JJSF-Jacquelyn Jestine Sanders Foundation

A STUDY PROJECTS

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LISTS OF ABBRIVIATIONS

AC: Alternative Current
DC: Direct Current
GHI: Global Horizontal Irradiation
HP: Horsepower
JIRAMA: Jiro sy Rano Malagasy
JJSF: Jacquelyne Jestine Sanders Foundation
MPPT: Maximum Power Point Tracking
PV: Photovoltaic
PWM: Pulse Width Modulation

LISTS OF DIAGRAMS

LISTS OF FIGURES

LISTS OF TABLES

Abstract

This Ankatso tower ensures the water supply for the university students. JIRAMA trucks regularly deliver the necessary water. This report takes an approach aimed at providing comprehensive details about this tower, highlighting its crucial importance in the residents' daily lives. Additionally, it offers detailed calculations to effectively size the components of a solar pumping system designed to continuously supply water to the storage reservoirs, thus ensuring a constant and sustainable water availability for the university community. We have also observed a tower where rainwater is pumped using energy from solar panels to fulfill the building's water requirements. We utilized both towers as inspiration for our design.

Figure 1: Real photo of the tower (Ankatso 1)

Figure 2 : Photo of the tower at the vaccination Ankatso

1 Design of the Tower:

The tower is a concrete structure that supports two storage tanks at different heights. Each storage tank is supplied independently and they have different volumes. In this image, it is even possible to install two more tanks on the lower levels. This means that the tower can simultaneously support four tanks, but the lower the tank is positioned, the lower the pressure will be.

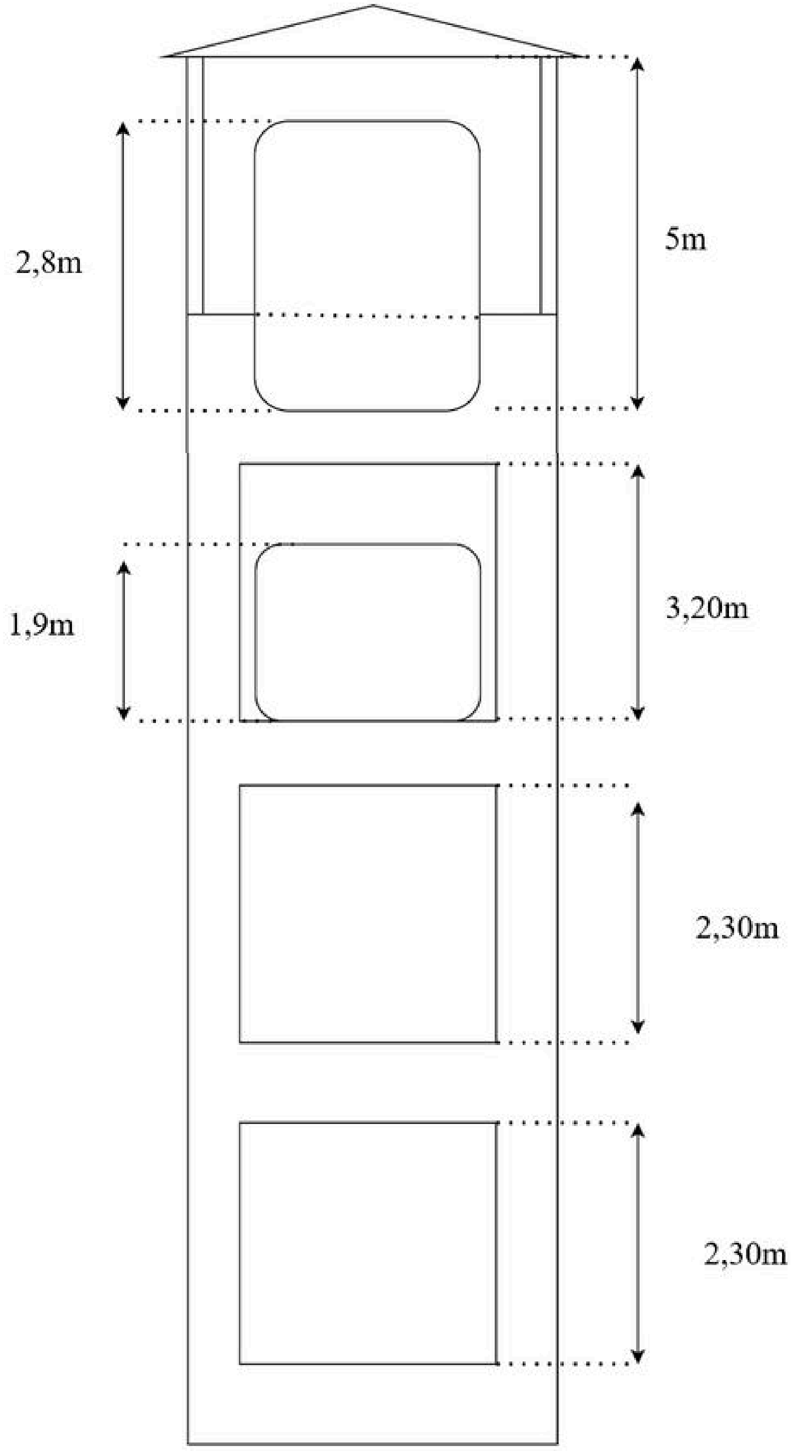


Diagram 1 : Design of the tower Ankatso 1

2 Volume of the tank:

These tanks are two categories of storage frequently used across the campus, with respective volumes of 1O and 5 cubic meters.

Tank 1: Diameter: 2m / Height: 3,18m / Volume: **~ 10 m3**

Tank 2: Diameter: 1,5m / Height: 2,83m / Volume: **~ 5 m3**

3 Design of the system:

3.1 Type of the pump :

Depending of the type of the pump, we should take those yield in consideration.

Table 1 : Benchmark Yield by Pump Type[1]

Pump type	Volumetric	Centrifugal (< 2 HP)	Centrifugal (> 2HP)
Benchmark yield	0,6	0,4	0,6

3.2 Topology of the system:

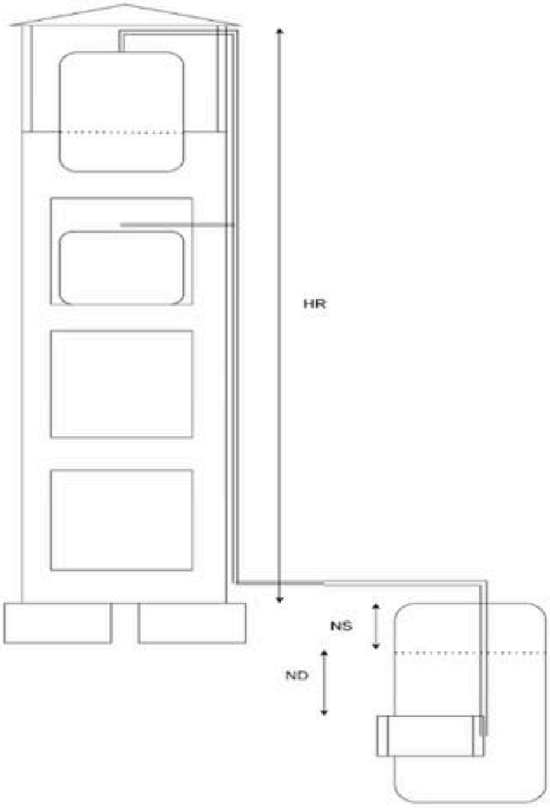


Diagram 2 : Pump System Schematic

Where

- H_R (Height of the water): It's the difference in height or altitude in meters (m) between the ground and the arrival at the highest point of the tank, tap, booster, etc.[2]
- N_S (Static level): It's the difference in height or altitude in meters (m) between the water level and the ground when the pump is stopped, so there are no variations in level.[2]

- N_D (Dynamic drilling level): It's a difference in height or altitude in meters (m) between the water level and the ground when the pump is running. The level can vary and even greatly in boreholes for example or depending on the seasons (evaporation). This information is obtained from the driller.[2]

Remark: For the tower at the Vaccination Research Building, we indeed have a tank for capturing rainwater, so both N_d and N_s are assumed to be references for the H_R.

Another point to consider is that we have the option to fill the tank from either the top or the bottom. Opting to pump from the top is advantageous for our design as it helps prevent sediment accumulation and ensures cleaner water quality.

The system in the vaccination building has been constructed to meet the general water requirements of the building.

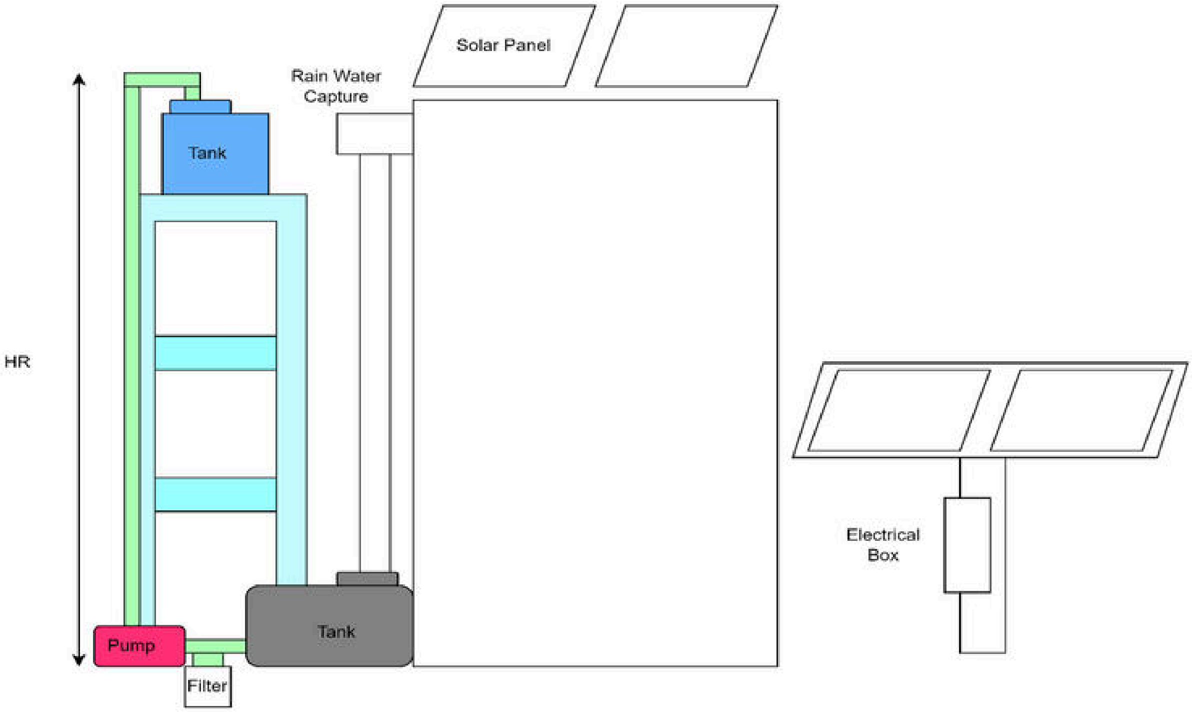


Diagram 3 : Solar Pumping system of the Vaccination Buildings

3.3 Role of the Component

Solar pump

A solar pump can be composed with several different technologies, volumetric (Shurflo), centrifugal or helical (Lorentz) and for varied uses such as surface pumping (pond, lake, river, tank) and submerged pumping (well, drilling).[2]

The advantage of this direct current supply is that we will able to adapt the rotation speed according to the energy available, which will allow pumping even with sunshine or low battery voltage. In addition, through technology or via a controller, we get rid of current peaks at start-up.[1]

⇒For the sizing of the system, the volume of the water that should be pumped and the height of the tank will be taken into consideration.

