CE4EUISLANDS FORUM 2025 | 14th – 15th MAY 2025

Energy transition and public policies for the Portuguese islands

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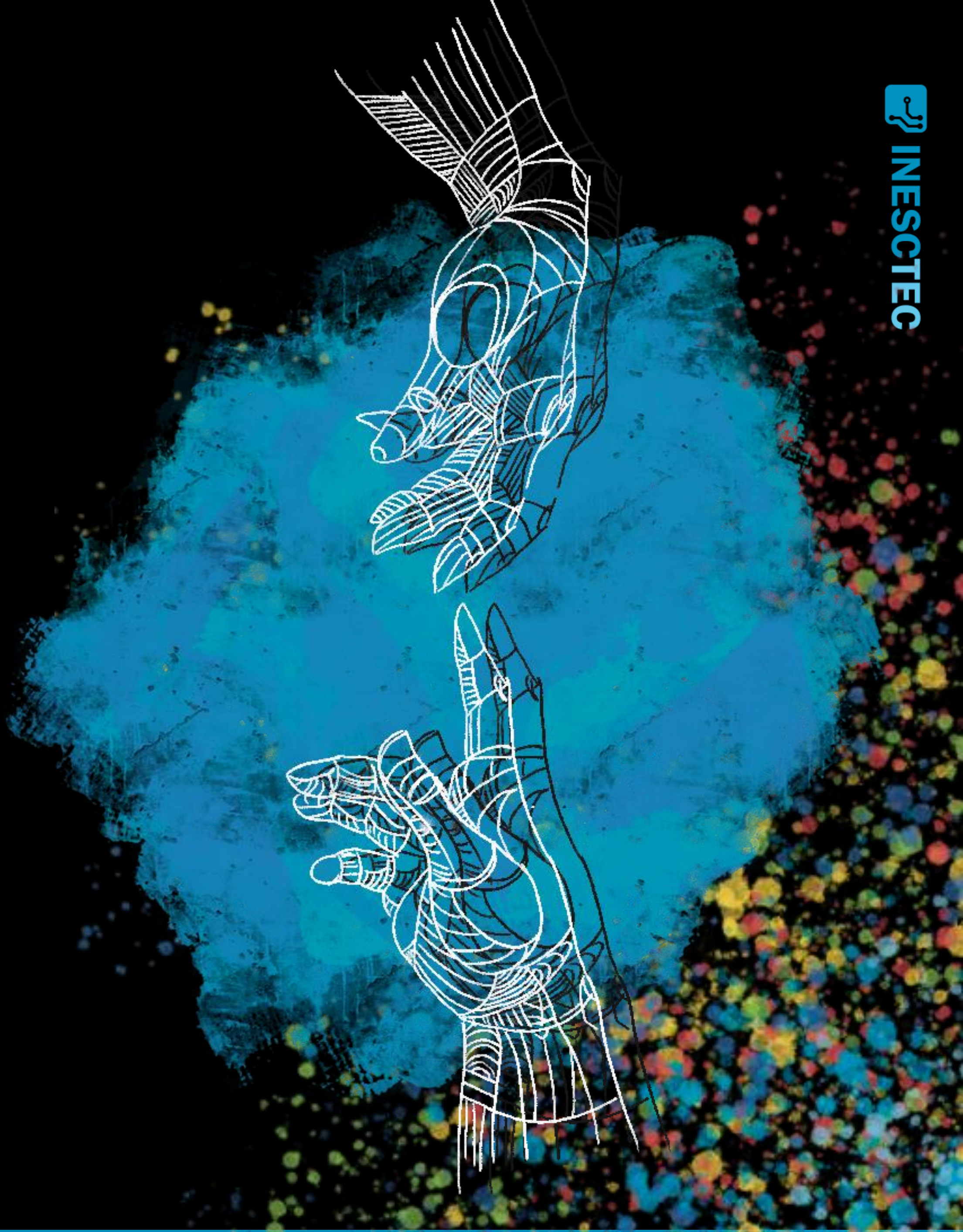


