Grüezi YouTubers. Here is the guy with the Swiss accent. With a new episode around sensors and microcontrollers.

We all have our gadgets, and all of them need some electricity. Usually, we use batteries or a power supply. Today I will start a small project to use solar energy to power our devices during the whole year. If we want to do so, we have to answer the following questions:

1. What size the solar panel has to be in order to power our device
2. What size of battery we need to survive times without sun?

These questions lead to the next row of questions:

1. How much energy can we harvest in one year?
2. How much energy does our device use during this year?
3. How is the energy distributed throughout the day and through the year?
4. How long do we want to survive with reduced or without sun?

Many questions. So, let’s start! But wait: A I have to warn you! This will not be easy stuff. But saving the planet with green energy will never be easy!

We will use a simple design: A solar panel, a “charging unit”, a battery, and our ESP8266

How much energy can we harvest in one year? This depends mainly on three factors:

1. The location where your solar panel is placed (and its direction towards the sun)
2. The size of the panel
3. The efficiency of your circuit to transfer solar energy to your ESP

The “location question” can be answered by looking at this map. If you want to know it more precise, you can go to the “solargis.com” page: I live near Basel and we get about 1200 kWh/m2.of solar energy per year.

What does this mean in relation to run a ESP8266 without deep sleep, which uses about 100 mA on 3.3 volt, which equals 0.33W?

The year has 8760 hours. If we divide the yearly energy by these hours, we get the Watts: 1200 kWh/8760 h equals 137Watt/ m2. This is the total radiation from the sun. Unfortunately, solar cells only have an efficiency of about 15%. So, we get about 20 W/ m2 out of the solar cell. This is further reduced by the efficiency of our charging device and the loss of the battery charging process. Let’s assume, we lose another 33%. Then, we get a usable energy of only 14W/ m2 or 1.4 mW/ cm2, because 1m2=10’000cm2.

With these two numbers, we can calculate the size of the needed panel: 0.33/14= 236cm2, which is around 15 x 15 cm. So, this panel should be sufficient to power my ESP8266 the whole year round. Great!

But, let’s quickly calculate the other way around: The supplier of this panel writes, that it delivers 4.5 watt. And our ESP only needs 0.33 watt. This is a big difference. So, do you know, where I made the error in my calculation? You do not find an error?

You are right: There is no error (at least, that is, what I hope), just an additional problem: The sun does not shine all the time. It fluctuates during each day, and also over the month. And the specifications of the panel only show us the peak power, and not in Switzerland, but somewhere else with lots of sun! And maybe it is even a little bit exaggerated, as usual with the specs on Aliexpress…

We have to continue our calculations. But because this is boring, and the sun shines outside, we first do some tests:

I bought a couple of small solar panels and one bigger one and want to do some tests now. The test setup is simple: I place the solar panel into the sun and connect it to my new electronic load.

An electronic load is a simple device: It behaves like a variable resistor plus a voltage and an Ampere meter.

The only difference is, that an electronic load automatically adjusts the resistor to either a constant current, a constant voltage, or a constant power. And it automatically calculates and displays the power, which is handy for these experiments.

Filming today is not easy, but I hope, you can see the numbers. I start without any load and measure the “open voltage” of the solar cell of 6.5volts. If I start to draw current, we see, that the power increases while the voltage drops a little. Suddenly, the voltage drops and we lose most of the power. If I try again with smaller steps, we see, that we can draw a maximum current of about 550 mA and get 2.8 Watt output. As soon as I draw more current, the voltage drops dramatically. Why is that?

This is a characteristic of Solar Panels. Here is the result of my measurements of the 16x16cm panel, and here is the theoretical curve. They match pretty good in shape.

And here, you see the expression MPP, or maximum power point. In order to get maximum power out of the panel, we always have to operate at this point. Unfortunately, this point moves if the lighting conditions of the panel change and we have to find it again. There are special devices available which do exactly that. They are called MPPT or maximum power point trackers. I will look at this topic in a future video.

You can buy monocrystalline or polycrystalline cells or panels. Monocrystalline silicon is used for most our electronic chips, and panels made from this material, theoretically have a higher efficiency, which means, they should produce more electricity with a defined light intensity. They should also be more expensive than Polycrystalline modules. In reality, the differences are small and we should not bother too much about that.

