TOWARDS A PORTABLE SOLAR/WIND REPLACEMENT FOR GAS GENERATORS

as far as we can get for now

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ABSTRACT

TBD

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1 GOAL

Create a semi portable unit comparable in size and power output to a standard gasoline or propane based electrical generator found in a typical hardware store. These typically provide anywhere from 1000 to 7500 W in power output and last for about 8 hours running with a full tank at half the rated wattage. These are commonly used without knowing how much power one actually needs. Because it provides more than enough power for a given situation, it lasts a little longer than the half power rating. We can either take the approach of creating a system which is equivalent to a generator working at half power, or we can take the approach that all the power is not needed and most of the energy contained in the gasoline is wasted while the engine runs creating noise pollution anywhere from 56dB to 78+dB.

1.1 Common Generator Models

In order to gain a better understanding of what is available on the market, the author started browsing the internet for common generators available at Walmart, Home Depot, Lowe's, and other similar outlets. A wide range of power outputs were found. The results are summarized below.

Table 1: Table of Generators

Generator Name					
Surge W	**Running W**	**Weight**	**Tank Size**	**Sound Level**	**Watt Hour rate**
Sportsman 1000W Inverter Generator					
1000W	800W	52lbs	0.55G	56+dB	6.3h at 400W
Honda 2000W Inverter Generator					
2000W	1600W	45.6lbs	0.95G	59+dB	6h at 800W
Sportsman 2000W Generator					
2000W	1400W	53lbs	1.2G	65+dB	9h at 700W
Honda 5000W Generator					
5000W	4500W	173lbs	6.3G	73+dB	11h at 2250W
Ryobi 5500W Generator					
6875W	5500W	194lbs	6G	78+dB	9h at 2750W
Dewalt 7000W Generator					
8750W	7000W	192lbs	7.5G	?dB	11h at 4500W

1.2 Summary of Generators

1. Each produces a lot of noise.
2. Each weighs anywhere from 46lbs to 192lbs.
3. Cost anywhere from [$1.30 @ $2.38/G, $1.71 @ $3.117/G] to [$17.85 @ $2.38/G, $23.37 @ $3.117/G] with one tank of gas.
4. Produces anywhere from 2520Wh to 49500Wh with one tank.
5. It cost anywhere from $4.95/24h to $6.51/24h to run the smallest model (9600Wh/day) and anywhere from $38.95/24hr to $50.99/24hr to run the largest model (108000Wh/day).

2 TYPICAL POWER REQUIREMENTS

Gasoline generators are capable of putting out a decent amount of power, but they don't always regulate their gas usage much while not under load. A lot of the newer ones try to be more efficient, but there's still a decent amount of waste of energy at low loads. Also, gasoline generators have been around since the age of electricity hogging devices like CRTs – now replaced by highly energy efficient LED flat panel displays. Not many people use as much power from a generator as the generator can provide.

2.1 Power Requirements for Typical Devices

In order charge a modern phone, it takes a minimum of 1.5A @ 5V or 7.5W. A tablet (or more recently, phones) takes at least 2.1A @ 5V or 10.5W. A Samsung Galaxy S7 Edge takes 1.8A @ 9V or 16.2W for 1:39. A Chromebook I have laying around takes 2A @ 12V or 24W and about an hour to charge. The laptop I typing on takes 3.42A @ 19V or approximately 65 W and about two hours to charge. The new modern USB-C spec has a charging mode which can negotiate up to 5A @ 20V or 100W. Standard lamps with LED or CFL lighting can be run at 15W to 20W. An LED TV can take anywhere from 24.2W (Vizio E1-A1 24") to 147W (Samsung 6 Series UE40JU6400K 4K UltraHD 40"). A regular sized refrigerator/freezer combo unit takes 70W to keep it running (I'm sure there's some variance in that so it probably spikes intermittently).

In many situations, people will have medical equipment which needs to be powered. Nebulizer machines can take anywhere from around 50W to 204W. A CPAP machine seems to fall within the same range (I'm having trouble finding the exact specs online for any model). A Fresenius 2008K@home dialysis machine uses 12.5A @ 120V or 1500W for as long as it takes to cycle all your blood through the system.

