Agri-Photovoltaic: An opportunity to generate electricity together with crop production

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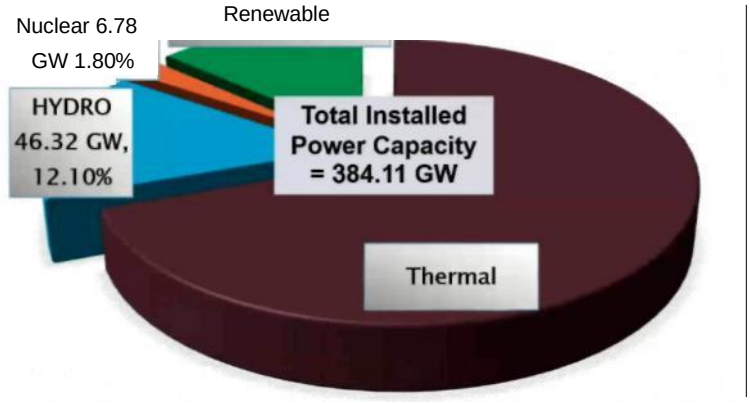
Structure of Presentation

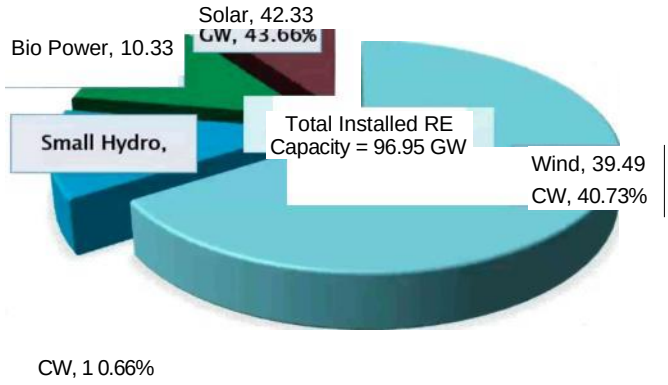
- ►Overview of Indian Power/RE Sector
- ►Standards , Specifications and Efficiencies of Solar Cells
- ►Introduction to Agri-voltaic of Agri-Photovoltaic
- ►Benefits of the Agri-voltaic Plant to the Society & the agriculture sector
- ►Challenges of Agri-voltaic Plants
- ►Sustainable Development Goals (SDGs)
- ►Application of Solar Energy in Agriculture
- ►Legal frame work for Agri-voltaics

NISE Indian Power Sector - Overview (as on 30.06.2021)



* Hydro Power does not include Small Hydro Plants (0 to 25 MW), which is included in Renewables;

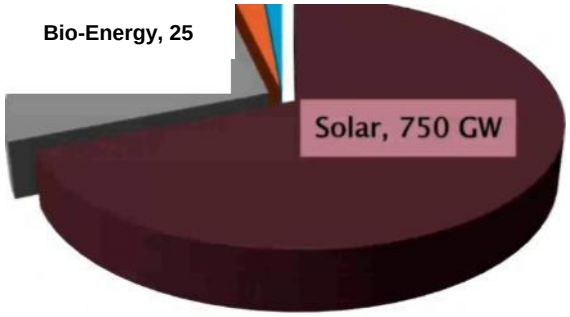
NISE Installed Renewable Power Capacity (as on 30.06.2021)



CW, 1 0.66%

Wind	Small Hydro	Solar	Biomass	Total
39.49 GW	4.80 GW	42.33 GW	10.33 GW	96.95 GW

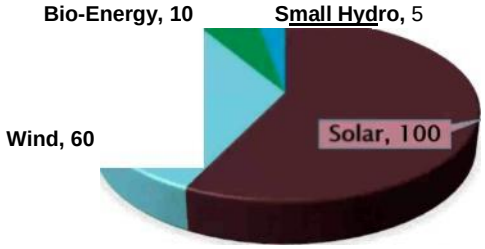
NiSE Renewable Energy Potential (> 1000 GW)



GW **Small Hydro 1 5 GW** **Wind, 300 GW**

E Road Map for Renewable Power

By 2022 - 175 GW India made a commitment in Paris Climate Agreement To reduce emission intensity of the economy by one-third; and For having at least 40 % electric power installed capacity from clean energy sources by the year 2030.