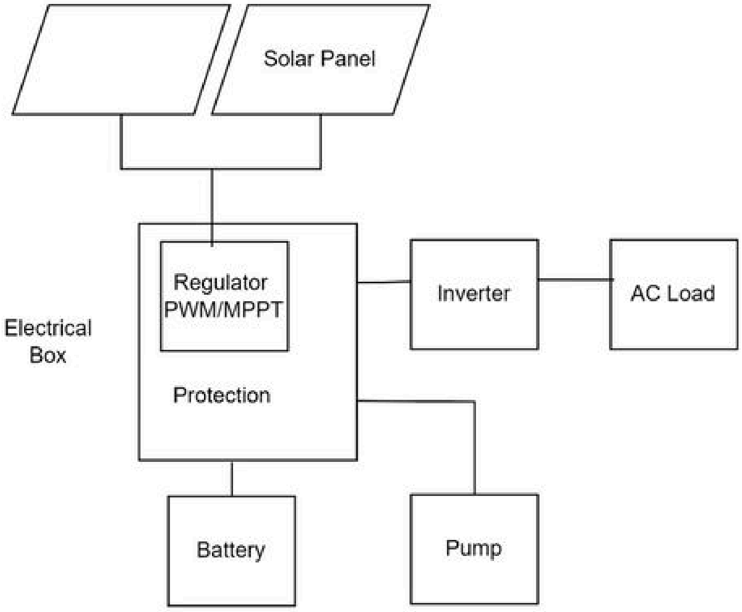


Diagram 4 : Components of a solar pumping system

In a solar pumping system, each component plays a critical role in ensuring efficient and reliable operation.

Solar Panel

The solar panel is the primary component that captures energy from the sun. Its role is to convert solar energy into electrical energy. This electricity is then used to power the water pump directly or stored in batteries for later use. The performance and size of the solar panel determine how much energy can be harvested and subsequently how much water can be pumped.

Battery

The battery in a solar pumping system stores electrical energy produced by the solar panels that is not immediately used. This storage allows the pump to continue operating during periods without sunlight, such as during the night or on cloudy days. Batteries ensure a consistent supply of electricity to the pump, thereby facilitating a stable operation regardless of varying solar conditions. However, the pump can work without using energy stockage if there are no other load that needs electricity that are connected to the system.

In other way, if we need to take into consideration the fact that there will be time that there won't be sunlight, instead of adding Batterie which should be expensive, we can build a bigger stockage of water.

Regulator (Charge Controller)

The regulator, or solar charge controller, manages the flow of electricity from the solar panels to the battery and the pump. Its main roles are:

- Preventing Overcharging: It ensures that the batteries do not overcharge, which can extend battery life and prevent safety issues.

- Regulating Voltage: It provides the correct voltage to the pump and prevents fluctuations that might damage the system.
- Maximizing Efficiency: Some advanced regulators include Maximum Power Point Tracking (MPPT) technology, which maximizes the efficiency of the solar panels by ensuring they operate at their optimal power output.

Protection

In a solar pumping system, protection plays a crucial role in ensuring the longevity and efficiency of the system. It safeguards against electrical faults, such as overcurrent and short circuits, which can damage components. Protection mechanisms also defend against environmental factors like lightning and power surges, ensuring the solar panels, pump, and controller operate safely and reliably.

Inverter

An inverter's role in a solar pumping system is to convert the DC (Direct Current) electricity generated by the solar panels and stored in the batteries into AC (Alternating Current). Most high-powered pumps, especially those used in large water systems, require AC to operate. Thus, the inverter is crucial for converting the stored DC into usable AC power for these pumps. Even if some smaller or specialized pumps operate on DC, systems designed for scalability or compatibility with existing infrastructure might still include an inverter.

3.4 Power needed calculation

To size the amount of energy that is needed we will break the problem for each of the tank.

To get the daily electrical energy we got the following formula:

$$E = \frac{V * mH * 0.2725}{np}$$

Where

- E represents the energy required in Watt-hours per day [Wh/d]
- V represents the volume in cubic meters per day [m^3/d]
- mH represents the manometric height (sum of the heights: N_S+ N_D+ Loss) in meters [m]
- 0.2725 represents the hydraulic coefficient
- n_p represents the efficiency of the pump

5- Choice of the pump:

The pump should then get the necessary power to pump during the day where the sun is available (~ 5 hours)

The power the pump should then be:

$$P = \frac{E}{nh}$$

Where:

P represents the power of the pump in Watt [W]

E represents the amount of needed energy in Watt-hours per day [Wh/d]

n_h represents the number of hour when there is sun

**It's important to emphasize that when choosing the pump, we must consider its flow rate, the maximum height to which it can pump water, and the pressure it can withstand.

3.5 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

P_p represents the total panel power to be installed in Watt-peak [Wp]

E represents the energy required in Watt-hour per day [Wh/d]

D_r represents the daily radiation in Kilowatt-hour per square meter per day [kWh/m^2/d]

K represents the efficiency coefficient of the photovoltaic array (depending on the type of panel support and operating conditions)

3.6 Solar radiation map (GHI)

A solar radiation map is an image that shows how much sunlight reaches various locations on Earth. It helps to know where there is a lot or little sun, which is important when deciding where to install solar panels or studying the climate and environment.[3]

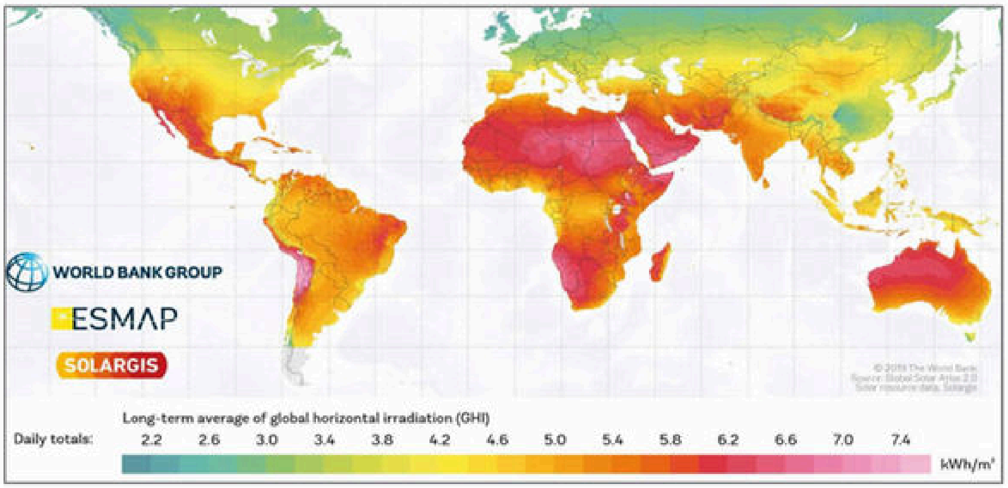
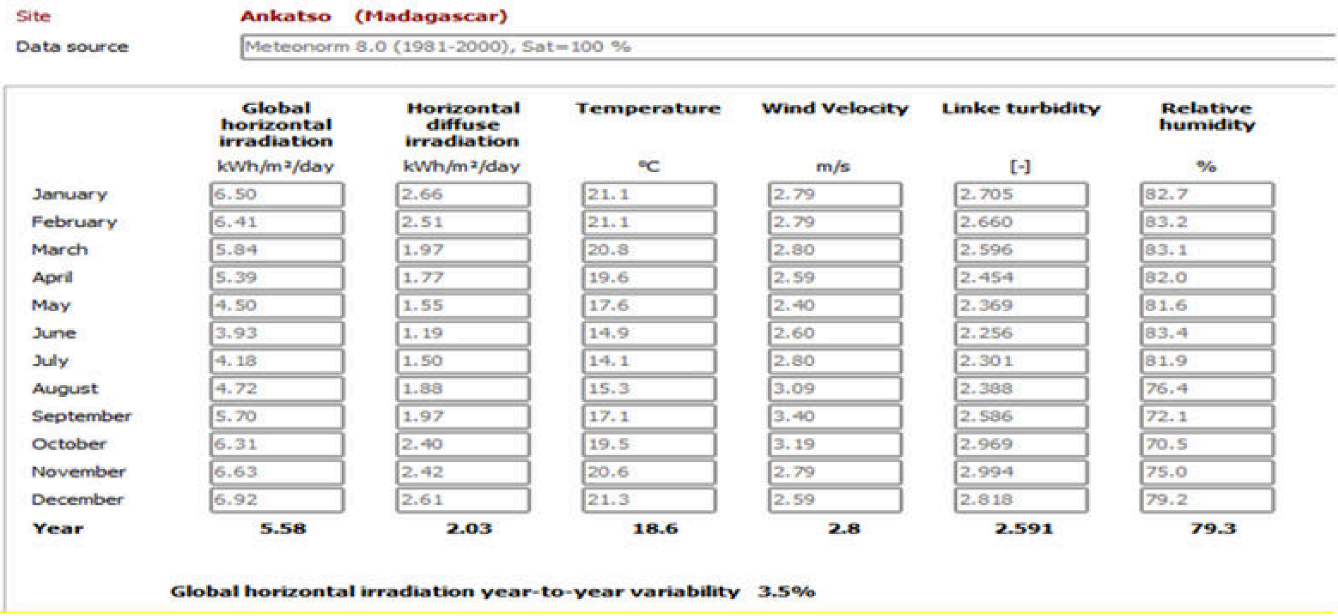


Figure 3 : Solar radiation map[3]

Our modular design approach for the solar water tower is intentionally designed to be adaptable to various geographic locations and usage contexts. Although our analysis focuses on the Antananarivo Campus tower, we have taken into account the need to adjust the sizing of solar panels and pump to meet the specific requirements of each site. Thus, our proposal can be implemented in various regions, providing a sustainable and scalable solution for water needs.

3.7 Solar irradiation for Madagascar

We obtained the following table, which displays the global irradiation data for Ankatso, sourced from the Meteonorm Dataset via PVSyst.



Site **Ankatso (Madagascar)**

Data source Meteonorm 8.0 (1981-2000), Sat=100 %

	Global horizontal irradiation kWh/m²/day	Horizontal diffuse irradiation kWh/m²/day	Temperature °C	Wind Velocity m/s	Linke turbidity [-]	Relative humidity %
January	6.50	2.66	21.1	2.79	2.705	82.7
February	6.41	2.51	21.1	2.79	2.660	83.2
March	5.84	1.97	20.8	2.80	2.596	83.1
April	5.39	1.77	19.6	2.59	2.454	82.0
May	4.50	1.55	17.6	2.40	2.369	81.6
June	3.93	1.19	14.9	2.60	2.256	83.4
July	4.18	1.50	14.1	2.80	2.301	81.9
August	4.72	1.88	15.3	3.09	2.388	76.4
September	5.70	1.97	17.1	3.40	2.586	72.1
October	6.31	2.40	19.5	3.19	2.969	70.5
November	6.63	2.42	20.6	2.79	2.994	75.0
December	6.92	2.61	21.3	2.59	2.818	79.2
Year	**5.58**	**2.03**	**18.6**	**2.8**	**2.591**	**79.3**

Global horizontal irradiation year-to-year variability 3.5%

Figure 4 : Global Irradiation at Ankatso

Table 2 : Solar panel efficiency by type and installation[1]

Choice of efficiency coefficient: depending on the type of panel support and operating conditions	Fixed installation of solar panels	Tracking the sun on the horizontal (modification of the inclination depending on the season)	Sun tracking with inclined or vertical axis (modification of the inclination according to the time of day)	Automatic sun tracking on 2 axes
Reference performance in a dusty environment or poor panel cleaning	0,5	0,6	0,7	0,8
Reference yield in a clean environment or regular cleaning of the panels	0,6	0,7	0,8	0,9

3.8 Result of the calculation :

The following constant were chosen for this calculation:

Pump efficiency = 40%

Solar efficiency = 80%

Irradiation = 5.9 kWh/m^2/d (according solar radiation map)

Loss = 1/10m (Manometric height)

Table 3 : Result of the calculation with normal irradiation (tank 1 and tank 2)

Volume tank $[m^3]$	Height of the tank [m]	well depth [m]	Loss [m]	Needed energy [Wh]	Power of the pump [W]	PV [W]
10	15	0	1,5	1124	191	238
10	15	10	2,5	1873	318	397
10	15	20	3,5	2623	445	556
10	15	30	4,5	3372	572	714
5	10	0	1,0	375	64	79
5	10	10	2,0	749	127	159
5	10	20	3,0	1124	191	238
5	10	30	4,0	1499	254	318

The irradiation is justified by the following figure from PV Syst while showing a 5.9 kWh/m^2/d minimum while we got a clear Sky.

