DESIGN PROPOSAL FOR A PHOTOVOLTAIC-DRIVEN PUMPING SYSTEM FOR A 4000-LITER FILTER SYSTEM

A STUDY PROJECTS
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JJSF Fellowship 2024, Rainwater Circulation and Aeration Team

Title:	Photovoltaic Pumping for Filtration
Revision:	Preprint
Issues:	Adding some detailed information about the system and its component
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Reviewed by:	Peer Review pending
Date:	May 29, 2024

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1 Project Overview

This proposal outlines the design and implementation of a photovoltaic-driven pumping system to support a 4000-liter filter system. The system aims to lift water from phytoremediation tanks to a specified height, ensuring efficient filtration and additional utility functions. The design considers daily operational requirements, system sustainability, and energy efficiency.

1.1 System requirements

Filtration Capacity:

The filter system has a capacity of 4000 liters.

Daily water input requirement is up to 1000 liters. And an additional 200 L for Shower

Pumping Height:

The system needs to lift water to a height of 3 meters.

Flow Rate:

Although no specific flow rate is mandated, the system design must accommodate the total daily irradiation during the least favorable day to ensure reliable operation.

1.2 Objectives

The photovoltaic pumping system is designed to harness solar energy to power a water pump, ensuring an eco-friendly and sustainable operation capable of lifting water to a height of 3 meters. Water will be introduced from the top of the tank to promote sedimentation and enhance the filtration process. The pump will have multiple functions, feeding the filter and supplying water to a shower heater. Additionally, the system will generate surplus energy, sufficient to charge electronic devices like phones or power lighting.

System Components

Photovoltaic Panels: Selection of solar panels with adequate capacity to generate sufficient power during the worst irradiation conditions.

Water Pump: A DC water pump compatible with the photovoltaic system and that has the according requirement (Maximum height and average flowrate) .
Energy Storage: Batteries to store excess energy generated during peak sunlight hours.

Control System:A controller to manage the distribution of power between the water pump, energy storage, and auxiliary devices.

We also have the following diagram that shows the proposed design for the system,

