Alternative Power Source for Dental Hygiene Device

Team 15

Nizar Almansouri

Francisco Health

Ningbao Jiang

Jin Niu

Jiaqi Xie

Concept Generation and Selection

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Department of Mechanical Engineering
Northern Arizona University
Flagstaff, AZ 86011

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Introduction

The NAU Department of Dental Hygiene provides humanitarian services in some remote areas of the world. Sometimes, these areas have limited access to electricity. In December, a team of students and professors of the Department of Dental Hygiene will be travelling to Mainpat in India to work on teeth. To get the work done, they will need to use the Wig-L-Bug, a device that can mix dental filling material.

The Wig-L-Bug requires electricity to run. Because there will not be electric power available, the team will need to bring a portable power source with them. This power source must be able to power the Wig-L-Bug ten hours a day for two weeks, without any downtime. It needs to be a convenient size and weight, so that it can be easily transported.

Concept Generation

In order to solve the problem we have encountered, we came up with 10 designs, in which we choose three as our final possible designs. These three designs are: combination of manual alternator and lithium battery, combination of solar generator and lithium battery and lithium battery only.

Design 1: Combination of manual alternator and lithium battery

1. **Description**

A crank with a chain or belt is connected to a small automobile or motorcycle alternator. The alternator is wired in parallel with a lightweight scooter battery. An inverter is used to invert DC to AC, so that that the battery can supply the power for the Wig-L-Bug. The battery can be capable of powering the Wig-L-Bug for about 20 minutes.

A simple model shown in Figure 1 could be built to be to be dissassembled for easy transportation.

Figure 1 Design#1

2. **Parts Details**

In the Table 1, there is a list of all of the parts required to build a combination of manual alternator and lithium battery system.

Part	Cost	Weight (lb)
Alternator	75	8
Battery	100	1
Inverter	50	1
Frame	75	8
Gears, Cranks, Pulleys, etc	150	5
Wiring, electronics, etc	50	1
TOTAL	500	24

Table 1 Part List

A. Alternator

Figure 2 Alternator

A small alternator can be bought with 50 - 75 dollars. Ideally, we obtain a small unit rated for less than thirty amps. While these units are not very efficient (about 60%), they are small, cheap, and very durable. Used in this application, an alternator in good shape should last forever.

The main disadvantage of the alternator is the low efficiency. The person pedaling will have to work harder than if a more efficient DC generator was used.

B. 12 Volt Battery

Figure 3

A lithium Ion Battery built to power scooters,motorcycles, and ATVs would be charged by the generator. These batteries are rated for 2000 discharge cycles, meaning if it was allowed to completely drain and then recharged every twenty minutes, it would be good for 600 hours of use. The lifespan would be longer if the generator was pedaled constantly. We will look into this.

C. Inverter

An off-the shelf device that converts the battery power into a form usable by the Wig-L-Bug.

D. Frame

An Aluminum tube frame would be welded up out of square tube stock. We will need to come up with some designs to determine the actual size and weight. Ideally, the frame will have hinges or pins to allow the frame to fold up or disassemble.

E. Gears, Cranks, Pulleys, etc.

This is the mechanical part of the design. Most of these parts could be scavenged from old bicycles. Certain items may need to be fabricated for the application. This could potentially be cheaper than the estimated price.

F. Wiring, Electronics, etc.

We will probably add charge indicators, switches, circuit protection, etc.

Design 2: Combination of solar generator and lithium

1. Description

The solar power source concept converts solar irradiance into electrical energy, which is used to provide energy for Wig-L-Bug.

In the Table 2, we analyze the advantages and disadvantages of a solar design.

Advantage	Disadvantage
Powerful	Cannot work under poor light condition
Portable	Has to be manually set towards the sun directly in order to get maximum power
No need to charge at night	Cost of a solar panel is high

Table 2

2. Parts Details

The following are the parts which will be used in this design.

A. 62 Watt Solar Charger

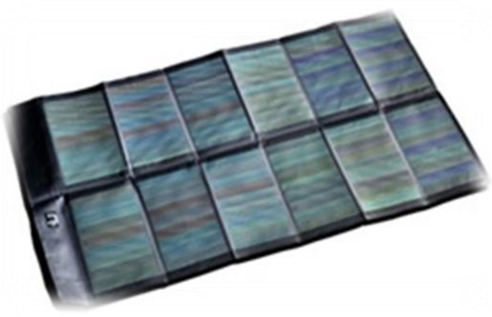

Figure 4

Cost: $ 940
Size: 30 in*52.5 in (Unfolded); 8.5 in*14.5 (Folded)
Weight: 3.2 lbs
Power Output: 20V @ 3100mA

B. **24V DC to AC 400W inverter**

Figure 5

Cost: $40
Size: W*H*D=5 in* 2.25 in *7.25 in
Weight: 4.2 lbs
Input: 20~30V DC
Output: 120V AC @ 3300mA Mod sine-wave

C. **24V DC to AC 400W inverter(Alternatives)**

Figure 6

Cost: $150
Size: W*H*D=11*2.4*4.2 in
Weight: 5 lbs
Output: 120 volt AC Pure sine-wave
We are not sure if this device can work under modified sine-wave, therefore there are two inverters considered to be used.

