Description of renewable energy options

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Director,
Photovoltaic Solar Energy department
Agenda

• Context for 2016 Renewable Energies development
• World Energy Mix. Prospects and forecasts
  – An approach to Renewable Energies (Wind, Biomass, Solar, Other)
• GCC countries
  – Opportunities
• Solar photovoltaic energy
  – Markets
  – Prices and the learning curve
  – Components production
Description of renewable energy options

Context for 2016 Renewable Energies development
2015 A YEAR OF RECORDS FOR RENEWABLE ENERGIES

• Cumulative world renewable capacity surpassed that of coal.
• A record amount of new Renewable Energy capacity was installed in 2015 that represented 55% of total additions
• 153 GW of new capacity connected to the grid:
  – 66GW record level wind additions
  – 49GW record level PV additions

Source: Global outlook report 2016, IEA
2015 A YEAR OF RECORDS FOR RENEWABLE ENERGIES

• COP21 Paris Agreement gives momentum to renewables
• Local air pollution & energy security are also key drivers
• Global Energy investment confirms transition to renewables
  – 17% investment in renewables
  – 12% investment in energy efficiency
• In order to continue that trend, policy makers need to provide investors more clarity & certainty
New policies underpin a more bullish forecast for renewables

Electricity and renewable generation growth by country/region

Source: Total electricity generation from World Energy Outlook 2016
New policies underpin a more bullish forecast for renewables

Renewable electricity capacity growth (GW) in MTRMR’s main case

Source: IEA Medium Term Market Report
2015 A YEAR OF RECORDS FOR RENEWABLE ENERGIES

• Other areas of investment for development of Renewable Energies
  
  – Strategies for system integration of variable renewables (wind and solar PV) must be developed and implemented
  – Application of renewable energy to heat (industry and buildings)
  – Biofuels also as an alternative for automotive industry
• More optimistic forecasts in some scenarios suggest that PV could reach 700GW in 2020 (Solar Power Europe, Global Market outlook 2016)

• A new global organization has been created:

Global solar power foundation
  – Headquarters in China
  – Secretariat in US
Description of renewable energy options

World Energy Mix. Renewable Energies
ESTIMATED RENEWABLE ENERGY SHARE OF GLOBAL FINAL ENERGY CONSUMPTION, 2014

Fossil fuels 78.3%

All renewables 19.2%

Modern renewables 10.3%

Traditional biomass 8.9%

Hydropower 3.9%

Biomass/ geothermal/ solar heat 4.2%

Wind/solar/ biomass/ geothermal 1.4%

Biofuels 0.8%

Nuclear 4.8%

Oil 31.3%

Coal 28.5%

Natural Gas 21.2%

Renewables 13.8%

Hydro 2.4%

Biofuels and waste 10.1%

Other renewable 1.3%

Other 0.3%

1. Other includes electricity from energy sources not defined above such as non-renewable wastes, peat, oil shale and chemical heat.
2. Other renewables includes geothermal, wind, solar, tide.

Note: Totals in graphs might not add up due to rounding.

IEA 2016 Key Renewable Trends
AVERAGE ANNUAL GROWTH RATES OF RENEWABLE ENERGY CAPACITY AND BIOFUELS PRODUCTION

<table>
<thead>
<tr>
<th>Energy Type</th>
<th>Growth Rate in 2015</th>
<th>Growth Rate End-2010 Through 2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geothermal power</td>
<td>3.7</td>
<td>42</td>
</tr>
<tr>
<td>Hydropower</td>
<td>2.4</td>
<td>2.9</td>
</tr>
<tr>
<td>Solar PV</td>
<td>2.7</td>
<td>28</td>
</tr>
<tr>
<td>CSP</td>
<td>35</td>
<td>9.7</td>
</tr>
<tr>
<td>Wind</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>Solar heating</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>Ethanol production</td>
<td>3</td>
<td>3.9</td>
</tr>
<tr>
<td>Biodiesel production</td>
<td></td>
<td>6.5</td>
</tr>
</tbody>
</table>

RENE21 Global Status Report 2016
RENEWABLE POWER CAPACITIES IN WORLD, EU-28, BRICS AND TOP SEVEN COUNTRIES, END-2015

*Not including hydropower (see Reference Table R2 for data including hydropower).

