Powercycle - Solar Cycle to Power Today

Anand Krishna Goyal
High School Student, Grade 11, The British School, New Delhi
Mentor
Ms Nimisha Arora, Senior Research Fellow, Department of Physics, Indian Institute of Technology Delhi

ABSTRACT
A photo-voltaic solar system powered cycle comprising of 150W panel, a 20AH Li-Ion battery, a charge protection circuit, and a brushless DC motor (250W). An experiment was devised to collect data regarding optimal geography and conditions for solar cycle's usage, per caloric savings. The cycle's viability as a daily mode of transport is discussed. With a solar powered electric motor assisting most of a day-time commute trip, the PowerCycle could possibly solve three major problems of energy, transport, and hunger in rural India.

Keywords: Solar Power, Power cycle, Solar Cycle, Energy Efficient Transport, Rural Transport

INTRODUCTION

Photo-Voltaic solar cells have seen a massive increase in both utility and efficiency in the past decade. The gross cost, $/Watt for solar panels has gone from $3.69 to $2.98, including all overhead costs of a full working system. The individual parts of the module can be recycled, this includes up to 95% of certain semiconductor materials as well as the glass or significant amounts of ferrous and non-ferrous metals. Solar is by far the cleanest of the renewable energy source of today, as it far outperforms hydrogen in efficiency, and is much more feasible than water or wind. Due to affordability and modularity, PV solar cells are already set up around more and more homes and offices each year.

In rural as well as parts of urban/developed India, the use of bicycles is observed often as a daily mode of transport for people, mostly the urban poor. In 2008 it was recorded that large cities such as Delhi see upwards of almost 30 Lakh trips. However, with around 1.7 Crore cycles being sold all over india in the year 2017-2018, it can easily be concluded that in a developing country such as India, there will be a large demand for cycles due to their low costs and ease of maintenance.

One important parameter which has been used consistently for defining poverty line relates to nutrition, the energy intake criterion in particular. As of now, the minimum dietary energy requirement norm, as set out by the Government of India (GoI) is 2400 kcal per person per day in the rural sector and around 2100 kcal per person per day in the urban sector. With economic growth and development involving structural and technological changes, observed consumption patterns have changed. This reflects changes in minimum nutritional requirements of populations. According to a report published by the National Sample Survey (NSS), average inflation adjusted monthly expenditure of households between 1983 and 2009-10, increased by 28% but calorie intake declined by 16% in rural India. Additionally, even as real expenditures and incomes have increase, average calorie intake has continued to decline over time. This clearly presents a puzzle, as the pattern suggests that while real per capita expenditure increases, average calorie intake move in opposite direction in rural India. There have been a variety of explanations put forward by theorists to explain this phenomenon. One of the major reasons cited is of declining calorie needs due to reduced physical intensity of work and improved epidemiological environment. Thus, less physical labour by the poor is expected to lower the calorie intake or food consumption thereby resulting in less per capita expenditure. The Power Cycle greatly reduces the physical labour required for cycling, which can reduce consumption and lead to economic gains for the individual who is using solar cycle instead of normal cycle.

Hypothesis

The hypothesis for this experiment was to determine if, under the proper conditions, the PowerCycle could viably save the time and energy of a cycle/on-foot commute, and thus possibly resolve problems in the energy, transport, and nutrition sector especially for the poor.

Materials

The PowerCycle's design has its ingenuity in its simplicity. The list of materials is as follows:

Table 1: Materials Required

Number	Item	Price (INR)
1	Bicycle	3808
2	PV Panel 150W, 24V	5040
3	Charge Controller 10A	420
4	BLDC Motor 250W	7670
5	Li-Ion Battery 20AH, 24V	8024

Total : 24,962 INR

Design

It is fabricated from a basic steel frame cycle, with additional steel bars to add structural and mounting support to a 150W PV solar panel as a kind of a roof. Some key specs for the panel are:

Table 2: Cycle Motor Specifications

Max Power (Pmax)	160Wp
Open Circuit Voltage (Voc)	43.30V
Short Circuit Current (Isc)	4.50A
Voltage at Max Power (Vmp)	36.50V
Current at Max Power (Imp)	4.40A

While at first some of these design choices may seem as heavy and far too simple, the basic truth about solar is that for it to actually make an appreciable difference to the rider in terms of power generated for use by the hungry 250W brushless motor, only a panel of this size could be used. The panel is also placed at an optimized angle directly on top of the rider to also provide shade under harsh sunlight. The motor feeds torque directly into the rear wheel axel for the most efficient power delivery possible with this setup.