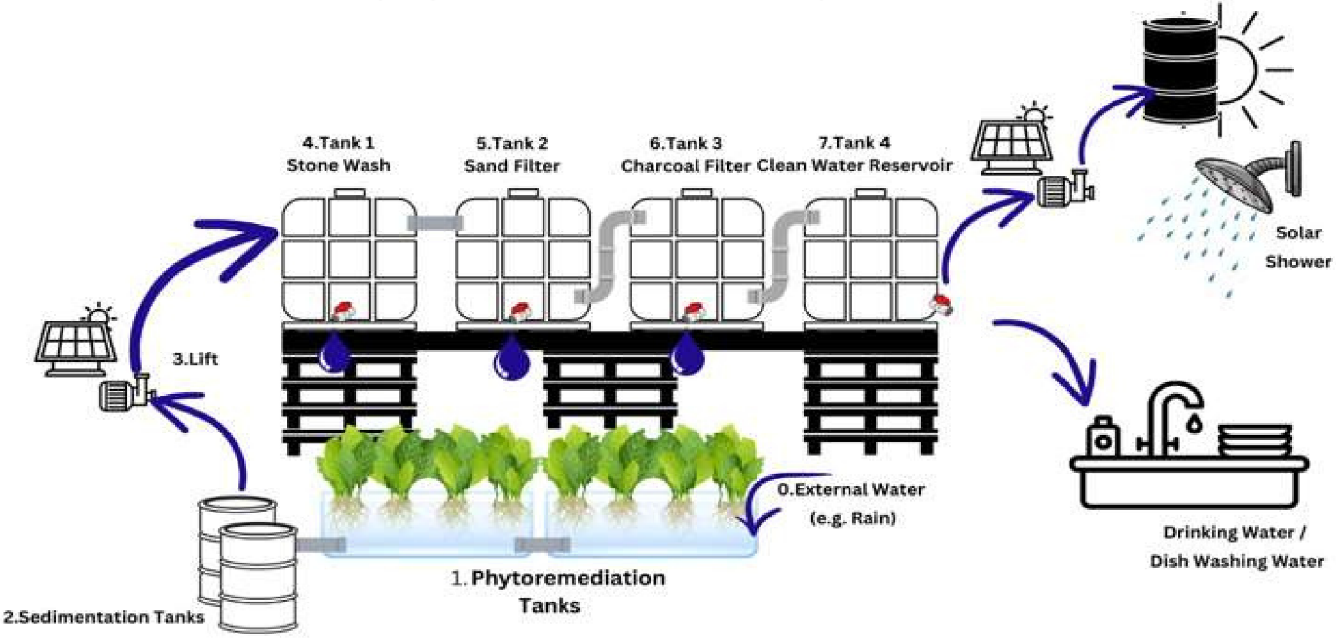


Figure 1 Illustration of the filtration system

2 Meteorological data

We agreed to dimensionate the System using the worst case in german in terms of daily irradiation and according to the data from Meteonorm we have the following graph :

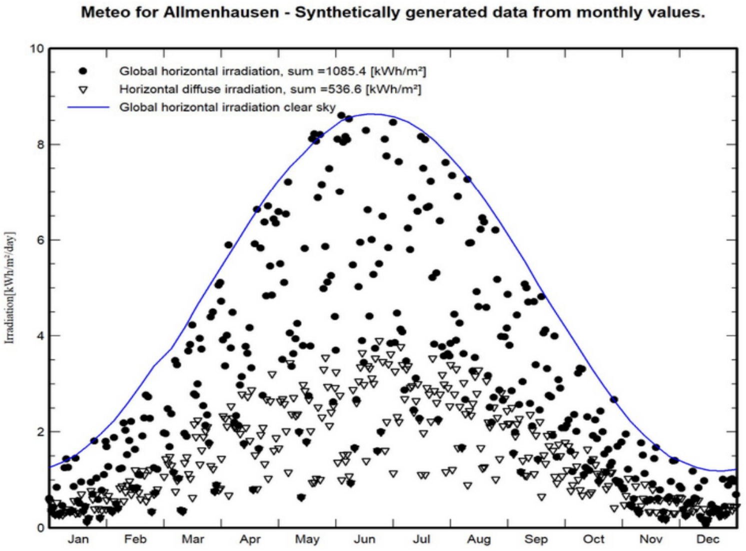


Figure 2 Irradiation data in German

It illustrates that the average irradiation for a day is between 2 kWh/m2/day and 4kWh/m2/day

The calculation of the average irradiation gave a 2.97 kWh/m2/day

From other source [1] we also have the following irradiation :

- Max : 3.4 kWh/m2/day
- Min : 2.6 kWh/m2/day

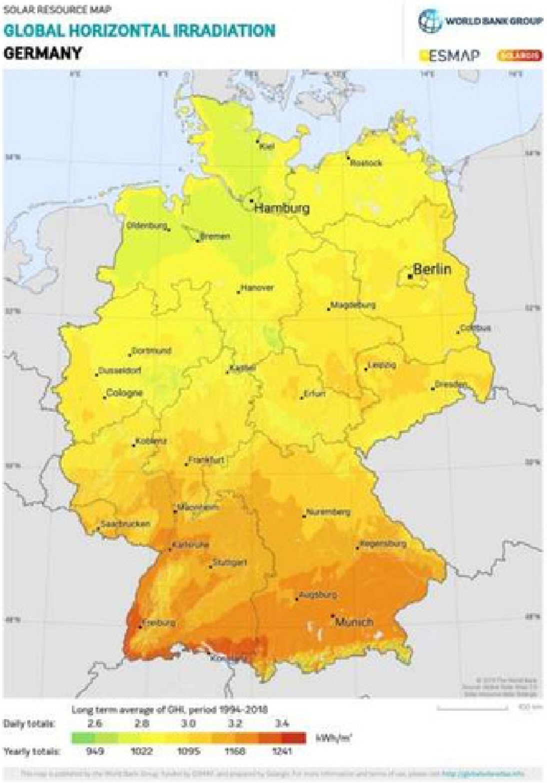


Figure 3 Average irradiation in German

3 System sizing baseline

We then use the following formula to get the appropriate Energy that the pump should have to lift the water and the relative solar panel that goes with it

$$E = \frac{V * mH * 2.725}{np}$$

Where

- E represents the energy required in Watt-hours per day [Wh/d]
- V represents the volume in cubic meters per day [m3/d] (~ 1200L)
- mH is the manometric height (sum of the heights: NS+ ND+ Loss) in meters [m] (~ 3m)
- 2.725 represents the hydraulic coefficient
- np represents the efficiency of the pump (~ 0.4)

