SoLiModule
Power to the Powerless

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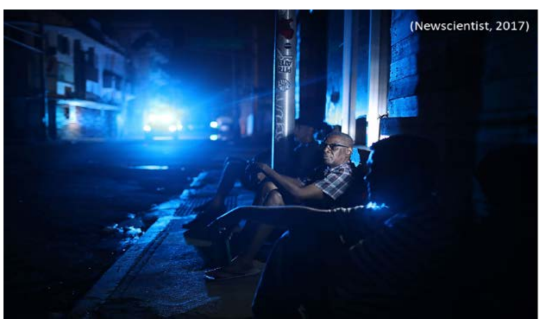
SUMMARY

SoLiModule is **a solar/Lithium-ion battery module** for off-grid systems for immediate response in emergencies, remote areas, and military applications.

PROBLEMS

An estimated 1.3 billion people worldwide live without electricity in their homes. It is difficult to be productive without electricity. Nights are lit by inferior substitutes such as moonlight, cooking fires, candles, and kerosene lamps. Everyone must rush to finish work by sundown. Also, catastrophic events can cause wide-scale power outages. Puerto Rico still has 400,000 people without power more than 5 months after Hurricane Maria hit the island. The lack of power makes it hard to refrigerate food and medicine as well as to run air conditioning – both essential in the hot Caribbean climate. For decades, people have used portable diesel-fueled generators, but they are noisy, emit noxious fumes, and require a steady supply of fuel which may be difficult to transport to the affected area. People may also use Flooded Lead-Acid Batteries (FLAs) connecting with solar panels, but FLAs are large and heavy and require regular watering to maintain electrolyte levels.

Emergencies



Remote Areas

What Do People Usually Do?

Portable Diesel Fueled Generators

- Polluting
- Noisy
- Steady supply of fuel

Recharge Lead-acid Battery through Solar Panel

- Regular watering
- Large and heavy
- Dangerous (Sulfuric acid)
- Toxic (Lead)

SOLUTIONS

Our goal is to provide safe, clean, reliable, and affordable renewable energy by integrating lithium-ion battery storage technologies and solar power. Due to its higher energy and power density, a lithium-ion solution can be a fraction of the size of an FLA battery bank while still supplying the same amount of power and containing the same amount of energy. The target weight for the module, including collapsible solar panel, is under 30 kg, to maximize its portability. The prototype will come in a durable, portable, water and dust resistant case that can reliably protect the batteries and electronics during the harshest emergency conditions. The module will contain an intelligent battery management system in order to ensure safe operation of the batteries and will include a bright flashlight for navigation in power outage situations. The module and solar panel are suitable for deployment indoors or out, and many modules can be configured in parallel in order to scale with the power and energy demands of the load. The target use-case is completely powering a single refrigerator, useful for both food and medicine, as this task offers unique technical challenges with both moderate energy usage and occasional very high-power spikes as the compressor starts up. The module is compact, easy to install, and free of maintenance.

While a refrigerator is a practical, long-term necessity, there can be more pressing needs in times of real emergency, including the powering of water pumps, electric chainsaws, cell phones, communication devices, medical devices, and cooking equipment, including the boiling of water. The vast majority of these devices have energy and power demands that are significantly lower than that of a refrigerator, so by designing for the most ambitious use-case, we necessarily exceed the demands of these lighter electrical loads.

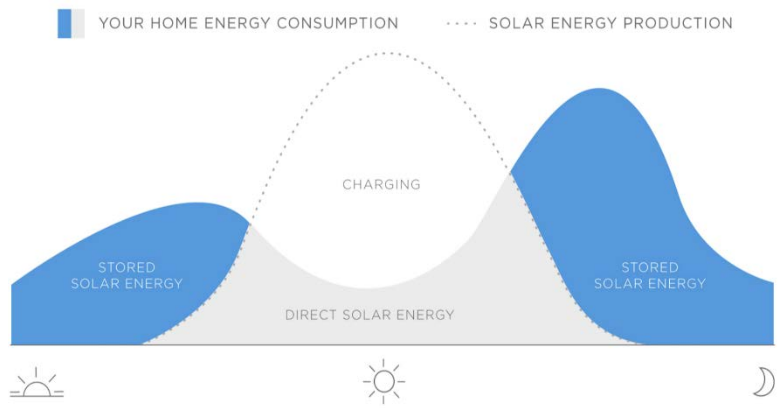
USE CASE ANALYSIS

Several solar-battery modules enable you to power your home independently day and night. During the day, solar panels may produce more energy than your home uses, so the battery can store the excess solar energy to be used on demand at night. (Figure) For a 1,100 sq. ft. US home without an air conditioner, the estimated energy usage is 24 kWh/day. This includes all the running appliances and activities such as cooking, doing house chores, reading, working, and using appliances such as a computer or phone.

