INTEGRATION OF RES AND H_2 STORAGE IN THE AZORES ARCHIPELAGO

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NEW AND RENEWABLE ENERGY TECHNOLOGIES FOR SUSTAINABLE DEVELOPMENT
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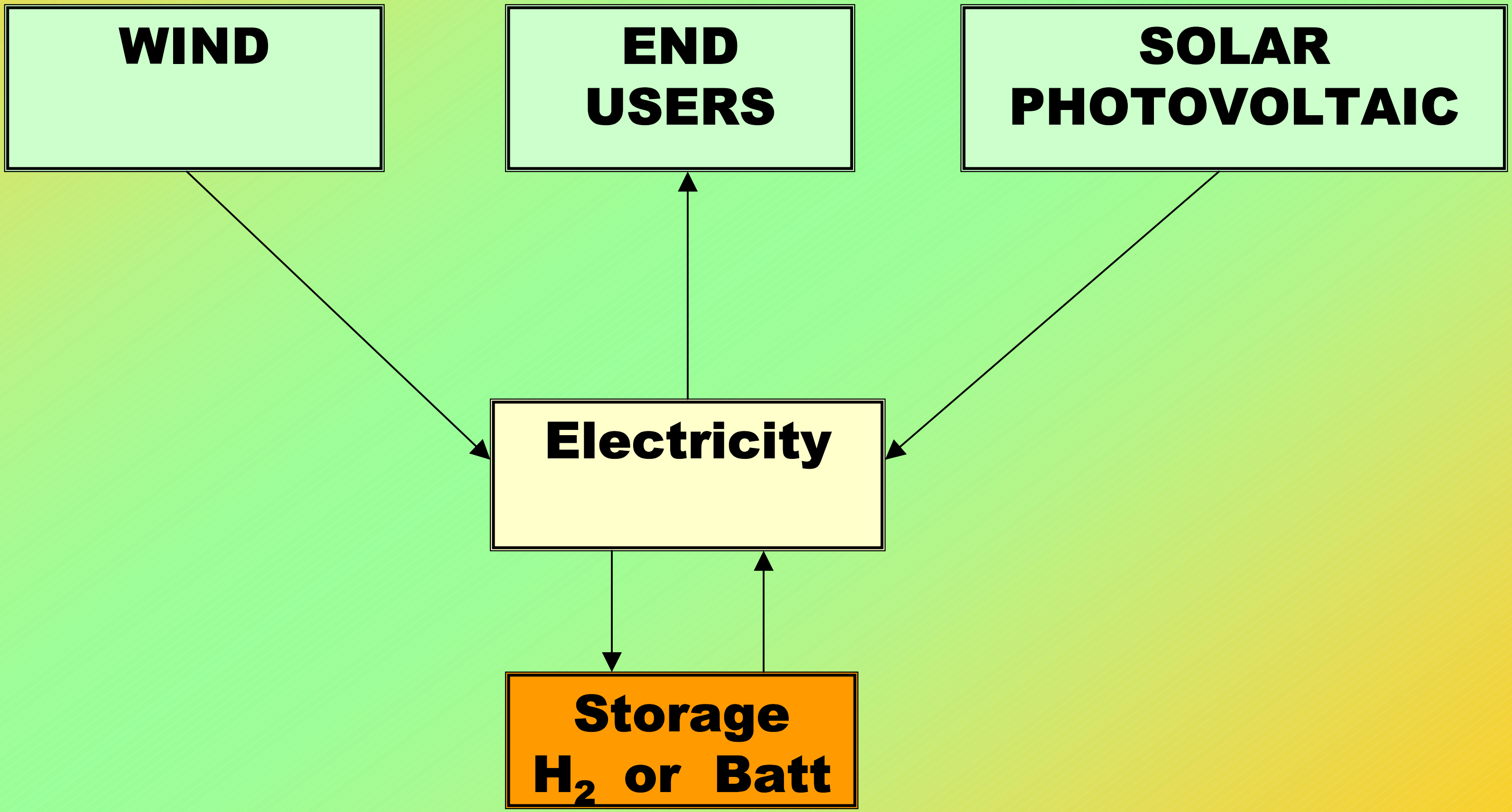
BACKGROUND

RE resources can be separated in two categories in terms of availability: those which are constant and continuous, possessing an intrinsic storage capacity, like hydro and geothermal, and those which are intermittent, lacking any such capacity. This last category is sub-divided into those resources varying periodically, like solar and tidal, and those that vary rather more randomly, such as wind and wave.

The Energy Storage

- The use of energy storage allows electricity generated during periods of high-availability/ low-demand to be converted (to a storable energy-form) and stored for subsequent re-supply during periods of low availability or high-demand.
- In the absence of storage, the intermittent resource has to be matched by dedicated conventional capacity in order to guarantee supply.

