NEW AND RENEWABLE ENERGY SOURCES FOR SUSTAINABLE COMMUNITIES

by

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CONTENTS OF THE PRESENTATION

- Characteristics of Sustainable Communities
- Types of Sustainable Communities
- Description of on-going projects for enhanced sustainability
- Conclusions

SUSTAINABLE COMMUNITIES

- Rio summit: Agenda 21
- EU White Paper for RES, Campaign for Take-off, ALTENER
- EU Green Paper on Security of Supply
- Kyoto Protocol

THE GOALS OF THE SUSTAINABLE COMMUNITY

- Integration of new technologies and concepts in socio-economic development
- Intensive use of RES
- Diversify energy sources
- Social and economic benefits

CHARACTERISTICS OF THE SOLUTIONS

- Competitive cost of NRET (when compared to conventional solutions)
- High percentage of NRES
- Decentralised generation
- Satisfy the needs of a community

$\rightarrow$ **INTEGRATION**

INTEGRATION

- **Integration of NRES:** Wind, Biomass, Small hydro, Geothermal, Distributed Generation, PV and solar heating, hydrogen, energy storage….
- Rational use of energy (buildings, energy management , CHP...) is also important

TYPES OF COMMUNITY

- Islands (small/medium)
- Isolated rural areas
- Non-isolate urban areas (blocks of buildings, neighbourhoods in residential areas, commercial / light industrial developments)

Islands

ISLANDS

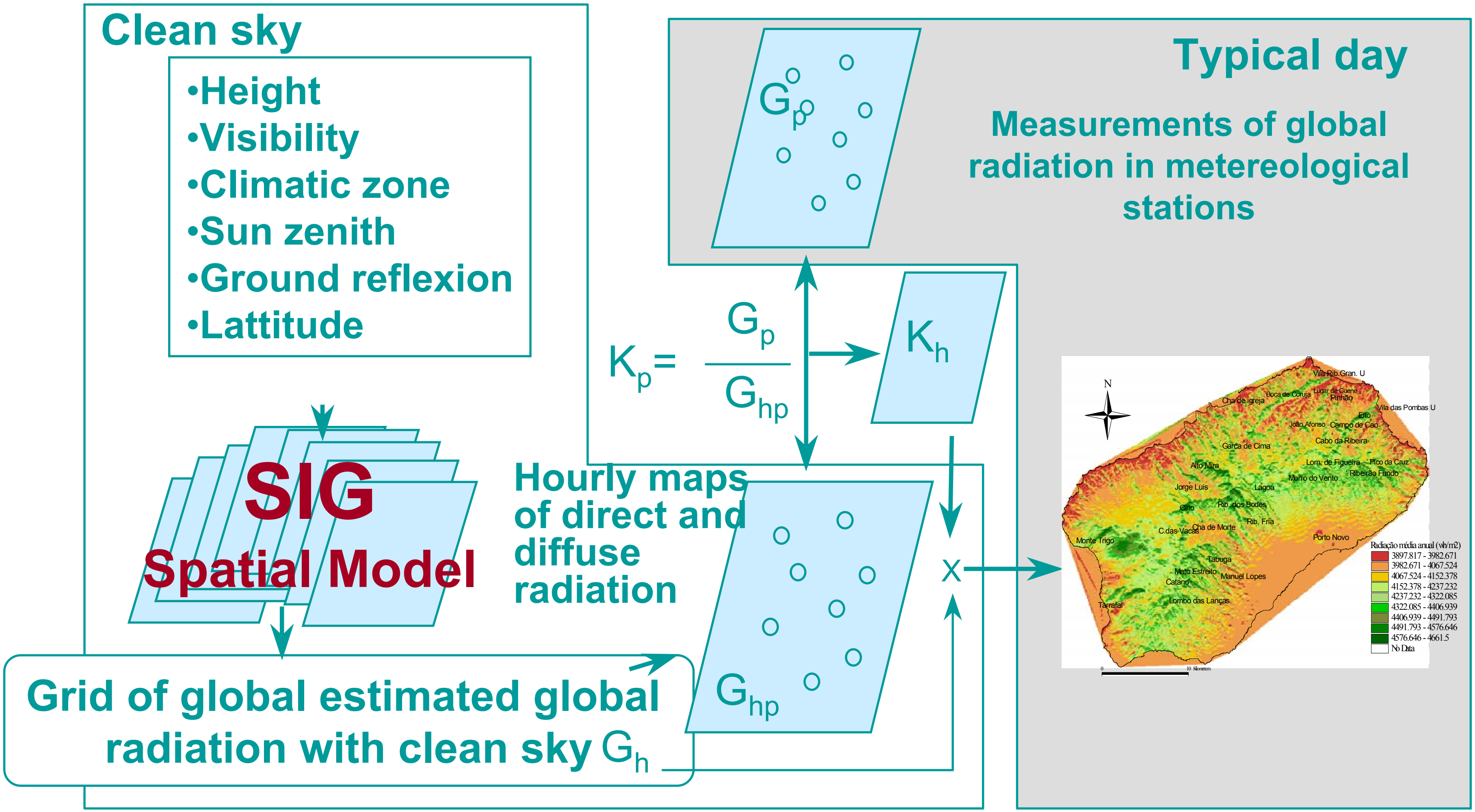
- High economic dependence on imported energy sources – High energy costs
- Environmental fragility
- Seasonability of energetic, water and waste disposal needs - Tourism
- Small size of the local grids

Island projects

SANTO ANTÃO

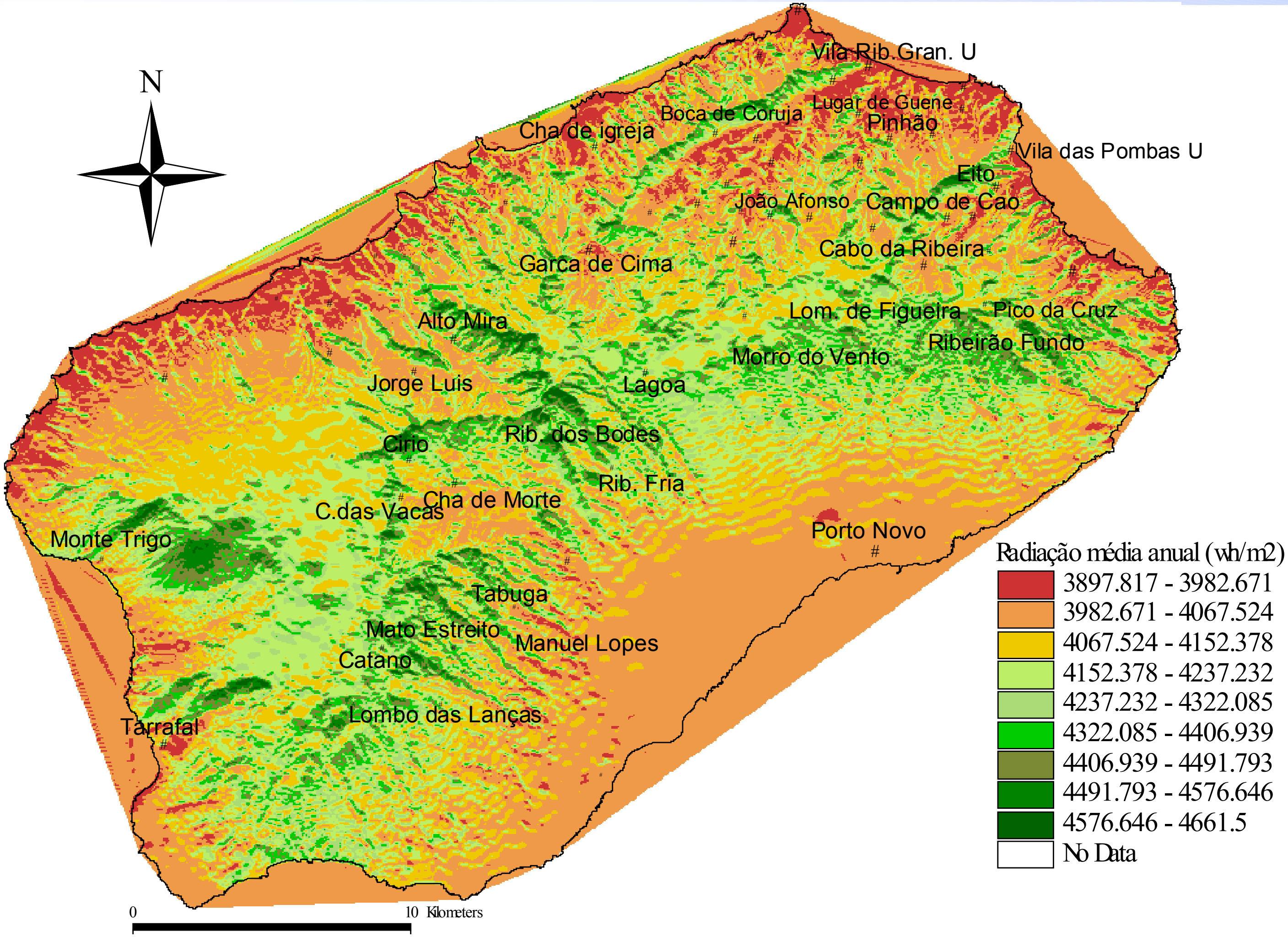
Metodology for the Evaluation of Renewable Energy Sources Potential

EVALUATION OF SOLAR POTENTIAL IN GIS

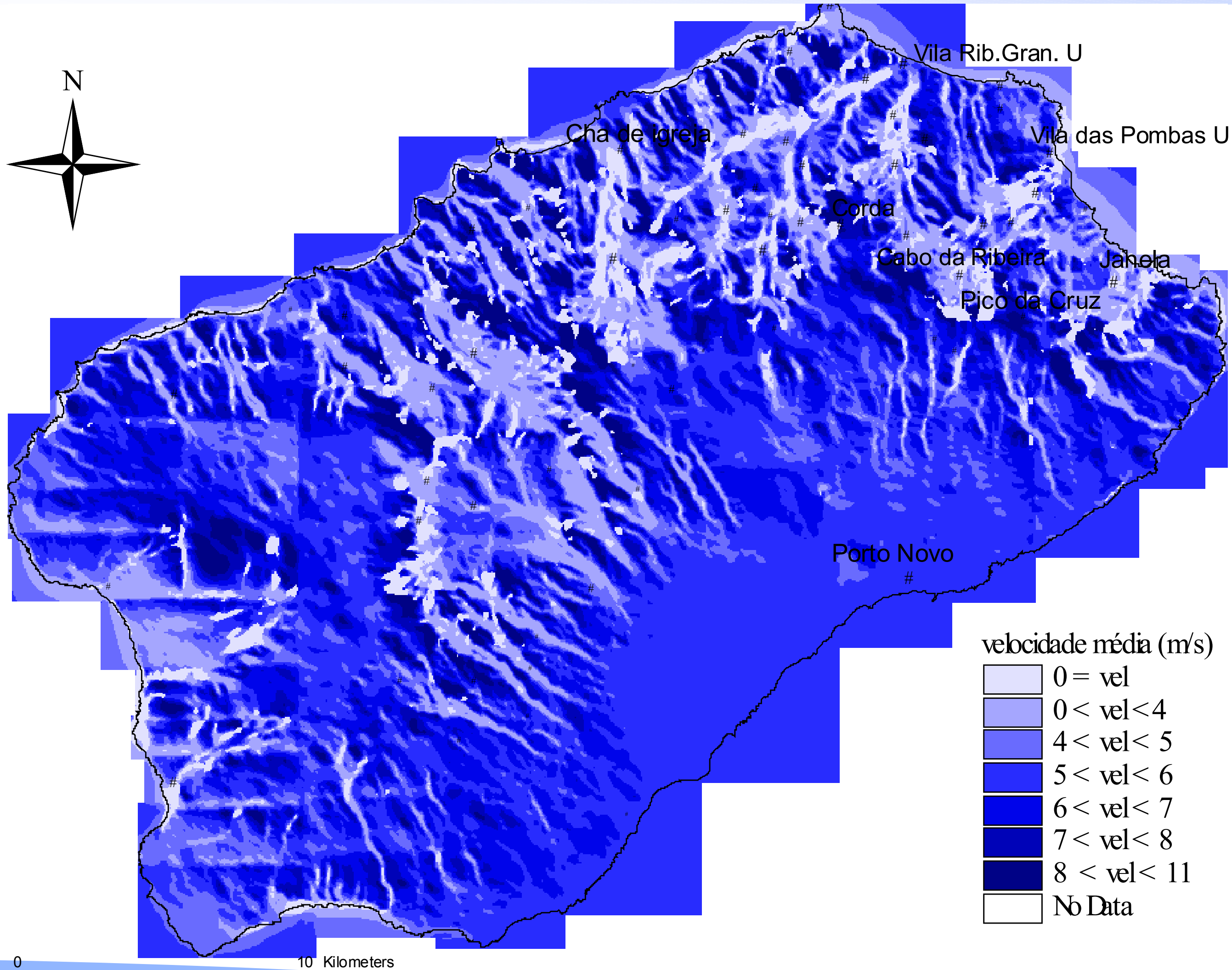


(METHODOLOGY DEVELOPED BY INESC – PORTO)

