Solar Economics – Is Grid Parity at Hand?

Georgia Tech Clean Energy series

February 27, 2013

McKinsey&Company

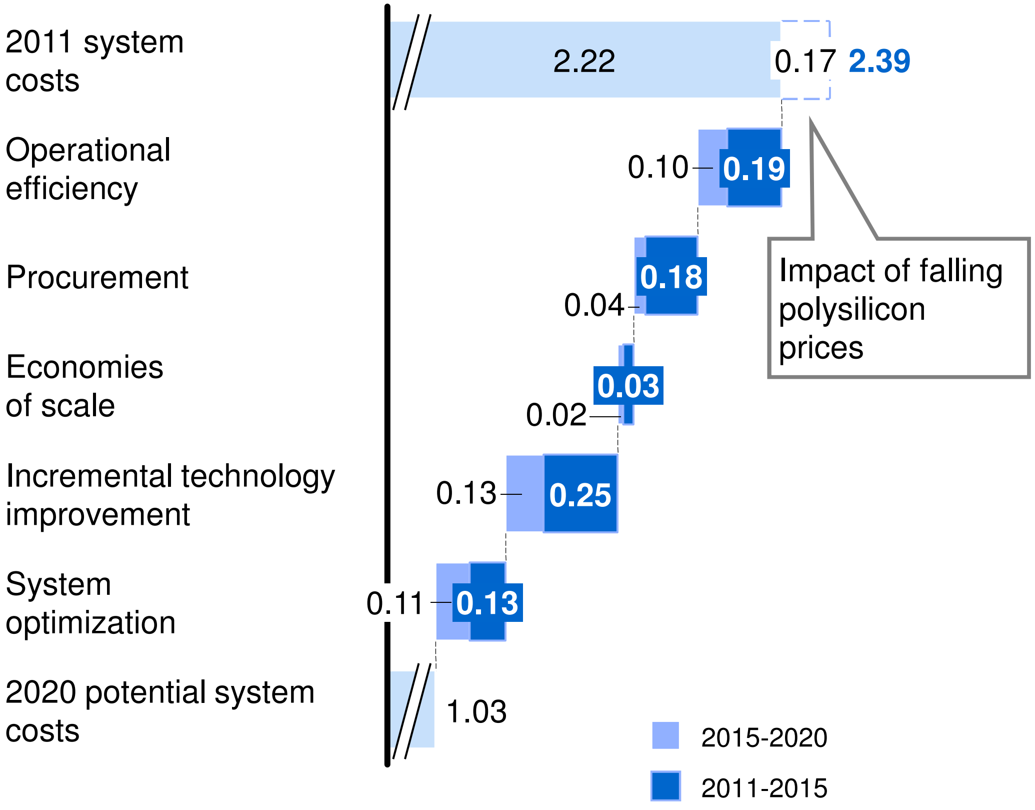
Executive summary

- The cost to produce a PV system could fall 40% by 2015 and nearly 60% by 2020 for both thin film and crystalline technologies driven by the well worn path of industrialization rather than the birth of new technologies.
- Increased productivity, supply chain optimization, economies of scale, incremental technology improvement and system design optimization can drive "best in class" costs down to nearly ~ USD 1 / Wp by 2020 for a large ground mounted system
- Achieving these levels of future cost will require improvements in module cost and balance of system cost (inverters, racking, installation costs)
- Beyond these areas, downstream companies will need continued innovation to reduce "soft" costs such as permitting, financing, and customer acquisition
- Determining "parity" needs to consider other factors beyond installation cost such as intermittency, reliability/durability, utility fixed/variable costs, and environmental impacts
- This "best in class" cost trajectory could open up 400-600 GW of additional, unsubsidized demand by 2020, with distributed generation dominant in North American and Europe and grid-scale dominating Asia, the Middle East, Africa and South America

The cumulative impact of industrialization makes USD ~1.00 / Wp by 2020 achievable for large (10 MW) c-Si ground mounted systems