Electricity production, storage and use

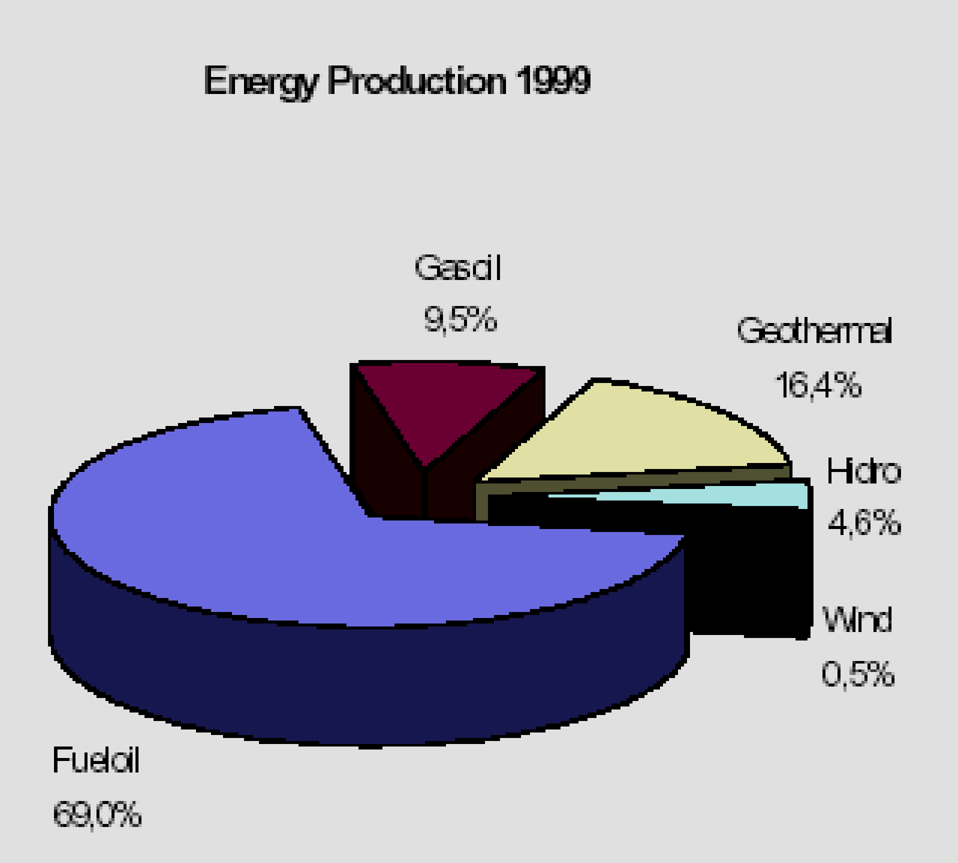


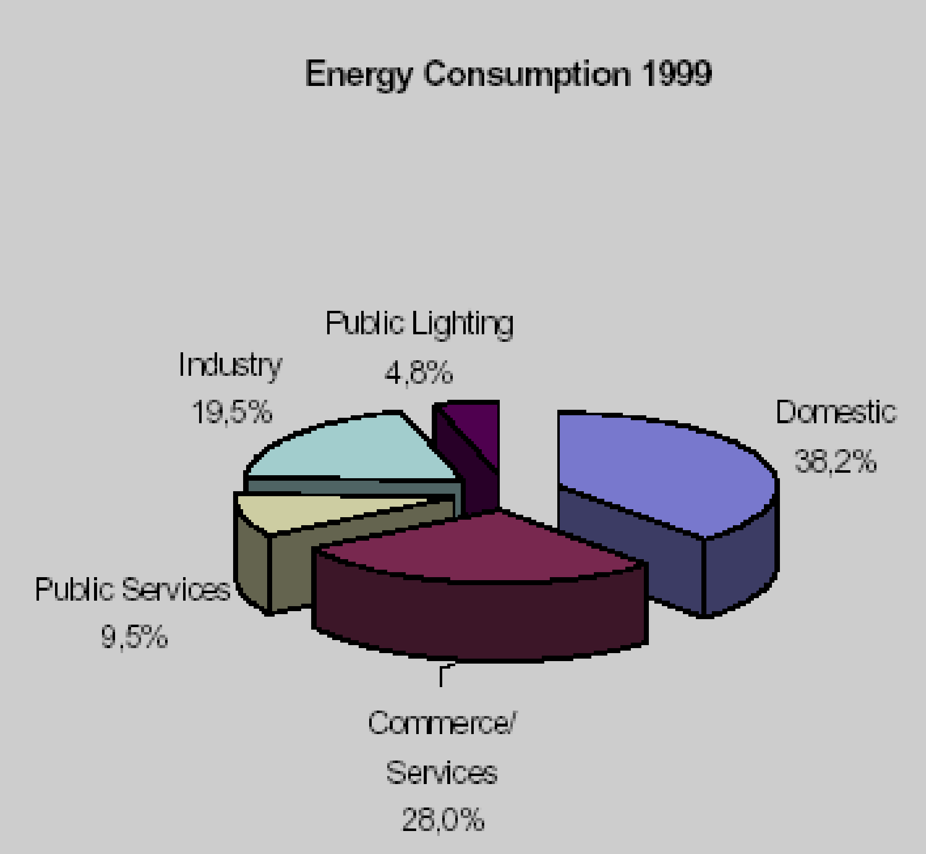
Objectives of the Work

- To look at ways to increase the penetration of Renewable Energy Sources in Corvo and Graciosa Islands
- To test the potentiality of the developed H2RES model devoted to this kind of work.
- To build and fully model scenaria for the Corvo and Graciosa islands to increase security of supply, and reduce pollution, based on existing load and meteorological data and envisaging the following technologies: wind, solar PV, and batteries and hydrogen storage.

The target islands for the case studies

The Azores Electricity Balance





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Electricity Balance for Corvo and Graciosa

Island of CORVO

Year	Consumption (GWh)	Production (GWh)
2000	0.678	0.763
2001	0.723	0.809

Island of GRACIOSA

Year	Consumption (GWh)	Production (GWh)
2000	7.188	8.016
2001	7.684	8.573

Factors influencing renewables integration

The variation of the power output has an impact on both operation of the power system and on the power quality of the system and this impact increases as the level of penetration increases

Impact	Threshold	Mitigation options
Change in renewable generation output	Generation subject to fluctuation >20% of peak demand	- Purchase additional controllable output
• Unpredictable instantaneous reduction in generation output	- Potential instantaneous loss >2% of peak demand	- Purchase additional frequency control measures
Unpredictable short-notice reduction output	- Potential loss >3% of peak demand in an hour	- Purchase additional reserve services

Scenaria for GRACIOSA island

MG.1 - An already planned enlargement by the local utility (EDA) of the wind park up to 530 kW with an imposed wind energy limit of 30% of the "instant" load in the system.