INESCTEC

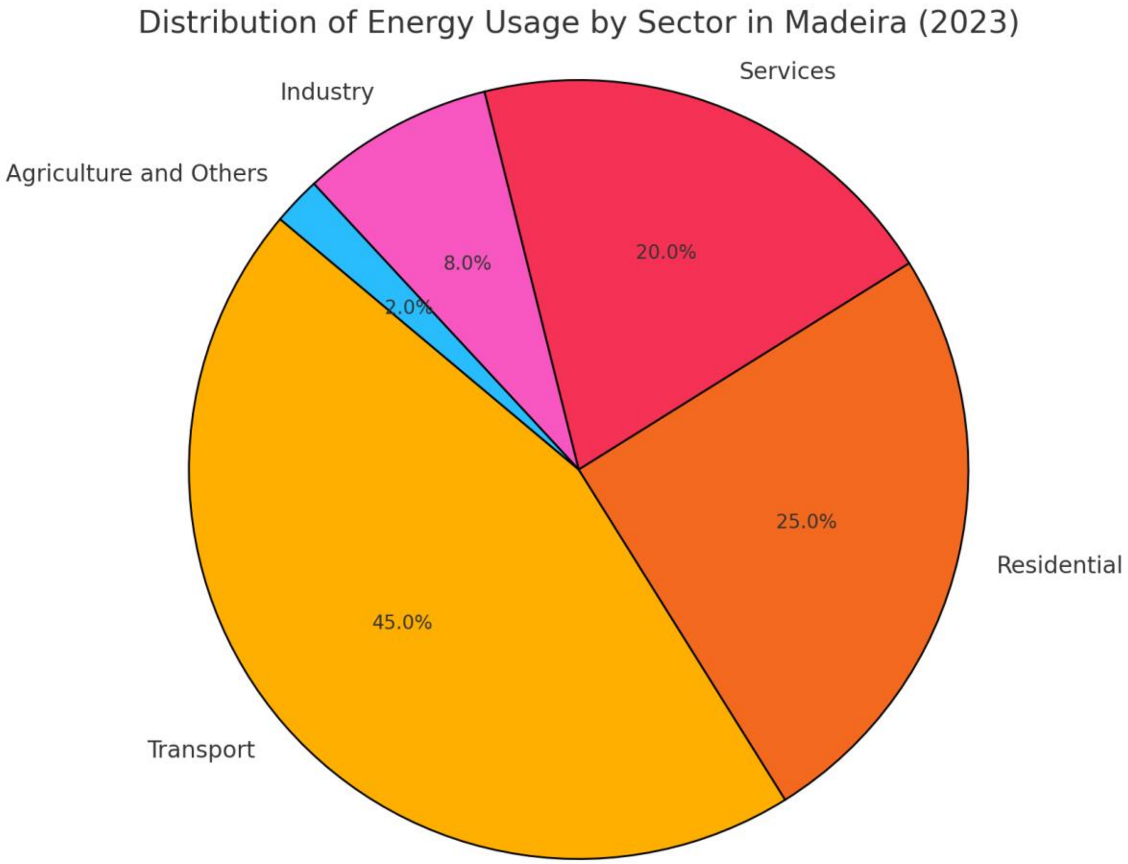
INSTITUTE FOR SYSTEMS
AND COMPUTER ENGINEERING,
TECHNOLOGY AND SCIENCE

Madeira

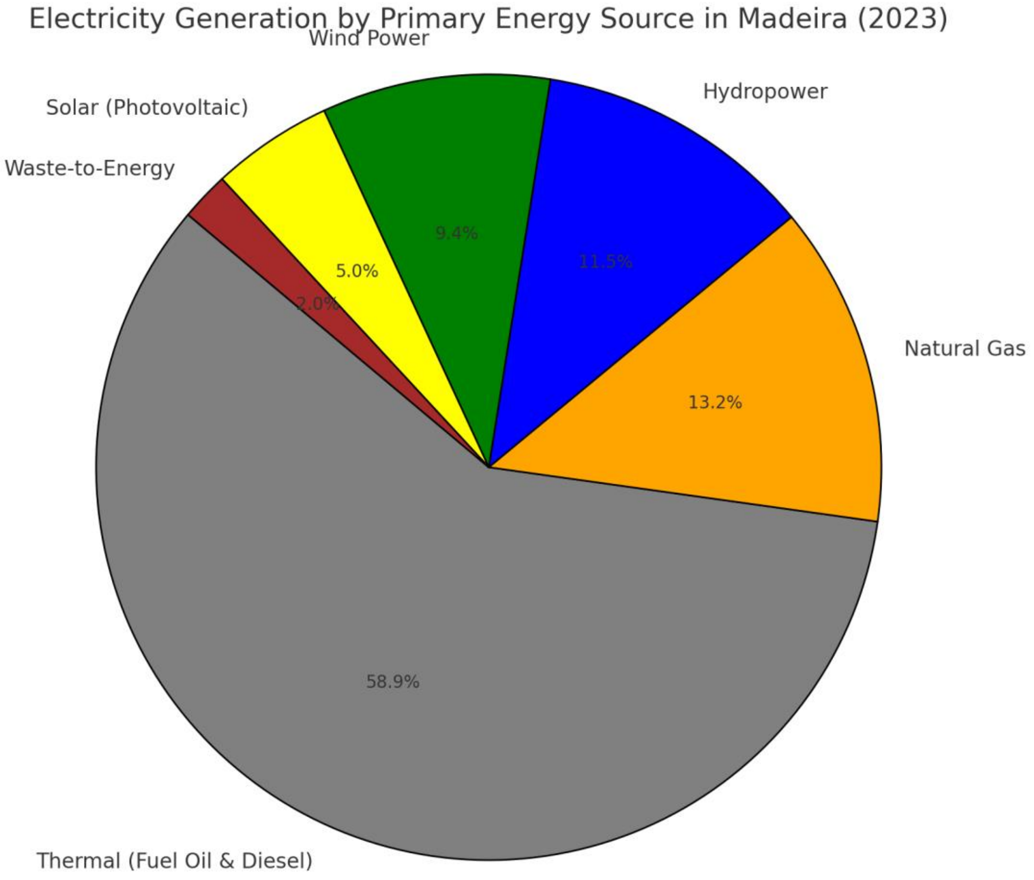
The archipelago of Madeira

- Two main islands in the Atlantic ocean with almost 260.000 inhabitants

Demand of Energy in Madeira in 2023

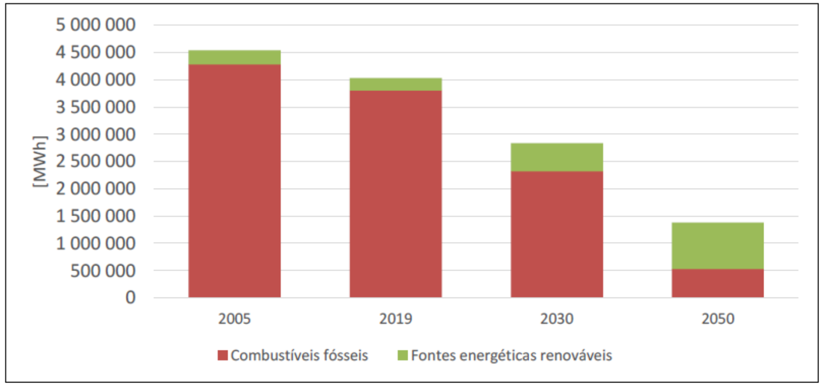


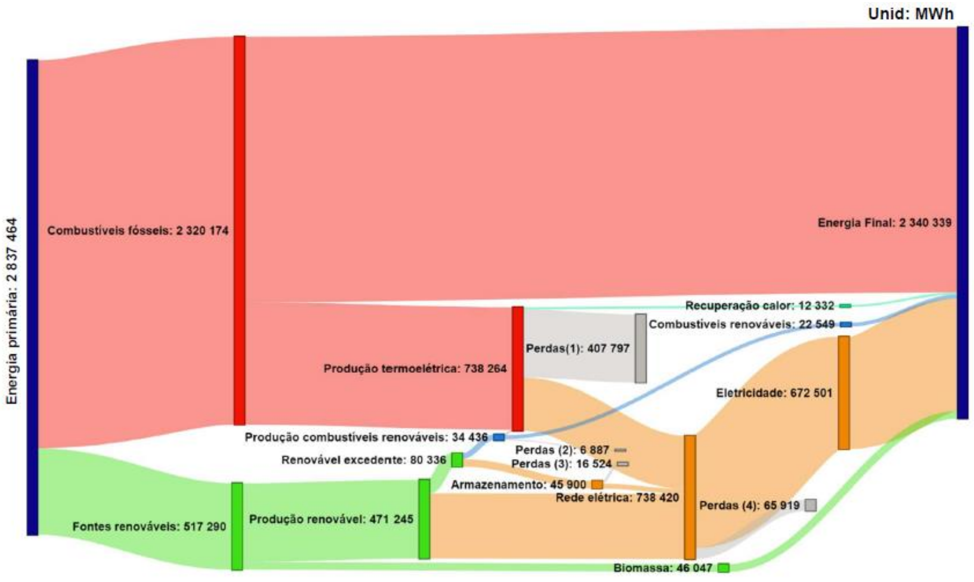
Generation of Electricity per primary energy source 2023



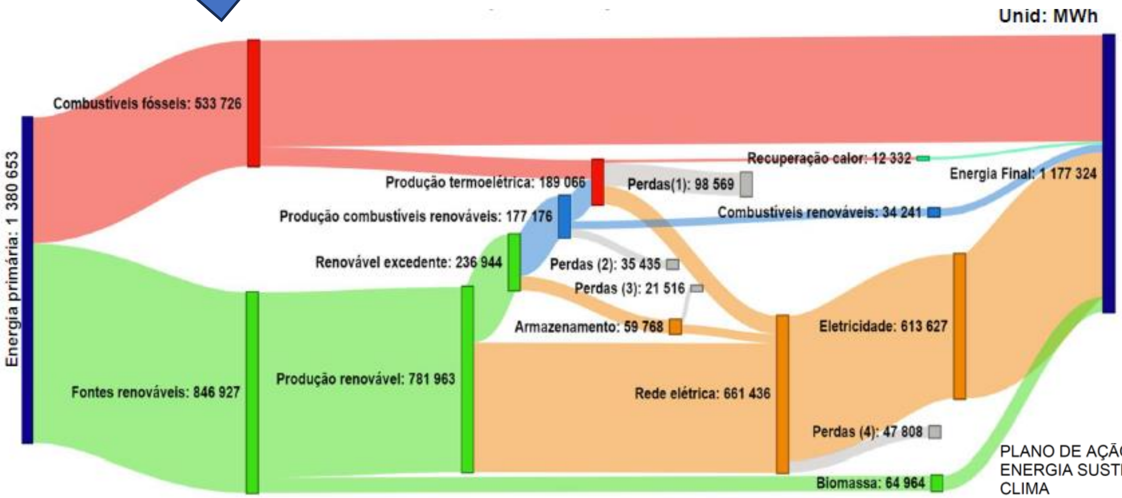
Definition of of Plan of action up to 2050

