CSTEP'S SOLAR TECHNO-ECONOMIC MODEL FOR PHOTOVOLTAICS (CSTEM PV)

User Guide



Center for Study of Science, Technology & Policy (CSTEP) May 14, 2020

CSTEP

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1. Introduction

The Center for Study of Science, Technology and Policy (CSTEP) built the CSTEP's Solar Techno-Economic Model for Photovoltaics (CSTEM PV). It is an open-access, Web-based tool which can serve as a useful model to perform prefeasibility analysis for utility-scale and mini-grid solar plants from a techno-economic standpoint. To establish ease of access and utility, the researchers at CSTEP built this model based on *publicly available/open data*. It is aimed to cater to policymakers, researchers, and industry-trackers for informed decision-making.

This tool is available at http://cstem.cstep.in/cstem/

It has two access options:

- Registered User Access to all features of the tool for case simulation, including download of outputs in excel and image formats
- Guest User Access to all features of the tool for case simulation; no provision for download of outputs in any format

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Ease of access and use has been a cornerstone in the design-thought process. The user interface of the tool has been designed to be intuitive and informative to the best possible extent. This manual covers the following topics to provide additional guidance to the user via screenshots:

- Creation of user account and log-in
- Building a new case
- Means to download outputs

2. Homepage and User Access

The landing page of the tool presents an introductory video and provisions for registration / login. The menu options provide the following information:

- About Brief details about CSTEP and the features of the CSTEM tool
- **Publications** Support publications like the manual for the tool, technical reports detailing the mechanics of the tool and some additional relevant publications
- **Credits** List of team members who contributed to the development of the tool
- Feedback Section to provide feedback, post queries and comments
- Contact Us Contact information of CSTEP
- **Disclaimer** User code of conduct, terms and conditions for using the tool

Figure 1 to Figure 3 provide some guiding information about the landing / homepage

COTTEM	Introductory video on CSTEM	Brief information about CSTEP and CSTEM Home About Publication Credits Feedback Contact Us Disclaimer STEP
2.001		Manual & support publications User feedback / comment / query section Email Password Click Here to Sign Up OR Continue as Guest (view only access) Continue as Guest (view only access) This work is licensed under a Creative Common Stitubiolo-NonCommercial 4.0 International License.

Figure 1: Home page: Pre-login



Figure 2: Access for existing users



Figure 3: Registration for new users

3. Building a Case for Analysis

Figure 4 illustrates the post-login landing page. The users can choose to:

- Check a demo-case to understand the various kinds of outputs presented postsimulation for a preset case definition
- Simulate their own case of interest



Figure 4: Post-login landing page

The inputs template differs for simulation of utility-scale and mini-grid systems. These are illustrated in sections 3.1 and 3.2. The output template however is similar for both utility and mini grid systems. The broad details and information pertaining to download of outputs is presented in section 4. Default benchmark numbers and valid ranges have been provided at every step to guide the user for building the case.

3.1 Inputs: Utility-Scale PV plant

Figure 5 to Figure 14 illustrate the details of the inputs sequence for simulating a utility-scale PV plant after clicking the 'Build New Case' button in Figure 4. The broad sequence of inputs for simulating the case is as follows:

- Case definition (Figure 5)
- Input-output mapping for a utility-scale PV plant (Figure 6)
- Choosing location of interest and additional details (Figure 7 and Figure 8)
- Plant-design details (Figure 9)
- Choice of technology (Figure 10)
- Loss and related details (Figure 11)
- Capital-cost-related components (Figure 12)
- Operation cost, bid and subsidy information (Figure 13)
- Financial parameters including loan, tax, etc. (Figure 14)

CSTEM	Home About Publication Credits Feedback Contact Us Disclair	mer CSTEP Logged in as Harshid Logou
	Plant Design Tool tips provide supporting context, hover on them for details	
	Capacity Based Area Based (Future)	Choose the broad parameters to
	Application Models to be	simulation
AN NA DE CAR	Grid Connected Utility Plant ● ○ Mini Grid ● Added soon A	
CHOOSE	Financial Assessment	
OF	O Basic Viability ●	Submit
INTEREST	Technology	
	PV O PV with Storage (only for mini grid cases)	Post case definition, click on submit when
1-1-1	Tracking	completed
	Fixed Panel O Single Axis Tracking (Future) Dual Axis Tracking (Future)	
THAT I		



C



Figure 6: Input-Output map for simulating a utility scale PV plant



Figure 7: Choosing the location of interest



Figure 8: Choice of surface area



Figure 9: Utility PV plant design

COTEN			Home About Publication Credits Feedback Contact Us Disclaimer	Logged in as Harshid Logout
Plant Details	Technology	Cost	and Other Details Financial Reset	Simulate
Move to 'Plant Details' menu	Here we choose the desired module and I Module	Power Conditioning Unit (PCU) for the pla	nt. Power Conditioning Unit (PCU)	Show Advanced Options
e -	Technology: Multi Crystalline Menufacturer: Select Manufacturer	Model : Power Rating (Wp): Select Model	Manufacturer: Select Manufacturer Model: Power Raling (KW): Select Model	Ð
First, choose Module from drop down menu in	Length (m): Module Type (m):	Broadth (m):	Second, choose the PCU from the filtered PCU set in order – Manufacturer and Model	Move to 'Cost' menu
order – Technology, Manufacturer and Model	Losses The operational losses in the PV system a be a bercentage of the PV ceneration.	are due to soiling of panels by dust and e	actrical losses in the conductors and other equipment. Here, we consider these far	itors to

