Hydrogen Applications for Small Islands

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Is Hydrogen a Hype?

Reasons:

- Availability of fossil fuels
- Decrease environmental impact of hydrocarbons use
- Energy independence & security of supply

In the future 2 basic energy carriers will exist:

- **Electricity** (lighting, informatics)
- **Hydrogen** (replacement of liquid & gaseous fuel in the transport sector, in autonomous stationary power systems and in the sector of heating)
Is Hydrogen a Hype?

Source: Shell Hydrogen
Role of RES
Role of RES

Characteristics:

- Confront the stochastic character of RES through energy storage in the form of hydrogen
- Potential of decentralised/distributed hydrogen production, using local Renewable Energy Sources
- Decrease fossil fuel imports
- Penetration of RES in the Transport Sector
H2 applications in the transport sector

Applications in Marine Transport

H2 applications in the transport sector

Applications in Road Transport

Transport sector:

The objective of the project is to create the basic infrastructure for refueling hydrogen vehicles and electric vehicles through the development of:

H₂ production unit & vehicle filling station

There will be hydrogen vehicles on the island for demonstration purposes.
Hydrogen Applications in the context of the Greek Green Island – Ai Stratis

BASIC EQUIPMENT INFO:

1) Hydrogen production unit through water electrolysis, driven only by RES, with a capacity of 60 - 100 kW, and hydrogen production capacity in the order of 10-20 Nm$^3$/hr
2) H$_2$ gaseous storage tanks at medium pressure (30 kg), metal hydride tanks (1-2 kg), H$_2$ gaseous storage tanks at high pressure (40 kg)
3) H$_2$ compressor with a compression capacity of 10-20 Nm$^3$/hr, at a pressure of 220 bar
4) Hydrogen filling station for vehicles
5) Hydrogen ICE for stationary applications with a capacity of 90 kW (installed at the central power station of the island)
Hydrogen Applications in the context of the Greek Green Island – Ai Stratis

Vehicles:

1) Hydrogen driven forklift
2) Small van or a sweeper driven by fuel cells
3) Fuel cell scooter
4) Replacement of diesel ICE with H2 ICE & integration in a fishing boat
Hydrogen Applications in the context of the Greek Green Island – Ai Stratis

Autonomous stationary applications:

1) CHP applications based on Fuel Cells for 5 non-interconnected small farms
2) 2 UPS applications based on Fuel Cells (telecom applications)
3) Demonstration application based on Fuel Cells (Lighting of the municipality building)
The STORIES Project: “Addressing barriers to storage technologies for increasing the penetration of intermittent energy sources”

Scope:

To increase RES penetration in remote, or non-interconnected areas through the adoption of energy storage methods
Expected Results:

- Increase exploitation of RES in islands by identifying all suitable solutions to increase renewable energies penetration
- Assessment and mapping of the national regulatory and legislative framework of all EU Member States applying in remote regions
- Quantifications of the social, economic and environmental benefits of energy storage applications and grid control systems
- Estimation of economic aspects such as costs of power generation from conventional fuels in comparison to RES-energy storage power systems
- Results from different tariff schemes for combined RES-energy storage power systems in various islands/remote regions all over Europe
- Development of a Roadmap including list of recommendations for the adoption of hybrid RES-energy storage power systems
- Communication and dissemination throughout the project with the key target groups to increase public acceptance of RES-energy storage systems
Hydrogen Applications

Advantages

• Zero emissions
• Increased efficiency
• Applications in Transport
• Liberation of energy market

Disadvantages

• Increased capital cost
• High requirements for hydrogen purity
• Public acceptance
The case study of Milos

• Existing power system
• Proposed power system based on RES & H2 Technologies
• Subsidised power system based on RES & H2 technologies
• More info on (http://www.storiesproject.eu/)
Milos island

- South western Aegean Sea, Cyclades
- 86 miles from Piraeus
- Island Area: 151 km$^2$, Coast length: 125 km
- 5,000 permanent inhabitants
- 5 times increase of population during summer
Milos Power Demand

Milos: Architecture of the existing power system

- 8 Thermal Generator Sets
  - 2 Sulzer 7TAF48 Units (1.75 MW, Heavy Oil)
  - 3 MAN G9V30/45 Units (0.7 MW Heavy Oil)
  - 1 CKD 12V27,5-B8S Unit (2 MW, Diesel)
  - 1 CKD 12V27,5-B8S Unit (1.9 MW, Diesel)
  - 1 FINCANTIERI BL230.12P Unit (1.75 MW, Diesel)

- 3 Wind turbines
  - 2 Vestas V – 44 (0.6 MW)
  - 1 Vestas V – 52 (0.85 MW)
Basic Simulation Inputs

- Heavy Oil: 0,34 €/L
- Diesel: 0,68 €/L
- Thermal generator sets: 250 – 300 €/kW
- Wind turbines: 1.200 €/kW
- Emission costs: 21 €/tn CO₂
- Project lifetime: 20 years
Simulation Results
Existing Power System

Monthly Average Electricity Production

- Wind
- SULGER, 7TAF48
- SULGER, 7TAF48
- MAN, G9V30/45
- MAN, G9V30/45
- MAN, G9V30/45
- CKD, 12V27, 5-B8S
- CKD, 12V27, 5-B8S
- FINCANTIERI, BL230.12P
Simulation Results
Existing Power System