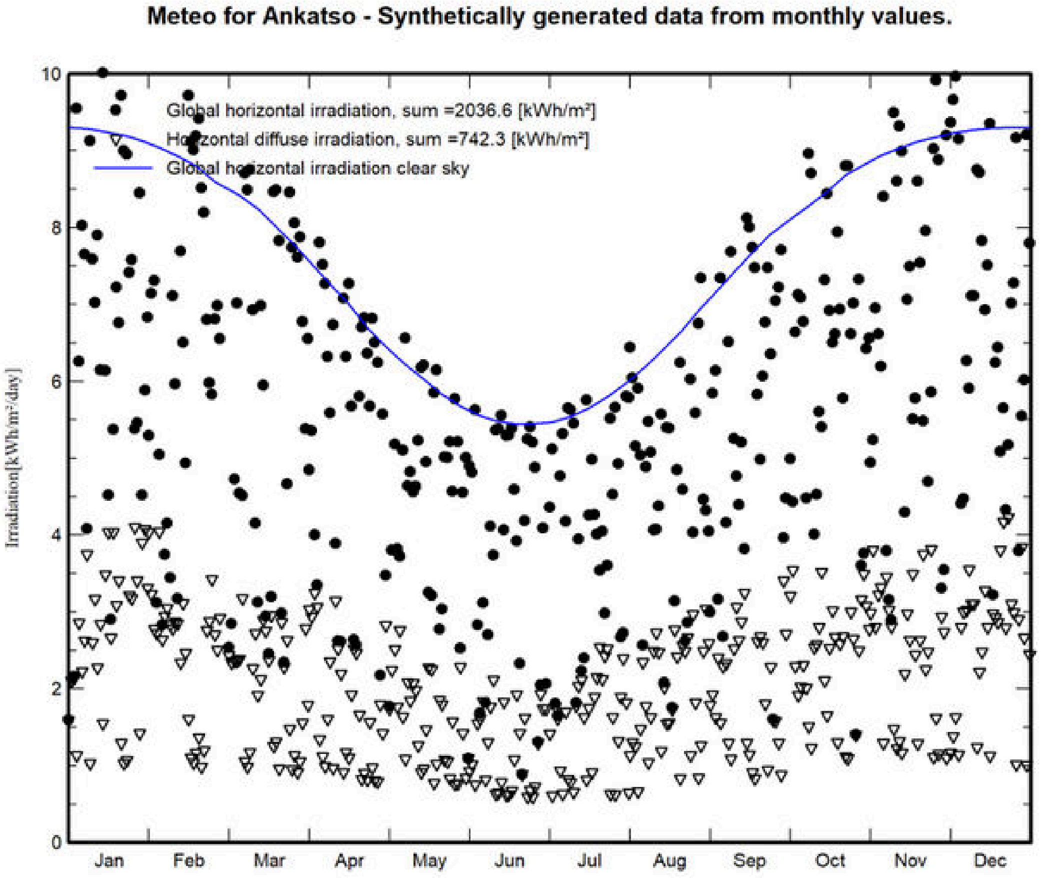


Figure 5 : Irradiation distribution at Ankatso

However, there are instances where we observe a minimal irradiation of 1.6 kWh/m2/d, which consequently yields the following result.

Table 4 : Result of the calculation with minimal irradiation (tank 1 and tank 2)

Volume tank [m3]	Height of the tank [m]	well depth [m]	Loss [m]	Needed energy [Wh]	Power of the pump [W]	PV [W]
10	15	0	1,5	1124	703	878
10	15	10	2,5	1873	1171	1464
10	15	20	3,5	2623	1639	2049
10	15	30	4,5	3372	2108	2635
5	10	0	1,0	375	234	293
5	10	10	2,0	749	468	585
5	10	20	3,0	1124	703	878
5	10	30	4,0	1499	937	1171

We can see in the result that we may need a total of 1171 W for the design up to the worst case.

We can also deduce that as the well depth increases, the power requirement for the pump also increases. In certain scenarios, a pump might meet the power criteria but fall short in delivering the required flow rate. Hence, it is crucial to thoroughly evaluate the characteristics of the pump.

⇒Then it's essential to size the component using software to simulate the scenario up to realistic data of the irradiation and the amount of water that is needed.

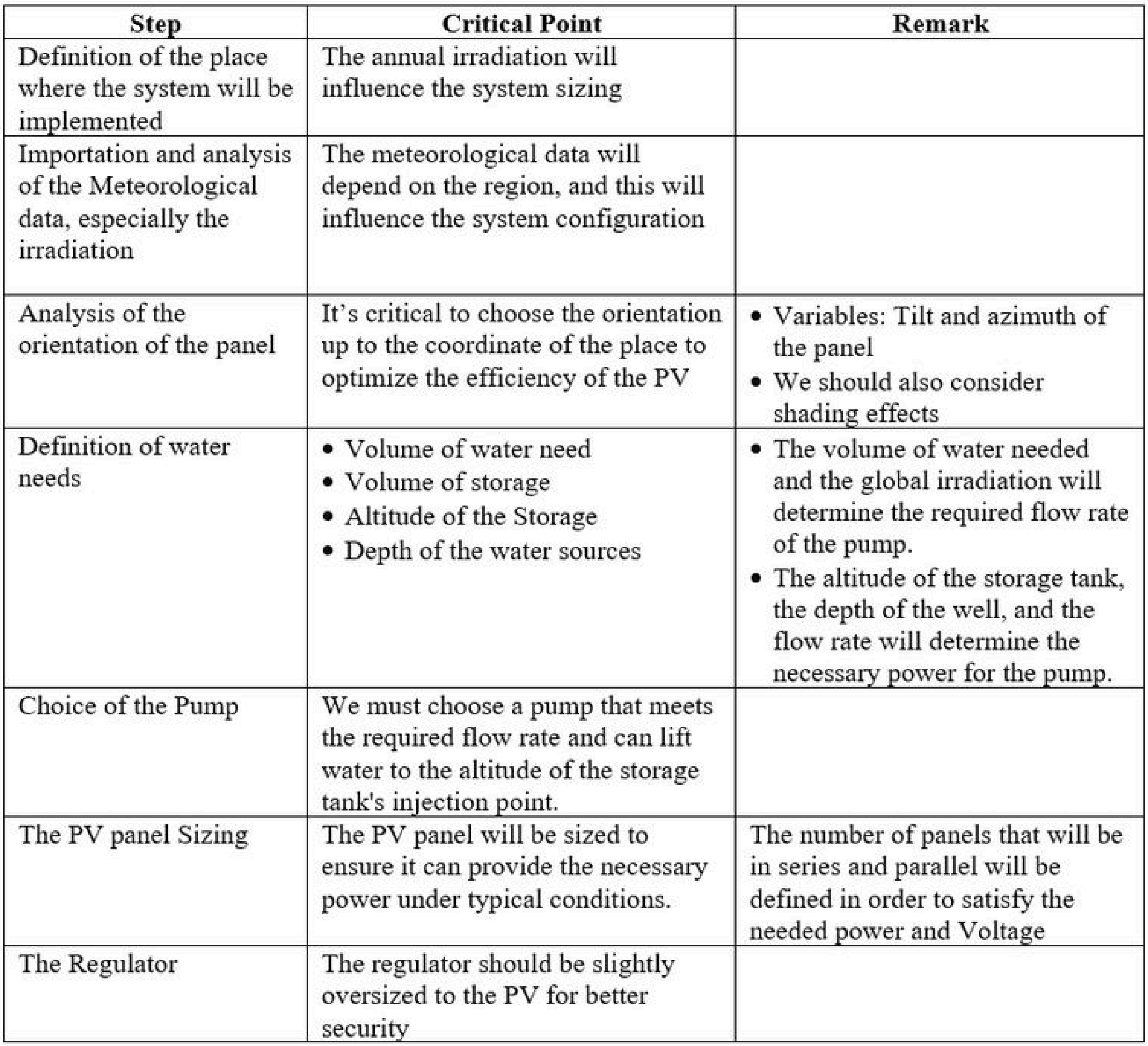
4 -Simulation with PV Syst

4.1 Overview of PV Syst

PVSyst is a widely used software tool for designing and simulating solar pumping systems. It enables precise system configuration by accurately sizing solar panels, pumps, and controllers based on specific water demand and solar irradiance data. PVSyst's simulation capabilities allow for detailed performance analysis, taking into account environmental factors such as solar radiation and temperature variations. The software also supports optimization of panel orientation and tilt angle to maximize energy capture.

4.2 Design roadmap

Table 5 : Steps in Designing a Solar Water Supply System



Step	Critical Point	Remark
Definition of the place where the system will be implemented	The annual irradiation will influence the system sizing	
Importation and analysis of the Meteorological data, especially the irradiation	The meteorological data will depend on the region, and this will influence the system configuration	
Analysis of the orientation of the panel	It's critical to choose the orientation up to the coordinate of the place to optimize the efficiency of the PV	• Variables: Tilt and azimuth of the panel • We should also consider shading effects
Definition of water needs	• Volume of water need • Volume of storage • Altitude of the Storage • Depth of the water sources	• The volume of water needed and the global irradiation will determine the required flow rate of the pump. • The altitude of the storage tank, the depth of the well, and the flow rate will determine the necessary power for the pump.
Choice of the Pump	We must choose a pump that meets the required flow rate and can lift water to the altitude of the storage tank's injection point.	
The PV panel Sizing	The PV panel will be sized to ensure it can provide the necessary power under typical conditions.	The number of panels that will be in series and parallel will be defined in order to satisfy the needed power and Voltage
The Regulator	The regulator should be slightly oversized to the PV for better security	

4.3 Orientation of PV Panel:

We first choose an orientation to the north by 25° to get the optimal inclination and Orientation of 0°Azimuth.

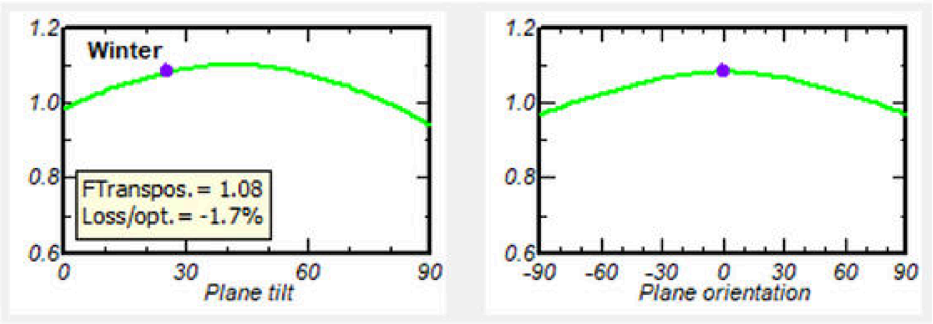


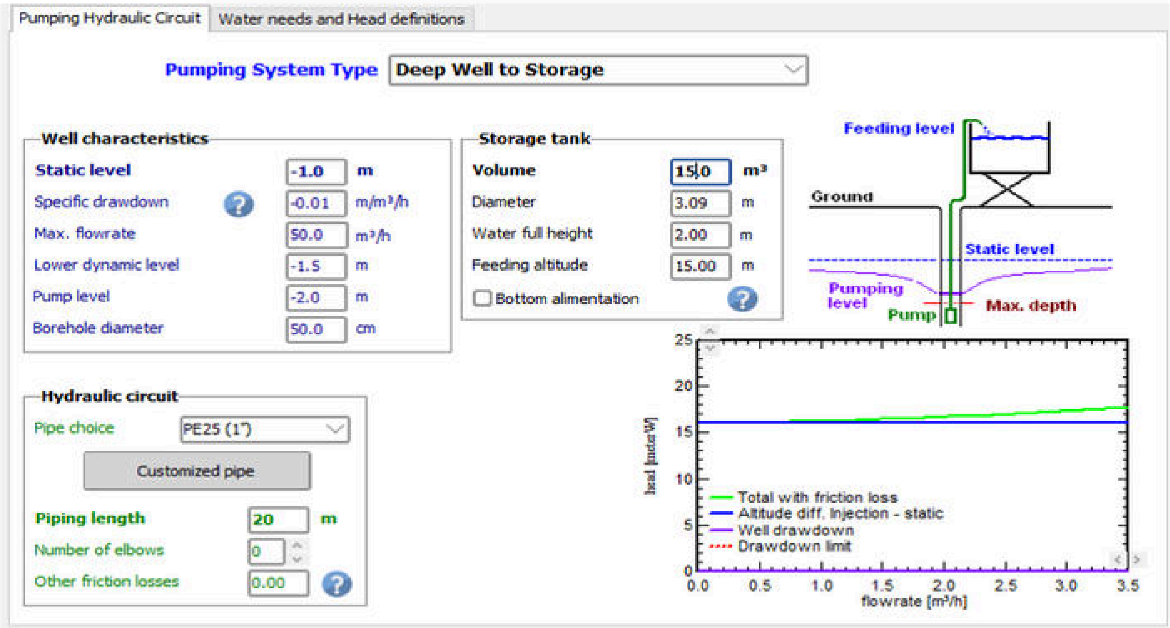
Figure 6 : PV orientation from PVSyst

Justification of the parameters

Orienting solar panels at a 25° angle to the north optimizes solar energy capture by aligning the panels with the sun's position in the sky, ensuring maximum exposure to direct sunlight throughout the day. Because Madagascar is located in the southern hemisphere, facing the panels northward directs them towards the equator, where the sun's path is most direct. The 25° tilt angle is selected to match Madagascar's latitude, maximizing the angle of incidence for sunlight year-round and thereby enhancing solar panel efficiency.

