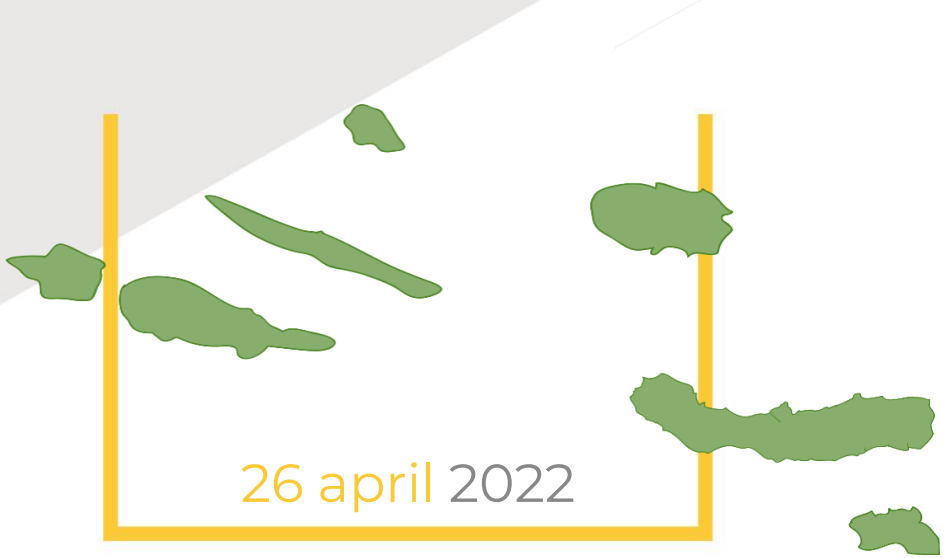
EDA
Electricidade dos Açores

energynautics
solutions for sustainable development

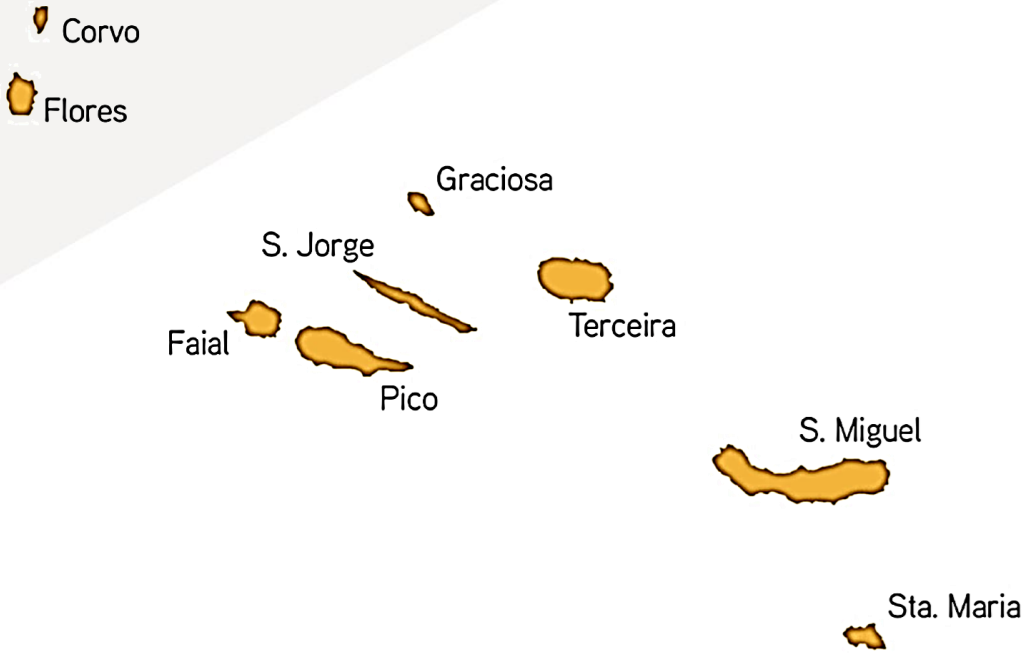
The Energy Challenges in Azores



26 april 2022

2022 6th INTERNATIONAL HYBRID POWER SYSTEMS WORKSHOP

Azores Archipelago

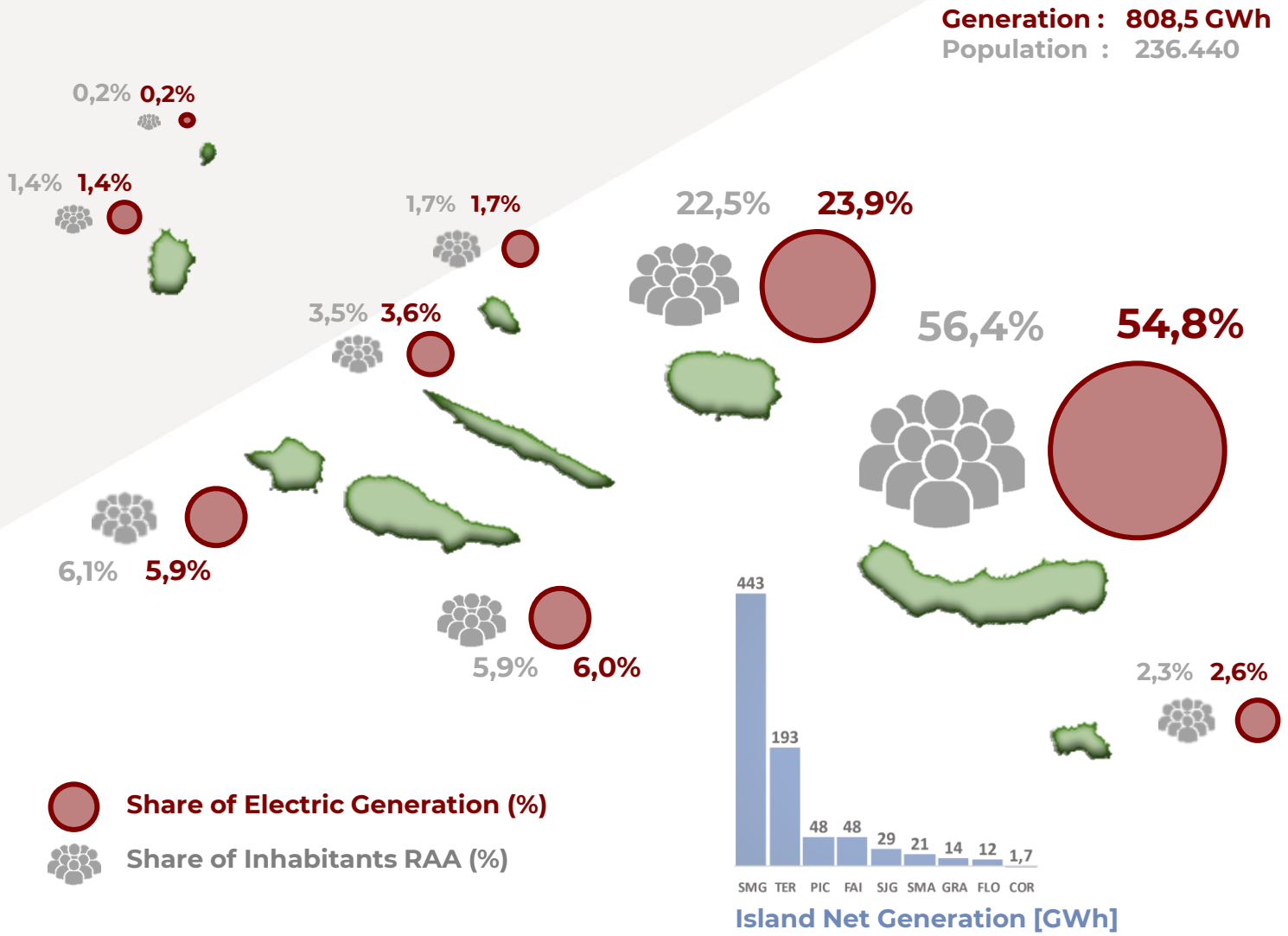


nine small independent electrical systems, without the capacity of exporting or importing renewable energy

electric interconnections between islands are expensive and not yet economically viable

Electric Power Generation 2021

- **9 Different Isolated Electric Systems**
  - **Largest: São Miguel** (72 MW Peak Power)
  - **Smaller: Corvo** (0,32 MW Peak Power)
- **2021 Total Generation: 808 GWh** (**34,0% Renewable**)
- **9 Thermal Power Plants** (216,43 MW)
- **9 Wind Farms** (36,65 MW)
- **3 Geothermal Power Plants** (27 MW)
- **12 Small Hydro Power Plants** (8,4 MW)
- **1 Waste to Energy Plant** (2,6 MW)
- **3 PV Power Plant** (1,67 MW)
- **1 Biogas Power Plant** (1 MW)



Electric Generation in Azores

First Achievements

1900 - São Miguel - 1st Hydro Plant

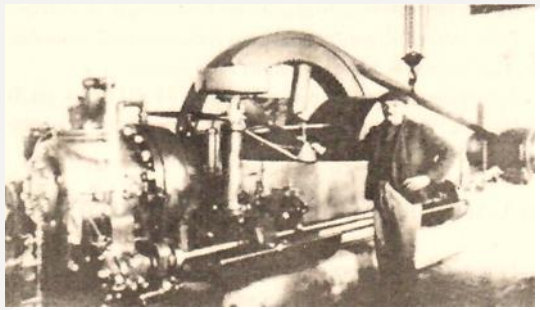
1980 - São Miguel - 1st Geothermal Plant

2005 - Flores - 1st Flywheel

1906 - São Miguel - 1st Energy Storage System

1988 - Santa Maria - 1st Wind Farm

2019 - Graciosa - 1st Photovoltaic Power Plant



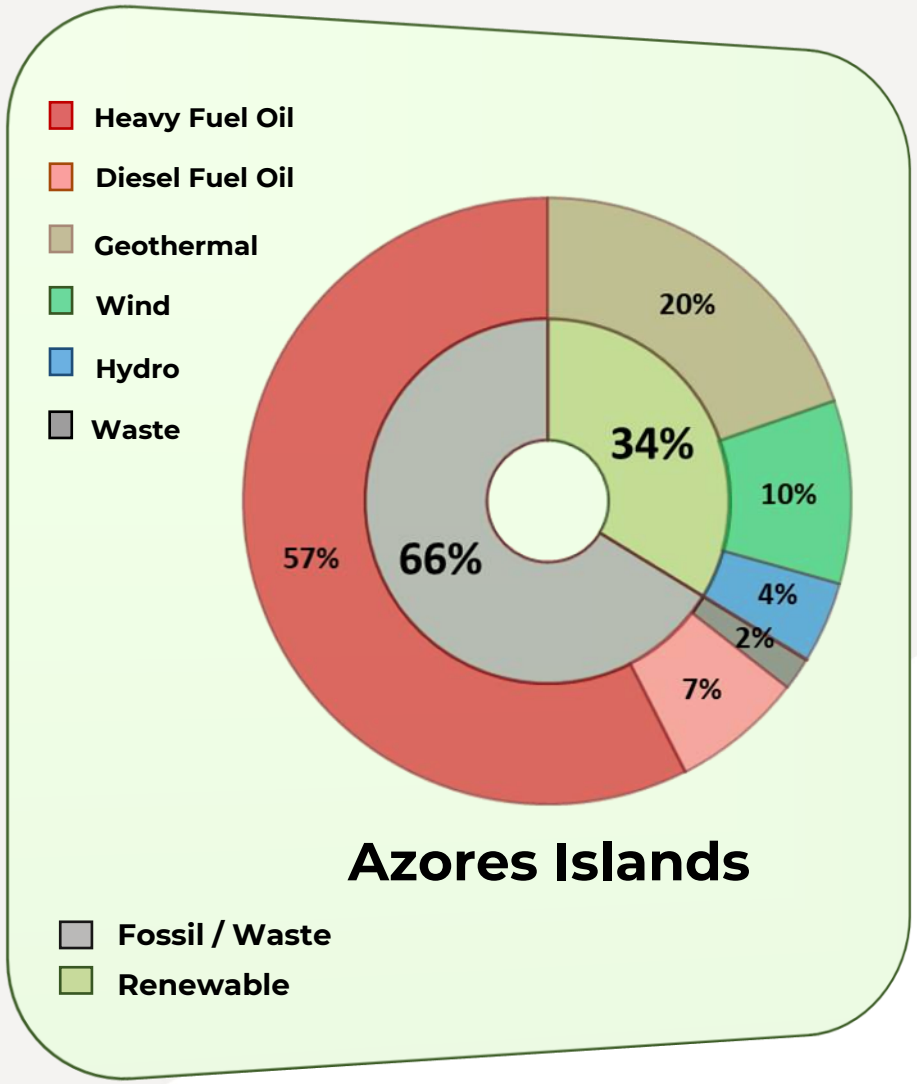
1908 - Terceira - 1st Thermal Power Plant

