Energy Storage For Azores

19.10.2023

Why Azores?

- 9 Islands
- It’s devided into three main groups
- Energy Systems on the islands depend mostly on fossil fuels
- The Energy has to be transported to the islands

Problems with the isolation of the islands

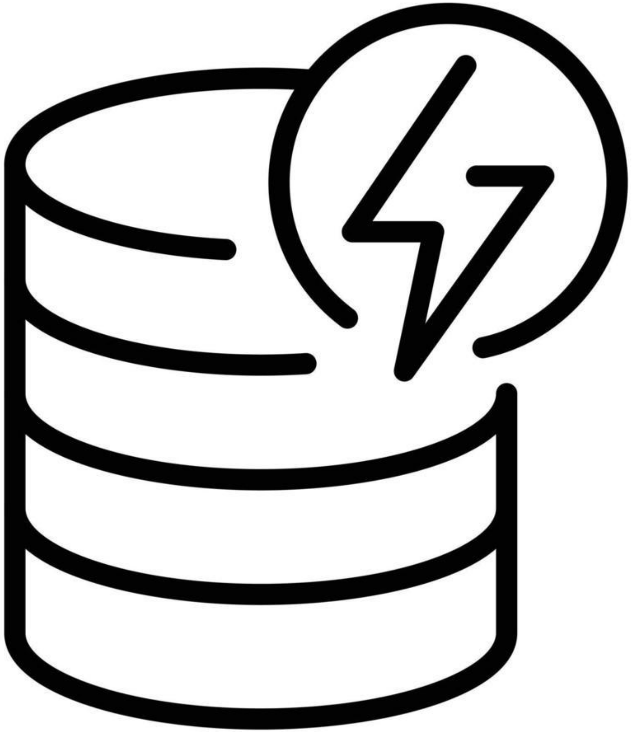
- Each island has its own independent energy system
- High Costs of transportation
- Problems related with the transportation of energy

Integration of Energy Storage

- Three islands: Faial, Flores and S. Miguel
- Different energy mixes
- Energy Storage System will be used to store energy during periods of high electricity production
- Reduce the energy production based on non-renewable sources
- Main goal: Energy independence of each island

Overview

1. Electrical Energy
2. Electrochemical Energy Storage
3. Thermal Energy
4. Thermal Energy Storage
5. Data Analysis



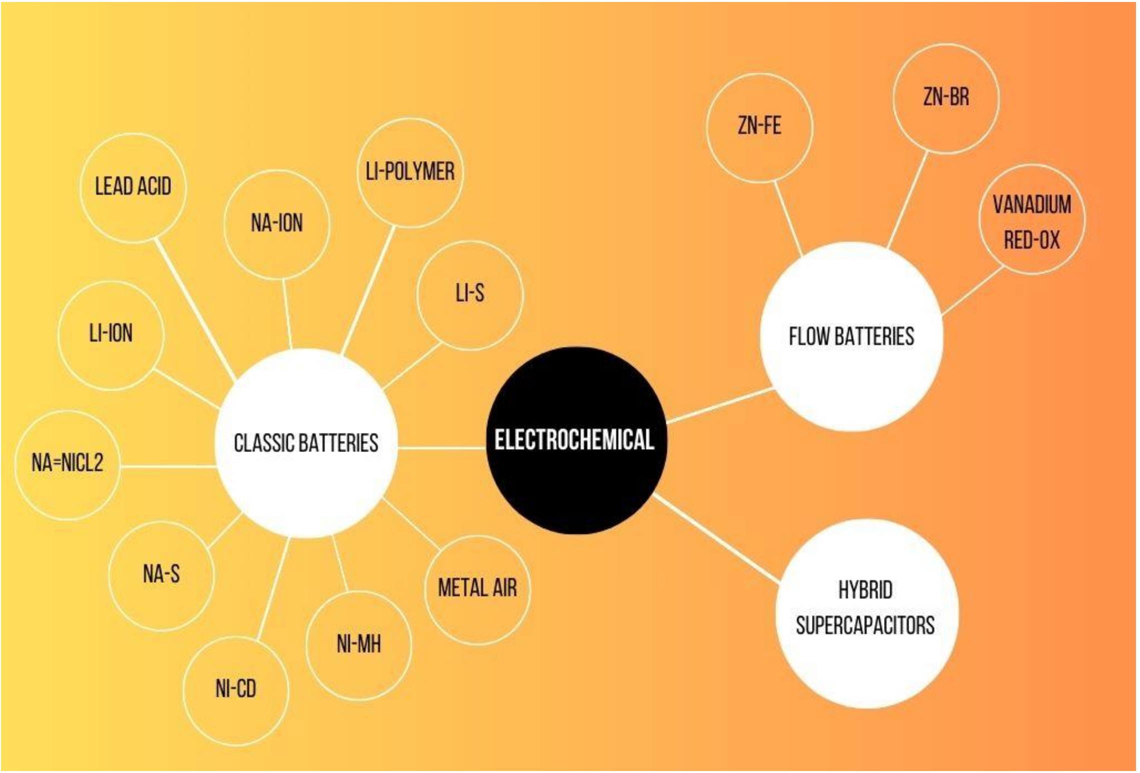
State of arts: Electrical Energy

Electrical energy is the potential ability to perform work using electric current. It is measured in watt-hours or joules.

