Prospects of Solar CSP Integration in the Oil & Gas Industry of the Middle East for Process Heating

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A pessimist sees the difficulty in every opportunity. 
An optimist sees the opportunity in every difficulty!

Winston Churchill
INTRODUCTION
Solar Power – World
Installed Capacity

- Continuous growth in solar power generation in the world

Source: IRENA Renewable Capacity Statistics 2017
Continuous growth in solar power generation in the Middle East

Source: IRENA Renewable Capacity Statistics 2017
Solar PV and CSP Growth
Installed Capacity

- Solar PV as well as Solar CSP growth rate in the ME is substantially higher than the growth rate in the World.

Source: IRENA Renewable Capacity Statistics 2017
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Solar CSP Technologies

- Parabolic Trough
- Linear Fresnel
- Solar Tower
- Point Focus
- Dish Stirling
Solar CSP
Parabolic Trough Power Plant

Solar Field

Thermal Block

Power Block
Solar CSP
Solar Tower Power Plant

Source: SolarReserve
Prospects of Solar CSP Integration in the Oil & Gas Industry for Process Heating

**POWER PLANT**

- **Solar Field**
  - Solar Energy
  - To Oil & Gas Industry
- **Thermal Block**
  - Steam: 100 MWh
  - Power: 38 MWh
- **Power Block**
  - Power: 62 MWh

**DIRECT STEAM USE**

- **Solar Field**
  - Solar Energy
- **Thermal Block**
  - Steam: 100 MWh
- **To Oil & Gas Industry**

- Lower CAPEX
- More Energy
- **Lower LCOE**

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Oil & Gas Industry
Energy Distribution and Solar CSP Integration

OIL & GAS INDUSTRY

FEED
Well Fluids from Oil & Gas Reservoir (Subsurface)

Solar CSP

Steam Generation

Steam Cond.

Fuel Distribution

Processing

Fuel internal use

Power Generation

Power Distribution

Power Import by Oil & Gas Industry

PRODUCTS

Crude Oil
Sales Gas
NGL, LNG, LPG
Sulphur
Hydrocarbon Condensate
Refined Petroleum Products
Petrochemicals

POWER

POWER INDUSTRY
Levelized Cost of Electricity
Cost Indicators and Boundaries

\[ \text{LCOE} = \frac{\text{Discounted Lifetime Cost}}{\text{Discounted Lifetime Generation}} \]

\[ \sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t} \]
\[ \sum_{t=1}^{n} \frac{E_t}{(1+r)^t} \]

Where:
- \( \text{LCOE} \) = the average lifetime levelised cost of electricity generation;
- \( I_t \) = investment expenditures in the year \( t \);
- \( M_t \) = operations and maintenance expenditures in the year \( t \);
- \( F_t \) = fuel expenditures in the year \( t \);
- \( E_t \) = electricity generation in the year \( t \);
- \( r \) = discount rate; and
- \( n \) = life of the system.

Source: IRENA RE Technologies Cost Analysis – CSP
TECHNICAL VIABILITY
Direct Normal Irradiance (DNI)

Middle East

- CSP plants require abundant direct solar radiation
- Limits CSP to hot, dry regions
- >2,000 kWh/m²/year DNI (to be economical)
  - Middle East is one of the ideal locations for Solar CSP

Source: Map (DLR), Sensitivity (IRENA)
## Temperature

### Solar CSP and Process End-Users

- **Oil & Gas Industry** process as well as steam system temperatures are lower than Solar CSP steam temperatures.
- Steam from Solar CSP can meet Oil & Gas Industry temperature requirements.
- There is no limit on HTFs temperature adequacy.