- Flux diagrams regarding primary energy and final energy between 2030 and 2050





2030



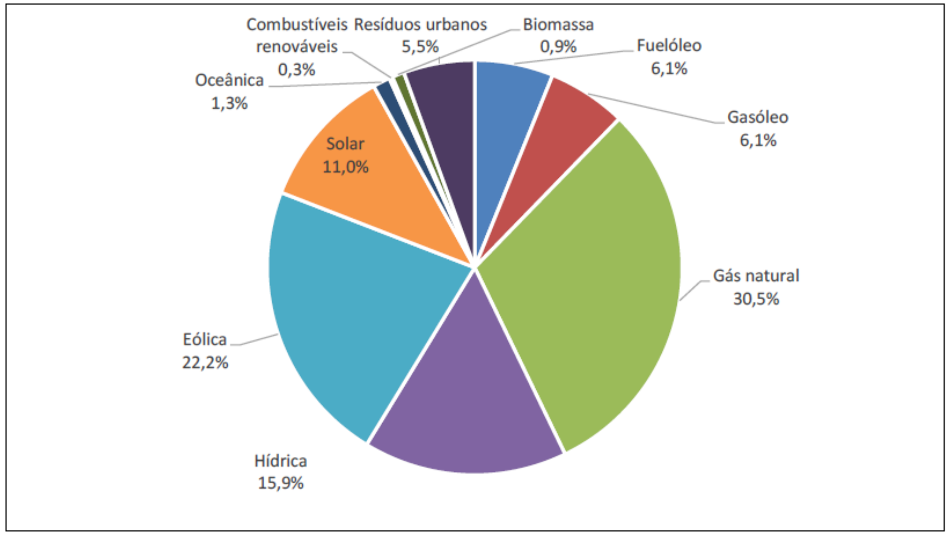
2050

PLANO DE AÇÃO PARA A ENERGIA SUSTENTÁVEL E CLIMA

REGIÃO AUTÓNOMA DA MADEIRA

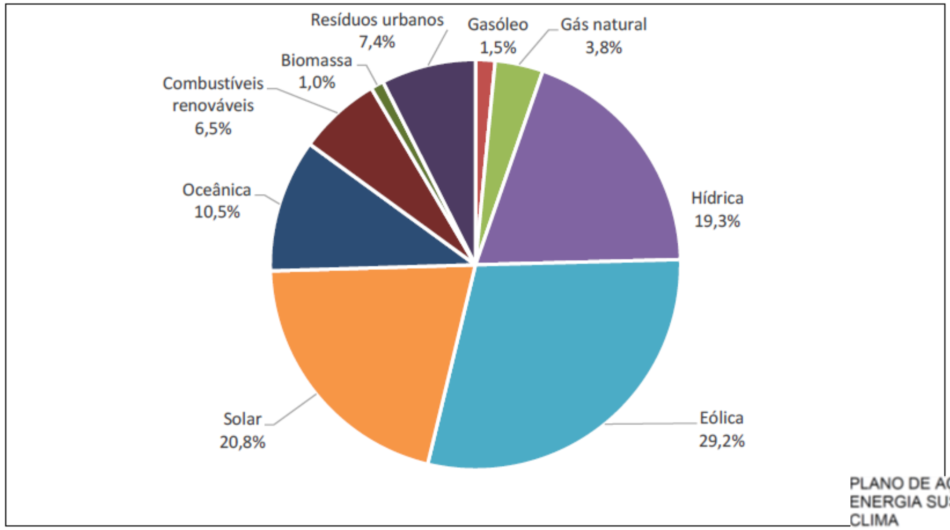
Foreseen evolution of the generation of electricity

- Large increase in renewable electricity between 2030 and 2050 (according to Action Plan for Sustainable Energy and Climate of the Autonomous Region of Madeira)



2030

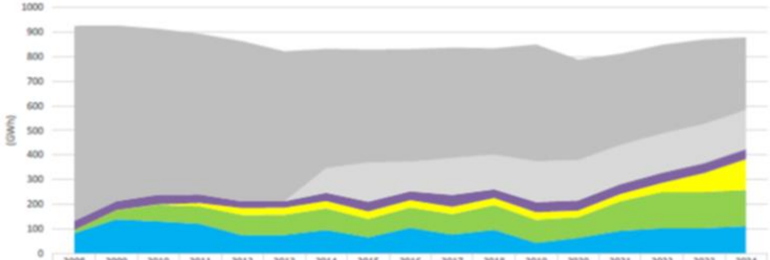
2050



PLANO DE AÇÃO PARA A ENERGIA SUSTENTÁVEL E CLIMA
REGIÃO AUTÓNOMA DA MADEIRA

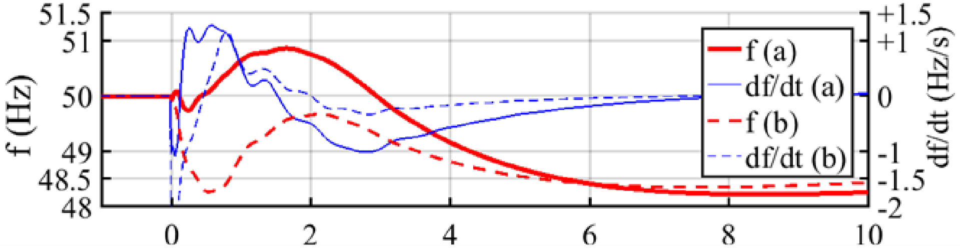
Foreseen evolution of the generation of electricity

- Wind and solar PV generation are expected to increase largely (mainly private investments);
- Hybridization of wind + solar PV plants;
- Auction mechanisms are will be adopted to define the remuneration of RES;



	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Térmica (Fuel)	791	712	673	651	649	608	482	458	456	447	430	473	406	369	359	342	293
Térmica (Gás)	0	0	0	0	0	0	101	160	121	151	141	166	164	160	160	160	160
Resíduos	37	37	39	34	28	26	33	39	36	48	35	41	41	40	41	39	40
Fotovoltaica	0	0	2	14	28	29	30	30	30	30	29	30	27	29	37	77	125
Eólica	13	37	67	71	83	82	88	75	82	83	101	94	84	120	147	147	147
Hídrica	83	140	131	121	75	76	96	66	105	78	97	44	64	93	103	103	111

- Specific legislation was prepared:
  - A specific grid code for Madeira was defined to define more demanding requirements for generation assuring robustness of operation (2019);
  - Establishes the organization and functioning of the electric system of the Region of Madeira (2023).
  - Defines the legal framework applicable to the production of electricity from renewable energy sources, based on a single production technology, with an installed capacity < 5 MW.

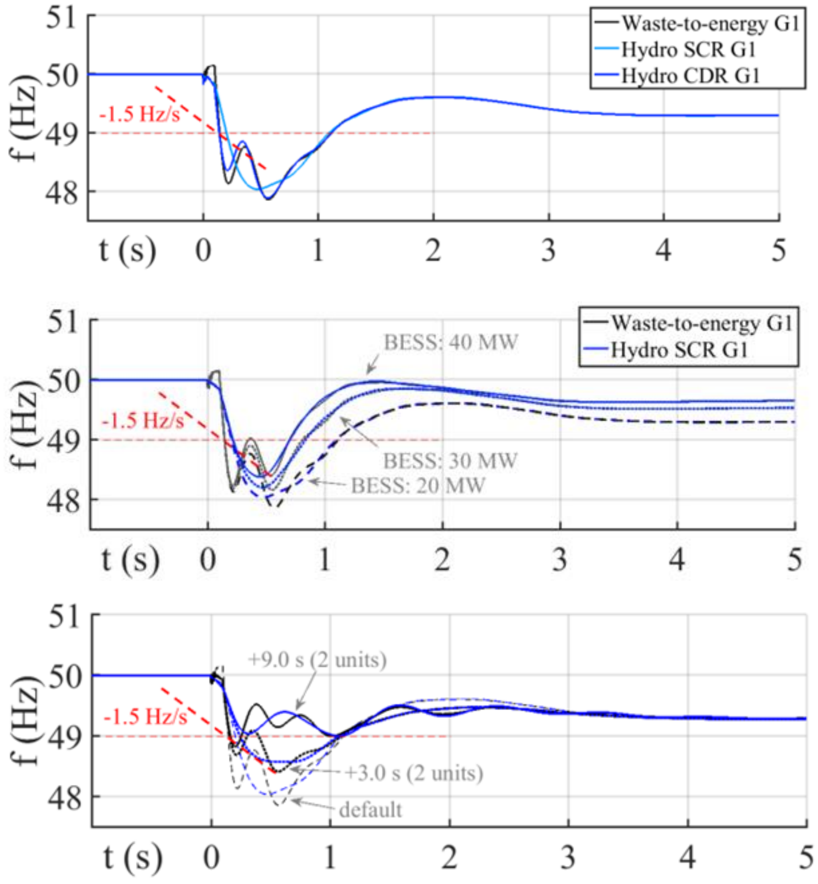


A transmission line short-circuit disturbance in an off-peak scenario, comparing the outcome with (dashed line) and without (solid line) priority to active current injection.

