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UP-TO-DATE LEVELISED COST OF ELECTRICITY OF PHOTOVOLTAICS

Background from Fraunhofer ISE relating to IPCC WGIII 5th Assessment Report, Final Draft, September 2014

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1 Background

Levelized Cost of Electricity (LCOE) is regularly used to compare the cost of different energy generation technologies. Also in chapter 7 of the final draft of the IPCC WGIII 5th Assessment Report "Climate Change 2014: Mitigation of Climate Change" (in the following: IPCC 5th draft report) LCOE values are presented. The IPCC values have been used quite often in the past to compare different energy generation options in terms of cost. In particular the comparison of fossil/nuclear and renewable sources is performed regularly. In the last years a strong cost reduction has been achieved for electricity from renewables. Therefore, a comparison of different electricity sources has to be based on up-to-date LCOE values.

The Fraunhofer Institute for Solar Energy Systems ISE has investigated LCOE of different energy generation technologies for several years, e.g. [1]. From our experience we find that the LCOE values of solar PV in the IPCC 5th draft report (Figure 1) are outdated, in light of 2013 costs. The real-life developments show how fast data on solar costs become outdated, and consequently any emission reduction models that assume old costs. Guidelines on up-to-date assumptions and LCOE values for solar PV are presented in the following.

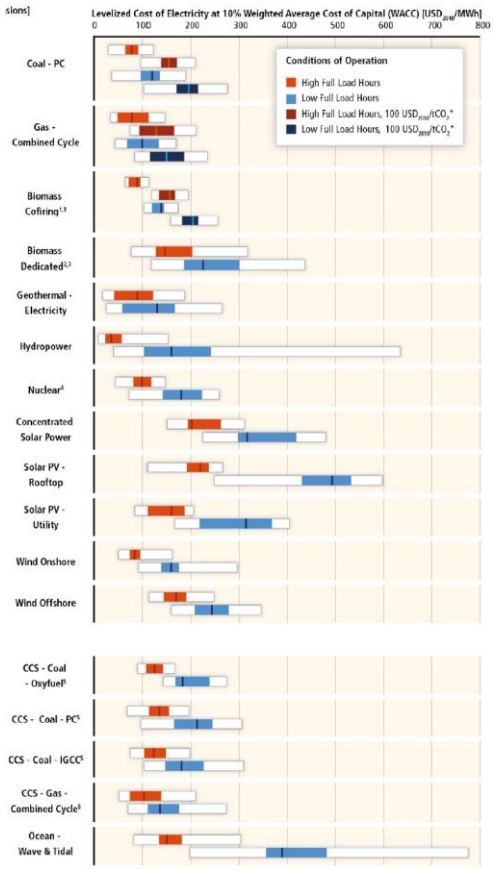

Figure 1: Levelized cost of electricity for various power-generation technologies as presented in the final draft of the IPCC WGIII 5th Assessment Report, chapter 7, page 38, 2014.

2 Assumption and input data for LCOE calculation

Table 1 lists the cost assumptions for the LCOE calculation of solar PV in the IPCC 5th draft report. While the O&M costs seem up-to-date from our experience the overnight capital expenditure does not reflect the recent cost decrease of solar PV adequately.

	Overnight capital expenditure (USD_{2010}/kW)	Fixed annual O&M cost (USD_{2010}/kW)	Variable O&M cost (USD2010/MWh)
Solar PV – rooftop	2200 / 4400 / 5300	17 / 37 / 44	0 / 0 / 0
Solar PV – utility	1700 / 3200 / 4300	12 / 20 / 30	0 / 0 / 0

Table 1: Cost parameters of solar PV as assumed in Table A.III.1., Annex III, final draft of the IPCC WGIII 5th Assessment Report. Figures refer to Min/Median/Max.

Table 2 lists recent overnight capex values of solar PV in exemplary countries. These values are well related to typical PV system prices as listed in Table 3. The minimum and maximum values assumed in the IPCC 5th draft report seem outdated against these values. Based on our research we propose a capex interval for solar PV as listed in Table 4.

In addition the median, which in the current version of the IPCC report is shifted to the higher LCOE values should be revised. The definition of a median requires a high number of cost data for individual Photovoltaics installations. Although such a database is currently not available at Fraunhofer ISE, we expect that the median should rather tend towards lower LCOE values as the majority of installations is carried out in countries with comparably low costs for solar PV (e.g. China, Germany). This is underlined by the market shares in 2013 as listed in Table 5. In section 3 average LCOE values for these countries are presented and compared with the IPCC median.