The five BRICS countries are Brazil, the Russian Federation, India, China and South Africa.
**HYDROPOWER**

- **China**: +16.1 gigawatts (Added in 2015: +100, 2014 total: 300)
- **Brazil**: +2.5 gigawatts
- **Turkey**: +2.2 gigawatts
- **India**: +1.9 gigawatts
- **Vietnam**: +1.0 gigawatts
- **Malaysia**: +0.7 gigawatts
- **Canada**: +0.7 gigawatts
- **Lao PDR**: +0.6 gigawatts
- **Colombia**: +0.6 gigawatts

*Funded by European Commission and REN21 Global Status Report 2016*
Electricity (and heat) generation in Biomass plants
BIFUELS GLOBAL PRODUCTION, SHARES BY TYPE AND BY COUNTRY/REGION, 2015

- **Ethanol**: 74%
- **Biodiesel**: 22%
- **HVO**: 4%

**United States**
- 46%

**Brazil**
- 24%

**Rest of World**
- 15%

**EU**
- 15%

*REN21 Global Status Report 2016*
Biofuels could technically substitute oil in all transport modes, with existing power train technologies and existing re-fuelling infrastructures. Use of biomass resources can also decarbonise synthetic fuels, methane and LPG.

- **First generation** biofuels are based on traditional crops, animal fats, used cooking oils. They include FAME biodiesel, bioethanol, and biomethane.

- **Advanced and second generation** biofuels are produced from ligno-cellulosic feedstock and wastes. They include bioethanol, HVO, higher alcohols, DME, BTL and biomethane.
From a feedstock and process point of view advanced biofuels should fulfill at least the following criteria:

- Focus on sustainability
- Feedstock production should not compete with food production
- Feedstock production should not harm the environment (e.g. cause deforestation, ground water pollution etc.)
- Feedstock production and fuel processing should be efficient from a GHG point of view.
The criteria from an end-use point of view:

• At least equivalent end-use quality compared with traditional mineral oil based fuels
• Compatibility with existing refueling infrastructure
• Compatibility with existing vehicles
• Fuel components that do not only provide heating value but also a possibility for reduced harmful exhaust emissions.
The production of biofuels from both food and energy crops (1st Gen) is limited by the availability of land, water, energy and co-product yields, and sustainability considerations, such as the lifetime accountancy of CO2 emissions. Second generation biofuels from wastes and residues are also limited by the availability of these materials.

The development of feedstock potential and of optimized production processes is of the highest priority.

A supportive policy framework and harmonized standards for biofuels are key elements for the future uptake of sustainable biofuels.
GEOTHERMAL ENERGY

• Depends on the type of resource available
  – High temperature resources (>150ºC): produce hot water and vapor. Can be used for heating and for electricity (water is given back to the original place).
  – Medium- low temperature (30ºC-150ºC): used mostly for district heating, spas, greenhouses... and in some cases for electricity
  – Low temperature (<30ºC): for clymatization, usually through a heat pump

• 2,3% growth rate since 1990 until 2015 and stable
Policy support and more R&D in order to find adequate applications are needed
Increase of medium-low temperature users