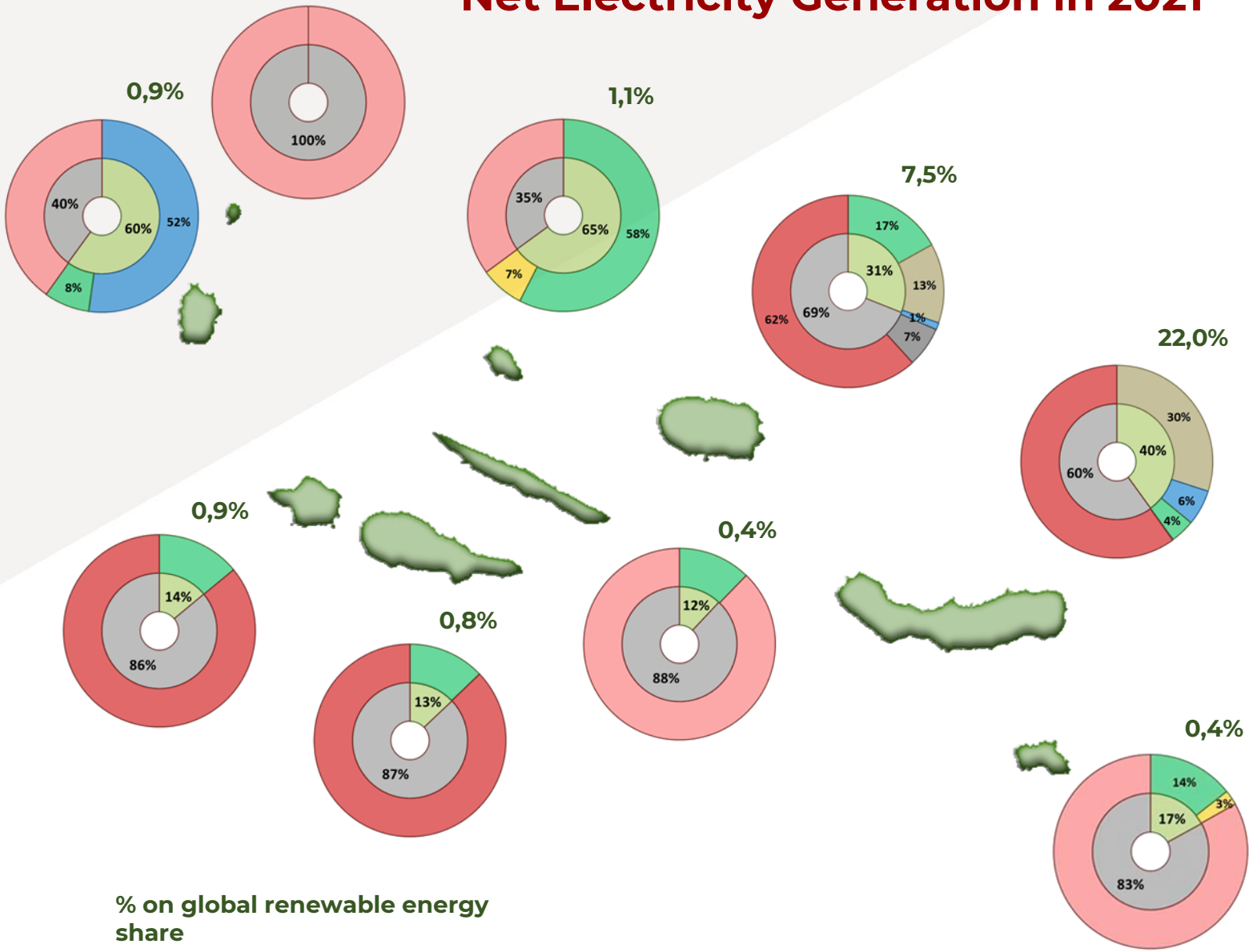
1999 - Pico - 1st Wave Energy Plant

2019 - Graciosa - 1st Battery Energy Storage System

Electric Generation by Energy Source

Net Electricity Generation in 2021





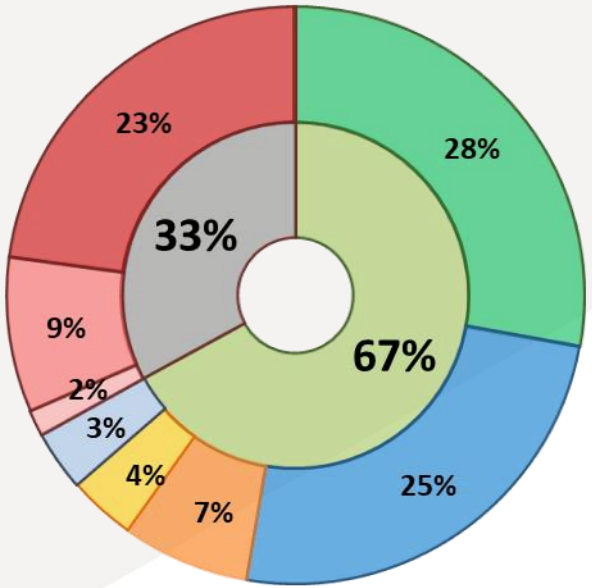
% on global renewable energy share

Electric Generation by Energy Source

Net Electricity Generation in 2021

Portuguese Mainland

Generation : 46,75 TWh
Population : 9.857.593

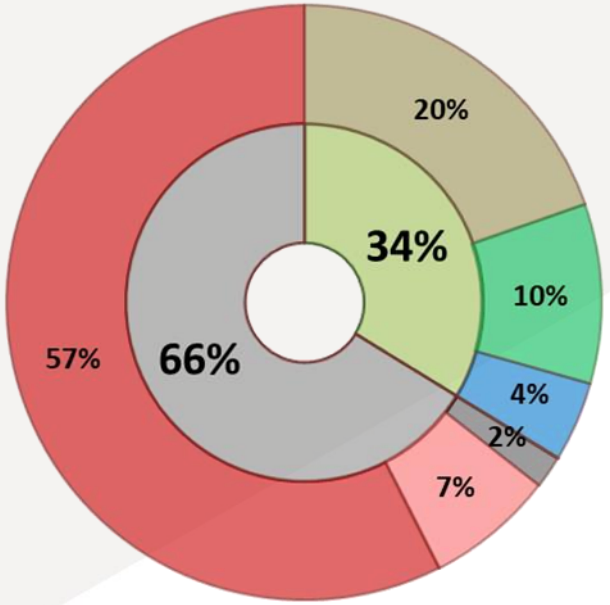


Natural Gas
Fossil
Coal
Hydro
Wind
Bioenergy
Solar
Pump Hydro

Fossil / Waste
Renewable

Azores Islands

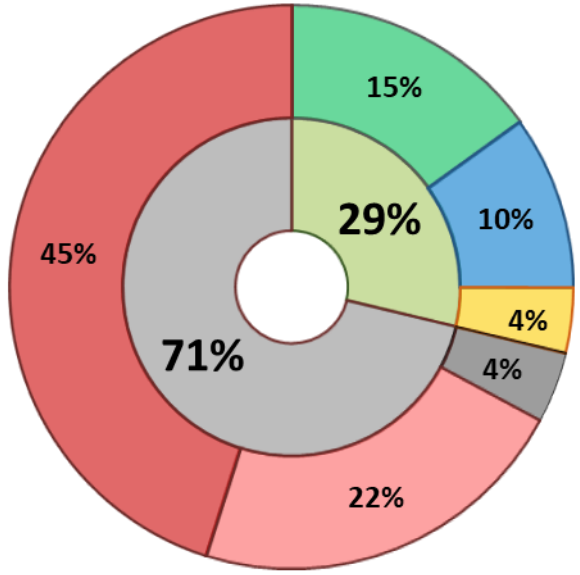
Generation : 808,5 GWh
Population : 236.440



Heavy Fuel Oil
Diesel Fuel Oil
Geothermal
Wind
Hydro
Waste

Madeira Islands

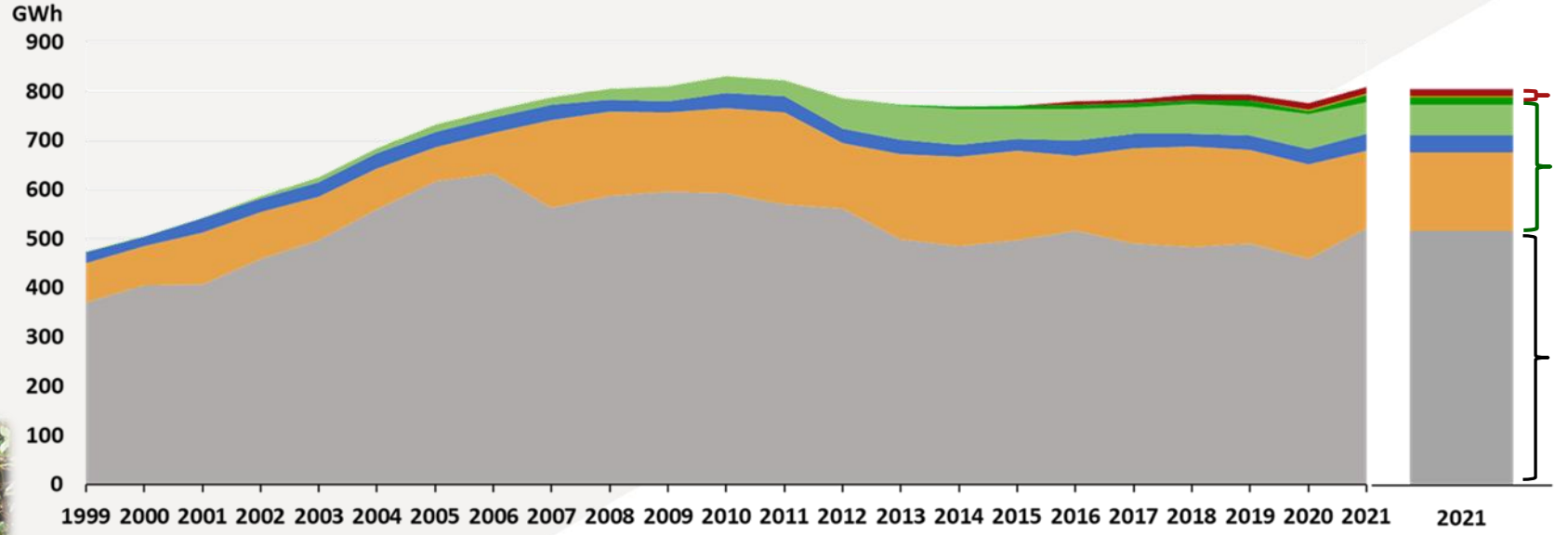
Generation : 817,9 GWh
Population : 250.769



Fuel Oil
Natural Gas
Wind
Hydro
Solar
Waste

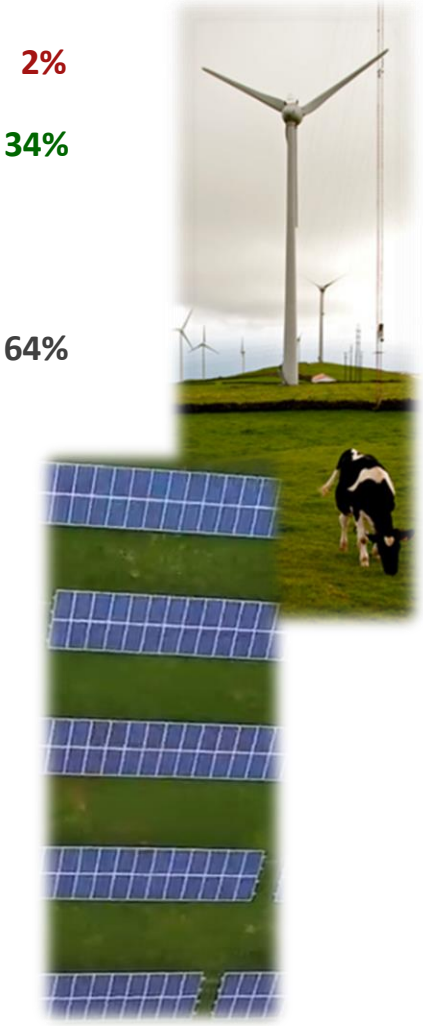
Electric Generation by Energy Source

Net Electricity Generation in the Azores from 1999 to 2021



22%	20%	25%	22%	21%	18%	16%	17%	29%	27%	27%	29%	31%	29%	36%	37%	36%	34%	38%	39%	38%	41%	36%	Endogenous
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1%	1%	2%	1%	2%	2%	Waste
22%	20%	25%	22%	21%	18%	16%	17%	29%	27%	27%	29%	31%	29%	36%	37%	36%	33%	37%	37%	37%	39%	34%	Renewable
1%	0%	0%	1%	2%	2%	2%	2%	2%	3%	4%	4%	4%	8%	9%	10%	9%	9%	8%	8%	9%	10%	10%	Wind
5%	4%	5%	5%	5%	4%	4%	4%	4%	3%	3%	4%	4%	4%	4%	3%	3%	4%	4%	3%	4%	4%	4%	Hydro
17%	16%	19%	16%	14%	12%	10%	11%	23%	21%	20%	21%	23%	17%	23%	24%	24%	20%	25%	26%	24%	25%	20%	Geothermal
78%	80%	75%	78%	79%	82%	84%	83%	71%	73%	73%	71%	69%	71%	64%	63%	64%	66%	63%	61%	62%	60%	64%	Thermal

Oil | Geothermal | Hydro | Wind | Others | Wind (IPP) | Waste (IPP) | Biogas (IPP)

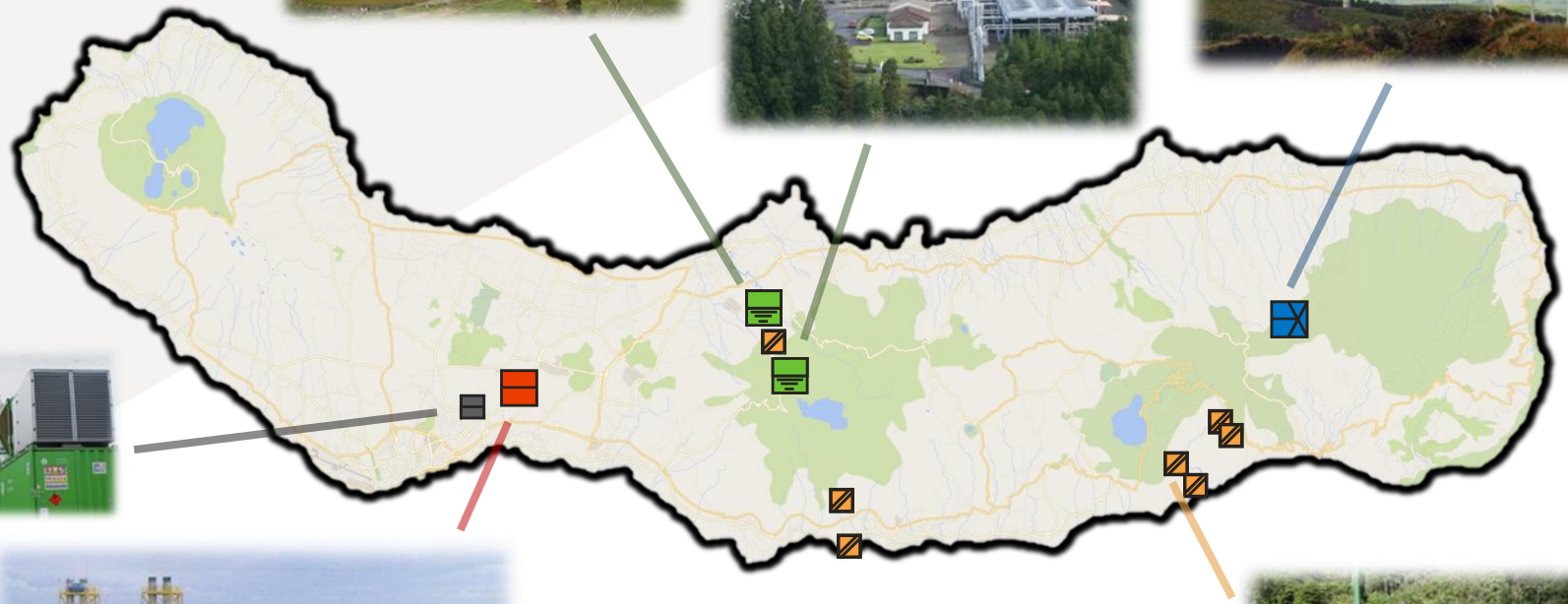


Renewable Energy Integration

São Miguel Island

Main Power Sources

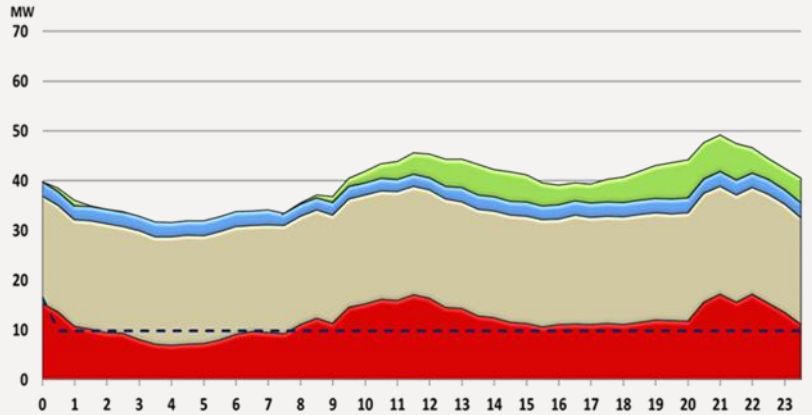
- 2021 Power Generation:
  - ✓ 442,9 GWh
  - ✓ 40,2 % Renewable Energy
    - Geothermal: 30%
    - Wind: 6%
    - Hydro: 4%
    - Biogas/Micro: 0,2%