The pump should then get the necessary power to pump during the day where the sun is available (~ 3 kWh/m2/day)

The power the pump should then be:

$$P = \frac{E}{n\mathrm{h}}$$

Where:

- P represents the power of the pump in Watt [W]
- We assume the next value :

After the calculation, we have the following result :

- E= 27Wh
- P=9 W

4 PV sizing

To size the PV system, we should take into account the daily solar irradiation, which depends on the region, as well as the efficiency of the pump and the PV, which varies with the type of materials used.

$$Pp= \frac{E}{Dr \times K}$$

Where

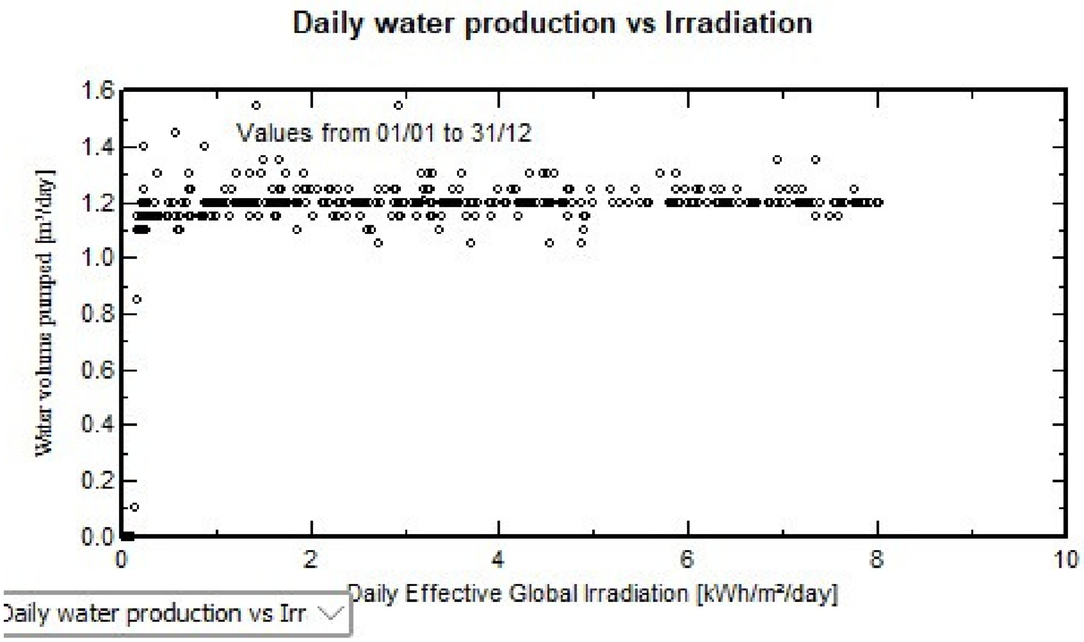
- Pp represents the total panel power to be installed in Watt-peak [Wp]
- E represents the energy required in Watt-hour per day [Wh/d]
- Dr represents the daily radiation in Kilowatt-hour per square meter per day [kWh/m2/d] (~ 3 kWh/m2/day)
- K represents the efficiency coefficient of the photovoltaic array (depending on the type of panel support and operating conditions)

