Roadmap for Solar PV

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IEA work on renewables

- Renewables analysis also a crucial part of other IEA work: e.g. World Energy Outlook, Energy Technology Perspectives, Tracking Clean Energy Progress
An Energy Revolution is needed

**Generation today:**
- Fossil fuels: 68%
- Renewables: 20%

**Generation 2DS 2050:**
- Renewables: 65 - 79%
- Fossil fuels: 20 - 12%
Where are we in the short to medium term?
Strong momentum for renewable electricity

Global renewable electricity production, historical and projected

*Renewable electricity projected to scale up by 45% from 2013 to 2020*
Dynamic solar markets

- Global PV market 39-40 GW in 2014 (37-38 GW in 2013)

- PV asset finance grew 15% over 2013

- Continued cost reductions
  - Si & TF module costs down 9-15%
  - All other costs down, incl. soft costs
  - Record-low bid prices per kWh in 2014

- Fragmented landscape
  - Australia, Europe slowing on large-scale; large-scale growing in South Africa, US
  - Rooftop growing in the US, resilient in Australia
Renewable investment costs falling

- With scale up of deployment and learning, investment costs of most dynamic technologies (solar PV and onshore wind) continue to fall
- Large scale wind and solar now increasingly competitive

Notes: Average unit investment costs are based on gross additions, which include capacity refurbishments that are typically lower cost than new capacity. Costs vary over time due to technology changes as well as where deployment occurs in a given year.
Still, wide cost ranges persist between markets, largely due to differences in “soft costs”
Cost of capital drives costs..... competition drives cost reduction

- Cost of capital an increasingly important component of cost
- WACC can be reduced by:
  - Sustainable long-term power purchase agreements that provide revenue certainty and facilitate access to debt and equity capital markets
  - Reducing non-economic barriers, reducing grid integration risks, increasing the creditworthiness of off-takers and reducing currency risks

Components of solar PV generation costs

Average awarded tender prices under South Africa Renewable Energy Independent Power Producer Procurement Programme

- Competition for long term PPAs have been effective at driving cost reductions
Generation costs for solar PV falling rapidly

- Growing economic competitiveness of utility-scale solar PV, with fewer incentives, versus other bulk power sources
- At present, the combination of low financing costs, low system prices and excellent resources remains exceptional
- Large ranges still exist between markets, i.e. China at low end, Japan at high end
Increasing examples of wind and solar PV costs comparable to new-build alternatives

Recent long-term remuneration contract prices (e.g. auctions and FITs)

Transition to new era of economic attractiveness for renewables where good resource and appropriate policy and regulatory framework are in place
Even with lower oil and gas prices, renewables can compete against new fossil-fuel generation.

Weighted average annual renewable investment costs, historical and projected

Note: Based on EGC median case, LCOE for OCGT is calculated using a 15% capacity factor and 7% discount rate and LCOE for CCGT is calculated using a 65% capacity factor and 7% discount rate. No carbon pricing is included in LCOEs.
Socket parity emerging as potential deployment driver for distributed PV

- **Economic attractiveness from offsetting electricity bill requires self-using most of the PV electricity**
  - Currently limits potential, in particular for households

- **Reaching socket parity is a driver for private actors**
  - But PV may still have significant impact on total system costs, in particular depending on allocation of fixed network costs
Rooftop PV proves resilient

Commercial in the US

Residential in Australia
Possible self-consumption (SC) varies

Match of PV supply and power demand for a residential/commercial customer in France

- Self-consumption higher for:
  - Some office and commerce buildings with high daily consumption, and relatively small systems on multi-storey dwellings

- Self-consumption potentially increased with DSI, storage

Source: ETP 2014, EDF
Distributed PV at grid-parity: 3 options

**Buy all – sell all**
- Remuneration EP na
- Specific rate for PV production

**Self-consumption and separate EP rate**
- Avoided cost SC grid electricity rate
- Remuneration EP special EP tariff

**Net-metering**
- Avoided cost SC grid electricity rate
- Remuneration EP grid electricity rate
Strong medium-term outlook for solar PV

- Strong growth in emerging markets and some OECD areas
- Policy debates over distributed PV a source of forecast uncertainty

This map is without prejudice to the status of or sovereignty over any territory to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.
Solar PV deployment segments vary by market

- Utility-scale and commercial-scale systems should each account for roughly 40% of capacity growth, followed by residential (17%) and off-grid (1%)
- In Europe, development more in commercial/residential systems
- Utility-scale driven by markets with excellent resources, e.g. Western China, the US Southwest, India, the Middle East, Africa and the non-OECD Americas
  - Still, a significant amount of distributed growth should occur in some of these markets
Higher solar PV under enhanced case

- Average annual market under baseline case = 38 GW (similar to 2013 growth)
- With certain market and policy enhancements -
  - Fair rules and appropriate electricity rate design for allocating the costs and benefits from fast-growing distributed solar PV
  - Greater implementation of ambitious policy aims (e.g. Middle East)
  - Faster-than-expected decreases in solar PV costs
- Solar PV could top 500 GW globally in 2020, with average market of 47-54 GW pa
Medium term solar PV market forecast

- New markets and scale up of distributed PV rooftop are main uncertainties
- Base case possibly increased
Where do we need to go to meet long-term objectives?
Rapid scale-up needed to meet climate change objectives in IEA scenarios