By 2030 - 450 GW

Status of RE projects
(as on 30/06/2021)

Sector	Target by 2022 (CW)	Installed capacity (CW)	Under Implementation (CW)	Tendered (CW)	Total Installed/ Pipeline (CW)
Solar Power	100	42.33	36.89	19.76	98.98
Wind Power	60	39.49	8.89	1.20	49.58
Bio Energy	10	10.34	0.00	0.00	10.34
Small Hydro	5	4.79	0.42	0.00	5.21
Wind Solar **Hybrid**	-	0	2.55	1.70	4.25
Round the Clock (RTC)/ assured Peak Power supply	-	0	1.60	2.50	4.10
Total	175	96.95	50.35	25.16	172.46

NISE Road Map for Renewable Power

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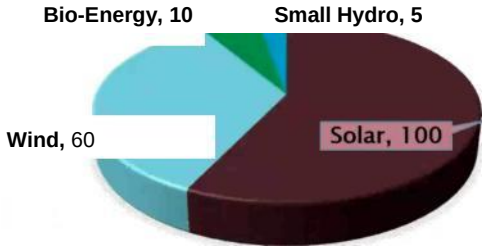

By 2030 - 450 GW

NISE | Road Map for Renewable Power

By 2022 -175 GW

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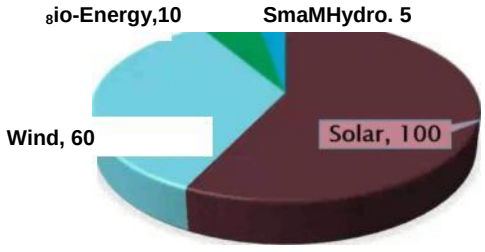
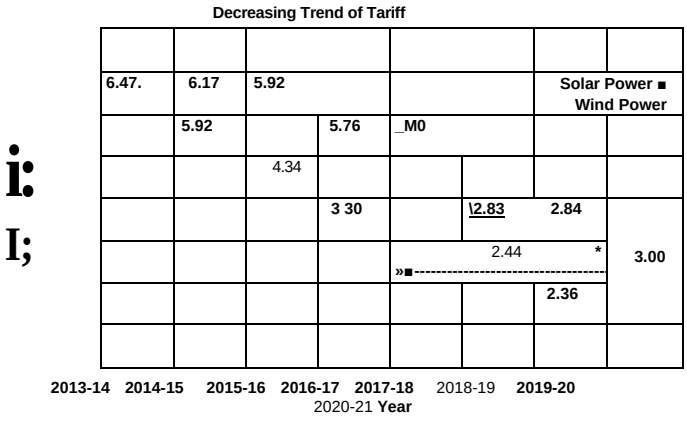


By 2030 - 450 GW

RE Tariff Trend



Cost of Installation and Power Generation from Various Sources

S.N	Source of Energy	Installation Cost (INR Crore/MW)	Power Generation Cost (INR/kWh)
1	Thermal (Coal)	4.5-5.0	3.05
2.	Thermal(Gas)	5.00	3.50
3.	Hydro	7-9	3.00
4.	Nuclear	$65,00 ,000	21-35
5	Solar(PV)/Thermal	3.5/12.0	2.50/8.0
6.	Wind	5.0	2.46
7.	Biomass-Biogas	10.0	4.50
8.	Biomass Bagasse Cogeneration	8.0	7.50
9.	Wind-Solar Hybrid	4.50	2.69