E = P * t, where:

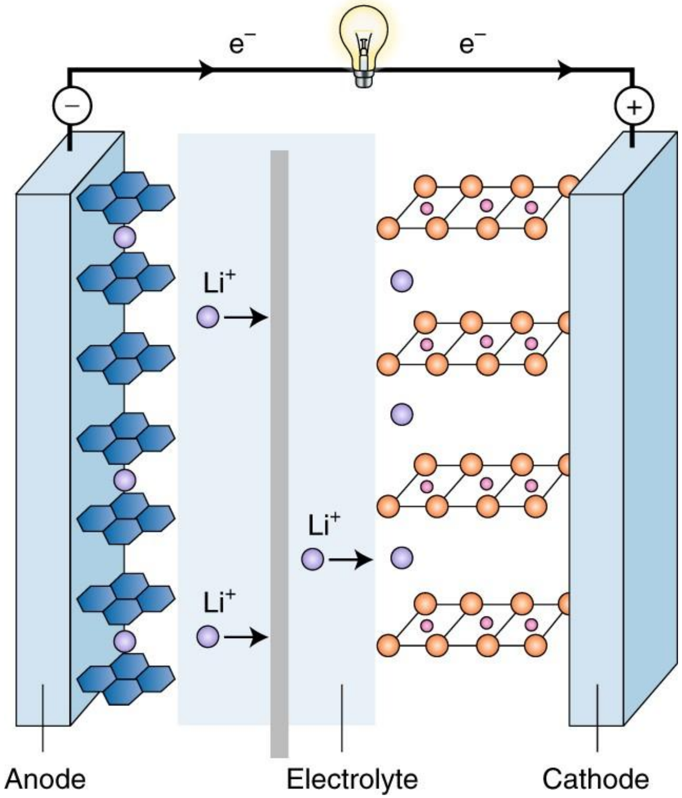
E - electrical energy (Wh); P - stands for power (W); t denotes time (h)

State of arts: Electrochemical Energy Storage



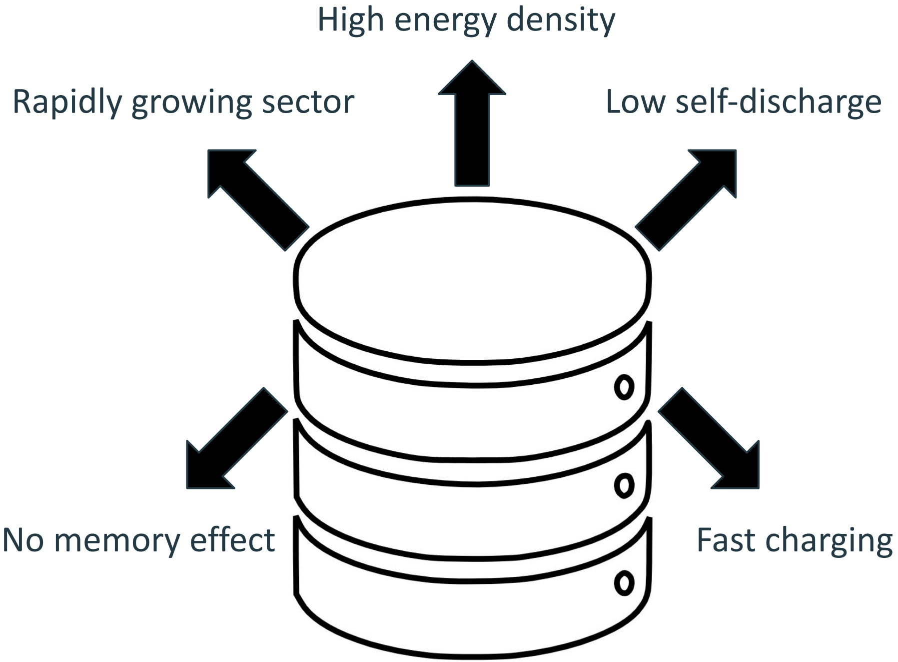
Lithium-ion Battery

Lithium Ion (Li-Ion) Battery System is an energy storage system based on electrochemical charge/discharge reactions that occur between a positive electrode (cathode) that contains some lithiated metal oxide and a negative electrode (anode) that is made of carbon material or intercalation compounds.



https://www.nature.com/articles/s41928-018-0048-6

Why Lithium-ion Battery?



Power range	1kW to 50 MW
Energy range	Up to 10 MWh
Discharge time	10min to 4h
Cycle life	2,000 - 10,000 cycles
Life duration	15 – 20 years
Reaction time	Some millisec
Efficiency	90 - 98 % [*]
Energy (power) density	120 - 180 Wh/kg
CAPEX: energy	700 – 1,300 €/kWh
CAPEX: power	150 – 1,000 €/kW