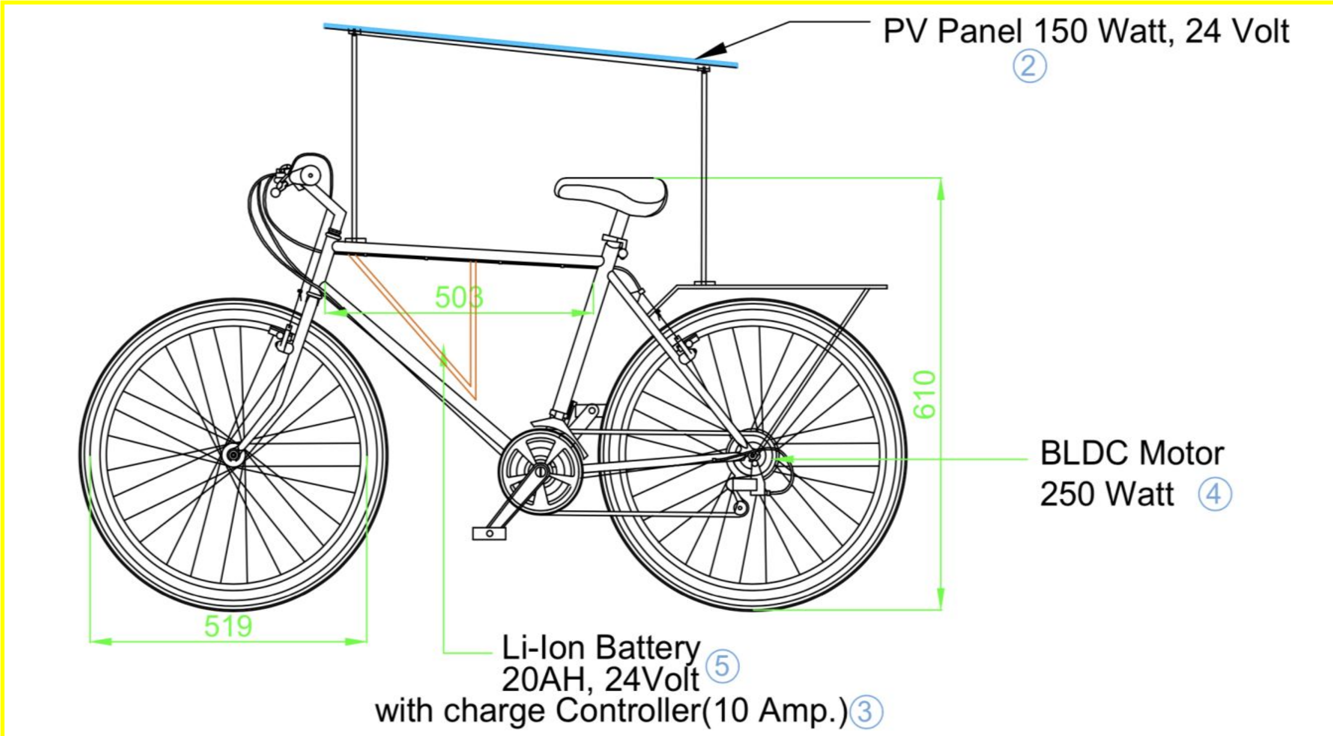


Figure 1: Solar Cycle Design

Another design choice would be the placement of the Li-Ion Battery and the charge controller. As seen in the PowerCycle's blueprint above, these components are placed in front of and below the rider. While mounting the battery above the rear tire would be far easier and more conventional, this design choice is far better as it lowers the center of gravity providing stability, as well as is shaded from the sun which minimises risk of overheating or exploding. After live testing it was obvious that these design choices paid off, as not only did the mechanical and electronic parts of the PowerCycle perform well, the test riders also had a confidently comfortable experience.

