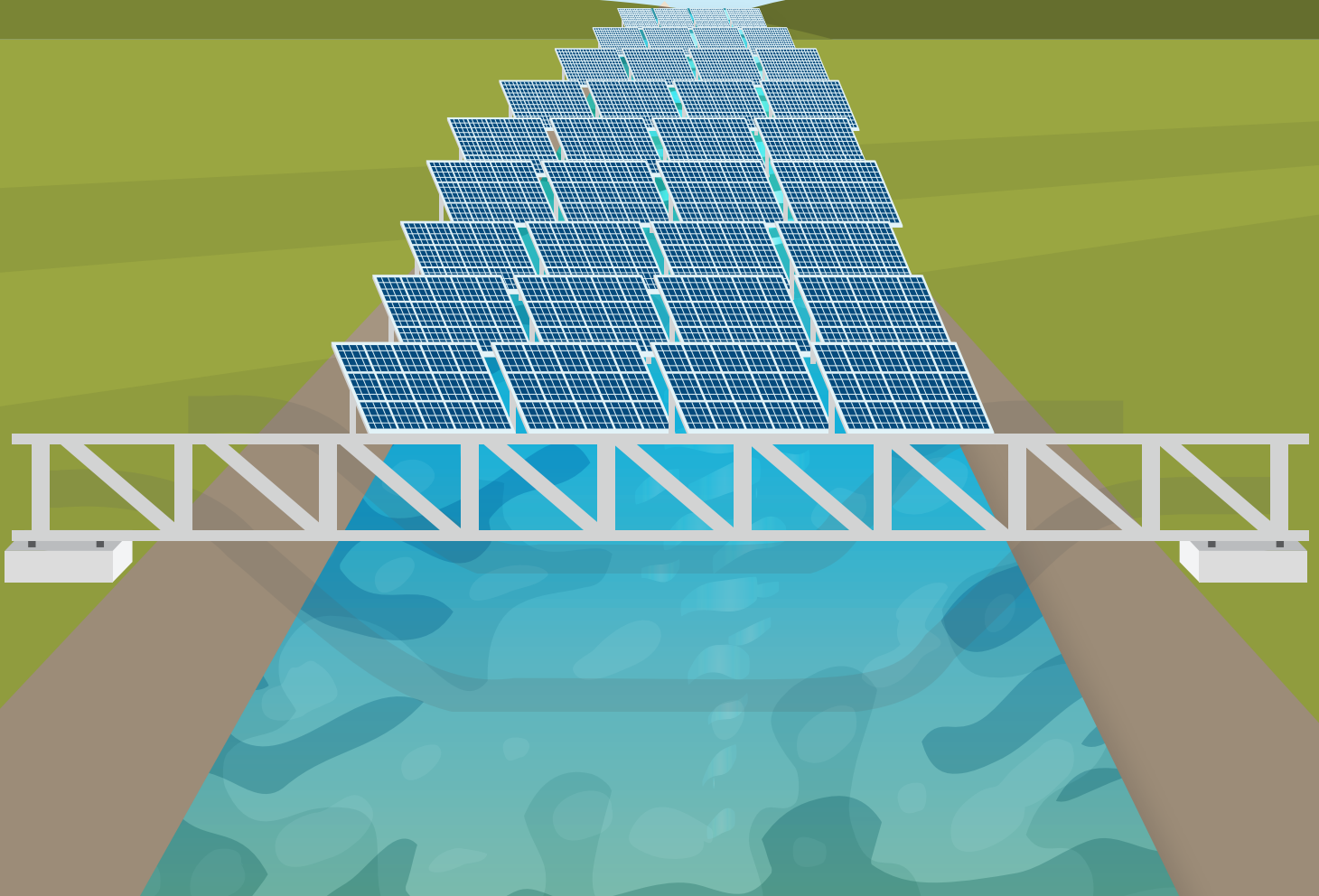


# Canal Top PV in India

January 2024





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As a federally owned enterprise, GIZ supports the German Government in achieving its objectives in the field of international cooperation for sustainable development.

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**As at:** New Delhi, January 2024

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On behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ)

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This publication has been prepared under the Indo-German Technical Cooperation on Innovative Solar (IN Solar) in India. The project has been initiated under the guidance of the Ministry of New and Renewable Energy, Government of India and is funded by the Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ). Ernst and Young LLP (EY LLP) has led this project along with CSTEP and Fraunhofer ISE (Germany) as partners. The project aims to explore the potential of the new and innovative solar applications (NISA) with reduced land utilization having the potential to foster the targeted expansion of solar PV applications in India. The NISA areas are agrivoltaics (APV), floating PV (FPV), canal top PV (CTPV), rail/road integrated PV (RIPV), building integrated PV (BIPV) and urban PV (UPV).

The project team is grateful for the guidance and support received from the Ministry of New and Renewable Energy (MNRE), especially from Dr Arun K. Tripathi (Scientist G), Dr Anil Kumar (Scientist E), Ms Priya Yadav (Scientist C), Mr Arun Kumar Choudhary (Scientist B).

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**Disclaimer**

The potential derived for the different integrated PV applications and the methodologies used have been derived with the sole purpose of estimating the national-level potential of these technologies for India. It is subject to certain assumptions to extrapolate the potential on a national scale. Statistical potential estimation methodology was utilized wherever there was a lack of precise GIS data. Realised potential on the ground might differ owing to a more precise system-level design at this scale.



# FOREWORD



**Henrik Personn**

Dear Readers,

The G20 declaration under India's presidency this year emphasizes the importance of "accelerating clean, sustainable, just, affordable and inclusive energy transitions," with a strong emphasis on rapidly expanding renewable energy deployment (G20, 2023). Bilateral efforts related to sustainable energy technologies are recognised as crucial in bringing this commitment to fruition.

In this regard, the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH is pleased to present this study on New and Innovative Solar Applications (NISAs). The identified NISAs are Agrivoltaics (AgriPV), Floating Photovoltaics (FPV), Canal Top Photovoltaics (CTPV), Rail/Road Integrated Photovoltaics (RIPV), Building Integrated Photovoltaics (BIPV) and Urban Photovoltaics (UPV). This study is a testament to the Indo-German Technical Cooperation under the Innovative New Solar Areas (IN Solar) project, a bilateral project initiated under the esteemed guidance of the Ministry of New and Renewable Energy (MNRE), Government of India, and funded by the German Federal Ministry for Economic Cooperation and Development (BMZ). The IN Solar project has been at the forefront of exploring NISAs with the potential to revolutionise India's renewable energy landscape.

Canal Top Photovoltaics (CTPV) entails applying photovoltaic systems on top of canal networks. This report explores four distinct designs of CTPV across varying canal widths within the extensive Indian canal system. Readers will not only get an overview of the CTPV potential in the country but also regarding the necessary skill set for scaling up the technology. Moreover, the report presents viable business models that benefit both water body owners and consumers, thus creating a win-win situation. This is particularly crucial in light of India's experience with CTPV demonstration projects in the state of Gujarat to date, which has been marked by challenges such as technical design hurdles and unexpectedly high project costs. Readers are encouraged to familiarise themselves with the potential and levelized cost of electricity (LCOE) associated with CTPV by exploring the GIS-based potential atlas available on the website <https://staai.cstep.in>. Ultimately, policy and regulatory suggestions are provided for implementing and mainstreaming CTPV across India.

Herewith I express my sincere appreciation to all individuals and organisations who have played a crucial role in the formulation of this report, especially the scientific team led by Ernst & Young (EY) LLP and their distinguished partners, the Center for Study of Science, Technology and Policy (CSTEP) (India) and Fraunhofer ISE (Germany) but also the project teams, stakeholders, diligent researchers, and of course the invaluable guidance of MNRE.

I hope that this document serves as a valuable resource and inspires continued innovation and collaboration in the realm of renewable energy.

Yours sincerely,

A handwritten signature in blue ink that reads "Henrik Personn". The signature is written in a cursive, flowing style.

Henrik Personn  
(Head of Solar Projects in GIZ India)



# PREFACE

On behalf of the entire project team, it is with great pleasure that we present this comprehensive report on Canal Top PV in India, which is a part of a series of six distinct reports showcasing the New and Innovative Solar Applications (NISAs) in India. The reports include:

- Potential Assessment of New and Innovative Solar Applications in India
- Agrivoltaics in India
- Floating PV in India
- Canal Top PV in India
- Building Integrated and Urban PV in India
- Rail and Road Integrated PV in India

The study encompasses potential assessments, various business models, implementation strategies, technical aspects, policy enablers, market dynamics, financial considerations, and the skill sets needed to catalyze the growth NISAs in India.

Another key element of this study includes creation and implementation of an online tool called the Solar Technology and Application Atlas for India (STAAI). This innovative tool is crucial for visualizing and analyzing the solar potential in India, providing stakeholders with a user-friendly experience. The STAAI goes beyond simple potential assessment by including decision tools like the Levelized Cost of Electricity (LCOE) calculator. Additionally, it allows the generation of district-wise or state-wise potential assessment reports for each NISA.

For further details on each of our report and to access the Solar Technology and Application Atlas for India (STAAI), please visit <https://staai.cstep.in/>

We extend our gratitude to all those who have contributed to the success of this project and express our anticipation for the positive impact that these reports and the STAAI will have on the solar energy landscape in India.

Thanks and Regards

Project Team

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# LIST OF ABBREVIATIONS

AT&C	Aggregate technical and commercial loss
APV	Agrivoltaics
BU	Billion units
BIPV	Building integrated photovoltaic
BAU	Business as usual
CTPV	Canal top photovoltaic
CAPEX	Capital expenditure
CEA	Central Electricity Authority
CAGR	Compound annual growth rate
DSCR	Debt service coverage ratio
EPC	Engineering procurement and construction
FIT	Feed-in tariffs
FPV	Floating photovoltaic
FTE	Full time equivalent
GBI	Generation-based incentive
GIS	Geographic information system
GW	Gigawatt
GHI	Global horizontal irradiance
Ha	Hectare
I&C	Installation and commissioning
ISUN	India - solar usage in new applications
IRR	Internal rate of return

kV	Kilovolt
kWh	Kilowatt hour
kWp	Kilowatt peak
KM	Kilometre
LCOE	Levelised cost of energy
LTOA	Long term open access
MIS	Management information system
MW	Megawatt
MU	Million unit
MNRE	Ministry of New and Renewable Energy
NPV	Net present value
NISA	New and innovative solar applications
OPEX	Operating expenditure
O&M	Operations and maintenance
PV	Photovoltaic
PPA	Power purchase agreement
PSA	Power selling agreement
RIPV	Rail/Road integrated photovoltaics
RESCO	Renewable energy service company
Sq km	Square kilometre
Sq m	Square meter
SOP	Standard operating procedure
TW	Terrawatt
VGf	Viability gap funding
Wp	Watt peak





# EXECUTIVE SUMMARY

---

00

In the quest for sustainable and clean energy solutions, solar power has emerged as a frontrunner in the renewable energy sector. While traditional land-based solar photovoltaic (PV) plants have proven to be effective in generating electricity, there is a growing need to explore New and Innovative Solar Applications (NISA) that offer distinct advantages. In particular, the concept of land-neutral or dual-use applications has gained significant traction. This approach seeks to maximize the utilization of available land by integrating solar installations with existing infrastructure or employing non-traditional spaces. By tapping into these alternative applications, we can not only overcome the limitations of land availability but also address environmental concerns, reduce conflicts over land use, and enhance overall efficiency and sustainability in the solar energy sector.

In this context, the Government of Germany and the Government of India signed a new project titled IN-Solar (Innovative -Solar). Under the project, GIZ (German Development Agency) and the Ministry of New and Renewable Energy (MNRE) initiated an activity titled India - Solar Usage in New Applications (I-SUN) which aims to explore the new innovative applications of solar with reduced land utilization having the potential to foster the targeted expansion of Solar PV applications in India. The NISA areas are Agrivoltaics, Floating PV, Canal Top PV, Rail/Road Integrated PV and Building/Urban Integrated PV.

In **Chapter 1**, the concept of CTPV is introduced, as one such innovative technology amongst Integrated PV, which has seen growing interest in the country. India has a substantial canal network spanning across different states. The majority of these canals are in Punjab and Gujarat. CTPV also referred to as canal solar is synonymous with solar panels fitted over canals, utilizing existing canal infrastructure resulting in several benefits which include increased panel efficiency, due to the cooling effect, reduced land use and reduced canal water evaporation.

CTPV has been categorized under four design approaches, the first three design configurations are for small and medium canals with widths lesser than or equal to 30 m, and the fourth design is for large canals with widths greater than 30 m. In the first three design configurations –the layouts are developed along with canal flow. The angle for linear canal stretches with respect to configuration type is dependent on the following directional compass. For canals with a width greater than 30 m, the configuration consists of modules that are installed vertically on both sides of the canal. Bifacial solar modules are used to harness solar radiation from both sides and generate maximum energy.

### Canal width less than 30 m



South flowing

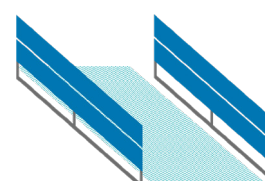


East-West flowing

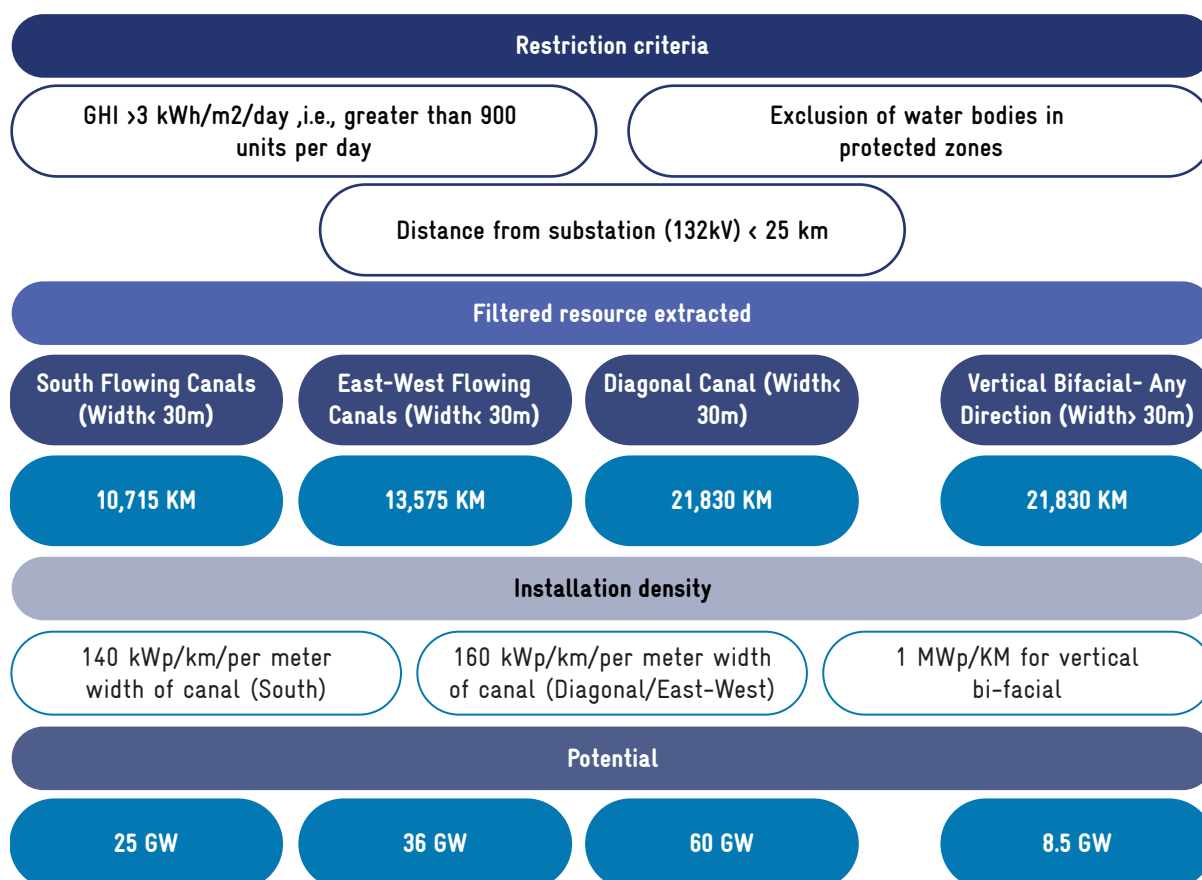


Diagonal canal

### Canal width greater than 30 m



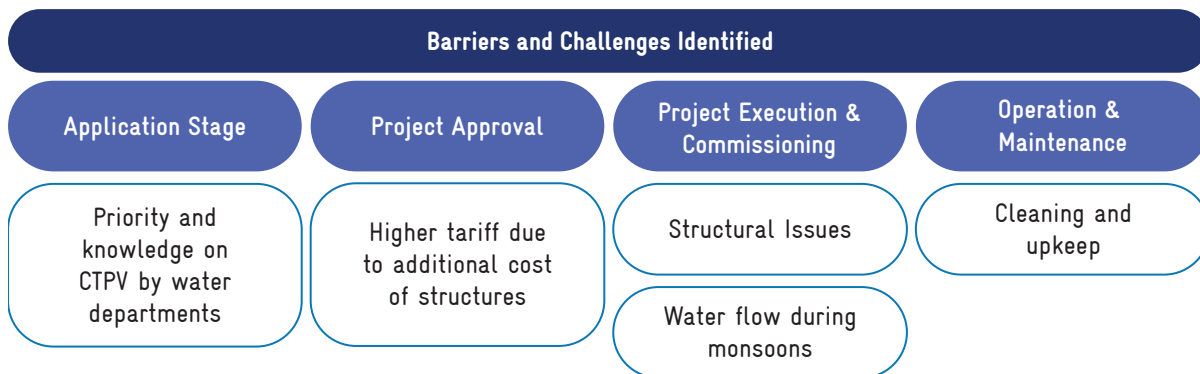
Vertical bifacial – any direction



The overarching potential estimation methodology in **Chapter 2** has been developed by estimating resource availability specific to each configuration body and overlapping with technical restriction criteria identified in GIS, before proceeding with estimating generation potential and financial feasibility. The total potential of canal top and canal bank PV is estimated to be around 131 GW.

The business models are discussed in **Chapter 3** of this report, the CTPV business models have been developed keeping in view a targeted object, fixed boundary conditions and stakeholder interactions. The levelised cost of generation also includes the rent component, which has been assumed to be charged at a conservative annual rate of INR 15,000 per acre or INR 3.71 per Sq m. The area required for a 1MW CTPV system is 5000 Sq m. As a result, the LCOE for a 1 MW CTPV system is derived as INR 5.89 per kWh with a capital expenditure of INR 6.2 Crores.

In **Chapters 4 and 5** of this report, the capacity projection of CTPV has been done from 2024 to 2040, It is estimated that the cumulative capacity projection will be 8 GW and 24 GW under the moderate and optimistic scenario respectively. The total investment required to realise the 8 GW capacity (moderate case) will be INR 37,688 Crores and INR 98,209 Crores for 24 GW. Based on the national average power procurement price in the day ahead market (DAM) during the 08:00 to 18:00 hours for DISCOMs in India and the LCOE of CTPV systems, the project team have also highlighted the viability gap funding (VGF) support required to make the business model viable for a 1 MWp CTPV systems. VGF is only considered in cases where LCOE is greater than the average DAM prices.

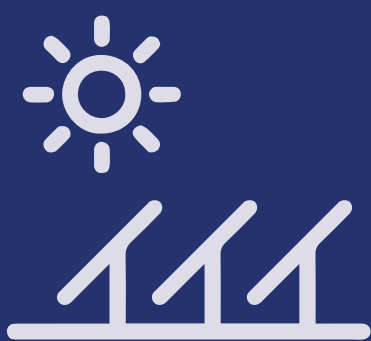


In **Chapter 6**, the project team explored and researched the policy and regulatory landscape for CTPV, prevailing in India, referencing published literature, consulting various stakeholders, and understanding the various stages in the life cycle of the project. This was accompanied by undertaking rigorous engagements with key stakeholders, like project developers, regulators, nodal agencies, market developers, etc., - along each of the stages.

Further based on the above-identified barriers and challenges, some key recommendations related to addressing bottlenecks in the effective implementation of CTPV projects

<b>Regulatory</b>	Structural test	Special wind load test procedures are required for structures resembling wind tunnel as formed under the structure in canals.
	Robust standards for components	Relevant technical standards and ratings to be complied for canal top systems. Technical standards/guidelines to be used by canal top systems shall be published by appropriate government department.
<b>Policy</b>	State/ Central roadmap	To designate a specified number of canals for solar installation within a given timeframe, the state governments and departments can be given goals by the central government.
<b>Awareness</b>	Capacity building of concerned departments	Is required as canals are owned by respective state/central irrigation departments and they lack knowledge on CTPV systems and are focused on managing the canals, ensuring a consistent water supply.

In the last chapter of this report, the project team has identified several gaps where skilling becomes necessary to boost the CTPV sector in India. As it is vital for increasing the penetration of CTPV, creating a skilled workforce, can ensure better utilization of renewable energy resources with high-quality workmanship on the deployed technologies. Under the moderate case, it is estimated that to meet a demand of 8 GW of CTPV by 2040, **31 thousand FTE** jobs will be required and for the Optimistic case, **93 thousand FTE** jobs to support distinct roles and responsibilities starting from application, project approval, detailed engineering, project execution-commissioning and operations and maintenance.



# INTRODUCTION TO CANAL TOP PV TECHNOLOGY

---

01

## CANAL TOP PV IN INDIA

Canal Top PV (CTPV) also referred to as canal solar is synonymous with solar panels fitted over canals, utilizing existing canal infrastructure resulting in several benefits which include increased panel efficiency, due to the cooling effect, reduced land use and reduced canal water evaporation. CTPV not only includes solar panels above canal surfaces but also along canal banks.

India has been at the forefront of CTPV and has set a benchmark for its development in the world. The Solarizing California Aqueduct programme is inspired by the development of CTPV in India. The technology is of high relevance to India, as most sub-regions in the country have high irradiance and more than 300 annual sunshine days. In addition, India's vast canal network complements the use case for the technology.

Some key initiatives undertaken by the government to harness this technology that strengthen the case for the technology are noteworthy. These include.

- MNRE launched a specific scheme titled – Pilot-cum-demonstration project for grid-connected PV projects on canal tops and canal Banks, cumulating to a total capacity of 100 MW.
- Strengthening evacuation infrastructure across the country, including agricultural feeders.

Taking reference to these initiatives and international research underway, the program has defined and categorized CTPV technology based on canal width as follows.

