
Workshop on RES and new technologies for energy production

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Malta
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DETAILS OF THE CURRENT RENEWABLE ENERGY PROJECTS

Prof. Ahmed Al-Salaymeh | The university of Jordan
What Kind of renewable energy projects in south of Jordan?

- PV projects
- Wind projects
Annual Electricity Consumption in the Jordan

University of Jordan
PV projects

There are three types of PV projects:

- Operated projects.
- Signed projects, but project company is looking for getting the financial close.
- Gulf Grant projects.
Shams Ma’an
Solar Electricity for Jordan

University of Jordan
SHAMS MA’AN
SOLAR ELECTRICITY FOR JORDAN

A world-class PV power plant and the cornerstone of Jordan’s energy security goals

20 year
Power Purchase Agreement with Jordan’s National Electric Power Company (NEPCO)

First Solar spent over 40,000 man hours on training, creating a new solar skills resource for Jordan.

600,000+
high-performance First Solar thin film modules deliver up to 5 percent more specific energy than conventional silicon panels.

~160 million kilowatt-hours electricity generated per year
= ~1% of Jordan’s energy production
= ~35,000 homes powered

University of Jordan
Skill Development Center

**Location:** East of downtown Ma’an

**Target population:** Those interested in working in the Industrial Park, mainly in the construction material sector.

Currently training held in cooperation with Vocational Training Center
High Precision Radiation Measurement Station in Maan for UoJ
Overview of the enerMENA stations situated in Morocco, Algeria, Tunisia, Egypt and Jordan.
List of enerMENA stations sorted by their activation date. TS refers to ‘Thermal Sensors’ stations whereas RSI refers to ‘Rotating Shadowband Irradiometer’ stations.

<table>
<thead>
<tr>
<th>Site</th>
<th>Country</th>
<th>Local partner</th>
<th>Station type</th>
<th>Altitude[m]</th>
<th>Lat.[°N]</th>
<th>Lon.[°E]</th>
<th>Activation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tataouine</td>
<td>Tunisia</td>
<td>CRTEn</td>
<td>TS</td>
<td>210</td>
<td>32.974</td>
<td>10.485</td>
<td>Dec. 13th, 2010</td>
</tr>
<tr>
<td>Ma'an</td>
<td>Jordan</td>
<td>University of Jordan</td>
<td>TS</td>
<td>1012</td>
<td>30.172</td>
<td>35.818</td>
<td>Jan. 11th, 2011</td>
</tr>
<tr>
<td>Oujda</td>
<td>Morocco</td>
<td>University of Oujda</td>
<td>TS</td>
<td>617</td>
<td>34.650</td>
<td>-1.900</td>
<td>Aug. 18th, 2011</td>
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<td>Cairo</td>
<td>Egypt</td>
<td>Cairo University</td>
<td>TS</td>
<td>104</td>
<td>30.036</td>
<td>31.009</td>
<td>June 6th, 2012</td>
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<tr>
<td>Ghardaia</td>
<td>Algeria</td>
<td>CDER</td>
<td>TS</td>
<td>463</td>
<td>33.465</td>
<td>3.780</td>
<td>Sep. 30th, 2012</td>
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<td>Adrar</td>
<td>Algeria</td>
<td>CDER</td>
<td>TS</td>
<td>262</td>
<td>27.880</td>
<td>-0.274</td>
<td>Sep. 27th, 2012</td>
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<tr>
<td>Missour</td>
<td>Morocco</td>
<td>IRESEN</td>
<td>TS</td>
<td>1107</td>
<td>32.860</td>
<td>-4.407</td>
<td>May 27th, 2013</td>
</tr>
<tr>
<td>Zagora</td>
<td>Morocco</td>
<td>IRESEN</td>
<td>RSI</td>
<td>783</td>
<td>30.272</td>
<td>-5.852</td>
<td>May 31th, 2013</td>
</tr>
</tbody>
</table>
Average annual global horizontal (AAGHI, blue) and direct normal (AADNI, yellow) irradiation in kWh/m² of the enerMENA stations.