Experiments

1. **Power generation**

To test the power generated in an actual use case scenario, a multimeter was used to log the power readings of Voc and Isc of the solar panel as the cycle was moving. These were recorded 3 times a day for the period of one hour, with data being logged every minute (2 x 60 data points), with a 4 hour interval (8AM, 12PM, 4PM), to have data about power generated not just at noon, but also around other peak commute times when the cycle would see use (120 x 3 data points). This experiment was also carried out in two different geographical spaces of a urban and a rural setting (360 x 2 data points). Finally, this experiment was also repeated for both sunny and cloudy days to ensure that the cycle wouldnt become obsolete weight to the rider's daily commute. Therefore a total of 720 x 2 = **1440 data points** were analysed. The key variables here are time of day, weather conditions, and geographical conditions (shade from trees, buildings, etc). The control here could be the test run at 12pm on a sunny day in an urban environment.

Below is a table of all the average values for each time and condition. All Voc values are in Volts, and all Isc values are in Amps.

Table 3: Power Generation

		Urban		**Rural**	
		Cloudy	**Uncloudy**	**Cloudy**	**Uncloudy**
8AM	**Voc**	39.3328	39.0639	39.3770	
	Isc	1.3256	1.0268	1.3231	
12PM	**Voc**	39.1689	39.4131	39.9375	39.1385
	Isc	2.5770	2.1184	1.0248	1.6792
4PM	**Voc**	39.5689	39.4617	37.2803	38.7918
	Isc	0.4849	1.3049	0.2561	1.3349

This data would allow us to construct a power curve (I vs V), which would be different from the one made by the manufacturer as the conditions of the PowerCycle's operation are far from STC due to its utility and practical use. Load balancing and Vmp and Imp were not considered due to this reason too, as the charge controller system would always give the same resistance anyway and thus never reach the same efficiency as the manufacturer's rating or even if the same system was installed in a stationary place. Instead, we can plot Amps vs Time to see how in an actually real situation the PowerCycle would perform, as voltage remained largely the same as the average. Below are the graphs for the same.