The Grid code of Madeira

- The grid code was issued in October 2019

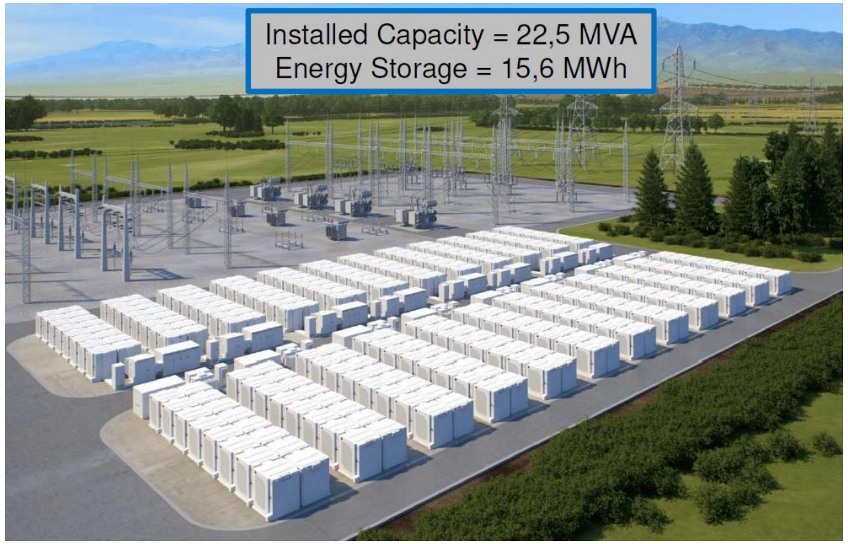
	Generation system type	Type A	Type B	Type C	Type D
	Installed capacity limit	< 0.1 MW	< 1 MW	< 5 MW	≥ 5 MW
Requirements	Low voltage ride-through	–	X	X	X
	High voltage ride-through	–	X	X	X
	Reactive current control	–	–	X	X
	Active current control	–	–	X	X
	Post-fault active power recovery gradient	–	X	X	X
	Limited frequency sensitive mode for overfrequency	X	X	X	X
	Limited frequency sensitive mode for underfrequency	–	–	X	X
	Active power ramps	–	–	-	X



- Grid code compliance studies are required to new generation plants

Foreseen evolution of the generation of electricity

- New energy storage systems were installed (hydro pumping with an artificial upper and lower reservoirs – 1 Mm3 of water) and battery energy systems
- Battery systems are operated with converters in grid forming mode which allows the disconnection of thermal units without loss of security (the battery converter is capable to replace one thermal unit if it trips) → increase the penetration of renewable generation minimizing RE curtailment;
- A synchronous condenser is also being installed to assure enough inertia to the system



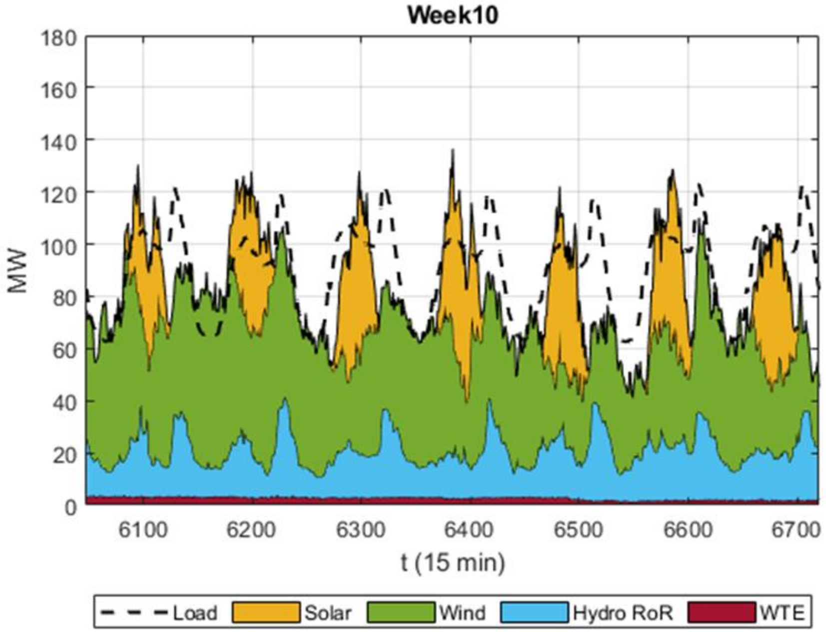
Grid expansion plan

- The grid expansion plan was revisited in order to accomodate more renewable generation and the hydro pumping systems

Security of supply assessment became a concern regarding the generation expansion

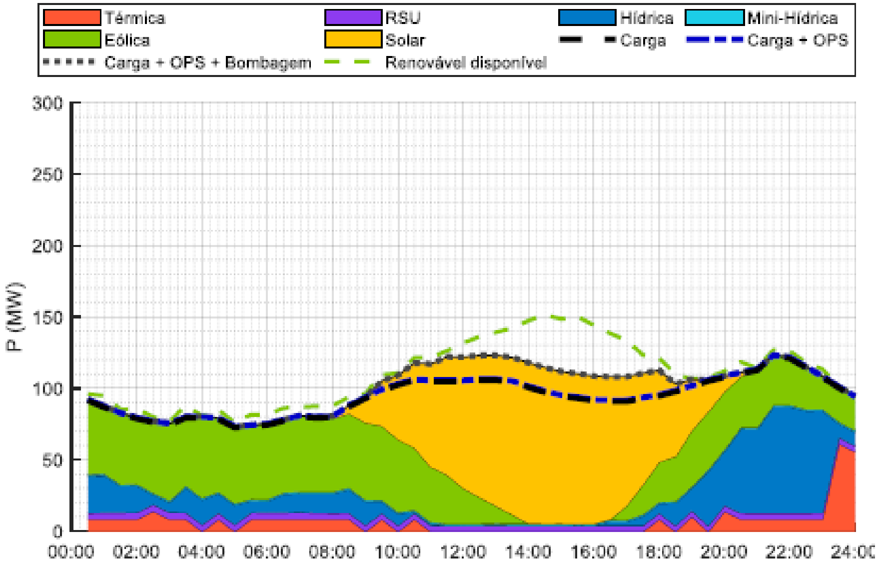
- Security of supply through reliability and generation adequacy assessment
  - Optimal expansion plans requires advanced models capable of addressing the time variabilities associated with renewable generation in different timeframes (e.g., daily, seasonal, and yearly variations) and the operation strategies adopted to guarantee the safe, economical, and continuous supply of electricity to end-users. This planning exercise can only be carried out with high-resolution models capable of simulating the hourly operation generation systems, enabling the emulation of the operator’s decisions throughout time, specifically, in terms of unit scheduling and storage use. → Chronological Monte Carlo simulation used to assess reliability indices.

Example of 2030

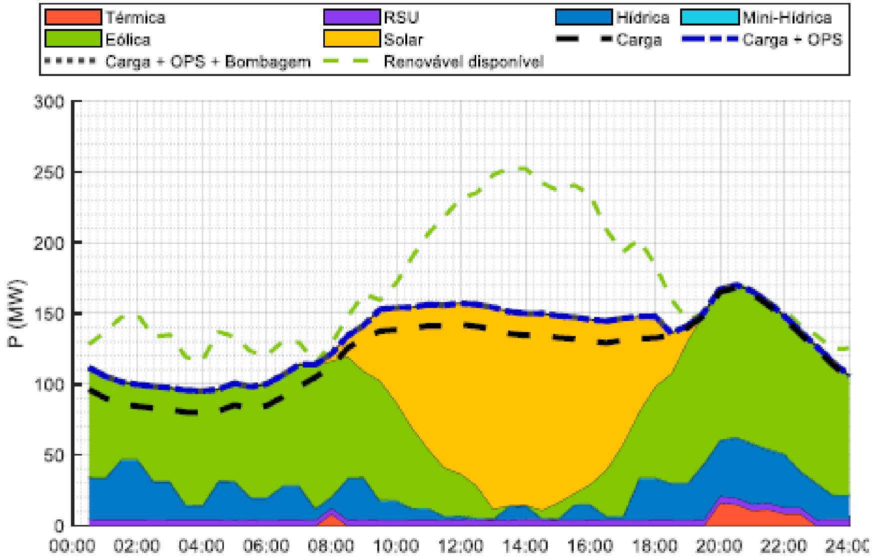


Green Ports

- The decarbonization of the ports of Madeira and Porto Santo was studied through the increase in renewable generation, addressing:
  - Security of supply;
  - Reinforcement of the grid structure;
  - Stability studies.



