Developments and lessons learned of Utility scale PV plants in the Middle East, including storage

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2. Lessons Learnt Large Scale PV IPPs
3. Pushing the limits with Electrical Energy Storage
The Fichtner Group

- Established in 1922 and family-owned ever since
- Germany’s biggest independent engineering and consultancy enterprise for infrastructure projects
- More than 1500 employees worldwide – over 500 of these in our Home Office
- Project experience in 170 countries
- Over 1800 ongoing projects – 600 of these in our Home Office
- Total turnover of €285 million in 2015
- Capital investment volume now under planning in the home office: €180 billion – of which some €53 billion is in renewable energies
With our Home Office in Stuttgart, 24 subsidiaries and affiliates as well as over 100 branch and project offices, we are present in 60 countries worldwide.
Range of Engineering and Consulting Services

**Analysis and Conceptual Design**
Feasibility studies • environmental impact and siting studies • economic and technical analyses • masterplans • integrated infrastructure concepts • plant concepts • preliminary planning and conceptual engineering • operation management concepts • IT concepts

**Engineering and Contract Award**
General planning • basic engineering • permit engineering • detail engineering • plant and functional specifications • tendering • bid evaluation • contract award recommendation • contractual negotiations • contract formulation

**Implementation**
Check of drawings • shop acceptances • specialist site management and supervision • coordination of commissioning • final acceptance • documentation • trial operation and warranty support • interface coordination • project steering • general project supervision • health and safety coordination • staff training

**Operation**
Process optimization • environmental, risk and quality management • maintenance scheduling • optimization of deployment • operation, management and environmental information systems

**Business Consultancy**
Market analyses • tariff studies • project development • strategy and organization • financial modeling • project financing • project management • lender’s engineering • due diligence • mergers & acquisitions • IT consultancy • sectorial IT solutions
Total Turnover of Fichtner Group, 2015

**By business sector**

<table>
<thead>
<tr>
<th>Sector</th>
<th>Turnover 2015</th>
</tr>
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<tbody>
<tr>
<td>Energy</td>
<td>185.8 m €</td>
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<tr>
<td>Environment</td>
<td>21.9 m €</td>
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<tr>
<td>Water &amp; Infrastructure</td>
<td>55.5 m €</td>
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<tr>
<td>Consulting &amp; IT</td>
<td>21.8 m €</td>
</tr>
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</table>

**Total turnover 2015** 285.0 m €

**By region**

<table>
<thead>
<tr>
<th>Region</th>
<th>Turnover 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germany</td>
<td>97.6 m €</td>
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<tr>
<td>Europe and CIS</td>
<td>59.4 m €</td>
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<tr>
<td>Africa</td>
<td>40.2 m €</td>
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<td>Middle East</td>
<td>36.8 m €</td>
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<tr>
<td>America</td>
<td>9.7 m €</td>
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<tr>
<td>Asia, Australia</td>
<td>41.3 m €</td>
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</table>

**Total turnover 2015** 285.0 m €
Fichtner realized more than 420 PV projects with a capacity of >17,000 MW, among others:

- 200+ lenders engineering projects
- 20+ owners engineering projects
- 30+ studies in connection with PV
- Technical Advisor on many large scale PV IPP Projects (KSA, Egypt, Jordan, Dubai, Abu Dhabi, Oman)
- PV Hybrid Projects (PV, Wind, Diesel, Electrical Storage, etc.)
Fichtner PV project experience (GW / Continent)

- Latin America: 1.6 GW
- Europe: 2.76 GW
- Africa: 3.94 GW
- Middle East: 6.3 GW
- Asia: 2.14 GW
- Americas: 0.17 GW
Fichtner Services

**Fichtner’s Services as Owner’s Engineer**

- **Collection, Review and Analysis of Available Data**
- **Conceptual Engineering**
- **Call for Tenders**
- **Negotiation and contract award**
- **Permitting Phase**
- **Construction Phase**
- **Commissioning and Testing Phase**
- **Operation**

