International Workshop on Renewable Energies Development in in Macaronesia and West Africa
May 30-31, 2016
Held at CERMI, in Praia

Active grid management of SAL island with medium/high level of renewable penetration Technical solutions to optimize the rate of penetration

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Ministério do Turismo, Investimentos e Desenvolvimento Empresarial

ECREEE Towards Sustainable Energy

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CAPE VERDE PRESENTATION

- Cape Verde is composed by 9 inhabited islands
- ELECTRA operates 9 independent and isolated electric systems
- Boa Vista Island is managed through a sub-concession to the company AEB
- In Sal Island, besides ELECTRA, there is APP, an independent producer.
- Electricity production managed by ELECTRA is based on:
  - 3 Diesel Power Plants (LFO e HFO)
  - 6 Diesel Power Plants (GO)
  - 5 Wind Farms
  - 2 Solar Power Plants
- Water production by ELECTRA is based on:
  - 3 Desalination Plants (RO) in São Vicente and Sal islands and in Praia

COMPANY PRESENTATION

COMPANY HISTORY
MAIN MILESTONES

1982

Launch

- ELECTRA was launched in April **17th 1982**

2000

Privatization

- Sale of 51% of the share capital. Private management on January **18th 2000**.

2006

Corporate Restructuring

- EDP/AdP transferred all its shares to the State of Cape Verde, which started to hold full control of the company with 85% stake, and the remaining 15% kept being held by the municipalities of Cape Verde - **August 31st 2006**,

2013

3 Companies separation

- Entry into operation of 3 companies from **July 1st, 2013:**
  ELECTRA SARL
  ELECTRA Sul
  ELECTRA Norte
- ELECTRA SARL owns all assets
- **ELECTRA Sul** (Maio, Santiago, Fogo e Brava) and **ELECTRA Norte** (Sto. Antão, S. Vicente, S. Nicolau e Sal) are operating companies.

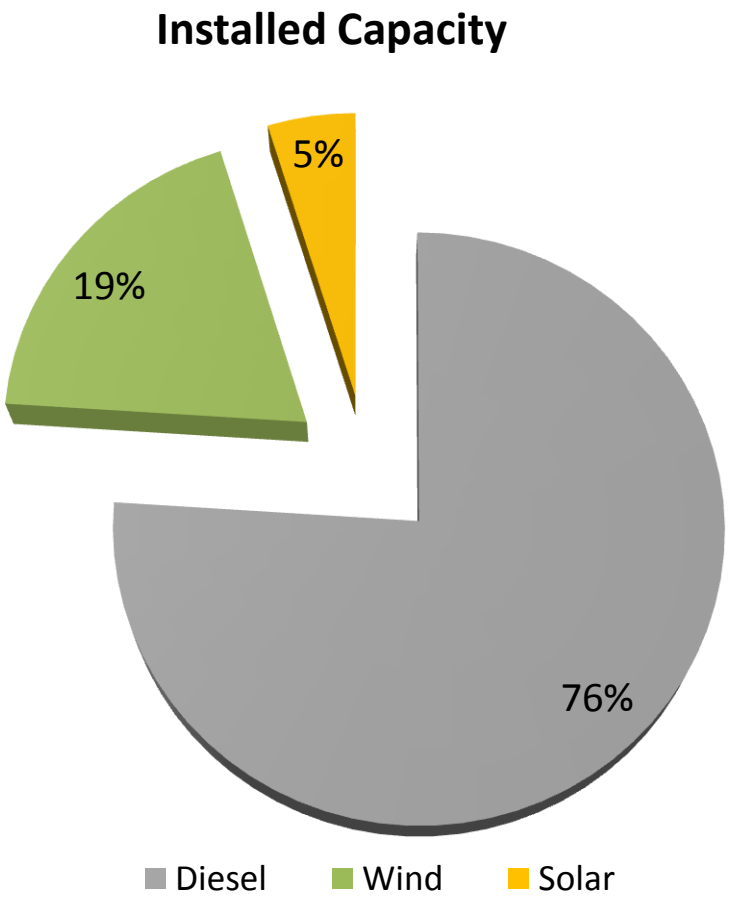
COMPANY PRESENTATION
ACTIVITY AREAS

ELECTRA ACTIVITY AREAS:

- Electricity transmission and distribution across the country, on an exclusive basis (except Boa Vista island)
- Water transport and distribution on S. Vicente, Sal and Praia, on an exclusive basis
- Electricity Production nationwide (except Boa Vista island)
- Desalinated water production on S. Vicente, Sal and Praia
- Wastewater collection and treatment for reuse in Praia, on an exclusive basis

COMPANY PRESENTATION

CONVENTIONAL AND RENEWABLE PRODUCTION MANAGEMENT



In recent years, Cape Verde has invested in renewable energy making use of its endogenous resources, mainly wind and solar resources.

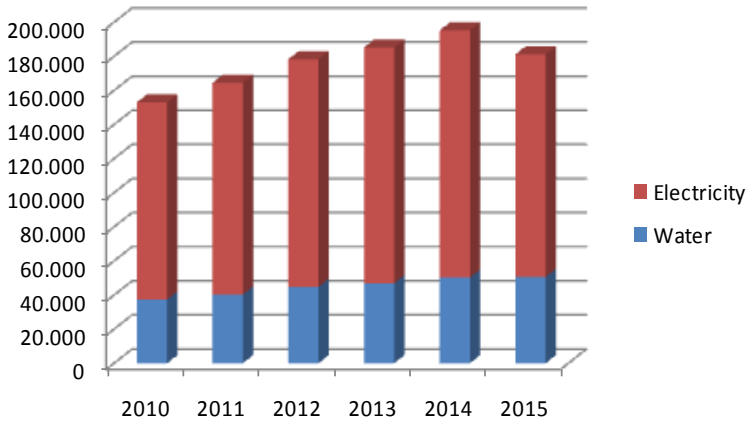
Presently ELECTRA manages **26,9 MW** of renewable capacity

(independent power producers and state owned renewable power plants represents **24%** of the total installed capacity of **140 MW**)

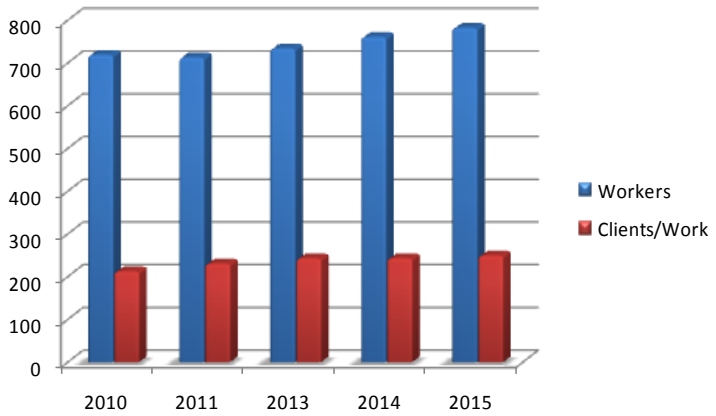
COMPANY PRESENTATION
RELEVANT NUMBERS…

At the end of 2015 ELECTRA had about **181 161 clients (130 641 electricity and 50 520 water)** and employs **782 workers**

Nº Clients



Clients/worker

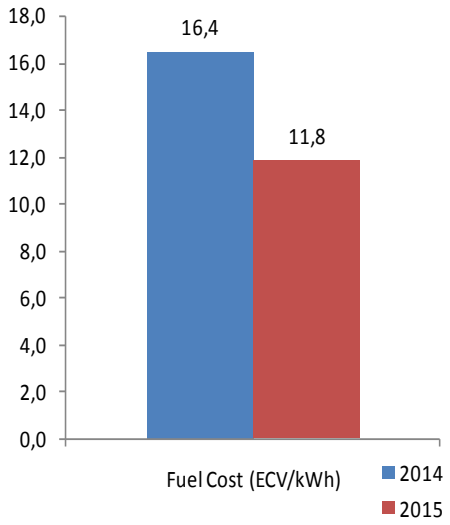


COMPANY PRESENTATION
RELEVANT NUMBERS…

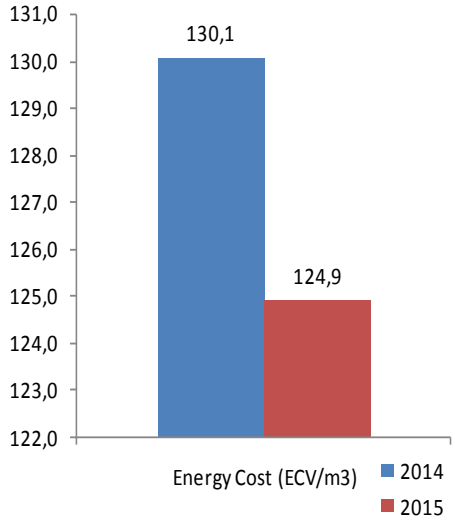
Energy and Water is **strongly dependent** on fuel and diesel power plants.

High cost of energy (fuel and electricity) leads to high cost of electricity and water production .

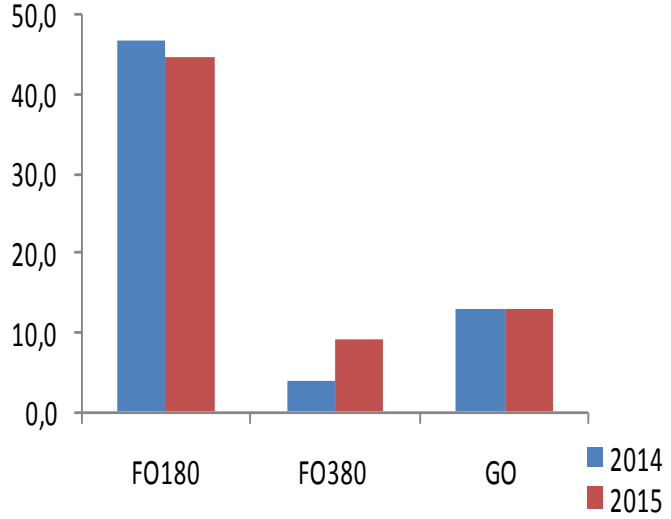
Fuel Cost per kWh



Energy Cost per m3 of Water Production



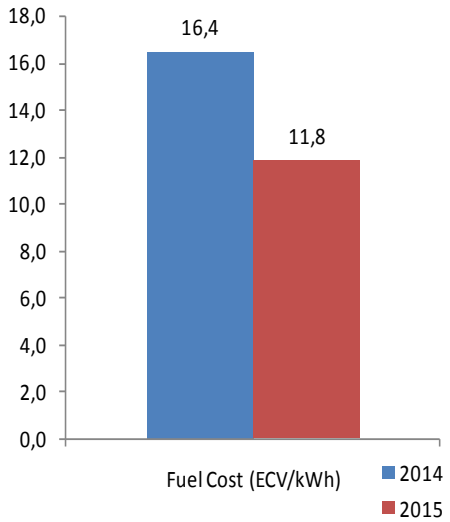
Fuel and Diesel Consumption (10^3 Ton)



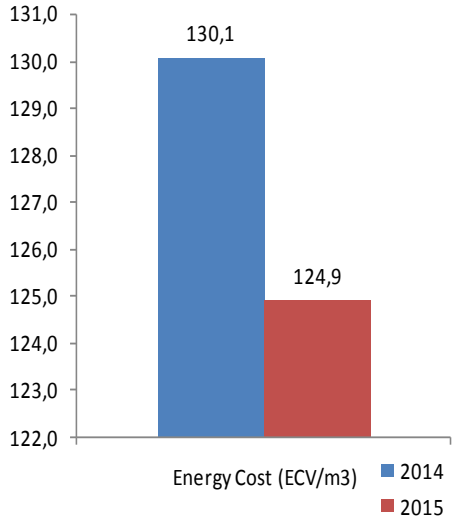
COMPANY PRESENTATION
RELEVANT NUMBERS…

Electricity and Water is **strongly dependent** on fuel and diesel power plants.
Fuel represented in 2015 54 % of electricity production cost .
Electricity represented 50 % of water production cost
Low cost of energy (fuel and electricity) leads to low cost of electricity and water production .