4.4 Configuration of the System

Here is the definition of the system and the needs



Pumping System Type: Deep Well to Storage

Well characteristics
- Static level: -1.0 m
- Specific drawdown: -0.01 m/m³/h
- Max. flowrate: 50.0 m³/h
- Lower dynamic level: -1.5 m
- Pump level: -2.0 m
- Borehole diameter: 50.0 cm

Storage tank
- Volume: 15.0 m³
- Diameter: 3.09 m
- Water full height: 2.00 m
- Feeding altitude: 15.00 m
- ☐ Bottom alimentation

Hydraulic circuit
- Pipe choice: PE25 (1")
- Piping length: 20 m
- Number of elbows: 0
- Other friction losses: 0.00

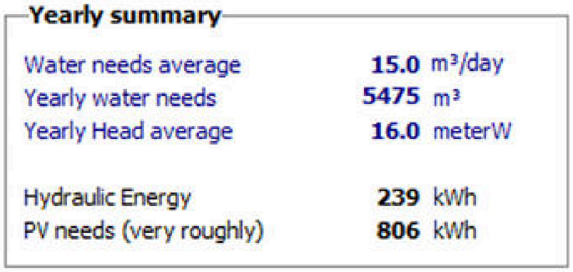
Figure 7 : Pumping Hydraulic Circuit from PVSyst

We have defined a 15m^3/day need of water to fill both of the tank in the tower in Picture 1.

Here is the rationale behind these parameters:

- The static level is set at 1 meter as a standard reference, but it can be adjusted according to actual requirements.
- The daily demand is 15 m^3, meaning both tanks will be emptied by the end of the day.
- We used the height of the highest tank as the reference point for designing the system.

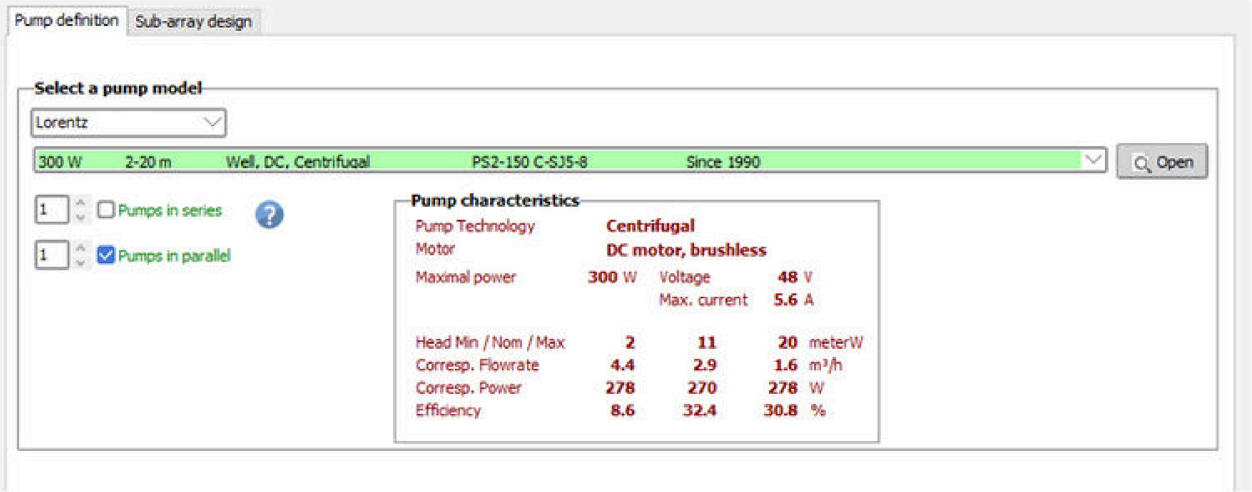
After adding the water need, we get the rough result from PVSyst:



Yearly summary

Water needs average	**15.0**	m³/day
Yearly water needs	**5475**	m³
Yearly Head average	**16.0**	meterW
Hydraulic Energy	**239**	kWh
PV needs (very roughly)	**806**	kWh

Figure 8 : Rough Estimation from PV Syst



Select a pump model

Lorentz

300 W 2-20 m Well, DC, Centrifugal PS2-150 C-SJ5-8 Since 1990

1 ☐ Pumps in series

1 ☑ Pumps in parallel

Pump characteristics

Pump Technology	**Centrifugal**			
Motor	**DC motor, brushless**			
Maximal power	**300** W	Voltage	**48** V	
		Max. current	**5.6** A	
Head Min / Nom / Max	**2**	**11**	**20**	meterW
Corresp. Flowrate	**4.4**	**2.9**	**1.6**	m³/h
Corresp. Power	**278**	**270**	**278**	W
Efficiency	**8.6**	**32.4**	**30.8**	%

Figure 9 : Pump definition from PVSyst

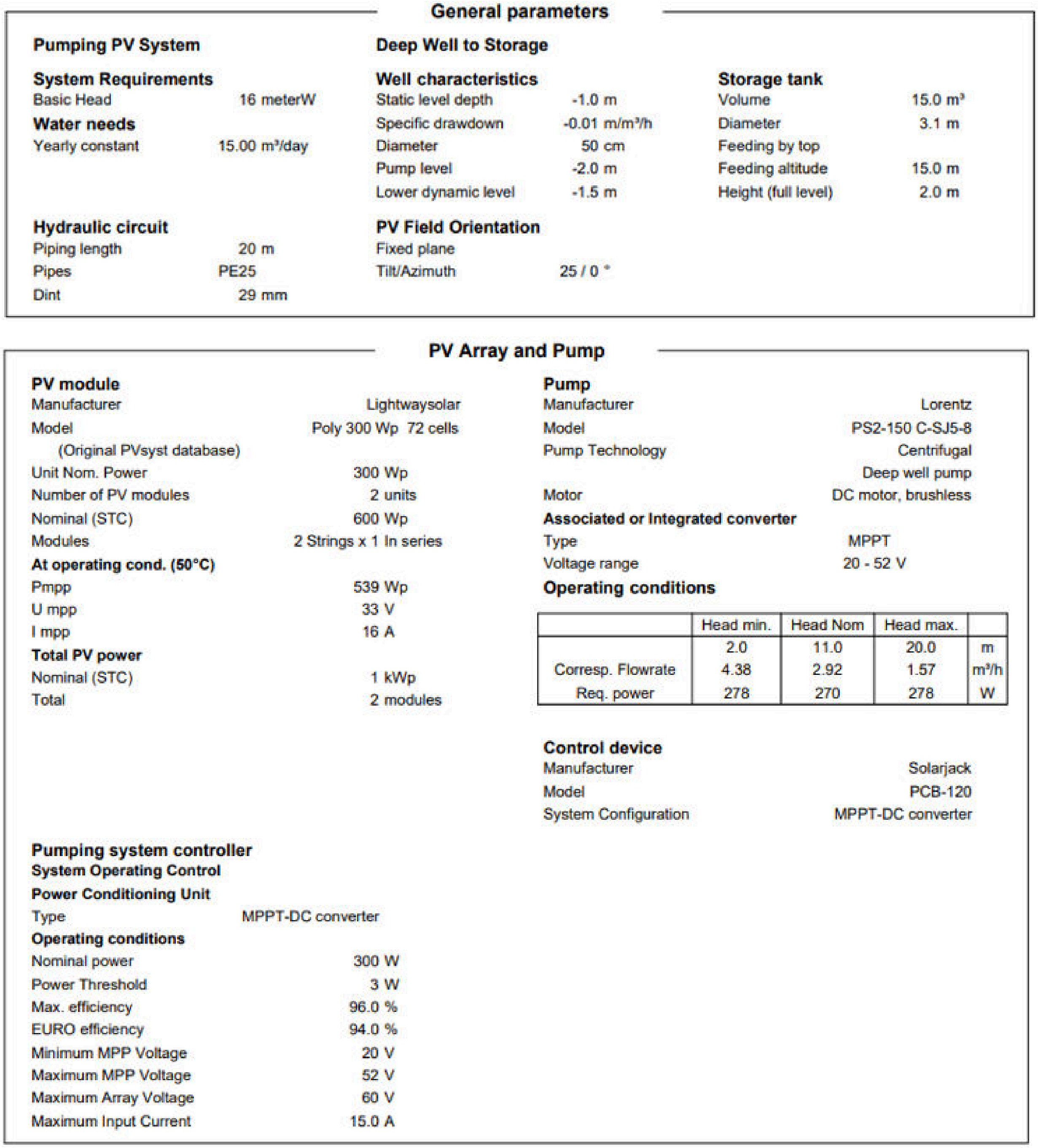
We choose a 300W 48V pump that has a 4.4m^3/h to 1.6m^3/h flow rate that potentially can fill the tank in 4 hours in an optimal use.

** We must emphasize the fact that all the materials that are cited during the simulation are just one choice many others they are neither recommended or preferred.*

Justification of the parameters:

The decision was influenced by both the flow rate and the maximum height, which spans from 2 to 20 meters. The specifications for power, voltage, and motor type may vary based on the materials at hand. In this scenario, opting for a pump that operates with lower power and voltage proves most compatible with the system, as it eliminates the necessity of adding extra panels to meet voltage requirements. This not only streamlines the design process but also cuts down on expenses and enhances the overall efficiency of the solar pumping system.

Here is the general configuration of the system*



General parameters

Pumping PV System

System Requirements

Basic Head	16 meterW

Water needs

Yearly constant	15.00 m^3/day

Hydraulic circuit

Piping length	20 m
Pipes	PE25
Dint	29 mm

Deep Well to Storage

Well characteristics

Static level depth	-1.0 m
Specific drawdown	-0.01 m/m^3/h
Diameter	50 cm
Pump level	-2.0 m
Lower dynamic level	-1.5 m

PV Field Orientation

Fixed plane	
Tilt/Azimuth	25 / 0 °

Storage tank

Volume	15.0 m^3
Diameter	3.1 m
Feeding by top	
Feeding altitude	15.0 m
Height (full level)	2.0 m

PV Array and Pump

PV module

Manufacturer	Lightwaysolar
Model	Poly 300 Wp 72 cells
(Original PVsyst database)	
Unit Nom. Power	300 Wp
Number of PV modules	2 units
Nominal (STC)	600 Wp
Modules	2 Strings x 1 In series

At operating cond. (50°C)

Pmpp	539 Wp
U mpp	33 V
I mpp	16 A

Total PV power

Nominal (STC)	1 kWp
Total	2 modules

Pump

Manufacturer	Lorentz
Model	PS2-150 C-SJ5-8
Pump Technology	Centrifugal Deep well pump
Motor	DC motor, brushless

Associated or Integrated converter

Type	MPPT
Voltage range	20 - 52 V

Operating conditions

	Head min.	Head Nom	Head max.	
	2.0	11.0	20.0	m
Corresp. Flowrate	4.38	2.92	1.57	m^3/h
Req. power	278	270	278	W

Control device

Manufacturer	Solarjack
Model	PCB-120
System Configuration	MPPT-DC converter

Pumping system controller

System Operating Control

Power Conditioning Unit

Type	MPPT-DC converter

Operating conditions

Nominal power	300 W
Power Threshold	3 W
Max. efficiency	96.0 %
EURO efficiency	94.0 %
Minimum MPP Voltage	20 V
Maximum MPP Voltage	52 V
Maximum Array Voltage	60 V
Maximum Input Current	15.0 A

Figure 10 : Summary of the System from PVSyst

** We must emphasize the fact that all the materials that are cited during the simulation are just one choice many others they are neither recommended or preferred.*

We can see the distribution of the amount of water stored in the tank up to the daily solar irradiation.