Source: ERA-NET GEOTHERMAL (2015)
GEOTHERMAL ENERGY

- There are concerns about environmental impacts
- On the technological side, there are six areas of interest:
  - Exploration, measurement and logging
  - Drilling technology
  - Reservoir creation and enhancement
  - Induced seismicity
  - Surface technology (heat and electricity production, ...)
- **Policy support** needed
- Effort on R&D
<table>
<thead>
<tr>
<th></th>
<th>World</th>
<th>China</th>
<th>Brazil</th>
<th>United States</th>
<th>India</th>
<th>Japan</th>
<th>Bangladesh</th>
<th>European Union</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Germany</td>
<td>France</td>
<td>Rest of EU</td>
<td></td>
</tr>
<tr>
<td>Solar PV</td>
<td>2,772</td>
<td>1,652</td>
<td>4</td>
<td>194</td>
<td>103</td>
<td>377</td>
<td>127</td>
<td>38</td>
<td>21</td>
<td>84</td>
<td></td>
</tr>
<tr>
<td>Liquid biofuels</td>
<td>1,678</td>
<td>71</td>
<td>821c</td>
<td>277l</td>
<td>35</td>
<td>3</td>
<td>3</td>
<td>23</td>
<td>35</td>
<td>47</td>
<td></td>
</tr>
<tr>
<td>Wind power</td>
<td>1,081</td>
<td>507</td>
<td>41</td>
<td>88</td>
<td>48</td>
<td>5</td>
<td>0.1</td>
<td>149</td>
<td>20</td>
<td>162</td>
<td></td>
</tr>
<tr>
<td>Solar heating/cooling</td>
<td>939</td>
<td>743</td>
<td>41d</td>
<td>10</td>
<td>75</td>
<td>0.7</td>
<td>10</td>
<td>6</td>
<td>19</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solid biomassa,g</td>
<td>822</td>
<td>241</td>
<td></td>
<td>152e</td>
<td>58</td>
<td>49</td>
<td>48</td>
<td>214</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biogas</td>
<td>382</td>
<td>209</td>
<td></td>
<td>85</td>
<td>9</td>
<td>48</td>
<td>4</td>
<td>14</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydropower (small-scale)p</td>
<td>204</td>
<td>100</td>
<td>12</td>
<td>5</td>
<td>8</td>
<td>12</td>
<td>31</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Geothermal energya</td>
<td>160</td>
<td>35</td>
<td></td>
<td>2</td>
<td>17</td>
<td>31</td>
<td>55</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CSP</td>
<td>14</td>
<td>4</td>
<td></td>
<td></td>
<td>0.7</td>
<td></td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>8,052h</td>
<td>3,523</td>
<td>918</td>
<td>769</td>
<td>416</td>
<td>388</td>
<td>141</td>
<td>355l</td>
<td>170</td>
<td>644k</td>
<td></td>
</tr>
</tbody>
</table>

---

* All the values are estimates and may vary depending on various factors.
* Solar PV: Solar Photovoltaic
* Liquid biofuels: Ethanol, Biodiesel, etc.
* Wind power: Onshore, Offshore
* Solar heating/cooling: Non-PV
* Solid biomass: Wood, Agriculture residues, etc.
* Biogas: Anaerobic digestion
* Hydropower (small-scale): Small hydroelectric power plants
* Geothermal energy: Geothermal energy production
* CSP: Concentrated Solar Power
* Estimated total: 8.1 million jobs worldwide.

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**Source:** IEA

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**Funded by:** European Commission

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**Centro Nacional de Energías Renovables**

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**Fundación CENER-CIEMAT**
Achieving the GCC Renewable Energy targets could create 140,000 jobs per year, and up to 210,000 in 2030, 85% Solar (PV and CSP).

*Source: Renewable Energy Market Analysis: the GCC region (IRENA-2016)*
PPA PRICE OFFERS FOR SOLAR PV AND WIND ONSHORE POWER PLANTS IN DIFFERENT COUNTRIES

FIGURE 1 PPA PRICE OFFERS FOR SOLAR PV AND WIND ONSHORE POWER PLANTS IN DIFFERENT COUNTRIES

Description of renewable energy options

Solar Photovoltaic Energy: Markets
EVOLUTION OF GLOBAL TOTAL SOLAR PV INSTALLED CAPACITY 2000-2015

*APAC excl. China

Funded by European Commission
EVOLUTION OF GLOBAL TOTAL SOLAR PV INSTALLED CAPACITY: confidence in numbers?