Ma'an: GHI = 2327 kWh/m²
DNI= 2798 kWh/m²
Operated projects

PV projects in Ma’an (Total 174MW):

- All projects have fixed selling price = 16.92 cent/kWh (USD) = 120 fils/kWh (JDS) except Shams Ma’an project.

- Shams Ma’an project has fixed price of 105 fils/kwh or 14.8 cent/kwh.
During six-month, a period of establishing the project there were about thousand of employees worked on the project, most of them residents of Ma`an and the rest from various governorates of the Kingdom.

- The Current Staff are forty employees:
  - Nineteen are technicians and maintenance staff.
  - Two Engineers and the rest are security.

- All Current staff are residents of Ma`an.
Shams Ma’an project

CSR

1. HRH Prince Firas Bin Ra’ad park.
2. Ma’an Orphanage Centre.
3. “We Love Reading” Program.
4. Bus Stop in Ma’an Governorate.
5. Printing of “Jordanian Dialogue Dictionary”.
7. Computers for King Hussein Bin Talal University.
8. Installation of Security Cameras For Ma’an Association.
Shams Ma’an project

CSR

9. School Backpacks in Ma’an Governorate.

10. Qur’an Recitation Center.

11. Queen Alia Competition in Ma’an.

12. Ma’an Karate Center.


15. Sponsoring Eid Celebration (Gifts + Food Parcels in Ramadan).

## PV projects in Ma’an

<table>
<thead>
<tr>
<th>Number</th>
<th>Project name</th>
<th>Installed Capacity (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Shams Ma’an</td>
<td>52.5</td>
</tr>
<tr>
<td>2</td>
<td>SunEdison</td>
<td>20.5</td>
</tr>
<tr>
<td>3</td>
<td>CEC</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>Catalyst</td>
<td>21</td>
</tr>
<tr>
<td>5</td>
<td>Ennera</td>
<td>10</td>
</tr>
<tr>
<td>6</td>
<td>Martifer</td>
<td>10</td>
</tr>
<tr>
<td>7</td>
<td>Bright power</td>
<td>10</td>
</tr>
<tr>
<td>8</td>
<td>Green Land</td>
<td>10</td>
</tr>
<tr>
<td>9</td>
<td>EJRE</td>
<td>20</td>
</tr>
<tr>
<td>10</td>
<td>Scatec</td>
<td>10</td>
</tr>
</tbody>
</table>
PV projects in Aqaba

There are one PV project in Aqaba “Shamsuna”

- Shamsuna project has selling price of 16.92 cent /kWh (usd) = 120 fils/ kWh (JD).

- Shamsuna project has Installed Capacity equaled to 9.8 (MW).

- Average selling price for all operated PV projects in south of Jordan: around 116 fils/kwh or 16.3cent/kwh.

- Total Installed Capacity for all operated PV projects in south of Jordan: 184 (MW).
Operated PV projects in south of Jordan

- Shams Ma'an: 50 MW
- SunEdison
- CEC
- Catalyst
- Ennera
- Martifer
- Bright power
- Green Land
- EJRE
- Scatec
- Shamsuna

Installed capacity (MW)
Gulf Grant projects

PV project in Qweira “Qweira Solar PV”

- Qweira Solar PV project has Installed Capacity equaled to 103 (MW).
- Expected year of operation Mid of 2017.
- Abu Dhabi Funds.
- Under final stage of evaluation of the 7 proposals out of the 15 qualified.
Wind projects

There are Three types of wind projects:

- Operated projects.
- Signed projects, but project company is looking for getting the financial close.
- Gulf Grant projects.
Operated projects

Wind projects in Tafilah “ JWPC ”

- JWPC project has selling price of 12cent /kWh (usd) = 85 fils/ kWh (JD)
- JWPC project has Installed Capacity equaled to 117 (MW).
- Its operation was on September of 2015.
- Equity fund (Inframed&Masdar).
## Signed projects (417 MW)