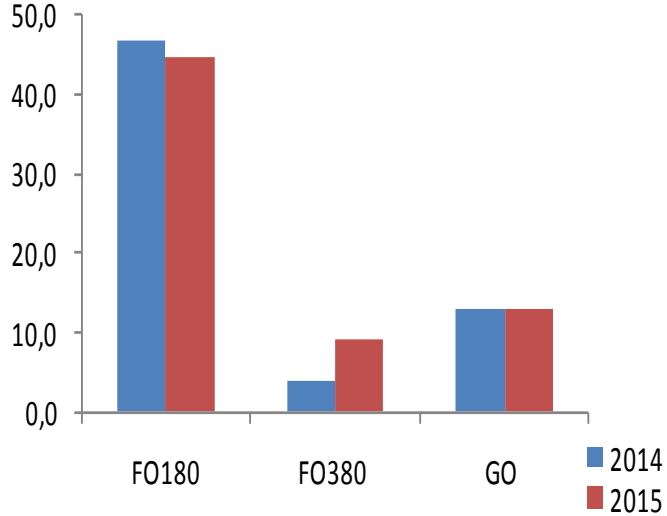
Fuel Cost per kWh



Energy Cost per m3 of Water Production

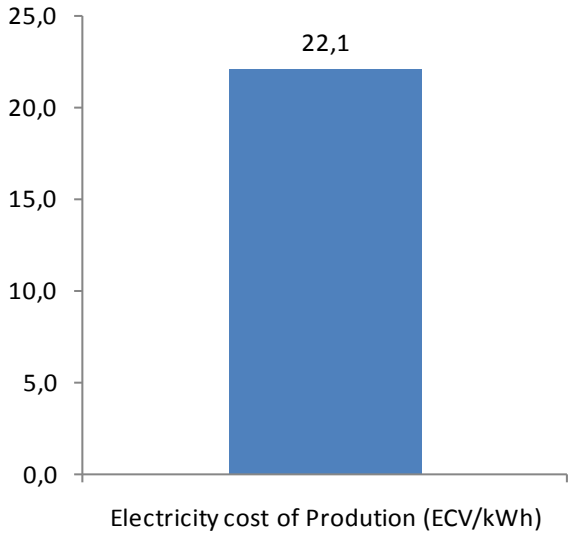


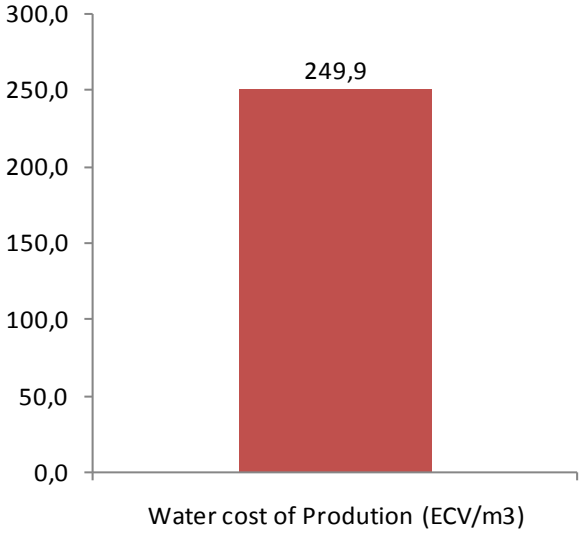
Fuel and Diesel Consumption (10^3 Ton)



COMPANY PRESENTATION
RELEVANT NUMBERS…

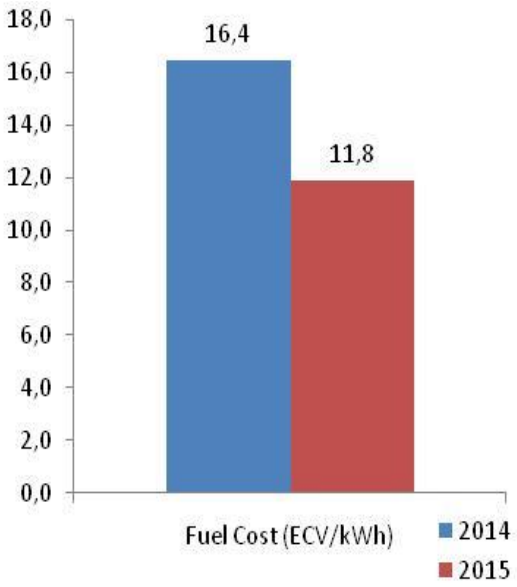
High cost of electricity and water production leads to the need of more renewable power in Cape Verde





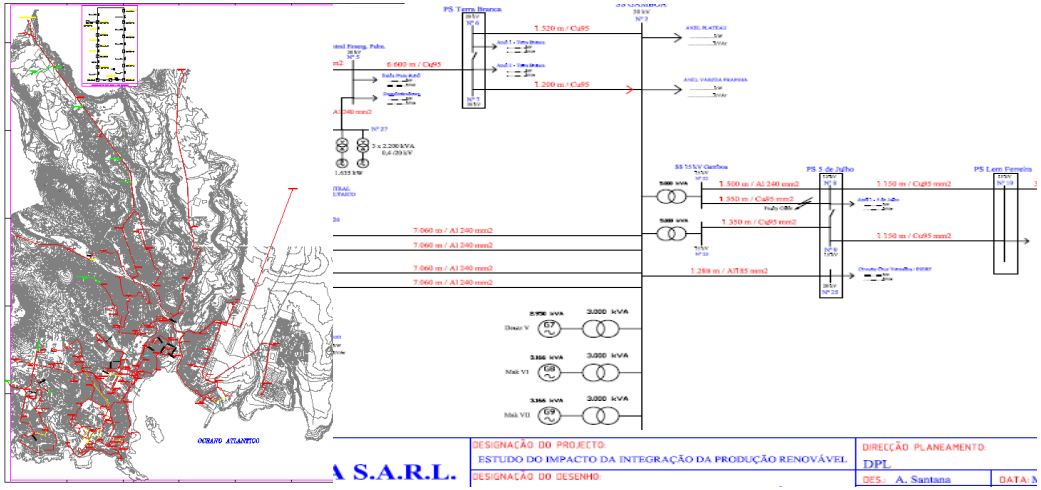
COMPANY PRESENTATION
RELEVANT NUMBERS…

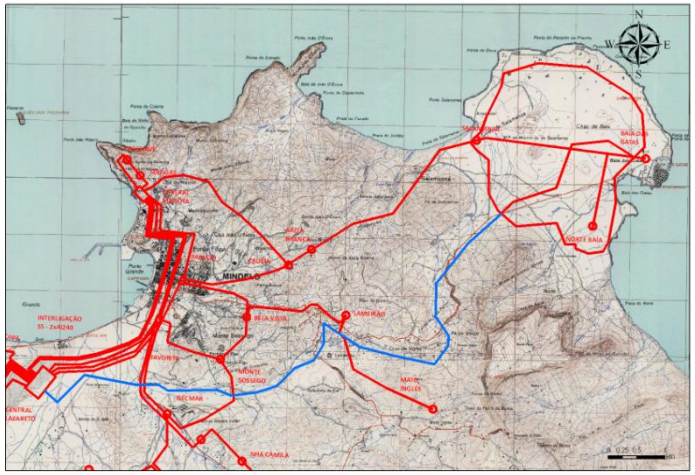
Lower cost of fuel has an impact on economic and financial viability of projects aiming to increase the renewable penetration rate to medium/high levels in Cape Verde.



ENERGY DISTRIBUCTION CURRENT GRID (2015)

Island	HV Overhead	MV Overhead	MV Underground	LV Overhead	LV Underground
Santiago	70	135	145	352	39
S. Vicente	-	16	117	214	17
Sal	-	0	135	36	32
Other islands	-	125	172	574	24
Total (km)	**70**	**276**	**569**	**1176**	**112**



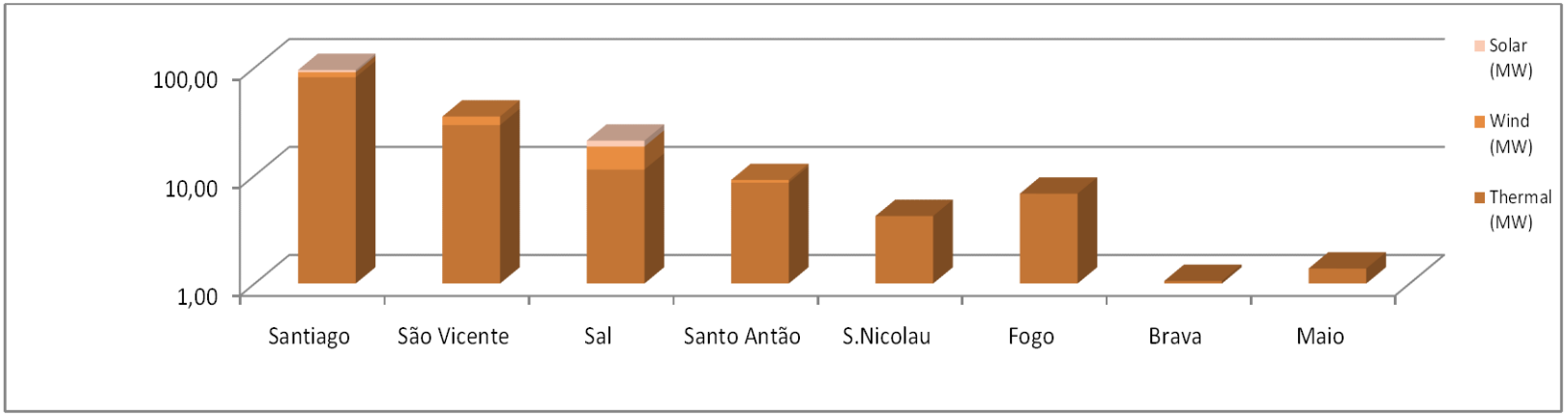


RENEWABLES IN CAPE VERDE

ENERGY PRODUCTION
INSTALLED CAPACITY

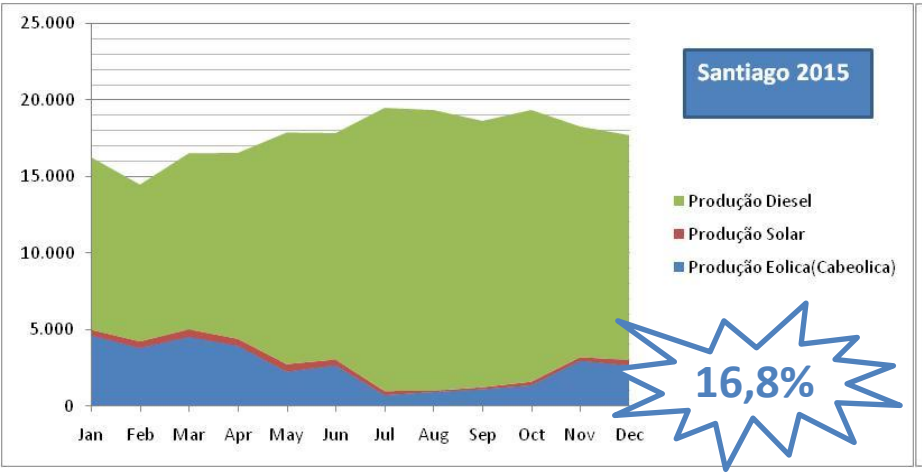
Presently ELECTRA manages **29,68 MW** of renewable capacity (independent power producers and state owned) in Santiago, São Vicente, Sal and Santo Antão.