• From 50 to 59 GW installed in 2015
  • Who’s right, who’s wrong?
  • Counting apples, pears… and more?
• Some rules
  • Counting AC numbers is simply wrong □ switch to DC or count both.
• What does « installed » means? Commissioned?
• Production > shipments > installations …
## EVOLUTION OF GLOBAL TOTAL SOLAR PV INSTALLED 2015: TOP 10 INSTALLATION AND TOTALS

### TABLE 1: TOP 10 COUNTRIES FOR INSTALLATIONS AND TOTAL INSTALLED CAPACITY IN 2015

<table>
<thead>
<tr>
<th>Rank</th>
<th>Country</th>
<th>Annual Installed Capacity (GW)</th>
<th>Cumulative Installed Capacity (GW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>China</td>
<td>15,2 GW</td>
<td>43,5 GW</td>
</tr>
<tr>
<td>2</td>
<td>Japan</td>
<td>11 GW</td>
<td>39,7 GW</td>
</tr>
<tr>
<td>3</td>
<td>USA</td>
<td>7,3 GW</td>
<td>34,4 GW</td>
</tr>
<tr>
<td>4</td>
<td>UK</td>
<td>3,5 GW</td>
<td>25,6 GW</td>
</tr>
<tr>
<td>5</td>
<td>India</td>
<td>2 GW</td>
<td>18,9 GW</td>
</tr>
<tr>
<td>6</td>
<td>Germany</td>
<td>1,5 GW</td>
<td>8,8 GW</td>
</tr>
<tr>
<td>7</td>
<td>Korea</td>
<td>1 GW</td>
<td>6,6 GW</td>
</tr>
<tr>
<td>8</td>
<td>Australia</td>
<td>0,9 GW</td>
<td>5,4 GW</td>
</tr>
<tr>
<td>9</td>
<td>France</td>
<td>0,9 GW</td>
<td>5,1 GW</td>
</tr>
<tr>
<td>10</td>
<td>Canada</td>
<td>0,6 GW</td>
<td>5 GW</td>
</tr>
</tbody>
</table>

©Snapshot of Global PV Markets – IEA PVPS
FIGURE 6: EVOLUTION OF MARKET SHARE OF TOP COUNTRIES

SOURCE IEA PVPS & OTHERS.
EVOLUTION OF GLOBAL TOTAL SOLAR PV INSTALLED
2015: ENERGY VERSUS POWER INSTALLED

FIGURE 4: NATIONAL PV PENETRATION IN % OF THE ELECTRICITY DEMAND BASED ON 2015 CAPACITIES

©Snapshot of Global PV Markets – IEA PVPS
EVOLUTION OF GLOBAL TOTAL SOLAR PV INSTALLED: WHAT ABOUT 2016 until 2020?

Source: PV Market Alliance – Becquerel Institute 2016
GLOBAL ANNUAL SOLAR PV MARKET SCENARIOS UNTIL 2020

Source: Solar Power Europe 2016
SCENARIOS FOR GLOBAL SOLAR PV ROOFTOP AND UTILITY SCALE SEGMENTS DEVELOPMENT 2015-2020

Source: Solar Power Europe 2016
A tale of 2 markets

Distributed PV

Producers

Grid injection, PPA, competition with utilities generation business

Self-consumption, energy efficiency, grid parity, competition with utilities distribution business

Prosumers

Centralized PV

One technology
SCENARIOS FOR GLOBAL SOLAR PV DEVELOPMENT
2015-2020: 2 MARKETS

FIGURE 11: SHARE OF GRID-CONNECTED CENTRALIZED & DECENTRALIZED PV INSTALLATIONS BY REGION IN 2015

- The Americas
- Europe
- Middle East & Africa
- Asia Pacific

Grid-connected decentralized and Grid-connected centralized

SOURCE: IEA PVPS & OTHERS.
MAIN POLICY DRIVERS FOR SOLAR PV IN 2015

Source: Data from IEA-PIPS.
Evolution of PV power installed in European countries
Installed PV power type in Europe by country to 2015
Description of renewable energy options