### Graphical Representation

![Graph showing temperature comparison between Oil & Gas and Solar CSP](image)

### Source

Source: HTFs Data (Applied Energy Journal, May 2015, Xinhai Xu et al.)
Energy Demand
Steam Consumption in the Oil & Gas Industry

- Huge steam consumption (particularly in gas processing)
- Large individual steam consumers

<table>
<thead>
<tr>
<th>Unit</th>
<th>Energy $(\text{MW}_{\text{th}})$</th>
<th>Process Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas Sweetening Unit</td>
<td>104</td>
<td>670 MMSCFD, 3.8% CO₂, 3.5% H₂S, 60 bar(g)</td>
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<tr>
<td>Gas Sweetening Unit</td>
<td>81</td>
<td>425 MMSCFD, 6.4% CO₂, 6.7% H₂S, 60 bar(g)</td>
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<tr>
<td>Residue Gas Compression</td>
<td>42</td>
<td>3 X 520 MMSCFD, Diff. Pressure 21 bar</td>
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<tr>
<td>Feed Gas Compressor</td>
<td>18</td>
<td>80 MMSCFD, Diff. Pressure 52 bar</td>
</tr>
<tr>
<td>De-Methanizer</td>
<td>11</td>
<td>NGL Unit (SRP Process)</td>
</tr>
</tbody>
</table>

- **Utility scale Solar CSP** is applicable even to fulfill steam demand of few consumers in the oil & gas industry of the Middle East

GASCO steam generation capacity is more than 5,000 Tons/h (3.84 GW$_{\text{th}}$)
System Interface and Energy Storage
Steam from Solar CSP to O&G Processing Facility

STEAM & CONDENSATE NETWORK

- BFW
- Fuel
- HP Steam
- LP Steam
- Condensate
- Make-up Water
- Boilers
- HP Steam Users
- LP Steam Users
- Water Treatment
- Solar CSP

- Steam supply
- Condensate return

Energy Storage
- Not mandatory
- Fuel fired boilers provide back-up

• Just mechanical tie-in is required
• Existing instrumentation and controls can manage fuel reduction in boilers on getting steam from Solar CSP

Incremental cost for thermal energy storage shall be justified against incremental fuel savings
COST ANALYSIS
Global Trend of Solar Power Prices
Average Auction Prices for Solar PV

- Substantial reduction in just couple of years
- The Middle East is the most competitive

Year 2016 RE Auctions
Eastern Hemisphere


World record of lowest ever Solar PV bid set in UAE (2.42 cents/kWh)
Low Solar PV Bids
World Records

59% reduction in Solar PV power price in the UAE in less than 2 years

Source: Cleantechnica
Factors Influencing Prices

Strategy for Low Price

- Access to finance and country specific conditions
- Business model adequacy
- Conducive environment for investor confidence
- Policy support to the RE sector
- Design of the auction
- Grid connection and management
- Risks and uncertainties

Low Price

Rock-bottom EPC cost
Optimized O&M concept
Low cost finance

Low Cost Finance

- 86% Debt-to-equity ratio
- 4% interest rate
- 27 years loan tenor
- 25 Years PPA with DEWA

800 MW Ph-3 Al Maktoum Solar Park, UAE
Masdar (UAE), FRV (Spain) and Gransolar Group (Spain)
(USD 29.9/MWh)

- Long term vision (5 GW)
- Unique financing structure
- Equity held jointly by developer (40%) and the government-owned utility – DEWA (60%)
- Contracts awarded in USD and indexed to inflation
- Resembles Public-Private Partnership instead of IPP model
- DEWA’s creditworthiness
- Low interest rate on debt
- Long tenors
- Low soft costs (land, energy, labour)
- Very low taxes

Is this strategy applicable on Solar CSP bids?
UAE Solar CSP Project
World Record for Lowest Bid

Mohammed Bin Rashid Al Maktoum Solar Park (Dubai)
- Phase-1: 13 MW Solar PV in Oct. 2013
- Phase-2: 200 MW Solar PV in Apr. 2017
- Phase-3: 800 MW Solar PV by 2020
- **Phase-4**: 200 MW Solar CSP by 2021
- Future Phases: Upto 5,000 MW by 2030

Dubai Clean Energy Strategy 2050
- Clean energy sources 75%
- Lowest carbon footprint city

The Dubai Electricity and Water Authority (DEWA) announced Phase-4 bids on **June 5, 2017**
- Upto 15 hrs of thermal storage