### Canal width less than 30 m



South flowing

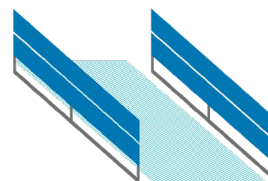


East-West flowing



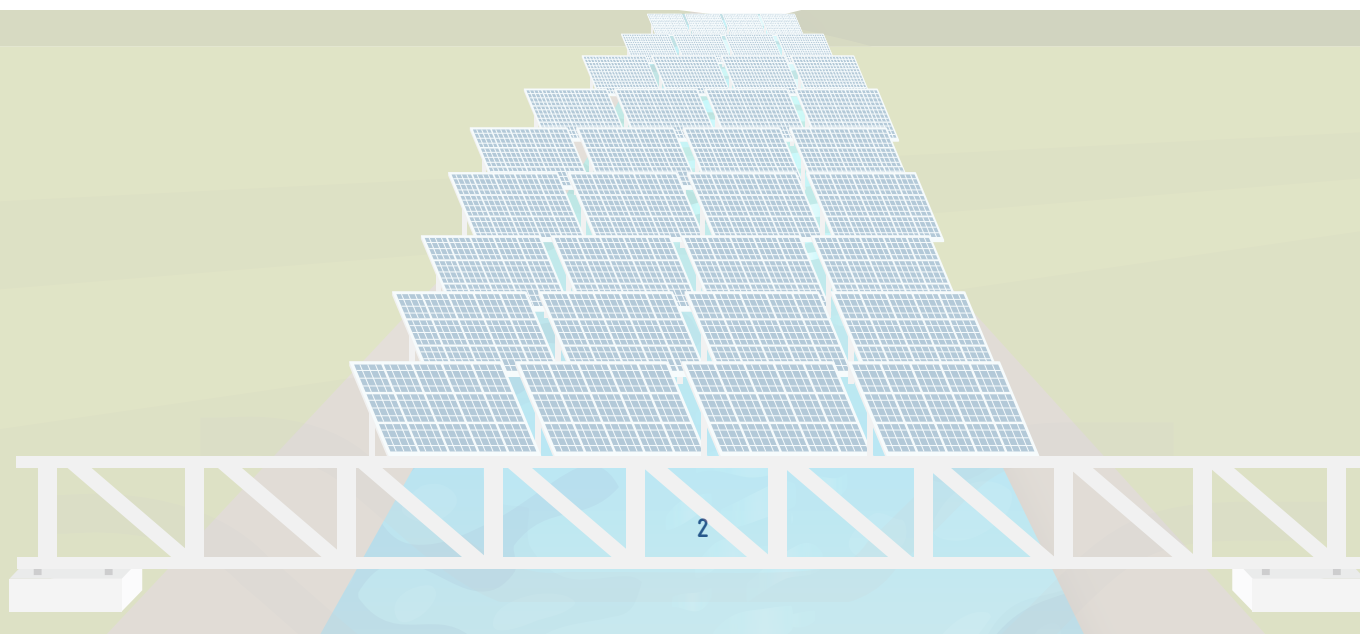
Diagonal canal

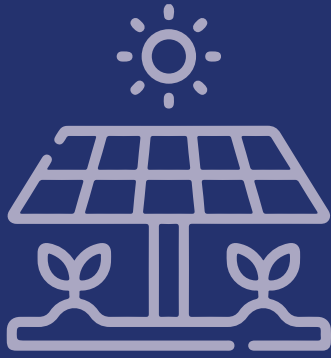
### Canal width greater than 30 m



Vertical bifacial – any direction

Figure 1: Different configurations of CTPV





# POTENTIAL ASSESSMENT OF CANAL TOP PV

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02

## 2.1. METHODOLOGY FOR POTENTIAL ASSESSMENT

The methodology for CTPV considered for potential assessment is undertaken using the following four steps, illustrated below.

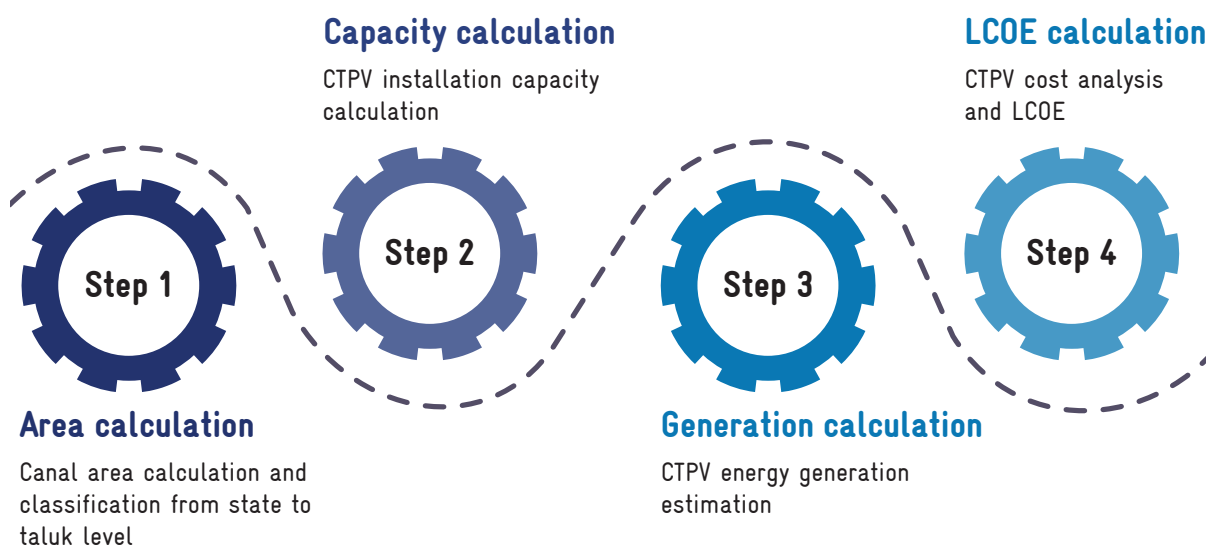
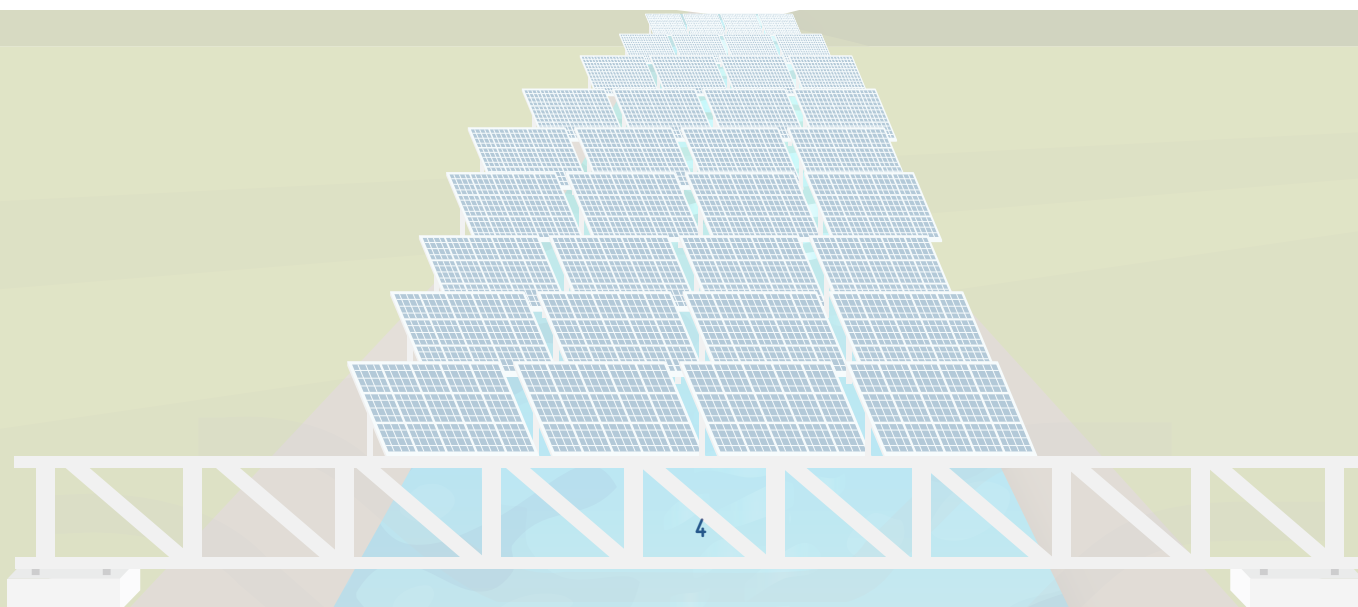


Figure 2: Key steps to assess the technical potential of CTPV

**In Step 1** – GIS data for canals in India is obtained from open street maps, which is used to calculate the length and width (km) of each canal. The data set is filtered to exclude canals falling under protective zones. The canals are then classified into small and medium ( $\leq 30$  m width) and large ( $\geq 30$  m width).

- Additionally, the technical restriction criteria are applied to the retrieved dataset, which includes canals with per day GHI  $> 3$  kWh/m<sup>2</sup>
- Canals with widths ranging between 3 m and 30 m
- Canals with distance from substation (132 kV)  $< 25$  km



Note: ISUN program has considered  $GHI > 3 \text{ kWh/m}^2$ , because of several climatic conditions. Namely

**Reflection and absorption:** When compared to land, water reflects and absorbs more sunlight. Some of the light emitted by the sun as it strikes the water surface, is reflected into the atmosphere, while some of the remaining light is absorbed by the water. The irradiance will be decreased as a result of less light reaching the surface below the water.

**Cloud cover:** Cloud cover over water bodies is frequently higher than over land. Sunlight can be reflected and blocked by clouds, which lowers the amount of irradiance that reaches the surface.

**Water bodies may have more humid air,** which can scatter and absorb sunlight. Different atmospheric conditions in comparison to drier air over land, may result in decreased irradiation.

**Temperature differences:** Surface temperatures of water bodies are often lower than those of land, which can lead to temperature inversions. Lower irradiance may arise from the air becoming more stable and not mixing as a result.

**In Step 2** - The capacity calculation for CTPV is considered using four design approaches. The first three design configurations are for small and medium canals (having a width  $\leq 30 \text{ m}$ ), and the fourth design is for large canals with a width  $\geq 30 \text{ m}$

## SMALL AND MEDIUM DESIGN CONFIGURATION

Firstly, three design configurations for small and medium canals have been illustrated in Figure 3.



**Figure 3:** Design configurations for small and medium canals

The configurations of the canal design are selected on the canal flow direction. The angle for linear canal stretches with respect to configuration type is dependent on the following directional compass.

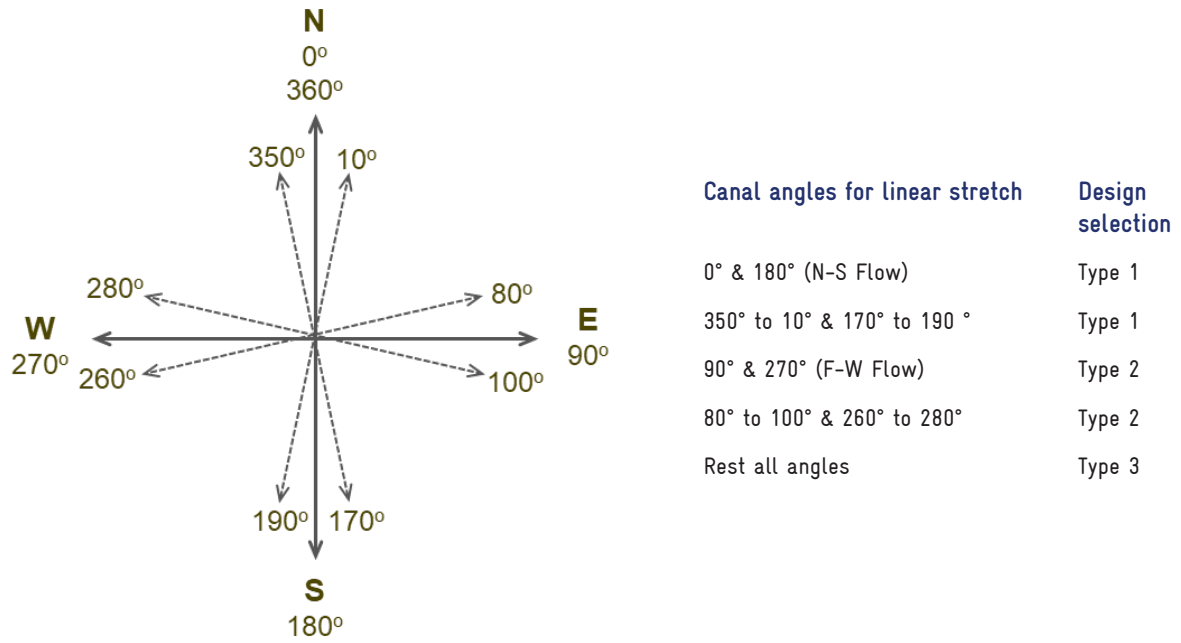


Figure 4: PV angle consideration for CTPV

### LARGE DESIGN CONFIGURATION (TYPE 4)

For canals with a width greater than 30 m, the configuration consists of modules that are installed vertically on both sides of the canal. Bifacial solar modules are used to harness solar radiation from both sides and generate maximum energy.

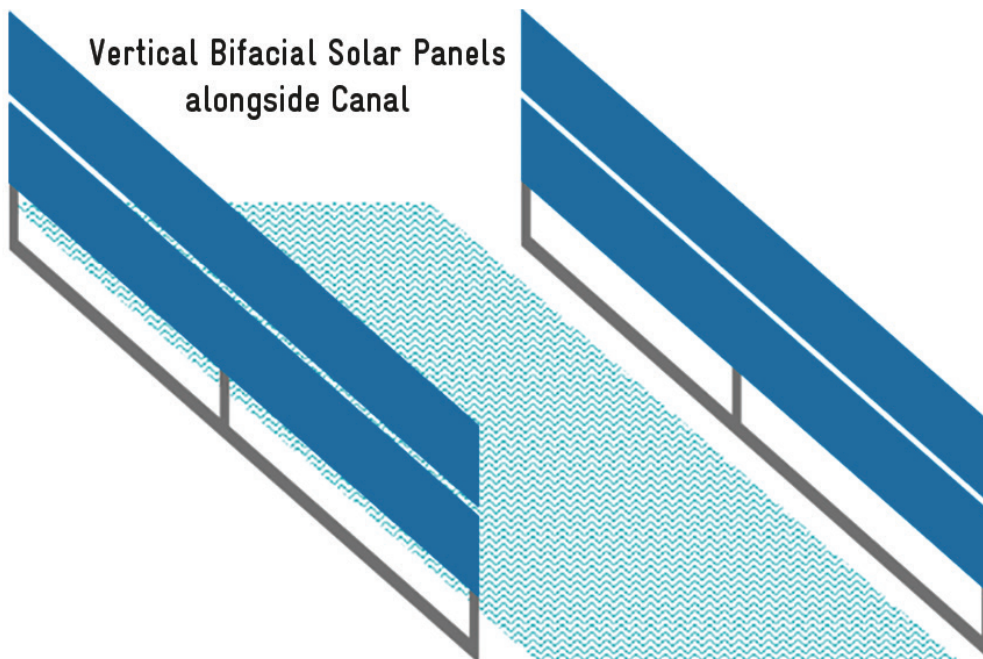


Figure 5: CTPV layout configuration- vertical PV alongside the canal

Moving forward, area optimisation of each type of CTPVs is calculated based on layout type (Type 1, 2, 3 and 4 described above) followed by capacity calculation. CTPV capacity has been summarised in the following table.

Table 1: CTPV configuration

CTPV Configuration	Type 1	Type 2 and 3	Type 4
Capacity	Varies 2.8-4.2 MWp per km for canal width ranging from 20-30 m.	Varies from 3.2-4.9 MWp per km for canal width ranging from 20-30 m.	Varies from 0.4-0.5 MWp per km for on one side of the canal

**For Step 3** - Energy generation estimates are done using satellite-based GHI data for each canal from Area Solar Radiation Tool, ArcGIS 10.5, while excluding water canals having per day GHI values less than 3 kWh/m<sup>2</sup>. This GHI data is converted into solar irradiance falling on panels based on CTPV configuration. Energy generation from the system is calculated by: Tilted solar radiation\* number of modules \* total area \* efficiency of modules ( $\eta_{\text{module}}$ ) \* efficiency of components ( $\eta_{\text{components}}$ ).

**Final Step 4** – Levelised Cost of Electricity (LCOE) generation is calculated for different system types using the standard financial parameters like capital expenditure (CAPEX), operational expenditure (OPEX), cost of finance, Return of Equity, module degradation rate and other

## 2.2. STATE-WISE TECHNICAL POTENTIAL ASSESSMENT

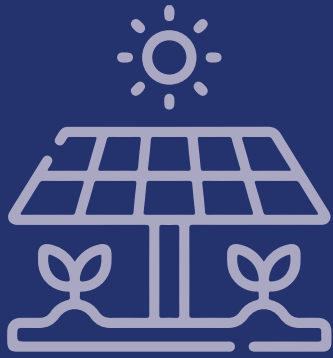
Based on the above methodology for potential assessment of CTPV in India, the following are the simulation results. Table below highlights state wise potential of CTPV along with the length of canal considered for deriving this potential.

Table 2: CTPV India potential assessment results

State	CTPV Technical Potential	
	Potential (MWp)	Length (km)
Uttar Pradesh	19,143	8,369
Bihar	11,878	5,037
Karnataka	11,232	4,628
Andhra Pradesh	11,040	4,530
Punjab	10,810	5,090
Gujarat	10,055	4,658
Haryana	10,019	3,891
Maharashtra	9,216	4,284
Tamil Nadu	6,738	2,711
Rajasthan	5,960	3,288

## CANAL TOP PV IN INDIA

State	CTPV Technical Potential	
	Potential (MWp)	Length (km)
Telangana	4,785	2,009
Madhya Pradesh	4,125	1,522
West Bengal	3,777	1,511
Kerala	3,572	1,751
Chhattisgarh	3,029	1,240
Odisha	2,662	1,224
Jammu and Kashmir	646	285
Delhi	541	218
Jharkhand	512	170
Uttarakhand	461	287
Assam	203	93
Goa	148	73
Daman and Diu and Dadra and Nagar Haveli	124	46
Himachal Pradesh	57	44
Puducherry	25	11
Manipur	1	0
Tripura	-	-
Sikkim	-	-
Andaman and Nicobar	-	-
Mizoram	-	-
Meghalaya	-	-
Lakshadweep	-	-
Nagaland	-	-
Chandigarh	-	-
Ladakh	-	-
Arunachal Pradesh	-	-
<b>Total (MWp)</b>	<b>1,30,759</b>	<b>56,970</b>
<b>Total (GWp)</b>	<b>130.76</b>	



# BUSINESS MODELS FOR CTPV

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03

The CTPV business models have been undertaken keeping in view a targeted object, fixed boundary conditions and limited stakeholder interactions. The ISUN program limits itself from an energy generation standpoint and does not focus on distribution/load side analysis. In line with this understanding, the following depicts the model objective, boundary conditions and stakeholder involvement in the model.

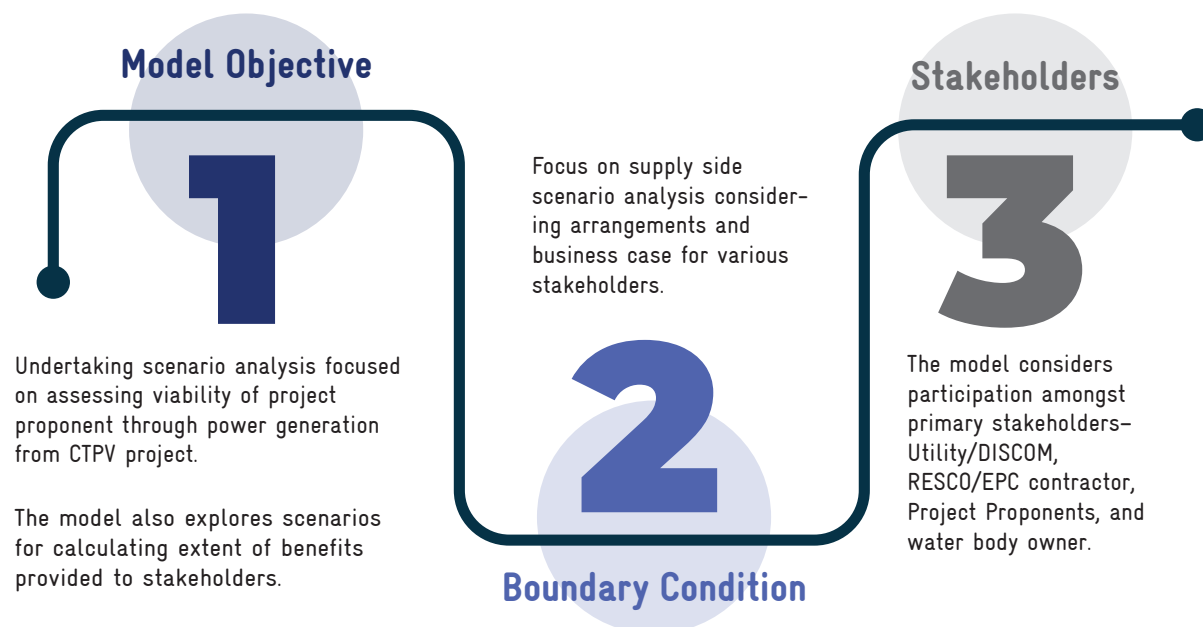


Figure 6: CTPV business model objective, boundary conditions

The financial model for CTPV, has been assumed for the layout described above. The detailed breakup of the capital cost consists of the following (Table 3).

Table 3: Financial model assumption for CTPV

Cost components	Sub-components	No.	INR lakh per MW	% Share	Assumptions rationale
Preliminary Cost			3		Cost pertaining to preliminary assessment, PFR, DPR, site visits etc.
EPC Cost	Modules Wattage (Wp)	550			Module wattage considered as per prevailing specs
	Module Cost (INR/Wp)	28			
	Number	2200			
	DC capacity (MWp)	1.21	338.80	64.52%	Conservative ratio of 1:1.2
	DC:AC (Ratio)	1.21			
	Inverter (INR/Wp)	3	36.30	6.91%	Considered same as large scale PV systems

	ACDB/DCDB (INR/Wp)	1	12.10	2.30%	Considered same as large scale PV systems
	Structure (INR/Wp)	3.5-4	48.40 – 42.35	8.06%	Structural costs are significantly more than conventional systems, primarily due to elevated structures and reinforced foundation requirement. Range represents costs for various layouts.
	Cables (INR/Wp)	0.75	9.08	1.73%	Considered same as large scale PV systems
	Other item transportation (INR/Wp)	1.5	18.15	2.77%	Considered same as conventional PV systems
	Installation and erection (including civil)	4 - 3.5	48.40 – 42.35	8.06%	Range represents costs for various layouts.
	Line Cost		0.00	0.00%	
	Evacuation (INR/Wp)	2	24.20	4.61%	Considered same as conventional systems
	SCADA		3.00	0.57%	The fixed standard cost for conventional systems
	Earthing (INR/Wp)	0.2	2.42	0.46%	Same as conventional systems
	Sub Total		540.85		
	GST	13.80%	74.64		
	Total		615.48		
	Infrastructure Cost		0.00		
	Project Management (@0.5%)		2.52		Industry-standard
	Contingency (@0.5%)		2.84		Industry-standard
	Interest During Construction (IDC)		14.82		Industry-standard
	<b>Total Costs</b>		<b>638.66 – 620.76</b>		

The aforementioned assumptions contribute to the capex required for an assumed systems size of 1 MW, with the help of which the levelised cost of electricity for 25 years has been calculated, using standard financial assumption (Annexure A). Here it is important to note, that the levelised cost of generation also includes the rent component, which has been assumed to be charged at a conservative annual rate of INR 15,000 per acre or INR 3.71 per sq m. The area required for a 1MW CTPV system as per layout is 5000 sq m.

As a result, the LCOE for a 1 MW CTPV system is derived as INR 5.89 and 6.35 per kWh (Annexure A).

### 3.1. BUSINESS-AS-USUAL SCENARIO FOR WATER BODY OWNER

The business-as-usual scenario for water body owners is depicted below.