<table>
<thead>
<tr>
<th>Project name</th>
<th>Area</th>
<th>Installed Capacity (MW)</th>
<th>Selling price (LCOE)</th>
<th>Expected year of construction/operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAJEF</td>
<td>Ma’an</td>
<td>83</td>
<td>11.28 cent/kWh (usd) = 80 fils/kWh (JD)</td>
<td>PPA was signed 10/2015, Expected operation is 10/2018</td>
</tr>
<tr>
<td>HECATE</td>
<td>The Project is moved from North Area of Jordan to the South</td>
<td>45</td>
<td>10.16 cent/kWh (usd) = 76 fils/kWh (JD)</td>
<td>PPA was signed, Expected operation is 2019</td>
</tr>
<tr>
<td>KOSPO1</td>
<td>Tafilah</td>
<td>50</td>
<td>11.28 cent/kWh (usd) = 80 fils/kWh (JD)</td>
<td>PPA was signed in 3/2016, Expected operation is 3/2019</td>
</tr>
<tr>
<td>XENEL</td>
<td>Tafilah</td>
<td>50</td>
<td>11.28 cent/kWh (usd) = 80 fils/kWh (JD)</td>
<td>PPA was signed in 3/2016, Expected operation is 3/2019</td>
</tr>
<tr>
<td>FUJAIJ1</td>
<td>FUJAIJ</td>
<td>89</td>
<td>11.28 cent/kWh (usd) = 80 fils/kWh (JD)</td>
<td>PPA was signed, Expected operation is 10/2018</td>
</tr>
<tr>
<td>MAAS (Iraki Group)</td>
<td>Tafilah</td>
<td>100</td>
<td>11 cent/kWh (usd) = 78 fils/kWh (JD)</td>
<td>PPA was signed in 5/2016, Expected operation is 2019</td>
</tr>
</tbody>
</table>
Gulf Grant projects

- Wind project in Ma’an “King Hussein University project”
- King Hussein University project has Installed Capacity equaled to 80 (MW).
- It is an operated project.
- Kuweit Funds.
Wind projects in south of Jordan

- JWPC
- RAJEf
- HECATE
- KOSPO1
- XENEL
- FUJAI1
- MAAS (Iraki Group)
- King Hussein University

Installed capacity (MW)
Ma’an station sorted by their activation date.

<table>
<thead>
<tr>
<th>Site</th>
<th>Country</th>
<th>Local partner</th>
<th>Station type</th>
<th>Altitude (m)</th>
<th>Lat. (°N)</th>
<th>Lon. (°E)</th>
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</tr>
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<tbody>
<tr>
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<td>Jordan</td>
<td>University of Jordan</td>
<td>TS</td>
<td>1012</td>
<td>30.172</td>
<td>35.818</td>
<td>Jan. 11th, 2011</td>
</tr>
</tbody>
</table>

**TS** refers to ‘Thermal Sensors’ stations whereas **RSI** refers to ‘Rotating Shadowband Irradiometer’ stations.
Measurement equipment

All stations measure wind speed and direction at 10 m height, temperature, relative humidity and air pressure. Data are available with up to 1 min resolution. Several stations have been and are being upgraded with enhanced instrumentation for CSP relevant parameters such as soiling, ageing, circumsolar radiation and atmospheric attenuation in tower plants.
Data quality control

