Industry Day Theme # {CLEAN ENERGY FOR SUSTAINABLE ECONOMY & ENVIRONMENT}

Managing End-of-Life Solar PV – A futuristic Problem

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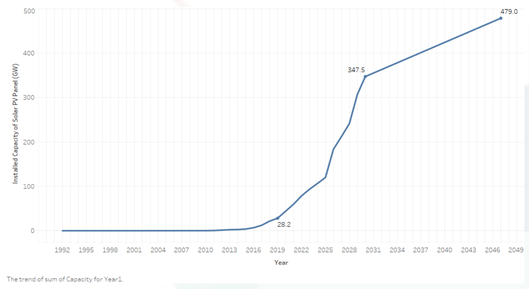
Abstract

Solar energy is seen as a key component in the fight against climate change. Backed by political commitment and falling costs, the sector is growing rapidly in India and across the world. While emphasis on more capacity addition, critical aspects related to module manufacturing and disposal at the end of their useful life are being ignored.

Introduction

Estimated solar potential of India - 750GW. Jawaharlal Nehru National Solar Mission (JNNSM):- Objective of achieving 100GW by 2022 of which 40GW has to be rooftop solar and 60GW has to be grid connected. India has already achieved 20.81GW till 31st March 2019(CEC 2019).



Materials

Panel Specifications

PV Technology	Area (m^2)	Area (m^2)/GW	Nominal Power (W)	Weight(tonn)/GW	Market Share
Si based	1.46	6517857	224	102678.5	89
CdTe	0.72	11076923	65	184615.4	5.2
CiGs	0.72	9000000	80	157500	5.8

Panel Materials

Material	Mass composition(ton/GW)		
Technology	Si based	cdte	cigs
Ag	57.95264	0	0
Al	16557.9	166.1538	13590
Cd	0	221.5385	270
Cr	0	33.23077	0
Cu	736.6308	5538.462	450
Ga	0	0	90
In	0	0	45
Fe	0	0	0
Mg	522.8123	0	423
Mn	0	0	0
Mo	0	0	90
Ni	1.062574	0	0
Pb	4.693577	7.753846	0
Se	0	0	90
Si	795.3006	553.8462	0
Sn	0.0588	0.002548	90
Steel	9582.72	2215.385	0
Te	0	221.5385	0
Ti	0.005222	0.000255	0
Zn	0.007823	0.000332	90
EVA	6518.857	6646.154	8100
Glass	65840.46	168369.2	135000

BOS Materials

Material	Mass (ton/GW)			
BOS	Inverter	Transformer	Cabling	Mounting
Al	753.25			25423.5
Cu	1949.25	799000	4712.07	
Steel	8268.5			
Mn	0.00575			
Ni	0.92			
Fe	0.2875	1573031		48891.4
Ag	2.1275			
Ta	0.115			
Sn	0.0575			
Mg	0.0575			
Pb	10.35			
Au	2.9325			
Zn	2.3			1760.09

Recycling Yield

	Metal	Recycling Yield (percentage)
Precious	Ag	95
	AU	36
Base & Special	Al	100
	Cr	20
	Cu	100
	Sn	32
	Fe	90
	Ti	52
	Zn	27
	Mo	18
	Ni	41
Toxic	Cd	95
	Pb	98
	Se	89
critical	Ga	90
	In	90
	Mg	33
	Te	95
other	Si	100