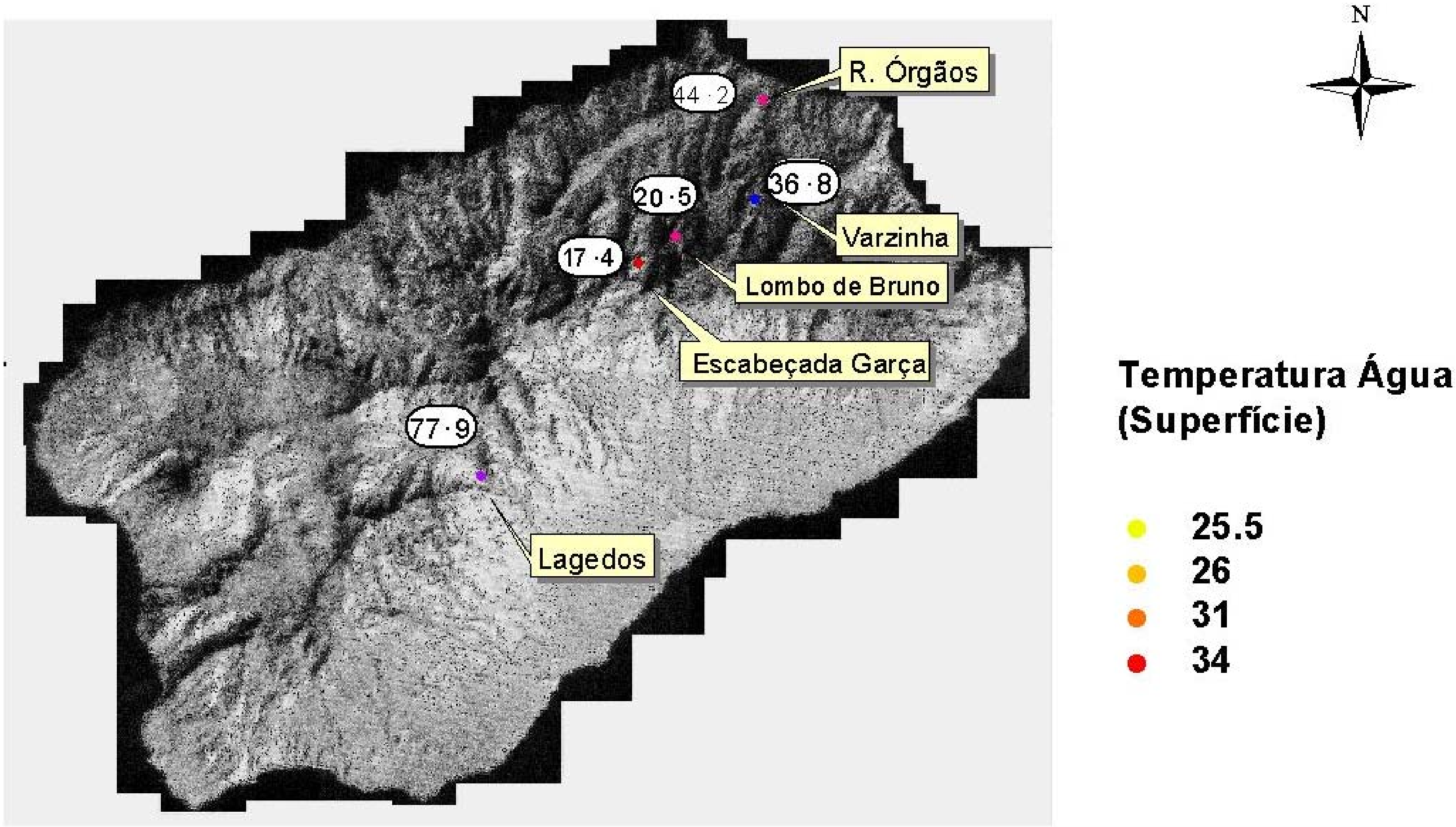
MAP OF RENEWABLE RESOURCES - SUN



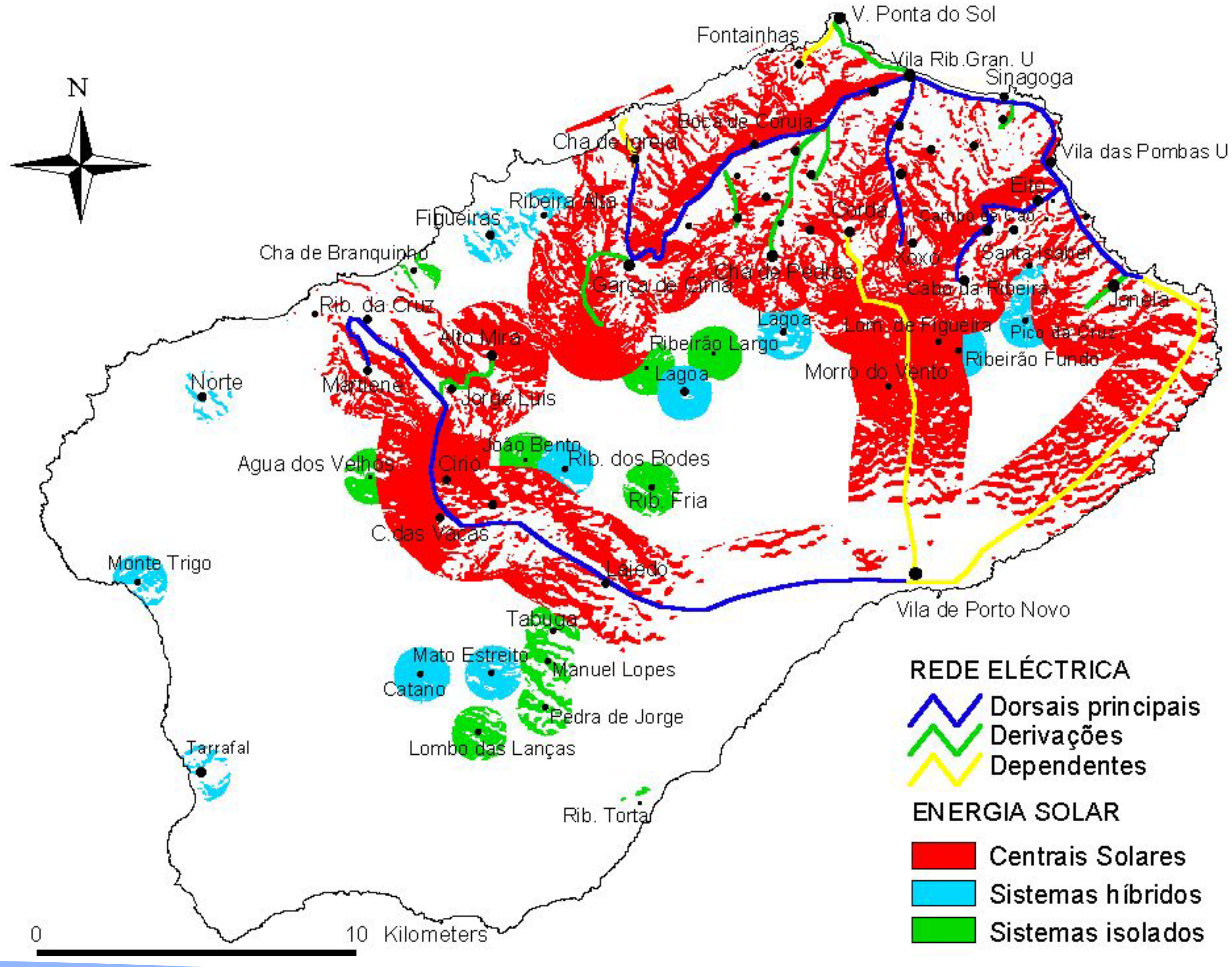
MAP OF RENEWABLE RESOURCES - WIND



MAP OF RENEWABLE RESOURCES - GEOTHERMAL



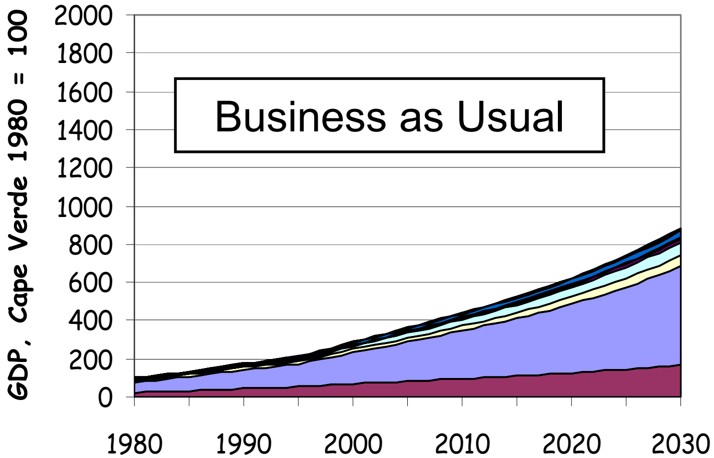
ELECTRICITY DISTRIBUTION NETWORK

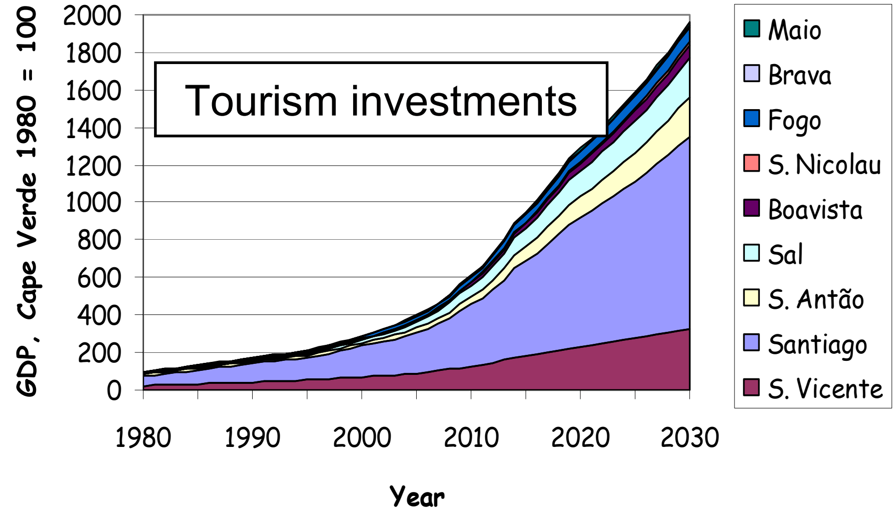


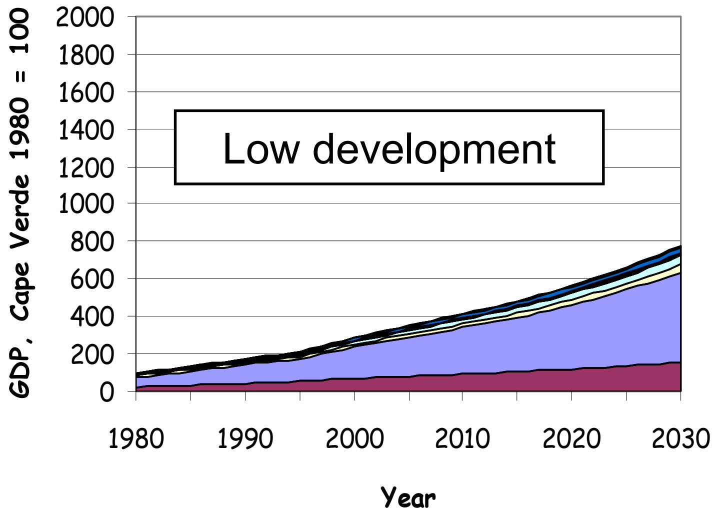
CABO VERDE

The potential for Clean Development Mechanism in Electricity Production

ECONOMY

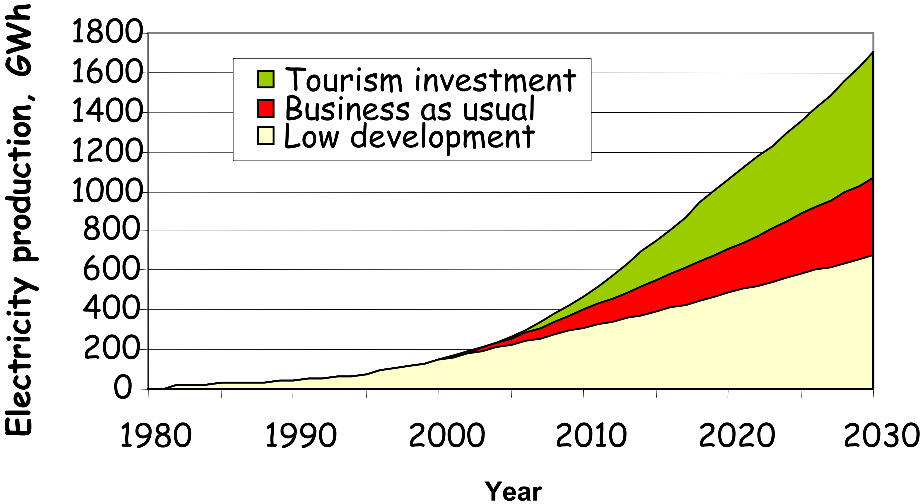


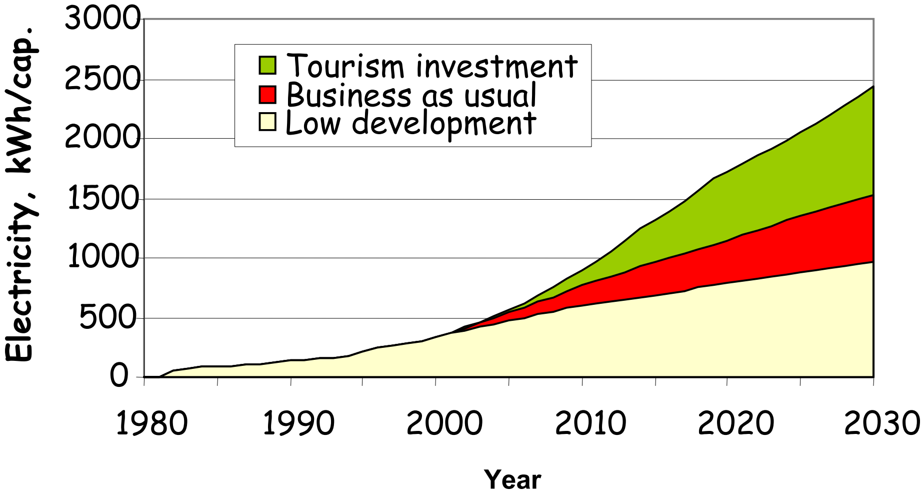




Regional GDP distribution for 3 economic scenaria, per island

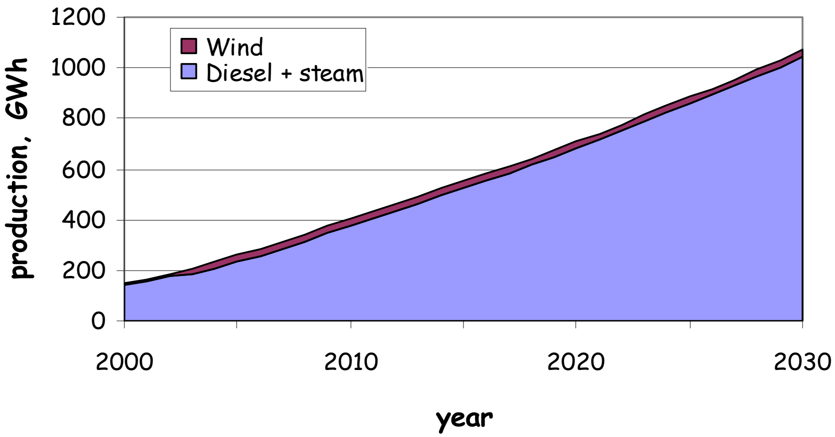
ELECTRICITY DEMAND



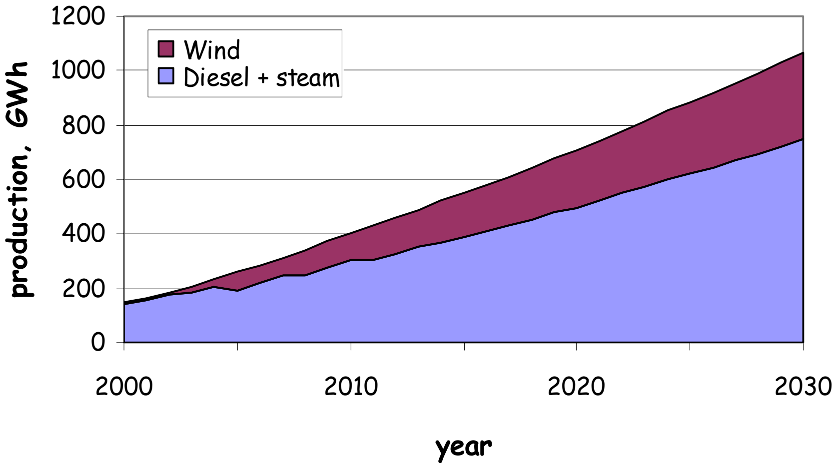


- Tourism sector
- Electrification rate
- Security of supply

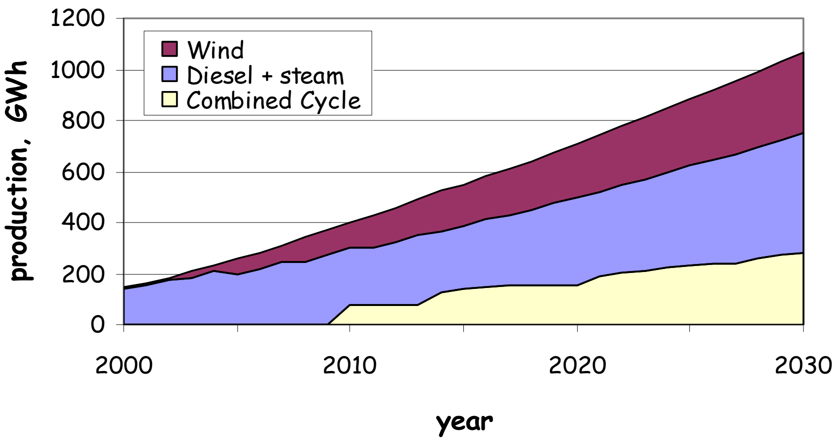
ELECTRICITY SUPPLY



← Baseline



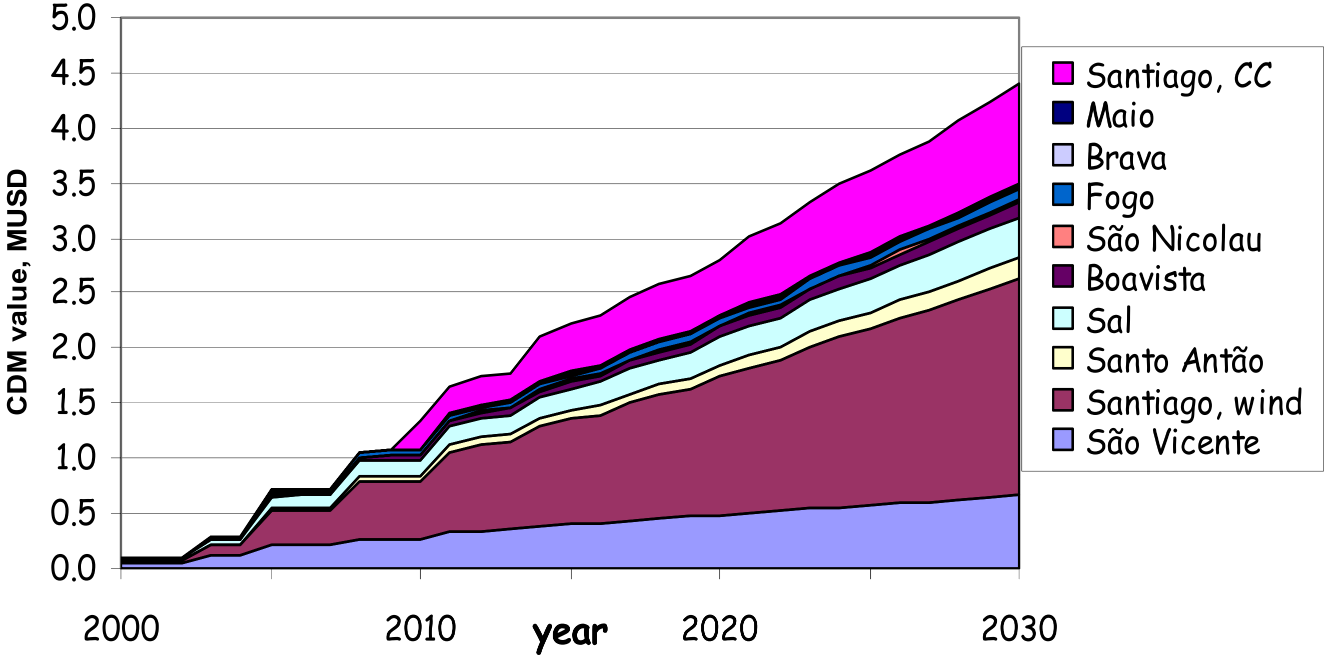
30% wind →



← Combined cycle 30% wind

Business as usual economic scenario

CDM VALUE

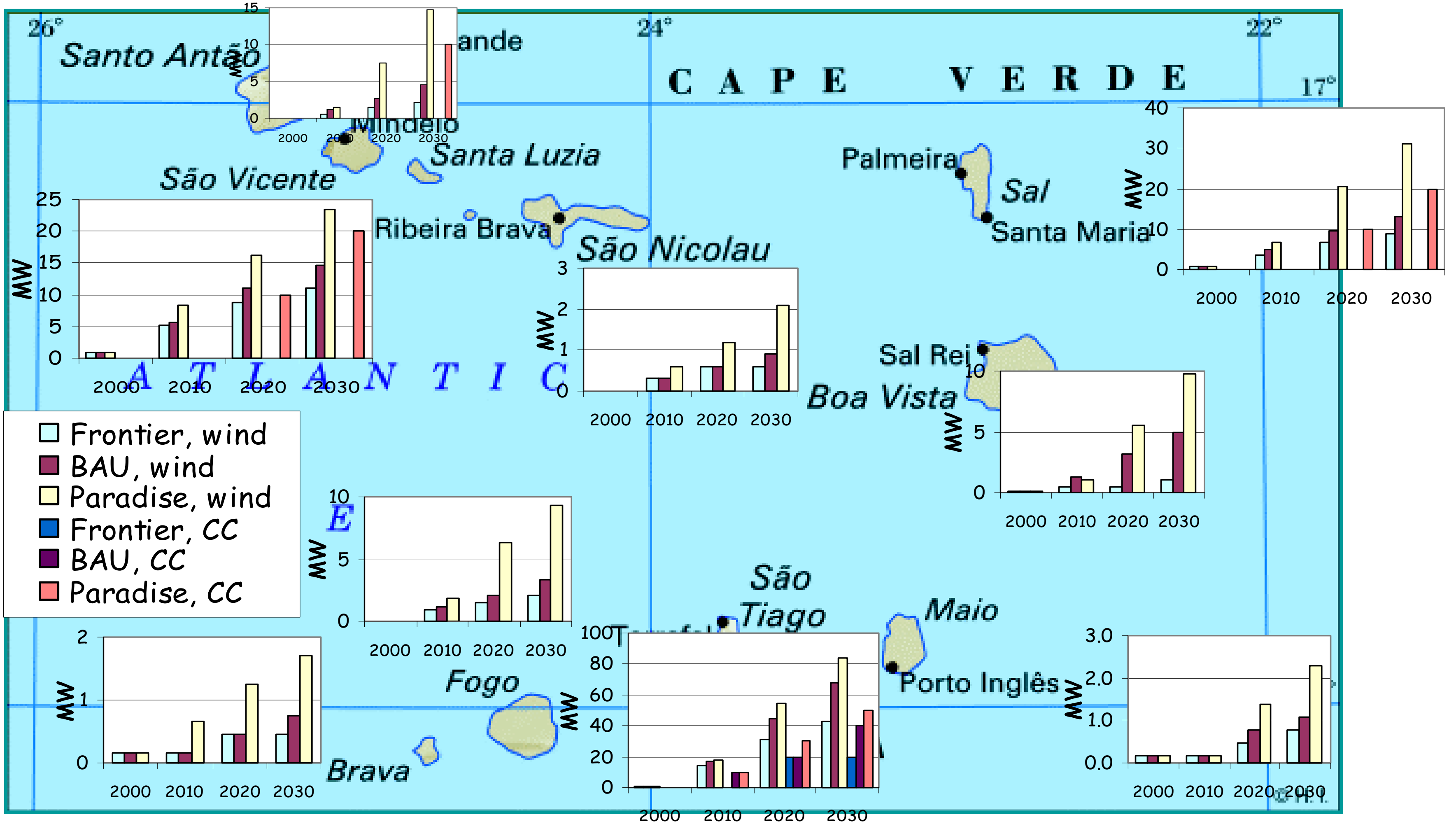


- Wind in all islands
- Combined cycle only in Santiago

Business as usual economic scenarium

Medium CDM price scenarium – 15$/t$CO_2$

INSTALLED POWER BY ISLAND