Meteorological data require being quality controlled, as lacking or erroneous ground data or data of unsecure quality are regrettably rather common at many sites but cannot be used for CSP yield analysis. Several error sources cause reduced data quality and completeness. The most common examples are broken sensors, sensor soiling, shading impacts caused by surrounding objects or animals and power outages. Most of those influences can be minimized by steady, frequent and thorough monitoring combined with regular site visits including maintenance and cleaning of the sensors. Some influences on the data can be treated – e.g. the signal reduction due to soiling can be corrected using a linear or more complex cleanliness reduction between two cleaning events, depending on the type of soiling. More difficult to treat are e.g. data gaps. These methods and corrections via interpolation or filling data from close stations or modelled data are required to determine the annual DNI sum of an entire year. However, the accuracy of the filled or soiling corrected data is reduced and is therefore marked as described in . For the documentation of data quality, text comments, automatic flags from ENDORSE and flags of data manipulation methods have been set. For all stations data availability, yearly DNI sums and sensor soiling have been evaluated, to be found below.
Sensor cleaning is crucial for the data quality. The recommendation for thermal sensors was to clean them every week day. For RSIs only weekly cleaning was recommended. Errors due to soiling can be corrected assuming a linear cleanliness reduction between two cleaning events. A mean cleanliness averaged over all stations with thermal sensors of 99.2 % and 99.3 % for RSI stations can be reached; however RSIs need 5 times less cleaning efforts to achieve a slightly better cleanliness as for thermal sensors, which can be of advantage at remote sites.

<table>
<thead>
<tr>
<th>Site</th>
<th>Average cleanliness</th>
<th>First date</th>
<th>Last date</th>
<th>Number of evaluated cleaning events</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ma'an</td>
<td>98.9%</td>
<td>July 16, 2014</td>
<td>July 12, 2015</td>
<td>119</td>
</tr>
</tbody>
</table>
Annual irradiation

Annual irradiation and yearly averages of selected meteorological parameters. The ‘first date’ and ‘last date’ indicate the evaluated interval for each station.

<table>
<thead>
<tr>
<th>Site</th>
<th>First date</th>
<th>Last date</th>
<th>Annual GHI sum [kWh/m²]</th>
<th>Annual DNI sum [kWh/m²]</th>
<th>Mean Temp. [°C]</th>
<th>Mean Rel. Hum. [%]</th>
<th>Mean Wind speed [m/s]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ma'an</td>
<td>June 1, 2011</td>
<td>May 31, 2015</td>
<td>2327</td>
<td>2798</td>
<td>17.9</td>
<td>39</td>
<td>3.8</td>
</tr>
</tbody>
</table>
### enerMENA High Precision Meteorological Station in Maan, Jordan

**Latitude:** 30.17°N  
**Longitude:** 35.82°E  
**Altitude (amsl):** 1012 m  
**Station:** CSFS.MT.09.201  
**Time zone:** 2 (UTC+2h)

**Month:** February 2015  
**Year:** 2015

#### Measured values:
- **GHI, DHI:** Global Horizontal Irradiance in W/m², Diffus Horizontal Irradiance in W/m², both measured with K&Z CMP21 pyranometer.
- **DNI:** Direct Normal Irradiance in W/m² measured with K&Z CHP1 pyrheliometer.
- **\( T_{\text{amb}} \):** Ambient Temperature in °C, measured with Campbell CS215.
- **RH:** Relative humidity from Campbell CS215.
- **WS, WS_{\text{max}}:** Wind speed in m/s, measured with NRG 40H Anemometer, WS_{\text{max}}: maximal measured wind speed within the time interval.
- **WD, WD_{\text{max}}:** Wind direction in °N (to East), measured with NRG 200 Wind Direction Sensor. Standard deviation of wind direction within measurement interval.
- **BP:** Air pressure from Campbell CS100 barometric pressure sensor.
- **Acc.:** Accuracy: deviation between measured and calculated DNI value from data base: DNI_{measured} - DNI_{calculated}.
- **Cleaning:** Cleaning of sensors: A cleaning event is marked with a "1".

#### 10 min average

<table>
<thead>
<tr>
<th>Unit</th>
<th>GHI W/m²</th>
<th>DNI W/m²</th>
<th>DHI W/m²</th>
<th>( T_{\text{amb}} ) °C</th>
<th>RH %</th>
<th>WS m/s</th>
<th>WS_{\text{max}} m/s</th>
<th>WD °N</th>
<th>WD_{\text{max}} °N</th>
<th>BP hPa</th>
<th>Acc. W/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>201</td>
<td>267</td>
<td>55</td>
<td>9.7</td>
<td>48</td>
<td>4.8</td>
<td>6.7</td>
<td>244</td>
<td>9.7</td>
<td>900</td>
<td>-2.9</td>
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#### 10 min minimum