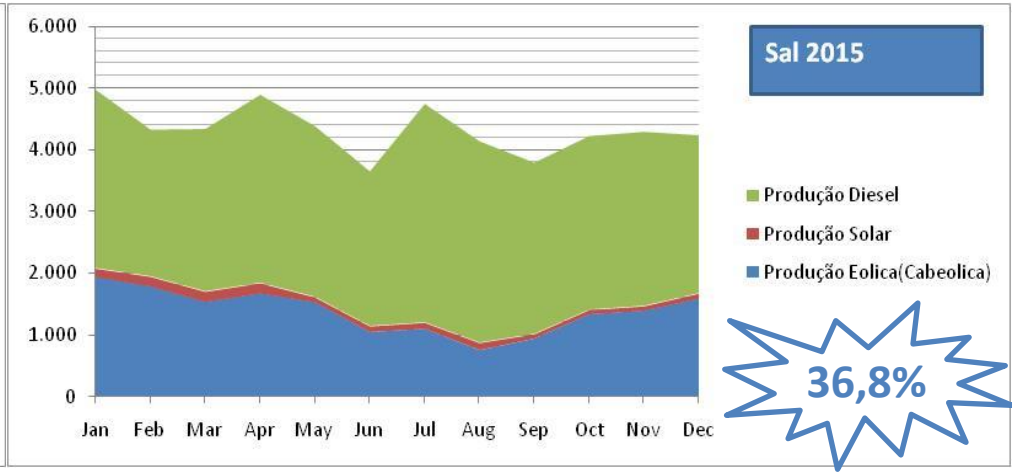
Installed Capacity	Santiago	São Vicente	Sal	Santo Antão	S.Nicolau	Fogo	Brava	Maio	TOTAL
Thermal (MW)	81,32	29,35	11,36	8,60	4,22	6,80	1,06	1,38	**144,08**
Wind (MW)	9,30	5,90	7,20	0,50					**22,90**
Solar (MW)	4,28		2,50						**6,78**
TOTAL (MW)	**94,90**	**35,25**	**21,06**	**9,10**	**4,22**	**6,80**	**1,06**	**1,38**	**173,76**
RE/TE Ratio	**16,7%**	**20,1%**	**63,4%**	**5,8%**					**20,6%**

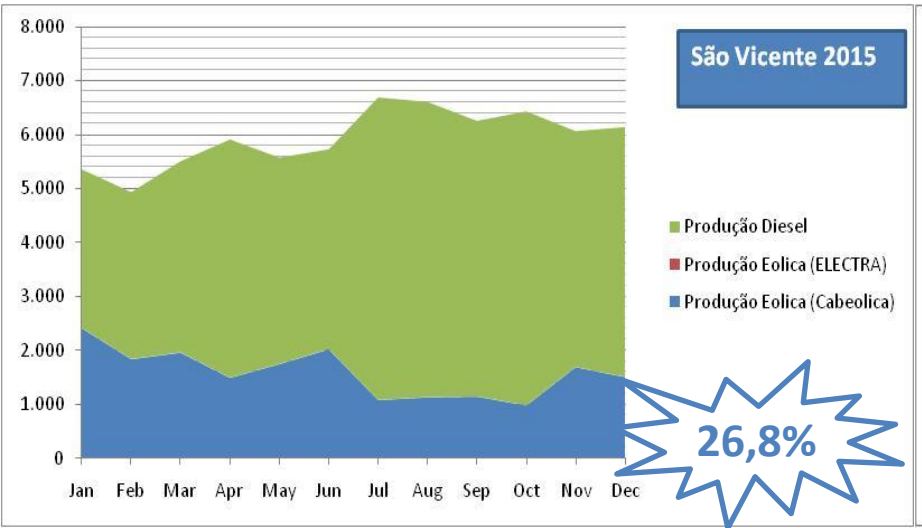


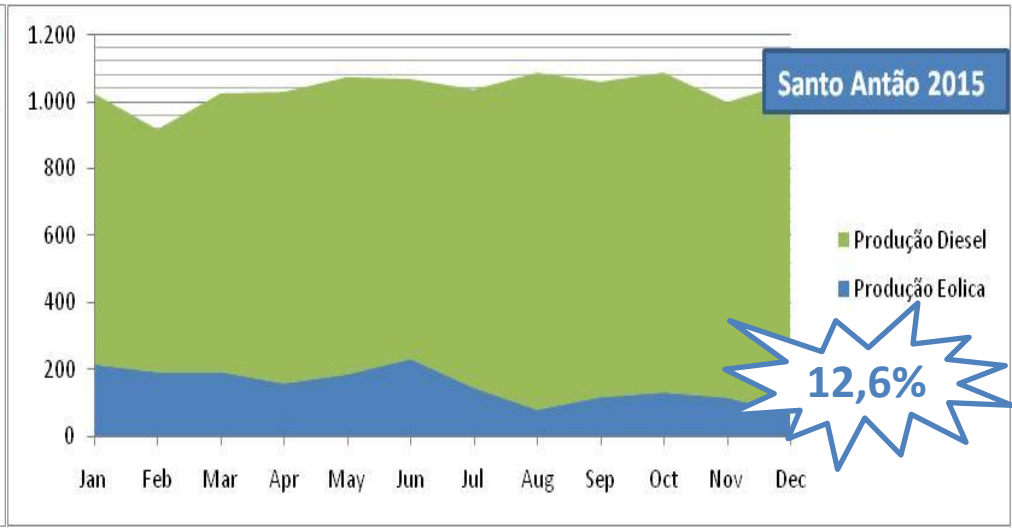
ENERGY PRODUCTION
2015 ENERGY MIX

In 2015 **Santiago, São Vicente, Sal and Santo Antão** islands registered relevant renewable energy penetration levels…



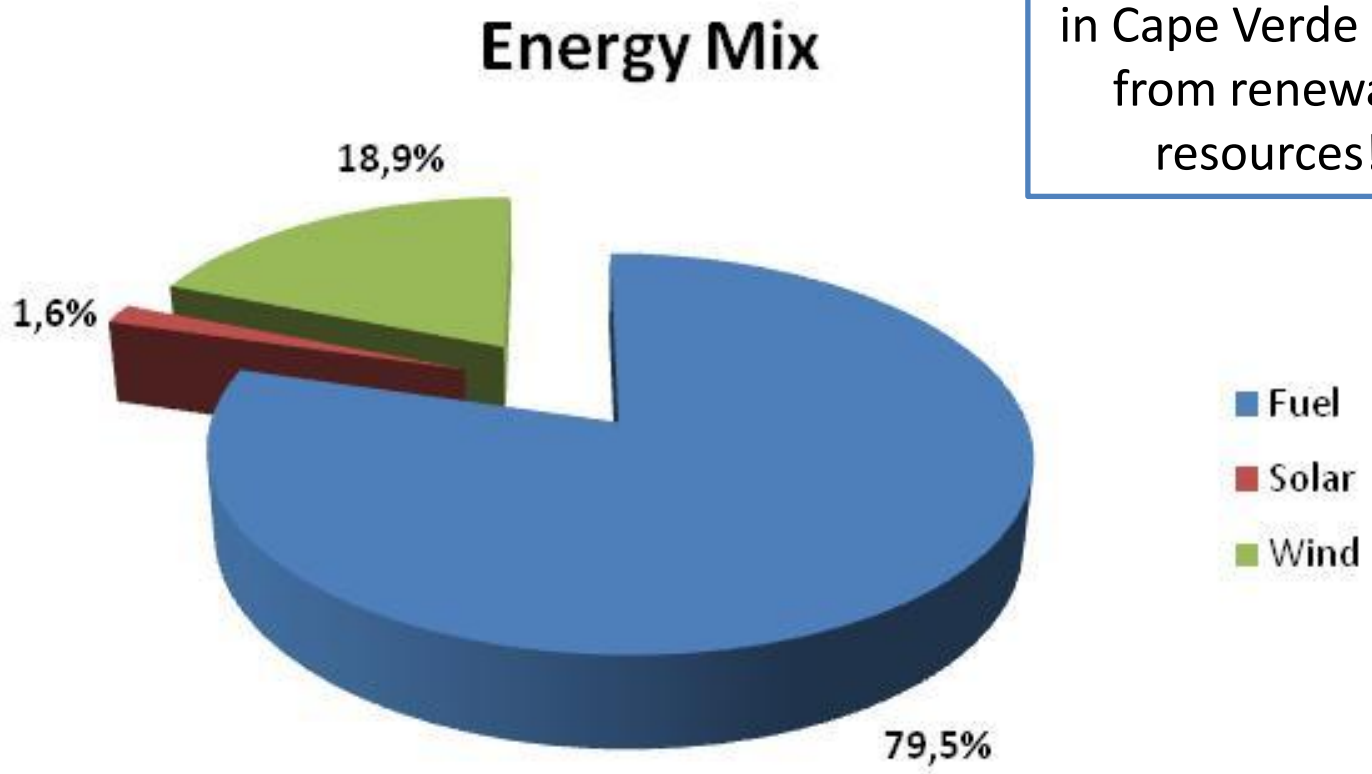






ENERGY PRODUCTION
2015 ENERGY MIX

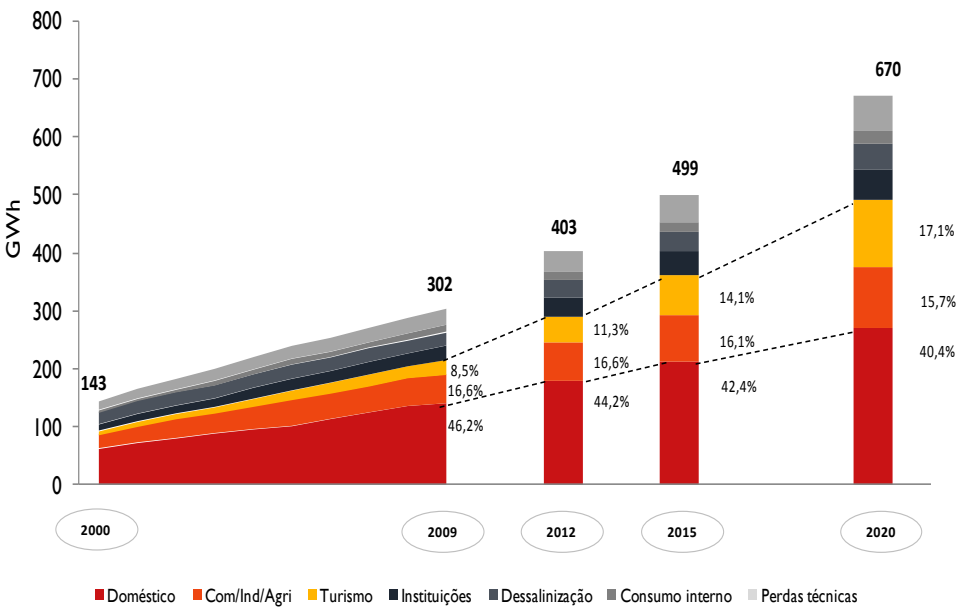
Currently, **20,5%** of the energy produced in Cape Verde comes from renewable resources!!!



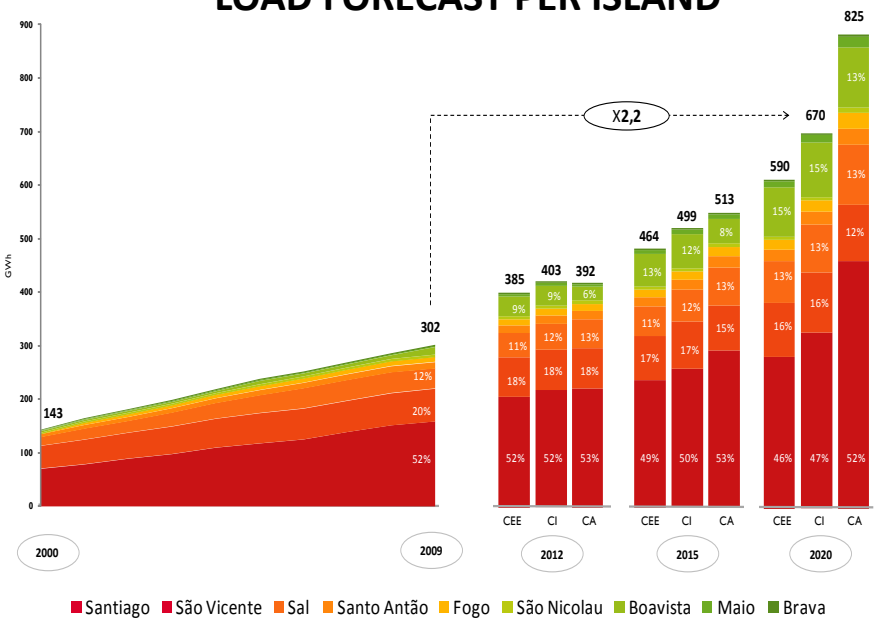
ELECTRA
LOAD FORECAST

In a moderate load growth scenario, it is expected that consumption in Cape Verde reaches **525 GWh** in 2020 with a total installed capacity of approximately **250 MW**

LOAD FORECAST PER SECTOR



LOAD FORECAST PER ISLAND



Source: Cape Verde 50%Renewable - Energy Master Plan 2010-2020 – Load Forecast Study (GESTO Energy 2010)