**Fichtner’s Services as Lenders Engineer**

- **Full Due Diligence**
- **Post Financial Close Due Diligence / Construction supervision as LTA**
- **Pre-Financial Close Due Diligence**
Project Constellation, Objectives, and Services

Investor

- PV Project
- special purpose vehicle / project company
- EPC contract
- O&M contract
- policies
- loans
- operation contract
- EPC contractor(s)
- EPC assistance
- insurance company
- technical support / insurance claim
- management

- Lender
  - Lender's engineer
  - lender's engineer
  - Techn. assistance during developm.
- Developer
  - project rights
  - power purchase agreement
  - grid studies / technical advisor

- Utility
  - Lender's engineer
  - owner's engineer
  - technical support during development
  - owner's engineer
  - power purchase agreement
  - technical support during operation
  - techn. assistance during operation
  - service company
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Feed-in-tariff (FIT), e.g. EU in the past

IPP Tender Rounds
- Sites to be secured by developer
  e.g. South Africa, KSA, Chile, India
- Pre-developed site available for bidder
  e.g. Dubai, Abu Dhabi, Egypt, KSA, Morocco, Jordan (Ma'an)
  - Site studies (e.g. topo, geotech, EIA screening)
  - Grid impact and compliance study at the POC
  - Permitting (to the extent possible)
With or without government shareholders

Unsolicited Bids with PPAs with state utility
e.g. Jordan, others

Private projects
e.g. Chile, Spain, KSA
### Alternative IPP Tender Rounds

#### Option 1
- **Tender**
- **Developer**
- **Project Company**
- **EPC Contractor**
- **EPC Contract**
- **Module Supplier 1**
- **Module Supplier 2**
- **Module Supplier 3**

#### Option 2
- **Tender**
- **Developer**
- **Project Company**
- **EPC Contractor**
- **EPC Contract**
- **Module Supplier 1**
- **Module Supplier 2**
- **Module Supplier 3**

#### Option 3
- **Tender**
- **Developer**
- **Project Company**
- **EPC Contractor**
- **EPC Contr. 1**
- **EPC Contr. 2**
- **EPC Contr. 3**
- **Module Supplier 1**
- **Module Supplier 2**
- **Module Supplier 3**

#### Option 4 and Option 5
- **Tender**
- **Devel. 1**
- **Devel. 2**
- **Devel. 3**
- **Project Comp. 1**
- **Project Comp. 2**
- **Project Comp. 3**
- **EPC Contr. 1**
- **EPC Contr. 2**
- **EPC Contr. 3**
- **Module Supplier 1**
- **Module Supplier 2**
- **Module Supplier 3**

### Summary for Opt. 1:
- + lower procurement cost
- + no interfaces with others
- + high security for EPC contractor
- + synergy effects
- + single operator advantage
- - concentration risk
- - market development risks ($$)
- - complex financing with multiple bank groups
- - response from the market limited to the “big players”
## What is requested?

### Dubai – MBR Phase III

| Parameters | • Defined area of around 20km²  
| - | • Defined power 800MW<sub>ac</sub> at point of connection  
| - | • DEWA as 60% Shareholder of the future IPP  
| Target | • Comply with technical, legal, financial requirements  
| - | • Lowest tariff  
| - | • Phased commissioning  
| Result | • 1-axis tracking system  
| - | • About 1,000 MW<sub>dc</sub>  
| - | • 2.99 USct/kWh  

### Abu Dhabi – Sweihan

| Parameters | • Defined area of 7.8 km²  
| - | • Grid connection max. 2 x 600MW<sub>ac</sub> at point of connection  
| - | • ADWEA as 60% Shareholder of the IPP  
| Target | • Comply with technical, legal, financial requirements  
| - | • Weighted tariff  
| - | • High power / electricity generation  
| - | • Increased tariff during summer months (high demand)  
| Result | • Fix east-west installation  
| - | • Cleaning “robots”  
| - | • Approx. 1,177 MW<sub>ac</sub> / 935 MW<sub>dc</sub> (1.5 MWdc/Ha)  
| - | • 2.46 USct/kWh charge rate (LCOE similar to DEWA Phase 3)  