Renewable Energy Integration

São Miguel Island

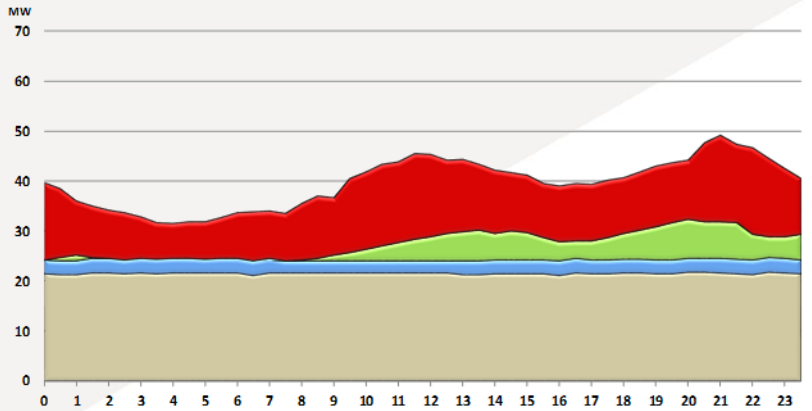
Daily Power Supply



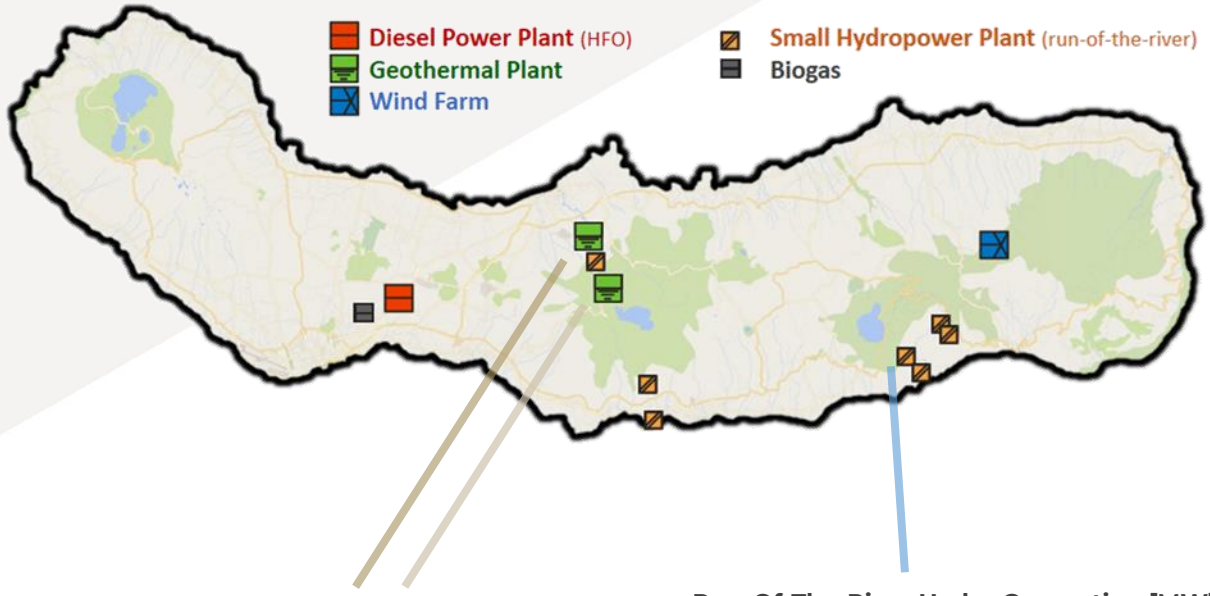
Minimum engines continuous load

Minimum two gensets online

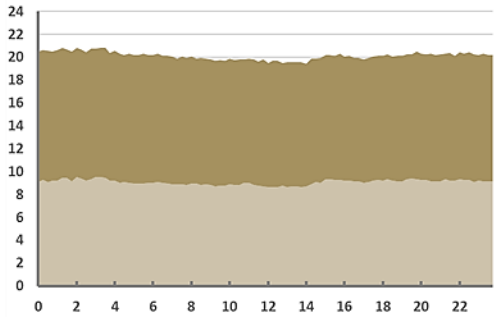
Thermal Geothermal Hydro Wind



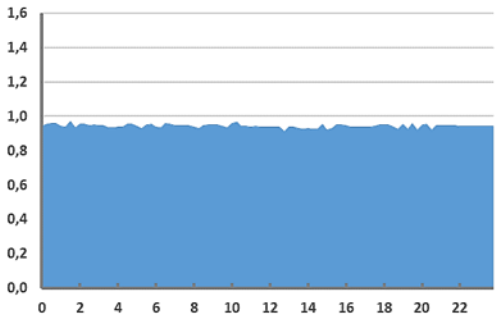
Baseload: Geothermal + Hydro



Geothermal Generation [MW]



Run-Of-The-River Hydro Generation [MW]

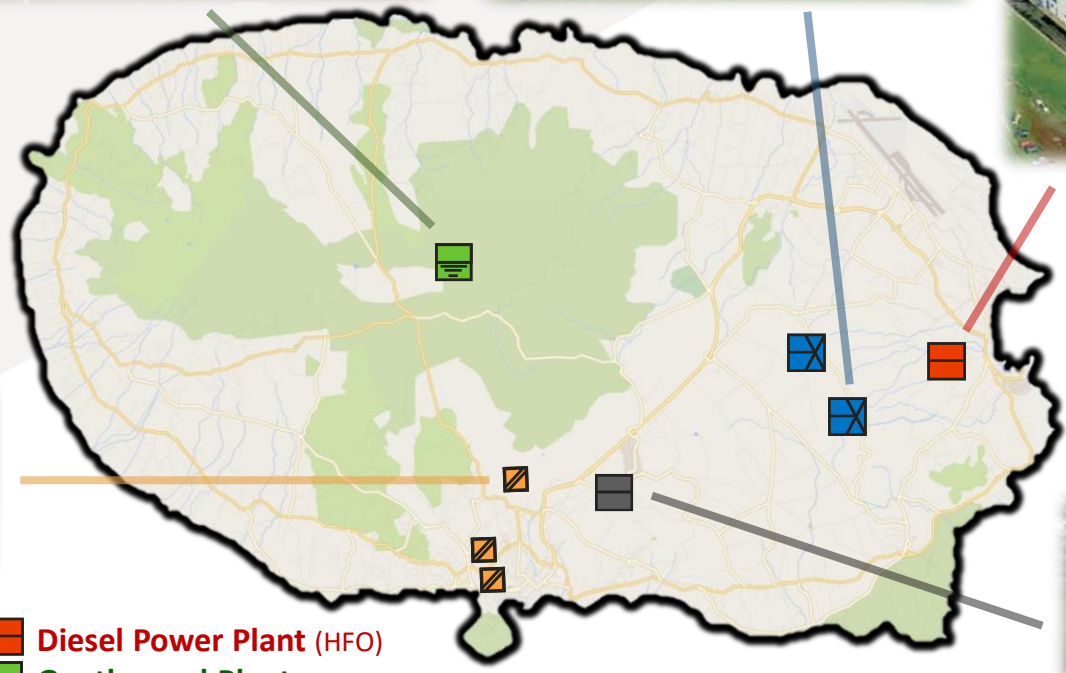


Renewable Energy Integration

Terceira Island

Main Power Sources

- 2021 Power Generation:
  - ✓ 193,1 GWh
  - ✓ 31,5 % Renewable Energy
    - Geothermal: 13,4%
    - Wind: 16,9%
    - Hydro: 1,2%
  - ✓ 6,8 % Waste Incineration

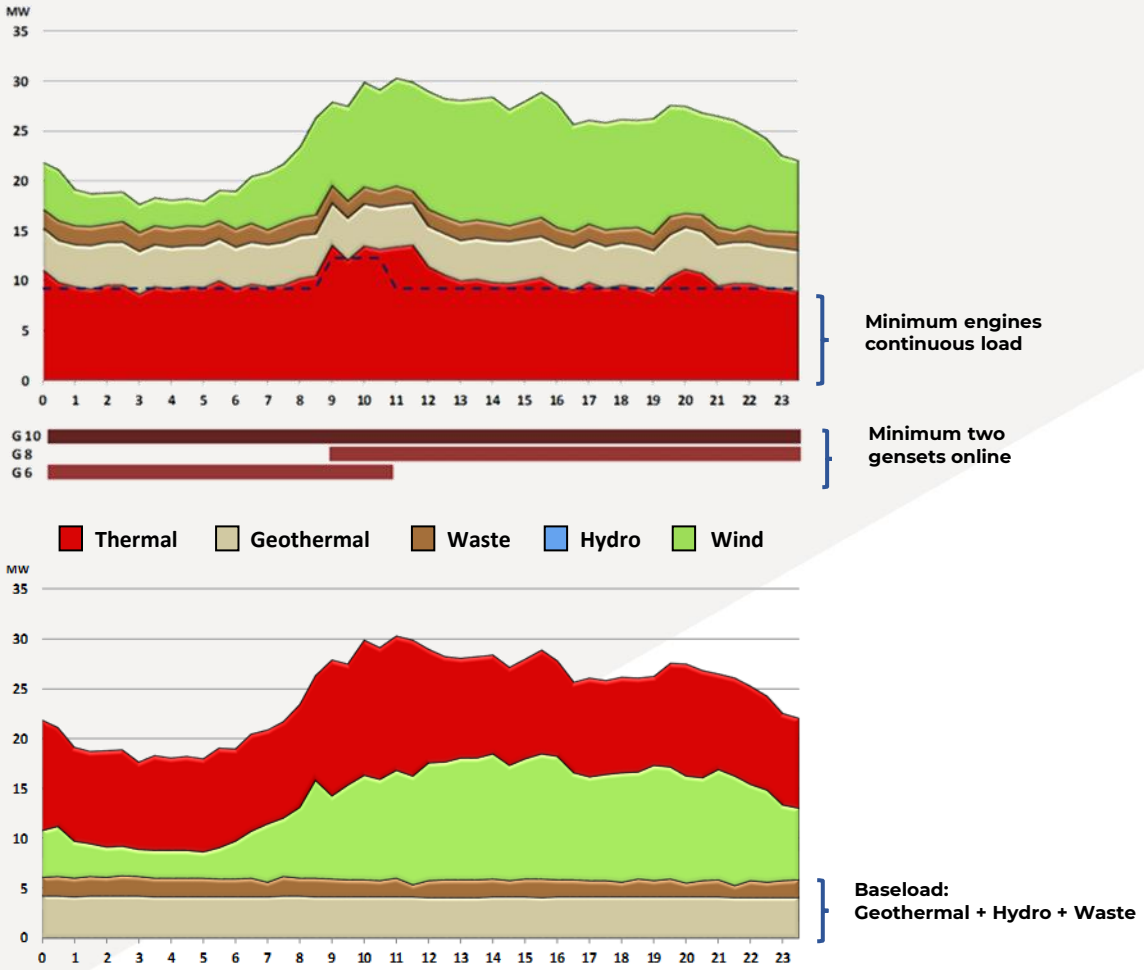


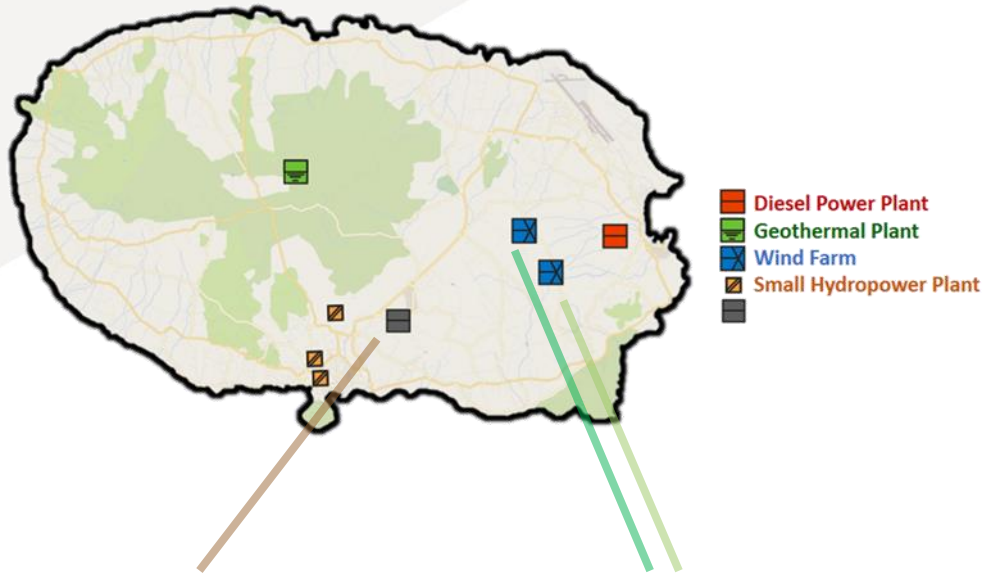
Diesel Power Plant (HFO)
Geothermal Plant
Wind Farm
Small Hydropower Plant (run-of-the-river)
Waste to Energy

