Solar energy perspectives

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Contents

- Renewables as seen by the IEA
- Solar electricity roadmaps
- Grid integration of variable renewables
- The PV boom and related policy issues
Growing shares of renewables in all sectors, for all scenarios

All scenarios point out a large growth of renewables
Renewables are the second most important contributors to CO2 emissions reduction.
The primary role of renewables in the BLUE scenarios

Renewables provide from almost half to three quarters of the global electricity mix in 2050
Growth of renewable power generation in the BLUE Map

Electricity generation from RE grows strongly. Wind, hydropower and solar provide the bulk of it.
RE generation in 2050 for key countries/regions

The mix varies according to resources
IEA Solar Technology Roadmaps

Technology Roadmap
Solar photovoltaic energy

Technology Roadmap
Concentrating Solar Power

International Energy Agency

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PV & CSP technology roadmaps

• Launched by IEA’s Executive Director Nobuo Tanaka in Valencia, 11 May 2010 (MSP Conf.)
• PV and CSP complementary to each other
• Solar electricity could represent up to 20% to 25% of global electricity production by 2050
  • Roughly half CSP, half PV
  • Producing up to 9000 TWh per year
  • Saving almost 6 billion tonnes CO₂ per year
• This decade crucial for effective policies to enable the development of solar electricity
• Need to plan and invest in grid infrastructure
PV & CSP complementarities

- PV takes all light
- PV almost everywhere
- Mostly at end-users’ Variable
- Peak & mid-peak
- Grid parity (retail) by 2020

- CSP takes direct light
- CSP semi-arid countries
- Mostly for utilities
- Firm, dispatchable backup
- Peak to base-load storage
- Competitive peak power by 2020
- HVDC lines for transport

Firm & flexible CSP capacities can help integrate more PV
<table>
<thead>
<tr>
<th>Receiver type</th>
<th>Focus type</th>
<th>Line focus</th>
<th>Point focus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed</td>
<td>Fixed</td>
<td>Collectors track the sun along a single axis and focus irradiance on a linear receiver. This makes tracking the sun simpler.</td>
<td>Collectors track the sun along two axes and focus irradiance at a single point receiver. This allows for higher temperatures.</td>
</tr>
<tr>
<td>Mobile</td>
<td>Mobile</td>
<td>Linear Fresnel reflector (IFR)</td>
<td>Solar Tower</td>
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<tr>
<td></td>
<td></td>
<td>Curved mirrors</td>
<td>Heliostats</td>
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<td></td>
<td>Absorber tube and reconcentrator</td>
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<td></td>
<td>Parabolic trough</td>
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<tr>
<td></td>
<td>Reflector</td>
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<tr>
<td></td>
<td>Absorber tube</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Solar field piping</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Parabolic dish</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Receiver engine</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reflector</td>
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Uses of storage

Mid load

Delayed mid load
Uses of storage

Base load

Peak load
Morocco 2017: load curve & merit order
Morocco 2017: load curve & merit order with PV
Morocco 2017: load curve & merit order w. CSP
**Temperatures and storage costs**

\[
\text{Stored Heat} = \sum mC_p \Delta T
\]

Stored Heat is Proportional to \( \Delta T \)

Large/Smaller \( \Delta T \) \( \approx \) 278°C/90°C

*Low Temperature Storage Requires \( \approx \) 3X mass*

<table>
<thead>
<tr>
<th>Troughs</th>
<th>Tower</th>
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<tbody>
<tr>
<td>~378°C</td>
<td>566°C</td>
</tr>
<tr>
<td>288°C</td>
<td>288°C</td>
</tr>
</tbody>
</table>

Low Temperature Storage \( \sim \) 3X Cost per MWt
CSP costs and global output

- Competition for peak and mid-peak loads
- Competition for base load
The CSP Roadmap: 2050

Repartition of the solar resource for CSP plants in kWh/m²/yr, and of the production and consumption of CSP electricity (in TWh) by world region in 2050 as foreseen in this roadmap. Arrows represent transfers of CSP electricity from sunniest regions or countries to large electricity demand centres.

Sources: Breyer & Knies, 2009 based on DNI data from DLR-ISIS and IEA Analysis.

HVDC lines will extend CSP areas

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Back-up and Hybridisation

- Back-up to « firm » electric capacities,
- Hybridisation to share the costs of the plant (except solar field)
- SEGS plants in California (25% NG), CSP plants in Spain (10-15%), EAU...

- ISCC plants (with N. Gas): Algeria, Egypt, Iran, Morocco...
- Solar pre-heating of feed water: Australia Florida... (a few %)
- Main steam substitution: towers in supercritical coal plants, from 30% to 70%: China, India, Morocco, RSA???
If sound policies are put in place, PV can provide 5% of global electricity generation in 2030, 11% in 2050
PV deployment and competitiveness

- Thanks to a steep learning curve, deployment-led cost cuts will progressively make residential PV, then utility-scale PV competitive and a cheap GHG mitigation option.