Table 1. Use Case – Common Applications

Appliance	**Watts**
Freezer - Upright - 15 cu. ft.	1240 Wh/day*
Fridge - 20 cu. ft. (AC)	1411 Wh/day*
Box Fan	200
TV – LCD	150
LED Bulb - 100 Watt Equivalent	23
Laptop	100
Smart Phone - Recharge	6
Clock Radio	7
Chain Saw - 12"	1100

* The daily energy values listed here are for the most efficient units in their class and the information was obtained from Consumer Guide to Home and the General Electric website.



(Image modified from Tesla's website)

TECHNICAL DETAILS

The Lithium-ion cell is a good candidate for the renewable off-grid power system. The comparison of the rechargeable batteries is listed in Table 2. Although the cost per kWh of Lithium-ion cells is higher, the cycle life is longer (you don't need to swap the batteries in remote area frequently) and the energy density is higher which means we have lighter battery packs to power the same device. These characteristics are critical in the use case of emergencies and remote areas. The energy storage medium we choose for storing the renewable energy (generated by solar for this project) is cylindrical lithium cells. Cylindrical lithium cells are mechanically stable - a hard metal outer shell protects them from most punctures and compressive loads. They also have a comparatively low cost per watt-hour, making them an economical choice.

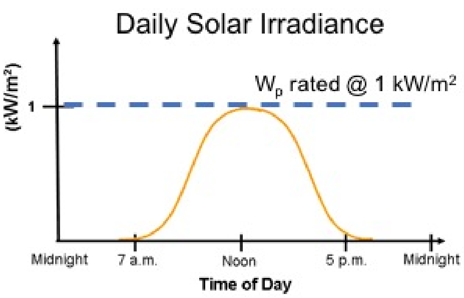
Table 2. The comparison of two common types of rechargeable batteries in the off-grid system

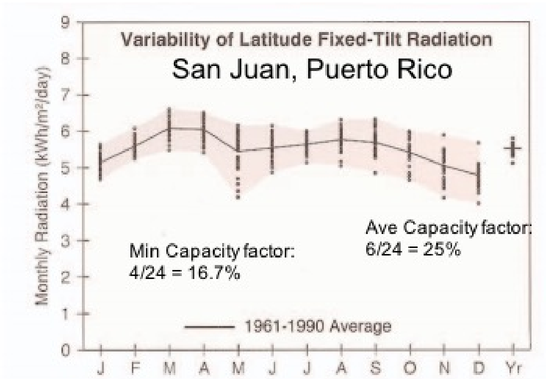
Battery Specs	**Lead–acid**	**Lithium-ion**
Specific energy density	33 - 42 Wh/kg	100 - 265 Wh/kg
Volumetric energy density	60 - 110 Wh/L	250 - 693 Wh/L
Specific power	180 W/kg	250 - 340 W/kg
Self-discharge rate	3 - 20%/mo	<10%/mo
Nominal cell voltage	2.1 V	3.635V
Charge temperature interval	−35 °C - 45 °C	0 - 45°C
Cost per kWh ($US)	$150	$450
SOC usage (%)	30%	80%
Cost/kwh lifetime ($/kwh)	1.42857	0.46875

To be cost-efficient for the prototype, a system like this must be designed for a specific use case. For us, this use case is supplying 100% of the power required to run a refrigerator full-time to store food and medicine in the event of a total power outage, an energy requirement of roughly 1.4 kWh per day (see Table 1). It is challenging regarding its high energy usage and occasional power spikes. The location will be Puerto Rico, selected for its ideal solar location and realistic needs for a solution like this.

