एनएलसी इंडिया लिमिटेड
(पूर्व में नेयवेली लिग्नाइट कॉरपोरेशन लिमिटेड)
(भारत सरकार का नवरत्न उद्यम)
अध्ययन एवं विकास केन्द्र
(ISO 9001:2015 प्रमाणित संस्थान)
ब्लाक–20, नेयवेली - 607803

NLC India Limited
(formerly Neyveli Lignite Corporation Limited)
'Navratna' – Govt. of India Enterprise)
LEARNING & DEVELOPMENT CENTRE
(An ISO 9001:2015 Certified Institution)
BLOCK–20, NEYVELI - 607803

CREATING WEALTH FOR WELLBEING

150 YEARS OF CELEBRATING THE MAHATMA

Telefax: 04142-228452 E-mail: gm.ldc@nlcindia.in Website: www.nlcindia.com

Regd. Office: NEYVELI HOUSE", 1st Floor,No.8, Mayor Sathyamurthy Road, FSD Egmore Complex of Food Corporation of India, Chetpet, Chennai – 600 031 (CIN: L93090TN1956GO1003507)

Lr. No. GM/L&D/Faculty Service /Prog.No.788-1/2019 **Date: 03.07.2019**

To

Dr. S. Gomathinayagam,
Technical Advisory,
Sustainable Global Energy Transition,
Chennai.

Sir,

Sub: L&DC-Programme on **"Solar Power Technologies and Development"** – Faculty Services – Requested.

*****

GREETINGS from Learning & Development Centre, NLC India Ltd., Neyveli.

A Two-day Training Programme on **"Solar Power Technologies and Development"** is organized at L&DC, NLC India Ltd., Neyveli from **17.07.2019 to 18.07.2019** as per the details below:

Topic	**: Solar Power Technologies and Development**
Date	**: 17.07.2019 to 18.07.2019.**
For whom	**: EXECUTIVES**
Time	**: 09:30 AM to 05:30PM**

As confirmed over phone, we are happy to invite you to conduct the above programme as per the following terms:

1. **Faculty Honorarium: Rs[redacted]/- plus 18% GST per day.**
2. **Travel Expense: Conveyance will be arranged by NLCIL.**

Hence, it is requested to confirm the programme. Also, kindly note that your accommodation has been arranged at NLCIL Guest House, Block-25, Neyveli-607 803 **(Phone No.04142-252 222).**

An early reply will help us in organizing the programme effectively.

Yours faithfully,
For NLC India Limited.,

3/7/19.

Dy. General Manager / L&D.

NLC INDIA
CREATING WEALTH FOR WELLBEING

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Lr. No. GM/L&D/Faculty Service /Prog.No.785-1/2019 **Date: 24.05.2019**

To

Dr. S. Gomathinayagam,
Technical Advisory,
Sustainable Global Energy Transition,
Chennai.

Sir,

Sub: L&DC-Programme on "**Renewable Energy Scenario by 2030 and 2050 in India**" – Faculty Services – Requested.

*****

GREETINGS from Learning & Development Centre, NLC India Ltd., Neyveli.

A Two-day Training Programme on "**Renewable Energy Scenario by 2030 and 2050 in India"** is organized at L&DC, NLC India Ltd., Neyveli from **12.06.2019 to 13.06.2019** as per the details below:

Topic	**: Renewable Energy Scenario by 2030 and 2050 in India**
Date	**: 12.06.2019 to 13.06.2019.**
For whom	**: EXECUTIVES**
Time	**: 09:30 AM to 05:30PM**

As confirmed over phone, we are happy to invite you to conduct the above programme as per the following terms:

1. **Faculty Honorarium: Rs[redacted]- plus 18% GST per day.**
2. **Travel Expense: Conveyance will be arranged by NLCIL.**

Hence, it is requested to confirm the programme. Also, kindly note that your accommodation has been arranged at NLCIL Guest House, Block-25, Neyveli-607 803 **(Phone No.04142-252 222).**

An early reply will help us in organizing the programme effectively.

Yours faithfully,
For NLC India Limited.,

24.5.19.

Dy. General Manager / L&D.

1

एनएलसी इंडिया लिमिटेड NLC India Limited
(पूर्व में नेयवेली लिग्नाइट कॉरपोरेशन लिमिटेड) (formerly Neyveli Lignite Corporation Limited)
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Lr. No. GM/L&D/Faculty Service /Prog.No.787-1/2019 **Date: 03.08.2019**

To

Dr. S. Gomathinayagam,
Technical Advisory,
Sustainable Global Energy Transition,
Chennai.

Sir,

Sub: L&DC-Programme on "Roof Top Solar Power Development in India-Policy Option Priorities" – Faculty Services – Requested.

*****

GREETINGS from Learning & Development Centre, NLC India Ltd., Neyveli.

A one day Training Programme on **"Roof Top Solar Power Development in India-Policy, Option & Priorities"** is organized at L&DC, NLC India Ltd., Neyveli on 07.08.2019 as per the details below:

Topic	**: Roof Top Solar Power Development in India-Policy, Option& Priorities**
Date	**: 07.08.2019.**
For whom	**: EXECUTIVES**
Time	**: 09:30 AM to 05:30PM**

As confirmed over phone, we are happy to invite you to conduct the above programme as per the following terms:

1. **Faculty Honorarium: Rs.** [redacted] **plus 18% GST per day.**
2. **Travel Expense: Conveyance will be arranged by NLCIL.**

Hence, it is requested to confirm the programme. Also, kindly note that your accommodation has been arranged at NLCIL Guest House, Block-25, Neyveli-607 803 **(Phone No.04142-252 222).**

An early reply will help us in organizing the programme effectively.

Yours faithfully,
For NLC India Limited.,

S. [signature] 3/8/19

General Manager / L&D.

एनएलसी तमिलनाडु पावर लिमिटेड
NLC TAMILNADU POWER LIMITED
एलसी इंडिया लिमिटेड (पूर्व में नेयवेली लिग्नाइट कार्पोरेशन लिमिटेड) एवं टंजेडको का संयुक्त उद्यम एवं एनएलसी इंडिया लिमिटेड का सहायक कंपनी)
(A JVC between NLC India Ltd {Formerly Neyveli Lignite Corporation Ltd} & TANGEDCO and a subsidiary of NLC India Ltd)
मुख्य कार्यकारी अधिकारी का कार्यालय
OFFICE OF THE CHIEF EXECUTIVE OFFICER
2*500 मेगावाट संयुक्त उद्यम ताप विद्युत परियोजना : 2*500 MW JV Thermal Power Project
हारबर इस्टेट/Harbour Estate, टूटिकोरिन/Tuticorin- 628004
फैक्स/Fax: 0461-2352480, फोन Phone : 0461-2352844, सीआईएन CIN : U40102TN2005GOI058050
ई-मेल E-mail: ceo.ntpl@nlcindia.com, वेब Web : www.ntplpower.com

15 YEARS OF CELEBRATING THE MAHATMA

Lr.No.NTPL/HR/1200/Training/2019/265 Date: 19.08.2019

To

Dr. S.Gomathinayagam.
Technical Advisory,
Sustainable Global Energy Transition,
Chennai.

Sir,

Sub: NTPL- HR- Training Programme "Renewable Energy Scenario by 2030 and 2050 in India" -Faculty Service- Requested -Reg.

-oOo-

Greetings from NLC Tamilnadu Power Limited, Tuticorin.

A two-day training programme "Renewable Energy Scenario by 2030 and 2050 in India" is organized at NTPL, Tuticorin from 30-08-2019 to 31-08-2019 as per the details below:

Topic : Renewable Energy Scenario by 2030 and 2050 in India

Date : 30-08-2019 to 31-08-2019

For Whom: Executives

Time : 09:30 hrs. to 17:30 hrs.

GSTIN : 33AACCN3238N1ZD

As confirmed over phone, we are happy to invite you to conduct the above programme as per the following terms.

Faculty Honorarium: Rs[redacted]- per plus 18% GST per day.

Travelling Charges: Conveyance will arranged by NTPL.

Hence, it is requested to confirm the programme. Also, kindly note that your accommodation has been arranged at NTPL Guest House

An early reply will help us in organizing the programme effectively.

Yours faithfully
For NLC Tamilnadu Power Ltd.

CHIEF MANAGER/HOHR

एनएलसी इंडिया लिमिटेड NLC India Limited
(पूर्व में नेयवेली लिग्नाइट कॉरपोरेशन लिमिटेड) (formerly Neyveli Lignite Corporation Limited)
(भारत सरकार का नवरत्न उद्यम) 'Navratna' – Govt. of India Enterprise)
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Telefax: 04142-228452 E-mail: gm.ldc@nlcindia.in Website: www.nlcindia.com
Regd. Office: NEYVELI HOUSE", 1st Floor, No.8, Mayor Sathyamurthy Road, FSD Egmore Complex of Food Corporation of India, Chetpet, Chennai – 600 031 (CIN: L93090TN1956GO1003507)

Lr. No. GM/L&D/Faculty Service /Prog.No.785-2/2019 **Date: 03.08.2019**

To

Dr. S. Gomathinayagam,
Technical Advisory,
Sustainable Global Energy Transition,
Chennai.

Sir,

Sub: L&DC-Programme on "**Renewable Energy Scenario by 2030 and 2050 in India**" – Faculty Services – Requested.

*****

GREETINGS from Learning & Development Centre, NLC India Ltd., Neyveli.

A Two-day Training Programme on "**Renewable Energy Scenario by 2030 and 2050 in India"** is organized at L&DC, NLC India Ltd., Neyveli from **08.08.2019 to 09.08.2019** as per the details below:

Topic	**: Renewable Energy Scenario by 2030 and 2050 in India**
Date	**: 08.08.2019 to 09.08.2019**
For whom	**: EXECUTIVES**
Time	**: 09:30 AM to 05:30PM**

As confirmed over phone, we are happy to invite you to conduct the above programme as per the following terms:

1. **Faculty Honorarium: Rs.[redacted] plus 18% GST per day.**
2. **Travel Expense: Conveyance will be arranged by NLCIL.**

Hence, it is requested to confirm the programme. Also, kindly note that your accommodation has been arranged at NLCIL Guest House, Block-25, Neyveli-607 803 **(Phone No.04142-252 222).**

An early reply will help us in organizing the programme effectively.

Yours faithfully,
For NLC India Limited.,

3/8/19

General Manager / L&D.

EXECUTIVE TRAINING PROGRAMME

(June 12-13, 2019 at NLCIL , Neyveli)

on

RENEWABLE ENERGY SCENARIO by 2030 and 2050 in INDIA

Dr.S.Gomathinayagam

A freelance Technical Adviser (Wind & Solar Energy, Structures & Foundations)
Former Director General, National Institute of Wind Energy, Chennai, India

Email: sgetgoms@gmail.com

NLC India Limited
(formerly Neyveli Lignite Corporation Limited)
'Navratna' – Govt. of India Enterprise)
OFFICE OF THE GENERAL MANAGER / L&D
LEARNING & DEVELOPMENT CENTRE
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NLC INDIA
CREATING WEALTH FOR WELLBEING

150 YEARS OF CELEBRATING THE MAHATMA

Renewable Energy Scenario by 2030 and 2050 in India

Compiled by Dr.S.Gomathinayagam , Former DG/NIWE and Technical Advisory

E-mail : sgetgoms@gmail.com

General

Berlin Energy Transistion Dialogue, April 9-11, 2019, BETD-2019, has demonstrated that as per the Fig.1., in the last 20 years globally alternate energy , mostly renewables has increased from a level of 18% to 25% . Use of electricity for vehicles (mobility) has increased in the rest of the world from 17% to 20%. In short the deployment of wind energy based electricity generation has increased 10 times and the solar electricity by over 25 times.

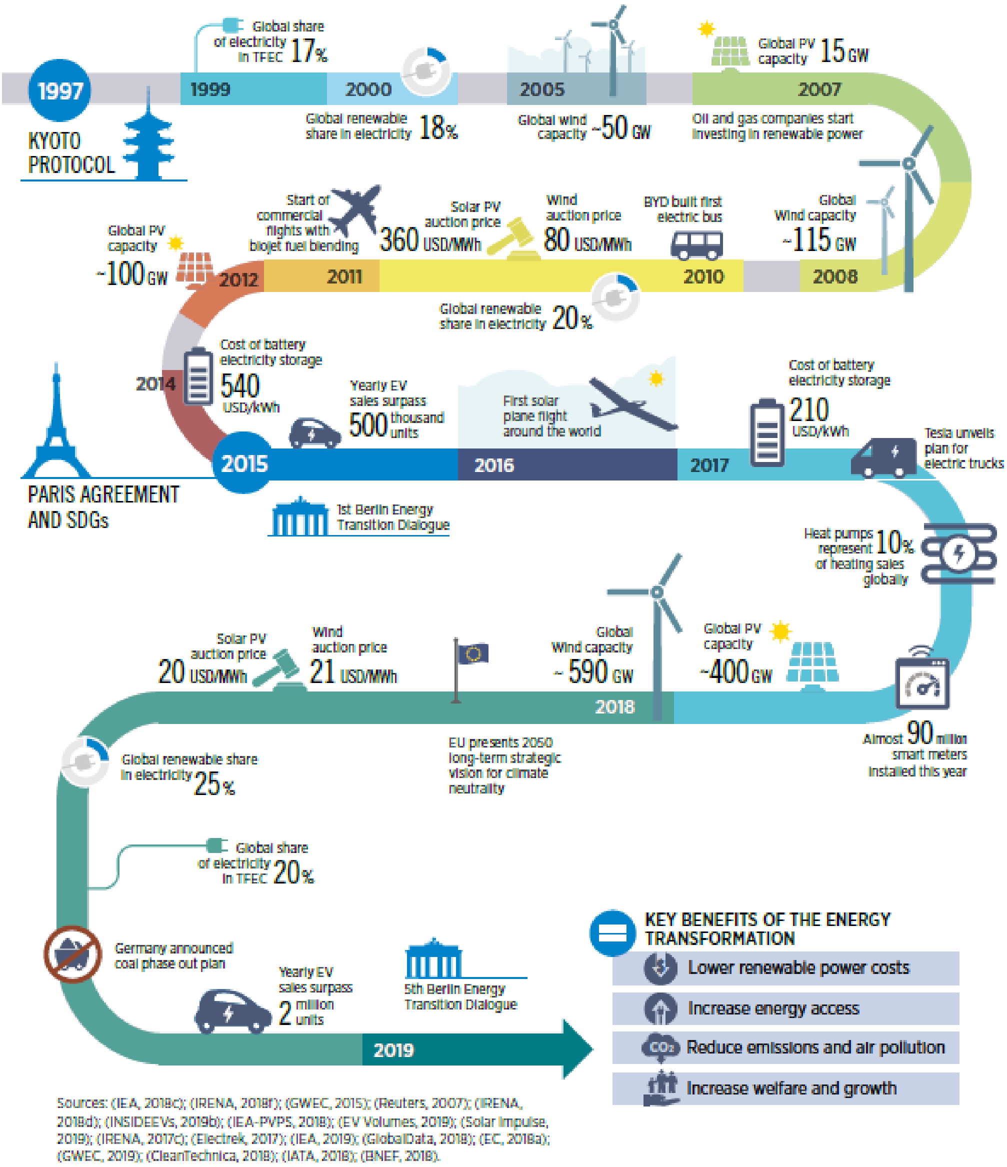

Fig.1. Global Energy Transition Status (IRENA – Global report 2019)

However if one looks at the atmospheric air pollution with higher levels of CO_2 the current status is illustrated in Fig.2. In the atmospheric air 60% (CO_2) needs to be reduced, for which almost 86% electricity generation should be using renewable sources ,and 66% electricity usage in terms of energy should be renewably generated green electricity. This essentially means 50% of energy used in the world should be electricity and that too generation of electricity should be without any atmospheric air pollution.

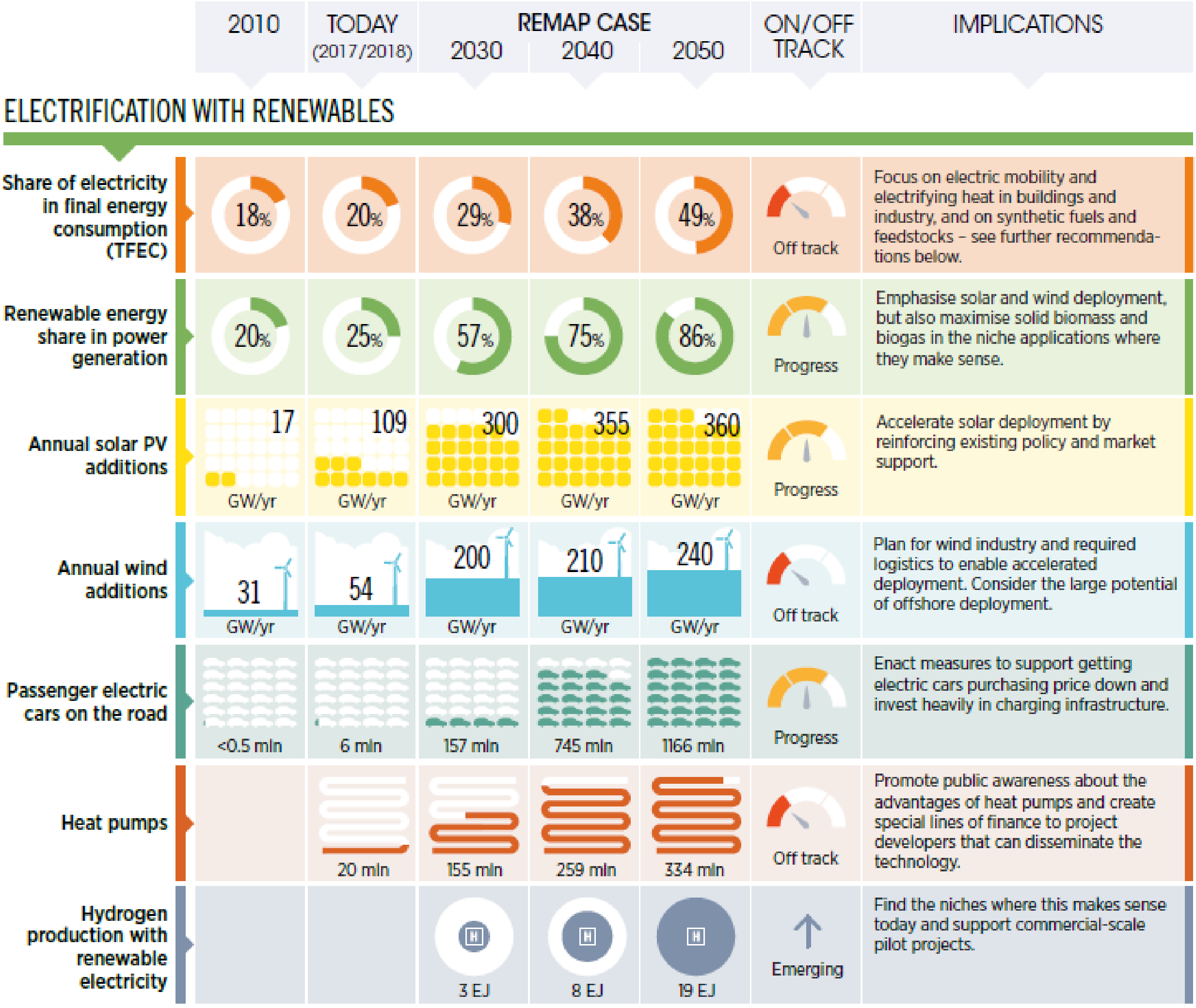

Fig.2. Electricity Generation from Renewables and their growth variations (IRENA , Global Report on Energy Transformation, 2019)

Today's electricity Generation stagnates still at 20% (Fig.2. and Fig.3) in which renewable contribution is quite good at 25%. While generation from solar energy seems to be fast tracking there is need to push the matured wind generated power to higher rates of growth. Globally even though 6 million (60 Lakhs) electrically operated vehicles are operational, India is yet to kick start the EV2030 targets. Applications of alternate energy as well as electricity should be increased in heating and cooling needs of the community as well as industry. There should be increased use of hydrogen as fuel and hydrogen generation should using renewable sources of energy.

India is unique in spite of high population , to remain in the top 5 countries of the world in electricity production and consumption. (Fig.3 and Fig.4)

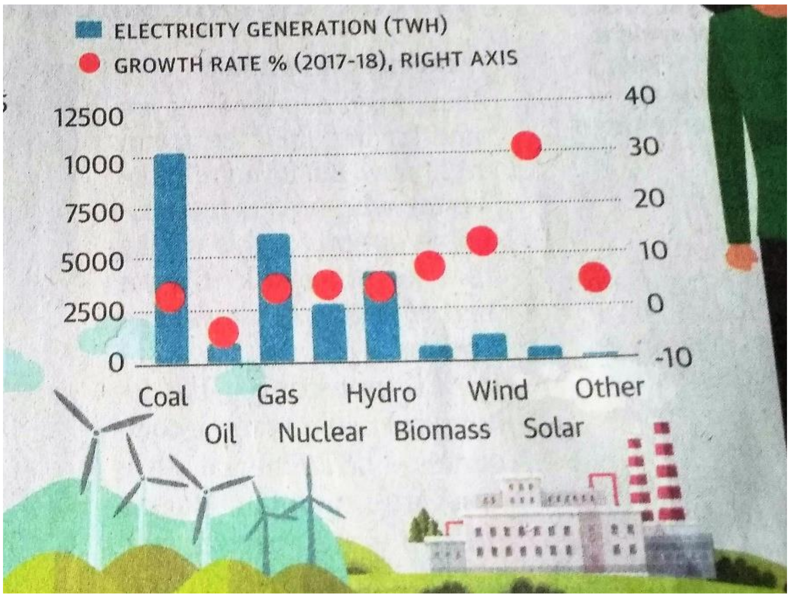

Fig.3. Fossil fuel usage need curtailment of growth rate.
(Ref The Hindu, International Energy Agency, IEA, 2018)

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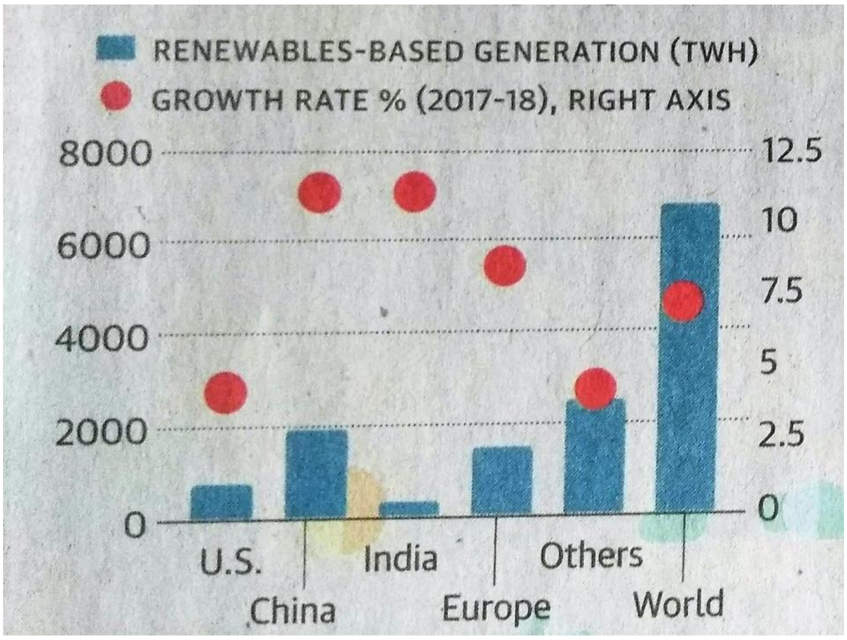


Fig.4. Significant higher rate of growth of renewable energy in India
(Ref The Hindu, International Energy Agency, IEA, 2018)

From Fig.3 it is easy to infer that world over in spite of dominance of fossil fuel (coal, oil and gas) in electricity generation their growth rates are reducing significantly with the higher penetration of renewable energy. The highest growth rates of renewables is happening at 11% world's highest level both in India and China (Fig.4) . Among the 16 defined Sustainable Development Goals- SDG , the seventh is SDG.7. Affordable and Clean energy, will influence more than 12 of the 16 SDG as shown in Fig. 5.

