

Agenda item 4.1 (a)

Paragraph 18 of the annotated agenda

Analysis of levelized cost of electricity generation and penetration rates of different types of grid-connected solar PV and on-shore wind technologies

CDM EB 104

Bonn, Germany, 9 to 12 September 2019



Background

- EB 100 considered the recommendation from the MP76 to graduate solar photovoltaic (PV) technology from positive list of technologies in
 - Methodologies ACM0002 and AM0103 and
 - Tool on ‘Demonstration of additionality of small-scale project activities’ (TOOL21).
- Extended the current validity of the positive list up to August 2020.
- Also requested MP to prepare an information note considering;
 - Levelised cost of electricity (LCOE) generation and penetration rates of different types of grid-connected **solar PV** and **on-shore wind** technologies and **comparable fossil fuel technologies**;
 - **thresholds of the small-scale** project activities;
 - non-Annex I countries; and
 - **representative and current information** from a **range of literature sources** taking into account **different national circumstances**.



Purpose

- To inform the Board about the analysis conducted by the Meth Panel in response to the EB 100 mandate and seek guidance from the Board.



- **ACM0002 and AM0103**

1. Includes following grid connected electricity generation technologies under positive list
 - (a) Solar photovoltaic technologies;
 - (b) Solar thermal electricity generation including concentrating Solar Power (CSP);
 - (c) Off-shore wind technologies;
 - (d) Marine wave technologies;
 - (e) Marine tidal technologies;
 - (f) Ocean thermal technologies.
2. Percentage share of total installed grid / isolated grid capacity of the specific technology in the total installed grid connected / isolated grid power generation capacity in the host country is ≤ 2 per cent; or
3. Total installed grid / isolated grid capacity of the technology in the host country is ≤ 50 MW.



- **TOOL21**

1. Includes following grid-connected and off-grid renewable electricity generation technologies under positive list;
 - (i) Solar technologies (photovoltaic and solar thermal electricity generation);
 - (ii) Off-shore wind technologies;
 - (iii) Marine technologies (wave, tidal);
 - (iv) Building-integrated wind turbines or household rooftop wind turbines of a size up to 100 kW;
 - (v) Biomass integrated gasification combined cycle (BIGCC).

Key assumptions

- Analysis includes
 - a) Data from **97 non-Annex I** countries;
 - b) **Country specific** generation and installed capacity data, for **recent 3 year** (2014-2016) for **grid-connected** solar PV and on-shore wind installations with **installed capacity ≤ 15 MW**;
 - c) **Country specific** economically viable fossil fuel plant capacity for 3 predominant types of fossil fuels i.e. HFO, Natural Gas and Coal;
 - d) Regional capacity factors of solar and wind installations;
 - e) LCOE calculation based on **global average fossil fuel cost** for 2016 and 2017;
 - f) **Global/regional** average values for plant lifetime, investment cost/kW, O&M cost, degradation factor;
- Severe lack of reliable data leads not to include **further sub types** of solar PV and on-shore wind technology.
- Not considered - country specific subsidies, taxes for fossil fuel and grants and feed-in-tariff policies and variable financing costs.



- a) **Penetration rate based on electricity generation / demand (PREG)** is the ratio of the annual renewable electricity generation to the difference between gross annual total electricity generation and export.
- b) **Penetration rate based on installed capacity (PRIC)** is the ratio of the cumulative renewable technology installed capacity to the cumulative installed capacity of all power generating sources.
- c) **Levelised cost of electricity generation (LCOE)**

LCOE is determined as

$$\text{LCOE} = \frac{\text{Total Cost During the Project Life Cycle}}{\text{Total Electricity Production During the Project Life Cycle}} \left[\frac{\$}{MWh} \right]$$