We need a PV of only 12 W if we want to lift the water

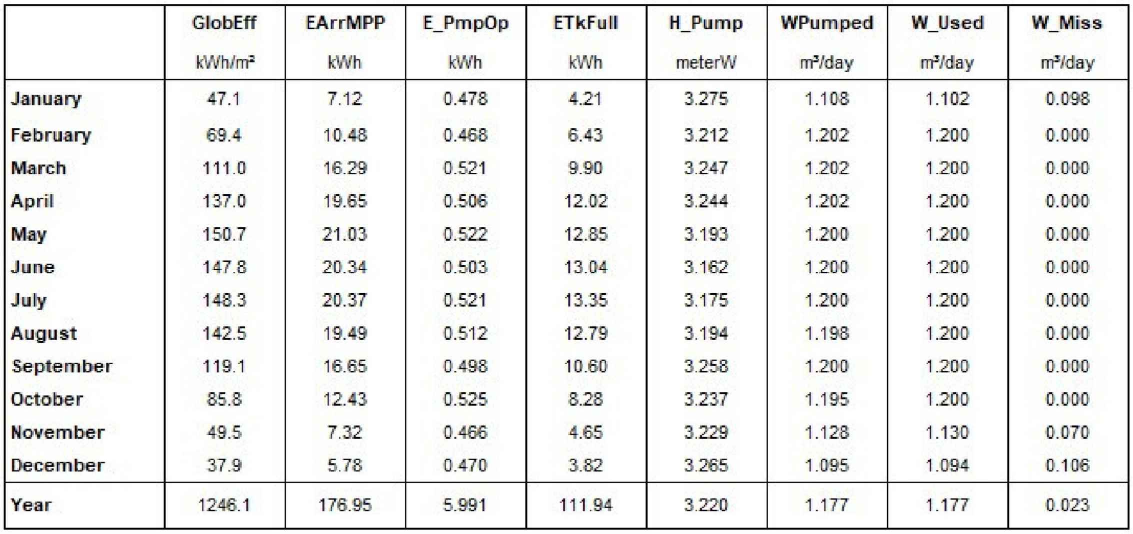
5 Simulation with PVSyst

The Simulation with PV syst give a detailed sizing of the system that take into account many parameters that may be unknown for some materials and situation but it can give an estimation of what we may need.

We did the Simulation with a 150 W Solar panel, and 50 W , 2-30 m Head Pump that has a 2m3 – 0.8 m3 Flowrate and also a MPPT controller
There is an operative threshold which is lower than 0.2 kWh/m2/day and the missing water is 1.9%



The Monthly result is shown in the table Bellow where the daily average of missing water is 0.1 m3/day



	GlobEff kWh/m²	EArrMPP kWh	E_PmpOp kWh	ETkFull kWh	H_Pump meterW	WPumped m³/day	W_Used m³/day	W_Miss m³/day
January	47.1	7.12	0.478	4.21	3.275	1.108	1.102	0.098
February	69.4	10.48	0.468	6.43	3.212	1.202	1.200	0.000
March	111.0	16.29	0.521	9.90	3.247	1.202	1.200	0.000
April	137.0	19.65	0.506	12.02	3.244	1.202	1.200	0.000
May	150.7	21.03	0.522	12.85	3.193	1.200	1.200	0.000
June	147.8	20.34	0.503	13.04	3.162	1.200	1.200	0.000
July	148.3	20.37	0.521	13.35	3.175	1.200	1.200	0.000
August	142.5	19.49	0.512	12.79	3.194	1.198	1.200	0.000
September	119.1	16.65	0.498	10.60	3.258	1.200	1.200	0.000
October	85.8	12.43	0.525	8.28	3.237	1.195	1.200	0.000
November	49.5	7.32	0.466	4.65	3.229	1.128	1.130	0.070
December	37.9	5.78	0.470	3.82	3.265	1.095	1.094	0.106
Year	1246.1	176.95	5.991	111.94	3.220	1.177	1.177	0.023

- W_missed : Missing water
- W_Used : Water used
- WPumped : Water pumped
- EArrMPP Energy at Maximum Power Point
- ETkFull : Unused Energy because the tank is full

We have a maximum of 13 kWh of unused energy each month that is equivalent of an average of 400 Wh/ day . this energy can be stored in a battery of 12V and 50 Ah and can be used for other usage

6 Simulation with other Load with PVSyst

6.1 Suggested Configuration

Component	Caracteristic	Comment
Solar Panel	410 W / 33 V	
Battery	12 V 100 Ah	
Controller	12-24 V 30 A MPPT	
Pump	12 V , Flowrate 0.8-2 m3/h P = 50W	Need to work about 1-2 hour to fill the tank We choose the 50W pump so we can have a flexibility when we will choose it

Then we got the following charge Profile:

From 10 Am to 2 Pm , we got the Pump working and we estimated its maximum power to 50 W