Significant cost reduction potential for a best-in-class c-Si ground mounted system through well known industrial levers

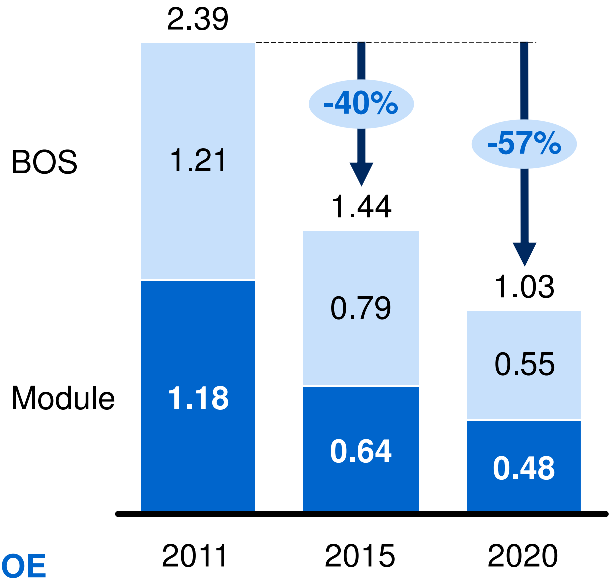
USD/Wp (no module margin)



Impact of falling polysilicon prices

Potential cost for best-in-class c-Si ground mounted system

USD/Wp (no module margin)



LCOE

USc/kWh

	2011	2015	2020
V. good sun[1]	16	10	7
Good sun[1]	19	11	8
Mod. sun[1]	28	17	12

[1] Very Good sun = market with solar energy yield ~ 1500 kWh/kWp (e.g., Australia, India); Good sun = markets with solar energy yield ~ 1300 kWh/kWp (e.g., California (average), Spain, Italy); Mod. sun = LCOE in markets with moderate with solar energy yield ~ 900 kWh/kWp (e.g., Germany). Assumes improvements in module efficiency from 15% to 16.8% to 18.8% in 2011, 2015, and 2020 respectively

SOURCE: iSuppli, GTM, Photon, industry experts, team analysis

Significant cost reduction potential exists for c-Si modules and BOS through 2020

BOS cost reductions becoming a higher focus for industry as module costs have come down

Sources of cost reduction	Example c-Si module cost reduction levers, 2011 - 2020	Example BOS cost reduction levers
Operational efficiency	▪ Continued productivity improvements (e.g., lean manufacturing) ▪ Improved factory floor layout in new capacity to debottleneck	▪ ~30% lower labor costs through improved installation techniques ▪ Production cost reduction for key components (e.g.,combiner box)
Procurement	▪ ~50% drop in polysilicon prices from 2011 levels ▪ Emergence of low cost providers for key inputs (e.g., metal paste)	▪ Design to value for key components (e.g., ~60% lower inverter cost through better design, margin compression, etc.) ▪ Increased competition among suppliers
Economies of scale	▪ Continued scale up of production capacity by smaller players to capture economy of scale	▪ Scale up key component manufacturing ▪ Larger scale PV solar installations to spread fixed costs, allow volume discounts
Incremental technology improvement	▪ Shift to psuedo-mono ingots and diamond wire sawing (wafer) ▪ Improved chemical etching processes (cell)	▪ Standardized component design to reduce costs of common components ▪ Next generation electrical components to reduce cost per watt
System design optimization	▪ Integrating BOS components with modules (e.g., frame) to lower total cost	▪ Optimized site layout to reduce material usage and labor costs ▪ Integrating BOS components with modules (e.g., frame) to lower total cost