Source: IEA Solar PV Technology Roadmap
Variable RE in 2050

- **2007**
  - Coal: 5 PWh
  - Coal+CCS: 3 PWh
  - Oil: 2 PWh
  - Natural gas: 1 PWh
  - Biomass and waste: 2 PWh

- **Baseline 2050**
  - Coal: 30 PWh
  - Coal+CCS: 5 PWh
  - Oil: 15 PWh
  - Natural gas: 5 PWh
  - Biomass and waste: 10 PWh

- **BLUE Map 2050**
  - Coal: 31 PWh
  - Coal+CCS: 4 PWh
  - Oil: 15 PWh
  - Natural gas: 5 PWh
  - Biomass and waste: 10 PWh
  - Natural gas+CCS: 1 PWh

- **BLUE High Renewables 2050**
  - Coal: 18 PWh
  - Coal+CCS: 5 PWh
  - Oil: 15 PWh
  - Natural gas: 5 PWh
  - Biomass and waste: 10 PWh
  - Natural gas+CCS: 1 PWh
  - Nuclear: 10 PWh
  - Solar PV: 15 PWh
  - Solar CSP: 5 PWh
  - Other: 5 PWh
Emerging challenges: grid integration

Variability is not new, but it does get bigger

Source: *Western Wind and Solar Integration Study, GE Energy for NREL (2010)*
There are 4 flexible resources

- Dispatchable power plants
- Demand side response (via smart grid)
- Energy storage facilities
- Interconnection with adjacent markets

A biomass-fired power plant

A pumped hydro facility

A pumped hydro facility

Scandinavian interconnections
Grid integration of var-RE

Snapshot of present penetration potentials

<table>
<thead>
<tr>
<th>Country</th>
<th>VRE penetration potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denmark</td>
<td>63%</td>
</tr>
<tr>
<td>Nordic market</td>
<td>48%</td>
</tr>
<tr>
<td>United States West (2017)</td>
<td>45%</td>
</tr>
<tr>
<td>NBSO area (of Canada)</td>
<td>37%</td>
</tr>
<tr>
<td>Great Britain and Ireland</td>
<td>31%</td>
</tr>
<tr>
<td>Mexico</td>
<td>29%</td>
</tr>
<tr>
<td>Spain and Portugal</td>
<td>27%</td>
</tr>
<tr>
<td>Japan</td>
<td>19%</td>
</tr>
</tbody>
</table>

Height of bar shows deployment potential based on technical flexible resource

Grid

Market

Score: High, Medium, Low
Current PV boom

Unexpected PV growth raises policy cost concerns in several EU countries

- Czech Rep., France, Germany, Italy, Spain

Sources: IEA PVPS, BP Statistical Report, BNEF
Impacts on total support costs: Spain

Support received vs. production, 2010

Production premium (€/MWh)

- Solar PV: 2.730 M€
- CSP: 210 M€
- Waste: 110 M€
- Waste processing: 250 M€
- Minihydro: 240 M€
- Biomass: 160 M€
- Wind: 1.850 M€
- Cogeneration: 1.370 M€
- Solar PV: 2.730 M€

Production (GWh)

Source: UNESA estimations (September 2010)
Are incentives following cost reduction quickly enough?

Policies are not adapting quickly enough

Country price differences mainly reflect incentives
Small-scale systems: Germany 2010

- Difficult to predict and monitor hundreds of thousands of investors

**German PV 2010 share of new installed capacity by size of installation**

- 52%: > 500 kWp
- 21%: 10 kWp - 100 kWp
- 16%: 0 kWp - 10 kWp
- 10%: 100 kWp - 500 kWp

**German PV 2010 number of new installations by size**

- > 500 kWp: 161,864
- 10 kWp - 100 kWp: 1,184
- 0 kWp - 10 kWp: 126,396
- 100 kWp - 500 kWp: 6,995

Source: Bundesnetzagentur, 2011
Will quantity caps be required?

- Controlling overall costs by controlling the level of incentives appear difficult and risky
  - Uncertain and fast-changing costs, large potential
  - Political risks for FITs
  - But Germany may succeed
Solar heat: the current leader
Another possible synergie between solar and coal for RSA: producing liquid fuels with lower CO$_2$ emissions
At global level, government support will continue to grow.

Government support remains the key driver – rising from $57 billion in 2009 to $205 billion in 2035 – but higher fossil-fuel prices & declining investment costs also spur growth.
Solar publication: a primer

- Publication in September
- All technologies, all sectors, all countries, all timescales

Markets and Outlook
- Electricity
- Buildings
- Industry
- Transport
- Testing the limits
- Policies

Technologies
- Photovoltaics
- Heat
- STE/CSP
- Solar fuels
A global approach

- Solar energy has the potential to become the largest source of electricity, and contribute to heating, cooling, process heat, transport fuel

- The bulk of the forthcoming growth of energy demand is in sunny countries

- Solar may also change million lives with access to modern energy services

- Efforts/benefits need to be shared globally
  
  “Spend wisely, share widely”