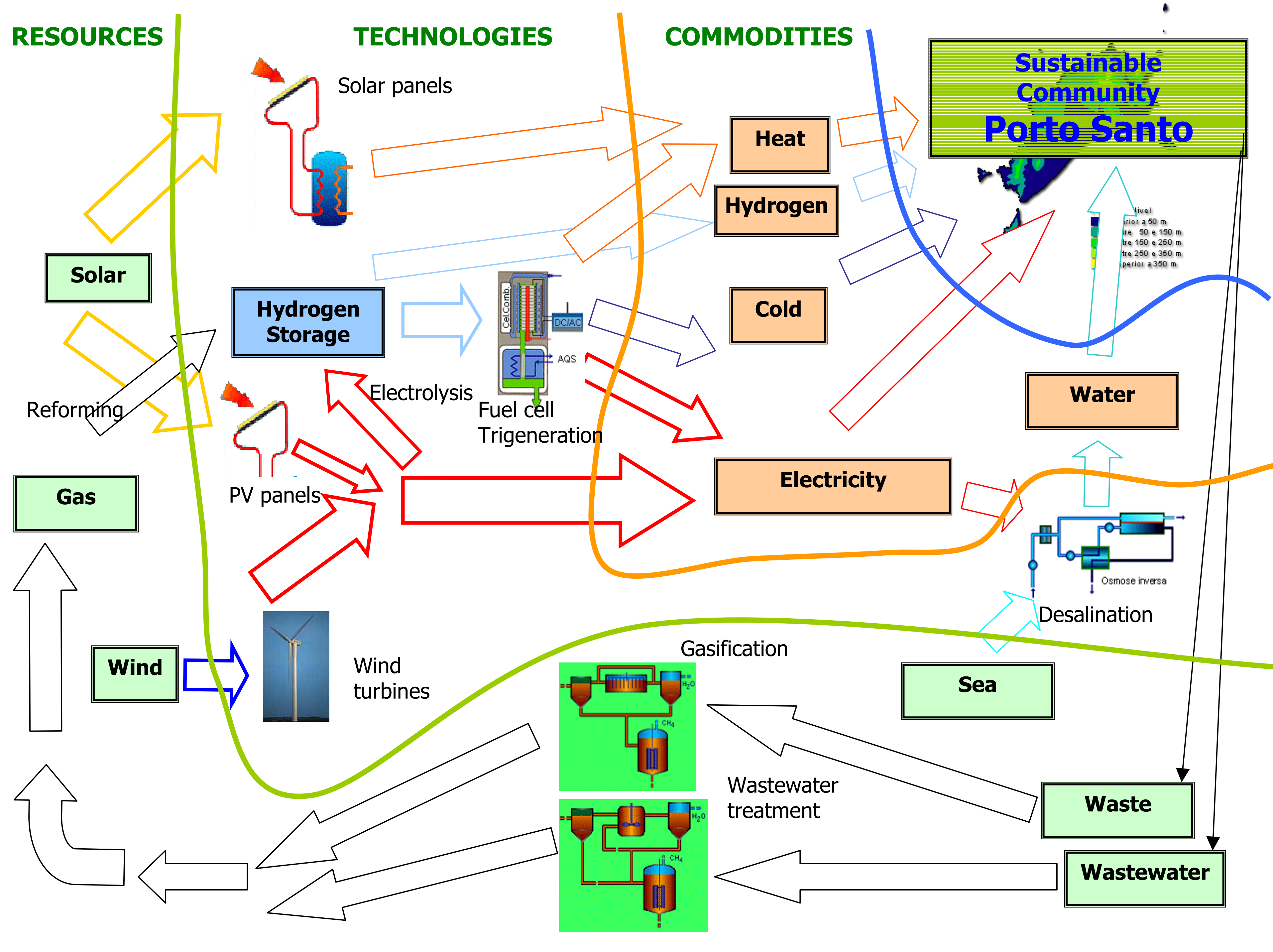


PORTO SANTO

Renewable Energy Solutions for Islands

100% RES Island


PORTO SANTO
Madeira, Portugal


RESOURCES
TECHNOLOGIES
COMMODITIES
Sustainable Community
Porto Santo
Solar panels
Heat
Hydrogen
Solar
Hydrogen Storage
Cold
Reforming
Electrolysis
Fuel cell
Trigeneration
Water
PV panels
Electricity
Gas
Osmose inversa
Desalination
Wind
Wind turbines
Gasification
Sea
Wastewater treatment
Waste
Wastewater

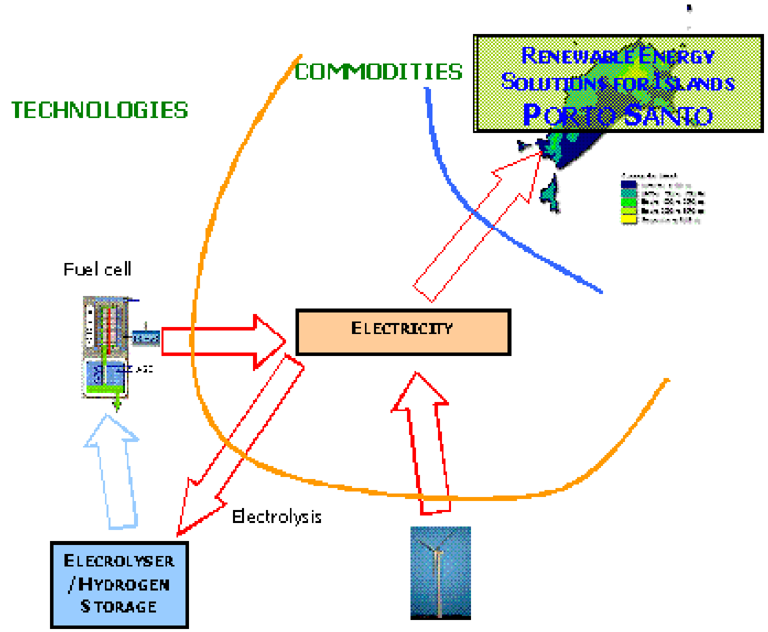
EQUIPMENT TO BE INSTALLED

PRESENT SITUATION

- 3.5 MW Diesel
- 3.4 MW Fuel Oil
- 1.1 MW Wind (4.4%)
- Peak Power – 5.6 MW
- Low Power – 2 MW
- Growth rate – 20%

PILOT HYDROGEN SYSTEM

- 75 kW Electrolyser
- 300 kWh Storage
- 25 kW Fuel Cell

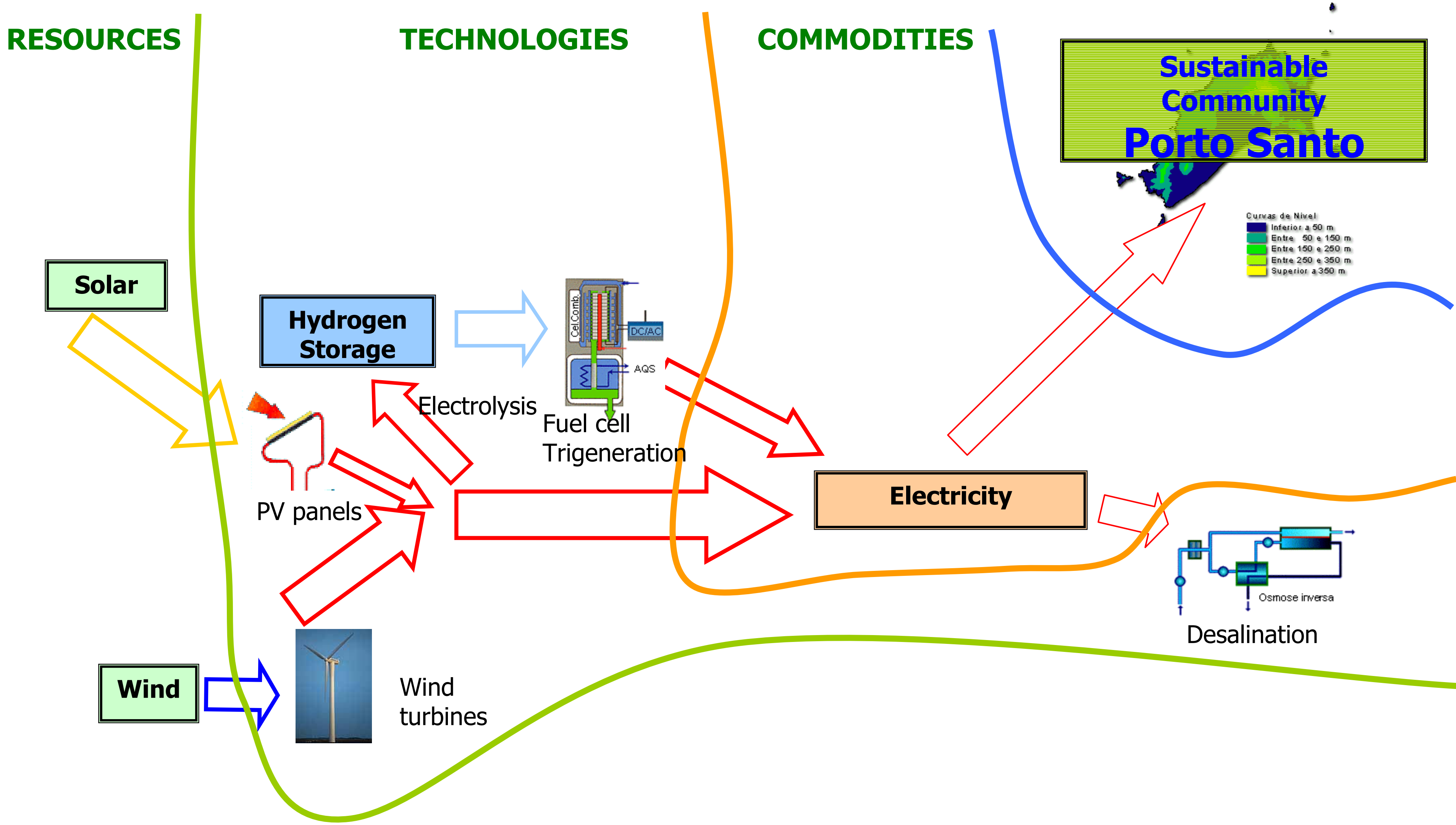


- Cost: 830,000 € (33,000 €/kW)

SAVINGS

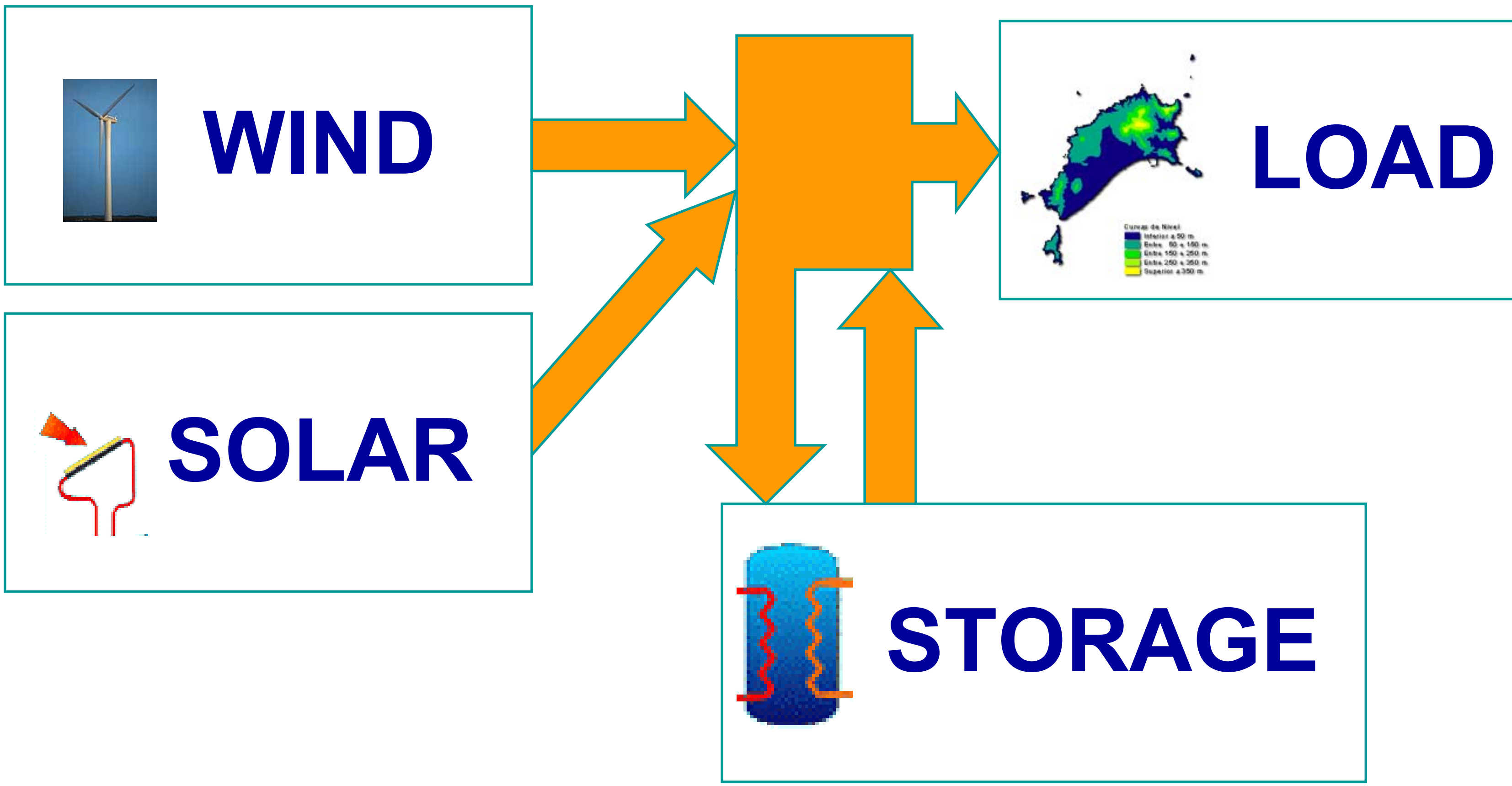
- 27 tCO_2/year

H_2RES MODEL



RESOURCES
TECHNOLOGIES
COMMODITIES
Sustainable Community
Porto Santo
Curvas de Nivel
Inferior a 50 m
Entre 50 e 150 m
Entre 150 e 250 m
Entre 250 e 350 m
Superior a 350 m
Solar
Hydrogen Storage
Cel.Comb.
DC/AC
AQS
Electrolysis
Fuel cell Trigeneration
PV panels
Electricity
Osmose inversa
Desalination
Wind
Wind turbines