MG.2 - The same conditions as in MG.1 + 2,000 m^2 of installed PV.

MG.3 - 30% RE contribution: wind power 1,200 kW, no restrains on the percentage of renewable energy with variable output placed into the grid.

MG.4 – 45% RE contribution to the annual consumption: 1,200 kW of wind power + 20000 m^2 of PV, in the same conditions as in MG.3.

MG.5 – 100% RE penetration: 9,000 kW of wind power + electrolyser with 8,900 kW power + 74 days hydrogen storage + fuel cell 1,600 kW power, allowing no renewable energy excess in the system.

MG.6 - 100% RE penetration: 5,000 kW of wind power + 80,000 m^2 of PV + electrolyser with 8,500 kW power + 31 days hydrogen storage + fuel cell 1,750 kW power, allowing no renewable energy excess in the system.

Scenaria for CORVO island

MC.1 – 60% re contribution to the annual consumption: 6,500 m^2 PV + 150 kW (18h) battery power, no restrains on the percentage of renewable energy with variable output placed into the grid.

MC.2 – 80% re contribution: 10,000 m^2 PV + 150 kW (36h) battery power, in the same conditions as MC.1.

MC.3 - 100% RE penetration: 25,000 m^2 PV + 170 kW (6 days) battery power

MC.4 - 50% RE contribution: 200 kW of wind power, no restrains on the percentage of renewable energy with variable output placed into the grid.

MC.5 - 30% RE contribution: 3,000 m^2 PV, in the same conditions as MC.4.

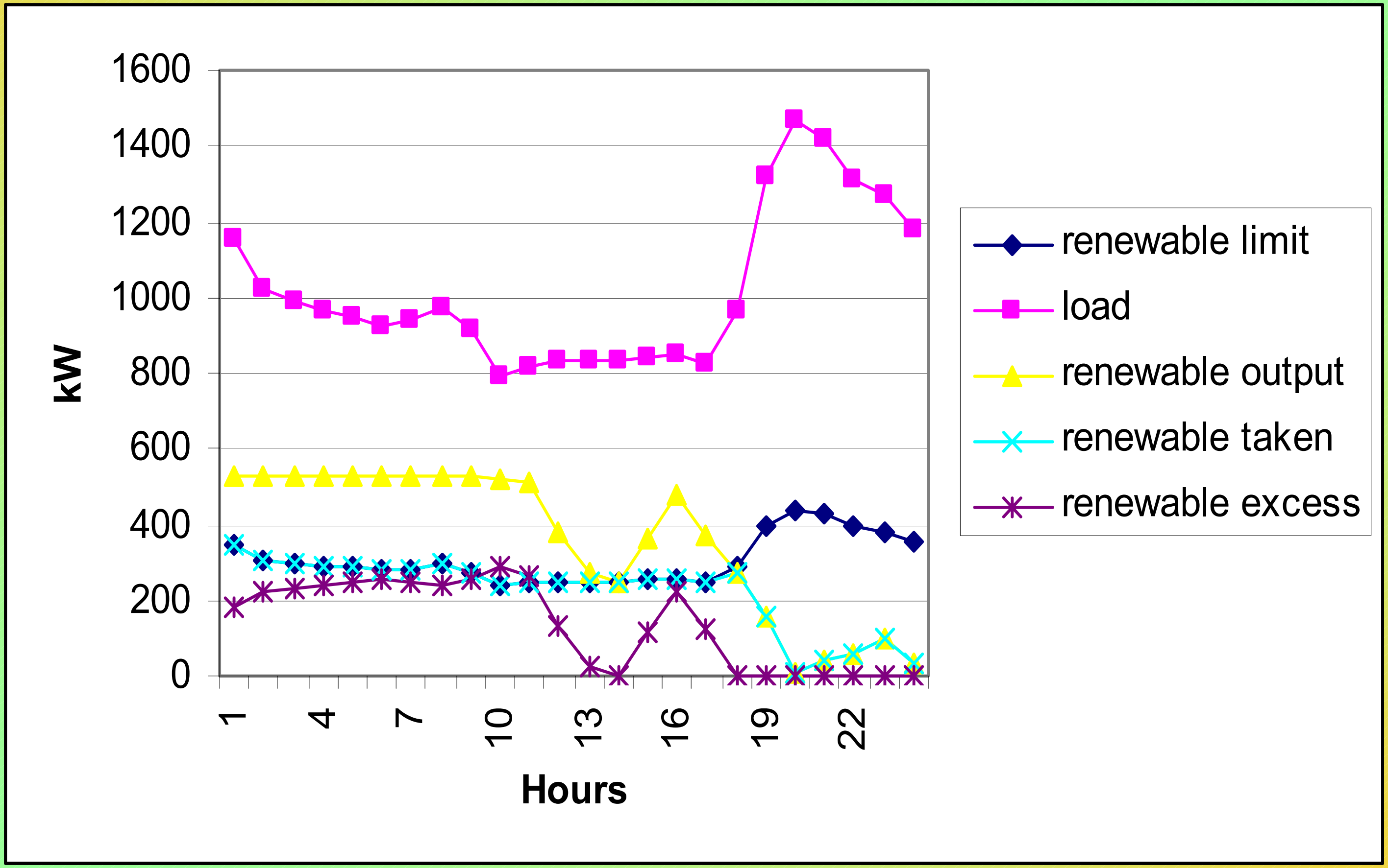
Analysis of the results for GRACIOSA island