Fig. 5. (Sustainable Development Goals- SDG)
(Ref. SDX India Index 2018 NITI Ayuog)

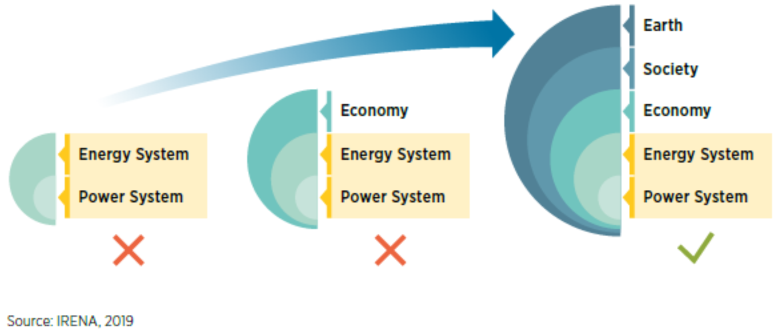


Fig.6. Energy Transition is now inclusive of economy, earth and the society

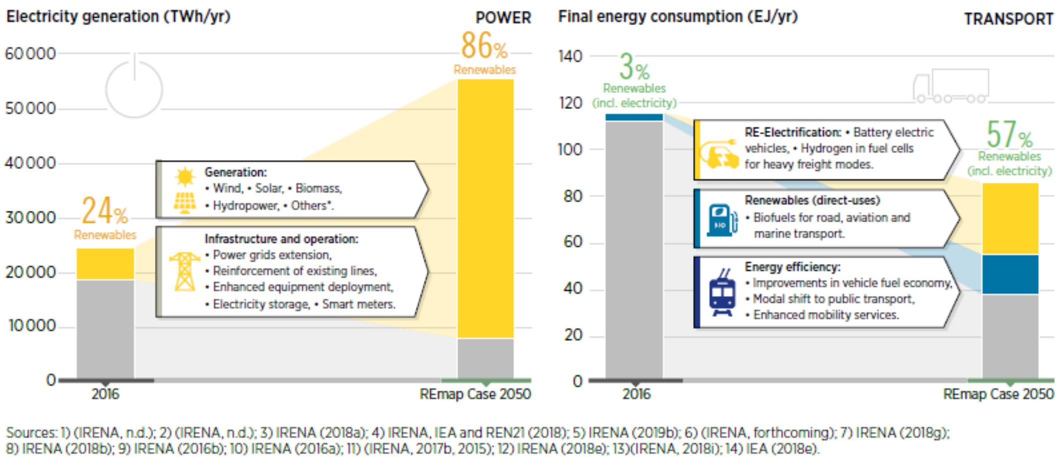


Fig.7. Electricity Generation and usage of Energy for transport/mobility

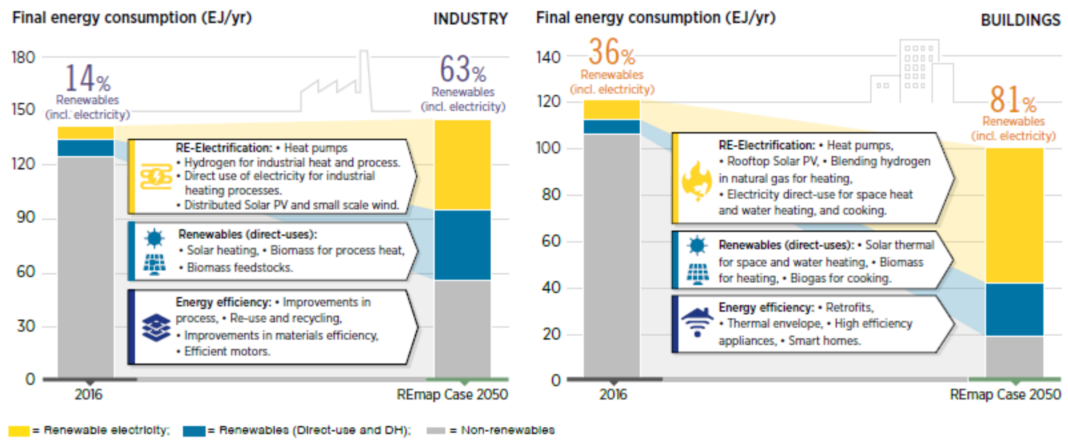
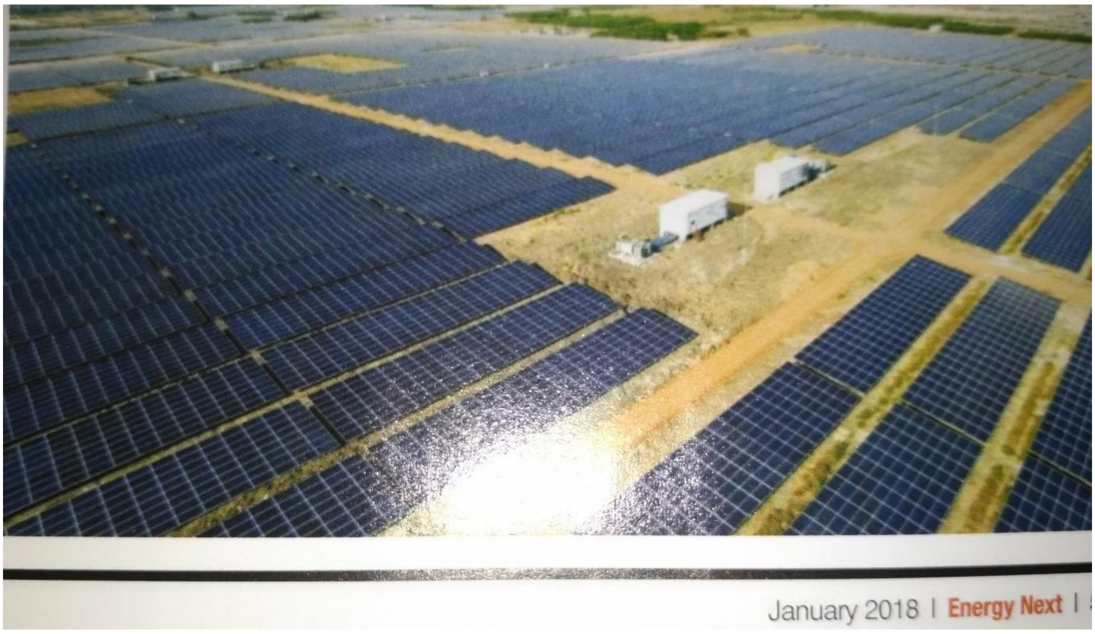


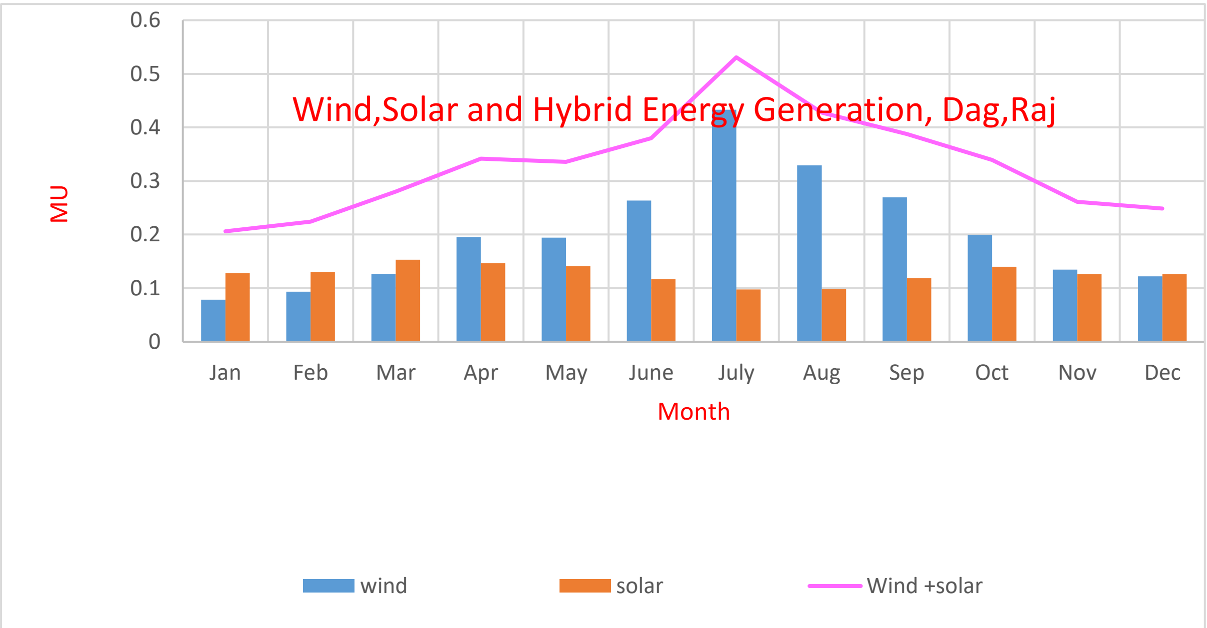
Fig.8 Energy Usage : Industries and Buildings

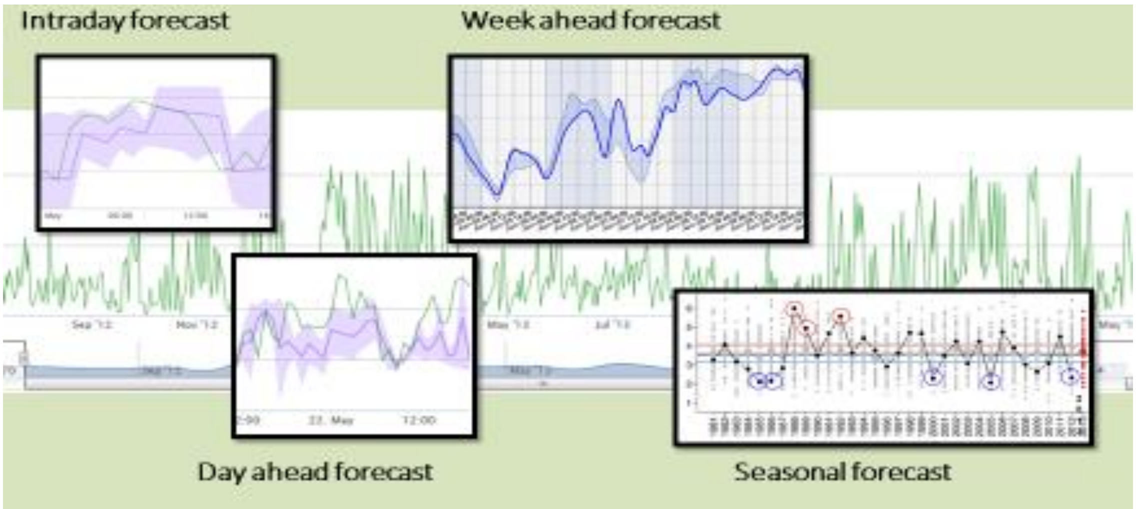
(IRENA Global Energy Transformation Road Map 2019, report) advocates in electricity generation Wind, Solar, Biofuel/Energy and other alternate forms of energy should become main stream. Eletricity transmission and distribution , smart metering, electricity conservation and storage should have better augmented strong infrastructure. Transport vehicles, industries and buildings should use directly as well as as electricity generated from renewables, with a clear focus on energy efficiency too.

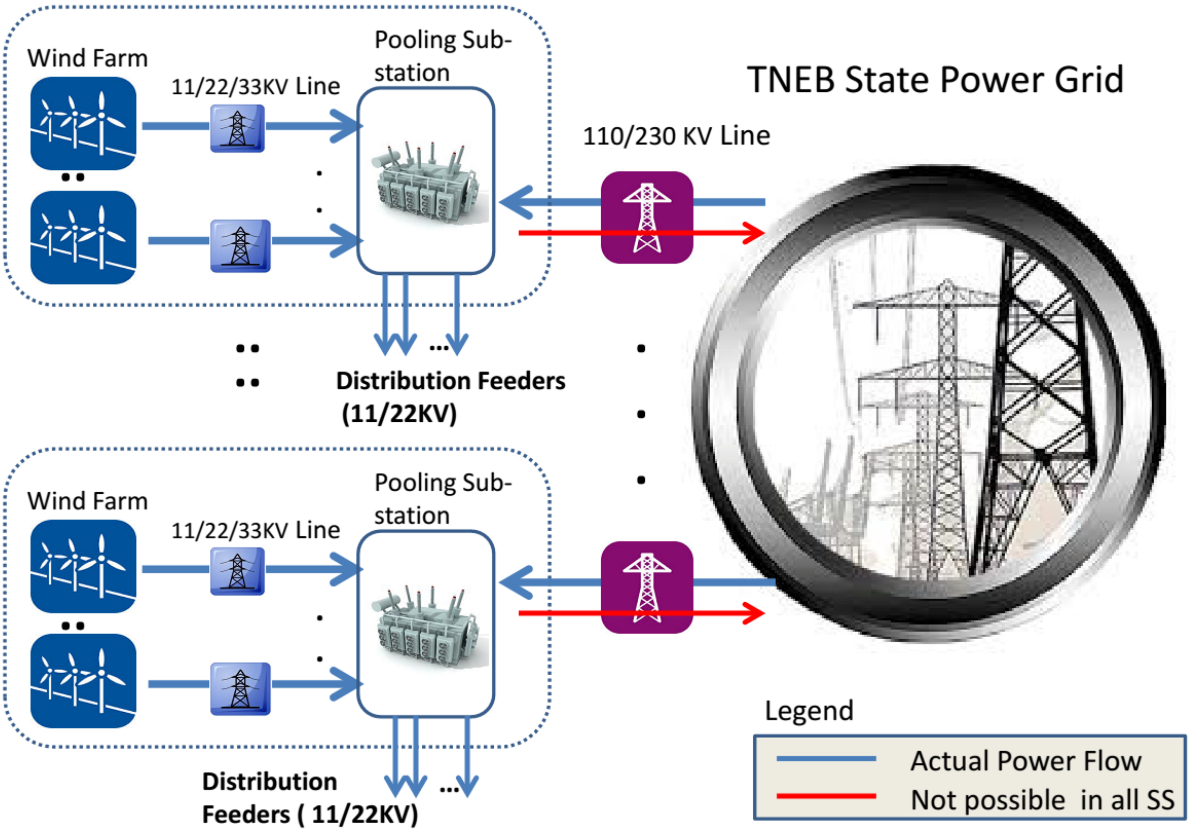
Indian Renewable Energy Scenario/Status:



Two major main stream renewable energy technologies have matured quite well viz. Wind Energy and Solar (SPV) energy specially photovoltaic roof top as well as mega super power plants. The intermittency of variable grid connected renewable energy from these two sources are also getting forecasting and scheduling with practical levels of accuracy thus achieving the grid parity through reverse and competitive bidding of unit price of electricity. Even wind solar hybrid farms are also slowly finding its due position.




Intraday forecast
Week ahead forecast
Day ahead forecast
Seasonal forecast


Wind Farm
11/22/33KV Line
Pooling Sub-station
TNEB State Power Grid
110/230 KV Line
Distribution Feeders (11/22KV)
Wind Farm
11/22/33KV Line
Pooling Sub-station
Distribution Feeders (11/22KV)
Legend
Actual Power Flow
Not possible in all SS

Ministry of New & Renewable Energy			
Programme/Scheme wise Physical Progress in 2019-20 & Cumulative upto April, 2019			
Sector	**FY- 2018-19**		**Cumulative Achievements**
	Target	**Achievement (April 2019)**	**(as on 30.04.2019)**
I. GRID-INTERACTIVE POWER (CAPACITIES IN MWp)			
Wind Power	4000.00	189.92	35815.88
Solar Power - Ground Mounted	7500.00	445.55	26829.87
Solar Power - Roof Top	1000.00	52.95	1849.34
Small Hydro Power	50.00	1.00	4594.15
Biomass (Bagasse) Cogeneration)	150.00	28.00	9131.50
Biomass (non-bagasse) Cogeneration)/Captive Power	100.00	0.00	674.81
Waste to Power	2.00	0.00	138.30
Total	**12802.00**	**717.42**	**79033.85**
II. OFF-GRID/ CAPTIVE POWER (CAPACITIES IN MW_{EQ})			
Waste to Energy	10.00	0.00	178.73
Biomass Gasifiers	1.00	0.00	163.37
SPV Systems	400.00	0.73	916.34
Total	**411.00**	**0.73**	**1258.44**
III. OTHER RENEWABLE ENERGY SYSTEMS			
Biogass Plants	86900.00	0.00	25561.00

While off-grid as well as grid tied applications of roof top solar is having slow growth and the small wind is yet to become competitive. However, they will soon find their market when distributed RE systems get more acceptance in the society, specially with the need for electric vehicle charging or battery swapping stations.

In line with the Global Energy Transition , Electricity generation, Electrical efficiency and needs and storage , Transportation or mobility sector, and finally heating, cooling/ventilation are the four prioritized areas. Of course in a few countries sustainability needs also has forced adoption of some cross sector coupling in energy transition.

Table 9: India's REmap overview

			Unit	2010/11	Reference Case 2030	REmap 2030
Energy generation and capacity	Power sector	**Total installed power generation capacity**	GW	**173**	**672**	**855**
		Renewable capacity	GW	55	261	523
		Hydropower (excl. pumped hydro)	GW	37	48	77
		Wind	GW	14	146	187
		Biofuels (solid, liquid, gaseous)	GW	3	11	28
		Solar PV	GW	1	48	196
		CSP	GW	0	0	11
		Geothermal	GW	0	0	2
		Marine, other	GW	0	0	0
		Off-grid and rural renewables (solar, wind, biogas)	GW	0.1	9	21
		Non-renewable capacity	GW	118	411	333
		Total electricity generation	TWh	**946**	**3 463**	**3 527**
		Renewable generation	TWh	136	628	1 223
		Hydropower	TWh	104	147	246
		Wind	TWh	21	345	471
		Biofuels (solid, liquid, gaseous)	TWh	10	35	105
		Solar PV	TWh	1	82	310
		CSP	TWh	0	0	28
		Geothermal	TWh	0	0	16
		Marine, other	TWh	0	0	0
		Off-grid and rural renewables	TWh	0	19	47
		Non-renewable generation	TWh	810	2 835	2 304
Final energy use – direct uses	Buildings and Industry	**Total direct uses of energy**	PJ	**13 055**	**27 567**	**25 256**
		Direct uses of renewable energy	PJ	6 639	7 638	5 966
		Solar thermal – Buildings	PJ	6	71	510
		Solar thermal – Industry	PJ	0	1	151
		Geothermal (Buildings and Industry)	PJ	9	9	19
		Bioenergy (traditional) – Buildings	PJ	4 063	4 259	0
		Bioenergy (modern) – Buildings	PJ	1 364	1 485	2 967
		Bioenergy – Industry	PJ	1 196	1 813	2 319
		Non-renewable – Buildings	PJ	1 023	4 740	4 740
		Non-renewable – Industry	PJ	5 116	14 553	13 914
		Non-renewable – BF/CO	PJ	278	636	636
	Transport	**Total fuel consumption**	PJ	**2 214**	**5 718**	**3 351**
		Liquid biofuels	PJ	8	109	468
		Conventional biogasoline	PJ	1	19	85
		Advanced biogasoline	PJ	0	1	37
		Biodiesel (conventional and advanced)	PJ	7	89	346
		Biomethane	PJ	0	0	0
		Non-renewable fuels	PJ	2 205	5 609	2 883

Based on IRENA estimates

ANNEX A:

Technology cost and performance data in 2030

	Capacity factor	Overnight Capital Cost	O&M* Costs	Conversion efficiency	Production cost
Power sector					
Renewable energy technology (RET)	(%, cap)	(USD/kW)	(USD/kW/yr)	(%)	(USD/GJ_e)
Hydropower (small)	37	2000	40	100	24
Hydropower (large)	43	1500	30	100	16
Wind onshore	26	1600	80	100	34
Wind offshore	44	2870	186	100	39
Solar PV (residential/ commercial)	16	1400	15	100	33
Solar PV (utility)	19	1000	12	100	20
Solar CSP no storage	30	3300	33	100	46
Biomass co-firing (retrofit)	70	500	12	38	35
Biomass steam cycle (non-OECD)	40	1200	30	38	46
Biomass fixed-bed gasifer	80	700	17	35	38
Biomass anaerobic digester	85	3300	82	35	53
Biomass steam cycle (waste)	40	2000	50	32	61
Biomass gasifier/ biogas anaerobic digester, off-grid	35	900	18	37.5	12
Solar PV – off-grid, partial storage, mobile towers	22	2000	20	100	42
PV/wind mini-grid – partial storage, households	25	3500	35	100	64
Geothermal	80	5500	220	10	35
Conventional technologies					
Coal (non-OECD)	80	1300	52	35	19
Diesel (Gen-set)	40	1500	37	42	88
Unserved Energy					105
Buildings sector					
RET	(%, cap)	(USD/kW)	(USD/kW/yr)	(%)	(USD/GJ_{th})
Space Cooling: Solar	12	1100	27	80	47
Water heating: Solar (thermosiphon)	11	215	7.5	100	11
Cooking: Solar	10	150	5	100	8
Cooking biogas (from anaerobic digester)	15	22	0.5	30	17
Cooking biomass (solid)	15	19	0.48	25	48
Cooking biogas (gasification)	15	22	0.5	30	41
Conventional technologies					
Space cooling: Electricity	10	90	2.2	75	44
Water heating: Electricity	10	90	2.2	75	44
Cooking traditional biomass	10	10	0.25	10	37

00 REmap: Renewable energy prospects for India

	Capacity factor	Overnight Capital Cost	O&M* Costs	Conversion efficiency	Production cost
Industry sector					
RET	(%, cap)	(USD/kW)	(USD/kW/yr)	(%)	(USD/GJ_{th})
Autoproducers, CHP electricity part (solid biomass)	50	692	17	70	23
Solar thermal	15	250	4	100	8
Geothermal	40	2000	50	100	23
Biomass gasification	80	200	5	85	15
Solar thermal (CST)	20	450	45	100	16
Biogas heat industry (from anaerobic digester)	50	150	4	85	7
Autoproducers, CHP heat part (solid biomass)	50	692	17	70	24
Conventional technologies					
Coal (steam boiler)	85	300	8	90	6

Transport Sector						
	Unit activity of renewable-driven vehicle	Overnight Cap. Cost	O&M Costs	Fuel demand	Production cost	Power demand
RET**	(p or t km/ yr/ vehicle)	(USD/ vehicle)	(USD/ vehicle/yr)	(MJ_f/p or t-km)	(USD/p or t-km)	(MJ_e/p or t-km)
First generation bioethanol (passenger road vehicles)	15000	28000	2800	0.9	0.52	0
Second generation bioethanol (passenger road vehicles)	15000	28000	2800	0.9	0.52	0
Biodiesel (public road vehicles)	60000	100000	10000	0.2	0.39	0
Biodiesel (passenger rail)	500000	500000	50000	1.04	0.28	0
Battery electric (passenger road vehicles)	15000	29000	2900	0	0.52	0.69
Battery electric (public road vehicles)	60000	84000	8400	0	0.35	0.27
Battery electric two-wheeler (passenger road)	5000	4020	442	0	0.25	0.07
City tram for passenger road vehicles	500000	1260000	126000	0	0.57	0.37
High speed train for passenger aviation	500000	1255000	125500	0	0.56	0.37

	Unit activity of renewable-driven vehicle	Overnight Cap. Cost	O&M Costs	Fuel demand	Production cost	Power demand
Conventional technologies						
Gasoline (passenger road vehicles)	15000	28000	2800	0.8	0.53	
Diesel (passenger road vehicles)	15000	30000	3000	1.54	0.60	
Diesel (public road vehicles)	60000	100000	10000	0.2	0.39	
Diesel (freight road vehicles)	110000	120000	12000	1.16	0.30	
Diesel (passenger rail)	500000	500000	50000	1.04	0.28	

* O& M = Operations and Maintenance

** *In this row the "p" stands for "passenger" and the "t" stands for "freight"*

IRENA –REMAP-India Predictions 2030

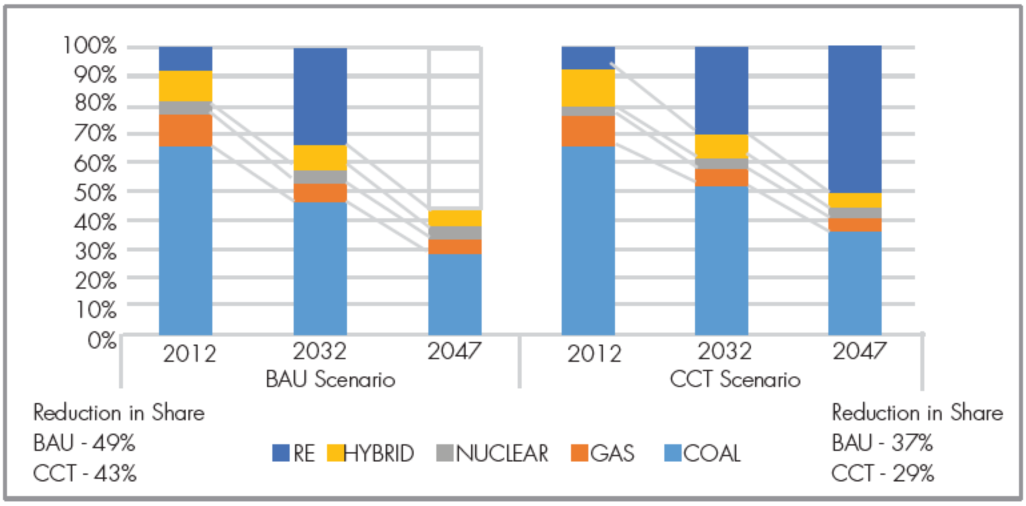


Figure 7: Electricity Generation Mix

Source Ref Ack: NITI Aayug –IEE Japan Energising India report 2017 –

Installed Capacity (GW)

	Coal	Gas - CCGT	Nuclear	Hydro	Biomass+ Cogen	Small Hydro	Wind	Solar	Waste to Electricity	Total
High RE	539	83	45	105	20	30	551	807	4	2184
Med RE	539	83	45	105	23	20	293	449	4	1561
Low RE	539	83	45	105	11	15	222	243	4	1267

Table 1: Total installed capacity (national) of RE and other technologies for each scenario

The tables below shows the annual energy generation in TWh/yr and the percentage share of each technology in the annual generation:

Annual Energy Generation (TWh/yr)

	Coal	Gas - CCGT	Nuclear	Hydro	Biomass+ Cogen	Small Hydro	Wind	Solar	Waste to Electricity	Total
High RE	2537	0	356	273	6	0	1325	1512	1	6010
Med RE	3704	0	356	278	14	0	733	891	2	5979
Low RE	4088	0	356	278	19	0	564	479	7	5790

Share in Annual Generation

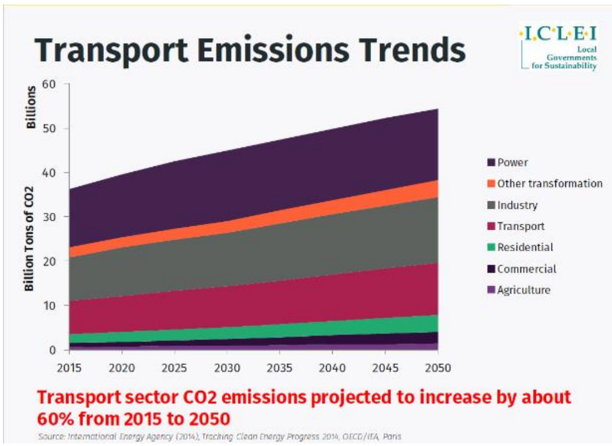
	Coal	Gas - CCGT	Nuclear	Hydro	Biomass+ Cogen	Small Hydro	Wind	Solar	Waste to Electricity	Total
High RE	42%	0%	6%	4%	0%	1%	22%	25%	0%	100%
Med RE	61%	1%	6%	5%	0%	1%	12%	15%	0%	100%
Low RE	67%	4%	6%	5%	0%	1%	9%	8%	0%	100%

Table 2: Annual energy generation in TWh/yr and the percentage share of each technology in the annual generation

Source Ref Ack: NITI Aayug –IEE Japan Energising India report 2017 – Riche Gupta

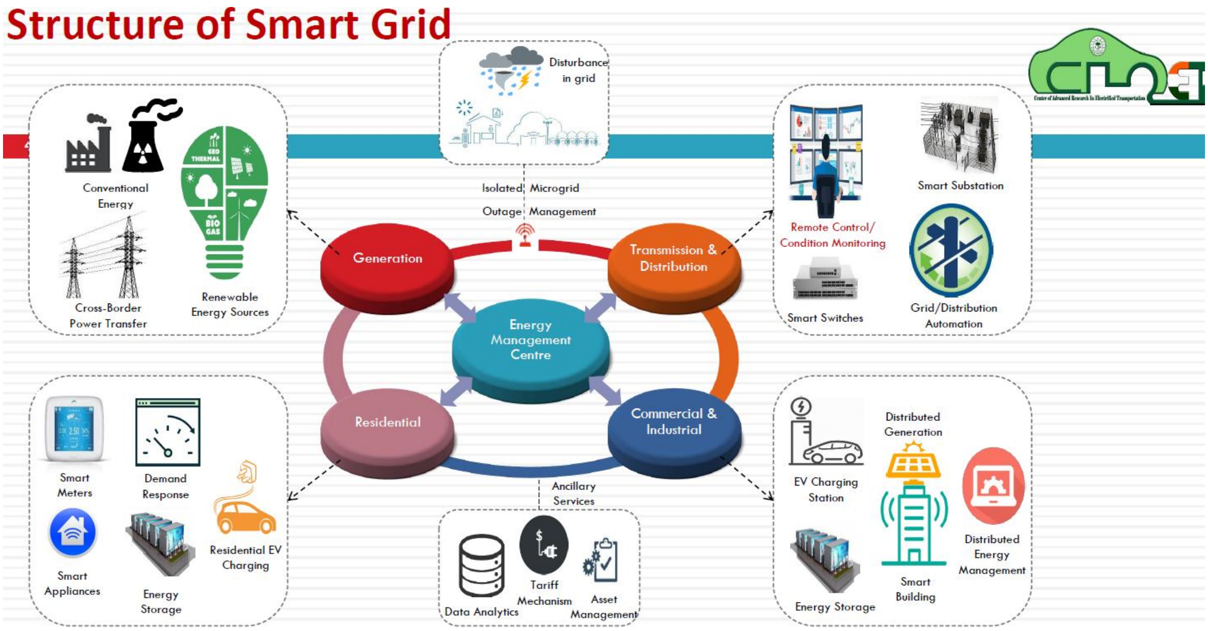
Transport Fuel Electricity/Hydrogen/FuelCell:

Unmindful of pollution, we keep using petrol, diesel in railways trains, lorries, busses, and cars. In FY 2017 , 81% oil has been imported which is 22.6% foreign exchange apart from paid pollution of atmosphere and environment.