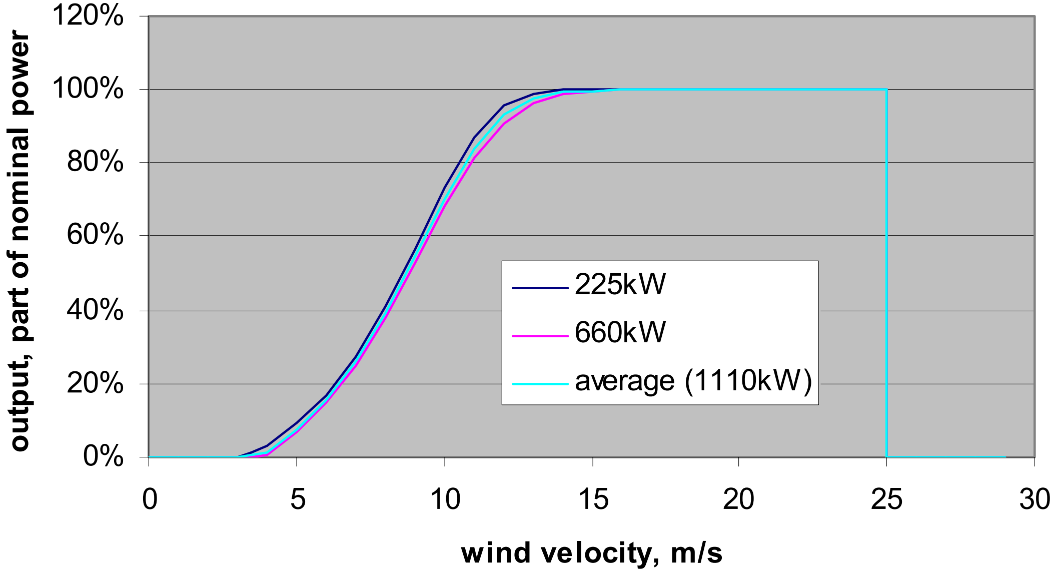
H_2RES MODULES



H_2RES – WIND MODULE

- Hourly wind velocity data obtained
- Adjusted to the hub height
- Converted into hourly potential output

$$v_z = v_{10}\left(\frac{z}{10}\right)^{0.14}$$



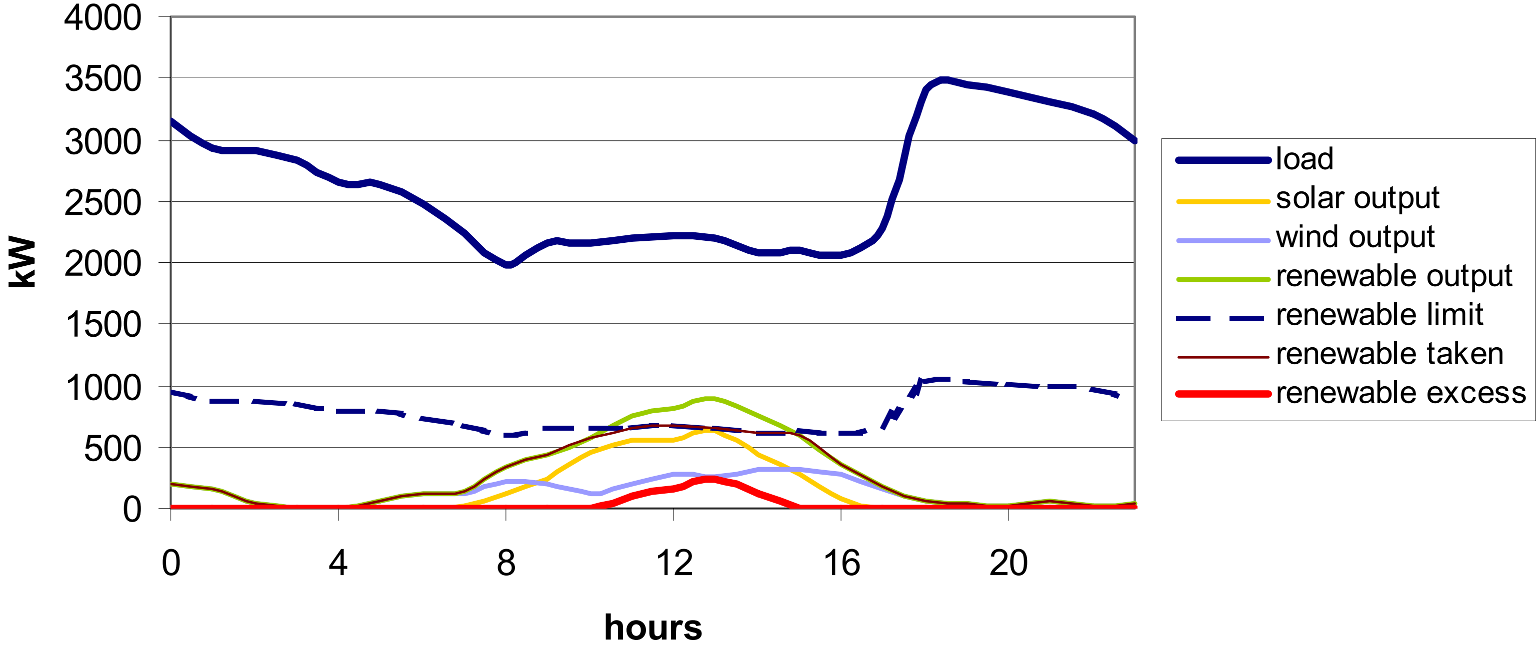
Example for VESTAS wind turbines, as installed on Porto Santo, Madeira, Portugal

H_2RES – SOLAR MODULE

- Hourly total radiation on horizontal surface obtained
- Adjusted to the inclined surface (RETSCREEN)
- Converted into hourly potential output by efficiency provided from supplier

H_2RES – LOAD MODULE

- Hourly load of power system obtained
- Limit to renewable intake
- Excess renewable rejected

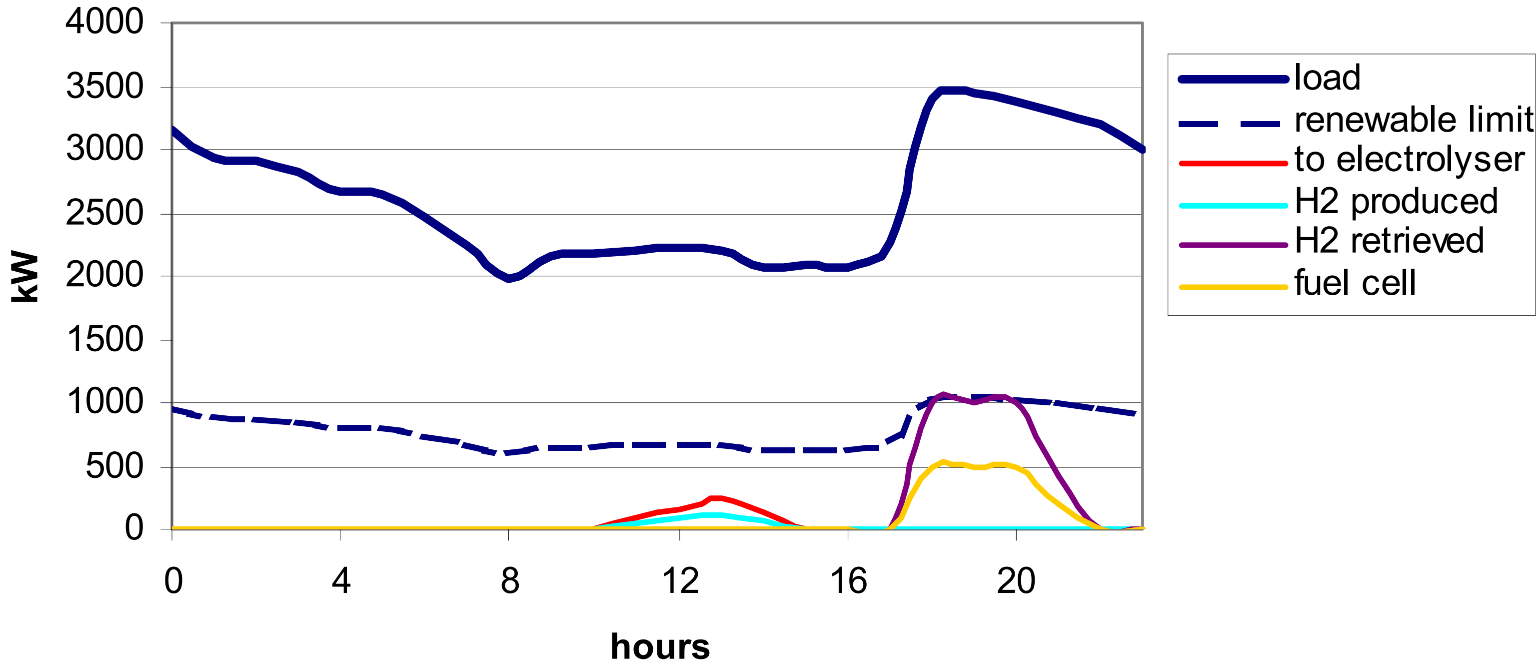


H_2RES – STORAGE MODULE – FILLING

- Excess renewable taken to electrolyser
  - If less than electrolyser capacity
  - If hydrogen tank not full
- The rest rejected – taken to desalination or other electricity dump

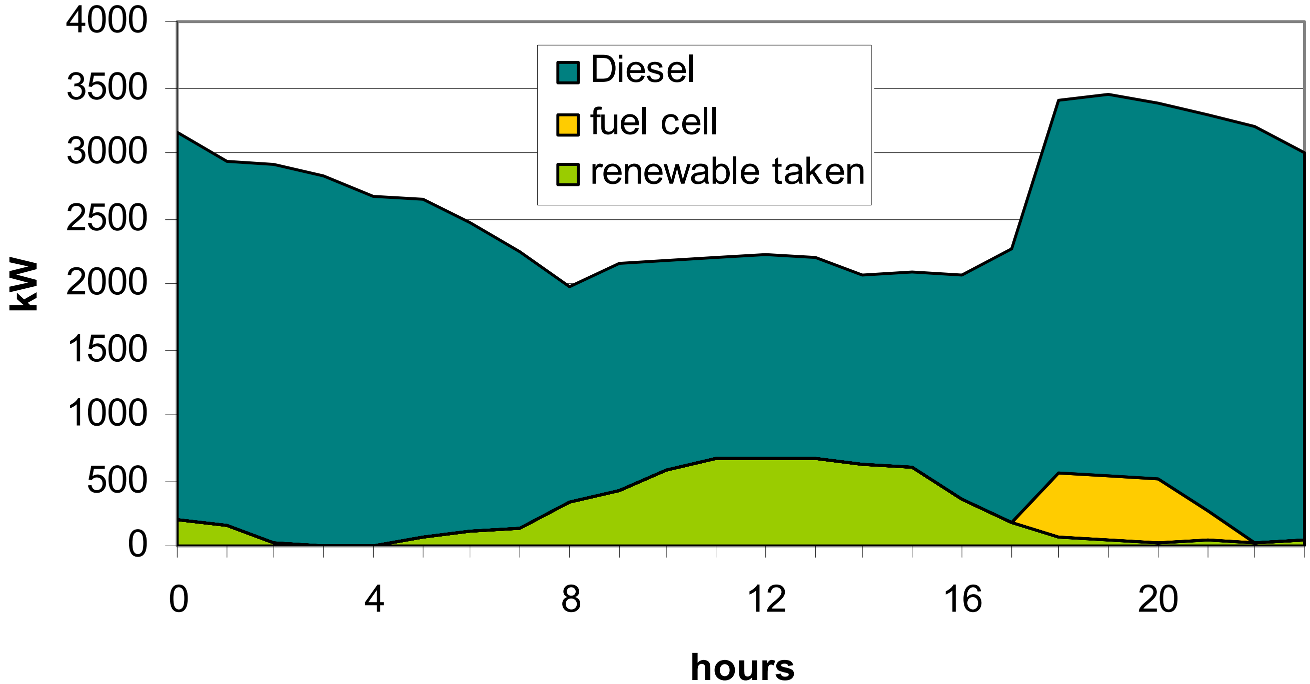
H_2RES – STORAGE MODULE – H_2 USED

- During peak hours (various definition) fuel cell is turned on using hydrogen stored until tank is empy



H_2RES MODEL

- Electricity delivered to power system

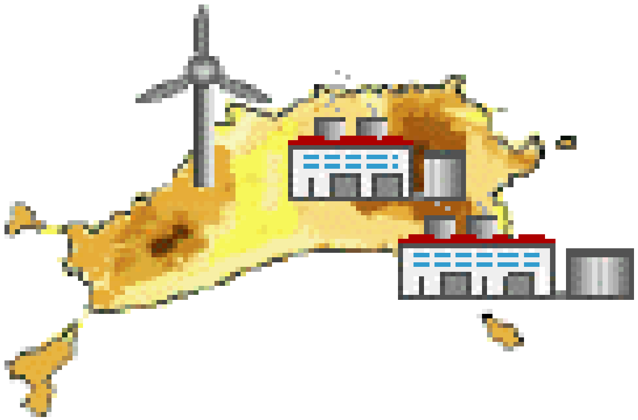


PORTO SANTO

- Population:
  5000 in winter ⇒ 20000 in summer

PORTO SANTO

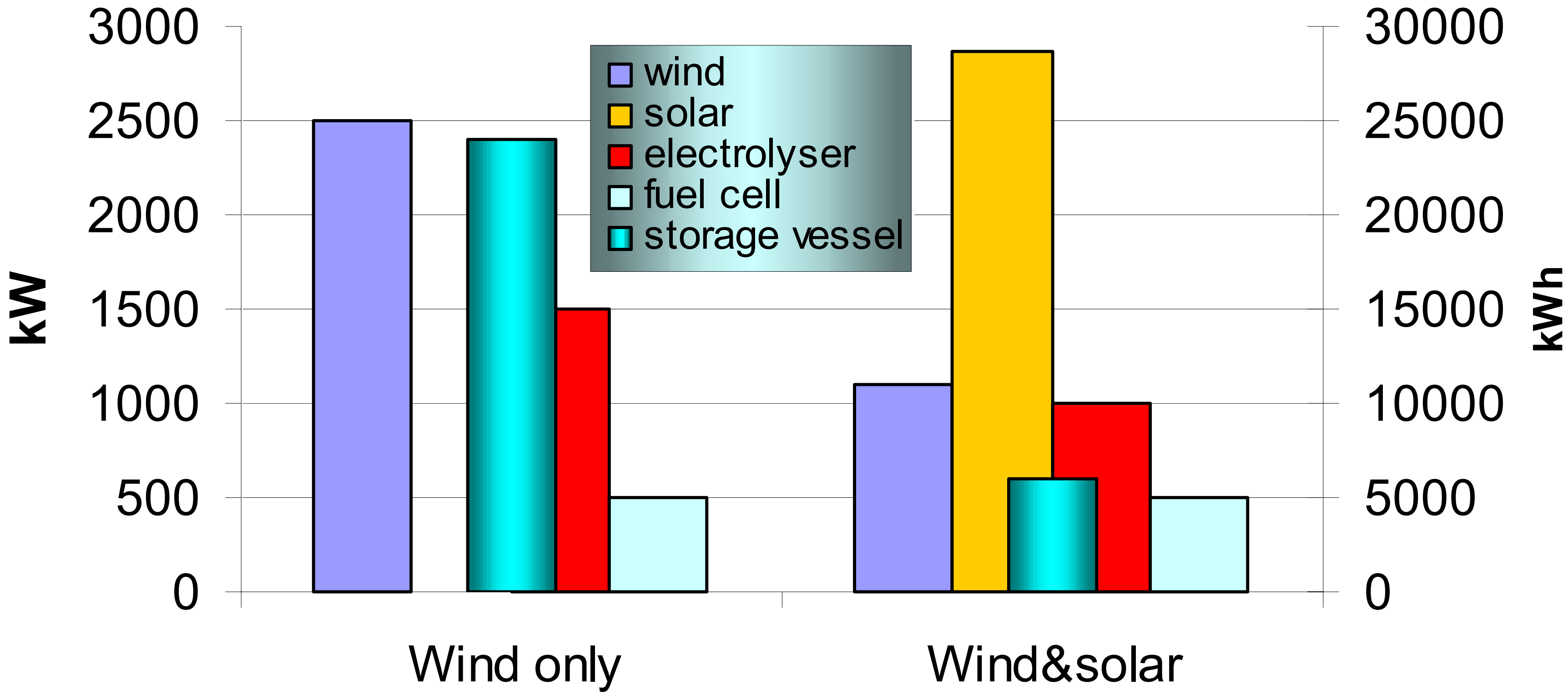
- Power system (2000):
  13.8 MW thermal + 1.1 MW wind
  24.1 GWh thermal + 1.1 GWh wind
  5.6 MW peak, 2 MW base, 20% growth



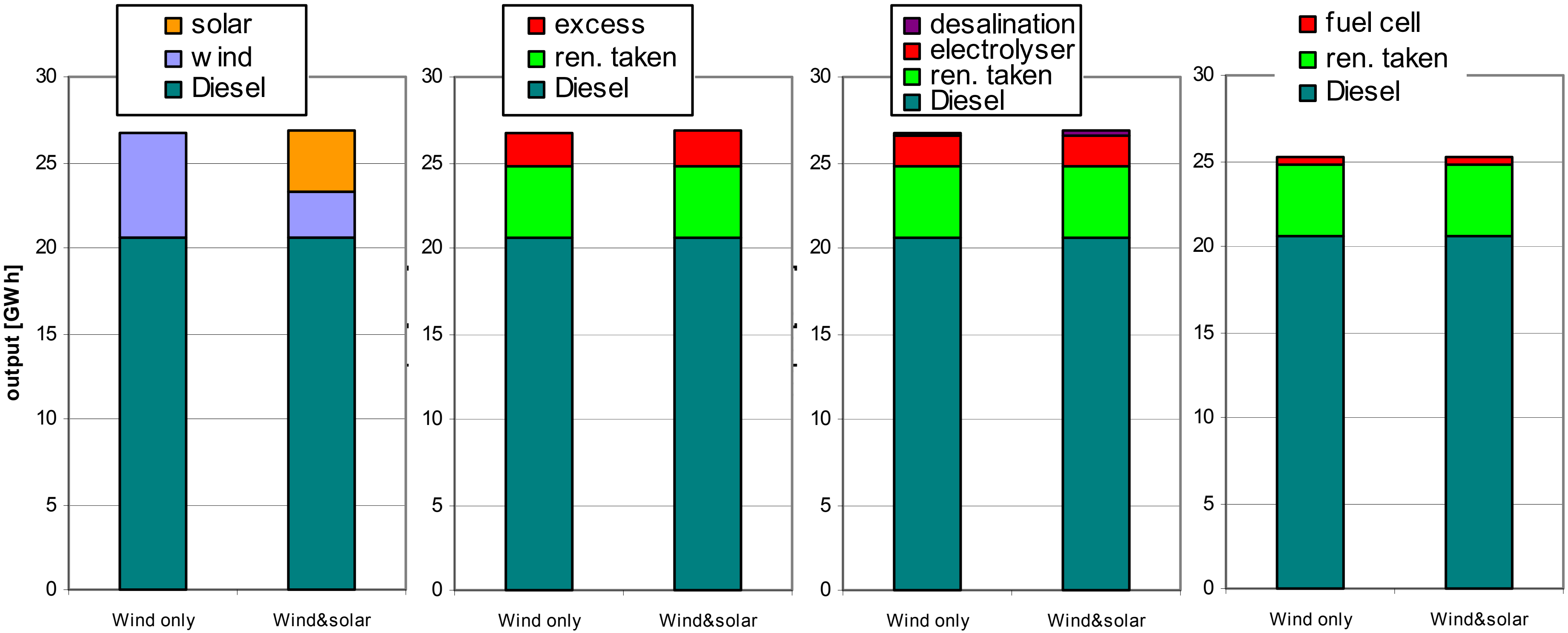
PEAK SHAVING SCENARIA

- Scenaria
  1. Wind only
  2. Wind as installed + solar
- Up to 30% renewable at any time can be taken by power system
- Excess to electrolyser
- Fuel cell for peak shaving, optimised at 1.8% of electricity delivered