Renewable Energy Integration

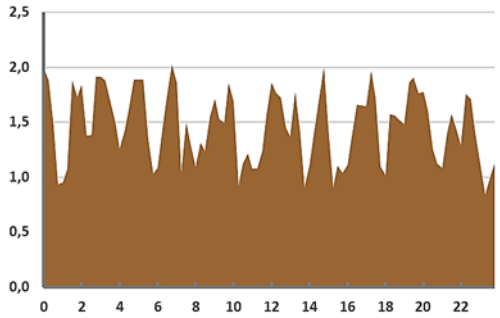
Terceira Island

Daily Power Supply

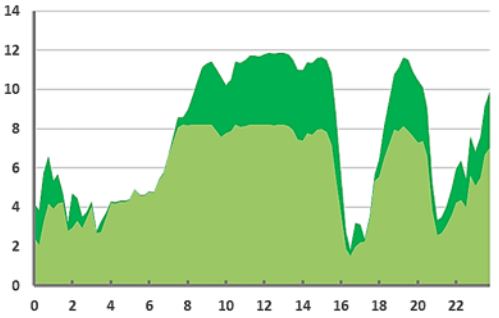




WtE Generation [MW]



Wind Generation [MW]

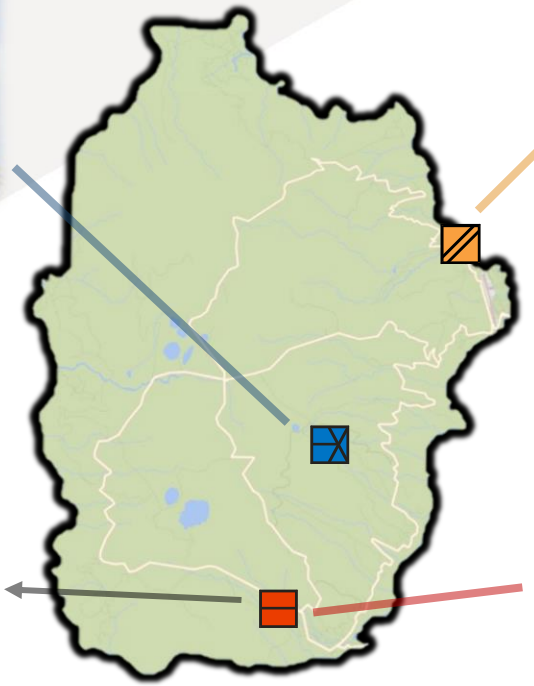


Renewable Energy Integration

Flores Island

Main Power Sources

- 2021 Power Generation:
  - ✓ 11,6 GWh
  - ✓ 59,8 % Renewable Energy
    - Hydro: 52,2%
    - Wind: 7,6%
- Periods of several hours operating in 100% RES due to the hydro and the presence of a flywheel. →

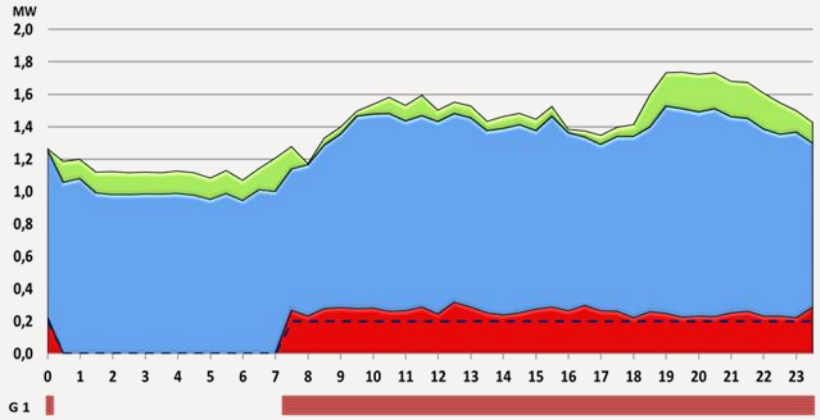


Diesel Power Plant
Wind Farm
Hydropower Plant (with a small reservoir; daily regulation scheme)

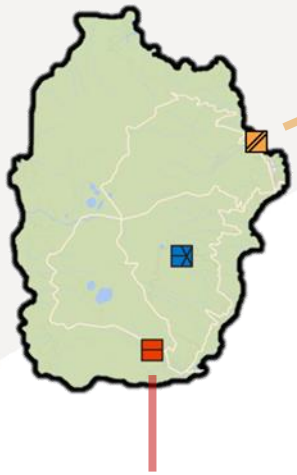
Renewable Energy Integration

Flores Island

Daily Power Supply

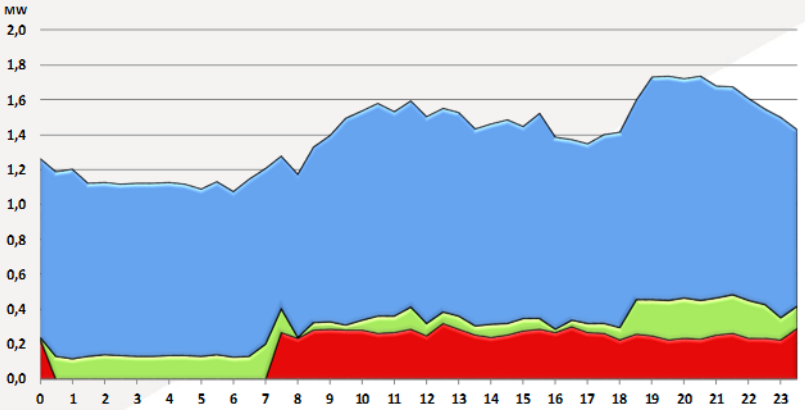


Minimum engine continuous load



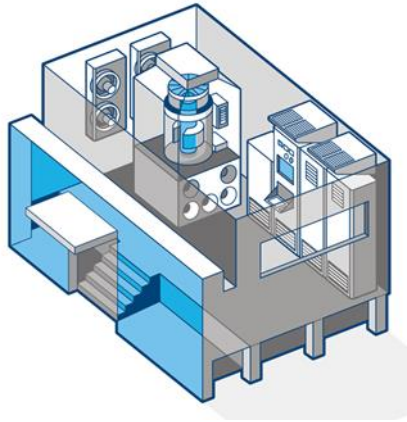
Diesel Power Plant
Wind Farm
Hydropower Plant

Thermal Hydro Wind

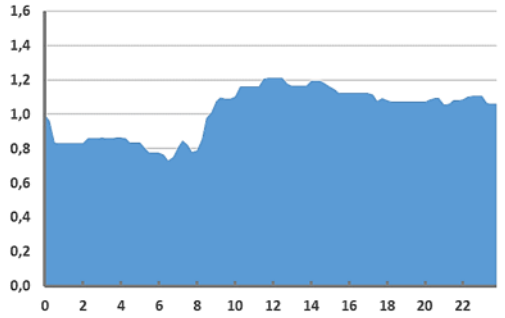


Load Following

Flywheel of 350kW/18MWs (5kWh) to improve frequency stability



Dam Hydro Generation [MW]

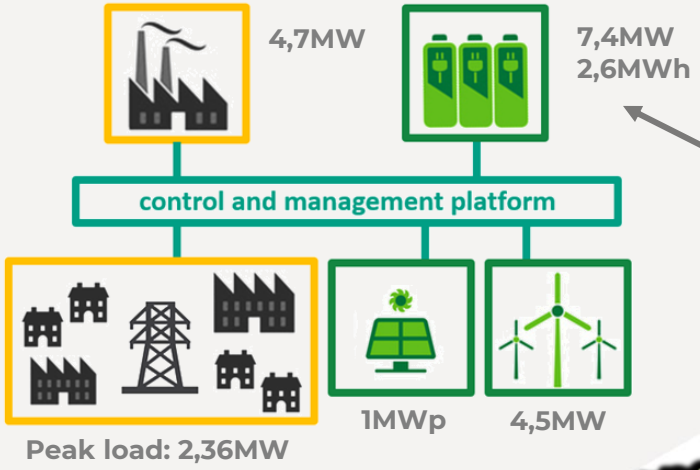


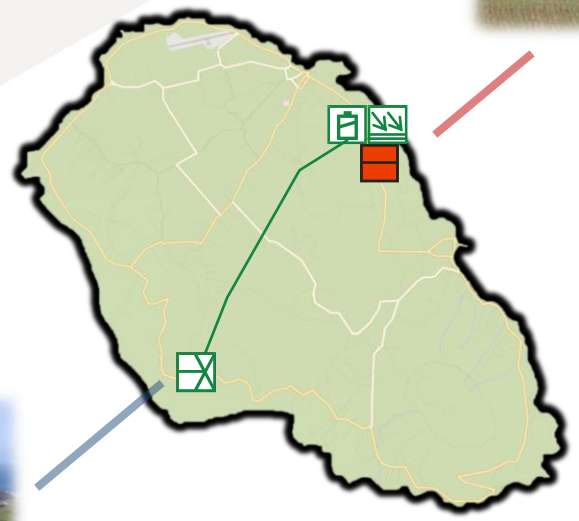
Renewable Energy Integration

Graciosa Island

Main Power Sources

- 2021 Power Generation:
  - ✓ 13,5 GWh
  - ✓ 64,9 % Renewable Energy
    - Wind: 57,5%
    - Solar: 7,4%
- Periods of several hours/days operating in 100% RES due to an innovative energy management system and the presence of a battery energy storage system.





Diesel Power Plant
Battery Energy Storage System
Wind Farm
PV Plant

Graciólica

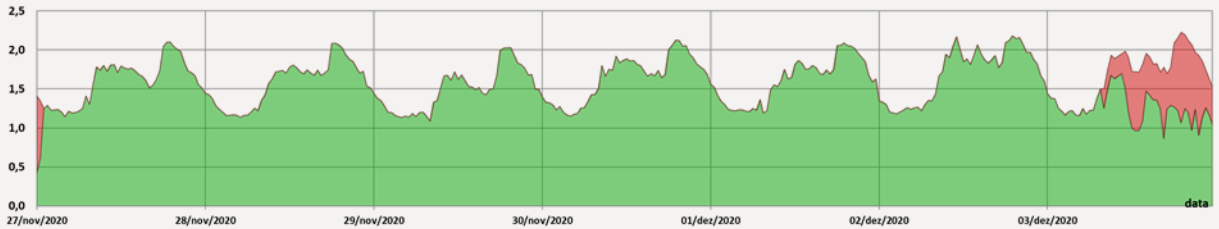
Renewable Energy Integration

Graciosa Island

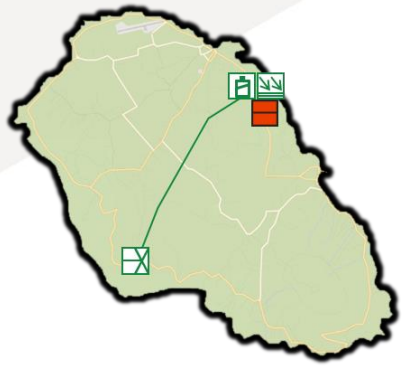
Power Generation

Fossil Renewable

2020 (november/december week)

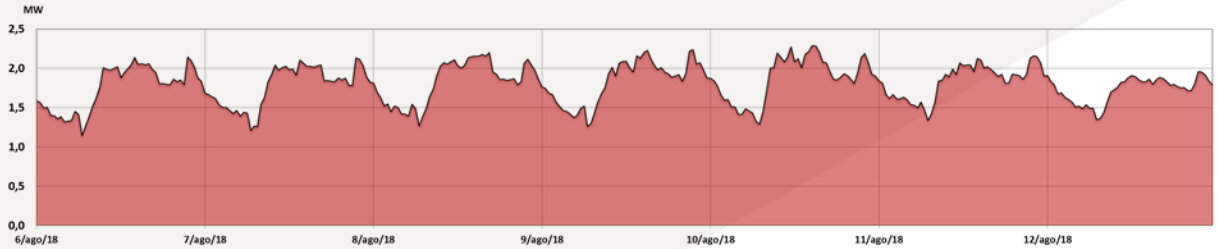


More than 6 days (150 consecutive hours), with production of electricity only from variable renewable sources.