The first aspect of the device to be sized is the solar panel. To power the refrigerator with sufficient uptime, it must generate at least the amount of energy consumed each day, including efficiency losses. Roughly speaking, this demand is 1.4kWh / 0.8 (inverter efficiency) / 0.8 (weather-compensating overdesign margin) for a total energy requirement of 2.2 kWh/day. The inverter efficiency ensures that after the power has gone from DC to AC, there is still sufficient energy to keep the refrigerator running, and the over-design factor allows for more robustness for weather events, i.e., cloudy days.

Solar panel power output is rated peak power output in watt-peak (Wp), which is the power output of the panel under a standard 1000 W/m^2 solar irradiance. The daily and yearly fluctuations in sunlight will cause the average power output to be much less than the peak output due to the day-night cycle, clouds, and latitude. The actual power output is typically quantified with a “capacity factor” which is the ratio of actual power output to peak power output. The annual capacity factor can be estimated from solar irradiance data, and for a solar panel in San Juan, Puerto Rico is ~25%. (Figure) We want to our system to provide enough power even in the dimmest time of the year, so we assume a capacity factor of 16.7% (4/24 kWh/m^2/day).





Using a conservative 16.7% capacity factor, it becomes possible to size the solar panel. Given the requirement of 2.2 kWh/day and 16.7% capacity factor, the solar panel needs to be rated for 2.2 kWh / (24hr x 16.7%) = 550 Wp. Considering the redundancy, that means we are safe to have two 330W solar panels to power a regular refrigerator continuously.

Now that the solar panels have been sized, the battery can be sized. The total energy used is 2.2 kWh/day, and the average load is 92 W. Each battery is estimated to use its 80% SOC (state of charge) window, so its total energy capacity of batteries will need to be 2.75 kWh. That is equivalent to 224 pieces of 12.24Wh 18650 Lithium-ion cells.

To make it portable, we propose that one solar panel (~20 kg) comes with 112 Lithium-ion cells (~10 kg). Therefore, if we put two modules in parallel, we can power a regular fridge, and each module (~30 kg) is portable with a cart. Two modules are the minimum number of modules that we can demonstrate the capability that people can configure in series or parallel by connecting with cables according to their applications.

COST

2 portable modules which cost $3,000 in prototyping provide 1.4 kWh per day to power a regular fridge 24/7. We are expecting to bring this cost down by 40% because of economy of scale advantages to volume manufacturing. The cost is even lower if we consider adopting the recycled batteries from King County Bus (The bus batteries still have 80% of its original capacity) or other stable resources, and the battery pack price will be around 25% of the new batteries.

MARKET

Although there is an estimated of 1.3 billion people who live without electricity in their homes, there is a huge correlation between poverty and lack of access to electricity. So direct sale to these potential users may be difficult. However, while SoLiModule may be costly for direct users (2 modules which cost $3,000 in prototyping provide 1.4 kWh per day to power a regular fridge), but it is still affordable for governmental and other organizations to have distributed grid. In this case, our major customers are expected to be non-government organizations (List below) like American Red-Cross, military units and hobbyists who need a portable, silent, self-contained, and eco-friendly power generator.

Charities	Revenue (FY16)	Rank in the US	Services
American National Red Cross	$2.07 B	#20	American National Red Cross provides emergency assistance, disaster relief and education inside the United States.
World Vision	$1.01 B	#15	World Vision is a Christian relief and development umbrella organization that combines staff efforts with donated goods to fight poverty around the world.
Habitat for Humanity International	$1.89 B	#6	Habitat for Humanity International musters donations and volunteer help to build actual homes for people that don't have them.

* Source: Forbes

COMPETITION

The idea of either using solar panels and Lithium ion battery for storage are not new. However, the current market only has either large scale stationary installation like Tesla Powerwall, Solar Roof or small solar-integrated phone charger. There is a missing part in the product spectrum, and our SoLiModule fits the market need. The reason we see this discontinuous market is majorly because most businesses are considering selling their products to end users, but their products cannot necessarily provide the need for remote areas or emergencies. By targeting FEMA, large charities, and non-profits, we can make our business sustainable as well as the environment and society – providing power to the powerless.

Direct Competition: Using Lithium-ion cells as energy storage media.