<table>
<thead>
<tr>
<th>Unit</th>
<th>GHI W/m²</th>
<th>DNI W/m²</th>
<th>DHI W/m²</th>
<th>( T_{\text{amb}} ) °C</th>
<th>RH %</th>
<th>WS m/s</th>
<th>WS_{\text{max}} m/s</th>
<th>WD °N</th>
<th>WD_{\text{max}} °N</th>
<th>BP hPa</th>
<th>Acc. W/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-1.5</td>
<td>2</td>
<td>0.0</td>
<td>0.0</td>
<td>0</td>
<td>0.0</td>
<td>890</td>
<td>-53.9</td>
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</table>

#### 10 min maximum

<table>
<thead>
<tr>
<th>Unit</th>
<th>GHI W/m²</th>
<th>DNI W/m²</th>
<th>DHI W/m²</th>
<th>( T_{\text{amb}} ) °C</th>
<th>RH %</th>
<th>WS m/s</th>
<th>WS_{\text{max}} m/s</th>
<th>WD °N</th>
<th>WD_{\text{max}} °N</th>
<th>BP hPa</th>
<th>Acc. W/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>889</td>
<td>1059</td>
<td>510</td>
<td>28.0</td>
<td>95</td>
<td>17.2</td>
<td>23.3</td>
<td>359</td>
<td>78.7</td>
<td>907</td>
<td>100.0</td>
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</table>

#### Month sum

<table>
<thead>
<tr>
<th>Unit</th>
<th>GHI kWh/m²</th>
<th>DNI kWh/m²</th>
<th>DHI kWh/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>134.7</td>
<td>179.1</td>
<td>37.0</td>
</tr>
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</table>

**Data completeness:** 100%
enerMENA High Precision Meteorological Station in Maan, Jordan - February 2015

Julian date
Irrad day

enerMENA High Precision Meteorological Station in Maan, Jordan - February 2015

GHI, DNI and DHI in kWh/(m²·day)

Julian date
Temp - RH freq

enerMENA High Precision Meteorological Station in Maan, Jordan - February 2015

ambient temperature

relative humidity

Total number of hours in month: 672 h
Wind Freq

enerMENA High Precision Meteorological Station in Maan, Jordan - February 2015

average wind speed and maximal speed at gusts

Wind Direction (in hours per month)

Wind speed in m/s

frequency in hours/month

CSP Services
Concentrating Solar Power Services
Thank You
Investigating, Analyzing the Performance of Tri-Generation Parabolic Trough System under Jordanian Climate Conditions and Establishing a Theoretical Model Correlated with Experimental Data Tri-Generation Parabolic Trough System
Introduction

- A unique Tri-Generation system based on the CSP technology was installed for the:
  1. Generation of electricity,
  2. Water desalination
  3. Cooling and heating
     - Location: in Muta'h University at the south of Jordan.
Nominal capacities of the Tri-gen system

- The system includes 120 kW thermal peak capacity PTSC.
- 80 kW superheated steam generator,
- 15 kW steam engine.
- 150 liter/hr water distillation system.
- two air cooled adsorption chillers each with 15 kW capacity and switching mechanism with heating.
The Tri-generation system
Parabolic Trough Solar Collector

Superheated steam generator

Water distillation system

Adsorption chiller
Importance

➢ The tri-generation system existing in Mu’tah University is a unique world-wide in it’s totally.

➢ If proven to be feasible and efficient it may help by providing Jordan with solutions to its water problems along with its energy needs.

➢ The solar field which utilizing CSP under Jordanian climate condition with its tri-generation system needs to be (No previous data available) investigated, also the performances should be monitored and analyzed.
All previous studies conducted the performances of different types of CSP solar fields on a large scale around the world but no study is carried out under Jordanian climate conditions and no previous study ever been conducted more than two production systems depending on solar energy as a single source of energy.