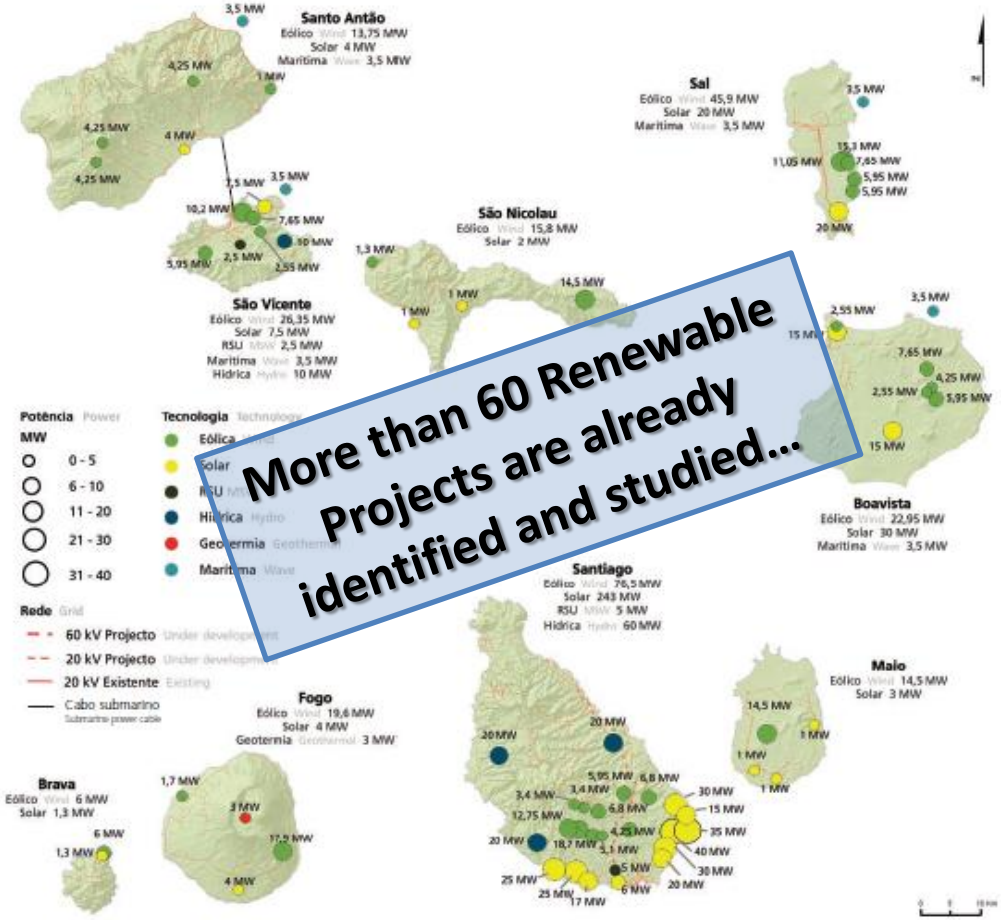
THE GOAL
RENEWABLE ENERGY MEDIUM PENETRATION

Given the dependence on petroleum products, ELECTRA intends to:

- Increase the penetration of renewable energy
- Reduce the diesel portion in the production mix
- Reduce the pollution emission gases

THE GOAL
RENEWABLE ENERGY MEDIUM PENETRATION

Cape Verde Renewable Energy Masterplan establishes a target of **50% Renewables penetration until 2020!!**



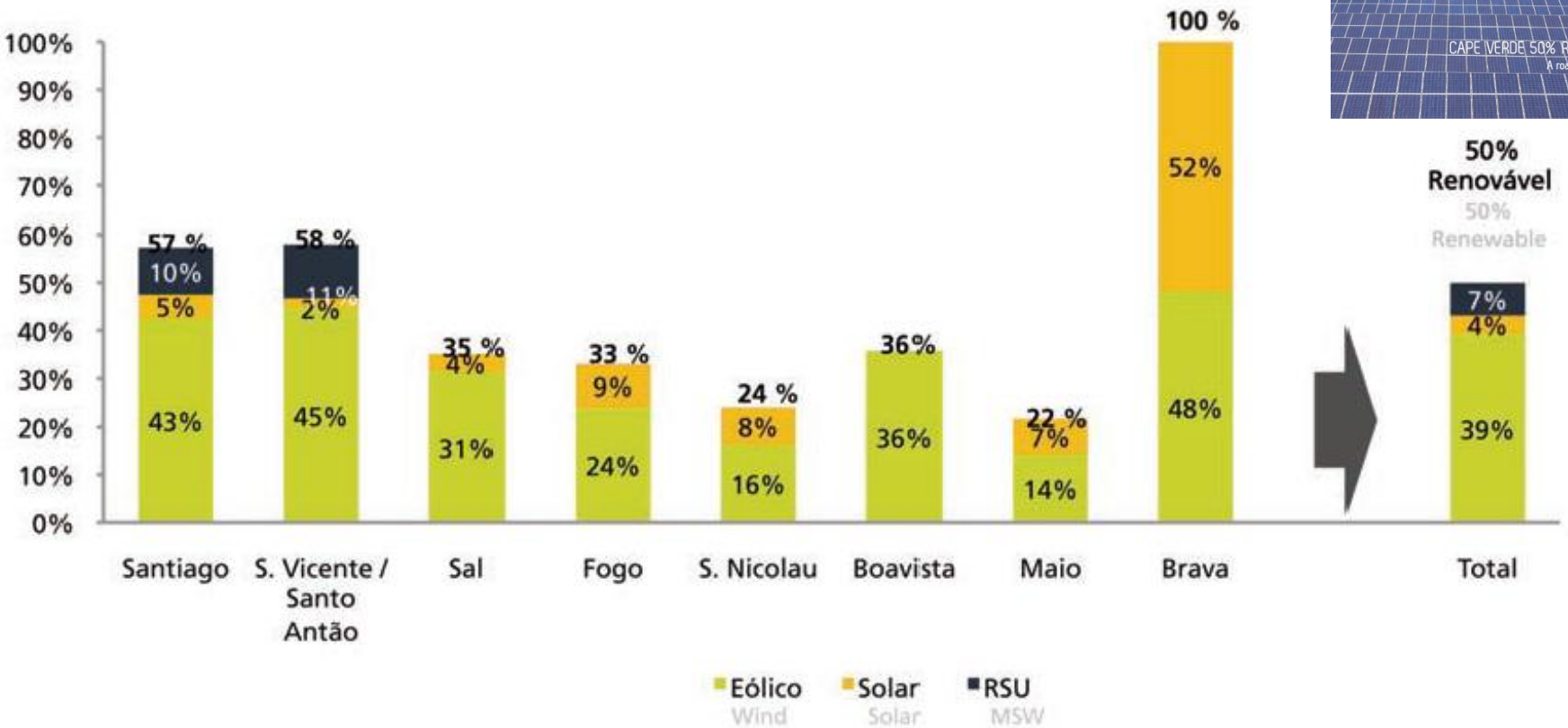
More than 60 Renewable Projects are already identified and studied…

Figura 7 - Localização dos projectos prioritários
Figure 7 - Priority projects location

Source: Cape Verde 50%Renewable - Energy Master Plan 2010-2020 (GESTO Energy 2010)

THE GOAL
RENEWABLE ENERGY MEDIUM PENETRATION

Cape Verde Renewable Energy Masterplan establishes different targets for each island in order to reach the 50% Renewables



Source: Cape Verde 50%Renewable - Energy Master Plan 2010-2020 (GESTO Energy 2010)

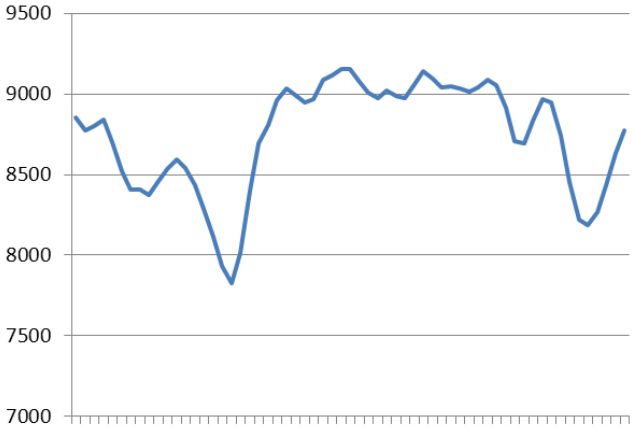
RENEWABLE ENERGY MEDIUM PENETRATION CHALLENGES…

GOAL

maximize the penetration of renewables ensuring the system stability and sustainability

CHALLENGE

Instability caused by a high penetration of renewable energy in isolated systems, small and weak



Large power variations in seconds

THE GOAL
RENEWABLE ENERGY MEDIUM/HiGH PENETRATION

CONCLUSION

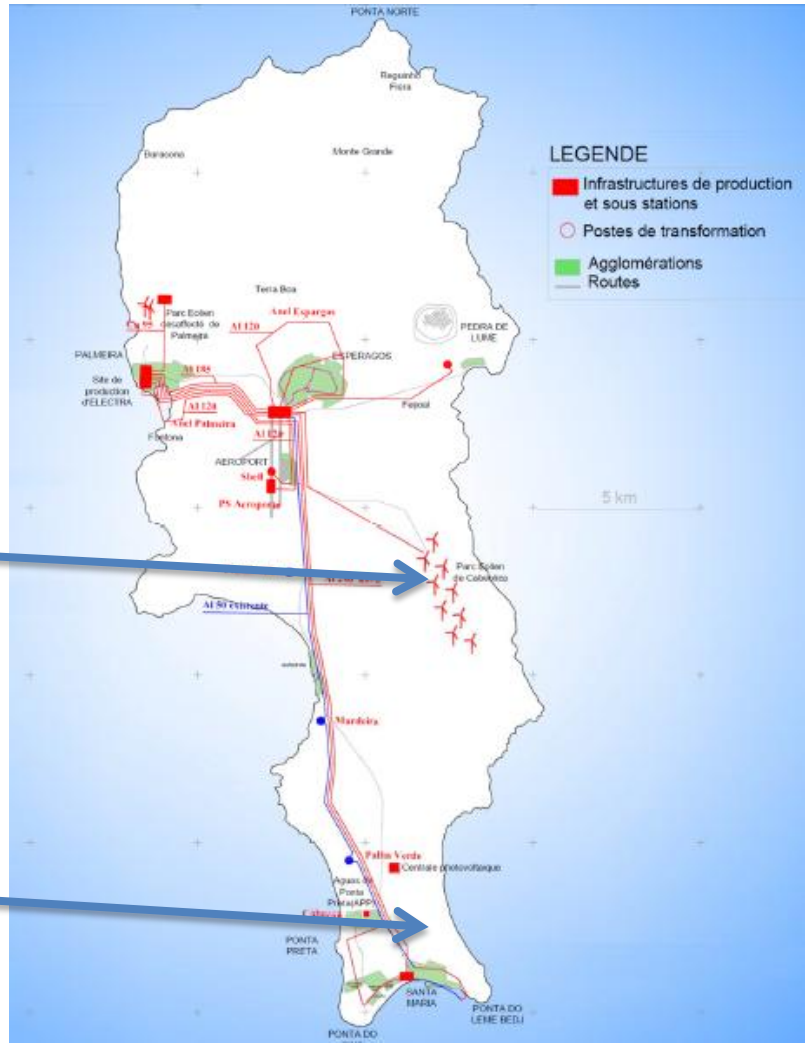
- ELECTRA is focused on the objective of maximizing the penetration of renewable . Therefore, when with medium/hight level of penetration problems such as electric quantity and quality arise. Thus, it is important to manage challenges in term of the quantity (surplus electricity and thermal capacity) and quality (voltage and frequency) of electricity.