Type of installation	Country	Overnight capital expenditure (USD/kW_p)	Reference
Solar PV – rooftop	Germany	1800-2500	[1]
	USA	2500-4500	[2]
	Morocco	1800 - 2500	Own research
Solar PV – utility	Germany	1300 - 1600	[1]
	China	1300 - 1500	Own research
	USA	1800 - 3000	[3]

Morocco	1600 - 2000	Own research

Table 2: Recent cost parameters of solar PV in various countries from different sources.

	Australia	**China**	**France**	**Germany**	**Italy**	**Japan**	**UK**	**US**
Residential	1800	1500	4100	2400	2800	4200	2800	4900
Commercial	1700	1400	2700	1800	1900	3600	2400	4500
Utility-scale	2000	1400	2200	1400	1500	2900	1900	3300

Table 3: Typical PV system prices in 2013 in selected countries in USD/kW_p according to the IEA [4].

	Overnight capital expenditure (USD/kW_p)
Solar PV – rooftop	1500 / 4900
Solar PV – utility	1300 / 3300

Table 4: Up-to-date capex parameters proposed by Fraunhofer ISE for the LCOE calculation in IPCC 5th draft report. Figures refer to Min/Max.

	Australia	**China**	**France**	**Germany**	**Italy**	**Japan**	**UK**	**US**
PV market volume [GW]	0.81	12.92	0.643	3.3	1.6	6.97	1.5	4.75
PV market share	2.0%	32.3%	1.6%	8.3%	4.0%	17.4%	3.8%	11.9%

Table 5: PV market share in 2013 in selected countries according to the IEA [5].

In addition to the outdated capex values we suggest to reconsider the assumption of uniform 10% weighted average cost of capital (WACC) for all power-generation technologies. Although this superficially facilitates comparison between the different technologies, a unique and relatively high WACC does not reflect the market situation adequately and is in particular disadvantageous for renewables, which mainly cause investments at the beginning of a project. Nevertheless in the following calculation a similar WACC of 10% is assumed to allow comparison with the IPCC results.

In order to calculate LCOE full load hours or the energy output [kWh/kWp] are required. In the IPCC report yearly full load hours between 1100 (1200) and 2400 (2400) are assumed for rooftop (utility) solar PV. In our calculations we will use specific numbers for the different locations as listed in Table 6.

	Australia	**China**	**France**	**Germany**	**Italy**	**Japan**	**UK**	**US**
Low full load hours [hr/a]	1200	1200	1200	1000	1200	1000	900	1200
High full load hours [hr/a]	2200	2200	1400	1200	1600	1400	1100	2200

Table 6: PV capacity utilization (full load hours) in selected countries according to Fraunhofer ISE.

3
Up-to-date LCOE values for solar PV

Based on the input data in section 2 LCOE values were calculated for the selected countries. Note that these countries made up for over 80% of the PV market in 2013. Figure 2 shows the results for rooftop PV. The LCOE values of most countries are significantly lower compared to the median value of the IPCC report. The same holds true for the LCOE values of utility scale PV (Figure 3).