Key data

	Africa	Asia	Middle East	Latin America and Caribbean	
Indicator	Value				Unit
Heat content of coal	25	25	25	25	GJ/ton
Cost of coal	53.42	53.42	53.42	53.42	USD/Ton
Cost of Natural Gas	5	5	5	5	USD/MMBTU
Cost of HFO	0.5	0.5	0.5	0.5	USD/liter
Gross efficiency of subcritical coal power plant	35%	36%	37%	39%	%
Gross efficiency of NG based Gas Turbine power plant	38%	38%	38%	38%	%
Gross efficiency of HFO based oil power plant	42%	42%	42%	42%	%
Investment cost for Coal Power plant	1300	1300	1300	1300	USD/kW
Investment cost for NG based Gas Turbine power plant	400	400	400	400	USD/kW
Investment cost for HFO based oil power plant	650	650	650	650	USD/kW
O& M costs for Coal Power Plant	45	45	45	45	USD/kW
O& M costs for Gas Power Plant	20	20	25	20	USD/kW
O& M costs for HFO based Oil Power Plant	15	15	15	15	USD/kW
Lifetime of sub-critical coal power plant	40	40	40	40	years
Lifetime of natural gas based gas turbine power plant	20	20	20	20	years
Lifetime of HFO based oil power plant	25	25	25	25	years
Minimum Investment cost solar PV	805	832 China – 1005, India - 661	1201	LatAm – 823 Caribbean – 1319	USD/kW
Maximum Investment cost solar PV	4735	4212 China – 1873, India - 1786	3850	LatAm – 3879 Caribbean – 2810	USD/kW
Weighted average Investment cost solar PV	2172	1248 China – 1058, India - 971	2487	LatAm – 2044 Caribbean – 1688	USD/kW
Minimum Investment cost on-shore wind	1485	1044	916	LatAm – 972 Caribbean – 1981	USD/kW
Maximum Investment cost on-shore wind	2850	3882	1857	LatAm – 2909 Caribbean – 3265	USD/kW
Weighted average Investment cost on-shore wind	2040	1221	1320	LatAm – 1829 Caribbean – 2184	USD/kW
Capacity factor for in-ground mounted solar PV	18	17	22	LatAm – 20 Caribbean – 17	%
Capacity factor for on-shore wind	37	25	20	LatAm – 40 Caribbean – 33	%
O& M cost for solar PV	10	10	10	10	USD/kW/year
O& M cost for on-shore wind	50	50, China – 35, India – 18	50	34	USD/kW/year
Annual module degradation factor - Solar PV	0.5	0.5	0.5	0.5	per year
Performance degradation factor - Onshore Wind	1.57	1.57	1.57	1.57	per year
Lifetime of solar PV and on-shore wind	25	25	25	25	year

Overview of key findings

1. Penetration rate of Solar PV and on-shore wind technology
2. Share of technologies in installed capacity addition in recent years
3. Comparison of LCOE of fossil fuels and solar PV
4. Comparison of LCOE of fossil fuels and on-shore wind technology



Key findings - Penetration rate of Solar PV and on-shore wind technology

Majority of the countries fall under the range of 0 to 2 per cent penetration irrespective of the estimation method or technology type.

Range of penetration rate (%)	Number of countries (out of 97 countries)			
	Solar PV		On-shore wind	
	Based on annual generation	Based on installed capacity	Based on annual generation	Based on installed capacity
0 to 2	90	71	83	80
2 to 5	4	21	9	7
5 to 10	2	4	2	6
More than 10	1	1	3	4



Key findings - Penetration rate of Solar PV and on-shore wind technology

Global avg penetration of **solar PV** is **<2%**, and **on-shore wind technologies** is **<4%**

Region	Number of countries covered	Avg. Penetration rate (%)			
		Solar PV		On-shore wind	
		Based on annual generation	Based on installed capacity	Based on annual generation	Based on installed capacity
NA-I	97	0.73	1.42	1.07	1.47
Asia	23	0.56	1.06	0.58	1.41
Latin America	16	0.85	1.74	3.43	3.93
Africa	39	0.92	1.65	0.91	1.11
Caribbean	7	0.54	1.14	0.29	0.40
Middle East	12	0.35	0.82	0.09	0.22