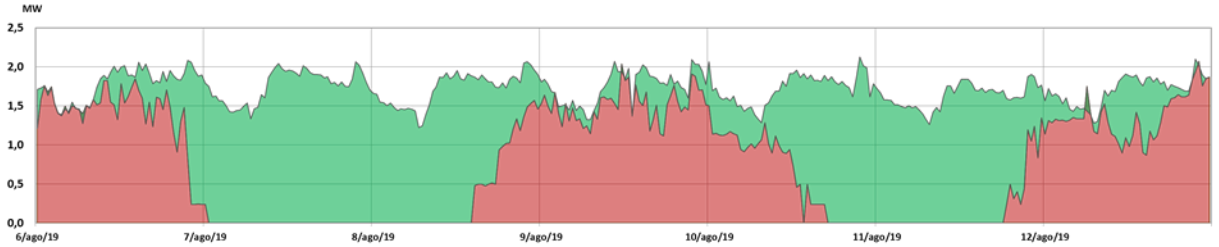


Diesel Power Plant
Battery Energy Storage System
Wind Farm
PV Plant

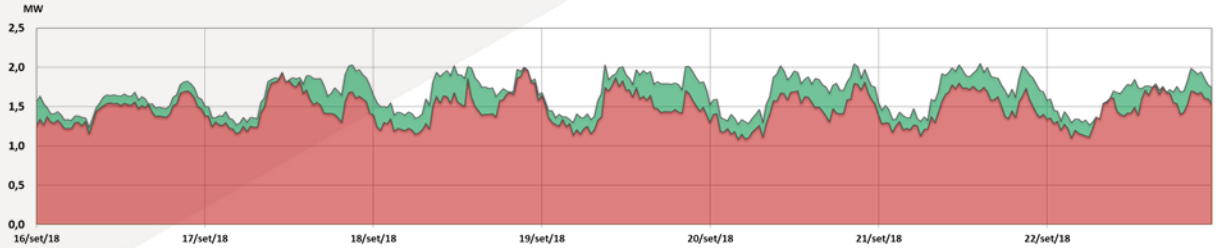
2018 (august week)



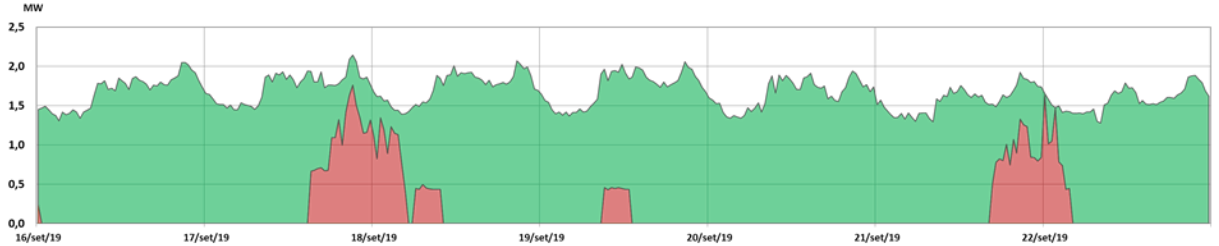
2019 (august week)



2018 (september week)



2019 (september week)



Renewable Energy Integration

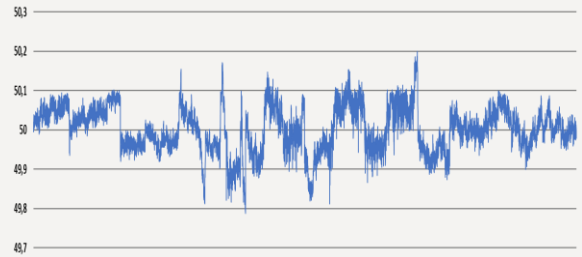
Graciosa Island

Power Quality

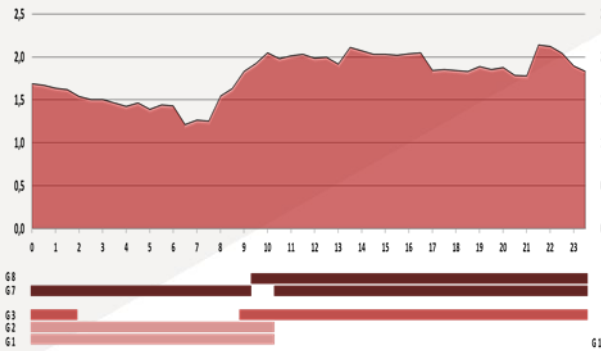
2018 (7th august)

Voltage [kV]

Frequency [Hz]

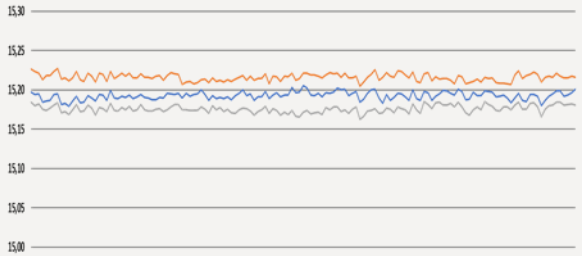


Electric Generation [MW]

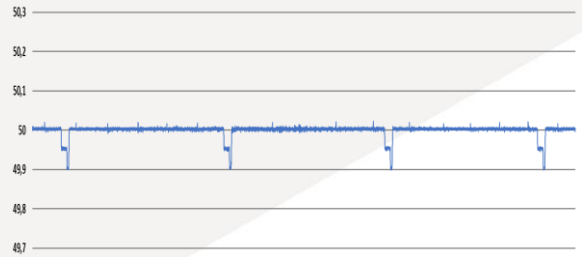


2019 (7th august)

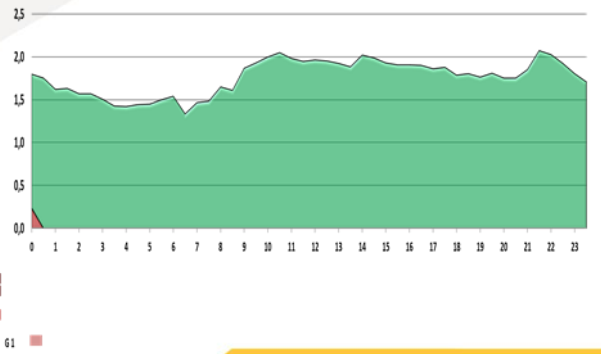
Voltage [kV]



Frequency [Hz]

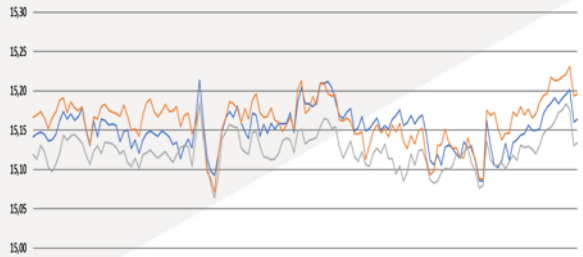


Electric Generation [MW]

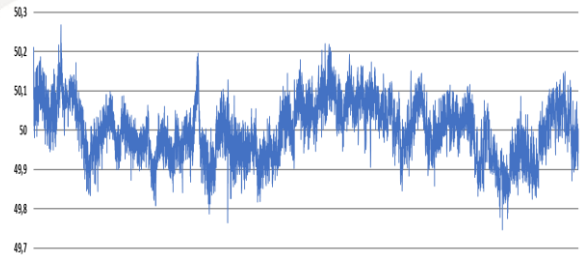


2018 (20th september)

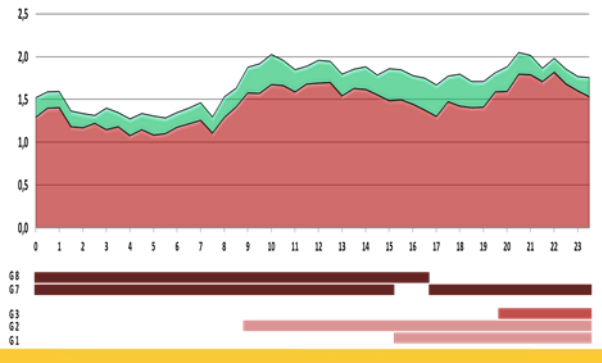
Voltage [kV]



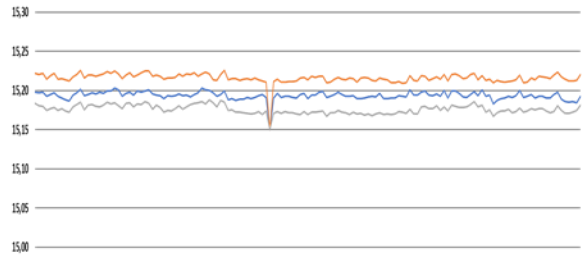
Frequency [Hz]

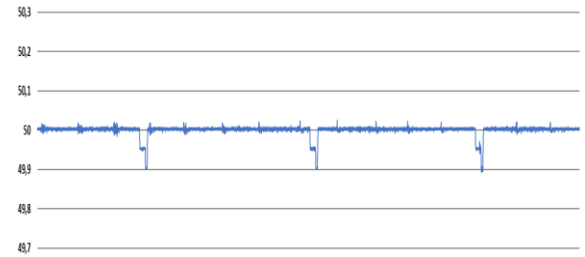


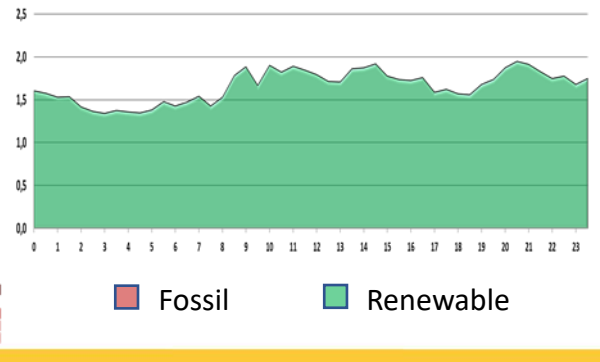
Electric Generation [MW]



2019 (20th september)



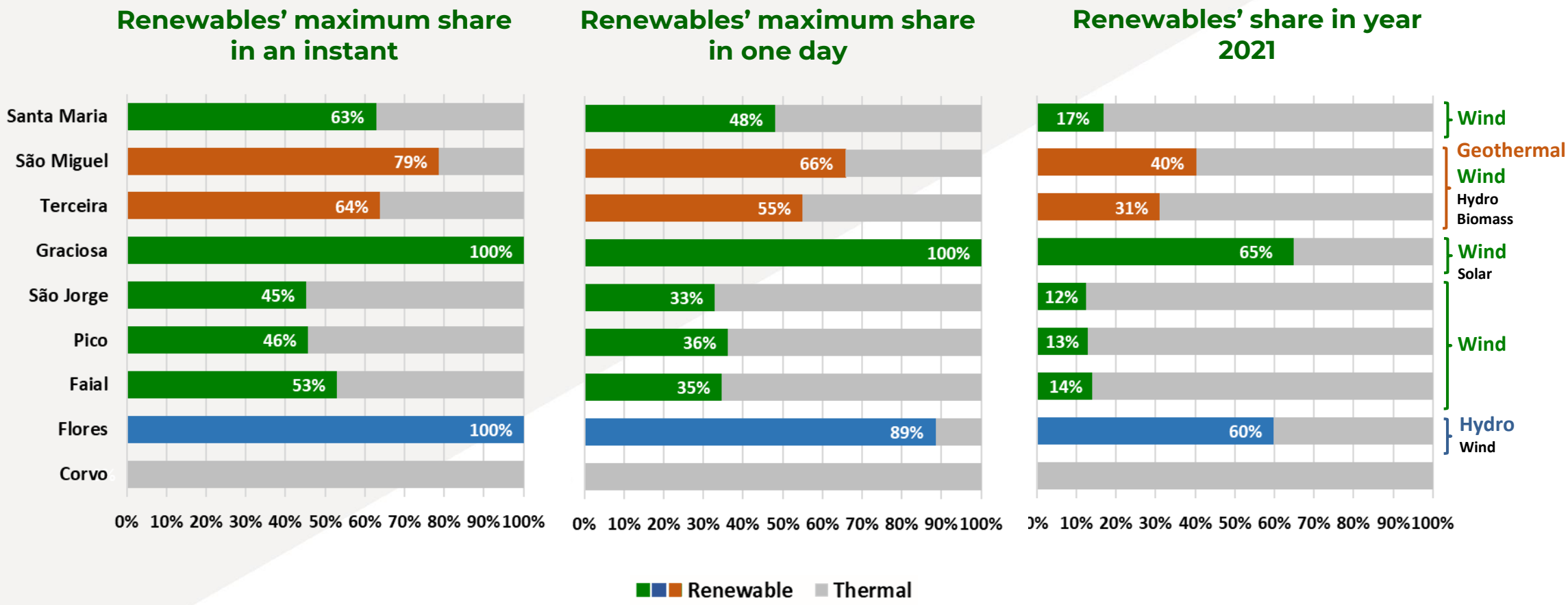




Fossil Renewable

Renewable Energy Integration

Maximum Share Achieved 2021



Renewable Energy Challenges

Investments made to increase renewable production

Investments on **Geothermal Power Plants**

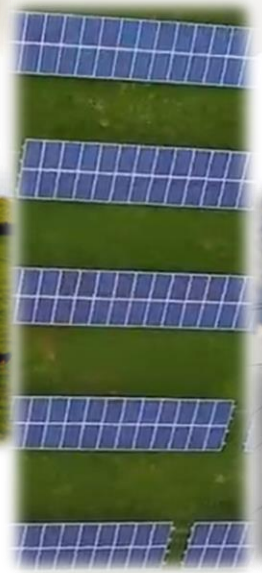
this power plants provide a continuous power supply of electricity throughout the year (relatively constant source)

Investments on **Hydro Power Plants**

this power plants provide a continuous power supply of electricity throughout large periods (and its production may be controllable)

Investments on **Wind Farms**

the wind resource is available in all islands with a good potential, although it's intermittency and seasonal variation



Investments on **Photovoltaic Power Plants**

the solar resource can be a complementary power source to wind, although with a lower potential and a higher intermittency

Investments on the **Power System**

increasing resilience and flexibility in power system:

- advanced automatic generation control
- advanced energy management systems
- energy storage systems
- transmission expansion and reinforcement
- advanced network protection and management tools