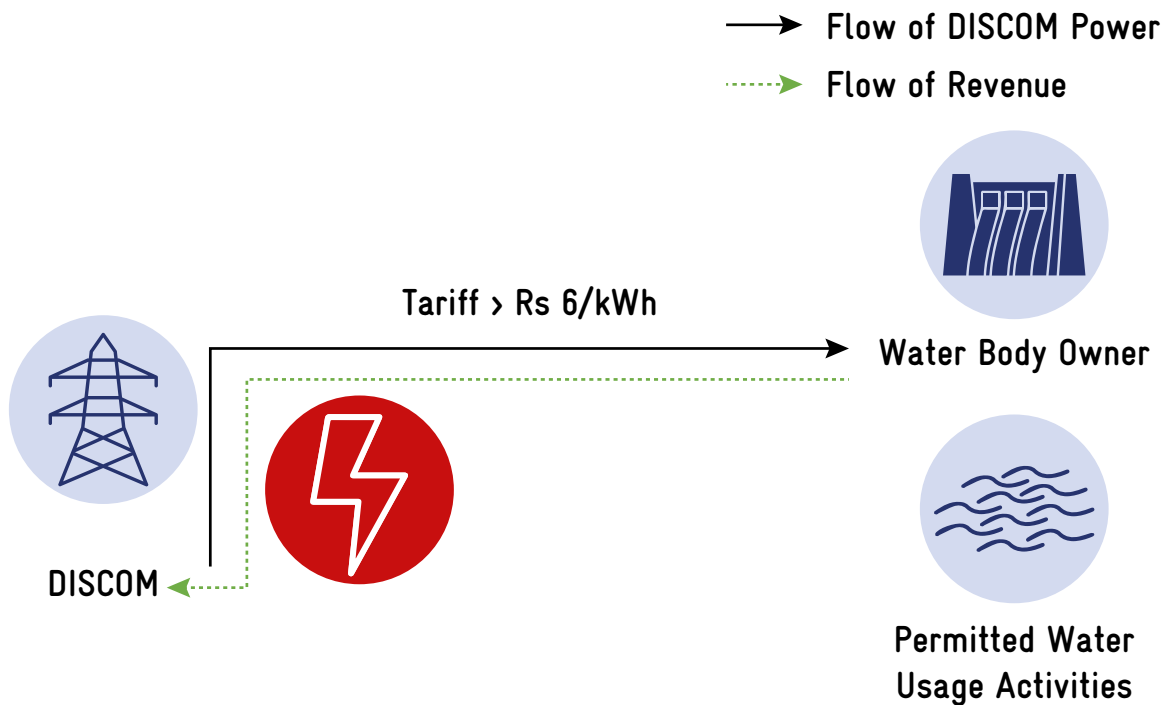


Figure 7: Business-as-usual water related commercial activities

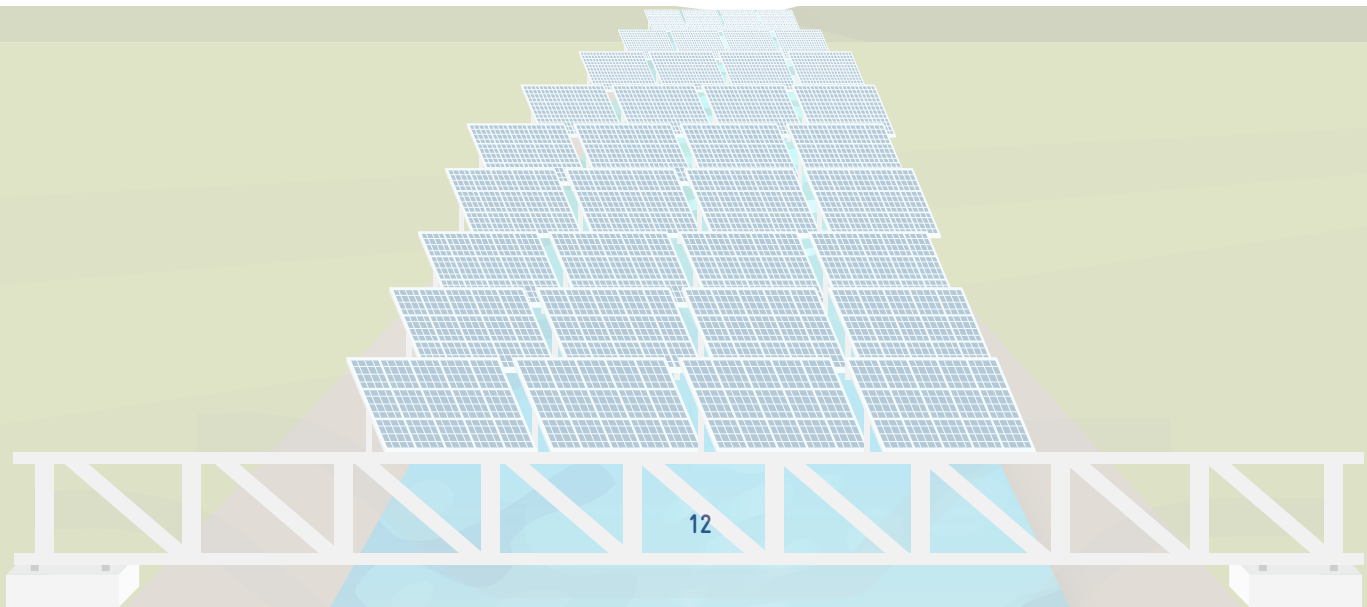


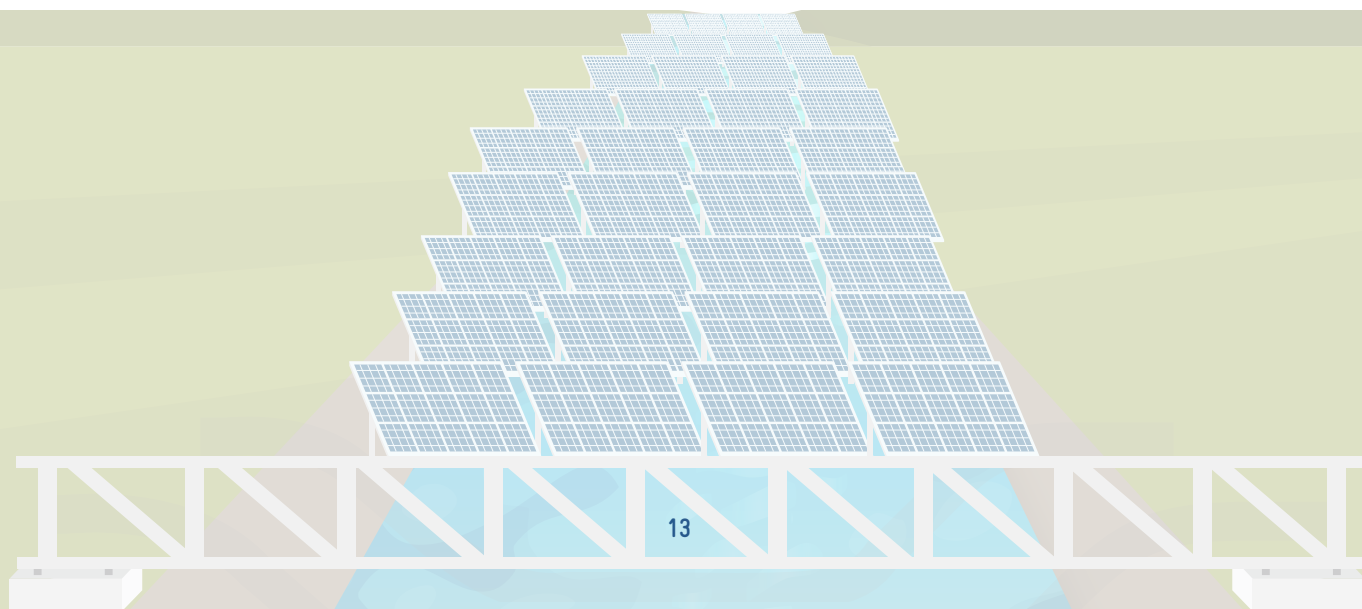
Table 4: Business-as-usual scenario for canals in India

S. No	Stakeholders	BAU/Characteristics
1	Water Body Owner	<p>The water body owner can be the water supply department that physically and legally owns the asset. Some other departments include - the irrigation department, state government, Public Sector Companies, etc.</p> <p>The water body owner can monetise assets by allowing activities in return for usage charges or rent, e.g. Fishing permits levied by the water dept.</p>
2	Activity Owner – Fishing (example)	<p>Revenue-generating activities that are undertaken on the water body, in lieu of rent/usage charges paid to the water body owner.</p> <p>Activities owners engage with water body owners through a working contract. e.g. Fishing department, tourism, etc.</p>

### 3.2. CTPV POWER GENERATION FOR SELF-CONSUMPTION

The business model includes the participation of a project aggregator, also known as a project proponent, with the responsibility of overseeing end-to-end project installation by developers. This is considering the assumption – that the water body owner would prefer to limit its involvement in a project only from an energy standpoint, due to a lack of expertise in the power sector. Examples of project proponents include – SECI, SNA, etc

The project proponent ensures that the project meets technical standards and generates clean power as per specification for the use by the water body owner. The water body owner may not have a corresponding load to consume all the power, in which case, the project proponent may choose to sell partial energy generated through sale to DISCOM or through sale to open access (figure 8). This scenario for business viability for the project proponent has been described in the following section.



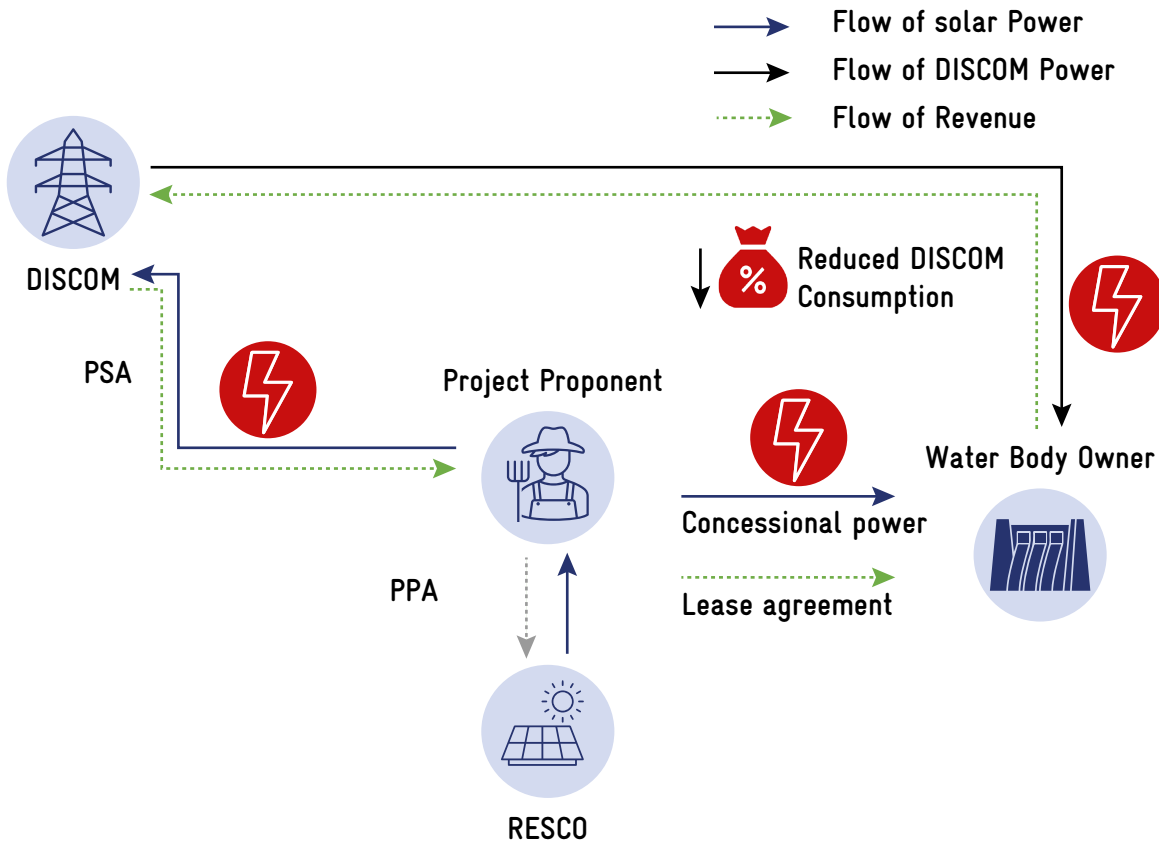


Figure 8: CTPV self-consumption Model

**Project proponents (SECI, NTPC, NHPC, SNA)**

- Aggregating agencies that sell power generated from CTPV project to DISCOM (PSA)
- Engage project developers through tender under Build Own and Operate model

**Project developers (RESCO developers)**

- Developers that install/operate and maintain CTPV project for optimum energy generation
- PPA with Project Proponents for sale of complete power
- Provide rent to water body owner for use of asset through rent agreement

**Water body owner (irrigation department, municipal department.)**

- Monetise assets by allowing power generation activities in return for usage charge (rent INR/Sq m)
- Designated entity may also consider additional revenue from sale of REC @ INR 1.10 per unit of clean energy generation

Table 5: CTPV self consumption activity framework

Operation	Project Developer	Project Proponent	DISCOM	Water Body Owner
Water body owner consumes power partially, Project proponent maximises return by sale to DISCOM or through LTOA	<p>Sets up CTPV project, ensures optimum generation for the project duration.</p> <p>Ensures PPA with Project Proponent @ LCOE, complies with other contractual requirements.</p> <p>Engages in rent agreement with Water Body Owner</p>	<p>Back-to-back contracting with a Project developer</p> <p>Aggregates several canal sections and bids collectively</p> <p>Ensures contractual engagement of project developer</p> <p>Supplies partial power for captive consumption of water body owner (at marginal rates)</p> <p>Maximum revenue by -</p> <ul style="list-style-type: none"> <li>Selling the remaining generation to bulk captive consumers through open access at a higher rate (greater than PPA).</li> <li>Sale to DISCOM as lesser than equal to APPC.</li> </ul>	<p>Contractual requirement for third-party captive consumption.</p> <p>Engages through PPA with Project Proponent for purchase of power at APPC for the quantum of power from the CTPV plant.</p>	<p>Shelves off expensive utility units for cheaper power from captive consumption</p> <p>May also receive additional rental income from the developer</p>

### 3.2.1. PARTIAL SELF CONSUMPTION SCENARIO

We have considered the lower limit of LCOE under this scenario, i.e., INR 5.89 per kWh for a 1 MW CTPV project. For states with tariffs for water body consumers higher than LCOE makes immediate viability (e.g., Maharashtra, M.P, etc). However, states with lower utility prices will require subsidy components. Under this scenario, the subsidy required to ensure project viability is 35% of the project cost.

Under this scenario, we have considered the utility tariff for the water body owner to be INR 6 per unit and build on project viability. The assumptions under the scenarios include

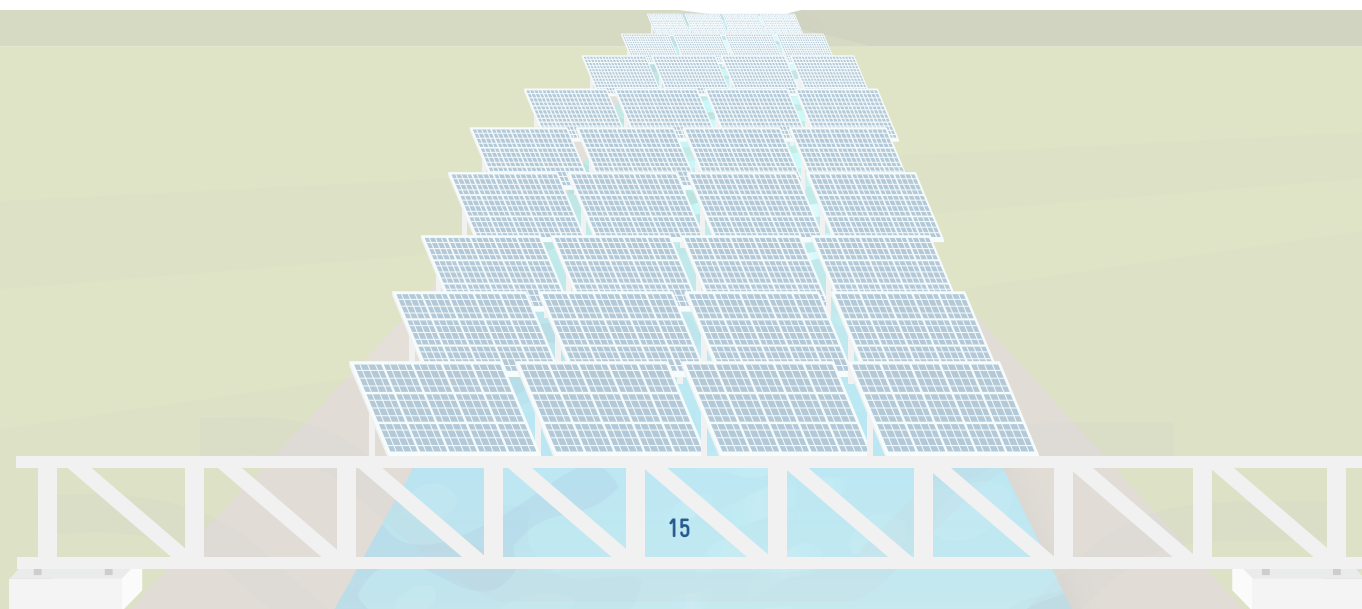


Table 6: Assumption parameters for partial self-consumption and sale to DISCOM

**Project parameters**

Project capacity	MW	1
Project cost	INR Lakh	621
VGf infusion	%	25%
Effective LCOE	INR/kWh	5.1
Percentage captive consumption by water body owner	%	30% (300 kW)
Percentage sale to DISCOM	%	35%
Percentage sale to LTOA	%	35%
Project proponent margin	INR/kWh	0.07
Utility price displaced- water body owner	INR/kWh	6

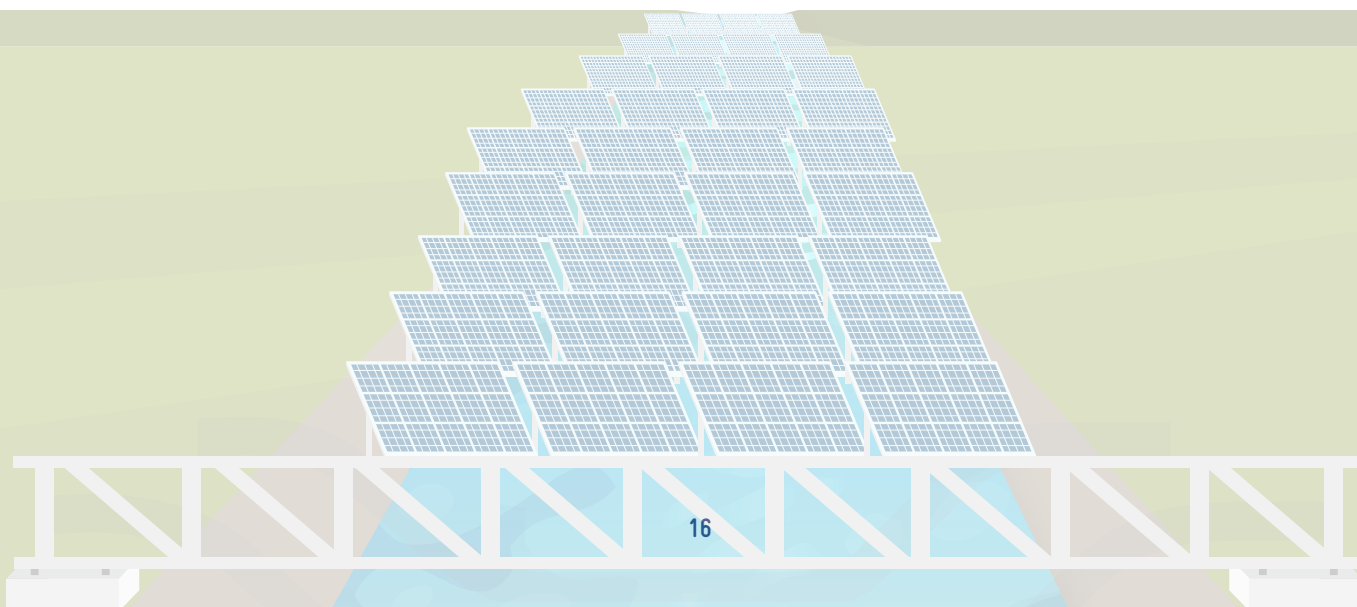
Here, the involvement of the project proponent is key in ensuring project viability, by owning the project. The project proponent charges a margin (7 paise per unit) as transaction charges for implementing the project from the water body owner. In addition, the project proponent also charges one-time upfront cost of INR 10 Lakh for undertaking bid process management. The project proponent ensures overall project viability through sales to DISCOM and LTOA. These cumulative costs for the project proponent, ensure project viability, with project IRR greater than 13% and payback of 8 years for the project proponent.

Other assumptions for calculating project proponent viability include.

Table 7: Project proponent transaction cost parameters

**Project proponent – transaction costs**

PSA – FiT – sale to DISCOM (average APPC)	INR/kWh	4.50
PPA –developer tariff (effective LCOE)	INR/kWh	5.1
% Sale to OA (% of total power)		35%
Avg. open market price of electricity (LTOA)	INR/kWh	6.50
Project proponent bid process management cost	INR Lakh	10.00
Per unit sale of captive units (+ margin)	INR/kWh	5.12



Project viability for the project proponent is ensured with +NPV and IRR>13% as illustrated in Table 8 below. Similarly, IR +NPV ensures net benefit.

**Table 8: Project proponent calculations**

Project proponent calculation	Years-->	0	1	2	3	4	5
Energy generation	kWh		15,82,713	15,82,713	15,82,713	15,82,713	15,82,713
PSA - DISCOM	INR Lakh		25	25	25	25	25
Revenue from captive power sale	INR Lakh		24	24	24	24	24
Revenue from sales to open access	INR Lakh		36.0	36.0	36.0	36.0	36.0
Cash inflow	INR Lakh		85.2	85.2	85.2	85.2	85.2
RESCO payment	INR Lakh		80	80	80	80	80
Lease payment	INR Lakh		0.0	0.0	0.0	0.0	0.0
Transaction cost	INR Lakh	10	6.2	6.2	6.2	6.2	6.2
Cash outflow	INR Lakh	-10.0	-86.1	-86.1	-86.1	-86.1	-86.1
FCF	INR Lakh	-10.0	-0.9	-0.9	-0.9	-0.9	-0.9
CFCF	INR Lakh	-10.0	-10.9	-11.8	-12.7	-13.6	-14.5
IRR		18%					
NPV	INR Lakh	₹86.48					
Payback period		8					

The importance of assessing this scenario is for estimating % Capex of viability fund. However, a key variable in this case is the falling cost of equipment's prevalent in the market underway. Like any new technology, CTPV tariffs are expected have a significant reduction in its cost of equipment, resulting in reduced effective project cost. Therefore, an increasing number of CTPV installation supported with VGF during initial phases, will push for subsidy withdrawal and enable project viability on its own.

*Additionally, the water body owner is the net beneficiary with net positive NPV for the entire duration of 25 years.*

Table 9: Water body owner calculations

Water body owner calculations	Years-->	0	1	2	3	4	5
Utility cost escalation	INR/kWh		6.00	6.12	6.24	6.37	6.49
Utility bill savings	INR Lakh		28.5	29.1	29.6	30.2	30.8
Revenue from lease	INR Lakh		0.2	0.2	0.2	0.2	0.2
Total savings - cash inflow	INR Lakh		28.7	29.3	29.8	30.4	31.1
Cash outflow - clean power captive	INR Lakh		24.3	24.3	24.3	24.3	24.3
FCF	INR Lakh		4.4	4.9	5.5	6.1	6.7
NPV	INR Lakh	₹88.13					

### 3.3. KEY LEARNINGS FROM CTPV BUSINESS MODELS

Key learnings from the CTPV models include -

- The learnings are not anyhow related to above explanation to the high cost of CTPV, project feasibility will rely on subsidies during the initial years. The reduction in CTPV tariff below average utility rate of the water body owner (INR 6 per kWh) will occur with scale and market competition, however, as the water body owner would seldom offtake all the power generated from the project, the onus lies on the project proponent to ensure viability by sale to DISCOM or Open Access consumers.
- Most canals are owned by government departments, that do not levy any rent on the use of water bodies. CTPV can help meet renewable energy targets set by most government departments.