The rest is residual needs like Light and Phone charger USB , We limited the user's need during the winter because we want to prioritize the pumping system and the light in the night

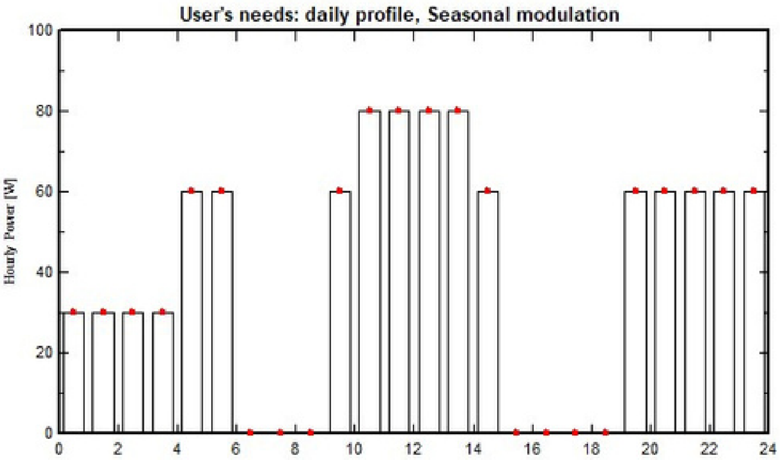


Figure 4 Summer daily profile

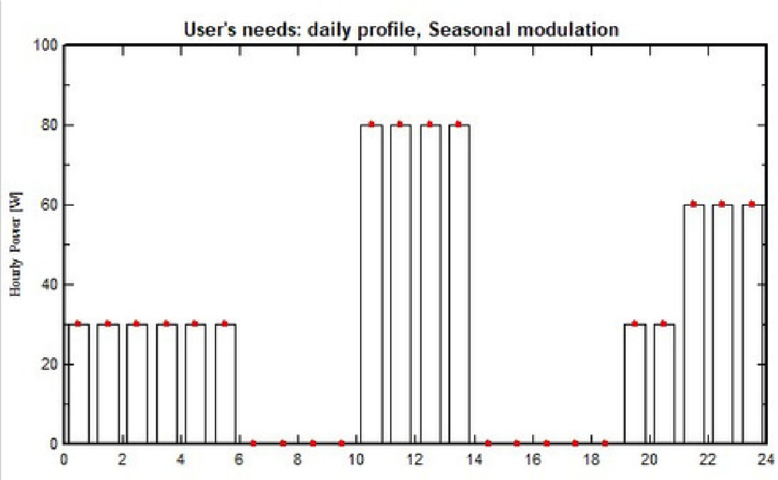


Figure 5 other Season's daily profile

After the simulation, we have the following result:

	GlobHor kWh/m²	GlobEff kWh/m²	E_Avail kWh	EUnused kWh	E_Miss kWh	E_User kWh	E_Load kWh	SolFrac ratio
January	22.7	47.3	17.03	1.23	8.79	14.15	22.94	0.617
February	39.8	69.5	25.60	6.07	2.71	18.01	20.72	0.869
March	81.6	110.8	40.31	13.68	1.27	21.67	22.94	0.945
April	124.2	136.7	49.14	21.58	0.00	22.20	22.20	1.000
May	156.7	150.2	52.78	23.15	0.00	22.94	22.94	1.000
June	164.8	147.4	50.89	16.78	0.38	29.02	29.40	0.987
July	162.0	147.9	50.90	15.12	0.00	30.38	30.38	1.000
August	137.5	142.2	48.93	13.61	0.15	30.23	30.38	0.995
September	95.1	118.8	41.67	15.43	0.00	22.20	22.20	1.000
October	57.3	85.8	30.47	5.14	0.00	22.94	22.94	1.000
November	26.0	49.6	17.49	1.31	7.02	15.18	22.20	0.684
December	17.7	38.1	13.59	0.00	10.74	12.20	22.94	0.532
Year	1085.4	1244.4	438.79	133.12	31.06	261.12	292.18	0.894

- GlobHor : Global horizontal irradiation
- GlobEff : Effective Global, corr for IAM and Shading
- E_Avail : Available Solar Energy
- EUnused- Unused Enegy (battery full)
- E_Miss : Missing energy
- U_User Energy supplied to the use
- E_load Energy need to the user (load)
- SolFrac Solar fraction (EUsed/ELoad)

We observed a missing energy range of 2 to 11 kWh per month, averaging 300 Wh per day. However, this shortfall won't impact the pumping system if we prioritize pumping. From April to October, the system operates with zero missing energy, demonstrating its high efficiency during this period.