Key findings - Share of technologies in recent installed capacity

	Africa		LatAm and Caribbean		Asia		Middle East	
	Capacity increase (GW)	% share in total increase	Capacity increase (GW)	% share in total increase	Capacity increase (GW)	% share in total increase	Capacity increase (GW)	% share in total increase
Total capacity	29		29		695		16	
Coal	2	7	1	3	83	12	0	0
Oil	5	17	2	7	48	7	1	6
Gas	12	41	2	7	209	30	14	88
Nuclear	0	0	0	0	51	7	0	0
Hydro	6	21	13	45	81	12	0	0
Bioenergy	0	0	1	3	17	2	0	0
On-shore wind	1	3	6	21	48	7	0	0
Geothermal	0	0	0	0	1	0	0	0
Solar PV	1	3	3	10	159	23	1	6
CSP	1	3	0	0	0	0	0	0
Marine	0	0	0	0	0	0	0	0



Key findings - Share of technologies in recent installed capacity

	South Africa		Brazil		China		India	
	Capacity increase (GW)	% share in total increase	Capacity increase (GW)	% share in total increase	Capacity increase (GW)	% share in total increase	Capacity increase (GW)	% share in total increase
Total capacity	7		14		249		59	
Coal	3	43	0	0	81	33	30	51
Oil	1	14	0	0	0	0	0	0
Gas	0	0	0	0	9	4	0	0
Nuclear	0	0	0	0	8	3	1	2
Hydro	2	29	8	57	24	10	2	3
Bioenergy	0	0	1	7	4	2	3	5
On-shore wind	0	0	4	29	35	14	8	14
Geothermal	0	0	0	0	0	0	0	0
Solar PV	1	14	0	0	88	35	14	24
CSP	0	0	0	0	0	0	0	0
Marine	0	0	0	0	0	0	0	0



Key findings - Comparison of LCOE of fossil fuels and solar PV

Summary of comparison of LCOE of fossil fuel and solar PV

Fossil fuel (FF)	Number of countries (out of 97) using the FF	Number of countries where		
		Solar PV_LCOE_Min < FF LCOE	Solar PV_LCOE_Max < FF LCOE	Solar PV_LCOE_WA < FF LCOE
HFO	54	54	0	20
Natural Gas	50	21	0	1
Coal	38	9	0	1



Summary of comparison of LCOE of fossil fuel and on-shore wind

Fossil fuel (FF)	Number of countries (out of 97) using the FF	Number of countries where		
		On-shore wind_LCOE_Min < FF_LCOE	On-shore wind_LCOE_Max < FF_LCOE	On-shore wind_LCOE_WA < FF_LCOE
HFO	54	54	36	51
Natural Gas	50	11	0	3
Coal	38	9	1	2



Limitations

- Cost of fossil fuel is not landing cost but global avg cost at exchanges
- LCOE analysis **considers only direct input costs** and indirect costs are not included.
- Considers that electricity generated from different sources has **same economic value**.
- LCOE analysis normally does not consider **variability of financing cost** of renewable energy techs as compared to financing cost of conventional techs.
- LCOE often used as a **metrics to evaluate cost of electricity generation**. However, due to intermittency, comparison of LCOE of _____ renewable energy tech at generation level would be misleading._____



Recommendations

- Meth Panel recommends the Board to **take note** of this information note and select one of the following options:
 - a) To maintain** the current positive list; or
 - b) To include** on-shore wind to the current positive list; or
 - c) To exclude** solar PV from current positive list;
in ACM0002, AM0103 and TOOL21. or
 - d) any other combination** of these options



- Based on the guidance received from the Board following work is envisaged;
 - **In case of option a) No further work** envisaged; or
 - In case of option b) c) or d) **Revision to** ACM0002, AM0103 and TOOL21 will be required to reflect Board's decision.