the most economic option. That is, if you can avoid paying the 20 KSh each time to have the torch charged at a battery charging shop, then the monthly operating cost for the torch drops to almost zero. In that case, the cost to use this torch over two years would be an impressively low amount of 280 KSh.

This observation is an important one, because it shows how the economics of torch use can change from one person to another. The ultimate preferred option depends on many assumptions, such as the way that the torch is used, whether or not the user has access to grid electricity, whether the buyer can afford to spend 1,000 KSh at once on a solar torch, whether two years is the correct time period for making the analysis, or whether the user is able to buy high or low quality dry cell batteries.

I encourage you to adjust the analysis that I present here to fit your own circumstances or those of your customers. That is, change any of the assumptions that I have made that do not fit your situation or the situation of your customers. You can then recalculate the economics to see which torch is best for that situation. If you do this, please write me with the results of your analysis. I will be interested to hear what you found.

Be sure to include a summary of all of the assumptions that you made.

In this article I have used this life cycle cost method to compare the economics of electric torches, but the same method can also be used in other situations. For example, this technique can be used to compare the costs of using kerosene for lighting and battery charging to operate a TV with the costs of purchasing and operating a small solar PV system to provide energy for these tasks. I will use this same technique to discuss these economics in a future issue of Solarnet magazine

p.s. For those of you who would like to write to me, my email address is arne@humboldt.edu

Table 4. An Economic Comparison of Four Types of Electric Torches

#	Type	Purchase Price (KSh)	Cost Per Month to Use* (KSh)	Additional Costs Over Two Years (KSh)	Overall Cost After Two Years (KSh)
1	Ordinary Torch with Two D Cell Batteries	200	140	50	3,610
2	LED Torch with Two D Cell Batteries	230	100	0	2,630
3	LED Torch with SLA Battery and Grid Charging	180	50	100	1,480
4	LED Torch with Solar Charging	1,000	0	0	1,000

* *Calculations assume that each torch is used for one hour per day. Torches #1 and #2 use Eveready "black" D size batteries at a cost of 70 KSh for a two-pack. Torch #3 is re-charged in a shop at a cost of 20 KSh per charge.*