# CAPACITY PROJECTION OF CTPV IN INDIA (2024-40)

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04

India has witnessed significant growth in electricity demand over the years, driven by numerous factors such as population growth, urbanisation, industrialisation and rising standards of living. This has led to a rising need for electricity in residential, commercial and industrial sectors. Additionally, the expanding middle class and improving living standards have resulted in increased usage of appliances and electronic devices, further driving up electricity consumption. This surge in electricity demand has posed both opportunities and challenges for the country's energy sector.

In 2021-22, the power demand of India was 1,374 billion units (BU) and is expected to reach 1,500 BU during 2022-23<sup>1</sup>. As per the Central Electricity Authority (CEA)'s optimal generation capacity mix report for 2029-30, the demand is further expected to reach 2,280 BU by 2030<sup>2</sup>. The current installed RE capacity as of July 2023 is around 177 GW. Within this, solar PV capacity takes a lead, contributing a cumulative capacity of 71 GW, followed by wind energy at 44 GW, bioenergy at 11 GW and hydro power at 51 GW. The percentage share of RE in total installed capacity is around 42%<sup>3</sup> and is estimated to reach 60% by 2030 (excluding pumped storage power). The solar PV installed capacity is expected to increase at a compound annual growth rate (CAGR) of 20% from 71 GW in 2023 to 293 GW in 2030 (CEA Optimal energy mix 2029-30). Thereby making it the largest among all other sources of power generation.

The International Energy Agency has also done some similar demand projections for electricity in India under the following scenarios:

- **The Stated Policies Scenario (STEPS):** assumes that the pandemic is gradually brought under control in 2021. Against that backdrop, it assesses the direction in which today's policy settings and targets seem likely to take the energy sector in India, taking into account a range of real-life constraints that might affect their realisation in practice.
- **The India Vision Case (IVC)** takes a more optimistic stance on the speed of economic recovery and long-term growth, and on the prospects for a fuller implementation of India's stated energy policy ambitions.
- **The Delayed Recovery Scenario (DRS)**, by contrast, examines the implications of a more prolonged pandemic with deeper and longer-lasting impacts on a range of economic, social and energy indicators than is the case in the STEPS.
- **The Sustainable Development Scenario (SDS)** takes a different approach, working backwards from specific international climate, clean air and energy access goals, including the Paris Agreement, and examining what combination of actions would be necessary to achieve them.

<sup>1</sup> Outlook India, Power Consumption Grows 9.5% To 1,503 Billion Units In 2022-23: Govt Data, Aug 2023

<sup>2</sup> CEA, Report on Optimal Generation Mix 2030- version 2.0, Apr 2023

<sup>3</sup> MNRE and CEA installed Capacity Reports

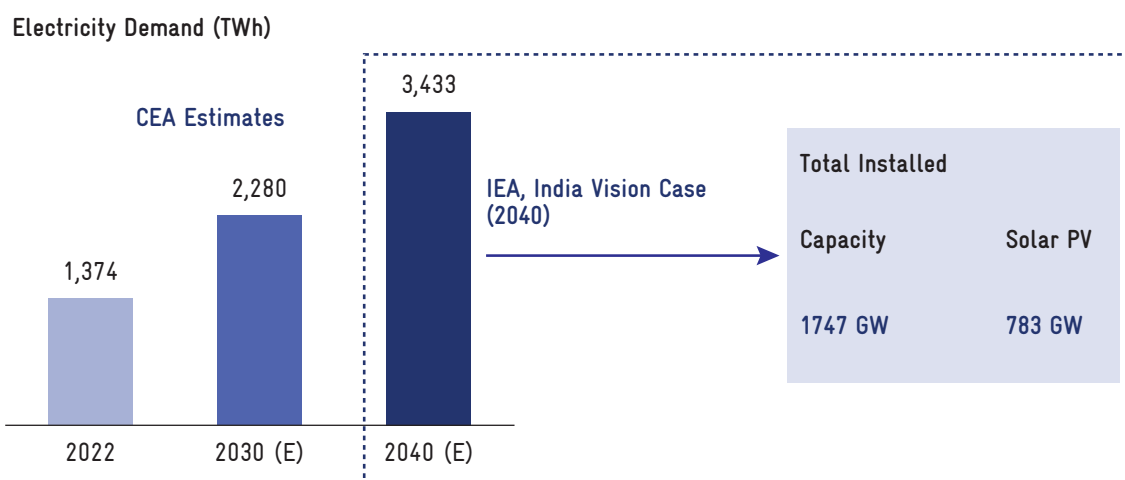


Figure 9: Electricity demand of India in 2030 and 2040

Source: CEA Optimal Energy Mix 2029-30 and India Energy Outlook 2021 (IEA)

The IVC scenario, considers the achievement of 450 GW of non-hydro renewable energy capacity by 2030, with a higher level of financial de-risking supported by an enabling regulatory environment. Further, it encompasses higher penetration of natural gas for power generation and batteries for widespread uptake of electric vehicles in the transport sector along with bioethanol/biodiesel as a fuel. A longer-term focus on the industrial sector's deep decarbonisation, which entails a boost in carbon capture and storage technology, along with early efforts to investigate hydrogen production pathways that result in some initial output from low-carbon sources. The estimated installed capacity is illustrated below for 2030 and 2040.

## 4.1. CAPACITY PROJECTION OF NISAs

For calculating the capacity for NISAs based on the IVC scenario, three different cases were considered

- **Business as usual (BAU):** the total solar PV installed capacity remains the same as stated under IEA's IVC scenario, i.e., 783 GW by 2040, with no additional NISA getting installed by 2040. The solar PV mentioned here only covers ground mount and rooftop solar.
- **Moderate:** the total solar PV installed capacity remains the same as stated under IEA's IVC scenario, i.e., 783 GW by 2040. It is assumed that under this scenario the percentage share of NISA grows to 10%, which will be 78 GW and the rest is ground mount and rooftop solar PV.
- **Optimistic:** the total solar PV installed capacity remains the same as stated under IEA's IVC scenario, i.e., 783 GW by 2040. It is assumed that under this scenario the percentage share of NISA will be 30%, which will be 235 GW, followed by ground mount solar at 50% and rooftop at 20%.

Table 10: Capacity projection scenarios of NISAs

Total solar PV installed capacity (2040)	BAU		Moderate		Optimistic	
	% Share	Cumulative capacity (GW)	% Share	Cumulative capacity (GW)	% Share	Cumulative capacity (GW)
		783		783		783
Ground mount	90%	705	60%	470	50%	392
Rooftop solar PV	10%	78	30%	235	20%	157
NISA	0%	-	10%	78	30%	235

Based on the above scenarios, the annual Capacity of NISAs for both moderate and optimistic scenarios is illustrated below. The Capacity projections for each NISAs are done using the optimistic scenario trajectory.

Annual Demand of NISAs (GW)

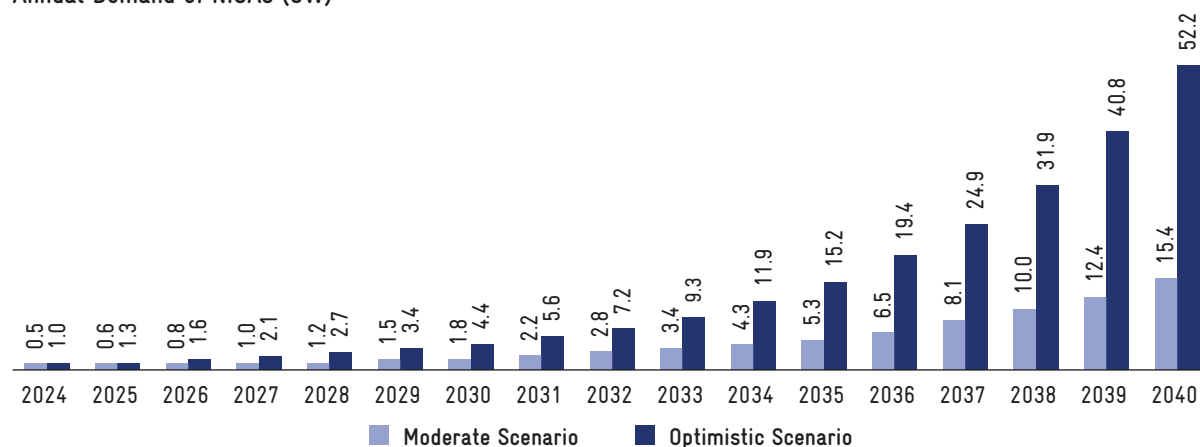
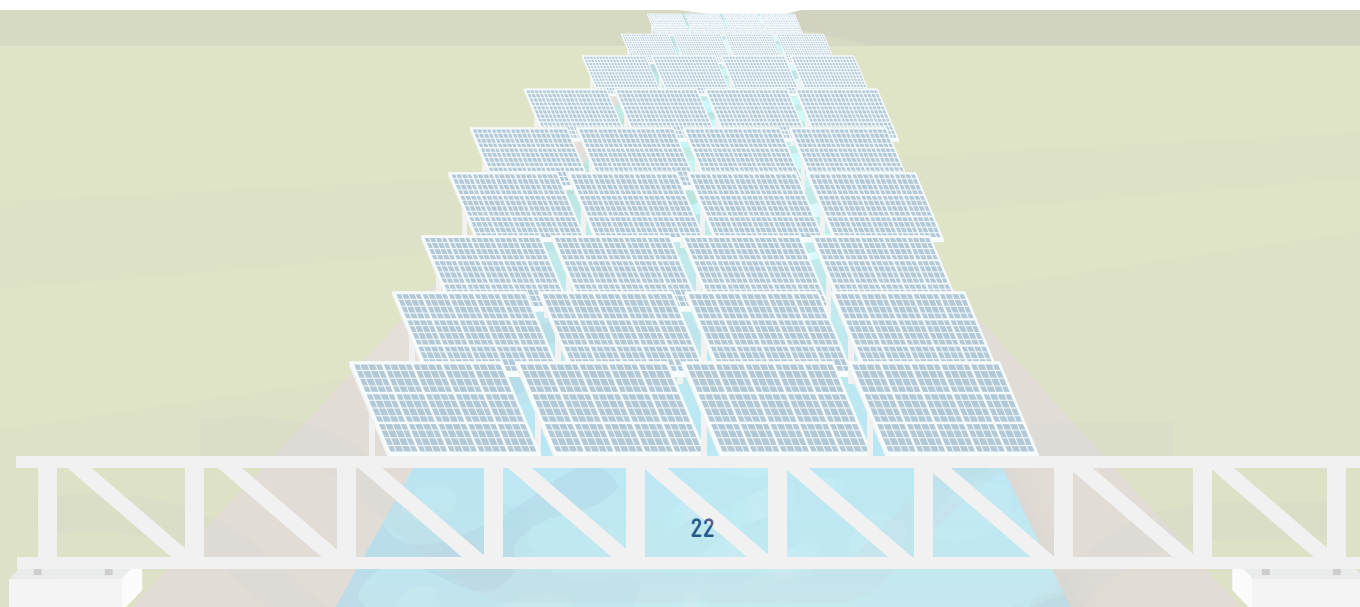


Figure 10: Annual demand of NISAs (moderate and optimistic case)



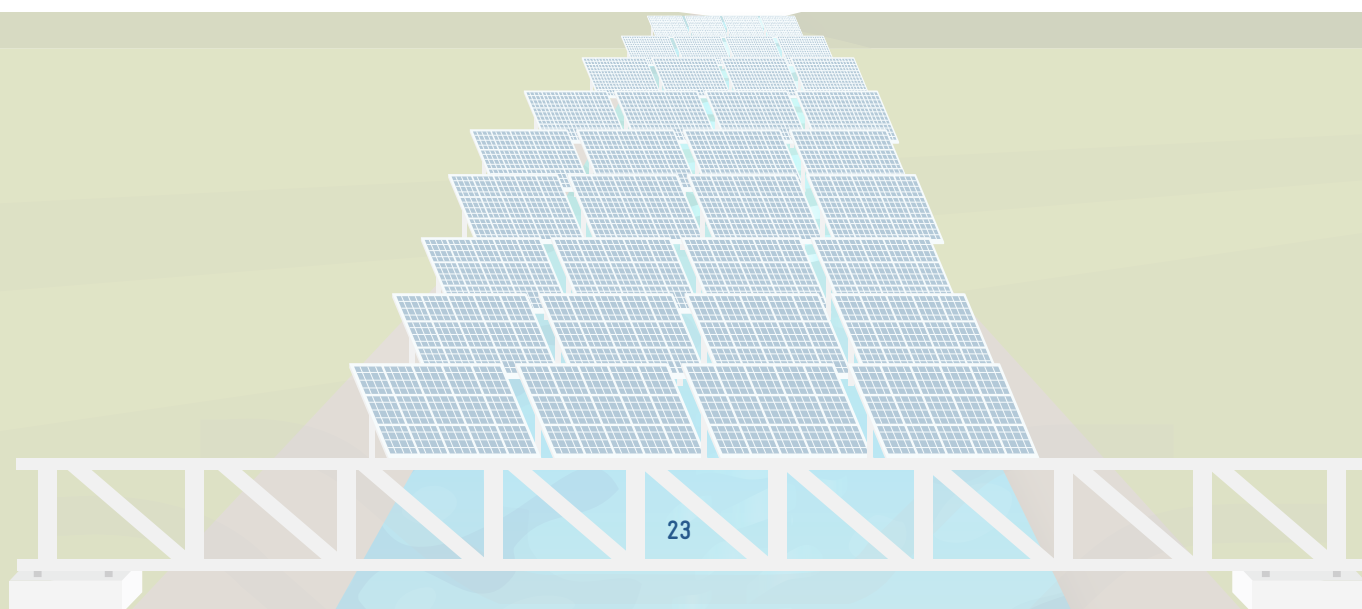
## 4.2. PENETRATION OF CTPV AMONGST OTHER NISAs (2024-40)

Amongst all NISAs, it is challenging to predict with certainty which specific solar integration technology will penetrate more in India by 2040. However, based on current trends, considerations, stakeholder inputs and future demand, some key observations are highlighted in Table 11.

Table 11: Penetration matrix of NISAs

Annual penetration matrix of NISAs	% Share	2024		% Share	2030		% Share	2040	
		Annual Demand (Moderate) MWp	Annual Demand (Optimistic) MWp		Annual Demand (Moderate) MWp	Annual Demand (Optimistic) MWp		Annual Demand (Moderate) MWp	Annual Demand (Optimistic) MWp
CTPV	15%	75	150	12.5%	226	551	10%	1,542	5,225
Other (FPV, APV, BIPV, RIPV)	85%	425	850	87.5%	1,583	3,857	90%	13,879	37,880

- **Floating solar PV:** Due to their potential for using water bodies like reservoirs, lakes, and ponds, floating solar power projects have gained popularity both internationally and in India. The use of floating solar projects is projected to rise in the upcoming years due to India's abundant water bodies. The capacities that are being installed in India are usually in Megawatts, with LCOE ranging between 3 to 4 Rs per unit, therefore making it one of the most feasible technologies amongst all NISA in the initial years. The current penetration level is considered to be 50% in the initial years and will be reduced to 35% by 2040.
- **Agrioltaics:** land utilisation plays a significant role in the implementation of Agri PV in India, which allows dual use of land where power generation, as well as an agricultural activity, can simultaneously take place on a single piece of land. Given the enormous potential of Agri PV found under this project it is expected to penetrate from 18% to 27.5% from 2024 to 2040 amongst all other NISAs.
- **Canal top solar PV:** India has already witnessed the implementation of canal top solar projects in certain regions under the MNREs pilot scheme for canal top and canal bank solar PV projects. Presently the penetration of canal top projects is assumed at 15 percent and is expected to decrease to 10% by 2040 as other NISAs also grow.



- Rail/Road integrated PV:** The Indian railways has invited bids for 3 GW solar projects on vacant land parcels and land parcels along the railway track through Railway Energy Management Company Ltd. (REMCL). Given this ongoing procurement, the current penetration level is 10% amongst all NISAs and further reduced to 12.5% by 2040. For Roadways there has been no target or long-term vision, hence for estimating Capacity for road-integrated PV, it is assumed that new projects might take off a bit late (after 2028) as compared to other NISAs.

Based on the above trends and assumptions, the annual capacity projection for CTPV is illustrated below for both moderate and optimistic cases.

Annual Demand of NISAs (GW)

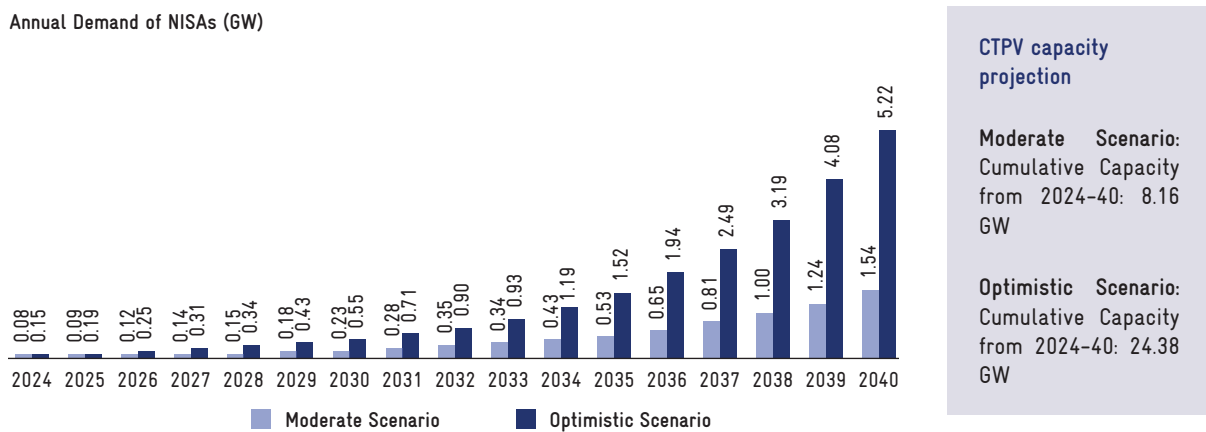
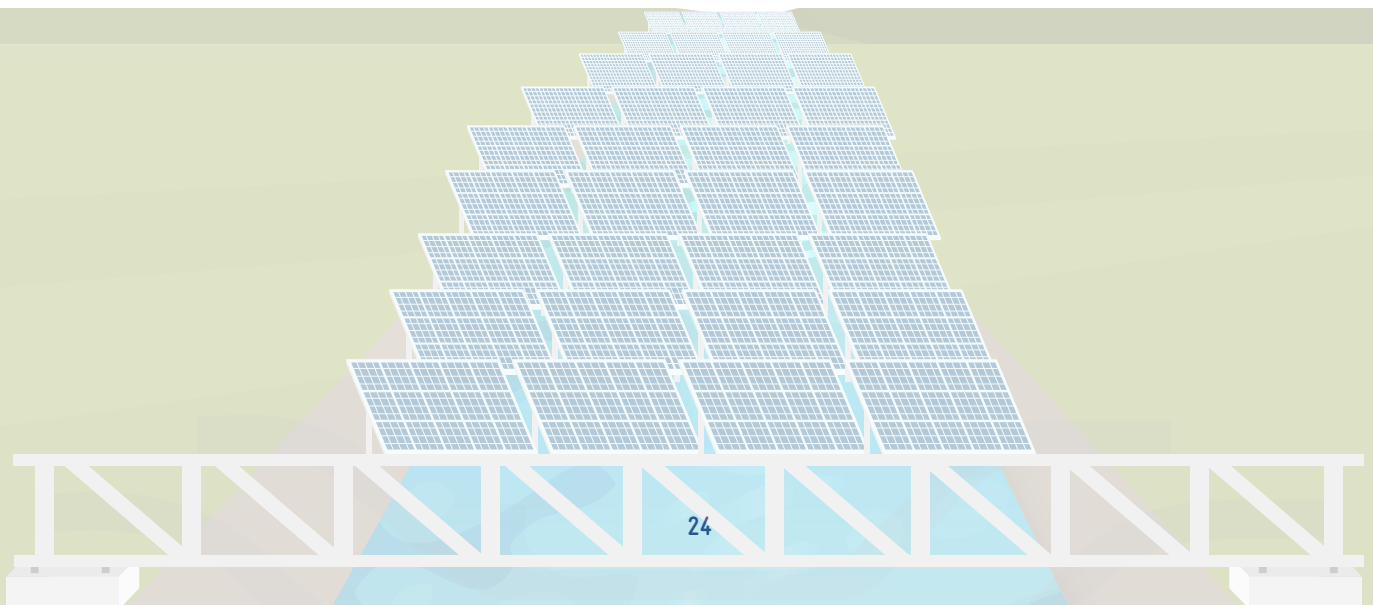
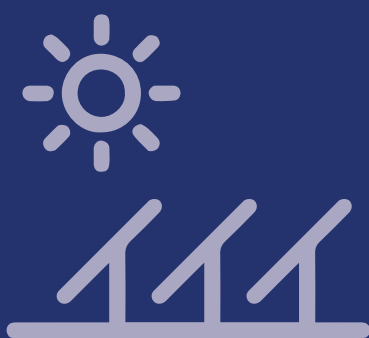


Figure 11: Capacity projections of CTPV from 2024-40





# FINANCING CTPV IN INDIA

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05

## 5.1. INTERVENTIONS TO SUPPORT THE FINANCING OF CTPV

Governments, financial institutions, and development organisations throughout the world are supporting clean energy projects through various means such as budgetary support, easy finance and running various programs for building the right ecosystem respectively. These are primarily done for various reasons such as:

- Overcoming barriers to developing renewable energy; and
- Promoting the adoption and growth of renewable energy

The section will primarily cover government interventions. These interventions can be classified into two types:

- Capital support
- Revenue support

Capital support reduces the capital required for the project and therefore reduces the requirement of debt to be raised and equity infusion. Revenue support comes every year once the project gets commissioned and therefore, it does not reduce the capital requirement.