	MG. 1 (30% limit)	MG. 2 (MG.1 + 2000 M^2 PV)
Wind (kW)	**530**	**530**
Solar (kWp)	**0**	**170**
Renewable (kW)	**530**	**700**

Analysis of the results for GRACIOSA island

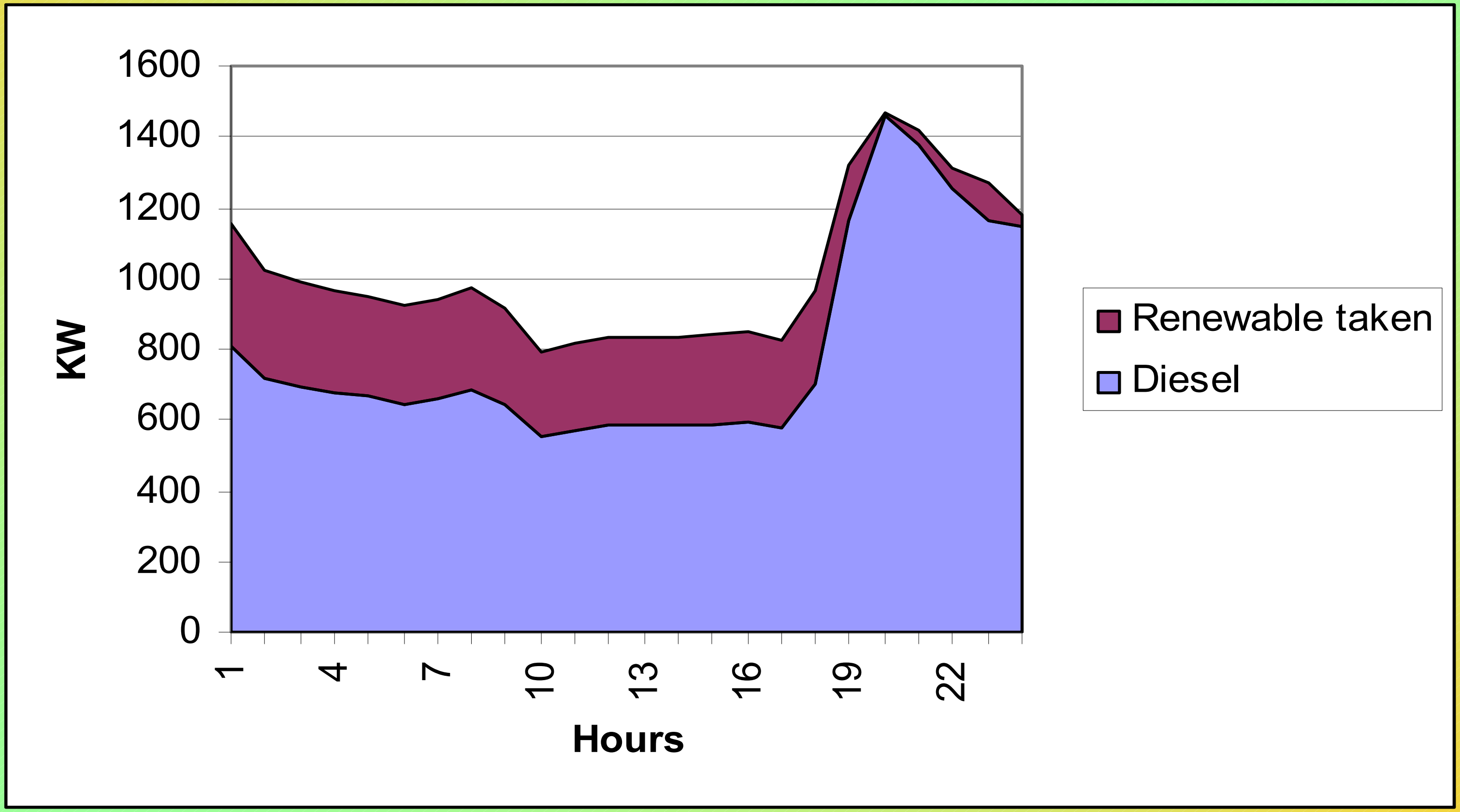
	MG. 1 (30% limit)	MG. 2 (MG.1 + 2000 M² PV)
Wind output (GWh)	**1.3**	**1.3**
Solar output (GWh)	**0**	**0.2**
Ren. output (GWh)	**1.3**	**1.5**
Ren. taken (GWh)	**1.1**	**1.2**
Dump (GWh)	**0.2**	**0.3**

Analysis of the results for GRACIOSA island



MG.1 simulation, January 1

Analysis of the results for GRACIOSA island



MG.1 simulation, January 1. The source of electricity taken by the power system.