PEAK SHAVING SCENARIA



PEAK SHAVING SCENARIA

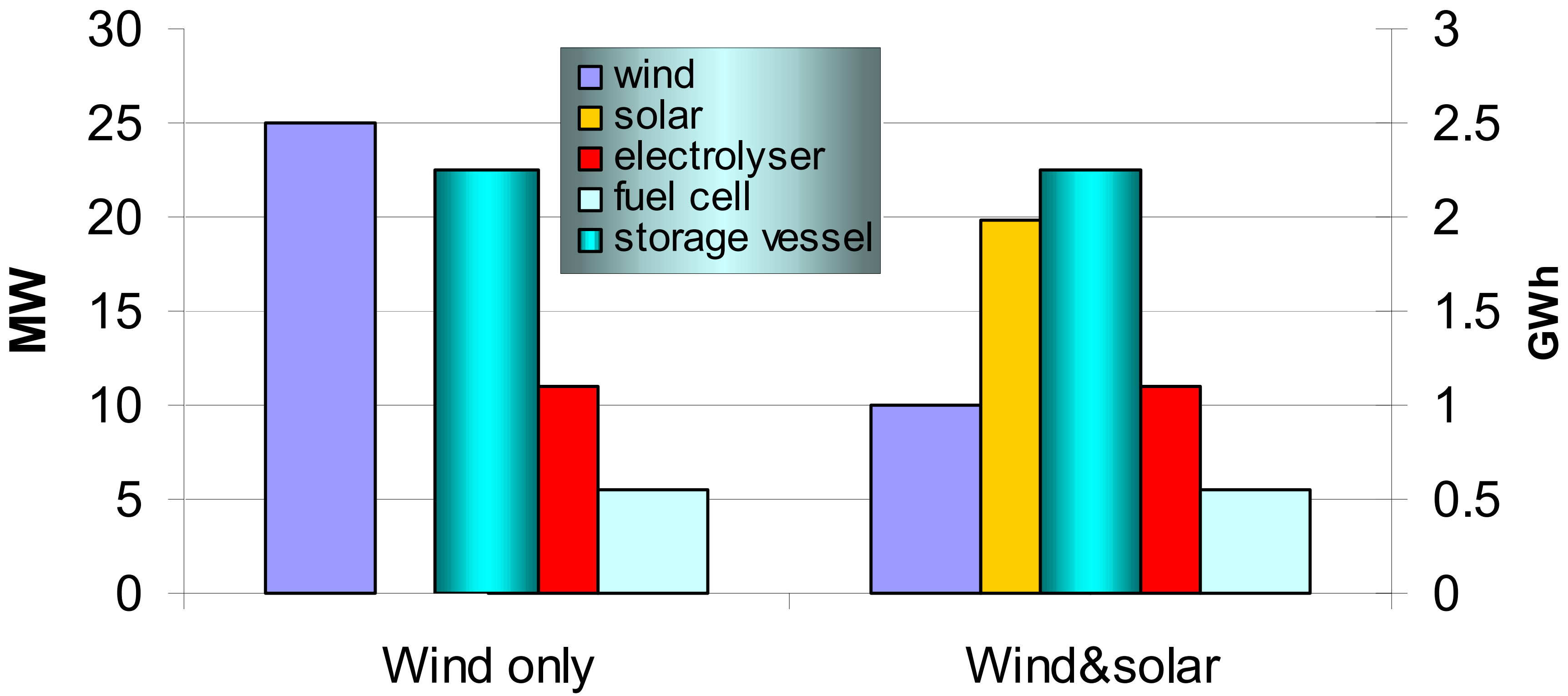


	peak serving time
Wind only	53%
Wind&solar	62%

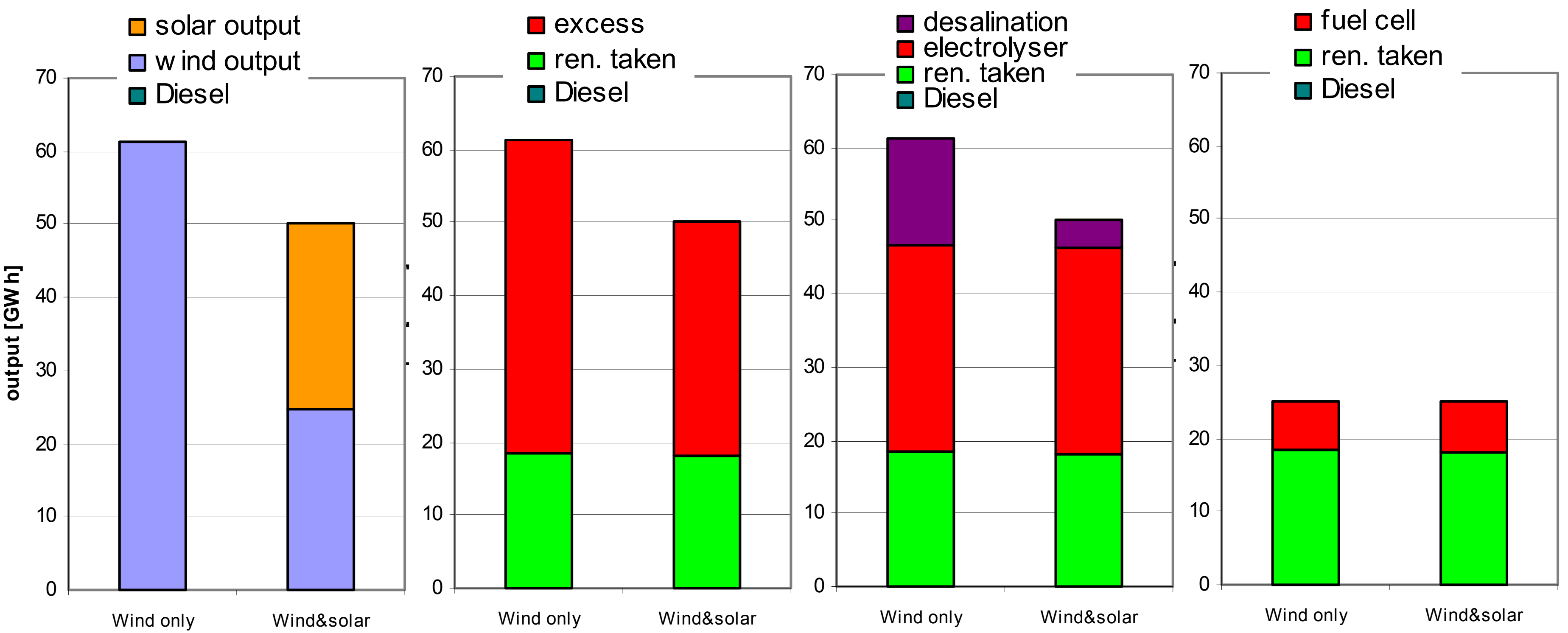
100% RENEWABLE SCENARIA

- Scenaria
  1. Wind only
  2. Wind + solar
- Up to 100% renewable at any time can be taken by power system
- Excess to eletrolyser + desalination
- Fuel cell to cover load when no renewable available
- Optimised on no Diesel

100% RENEWABLE SCENARIA

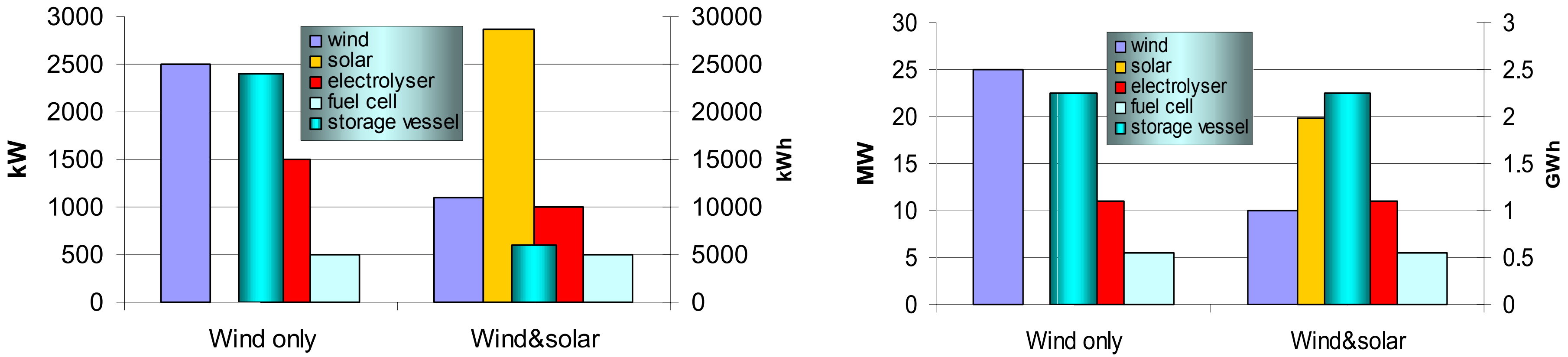


100% RENEWABLE SCENARIA



	fuel cell serving time
Wind only	37%
Wind&solar	41%

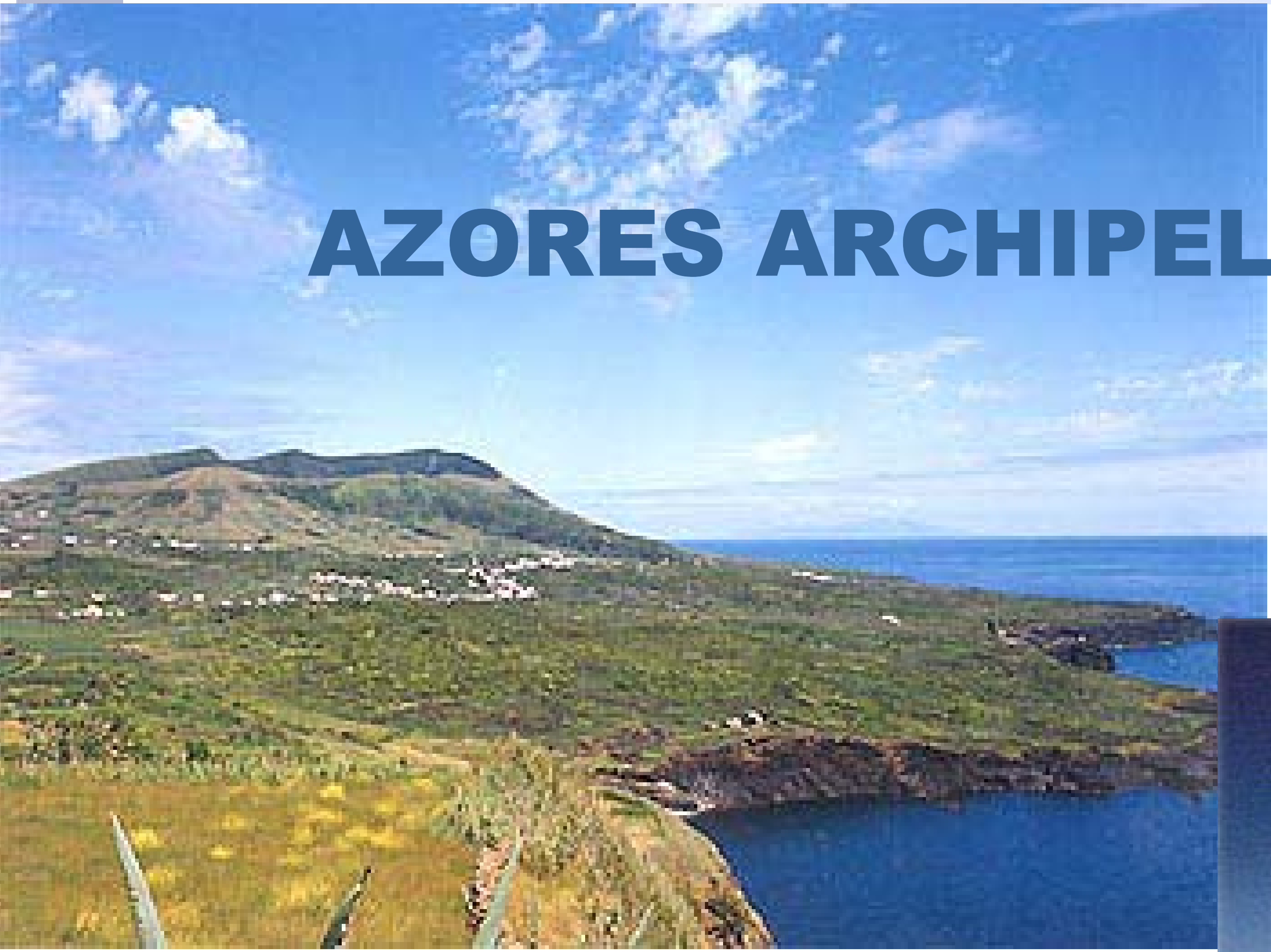
H_2RES CONCLUSIONS



- For peak shaving wind&solar takes smaller storage and electrolyser
- For 100% renewable better wind only

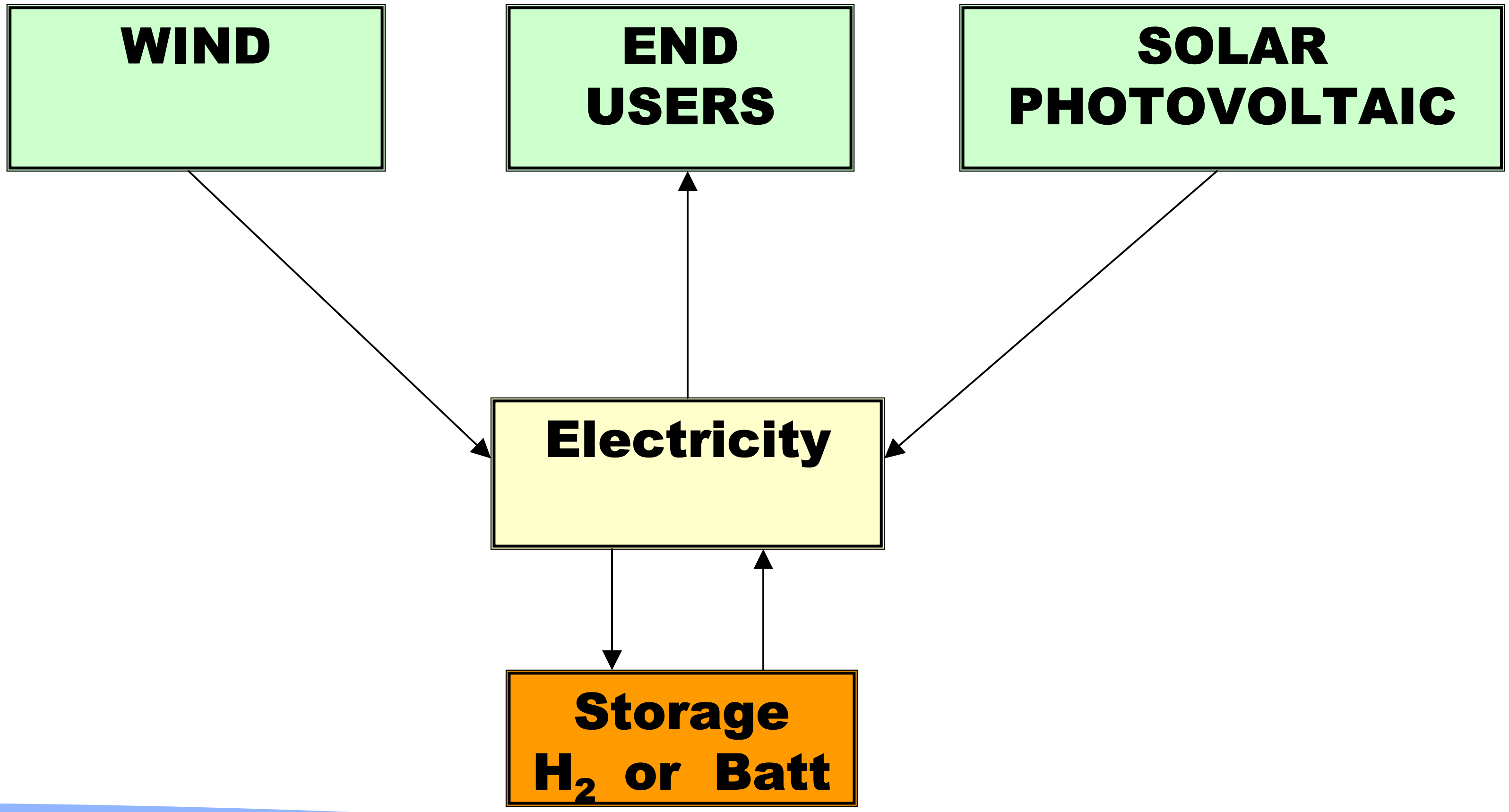
CONCLUSIONS FOR PORTO SANTO

- A model for optimising integration of hydrogen storage with intermittent renewable energy sources (wind and solar) was devised
- Storage module can be upgraded to work with batteries or pump storage
- The model was applied to Porto Santo
- The results were intriguing



AZORES ARCHIPELAGO

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

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.