Table 2: Table of Common Devices

Device	W	A	V	T	Wh
Generic Cellphone	7.5W	1.5A	5V	6h	45Wh
Generic 3.0A USB Charger	15W	3A	5V	3h	45Wh
Generic Tablet	10.5W	2.1A	5V	6h	63Wh
Samsung Galaxy S7 Edge*	16.2W	1.8A	9V	1h 39m	26.73Wh
ASUS C100P Chromebook*	24W	2A	12V	2h	48Wh
ASUS Q522U Notebook PC*	65W	3.42A	19V	2h	130Wh
LED or CFL Lamp*	20W	$\frac{1}{6}$A	120V	8h	160Wh
Vizio 24" 1080 HDTV*	24.2W	?	120V	4h	96.8Wh
Samsung 4K UltraHD 40"*	147W	?	120V	4h	588Wh
Refrigerator/Freezer*	70W+40W	?	120V	24h	1680Wh
Nebulizer*	50W	0.42A	120V	1h	50Wh
CPAP*	50W	0.42A	120V	8h	400Wh
Dialysis*	1500A	12.5A	120V	*varies*	*varies*

* Uses an external AC adapter to charge.

2.2 Phone

Let's go really basic for a moment. Let's assume all we want for emergency situations is our phone and a lamp. We can go for the lowest common denominator and just provide a USB port for charging that provides 2.1A and requires up to 8 hours to charge newer phones. That's 16.8Ah/per phone charge and since this is an emergency situation it would be nice to charge it at least three times. That brings us to 50.4Ah or 252Wh with a 2.1A discharge rate.

2.3 Phone and Lamp

2.4 Phone, Tablet, and Lamp

2.5 Phone, Tablet, Laptop, and Lamp

3 CHOOSING A BATTERY

In order to choose the proper battery we need to know the number of Amp-Hours [Ah] we need to produce a certain number of Watt-Hours [Wh] in AC. This means we need to know the conversion efficiency of our inverter, since one hasn't been chosen, we will assume a typical conversion rate of 90%.

$$\mathit{Necessary}_{Wh} = \frac{AC_{Wh}}{\mathit{Conversion}_{\mathit{Efficiency}}} \tag{1}$$

$$\mathit{Necessary}_{Ah} = \frac{AC_{Wh}}{\mathit{Conversion}_{\mathit{Efficiency}} \cdot \mathit{Battery}_{Vdc}} \tag{2}$$

3.1 Battery Types

Additionally, we need to take into consideration what kind of battery we're using. We can choose from:

- Lead-acid
  - Flooded Cell
  - AGM
  - Gelled Electrolyte
- Nickel-Cadmium (NiCad)
- Nickel-Metal Hydride (NiMH)
- Lithium-ion (Li-ion)
- Lithium-polymer (LiPo)

Each type of battery has it's own kind of characteristics. These can encompass how much charge the battery can hold, how well the battery performs at a certain temperature, how long it lasts while powering a load, the ability to hold a charge in storage, how quickly it can be charged, and a number of other parameters. Typically, a solar or wind system will use a lead-acid battery because they are readily available and certain kinds of lead-acid batteries work better in cold weather than others. Lithium-ion batteries are widely used in many devices. Most phones, tablets, and other portable computers use Li-ion because of their energy density. They do have the habit of catching on fire if misused. In the following calculations we'll stick to lead-acid.

3.2 Battery Discharge Time

All batteries have a different behavior Lead-acid batteries have a discharge rate which is governed by the rate of the chemical reactions in the acid electrolyte paste. Instead of having a linear relationship as one might expect, there's an exponential relationship governed by Peurkert's Law. The law is typically stated in terms of the Amp-hour rating for a certain period in hours:

$$t = H\left(\frac{C}{I \times H}\right)^{k}, \tag{3}$$

where

- t is the number of hours until a battery is discharged.
- I is the current being drawn in Amps.
- H is the number of hours specified in the N Hour Rate of the battery.
- C is the capacity in Amp-hours specified for the N Hour Rate of the battery.
- k is a dimensionless constant called the Peukert Constant (from the name of the law).