Analysis of the results for GRACIOSA island

	MG. 3 (30% RE)	MG. 4 (MG. 3 + 45% RE)
Wind (kW)	**1200**	**1200**
Solar (kWp)	**-**	**1700**
Renewable (kW)	**1200**	**2900**
Wind output (GWh)	**2.8**	**2.8**
Solar output (GWh)	**-**	**1.7**
Ren. output (GWh)	**2.8**	**4.5**
Ren. taken (GWh)	**2.7**	**4.0**
Dump (GWh)	**0.1**	**0.5**

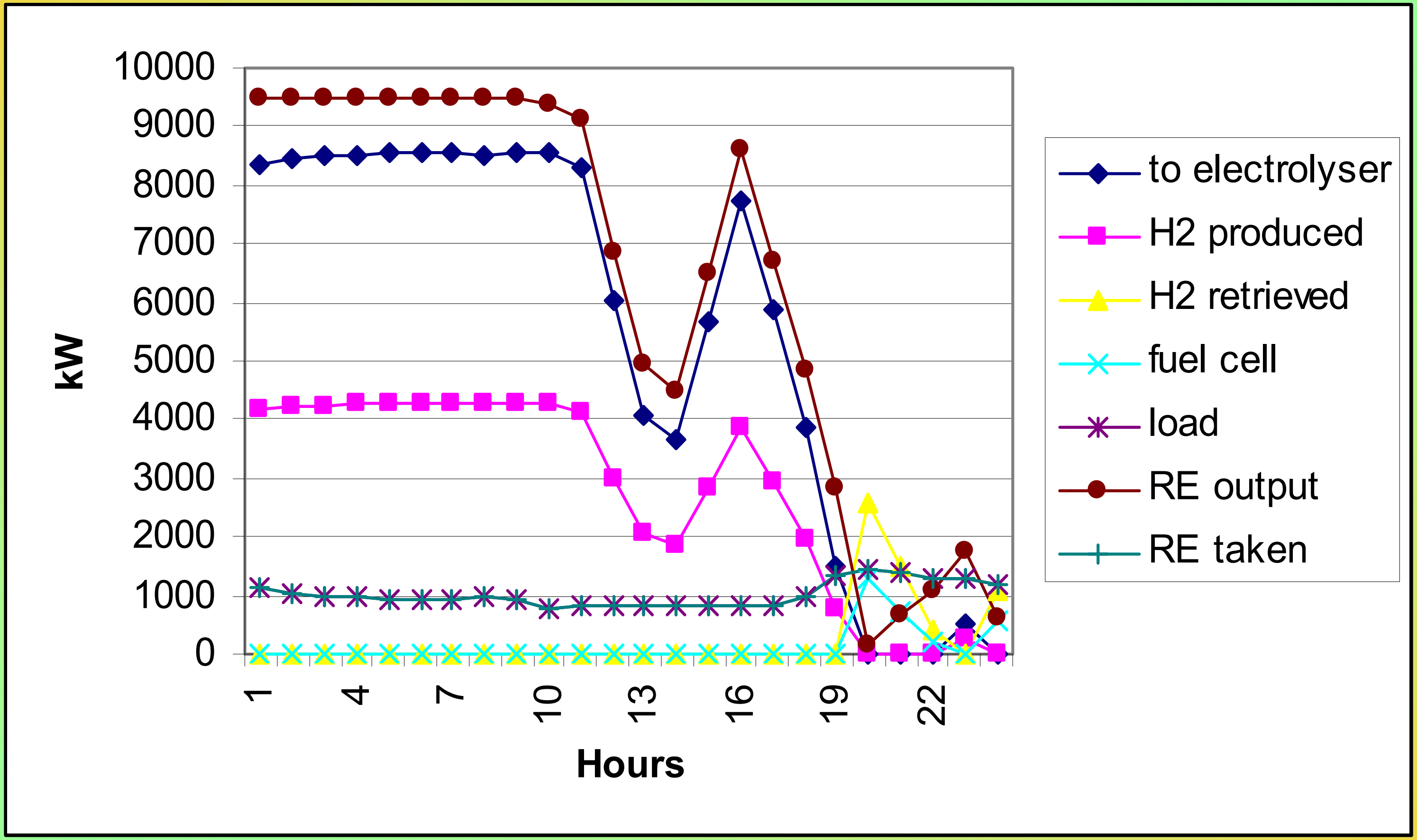
Analysis of the results for GRACIOSA island

	MG. 5 (100% RE)	MG. 6 (100% RE)
Wind (kW)	**9000**	**5000**
Solar (kWp)	**-**	**6800**
Renewable (kW)	**9000**	**11800**
Electrolyser (kW)	**8900**	**8500**
Storage vessel (GWh)	**2.8**	**1.3**
H2 storage (days)	**74**	**31**
Fuel cell (kW)	**1600**	**1750**