2030



2035

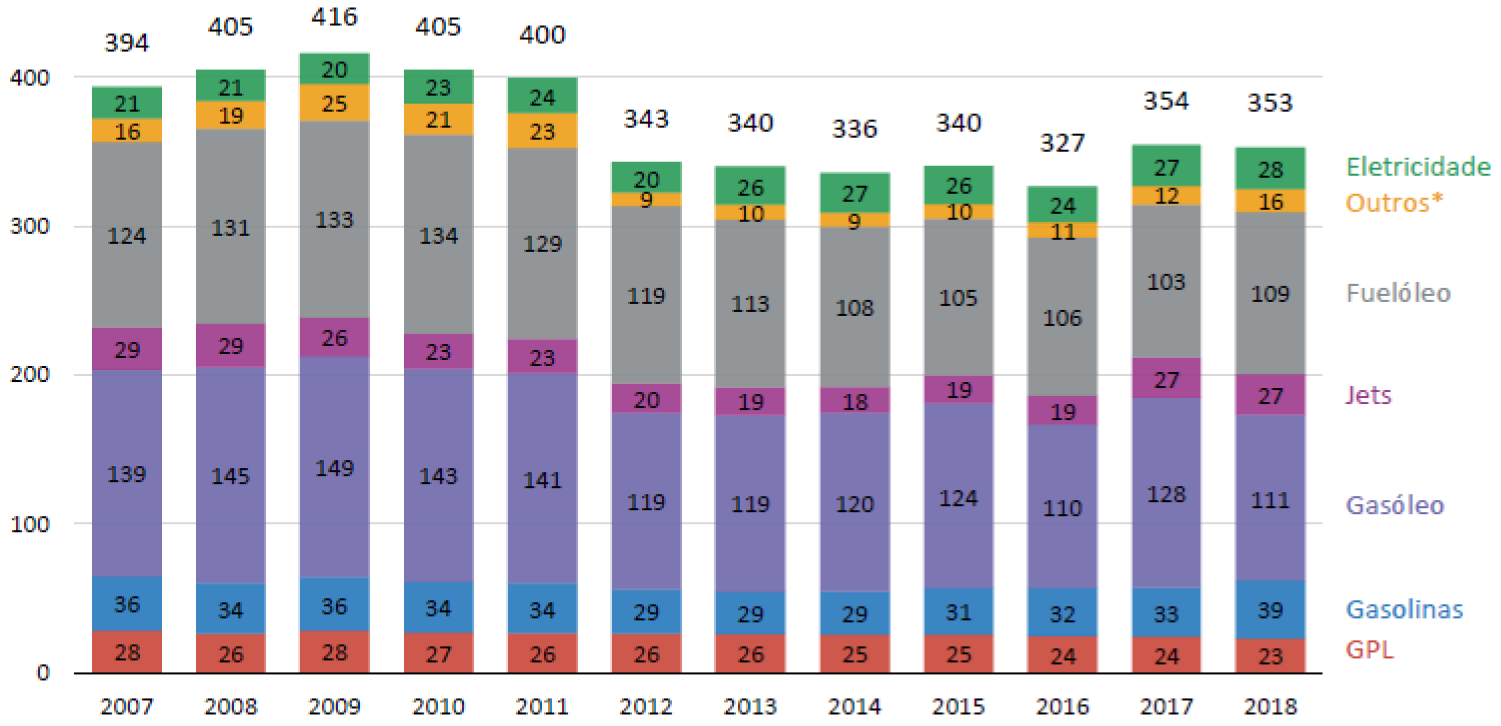
Azores

The archipelago of Azores

- Nine islands in the Atlantic ocean with almost 250.000 inhabitants

Primary Energy Comsumption

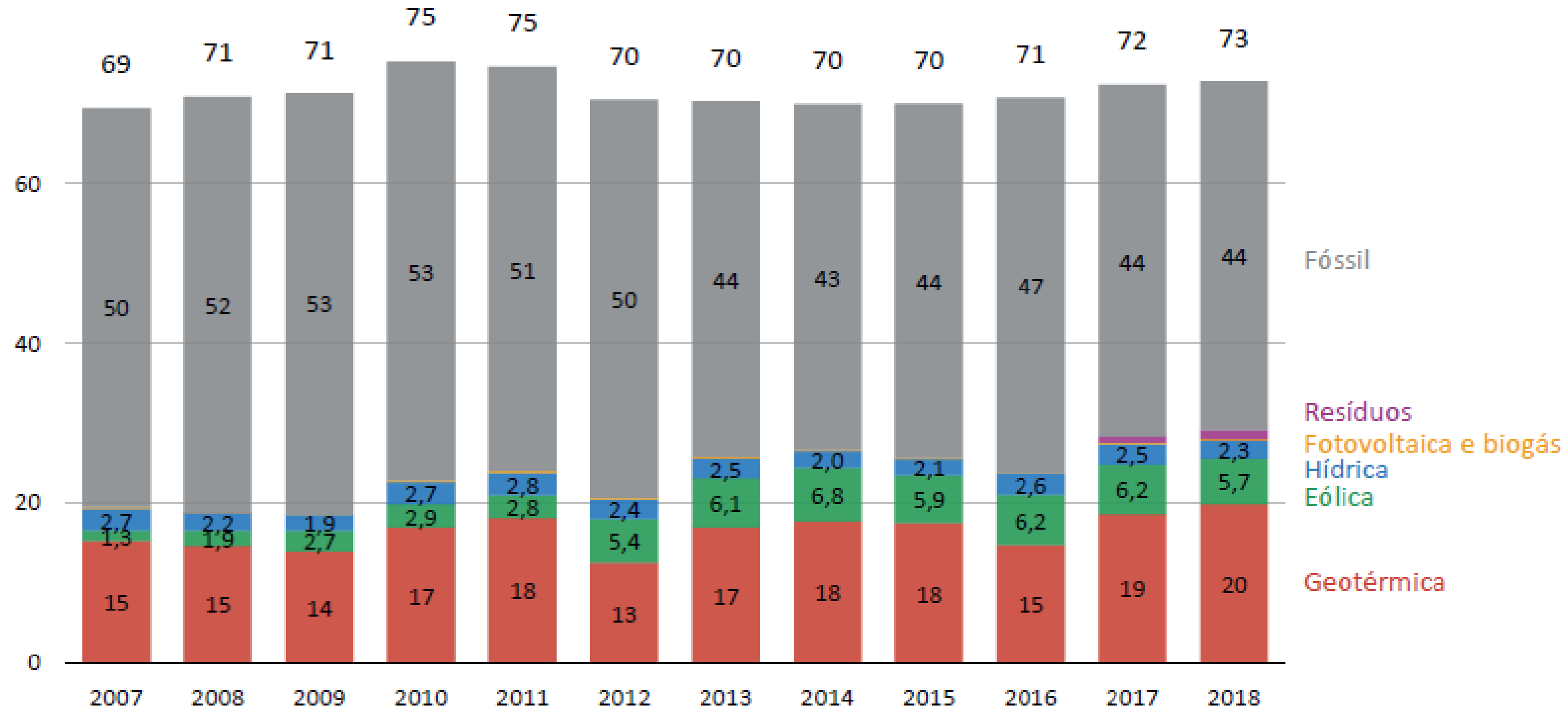
- Consumption in ktoe



From: Energy Strategy 2030 for Azores

Origin of electricity in Azores

- Generation of electricity in ktoe



From: Energy Strategy 2030 for Azores

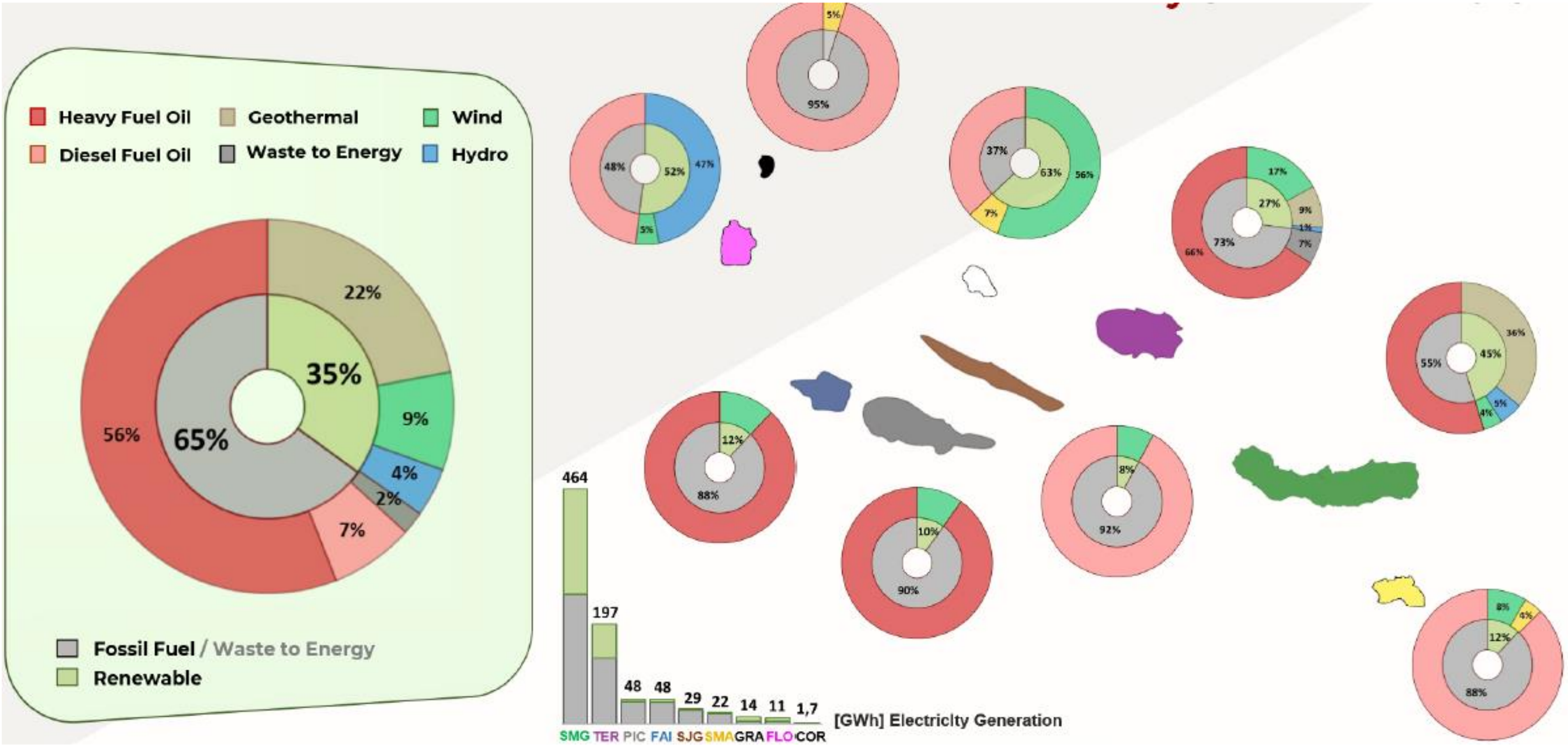
The portfolio of generation in the Island of Azores