6.2 **Solar Pumping System Diagram**

Component		Ref
Solar Panel	410 W 35V	JA Solar JAM72-S10-410-PR
Battery	12V 100 Ah	Pb Seald Gel
Controller	MPPT 500 W 35 A	SmartSolar MPPT 150/35 12 V
Pump	50 W	To be defined

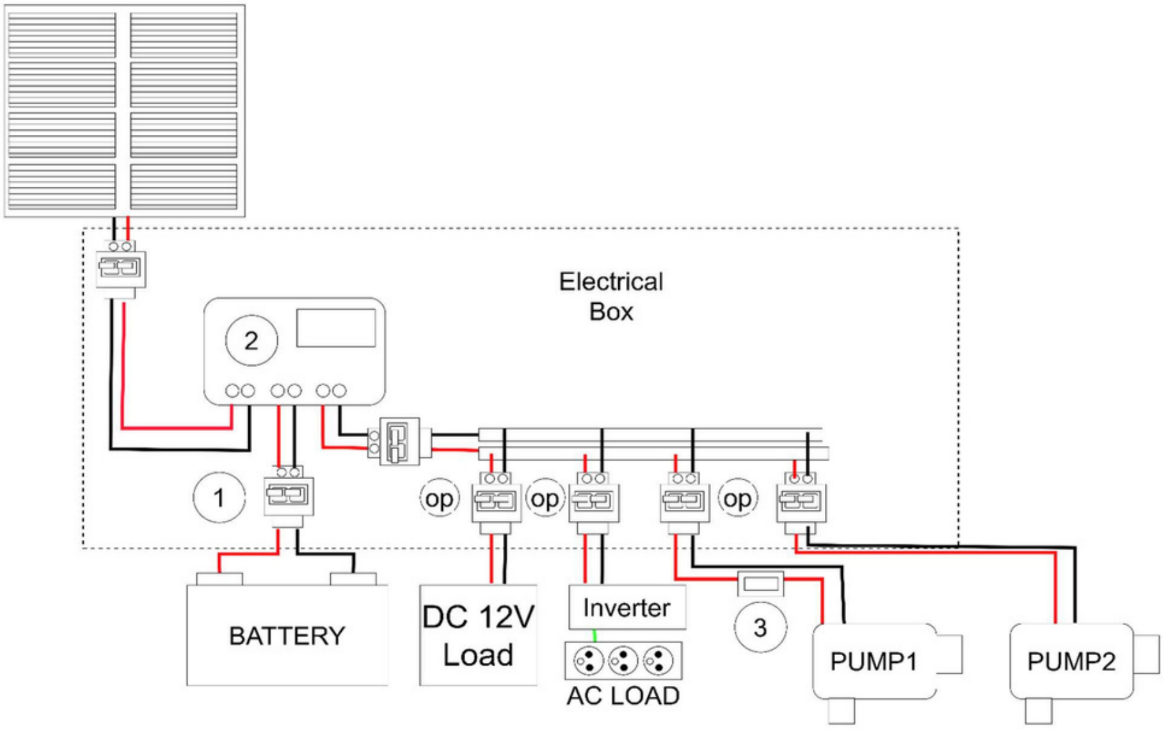


Figure 6 Illustration of the System

1- Circuit Breaker (Some of the Circuit breaker are Optional)

The Circuit breaker should have a calibre more than the flowing current and tension – for our case a 50 V 30 A will work fine

2- Controller

3- Switch (if the pump use more than 10 A it will be wise to use relay)

6.3 Suggestion

Presence of the Battery

Indeed, we don't need battery for the puping part, However if we want to store all the unused energy, it will be better to use battery to allow us to use the energy when the sun won't be available.