Analysis of the results for GRACIOSA island

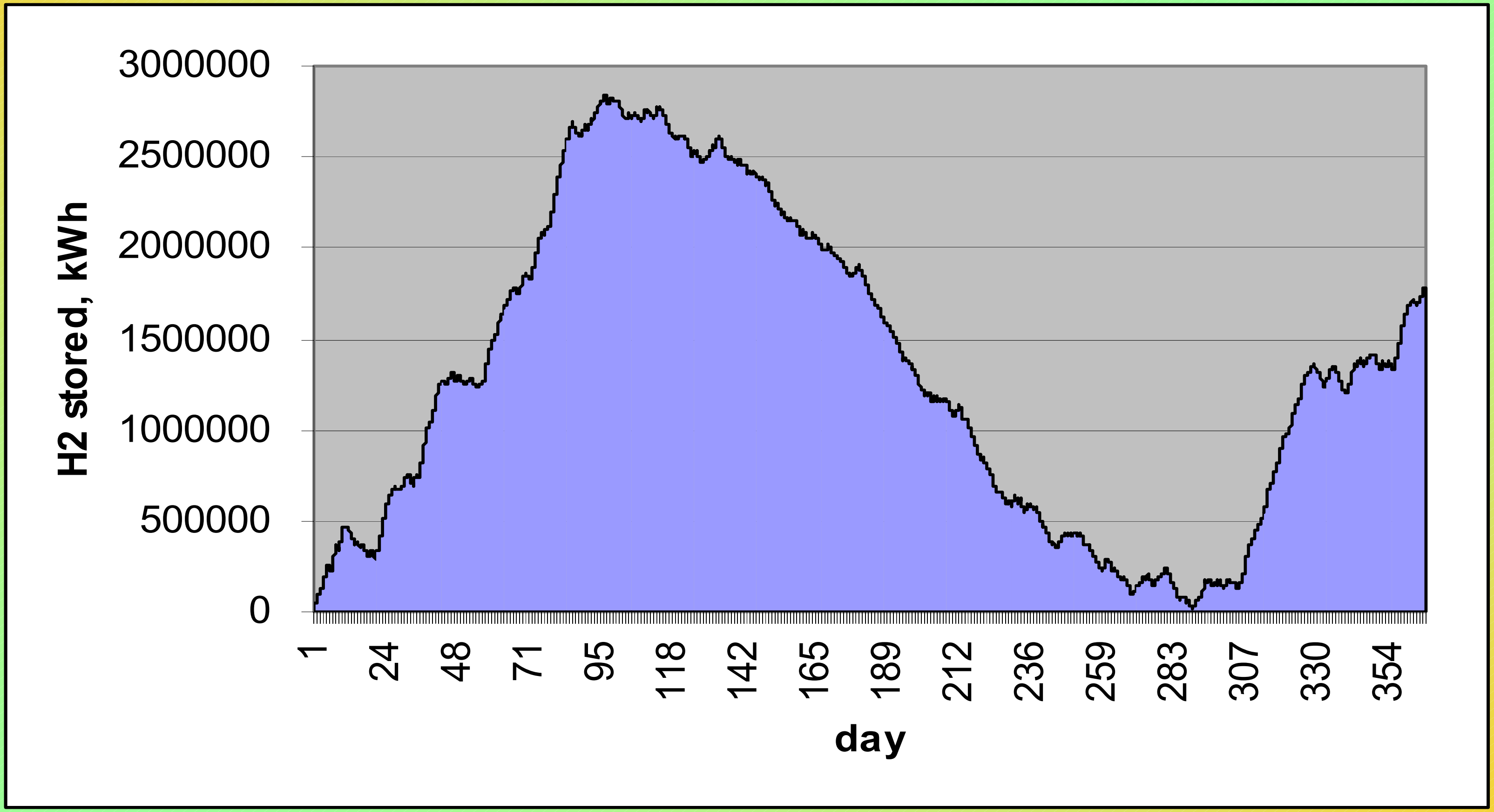
	MG. 5 (100% RE)	MG. 6 (100% RE)
Wind output (GWh)	**22.4**	**11.8**
Solar output (GWh)	**-**	**6.9**
Ren. output (GWh)	**22.4**	**18.7**
Ren. taken (GWh)	**5.8**	**6.3**
Electrolyser (GWh)	**16.6**	**12.4**
Dump (GWh)	**0**	**0**
Fuel cell (GWh)	**3.2**	**2.8**
Fuel cell serving time (%)	**45 %**	**40 %**

Analysis of the results for GRACIOSA island



MG.5 simulation, January 1, for this particular day more hydrogen is stored than retrieved