Below are some of the interventions classified under both heads:

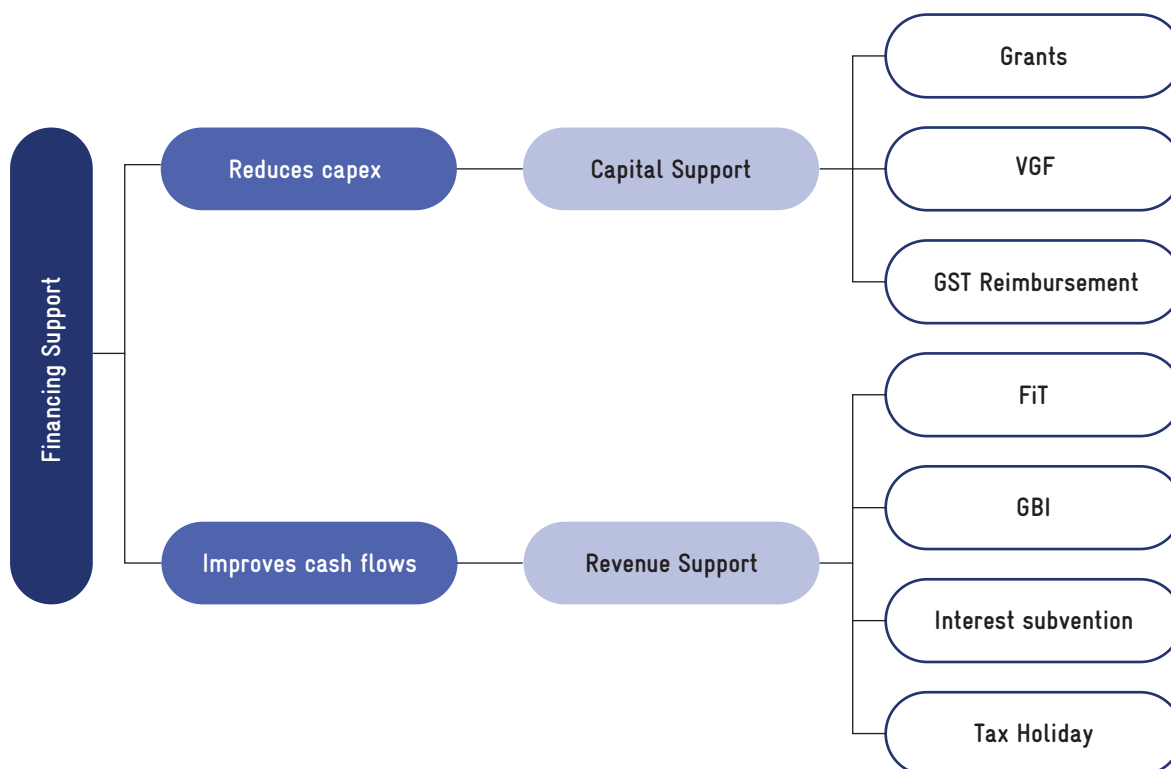


Figure 12: Financing interventions

A comparative analysis of the above interventions is shown in the table below:

Table 12: Comparative analysis of financing interventions

	Type	Impact on developer	Impact on Exchequer
Grant	Capital support	Reduces the funding obligation upfront	Upfront burden
VGF	Capital support		
GST reimbursement	Capital support	It does not reduce funding obligations upfront but boosts cash inflow once reimbursement is met.	
FiT	Revenue support	Improves the cash flows	Benefits need to pass over a period based on KPI. Therefore, a monitoring and disbursement agency needs to be appointed
GBI	Revenue support		
Interest subvention	Revenue support	Reduces the financing cost	Benefits need to pass over a period but no disbursement or monitoring is required.
Tax holiday	Revenue support	Reduces tax burden but developers generally use financing instruments such as quasi-equity instruments to reduce the tax burden	

### GRANTS:

Grants in the renewable sectors refer to financial assistance provided by governments, non-profit organisations and other entities to support the development, installation or research of new technologies. The funds can be used to offset the upfront expenses and make solar installations more affordable for individuals, businesses, or communities. The implementation of pilot demonstration projects may be supported through grants. These initiatives demonstrate the viability and advantages of any project in practical contexts like residential communities, business structures, or public infrastructure. Equipment, installation, and monitoring costs might all be partially covered by the financing.

### VIABILITY GAP FUNDING (VGF):

Viability Gap Funding (VGF) is a financial assistance to close the financial gap between project costs and expected developer revenues. It tries to make projects profitable and appealing to private investors. The VGF mechanism was established by the Indian government under the Jawaharlal Nehru National Solar Mission (JNNSM) in 2013 to support grid-connected solar power plants. Through a process of open competition, the government supplies VGF. For instance, solar projects were chosen through a reverse auction procedure in Phase-II Batch-I of JNNSM where developers stated their tariffs. The government awarded the projects with the lowest tariffs, and VGF was granted to close the viability gap and support the projects' financial sustainability.

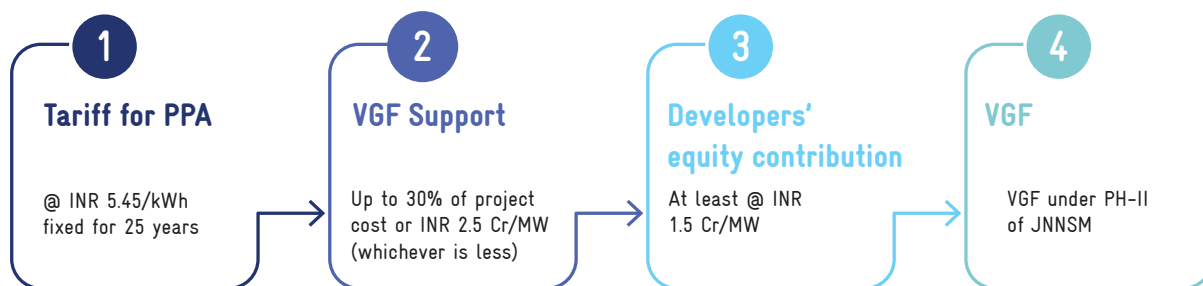


Figure 13: Viability gap funding under Ph-II of JNNSM

### FEED IN TARIFFS:

Governments utilise feed-in tariffs (FiTs) as a policy tool to promote the use of renewable energy technology, particularly in the production of electricity. It is a type of monetary reward given to producers of renewable energy, who are often individuals or companies, for the electricity they produce and feed into the grid. The government or regulatory authority establishes a predetermined payment rate per kilowatt-hour (kWh) of electricity produced by renewable energy sources under a feed-in tariff programme. This rate is often guaranteed for a specific period, frequently between 10 and 20 years. A reasonable return on investment for the renewable energy project is ensured by the payment rate level.

To give producers of renewable energy a financial incentive, feed-in tariffs are often higher than the going rates for power on the market. This helps to make renewable energy technologies more economically viable and appealing to investors by offsetting their greater upfront costs.

Feed-in tariffs' primary goals are to encourage the growth of renewable energy projects, raise their proportion in the total energy mix, and lower greenhouse gas emissions. Feed-in tariffs minimise the financial risks involved with such investments by ensuring a fixed payment rate and offering renewable energy providers a steady and predictable revenue stream. Many nations around the world, including Germany, Spain, and numerous other European countries, have effectively implemented feed-in tariffs. To assist the development of renewable energy, several nations have switched to alternate mechanisms such as auctions or quota systems. It is important to note that the acceptance and efficacy of feed-in tariff schemes have fluctuated over time.

### INTEREST SUBVENTION:

Interest subvention in solar projects refers to a financial support mechanism where the government or another entity provides a subsidy or reduces the interest rate on loans taken for financing solar energy projects. It aims to make the cost of borrowing for solar projects more affordable, thereby incentivising investment in the sector. In certain situations, the government might offer a subsidy or reimburse a portion of the interest paid by the borrower rather than lowering the interest rate directly. Direct payments or interest amounts offset against taxes or other debts may be used to accomplish this. Here's how interest subvention typically works for a renewable energy plant:



Figure 14: Steps of interest subvention

#### GENERATION-BASED INCENTIVE:

A generation-based incentive (GBI) is a financial incentive offered by the government to encourage the production of energy from solar power facilities. The GBI scheme provides solar power developers with a subsidy based on the actual electricity generated to encourage them to produce clean and renewable energy.

Developers of solar power gain an extra incentive under the GBI programme for each unit of electricity their solar power plants generate. Usually, this incentive is given in addition to the money made by selling electricity to the grid. The GBI aids in closing the cost gap between the production of conventional power

and the production of solar power, increasing the viability of solar projects.

- In 2008, India implemented the first generation-based incentive (GBI) for renewable energy, including solar electricity. As a component of the Jawaharlal Nehru National Solar Mission (JNNSM), the Indian government introduced the GBI initiative.
- The GBI programme was initially developed for solar photovoltaic (PV) power projects to encourage the construction of grid-connected solar power plants. In addition to the applicable feed-in tariff (FIT) or power purchase agreement (PPA) prices, the GBI was offered to the power producers.
- The GBI programme was created to last from 2010 to 2020, ten years. However, because each state in India had the freedom to choose whether to adopt the GBI plan and set its unique terms and conditions, the GBI's implementation and length differed among the country's various states and regions.
- Presently, new mechanisms like competitive bidding, tariff-based auctions, and subsidies under various state and central government schemes are being adopted to support renewable energy development in India. However, GBI provided a push to achieve a larger participation and portfolio development in the initial years.

### TAX HOLIDAY

A tax holiday is a governmental incentive that temporarily reduces or eliminates taxes for businesses. By providing a tax holiday for a specified number of years, the effective tax rate in those years shall be zero. The business losses and /or unabsorbed depreciation guidelines may remain as such. Such a scheme reduces the tax outgo and hence boosts the cash flows and hence returns. This will enable developers lower the LCOE.

## 5.2. CAPTURING LENDER'S PERSPECTIVE

Lenders evaluate borrowers from a financial and risk perspective to determine whether they are creditworthy and whether it is prudent to lend money to them. Lenders will decide the SOP basis on the borrower, whether it is an individual or a company. However, canal top solar power plants are typically developed by Renewable Energy Service Companies (RESOs) or companies rather than individuals. These projects require significant financial resources, technical expertise, and regulatory approvals, making them challenging for individual investors or borrowers to undertake on their own. Lenders want to ensure that the company or RESO (borrower) has the financial strength, technical expertise, and operational capability to successfully execute and maintain the CTPV project. The perspective on borrowers is typically decided by considering various factors as highlighted in the following table.

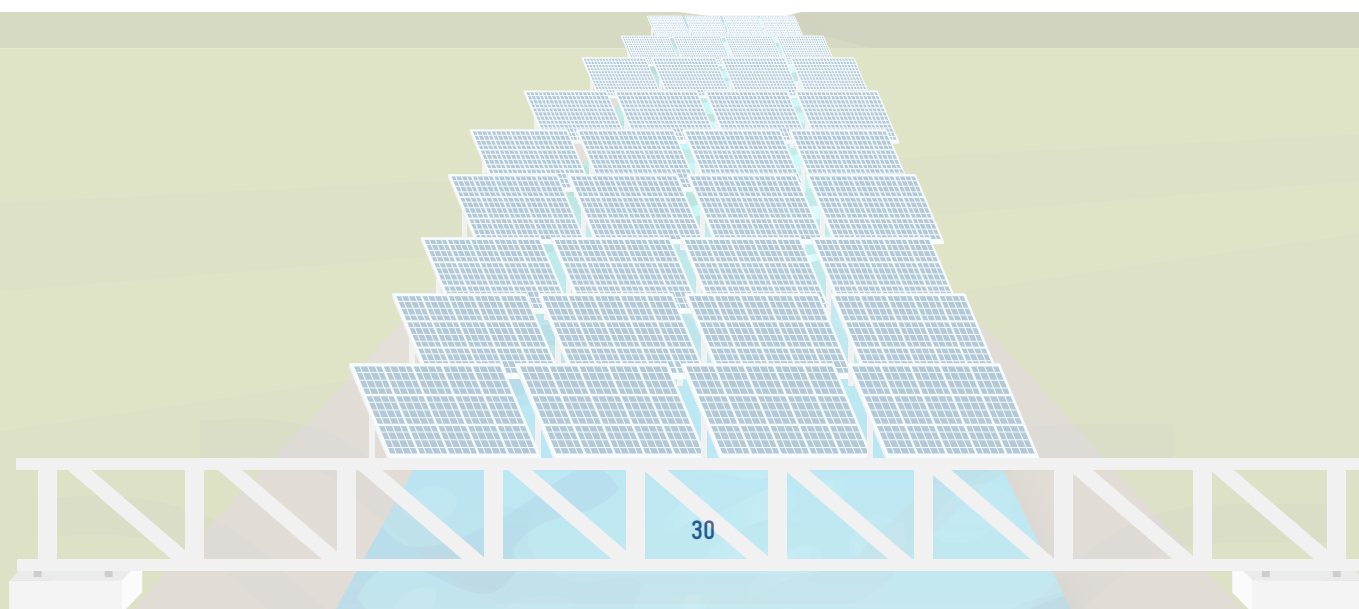


Table 13: Information required by lenders from borrowers

Category	Canal Owner (State Government/Departments)	Company (RESCO)
Information required by lender from borrower	<p>The end use of the funds – for the project</p> <ul style="list-style-type: none"> <li>• Details of CAPEX and technology</li> <li>• Vendors from whom procurement will be done</li> <li>• Queries may be asked about the protection of PV systems against theft, vandalism and natural disaster, maintenance mechanism etc.</li> </ul> <p>For the said purpose, hypothecation/mortgage/assignment of pertinent movable and immovable assets may be opted</p>	<p>About promoters</p> <ul style="list-style-type: none"> <li>• Experience of promoters</li> <li>• History of default of promoters or any of the affiliates of promoters</li> <li>• Director's profile</li> <li>• Reputation</li> <li>• Financial health – the ability to bring corresponding equity, group leverage</li> <li>• Nature of promoter contribution instruments</li> <li>• Corporate governance</li> <li>• Credit rating</li> <li>• About project company</li> <li>• Experience with the project company</li> <li>• Details of concession/contract</li> <li>• Details of technology and suppliers</li> <li>• Management profile</li> <li>• Credit rating</li> <li>• Leverage – debt to equity, debt to earnings before interest, taxes, depreciation, and amortisation (EBITDA)</li> <li>• Projected finances around the following profile <ul style="list-style-type: none"> <li>• Debt service coverage ratio (average and minimum)</li> <li>• Debt to EBITDA</li> <li>• Project internal rate of return (IRR)</li> <li>• Loan life coverage ratio</li> </ul> </li> </ul>
Security required	<p>Primary security</p> <ul style="list-style-type: none"> <li>• By Mortgage of borrower's all immovable assets, present and future including the project land.</li> <li>• By Hypothecation of all the borrower's movable properties, including plant and machinery, machinery spares, equipment, tools and accessories, furniture, fixtures, vehicles, stocks and all other movable assets, present and future, and of all Borrower's present and future book debts, bills, receivables, money including bank accounts, claims of all kinds and stocks including consumables and other general stores.</li> <li>• By Assignment. A first charge by way of assignment or creation of security interest including all rights, title, interest, benefits, claims, and demands whatsoever of the borrower.</li> <li>• By Pledge of shares of the project company</li> </ul> <p>Secondary security</p> <ul style="list-style-type: none"> <li>• State government guarantee</li> </ul>	<p>Primary security</p> <ul style="list-style-type: none"> <li>• By Mortgage of borrower's all immovable assets, present and future including the project land (or water body).</li> <li>• By Hypothecation of all the borrower's movable properties, including plant and machinery, machinery spares, equipment, tools and accessories, furniture, fixtures, vehicles, stocks and all other movable assets, present and future, and of all Borrower's present and future book debts, bills, receivables, monies including bank accounts, claims of all kinds and stocks including consumables and other general stores.</li> <li>• By Assignment. A first charge by way of assignment or creation of security interest including all rights, title, interest, benefits, claims, and demands whatsoever of the borrower.</li> <li>• By Pledge of shares</li> </ul> <p>Secondary security</p> <ul style="list-style-type: none"> <li>• Corporate guarantee</li> <li>• Personal guarantee</li> </ul>

## 5.3. INVESTMENT REQUIRED IN CTPV (2024-40)

### 5.3.1. MODERATE SCENARIO (8 GW BY 2040)

Over the past four years, the costs associated with traditional solar power plants have exhibited a fluctuation ranging from INR 3.4 to 4.8 Crore per MW<sup>4</sup>. In contrast, when considering CTPV plants, a greater initial capital expenditure incorporates higher structural cost as it is made in accordance with the canal's width. The expenses for maintenance and cleaning are also higher as the plant is mounted over a water canal and sometimes requires additional resources for cleaning debris under the modules, especially during flooding/monsoon. While the electricity tariff from canal top solar projects may currently be higher than that of utility-scale solar projects, it is anticipated to decrease as the industry matures and benefits from economies of scale and technological advancements.

Under the moderate scenario, the cumulative demand of CTPV in India is projected to be 8.16 GW from 2024 to 2040 (as discussed in Chapter 4). We have assumed 1 MW of CTPV plant having CAPEX of INR 6.21 crore, which is equivalent to an LCOE of INR 5.89/kWh.

Consequently, we have assumed an annual reduction of 2.5% in the capital expenditures (CAPEX), resulting in a gradual decline of the LCOE from CTPV plants, starting from 2024 and extending through 2040. The CAPEX and LCOE for each year are illustrated in table 14 below.

### VGF SUPPORT FOR CTPV:

There are two approaches to assess the VGF amount based on the power that the DISCOM can avoid purchasing.

- **Approach 1: In general, it is expected that this will replace the energy supplied from the coal-fired capacity tied up by DISCOMs.**

It is observed that the national average variable cost of coal-fired power capacity is INR 2.71/kWh<sup>5</sup> for FY 2022-23. This energy is provided from the long-term/medium-term capacities tied up by the DISCOMs under a power purchase agreement. The energy is scheduled and dispatched on day day-ahead basis based on the merit order of stations (from cheapest to highest variable cost).

It is anticipated that any incremental generation from these CTPV sources may help DISCOMs avoid this marginal cost of procurement. Assuming the above as marginal costs for DISCOMs, there is a potential saving of INR 2.71/kWh for DISCOMs in the form of avoided energy procurement.

- **Approach 2: Another approach to assessing the potential savings of DISCOMs is to consider the energy procurement from spot markets for solar hours (i.e., 08:00 – 18:00 hrs). It is observed that the national average power procurement price in the DAM (0800 hrs - 1800 hrs) for FY 2022-23 was INR 5.12/kWh<sup>6</sup>.**

<sup>4</sup> Based on the cost analysis of utility scale solar PV projects conducted by the ISUN team from 2017 to 2023

<sup>5</sup> NITI Aayog, India Climate and Energy Dashboard, <https://iced.niti.gov.in/energy/electricity/distribution/power-purchase>

<sup>6</sup> IEX DAM Prices for FY 2022-23 between 08:00 to 18:00 hours

It is anticipated that generation from these CTPV sources may help DISCOMs avoid this marginal cost of procurement from the spot market during solar hours. Assuming the above as marginal costs for DISCOMs for solar hours, there is a potential saving of INR 5.12/kWh for DISCOMs in the form of avoided energy procurement.

It is apparent that the potential savings for DISCOMs is expected to be in the range of INR 2.71/kWh to INR 5.12/kWh (from Approach 1 and 2 above). When compared with the expected CTPV system energy cost of INR 5.89 kWh (at CAPEX of INR 6.21 Crore per MW), it is observed that there is a realization gap of INR 0.77 to 3.18 /kWh for the developer who will invest and set up the CTPV system. This is equivalent to INR 0.81 to 3.35 Cr/MW of support on CTPV system cost.

For purpose of our analysis we have used marginal cost of procurement under Approach 2 (i.e. INR 5.12 per kWh) as tariff threshold for viability gap eligibility. This means that a tariff rate of INR 5.12/kWh is kept as the benchmark or threshold to determine whether an CTPV project is financially viable or not for the DISCOMs. When the LCOE of CTPV plant is higher than INR 5.12 per kWh. In such a situation, the difference between the LCOE and the INR 5.12 tariff rate is used as Viability Gap Funding (VGF). It is to be noted that VGF will only be required for initial years, when LCOE is greater than tariff viability benchmark.

In our model, the LCOE of CTPV plant and CAPEX is reducing every year therefore the VGF amount per MW will vary for each year. It is calculated by using the following formula:

- Per MW VGF required in 20XX year = (LCOE in 20XX – Tariff Viability) X (Cost per MW (CAPEX)/LCOE in 20XX)

Further, the per MW VGF required amount is multiplied with the associated annual capacity to get the Annual VGF required (INR Crore). Note that for purpose of VGF, escalation / decline in marginal cost of procurement under approach 2 is not considered. However, this threshold tariff can be computed periodically based on historic data (say a quarter) and be VGF may be updated on a periodic basis.

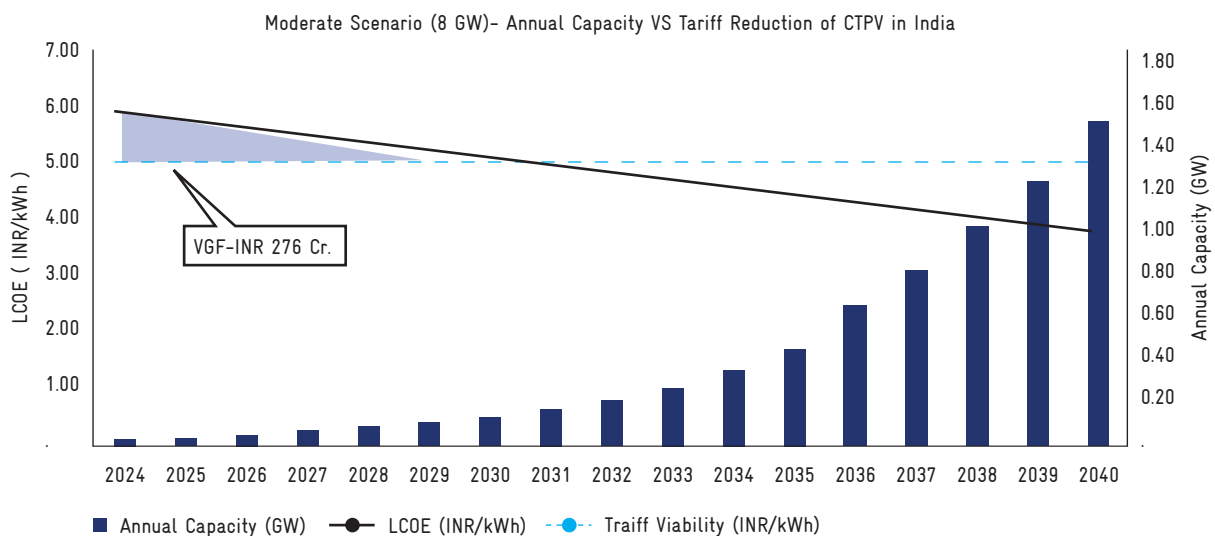


Figure 15: Annual capacity vs tariff reduction of CTPV (moderate scenario)

## CANAL TOP PV IN INDIA

The total VGF required to ensure model viability for the projected capacity in line with the depreciated tariff is calculated as INR 276 Cr for a total capacity of 760 MW till the year 2029-30.

The total investment that will be required to realise the above-mentioned capacity (i.e., 8 GW) will be INR 37,688 Crores to realise this target. The table below highlights the year-on-year capacity and investment potential.

**Table 14: Investment and capacity projection for CTPV (moderate scenario)**

Year	Investment and Capacity Projection for CTPV (Moderate Scenario)				VGF Calculations	
	Annual Capacity (GW)	Cost per MW (INR Crore)	LCOE (INR/kWh)	Investment required (INR Crore)	Per MW VGF required for project viability (INR Crore)	Annual VGF required (INR Crore)
2024	0.08	6.21	5.89	466	0.81	60.89
2025	0.09	6.05	5.74	563	0.66	61.01
2026	0.12	5.90	5.60	680	0.51	58.17
2027	0.14	5.76	5.46	821	0.36	51.02
2028	0.15	5.61	5.32	827	0.21	31.48
2029	0.18	5.47	5.19	999	0.07	13.40
2030	0.23	5.33	5.06	1,206	-	-
2031	0.28	5.20	4.93	1,457	-	-
2032	0.35	5.07	4.81	1,760	-	-
2033	0.34	4.94	4.69	1,701	-	-
2034	0.43	4.82	4.57	2,055	-	-
2035	0.53	4.70	4.46	2,483	-	-
2036	0.65	4.58	4.35	2,999	-	-
2037	0.81	4.47	4.24	3,623	-	-
2038	1.00	4.36	4.13	4,376	-	-
2039	1.24	4.25	4.03	5,287	-	-
2040	1.54	4.14	3.93	6,387	-	-
<b>Total</b>	<b>8.16</b>			<b>37,688</b>		<b>276</b>

Note: The VGF calculations that we have explained above have been derived at CAPEX of INR 6.21 Cr/MW with LCOE of INR 5.89/kWh. However, this is an indicative number based on our discussion and consultations with developers and concerned stakeholder. The per MW cost of CPTV system may vary from INR 6.2 to 6.8 Cr, with LCOE ranging from 5.89 to 6.45/kWh. The VGF may vary from INR 276 to 933 Crores.