Standards & Speci fications

si. No.	Title	Indian Standard (IS)/IEC Number	BIS Recognition	NABL Accreditation
I.	Solar PV Module Test	IS 14286 IS 61 701	IS 14286 Yes -	
2.	Solar PV Inverter Test	IS 16221 IS 16169 IS/IEC 61683:1999 CSN EN 50530 IEC 60068-2-1 Cold IEC 60068-2-2 Dry Heat IEC 60068-2-14 Change of temperature IEC 60068-2-30 Damp heat. cyclic IEC 62509:2010	IS 16169 Yes	
3.	Storage Battery Test	IS 16270 IS 1651:1991 IS 13369:1992 IS 15549:2005 IEC 61427	IS 16270	
4.	Lighting Lab Test	IEC 62509	..	
	SPV Water Pump Test			
6. Test	Solar Thermal	IS 16648 (Part 5)		

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Best Research - Cell Efficiencies (Lab Scale)

Technology		Technology	Efficiency
Multi-Junction Cells (2-terminal, monolithic)		Thin-Film Technologies	
Three-junction (concentrator)	44.4%	CIGS (concentration)	23.3%
Three-junction (non-concentrator)	3 7.9%	CICS	23.4%
Two-junction (concentrator)	3S.S%	CdTe	22.1%
Two-junction (non-concentrator)	32.9*	Amorphous Si:H (stabilized)	14.0%
Four-junction or more (concentrator)	47.1%	Emerging PV Technologies	
Four-junction or more (non-concentrator)	39.2%	Dye-sensitized cells	12.3%
Single-Junction CaAs		Perovskite cells	25.2%
Single crystal	27.8*	Perovskite/Si tandem (monolithic)	29.1%
Concentrator	30.5%	Organic cells (various types)	17.4%
Thin-film crystal	29.1%	Organic tandem cells	14.2%
Crystalline Si Cells		Inorganic cells (LZISSe)	12.6%
Single crystal (concentrator)	27.6%	Quantum dot cells (various types)	16.6%
Single crystal (non-concentrator)	26.1%		
MLillkiystalline	23.3%		
Silicon Hetero Structures (HIT)	26.7%		
Thin-film crystal	**21.2%**		

Agri-PV or Agri-voltaic

i Agro-PV or Agri-voltaic is the new application of Solar photovoltaic plant **for** effective and efficient use of available space.

> Agrivoltaics - Synergistic Production of Food and Energy

> To facilitate the farming and PV generation together, the PV panels are mounted at additional height (e.g. 2 m or high) to increase the spacing between them to avoid excessive shading for the crops underneath the PV panels.

> Agri-voltaic can resolve land-use conflicts between energy **and** agriculture production, by combining both on the same site and increasing land productivity.

https://www.univergysolar.com/en/agrivoltaic-energy/

https://www.next2sun.de/en/references/

https://agrovoltaics.com/index.php

Benefits of the Agri-PV Plant

► Increasing land productivity

► Reductions in electricity and water pumping bills for farmers

i Farmers benefits from increase in income while diversifying their risk, cost savings through self-consumption of electricity, improved agricultural practices.

► Lower requirement of water for irrigation

» Creation of local employment and yield is used for medicinal purposes. » Increase in income while diversifying their risk . The additional benefits for the public sector include increased decentralized and local electricity production.

Challenges of Agro-PV Plants

i Agri-PV plants are subjected to two key challenges - module cleaning and weed removal. These require regular manual efforts and investments.

- Uncontrolled vegetation disrupts maintenance and causes shadows on PV arrays, leading to hot spots and energy generation loss. It also causes safety hazards as it becomes a haven for reptiles.

> Complete cleaning of these unwanted vegetation incurs a higher soiling rate as well as high manpower, thus reducing the production and attracting higher cleaning frequencies.

- Dry vegetation collected leads to a higher risk of fire. Thus weed removal is a cost and resource burden to any solar project.