The battery should be dimensionate up to the needed energy during the day

$$Energy\ during\ the\ day = \quad Power\ of\ device * hour\ of\ operation$$

The capacity of the Battery is then determined by :

$$Capacity = \frac{Energy\ during\ the\ day}{Voltage * 0.6}$$

0.6 is the safety factor for voltage drop of the battery

For our case (load profile in Summer) we have a total of 460Wh that means we need a 64 Ah Battery,

We then can work with a 100 Ah Battery with few irradiation for 2 days and still got enough power if the battery was full

There are two main types of batteries used in solar power systems: Lead-Acid and Lithium-Ion. Lead-Acid batteries, including Flooded (FLA) and Sealed (SLA) types, are cost-effective and reliable, with FLA requiring regular maintenance and SLA being maintenance-free but more expensive. Lithium-Ion batteries, particularly Lithium Iron Phosphate (LiFePO4), offer high energy density, longer lifespan, and better efficiency. They are maintenance-free and, despite a higher upfront cost, can be more cost-effective over time due to their durability.

A DC System rather than using inverter for AC needs

Opting for a DC system instead of using an inverter in a solar-powered house offers several advantages. Inverters, which convert DC from solar panels to AC for household use, result in energy losses. A DC system avoids this conversion, retaining more of the generated power and improving overall efficiency. Additionally, inverters add to both the initial setup and maintenance costs, so eliminating the inverter reduces these expenses, making the system more economical. A DC system is also simpler, with fewer components that can fail or require maintenance, leading to increased reliability and ease of installation and troubleshooting. Overall, a DC system can offer a more efficient, cost-effective, and reliable solution for solar-powered homes compared to using an inverter.

The power of the inverter should be calibrated based on the total AC load it will need to support simultaneously. According to the daily usage profile, the peak load is estimated to be 80 W. However, this may vary depending on the user's habits and usage patterns. Therefore, it is essential to consider potential variations in power consumption to ensure the inverter can handle occasional surges and maintain reliable operation under different conditions. By accurately matching the inverter capacity to the anticipated load, users can optimize performance and efficiency.

A small DC Pump that meet the requirement

There are many Pump on the internet that have a Lower Power but still has the ability to pump at the needed Head and Flowrate that we want.

- A 23W 12 V DC pump with 0.9 m3/h and 5m Head :

Figure 7 example of pump

https://www.walmart.com/ip/CIVG-Mini-Water-Pump-DC-12V-Submersible-900L-H-Durable-High-Flow-Pumps-Compact-Lift-Diesel-Oil-House-Shower-Garden-Drainage-System/1462449915

- A 19W 12 V DC pump with 0.8 m3/h and 5m Head :

Figure 8 example of pump

https://fr.aliexpress.com/i/1005004528293507.html?gatewayAdapt=glo2fra

An automated system that will shut off the pump when the tank is full

The system should include an automated feature that shuts off the pump when the tank reaches full capacity. This ensures efficient water management by preventing overflow and conserving energy. By automatically stopping the pump at the appropriate time, the system reduces the need for manual monitoring and intervention, enhancing overall convenience and reliability. It can replace the swithc in the figure 5

The Choice of the regulator

There are two types of regulators: PWM (Pulse Width Modulation) and MPPT (Maximum Power Point Tracking). The MPPT regulator is more efficient than the PWM regulator but can be more expensive. Regardless of the type chosen, the regulator should have a power rating higher than that of the PV system and be capable of handling the input current.

In our scenario, we have a single solar panel rated at 410 W and 35 V, which produces a current of 11 A. We have selected an MPPT regulator with a power rating of 500 W and a maximum current capacity of 30 A. This setup ensures the regulator can manage the input from the panel efficiently.

In some cases, the system may include additional strings or series of PV panels. The configuration will depend on the input voltage and current specifications of the controller. Properly matching these parameters ensures optimal performance and protection of the PV system.

Remark : In some cases, the regulator may not have a Load output pin but only a Battery charge controller. In such systems, the load should be connected directly to the battery. The solar panels will connect to the regulator, which then charges the battery. The inverter, if used, and other loads will draw power directly from the battery, ensuring continuous power supply even when solar input fluctuates.