- Installed capacities for generation of electricity

- **9 Different Isolated Electric Systems**
  - **Largest: São Miguel** (77 MW Peak Power)
  - **Smaller: Corvo** (0,33 MW Peak Power)
- **Total Generation: 836 GWh** (**35,0% Renewable**)
  - **9 Thermal Power Plants** (226,5 MW)
  - **9 Wind Farms** (36,65 MW) - 2 private owned
  - **3 Geothermal Power Plants** (27 MW)
  - **12 Small Hydro Power Plants** (8,4 MW)
  - **1 Waste to Energy Plant** (2,6 MW) - private owned
  - **3 PV Power Plant** (1,67 MW) - 1 private owned
  - **1 Biogas Power Plant** (1 MW) - private owned

Source: EDA

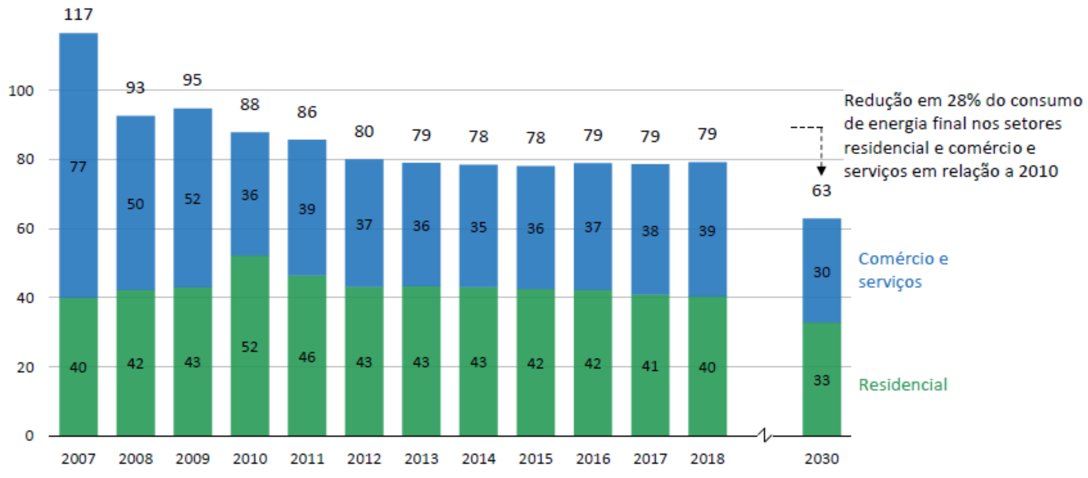
Origins of the electricty produced

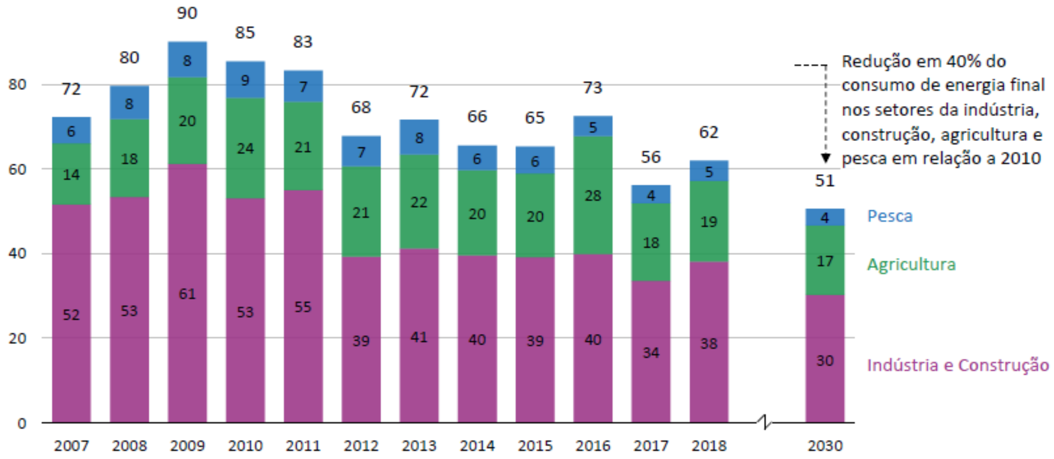


Source: EDA

Foreseen evolution of the consumption of energy

- An increase in efficiency and electrification of consumption is foreseen





ktoe

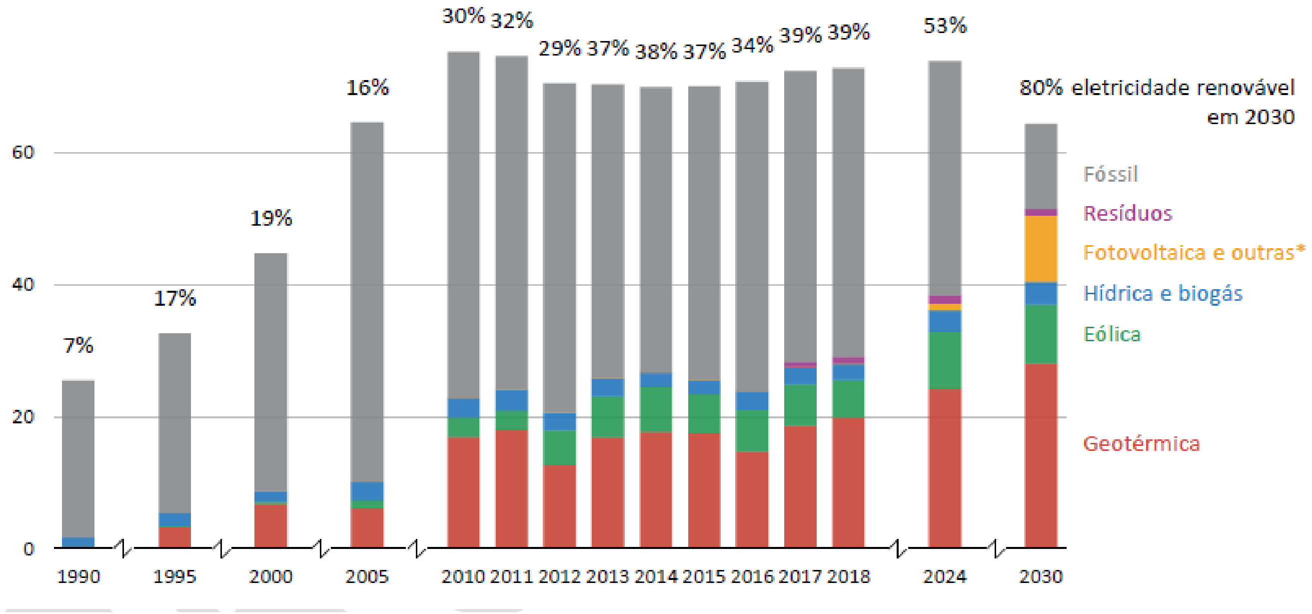
Residential and services sectors

Industry, construction, agriculture and fishing

From: Energy Strategy 2030 for Azores

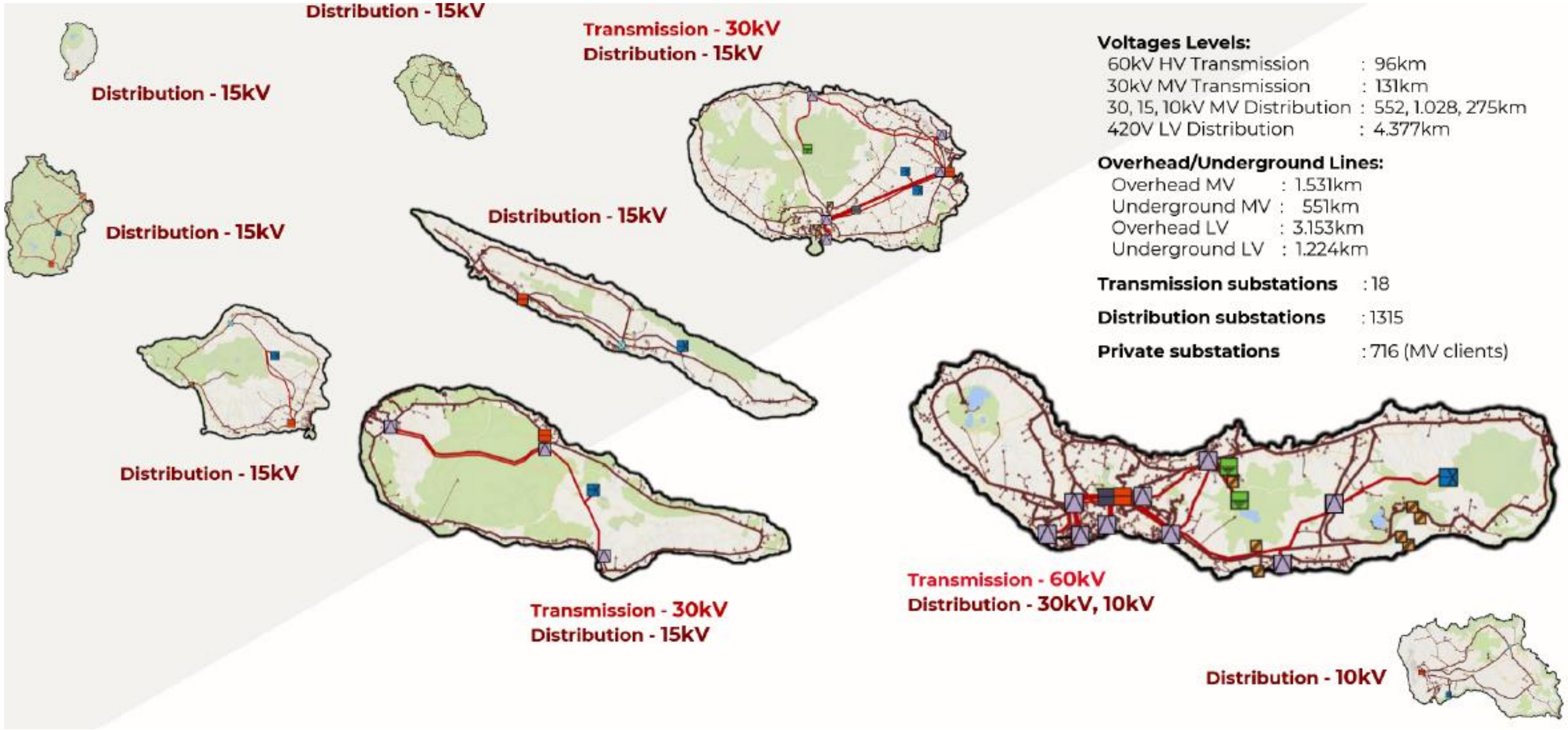
Evolution of the electricity generation sources