• Cost of Energy Production (COE): 0,114 €/kWh
• Energy produced from Wind: 5.316.007 kWh/yr
• Renewable fraction: 0,134
• Heavy Oil: 8.128.720 L/yr
• Diesel: 704.548 L/yr
Milos: Architecture of the proposed power system

- 4+1 Thermal Generator Sets
  - 2 Sulzer 7TAF48 Units (1.75 MW Heavy Oil)
  - 2 MAN G9V30/45 Units (0.7 MW Heavy Oil)
  - 1 Rental Unit (1.032 MW, April-September)

- 30 Wind turbines
  - 2 Vestas V – 44 (0.6 MW)
  - 28 Vestas V – 52 (0.85 MW)
  - Electrolyser (2 MW)
  - Fuel Cell (PEM, 1 MW)
  - Hydrogen Tank (4,000 kg)
Basic Simulation Inputs

- Heavy Oil: 0,34 €/L
- Diesel: 0,68 €/L
- Thermal generator sets: 250 – 300 €/kW
- Wind turbines: 1.200 €/kW
- Emission costs: 21 €/tn CO₂
- Electrolyser: 2.000 €/kW
- Fuel Cells: 3.000 €/kW
- Hydrogen tanks: 800 €/kg
- Project lifetime: 20 years
Simulation results
Proposed power system

Monthly Average Electricity Production

- Wind
- SULGER, 7TAF48
- SULGER, 7TAF48
- MAN, G9V30/45
- MAN, G9V30/45
- Rental
- Fuel Cell
Simulation results
Proposed power system

• Cost of Energy production (COE): 0,144 €/kWh
• Energy produced from Wind: 69.124.688 kWh/yr
• Renewable fraction: 0,85
• Heavy Oil: 3.266.430 L/yr
• Diesel: 147.023 L/yr
Basic Architecture of Systems

Vestas V - 52
Vestas V - 44
SULGER, 7TAF48
MAN, G9V30/45
MAN, G9V30/45
MAN, G9V30/45
CKD, 12V27, 5-88S
CKD, 12V27, 5-88S
FINCANTIERI, BL2...

Milos Load Profile
109 MWh/d
8.9 MW peak

Hydrogen tank

Electrolyzer

Vestas V - 52
Vestas V - 44
SULGER, 7TAF48
MAN, G9V30/45
MAN, G9V30/45
Man, G3V30/45
Fuel Cell
Rental

Milos Load Profile
109 MWh/d
8.9 MW peak
## Simulation Results

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Existing System</th>
<th>Proposed hybrid system without subsidies</th>
<th>Proposed hybrid system with subsidies (30% on WT &amp; 50% on H2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost of Energy (€/kWh)</td>
<td>0,114</td>
<td>0,144</td>
<td>0,112</td>
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<tr>
<td>RES penetration</td>
<td>13.4%</td>
<td>85%</td>
<td>85%</td>
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<tr>
<td>Number of Thermal Units</td>
<td>8</td>
<td>4+1</td>
<td>4+1</td>
</tr>
<tr>
<td>Wind turbines</td>
<td>3</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Diesel (L/yr)</td>
<td>704,548</td>
<td>154,906</td>
<td>154,906</td>
</tr>
<tr>
<td>Heavy oil (L/yr)</td>
<td>8,128,720</td>
<td>3,054,863</td>
<td>3,054,863</td>
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</table>
## Emissions (kg/yr)

<table>
<thead>
<tr>
<th>Emissions</th>
<th>Existing System</th>
<th>Proposed hybrid system</th>
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</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>26,961,874</td>
<td>9,841,757</td>
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<tr>
<td>CO</td>
<td>57,416</td>
<td>21,809</td>
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<tr>
<td>Unburned H/C</td>
<td>6,360</td>
<td>2,416</td>
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<tr>
<td>Particulate matter</td>
<td>4,328</td>
<td>1,644</td>
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<tr>
<td>SO₂</td>
<td>525,409</td>
<td>196,873</td>
</tr>
<tr>
<td>NOₓ</td>
<td>512,329</td>
<td>194,607</td>
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</table>

CONCLUSIONS

The introduction of hydrogen as energy storage method in Milos results in:

• relatively small increase in the power generation cost of the island (ca. 26%)

• huge increase on RE penetration on the island (from 13% to 85%)

• significant reduction in emissions produced (especially CO$_2$)

• further reduction on the cost of hydrogen energy equipment and the introduction of external costs makes the hydrogen-based system economically competitive to the existing one
GREEK H2 & FUEL CELLS TECHNOLOGY PLATFORM

- Established in 2006
- Similar structure to the European HFP
- 4 working Groups
  - Hydrogen production
  - Hydrogen storage & distribution
  - Hydrogen applications (stationary & transport)
  - Socio-economic issues
- Developed the Greek H2 and Fuel Cells Roadmap in 2007 (already submitted to Ministry of Development and the GSRT)
PROPOSALS OF THE GREEK HFP

- Inclusion of H2 & FC technologies in the national energy planning.
- Call for a demonstration project where energy storage in the form of pump hydro, H2 & desalination for island power systems in combination with RES will be studied.
- Calls for proposal from GSRT for all fields of H2 & FC technologies.
PROPOSALS OF THE GREEK HFP

- Introduction of a support framework for the development of H2 & FC applications.
- Modifications to the existing Law (3468/2006) for RES & CHP.
- Subsidies on capital cost combined with promotional feed-in tariffs for autonomous power systems such as the islands.
- Support of 2 Lighthouse Projects (Milos & Ios).
THANK YOU !!