Solar Photovoltaic Energy: Production
Production of photovoltaic cells and modules by region

Global Annual Production [GWp]

Year

Europe
Japan
China & Taiwan
North America
ROW


0 5 10 15 20 25 30 35 40 45

Navigant Consulting and Paula Mints; graphics PSE AG 2016

Funded by European Commission

CENER

CENTRO NACIONAL DE ENERGÍAS RENOVABLES
FUNDACIÓN CENER-CIDET"
Production share of cells and photovoltaic modules by region

Year

Percentage of Total Production [MWp]

100%
80%
60%
40%
20%
0%

Europe
Japan
China & Taiwan
US
ROW


Navigant Consulting and Paula Mints; graphics PSE AG 2016

Funded by European Commission
Main photovoltaic cell and module companies in 2015

<table>
<thead>
<tr>
<th>Company</th>
<th>Products</th>
<th>Country</th>
<th>Production sites location</th>
<th>Production capacity (MWp)</th>
<th>Shipment (MWp)</th>
<th>Net revenues (€M)</th>
<th>Employees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trina Solar</td>
<td>Ingots, wafers, cells, modules</td>
<td>China</td>
<td>China</td>
<td>5,000</td>
<td>5,740</td>
<td>2,762</td>
<td>14,200</td>
</tr>
<tr>
<td>Jinko Solar</td>
<td>Ingots, wafers, cells, modules</td>
<td>China</td>
<td>China, Malaysia, South Africa, Portugal</td>
<td>4,000</td>
<td>4,512</td>
<td>2,258</td>
<td>15,000</td>
</tr>
<tr>
<td>Canadian Solar</td>
<td>Ingots, wafers, cells, modules</td>
<td>Canada, China</td>
<td>China, Canada</td>
<td>4,330</td>
<td>4,384</td>
<td>3,156</td>
<td>8,673</td>
</tr>
<tr>
<td>JA Solar</td>
<td>Wafers, cells, modules</td>
<td>China</td>
<td>China</td>
<td>3,500</td>
<td>3,673</td>
<td>1,900</td>
<td>12,300</td>
</tr>
<tr>
<td>Hanwha Q-cells</td>
<td>Ingots, wafers, cells, modules</td>
<td>Korea, Germany</td>
<td>China, Germany</td>
<td>3,500</td>
<td>3,306</td>
<td>1,038</td>
<td>1,400</td>
</tr>
<tr>
<td>First Solar</td>
<td>Thin film modules (CdTe)</td>
<td>USA</td>
<td>Malaysia, USA</td>
<td>2,800</td>
<td>2,900</td>
<td>3,265</td>
<td>6,350</td>
</tr>
<tr>
<td>Yingli Green Energy</td>
<td>Ingots, wafers, cells, modules</td>
<td>China</td>
<td>China, Thailand</td>
<td>2,450</td>
<td>2,400</td>
<td>1,371**</td>
<td>19,000</td>
</tr>
<tr>
<td>Renesola</td>
<td>Ingots, wafers, cells, modules</td>
<td>China</td>
<td>China and though joint ventures: Poland, South Africa, India, Malaysia, South Korea, Turkey, Japan</td>
<td>1,700</td>
<td>1,600</td>
<td>1,167</td>
<td>6,950</td>
</tr>
<tr>
<td>SunPower</td>
<td>Cells, modules</td>
<td>USA</td>
<td>Philippines, USA</td>
<td>1,400</td>
<td>969</td>
<td>2,370</td>
<td>8,300</td>
</tr>
<tr>
<td>Solar World</td>
<td>Cells, modules</td>
<td>Germany</td>
<td>Germany, USA</td>
<td>1,500</td>
<td>1,159</td>
<td>763</td>
<td>2,950</td>
</tr>
</tbody>
</table>