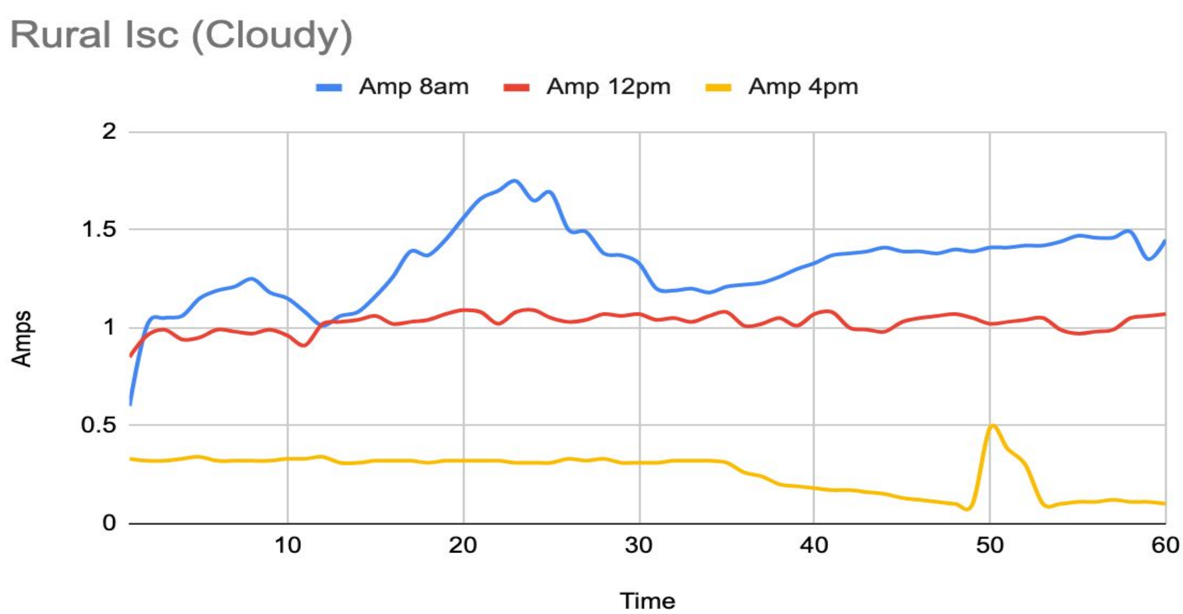


Figure 2: Isc Reading in Rural, Cloudy Setting

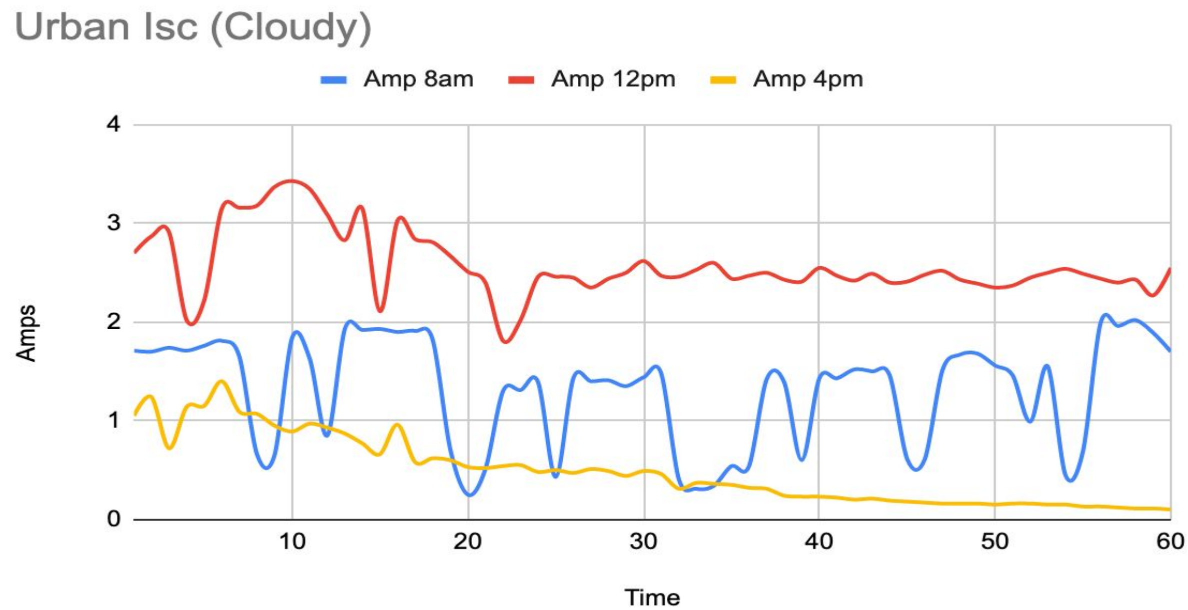


Figure 3: Isc Reading in Urban, Cloudy Setting

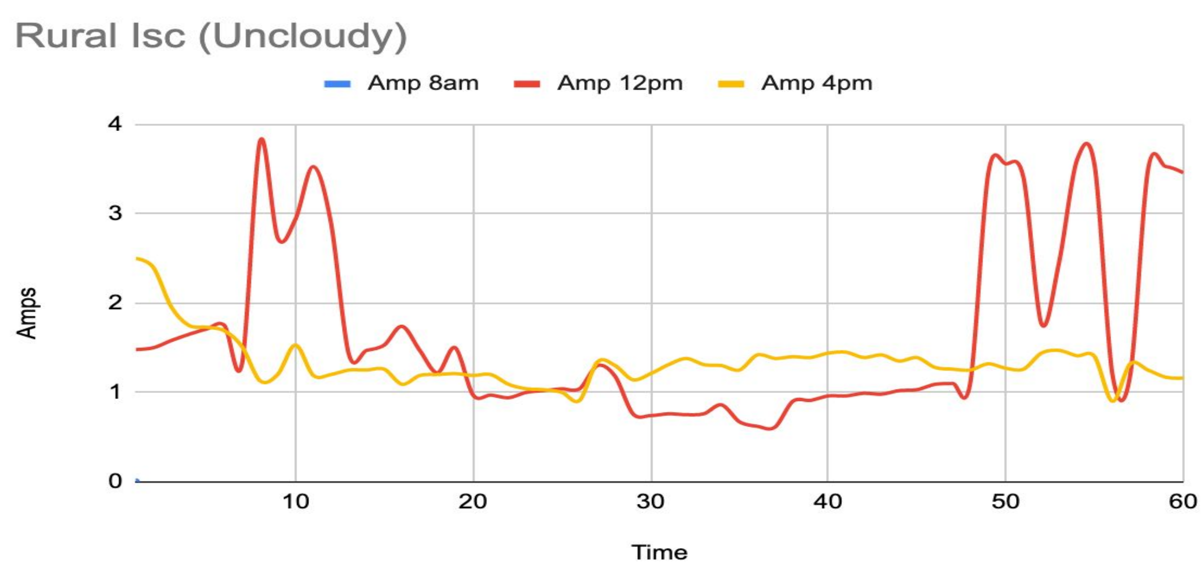
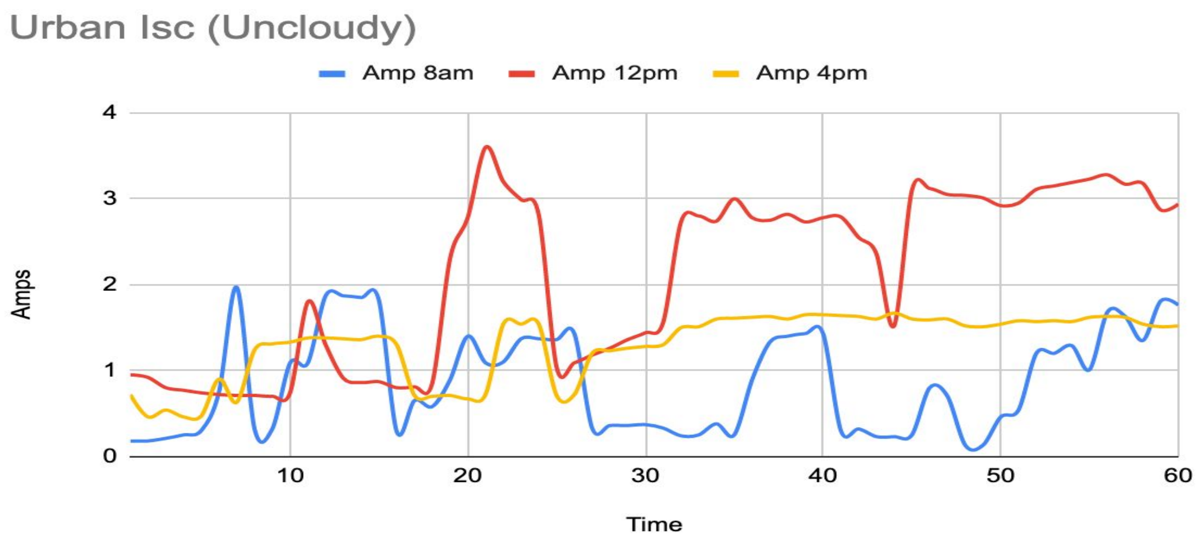


Figure 4: Isc Reading in Rural, Un-Cloudy Setting

A few very key observations can be made from these graphs, firstly about the reason for the average power being generated being lower than the manufacturer's specifications. We can clearly see large amount of fluctuations in the data, which makes sense when we consider the fact that unlike a traditional 45deg roof mounted solar array, our panel is much closer to the ground and always moving and so is bound to run into problems such as shade from trees, buildings, etc. This was the reason the experiment was done at different times as well as different environments, as even without testing anyone would know that optimal use of a PV panel is at noon. With this experiment though it can be seen that despite having conditions stacked against it, the PowerCycle can perform well enough to carry out its primary function to assist bicycle riders and generate enough power.

Figure 5: Isc Reading in Urban, Un-Cloudy Setting



Further tests also included a general time test for **fully charging** the battery (20AH), which came to **2 hours** on a sunny day.

NOTE: As mentioned previously, the PowerCycle was designed to prioritise user experience and actual benefit over raw power generation, and so all results should be viewed with that in mind.

2. **Power savings (Rider calorie saving)**

The second major test about the PowerCycle's utility revolved around how much energy could it directly save a rider. For this experiment, the PowerCycle was ridden from one point to another on a straight path on a single full charge. This distance covered was recorded and came out to 12.6km. With this, we can calculate exactly how many calories would have been spent if the trip was completed by a cyclist manually.