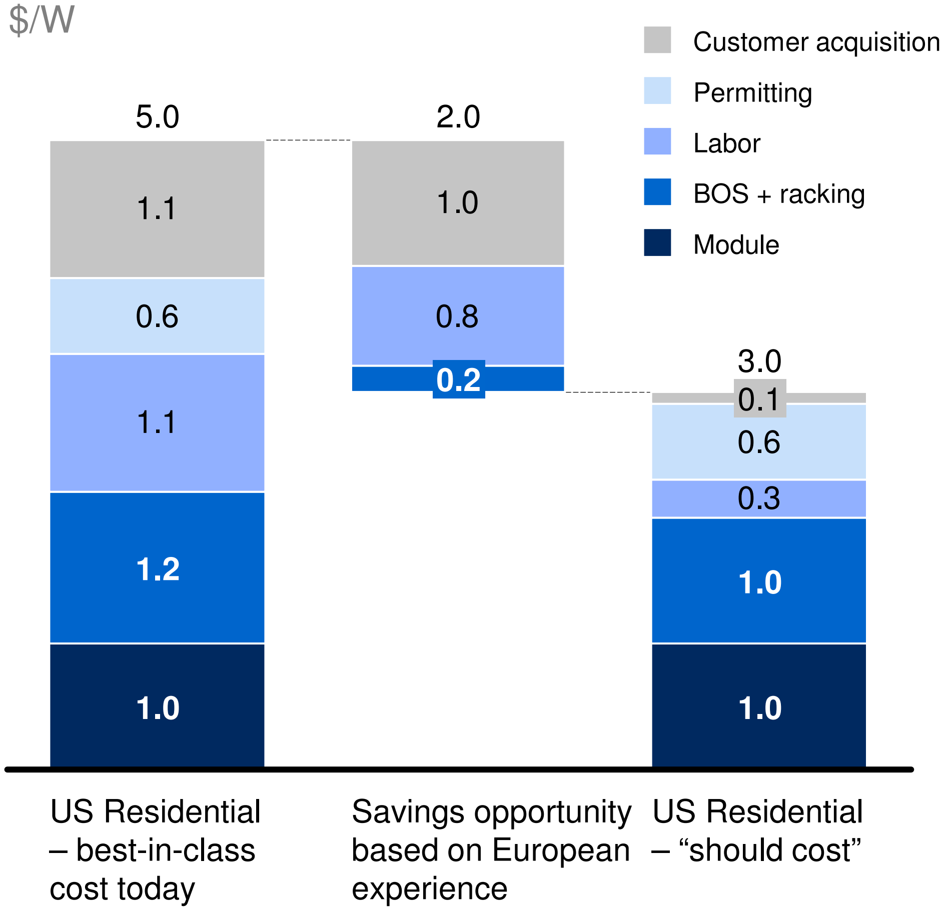
1 Includes SG&A, R&D, depreciation and margin on polysilicon feedstock. Does not include margin on processing costs.

SOURCE: iSuppli, GTM, Photon, industry experts, team analysis

Adoption of best-practice techniques from established European installers show how costs can be reduced

All-in installed system cost – Example US residential 3kW system

$/W

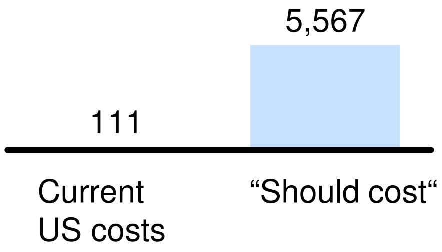


What best-practice European players do differently:

- Targeted acquisition of high-value customers -- rooftops assessed for suitability & customers for credit risk early in pipeline
- Limited ad spend & door-to-door sales
- Word-of-mouth advertising (e.g., rebates to customers posting signs)
- 2 trips per customer vs 4-5 trips in US
- 1 day vs 4 days for installation

Estimated NPV[1] – example US residential 3kW system

$



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1 NPV calculation included in appendix; System lifetime is assumed to be 20 years with no residual value