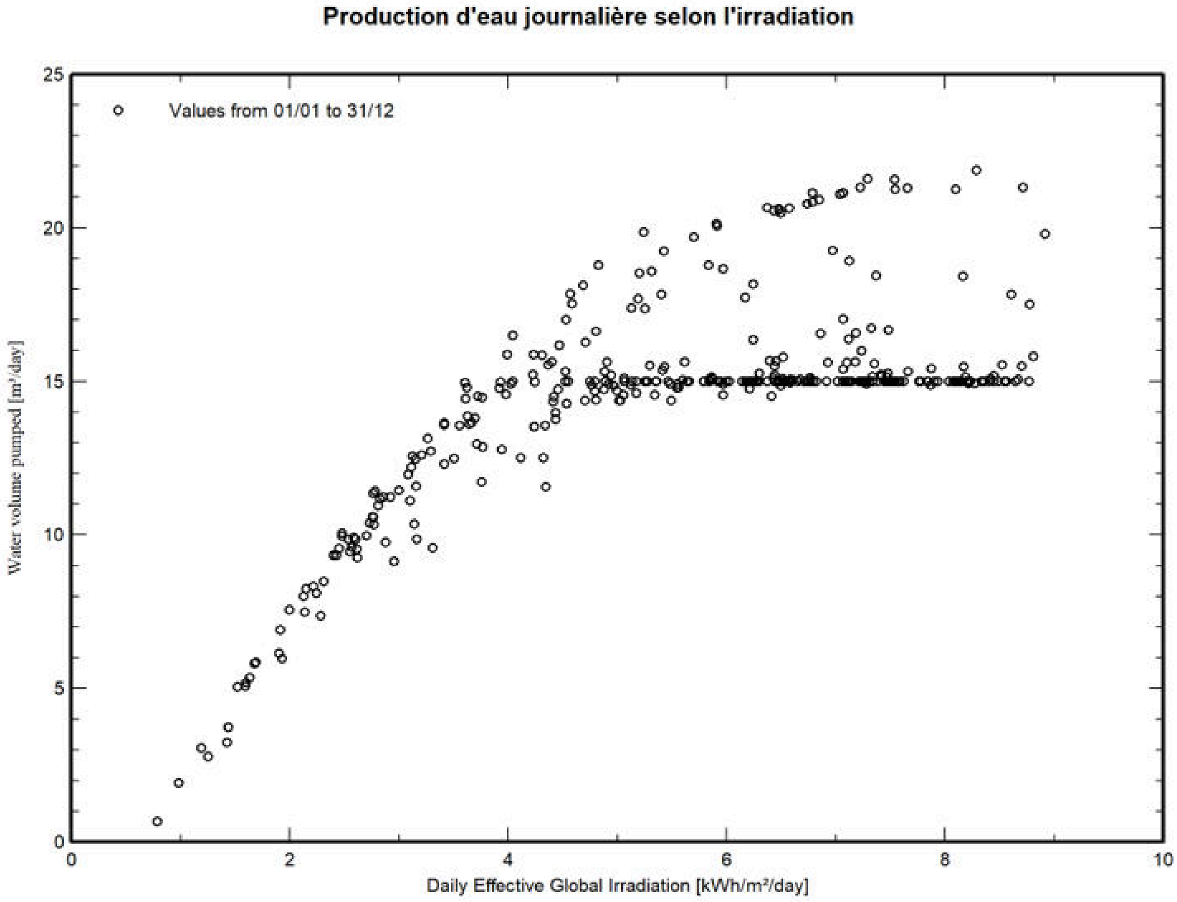
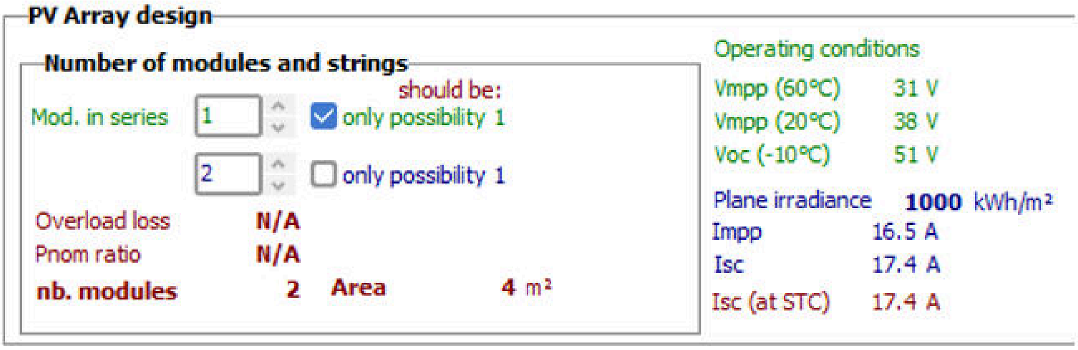


Figure 11 : Water volume pumped related to daily Global Irradiation

We can see that most of the time, the tank of 15m³ is full. This graph illustrates that the water pump, when paired with the solar panel, exhibits a threshold of irradiation that must be surpassed for optimal efficiency (3.5 kWh/m2/day in our case for a daily output of 10m3, and 4 kWh/m2/day for a full 15m3). In our scenario, we engineered the system based on recommendations from the software and the materials accessible to us.

Here is the PV characteristic that shows the needed area of 4 m2



PV Array design

Number of modules and strings

should be:

Mod. in series 1 ☑ only possibility 1

2 ☐ only possibility 1

Overload loss N/A

Pnom ratio N/A

nb. modules **2** **Area** **4** m²

Operating conditions

Vmpp (60°C) 31 V

Vmpp (20°C) 38 V

Voc (-10°C) 51 V

Plane irradiance **1000** kWh/m²

Impp 16.5 A

Isc 17.4 A

Isc (at STC) 17.4 A

Figure 12 : PV system configuration from PVSyst

The graph below illustrates the pumped water volume and the deficit for each month. It is evident that the most critical scenario occurs in June, with a shortfall of 50m³. This lack of water is also justified by the table in the Figure 4.

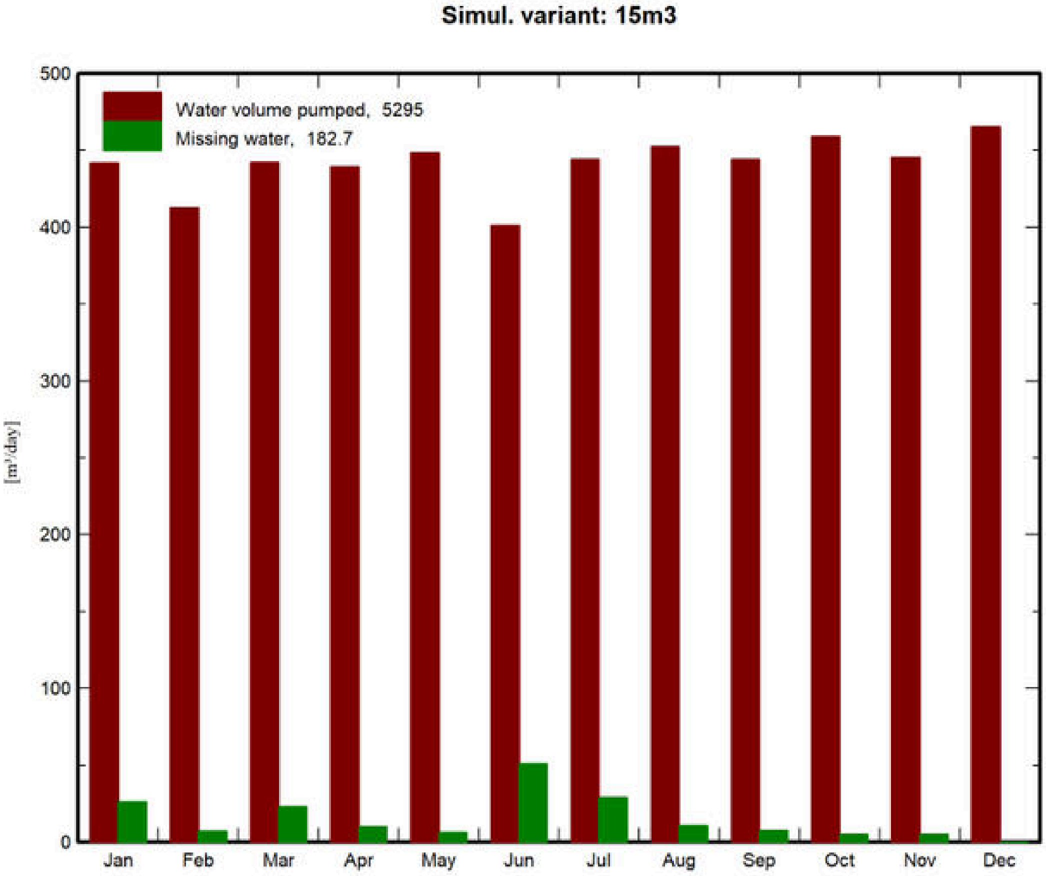
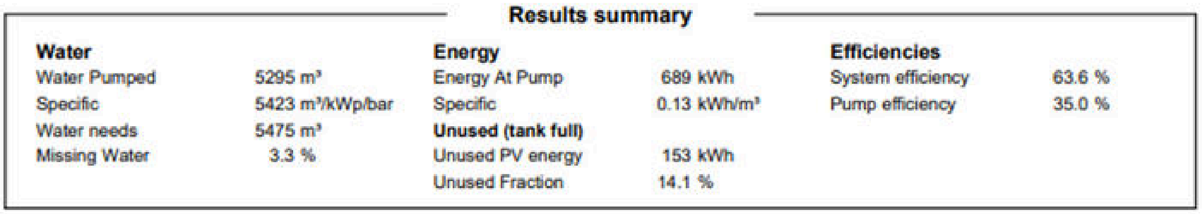


Figure 13 : Total of pumped and missing water

Conclusion:

A PV system with two 300kW, 30V solar panels, an MPPT controller of 500W, and a 300W water pump capable delivering 4.4m³ per hour can operate with only a 3.3% water shortage. This demonstrates the resilience and adaptability of solar-powered systems in managing resources effectively.



Results summary

Water		Energy		Efficiencies	
Water Pumped	5295 m³	Energy At Pump	689 kWh	System efficiency	63.6 %
Specific	5423 m³/kWp/bar	Specific	0.13 kWh/m³	Pump efficiency	35.0 %
Water needs	5475 m³	**Unused (tank full)**			
Missing Water	3.3 %	Unused PV energy	153 kWh		
		Unused Fraction	14.1 %		

