INTEGRATION OF RENEWABLE ENERGY SOURCES AND HYDROGEN STORAGE IN PORTO SANTO

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OBJECTIVES

- To show a model optimising hydrogen storage integration with renewable energy sources
- To show a way to increase RES penetration
- To show a way for increasing security of energy supply for islands
- To show a path for sustainable development of islands
ISLANDS - PROBLEMS

- Isolation
- Small local markets
- Higher costs of energy, transport and communication
- No economies of scale
- Security of supply problems
- High strain on energy, water, waste, environment and social systems
ISLANDS – ADVANTAGES

- Renewable sources better economic viability due to depending less on size and fuel handling infrastructure.
- Usually good renewable resources.
- Renewable energy appeal to high quality tourists.
H₂RES MODEL

RESOURCES
- Solar
- Wind

TECHNOLOGIES
- Hydrogen Storage
- Electrolysis
- Fuel cell
- Trigeneration
- PV panels
- Desalination

COMMODITIES
- Electricity
- Sustainable Community Porto Santo

Desalination
H$_2$RES MODEL

- Energy planning tool
  - Small and medium power systems
  - Higher penetration of renewables
  - Integration of energy storage
  - Electricity dump: desalination or other
- Need to use time series instead of usual approach (LDC, Weibull)
H$_2$RES MODULES

WIND

SOLAR

HYDRO

LOAD

STORAGE
H₂RES – 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.
H₂RES – WIND MODULE

The graph shows the wind velocity in meters per second (m/s) over time, with the output percentage indicated. The x-axis represents the hour, and the y-axis shows the wind velocity and output percentage. The graph indicates variability in wind conditions and corresponding output over the observed period.
H₂RES – 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
*Hourly load* of power system obtained

*Limit* to renewable intake

*Excess* renewable rejected
H₂RES – 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
During peak hours (various definition) fuel cell is turned on using hydrogen stored until tank is empty.
Electricity delivered to power system
PORTO SANTO

- Population:
  5000 in winter $\Rightarrow$ 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 SCENARIO

- 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 SCENARIO

<table>
<thead>
<tr>
<th></th>
<th>Wind only</th>
<th>Wind&amp;Solar</th>
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<tbody>
<tr>
<td>Output [GWh]</td>
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<td>Diesel</td>
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<td>Total</td>
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Peak serving time:
- Wind only: 53%
- Wind&Solar: 62%

Legend:
- Solar
- Wind
- Diesel
- Excess
- Renewable taken
- Fuel cell
- Desalination
- Electrolyser
- Renewable taken
- Diesel
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 electrolyser + desalination
- Fuel cell to cover load when no renewable available
- Optimised on no Diesel
100% RENEWABLE SCENARIOS

Wind only vs. Wind & Solar

- **Wind**: 25 MW
- **Solar**: 0.5 MW
- **Electrolyser**: 30 GWh
- **Fuel Cell**: 3 GWh
- **Storage Vessel**: 1.5 GWh

[Diagram showing the comparison between Wind only and Wind & Solar scenarios]
100% RENEWABLE SCENARIOS

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fuel cell serving time

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

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