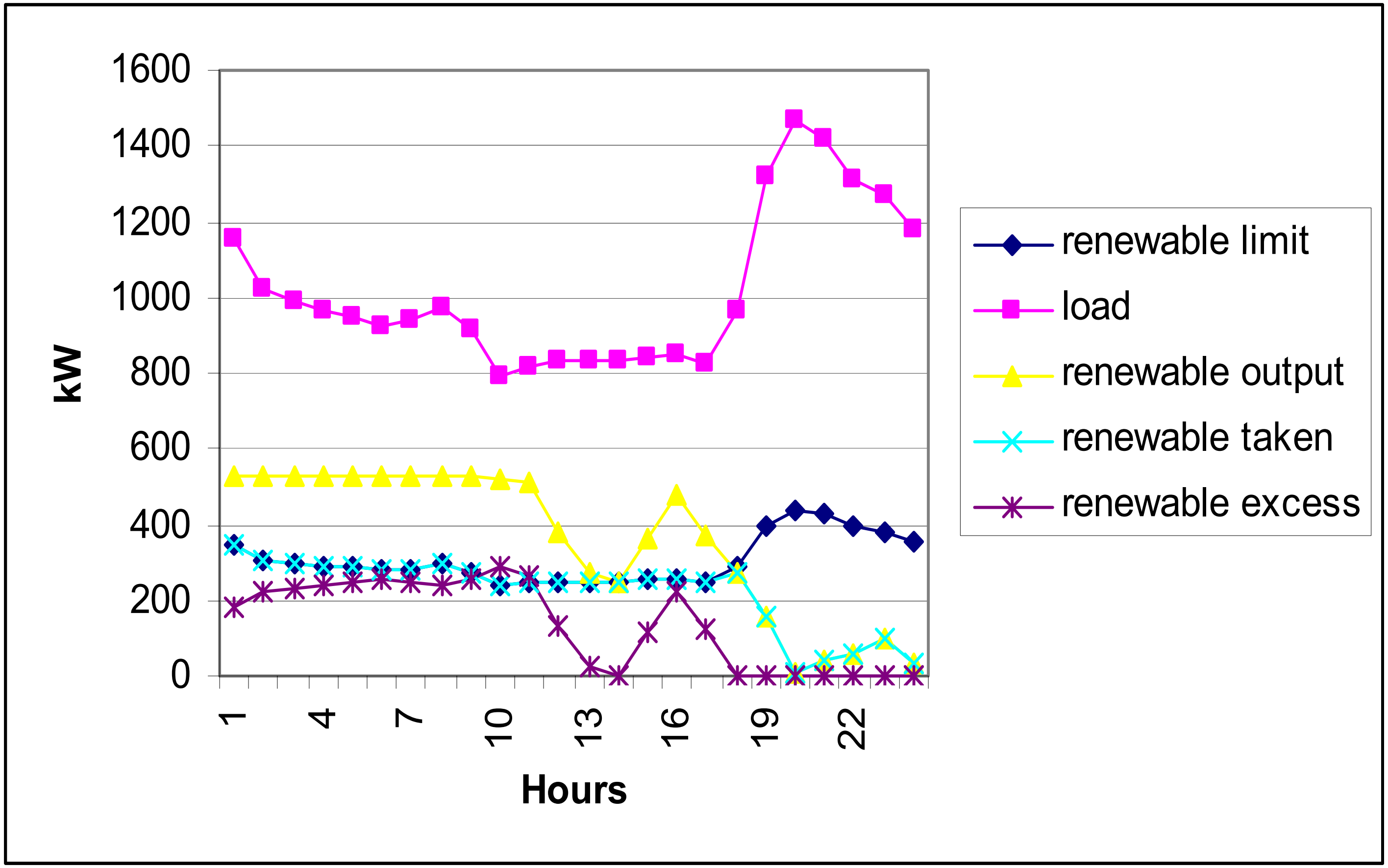
RESULTS FOR GRACIOSA ISLAND

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

RESULTS FOR GRACIOSA ISLAND

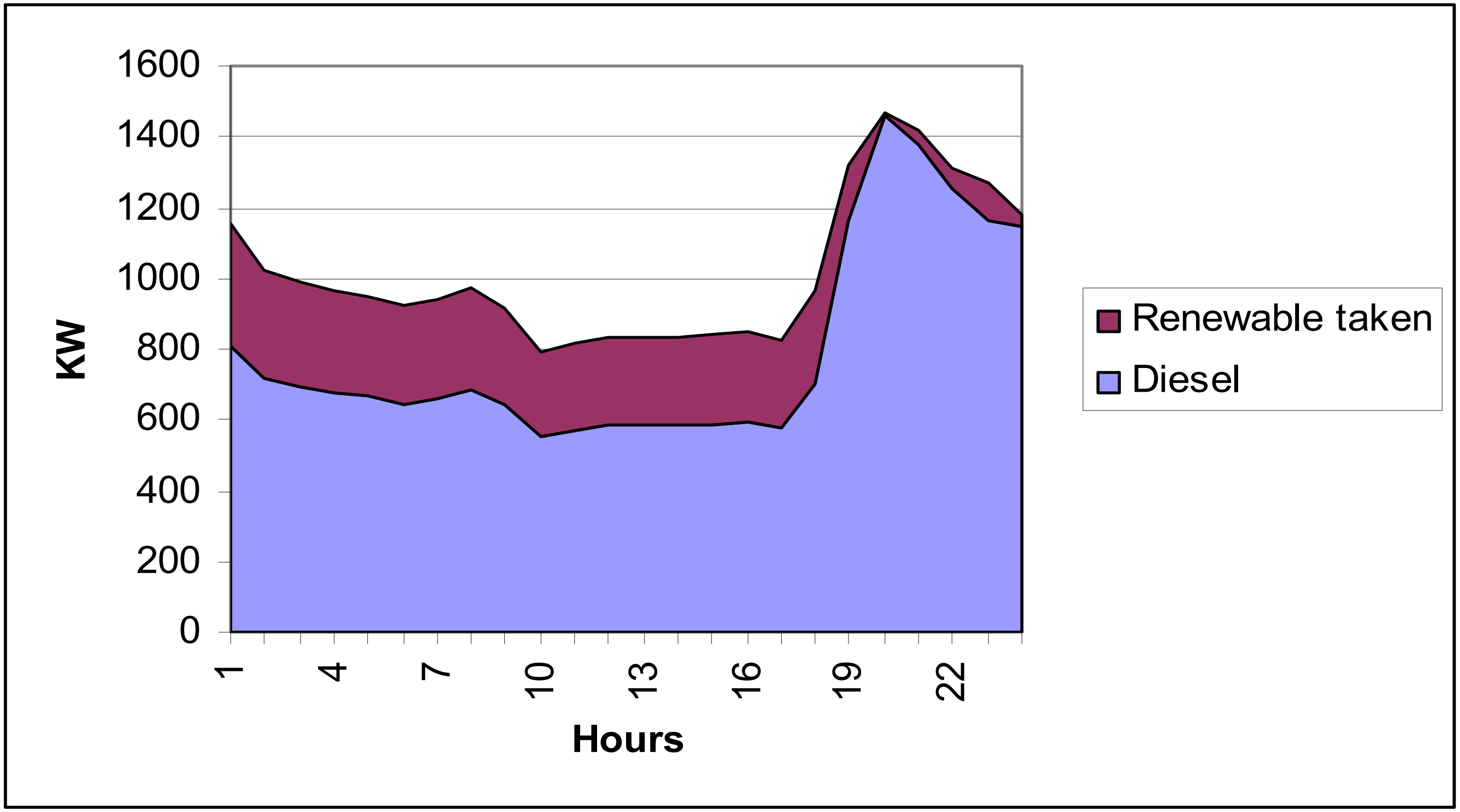
	MG. 1 (30% limit)	**MG. 2** (MG.1 + 2000 M² PV)
Wind output (GWh)	**1.3**	**1.3**
Solar output (GWh)	**0**	**0.2**
Ren. output (GWh)	**1.3**	**1.5**
Ren. taken (GWh)	**1.1**	**1.2**
Dump (GWh)	**0.2**	**0.3**

RESULTS FOR GRACIOSA ISLAND



MG.1 simulation, January 1

RESULTS FOR GRACIOSA ISLAND



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

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**

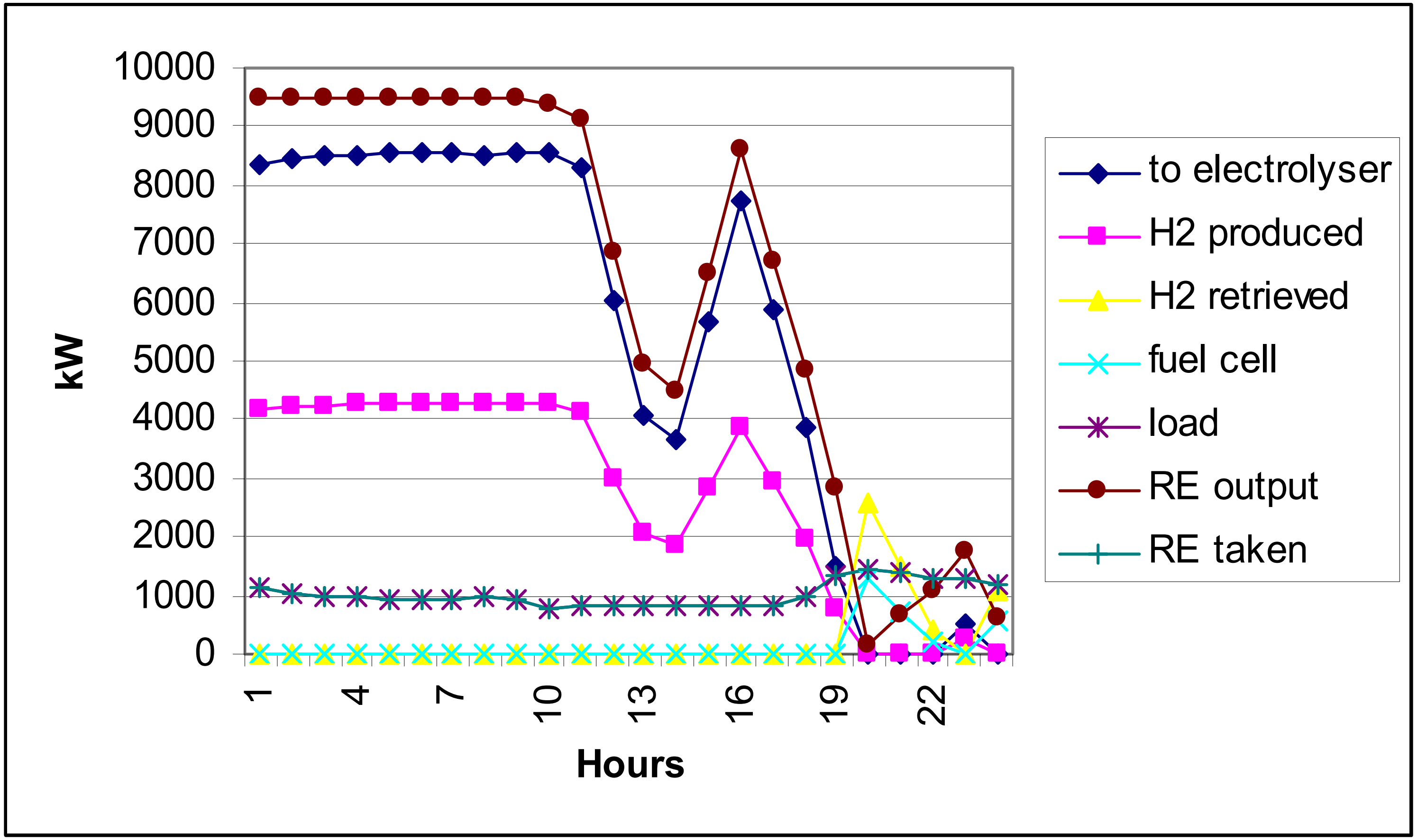
RESULTS FOR GRACIOSA ISLAND

	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**

RESULTS FOR GRACIOSA ISLAND

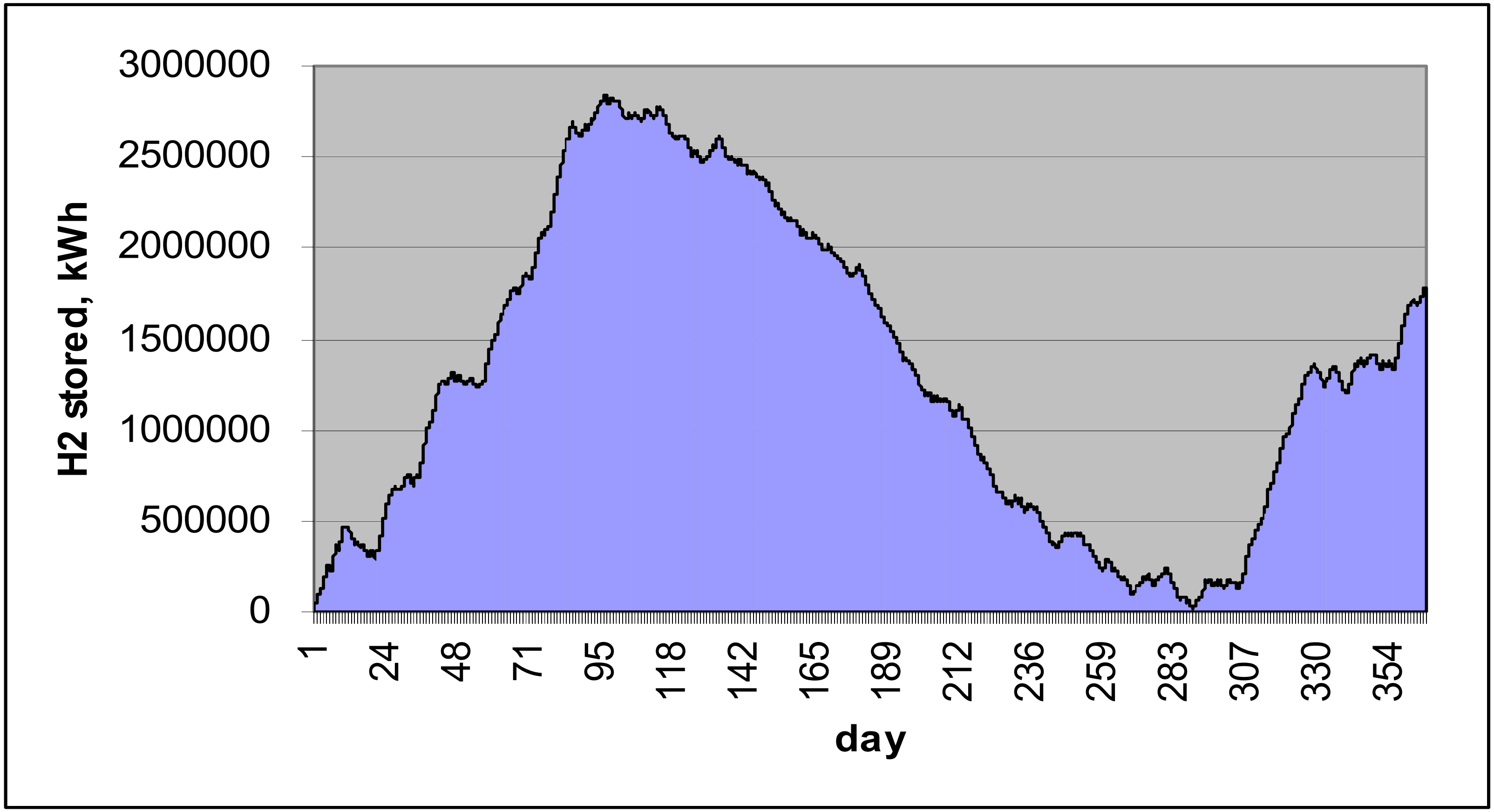
	MG. 5 (100% RE)	MG. 6 (100% RE)
Wind output (GWh)	**22.4**	**11.8**
Solar output (GWh)	**-**	**6.9**
Ren. output (GWh)	**22.4**	**18.7**
Ren. taken (GWh)	**5.8**	**6.3**
Electrolyser (GWh)	**16.6**	**12.4**
Dump (GWh)	**0**	**0**
Fuel cell (GWh)	**3.2**	**2.8**
Fuel cell serving time (%)	**45 %**	**40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

RESULTS FOR GRACIOSA ISLAND



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

RESULTS FOR GRACIOSA ISLAND



MG.5 simulation, hydrogen stored during the year

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.

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.

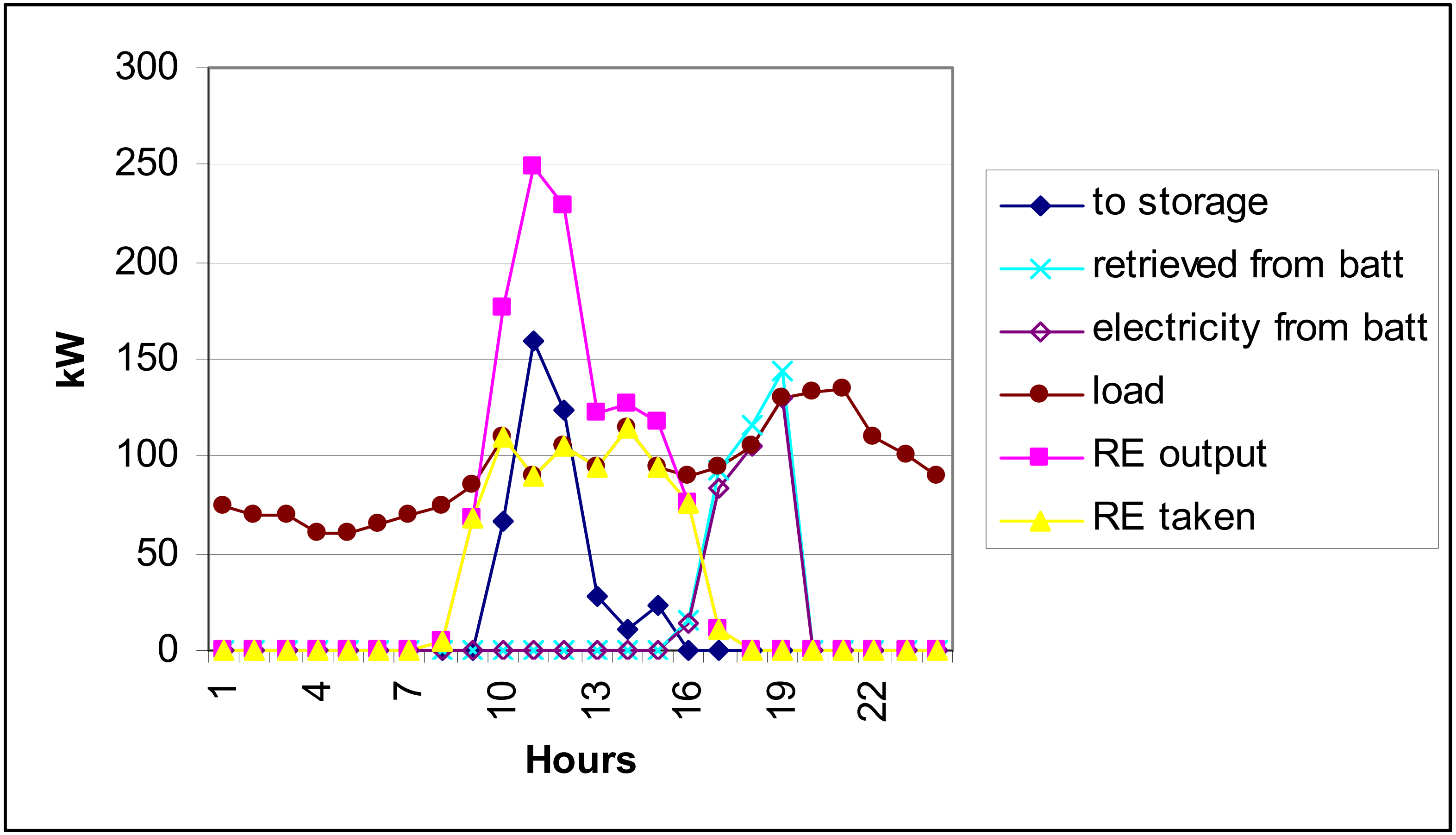
MC.2 – 80% re contribution: 10,000 m^2 PV + 150 kW (36h) battery power, in the same conditions as MC.1.