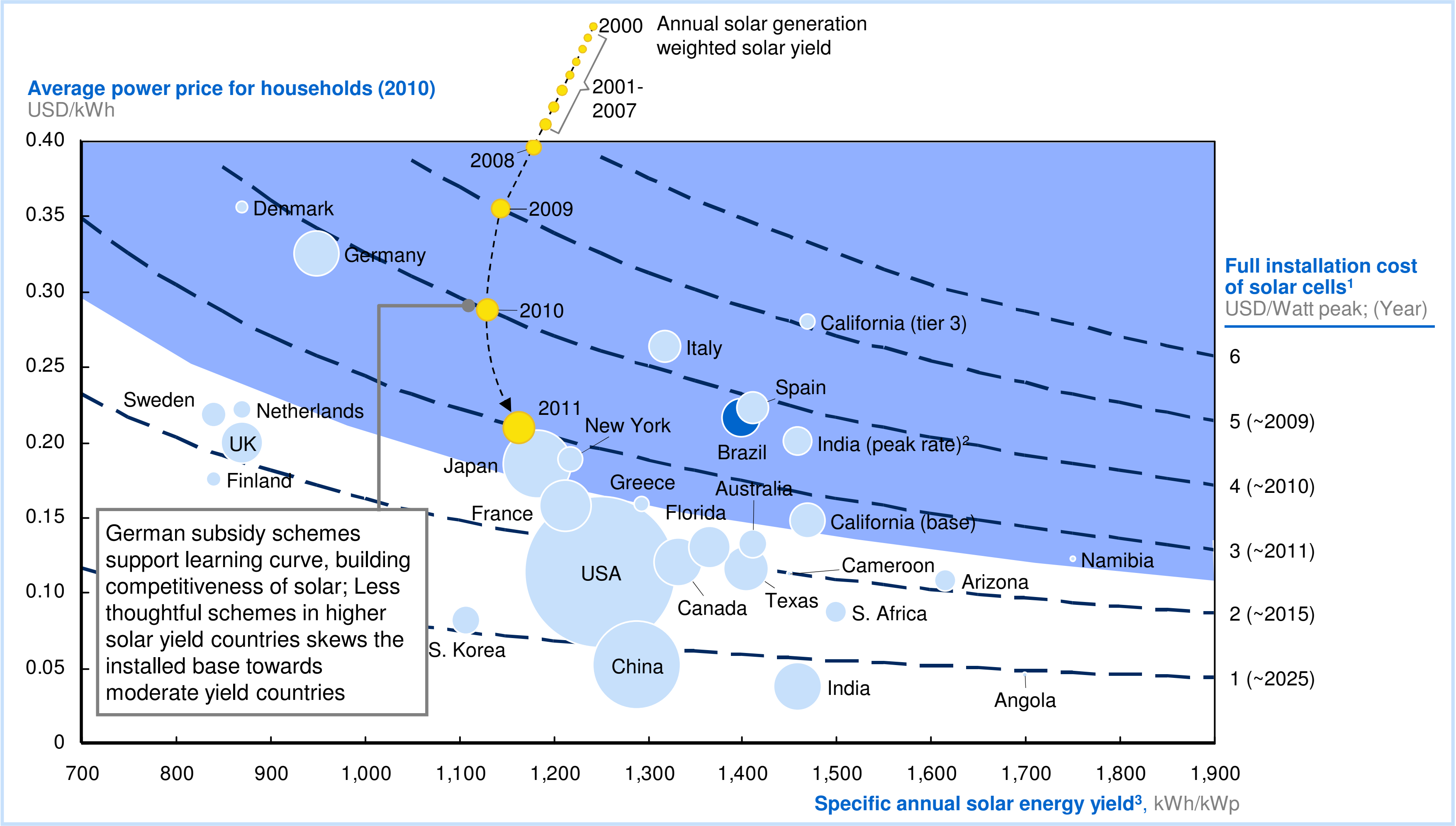
SOURCE: Expert interviews

Rapidly falling costs are making larger pockets of demand “competitive” with retail prices