We can also look at how the actual effective capacity of the battery changes given a specific current draw

$$I_t = C\left(\frac{C}{I \times H}\right)^{k-1}, \tag{4}$$

where I_t is the effective capacity of the battery and all other variables are the same as above.

34AH @ 24H RATE The following charts are for a battery with a capacity of 34Ah for a 24h rate:

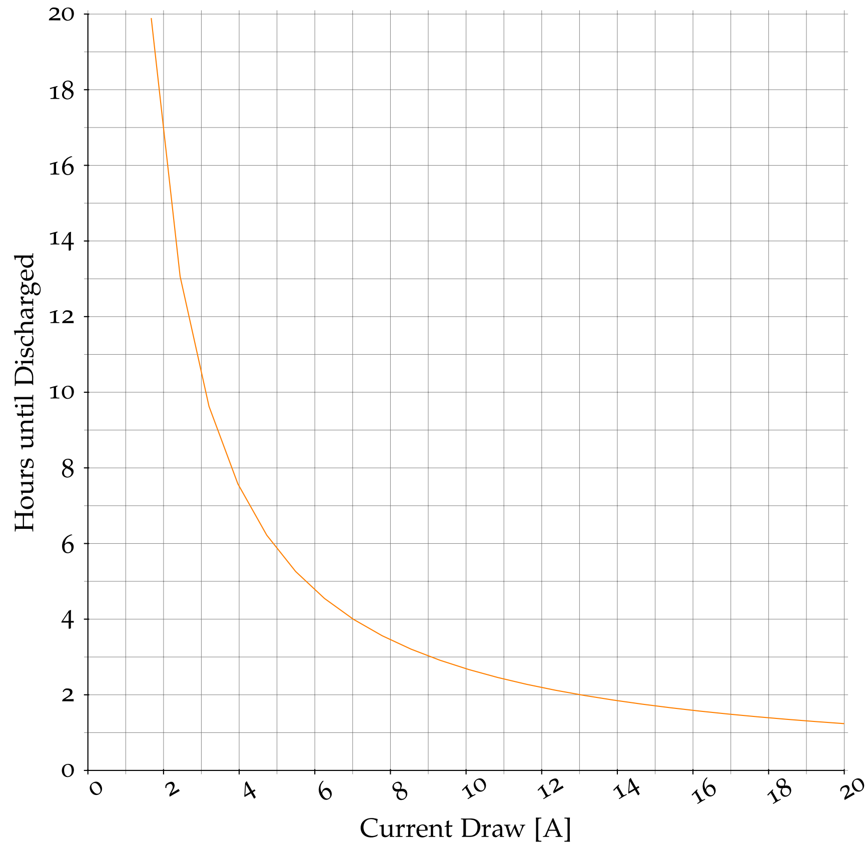

Figure 1: Time until discharge as a function of current draw on a lead acid battery w/a capacity of 34Ah for a 24h rate.

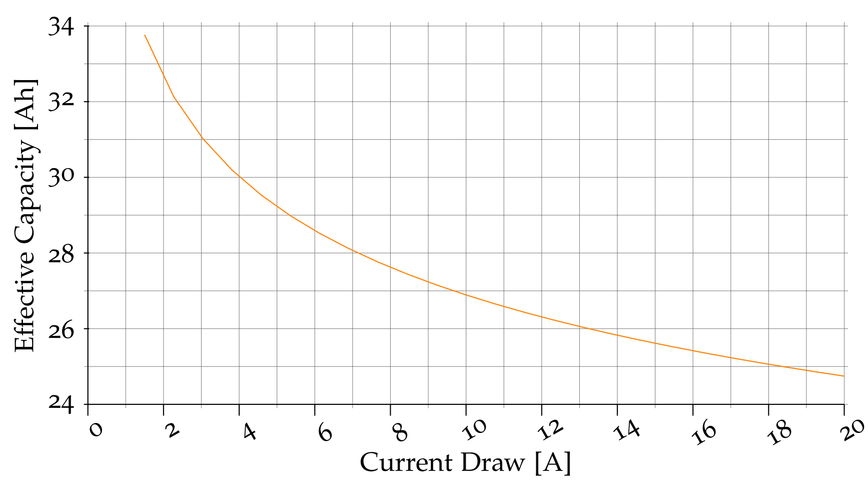

Figure 2: Effective capacity as a function of current draw on a lead acid battery w/a capacity of 34Ah for a 24h rate.