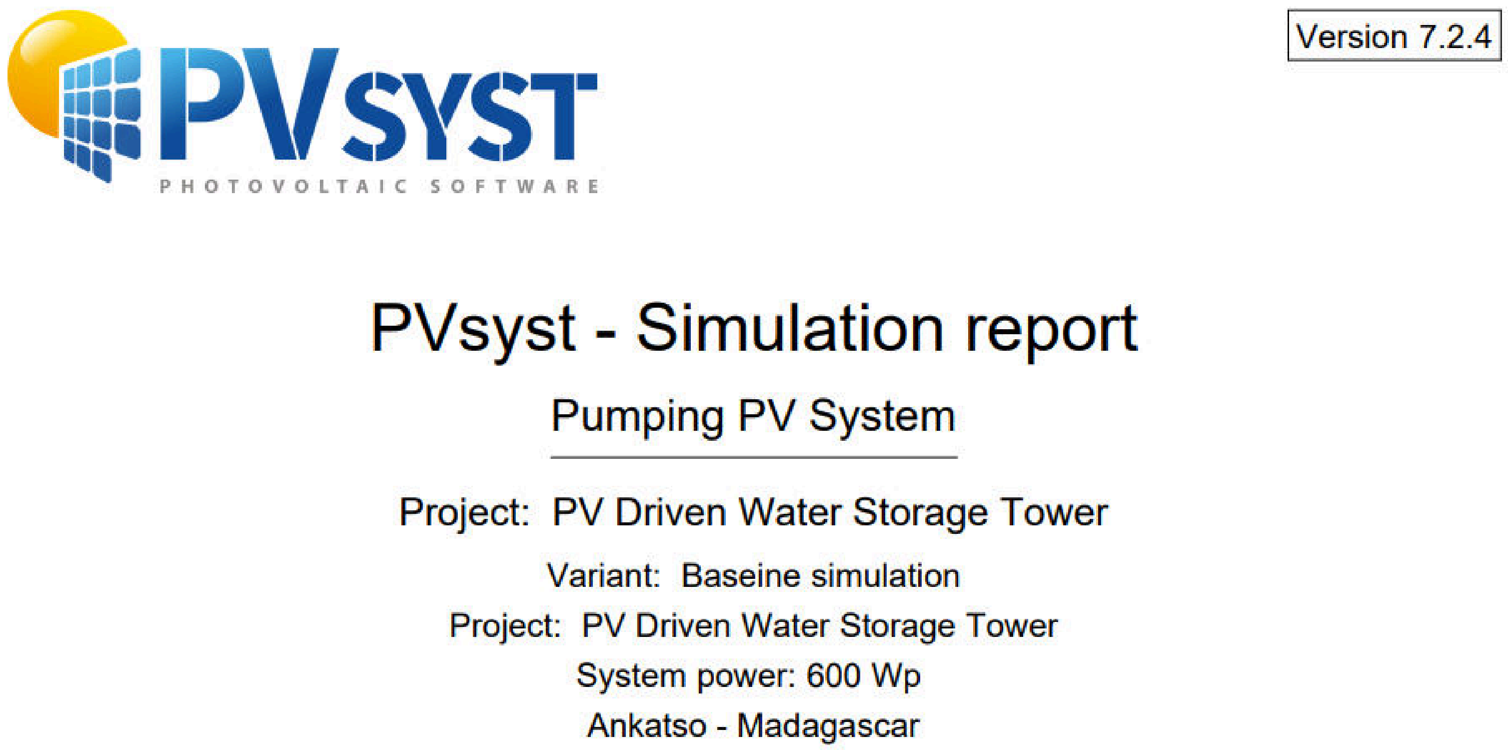
Figure 14 : Result Summary from PVSyst

The main result shows here that for the 5475 m³ of water that is needed, the system is capable of delivering 5295 m³ and with a 14,1% of electricity that is unused that mean 153 kWh of energy that can be used for other needs.

⇒ According to figure 12, the roof will not provide enough space for installing solar panels.

Open Discussion for Other Design

The simulations conducted using PVSyst enable us to construct a system based on realistic data rather than overestimating it for worst-case scenarios, which offers distinct advantages. This approach facilitates accurate sizing of system components, such as solar panels and pumps, in accordance with actual water demand and solar irradiance conditions. By avoiding unnecessary overestimation, we can reduce initial costs and construct a more efficient system that functions optimally under typical operating conditions. This ensures that the solar pumping system is both cost-effective and dependable. It's worth noting that all results presented in this report pertain to the baseline system configuration. Adjustments in the well depth and water tower height can be made to accommodate specific requirements. This adaptability permits customization of the system to various site conditions, ensuring optimal performance and cost-effectiveness tailored to the local context.



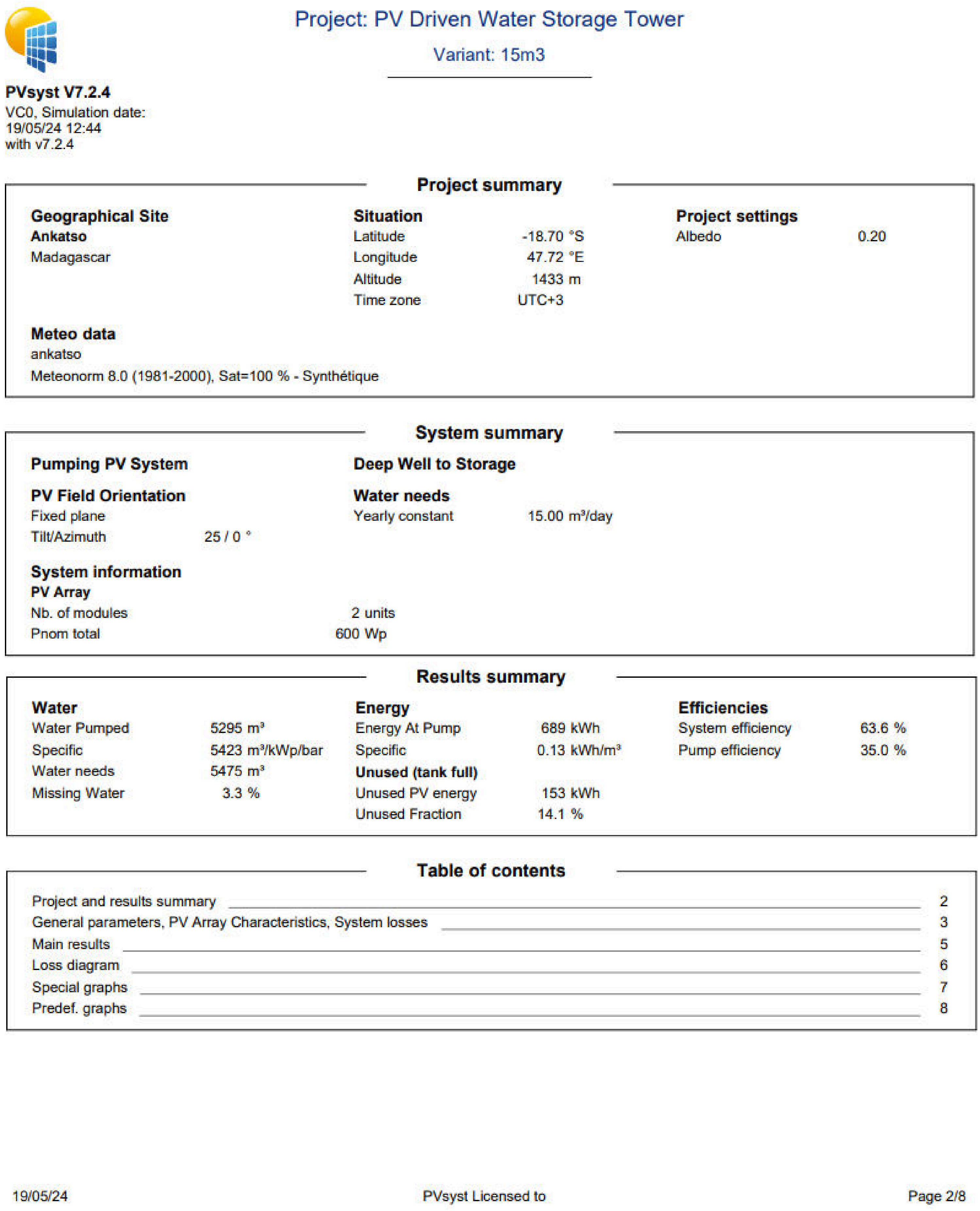
PVSYST
PHOTOVOLTAIC SOFTWARE

Version 7.2.4

PVsyst - Simulation report

Pumping PV System

Project: PV Driven Water Storage Tower
Variant: Baseine simulation
Project: PV Driven Water Storage Tower
System power: 600 Wp
Ankatso - Madagascar



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VC0, Simulation date:
19/05/24 12:44
with v7.2.4

Project: PV Driven Water Storage Tower

Variant: 15m3

Project summary

Geographical Site	Situation		Project settings	
Ankatso	Latitude	-18.70 °S	Albedo	0.20
Madagascar	Longitude	47.72 °E		
	Altitude	1433 m		
	Time zone	UTC+3		

Meteo data
ankatso
Meteonorm 8.0 (1981-2000), Sat=100 % - Synthétique

System summary

Pumping PV System — **Deep Well to Storage**

PV Field Orientation		Water needs	
Fixed plane		Yearly constant	15.00 m³/day
Tilt/Azimuth	25 / 0 °		

System information
PV Array

Nb. of modules	2 units
Pnom total	600 Wp

Results summary

Water		Energy		Efficiencies	
Water Pumped	5295 m³	Energy At Pump	689 kWh	System efficiency	63.6 %
Specific	5423 m³/kWp/bar	Specific	0.13 kWh/m³	Pump efficiency	35.0 %
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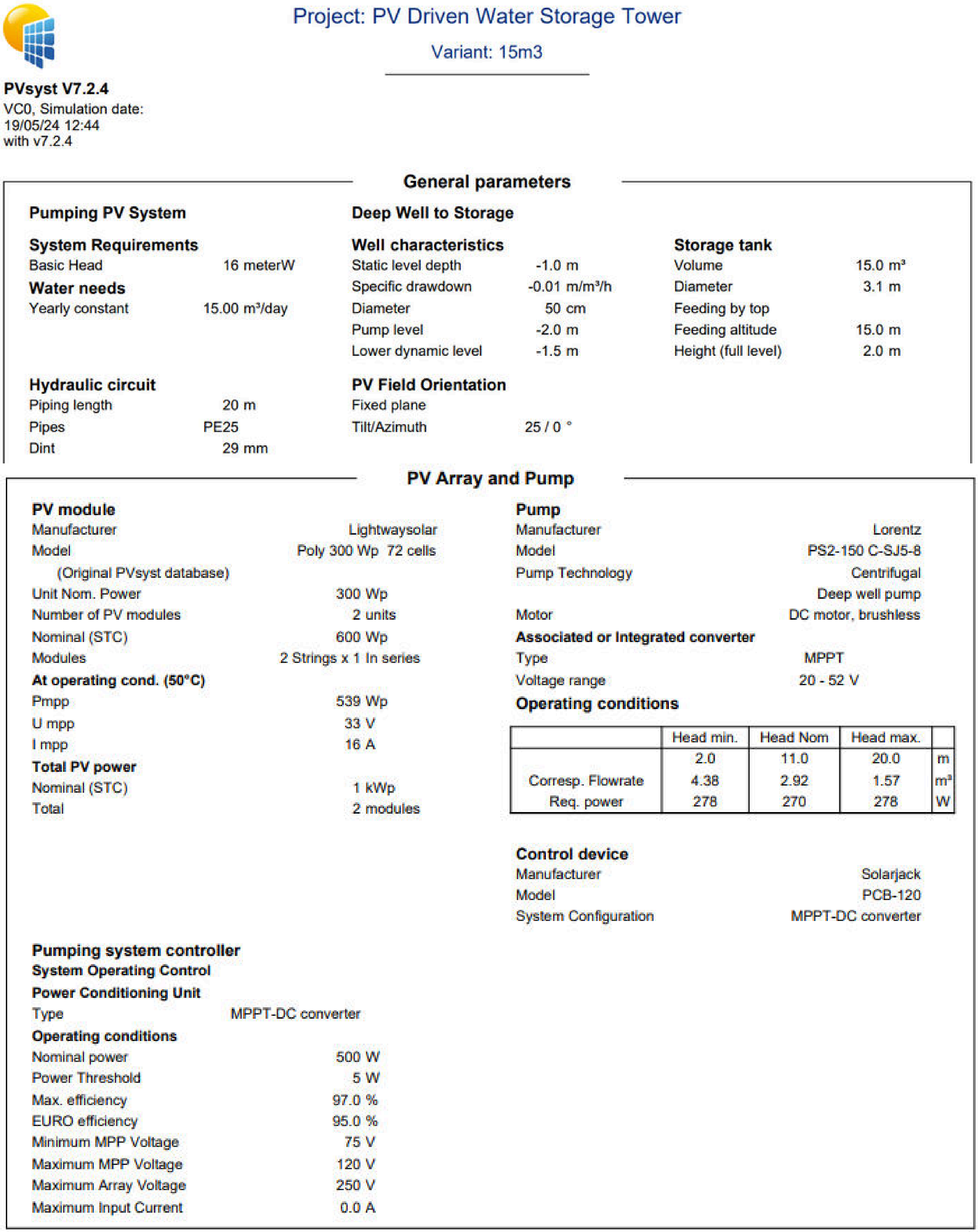
Table of contents



Project: PV Driven Water Storage Tower

Variant: 15m3

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General parameters

Pumping PV System

System Requirements

Basic Head	16 meterW

Water needs

Yearly constant	15.00 m³/day

Hydraulic circuit

Piping length	20 m
Pipes	PE25
Dint	29 mm

Deep Well to Storage

Well characteristics

Static level depth	-1.0 m
Specific drawdown	-0.01 m/m³/h
Diameter	50 cm
Pump level	-2.0 m
Lower dynamic level	-1.5 m