https://ease-storage.eu/energy-storage/technologies/

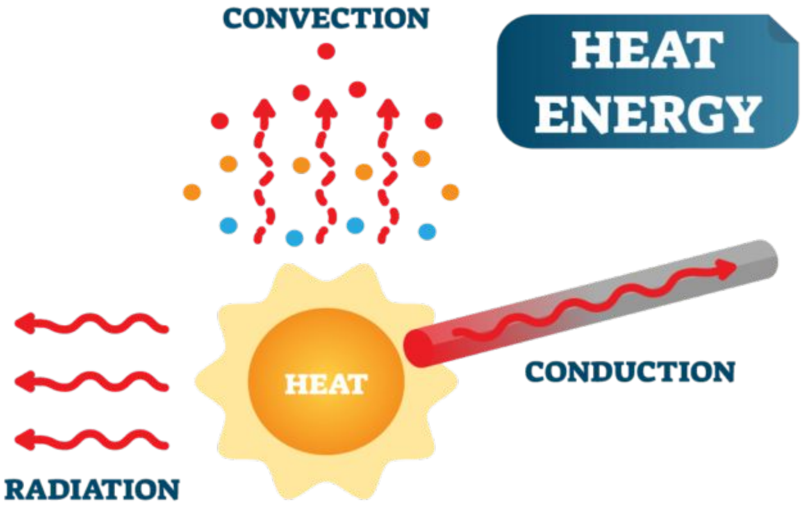
State of arts: Thermal Energy

The energy required „E” to heat a volume „V” of a substance from a temperature „T1” to a temperature „T2” is given by (Dincer, Rosen; 2011):

$$\mathbf{E = mC(T2 - T1) = \rho VC(T2 - T1)}$$, where:

m-mass; C-specific heat capacity; T2-T1-temperature difference; ρ-density; V-volume

State of arts: Thermal Energy



State of arts: Thermal Energy Storage

SH

Sensible Heat Energy

- Graphite
- Ceramics, silica and sand
- **Molten Salts**
- Concrete
- Rocks
- Steel
- Underground water
- Water

LH

Latent Heat Storage

- Microencapsulated metals
- Inorganic salts and eutectic mixtures
- Sodium
- Other liquid metals
- Molten aluminium alloy
- Paraffin waxes, fatty acids
- Salt hydrates
- Salt-water mixtures
- Ice
- Liquid air

TCS

Thermochemical Heat Storage

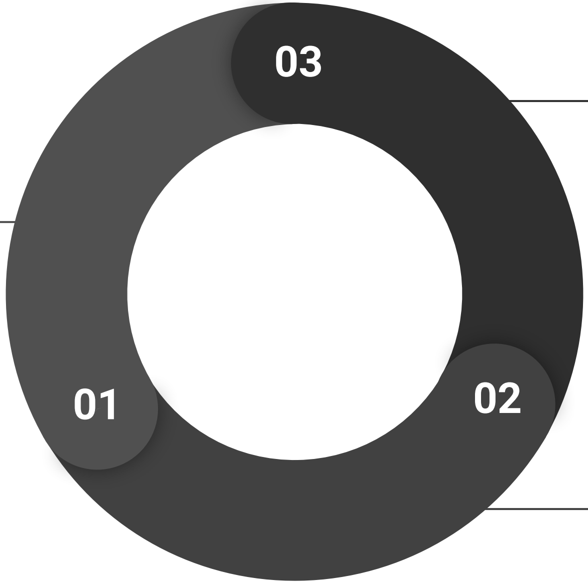
- Chemical Reaction Storage **(f.e. ammonia)**
- Absorption
- Adsorption

EASE, 2023

Molten Salts - Advantages

Wide Operating Temperature Range

Molten salts, such as nitrate salts have lower freezing points (reducing the risk of freezing) and higher maximum temperature limits (exceeding 600℃) as opposed to different heat transfer fluids.



Low Vapor Pressure

Molten salts experience minimal vapor pressure even at high temperatures, reducing the need for costly high-pressure equipment.

Efficiency

Molten salts offer good thermal stability and efficient heat transfer, resulting in eco-friendly and cost-effective operation.

Ammonia, as a Thermochemical Material - Advantages

$$2NH_3 + \Delta H \overset{catalyst}{\rightleftharpoons} N_2 + 3H_2$$

Controlled and Reversible Reaction of ammonia dissociation	Efficient Energy Storage	„Industrial Expertise”	Wide Range of Operating Temperature	Decoupled Temperature Control
There is no chance of occuring unwanted side reactions, making the system **highly manageable.**	Operating above the ambient temperature saturation pressure of ammonia allows most of it to remain in a liquid state, **simplifying phase separation**.	Benefit from over a century of industrial experience with the **well-established 'Haber-Bosch' process**.	The system can operate at a big temperature range, **from several hundred degrees to over 1,000°C**, offering flexibility for various applications.	The dissociation process and heat recovery are decoupled. This flexibility enables **efficient power production** and can act as a **chemical heat pump**.