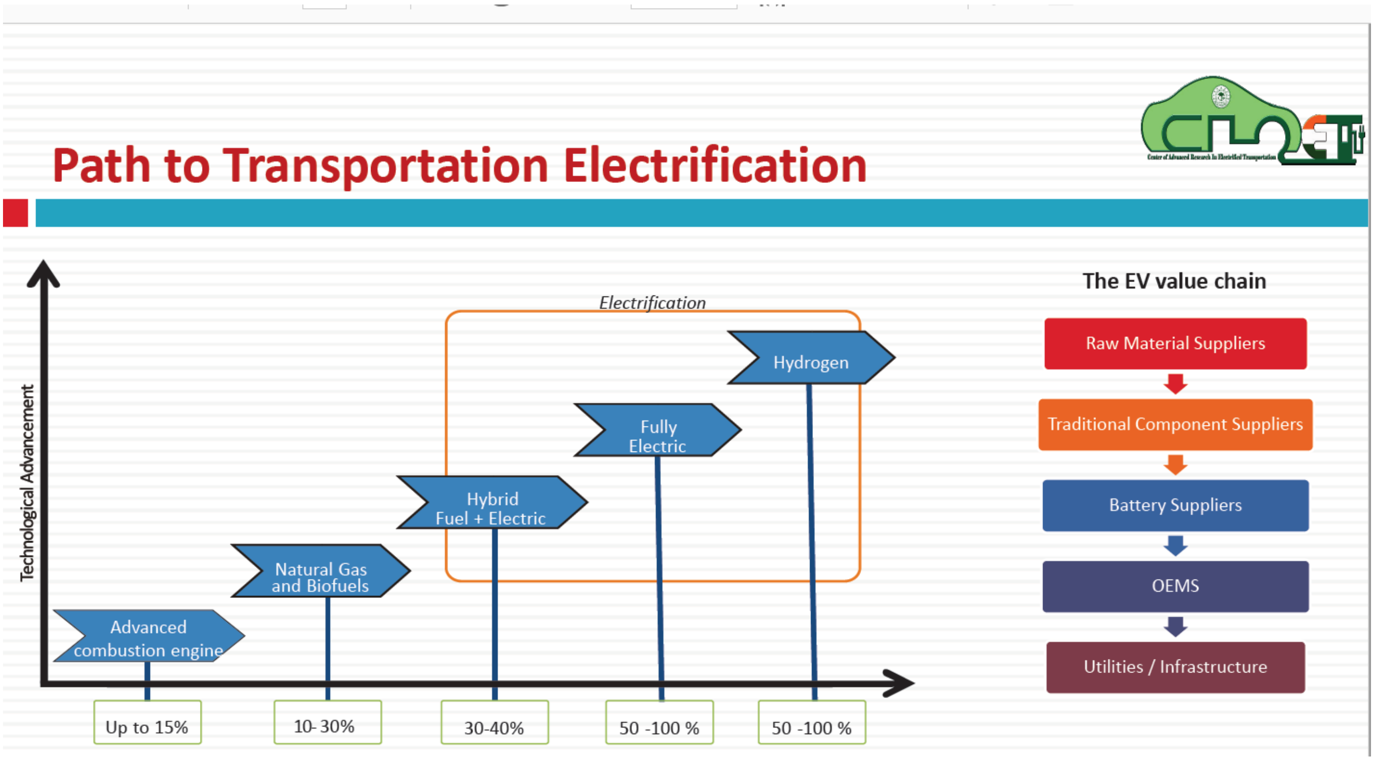


Courtesy &Ack: Santhosh Kodikula, Berlin, 2016

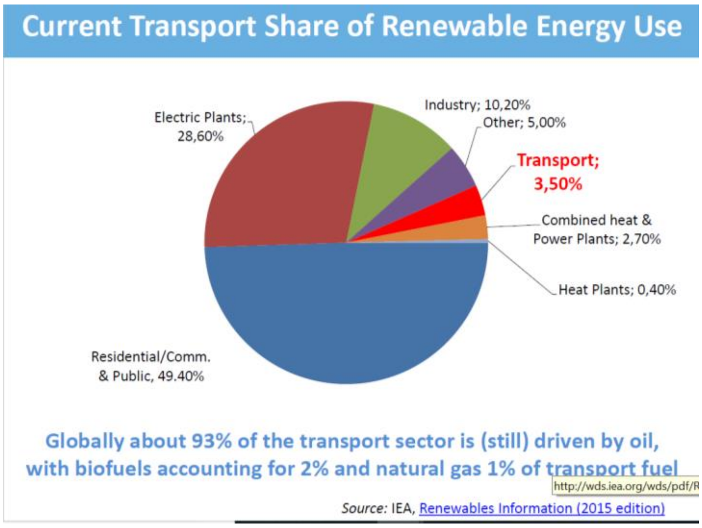
Sensing this danger ahead, Government of India has launched two programmes, firstly the National Electric Mobility Mission Plan – NEMMP-2020 and following that Faster Adaptation and Manufacturing of Electric Vehicles FAME -2030 . With these two schemes if implemented rigorously, by 2030 all vehicles would go electric, in four phases technology development, EV-market demand creation, model prototypes,and battary charging/swapping infrastructure. If the later development is by renewables distributed with solar and wind energy, it will be the best option for inclusive growth of economy. TESLA charger can charge in 8 minutes and the EV can cover a distance of 200kM. While American TESLA focusses on fast charging, TOYOTA car company has advanced in fuel cell technology, since generation of hydrogen can be done by many ways with renewables as well.



Courtesy and Ack: Saad Alam, IEX workshop IIT, Kanpur 2018

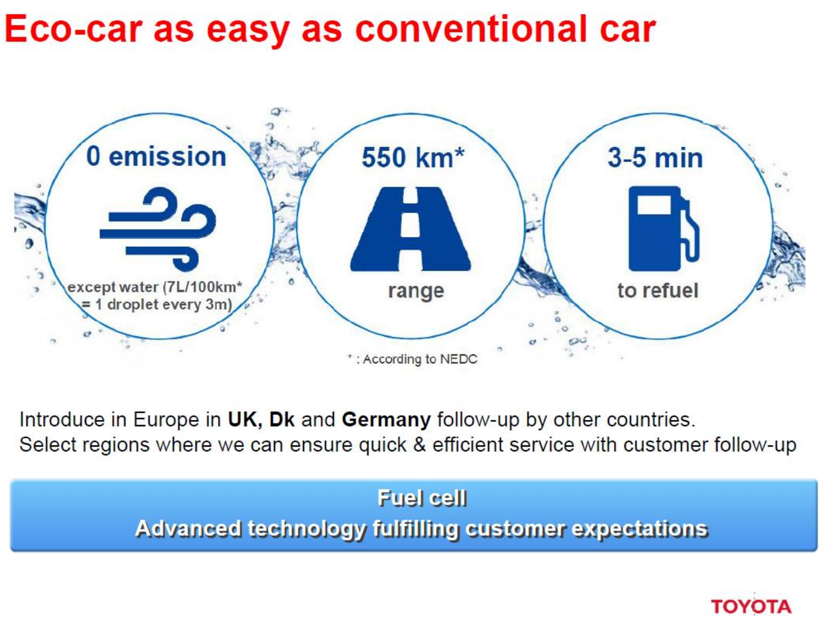


Courtesy and Ack: Saad Alam, IEX workshop IIT, Kanpur 2018



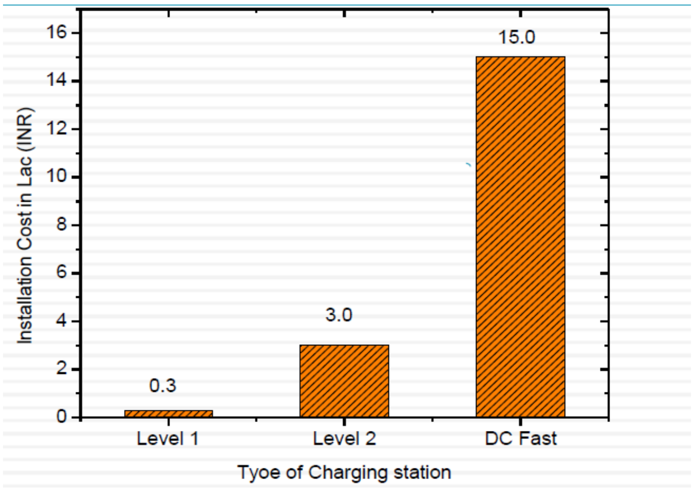
Ack: Heather Allen , Berlin 2016

BEV, BHEV (hybrid) powered vehicles use only battery as a main source, fast charging technology for long distance travel before next charge is now available , but stations for charging are not enough. This is why India is far behind EV30 targets, in spite India stands 5th in passenger car/vehicles.



Courtesy & Ack. Dr.M.Desaeger, Berlin 2015

Cost of establishing battery charging /swapping stations will be less than that of a normal petrol bunk. Car travel sharing is common in USA and Europe, even though it is yet o be popular in India. Yet, OLA, UBER like IoT services are getting accepted in tier one cities and probably in some big towns as well. Mobile APP based selectable multi-owned cars (instead of single or self owned) are yet to be operational in India, if that picks up BEV proliferation on the roads can happen.



Level 1 charger of 1.5kW, Level 2 charger of 6.6kW and DC fast charger of 50kW capacity.

Courtesy and Ack: Saad Alam, IEX workshop IIT, Kanpur 2018

On a single ticket multi-modal public transport is certainly viable but yet to be implemented in Indian metro,MRTS,Electric train,MTC Buses. Indian Railways through it's REMC (railway Energy Management Company) is now spending 26500 crores of rupees for energy or fossil fuel, it has planned to fast track railway electrification also by doubling the number of electric locomotive engines from 4400 to 9400 in 5 years there by reducing the energy expenditure to 16000 crores.

Alternate Transport Renewable Fuel (Electricity&Biofuels) :

Electricity Generation in energy penetration with renewables in India has reached 10% already, but even globally only 3.5% of electricity is directly used as transport fuel.

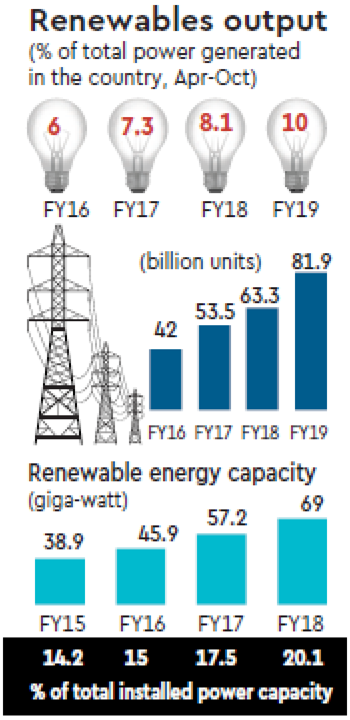


Fig.1. 10% Renewable Energy in India FY19

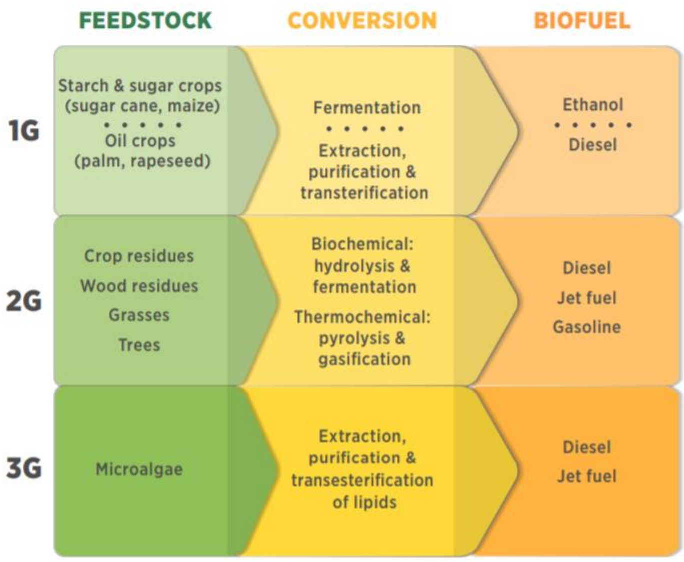


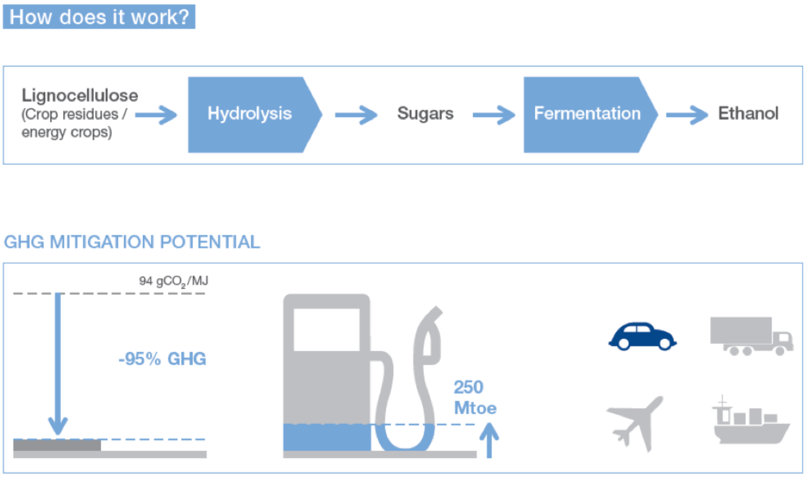
Fig.2 1G,2G,3G Biofuel Production process (IRENA report 2016)

Very little progress has been made in electric vehicle usage in spite of mamooth efforts by Government of India. Apart from fuel cell powered or battery powered vehicles , in a agriculturally based country like India bio-fuels equivalent to fossil fuel replacement is highly important. Basic 1-G first generation bio-fuel is generated from food waste, bio-gas/ bio-diesel. From non-edible seeds, starch, forest vegetation wastes second generation 2-G bio fuel such as ethanol (slightly costly) is prepared, which can be blended with petrol. From algae or using municipal solid wastes 3-G bio-fuel can be made with exclusive industrial process (Fig.2).

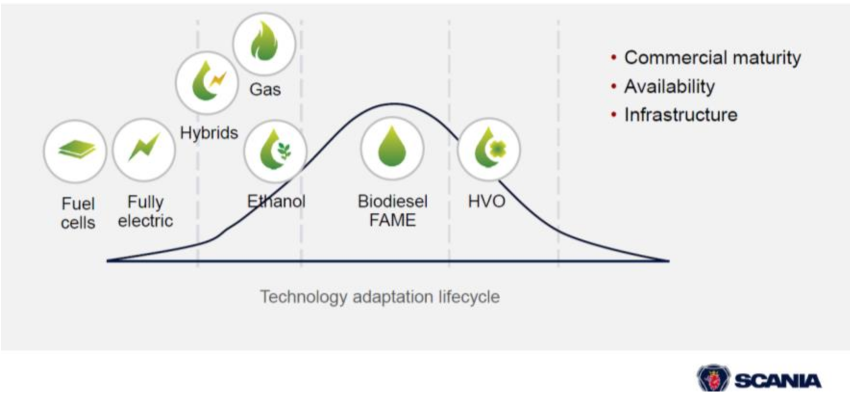
Now, India permits blending of fraction of ethanol, with petrol, thereby reducing CO_2 in air.

Waste is wealth , from such soild wastes we can prepare (biogas, methane) , by a process of fermentation and biomethanisation. Liquid bio fuel such as (methanol), (dimethyl ether – DME) can be stored. Since this is alternate to petrol, reduces foreign exchange,and can also be used occationally for elctricity generation for battary charging, for easy method of hydrogen generation for use in fuel cell powered vehicles.

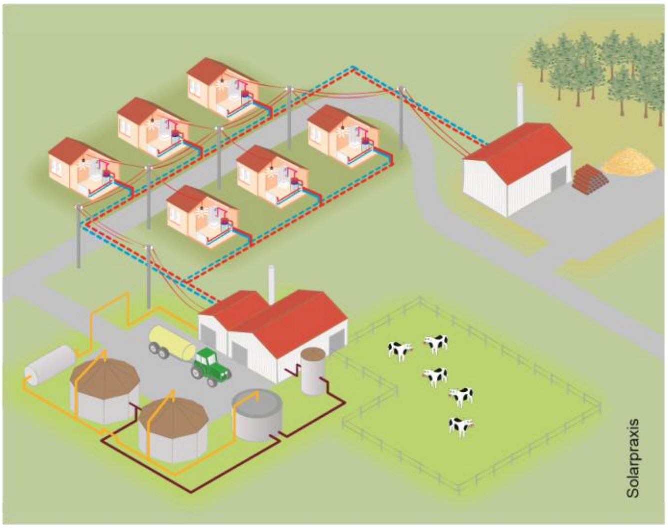
This type of SME, MSMEs for manufacturing distributed energy modules , cross sector coupled renewable energy in rural areas. In turn will pave way for more exploitation of Electric vehicles in India.



(SourceAck: Bernardo-Gradin, Berlin 2016)



(Source Ack: Magnus-Hoglund, Berlin 2016)



Unlike natural gas, biogas can be generated close to the end-consumers. Farmers can also sell biogas to open up a further source of income for

The production of biomethane from residual materials and waste avoids competition with food production in the use of materials.

(Ref Source Ack: Renewables made in Germany, 2016)

Solar Thermal:

Solar Photo Voltaic (SPV) uses light energy fraction of sun’s abundant Energy, even today India imports most of solar cells from Europe, China and USA. India being tropical country the solar heat energy can be very efficiently used in many ways leading with indigenous technology. Direct use of sun’s heat for cloth drying, grain and coal drying is more than straight forward. Concentrated solar thermal, CST-collectors as shown below can focus heat energy to point or line concentrators and heat water as super heated steam through metallic pipes and can be used for several applications, by storing heat energy, or using the same for heating, cooling, desalination and for even electricity generation purposes.

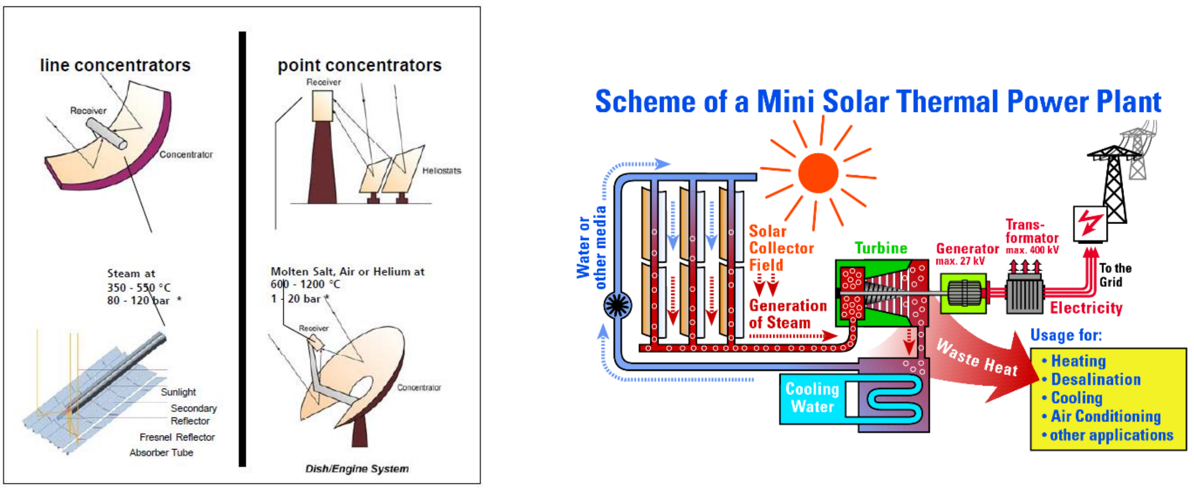


Fig. 1. CST* Concentrated Solar thermal application

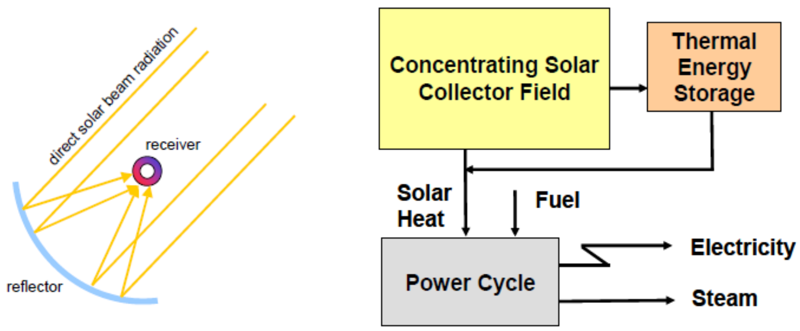


Fig. 2. CST* Concentrated Solar thermal application with storage

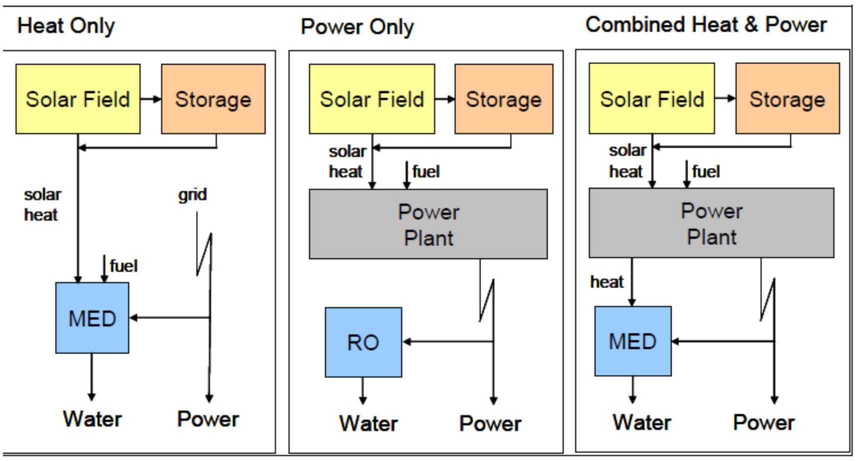


Fig. 3. CSP* Concentrated Solar thermal multi-purpose designs

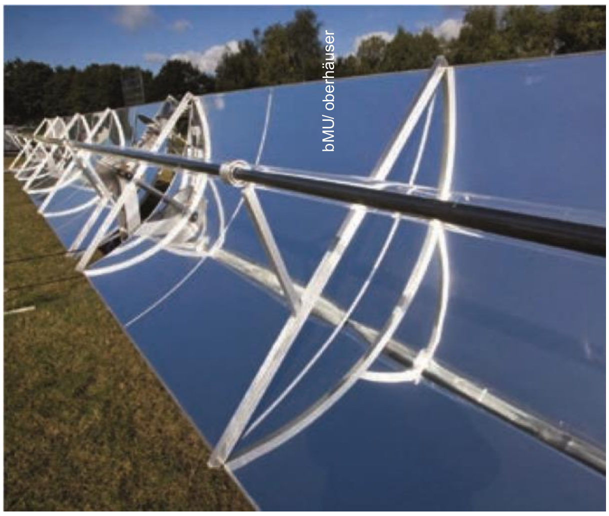


Fig. 4 Line concentrators using (parabolic mirrors)*

Fig. 5. Flat Mirrors with single axis tracking for power and water (flat mirrors –CSP KGSL-Coimbatore – single Axis tracking sun's movement)

Fig. 6. CSP* Concentrated Solar thermal for power generation (ABD,TNAU,CBE-Dual axis tracking installation)
(ABD-TNAU coimbatore : Dual axis tracking of sun’s movement)

Figure 3-32: PS 10 central receiver solar tower facility near Sevilla, Spain (Abengoa Solar). In the background the PS20 facility can be seen under construction

Fig. 7. Concentrated Solar thermal tower liquid salt used for heat transfer and storage(Sources Ack. Renewables made in Germany, 2016 and Web-resources)

Just like multi-purpose hydro-electric power houses (flood control, irrigation, and power generation), several multi-purpoe engineering research with solar thermal is possible to be done leading with indigenous knowhow and technology for , power, drinking water from sea water, electric car battery charging /or battary swapping station establishment, as well as industrial pre heating and air conditioning.

NLCIL has a corporate social responsibility programme which is highly focussed on sustainable technologies, for aforestation, drinking water management, waste to energy, environmental protection, mitigation and counter efforts for carbon emission from power generation, renewable energy expolitation, green technology adoptation, skill development, human resource development, Inclusive economic, earth saving environmentally benign development.

All forms of renewable energy adoption at kW level, local domestic residential level, MW level plants, will certainly grow the India's multi-cultural corporate communiity (township) net-zero energy community with the national mission of Zero-defect and Zero-effect PSU.

EXECUTIVE TRAINING PROGRAMME

(July 17-18, 2019 at NLCIL , Neyveli)

on

Solar Power Technology and Development

Compiled by Dr.S.Gomathinayagam ,

Former DG/NIWE and Technical Advisory

E-mail : sgetgoms@gmail.com

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(formerly Neyveli Lignite Corporation Limited)
'Navratna' – Govt. of India Enterprise)
OFFICE OF THE GENERAL MANAGER / L&D
LEARNING & DEVELOPMENT CENTRE
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BLOCK-20, NEYVELI – 607803

General

Recalling definitions of power (in this case we deal with electrical power) we have the following :

- **Power (P):** **the rate of energy** conversion measured in ***Watts***
- **Voltage (V):** **the potential difference** in electrical charge between two points measured in ***Volts***
- **Current (I):** **the flow of electrons** in a circuit/wire between two points measured in ***Amperes***
- **Resistance (R):** **the opposition to the flow** of electrical current in the material through which it is passing measured in ***Ohms***
- **Energy (E):** **refers to the capacity for work** i.e. the power used over time, measured in ***Watt hours***

The following equations show the relationship between the above parameters:

Power = Volts x Current	**P = V X I**	Watts
Volts = Power ÷ Current	**V = P ÷ I**	Volts
Current = Power ÷ Volts	**I = P ÷ V**	Amperes
Resistance = Volts ÷ Current	**R = V ÷ I**	Ohms
Energy = Power x Time	**E = P x t**	Watt-Hours

Growth of Solar electricity in the world in the last two decades has been quite significant and is by over 25 times (IRENA RE30 Road map report 2019). Solar (SPV) energy specially photovoltaic roof top as well as mega super power plants. The intermittency of variable grid connected renewable energy from these two sources are also getting forecasting and scheduling with practical levels of accuracy thus achieving the grid parity through reverse and competitive bidding of unit price of electricity.

India's Solar deployment and development progress has also been exponential in growth. While off-grid as well as grid tied applications of roof top solar is having slow growth owing to frequent policy drift in different states and lack of awareness of the advantages easiness of solar power technology adoption by societies, ground mounted MW/GW plants are growing very fast. However, they will soon find their market when distributed RE systems and with Solar based rural micro-grids, get more acceptance in the society, specially with the need for electric vehicle charging or battery swapping stations.

Programme/Scheme wise Physical Progress in India 2019-20 & Cumulative upto April, 2019			
Sector	**FY- 2018-19**		**Cumulative Achievements**
	Target	**Achievement (April 2019)**	**(in MW installed as on 30.04.2019)/ in GW 2022**
I. GRID-INTERACTIVE POWER (CAPACITIES IN MWp)			
Solar Power - Ground Mounted	7500.00	445.55	26829.87 /**60GW**
Solar Power - Roof Top	1000.00	52.95	1849.34 /**40GW**
II. OFF-GRID/ CAPTIVE POWER (CAPACITIES IN MW_{EQ})			
SPV Systems	400.00	0.73	916.34
Source : www.mnre.gov.in			

In this short two day training programme we will cover the basics of electricity generation using Solar technology and visit through case studies the past, present and possible future development specially in India with due reference to the global Solar Technology developments.

Solar Energy and Solar Power:

The term solar energy refers to heat and light radiation from the sun on the earth's atmosphere. The following picture shows what is energy fraction that reaches the earth.