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

MC.4 - 75% RE contribution: 300 kW wind power, Pão de Açucar, + reversible hydro power plant (RHPP, 150 kW pump, 150 kW turbine, 2x2000 m3 reservoir).

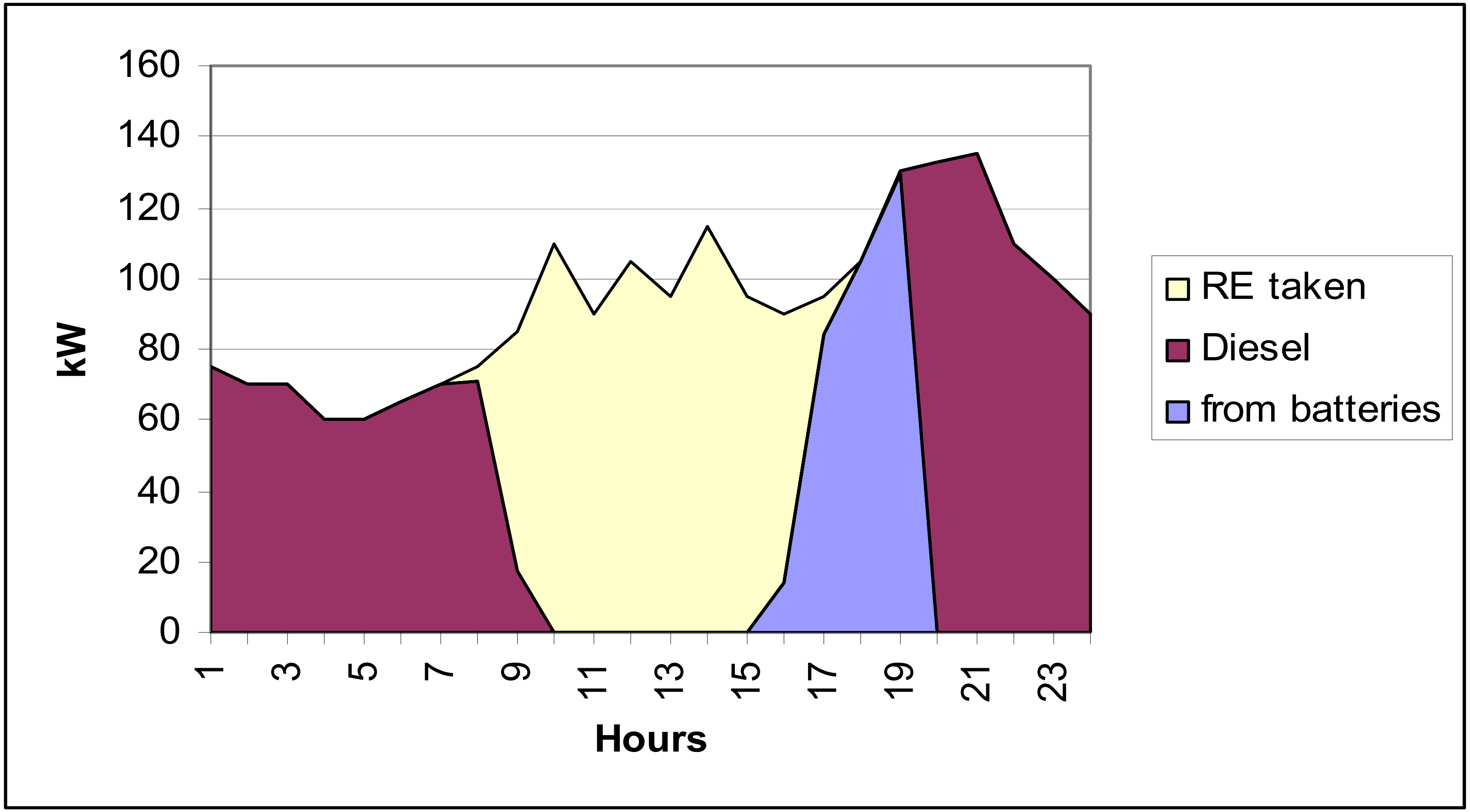
MC.5 - 96% RE contribution: 300 kW wind power, Morra da Fonte, + RHPP (100 kW pump, 150 kW turbine, 2x2000 m3 reservoir).

RESULTS FOR CORVO ISLAND



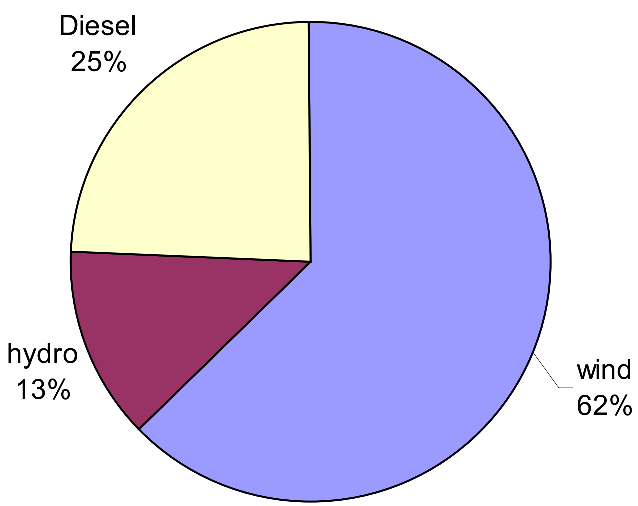
MC.2 simulation, January 1

RESULTS FOR CORVO ISLAND

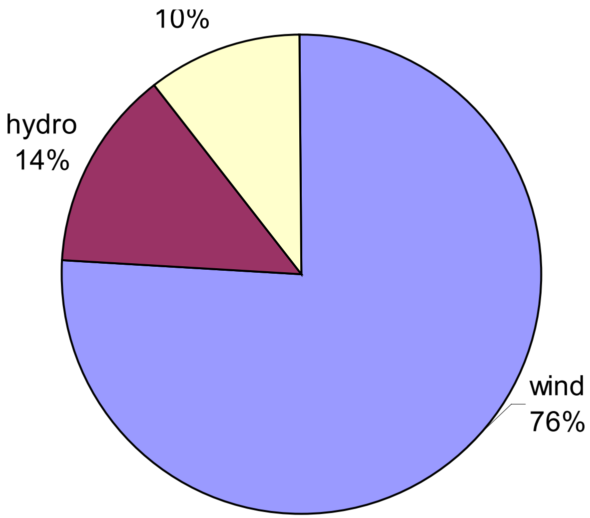


MC.2 simulation, January 1, the source of electricity taken by the power system.

RESULTS FOR CORVO ISLAND



MC.4 Pão de Açucar



MC.5 Morra da Fonte

CONCLUSIONS FOR CORVO ISLAND

- For a small energy system, very high intermittent RE penetration can only be reached by energy storage.
- PV needs large area – might be unacceptable for Corvo.
- Morra da Fonte – excellent location for wind turbine, possible to achieve 90% RE penetration with 300 kW wind – need for MT grid connection.
- Pão de Açucar – needs more study – with 300 kW wind turbine hard to achieve more than 75% RE penetration

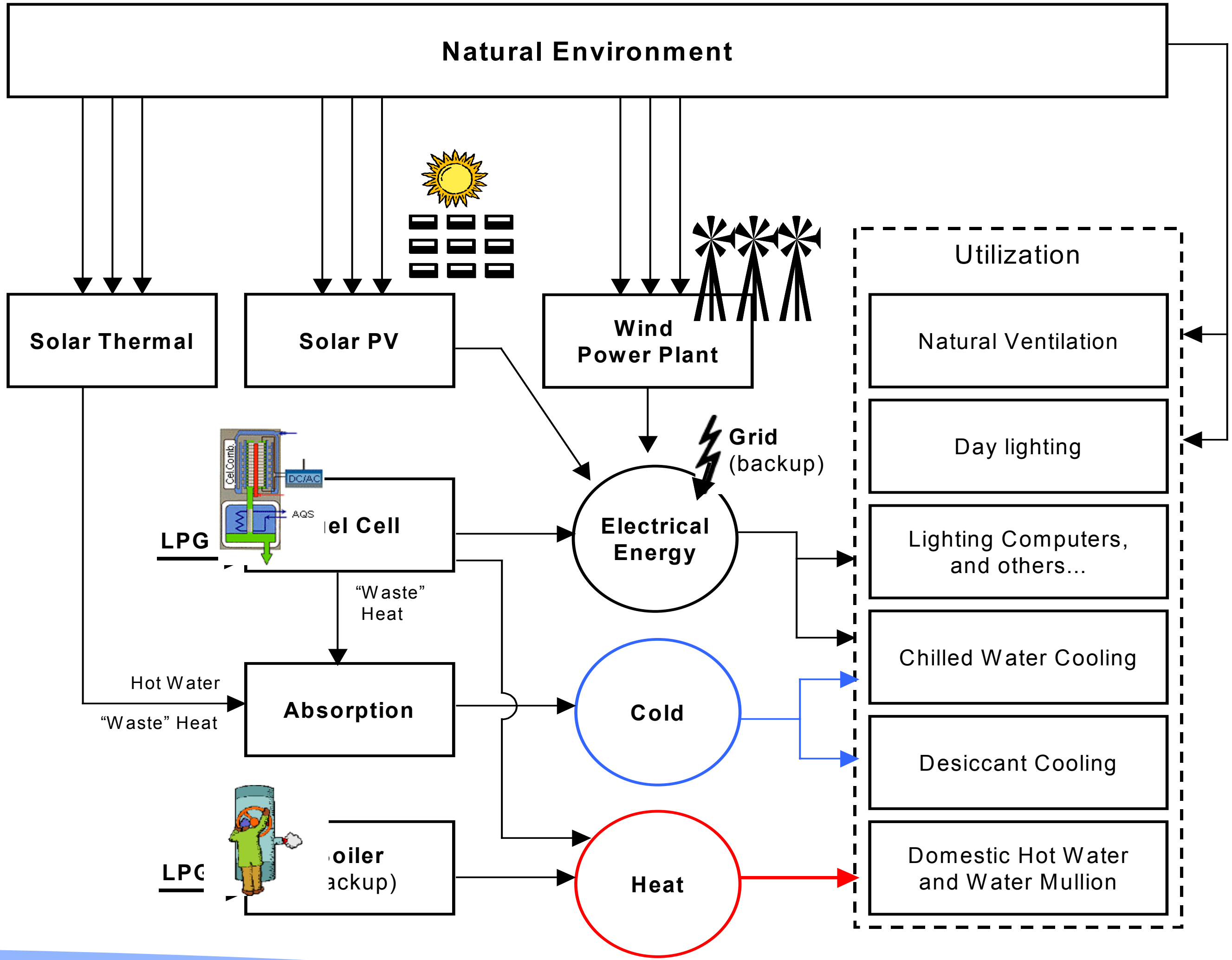
ISOLATED RURAL AREAS

ISOLATED RURAL AREAS

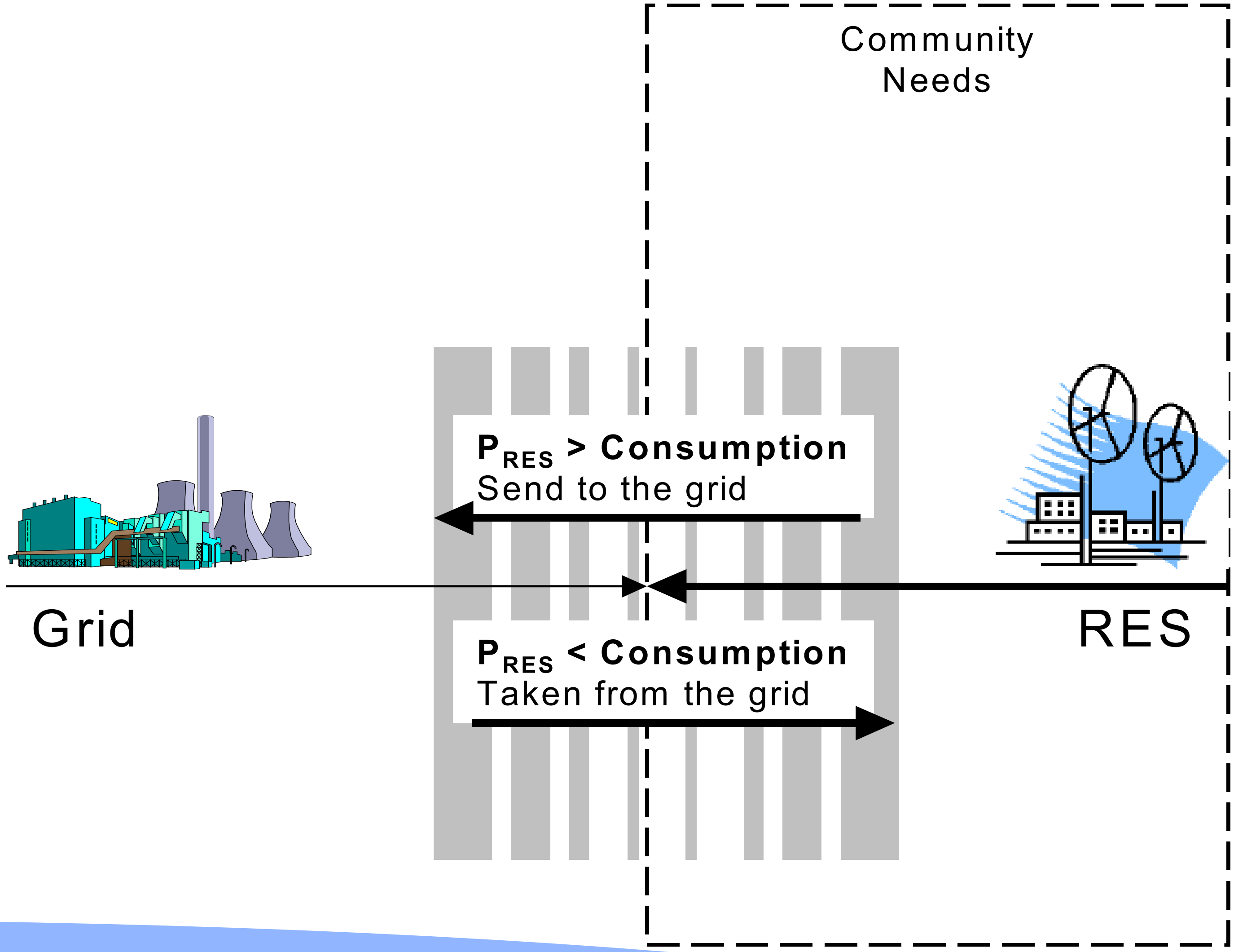
- Variable energy demands (tourism)
- Low degree of grid connection
- Protected environments
- Dificult accessibility for maintenance
- High installation costs due to remoteness