- ELECTRA is conducting various technical and economical studies in order to achieve this objective, while maintaining system stability and quality of power supply:
  - Use of energy storage in some islands:
    - Flywheels
    - Batteries
  - Brava Island 100% Renewable;
  - …

SAL ISLAND CURRENT STATUS AND ISSUES

SAL ISLAND
RENEWABLE ENERGY MEDIUM PENETRATION ISLAND

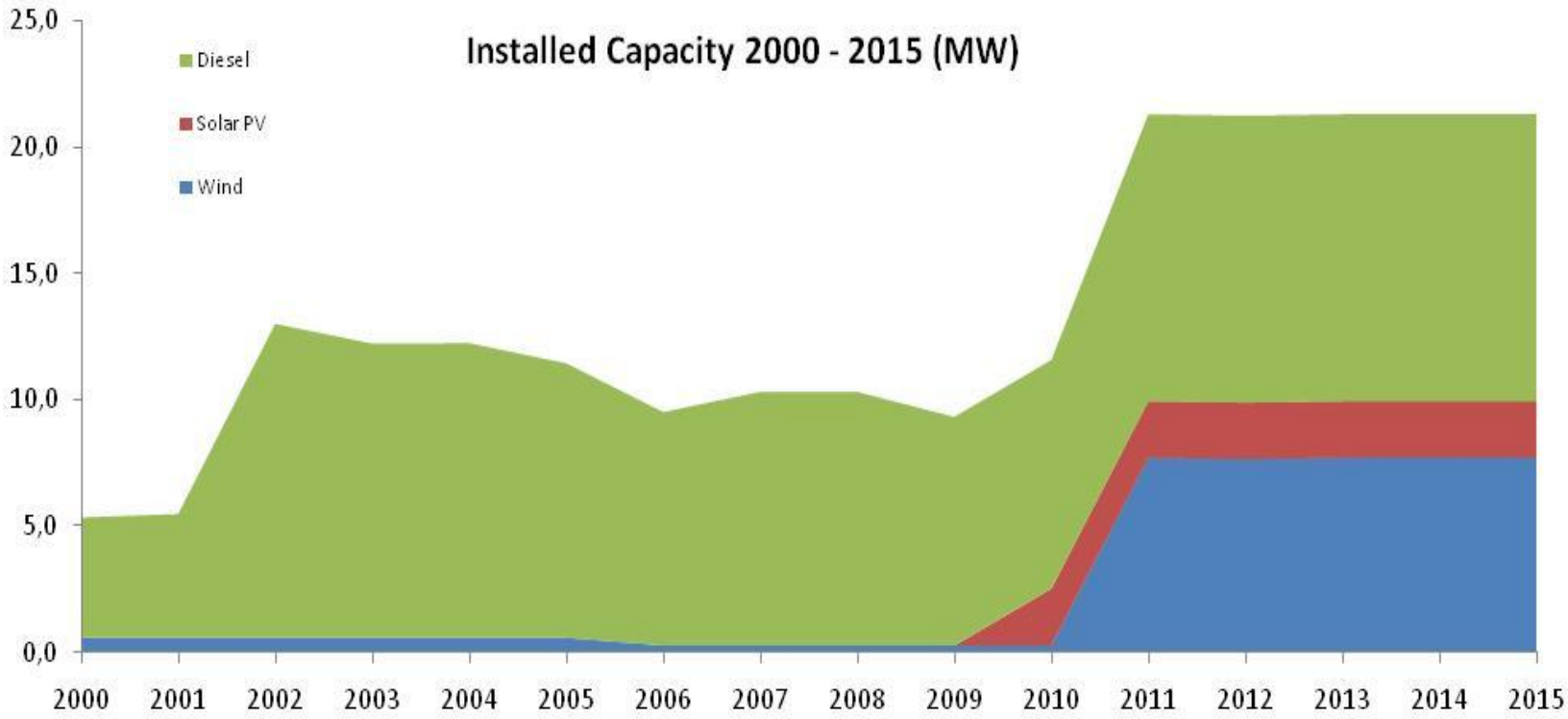
ELECTRA has been conducting studies in order to find optimum technical and economical solutions to optimize the increase of the penetration level of renewable energy on Sal island



Source: Report «Projet de renforcement et d'optimisation du système d'énergie électrique de l'île de Sal»

