MiGUEL
ENERGY SYSTEM MODELING

Report: Off grid system

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Technology
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EnerSHelf

Energy system: Off grid system

Introduction

The following report was automatically created using the Micro Grid User Energy Planning Tool Library (MiGUEL). MiGUEL was developed as part of the project 'Energy Supply for Healthcare Facilities in Ghana' (EnerSHelF) and will be published as an python-based open source planning tool to design and optimize Renewable Energy-Diesel-Hybrid systems. EnerSHelF was funded by the German Federal Ministry of Research and Development for the period from June 2019 to March 2023. EnerSHelF aims at improving the energy access and reliability of healthcare facilities in Ghana. The project's goal is to address the challenges faced by healthcare facilities in accessing reliable and sustainable energy sources by implementing a new reliable energy system. This will not only improve the energy efficiency of healthcare facilities but also support the delivery of quality healthcare services. The project will also raise awareness about the benefits of clean and sustainable energy sources and provide training and support to healthcare facility staff to ensure effective use and maintenance of the new energy solutions. EnerSHelF seeks to contribute to the improvement of healthcare in Ghana by ensuring healthcare facilities have access to reliable and sustainable energy sources.

The report is divided into the following parts:

1) Input Data
2) Weather Data
3) Energy consumption
4) System configuration
5) Dispatch
6) Evaluation

Summary

The selected system is considered an 'Off Grid System'. With the selected system configuration, THE ANNUAL ENERGY DEMAND OF 150,000 kWh IS NOT COVERED. The remaining energy to be covered equals 93,405 kWh. The highest load peak to be covered equals 33.478410000000004 kW. The PV system(s) account for 38.0% (57,059.0 kWh); The wind turbine(s) account for 0.0% (0 kWh); The grid accounts for 0.0% (0 kWh); The hydrogen system(s) includes:

- Electrolyzer energy input: 0 kWh
- Fuel Cell energy output: nan kWh
- H2 Storage charged with: 0 kWh and discharged with: 0 kWh

The battery system provided 0 kWh and was charged with 0 kWh.

The table below shows the energy system's key parameters, which will be described in detail in the upcoming report.

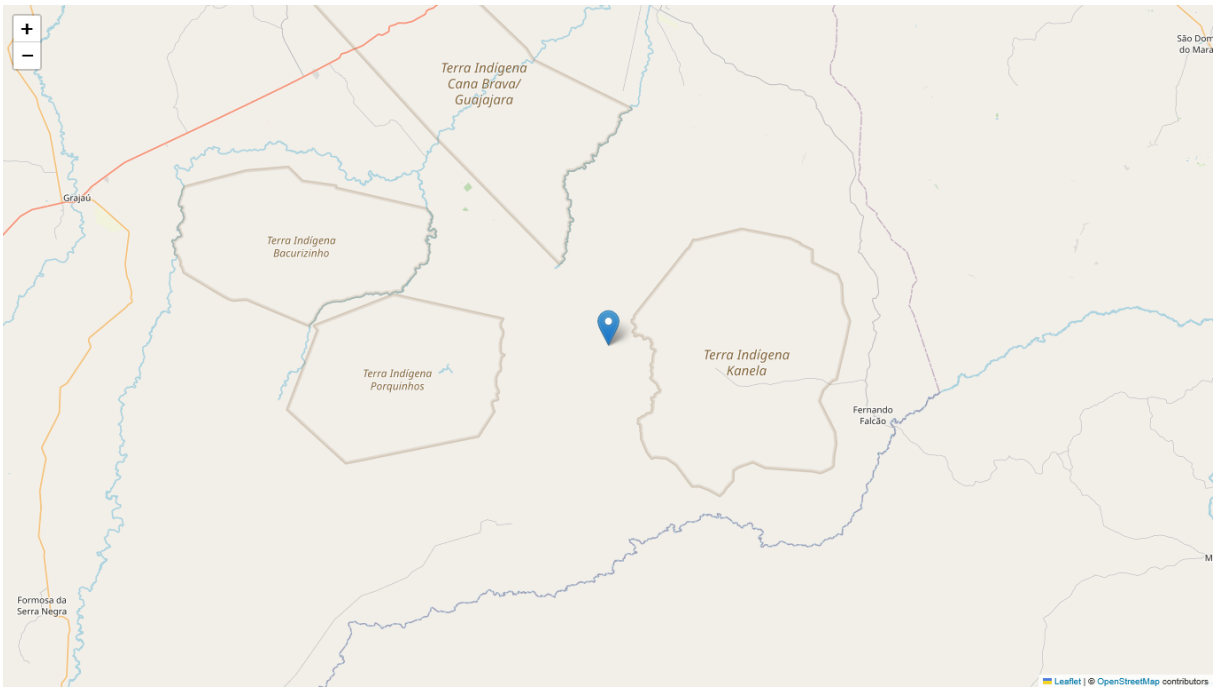
Component	Lifetime energy [kWh]	Invest. Cost [US$]	LCOE [US$/kWh]	Lifetime CO2 emissions [t]
PV_1	580,664.0	14,880.0	nan	nan
PV_2	293,695.0	14,880.0	nan	nan
ES_1	27,766.0	62,787.0	nan	nan
ES_1_charge	-28,119.0	nan	nan	nan
ES_1_discharge	27,766.0	nan	nan	nan
H2_Storage	0.0	nan	nan	nan
H2_Storage_storage	0.0	nan	nan	nan