Analysis of the results for GRACIOSA island

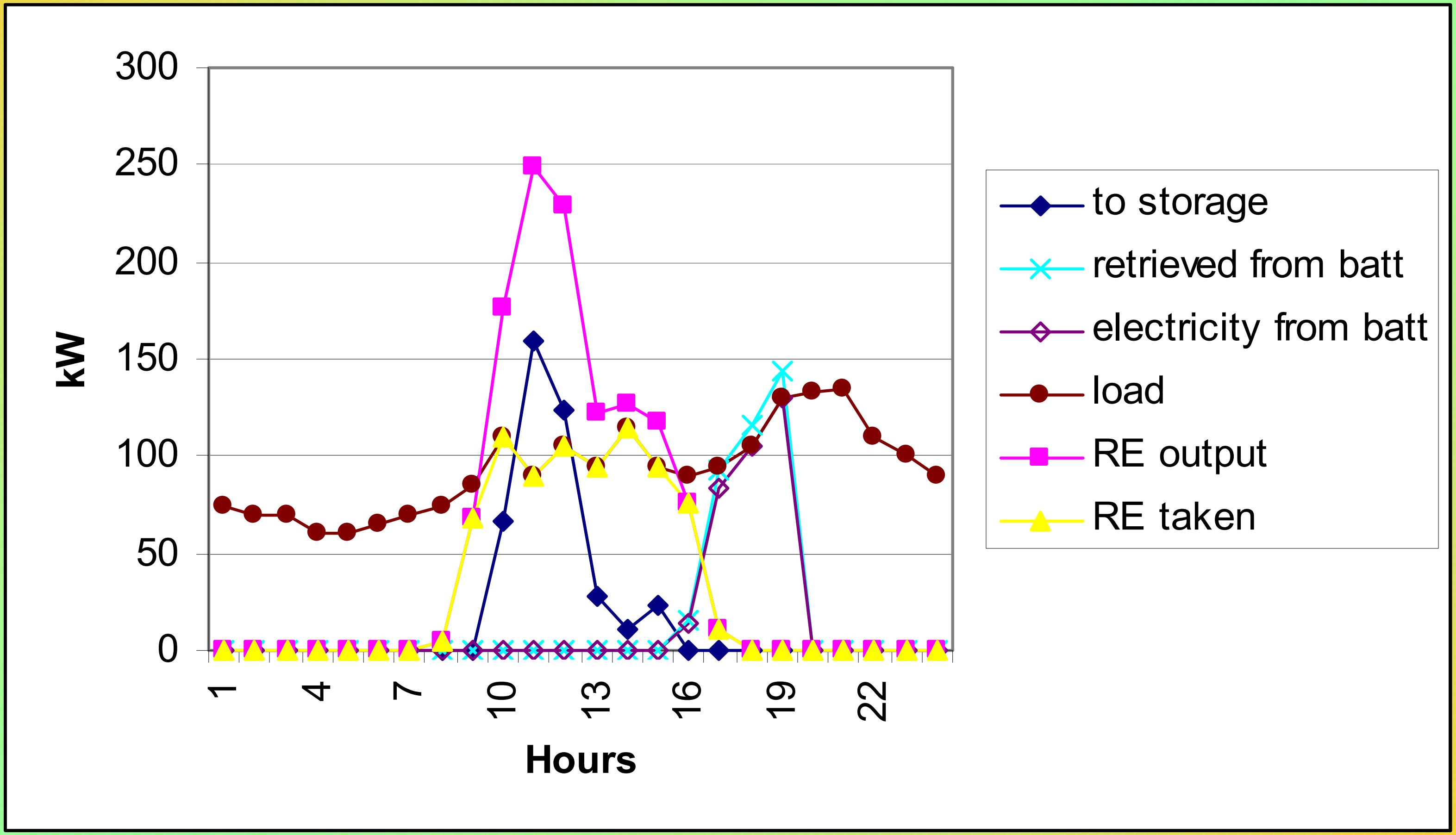


MG.5 simulation, hydrogen stored during the year

Analysis of the results for CORVO island

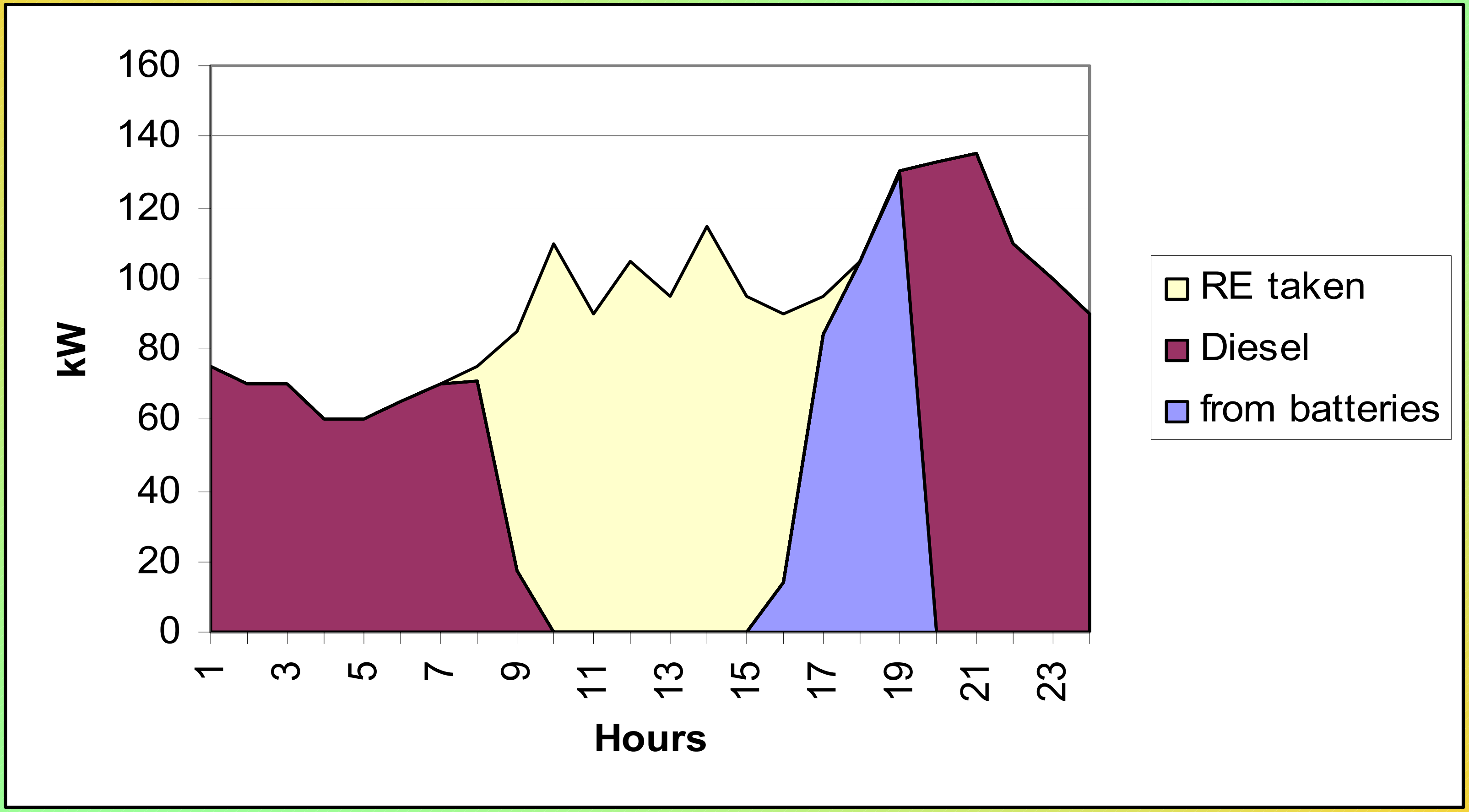
	MC.1 (60% RE)	MC.2 (80% RE)	MC.3 (100% RE)
Solar (kW)	**553**	**850**	**2125**
Batteries (hours)	**18**	**36**	**144**
Batteries (kW)	**150**	**150**	**170**
Solar output (GWh)	**562**	**864**	**2160**
Ren. taken (GWh)	**314**	**350**	**403**
Excess (GWh)	**248**	**514**	**1758**
Stored (GWh)	**245**	**411**	**560**
Dump (GWh)	**3**	**103**	**1198**
Batteries serving time (%)	**29**	**46**	**59**