Methods

Amount of waste for Fixed Loss

$$W_{jx} = U_j \, w_{xi} p_x$$

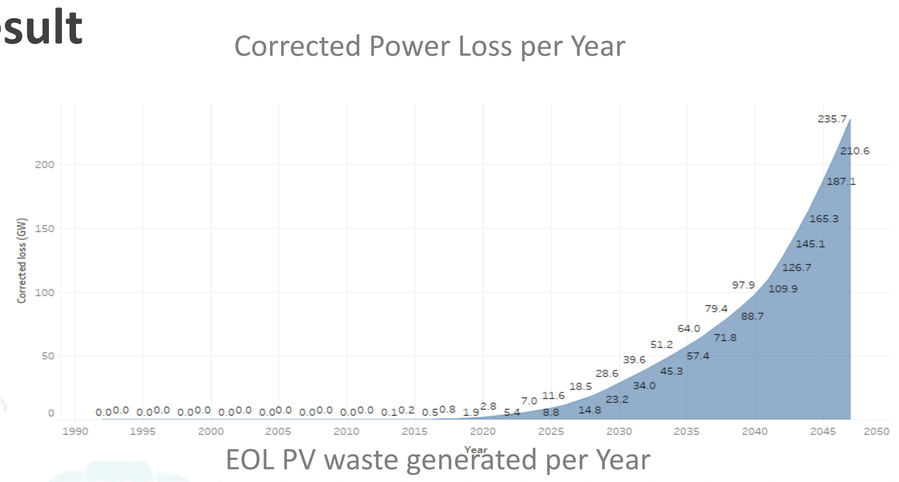
W = Solar panel WEEE in year j (tonnes)
j = year of waste generation (j = i + 30, i≥2015)
j = i + 25, I < 2015
i = year of installation
U = Corrected power loss in a particular year (GW)
w = weight of solar panel composition per GW for technology x (Tonn/GW)
x = technology (out of Silicon based, cdte, cigs)
p = market share percentage of technology x

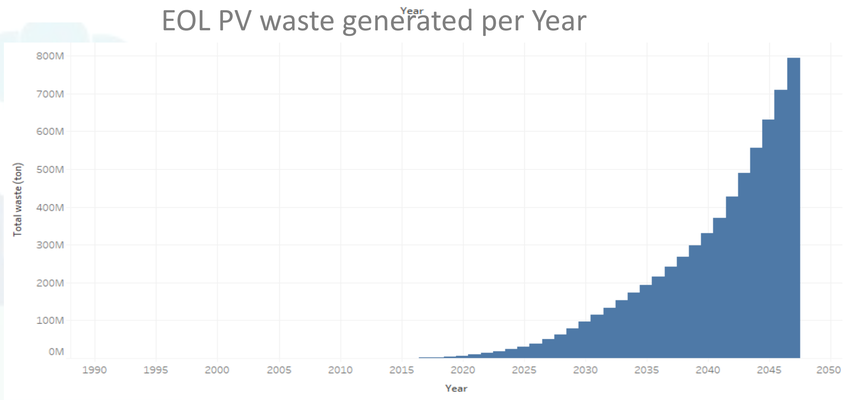
Amount of waste Early and Regular loss

$$F(t) = 1 - e^{-(\frac{t}{T})^{\Upsilon}}$$

where t = time in years
T = average lifetime
ϒ = shape factor
Shape factor for Early loss and Regular loss is taken as 2.4928 and 5.3759 respectively.

Result





year	Corrected loss	Total waste(Ton)	Au recovered	Ag Recovered
2019	1.218655749	3075761.789	1.250798	62.17567
2020	1.886762262	4761993.923	1.936526	96.26238
2021	2.791547743	7045579.434	2.865175	142.4244
2022	3.97779737	10039551.5	4.082712	202.9467
2023	5.38594179	13593563.21	5.527996	274.7901
2024	6.985637392	17631030.41	7.169884	356.4064
2025	8.788989374	22182505.36	9.020799	448.4132
2026	11.57652745	29217964.8	11.88186	590.633
2027	14.80421058	37364305.11	15.19467	755.309
2028	18.49016428	46667273.2	18.97784	943.3659
2029	23.21701748	58597364.59	23.82937	1184.529
2030	28.59824265	72179023.54	29.35252	1459.079
2031	34.03809933	85908662.39	34.93585	1736.62
2032	39.58074111	99897720.25	40.62468	2019.405
2033	45.27706305	114274651.1	46.47125	2310.03
2034	51.19239857	129204349.6	52.5426	2611.83
2035	57.41764772	144916238.3	58.93204	2929.441
2036	64.00129857	161532696	65.68933	3265.339
2037	71.75558724	181103723.2	73.64814	3660.961
2038	79.41974379	200447266.2	81.51444	4051.986
2039	88.72906665	223943039.7	91.0693	4526.946
2040	97.93299851	247172817.3	100.516	4996.53
2041	109.9245797	277438335	112.8238	5608.339
2042	126.7013453	319781166.1	130.0431	6464.287
2043	145.1408103	366320479.6	148.9689	7405.067
2044	165.2774145	417143197.8	169.6366	8432.434
2045	187.1156319	472260612.9	192.0508	9546.617
2046	210.6226224	531589839.4	216.1778	10745.94
2047	235.7228075	594940125.5	241.94	12026.55