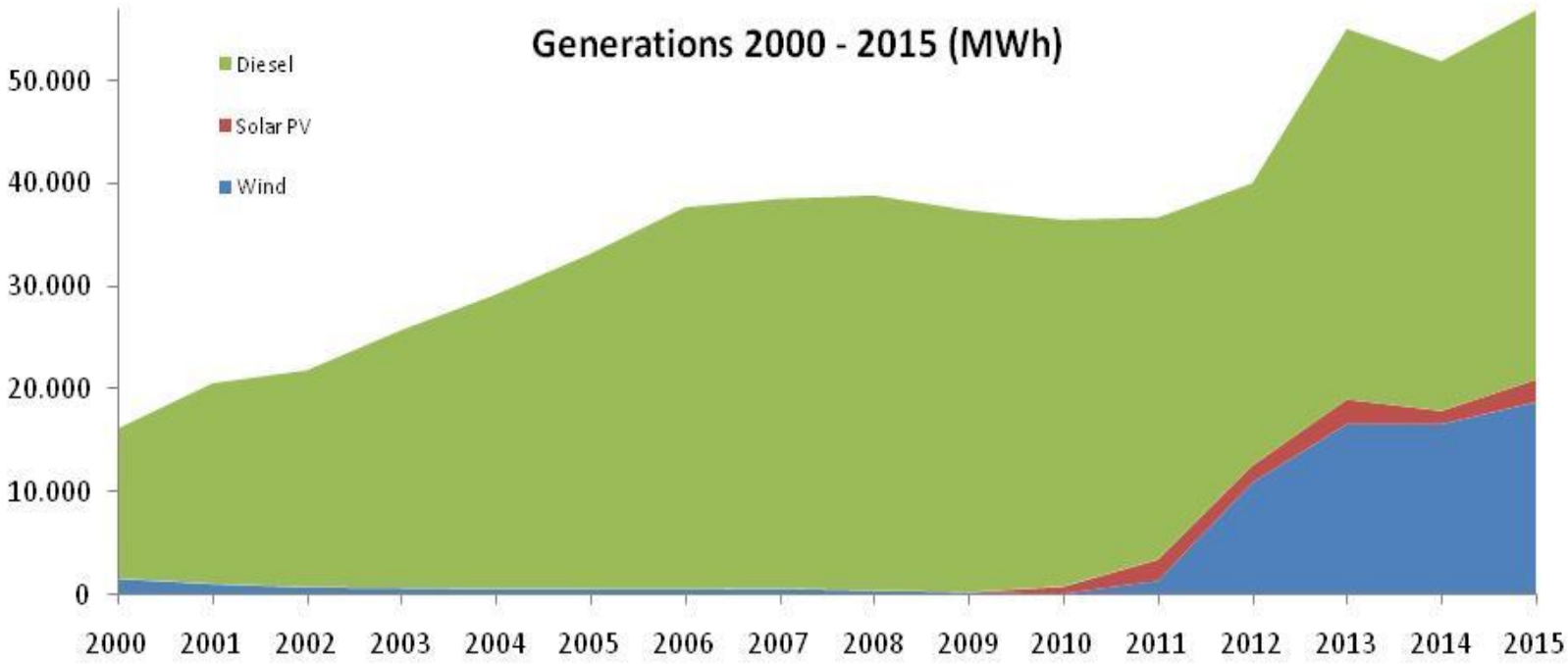
SAL ISLAND
INSTALLED CAPACITY

Sal Island



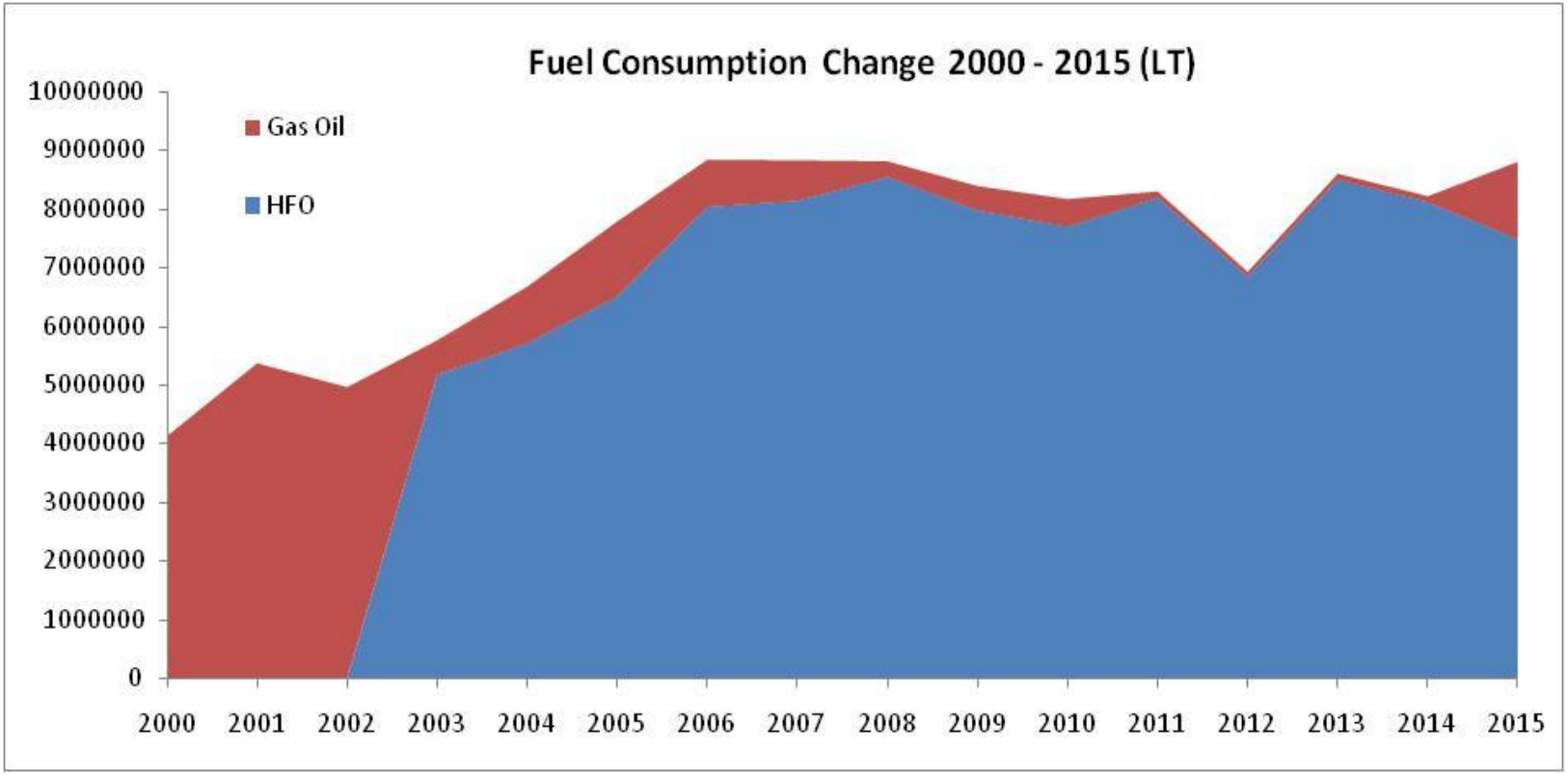
SAL ISLAND GENERATIONS

Sal Island



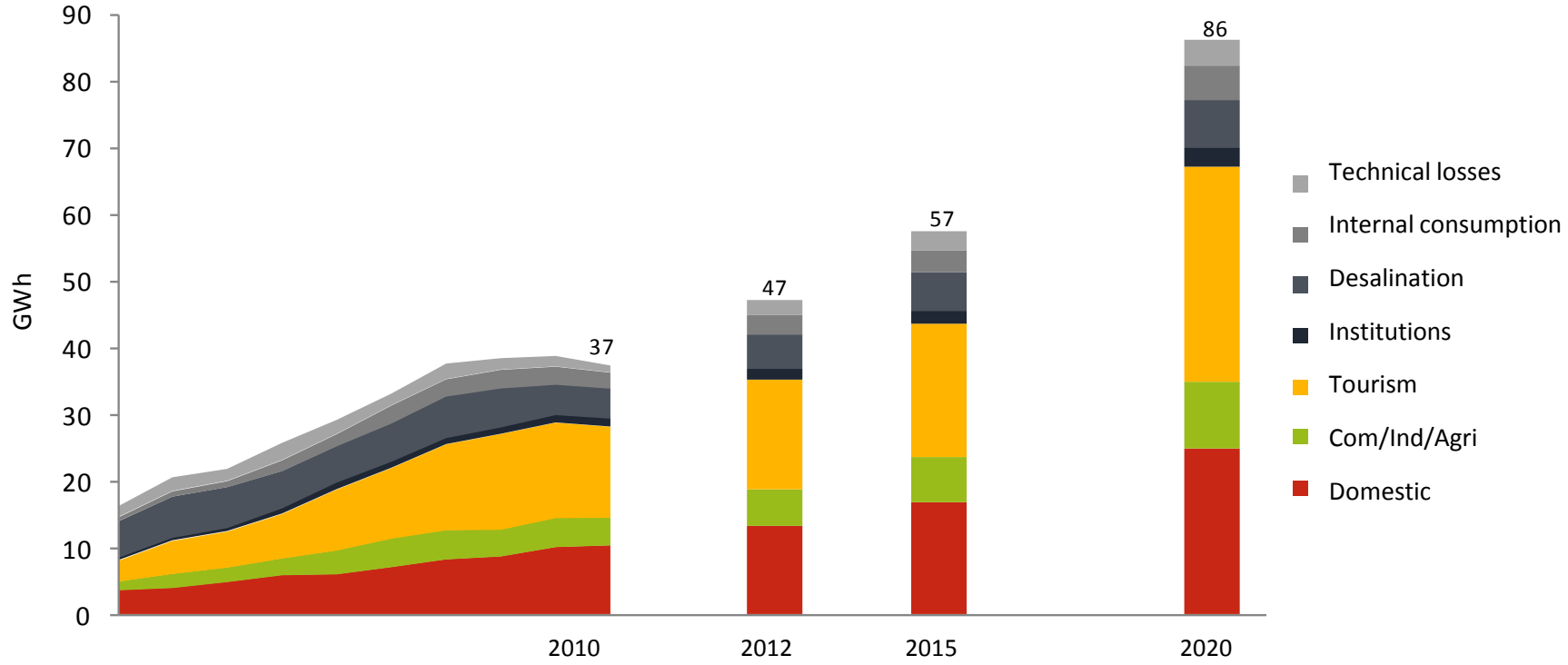
SAL ISLAND
FUEL CONSUMPTION CHANGE

Sal Island



SAL ISLAND
LOAD FORECAST 2020

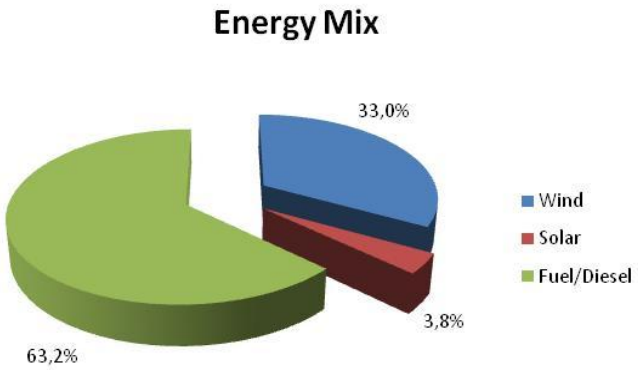
It is expected that the consumption on the island of Sal reaches **86 GWh** in 2020, strongly driven by the Tourism sector

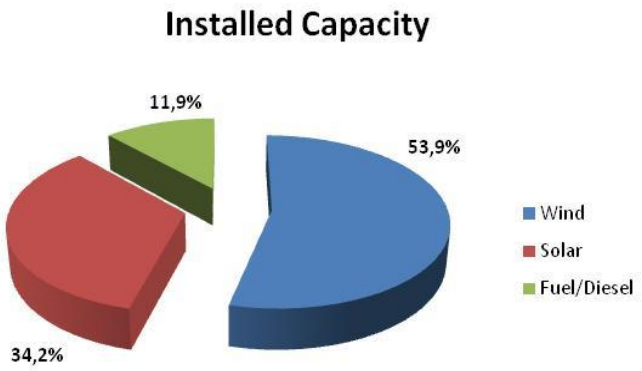


Source: Cape Verde 50%Renewable - Energy Master Plan 2010-2020 – Load Forecast Study (GESTO Energy 2010)

SAL ISLAND
ENERGY MIX AND INSTALLED CAPACITY

Sal Island currently has a renewable installed capacity of **9.7 MW** (7.2 MW wind and 2.5 MWp Solar) and reached a penetration of renewable energy of approximately **36.8%** in 2015





Sal 2015		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL
Wind	MWh	2.206	1.611	2.026	2.045	1.880	1.829	757	981	964	1.049	1.946	1.483	**18.776**
Solar	MWh	89	74	170	277	280	173	254	184	146	174	166	185	**2.173**
Fuel/Diesel	MWh	1.725	2.297	3.111	2.811	2.672	2.477	4.393	4.541	3.012	3.385	2.584	2.930	**35.938**
Total	MWh	**4.021**	**3.982**	**5.308**	**5.133**	**4.832**	**4.479**	**5.404**	**5.706**	**4.123**	**4.608**	**4.695**	**4.598**	**56.887**

Wind penetration ratio	%	54,9%	40,5%	38,2%	39,8%	38,9%	40,8%	14,0%	17,2%	23,4%	22,8%	41,4%	32,3%	**33,0%**
Solar penetration ratio	%	2,2%	1,9%	3,2%	5,4%	5,8%	3,9%	4,7%	3,2%	3,6%	3,8%	3,5%	4,0%	**3,8%**
Total penetration ratio	%	**57,1%**	**42,3%**	**41,4%**	**45,2%**	**44,7%**	**44,7%**	**18,7%**	**20,4%**	**26,9%**	**26,5%**	**45,0%**	**36,3%**	**36,8%**

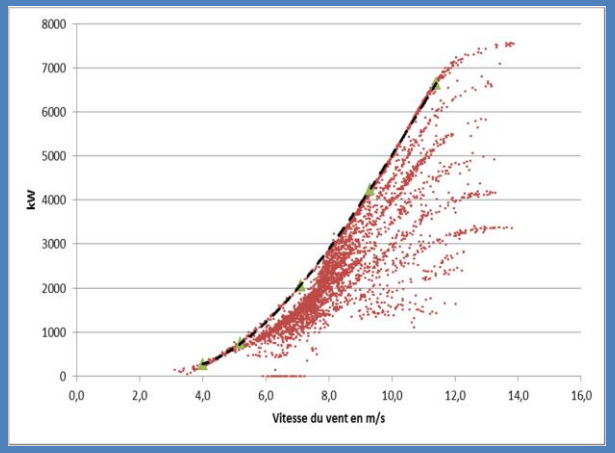
RENEWABLE ENERGY MANAGEMENT STRATEGY MEDIUM PENETRATION (20% - 40%)

Spinning Reserve 50%
(50% of the renewable power supplied)

Currently the spinning reserve is managed manually by imposing **remote limitation set points** to the Windfarm turbines.

Remote limitation setpoints

Wind Turbine derating



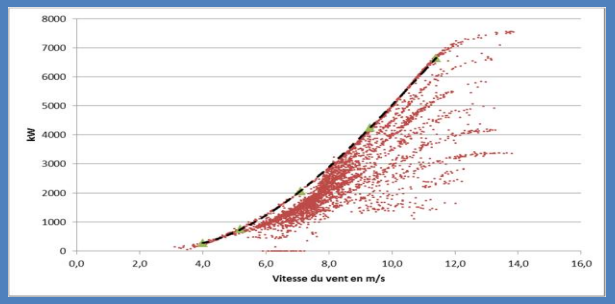
RENEWABLE ENERGY MANAGEMENT STRATEGY MEDIUM PENETRATION (20% - 40%)

Unit Commitment

- Unit commitment solves the problem of determining which generation units should be running in each period so as to satisfy a predictably varying demand for electricity, considering the minimum technical unit output limited in 50% of the nominal unit capacity.
- Period of optimization is variable (up to 10 days)

Remote limitation setpoints

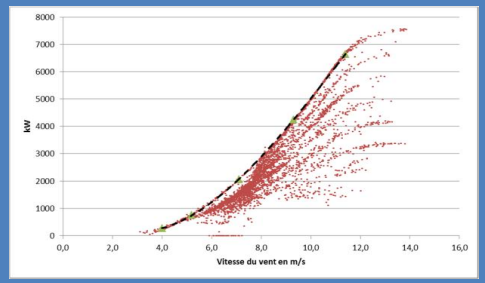
Wind Turbine derating



RENEWABLE ENERGY MANAGEMENT STRATEGY MEDIUM PENETRATION (20% - 40%)

Load Forecast
And
Renewables Forecast

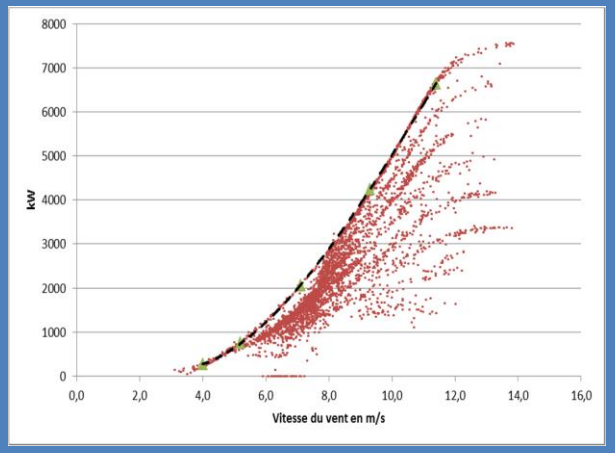
- Forecast based on history, day type, weather and current system sate
- Short-term forecast – 7 days with one hour granularity
- Bottom-up approach
- Support for solar and wind generation forecast
- Forecast based on history, weather (current and forecasted) and current system state
- Near – term forecast – 24h with one hour granularity
- Short – term forecast – 7 days with one hour granularity



RENEWABLE ENERGY MANAGEMENT STRATEGY
MEDIUM PENETRATION (20% - 40%)

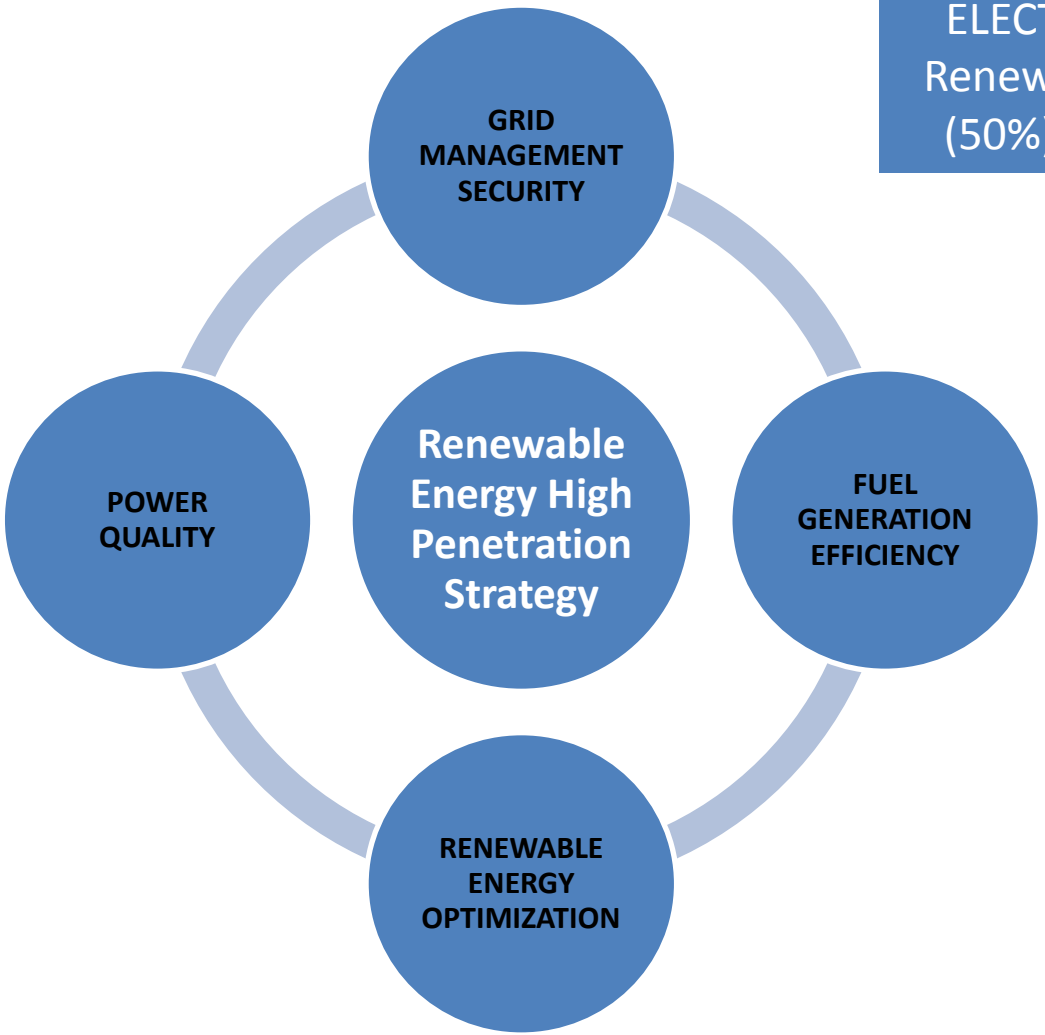
Load Shedding

- 10 levels of consumer priorities
- Fast response time



RENEWABLE ENERGY MANAGEMENT STRATEGY MEDIUM PENETRATION UP TO 50%

ELECTRA is working in a medium term Renewable Energy Penetration Strategy (50%) for Sal Island based on 4 drivers