Different parameters and targets lead to different optimized concepts and layouts in the bids:

**fix east-west** ➔

**horizontal 1-axis**

Project specific optimization is required to win projects!
Project Examples

Recent examples for IPP with different parameters and targets

- MBR Solar Park, Dubai: 13+200+800+700 MW (Phase I - IV)
  - up to 5 GW solar capacity by 2030
- Sweihan, Abu Dhabi: 1,177 MW dc

Sources: Google Earth
Fichtner Value Engineering Approach

1. p-Si / fix installation
   - Specific: CAPEX, OPEX, Yield
   - Cost-Benefit Optimization
   - Optimized Concept
     - Total: CAPEX, OPEX, Yield
     - Optimal: LEC, IRR, NPV
     - Land requirement
     - # of suppliers

2. p-Si / east-west tracking
   - Specific: CAPEX, OPEX, Yield
   - Cost-Benefit Optimization
   - Optimized Concept
     - Total: CAPEX, OPEX, Yield
     - Optimal: LEC, IRR, NPV
     - Land requirement
     - # of suppliers

3. p-Si / 2-axis tracking
   - Specific: CAPEX, OPEX, Yield
   - Cost-Benefit Optimization
   - Optimized Concept
     - Total: CAPEX, OPEX, Yield
     - Optimal: LEC, IRR, NPV
     - Land requirement
     - # of suppliers

x. CdT / 1-axis tracking
   - Specific: CAPEX, OPEX, Yield
   - Cost-Benefit Optimization
   - Optimized Concept
     - Total: CAPEX, OPEX, Yield
     - Optimal: LEC, IRR, NPV
     - Land requirement
     - # of suppliers

Ranking of Concepts
- NPV
- LECs
- IRR

Determined by this approach:
- ≈ 70% of CAPEX
- ≈ 80% of OPEX
- ≈ Land requirement

CAPEX: Capital Expenditures, OPEX: Operational Expenditures, LEC: Levelized Electricity Costs, IRR: Internal Rate of Return, NPV: Net Present Value
Fichtner Value Engineering Approach

Technical Parameters for Yield Simulation:
- PV modules (no./ type)
- Inverters (no. / type)
- String length (modules in series)
- Structure type (tracking or fixed)

⇒ Variation of rows, distance, tilt, and azimuth
⇒ Impact of mutual shading
⇒ Required surface
Hundreds of “Batch Simulations”

Financial Parameters
- Specific CAPEX and OPEX
- Land availability and cost
- Investment duration
- PV Modules degradation
- Irradiance and fluctuation
- Interest rate and inflation
- Energy price / Feed-in Tariff

Cost-Benefit Optimization Parameters (Fichtner Model):
- Specific / overall energy production (MWh, kWh/kWp)
- Levelized Electricity Cost (LEC)
- Net Present Value (NPV)
- Internal Rate of Return (IRR)
- Installable power (per given area)

Apparently, the results are sensitive to input data, such as cost assumptions, solar irradiation, yields, etc.
Optimization Results - Yield

Energy Yield estimated for the 1st year of operation

Fix South-oriented Installation

1-axis Tracking

Maximum: 1,708,581 MWh
(Tilt 10°, DC/AC 1)

Maximum: 2,017,719 MWh
(DC/AC 1)
Optimization Results - LCOE

Levelized costs of electricity calculated over project term and (simplified) CF-Model

Fix South-oriented Installation

Minimum: 0.845 €/kWh
(Tilt 10°, DC/AC 1.25)

1-axis Tracking

Minimum: 0.0829 €/kWh
(DC/AC 1.25)
Optimization Results – comparison of concepts

Development of the specific yield with increasing land usage

![Graph showing the development of specific yield with land usage](image)
Fichtner Value Engineering Approach

Example of a PV plant optimized layout (Helios3D): Golf course in Japan
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Electrical Storage

Use of electrical storage for e.g.