You can easily see the difference between mono or poly modules, as they are usually called: The mono modules are darker, nearly black and the polys are grey.

You find the results of a sunny Sunday afternoon work in this chart. Be aware that the results are not completely dependable since smallest clouds can have an influence and I had to do my measurements in series , not in parallel. And in the middle, I had to make a stop to drink a beer, because the weather was really hot…

We see, that I got a power per cm2 between 5 and 10 mW. We also have to consider, that not the whole area of the panel is used to convert light. There are also areas for connecting the different cells, because one cell only produces around 0.5 volts.

So far, we know how much energy we can harvest over the whole year, and also during a sunny day. Let’s now continue to find out the real size of the needed panel, and the size of the battery big enough to power our ESP safely during the whole year.

Here in Basel, we get 2.6 times less solar irradiance in December than in July. And the sun disappears every night for a few hours. And, especially in winter, we experience bad weather and sometimes, we do not see the sun for days.

This creates three additional problems for our project:

* Make sure, our device survives the long winter nights
* Make sure, our device survives a period of bad weather without sun
* and make sure, our device survives the whole month of December

Of course, these problems differ in different location. This is, why I show the formulas and the sources of my data. With this, you should be able to make your own calculations.

The first problem can be solved with a battery, which is charged during the day and discharged during night. Let’s quickly calculate the size of this battery for December.

Day length is about 8.5h and night therefore 15.5h. So, our battery has to be: 15.5h x 0.1A= 1.6 Ah. This is less than the capacity of a 18650 cell.

Now the second problem: If we assume bad weather without sun for 2 weeks, we need a bigger battery: 14 daysx24hx0.1A=34 Ah. Here, we need about 14 18650 cells in parallel.

If this is the worst case, we know now the size of the battery. The next thing is the calculation of the size of the solar panel. We can assume, that the bad weather conditions are included in our average values for a particular location. So, we can design our solar panel for the worst month of the year. We take our 1.62 kWh/m2 per day average solar energy for December, divide it by 24h, and multiply it by the 10% to get the electrical energy. It is 6.7W/m2

Because we need 0.33W, we need a solar panel of 448 cm2 to harvest enough energy to drive our device throughout December. These numbers are for an average year. But these days, we never have average years. So, maybe we have to add a little to account for that and we end up with a panel size of 25x25cm which equals 625 cm2. Pretty big!

So, to summarize, we can make the same calculation for Dubai, were it is quite hot in summer. First, we search the radiation per m2 for the worst month of the year. It is 3.68 kWh/m2/day. Then, we divide this value by 242, and divide the power needs of our device by this number, and we get the size of our panel: 197 . The battery size can be smaller, because we do not need to anticipate 14 days of consecutive bad weather. Let’s assume 5 days. The day is10.5 hours long and therefore, the night, 13.5h. So, the size of the battery is only 12 Ah, which is about 5 18650 cells.

Some of you might remember my videos about sleep modes. If we are able to reduce the power consumption of our device by a factor of 10, our battery size is reduced to one 18650 for Switzerland, and our solar panel to the size of 10x10 cm. And if we would be able to reduce power consumption even more, for example by using LoRa instead of WiFi, the battery and the panel size would be reduced even more. Great!

Today, we calculated the size of a solar panel and the battery for a year-long usage. In one of the next videos we have to concentrate on the charging device between the Solar panel and the ESP.

This device has to fulfill quite some needs:

1. Find and keep the MPP under all lighting conditions to get maximum power from the solar panel
2. Make sure, we have a constant voltage of 3.3 volt for the ESP
3. Switch charging of battery off if it reaches 4.2 volts. This is particularly important because we had to design the solar panel for the worst month of the year. In all other months, we will have far too much energy
4. Protect the battery from too low voltage
5. Signal low voltage to the ESP in order to make it possible react accordingly. E.g. send a message out

I hope, this video was useful or at least interesting for you. If true, then like. Bye

<http://solargis.com/assets/graphic/free-map/GHI/Solargis-Switzerland-GHI-solar-resource-map-en.png>

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<https://www.timeanddate.com/sun/switzerland/basel?month=7&year=2017>