*Shipment figures may be higher than production capacity due to stocks and undisclosed outsourcing.* **Q15 revenues have been estimated based on Yingli's shipment outlook of Q35. Final results may differ. Source: EuroObserver 2016**
Evolution of the main companies producing cells / modules

Source: IHS Research, CompareMySolar.co.uk

1. Yingli (China)
2. Trina Solar (China)
3. Canadian Solar (China)
4. Sharp (Japan)
5. Jinko Solar (China)
6. First Solar (USA)
7. ReneSola (China)
8. Kyocera (Japan)
9. JA Solar (China)
10. Hanwha SolarOne (China)
50.6GWp production at 2015
93% was c-Si wafer based, multi-Si, 69%,
Evolution of the market share of thin film technologies

Production 2015 (GWP)

- Cd-Te: 2.5
- a-Si: 0.6
- Cl(GS): 1.1

Percentage of Thin-Film Market Share

Year

0% 2% 4% 6% 8% 10% 12% 14% 16% 18%


Funded by European Commission
PSE AG 2016

CENER
ADtech
CENTRO NACIONAL DE ENERGÍAS RENOVABLES
FUNDACIÓN CENER-CIMAT
Evolution of the market share of HCPV and LCPV technologies

HCPV from 300 to 1000 times concentration, LCPV under 300
Energy Pay-Back Time for PV and CPV Systems
Different Technologies located in Catania, Sicily, Italy

Global Irrad.: 1925 kWh/m²/yr, Direct Normal Irrad.: 1794 kWh/m²/yr

- Tracker
- Inverter
- Mounting + cabling
- Frame
- Laminate
- Cell
- Ingot / crystal + wafer
- Si feedstock

## Evolution of the market share and price of PV inverters and converters

<table>
<thead>
<tr>
<th>Inverter / Converter</th>
<th>Power</th>
<th>Efficiency</th>
<th>Market Share (Estimated)</th>
<th>Remarks</th>
</tr>
</thead>
</table>
| String Inverters     | up to 100 kWp     | up to 98%  | ~ 37%                    | • 11 - 19 €-cents /Wp  
• Easy to replace                                                |
| Central Inverters    | More than 100 kWp | up to 98.5%| ~ 61%                    | • ~ 10 €-cents /Wp  
• High reliability  
• Often sold only together with service contract                  |
| Micro-Inverters      | Module Power Range| 90%-95%    | ~ 2%                     | • ~ 35 €-cents /Wp  
• Ease-of-replacement concerns                                    |
| DC / DC Converters   | Module Power Range| up to 98.8%| n.a.                     | • ~ 10 €-cents /Wp  
• Ease-of-replacement concerns  
• Output is DC with optimized current  
• Still a DC / AC inverter is needed  
• ~ 1 GWp installed in 2014                                      |

Description of renewable energy options

Solar Photovoltaic Energy: Prices and the learning curve
Evolution of the average monthly price of modules sold in Europe by technology and country of origin

Manufacturing costs continue to be reduced, although there is a slight slowdown

Funded by Evolution of the average monthly price of modules sold in Europe by technology and country of origin

Manufacturing costs continue to be reduced, although there is a slight slowdown

Funded by EUGCC Cleanergy.Net

PvXchange and GTM research
• The Learning curve concept is an empirical way of looking at COSTS decrease (due to technology improvements).
• Has been theorized for semi-conductors well before PV (BCG)
• Prices vs Costs
• Automation, industrialization, different cost paradigm in China (cheaper equipment…)
  • Range of costs and prices: LC is perfect for low prices but what for emerging technologies?
• Modules or cells?
EVOLUTION OF MODULES PRICE: THE LEARNING CURVE
EVOLUTION OF MODULES PRICE: THE LEARNING CURVE

Estimated cumulative production up to Q4, 2015:
- c-Si: 235 GWp
- Thin Film: 24 GWp