FuelCell_3	0.0	nan	nan	nan
FuelCell_3_discharge	0.0	nan	nan	nan
System	2,298,569.0	92,547.0	0.04	0.0

1 Base data

The following parameters are provided through the user. If no values were entered default values will be used. The chapter functions as an overview of the base parameters. The location is displayed on the map below.

Parameter	Value
Project name	Off grid system
City	None
ZIP Code	None
State	Maranhão
Country	Brasil
Country Code	br
Latitude [°]	-6.045612
Longitude [°]	-45.31375
Start time	2022-01-01 00:00:00
End time	2022-12-31 23:59:00
Time resolution	0:15:00
Currency	US$
Electricity price [US$/kWh]	0.152
Feed in possible	0
PV Feed-in tariff [US$/kWh]	0
Wind turbine Feed-in tariff [US$/kWh]	0
System lifetime [a]	20
Discount rate	0.03
CO2 equivalent Grid [kg/kWh]	0.098



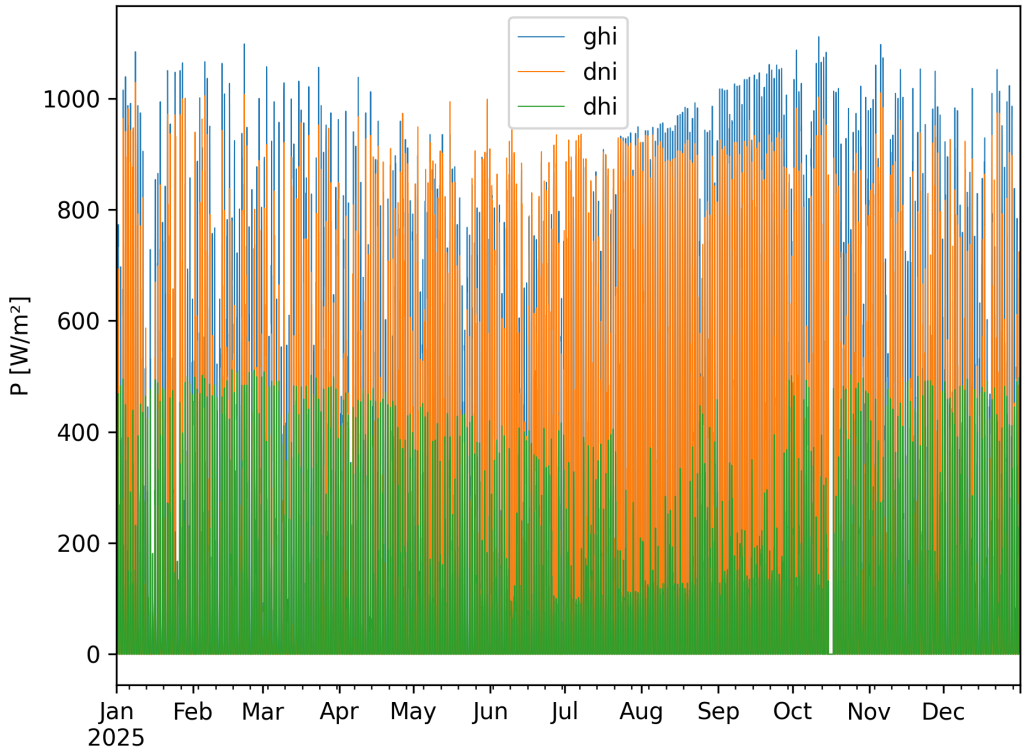
2 Climate data