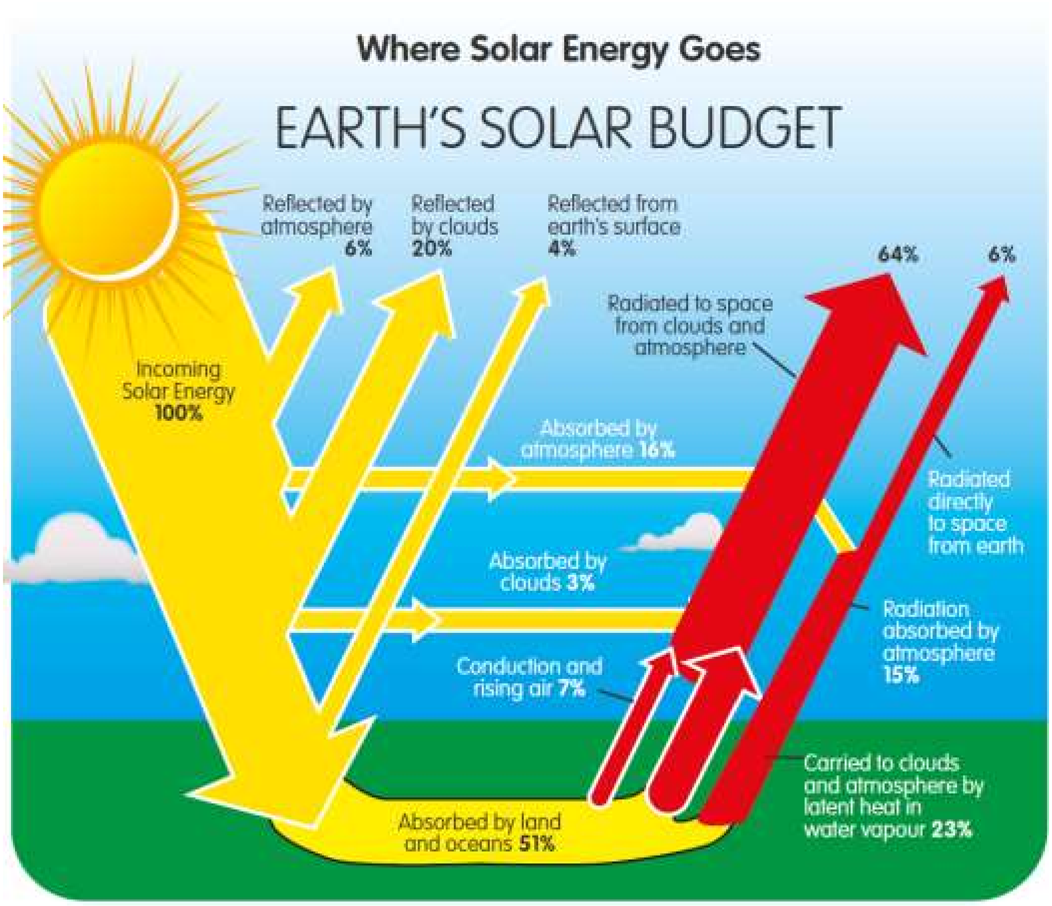


Fig.1 Solar Irradiation and Earth's atmosphere

Out of 365 days in a year , our country India is blessed with almost 300 days of sun shine in many parts of India. Depending on land use and land cover there is an enormous potential of solar Energy in the country , approximately over 700GW. However , solar power technologies can tap this solar resource using appropriate technology and site specific adaptations.

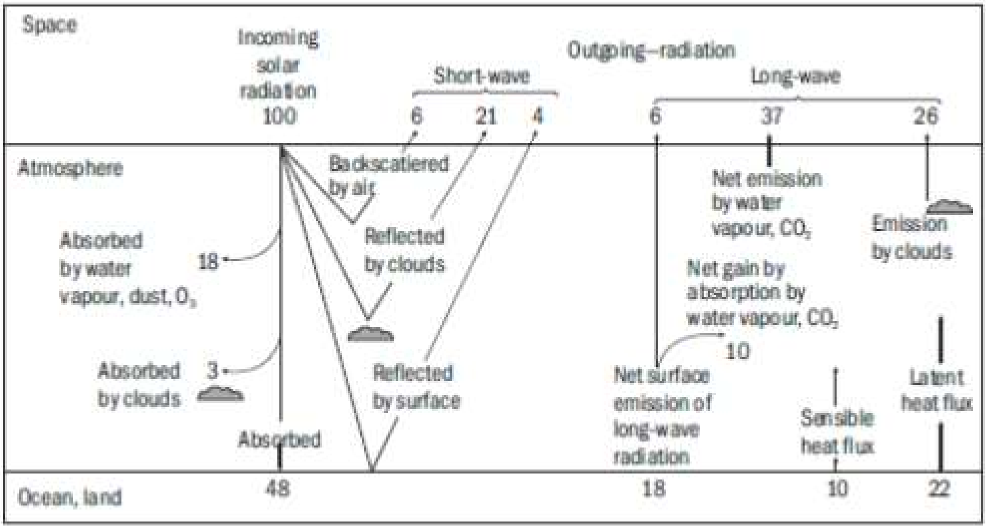


Fig.2 The composition of long wave and short wave of solar radiation

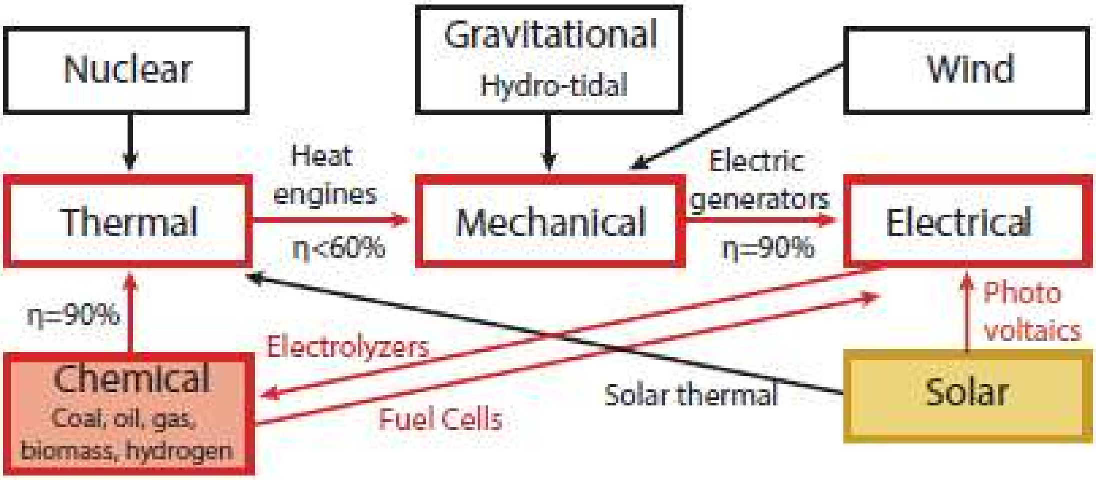


Fig.3 Linkage between Energy carriers and human usage levels

The two major Solar Power technologies that can be harnessed is using Solar Photo Voltaic (SPV) and Solar Thermal (STh) and it is important to note that the former uses light energy (works better in cold dry clean bright sun light in the atmospheres like Ladak, in the Himalayas, than hot tropical desserts like that in Rajesthan) , while the later uses heat energy (will work extended hours beyond day time with latent heat in the atmosphere) . The energy conversion and capture systems by human designs have varied efficiencies from one form to other form. But for generating electricity solar power technologies using SPV may have lower efficiency but also has lower investment and maintenance costs when compared to STh. That is the reason the SPV technology is more popular globally. The amount of solar energy available (irradiance or insolation) at a particular location of the earth depends on the latitude, earth's tilt and time of the year. The average insolation is known as irradiance and is measured in Watts/sq.m. The Indian Solar Atlas in GIS (Geographic Information System) format is relased by NIWE, National Institute of Wind Energy (web site: niwe.res.in) in a GIS format and can be viewed in "SWurja" mobile app downloadable freely in play store in Android mobiles. Measured irradiation is disseminated in three forms GHI (Global horizontal irradiation) , DNI (Direct normal irradiation) and DHI (Diffused Horizontal Irradiation) as shown in Fig. 3 and Fig.4

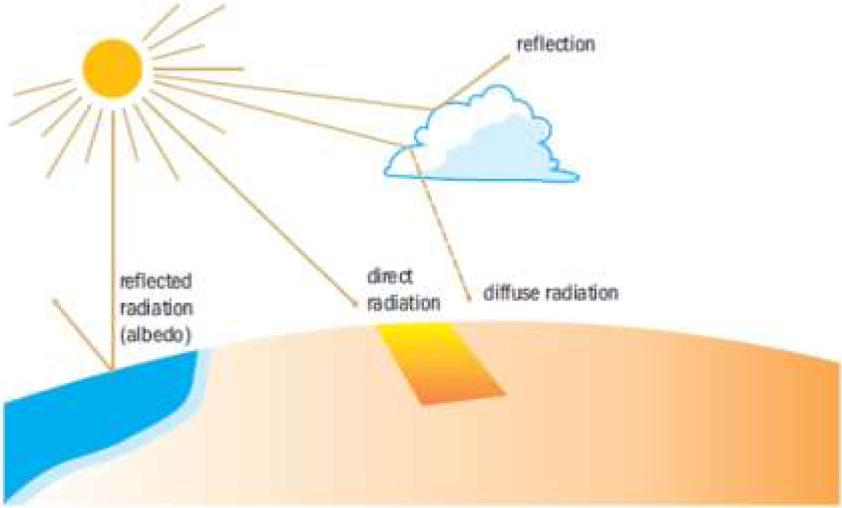


Fig.3 Types of Measured irradiation on earth's surface

The Solar Radiation Resource Assessment (SRRA) division of NIWE , Chennai has established a network of high quality measurement stations (Fig.4)

Fig.4 Sensors of a typical SRRA station

spread across India, and has published a well validated accurate Solar Atlas for India , the GHI map which is widely used for SPV solar power plants is given in Fig.5

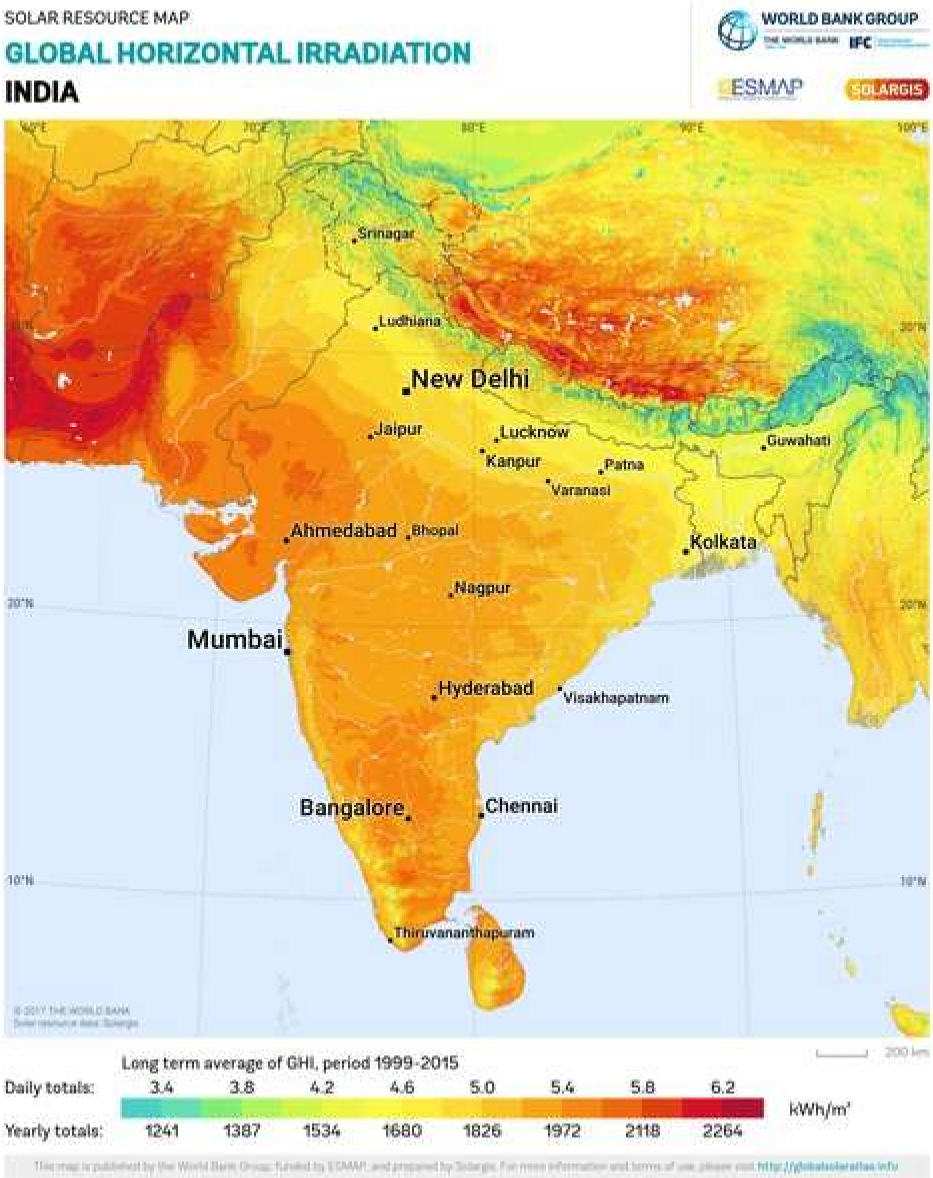


Fig. 5 The Indian Solar Atlas of SRRA/NIWE (GHI)

SPV: Solar Photo Voltaic Power Technology:

Solar Photo Voltaic (SPV) uses light energy fraction of sun's abundant Energy, even today India imports most of solar cells from Europe, China and USA. The term photovoltaic means electricity from the sun. Photovoltaic technology is used to convert light energy into electrical energy. This technology has been developed on the basis that some semiconductor materials such as silicon generate voltage and current when exposed to light. A thin wafer consisting of an ultra-thin layer of N-type silicon on top of a thicker layer of P-type silicon (where N – Negative and P – Positive) will have an electrical field where these two materials are in contact, called the P-N junction. When sunlight strikes the surface of the wafer, it causes the electrical field to provide momentum and direction to light-stimulated electrons, resulting in a flow of electrical current to any electrical load connected. Fig.6 below illustrates this principle.

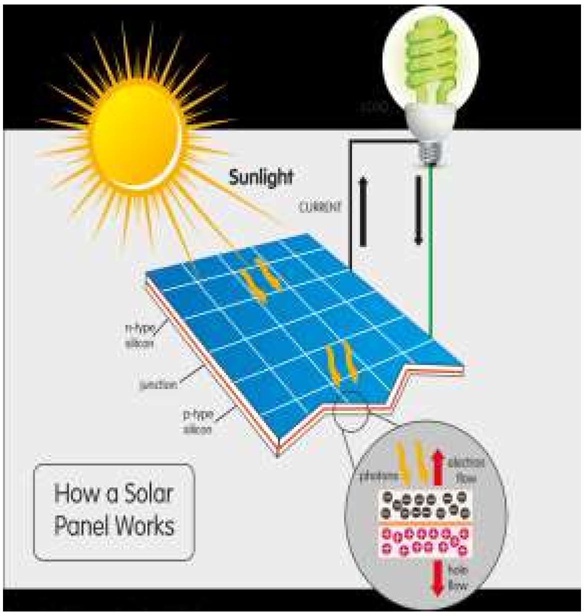


Fig.6. Photons of sun’s radiation trigger free electrons

A simple home Solar system will have cells in series to form modules with higher voltage and as per the need the modules to form strings in series or arrays with parallel strings

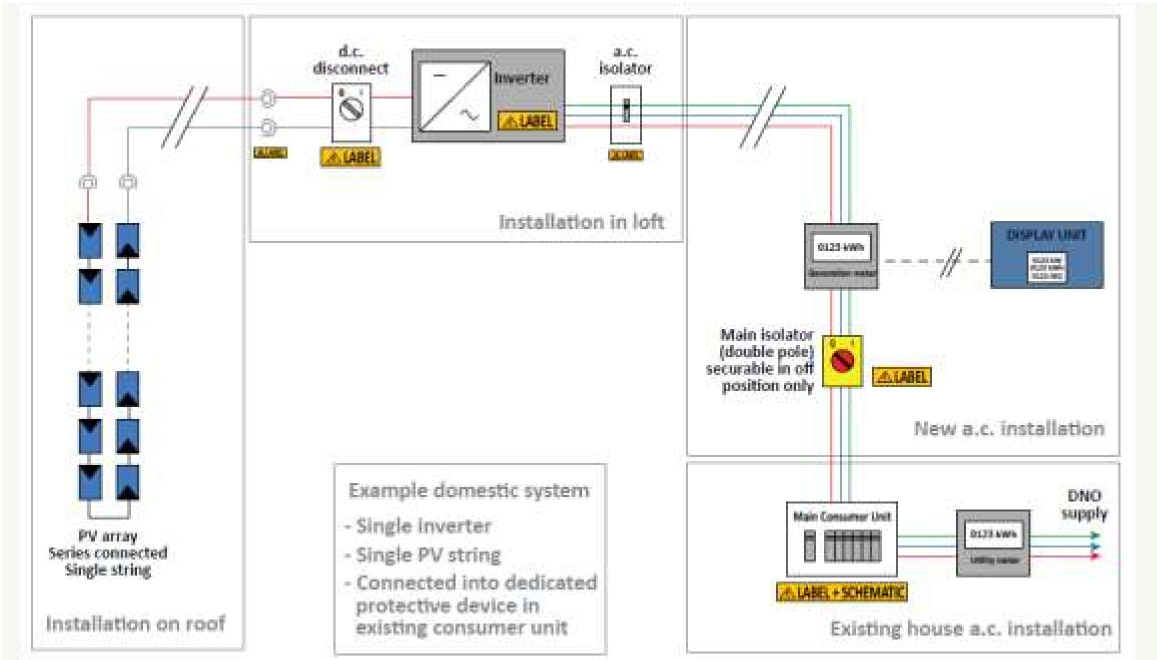


Fig.7. Single line Diagram of domestic grid tied Solar Power system (IFC,2015)

PV Panel

Photovoltaics (PV) or solar cells are the building blocks of solar panels. They are made of semiconductor materials as described in Unit 2. They convert sunlight into direct current (DC) electricity.

In practice a typical silicon PV cell produces voltage of 0.5 – 0.6 DC under open-circuit, no-load conditions. The current (and power) output of a PV cell depends on its efficiency and size (surface area), and is proportional to the intensity of sunlight striking the surface of the cell. For example, under peak sunlight conditions a typical commercial PV cell with a surface area of 160cm² will produce about 2 watts peak power.

Image 6: Typical Solar Cell

Groups of PV cells are electrically configured into modules/panels which can be connected into arrays to achieve desired power and voltage outputs. Photovoltaic modules consist of PV cell circuits sealed in an environmentally protective laminate, while panels include one or more PV modules assembled as a pre-wired, field-installable unit. A photovoltaic array is the complete power-generating unit, consisting of any number of PV modules and panels.

Fig.8. Single Solar cell-string-array integrated as Solar Generator

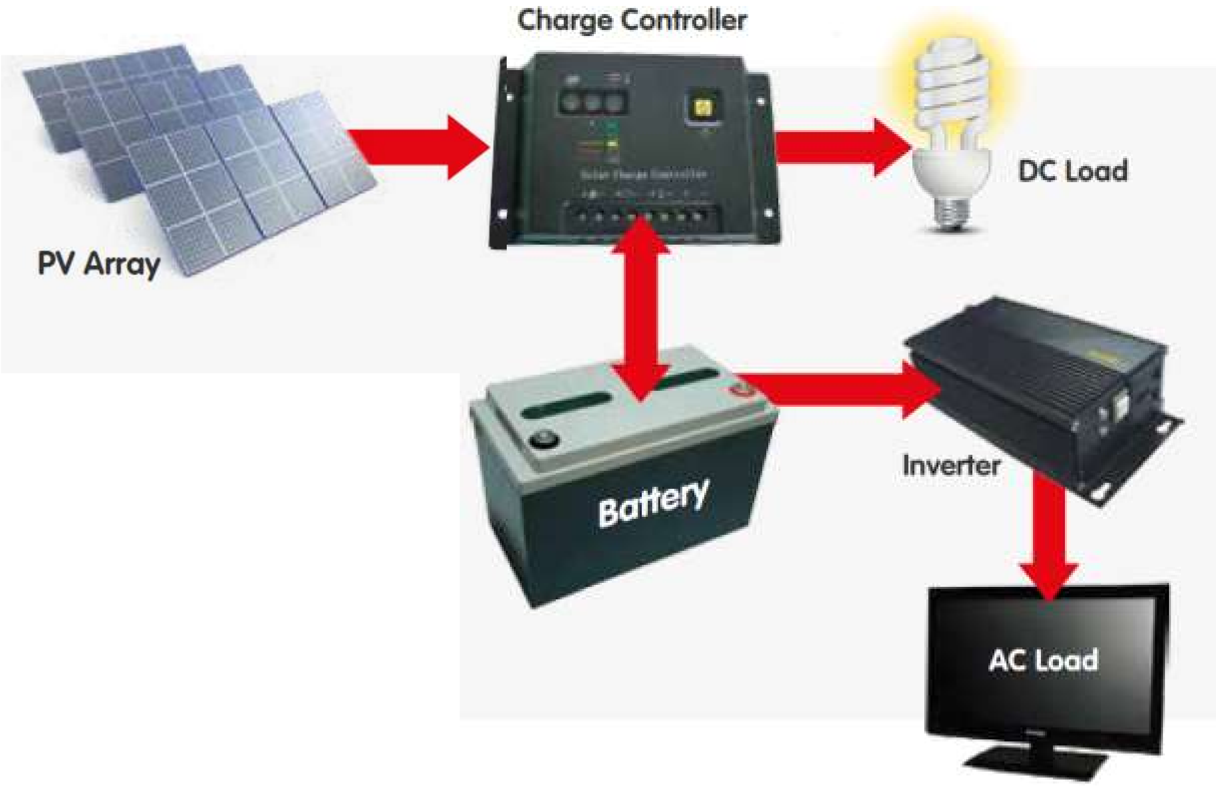


Fig.*9. Solar* Power off-grid domestic system with battery (1-3 kW solar system)

Fig.10 Mega watt or Utility scale Solar Power Plant System (100s MW)

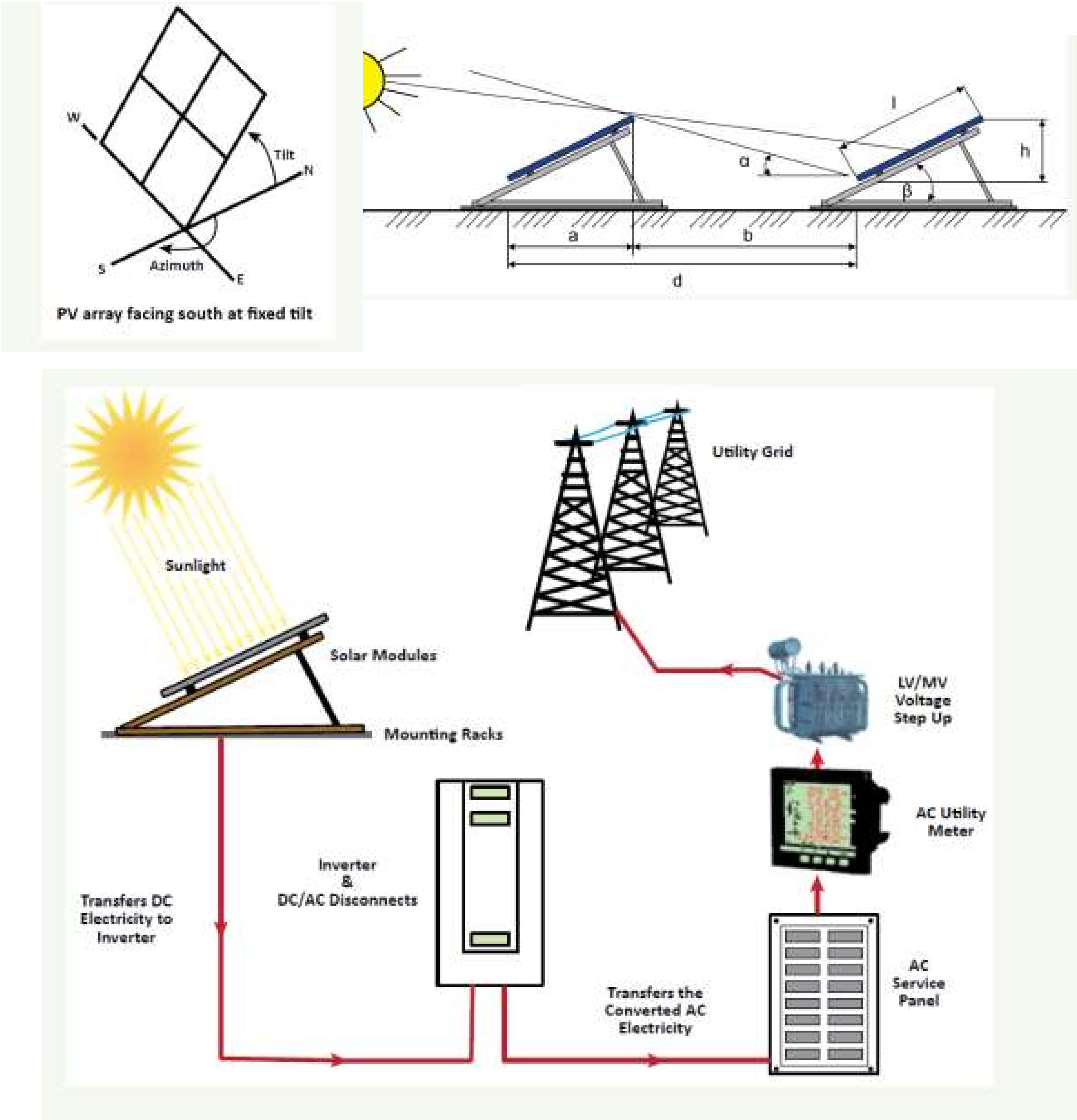


Fig.11 Design Components of Megawatt Solar Power Plants

STh: Solar Thermal Power Technology:

Solar thermal systems operate when radiation/heat from the sun is directed to a device which captures and concentrates the heat to a carrying media (air or water). The fluid gains heat from the pipes/fins installed within the system and delivers it through an outlet either as warm or hot. Fig.12 below illustrates the concept using water as the medium.

India being tropical country the solar heat energy can be very efficiently used in many ways leading with indigenous technology. Direct use of sun's heat for cloth drying, grain and coal drying is more than straight forward. Concentrated solar thermal, CST-collectors as shown below can focus heat energy to point or line concentrators and heat water as super heated steam through metallic pipes and can be used for several applications, by storing heat energy, or using the same for heating, cooling, desalination and for even electricity generation purposes.