> Increase in structure cost due to additional mounting height of the PV panels

Sustainable Development Goals (SDCs)

An Agro-PV system supports the goals:-

» Affordable and clean energy
> Decent work and economic growth
► Industry, innovation and infrastructure
> Sustainable consumption and production
► Sustainable cities and communities
► Health and well-being
> Climate protective measures

KUSUM (Kisan Urja Suraksha evam Utthaan Mahabhiyan) Scheme

- Government has launched 'Pradhan Mantri Kisan Urja Suraksha evam Utthaan Mahabhiyan (PM KUSUM) Scheme' with the objective of providing financial and water security to farmers. Government guidelines in this regard have been notified on 22 July 201 9. The above scheme has three components:

► Component-A: 10,000 MW of Decentralized Ground Mounted Grid Connected Renewable Power Plants -individual plant size upto 2 MW.
► Component-B: Installation of 17.50 lakh stand-alone Solar Powered Agriculture Pumps - individual pump capacity upto 7.5 HP.
► Component-C: Solarisation of 10 Lakh Grid-connected Agriculture Pumps - individual pump capacity upto 7.5 HP.

KUSUM (Kisan Urja Suraksha evam Utthaan Mahabhiyan) Scheme contd....

Pilot Mode-: Component-A & C will be initially on pilot mode for 1000 MW capacity and one lakh
? rid connected agricultural pumps respectively.
? omponent-B will be in full fledged manner with total CFA of Rs.19036.5 Cr.

Further Scale-up and Modifications: After successful implementation of Components-A & C, the same shall be scaled up with necessary modifications based on the learning from pilot phase with total CFA of Rs.l 5385.5 Cr. Object of the scheme-: All the three components of the scheme aim to add capacity of 25,750 MW by 2022 with CFA of Rs.34,422 Cr.

Application of Solar Energy in Agriculture

- Solar energy has a huge potential for solar irrigation, to pump water for livestock, drying of crops, milling of grains, drying fruits & vegetables, dry fruits etc.
- Solar Energy can be used for refrigeration of agricultural products, heating of water electric fencing, solar street lights, poultry lightning etc.
- Solar power for various agricultural operations i.e. threshing, winnowing, grading etc.
- Effective usage of greenhouse for controlled temperature

Solar PV Water Pumping System

Large dependency of farmer on Diesel Engines

Availability of interrupted grid supply.

Clean energy

Reduces fossil fuel burden

Cost payback time very less

Various applications like irrigation, livestock watering, drinking water supply etc.

SWPs of various capacities available in market

NISE

Solar products developed at NISE for Agri applications

K vf.*».j

Solar Dryer-cum-Space Heating Systems

> NISE has developed Solar Dryer-cum-Space Heating System for the benefits of farmers to preserve fruits, vegetable and other agro products.

> 310 nos. of these systems have been installed in Leh (165 nos.) and in Kargil (145 nos.).

NISE

Solar products developed at NISE for Agri applications

Solar Powered Cold Storage Systems

> NISE has developed Solar Powered Cold Storage system for the benefits of farmers to preserve fruits, vegetable and other agro products.

> Solar Powered Cold Storage system (5-10 tons capacity) design and developed in collaboration with M/s Inficold.

> 20 nos. of these systems have been installed in Assam (03), Karnataka (03), Kerala (01), Tripura (03), Rajasthan (01), Orissa (04), Meghalaya (01) and Uttar Pradesh (04).

> The systems adopted by Ministry of Agriculture and Farmers Welfare under MHID scheme.

Solar Powered Cold-storage with Thermal Storage System

20 nos. of these systems have been installed in Assam (03), Karnataka (03), Kerala (01), Tripura (03), Rajasthan (01), Orissa (04), Meghalaya (01) and Uttar Pradesh (04).

rb MT Storage Capacity
>Primilary for Pineapples Precooling
"High Precooling Capacity
^14 kWP SPV Plant
*-30 Hrs Cooling Backup from Thermal Storage
^-Remotely Monitored

Vertically installed bifacial PV modules for Agri-voltaic use

NISE

LI More energy in early morning and late evening: Potentially reduces the storage need

O Minimum space required

Q Dual purpose use. e.g.. Noise barrier, fencing, Agri-photovoltaic, etc.

Vertically Mounted Bifacial Modules

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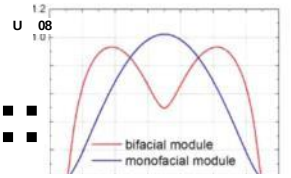

S. Guo et.al. *Energy*, vol 61, pp.447-454 (2013)

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Vertically installed bifacial PV modules

Pilot project Study at NISE, Gurugram, India

□ Objectives:

> Evaluate the performance of bifacial PV modules in vertical installation conditions and comparison with bifacial and monofacial module installed at latitude tilt.