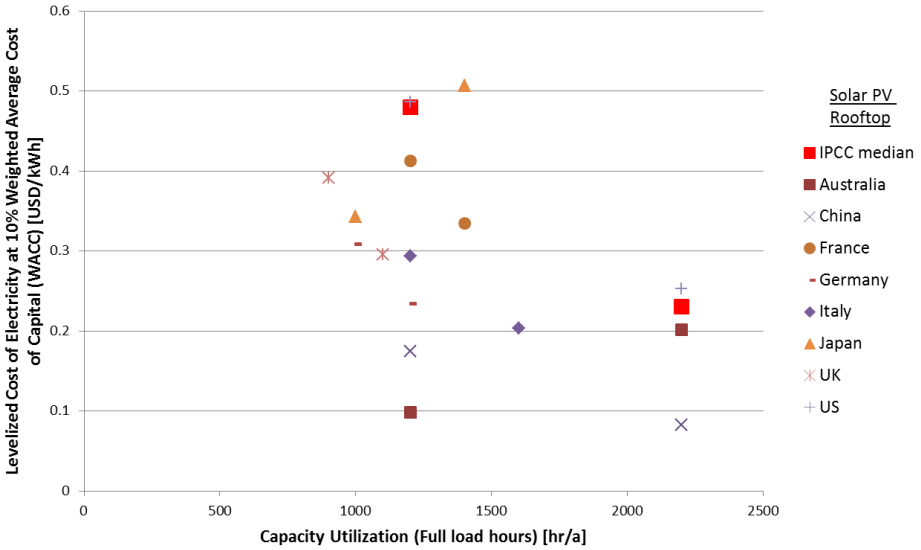

Figure 2: Levelized Cost of Electricity for solar PV rooftop. Selected countries are compared to the median values for low and high full load hours from the IPCC report.

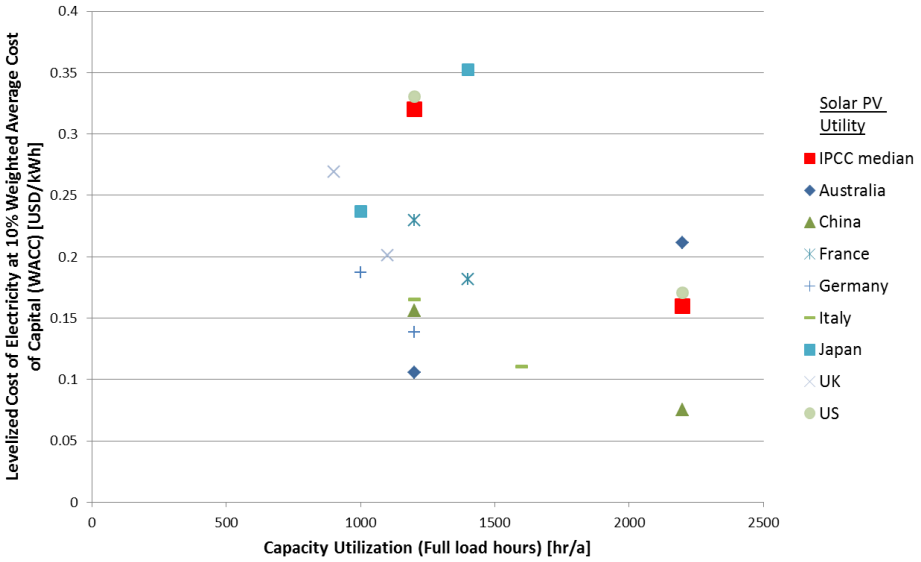

Figure 3: Levelized Cost of Electricity for solar PV utility. Selected countries are compared to the median values for low and high full load hours from the IPCC report.

4 Conclusion

Recent LCOE values for solar PV were calculated. The results underline that the LCOE values in the IPCC report are too high. This refers in particular to the median values, which are shifted towards comparably high LCOE values. In particular the following assumptions and input data should be revised:

1. Up-to-date maximum and minimum overnight capital expenditure or system prices of solar PV – both rooftop and utility – are significantly lower than assumed. Therefore the minimum and maximum LCOE values should be lower.
2. The median LCOE should rather tend towards lower LCOE values as the majority of installations is carried out in countries with comparably low costs for solar PV.
3. The assumption of a uniform 10% weighted average cost of capital (WACC) for all power-generation technologies should be revisited. A unique and relatively high WACC does not reflect the market situation adequately and is in particular disadvantageous for renewables, which cause mainly investments at the beginning of a project. A WACC of 5% for PV is sufficient in many countries to create huge investments in PV systems (especially roof-top systems). This is in contrast to large-scale power generation for which a higher WACC is necessary.

5 Literature

[1] Fraunhofer ISE, Levelized Cost of Electricity - Renewable Energy Technologies, (2013).

[2] G. Barbose, S. Weaver, N. Darghouth, Tracking the Sun VII: An Historical Summary of the Installed Price of Photovoltaics in the United States from 1998 to 2013, (2014).

[3] M. Bolinger, S. Weaver, Utility-Scale Solar 2013: An Empirical Analysis of Project Cost, Performance, and Pricing Trends in the United States, (2014).
[4] International Energy Agency (IEA), Technology Roadmap Solar Photovoltaic Energy, (2014).
[5] International Energy Agency (IEA), Trends 2014 in Photovoltaic Applications: Survey Report of Selected IEA Countries between 1992 and 2013 (2014).