In the upcoming chapter displays climate conditions at the selected location. The provided data originates from the Photovoltaic Geographical Information System (PVGIS) hosted by the European Commission.The data is created from a typical meteorological year (TMY). For this purpose, the typical meteorological month is selected. The table shows the month and the years where the data is taken from.

January	February	March	April	May	June	July	August	September	October	November	December
2005	2017	2016	2019	2005	2013	2012	2021	2010	2016	2017	2016

2.1 Solar irradiation

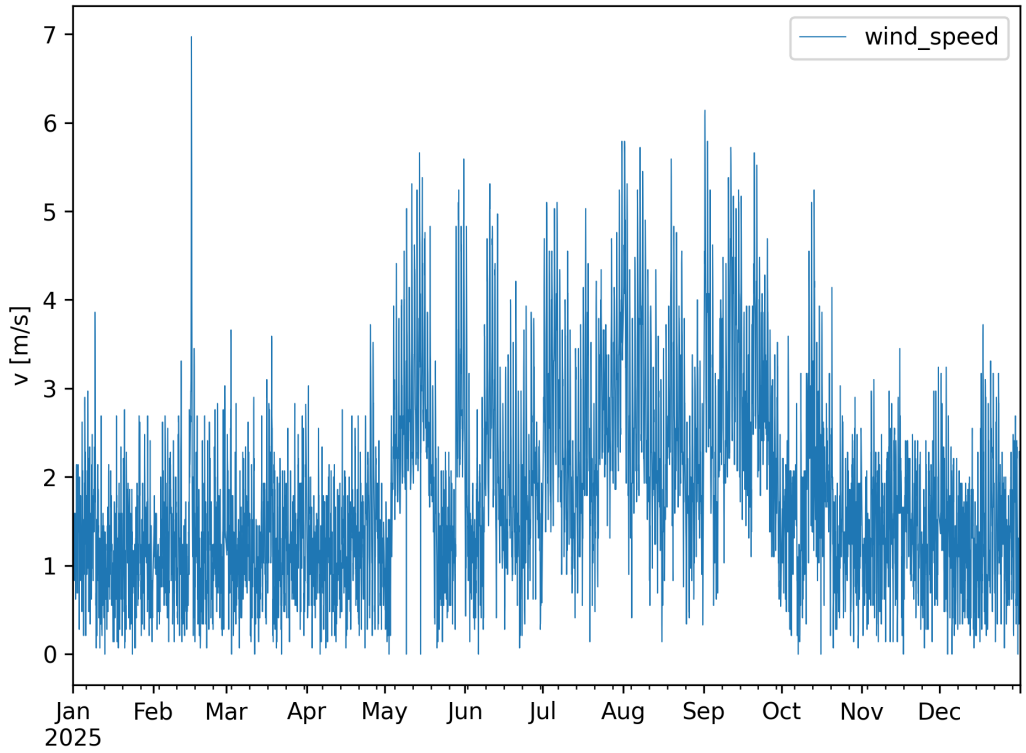
The plot shows the global horizontal irradiation (GHI), direct normal irradiation (DNI) and the direct horizontal irradiation (DHI) at the selected location in an hourly resolution based on the TMY. The table shows the average monthly GHI, DNI and DHI values.