Renewable Energy Challenges

Constraints to renewable energy integration

Geothermal

Geothermal power plants are not dispatchable

Hydro

Hydro resources are limited and vary throughout the year

Wind Farms and Photovoltaic Power Plants

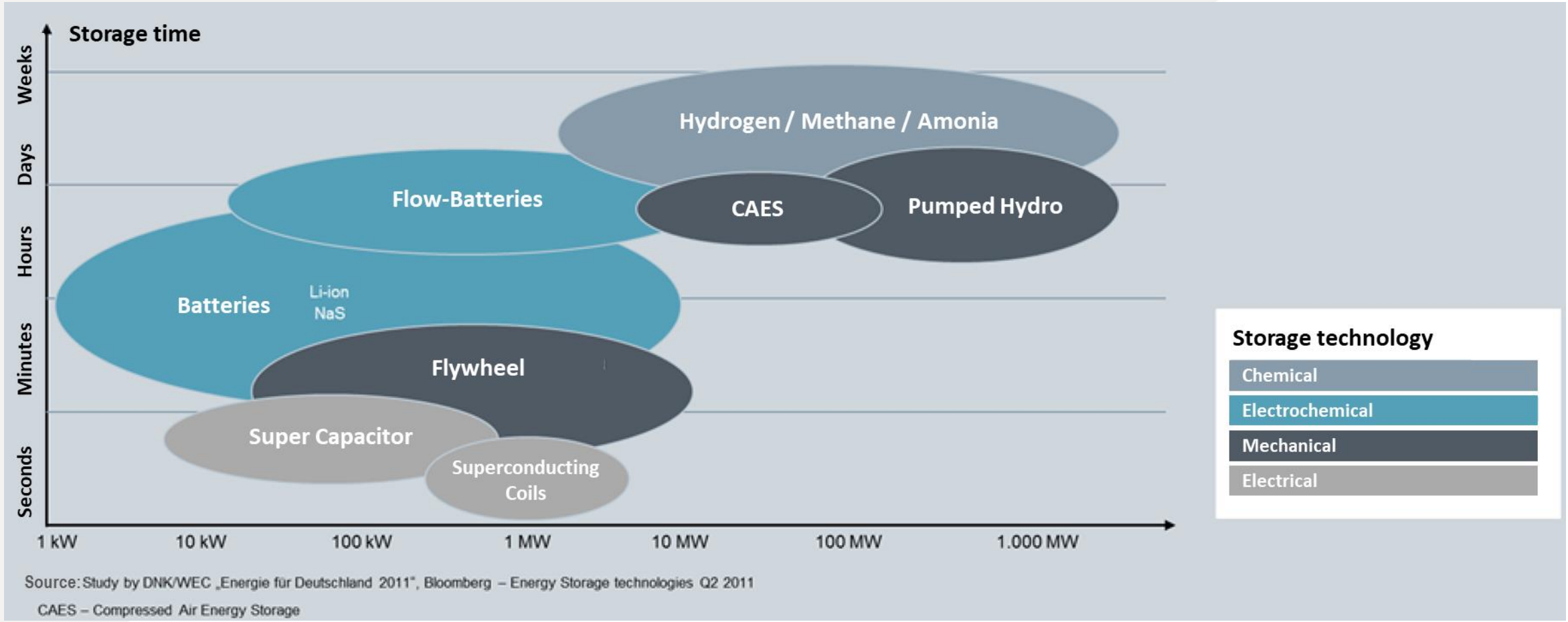
Wind and photovoltaic resources are intermittent and vary throughout the year

Thermal Power Plants

Thermal production is still necessary to assure all the ancillary services needed to maintain the electric system stable and reliable, and to ensure power quality

Renewable Energy Challenges

Storage Systems as a new driver

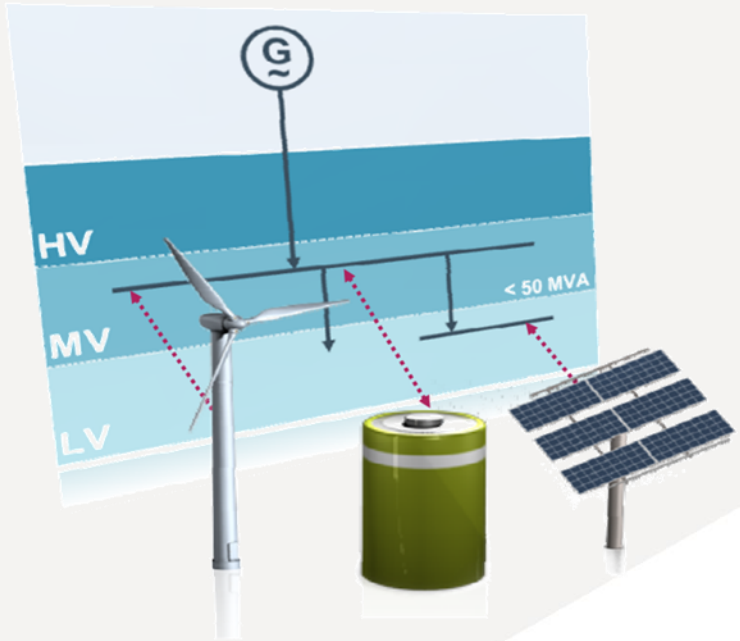


Source: Study by DNK/WEC „Energie für Deutschland 2011", Bloomberg – Energy Storage technologies Q2 2011

CAES – Compressed Air Energy Storage

Renewable Energy Challenges

Battery Energy Storage System Sizing



The optimum combination of power electronics and storage system based on Li-ion batteries provides power in milliseconds for:

- Sufficient available balancing power
- Additional spinning reserve
- Active and reactive power control
- Uniformly distributed network load
- Adequate short-circuit power
- Black start

- Stability of the grid
- Power reliability / quality

Application 1
Spinning Reserve
Application 2
Frequency Regulation
Application 3
Renewable Integration

Battery Energy Storage System (BESS) based on litium-ion batteries technology

with **grid forming inverters**

Capability (EoL): ??MW/??MWh

EoL – End of Life (10 years)

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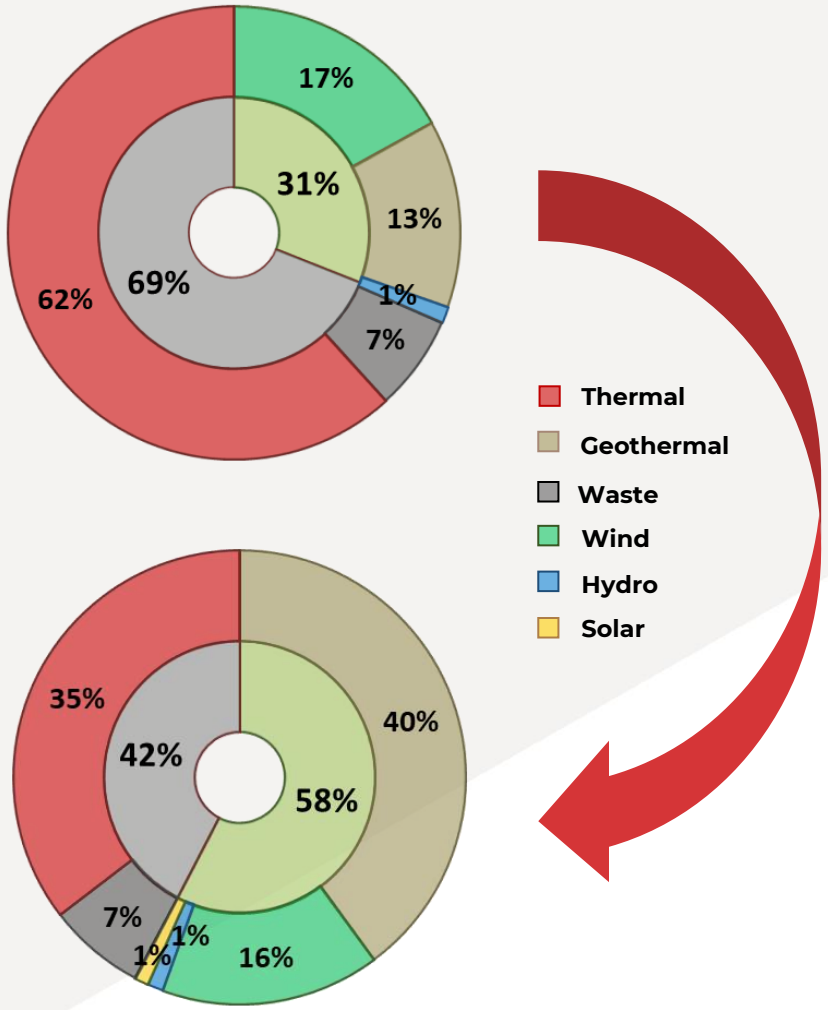
Renewable Energy Challenges

Terceira Island

Renewable Generation Forethought

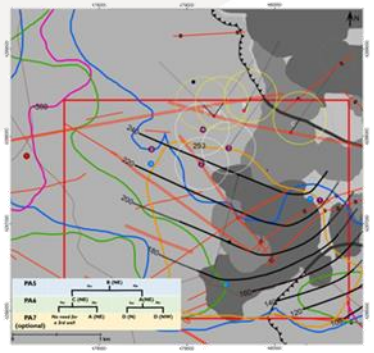


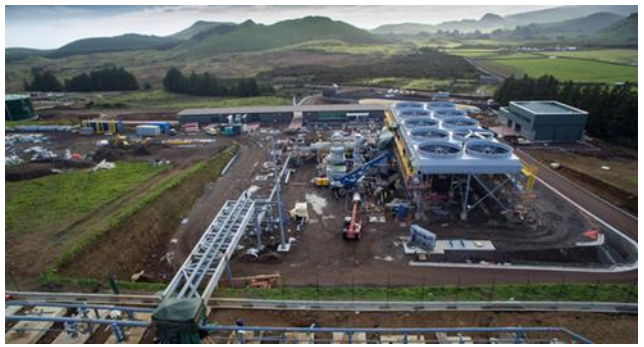
New photovoltaic power plant (2MWp)

Expansion of the Pico Alto geothermal power plant (+7MW)

Drill up to 3 additional production wells to sustain the long-term operation of the 4 MW power plant
Expand the power plant capacity from 3 to 10 MW

Energy Storage System to provide effective spinning reserve and frequency regulation