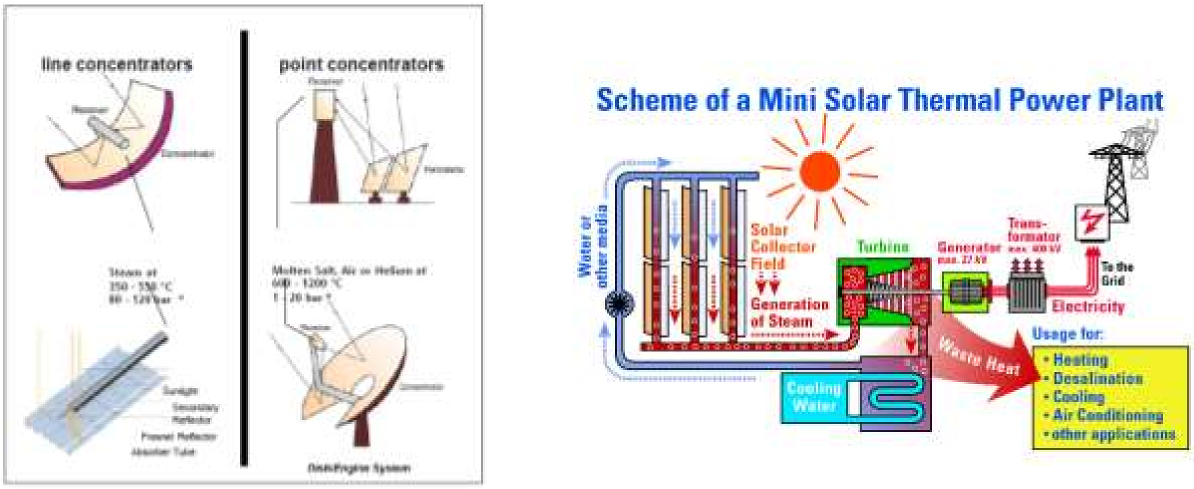


Fig.12. CST* Concentrated Solar thermal application

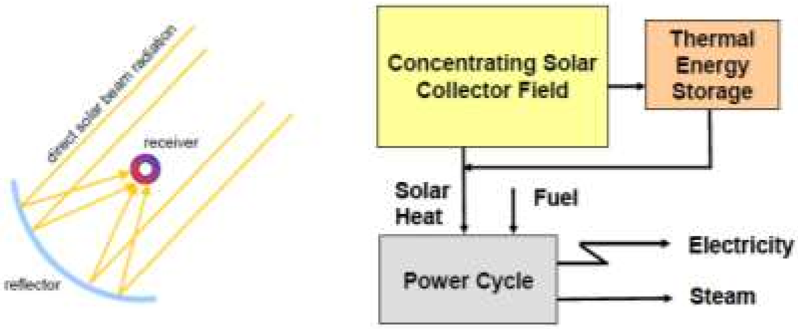


Fig.13. CST* Concentrated Solar thermal application with storage

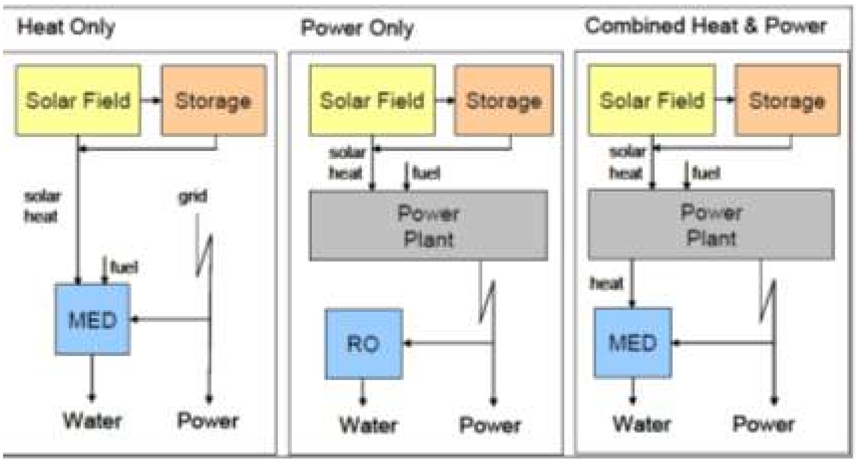


Fig.14 CSP* Concentrated Solar thermal multi-purpose designs

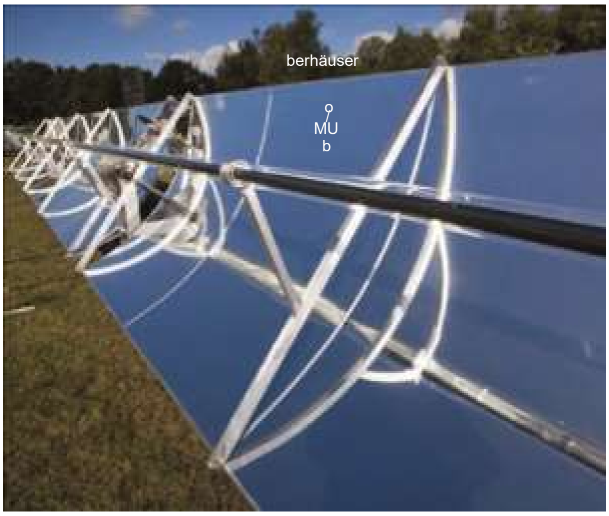


Fig.15. CSP* Line concentrators using (parabolic mirrors)*

Fig.16 Flat Mirrors with single axis tracking for power and water
(flat mirrors –CSP KGSL-Coimbatore – single Axis tracking sun's movement)

Fig.17 CSP* Concentrated Solar thermal for power generation (ABD,TNAU,CBE-Dual axis tracking installation)(ABD-TNAU coimbatore : Dual axis tracking of sun’s movement

Figure 3-32: PS 10 central receiver solar tower facility near Sevilla, Spain (Abengoa Solar). In the background the PS20 facility can be seen under construction

Fig.18. Concentrated Solar thermal tower liquid salt used for heat transfer and storage(Sources Ack. Renewables made in Germany, 2016 and Web-resources)

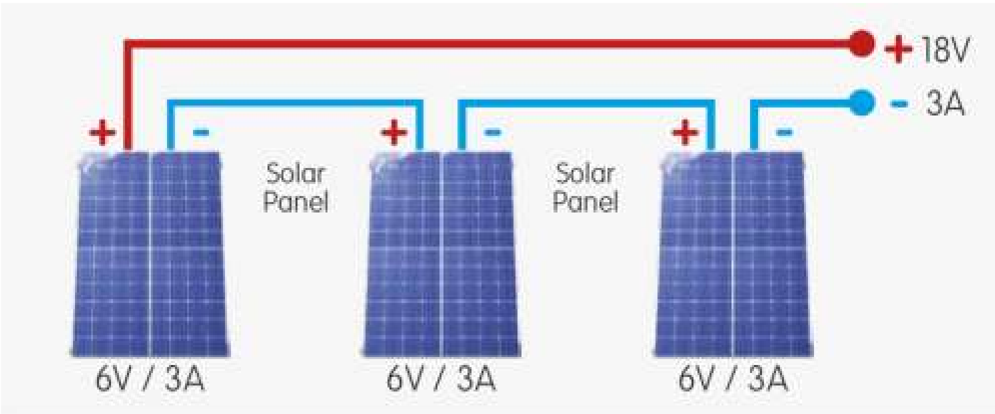
Sizing Calculations SPV-Case Study-1 :
Stand-alone offgrid Roof top system with battery

Design a stand alone SPV roof top (no shade) for the following house hold electrical appliances located in Neyveli Township area

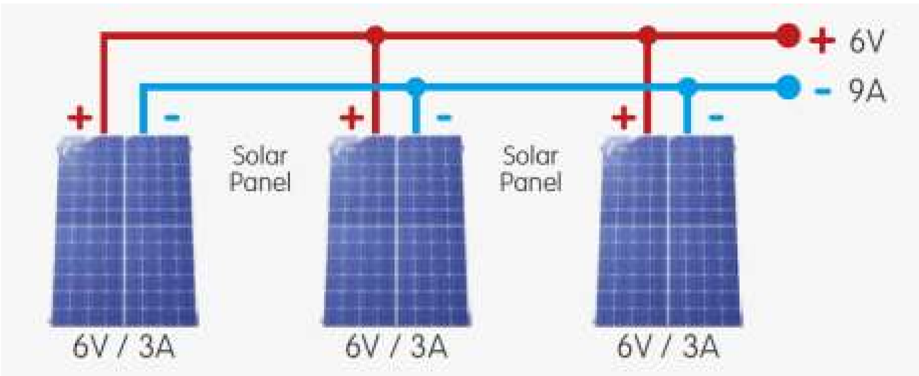
- 2 CFL bulbs 10W, 15W 5 hours /day
- 5 Fans 60W 4
- Airconditioner 1500W 3
- Refrigerator 225W 24
- Water heater 1000W 1
- LED TV 100W 4

Other Plant component performance:

90% for temperature losses (generation decreases at higher temperatures)
85% for battery losses
97% for wiring losses



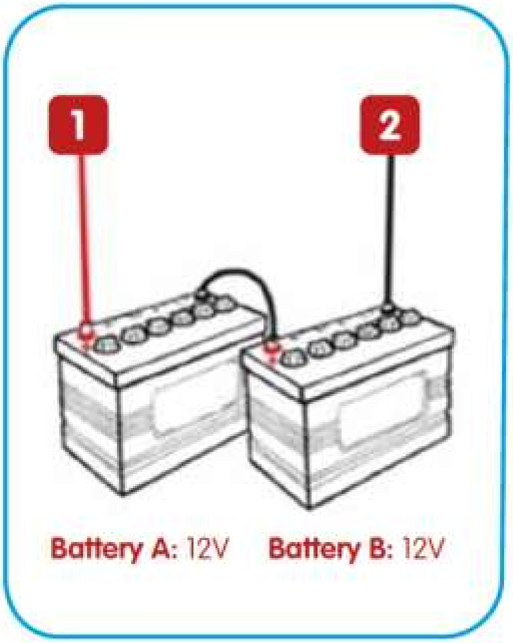
Using panels in series current constant System voltage up



Using panels in parallel with Voltage constant and current up

Series Connection of Batteries

In this connection the positive terminal of one battery is connected to the negative terminal of the second battery thus the remaining two terminals of the batteries are left loose to be connected to the load as indicated by 1 and 2 below.



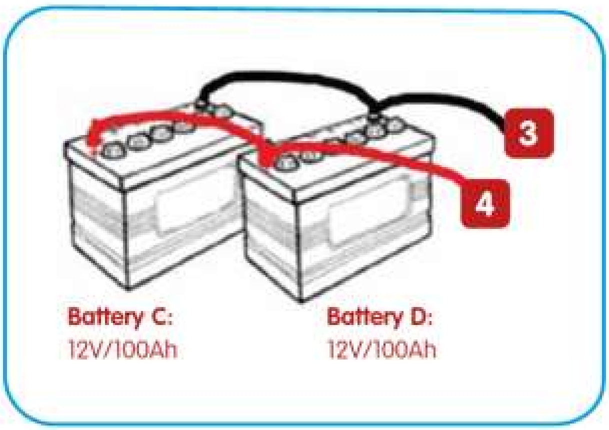
When batteries are connected in series the voltages add up.

As indicated in the diagram above Battery A and Battery B are connected in series, the output voltage at the positive terminal (1) of battery A and the negative terminal (2) of Battery B is given by adding the voltages:

12 + 12 = 24 Volts

Parallel Connection of Batteries

In this connection the positive terminal of one battery is connected to the positive terminal of the second battery thus the batteries are connected together and the load is connected at points indicated by 3 and 4 below.



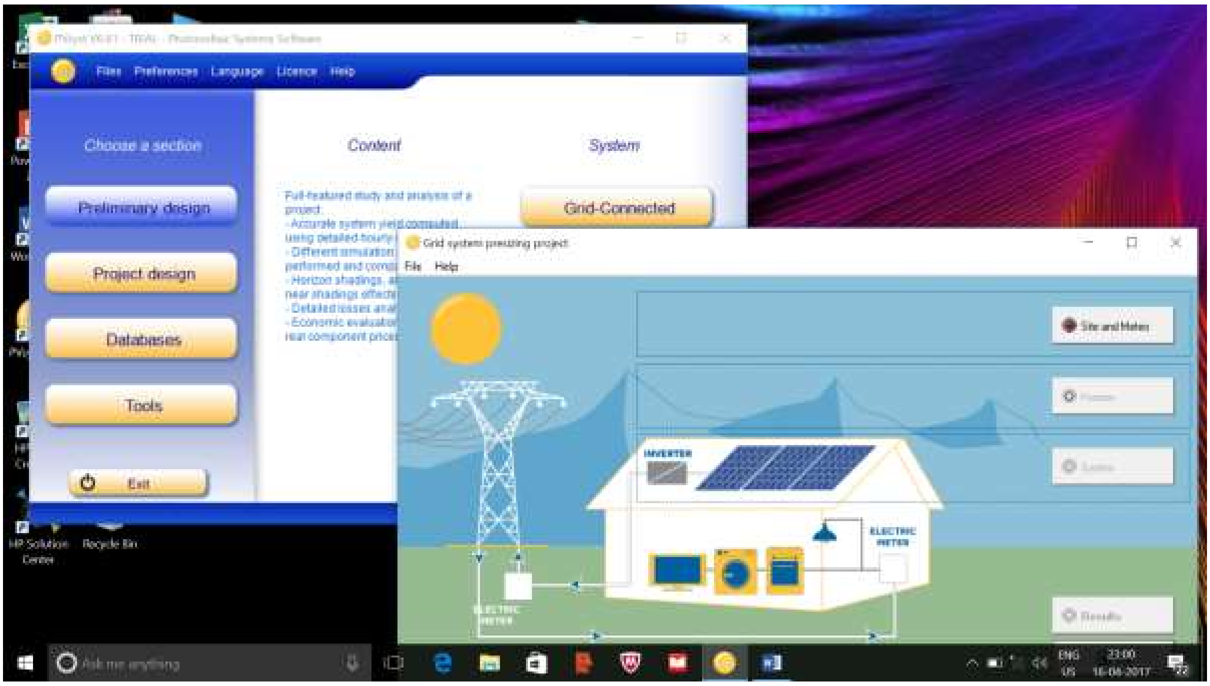
When batteries are connected in parallel the voltage remains the same but their capacity is doubled.

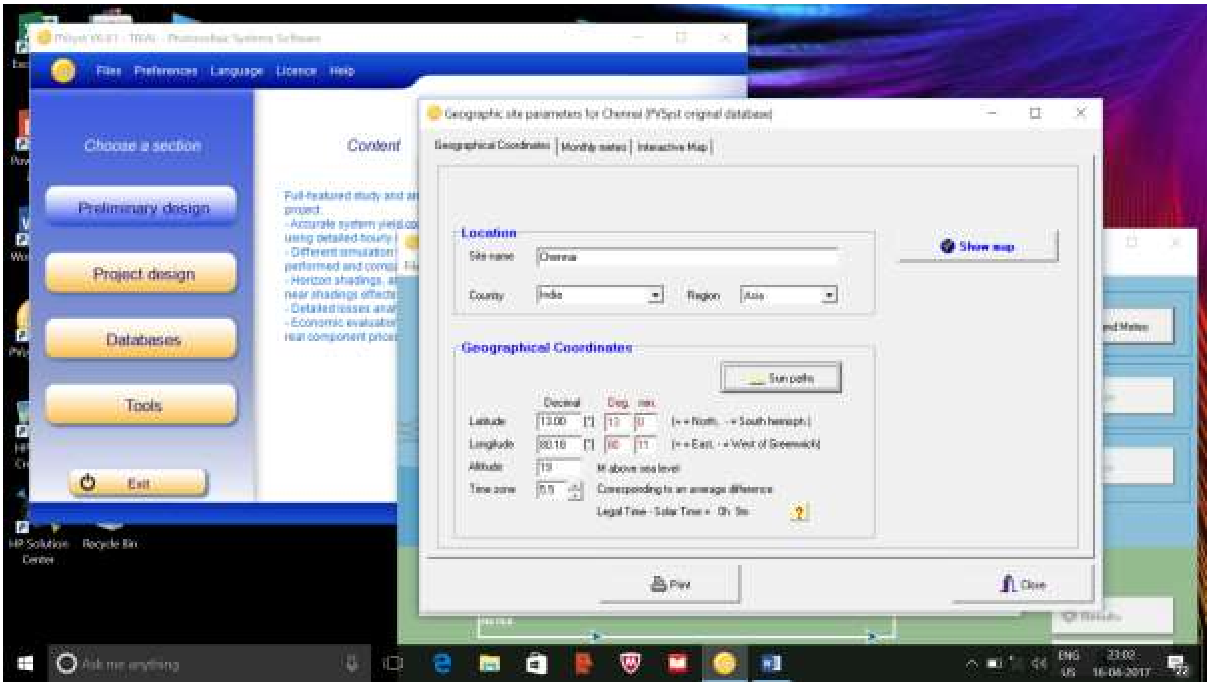
This means that the system will last twice as much as compared to using a single battery. As indicated in the diagram above Battery C and Battery D are connected in parallel, the output voltage at the negative terminal (3) and the positive terminal (4) is the same at 12 volts. However, the capacity adds up and is given by adding the individual capacities:

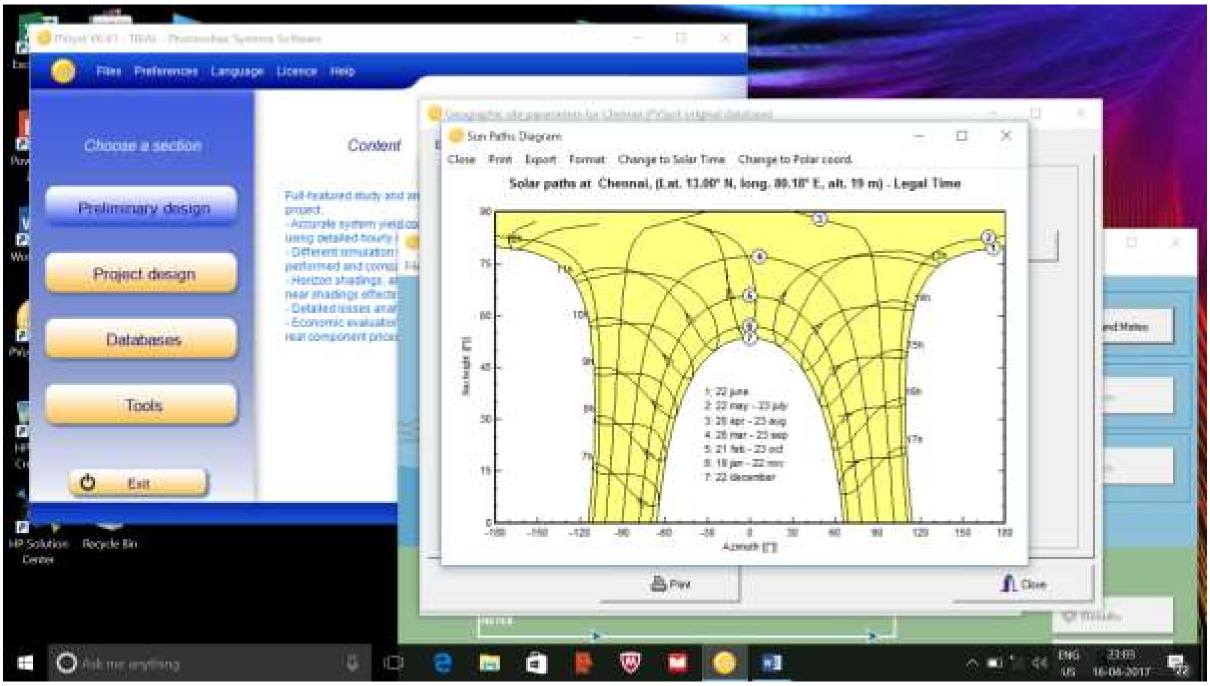
100 + 100 = 200 Ampere – hours

Ground mounted Grid connected SPV Plant 5MW -Case Study-2

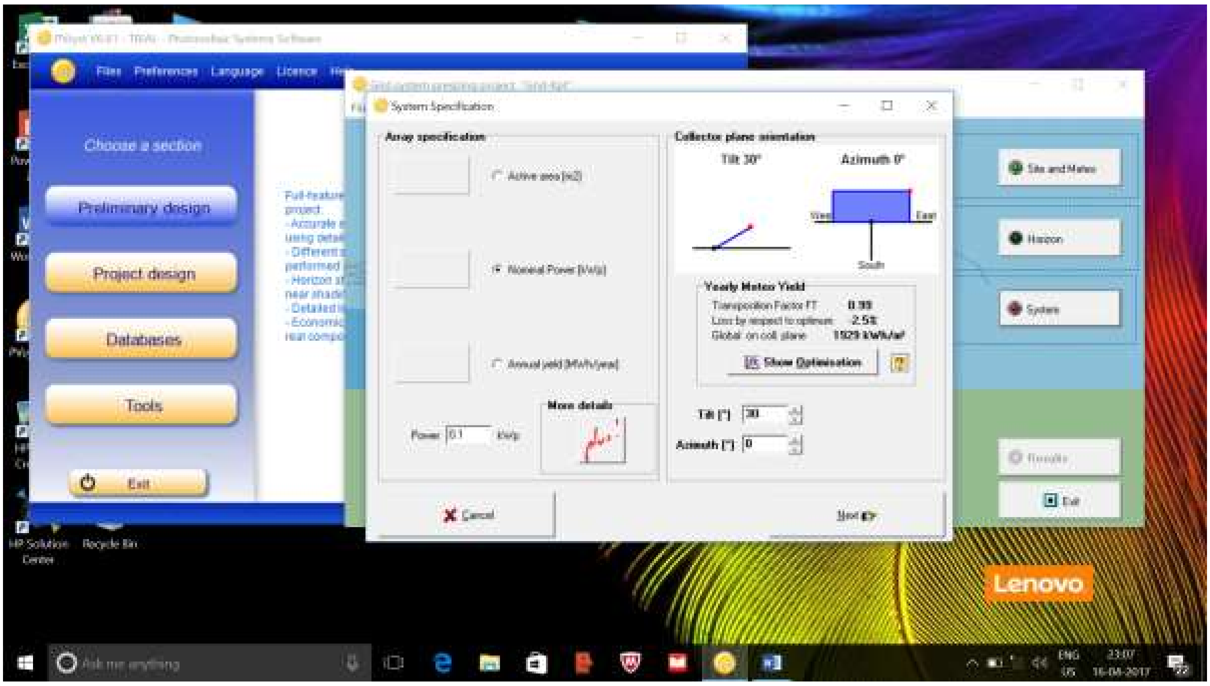
Trail sizing with PVSYST (only screen shots for information)



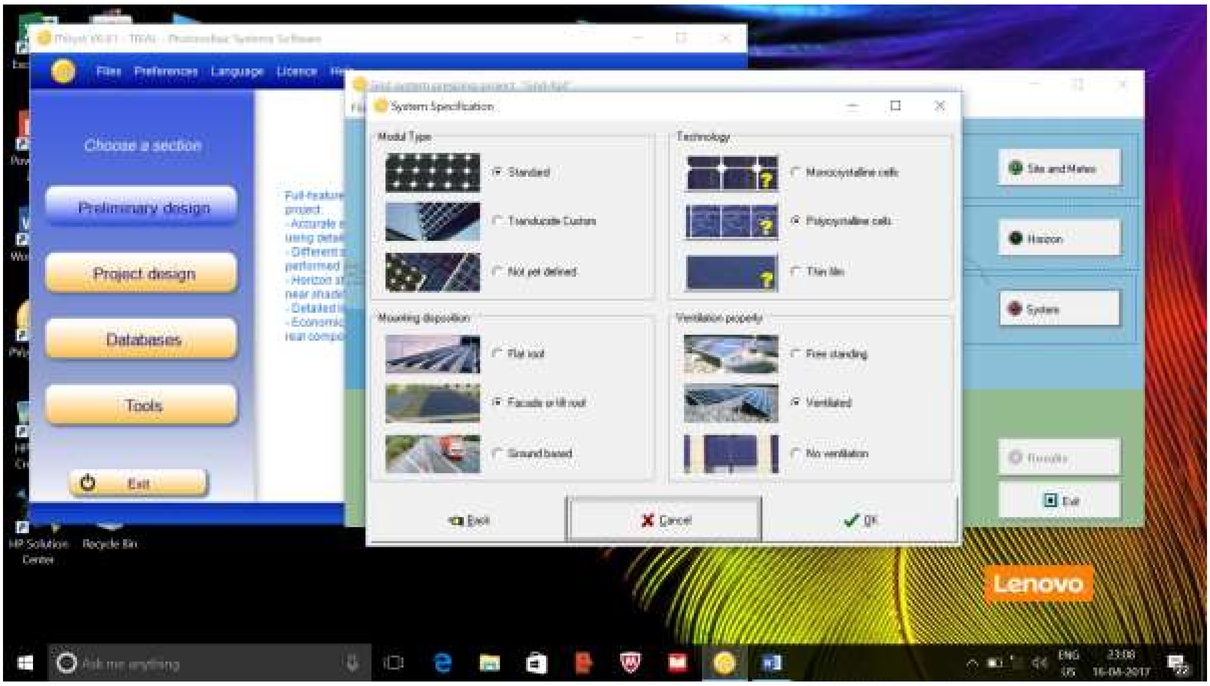




Files Preferences Language Licence Help
Choose a section
Preliminary design
Project design
Databases
Tools
Exit
Sun Paths Diagram
Close Print Export Format Change to Solar Time Change to Polar coord.
Solar paths at Chennai, (Lat. 13.00° N, long. 80.18° E, alt. 19 m) - Legal Time
1: 22 june
2: 22 may - 23 july
3: 20 apr - 23 aug
4: 20 mar - 23 sep
5: 21 feb - 23 oct
6: 19 jan - 22 nov
7: 22 december
Azimuth [°]
Print
Close