Residential segment example

● Residential power demand (2009); TWh/Year

■ Countries/Locations where best in class solar is currently economically competitive for some segments



German subsidy schemes support learning curve, building competitiveness of solar; Less thoughtful schemes in higher solar yield countries skews the installed base towards moderate yield countries

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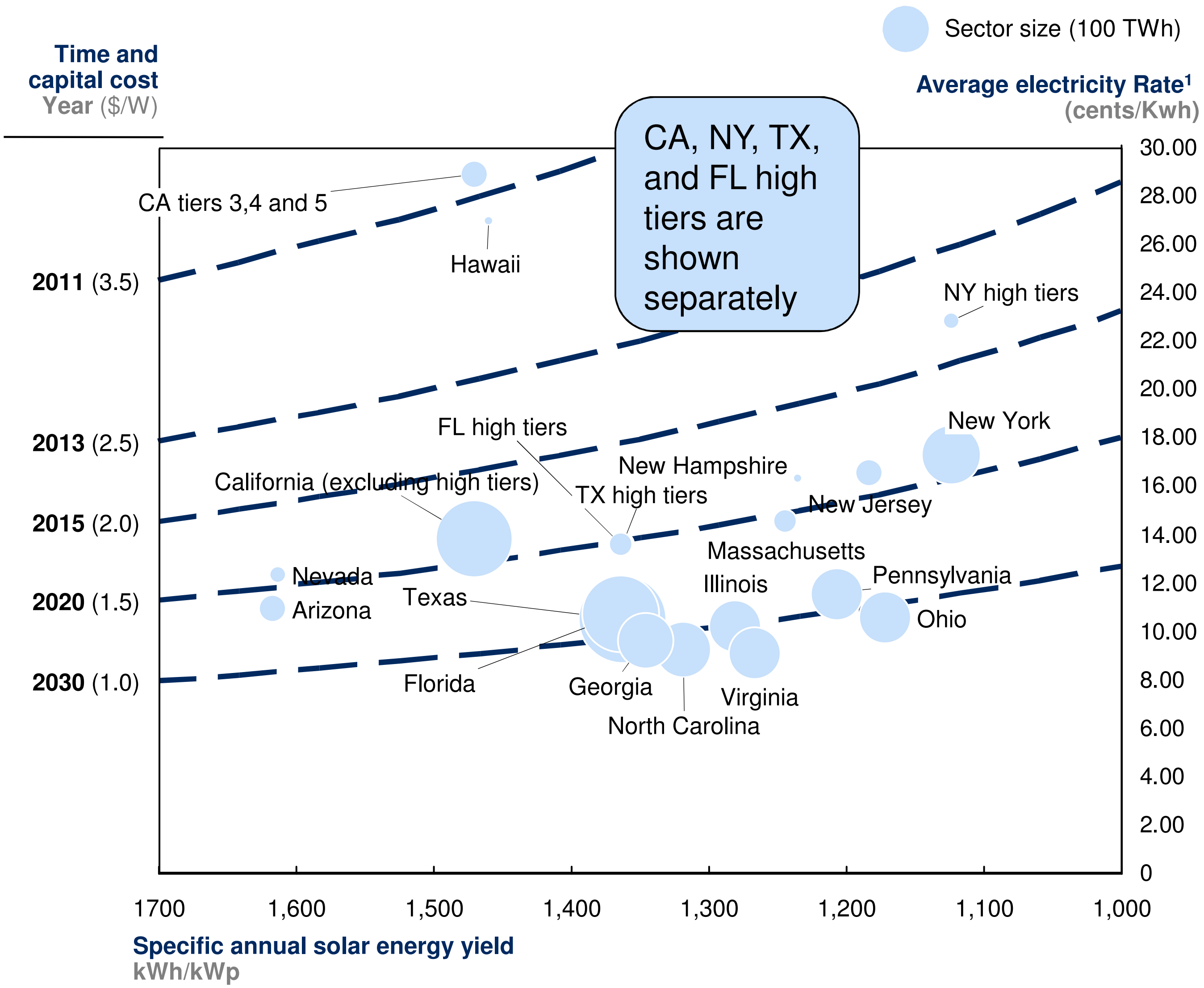
1 Cost to generate power with solar cells corresponding to solar intensity, using the following assumptions: 5% cost of finance, 30 yr lifetime, 0.3% annual degradation, fixed O&M 1% of full installation cost