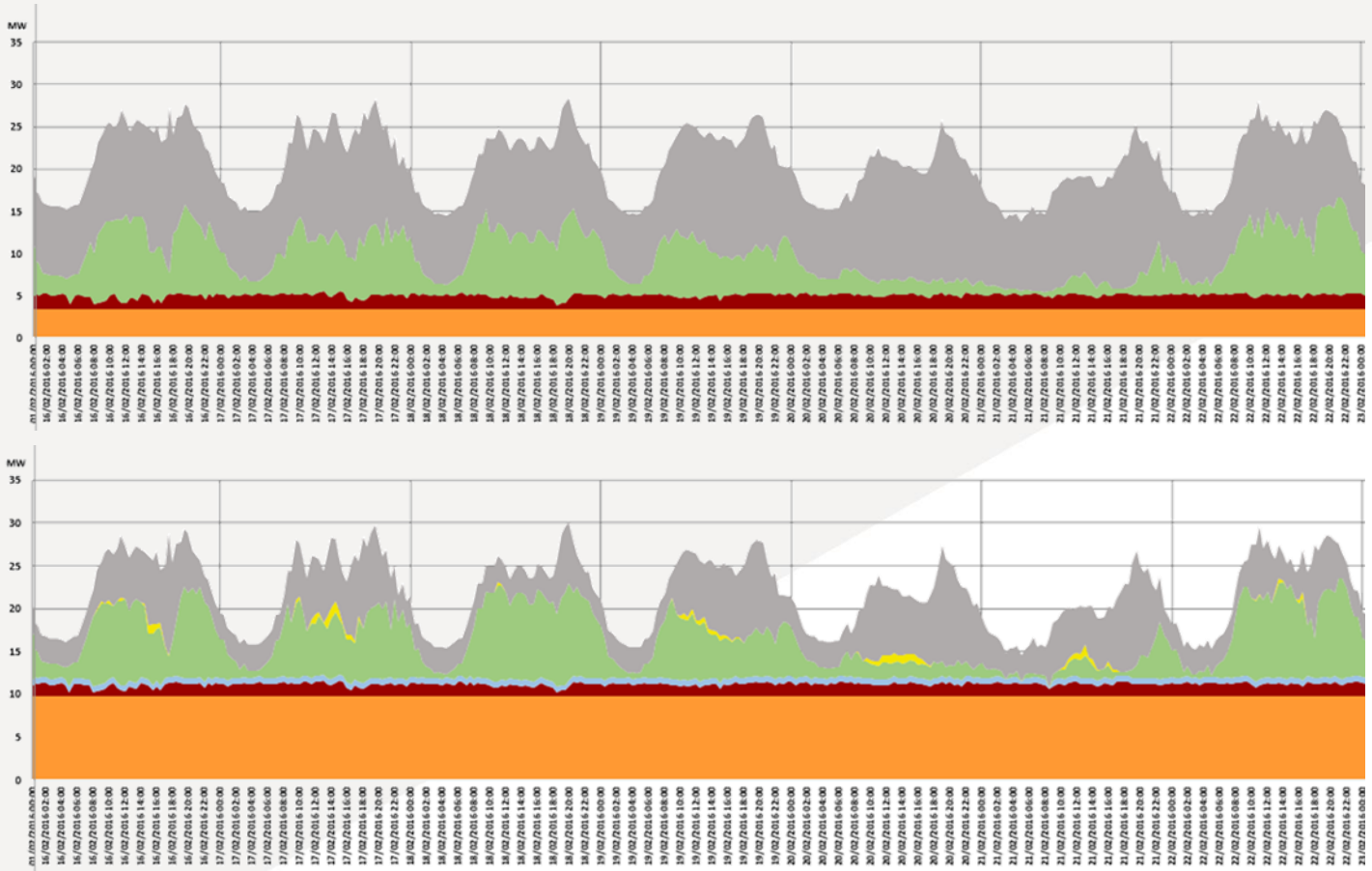


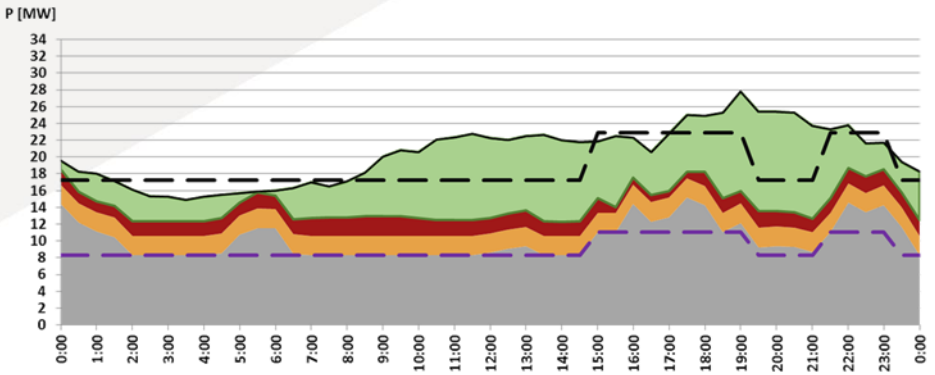


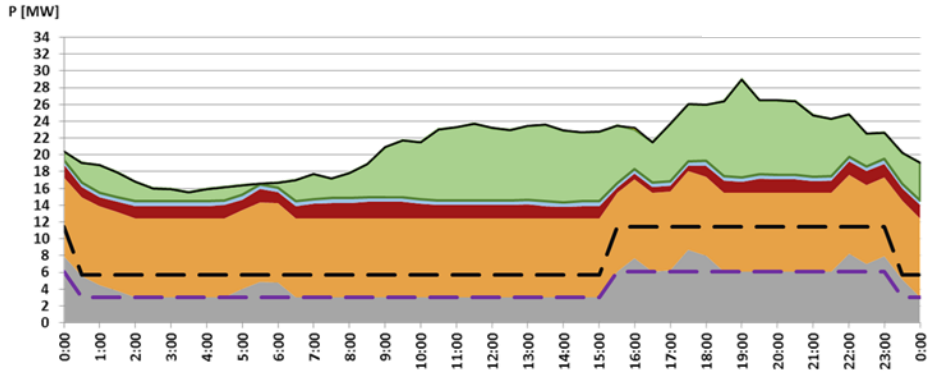
Renewable Energy Challenges

Terceira Island

Energy Yield Analysis





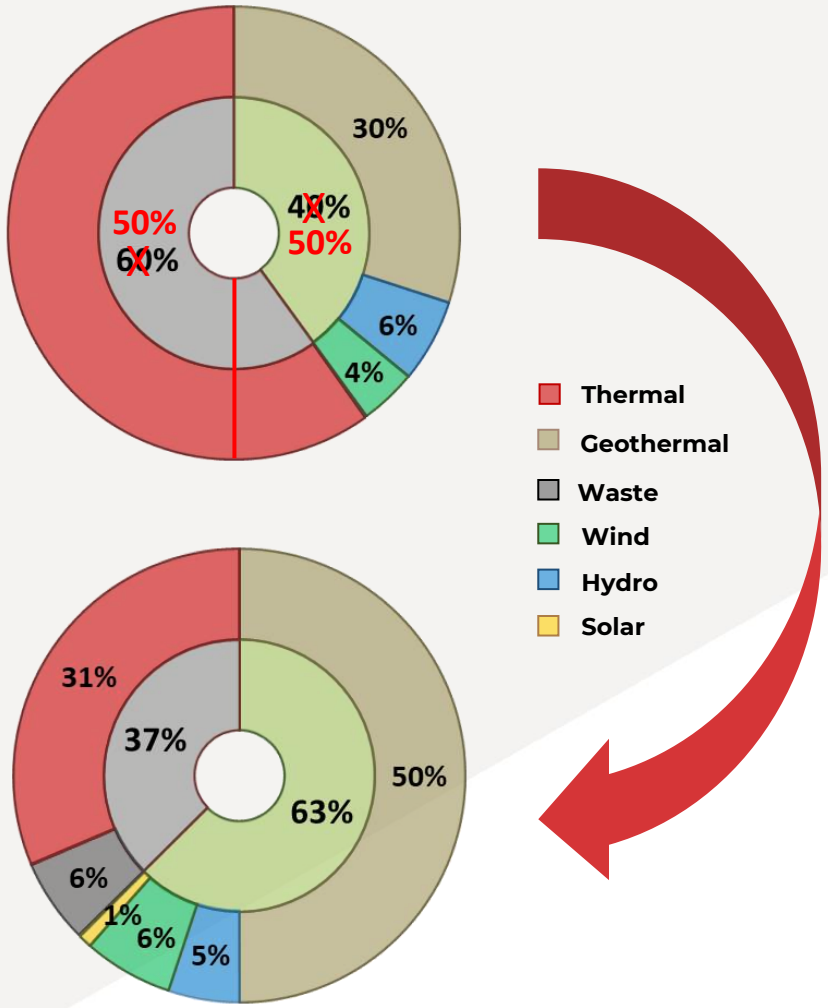


Geothermal
Hydro
Solar
Diesel Engines Maximum Load
Thermal
Waste-to-Energy
Wind
Diesel Engines Minimum Load

Renewable Energy Challenges

São Miguel Island

Renewable Generation Forethought



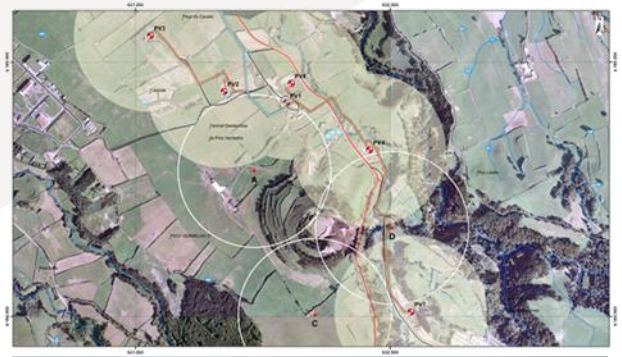
Expansion of the Pico Vermelho geothermal power plant (+5MW)

Expansion with the drilling of 2 to 3 production geothermal wells

Saturation of the Ribeira Grande geothermal power plant (+5MW)

Increase the production of geothermal fluid, with the drilling of new production geothermal wells

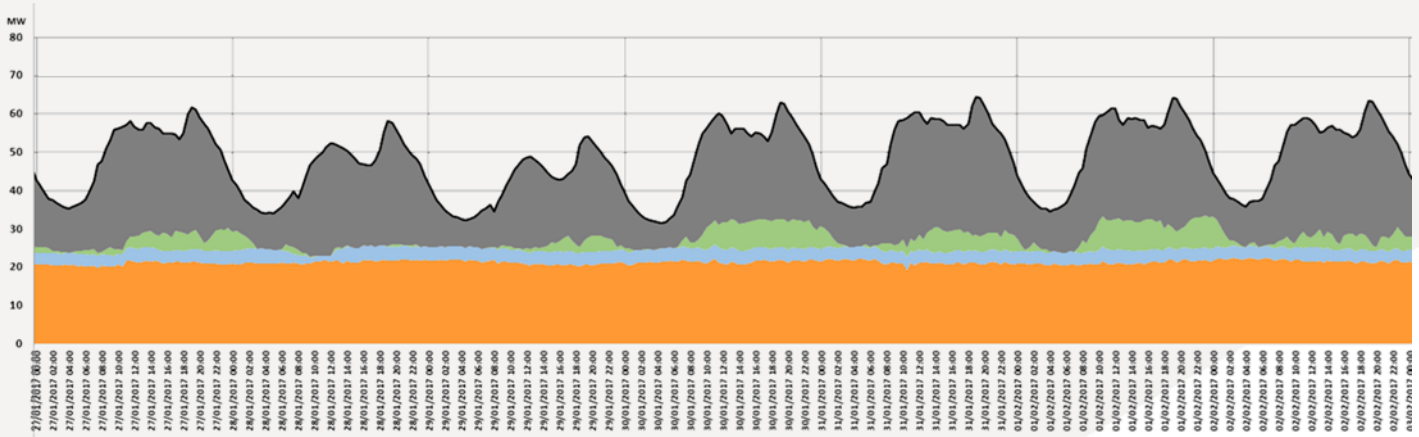
Energy Storage System(s) for load shifting (daily load leveling) or/and to provide effective spinning reserve and frequency regulation

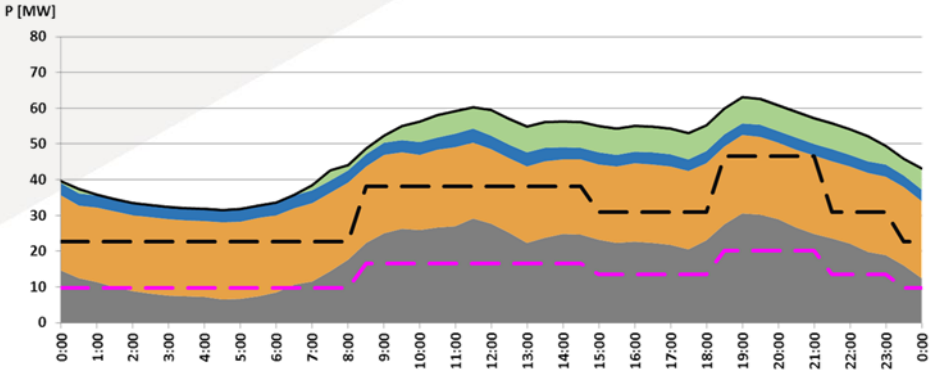


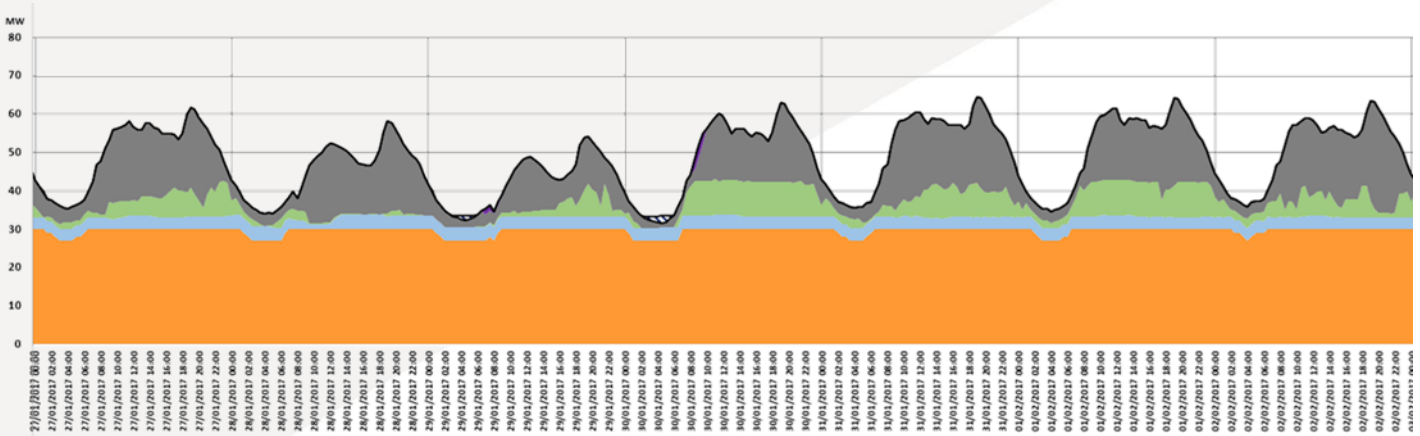
Renewable Energy Challenges

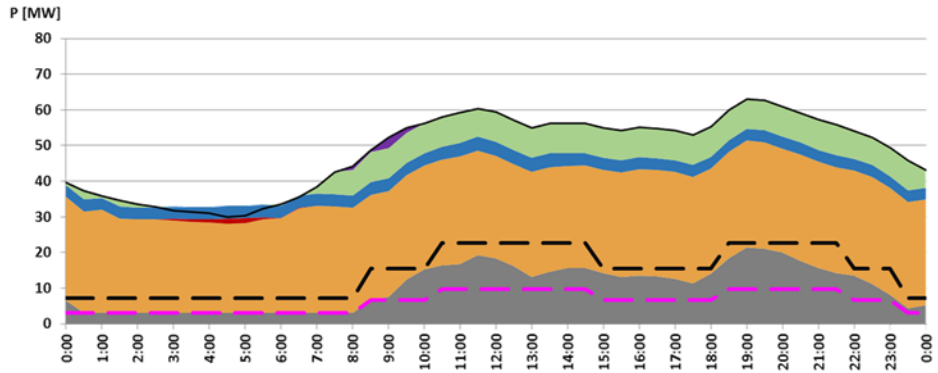
São Miguel Island

Energy Yield Analysis







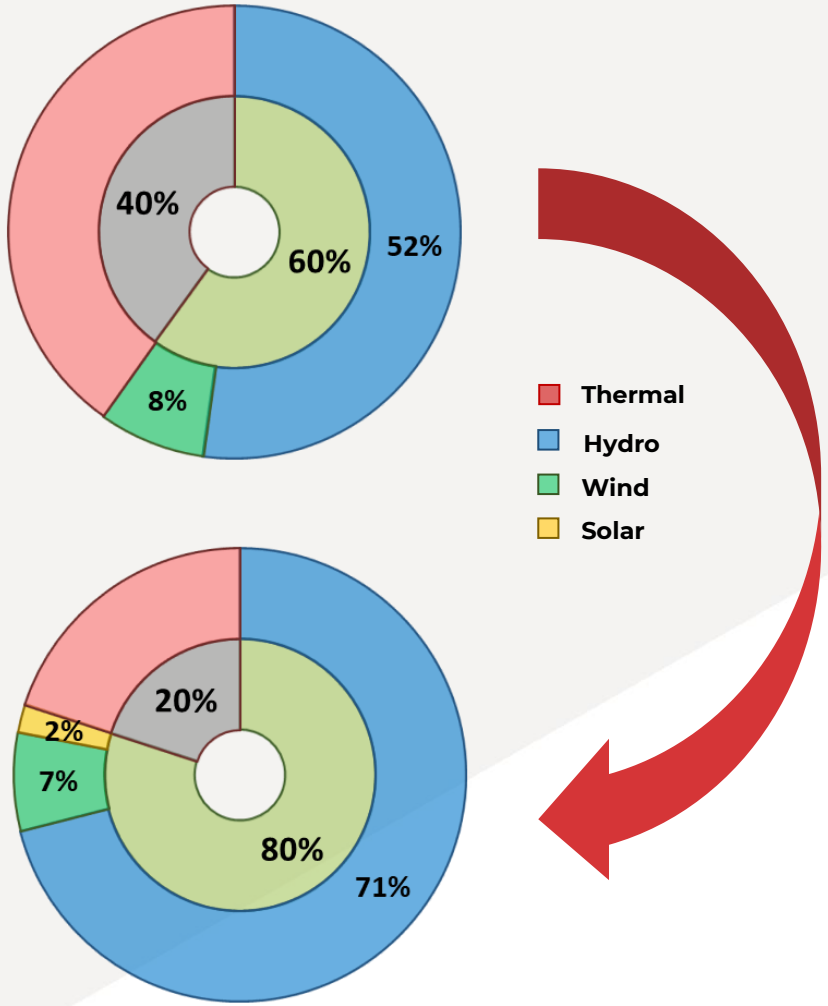


Geothermal
Wind
Diesel Engines Maximum Load
ESS discharging
Thermal
Hydro
Diesel Engines Minimum Load
ESS charging