### Capacities required by 2025

<table>
<thead>
<tr>
<th></th>
<th>6DS</th>
<th>2DS</th>
<th>2DS hi-Ren</th>
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<tbody>
<tr>
<td>GW</td>
<td></td>
<td></td>
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<tr>
<td>PV</td>
<td>366</td>
<td>560</td>
<td>823</td>
</tr>
<tr>
<td>STE (CSP)</td>
<td>15</td>
<td>68</td>
<td>116</td>
</tr>
<tr>
<td>Wind land</td>
<td>717</td>
<td>1129</td>
<td>1282</td>
</tr>
<tr>
<td>Wind offshore</td>
<td>37</td>
<td>101</td>
<td>137</td>
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### Generation required by 2025

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<tr>
<td>TWh</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>PV</td>
<td>468</td>
<td>742</td>
<td>1108</td>
</tr>
<tr>
<td>STE (CSP)</td>
<td>52</td>
<td>214</td>
<td>353</td>
</tr>
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<td>Wind land</td>
<td>1489</td>
<td>2460</td>
<td>2795</td>
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<td>108</td>
<td>332</td>
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</table>
New vision: PV grows faster and beyond previous scenario

Solar PV reaches 16% share of total electricity in hi-Ren scenario
Solar PV module costs to decline further

- Current vision: learning rate ~20%
- Regression 1976-2014
But cost declines may proceed faster than expected

- **Alternative vision: learning rate ~23%**
  - **Regression 1976-2003**
Commercial 1-sun module efficiencies

Note: SPW stands for SunPower, HIT S/P stands for Heterojunction Intrisic Thin layer Sanyo/Panasonic.
Integrating large shares of PV is a challenge.

- **High shares of PV (and wind) require more flexible power systems**

Expected evolution of the net load of a typical spring day in California.

Complementary roles of PV and STE

Thanks to thermal storage, STE is generated on demand when the sun sets while demand often peaks
PV could provide 16% of global electricity by 2050 and 20% of CO2 emission cuts

Based on cautious cost assumptions and 8% WACC

Key factor will be flexibility of power systems to integrate large share of v-RE; STE will play a complementary role to PV
Shares vary significantly by region.
## Detailed Actions and milestones

<table>
<thead>
<tr>
<th><strong>Cells and modules</strong></th>
<th><strong>Technology</strong></th>
<th><strong>System Integration</strong></th>
<th><strong>Forecast and grids</strong></th>
<th><strong>Electricity Markets</strong></th>
<th><strong>Power system flexibility</strong></th>
<th><strong>Non-economic barriers</strong></th>
<th><strong>In new or emerging PV markets</strong></th>
<th><strong>In mature PV markets</strong></th>
<th><strong>In island and off-grid markets</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Develop meteorological PV forecast</td>
<td></td>
<td>Increase module efficiencies to 50% (HCPV), 28% (tandem cells), 22% (mc-Si, CdTe, CIGS) or 16% (others)</td>
<td>Increase performance ratios and decrease degradation rates</td>
<td>Develop meteorological PV forecast</td>
<td>Introduce time-of-delivery payments</td>
<td>Authorise generation by independent power producers</td>
<td>Streamlining permitting and connecting, also on buildings</td>
<td>Create a stable, predictable financing environment</td>
<td>Reduce subsidies to retail prices, develop alternative energy sources and implement targeted support to the poor</td>
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<tr>
<td>Increase performance ratios and decrease degradation rates</td>
<td>Develop low cost high efficiency high output bifacial 1-sun tandem cells</td>
<td>Elaborate and enforce grid codes</td>
<td>Develop meteorological PV forecast</td>
<td>Incentivise flexibility from existing capacities</td>
<td>Authorise generation by independent power producers</td>
<td>Train and certify PV installers</td>
<td>Adopt or update medium and long term PV targets</td>
<td>Implement priority dispatch to jump-start PV deployment</td>
<td>Develop and implement business models for off grid and mini-grid PV</td>
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<tr>
<td>Reduce Si consumption to 3 g/W and silver consumption</td>
<td>Develop specific PV materials for specific supports</td>
<td>Prevent PV hot spots with geographical spread</td>
<td>Elaborate and enforce grid codes</td>
<td>Investigate options for new PHS plants</td>
<td>Authorise generation by independent power producers</td>
<td>Implement or update support mechanisms</td>
<td>Develop new storage capabilities</td>
<td>Facilitate distributed PV generation with tariffs or net-metering</td>
<td>Avoid retroactive changes</td>
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<td>Develop low cost high efficiency high output bifacial 1-sun tandem cells</td>
<td>Diversify module specifications for variable environments</td>
<td>Shorten gate closure times and trading block length trading block length</td>
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**SYSTEM INTEGRATION**
- Improve Forecast
- Optimise electricity markets for v-Re
- Increase Power system flexibility
Detailed actions and milestones

**POLICY AND FINANCE**

- Set / update long-term targets
- Predictable policy framework to de-risk financing
  - In new & emerging PV markets
    - Permitting and connecting
  - In mature PV markets
    - Progressively expose to market signals
    - Facilitate distributed PV generation and self-consumption
Concluding remarks

- Renewables including wind and solar PV are increasingly competitive, even in a lower fossil price regime.
- High levels of financial support no longer required if appropriate market and regulatory framework in place.
- Policies should focus on creating the right market and regulatory frameworks.
- Electricity market designs sub-optimal today for low-carbon generation.
Selected messages to policy makers

1. **Set or update long-term targets**
   - Consistent with overall energy strategies
   - Taking into account past and future cost reductions

2. **Develop market designs in a system-approach, e.g:**
   - Fair rules for residential and commercial PV rooftops
   - Time-of-delivery remuneration to take full advantage of dispatchable and flexible generation from STE

3. **De-risk financing with predictable policies**
   - Both capital-intensive technologies
   - Policy predictability most effective and efficient way to reduce risk, thereby improving competitiveness