- A very ambitious target has been proposed: 80% renewable electricity by 2030.



From: Energy Strategy 2030 for Azores

Transmission and distribution grids in Azores



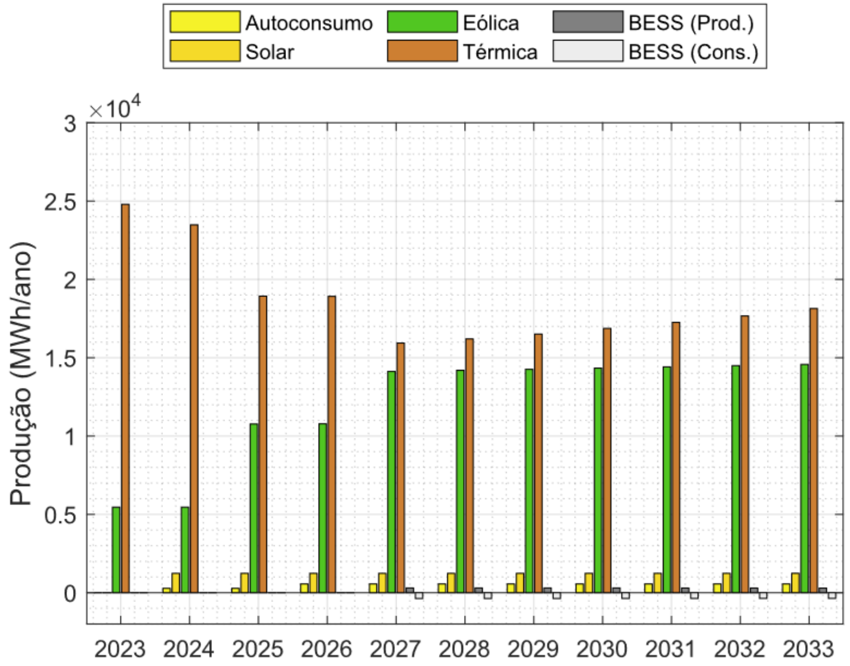
Source: EDA

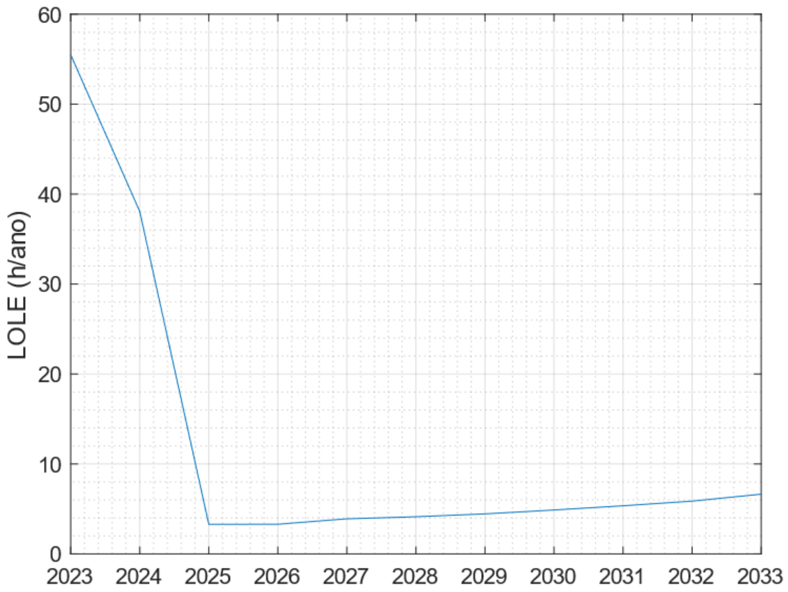
Foreseen evolution of the power sector in Azores

- Large increase in geothermal, wind and solar PV generation (private investors);
- Installation of energy battery storage systems in all islands
  - BES operated with converters in grid forming mode which allows the disconnection of thermal units without loss of security (the battery converter is capable to replace one thermal unit if it trips → increase the penetration of renewable generation minimizing RE curtailment;
- Hybrid solar PV plants (Solar PV + battery energy systems);
- Adoption of similar to Madeira requirements for generation for new RES plants;
- Grid code compliance studies are required to new generation plants;
- Preparation of legislation that establishes the organization and functioning of the electric system of Azores (2024 - 2025).
- Development of security of supply studies to define the trajectory of evolution of the portfolio of generation