PV Field Orientation

Fixed plane

Tilt/Azimuth	25 / 0 °

Storage tank

Volume	15.0 m³
Diameter	3.1 m
Feeding by top	
Feeding altitude	15.0 m
Height (full level)	2.0 m

PV Array and Pump

PV module

Manufacturer	Lightwaysolar
Model	Poly 300 Wp 72 cells
(Original PVsyst database)	
Unit Nom. Power	300 Wp
Number of PV modules	2 units
Nominal (STC)	600 Wp
Modules	2 Strings x 1 In series

At operating cond. (50°C)

Pmpp	539 Wp
U mpp	33 V
I mpp	16 A

Total PV power

Nominal (STC)	1 kWp
Total	2 modules

Pump

Manufacturer	Lorentz
Model	PS2-150 C-SJ5-8
Pump Technology	Centrifugal
	Deep well pump
Motor	DC motor, brushless

Associated or Integrated converter

Type	MPPT
Voltage range	20 - 52 V

Operating conditions

	Head min.	Head Nom	Head max.	
	2.0	11.0	20.0	m
Corresp. Flowrate	4.38	2.92	1.57	m³
Req. power	278	270	278	W

Control device

Manufacturer	Solarjack
Model	PCB-120
System Configuration	MPPT-DC converter

Pumping system controller

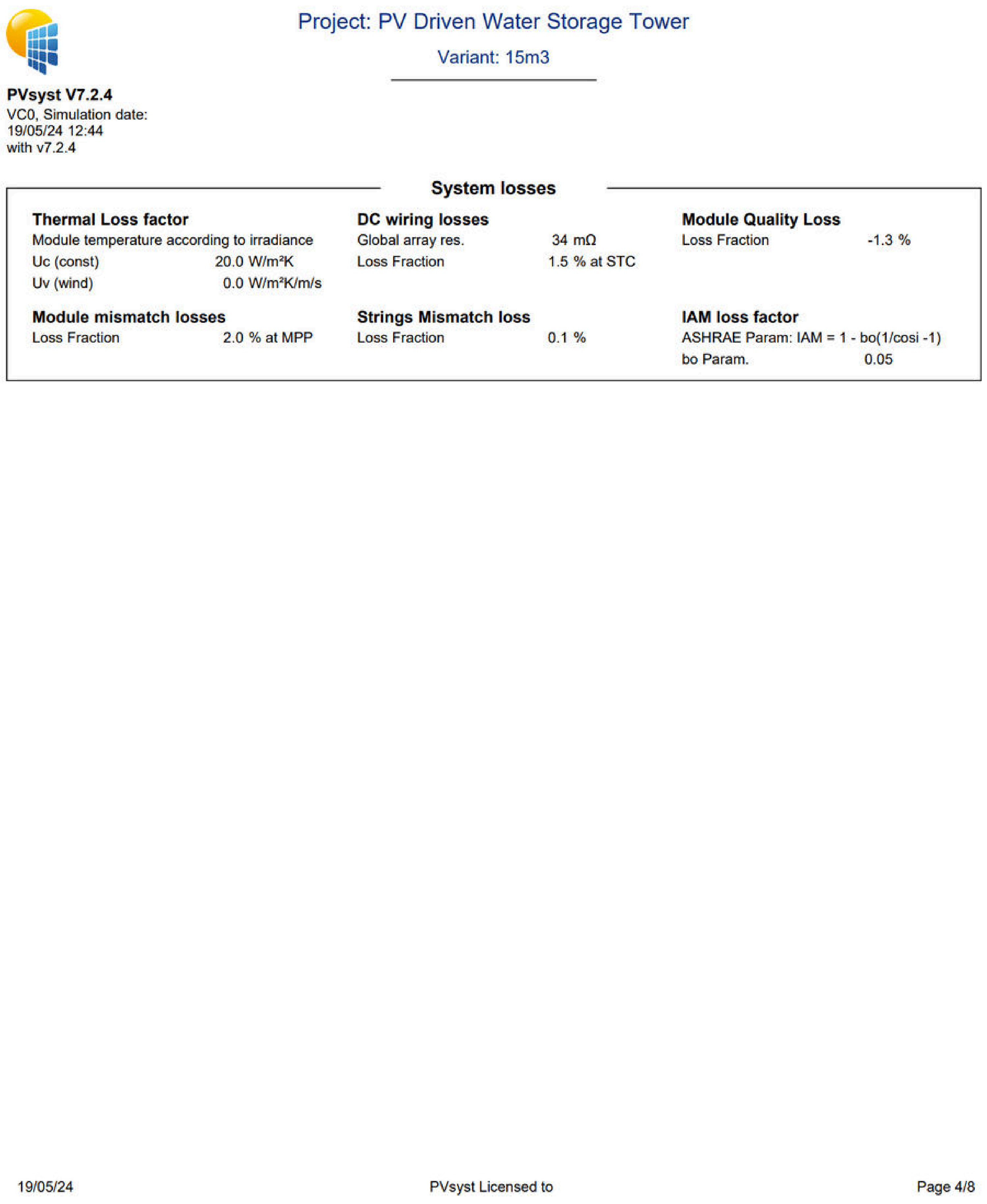
System Operating Control

Power Conditioning Unit

Type	MPPT-DC converter

Operating conditions

Nominal power	500 W
Power Threshold	5 W
Max. efficiency	97.0 %
EURO efficiency	95.0 %
Minimum MPP Voltage	75 V
Maximum MPP Voltage	120 V
Maximum Array Voltage	250 V
Maximum Input Current	0.0 A



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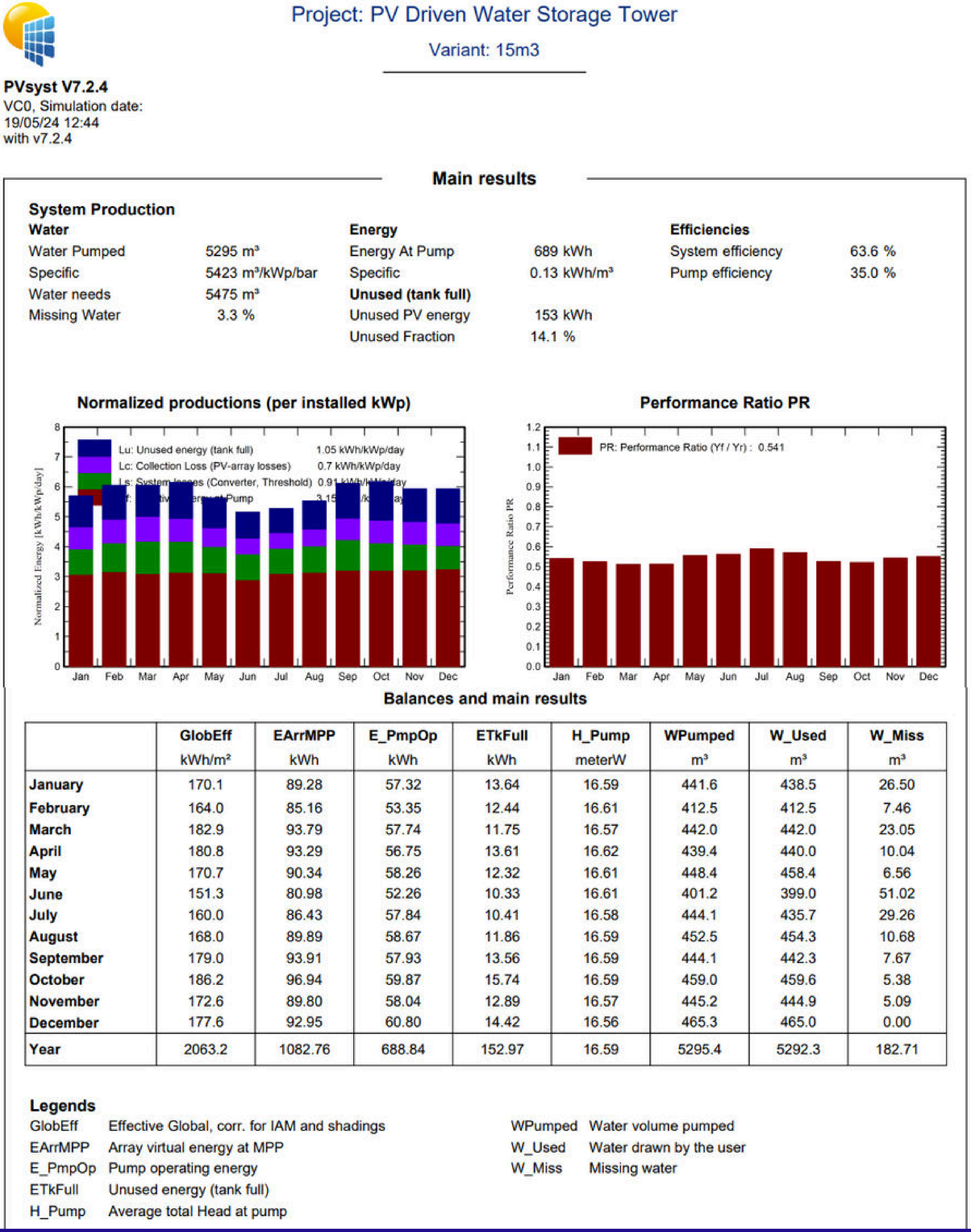
VC0, Simulation date:
19/05/24 12:44
with v7.2.4

System losses

Thermal Loss factor		**DC wiring losses**		**Module Quality Loss**	
Module temperature according to irradiance		Global array res.	34 mΩ	Loss Fraction	-1.3 %
Uc (const)	20.0 W/m²K	Loss Fraction	1.5 % at STC		
Uv (wind)	0.0 W/m²K/m/s				
Module mismatch losses		**Strings Mismatch loss**		**IAM loss factor**	
Loss Fraction	2.0 % at MPP	Loss Fraction	0.1 %	ASHRAE Param: IAM = 1 - bo(1/cosi -1)	
				bo Param.	0.05

19/05/24 PVsyst Licensed to Page 4/8



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PVsyst V7.2.4
VC0, Simulation date:
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Main results

System Production

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Water Pumped	5295 m³	Energy At Pump	689 kWh	System efficiency	63.6 %
Specific	5423 m³/kWp/bar	Specific	0.13 kWh/m³	Pump efficiency	35.0 %
Water needs	5475 m³	**Unused (tank full)**			
Missing Water	3.3 %	Unused PV energy	153 kWh		
		Unused Fraction	14.1 %		

Normalized productions (per installed kWp)