Files Preferences Language Licence Help
Choose a section
Preliminary design
Project design
Databases
Tools
Exit
System Specification
Array specification
Active area [m2]
Nominal Power [kWp]
Annual yield [MWh/year]
Power 0.1 kWp
More details
Collector plane orientation
Tilt 30°
Azimuth 0°
West
East
South
Yearly Meteo Yield
Transposition Factor FT 0.99
Loss by respect to optimum -2.5%
Global on coll. plane 1929 kWh/m²
Show Optimisation
Tilt [°] 30
Azimuth [°] 0
Cancel
Next
Site and Meteo
Horizon
System
Results
Exit
Lenovo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Modul Type
Standard
Translucide Custom
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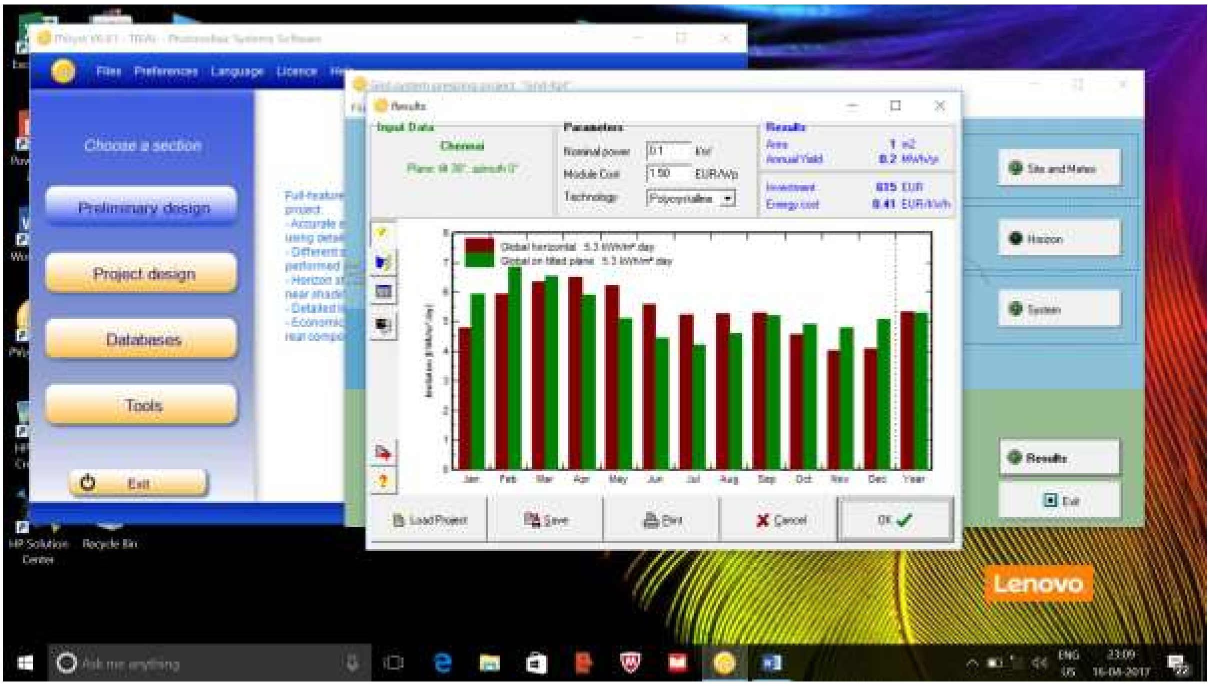
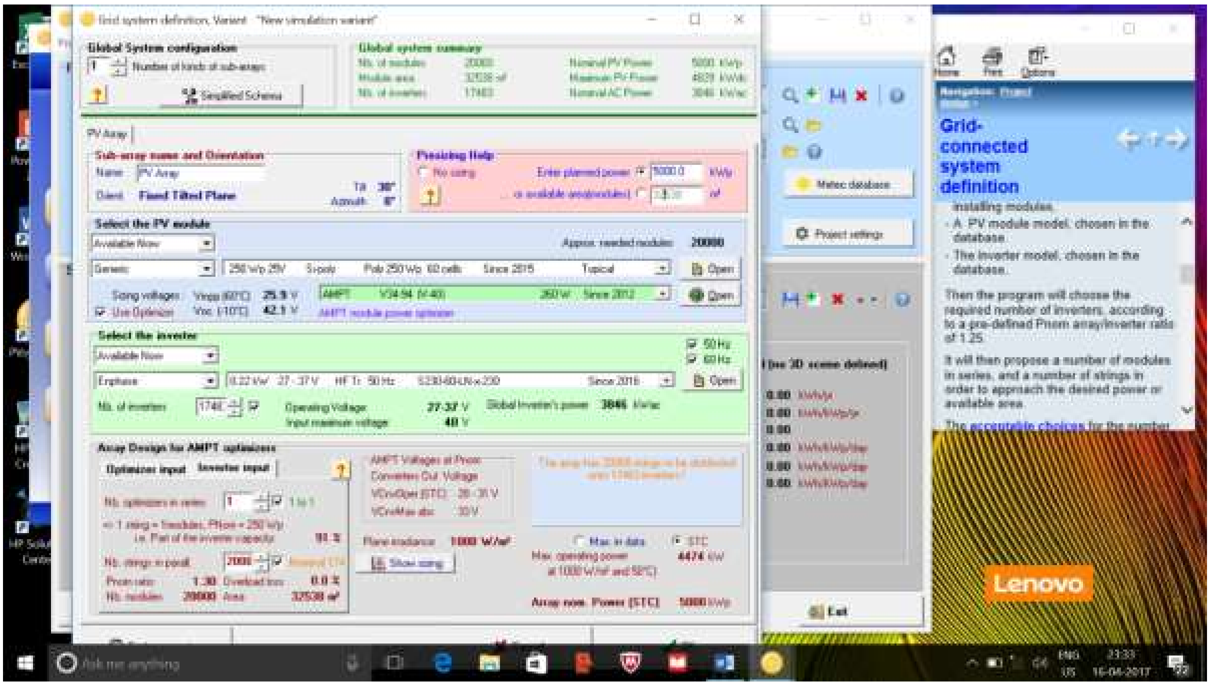
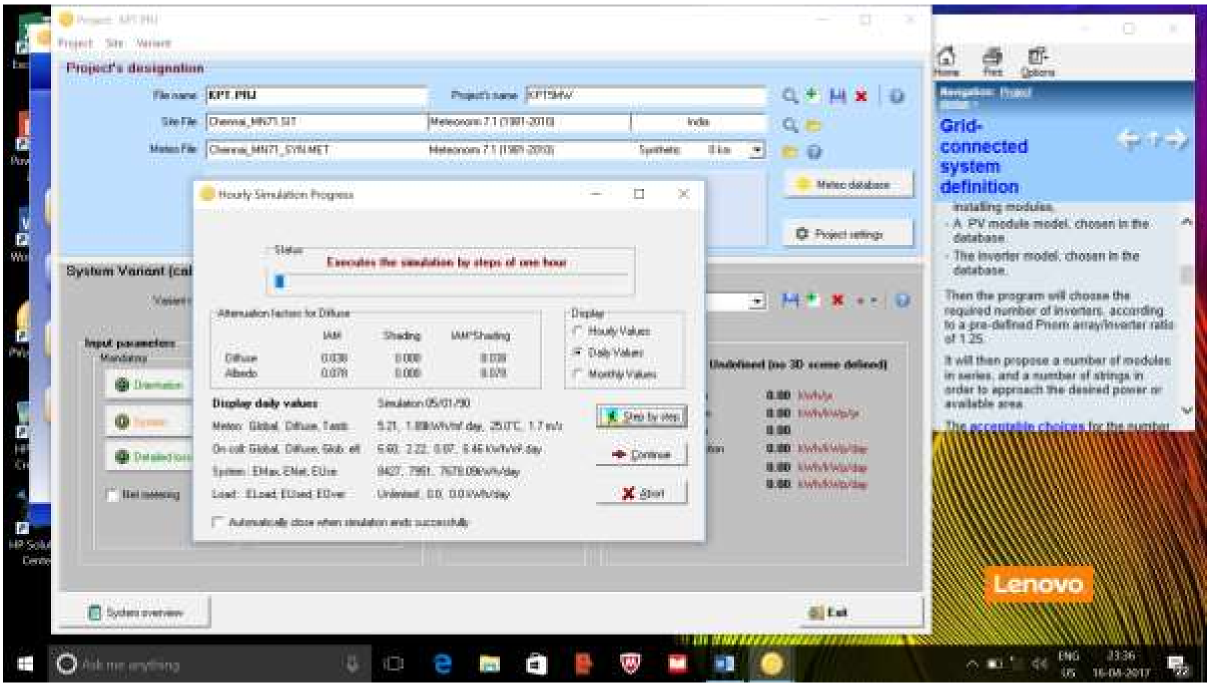
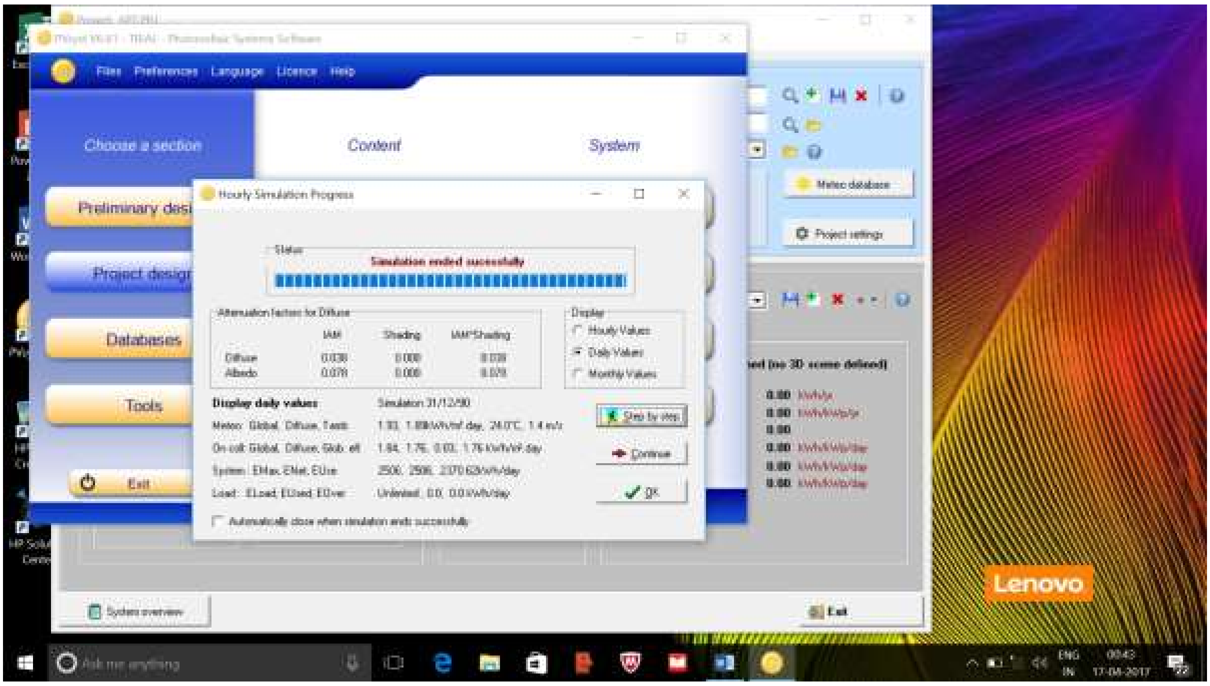
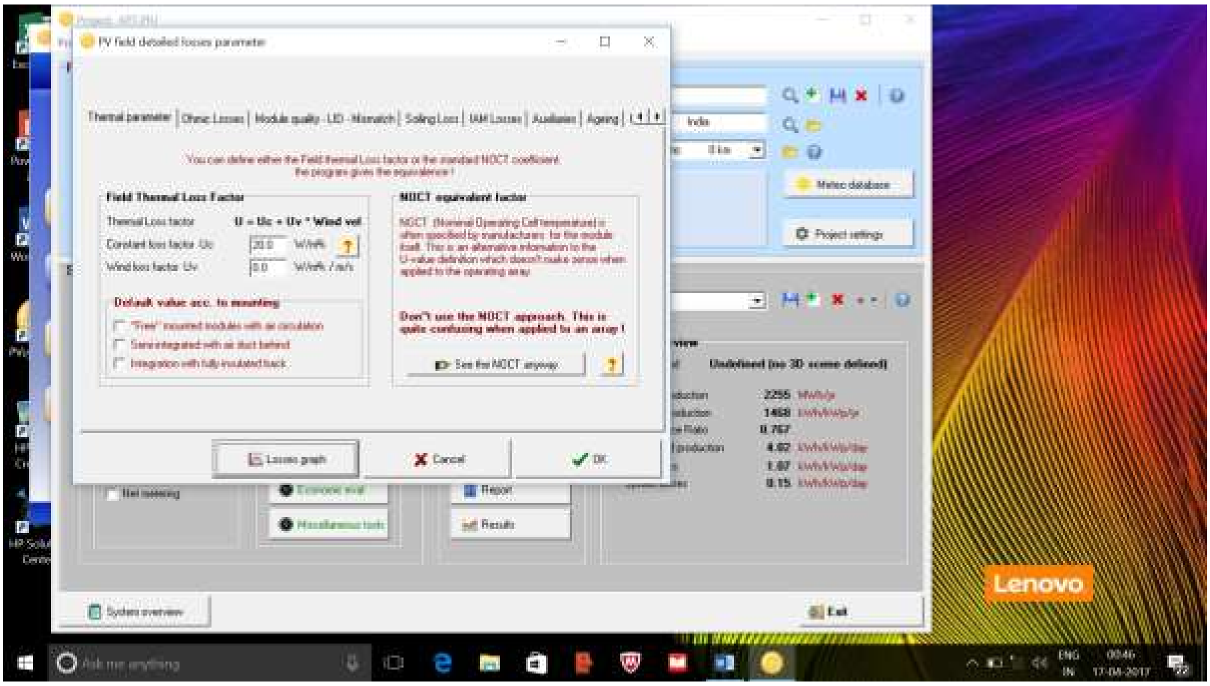
Technology
Monocrystalline cells
Polycrystalline cells
Thin film
Mounting disposition
Flat roof
Facade or tilt roof
Ground based
Ventilation property
Free standing
Ventilated
No ventilation
Back
Cancel
OK
Choose a section
Preliminary design
Project design
Databases
Tools
Exit
Site and Meteo
Horizon
System
Results
Lenovo

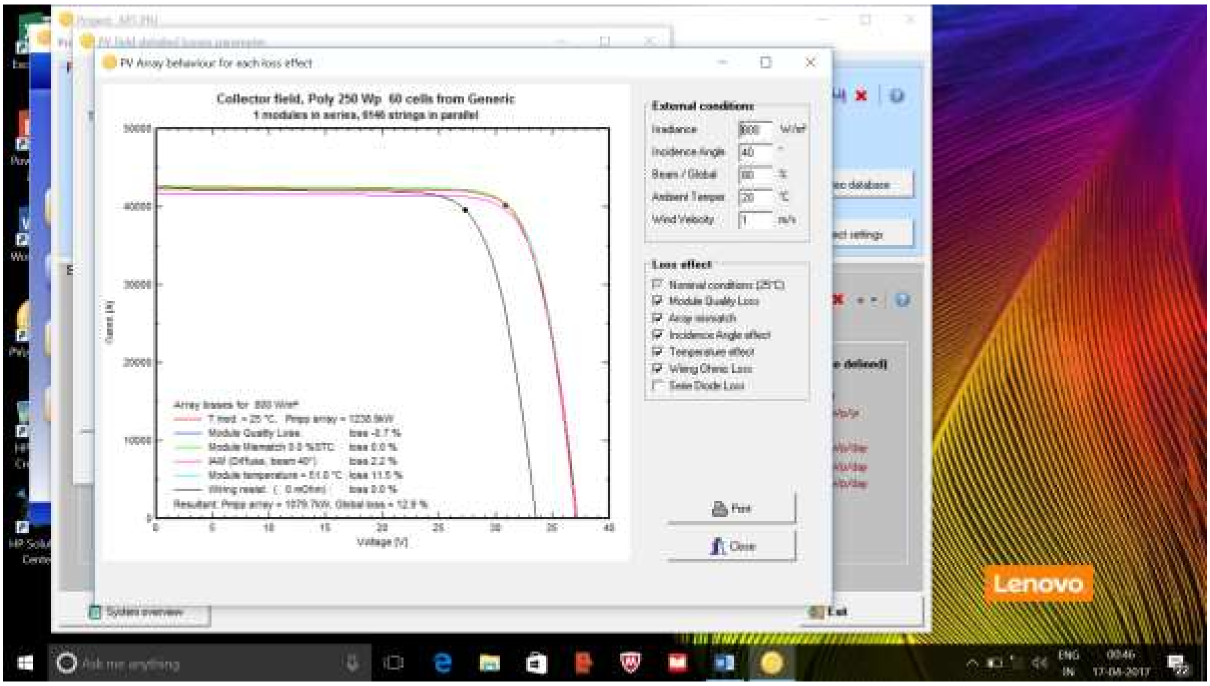

Results
Input Data
Chennai
Parameters
Nominal power 0.1 kW
Module Cost 1.50 EUR/Wp
Technology Polycrystalline
Results
Area 1 m2
Annual Yield 0.2 MWh/yr
Energy cost 0.41 EUR/kWh
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
Load Project
Save
Print
Cancel
OK
Choose a section
Preliminary design
Project design
Databases
Tools
Exit
Site and Meteo
Horizon
System
Results
Lenovo

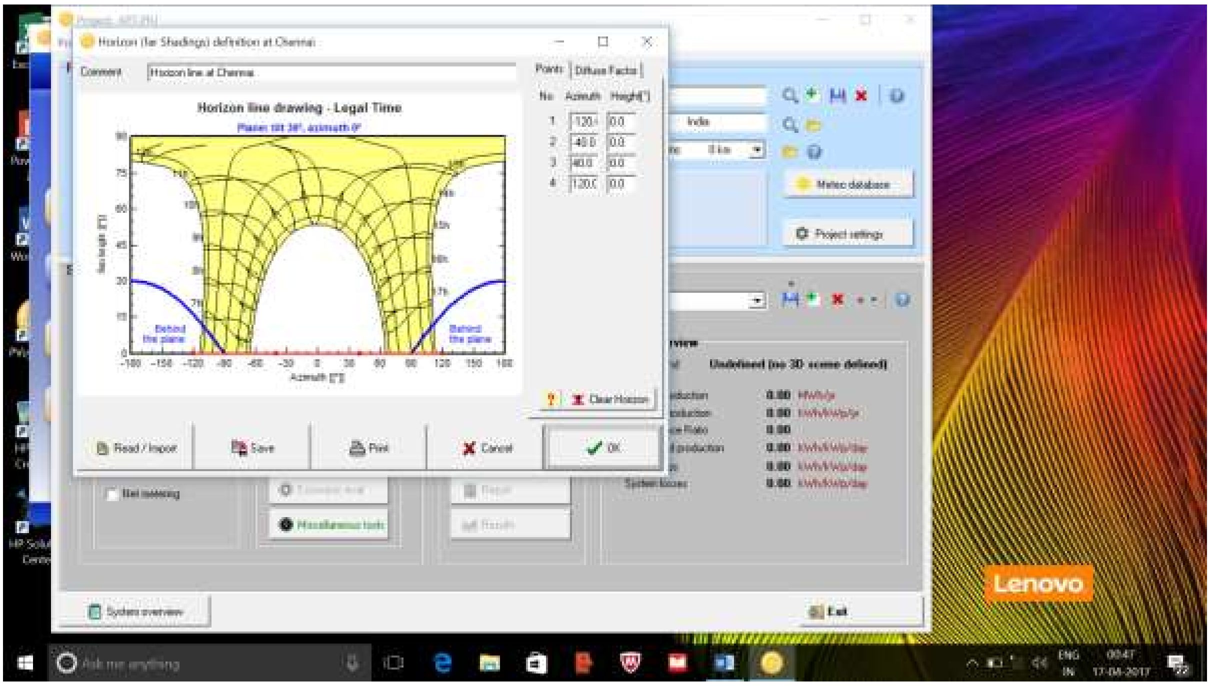





Hourly Simulation Progress
Simulation ended successfully
Choose a section
Content
System
Preliminary design
Project design
Databases
Tools
Exit
Display daily values
Meteo database
Project settings
System overview
Exit
Lenovo


PV field detailed losses parameter
Thermal parameter
Ohmic Losses
Module quality - LID - Mismatch
Soiling Loss
IAM Losses
Auxiliaries
Ageing
Field Thermal Loss Factor
NOCT equivalent factor
Default value acc. to mounting
Don't use the NOCT approach. This is quite confusing when applied to an array !
See the NOCT anyway
Losses graph
Cancel
OK
Meteo database
Project settings
System overview
Exit
Lenovo


PV Array behaviour for each loss effect
Collector field, Poly 250 Wp 60 cells from Generic
1 modules in series, 6146 strings in parallel
External conditions
Irradiance
Incidence Angle
Beam / Global
Ambient Temper.
Wind Velocity
Loss effect
Nominal conditions (25°C)
Module Quality Loss
Array mismatch
Incidence Angle effect
Temperature effect
Wiring Ohmic Loss
Serie Diode Loss
Print
Close
Voltage [V]
System overview
Exit
Ask me anything
Lenovo


Horizon (far Shadings) definition at Chennai
Comment
Horizon line at Chennai
Horizon line drawing - Legal Time
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Diffuse Factor
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Azimuth
Height[°]
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Behind the plane
Azimuth [°]
Clear Horizon
Read / Import
Save
Print
Cancel
OK
Meteo database
Project settings
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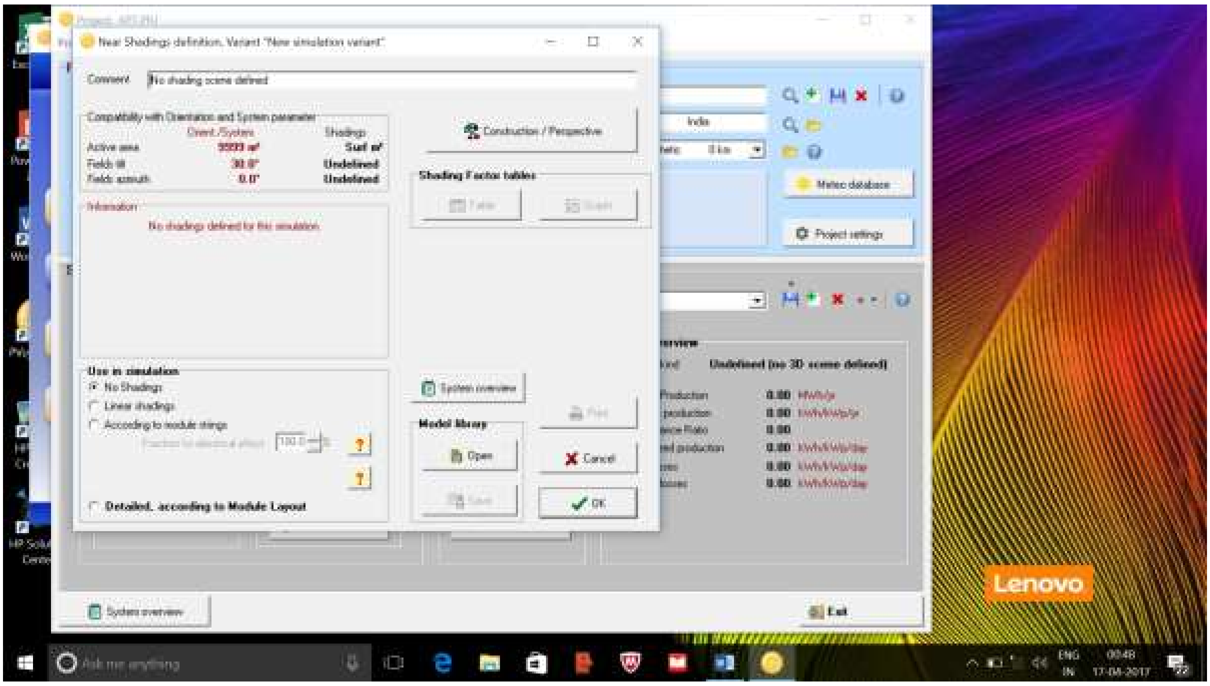
System losses
System overview
Exit
Ask me anything
Lenovo



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Compatibility with Orientation and System parameter
Orient./System
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Active area
Fields tilt
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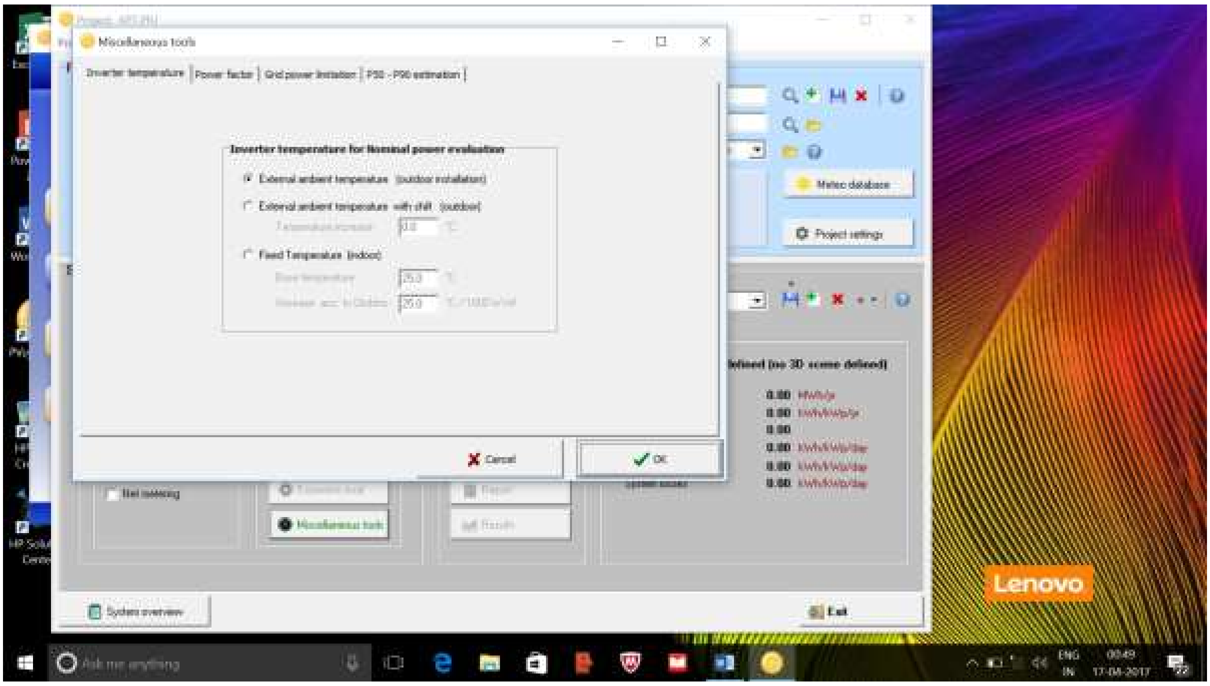
Undefined
Fields azimuth
0.0°
Undefined
Construction / Perspective
Shading Factor tables
Information
No shadings defined for this simulation.
Use in simulation
No Shadings
Linear shadings
According to module strings
System overview
Model library
Open
Cancel
OK
Detailed, according to Module Layout
Meteo database
Project settings
System overview
Exit
Lenovo
Ask me anything
ENG
IN
00:48
17-04-2017



Miscellaneous tools
Inverter temperature
Power factor
Grid power limitation
P50 - P90 estimation
Inverter temperature for Nominal power evaluation
External ambient temperature (outdoor installation)
External ambient temperature with shift (outdoor)
Fixed Temperature (indoor)
Cancel
OK
Net metering
Miscellaneous tools
Meteo database
Project settings
System overview
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Ask me anything
ENG
IN
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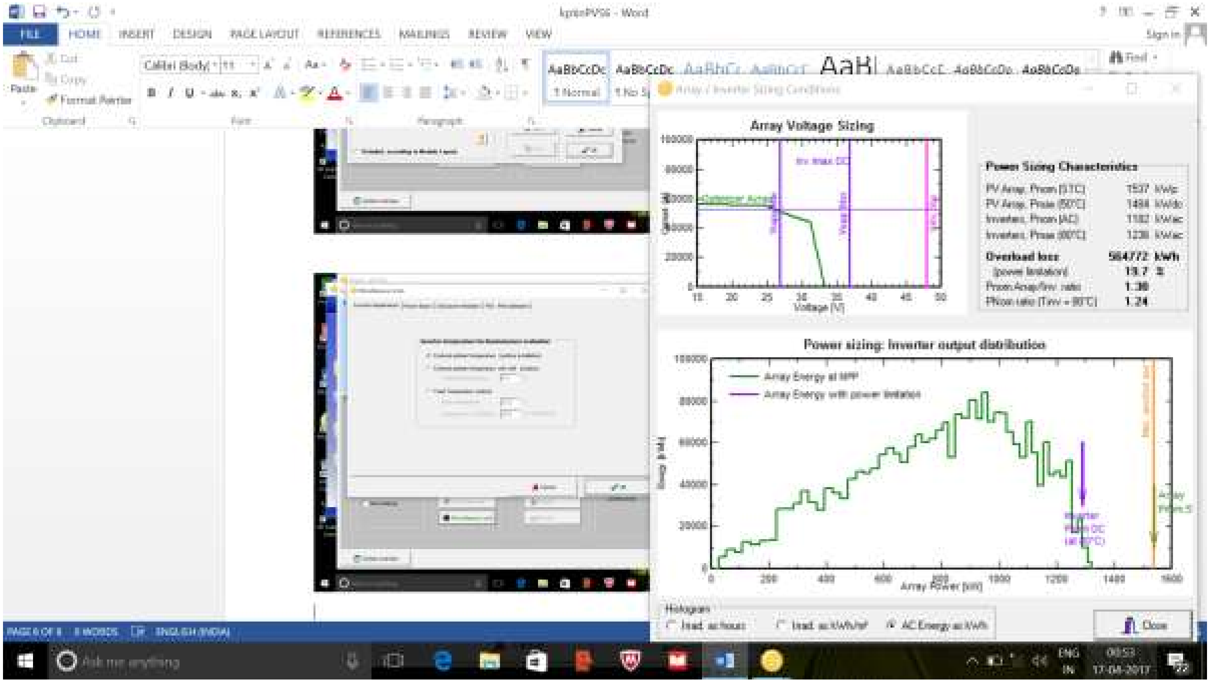
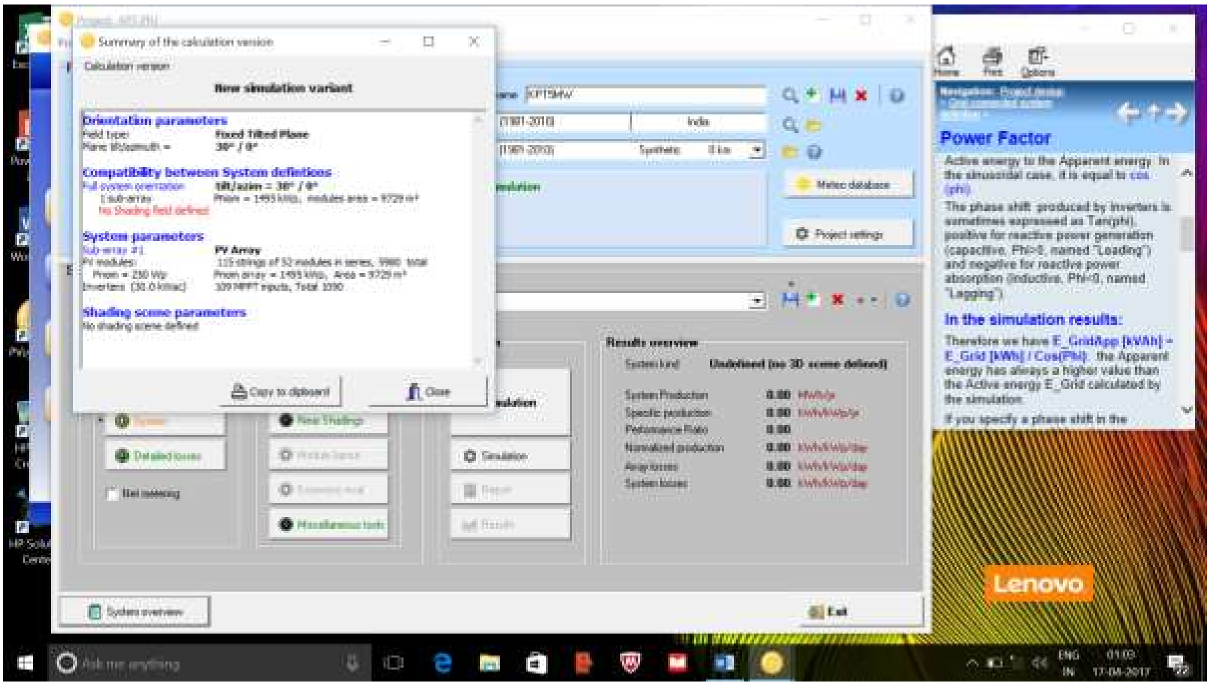
17-04-2017


Array Voltage Sizing
Power Sizing Characteristics
PV Array, Pnom (STC) 1537 kWp
PV Array, Pmax (50°C) 1484 kWdc
Inverters, Pnom (AC) 1182 kWac
Inverters, Pmax (60°C) 1238 kWac
Overload loss 564772 kWh
(power limitation) 19.7 %
Pnom Array/Inv. ratio 1.30
Pnom ratio (Tinv = 60°C) 1.24
Power sizing: Inverter output distribution
Array Energy at MPP
Array Energy with power limitation
Array Power [kW]
Irrad. as hours
Irrad. as kWh/m²
AC Energy as kWh
Close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New simulation variant
Orientation parameters
Field type: Fixed Tilted Plane
Plane tilt/azimuth = 30° / 0°
Compatibility between System definitions
Full system orientation tilt/azim = 30° / 0°
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System parameters
PV Array
Shading scene parameters
No shading scene defined
Copy to clipboard
Close
Meteo database
Project settings
Results overview
System kind Undefined (no 3D scene defined)
System Production 0.00 MWh/yr
Specific production 0.00 kWh/kWp/yr
Performance Ratio 0.00
Normalized production 0.00 kWh/kWp/day
Array losses 0.00 kWh/kWp/day
System losses 0.00 kWh/kWp/day
Detailed losses
Net metering
Near Shadings
Miscellaneous tools
Simulation
System overview
Exit
Power Factor
In the simulation results:
Lenovo

Case Studies of Miscellaneous Applications

Solar Photovoltaic (PV) Systems:

Solar PV systems directly convert sunlight into electricity. There are two types of solar PV systems exists. Standalone or off-grid PV systems and grid connected or on-grid PV systems. Standalone systems are generally smaller in size and distributed.