Analysis of the results for CORVO island



MC.2 simulation, January 1

Analysis of the results for CORVO island

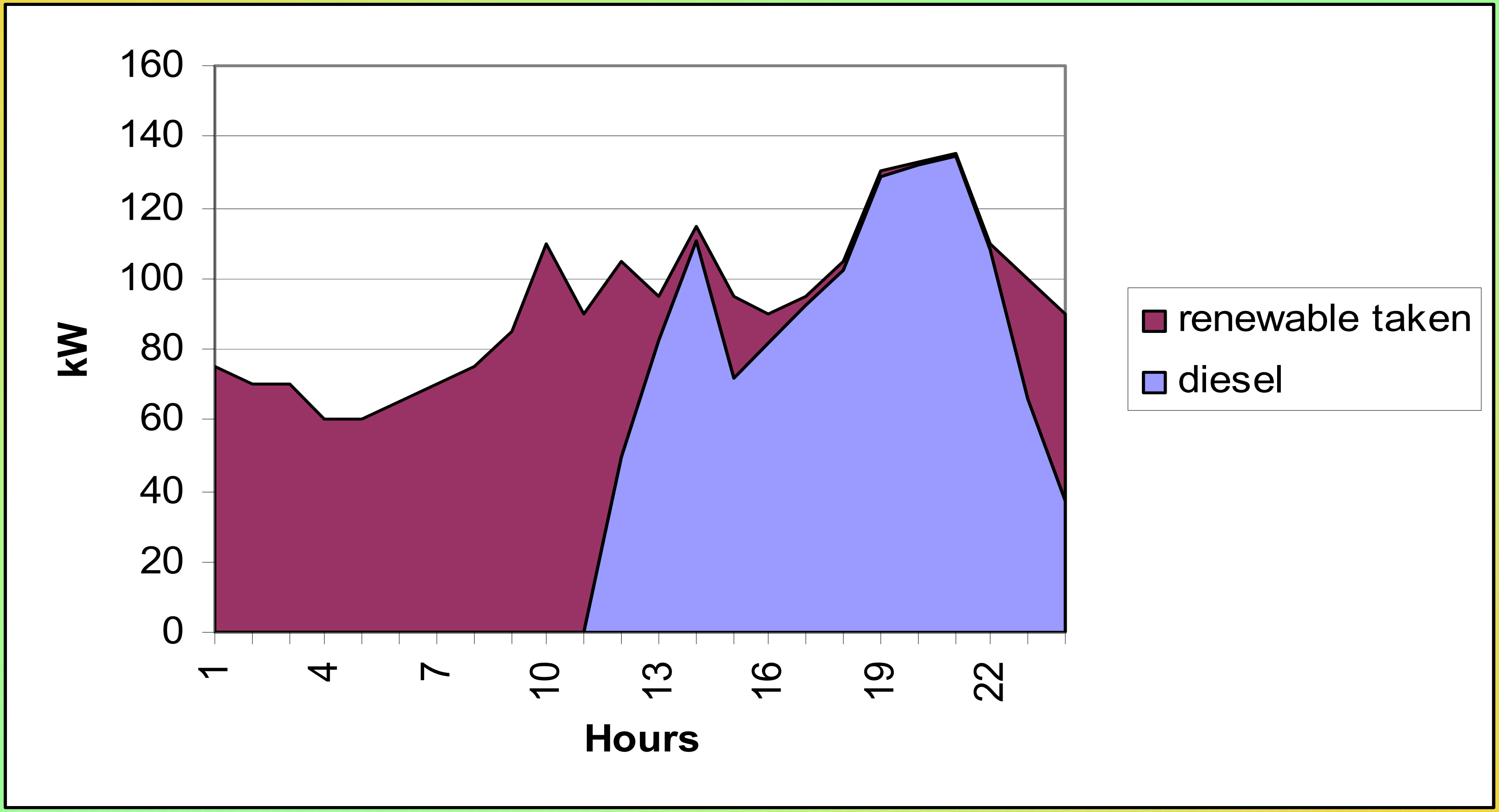


MC.2 simulation, January 1, the source of electricity taken by the power system.

Analysis of the results for CORVO island

	MC.4 (50% RE)	**MC.5** (30% RE)
Wind (kW)	**200**	**-**
Solar (kW)	**-**	**255**
Renewable (kW)	**200**	**255**
Wind output (GWh)	**462**	**-**
Solar output (GWh)	**-**	**259**
Ren. taken (GWh)	**337**	**226**
Dump (GWh)	**125**	**33**

Analysis of the results for CORVO island



MC.4 simulation, January 1, the source of electricity taken by the power system.

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CONCLUSIONS FOR GRACIOSA ISLAND

- The choice among the different scenaria depends mainly on comparing the costs of PV installation and of the hydrogen storage and on the available space.
- Due to actual high cost of PV, the scenaria involving only wind seems to be preferable.

CONCLUSIONS FOR CORVO ISLAND

- For such a small energy system, 100% RE penetration with variable output, can only be reached by oversizing the power installed.
- This fact results in unacceptable values of energy excess. The possibility of using this energy excess to pump water for later energy generation in a mini-hydric power plant may be an option if the objective is 100% RE penetration.
- In order to reduce dumping, bigger batteries are needed.

CONCLUSIONS

- All options should be considered
- Wind + storage a possible way for 100% renewable Graciosa
- PV + storage a possible way for 100% renewable Corvo
- Intermittent RE + storage penetrations of up to 60% more viable – already significantly increasing security of supply and reducing pollution