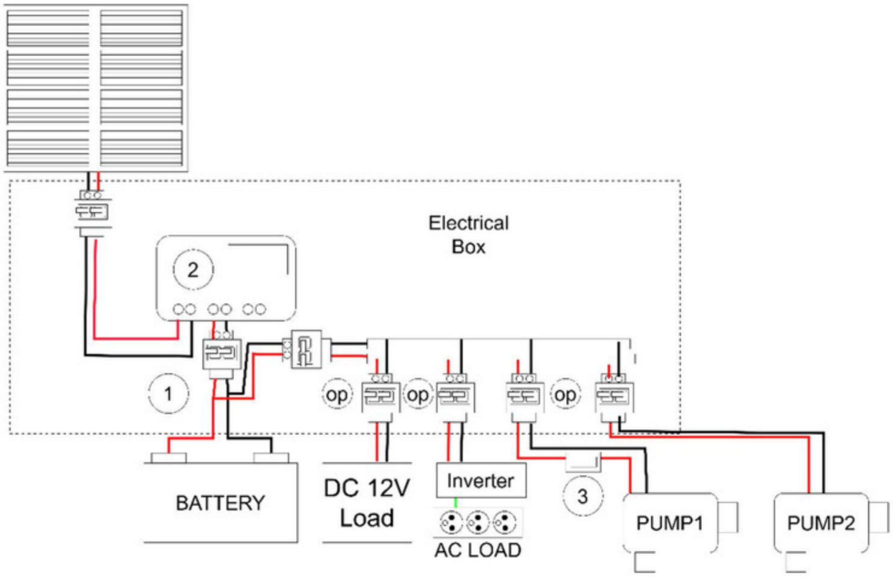


Figure 9 Illustration of the system with a controller without load Pin

Here is the summary of the system where we can use two of the 23 W Water pump to lift water for each need

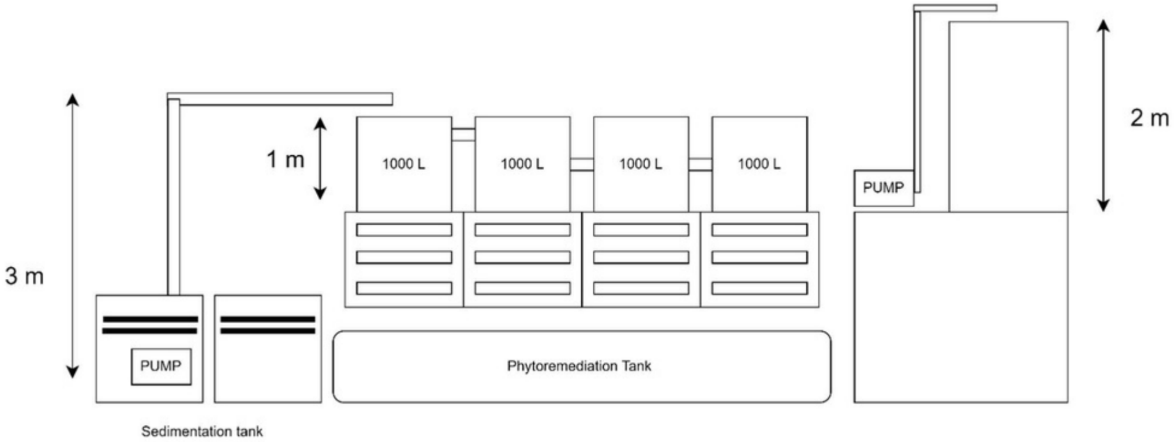


Figure 10 Illustration of the System

7 Conclusion:

In Conclusion a system that has a 410 W – 33 V Solat panel added to a 500 W MPPT Controller and a 12 V 100 Ah Battery can support two Mini Water Pump to lift the water to a 4000 L Filter with a 1000L/day Flowrate and to a shower with 200 L/day. Additionaly we can use the unused energy for lightning and phone charging or other use. This system was designed for worst case so that we can always pump during the day.

8 References:

[1] https://globalsolaratlas.info/download/germany

[2] PVsyst SA – Pompage au fil du soleil – Circuit Hydraulique

[3] Guillaume Aubourg et Jean-Marie Ily (pS-Eau), Denis Dangaix (Arene Ile-de-France). Le pompage solaire Options techniques et retours d’expériences Des repères pour l’action

[4] M.BAKRI LE POMPAGE SOLAIRE PHOTOVOLTAIQUE ,Manuel de cours, CDER