Distance = 12.6km
Speed ~20km/h (Top speed, saw minor fluctuations)
Time = 21.6
Weight of cyclist = 84kg
Weight of the PowerCycle ~ 50kg
Rolling resistance coefficient C_r = .005 (Cycle tire)
Air resistance coefficient C_w = .9
Frontal surface area A_f ~ .6m^2
C_w x A_f = 0.54m^2
Air resistance $F_{air} = ½ \times \rho \times v^2 \times C_w \times A_f = 10.8N$

Rolling resistance $F_{rol} = m_{tot} \times g \times C_r = 6.6N$
Energy delivered per minute $E = F_{tot} \times v \times t$ (t = 60s), = 1.4kcal/min (5.8kJ/min)
Energy "burned" per minute = 11.4kcal/min (47.7kJ/min) (At this speed, we assume 12.1% efficiency of cyclist as per sources)
∴ Total energy delivered E = P x t = 52kcal (218kJ),
∴ Total energy consumed (burned) = 431kcal (1805kJ)

From this performance test, we can conclude that the PowerCycle would be able to cover a 12.6km trip at 20km/h, and save **431kcal** for that trip. This is very important as that amount of calories is 18% of the daily requirement of a person in rural India (2400 kcal). This would also work for the trip back, as the cycle **fully charges** under the sun in **2 hours,** effectively **saving 36% of a person's daily calorie requirement**.

With all this information, we can infer a daily scenario use case for the PowerCycle. A worker in a rural area would start his day with a fully charged PowerCycle waiting for him outside his front door, commute to his work at a fairly manageable yet fast enough speed, show up without having used any of his own energy and ready to start his work day, work his shift while the PowerCycle charges passively throughout the day. At the end of his shift/work day, he would simply sit on and ride his fully charged PowerCycle back to his family where he would leave it outside to charge for the next day, and the virtuous cycle would repeat.

Possible challenges & feasibility

The PowerCycle just like any other daring new project does face a few setbacks and obstacles, but none that cannot be resolved with time and ingenuity.

- **Strength:** With steel reinforcements and a balanced weight distribution, the PowerCycle is not much more at risk of damage than an ordinary cycle. Obviously with a solar panel over your head you have to be a little more careful but it won't compromise use on biking paths.
- **Efficiency:** As observed in the experiment, the PowerCycle generates enough power to power the motor for practical use and this would only get better with time as more efficient PV solar panels are made.
- **Cost:** Perhaps the biggest challenge for the PowerCycle before it can help thousands of people would be its total cost. This issue however diminishes significantly in the bigger picture, as economically the PowerCycle would also be saving money. It would be generating and storing power even when not in use, and so could very easily be used to power a poor and remote village home. Further, by saving the rider energy, the PowerCycle would also stand to save money in calorie expense. With these two key savings along with economic prosperity to the actual rider, allowing them to commute to work over longer distances, the PowerCycle would eventually pay for itself.

FUTURE PROSPECTS

Like any great innovation, the PowerCycle has a broad horizon for expansion and improvement, with possible features such as:

- Using in built battery to run low power essential devices in poor households such as LED lights, etc.
- All aluminum construction for a cheaper and lighter design.
- Improvements in both battery and solar panel technology over time for better performance per rupee.
- Government or NGO collaborations for subsidising cost to poor consumers.
- Additional seat for carrying kids to school in rural areas without public transport.

CONCLUSION

It is visibly obvious to us now that the world continues to face multiple crises of hunger, poverty, energy, and climate change, and India is no exception to any of those. Over time, the problems mentioned will only get worse and the time to fix them will only slip away. The PowerCycle has demonstrated its ability to help out with each of those issues for at least one person and indirectly their family, and help bring people a better life. With this fascinating use of pre-existing technology, poor laborers, farmers, or anyone you have seen ride a cycle for a daily long commute in harsh weather, even after a long work day, will finally be able to focus on self-economic growth instead of simply trying to survive. The concept of a solar cycle is not unheard of before, but far too many of them only focus on it as a consumer product with form over function or being far more expensive for lower or similar performance, or not being easily manufacturable. The PowerCycle's aim is far beyond its engineering. Its goal is to be a readily deployable and reliable tool to rural or even urban poor households, helping solve daily problems which are a privilege to us.

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