Solar field of Muta'h has a unique system involves three production systems all of them need to be investigated and analyzed and determining the feasibility of such similar larger scale systems.
➢ Considerable attention has been paid to the solar thermal as a mover of power generation, solar cooling technologies and electricity production or steam generation for medium sizes industries in more efficient ways.

➢ Great concern should be paid to minimize the consumption of fossil fuels and promote wider use of solar energy, particularly in air-conditioning.
Description of the Solar Tri-generation System

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
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<tbody>
<tr>
<td>Latitude [°N]</td>
<td>31.162</td>
</tr>
<tr>
<td>Longitude [°E]</td>
<td>35.717</td>
</tr>
<tr>
<td>Altitude [m a.s.l.]</td>
<td>1010</td>
</tr>
<tr>
<td>Climate region</td>
<td>IV, 2</td>
</tr>
</tbody>
</table>

University of Jordan
Parabolic trough field and piping at Muta'h solar field.
# PTC specifications

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Receiver</td>
<td>95%</td>
<td>Heat Collection</td>
<td>25 mm</td>
</tr>
<tr>
<td>Absorptivity</td>
<td></td>
<td>Element, O.D.</td>
<td></td>
</tr>
<tr>
<td>Mirror Reflectivity</td>
<td>89%</td>
<td>Focal Length</td>
<td>304.8 mm</td>
</tr>
<tr>
<td>Receiver Emittance</td>
<td>0.25</td>
<td>Flow rate</td>
<td>22.7-45.4 liter/min</td>
</tr>
<tr>
<td>Glass</td>
<td>91%</td>
<td>Operating Temperature</td>
<td>50-270°C</td>
</tr>
<tr>
<td>Transmissivity</td>
<td></td>
<td>Ranges</td>
<td></td>
</tr>
<tr>
<td>Collector Length</td>
<td>3.657 m</td>
<td>Collector Width</td>
<td>1.65 m</td>
</tr>
</tbody>
</table>
** COLLECTOR PERFORMANCE **

** Design DNI - 850 W/m²  
Ambient Air - 26 °C  
Wind Speed - 3 m/s  
Collector Optical Eff - 67.3%  
Zero Incident Angle  

(Temperature Difference) (Temperature of HTF - Ambient Temperature) vs. Thermal Output (kW)
Components of the Tri-generation system

University of Jordan
HTF PUMP
16 USG per minute.
Three way valve
The Steam Generator (Boiler HX₁)
The Super-heater HX1-1

![Diagram of Super-heater HX1-1]

Fig. 3.7 Super-heater HX1-1

![Image of Super-heater HX1-1 with temperature and pressure sensors]

Fig. 3.8 Temperature and pressure sensors

University of Jordan
Steam engine and the electric-generator
The Heat exchanger HX2

Vapor of Brackish water

Condensated steam

Steam from the Steam engine

Brackish water inlet

Pressure & Temperature Gauge

Sight glass level
Heat exchanger HX3
Schematic drawing of a two stage ADC-2P activated carbon adsorption chiller (AL-Maaitah, 2009)

University of Jordan
Hot water storage tank

University of Jordan
Chilled water tank and accessories
tank & Evaporator
The Dry cooler
❖ Measuring and Monitoring Systems