D. Inverter Cable

Figure 7

Cost: $30:
Size: W*H*D=5.0 x 9.5 x 2.5 in
Weight: 0.8 lbs

3. **Cost Analysis**

Component	Size(in)	Weight(lb)	Cost($)	Quantity	Total Cost($)
Solar Charger	8.5*14.5	3.2	940	1	940
24V Inverter Modified Sine-wave	5x2.25x7.25	4.2	40	1	40
Cable	5x9.5x2.5	0.8	30	1	30
Total	14.5x8.5x5	8.2			1010

Table 3

Design 3: Battery only

1. **Description**

In battery design, we mainly use the battery as the power supply for the project. For the battery standard, we need four batteries and the standard voltage has to be 3.7V. So, the total will be 14.8V. The capacity has to 10-20 Watt hours. Charge current is 3 A, and discharge current is 7 A. In this project the weight is the most important factor which we have to consider because it has to fit the suit case in the airplane. So, the four batteries will be 7Ib.

2. **Parts Details**

A. **Charger**

Charger is needed to charge the power source. In India the standard voltage is 220V. So, the charger will work with the voltage.

B. **Inverter**

An inverter is used to convert the battery power so can be used by the Wig-L-Bug. And the quantity for that is one.

C. Frame

For the frame, we mainly use the plastic board as a material, because it is insulated which can prevent workers from getting an electronic shock. At the same time it is a light weight that it would carry it without damage it.

3. Cost Analysis

Since the cost is one of the most important criteria in the project, we got every item how much is cost. Table 4 is a cost analysis of battery only design. Since we will use four batteries the total is 240$. And the charger price is 30$. For the inverter and the fame, the cost is 20$ each. So, for the whole project the total comes up to 310$.

Raw comparison

Parts	Quantity	Price ($)	Subtotal ($)
Battery	4	60	240
Charger	1	30	30
Inverter	1	20	20
Frame	1	20	20
		Total	310

Table 4

We have three possible designs: solar, generator and battery only. All three projects have different advantages and disadvantages. For the solar the uninterrupted power is 20% but for the generator and the battery only is 0%. The cost for the solar is almost 1000$ and for the generator is 450$. For the last one the battery is 310$.

	Solar	Generator	Battery
Uninterrupted power(% down time)	20	0	0
Cost($)	1000	450	310
Weight (Ib)	12	25	25
Life Span(hour)	500	500	1000
Size(within56x45x25cm)	yes	yes	yes
Peak output(watt)	120	400	250

Table 5

Criteria Selection

	Solar Charger	**Hand Generator**	**Battery Pack**
Uninterrupted Power (% Down Time)	20	0	0
Cost ($)	1000	450	300
Weight (lb)	12	25	25
Life Span (hour)	500	500	1000
Size (Within 56 x 45 x 25 cm)	yes	yes	yes
Peak Output (W)	120	400	250

Table 6: Raw Numbers

The first step in comparing the criteria is to normalize the raw data. To do this, the numbers from table one were converted to a 0-10 scale. The worst in each category received a zero, and the best received a ten. Numbers that were in between were scaled appropriately.

	Solar Charger	Hand Generator	Battery Pack
Uninterrupted Power (% Down Time)	0	10	10
Cost ($)	0	8	10
Weight (lb)	10	5	5
Life Span (hour)	5	5	10

Table 7: Normalized Data

The next step was to rank each criterion in order of importance. To do this, the criteria were ranked in importance relative to other individual criterion. In the table below, the criterion in the row is ranked in importance to the criterion in the column. If the row criterion is much more important, it receives a three. If it is just as important, it receives a one.

- Uninterrupted Power: The main purpose of the power source is to provide sufficient power for dental device. So it makes sense to treat the uninterrupted power as a major criterion. Moreover, our client may experience different situations in India when there is insufficient sunlight, labor or she is suffering an extreme weather. Then an interrupted power becomes the most important thing. We need to make sure the power source not only powerful but also reliable. Taking all this into consideration, it is reasonable to have uninterrupted power as the most important criterion.
- Cost: It is necessary to limit our total cost within the client's requirement. In fact, the team wants to minimize total cost without compromising its full functions in order to make our design more competitive.
- Weight: Portability also has to be included because our client has to carry that on a flight. In addition, our customer is going to remote settlement and there will not be convenient transportation. So limiting the weight also becomes an important requirement.
- Lifespan: Since all our designs satisfy the lifespan constrains it becomes less important.

	Uninterrupted Power	Cost	Weight	Lifespan	Raw Total	Normalized Total
Uninterrupted Power	1.00	2.00	3.00	3.00	9.00	0.43
Cost	0.50	1.00	3.00	2.00	6.50	0.31
Weight	0.33	0.33	1.00	2.00	3.66	0.17
Lifespan	0.33	0.20	0.50	1.00	2.03	0.10

Table 8: Weighted Criteria

Uninterrupted power was judged to be the most important compared to other design criteria. Our client only has a limited amount of time to get the work done. Any down time is wasted time, and that is unacceptable. Keeping cost low is important. If we can save money by adding a few pounds to the device, this is acceptable, as long as the power supply is still portable. Lifespan received the lowest ranking, because all of these designs will likely last for years.

Table 9 shows each design ranked by the normalized and weighted criteria.

		Design Options					
		Solar Charger		Hand Generator		Battery Pack	
Design Criteria	**Weight**	**Raw**	**Weight**	**Raw**	**Weight**	**Raw**	**Weight**
Uninterrupted Power	0.43	0	0.00	10	4.25	10	4.25
Cost	0.31	0	0.00	8	2.46	10	3.07
Weight	0.17	10	1.73	5	0.87	5	0.87
Lifespan	0.10	5	0.48	5	0.48	10	0.96
	Total		2.21		8.05		9.15

Table 9: Decision Matrix

Conclusion

It is clear from Table 9 that battery pack design has the highest total weighted score and solar power is out of the question. High cost and inconsistent power delivery bring the score down to a non-competitive level. The manual generator and the battery are very close in score. At this point, the team will go ahead and design the battery. The manual generator will be considered for later construction at the sponsor's request.