HYMENSO

Hybrid CSP – PV Plants for MENA Region

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The University of Jordan (Jordan)
CDER (Renewable Energy Development Center, Algeria)
CRTEn (Research and Technology Centre of Energy, Tunisia)
University of Patras (Greece)

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Project Objectives

HYMENSO aims at increasing the deployment of solar power plants in the MENA region, considering the specific boundary conditions in Tunisia, Algeria and Jordan.

It may have an impact on the energetic and environmental sector and provide improvements to the social and labor situation in these countries.
Work Packages

• **WP1 Market Research**: meteorological conditions, electricity demand, water and fuel costs, energy policy, potential sites, etc. for Jordan, Tunisia and Algeria.

• **WP2 Technology Development**: select CSP-PV technologies, determine technical and economic parameters, calculate yearly energy yield and search optimal configurations.

• **WP3 Demonstration**: Identify infrastructure at the partner’s facilities to be used for data collection, refurbish those systems, operate and gather measured data.

• **WP4 & WP5 Knowledge Transfer & Dissemination** of project results
Main Results: WP1 Market Research

Sites Selected for Simulation

Ma’an, Jordan
Source: Google 2018

Ghardaia, Algeria
Source: Google 2018

Tataouine, Tunisia
Source: Google 2018
Main Results: WP1 Market Research

Location of enerMENA meteostations

Source: DLR

Solar irradiance model calculations and validation

Methodology:
- MODIS v6 data (clouds, aerosols, etc.)
- Interpolation Scheme
- Radiative Transfer Model
- DNI, GHI (averaged times)
- DNI, GHI (daily integrals)

Part A: Simulation

Part B: Validation
- Measurements
- Validation

Part C: Correction
- Final Product (DNI, GHI)

Sample Results:
- Source: University of Patras

Source: University of Patras
Main Results: WP1 Market Research

Load Curves

Jordan
Source: NEPCO

Algeria
Source: SONELGAZ

Tunisia
Source: STEG
Main Results: WP1 Market Research

Example of Local Boundary Conditions

<table>
<thead>
<tr>
<th>Country</th>
<th>Jordan</th>
<th>Algeria</th>
<th>Tunisia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land Cost ($/m²) or Rent cost ($/m²/year)</td>
<td>5.46 $/m²</td>
<td>0.01 $/m²/year</td>
<td>Power plant 0$/m² (source: STEG) Regular Land Cost 20 $/m²</td>
</tr>
<tr>
<td>Water Cost ($/m³)</td>
<td>Treated wastewater tariff is 0.07 $/m³ for industrial reuses including power generating and cooling</td>
<td>0.05 $/m³</td>
<td>0.24 $/m³ Water pumped from well</td>
</tr>
<tr>
<td>Fuel Type &amp; Cost</td>
<td>Natural Gas for industries: 34.3 $/MWh (4/2017)</td>
<td>Natural Gas 1.48 to 2.86 $/MWh (average value 2.5 $/MWh)</td>
<td>- Natural Gas for industry: 30.7 US$/MWh</td>
</tr>
</tbody>
</table>

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<tbody>
<tr>
<td>Total Installed Capacity in The Country</td>
<td>4282 MW, 18911 GWh (2015)</td>
<td>15385 MW</td>
<td>In 2016 the installed capacity reached 5400 MW</td>
</tr>
<tr>
<td>Expected Demand in the Following years</td>
<td>3678 MW (2017), 3884 MW (2018), 4106 MW (2019)</td>
<td>25415 MW by 2025</td>
<td>CDER projection: 7800 MW by 2030</td>
</tr>
</tbody>
</table>
Main Results: WP2 Technology Development

Selected Cases

**Case CP1:**
Parabolic Trough with Thermal Oil HTF and Thermal Energy Storage + Natural Gas Back-Up + PV Polycrystalline single axis tracked

**Case CP2:**
Parabolic Trough with Molten Salt HTF and Thermal Energy Storage + Natural Gas Back-Up + PV Polycrystalline single axis tracked

**Case CP3:**
Solar Tower with Molten Salt HTF and Thermal Energy Storage + Natural Gas Back-Up + PV Polycrystalline single axis tracked

Source: DLR
Main Results: WP2 Technology Development

**Set-Ups Defined:**
- 3 Sites: Jordan, Algeria, Tunisia
- 3 Technology Cases: CP1, CP2, CP3
- 2 Options: with Natural Gas and Solar-Only

= 18 Set-Ups

**Parametric variation ranges:**
- CSP Solar Multiple: 1.8 to 3.4 in 0.2 steps, plus 1.4 case
- Thermal Energy Storage: 3 to 21 h capacity in steps of 3h
- PV Capacity (DC output): 0 – 227 MWp (10 Steps, 28.4 MWp)

= 700 Configurations x 18 Set-Ups = **12,600 Configurations to Simulate**
Main Results: WP2 Technology Development

Methodology

1) Techno-Economic modelling
2) Parametric variation ranges
3) Automatic performance calculation with INSEL software
4) Economic evaluation

→ **Goal:** search for **LCOE minima** per CO₂ emission range or demand coverage
Main Results: WP2 Technology Development

Low Fuel Use example. 30 g CO2/kWe, solar share 94%, LCOE 10.9 €cent/kWh
CSP solar multiple 2.4; TES capacity 21 h; PV cap. 170 MW
Main Results: WP2 Technology Development

High Fuel Use example: 188 g CO2/kWh, solar share 66%, LCOE 8.6 €/cent/kWh
CSP solar multiple 1.4; TES capacity 9 h; PV cap. 57 MW
Main Results: WP2 Technology Development

**Solar-Only example:** 0 g CO2/kWhe, Demand covered 80%, LCOE 9,1 €cent/kWh
CSP solar multiple 2.2; TES capacity 12 h; PV cap. 57 MW
Main Results: WP2 Technology Development

Configuration Selection, with Natural Gas

CO2 emissions (g/kWhe)
Main Results: WP2 Technology Development

Configuration Selection, Solar-Only

% of demand covered
Main Results: WP2 Technology Development

Back-Up Fuel vs. Solar Only

Similar LCOE for configuration with **100 gCO2/kWhe** (84% Solar Share) and **100% demand covered** as solar-only (100% solar share) and **80% demand covered**
Main Results: WP3 Demonstration


9.54 KW (DC) Grid – Connected Photovoltaic system at CDER, Algeria. The PV system consists of 90 Isofotoni106 monocrystalline PV modules.

16 KWth Parabolic trough used to power an absorption chiller for air conditioning. Borj Cedria Tunisia CRTEn.
Main Results: WP4 & WP5 Knowledge Transfer & Dissemination

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Conclusions and Next Steps

It has been confirmed, that the conditions in the analyzed MENA countries are excellent for the deployment of hybrid CSP-PV plants.

The load curves can be satisfied to a large extension with solar-only plants or to its totality if fossil back-up is allowed.

The combination of CSP + PV leads to electricity costs higher than PV but lower than CSP alone by increasing the capacity factor and the grid stability.

A complete system demonstration was not possible in HYMENSO due to lack of funding.
THANK YOU
for your attention!

THANKS to my colleagues
for their work and input

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