- Typical PV-diesel-battery hybrid Projects worldwide (“fuel-saver”)
- Energy shifting of load or renewable energies
- Grid Stabilization (ramp rates, frequency and voltage control, spinning reserves)
- Transmission & distribution savings
- PV Plant Repowering with existing PPAs (inclusion of new PV and storage)
- Large storage projects in the Middle East with Fichtner’s involvement
  - Recent 30 MW/60 MWh IPP in Jordan for ramp-rate control and energy shift
  - Green peakers and up to 1,000 MW storage by 2030 foreseen in Dubai
Challenge: Ramp rates due to clouds

- Incoming solar irradiation can vary e.g. due to clouds (see figure)
- Clouds move over the field, but shading does not happen at once
- Usually there is always some diffuse irradiation available for PV generation
- Impact depends on plant size, plant shape and the cloud (type of the cloud, speed, direction, height, density…)

![Solar Irradiation Graph](Image)
Electrical Storage – ramp rates

Solution: **Battery storage**.
Example: PV-Battery hybrid system in the Caribbean

Ramp rates according to the grid code must be fulfilled, even with higher shares of PV generation.

Electrical storage **controls the ramp rates** and **flattens the generation profile**.

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![Graph](image-url)
Electrical Storage – provision of peak load

Management and shift of PV generation:

- Power injection up to the allowed capacity
- Provision of energy at peak demands
- Efficient operation with reduced curtailment of PV power
- Provision of power at times where otherwise conventional peak plants with the highest generation costs have to be started
Hybrid and Storage IPP – Examples

**Saudi Arabia**: PV-battery-diesel Hybrid IPP (TA: Fichtner)

**Jordan**: Electrical storage IPP (TA: Fichtner)

**Kauai Island, Hawaii**: Hybrid IPP
Hybrid and Storage IPP – Dairy farm in Saudi Arabia

Project Background
- 75,000 cows at 30-50°C in the Arabian desert
- Peak electrical demand between 75 – 100 MWe
- Heating and Cooling demand for milk processing
- Currently powered by multiple 4-8 MW diesel generators
- LFO price today at 12 USct./liter

Challenge
- Increasing production and energy demand
- Fuel price increase
- Fuel budget limitation
- Disposal of manure

Hybrid Project Solution with storage
- Fuel saver
- Increase maximum power output
- Implementation in stages until 2022
Diesel Generator specifications:
- 8 x 8 MW engines (Prime) running on HFO
- 48 MW Back-up generators distributed over Dairy farms running on LFO

Objective:
- Main power supply
- Active and reactive power control
- Ramp rate + frequency control
- Peak power supply
- Back-up power

Generation costs:
- HFO: 3.1 USct./kWh
- LFO: 4.9 USct./kWh
Hybrid and Storage IPP – Dairy farm in Saudi Arabia

**PV Plant**

**Objective:**
- Provision of electricity (active + reactive)
- Increase maximum power output during day
- Save diesel fuel

**Specifications:**
- 40 MVA (Stage I) + 50 MVA (Stage II)
- DC/AC ratio: 1.1 (cos Phi requirement)

**Interfaces:**
- Switchgear at Main Power Station

**Estimated generation costs:**
- 1-axis tracked: 4.65 USct./kWh (2016)
- Fixed mounted: 4.85 USct./kWh (2016)
Electrical Storage

Objective:
- Increase of maximum power output
- Provision of reactive power
- Provision of spinning reserve (bridging the time the diesel generators need to start up)
- Firming of short-term fluctuations of PV (e.g. clouds, sand storms) until ramp rate capabilities of the diesel generators
- Load shifting of PV energy production to increase PV utilization
- Black-start capability

Specifications of Storage:
- Lithium-ion technology
- 50 MW / 25 MWh (Final Stage)