Integrating Self Supply Into End Use For Sustainable Tourism

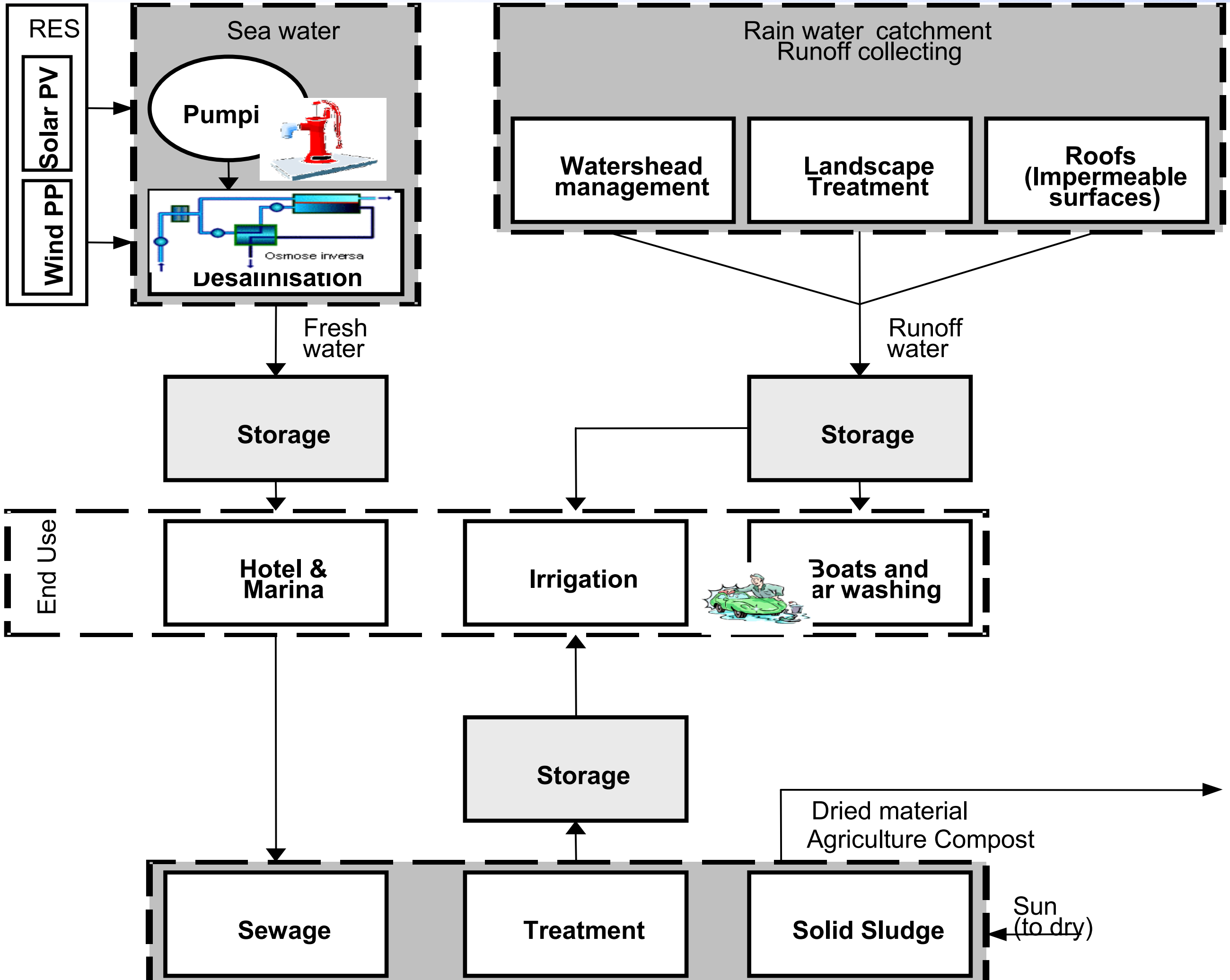
INTEGRATED ENERGY SYSTEM



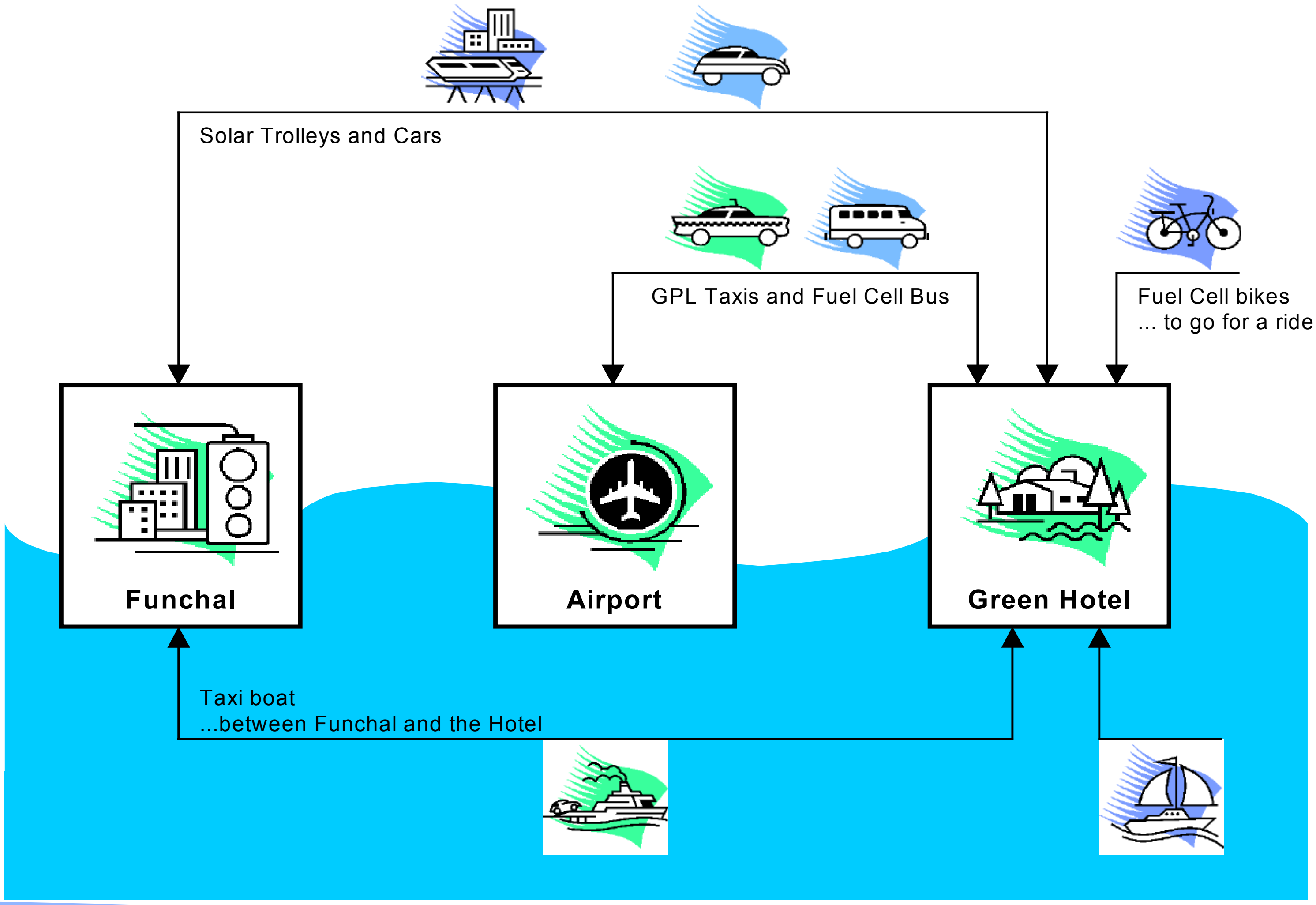
INTERFACE NETWORK / RES



INTEGRATED WATER SYSTEM



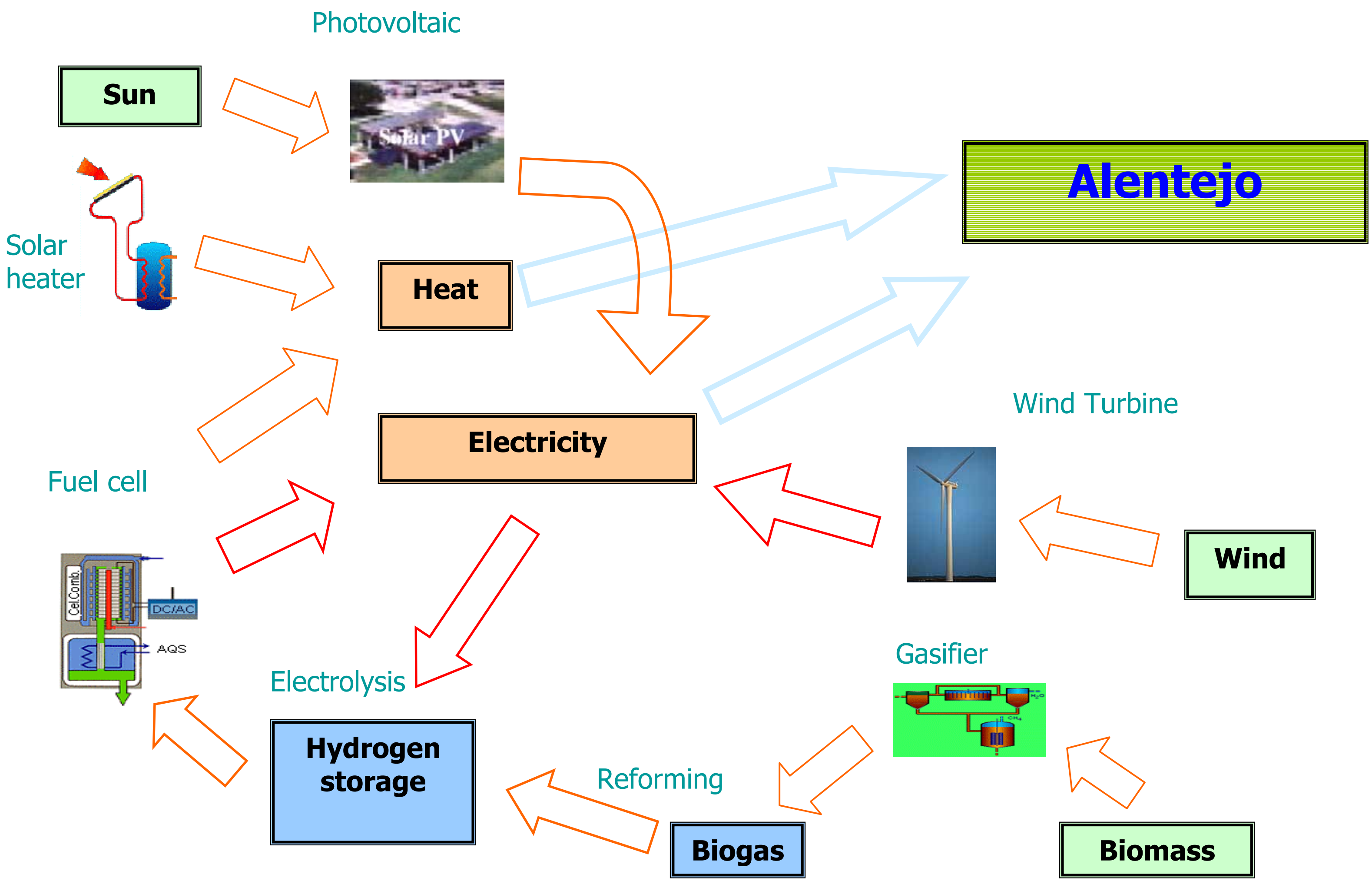
INTEGRATED MOBILITY PLAN



VIEW OF THE HOTEL AND MARINA

RURAL TOURISM IN ALENTEJO (EDEN PROJECT)

RURAL TOURISM IN ALENTEJO



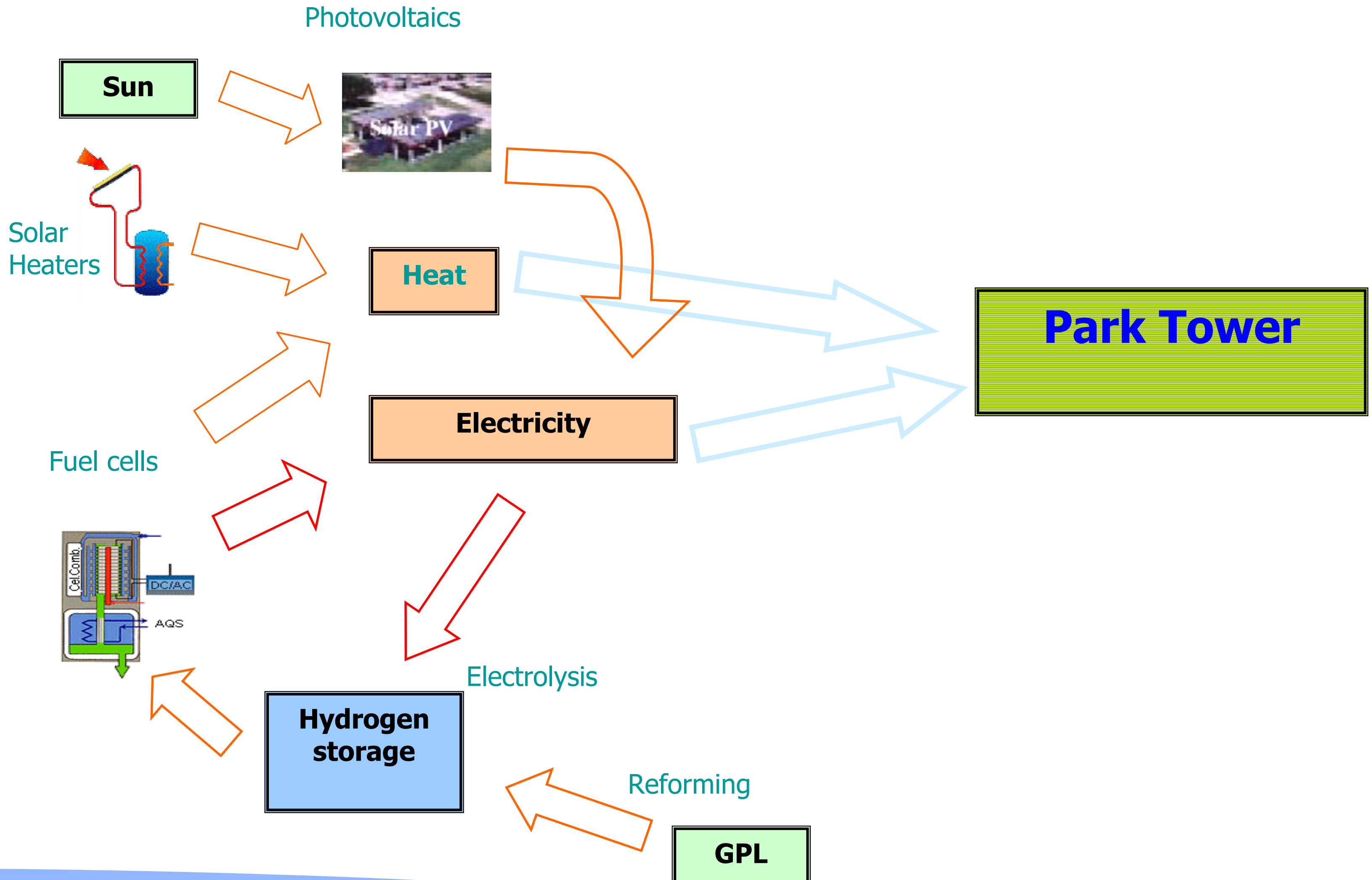
NON-ISOLATED URBAN AREAS

NON- ISOLATED (URBAN) AREAS

- Innovative approach for increasing RES awareness in Communities
- New opportunities for showcase projects involving industry and consumers
- Opportunities for residential communities
- Integrate the users of energy services in the production

MADEIRA TECNOPOLO
(EDEN PROJECT)

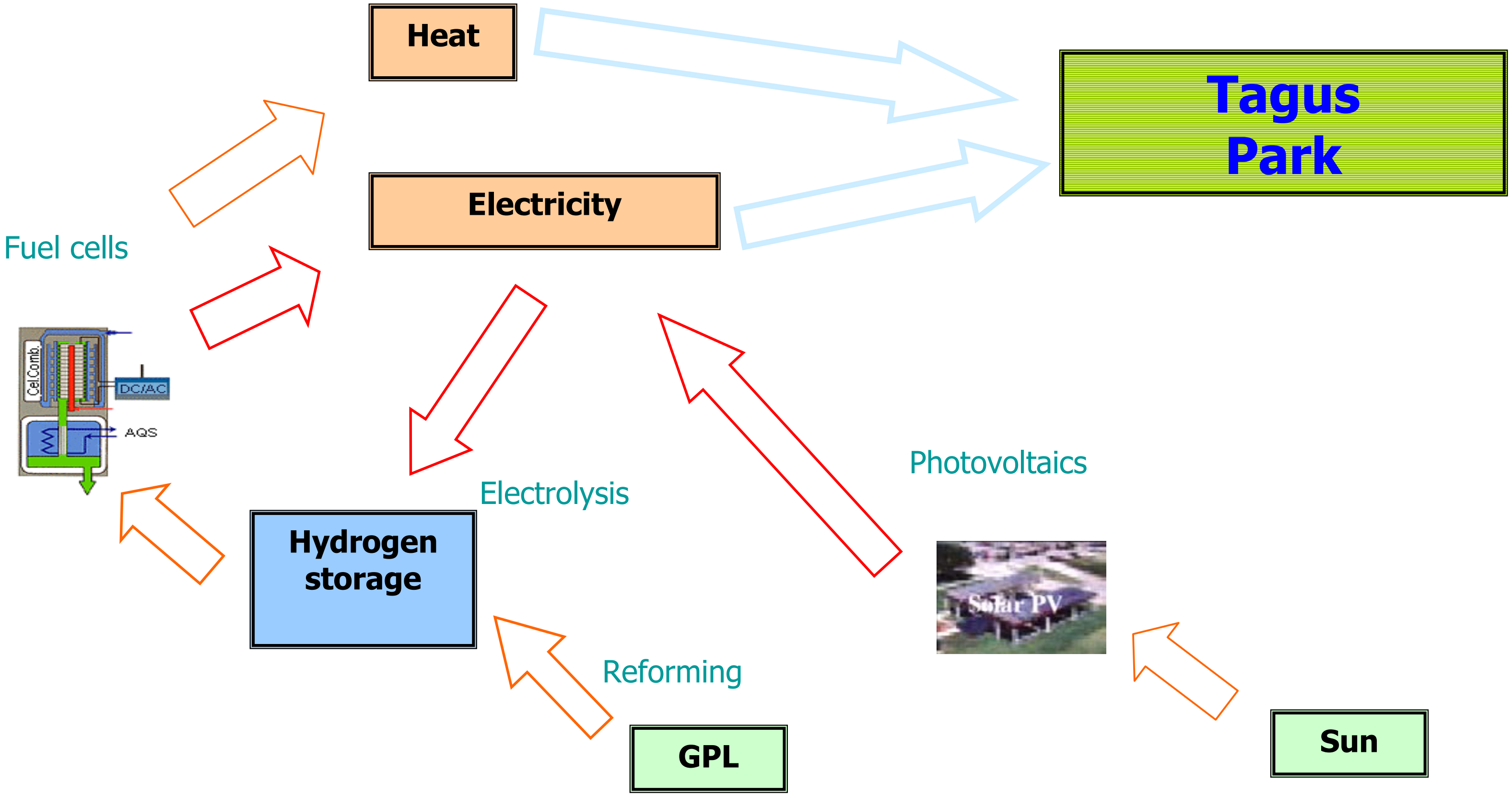
MADEIRA SCIENCE AND TECHNOLOGY PARK



TAGUS PARQUE
(EDEN PROJECT)

TAGUS PARQUE

TAGUS PARQUE



CONCLUSIONS

- Combine diverse (renewable) energy sources and technologies to resolve in an integrated way the problems of energy, water and residues
  → **Integrated solutions**

- Better integration between suply and demand

- Island and remote regions as pioneers of zero emission society (e.g. Iceland), following the prophecy of Jules Verne in "L'Île mystérieuse".

FINANCING INSTITUTIONS

- European Commission
  - DG Research
  - DG Tren
- Direcção Geral de Energia – Portugal
- Ministério da Ciência e Tecnologia - Portugal