Crystalline Technology
(from Q2-2006 to Q4-2015) LR 27.0
Thin Film Technology
(from Q2-2006 to Q4-2015) LR 23.5

Data: from 2006 to 2010 estimation from different sources: Navigant Consulting, EUPD, pvXchange; from 2011 to 2015: IHS. Graph: PSE AG 2016
Cost reduction based on:

- Polisilicon reduction (thickness)
- Efficiency of PV cell
- Automation and manufacturing Processes, cell and module
- 20% in 2 years
- In the case of thin film technology reduction mostly due to efficiency increase and manufacturing improvement

Module (33%, 46%, 41%)
- Jinko announced (Q1-2016):
  - 0.37 USD/Wp production costs (others are close: 0.41-0.43)
  - 0.29 USD/Wp end 2017
  - 0.25 USD/Wp in 2020 (First Solar as well)
  - With GPM at 20%: 0.44 USD/Wp (and 0.35 USD FY 2017)

- Prices and cost decline on a 30%+ learning curve

- Official low market prices (Q3-2016): 0.38 USD/Wp

- Prices for large orders: Down to 0.3x USD/Wp?

- Super competitive tenders (Dubai, Jordan, Peru, India) are done with multi-Si, CdTe or aSi.

- Large part of the PV market with higher prices!
### Evolution of the market share and price of PV inverters and converters

<table>
<thead>
<tr>
<th>Inverter / Converter</th>
<th>Power</th>
<th>Efficiency</th>
<th>Market Share (Estimated)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>String Inverters</td>
<td>up to 100 kWp</td>
<td>up to 98%</td>
<td>~ 37%</td>
<td>• 11 - 19 €-cents /Wp</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Easy to replace</td>
</tr>
<tr>
<td>Central Inverters</td>
<td>More than 100 kWp</td>
<td>up to 98.5%</td>
<td>~ 61 %</td>
<td>• ~ 10 €-cents /Wp</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• High reliability</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Often sold only together with service contract</td>
</tr>
<tr>
<td>Micro-Inverters</td>
<td>Module Power Range</td>
<td>90%-95%</td>
<td>~ 2%</td>
<td>• ~ 35 €-cents /Wp</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Ease-of-replacement concerns</td>
</tr>
<tr>
<td>DC / DC Converters (Power Optimizer)</td>
<td>Module Power Range</td>
<td>up to 98.8%</td>
<td>n.a.</td>
<td>• ~ 10 €-cents /Wp</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Ease-of-replacement concerns</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Output is DC with optimized current</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• Still a DC / AC inverter is needed</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>• ~ 1 GWp installed in 2014</td>
</tr>
</tbody>
</table>

• We have been speaking about price of components, however, is the cost of kWh obtained what will make PV technology competitive

On the technical side:
• Good irradiation conditions (site)
• Optimum design
• Optimum components (modules & BOS)
• Adequate M&O

On the financial side:
• FIT or alternative support policy (or not)
• Banking conditions…
PV Systems: Levelized Cost of Electricity (Systems >100kWp)

→ LCoE reduction = key for future success of PV

- System prices:
  → 2016: 1090 $ / kWp
  → 2026: <800 $ / kWp

- LCoE
  → 2016: 4.4 ..... 9 $/cent
  → 2026: 3.1 ..... 6 $/cent are expected

- System live times >25 years are assumed

- Extended service live to 30 years
  → further LCoE reduction expected

Calculated LCoE values for different insolation conditions. Financial conditions: 80% debt, 5%/a interest rate, 20-year loan term, 2%/a inflation rate, 25 years usable system service life.
PPA PRICE OFFERS FOR SOLAR PV AND WIND ONSHORE POWER PLANTS IN DIFFERENT COUNTRIES

FIGURE 1 PPA PRICE OFFERS FOR SOLAR PV AND WIND ONSHORE POWER PLANTS IN DIFFERENT COUNTRIES