CAPEX assumption: 28 mio. USD (2016)
Electrical Storage IPP – Jordan

**Electrical Storage**
- Ma’an Solar Substation, Q2/2019
- PV power: 160 MW
- Battery Storage: 30 MW / 60 MWh

**Objective:**
- Ramp-rate control
- Wind and solar energy shifting
- Spinning reserve
- Emergency frequency control

**Status:**
- PQ phase going on
- Storage Lease agreement between Developer and utility (NEPCO)
- Built, Owned and Maintained by Developer but **Operated by Utility**
- Utility can optimize utilization in the future
- Compensation of Developer by usage of utility plus fixed capacity payment
Electrical Storage IPP – Hawaii

Kauai Island, Hawaii, Utility Cooperative, Q1/2017

- PV power: 13 MW
- Battery Storage: 13 MW / 52 MWh

Objective:
- Solar energy shifting
- Future “Renewable Peaker Plant”:*  

Numbers:
- PPA signed with AES
- LCOE 11 USc/kWh
- 28 MW PV
- 20 MW / 100 MWh storage
- Fossil fuel saving: 14,000,000 liters/a
- expected COD Q4 2018

Summary and Conclusion

- IPPs differ from each other with regards to
  1. Ownership
  2. Project development and
  3. “Target function”.

→ Project specific technical design optimization required

- Increasing shares of renewable energies together with decreasing storage prices lead to viability of storage projects not only for grid stability but to time-shift renewable energy generation (“renewable peaker plants”).

- First large scale storage projects are being implemented as IPP, i.e. similar to power plants instead of typical EPC schemes in grid infrastructure.
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## Organization Home Office

### Board of Directors

<table>
<thead>
<tr>
<th>Business Development</th>
<th>Compliance / HSE</th>
<th>Power Plants / Solar Thermal / Desalination / Oil &amp; Gas</th>
<th>Electrical Systems / Network</th>
<th>Renewable Energies / Environment</th>
<th>Logistics / Human Resources</th>
<th>Finances / Deputy Chairman</th>
<th>IT</th>
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<tbody>
<tr>
<td>Tilman Herzig</td>
<td>Hans Kalb</td>
<td>Theophil Laukemann</td>
<td>Ralf Epping</td>
<td>Roland Pröger</td>
<td>Georg Fichtner</td>
<td>Dr. Andreas Weidler</td>
<td>Michael Wilfer</td>
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</tbody>
</table>

### Business Development

- **Germany & Western Europe (V1)**
  - Christian Wilckens
- **CEE, CIS & Turkey (V2)**
  - Artur Makaryan
- **Asia & Oceania (V3)**
  - Volkmar Hirsching
- **Middle East & Americas (V4)**
  - Matthias Schnurrer
- **Africa (V5)**
  - Thomas Prosy

### Central Divisions/Services

- **Human Resources**: Dr. J. Koblishcke
- **Logistics**: R. Witschel
- **Controlling, Taxes**: C. Klein
- **Accounting**: B. Raquet
- **IMS**: D. Hans
- **Contract Management, Communications**: A. Miralles
- **IT**: M. Wilfer
- **Protection of Data**: A. Kutschka
- **IT Safety**: J. Hartig
- **Information**: B. Feistritzer

### Business Division – G1

- **Power Plants, Solar Thermal, Desalination, Oil & Gas**
  - Theophil Laukemann

### Business Division – G2

- **Electrical Systems & Networks**
  - Ralf Epping

### Business Division – G3

- **Renewable Energies & Environment**
  - Roland Pröger

### Compliance Officer

- **Uwe Ohls**
Overview of Transaction Process

1. **Feasibility Phase**
   - Determine objectives / project constraints
   - Determine optimal technical option, IPP project structure and transaction strategy

2. **Pre-qualification Phase**
   - Prepare RfQ
   - Call for Statements of Qualification (SoQ)
   - Select qualified potential investors

3. **Bidding and Evaluation Phase**
   - Prepare and issue RfP (tender documents)
   - Bid submission
   - Evaluation of Bids
   - Recommend Preferred Bidder

4. **Negotiation and Financial Close**
   - Negotiation
   - Project Award
   - Finalize Project Agreement(s)
   - Sign PPA

5. **Financial Close**