SAL ISLAND
RENEWABLE ENERGY INCREASE STRATEGY

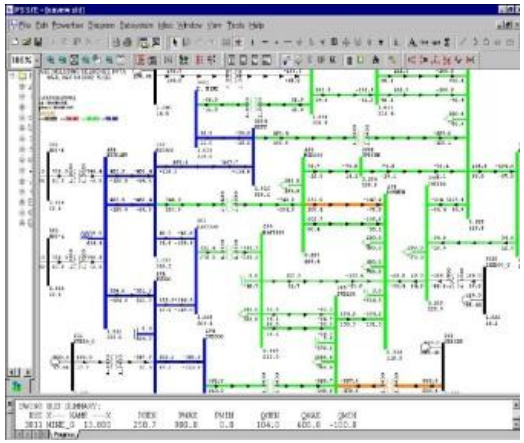
1st STAGE

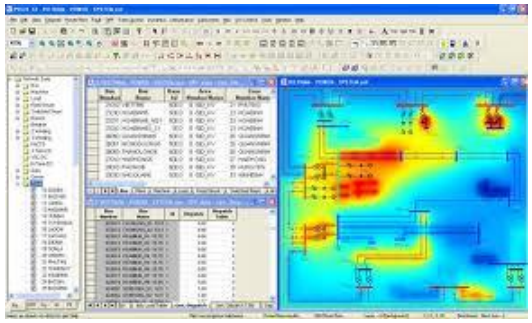
...

Grid Studies

Selectivity and protections coordination studies, complemented with steady state and dynamic grid studies, in order to ensure the stability of the grid in different contingency scenarios:

- Building the static model of each network.
- Building of dynamic models and preparation of the scenarios for dynamic stability simulations.
- Load Flow and Short Circuit studies.



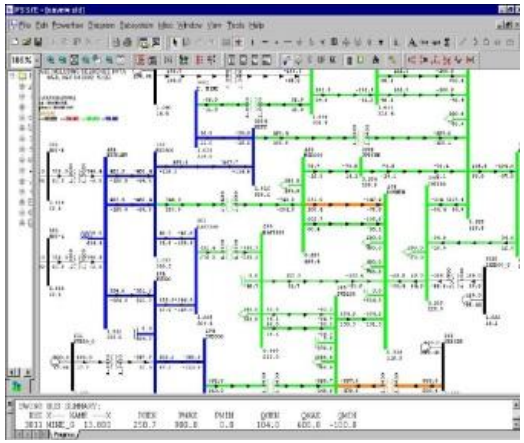


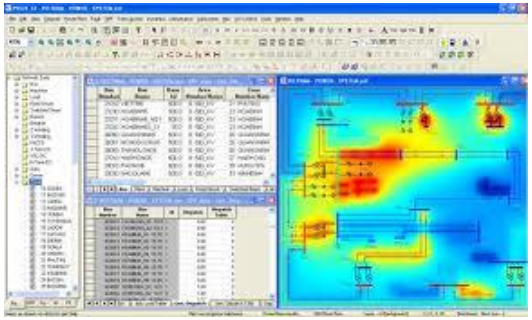
SAL ISLAND
RENEWABLE ENERGY INCREASE STRATEGY

… 1st STAGE …

Grid Studies

- Dynamic stability simulations: calculation of critical clearing times and Frequency response at Loss of largest diesel generator, largest wind farm/aero generators, Loss of major load, up to 10 contingency scenarios, e.g. three-phase short circuit followed by outage of line or bus bar.
- Identification of limitation and actual problems that can affect the system stability.
- Analysis of weaknesses in the protection system and recommendations to its improvement.





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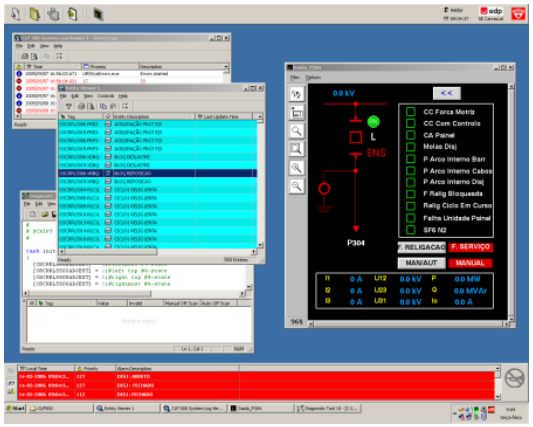
…

2nd STAGE

…

Standard Dispatch System

installation of a national standard dispatch system (to be commissioned within the next 18 months) to efficiently manage the existing power plants and grids in safety conditions



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RENEWABLE ENERGY INCREASE STRATEGY

... 3rd STAGE ...

Advanced Dispatch System and Energy Storage Systems

- To integrate the simulation software and grid models developed in Stage 1 with the Dispatch System, in order to ensure the stability of the grid on contingency scenarios with relevant fluctuation of renewable power;

- Study the use of complementary systems with the purpose of creating conditions to safely integrate more renewable energy power into the grid (Flywheels systems, Battery Systems, Energy Storage Control Systems, etc.);

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RENEWABLE ENERGY INCREASE STRATEGY

... 3rd STAGE ...

Advanced Dispatch System and Energy Storage Systems

- Upgrade the Standard Dispatch System with advanced and specific modules configured to manage massive amounts of Renewable Power, based on algorithms specially dedicated to the management of high renewables penetration grids, optimizing the use of Renewable Energy, ensuring grid stability and safety conditions including, namely:
  - Master control system configuration to control the renewable's power output smoothing and grid operation stability;
  - Monitoring system configuration to meet monitoring and management needs of network operation;

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RENEWABLE ENERGY INCREASE STRATEGY

...

3rd STAGE

Advanced Dispatch System and Energy Storage Systems

- Refurbishment of the protection systems based on the recommendations of the result of the selectivity and coordination of protection systems studies, accomplished in Stage 1;

- Development of the terms of reference for a pilot-project in Sal island containing:
  - Overall Design of Energy Storage (Energy storage system should include at least three dimensions: energy storage stack design, battery management systems and energy storage inverter).
  - Energy storage system configuration

Necessity for Power Storage

- For stable expansion of renewable energy power storage is indispensable.

Objectives of Power Storage

1. Short cycle

- To maintain frequency,

50±2Hz is adopted, but need to maintain frequency may be low

RENEWABLE ENERGY MANAGEMENT STRATEGY
MEDIUM PENETRATION UP TO 50%

2. Long cycle

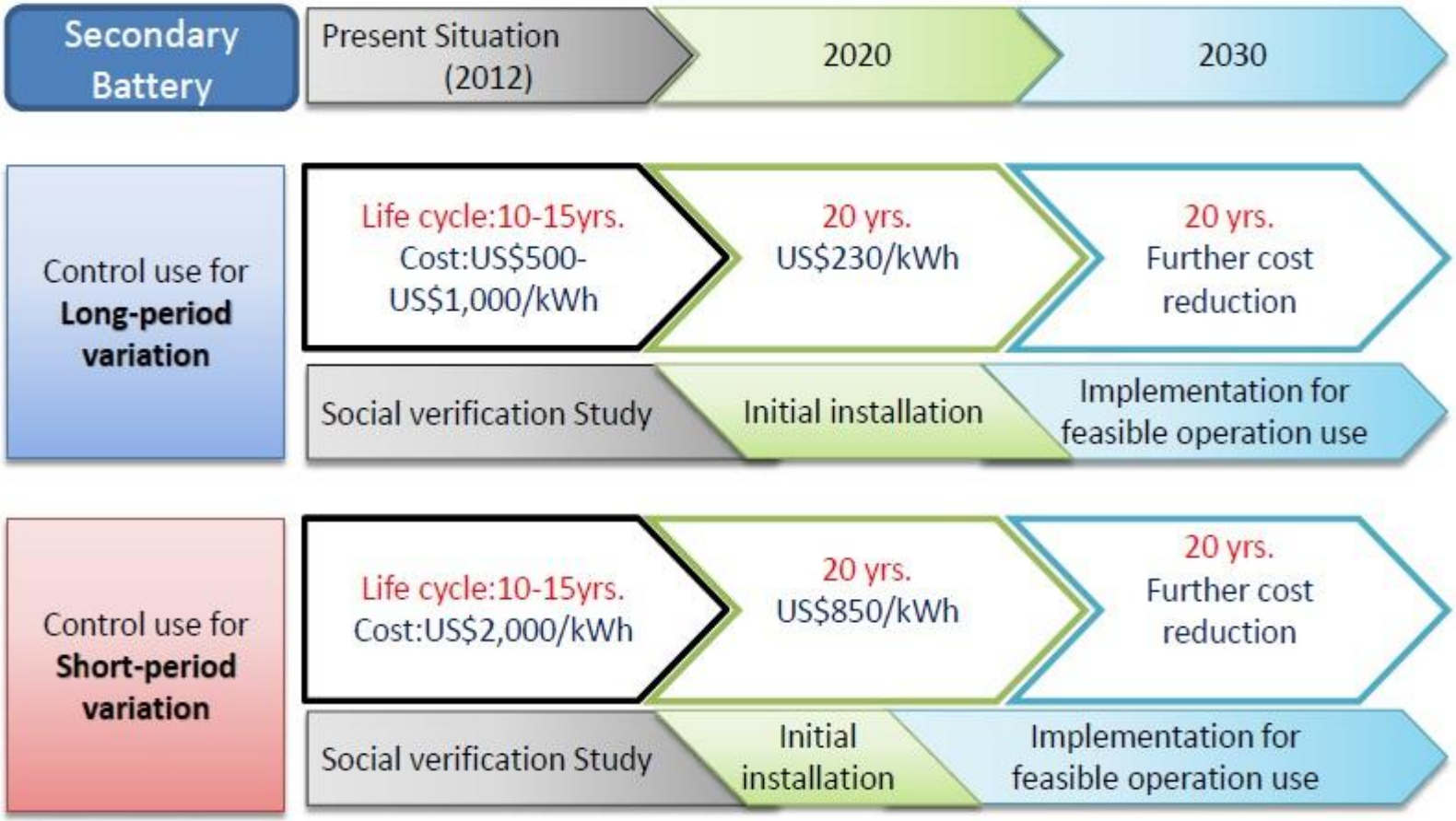
- To maintain minimum diesel output (50%),
- *Store surplus power generated over and above demand, and discharge stored power at peak demand times

Suppress diesel output →fuel cost reduction
Effective use of potential renewable energy

*Need to consider associated costs and charging/discharging losses

RENEWABLE ENERGY MANAGEMENT STRATEGY MEDIUM PENETRATION UP TO 50%

Perspective of Secondary Battery for Power Grid



Source: "Battery Road Map 2013" by New Energy and Industrial Technology Development Organization, JAPAN