Renewable Energy Challenges

Flores Island

Renewable Generation Forethought

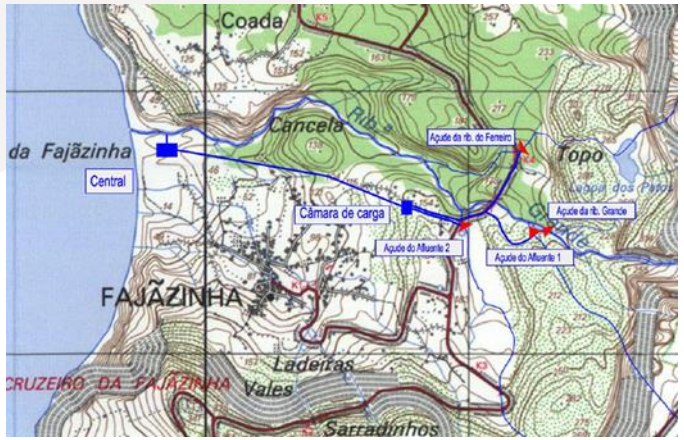


New hydroelectric plant (1,1MW)

New solar PV plant (0,4MW)

Upgrade of the wind park (0,6 -> 0,9MW)

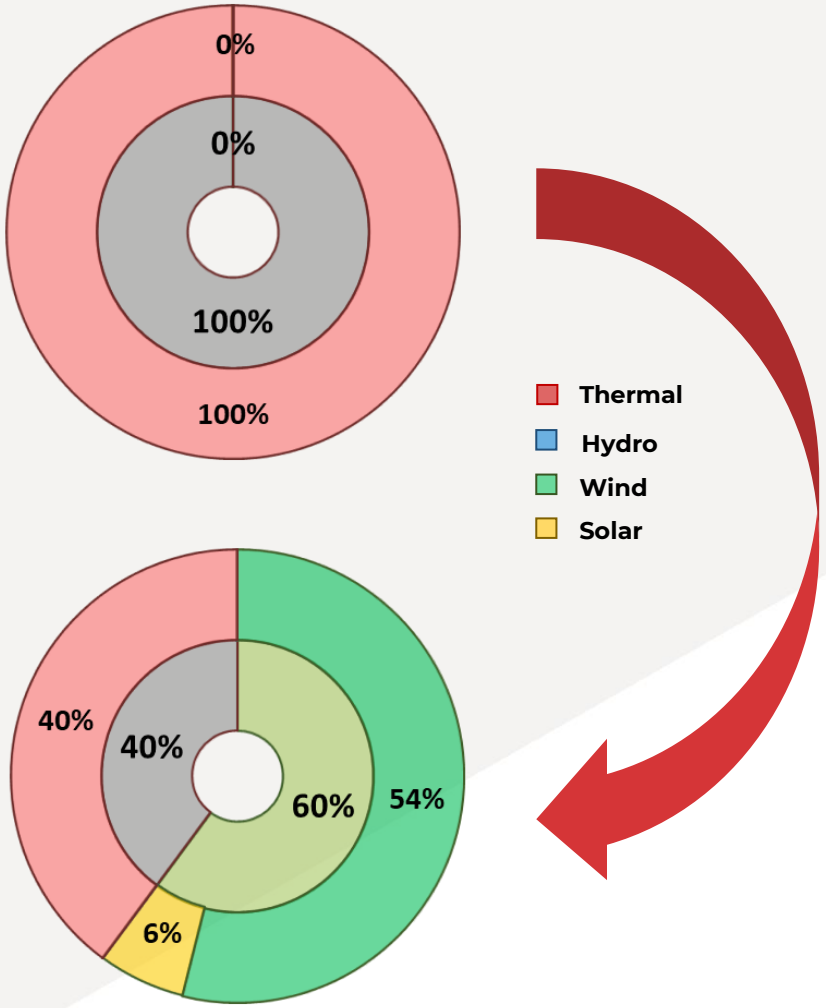
Additional Energy Storage System to improve frequency regulation



Renewable Energy Challenges

Corvo Island

Renewable Generation Forethought



New wind farm (700kW)

Expansion of the photovoltaic plant (75 -> 150kW)

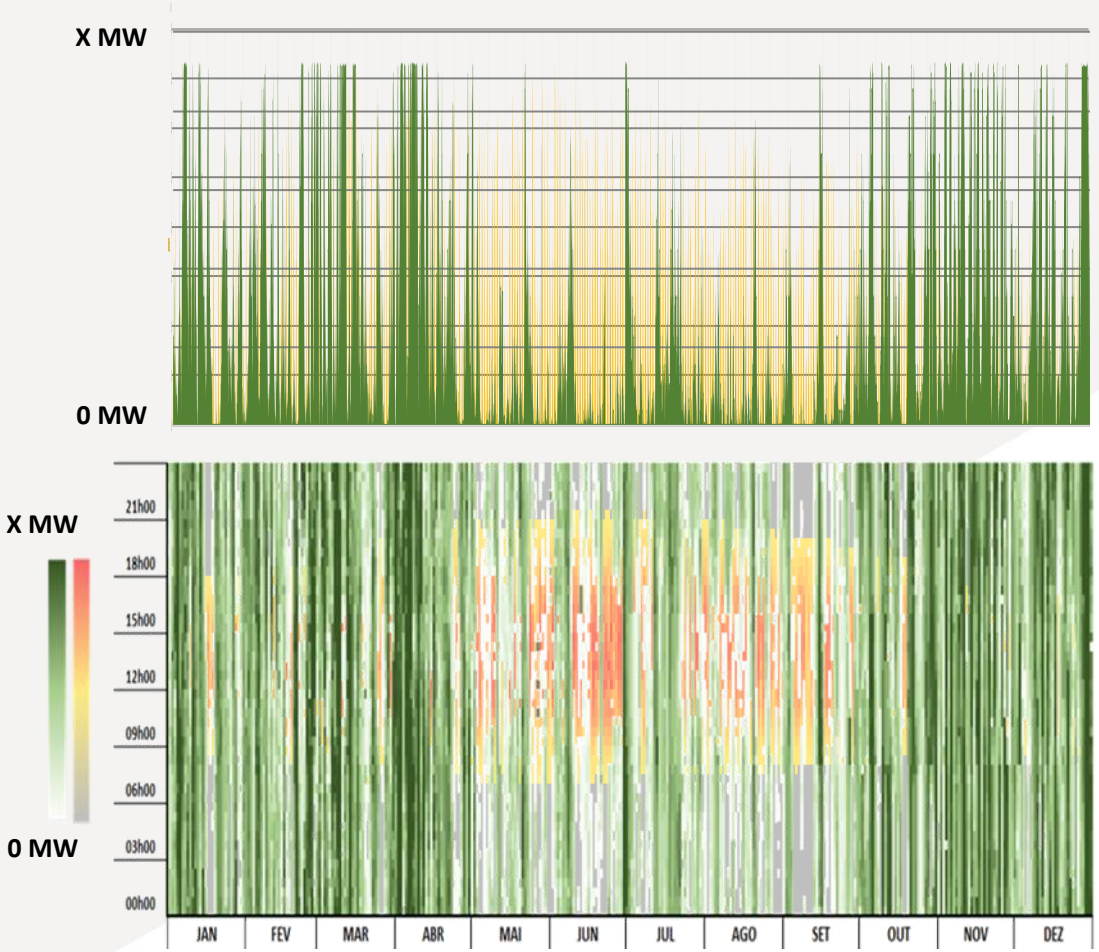
Energy Storage System to provide effective spinning reserve and frequency regulation

Renewable Energy Challenges

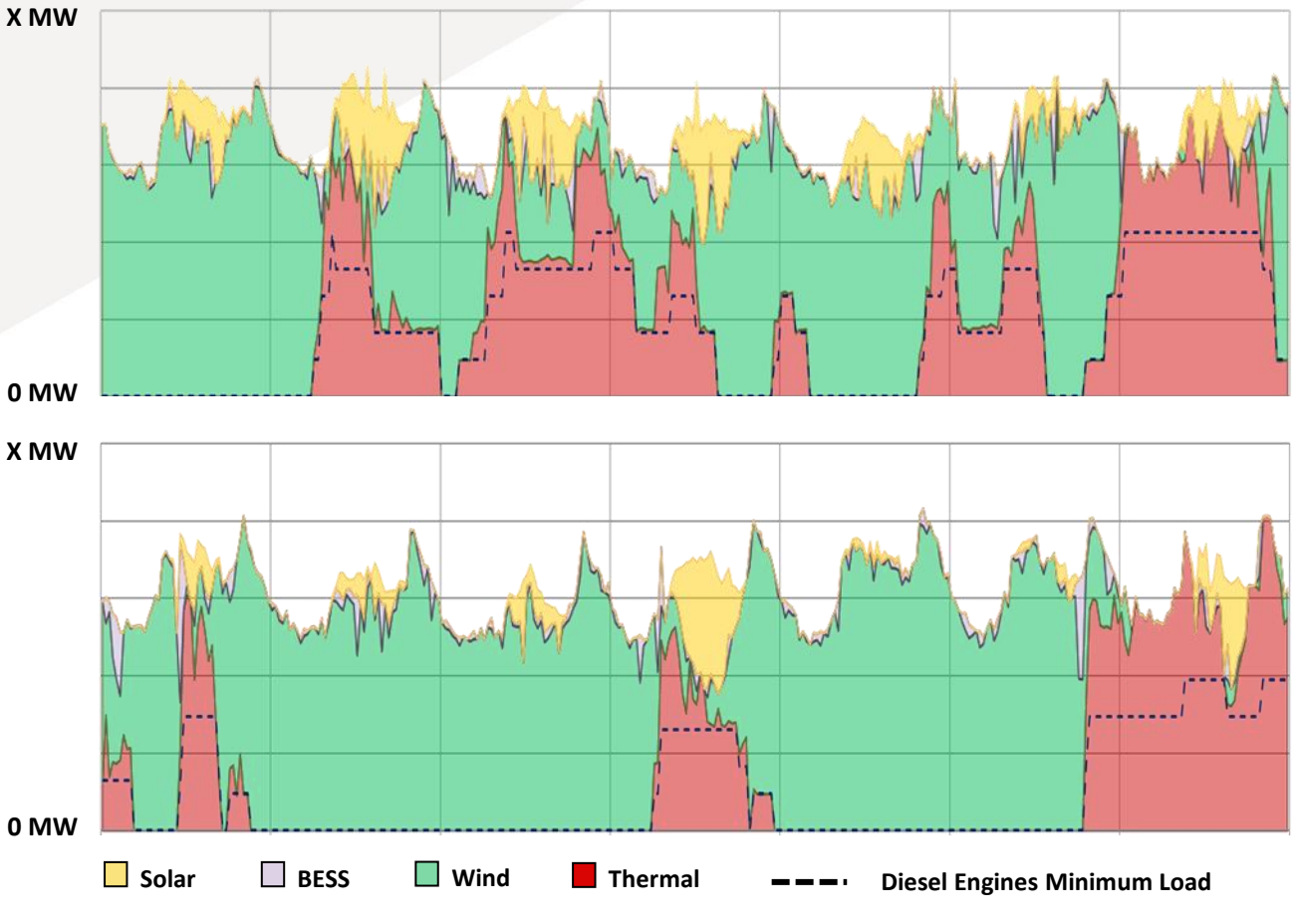
Wind and Solar Power Variability

Electric generation on an isolated system with a grid-scale battery energy storage system and oversized power plants of variable renewable energy sources

Example of one year wind and solar potential



Example of two weeks electric generation

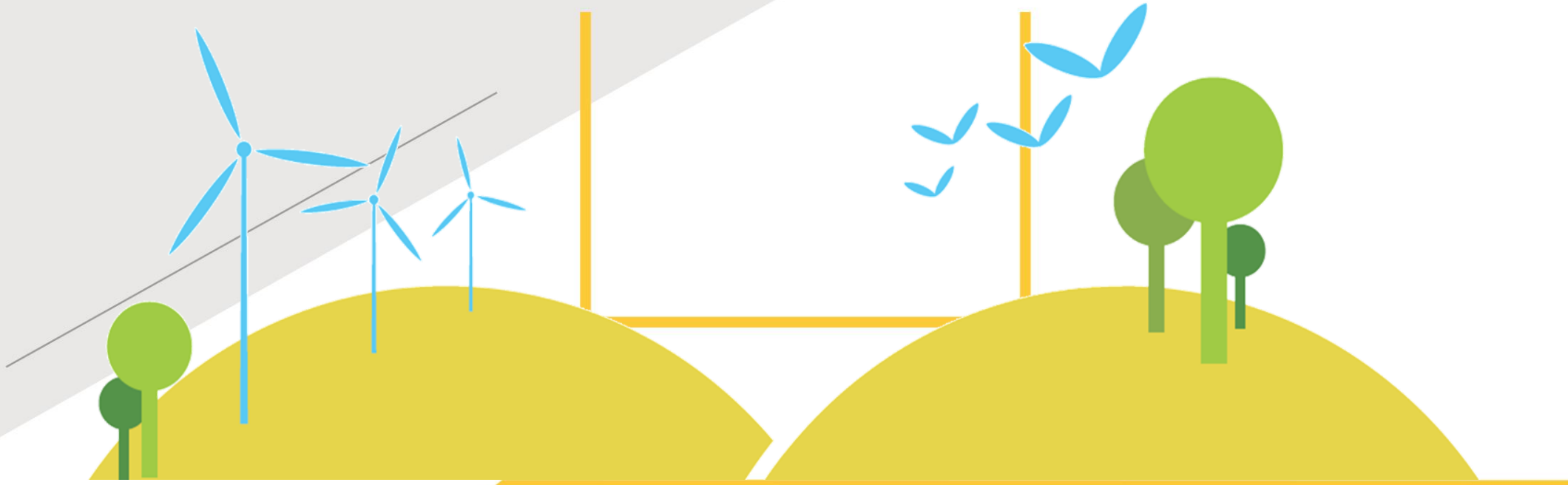


Renewable Energy Challenges

EDA Current Status

- EDA is focused on the objective of **maximizing the integration of energy from renewable sources**.
- EDA is carrying out several projects in order to achieve this objective, always **keeping the stability of the systems and the quality of energy supply** as the main concern.
- Support from **Community Programs** is essential to allow the implementation of innovative projects, which will reinforce islands energy autonomy.
- EDA is also monitoring progress in **synthetic/green fuels**, as thermal generator sets will continue in the near future to be essential for the operation of small-scale isolated power systems, such as remote islands.
- The know-how that EDA is seeking to obtain will enable **sustainable energy solutions** for the future.

EDA
Electricidade dos Açores

2022 6th INTERNATIONAL HYBRID POWER SYSTEMS WORKSHOP

Obrigado
Thank you