Month	Avg. GHI [W/m²]	Avg. DNI [W/m²]	Avg. DHI [W/m²]
January	209.079	152.153	101.559
February	208.628	114.625	119.365
March	203.199	119.65	109.661
April	207.561	142.032	104.01
May	217.392	195.004	88.547
June	206.956	207.751	75.554
July	246.965	280.29	62.028
August	265.302	278.102	69.233
September	296.114	304.986	69.965
October	243.828	200.916	92.82
November	243.294	184.155	107.838
December	216.911	132.76	118.617

2.2 Wind speed

The plot shows the wind speed at 10m height in hourly-resolution. The table shows the monthly average wind speed and direction.

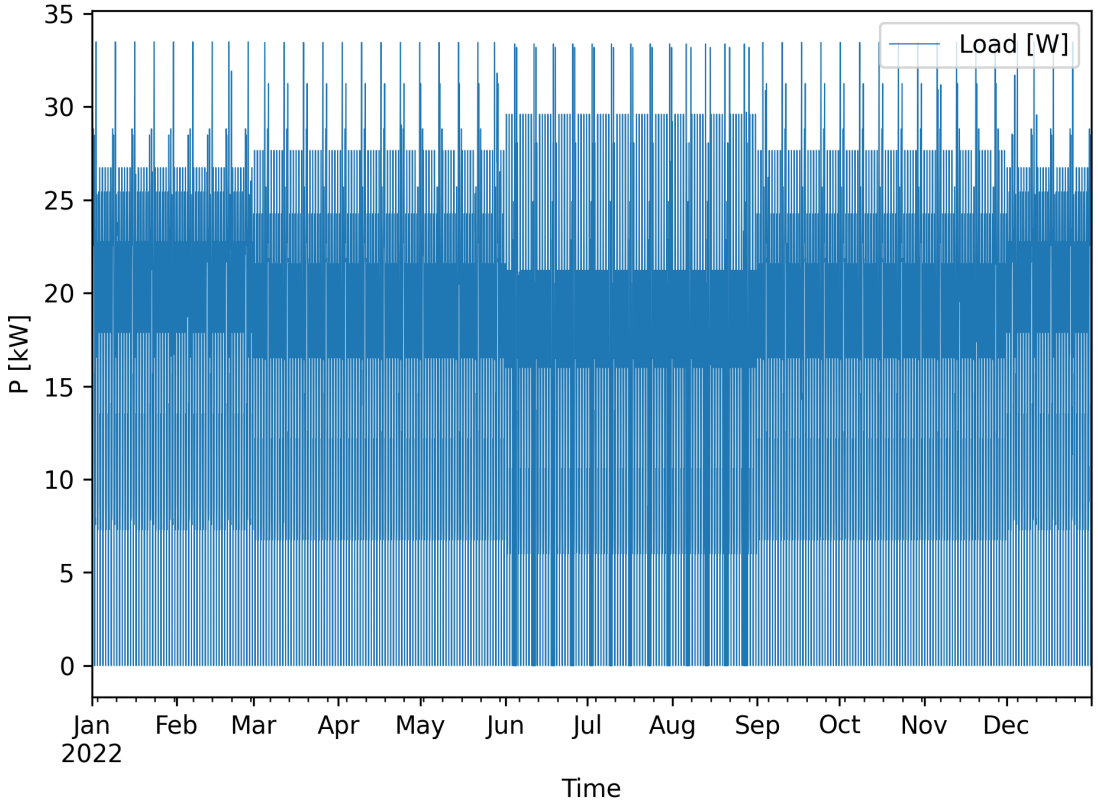


Month	Avg. Wind Speed [m/s]	Avg. Wind direction [°]
January	1.209	154.374
February	1.302	192.842
March	1.27	157.575
April	1.242	131.539
May	2.252	128.489
June	1.892	107.965
July	2.63	112.918
August	2.541	114.23
September	2.918	115.072
October	1.706	146.138
November	1.431	162.235
December	1.368	170.44

The main wind direction is 141.151°. The annual average wind speed is 1.813 m/s. The highest monthly wind speed occurs in September and is 2.918 m/s.