### 5.3.2. OPTIMISTIC SCENARIO (24 GW BY 2040)

Under the optimistic scenario, the cumulative demand of CTPV in India is projected to be 24.38 GW from 2024 to 2040. Similar to the moderate scenario, here we have assumed an annual reduction of 3.5% instead 2.5 % in the capital expenditures (CAPEX), resulting in a gradual decline in the LCOE from CTPV plants, starting from 2024 and extending through 2040. The CAPEX and LCOE for each year is illustrated in table 15 below.

Similar to the moderate scenario, we have used marginal cost of procurement under Approach 2 (i.e. INR 5.12 per kWh) as tariff threshold for viability gap eligibility. This means that a tariff rate of INR 5.12/kWh is kept as the benchmark or threshold to determine whether an CTPV project is financially viable or not for the DISCOMs. When the LCOE of CTPV plant is higher than INR 5.12 per kWh. In such a situation, the difference between the LCOE and the INR 5.12 tariff rate is used as Viability Gap Funding (VGF). It is to be noted that VGF will only be required for initial years, when LCOE is greater than tariff viability benchmark.

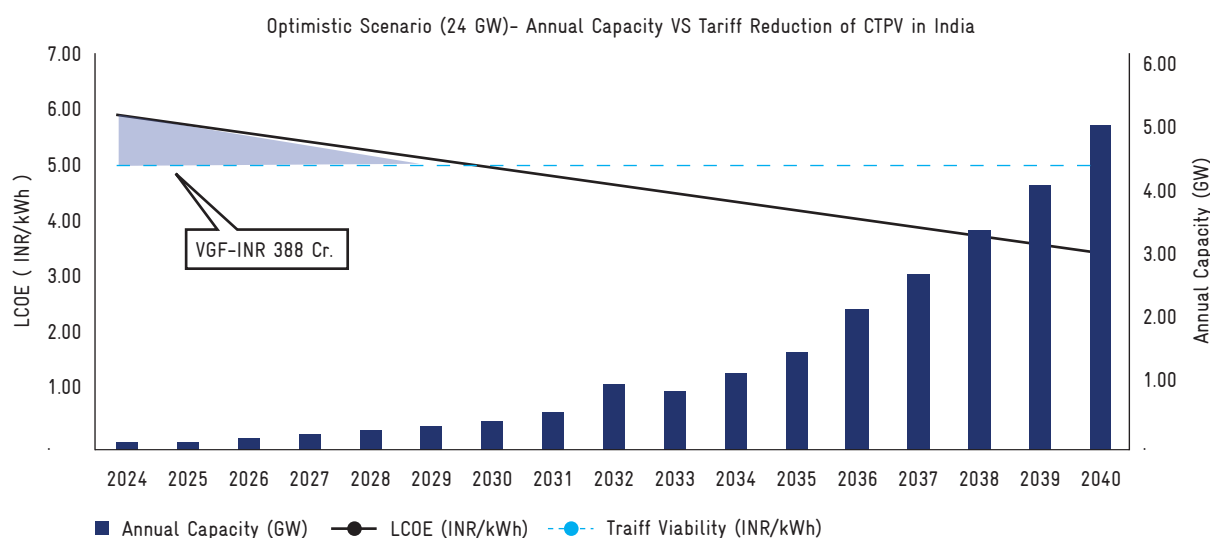


Figure 16: Annual capacity vs tariff reduction of CTPV (optimistic scenario)

The total VGF required to ensure model viability for the projected capacity in line with the depreciated tariff is calculated as INR 388 Cr for a total capacity of 900 MW till the year 2027-28.

The total investment that will be required to realise the above-mentioned capacity (i.e., 24.38 GW) will be INR 98,209 Crores to realise this target. The table below highlights the year-on-year capacity and investment potential.

Table 15: Investment and capacity projection for CTPV (optimistic scenario)

Year	Investment and Capacity Projection for CTPV (Optimistic Scenario)				VGF Calculations	
	Annual Capacity (GW)	Cost per MW (INR Crore)	LCOE (INR/kWh)	Investment required (INR Crore)	Per MW VGF required for project viability (INR Crore)	Annual VGF required (INR Crore)
2024	0.15	6.21	5.89	932	0.81	121.78
2025	0.19	5.99	5.68	1,151	0.59	114.19
2026	0.25	5.78	5.48	1,422	0.38	94.63
2027	0.31	5.58	5.29	1,758	0.18	57.43
2028	0.34	5.39	5.11	1,810	-	-
2029	0.43	5.20	4.93	2,236	-	-
2030	0.55	5.01	4.76	2,763	-	-
2031	0.71	4.84	4.59	3,415	-	-
2032	0.90	4.67	4.43	4,219	-	-
2033	0.93	4.51	4.27	4,171	-	-
2034	1.19	4.35	4.12	5,154	-	-
2035	1.52	4.20	3.98	6,369	-	-
2036	1.94	4.05	3.84	7,870	-	-
2037	2.49	3.91	3.71	9,725	-	-
2038	3.19	3.77	3.58	12,017	-	-
2039	4.08	3.64	3.45	14,849	-	-
2040	5.22	3.51	3.33	18,349	-	-
<b>Total</b>	<b>24.38</b>			<b>98,209</b>		<b>388</b>

Note: The VGF calculations that we have explained above have been derived at CAPEX of INR 6.21 Cr/MW with LCOE of INR 5.89/kWh. However, this is an indicative number based on our discussion and consultations with developers and concerned stakeholder. The per MW cost of CTPV system may vary from INR 6.2 to 6.8 Cr, with LCOE ranging from 5.89 to 6.45/kWh. The VGF may vary from INR 388 to 1034 Crores.

## 5.4. FINANCING INTERVENTIONS REQUIRED FOR CTPV

India's exploration of Canal Top Photovoltaic (CTPV) systems began with the pioneering development of a 1 MW Canal Top Solar Project on the Vadodara branch of the Sardar Sarovar Narmada canal in Gujarat in 2012. This was followed by the implementation of a 10 MW CTPV project on the Sanand Branch Canal in the same state. With the potential capacity for Canal Top PV in India estimated at several gigawatts, policymakers recognized the need to employ aggregated or solar park models to achieve economies of scale and incentivize private sector investment.

Under MNRE's scheme on 'Pilot-cum-Demonstration Project for Development of Grid Connected Solar PV Power Plants on Canal Banks and Canal Tops', financial support was allocated based on specific criteria. For Canal Top SPV projects, the financial aid amounted to INR 3 crore/MW or 30% of the project cost, whichever was lower. Similarly, for Canal Bank SPV projects, the support extended was INR 1.5 crore/MW or 30% of the project cost, depending on the lower value. The total financial assistance available was capped at INR 225 crore, designated for 100 MW of combined capacity, with 50 MW allotted for both Canal Tops and Canal Banks. This financial aid was disbursed over a period of up to 2 years after the authorization of the projects. Specifically, 40% of the financial support was provided upon project sanctioning, while the remaining 60% was granted upon the successful commissioning of the respective projects<sup>7</sup>.

The above scheme has seen encouraging results in implementation and disbursement of the above pilot scheme by MNRE on Canal Top and Canal Bank. Several states have now gained substantial experience in developing CTPV installations. These successful demonstration projects have helped in showcasing the tangible benefits and the potential of CTPV technology, thereby instilling confidence in lenders, investors, policymakers, and local communities. This significant progress has effectively mitigated the technology risk for lenders, investors, distinguishing it from other NISAs such as Agrivoltaics and rail/road integrated PV. Moreover, the success of the pilot program encourages knowledge sharing and best practice dissemination, fostering a collaborative environment that nurtures the development and widespread adoption of CTPV technology across different regions and states.

While CTPV has emerged as a proven and reliable technology, the capex and LCOE continues to concern the buyer/ consumers of electricity. It is therefore important to continue central financial assistance at a much larger scale to tap into the vast deployment potential.

Based on the capacity projections and VGF calculations, as outlined in Chapter 4 and section 5.3 above, under the moderate scenario India's cumulative demand for CTPV is estimated to reach 8.16 GW between 2024 and 2040. The anticipated savings for DISCOMs are projected to fall between INR 2.71/kWh and INR 5.12/kWh, as observed from Approach 1 and 2. Comparing this range with the expected CTPV system energy cost of INR 5.89/kWh (at CAPEX of INR 6.21 Crore per MW), it becomes evident that there exists a realization gap of INR 0.77 to 3.18/kWh for the investing developers. This translates to an equivalent support requirement of INR 0.81 to 3.35 Crore per MW of the CTPV system cost. If till 2030, 760 MW of CTPV systems are to be installed in India, financial assistance of INR 276 would be required. Similarly, under the optimistic scenario, for installing 900 MW of CTPV projects by 2027-28, a total of INR 388 Crore would be required as central financial assistance.

<sup>7</sup> PIB, Government of India, MNRE; Schemes launched by the Government to promote Solar Energy in the country, Dec 2017; <https://pib.gov.in/Pressreleaseshare.aspx?PRID=1514462>

To encourage the scaling of Canal Top PV installations in India, several financial interventions can be considered:

### CONSORTIUM GREEN BONDS:

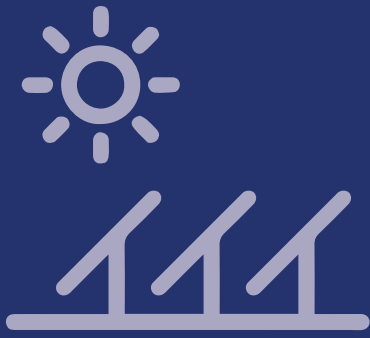
A consortium of lenders/ FIs can come together and issue green bonds specifically for CTPV projects. This way they can tap into the capital flow focused on ESG projects deployment. The banks/ FIs provide the backing to the investors subscribing to these bonds. These bonds can be used to fund multiple projects and provide long-term financing options. This limits the exposure of banks/ FIs to the extent of their guarantee for identified tranche. This way they can gain exposure to CTPV and gain valuable insights for their risk management practices. Consortium of banks/ FIs holds the key for raising this fund. It is likely that this will require an additional layer of fund manager for channelising the project deployments as well as managing the obligations towards the investors.

#### Approach for Utilising Green Bonds for CTPV Installations

A consortium of Banks/ Financial institutions / NBFCs / PSUs come together to issue a series of green bonds dedicated to funding CTPV projects. These bonds are specifically designated as "Canal Top Solar Green Bonds" with following illustrative aspects:

- Issuer: A consortium of government entities and financial institutions.
- Bond Type: Green Bonds
- Total Value: INR 1,000 crores
- Maturity: 10 years

The proceeds from the green bonds are channelled into canal top solar projects throughout India, focusing on various canals.



# POLICY AND REGULATORY ANALYSIS

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06

MNRE in its scheme titled “Pilot-cum-Demonstration Project for Development of Grid Connected Solar PV Power Plants on Canal Banks and Canal Tops” defines canal top systems as solar PV systems installed over canal surface or along canal banks. A canal-top solar PV requires no additional land, benefits local ecology, and can be easily utilised with existing infrastructure. In addition, most canal banks are owned by irrigation departments/state governments. They can aid in water resource conservation by lowering water evaporation, which is crucial in arid areas. It is estimated that 1MW of canal-top solar PV can save 9 million litres of water per year<sup>8</sup>. By lessening the quantity of sunlight that reaches the water and discouraging the development of toxic algae, thereby enhancing the quality of the water.

In India, the first CTPV system of 1 MW capacity was installed on a 750-meter stretch of the Narmada branch canal at Chandrasan village in 2012. The successful implementation of this project has provided learnings for other states. With a number of canals still unutilised, more and more states are now installing more canal-top solar PV systems. As of Dec 2021, around 94 MW canal top solar PV projects have been installed across India<sup>9</sup>. CTPV has been to date considered from a program perspective, with its mention in the 12<sup>th</sup> 5-year plan of GOI<sup>10</sup> and having allotted an estimated CFA of INR 228 Cr. The objective of the scheme is to achieve gainful utilisation of the unutilised area on top of and beside Canals, by setting up grid-connected solar PV plants up to a total capacity of 100 MW. The following section tries to unearth the barriers and challenges in the adoption of CTPV in India.

## 6.1. METHODOLOGY TO UNDERSTAND BARRIERS AND CHALLENGES

The I-SUN program has explored and researched the policy and regulatory landscape for CTPV, prevailing in India, referencing published literature, consulting various stakeholders, and understanding the various stages in the life cycle of the project. This was accompanied by undertaking rigorous engagements with key stakeholders like project developers, regulators, nodal agencies, market developers etc. along each of the stages. In addition, a questionnaire was prepared and floated to large audiences to understand the policy and regulatory barriers to large-scale adoption of CTPV in India. The framework included the steps shown in Figure 17.



Figure 17: Methodology for understanding barriers and challenges

In **step 1**, the project team has analysed and mapped out the various stages involved in building a CTPV plant. Analysing the full lifecycle allows stakeholders to make informed decisions and establish strategies for successful implementation by identifying the barriers and challenges connected with each step of the lifecycle.

<sup>8</sup> Sairam, P. M. N., and Aravindhan, A. (2020). Canal top solar panels: a unique nexus of energy, water, and land. *Materials Today: Proceedings*, 33, 705-710.

<sup>9</sup> MNRE Annual Report 2021-22

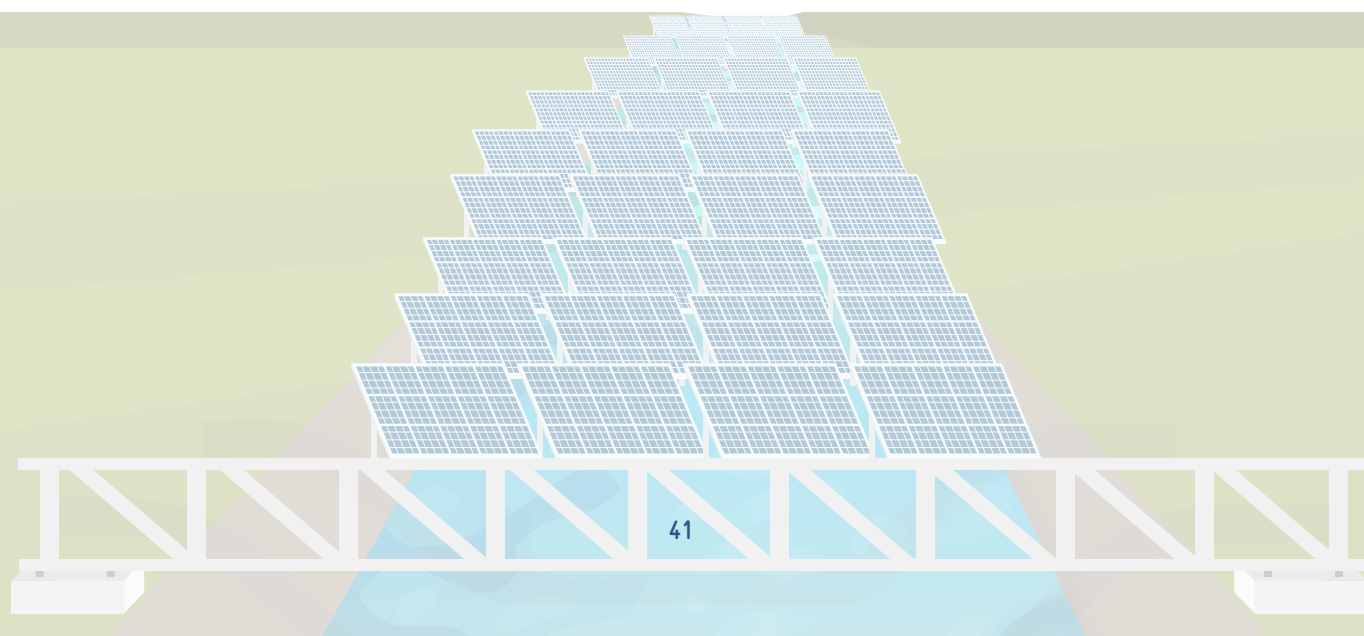
<sup>10</sup> MNRE, Government of India, Pilot-cum Demonstration Project for Development of Grid Connected Solar PV Power Plants on Canal Banks and Canal Tops scheme, Dec 2014; [https://www.seci.co.in/web-data/docs/1\\_%20Canal%20Top%20%26%20Bank%20Solar%20PV%20Scheme.pdf](https://www.seci.co.in/web-data/docs/1_%20Canal%20Top%20%26%20Bank%20Solar%20PV%20Scheme.pdf)

The lifecycle of CTPV has the following phases:

- **Feasibility study and application:** The first stage is to conduct a feasibility study to determine if a canal-top solar PV plant is suitable for the specific location. This includes analysing the canal, solar irradiation data of that particular location, the water flow rate of the canal (pre/post-monsoon), and power evacuation infrastructure that may impact the project's viability. If the feasibility study is positive, the project team can submit an application to the relevant authorities for project approval.
- **Project approval and permitting:** The project team must obtain all necessary approvals and permits from local authorities. The process for obtaining permits can vary by location and may involve consultation with stakeholders such as community members, water resource departments, and environmental agencies.
- **Detailed engineering:** Once the project is approved and permitted, the next stage is to develop detailed engineering plans, including the design and layout of the solar panels, foundations, supporting structures, and electrical systems. Detailed engineering plans must meet all relevant codes, standards, and regulatory requirements.
- **Project execution:** After completing the detailed engineering plans, the project team can begin the construction phase. This involves procurement of materials and equipment, site preparation, installation of solar panels and supporting structures, and connection of electrical systems. The project team must ensure that construction work meets all safety, quality, and regulatory requirements.
- **Commissioning:** Once the construction is complete, the project team will conduct a commissioning process to test and verify the performance of the solar power system. This includes testing the electrical systems, checking the alignment of solar panels, and verifying the system's capacity and efficiency.
- **Operations and maintenance:** The final stage is to operate and maintain the canal-top solar PV plant. This involves ongoing monitoring of the system's performance, regular maintenance of the solar panels, and replacement of any faulty equipment or components. The project team must also ensure compliance with all regulatory requirements and safety protocols.

Overall, the implementation of a canal-top solar PV plant involves several stages that require careful planning, engineering, and execution to ensure successful implementation and long-term operation. It is important to monitor the plant's performance, optimise its energy output, and ensure that it meets all environmental and regulatory requirements.

During **step 2**, the project team engaged in extensive conversations with key stakeholders in the CTPV domain, ranging from those responsible for project implementation to the authority's overseeing regulations, agencies coordinating efforts, and individuals shaping the market.



Simultaneously, a structured questionnaire was created in **step 3** and shared widely among a diverse set of respondents. The primary goal was to gather comprehensive information about the hindrances caused at each stage of project lifecycle. The questionnaire allowed for a more inclusive and holistic understanding of the challenges in this domain by collecting insights from a broad cross-section of stakeholders, ultimately aiding in the formulation of strategies and policies for overcoming these impediments. In order to understand the barriers and challenges in implementing CTPV in India, the project team consulted a variety of different stakeholders (Figure 18). Detailed list can be referred from Annexure B.



Figure 18: Stakeholders consulted

## 6.2. BARRIERS AND CHALLENGES IN CTPV

Based on the in-depth literature review and stakeholder consultations, the project team was able to identify the following barriers and challenges in different stages of the plant life cycle. This is a part of step 4 of the methodology as discussed in the section above (figure 17). A summary of barriers and challenges is illustrated in Table 16.

Table 16: Summary of barriers and challenges

Barriers and Challenge	Category	Criticality Factor
Ownership and priority	Social	Low
Higher tariff	Economic	High
Structural issues	Technical	Medium
Water flow	Operational	Medium
Cleaning and upkeep	Operational	Medium

## APPLICATION STAGE

### Social

**Ownership:** Major Canals in India are owned and managed by the Central Water Commission (CWC), and are responsible for planning, development and management of water resources across the country. On the other hand, the minor canals are owned and managed by the water resource departments of the respective states.

**Priority:** The concerned water departments lack knowledge of CTPV systems and are focused on managing the canals, ensuring a consistent water supply.

## PROJECT APPROVAL

**Economic** Higher tariff: The tariff for canal-top solar PV (CTPV) plants may be higher than conventional solar PV plants due to the additional costs involved in constructing and operating the CTPV plants.

The structural cost is higher as compared to conventional solar power plants because the structure is made in accordance with the canal's width. The expenses for maintenance and cleaning are also higher as the plant is mounted over a water canal and sometimes requires additional resources for cleaning debris under the modules, especially during flooding/monsoon.

Given the higher capital investment, the tariffs are usually higher in CTPV projects as compared with normal solar tariffs.

## PROJECT EXECUTION AND COMMISSIONING

**Technical** Structural issues: Installation of solar panels on canals may present structural difficulties. A high air-flowing area is developed beneath the mounting structure, resembling a wind tunnel. Hence special care is required while designing the structures.

**Operational** **Water flow:** Since the structure of a canal-top solar PV system is mounted or suspended over the water, during the monsoon season, canals can experience heavy flow and overflow, which can pose a challenge for canal-top solar PV systems.

- **Damage to the solar panels:** If the canal overflows, floating debris or strong currents may cause damage to the solar panels.
- **Electrical safety:** Because of flooding and other damp circumstances, there is a potential for electrical hazards during the monsoon season.
- **Maintenance and cleaning:** It can be difficult to gain access to the canal-top solar PV construction during the monsoon season due to the excessive flow of water.
- **Erosion:** The monsoon season's high-water flow can erode canal banks, which may compromise the integrity of the canal top solar PV construction.

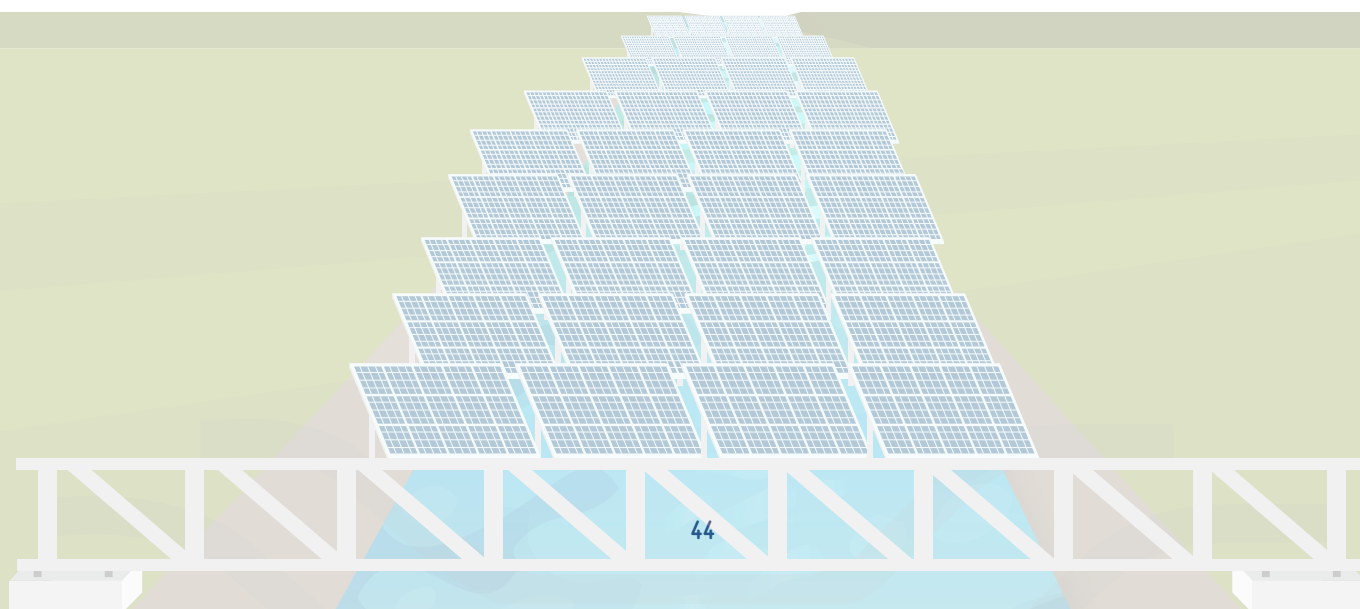
## MAINTENANCE

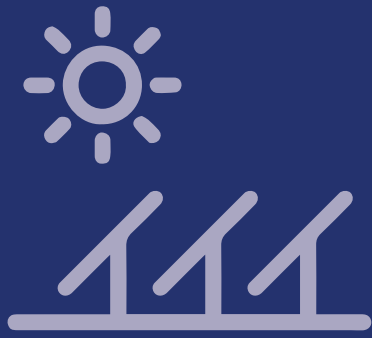
**Operational** Cleaning and upkeep: To maintain maximum effectiveness, the solar panels must be cleaned occasionally. Access to the structure is challenging in canal-top solar plants as the structure is mounted or suspended over the canal, thereby making it difficult for preventive maintenance and cleaning for both canals and solar plants.