Dunn, 2016

Data Analysis

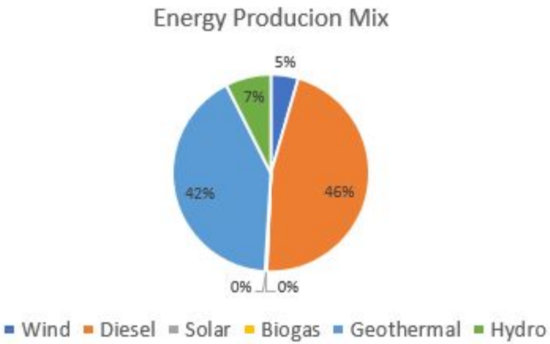
2 Models

Current Situation

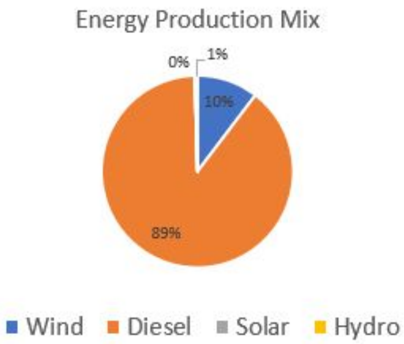
100% Renewable Solution

Energy Production Mix

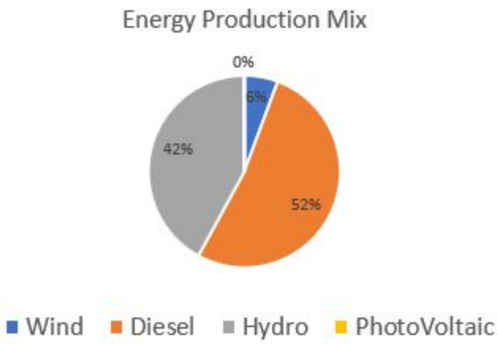
São Miguel



Faial

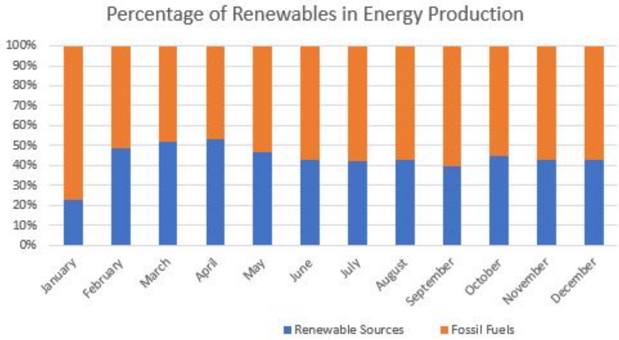


Flores



Share of Renewables

São Miguel



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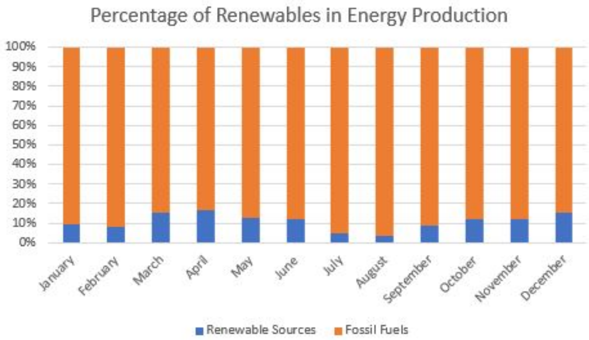

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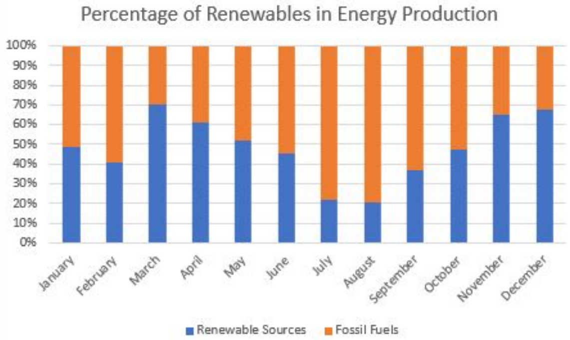
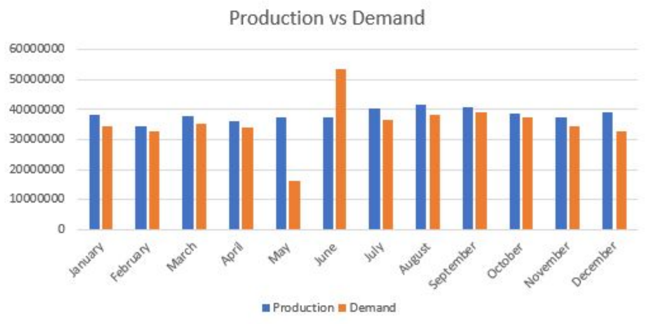
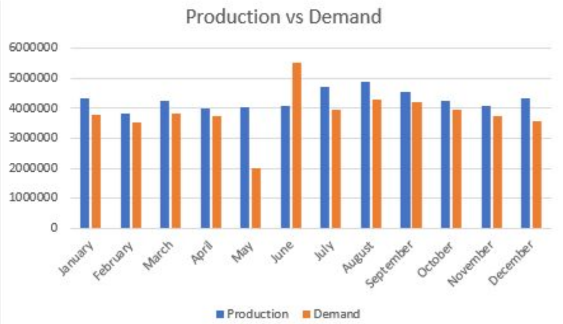


Production vs Demand

São Miguel



Faial



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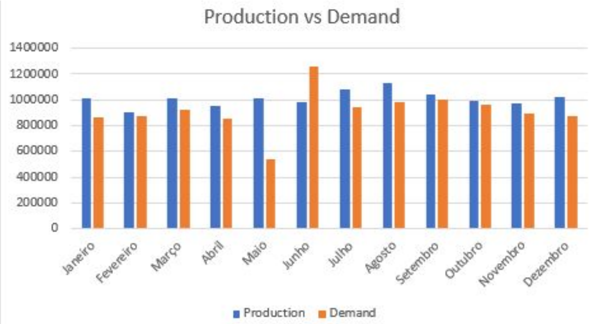


Data Analysis:

Storage Data

3 commercially used batteries

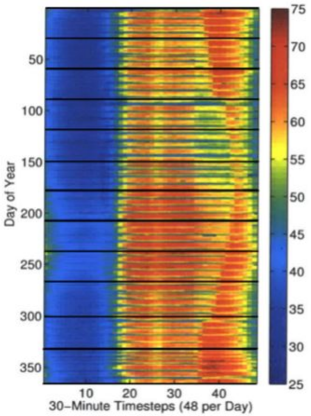
	Capacity [kWh]
Battery 1	13.8
Battery 2	2.56
Battery 3	1.28

2 Theoretical storage systems:

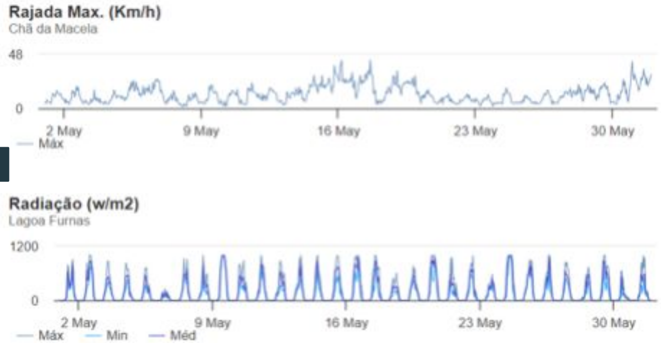
	Molten Salts	Ammonia System
Storage Capacity/ Energy Density	110 kWh/ton	4.3 kWh/L

Our Model

Demand Profile

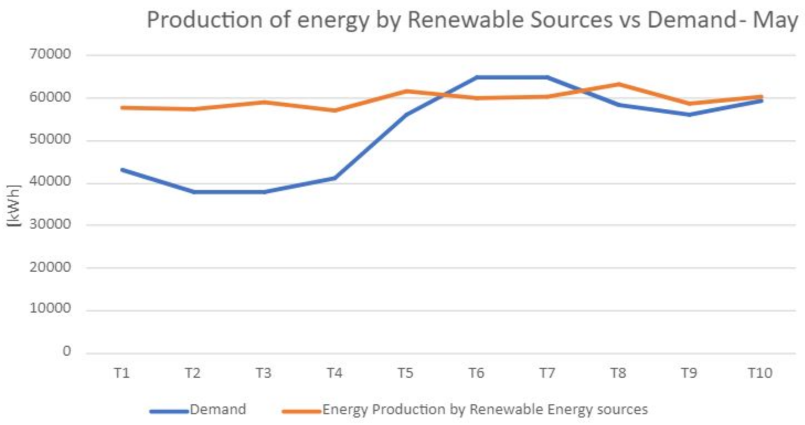


Climate Data



Average conditions throughout a day

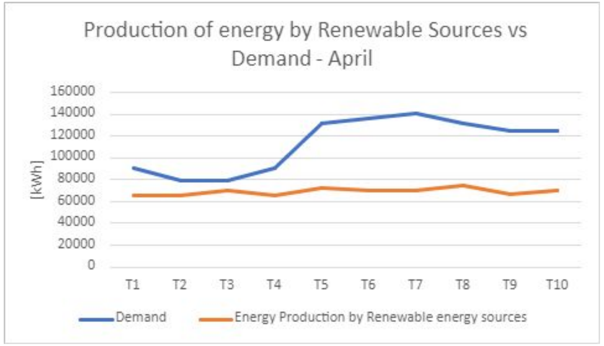
São Miguel

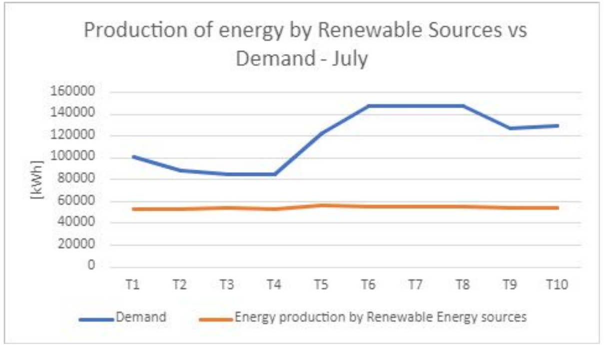


Ammount to store:	11324.38	kWh

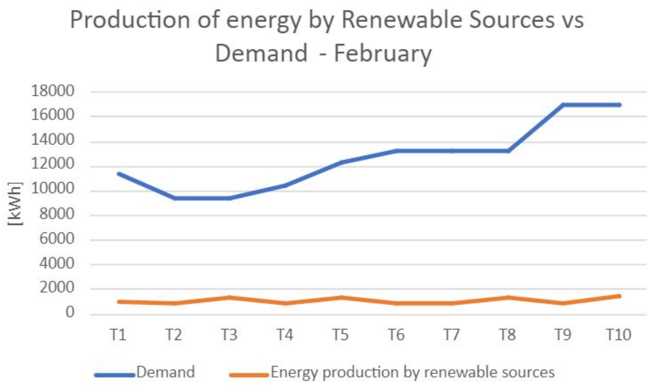
BAT1	BAT2	BAT3	Molten Salts (ton)	Amonia (L)
821	4424	8847	102.95	2633.58

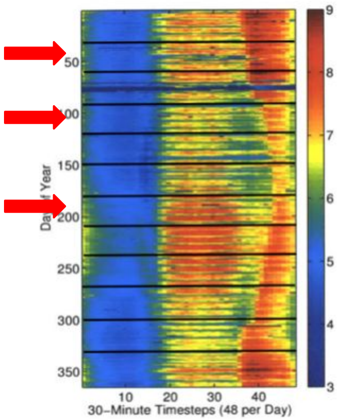
Fuel Imports in May 2022 for energy production:	2 566 465,28 L