Examples of Standalone PV systems: solar water pumping system, street lighting, rural micro grid and solar home system

Surface and **Submersible** Pumps

- Solar pumps are rated according to the voltage of electricity that should be supplied. A 12 Volt pump is a small one, 24 Volt is more the norm, while 48 Volts and upwards will require more power and might pump more water.
- In most cases these solar water pumps come with specifications of vertical lift or head.
- The manufacturer or distributor will usually specify what is required; it is important to always refer to product manuals when operating these pumps.
- DC water pumps in general use one-third to one-half the energy of conventional AC (alternating current) pumps.

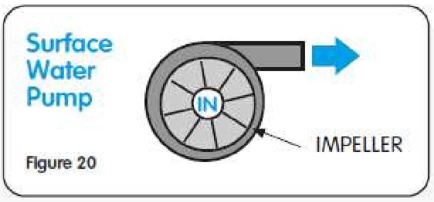


Figure 20

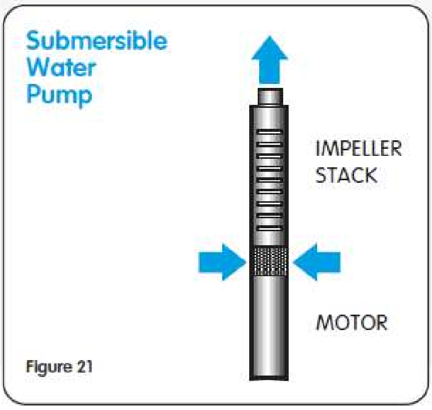
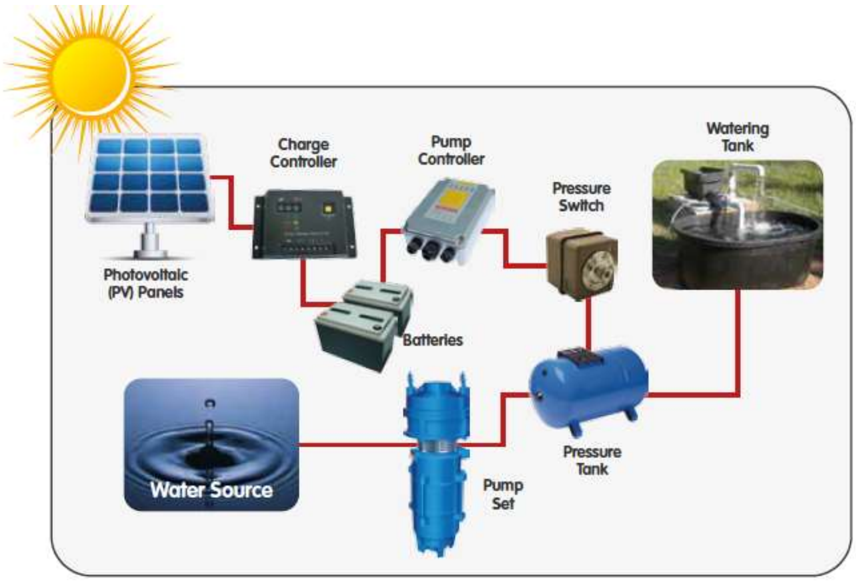


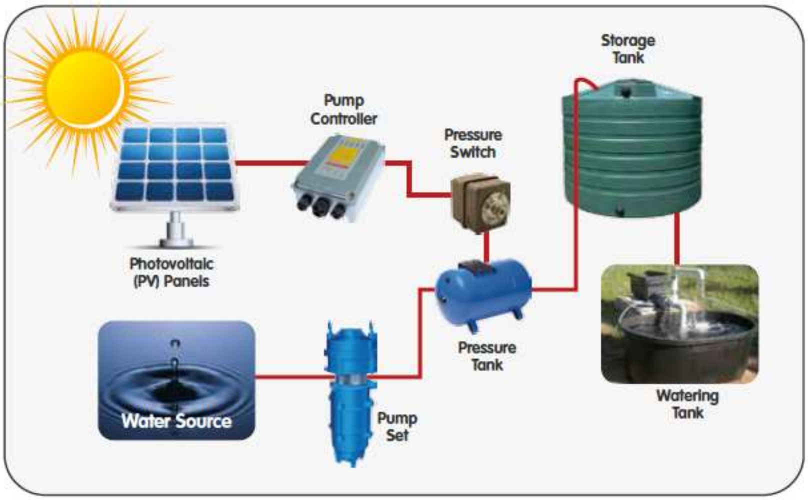
Figure 21

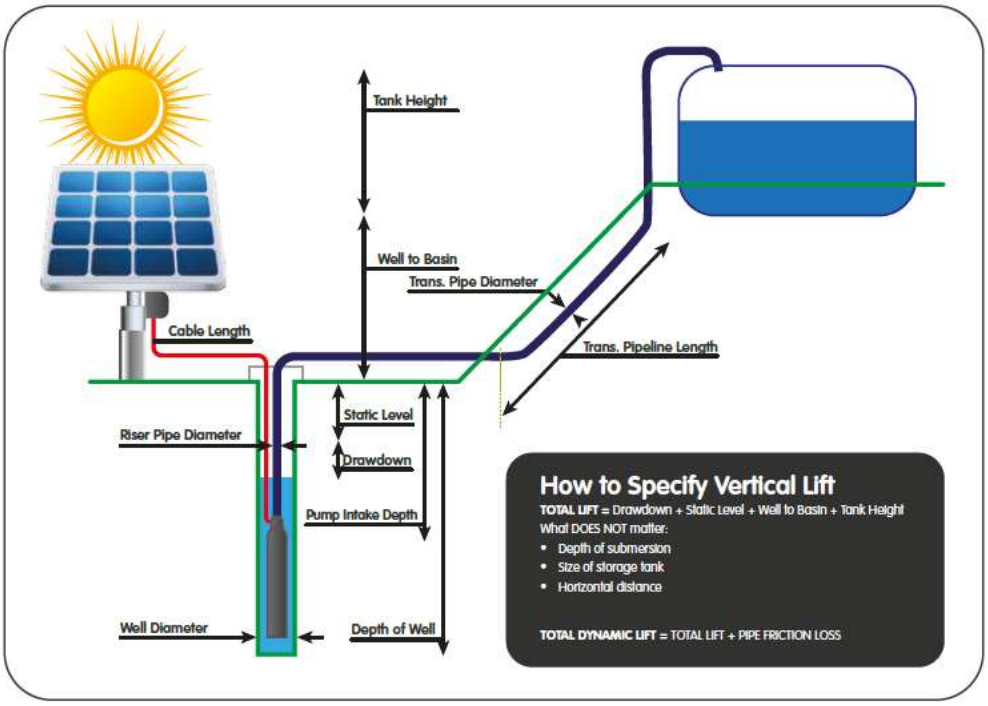
Surface Water Pump System

Submersible Water Pump System

Images 18 & 19: Examples of surface and submersible water pumps


Charge
Controller
Pump
Controller
Watering
Tank
Pressure
Switch
Photovoltaic
(PV) Panels
Batteries
Water Source
Pressure
Tank
Pump
Set


Storage
Tank
Pump
Controller
Pressure
Switch
Photovoltaic
(PV) Panels
Pressure
Tank
Watering
Tank
Water Source
Pump
Set



Interactive Sessions and Experience sharing of Best Practices :

- **Final Word :** The short compilation has been indicative of Solar Power Technology and Developments based on public domain information and personal experience. Solar Power development is still evaolving in every stage
- starting from more efficient cell development,
- cost effective inverter and charge controllers,
- industrial internet of things (IIoT) for large plant monitoring,
- lighter and stronger Module mounting systems,
- tracking systems, and waterless cleaning systems,
- printable flexible solar cells, robotic cleaning systems,
- Faster erection and installation detailing,
- remote monitoring and string wise/panel level fault fixing
- SCADA monitoring systems,
- accurate forecasting system along with grid friendliness and so on… .

The ground mounted utility class MW/GW plants the key element of success is the detail engineering and execution of EPC including project management covering land use land cover and environmental permissions.

Yet, major reasons for lack of capacity addition in roof top development is mainly policy uncertainty and lack of awareness to multi-purpose sustainable technologies and socio-political will to proactively adapt solar power technologies coupled with electric vehicles and solar DC applications.

Additional reading Bibiliography in pdf form

1. Solar Electricity Handbook 2017 Edition
2. IFC-report on Utility scale Solar Power plants , 2015
3. Solar thermal and Photo voltaic field engineers training course 2012, TERI
4. Installation and O&M of Solar SPV based microgrid systems , 2016
5. Solar PV standardised training Manual – SNA Zimbabwe, 2009

ROOF TOP SOLAR POWER DEVELOPMENT IN INDIA-POLICY OPTION PRIORITIES

(August 7, 2019 executive training at LDC, NLCIL Ltd.)

(An internet and web resource edited compilation for one day Training at NLCIL)

Dr.S.Gomathinayagam

A freelance Technical Adviser (Wind & Solar Energy, Structures & Foundations)
Former Director General, National Institute of Wind Energy, Chennai, India

Email: sgetgoms@gmail.com

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'Navratna' – Govt. of India Enterprise)
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LEARNING & DEVELOPMENT CENTRE
(An ISO 9001:2015 Certified Institution)
BLOCK–20, NEYVELI – 607803

150 YEARS OF CELEBRATING THE MAHATMA

ROOF TOP SOLAR POWER DEVELOPMENT IN INDIA-POLICY OPTION PRIORITIES
(An internet and web resource edited compilation, not for sale)

Dr.S.Gomathinayagam , Independent Technical Advisory
Email: sgetgoms@gmail.com

Abstract

Roof Top Solar (RTS) power development in India had a fast track capacity addition of 52MW , in the last financial year 2018-19 in India. The target of 40GW by 2022 is still a long way to go with cumulative achievement pegged at a bare minimum of 4.3GW. This one day accelerated course is aimed at Engineers and technicians to have a first hand practical "DIY" (Do It Yourself) knowledge on schemes and best practices combined with benefits of going solar. The outcome at the end of the day is focused on enabling the participant identify the various list of policy and schemes available for roof top PV in India. The content covers also the explanation of the construction , commissioning and operation of Roof Top Solar Plants. In addition to enabling the participants to have an overview of offgrid/ongrid/and grid interactive with or without battery in the RoofTopSystems (RTS) , briefly covers the aspects of micro and mini grids' role and immediately needed focus on distributed electricity generation in India.

1. Introduction to Solar roof top PV

Roof Top Solar (RTS) power development involves exploitation of enormous energy in the solar radiation (direct, inclined and reflected as well as diffused) falling on the built-up roof space , through photovoltaic or solar thermal energy capture technologies.

Out of 365 days in a year , our country India is blessed with almost 300 days of sun shine in many parts of India. Depending on land use and land cover there is an enormous potential of solar Energy in the country , approximately over 700GW. However , solar power technologies need to tap this solar resource using appropriate technology and site specific adaptations.

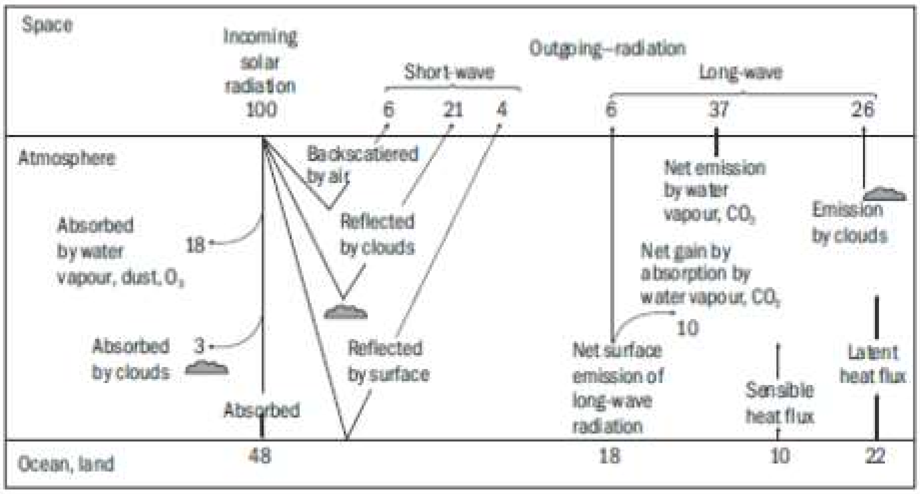


Fig.1 The composition of long wave and short wave of solar radiation

The two major Solar Power technologies that can be harnessed is using Solar Photo Voltaic (SPV) and Solar Thermal (STh) and it is important to note that the former uses light energy (works better in cold dry clean bright sun light in the atmospheres like Ladak, Leh, in the Himalayas, than hot tropical desserts like that in Rajesthan) , while the later can use heat energy (will work extended hours beyond day time with latent heat in the atmosphere)(Fig.2). For generating electricity solar power technologies using SPV may have lower efficiency but also has lower investment and maintenance costs when compared to STh. That is the reason the SPV technology is more popular globally. The amount of solar energy available (irradiance or insolation) at a particular location of the earth depends on the latitude, earth's tilt and time of the year. The average insolation is known as irradiance(Fig.3) and is measured in Watts/sq.m. The Indian Solar Atlas in GIS (Geographic Information System) format is relased by NIWE, National Institute of Wind Energy (web site: niwe.res.in) in a GIS format and can be viewed in "SWurja" mobile app downloadable freely in play store in Android mobiles.

Fig.2 Commonly used two Roof Top solar technologies (SPV- light or STh-heat)

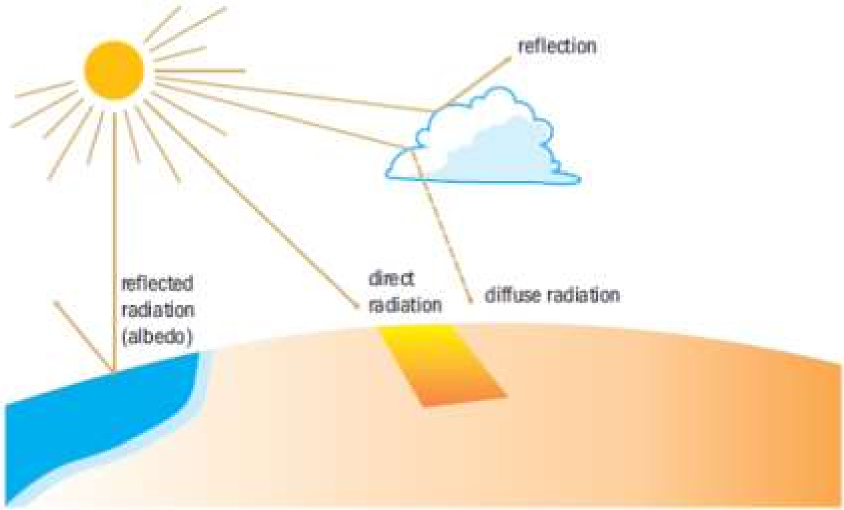
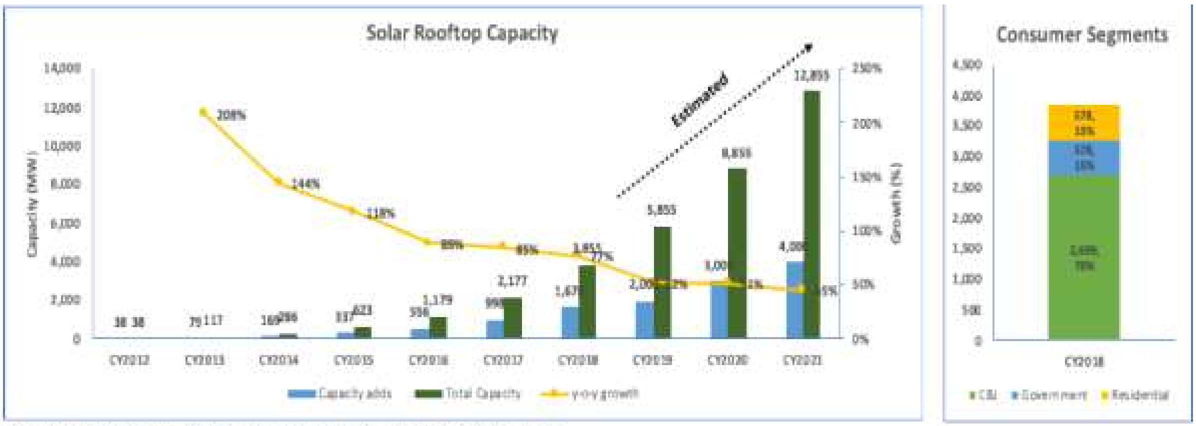


Fig.3 Types of Measured irradiation on earth's surface

The solar irradiation (light energy) falls on a solar photo voltaic panel kept on the roof, the energized photons trigger free electrons in the P-N junctions of Silicon material which are streamlined through a conductor carrying the direct current which is then combined in series and parallel to generate electricity at a operational voltage and current. Thus the panels generate DC power which can be used to charge a battery or used through a inverter as converted AC power to run the usual domestic electrical appliances . There are four types of solar roof top (Fig.4)

Fig.4 Components of Roof Top Solar system

It can be a stand alone offgrid system (charging a battery and usable as DC/AC powered appliances without/with an inverter). It can be grid tied saving transmission losses (T&D) being used where it is produced. It can be grid interactive (with a battery storage of adequate capacity) , excess energy after using energy or charging in the house, will be exported to gird. It can be grid fall back (it's like solar UPS) coupled with storage. The growth of roof top development in India is rather slow when compared to the higher-growth rate of the ground based plants installed capacity crossing 30GW.



Source: Bridge to India, Mercom India, IEEFA Estimates

Fig.5 Growth and prediction for the future of Roof Top solar developments

In this one day tour of the roof top solar systems we will see the concept to commissioning with policy promotions from time to time to reach the roof top target of 40GW at 2022 in India.

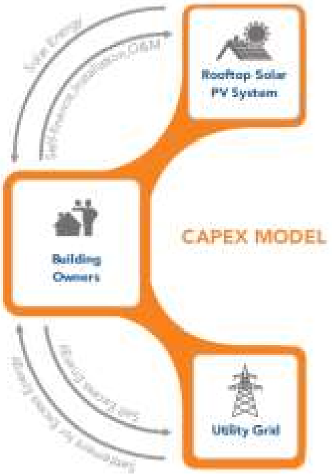
2. Solar energy policies in India ,International Solar Alliance

The Solar energy development policies have always been proactive in the solar power development in India, with the announcement of National Solar Mission, and spate of subsidies (through central financial assistance CFA, performance based awards, enabling banks to finance the roof top systems) and market development and cost reduction through competitive bidding. India is proud to have a global organization International Solar Alliance (ISA) involving over 120 countries around the world mostly those with excellent solar irradiation , with it's head quarters in NewDelhi, India.

The Roof Top Solar (RTS) policies in India can be classified into two categories one based on financial subsidy based, and the other, technology & tariff based. The policy interpretation and implementation have been quite unclear and has some of the RTS developers interested while others had got discouraged by the processes and policy swings from time to time in every state as power being concurrent subject of the centre and states in India.
An excellent statewise policy perspective for residential (R), commercial(C) and commercial&Industrial (C&I) RTS can be read in
https://www.itsmysun.com/solar-state-wise-policy/

Policies of Financial Sops :

Central Financial Assistance of 30% on the CAPEX (Capital Expenditure) has subsidy being implemented through state nodal Agencies (SNAs). In addition to the CFA some states have their own stated subsidies to promote RTS deployment. However one should note any subsidy driven programme the motivation is limited to getting the government subsidy but quality and performance suffers. Again, the subsidy is always limited by the budget allocation and hence not available to every interested investor. There are also other business models to attract RTS investors/developers called RESCO model , i.e Renewable Energy Supply Companies which can lease your roof and operate



Year – wise target (MW)

Realizing our immense RTS potential and the ambitious targets, MNRE had launched Grid Connected Rooftop and Small Solar Power Plant Programme with increased budget of ₹5,000 Crore (₹50 billion) for rooftop solar photovoltaic (RTS) projects up to 2019-20.

Under this programme, RTS capacity in the commercial and industrial sectors to be developed without any subsidy support. RTS plants on rooftops and vacant area of buildings in residential/ social/ institutional/ Government/ PSU sectors would be developed based on subsidy/ incentive as follows:

a. For rooftops and vacant areas of buildings in residential/ social/ institutional sectors, capital subsidy at the rate of upto 30% of project cost or benchmark cost whichever is lower for General Category States and upto 70% of project cost or bench mark cost whichever is lower for Special Category States/Islands.

b. For rooftops and vacant areas of buildings in Government/ PSU sectors, financial incentive at the following rates:

Achievement vis-a-vis Target Allocation	Incentives for General Category States	Incentives for Special Category States/UTs
80% and above within sanctioned period	₹18,750/- per kW	₹45,000/- per kW
Below 80% and upto 50% within sanctioned period	₹11,250/- per kW	₹27,000/- per kW
Below 50% delayed commissioning up 6 months beyond sanctioned period	₹ 7,500/- per kW	₹18,000/- per kW

- **Special Category States/Islands:** North Eastern States including Sikkim, Uttarakhand, Himachal Pradesh, Jammu & Kashmir and Lakshadweep, Andaman & Nicobar Islands.
- **General Category States:** All other States/UTs not covered under special states.
- **Residential buildings:** All types of residential buildings, including group housing.
- **Social sector buildings:** Community centers, welfare homes, old age homes, orphanages, common service centers, common workshop for artisans or craftsman, facilities used for the community. Trusts/NGO/Voluntary organizations/ training institutes, any other establishments for common public use, etc.

Source : GoI notification on SPV 2017, MNRE GoI

SPV plants under both metering technology options , viz. net meter and gross meter can be the choice of RESCO model. To ensure faster growth of RTS the Government also set targets for development and those interested PSUs /Govt. Institutions are provided incentive based on % deployment meeting the target.

Policies Based on technology/tariff

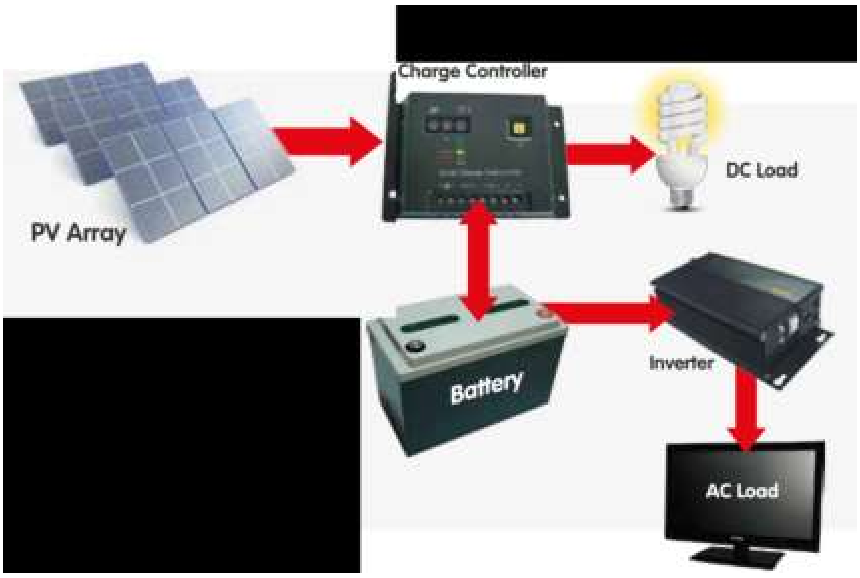
The net-metering policy had been very attractive in reducing the electricity bills of individual consumers and the meter is bi-directional and records both export of power to grid and import of power from the grid and the consumer is allowed to pay only the positive net consumption (import > export) . In most states the consumer may not be able get payment beyond certain % load demand (export < import), at the rates of tariff approved by state-regulatory commissions. Alternatively,

the gross metering provides for RTS investors who lease roof area on rent and export excess power to grid based on a mutually agreed PPA with the roof owner and utility. Most of the DISCOMs being in financial stress owing to free electricity for farmers, and lack of efficient proactive implementation of revenue e-billing process and electricity theft in some cases, the fear of loss of DISCOM profitability in the long run, RTS approvals with net-meters are having a indirect resistance for effective implementation.

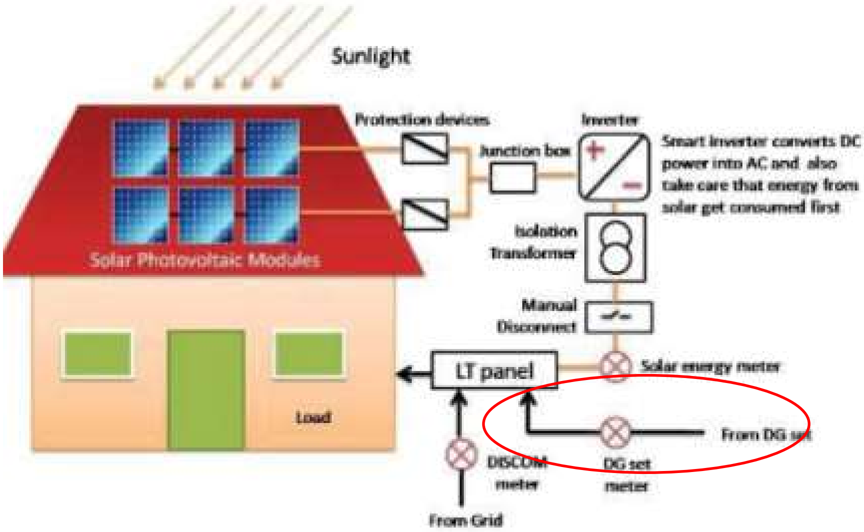
Current trends of not offsetting captive generations directly against consumption, and charging the consumers at normal tariffs and paying for exported energy at regulatory approved rates will certainly extend the concept of gross metering to individuals which will hamper the growth of the RTS sector.