<table>
<thead>
<tr>
<th>Consortium</th>
<th>Bidding Price (cents/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACWA Power (Saudi Arabia), Shanghai Electric (China), BrightSource (USA)</td>
<td>9.45 [World record of Lowest Solar CSP Bid]</td>
</tr>
<tr>
<td>Masdar (UAE), EDF (France), Abengoa (Spain), Harbin Electric (China)</td>
<td>10.59</td>
</tr>
<tr>
<td>Engie (France), SolarReserve (USA), Power China (China), Sepco3 (China)</td>
<td>11.42</td>
</tr>
<tr>
<td>Alfanar (Saudi Arabia), Suncan (China)</td>
<td>17.35</td>
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In Chile, SolarReserve bid a world-record-breaking low price at just **6.3 cents per kWh** for dispatchable 24-hour solar (260 MW CSP + 150 PV)
### LCOE Improvement Achieved


<table>
<thead>
<tr>
<th></th>
<th>2010</th>
<th>2016</th>
<th>Improvement</th>
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<th>2010</th>
<th>2016</th>
<th>Improvement</th>
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<tbody>
<tr>
<td>Solar - PV (IRENA)</td>
<td>0.347</td>
<td>0.131</td>
<td>62%</td>
<td>0.301</td>
<td>0.242</td>
<td>20%</td>
<td>0.250</td>
<td>0.056</td>
<td>78%</td>
<td>0.270</td>
<td>0.070</td>
<td>74%</td>
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<td>Solar - CSP (IRENA)</td>
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<tr>
<td>Solar - PV (LAZARD)</td>
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<tr>
<td>Solar (SUNSHOT)</td>
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</tbody>
</table>

**Source:** IRENA, LAZARD and Sunshot - US DOE
LCOE Improvement Forecast
Solar Power

LCOE Improvement
For Solar CSP Integration in the Oil & Gas Industry

![Graph showing LCOE improvement over time for different Solar CSP and Solar PV options.](image_url)
Breakeven LCOE
For Solar CSP Integration in the Oil & Gas Industry

**Boiler Efficiency**: 80%
**Solar CSP Power Gen. Eff.**: 38%

**LNG Price (2017)**
5.0 to 5.5 US$/MMBTU

**LNG Price (2012 - 2014)**
> 15 US$/MMBTU

**UAE Solar CSP Bid (2017)**
6.61 cents/kWh
(w/o P & TES Blocks)

**LCOE Breakeven Line**

**LCOE_{TH}**

**Steam from Fuel Boiler**

**Steam from Solar CSP**
CONCLUSION
Conclusion

1. Solar PV as well as Solar CSP **growth rate** in the ME is substantially higher than the growth rate in the world

2. **Direct use of steam** from Solar CSP by **removing power block** will reduce CAPEX resulting in lower LCOE

3. Solar CSP installation in ME and its integration in the oil & gas industry is **technically viable**

4. **Thermal energy storage** is not mandatory:
   - Fuel fired boilers back-up available
   - Incremental cost for thermal energy storage shall be justified against incremental fuel savings

5. Globally **substantial reduction in Solar PV power price** in just couple of years has been observed:
   - The Middle East is the most competitive in low prices
   - World record of lowest ever Solar PV bid has been set in UAE (**2.42 cents/kWh**) in year 2016
   - 59% reduction in Solar PV power price in the UAE in less than 2 years
Conclusion (continued)

6. A special **strategy**, mainly focusing **low cost financing**, has been adopted in the Middle East (mainly UAE as of now) to achieve low prices:
   - It is equally applicable on Solar CSP projects
   - World record of lowest Solar CSP bid has also been set in UAE (**9.45 cents/kWh**) in year 2017

7. Excluding Power and Thermal Blocks from Solar CSP project can reduce the LCOE by around 30%

8. At current LNG price, using Solar CSP for steam supply to Oil & Gas Industry has reached at **breakeven** in the UAE

9. Further reduction in Solar CSP LCOE is anticipated:
   - Projected by IRENA and US DOE (Sunshot Initiative)
   - Observed in the Middle East for Solar PV

10. Solar CSP is a **promising source** of steam supply to Oil & Gas Industry:
    - Competing with fuel boiler **economically**
    - Provides major relief in **energy security** for NG or LNG importers
Thank You!