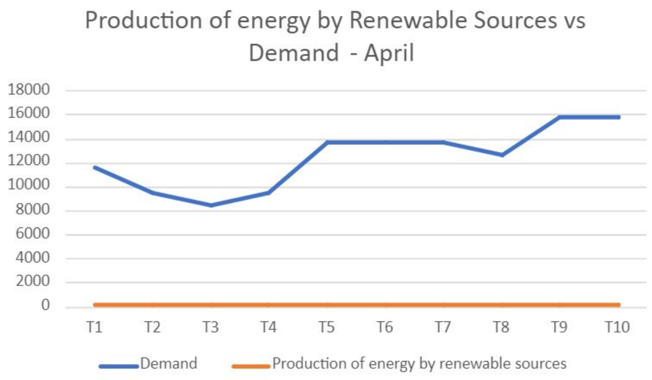


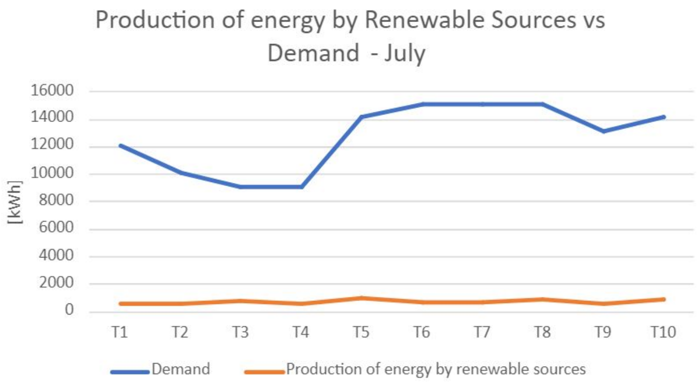
Faial



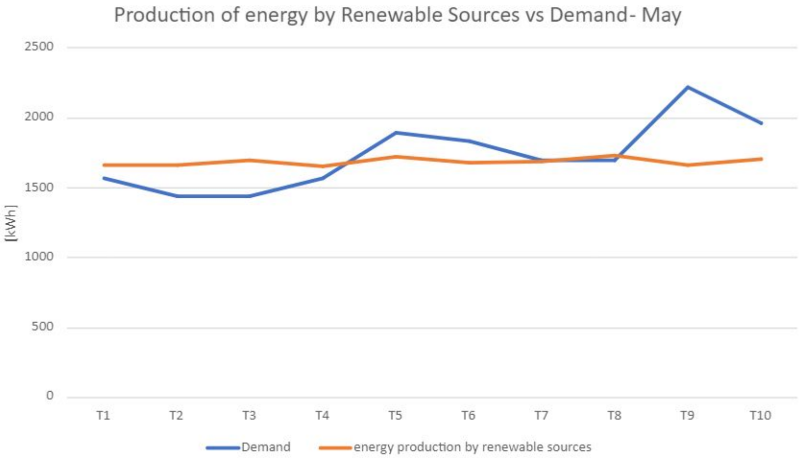


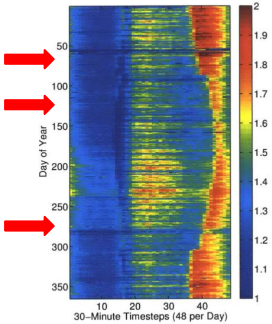
(a) Faial





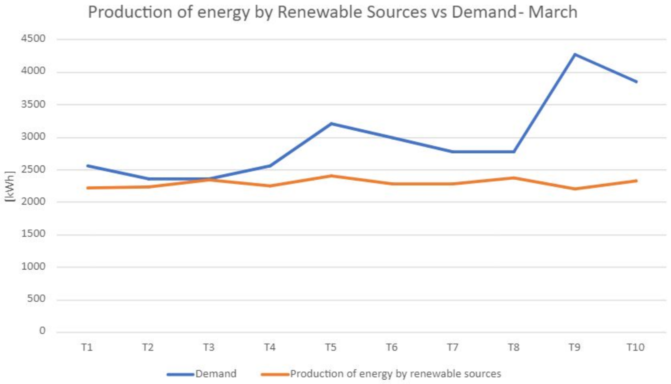
Flores

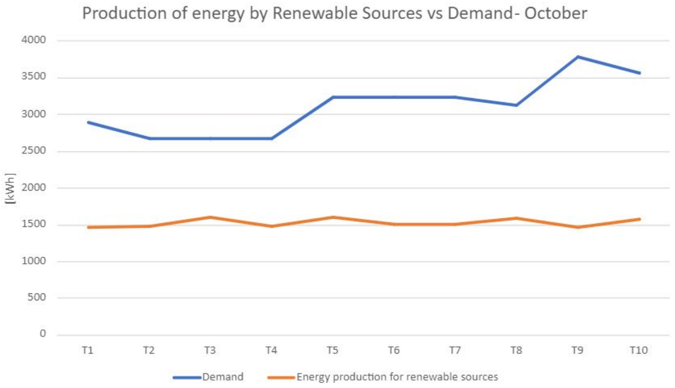




Ammount to store:	833.025	kWh

Battery 1	Battery 2	Battery 3	Molten Salts (ton)	Amonia (L)
60	325	651	7.57	193.73