3. Concept and Construction of Solar roof top PV,

If one understands that photons from the solar irradiation falling on solar panels generates electricity , then the concept of RTS is as simple as a plug and play type of system integration of various components, with panels installed on the roof in a shade free (minimum shaded) area. There are two configurations of construction of RTS one is stand alone and the other is grid tied.



Stand Alone/offgrid RoofTopSolar System



Grid-tied or grid interactive (DG-set or battery bank) Roof top Solar system

While the grid tied system will stop functioning even during day time if there is a power cut, the grid interactive will continue functioning with auxiliary DG set or battery storage of adequate hours of operation. Regarding construction, all that is needed is a structural support system which is anchored to the roof to hold the solar panels against the sun to generate electricity. In most of the roof the uplift pressure on the panels induced by kinetic energy of wind can be easily designed by proper sizing of the steel pole embedded in the heavier weight of concrete pedestal or freely kept reinforced concrete frame work. In the electrical side the positive and negative poles of solar panels should be safely combined and then wired through a charge controller , isolator, and DC-AC inverter with islanding switch to the grid interface which are housed indoors through the metering system.

4. Step by step procedure of commissioning, operation of Solar roof top PV

The step by step procedure in sequence have to be meticulously followed for commissioning and successful operation of a Roof Top Solar (RTS) PV system.

(i) Solar insolation hours(irradiation in a given time, kWhs/sq.m/day) on the roof (a minimum of 1000watts/sq.m for 1 hour @ 25 deg. Temp)

(ii) Available shade free area at the desired tilt and azimuth of solar panel (90-100 sq.ft per kWp depending on efficiency and brand of panel)

(iii) Electrical load designed to be met with solar generation

(iv) Type of roof top Solar system and choice of solar cell and technology

(v) String size of solar panels in series and in parallel to have desired DC kWhs

(vi) Checking the Roof strength and designing module mounting system fixures

(vii) Charge controller and string monitoring in case of battery storage

(viii) Design sizing of invertor capacity with adequate DC:AC ratio

(ix) System integration of various components with safe isolators both at DC level and AC level along with islanding feature of RTS PV system.(to avoid electric shock to technicians attending repair in the distribution line after a line off condition.)

(x) Implementation of DC level meters and Utility meters (uni directional or bi-directional as per the design case)

For a complete design of components and RTS PV-system please use

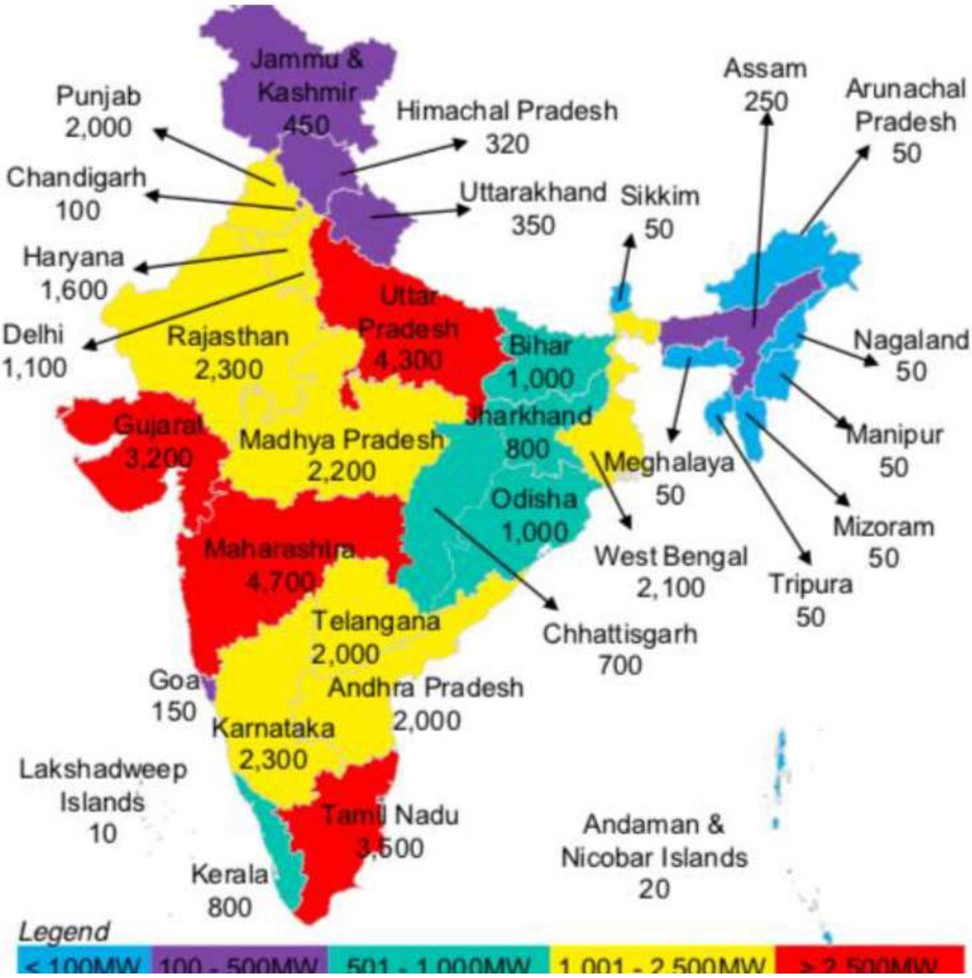
https://teda.in/spv-simulation-tools/

5. Operation and maintenance aspects of Solar roof top PV

Roof Top Solar (RTS) projects which are domestic or residential applications, it is fairly maintenance free, except for cleaning the solar panels and checking for all the wired connections in the RTS PV system. Specially safe earthing of the system is also essential. In the case of RTS of MW capapcity institutional projects, we may have to employ a few skill-trained teams of unskilled as well as engineers and technicians to monitor the strings of SPV panels for physical hot spots, damage to wired connections, proper inspection of structural support systems and their bolted and grouted joints for any possible cracks leading to roof leakages etc. The system may be also closely monitored with SCADA kind of sensor based IIoT (Industrial internet of Things) . In some rare cases robotic cleaning of modules may be resorted to.

6. **Current challenges and outlook for India,**

Roof Top Solar (RTS) power development has clear case of set targets for each state of India, challenges are policy implementation including central and state financial assistance initiatives.



The outlook for RTS which has just completed 10% of the target set for 2022 40GW, but the focus on PSUs, Government Institutions, commercial business model (RESCO , CAPEX, OPEX) companies, Commerce and industrial

(C&I), individuals/residential uses is likely steer growth in the rest of years before 2022.

Various factors have contributed to this slow growth including:

- Timely disbursement of subsidies
- Low residential electricity tariffs
- Availability of finance
- The difficulty of the process and the lack of timely approvals of net metering applications
- Lack of consumer awareness
- Policy uncertainty
- Bureaucratic hassles
- Limited support from loss-making discoms that fear revenue leakage.

Recently, the Government of India announced Phase II of the Grid Connected Rooftop Solar Programme.

In the second phase, the government is offering a 20- 40% financial subsidy to residential consumers for new rooftop solar installations ranging between 3-10kW, including user-clusters such as housing societies.[12] This financial support should accelerate residential rooftop solar installations.

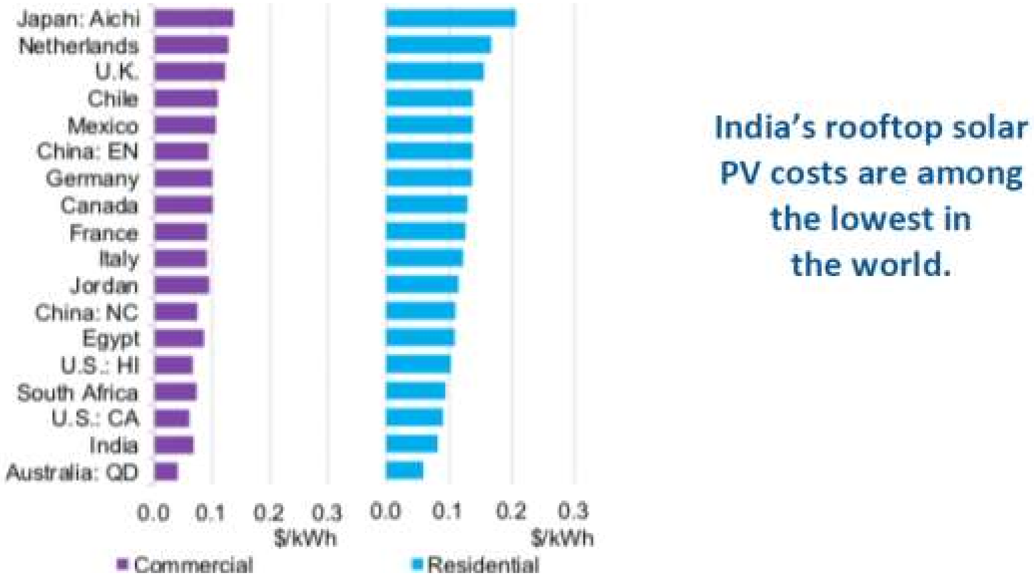
Rooftop solar is a win-win solution for consumers and discoms.

Rooftop solar can be a win-win solution for both consumers and discoms while reducing Indian reliance on imported fossil fuels.

Source: IEEFA-India_Vast-Potential-of-Rooftop-Solar-In-India, 2019

7. Cost of roof top solar and different subsidiary schemes in India

Roof Top Solar (RTS) costs have been revised time to time revised by the Ministry, by notifying benchmark costs for dispersal of incentives as a %. For various schemes of RTS. While the announcement is always clearly stated for special status states which are yet to start building systems in their state.



StandAlone RTS with battery back up Amp. Hours

Capacity	Battery back-up (hrs)	Benchmark Costs (Rs./Wp)	
		General Category States	North Eastern States/Hill States/ Island UTs
Up to 10 kW	6	94	103
	3	74	81
	1	62	68
Above 10 kW and up to 25 kW	6	84	92
	3	66	72
	1	55	60

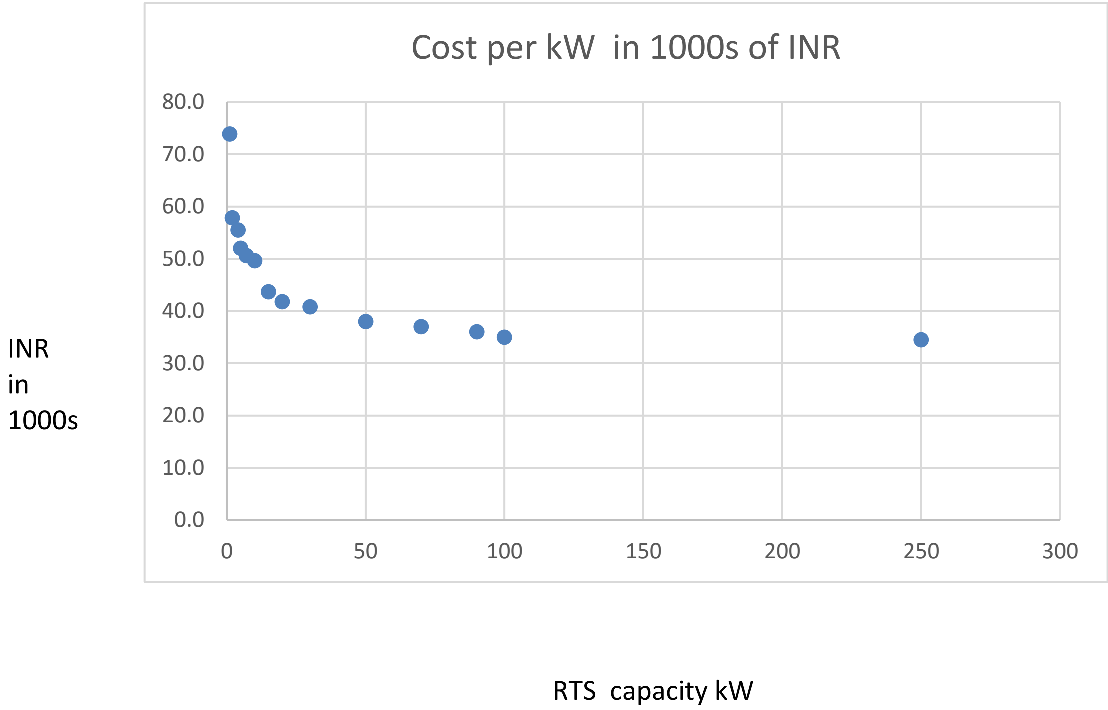
For Grid Connected RTS PV systems

In continuation to this Ministry's OM no. 318/38/2018-GCRT dated 15th June 2018, the undersigned is directed to say that benchmark costs for Grid Connected Rooftop Solar Power Plants for the Year 2019-20 will be as under:-

Capacity	Benchmark cost (Rs/Wp) other than Special Category States	Benchmark cost (Rs/Wp) for Special category States which includes North Eastern States, Hilly States of Uttarakhand, Himachal Pradesh, J&K and UTs of Andaman & Nicobar Island and Lakshadweep
Above 1 kW and upto 10 kW	54	59
Above 10 kW and upto 100 kW	48	53
Above 100 kW and upto 500 kW	45	50

Source MNRE notification for RTS PV systems , 2019

The commercial pricing of the grid connected roof top systems are likely to be confidential and is likely to vary with vendor and the RTS PV system's add on features and performance. One typical table of costing seems to indicate as you scale up the installed capacity the prices are falling per kWp.



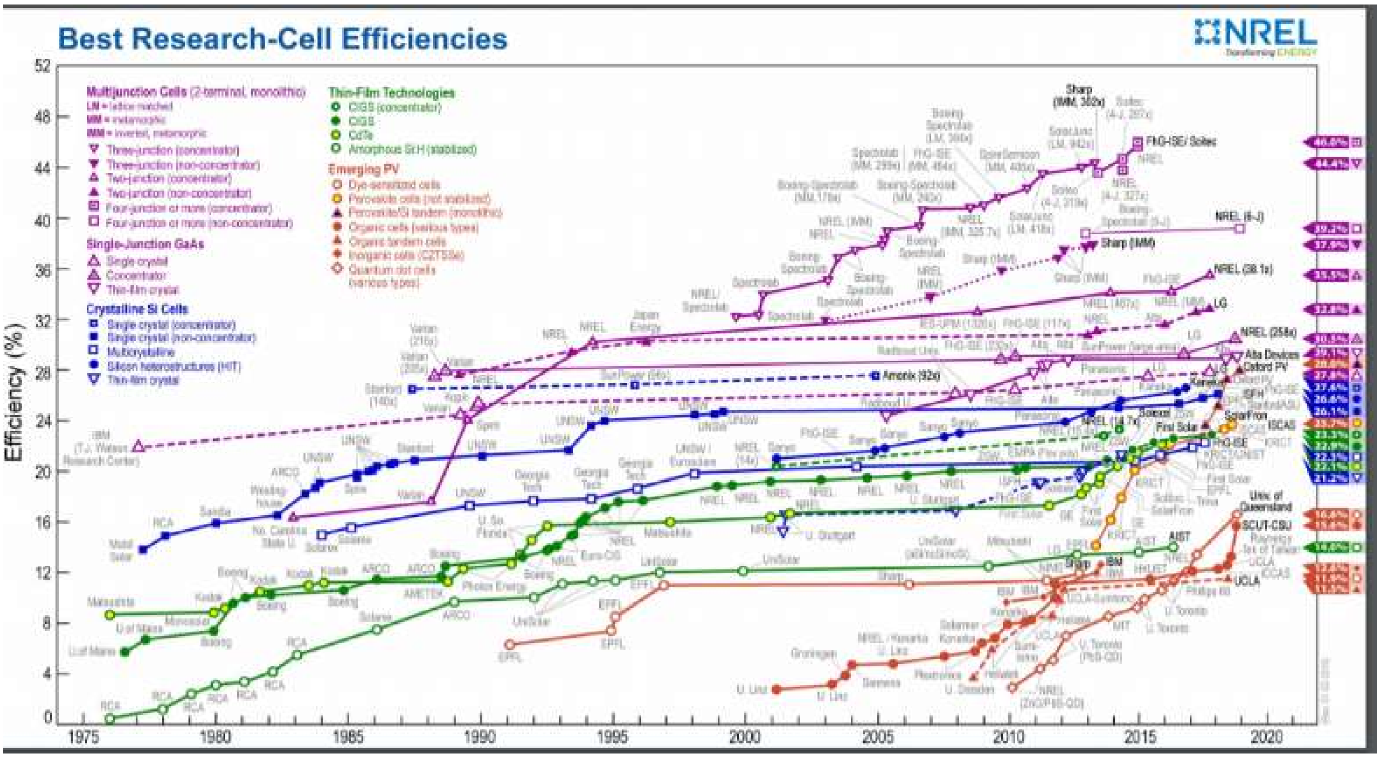
Just like any other appliance, you will get products with varying costs in the market for Solar PV as well. But then just like any other appliance, you have to be aware of the quality of the product so that your expectations are matched with the product's performance. Tier 1 manufacturers (the ones listed above on this page) would be expensive, but their products will perform better over a longer period, whereas the cheaper ones may not perform so well over time. The benchmark costs of Solar PV rooftop "Grid Connected" system has varied between Rs 75,000/kWp and Rs 1,00,000/kWp in the last few years. In fact, if you check the prices right now, the quotations that you would get would vary between Rs 60,000/kWp and Rs 90,000/kWp (for decent quality systems).

If your connected load is 5 kW and you have enough space to install a 5 kWp system, then it would cost roughly Rs 3,75,000. Typically a 1 kWp panel would generate about 1300-1400 units of electricity per year (it will be more on days with abundant light and less on days with low light). So a 5 kWp system would offset about 6500 units from your electricity bill every year. If your average per unit cost is Rs 7 then that works out to savings of Rs 45,500 per year. At Rs 7 per unit, you will recover cost of project in 8 years (without subsidy) and in 5 years (with 30% subsidy). If the cost per unit is more, then the cost recovery will be faster. However, owing to the fear of revenue loss to DISCOMs uniform practice of unit to unit generated and consumed is not going to be available in many states in the implementation as the reverse bidding has brought down the price of solar electricity as low as 2.44 paise per kWh. This will hamper the rate of growth of this sector with reference to investors of RTS.

8. Manufacturing of solar cells and R&D,

Manufacturing of solar cells is a highly energy intensive process, specially using semi conductor materials such as Silicon, cadmium, Teleroid …. and other materials in different forms. Basic research involving development of new cost effective affordable and easy to manufacture solar cell is not being carried out in such rigor in this niche area specially in India. US, Japan, China and Europe, Germany seem to lead these innovations. But make-in-India has raised several manufacturers of solar modules using indigenous or imported solar cells. The national renewable research laboratory of USA is involved in innovations in solar basic cell research and development.

Please follow the latest updated link for more details :



https://www.nrel.gov/pv/assets/pdfs/pv-efficiency-chart.20181221.pdf

As per the data available on Wikipedia, top international brands based on capacity of installation, and based on public information from the industry are:

- First Solar (Malaysia)
- Trina (China)
- Canadian Solar (Canada)
- Sharp (Japan)

If you are looking for familiar brands (names) then you can look at the likes of:

- Mitsubishi
- Panasonic
- Bosch

However, if you are looking for Subsidy on your solar PV installation, then you will have to go for panels that are Made in India. Based on information from MNRE (link), manufacturers/brands that lead the solar PV manufacturing market are:

- Vikram Solar
- Waaree Solar
- Goldi Green Technologies
- Tata Power Solar

Please note that among the Indian brands, Vikram Solar is the only one that appears in the global list on Wikipedia, and Waaree Solar has similar capacities.

Just like panels, there are multiple brands of Inverters (from various areas) available in India. However, in case of inverters, your subsidy does not depend on the make of the inverter; you can buy any inverter which meets MNRE specifications and get subsidy.

Top international brands of solar inverter (available in India) are:

- SMA Solar
- ABB
- Schneider
- Fronius
- Huawei

Indian manufacturers of Inverters are also into manufacturing Solar Inverters, so you can also get:

- Su-kam
- Luminous

While selecting an inverter, please make sure that the efficiency of the inverter (to convert DC to AC) is high. International brands have energy efficiency as high as 98%. Which means, almost all the DC energy that your PV panel generates gets converted to useful AC energy.

Inverters these days also have in-built software solutions to manage and monitor electricity generation from the solar panels. So. make sure that you get one that has the capability. If you go for subsidy, then most of the basic requirements (including the software) are covered in the requirements by MNRE.

Depending on the type of your connection, you also have to make sure that it is a single phase inverter or three phase inverter.

A good heat sink along with use of electrolytic capacitors can make a good inverter, almost a fit-and-forget kind of system which you need not worry about for years.

Other accessories needed for a Solar PV Grid Connected system are:

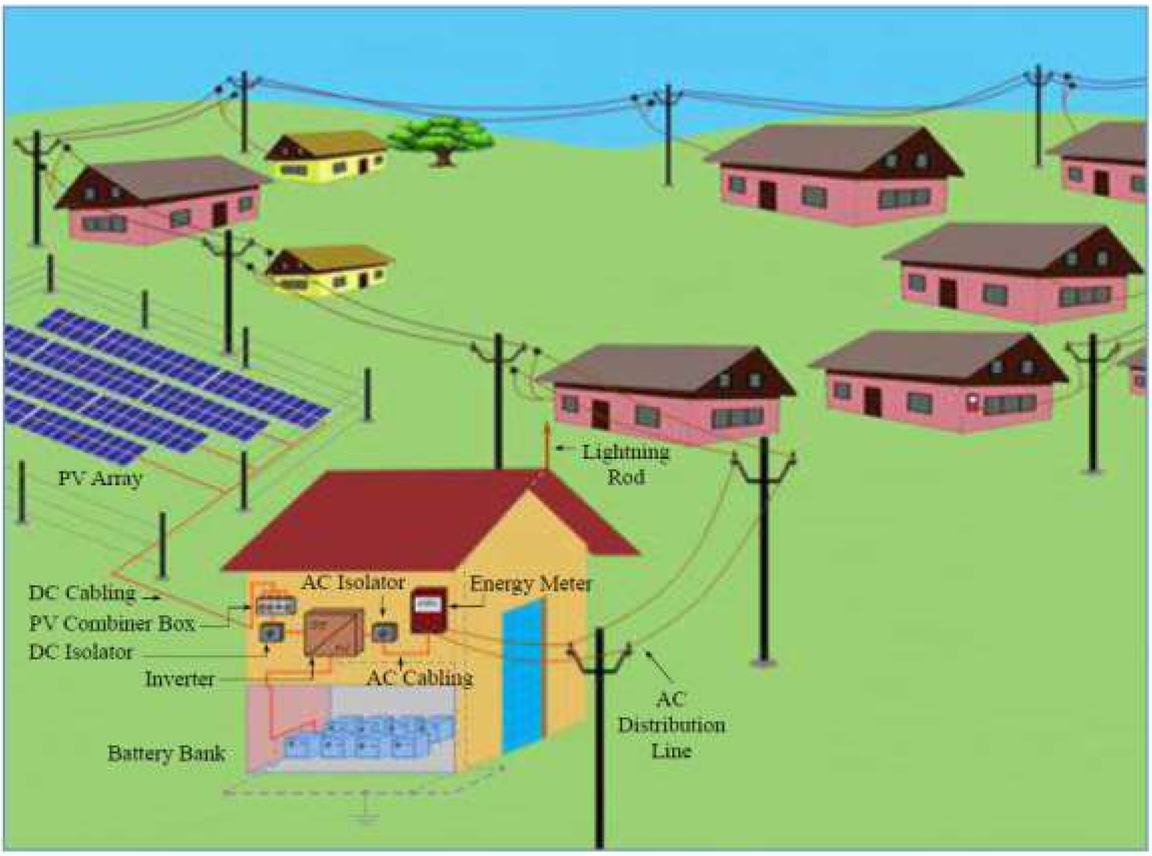
- AJB (Array Junction Boxes) – for protection as there is no earthing.
- AC and DC distribution boxes – for protection as there is no earthing.
- DC Cables

While buying these, just make sure that you go for good brands like Havells, Finolex, Polycab or any top Indian brand that makes products as per BIS standards.There are over 9000 registered channel partners for system integration services for RTS with varied levels of expertise and experience. The module mounting structural systems have also become cost effective owing to the shift to cold formed steel sections which are functionally light gauge but strong enough to safely support solar panels subjected to wind induced uplift pressures, from the earlier choice of heavier hot rolled steel sections for the support of RTS.

9. Micro and mini grid development for distributed generation

The micro and mini grid development and distributed electricity generation would be the key area India needs to focus on in the years to come owing to the vast potential of readily available roof top spaces spread across India with abundant solar irradiation. In locations where 24x7 grid connected electricity is not possible owing to geographical or technical issues DC power for clusters, of small homes are possible. Please follow the video link for an excellent overview.

https://www.youtube.com/watch?v=DZoZBmS_wIQ (USEFUL DC HOME Cygni) .



A conceptual schematic of solar microgrid system

Rated Capacity at STC (Wp)	I_{sc}	I_{mp}	V_{oc}	V_{mp}	Length (mm)	Width (mm)	Weight (kg)
50Wp	3.04	2.8	21.77	17.89	608	666	4.6
100Wp	6.11	5.57	21.84	17.99	1152	666	8
200Wp	8.1	7.48	32.65	26.74	1486	982	15.5
250Wp	8.71	8.18	37.55	30.58	1639	982	17.45
300Wp	8.74	8.05	45.1	37.28	1956	992	27

http://isolaralliance.org/docs/Microgrid-Trainers-Handbook.pdf

Battery storage – type and classifications

In a standalone PV system, battery storage is required if electrical loads are required to operate at night time, or during extended periods of cloudy or overcast weather when the PV array by itself cannot supply enough power. The primary functions of a storage battery in a PV system are:

(i) Energy Storage Capacity and Autonomy

(ii) Voltage and Current Stabilization

(iii) Supply Surge Currents

In general, electrical storage batteries are broadly classified as Primary and Secondary Batteries. Primary batteries are not used in PV systems because they cannot be recharged. A secondary battery can store and deliver electrical energy, and can also be recharged by passing a current through it in an opposite direction to the discharge current.

		
Flooded Electrolyte LA battery	VRLA battery	Lithium Ion battery

The batteries that are commercially available and viable for use in photovoltaic system include:

- Flooded Lead Acid Batteries
- Valve Regulated Lead Acid (VRLA) Batteries
- Nickel Cadmium (NiCd)
- Nickel metal Hydride (NiMH)
- Lithium Ion (Li-ion)

10.Summary

Roof top Solar (RTS) systems are of DIY- Do it Yourself category if they are in small capacities (1-5kW) domestic, for both DC-home applications as well as AC-Grid tied applications , if not in the township (owing to tree coverage), at your own houses, native districts, mining areas, and other open terraces or neighboring village hamlets as part of CSR. PSU special allocation funding for achieving roof top targets committed can be also a bonus revenue generating stream. The expertise needed is system integration with suitable component sizing and a certified electrician.In the case of larger RTS on institutional building terraces more clear planning and designing the system components is required along with trained technicians and engineers . Microgrids established with a team of experts of NLCIL could become a commercially deliverable electricity packaged products for villages or communities which want to be green and partly off-load their demand from Utility grids of the states.

11.Additional Acknowledged Web Reading and References

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