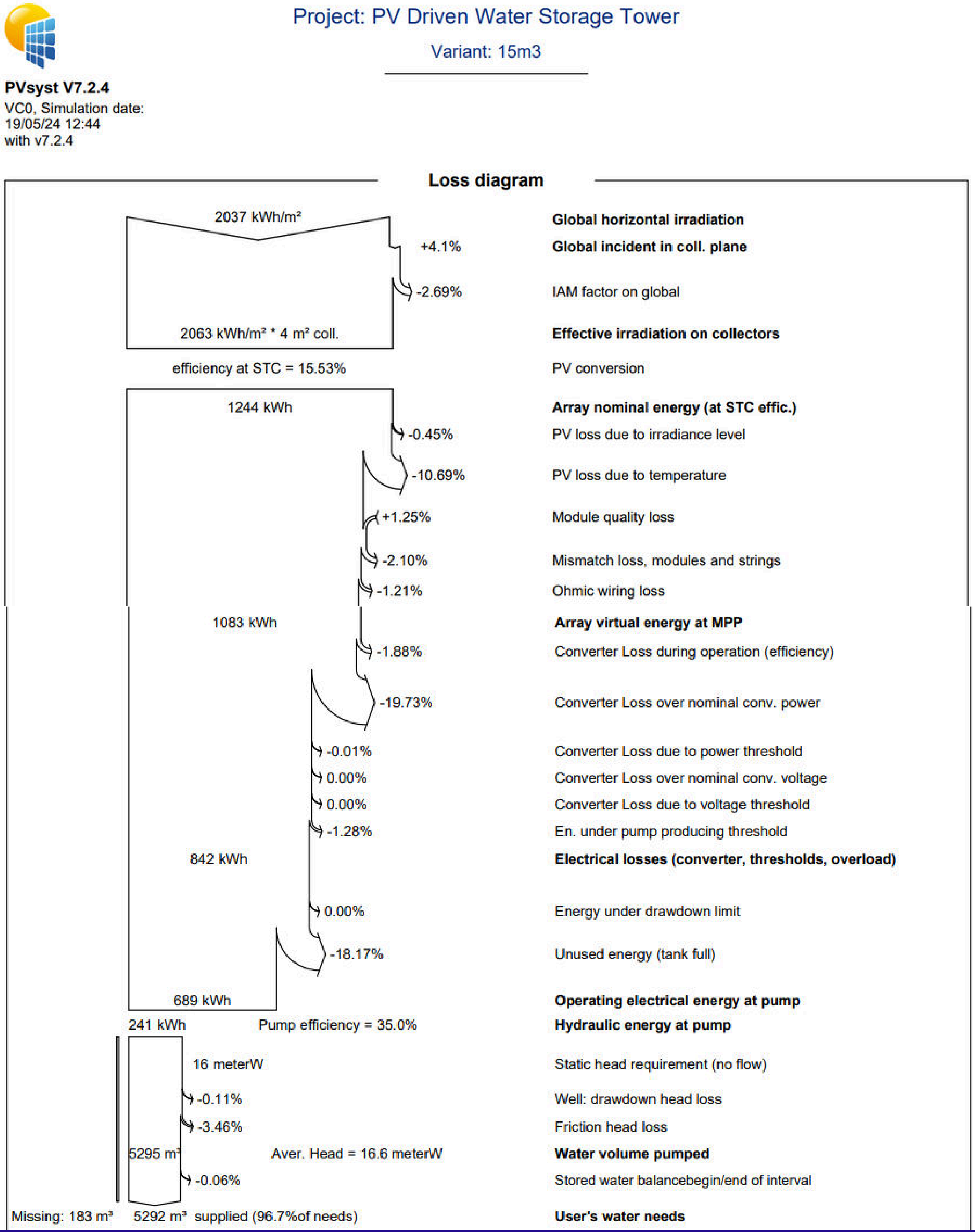
Performance Ratio PR

Balances and main results

	GlobEff	EArrMPP	E_PmpOp	ETkFull	H_Pump	WPumped	W_Used	W_Miss
	kWh/m²	kWh	kWh	kWh	meterW	m³	m³	m³
January	170.1	89.28	57.32	13.64	16.59	441.6	438.5	26.50
February	164.0	85.16	53.35	12.44	16.61	412.5	412.5	7.46
March	182.9	93.79	57.74	11.75	16.57	442.0	442.0	23.05
April	180.8	93.29	56.75	13.61	16.62	439.4	440.0	10.04
May	170.7	90.34	58.26	12.32	16.61	448.4	458.4	6.56
June	151.3	80.98	52.26	10.33	16.61	401.2	399.0	51.02
July	160.0	86.43	57.84	10.41	16.58	444.1	435.7	29.26
August	168.0	89.89	58.67	11.86	16.59	452.5	454.3	10.68
September	179.0	93.91	57.93	13.56	16.59	444.1	442.3	7.67
October	186.2	96.94	59.87	15.74	16.59	459.0	459.6	5.38
November	172.6	89.80	58.04	12.89	16.57	445.2	444.9	5.09
December	177.6	92.95	60.80	14.42	16.56	465.3	465.0	0.00
Year	2063.2	1082.76	688.84	152.97	16.59	5295.4	5292.3	182.71

Legends

GlobEff	Effective Global, corr. for IAM and shadings	WPumped	Water volume pumped
EArrMPP	Array virtual energy at MPP	W_Used	Water drawn by the user
E_PmpOp	Pump operating energy	W_Miss	Missing water
ETkFull	Unused energy (tank full)		
H_Pump	Average total Head at pump		



Project: PV Driven Water Storage Tower

Variant: 15m3

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19/05/24 12:44
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Loss diagram

2037 kWh/m² — **Global horizontal irradiation**
+4.1% — **Global incident in coll. plane**
-2.69% — IAM factor on global
2063 kWh/m² * 4 m² coll. — **Effective irradiation on collectors**
efficiency at STC = 15.53% — PV conversion
1244 kWh — **Array nominal energy (at STC effic.)**
-0.45% — PV loss due to irradiance level
-10.69% — PV loss due to temperature
+1.25% — Module quality loss
-2.10% — Mismatch loss, modules and strings
-1.21% — Ohmic wiring loss
1083 kWh — **Array virtual energy at MPP**
-1.88% — Converter Loss during operation (efficiency)
-19.73% — Converter Loss over nominal conv. power
-0.01% — Converter Loss due to power threshold
0.00% — Converter Loss over nominal conv. voltage
0.00% — Converter Loss due to voltage threshold
-1.28% — En. under pump producing threshold
842 kWh — **Electrical losses (converter, thresholds, overload)**
0.00% — Energy under drawdown limit
-18.17% — Unused energy (tank full)
689 kWh — **Operating electrical energy at pump**
241 kWh Pump efficiency = 35.0% — **Hydraulic energy at pump**
16 meterW — Static head requirement (no flow)
-0.11% — Well: drawdown head loss
-3.46% — Friction head loss
5295 m³ Aver. Head = 16.6 meterW — **Water volume pumped**
-0.06% — Stored water balancebegin/end of interval
Missing: 183 m³ 5292 m³ supplied (96.7%of needs) — **User's water needs**

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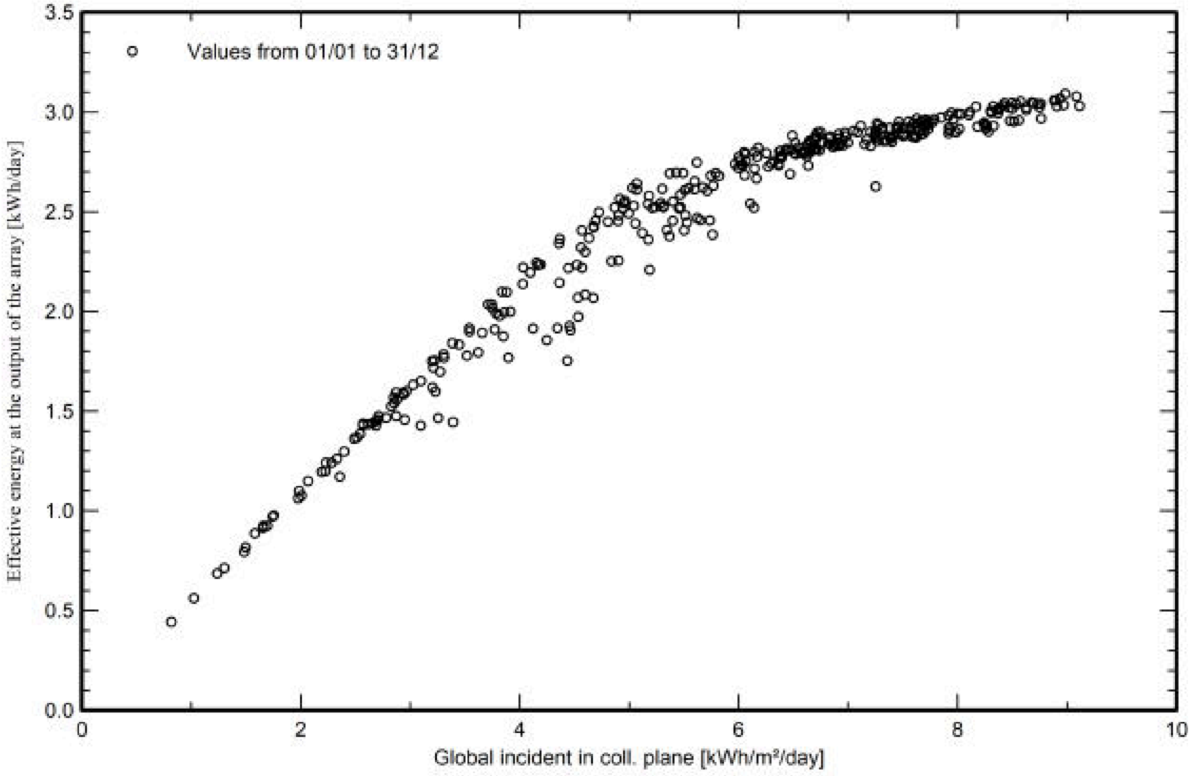
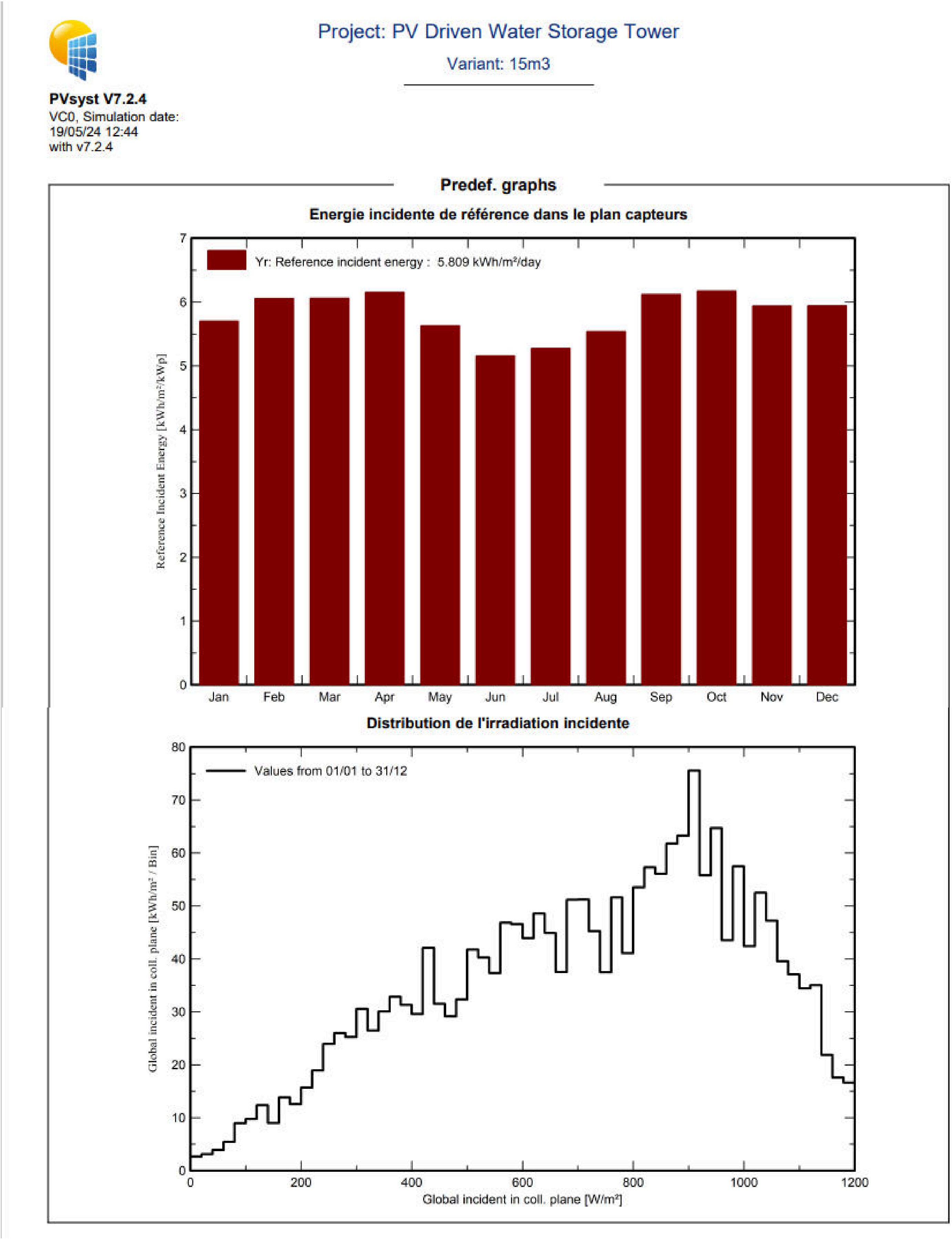
Special graphs

Diagramme d'entrée/sortie journalier





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Predef. graphs

Energie incidente de référence dans le plan capteurs

Distribution de l'irradiation incidente