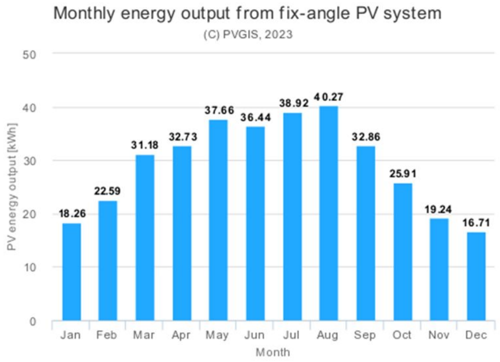


100% Renewable Solution

Wind turbines and PV panels sizing - São Miguel

	Renewable [kWh]	Demand [kWh]	Highest difference
June	15986398	53649730	37663332

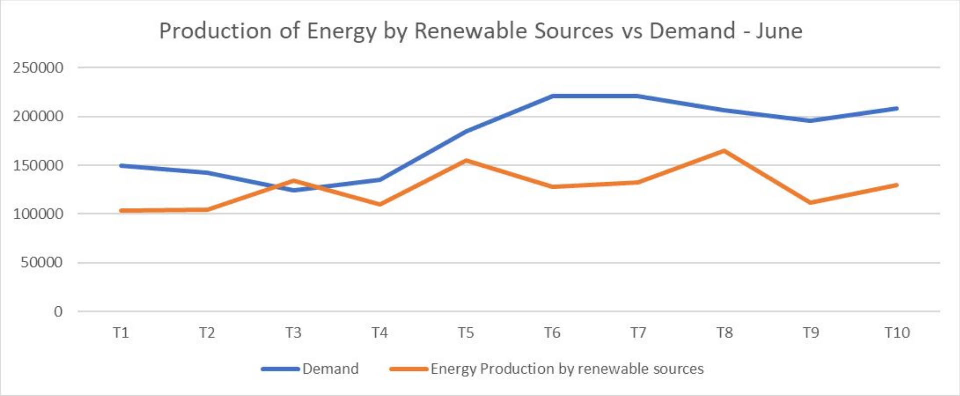
Number of Wind turbines and PV panels



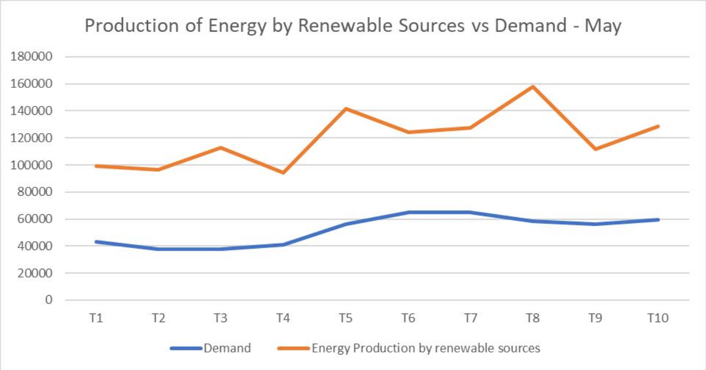
- Model: E44/900
- Rated power: 900 kW
- Rotor diameter: 44 m