Solution Measures for Sal Island

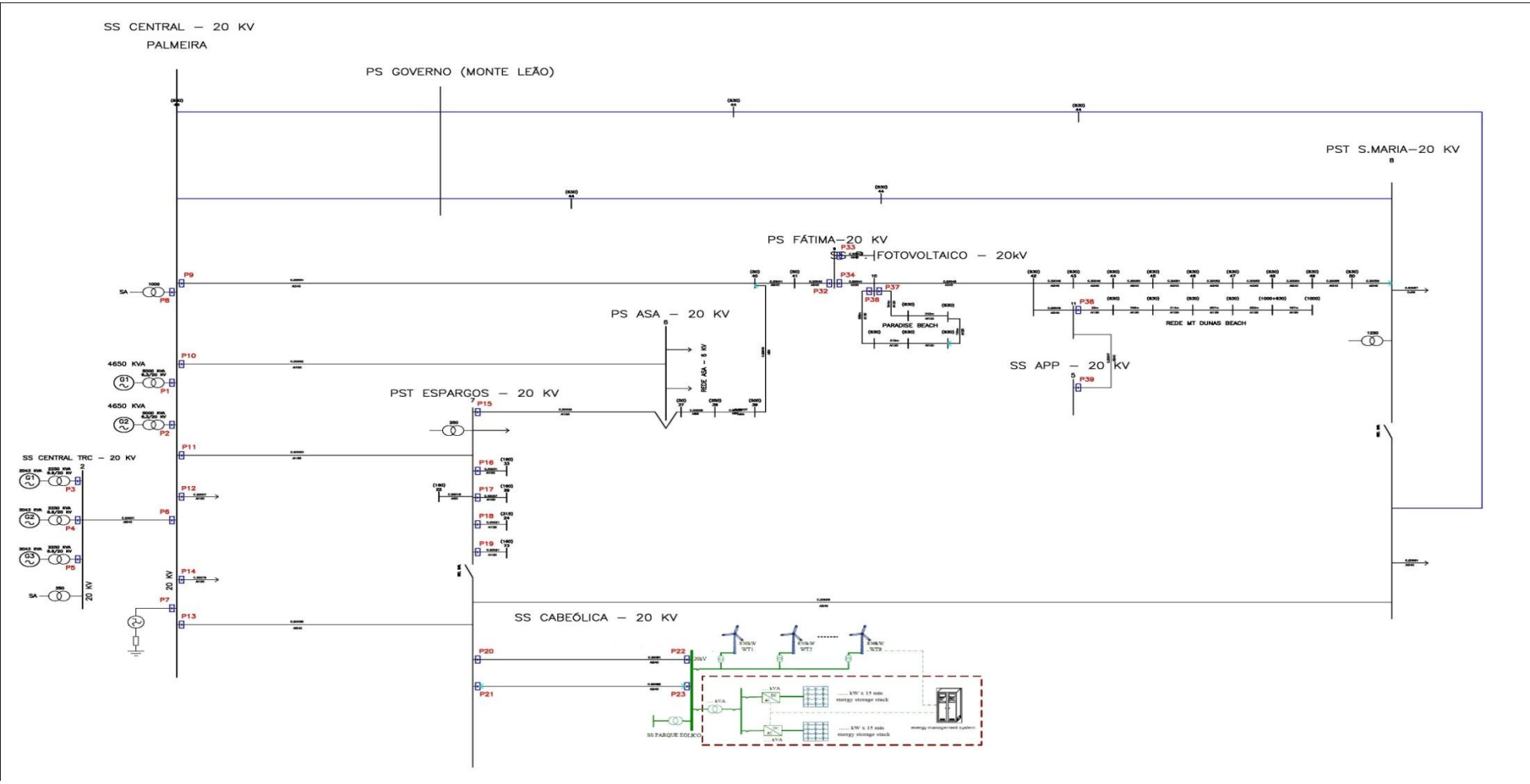
- Calculate the amount of renewable that can be connected ensuring the system stability without using batteries
- Suppression of wind power output is being carried and storage batteries is required to make more effective use of installed renewable plants.
- Make use of storage batteries at peak times.
- For introduction of batteries the optimal battery system that would bring economic value in terms of cost reduction should be considered.
- The adopted solution should ensures grid security and stability, reduces diesel fuel consumption, and improves wind turbine and PV power supply ratio.

Solution Measures for Sal Island

- To increase the level of penetration above the current rate (36,8%), namely the following grid configurations should be analysed in order to find the best technical and economic/financial solution.

RENEWABLE ENERGY MANAGEMENT STRATEGY
MEDIUM PENETRATION UP TO 50%

Scenario 1



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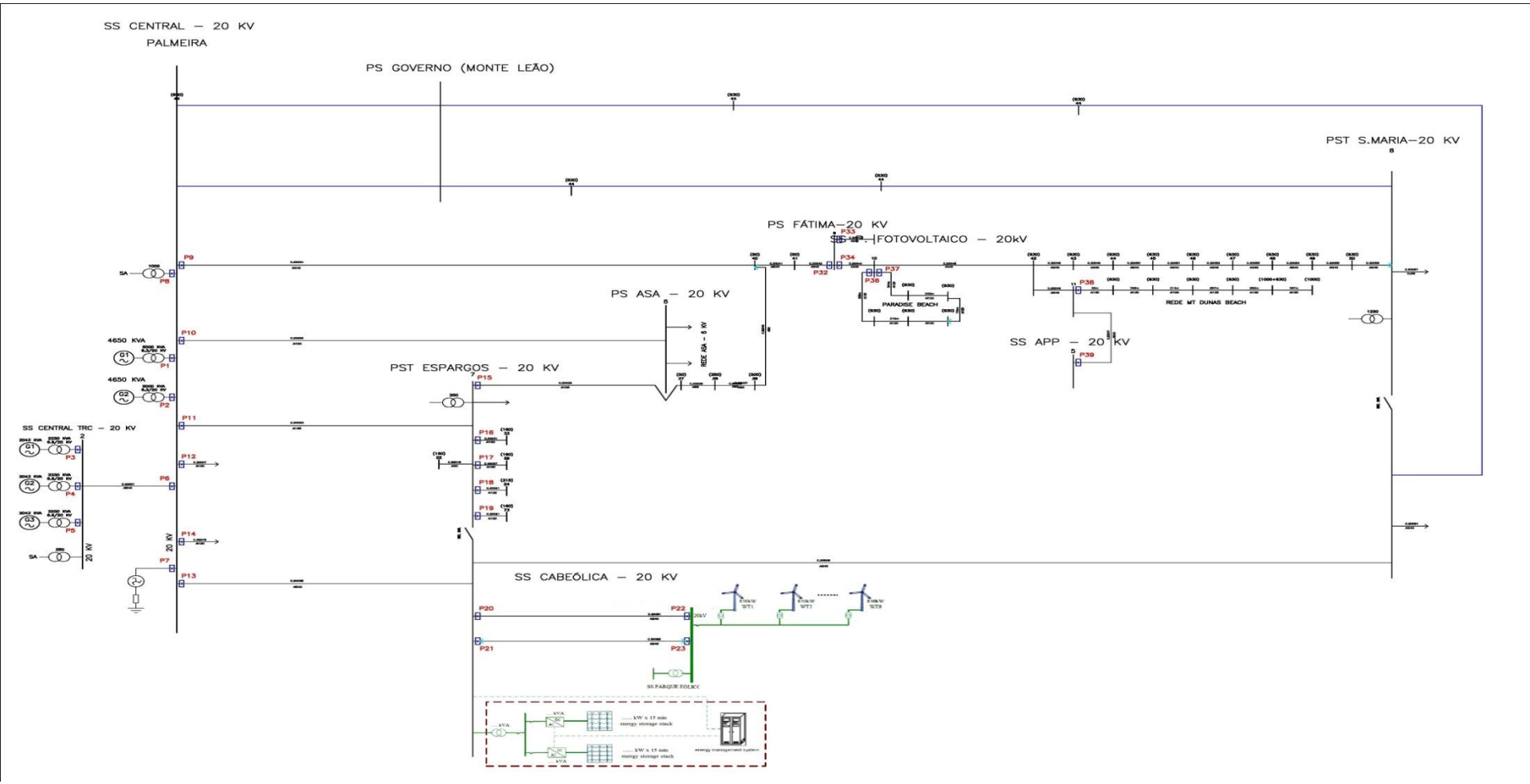
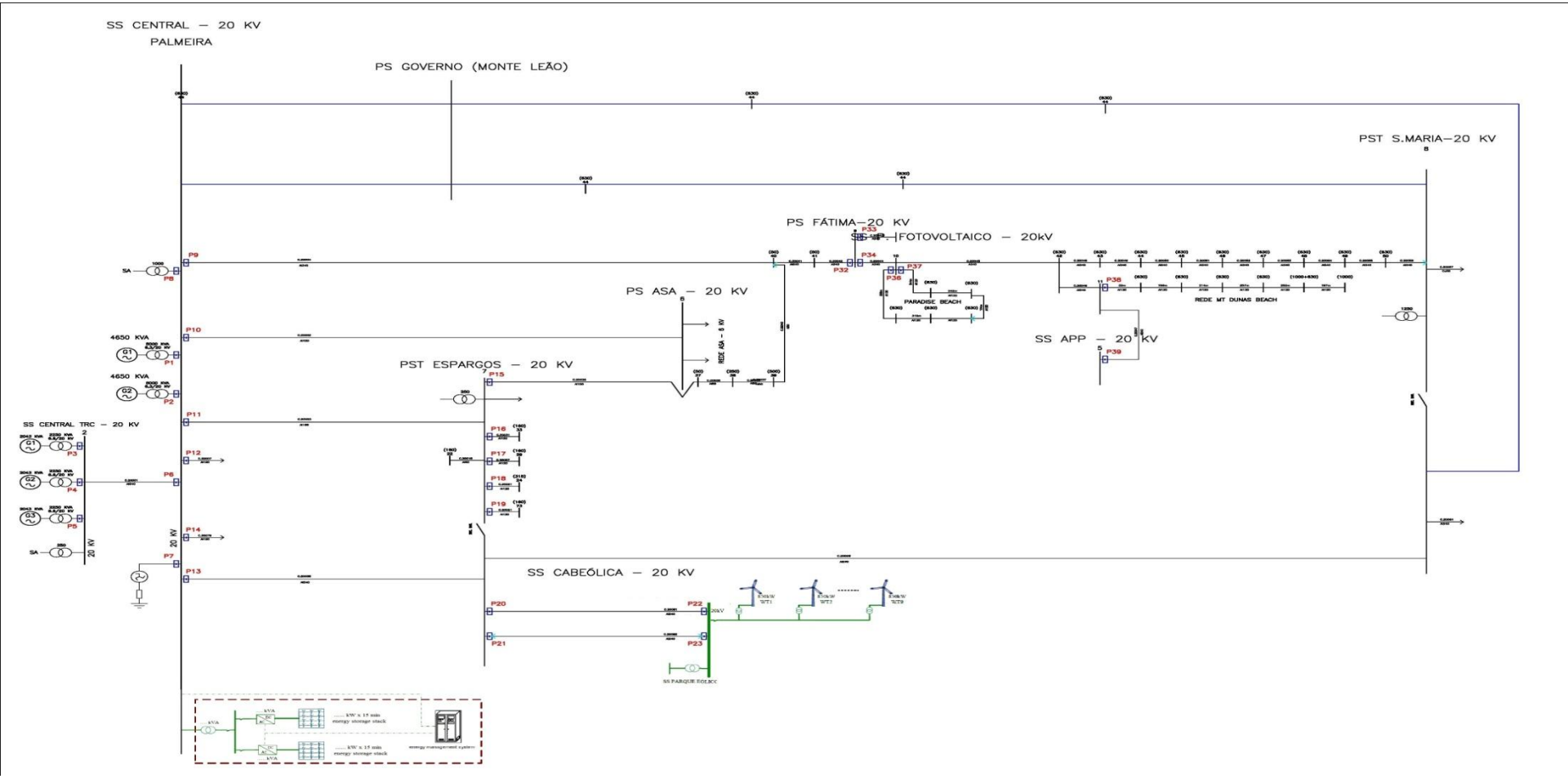
MEDIUM PENETRATION UP TO 50%

Scenario 2



RENEWABLE ENERGY MANAGEMENT STRATEGY MEDIUM PENETRATION UP TO 50%

Scenario 3



Solution Measures for Sal Island

Main points of the solution:

- Energy storage system configuration (battery stack + energy storage inverter), step up transformer connected to the 20kV rated busbar of the windfarm or the public grid.
- Master control system configuration, to control the wind power output and grid operation stability.
- Monitoring system configuration, to meet monitoring and management needs of the network operation.

Solution Measures for Sal Island

Scope of Supply:

- Overall Design of Energy Storage
- Energy storage system includes: energy storage stack design, battery management systems, and energy storage inverter.

Solution Measures for Sal Island

- The optimum solution should bring economic value in term of cost reduction.

Thanks!

Merci!

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