2 Only 2008 data available. Peak rate refers to rate without artificial cap imposed to close the peak power deficit filled by diesel generated power

3 Amount generated by a south-facing 1 kWp module in 1 year (a function of solar intensity)

SOURCE: Enerdata; EIA; PV Watts; SERC; India Central Electricity Authority; Utility publications; IEA; McKinsey Global Solar Initiative

Some US markets are already at grid parity and many will reach “grid parity” in the coming years



CA, NY, TX, and FL high tiers are shown separately

Economic demand can only be directionally determined by state-wide averages, for accurate economic demand utility-level pricing must be used

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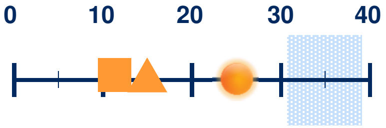
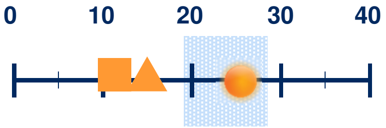
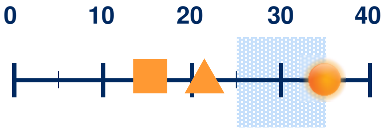
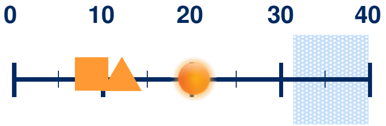
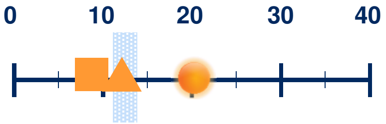
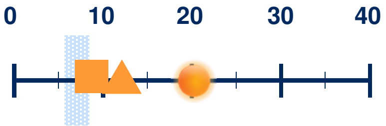
1 2010 State average prices where not specified. LCOE lines are calculated assuming 8% interest rate and 20 year lifetime

SOURCE: EIA, Ventxy Energy Velocity, Utility filings, NREL

PV Solar is in the willingness to pay zone of multiple market segments

▨ Willingness to pay ● Cost of Solar PV, 2011 ▲ Cost of Solar PV, 2015 ■ Cost of Solar PV, 2020

Segment	Market description	Solar vs. alternative cost US$c/kWh, 2011	Cumulative market potential[1] 2012-2020, GW	Timing of viability
1 Off-grid	With less developed grids (e.g India, SE Asia, Africa, and parts of Middle East)		15 20	Now
2 Residential and commercial; good sun conditions	Developed markets in sunbelt (e.g. California, Spain, Italy, Australia)		150 250	Now
3 Residential and commercial; medium sun conditions	Developed markets with moderate solar yields (Germany, Netherlands, Denmark, UK, Canada)		65 120	2012/13->
4 Isolated grids (Diesel)	Small, local grids mainly fueled by small diesel generators; Large latent demand (e.g. Africa)		25 30	Now
5 New built peak capacity (Gas turbines)	Growth markets; Large power investments (e.g. India, Middle East, Africa and China)		150 170	2014/15->
6 New power plant (Nuclear and Coal)	Growth markets; Large power investments (e.g. India, Middle East, and China)		Marginal	2025->
Total			**~400-600**	

Compared to ~65GWp Installed base (2011)

1 Adjusted for implementation time

SOURCE: EIA; McKinsey Global Solar Initiative, McKinsey PV Solar Cost Model