## 6.3. KEY RECOMMENDATIONS

In this section, the project team have formulated recommendations based on the insights and findings gathered during the previous steps of the methodology (figure 17). These recommendations are essential for guiding the project's direction, addressing identified challenges, and optimizing its overall success. I-SUN Program proposes the following recommendations:

- **Structural tests:** Installation of solar panels on canals may present structural difficulties. A high air flowing area beneath the mounting framework is also produced, resembling a wind tunnel. The developers need to use structures which have been passed through a wind stress test before installations.
- **Government involvement:** The CTPV projects can only be driven through government cooperation as canals are considered public property and can't be directly given to private developers. Hence, the government has to pro-actively work with the developers to execute such projects by including readily available feasible stretches of canals.
- **Robust standards for components:** In order to protect the components of the CTPV system from the overflow or flooding of water during the monsoon season, special technical guidelines should be followed
  - Relevant technical standards and ratings are to be complied with for canal top systems. Technical standards/guidelines to be used by canal top systems shall be published by appropriate government departments.
  - The structure must be built to withstand the effects of water currents and safeguard the solar panels, the electrical parts of the canal-top solar PV system ought to be waterproof and made to tolerate wet environments. The necessity for access during the monsoon season should be considered when designing the structure. The structure should be built to withstand water pressure and prevent erosion.
- **Susceptance to higher tariff:** Given the higher cost of the CTPV system due to its unique design and location, the tariff is usually higher as compared to other conventional solar PV plants. It is important to demonstrate the long-term economic, social, and environmental benefits of CTPV systems to regulators and policymakers to justify the higher tariff. This can include conducting comprehensive feasibility studies that take into account the unique aspects of CTPV systems, such as their design, location, and the potential for co-benefits.





# SKILL GAP ASSESSMENT AND JOBS REQUIRED IN CTPV SECTOR

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07

Skilling is vital for increasing the penetration of NISA (New Innovative Solar Applications). By creating a skilled workforce, we can ensure better utilisation of renewable energy resources with high-quality workmanship on the deployed technologies. The skilling interventions must ensure better sustainability of the technology, quality of the deployment and increased rate of deployment, which will create new jobs and livelihood opportunities for many. Skill development initiatives will be majorly required in project engineering, project execution, project commissioning, operation and maintenance and creating awareness. The following four major reasons are crucial for increasing adaptation of NISA:

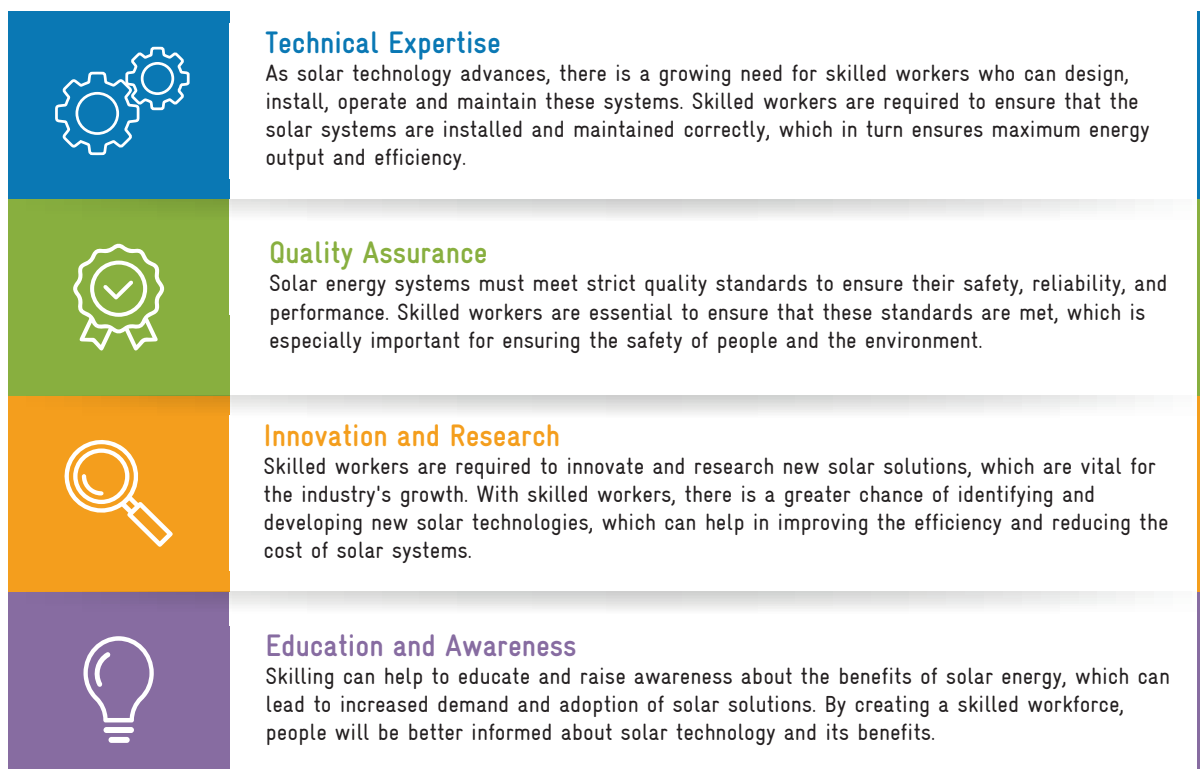


Figure 19: Crucial requirements for skilling

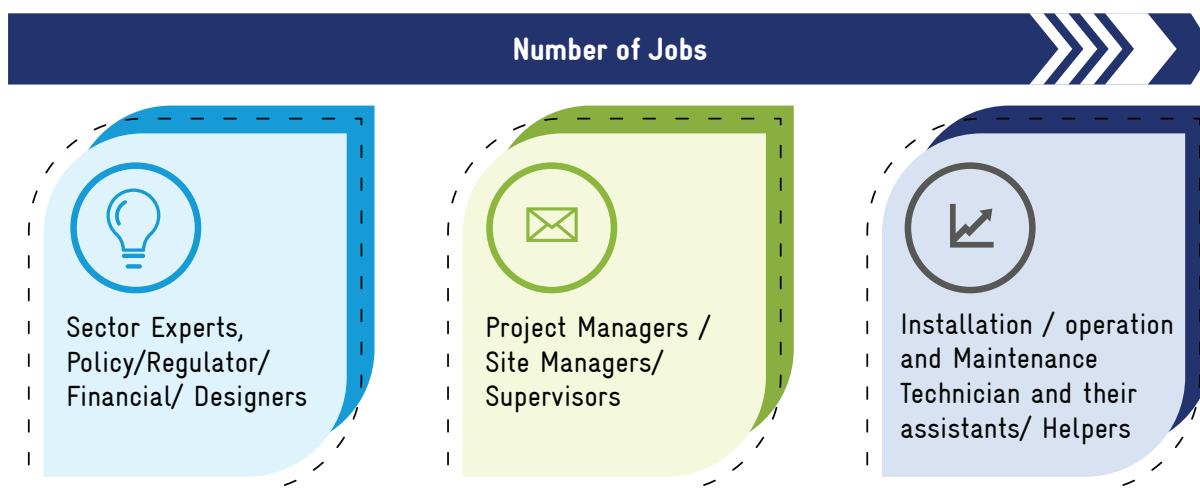


Figure 20: Number of jobs as per skills and designations

The targeted skilling measures not only increases the penetration of new innovative solar application but also creates numerous direct and indirect jobs across the sector, most jobs will be at the operational level of manufacturing, installation and maintenance.

The majority of the Jobs will be created at the technician level or below, whereas the high-paid jobs that are doing value addition in the sector will be comparatively less.

Though all the skilling initiatives will not result in new job creation but may provide better/ alternate livelihood opportunities for existing manpower migrating from other sectors to these new sectors.

## 7.1. SKILLING REQUIRED IN CTPV

The project team has identified several gaps where skilling becomes necessary to boost the CTPV sector in India.

Table 17: Skill gap assessment and interventions

Stakeholder	Gaps	Skilling required	Skilling intervention
<b>State water and irrigation department</b>	The State Irrigation Department lack knowledge on implementing CTPV projects and is focused on managing the canals, ensuring a consistent water supply.	Capacity building of state irrigation/water departments is required. Developing an understanding that CTPV can also be a source of income for the department.	Capacity building program, workshops and site visits.
<b>I&amp;C and O&amp;M technicians</b>	Operation and maintenance of CTPV is a challenge due to structures lying above water and especially cleaning of the canal during monsoon.	Training of technicians for operation and maintenance of canal top solar PV needs to be integrated into their training programs.	Development of chapters on I&C and O&M.

### Capacity building interventions for the Water/irrigation department:

The objective of the skilling interventions is to upgrade the knowledge and skills of the officials of the Water/irrigation department, the capacity building will result in faster adaptation of CTPV. Following are the few major benefits of the capacity building of the Water/irrigation department Officials.

- **Renewable Energy Policy Development:** Skilling programs can assist department officials in understanding and formulating policies, incentives, and regulations to support the development of CTPV projects.
- **Permitting and Regulatory Processes:** Training on permitting procedures, environmental impact assessments, and regulatory compliance will help government agencies streamline the approval and licensing processes for canal top solar PV projects.
- **Monitoring and Evaluation:** Skilling interventions can focus on monitoring and evaluation techniques to ensure effective implementation, compliance, and assessment of CTPV projects.

### Capacity building interventions of I&C and O&M Technicians

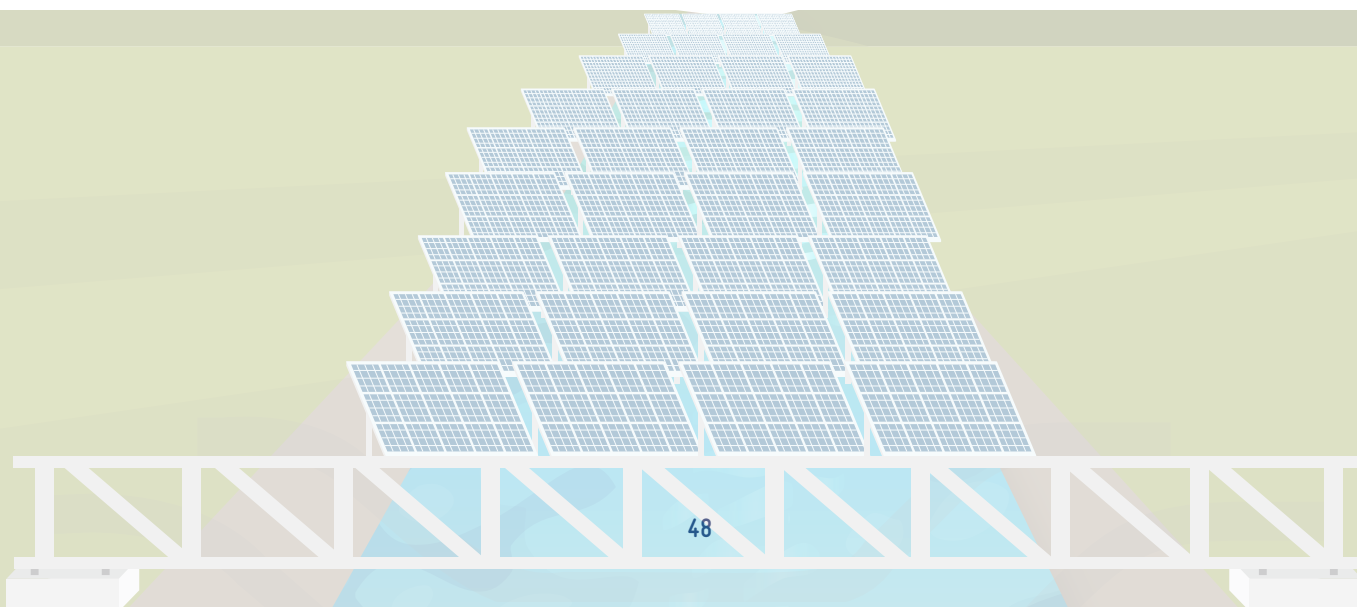
The objective of the skilling interventions is to upgrade the knowledge and skills of the I&C and O&M technicians, the capacity building will result in increasing reliability and performance of CTPV and reduction of accidents. Following are the few benefits of the capacity building of the **I&C and O&M technicians**.

- Safety and Emergency Response: Training programs can focus on safety protocols, emergency response procedures, and risk management for O&M activities in CTPV projects.
- O&M Techniques and Best Practices: Skilling interventions can cover maintenance procedures, troubleshooting, performance monitoring, and optimisation strategies specific to canal top solar PV systems.
- Performance of the system: Skilling intervention should cover the importance of technical standards and how it is different from the ground mounted PV or other solar PV technologies along with case studies.

## 7.2. WORKFORCE REQUIRED FOR CTPV SECTOR (2024-40)

To analyse the number of jobs created and workforce required in the CTPV sector based on the potential derived under this assignment, the project team referred to previously developed reports on skilling and workforce by CEEW (Council on Energy Environment and Water), NRDC (Natural Resources Defense Council) and SCGJ (Skill Council of Green Jobs) along with stakeholder consultations.

The analysis was done under different job roles during the application stage, project approval, detailed engineering, project execution and commissioning, and operations and maintenance. i.e., the workforce required to perform these job roles per MW of installation. The full-time equivalent is simply a ratio of the time spent by an employee on a particular task/project each year to the standard total working hours in that particular year.



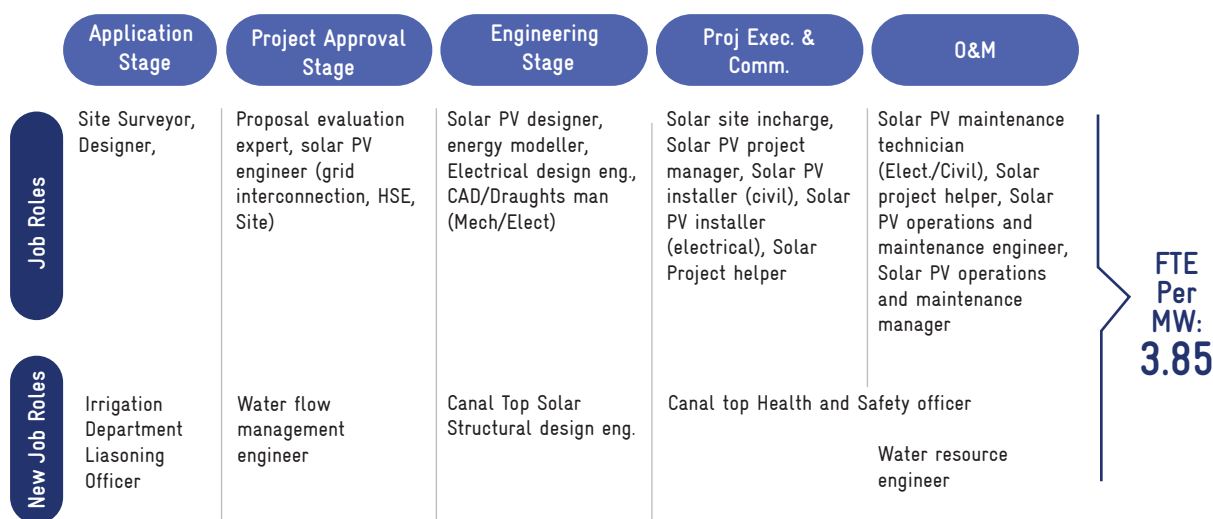


Figure 21: FTEs required in the CTPV sector

Source: Author’s analysis, stakeholder discussions and literature review<sup>11</sup>

### 7.3. STATE-WISE DEPLOYMENT OF CTPV BY 2040

Based on the annual demand trajectory of CTPV in India, and the potential derived under this project, the state wise annual demand was mapped. Which was further used to find the full-time equivalent jobs that would be required in each of the states.

Under the moderate case, it is estimated that to meet a demand of 8.16 GW of CTPV by 2040, **31 thousand new FTE** jobs will be required and for the Optimistic case, **93 thousand FTE** jobs (24 GW) to support distinct roles and responsibilities starting from application, project approval, detailed engineering, project execution-commissioning and operations and maintenance. The table is annexed below.

<sup>11</sup> India’s expanding clean energy workforce- opportunities in solar and wind energy sector (2022), CEEW, NRDC, SCGJ; Greening India’s workforce- gearing up for expansion of solar and wind power in India (2017), CEEW, NRDC; Skill gap report for solar, wind and small hydro sector (2016), SCGJ

Table 18: FTE required under moderate and optimistic case

**Moderate Case**

It is estimated that the total capacity that may be installed from 2024-40 in India will be **8.16 GW**

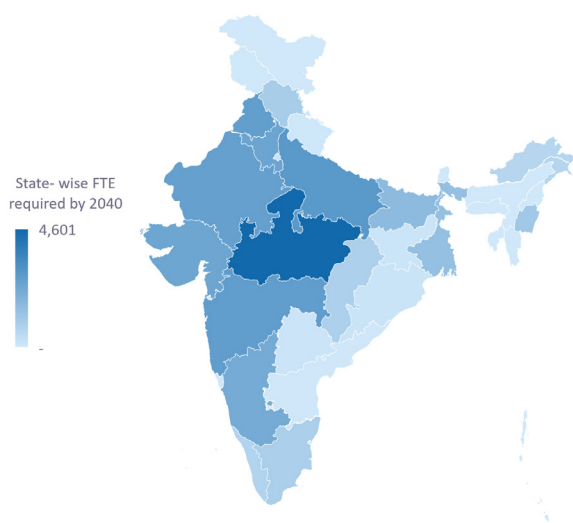
To realise 8.16 GW of capacity, a total of 31 thousand FTE manpower will be required from 2024-40

**Optimistic Case**

It is estimated that the total capacity that may be installed during 2024-40 in India will be **24 GW**

To realise 24 GW of capacity, a total of 93 thousand FTE manpower will be required from 2024-40

State- wise FTE required in CTPV sector from 2024-40 (Moderate Case)



State- wise FTE required in CTPV sector from 2024-40 (Optimistic Case)

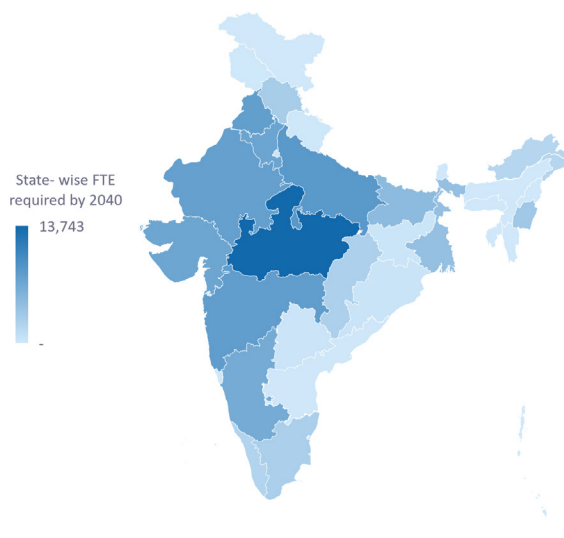
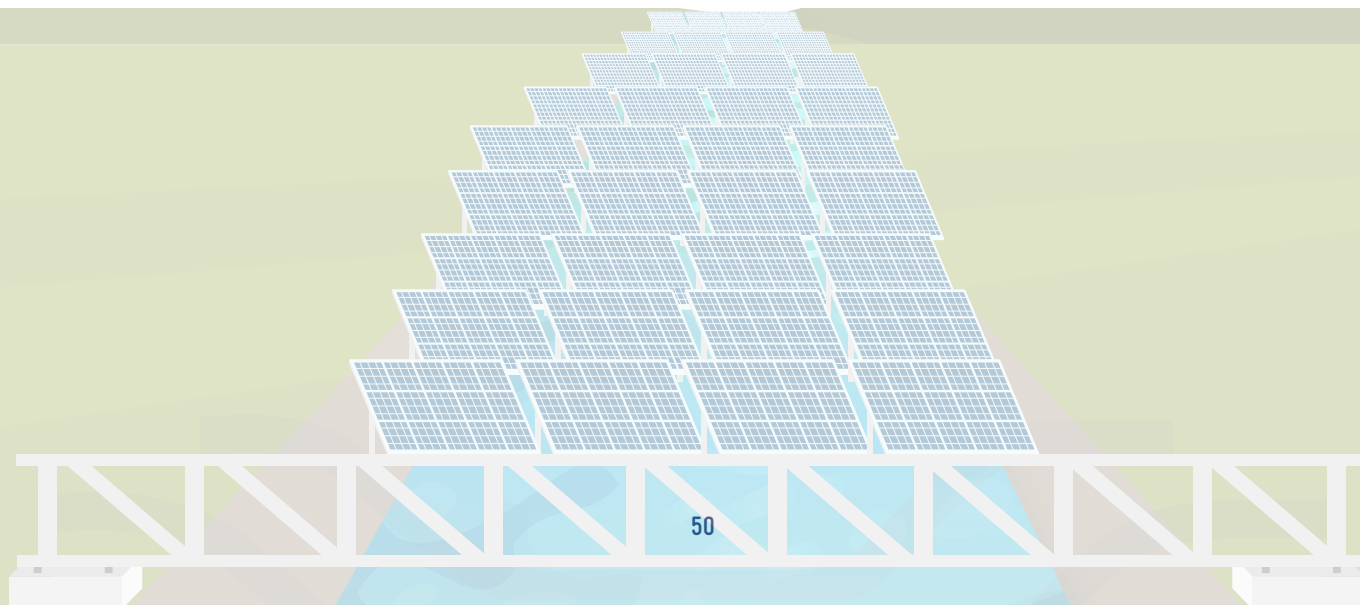
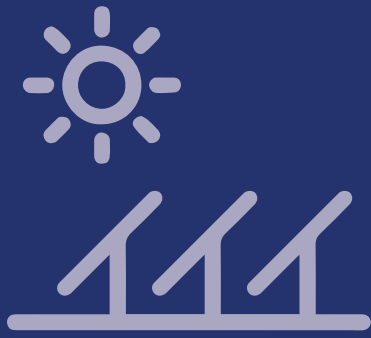


Figure 22: State wise FTE required in CTPV sector by 2040





# CONCLUSION AND WAY FORWARD

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08

The Canal Top Photovoltaic (CTPV) technology has emerged as a transformative solution in the realm of renewable energy, offering a plethora of opportunities to harness the potential of solar power generation by utilising India's extensive network of canals. The Ministry of New and Renewable Energy (MNRE) introduced a scheme to support pilot projects on Canal Banks and Tops, with financial assistance of INR 3 crore/MW or 30% of the project cost, capped at INR 225 crore for a total combined capacity of 100 MW. The successful implementation of the pilot scheme has instilled confidence in stakeholders and facilitated knowledge sharing, promoting the widespread adoption of CTPV technology.