➢ Measuring and Monitoring Systems for the solar matrix
## Monitored parameters

<table>
<thead>
<tr>
<th>Monitored Parameter</th>
<th>Nomenclature</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global horizontal radiation</td>
<td>GH</td>
<td>W/m²</td>
</tr>
<tr>
<td>Diffused horizontal Radiation</td>
<td>DH</td>
<td>W/m²</td>
</tr>
<tr>
<td>Ambient Temperature</td>
<td>T&lt;sub&gt;a&lt;/sub&gt;</td>
<td>ºF</td>
</tr>
<tr>
<td>Relative humidity</td>
<td>Rh</td>
<td>%</td>
</tr>
<tr>
<td>Leaving PTCs temperature</td>
<td>T&lt;sub&gt;o-solar&lt;/sub&gt;</td>
<td>ºC</td>
</tr>
<tr>
<td>Entering PTCs temperature</td>
<td>T&lt;sub&gt;i-solar&lt;/sub&gt;</td>
<td>ºC</td>
</tr>
<tr>
<td>HTF volumetric flow rate</td>
<td>V&lt;sub&gt;HTF&lt;/sub&gt;</td>
<td>USG/min</td>
</tr>
<tr>
<td>Superheated steam temperature</td>
<td>T&lt;sub&gt;sup&lt;/sub&gt;</td>
<td>ºC</td>
</tr>
<tr>
<td>Superheated steam pressure</td>
<td>P&lt;sub&gt;sup&lt;/sub&gt;</td>
<td>Bar</td>
</tr>
<tr>
<td>Feed water Temperature</td>
<td>T&lt;sub&gt;w&lt;/sub&gt;</td>
<td>ºC</td>
</tr>
</tbody>
</table>
Monitoring system. For the solar cooling system
Measuring points in the solar cooling system

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Modeling the solar field

SOLAR FIELD MODEL

Tin, m-HTF, Winds, DNI, Tamb, Reh, Tout, η_pfc, Qloss, Qabs
Incidence angle modifier (IAM) versus $\theta$
Row Shading vs Longest & shortest day light in the year
End losses versus $\theta$ for SopoNova collector

End losses

$E_{loss}$

$\theta$ [deg]

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Thermal losses
Absorber (Receiver) losses
\[ Q_{\text{Receiver losses}} = A_0 + A_1 T_1 + A_2 T^2 + A_3 T^3 + (B_0 + B_1 T) \times \text{DNI} \]
TRNSYS Model for Mut'ah Solar Matrix

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Solar radiation in 21 June 2012

- $G_H (W/m^2)$
- $DNI (W/m^2)$
- $D (W/m^2)$

Time (0.00 to 24.00)

$W/m^2$ (0.00 to 1200)
Solar radiation in 21 Dec, 2012

- GH (W/m²)
- DN (W/m²)
- DI (W/m²)

Time

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Irradiance in 10 December 2012

Solar Time

W/m²

GH
DNI
Diffused

DNI and DNI Tracked in 10 December 2012

Solar Time

W/m²

DNI
DNI Tracked
CO2 saving = 61.3 [ton]/yr
1000 kW thermal in Muta’h
Conclusions and Recommendations

Conclusions:

- A first unique tri-generation system utilizing the solar radiation by means of CSP technology was successfully built.
- The Tri-generation system was operated and tested.
- The performance of the Tri-generation system was investigated.
- The thermal efficiency of the solar field was obtained and it could be said that the 50% is the dominant value of this efficiency.
- The maximum outlet temperature of the solar field was obtained and controlled to be not reaching more than 260 °C for safety issues.
- The desalinated water rate was determined and the rate of 150 lit/hr is obtained in certain condition.
Conclusions:

• The performance of the adsorption chillers was obtained.
• It was found that the best values of COP and the normalized capacity are 0.3, 0.91 respectively at hot water temperature of 95[°C] and chilled water temperature of 16 [°C] and Temperature of condensation or re-cooling of 35[°C].
• While the worst values of the COP and the normalized capacity were 0.21, 0.1 respectively at hot water temperature of 65[°C] and chilled water temperature of 7 [°C] and Temperature of condensation or re-cooling of 35[°C].
Conclusions:

• The variation of electricity generation is obtained and it was found that the system can produce about 15 KW of electricity at 195 kg/hr of superheated steam.
• The Tri-generation system could produce 4122.2693 MW-hr/year.
• The Tri-generation system could produce about 123 GW-hr in 30 years.
Conclusions:

• The Tri-generation system could save 1,071,790 JD and 32,153,700.54 JD yearly and in 30 years respectively.

• The payback period of such systems was computed and a period of two years and 45 days was obtained.

• The CO2 saving by utilizing such these system is about 61.3 ton/year and 1,839 ton in 30 years of operation.
THANK YOU

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