Product	Portable	Scalable	Solar panel	Capacity	Cost	Energy Acquisition	Target Consumers
SoLiModule	Y (battery 10 kg)	Y	Y (300W)	1.2kWh	$1,500	Solar	Off-grid emergencies, remote areas, and military applications
Tesla Powerwall	N (125 kg)	Y (up to 10 unit)	Optional	13.5kWh	$5,500 + $700 Supporting hardware	Grid or Solar Roof	High-income homeowners in the US
RokPak	Y (0.81kg)	N	Y	12Wh	$179	Solar Panel	Adventurers
M-KOPA	N	N	Y (20W)	Unknown	$35 (down payment) + $164.25 (including solar panel, 20" TV, lights and phone charger.)	Solar Panel	People in Kenya, Tanzania, and Uganda
Kingo	Y	N	Y (100W)	Unknown	Prepaid solar system – continuously charge users (rate unknown)	Solar Panel	low income households
Anker	Y (4.2kg)	N	N	400Wh	$500	Grid	Campers
Goal Zero	Y (3.6 kg)	N	N	300Wh	$460	Grid	Campers
LFP 80 Portable Solar Power	Y (15 kg)	Y	Optional	1kWh	$3,695	Solar	Off-grid, military

Indirect Competition: For those who use Lead-acid batteries or diesel generators.

Product	Portable	Solar panel	Capacity	Cost	Technology
Solarator	N (415 kg)	2 x 300W	300 Ah	Unknown	Lead acid battery + Solar
Genex Solutions	Y (38 kg)	150W	60 Ah/720 Wh SLA battery	$999.99	Lead acid battery + Solar
Honda	N (67kg)	N	NA	$1,499.00	4000-Watt Gasoline Generator

GO-TO MARKET PLAN

We will validate the idea through **Alaska Airline Environmental Innovation Challenge**. Based on the feedback, we will adjust the design and/or market approach and participate in **Business Plan Competition** with the goal to generate traction and seek more industrial advisors/investors. By the end of the May, we anticipate receiving $25k cash from the prize. We will start to sell 5 modules to charities and get feedback from them. After getting feedback from the real customers, we aim to raise a $750k SEED round at a valuation of $1.5M in October 2018 for the small volume manufacturing (500 modules). We will invest the funds in tooling, manufacturing those modules. We will come back in 1.5 year at a 3 times valuation to raise $2.5M SERIES A to ensure we have stable manufacturing vendors and customers.

PROTOTYPE

PORTABLE

- Easy to transport with the two-wheeled cart
- Weighs around 30 kg (cart excluded) – Panel: ca. 20 kg; battery pack: ca. 10 kg.

VERSATILE

- A 12V DC to 110V onboard AC inverter capable of delivering continuous power
- Can configure the modules in series or parallel according to applications

MAINTENANCE FREE

- No moving parts
- No watering
- No emission

SMART

- **Battery Monitoring System** tells you how many hours/minutes left
- **Battery Management System** can extend the battery life and utilization with the help of the BMS technology from the UW spin-off company, BattGenie®.

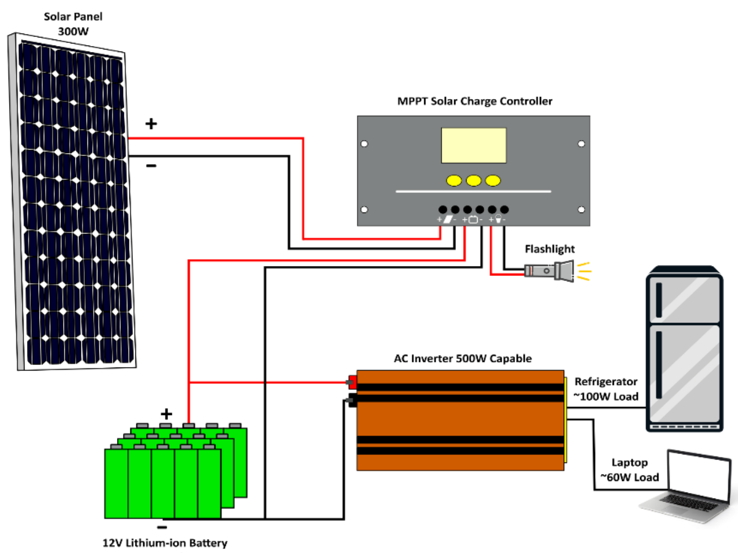
ECO

- Low toxicity
- Quiet - wildlife is not disturbed

SAFE

- Waterproof battery pack to avoid any short circuit
- Automatic shutdown protection against overload, over-temperature conditions

DESIGN DIAGRAM



SNAPSHOTS