'*■ Study the impact of albedo, environment and installation conditions on bifacial gain for vertical and latitude tilt

> Based on the experimental results, Simulation of bifacial module gain for different location in India (vertical & latitude tilt)

> To test the bifacial modules for performance enhancement of the solar water pumping systems

□ For this study NISE has installed:

r5 kW Bifacial PV system (mono-PERC): **vertically installed** >*5* kW

Bifacial PV system (mono-PERC): **at latitude tilt >10** kW

monofacial PV system (mono-PERC): **at latitude tilt**

NISE

Vertically installed bifacial PV modules

Pilot project Study at NISE, Gurugram, India

LI Status: Operational since June 2021

- □ Prior to installation, all the modules were measured under STC at NISE's state-of-the-art testing and characterization lab.
- □ Energy generated is fed into the grid.
- □ In addition to the array of 5 kWp, individual modules also being tested in outdoor conditions.



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Simulation Study

- □ Location: Delhi/Gurugram
- □ System size: 5 kW
- □ Albedo: 0.3, Module Bifaciality: 0.85

900

■ Bifacial at latitude vertical ■ Monoladal at latitude ■ Blfadal

Jan Feb Mar Apr May Jun Jul Aug Sep
Oct Nov Dec

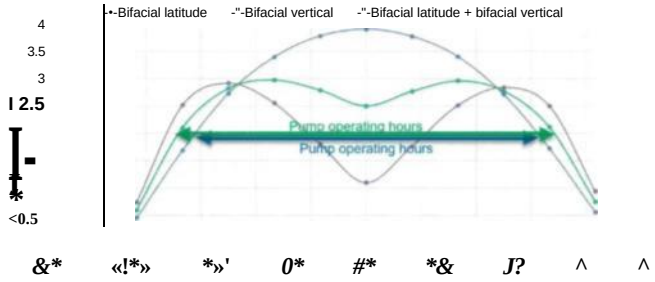
□ Generation of bifacial vertical is
- 13% lower compared to rnonofacial LI Generation of bifacial latitude is
~ 8.5% higher compared to rnonofacial

NISE **Bifacial module to enhance solar water pumping efficiency**

_i Flattened generation curve

J Combination of bifacial vertical and bifacial at latitude tilt can enhance the operating hours of the solar PV pump with increase in wire to water efficiency

At NISE, we are also evaluating the wire to water efficiency and daily discharge of solar PV pump.



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Legal frame work for Agri-voltaics

► In order to achieve the energy policy goals, the number of ground mounted PV systems is constantly increasing. The policy for Agri-voltaics should support the investment with economic viability The privileged project may include » Land used for agricultural or forestry operation ■ Land used for horticultural production operation Rooftops and exterior walls of buildings

Requirement for implementation

►Common understanding of Agri-voltaics,
►Social acceptance with a focus on land use competition,
» Necessary adjustments in legislation
►Relevant works for greenhouse photovoltaics.
►Selection of crops
• Shading and sheltering benefit °
Irrigation need
Farmers' agricultural knowhow
Marketing opportunities
Investment requirements
Profit margin

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Summary

J Agri-voltaics is a promising way to resolve land-use conflicts between energy and agriculture production.

i A policy framework is required for Indian prospective.

J Bifacial technology can play an important role together with agriculture in India, giving additional benefits to the farmers.

j Present pilot study at NISE will be helpful in providing a roadmap for scope of bifacial PV modules in India with necessary guidelines for different applications.

J India has huge potential for Solar PV pumping (Govt, of India has KUSUM scheme in place for promoting the solar PV pumping across the country). Bifacial modules can play an important role efficient PV pumping, further supporting the Agri-photovoltaic.

j Vertical bifacial PV can be used along India's huge highways and rail network (significant part of this required noise barriers and fencing). Of course, a customised module design needed for effective noise barrier property.