3 Energy consumption

The energy consumption is calculated based on the load profile. The total load profile over the considered period is created by repeating the input load profile. The total energy consumption, peak load, energy cost and CO2 emissions are calculated using the total load profile. The energy costs and CO2 emissions refer to a power generation by the power grid or a diesel generator and are used as comparative values for grid-connected and off-grid systems.



	Power Grid	Diesel Generator	
Energy consumption [kWh]	150,000.0	150,000.0	
Peak load [kW]	33.478	33.478	
Energy cost [US$]	No grid connection	-	-
CO2 emissions [t]	No grid connection	-	-

4 System configuration

The chapter system configuration contains detailed information about the selected system components. This includes parameters such as nominal power/capacity, specific investment and operation andmaintenance cost (chapter 4.1). Furthermore the renewable energy energy supply is displayed (chapter 4.2).

4.1 System components

The upcoming tables list all system components of the energy system. The system components are split up into the categories energy supply and energy storage.

Energy supply:

Component	Name	P [kW]	i_c [US$/kW]	I_c [US$]	om_c [US$/kW]	OM_c [US$/a]
PV System	PV_1	30.0	496	14,880	7	226
PV System	PV_2	30.0	496	14,880	7	226

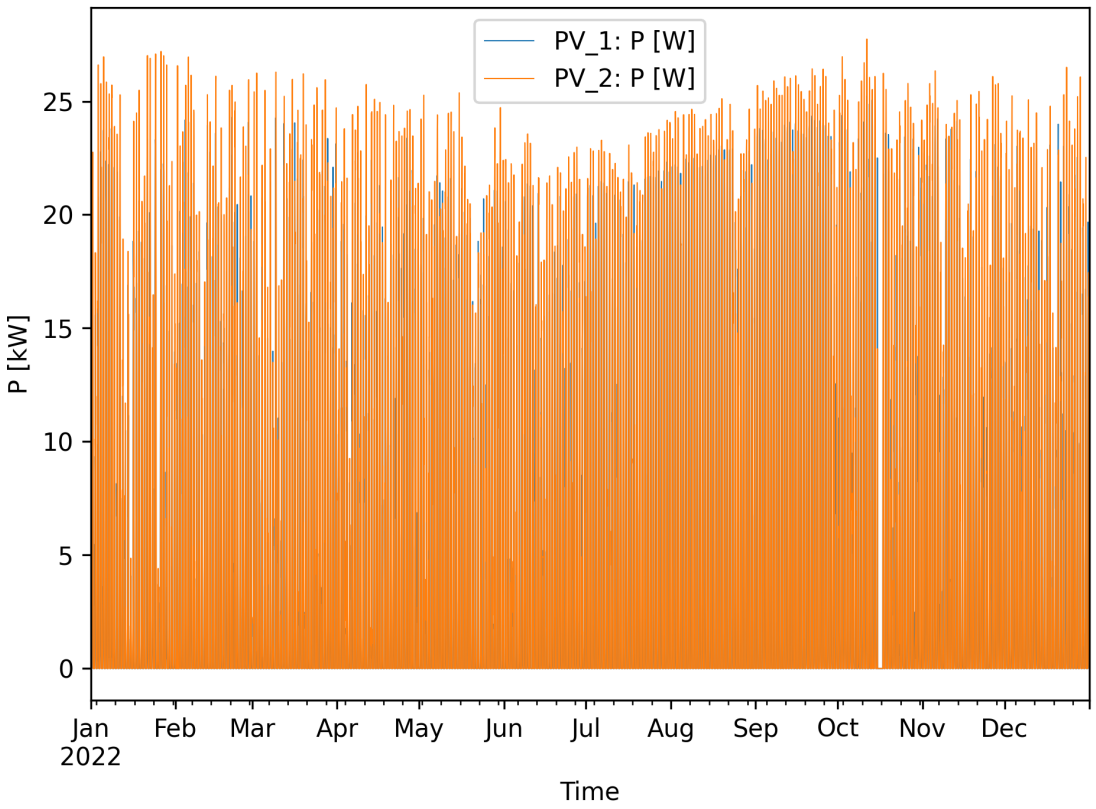
Energy Storage:

Component		Name		Capacity		storage level			
H2 Storage		H2_Storage			500		0		
Component	Name	P [kW]	W [kWh]	i_c [US$/kWh]	I_c [US$]	om_c [US$/kWh]	OM_c [US$/a]		
Energy Storage	ES_1	10.0	30,000	1,200	12,000	30	900	nan	
Hydrogen Storage	H2Storage_2250883047696	nan	nan	nan	nan	nan	nan	500.0	

P : Nominal power
i_c: Specific investment cost
I_c: Investment cost
om_c: Specific operation maintenance cost
OM_c: Operation maintenance cost
W: Capacity

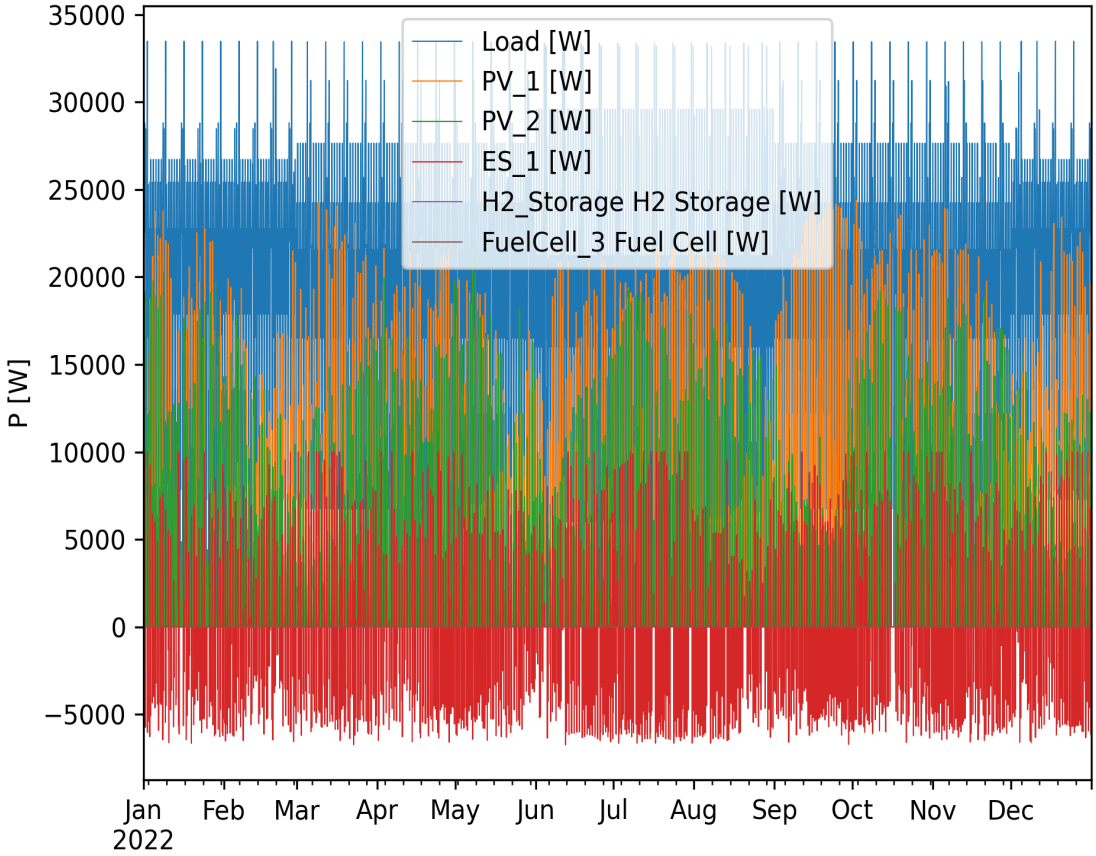
4.2 Renewable energy supply

The plot shows the total wind power and PV output during the period from 2022-01-01 00:00:00 to 2022-12-31 23:59:00 in a 0:15:00 resolution:
Photovoltaic total: 390,721 kWh
Wind turbine total: 0 kWh.