This report has delved into various facets of CTPV, ranging from its potential assessments to the skill sets required for its successful implementation. In this concluding chapter, we synthesize the key findings and insights from each section to present a comprehensive overview of the CTPV landscape within India. The estimated total potential of Canal Top Photovoltaic (CTPV) is an impressive 130 GW.

Stakeholders from a diverse spectrum of sectors stand to benefit significantly from the insights and recommendations presented in this report. State governments, water departments and canal management authorities are at the forefront of canal infrastructure and water management. They can use this report to explore the multifaceted benefits of incorporating CTPV technology into their canal networks. By understanding the technical aspects and implementation strategies, these departments can make informed decisions on how to integrate solar panels into existing canals. Additionally, the report's financial considerations and business models offer valuable insights into generating revenue through CTPV projects, which can contribute to canal maintenance and water management efforts. Private investors, banks, and financial institutions can utilize the report's in-depth analysis of the financial considerations and potential business models to make informed investment decisions, mitigating risks and ensuring profitability.

Companies in the renewable energy sector, including solar technology manufacturers and service providers, can leverage the technical aspects and market dynamics sections to refine their product offerings and market strategies, promoting growth and innovation. Communities residing near canal sites can benefit from improved access to electricity, potential job opportunities, and the positive environmental impacts of CTPV projects. This report empowers them to engage with developers and governments to ensure their interests are considered. Educational and research institutions can use this report to deepen their understanding of CTPV technology, contributing to the development of skilled professionals and innovative solutions in the renewable energy sector.

In addition to this, our report has provided crucial insights into business models and the Levelized Cost of Energy (LCOE), emphasizing the importance of subsidies during the initial years due to the high cost of CTPV installations. As most canals are government-owned (state water departments), by leasing canal space for CTPV projects, water departments can diversify their income streams, promote sustainability, and support India's transition to renewable energy.

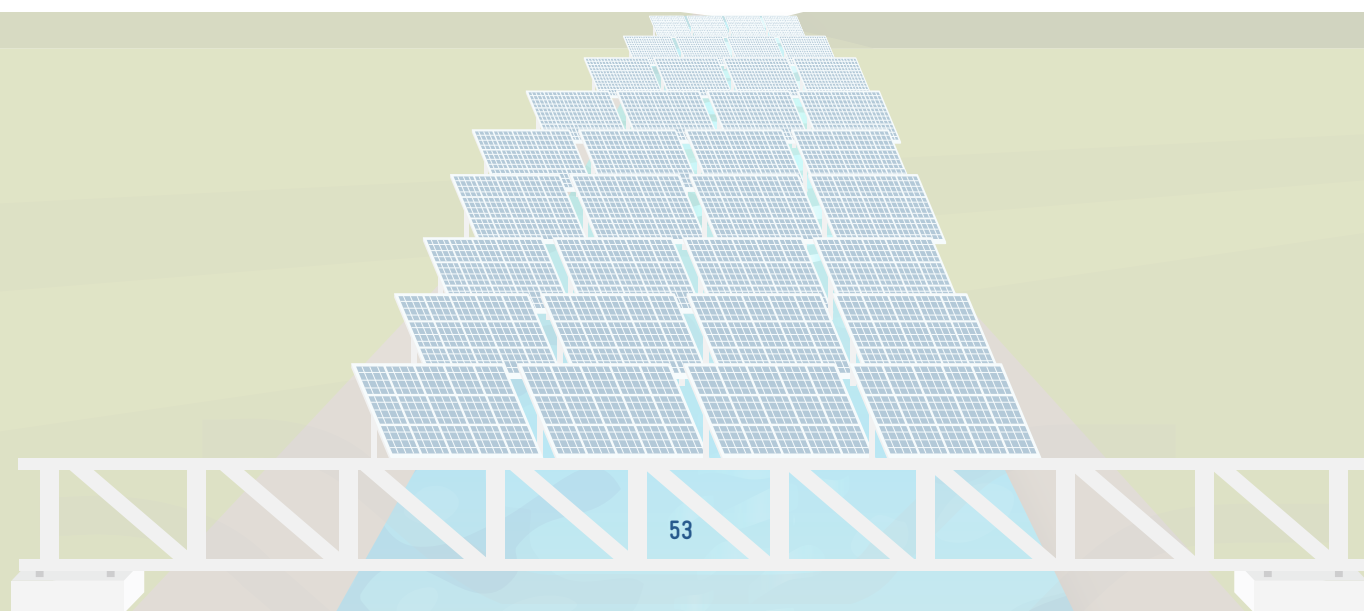
CTPV installations have the capacity to generate a substantial number of jobs across various stages of project development and maintenance. These jobs can range from engineering and construction positions during the initial setup of the CTPV systems to maintenance and operations roles throughout their lifespan. Furthermore, local communities near canal sites can benefit from employment opportunities and skill development programs associated with CTPV projects. As the renewable energy sector expands, the growth of CTPV can significantly contribute to job creation, stimulating economic development and supporting sustainable energy initiatives.

As next steps, successful implementation of CTPV in India stresses the need of government involvement in driving CTPV initiatives, as canals are considered public property, necessitating public-private cooperation. To address the higher tariff associated with CTPV systems due to their unique design and location, the report suggests demonstrating their long-term economic, social, and environmental benefits. This can be achieved through comprehensive feasibility studies, considering their design, location, and potential co-benefits when justifying the tariff to regulators and policymakers. In terms of technical and structural standards, adoption of robust structural tests is required to ensure the stability of CTPV installations, underlining the importance of wind stress tests and compliance with technical standards to safeguard components during monsoon seasons.

Despite its proven reliability, concerns persist over the capital expenditure and levelized cost of electricity (LCOE), necessitating continued financial support for large-scale deployment.

To encourage the expansion of CTPV installations, the proposal suggests the establishment of a Consortium Green Bonds initiative, wherein a group of lenders or financial institutions issue green bonds specifically for CTPV projects. This strategy aims to attract capital focused on environmental, social, and governance (ESG) projects, while managing risk exposure for the participating banks and gaining insights for risk management practices through project deployment. The consortium would likely require an additional layer of fund management for effective project channelization and investor obligation management.

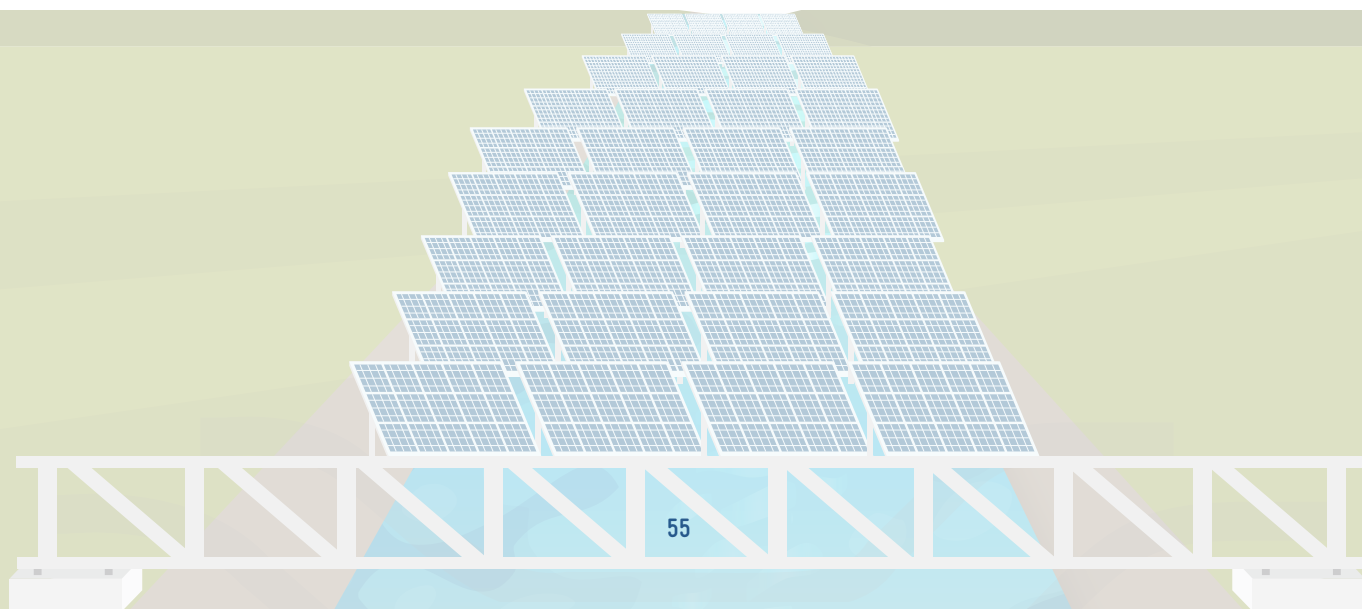
Projected demand estimates suggest the need for substantial financial assistance, ranging from INR 276 crore to INR 388 crore over the next 5-7 years under different scenarios. This may help scale up canal PV projects.



## ANNEXURE A- PROJECT AND FINANCIAL ASSUMPTION

Sl. No.	Assumption Head	Sub-Head 1	Sub-Head 2	Unit	Value
1	Power Generation	Capacity	Installed Power Generation Capacity	MWac	1.0
			Capacity Utilisation Factor (CUF)	%	15.00%
			Useful Life	Years	25.00
2	Project Cost	Capital Cost/ MW	Power Plant Cost	INR Lakh/MWp	620.76
			Lease	INR/sqm	3.71
			Area for 1 MW	sqm	5,000.00
			Total Lease annum	INR Lakh	0.19
			Lease escalation	%	5%
			Offtaker Equity	%	0.00%
			Power Plant Cost to RESCO	INR Lakh/MWp	620.76
3	Financial Assumptions	Debt Equity	Debt	%	70.00%
			Equity	%	30.00%
			Total Debt Amount	INR Lakh	434.53
		Debt Component	Total Equity Amount	INR Lakh	186.23
			Loan Amount	INR Lakh	434.53
			Moratorium Period	Years	-
			Repayment Period(Including Moratorium)	Years	15.00
			Interest Rate	%	9.00%
			Equity Component	Equity Amount	INR Lakh
		Nominal RoE		%	14%
		Return on Equity for First 20 Years		% p.a	16.96%
		Return on Equity 21ST Year onwards		% p.a	21.52%
		Weighted Average of ROE	% p.a	20.55%	
Discount Rate (Post Tax WACC)	%	9.55%			

4	Financial Assumptions	Fiscal Assumptions	Corporate Tax	%	34.94%
			MAT Rate	%	17.47%
		Depreciation	Book Depreciation Rate for First 15 Years	%	4.67%
			Book Depreciation Rate 16th Year Onwards	%	2.00%
			Depreciation tax purpose SLM	%	5.28%
			Depreciation tax purpose AD	%	40.00%
5	Working Capital	For Fixed Charges	O&M Charges	Months	1.00
			Maintenance Spare(%age of O&M Expenses)	%	15.00%
		Receivables from Debtors	Months	1.50	
6	Operation & Maintenance	For Variable Charges	Interest on Working Capital	%	10.50%
		Power Plant	O&M Charges	INR Lakh	9.31
			O&M Expense Escalation	%	3.84%



## LEVELISED COST OF GENERATION

	Unit	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	
O&M Expenses	INR Lakh		9.31	9.67	10.04	10.43	10.83	11.24	11.67	12.12	12.59	13.07	13.57	14.09	14.63	15.20	15.78	16.39	17.02	17.67	18.35	19.05	19.78	20.54	21.33	22.15	23.00	
Depreciation	INR Lakh		28.99	28.99	28.99	28.99	28.99	28.99	28.99	28.99	28.99	28.99	28.99	28.99	28.99	28.99	28.99	28.99	28.99	28.99	28.99	28.99	28.99	28.99	28.99	28.99	28.99	28.99
Interest on Term Loan	INR Lakh		37.80	35.20	32.59	29.98	27.38	24.77	22.16	19.55	16.95	14.34	11.73	9.13	6.52	3.91	1.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interest on WC	INR Lakh		1.86	1.87	1.88	1.89	1.90	1.91	1.92	1.93	1.94	1.95	1.96	1.98	1.99	2.00	2.02	2.03	2.05	2.06	2.08	2.10	2.12	2.13	2.15	2.17	2.19	
Return on Equity	INR Lakh		31.59	31.59	31.59	31.59	31.59	31.59	31.59	31.59	31.59	31.59	31.59	31.59	31.59	31.59	31.59	31.59	31.59	31.59	31.59	31.59	31.59	31.59	31.59	31.59	31.59	31.59
Lease Payment Requirement	INR Lakh		0.19	0.19	0.20	0.21	0.23	0.24	0.25	0.26	0.27	0.29	0.30	0.32	0.33	0.35	0.37	0.39	0.40	0.42	0.45	0.47	0.49	0.52	0.54	0.57	0.60	
Total COG	INR Lakh		109.74	107.51	105.29	103.09	100.90	98.73	96.58	94.44	92.33	90.23	88.15	86.09	84.06	82.04	80.05	82.81	63.47	64.16	64.88	65.62	74.88	75.68	76.52	77.38	78.28	
Discount Rate	%		9.55%																									
Discount Factor			1.00	0.91	0.83	0.76	0.69	0.63	0.58	0.53	0.48	0.44	0.40	0.37	0.33	0.31	0.28	0.25	0.23	0.21	0.19	0.18	0.16	0.15	0.13	0.12	0.11	
Present Value of COG	INR Lakh		109.74	98.14	87.73	78.41	70.06	62.57	55.87	49.88	44.51	39.70	35.41	31.57	28.13	25.06	22.32	15.99	14.75	13.61	12.56	11.60	12.08	11.15	10.29	9.50	8.77	
Per Unit COG	Levelized																											
Per Unit of O&M	INR/kWh		0.59	0.56	0.53	0.50	0.47	0.45	0.43	0.40	0.38	0.36	0.34	0.33	0.31	0.29	0.28	0.26	0.25	0.24	0.22	0.21	0.20	0.19	0.18	0.17	0.16	
Per Unit value of Depreciated Amount	INR/kWh		1.83	1.67	1.53	1.39	1.27	1.16	1.06	0.97	0.88	0.81	0.74	0.67	0.61	0.56	0.51	0.20	0.18	0.17	0.15	0.14	0.13	0.12	0.11	0.10	0.09	
Per Unit Interest of Term Loan Interest	INR/kWh		2.39	2.03	1.72	1.44	1.20	0.99	0.81	0.65	0.52	0.40	0.30	0.21	0.14	0.08	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Per Unit value of WC Interest	INR/kWh		0.12	0.11	0.10	0.09	0.08	0.08	0.07	0.06	0.06	0.05	0.05	0.05	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	
Per Unit Value of ROE	INR/kWh		2.00	1.82	1.66	1.52	1.39	1.27	1.15	1.05	0.96	0.88	0.80	0.73	0.67	0.61	0.56	0.51	0.46	0.42	0.39	0.35	0.41	0.37	0.34	0.31	0.28	
Per Unit Lease Required	INR/kWh		0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	
Per Unit Value of Cost of Generation	INR/kWh		6.93	6.20	5.54	4.95	4.43	3.95	3.53	3.15	2.81	2.51	2.24	1.99	1.78	1.58	1.41	1.01	0.93	0.86	0.79	0.73	0.76	0.70	0.65	0.60	0.55	
Levelized Tariff	INR/kWh																											5.89

## ANNEXURE B- STAKEHOLDER CONSULTATIONS

**Organisation**

The World Bank Group

Gensol Solar

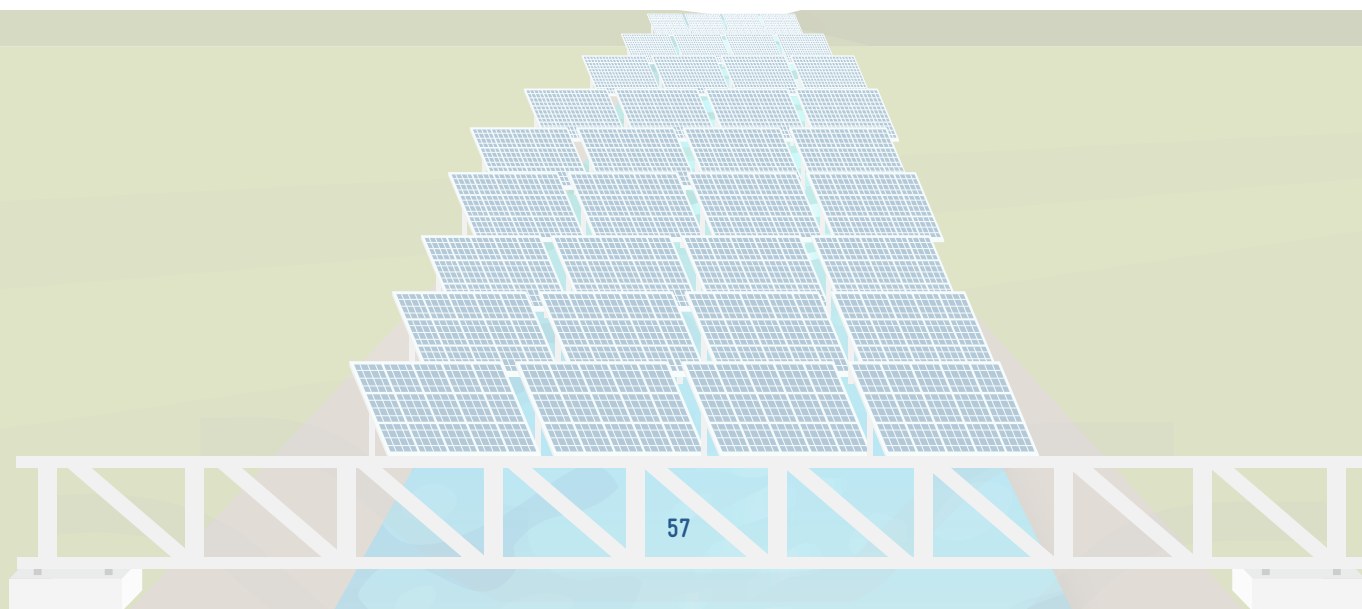
PEDA

**Name of Person**

Mr Vivek Jha

Mr Sumanth

Mr M P Singh



## ANNEXURE C- STATE WISE CAPACITY PROJECTION AND FTES (OPTIMISTIC CASE)

Year	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	Total (MW)	State- wise FTE required by 2040
Madhya Pradesh	22	28	36	46	49	63	81	103	132	136	174	222	285	364	467	597	765	3,570	13,743
Uttar Pradesh	14	17	22	29	31	39	50	64	82	84	108	138	177	226	289	371	475	2,215	8,527
Maharashtra	13	16	21	27	29	37	47	61	78	80	102	130	167	214	274	351	449	2,094	8,063
Punjab	13	16	21	27	28	36	47	60	76	78	100	128	164	210	269	344	441	2,058	7,923
Rajasthan	12	16	20	26	28	36	46	58	75	77	98	125	161	206	263	337	432	2,016	7,760
Haryana	12	15	19	24	26	33	42	54	69	71	91	117	149	191	245	314	402	1,875	7,218
Gujarat	11	15	19	24	26	33	42	54	69	71	91	116	149	191	244	313	400	1,868	7,193
Karnataka	11	14	17	22	24	30	39	50	64	65	84	107	137	175	225	288	368	1,718	6,616
Bihar	8	10	13	16	17	22	28	36	47	48	61	78	100	128	164	210	269	1,256	4,837
West Bengal	7	9	11	14	15	20	25	32	41	42	54	69	89	113	145	186	238	1,111	4,279
Manipur	5	7	9	12	12	16	20	26	33	34	43	56	71	91	117	149	191	892	3,435
H i m a c h a l Pradesh	5	6	8	10	11	14	17	22	29	29	37	48	61	79	101	129	165	769	2,961
Tamil Nadu	4	6	7	9	10	12	16	20	26	27	34	44	56	72	92	118	151	704	2,711
Chhattisgarh	4	5	7	9	9	12	15	19	25	25	32	41	53	68	87	111	143	666	2,564
Kerala	3	4	6	7	8	10	13	16	21	21	27	35	45	58	74	95	121	565	2,175
A r u n a c h a l Pradesh	3	4	5	6	7	9	11	14	18	19	24	31	40	51	65	83	106	496	1,911
Odisha	1	1	1	2	2	2	3	3	4	5	6	7	10	12	16	20	26	120	464
Telangana	1	1	1	1	1	2	2	3	4	4	5	6	8	10	13	17	22	101	388
Delhi	1	1	1	1	1	2	2	3	4	4	5	6	8	10	12	16	20	95	368
Jharkhand	1	1	1	1	1	2	2	2	3	3	4	5	7	9	11	14	18	86	331

Uttarakhand	0	0	0	0	1	1	1	1	1	1	2	2	3	4	5	6	8	38	146
Andhra Pradesh	0	0	0	0	0	1	1	1	1	1	2	2	2	3	4	5	6	28	106
Puducherry	0	0	0	0	0	1	1	1	1	1	1	1	2	2	3	4	5	23	89
Jammu and Kashmir	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	2	2	11	41
Chandigarh	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	5	18
Lakshadweep	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Tripura	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sikkim	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Andaman and Nicobar Islands	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mizoram	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Meghalaya	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Goa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nagaland	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Assam	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ladakh	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Daman and Diu	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Installation Per year (MW)	150	192	246	315	336	430	551	706	904	926	1,185	1,518	1,943	2,488	3,187	4,080	5,225	24,382	93,869

## ANNEXURE D- STATE WISE CAPACITY PROJECTION AND FTES (MODERATE CASE)

Year	Total (MW)												State- wise FTE required by 2040						
	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035		2036	2037	2038	2039	2040	
Madhya Pradesh	11	14	17	21	22	27	33	41	51	50	62	77	96	119	147	182	226	1,195	4,601
Uttar Pradesh	7	8	10	13	13	17	21	25	32	31	39	48	59	74	91	113	140	742	2,855
Maharashtra	6	8	10	12	13	16	19	24	30	30	37	45	56	70	86	107	132	701	2,700
Punjab	6	8	10	12	12	15	19	24	29	29	36	45	55	68	85	105	130	689	2,653
Rajasthan	6	8	10	12	12	15	19	23	29	28	35	44	54	67	83	103	127	675	2,598
Haryana	6	7	9	11	11	14	17	22	27	26	33	41	50	62	77	96	119	628	2,417
Gujarat	6	7	9	11	11	14	17	21	27	26	33	40	50	62	77	95	118	626	2,408
Karnataka	5	7	8	10	10	13	16	20	24	24	30	37	46	57	71	88	109	575	2,215
Bihar	4	5	6	7	8	9	12	14	18	18	22	27	34	42	52	64	79	421	1,620
West Bengal	3	4	5	7	7	8	10	13	16	16	19	24	30	37	46	57	70	372	1,433
Manipur	3	3	4	5	5	7	8	10	13	13	16	19	24	30	37	46	56	299	1,150
H i m a c h a l Pradesh	2	3	4	5	5	6	7	9	11	11	13	17	21	26	32	39	49	258	992
Tamil Nadu	2	3	3	4	4	5	7	8	10	10	12	15	19	23	29	36	45	236	908
Chhattisgarh	2	3	3	4	4	5	6	8	9	9	12	14	18	22	27	34	42	223	859
Kerala	2	2	3	3	3	4	5	6	8	8	10	12	15	19	23	29	36	189	728
A r u n a c h a l Pradesh	2	2	2	3	3	4	5	6	7	7	9	11	13	17	20	25	31	166	640
Odisha	0	0	1	1	1	1	1	1	2	2	2	3	3	4	5	6	8	40	155
Telangana	0	0	0	1	1	1	1	1	1	1	2	2	3	3	4	5	6	34	130









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