Year	Annnual Installed Capacity	Commulative Installed	No. of Module Require	No. of Inverter Requittre	Transformer	AG Mass Require	Au Mass Require
2019	17.03022	28.18	76027763	1620350	8515109	986.9461	49.94112
2020	17.62357	44	78676633	2530000	8811783	1021.332	51.68111
2021	21.52067	59.75	96074440	3435625	10760337	1247.18	63.10938
2022	18.94454	78.5	84573837	4513750	9472270	1097.886	55.55486
2023	18.33284	93.5	81843014	5376250	9166418	1062.436	53.76104
2024	20.40111	106.5	91076381	6123750	10200555	1182.298	59.82625
2025	72.15554	120	3.22E+08	6900000	36077770	4181.604	211.5961
2026	39.86835	183.5	1.78E+08	10551250	19934173	2310.476	116.9139
2027	43.98408	212	1.96E+08	12190000	21992041	2548.994	128.9833
2028	83.50549	241.5	3.73E+08	13886250	41752747	4839.364	244.8799
2029	62.99484	307	2.81E+08	17652500	31497422	3650.718	184.7324
2030	27.53904	347.5	1.23E+08	19981250	13769521	1595.96	80.75824

Metal	Waste from 2020 to 2047	Mass %	Mass Get after recycling
Au	5678.35428	0.000116189	2044.208
Ag	103992.1	0.002127866	98792.5
Fe	3060150663	62.6161987	2.75E+09
Mg	948608.432	0.019410238	313040.8
NI	3608.19961	7.38303E-05	1479.362
Pb	29678.6714	0.000607279	29085.1
Si	1426345.67	0.029185603	1426346
Sn	10209.3508	0.000208902	3266.992
Ta	222.68056	4.55645E-06	46.76292
AL	80783048.5	1.65296679	80783049
Ti	9.02158339	1.84598E-07	4.691223
Zn	3422731.84	0.070035263	924137.6
Cd	52630.0701	0.001076906	49998.57
Cu	1562647020	31.97457481	1.56E+09
Cr	3345.94	6.8464E-05	669.188
GA	10107.7611	0.000206823	9096.985
In	5053.88053	0.000103412	4548.492
Mn	11.134028	2.27822E-07	4.11959
MO	10107.7611	0.000206823	1819.397
Se	10107.7611	0.000206823	8995.907
Te	22305.931	0.00045642	21190.63
Steel	32748217.5	0.670087561	32748217
EVA	12813187.2	0.262180906	12813187
Glass	131935730	2.69964285	1.32E+08

Conclusions

Waste from end of life of electronic waste is increasing at a higher pace therefore, waste management and secondary raw material extraction becomes important to conserve resources and reduce production costs. This research hence focuses on robust circular supply chain considering recycling, remanufacturing, reuse and repair in an integrated manner under the umbrella of circular-economy.

Industrial Significance

EOL PV system waste in India is estimated to grow to 327 million ton by 2030 and 4895million ton by 2047 with 5678.3 ton Gold, 10399.2 ton Silver and other rare earth resources.

Technology Readiness Level:

India is poorly positioned to handle PV waste. Country neither has policies guidelines nor Recycling infrastructure.

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Acknowledgement

Special thanks to Professor Prem Vrat and Professor Ravi Shankar for their support and suggestions through out the project, my numerous colleagues for their assistance during lab work and last but not least to my parents for their support.