Security of supply studies

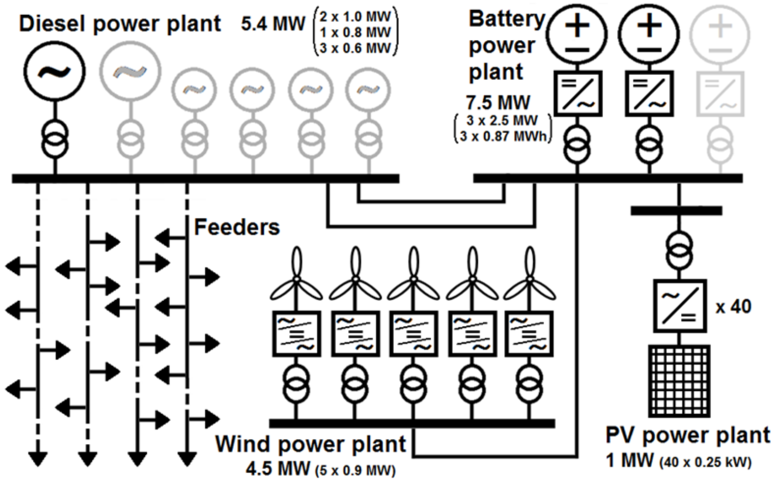
- Contribution of each technology to supply demand and LOLE evolution





The case study of Graciosa

- Using islanded systems is the best way to demonstrate the importance of storage systems (in this case batteries)
- The hybrid system of Graciosa (in Azores)

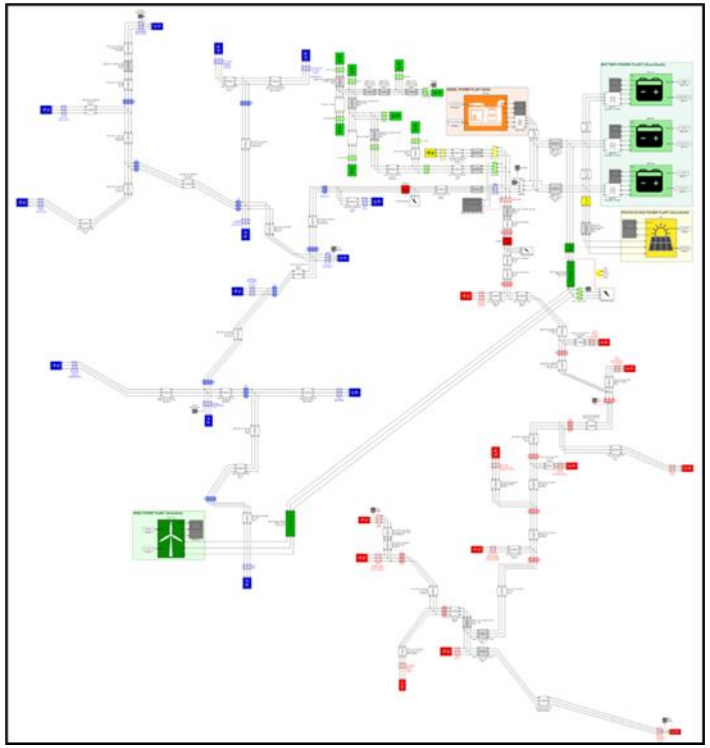


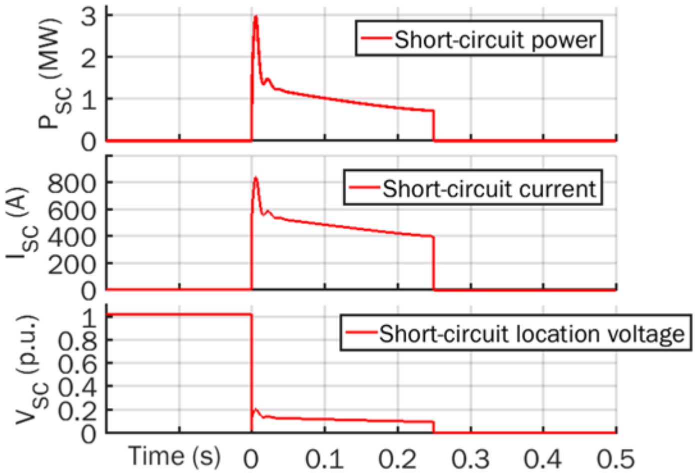
+ **EMS**
Management of the System:
Forecasts of demand + forecasts of renewable generation
→ Optimized management of the generation portfolio

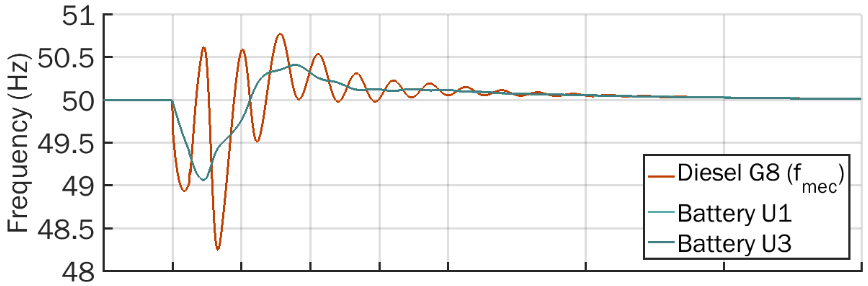
- Operation of the converters in grid forming mode
- Overdimensioning of the converters to assure the operation of the protections

Dynamic behaviour analysis studies in Graciosa

- Studies performed for the SAT





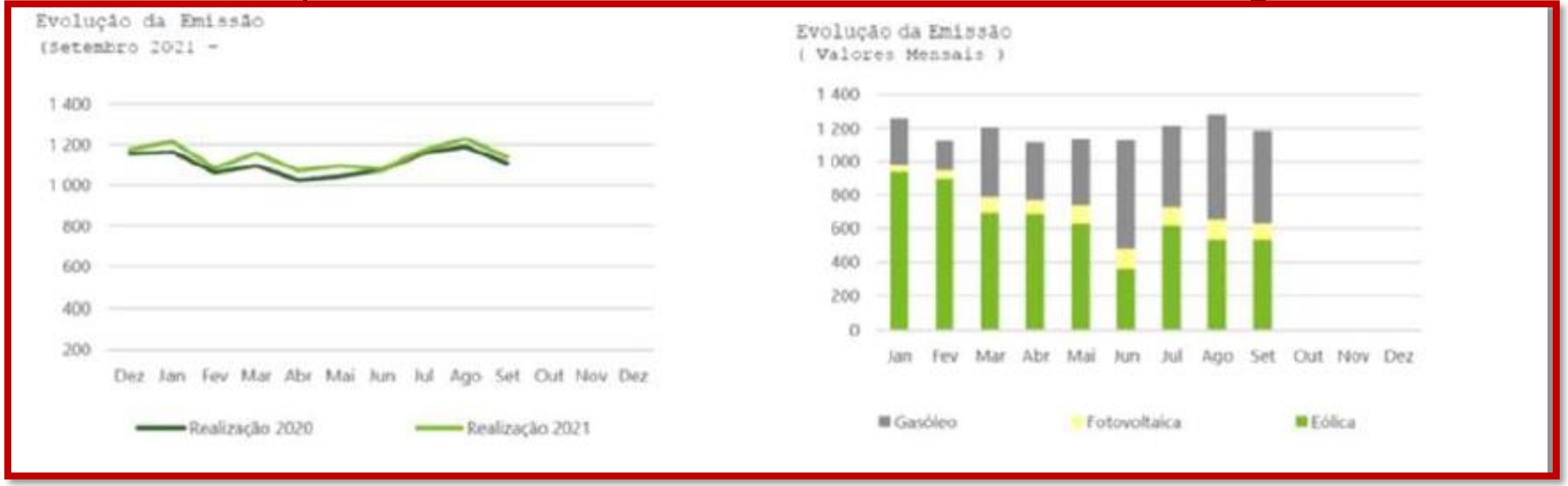


Batteries and their use in islands

- The study case of Graciosa

A power system fully dependente on Diesel units passes to operate with > 60% of renewable energy (wind power and solar PV):

- 2020: Consumption 13,4 GWh → 8,13 GWh of renewable origin



- Several consecutive days with only generation from renewable power sources.

Source EDA

Conclusions

- Large increase in efficiency will lower primary energy consumption in both Madeira and Azores;
- Electrification of the local economies is expected to take place up 2050;
- Very ambitious targets for renewable energy integration are foreseen up to 2050 in Madeira and Azores;
- A priority to the integration of renewable energy sources, requires:
  - To largely increase energy storage usage;
  - To enhance grid infrastructures;
  - To enforce grid code requirements;
  - To assess periodically security of supply and assess dynamic behavior of the islanded grids;

- Reliable, robust, clean, and resilient power system can then contribute to decarbonize island economies.