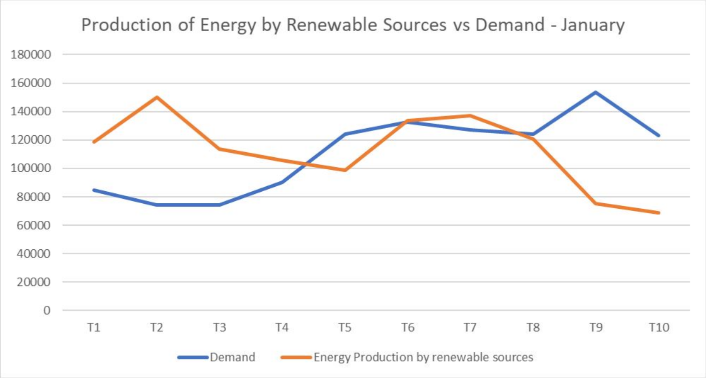
Adding Storage → Optimization Problem

São Miguel

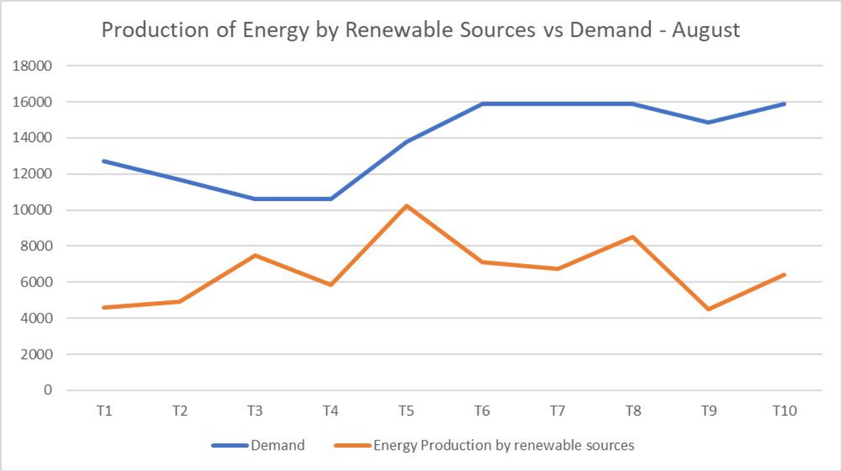


Nº PVs	Nº Wind Turbines
10000	183

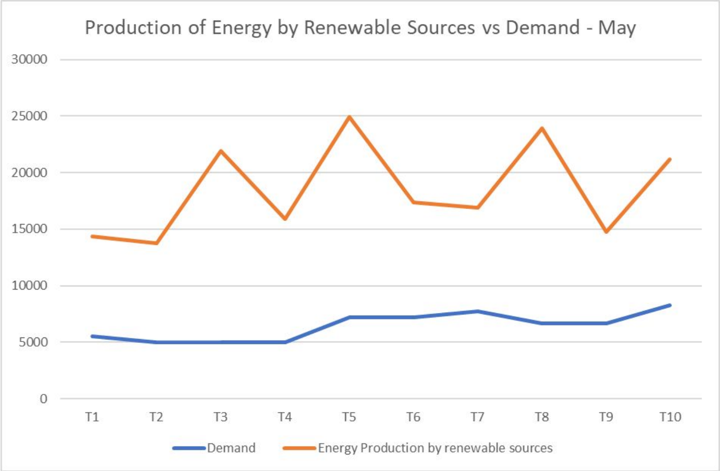




Faial

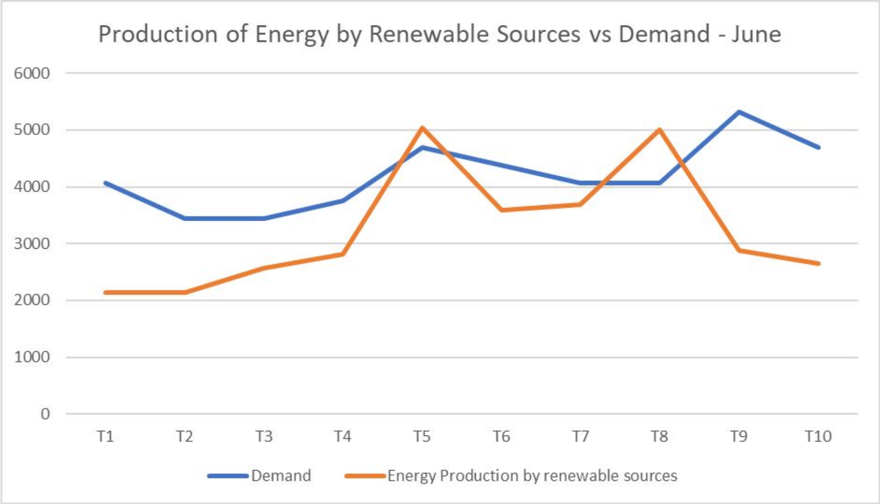


Production of Energy by Renewable Sources vs Demand - August
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
Demand
Energy Production by renewable sources

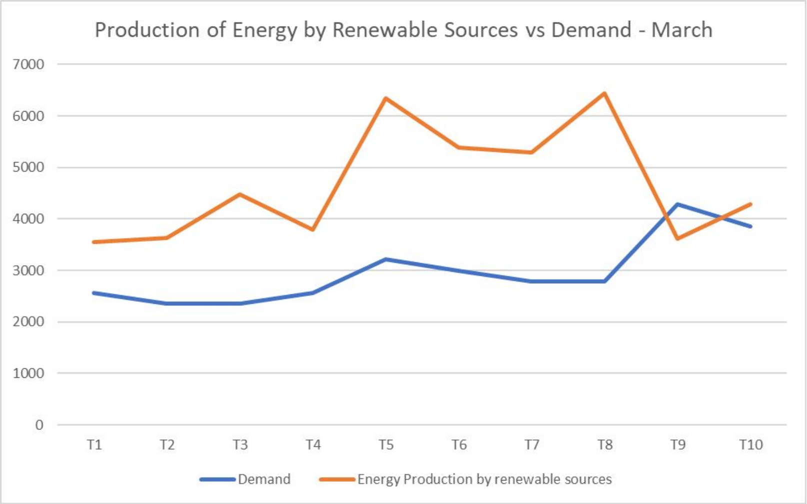


Production of Energy by Renewable Sources vs Demand - May
30000
25000
20000
15000
10000
5000
0
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
Demand
Energy Production by renewable sources

Flores



Production of Energy by Renewable Sources vs Demand - June
6000
5000
4000
3000
2000
1000
0
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
Demand
Energy Production by renewable sources



Production of Energy by Renewable Sources vs Demand - March
7000
6000
5000
4000
3000
2000
1000
0
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
Demand
Energy Production by renewable sources

100% Renewable Storage

São Miguel

Ammount to store	524440,6	kWh

BAT1	BAT2	BAT3
190015	204860	409719

Molten Salts 100%	4767,642024	ton
Amonia	121962,9	L

Faial

Ammount to store	94002,48	kWh

BAT1	BAT2	BAT3
34059	36720	73439

Molten Salts 100%	777,65	ton
Amonia	21861,04276	L

Flores

Ammount to store	10635,17	kWh

BAT1	BAT2	BAT3
3853	4154	8309

Molten Salts 100%	96,683	ton
Amonia	2473,296487	L

Thank you for attention!

Pedro Teixeira,
Pedro Manuel,
António Lobo Vilela,
Gabriela Boroń,
Julia Grochowska

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