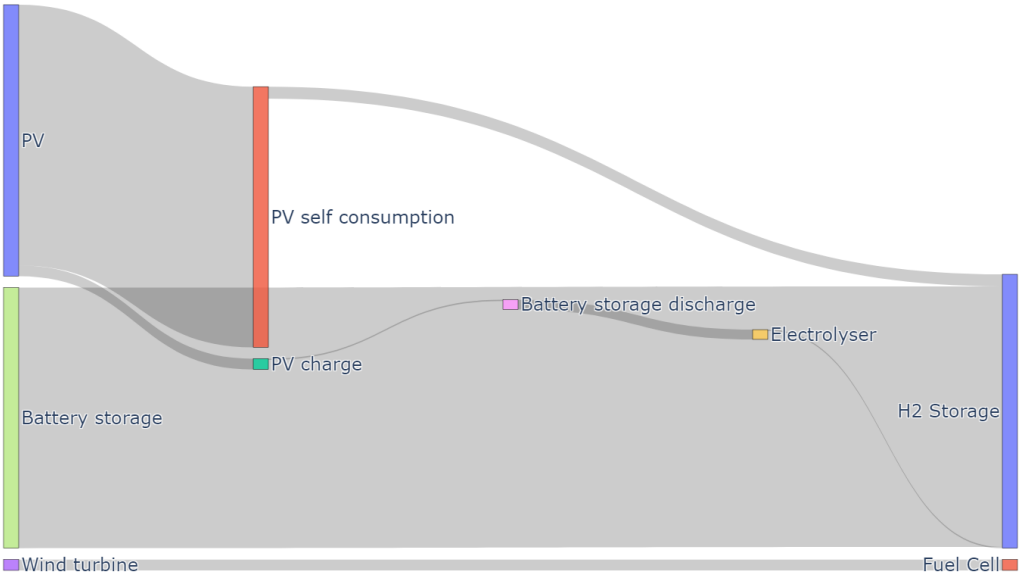

PV_1: P [W]
PV_2: P [W]
P [kW]
25
20
15
10
5
0
Jan
2022
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Time

5 Dispatch

This chapter presents the dispatch of the power system. The system is considered a 'Off Grid System'. The plot below shows the load profile and the power the system components supply in kW. Energy storage systems can both consume and supply power. Negative values correspond to power output (power source), positive loads to power input (power sink).



The sankey diagram below illustrates the annual energy flows of the system components. The energy flows are represented to scale in kilowatt-hours.


PV
PV self consumption
Battery storage discharge
Electrolyser
PV charge
Battery storage
H2 Storage
Wind turbine
Fuel Cell

6 Evaluation

In this chapter, the selected system configuration is evaluated from an ecological and economic point of view. The economic evaluation is based on the levelized cost of energy (LCOE). The ecological evaluation focuses on the CO2 emissions.

6.1 Economic evaluation

The key parameter to evaluate energy systems on an economical basis are the LCOE. LCOE stands for Levelized Cost of Energy and is a metric used to compare the cost of energy produced by different sources. It represents the average cost of energy over the lifetime of a power generation project, including all costs such as capital costs, operating costs, fuel costs, CO2 costs and maintenance costs and revenues (e.g. through feed-in). The LCOE allows for a fair comparison of energy generation options, as it takes into account all costs and revenues over the lifetime of a project, rather than just the upfront capital costs. The LCOE is often used to compare different types of energy generation, including conventional fossil fuels and renewable energy sources, and is an important tool for energy planning and investment decisions.

Component	Annual Energy [kWh]	Lifetime cost [US$]	Invest. Cost [US$]	Annual Cost [US$/a]	LCOE [US$/kWh]
PV_1	37,893.0	0.0	14,880.0	nan	nan
PV_2	19,166.0	0.0	14,880.0	nan	nan
ES_1	1,812.0	0.0	62,787.0	nan	nan
ES_1_charge	-1,835.0	nan	nan	nan	nan
ES_1_discharge	1,812.0	nan	nan	nan	nan
H2_Storage	nan	nan	nan	nan	nan
H2_Storage_storage	nan	nan	nan	nan	nan
FuelCell_3	nan	nan	nan	nan	nan
FuelCell_3_discharge	-0.0	nan	nan	nan	nan
System	150,000.0	0.0	92,547.0	0.0	0.04