104AH @ 24H RATE The following charts are for a battery with a capacity of 104Ah for a 24h rate:

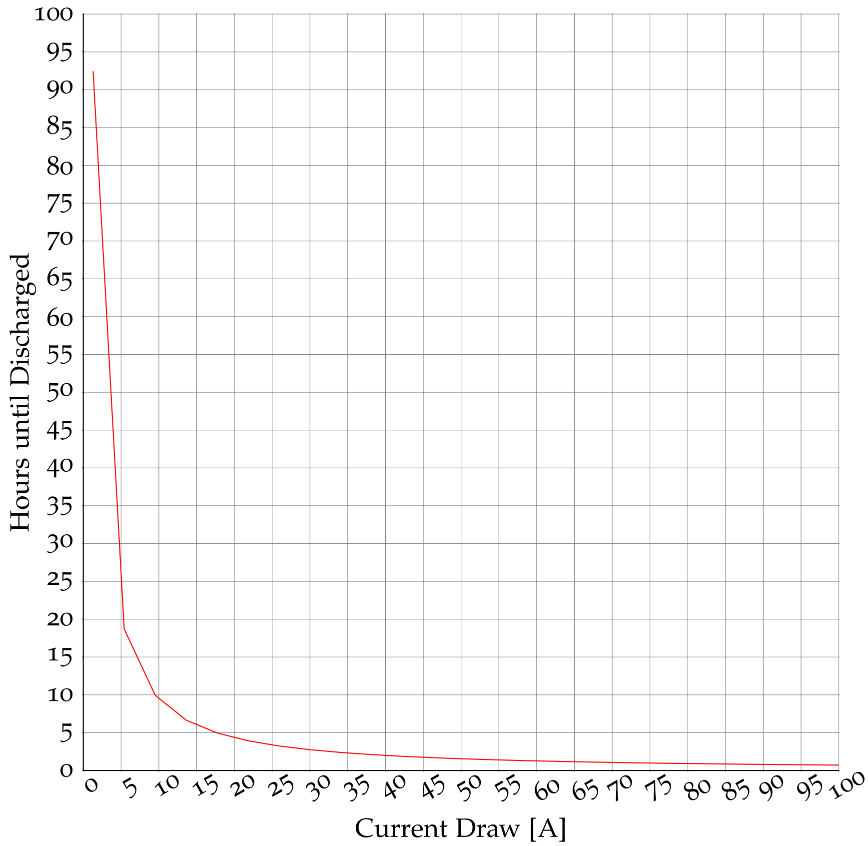

Figure 3: Time until discharge as a function of current draw on a lead acid battery w/a capacity of 104Ah for a 24h rate.

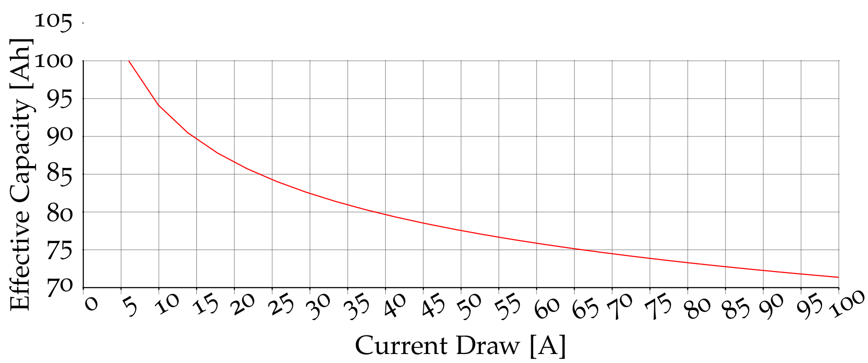

Figure 4: Effective capacity as a function of current draw on a lead acid battery w/a capacity of 104Ah for a 24h rate.

3.3 Temperatures Effect on Capacity

4 CHARGING BATTERIES