Figure 10: Choice of technology

	Losses	Fill other parameters in the "Technology' menu as per discretion.		Valid range and default valu indicated when clicked in t input field	ues are he
	The operational loss be a percentage of	ses in the PV system are due to soiling of panels by dust and e the PV generation.	lectrical losses in the conduc	ctors and other equipment. Here, we consider these facto	ors to
	Soiling Loss (%)		Electrical Loss (%)	Range: 0 - 25, Default value = 10	
love to Plant	5		10		
menu	Module Degrada	ation			
[During the lifetime of	of the plant, PV modules like any equipment degrade and hence	e contribute to the energy los	as in the plant.	
	During the lifetime o	of the plant, PV modules like any equipment degrade and hence	e contribute to the energy los per datasheet; unch	is in the plant. eck this to input custom values	
	During the lifetime o	of the plant, PV modules like any equipment degrade and hence et Degradation details: default – as of of 1st Year (%):	e contribute to the energy los per datasheet; unch- Year on Year Degradation	is in the plant. eck this to input custom values	
	During the lifetime of Z As per datashe Module Rating at Er 97	of the plant, PV modules like any equipment degrade and hence et d of 1st Year (%)	e contribute to the energy los per datasheet; unch Year on Year Degradation 0.67	is in the plant. eck this to input custom values	
)	During the lifetime of As per datashe Module Rating at Er 97 Auxiliary Consu	of the plant, PV modules like any equipment degrade and hence et ← Degradation details: default – as d of 1st Vear (%) mption	a contribute to the energy los per datasheet; unch Year on Year Degradation 0.67	is in the plant. eck this to input custom values	Move to 'Co menu
	During the lifetime of As per datashe Module Rating at Er 97 Auxiliary Consu Refers to the in-hou	If the plant, PV modules like any equipment degrade and hence to be be a set of the plant of the operation. Here, we can be a set of the plant for its operation. Here, we can be a set of the plant of the plant of the operation.	e contribute to the energy los per datasheet; unch Vear on Year Degradation 0.87	is in the plant. eck this to input custom values Rate (% / Year): the annual generation at the end of year 1,	Move to 'Co menu
	During the lifetime of As per datashe Module Rating at Er 97 Auxiliary Consu Refers to the in-hou PV Plant (%):	If the plant, PV modules like any equipment degrade and hence et Degradation details: default – as plant of the two of t	e contribute to the energy los per datasheet; unch Vear on Year Degradellor 0.67	is in the plant. eck this to input custom values Rate (% / Year): the annual generation at the end of year 1,	Move to 'Co menu

Figure 11: Loss and related details

GITEM	Fill in the cost related parameters as per user discretion. Click on the fields to view valid ranges. Click on tooltips for additional context	Но	me About Publication Credits Feedback Contact Us Disclaimer	Logged	in as Harshid Logout
Plant Details	Technology Cost	O&M an	d Other Details Financial Reset		Simulate
Move to 'Technology' menu	We now define the various costs and expenses. These are categorised under Machinery	r Machine	ry, Infrastructure and Other expenses.	<mark>√</mark> Sh	ow Advanced Options
¢	This includes the core electrical components like the PV modules, Inverters on PV Module (? / Wp): 21	er Power (Conditioning Unit (PCU) and (Batteries for mini grid cases only). PCU or Inverter Price (& Lakhs / MWp): 30	0	€
	Infrastructure		Other Expenses		1
	Land (₹ Lakh/Acre):		Civil and General Works (₹ Lakh / MWp):		Move to
	5 PV Module Mounting Structure (₹ Lakhs / MWp):	0	25 Preliminary and Pre-operative Costs (₹ Lakh / MWp):	0	'O&M and Other
	30	0	35	0	Details' menu
	Power Evacuation Infrastructure (₹ Lakhs / ħfWp):		Miscellaneous (₹ Lakh / MWp):		
	40	0	30	0	

Figure 12: Capital cost-related components

CATTIM	Fill in the cost related parameters as per user discretion. Click on the fields to view valid ranges.	Home About Publication Credits Feedback Contact Us Disclaimer	ogged in as Harshid Logout
Plant Details	Technology Cost O	08M and Other Details Financial Reset	Simulate
Move to 'Cost' menu	Operation and Maintenance Cost This accounts for all expenses governing the day to expenses such as salaries, b	bills and spares.	Show Advanced Options
Ġ	O&M Cost For 1st Year (₹ Lakh/MWp). 6	O&M Escalation Rate Per Annum (%): 5.72	Ģ
•	Subsidy	Target Bid Bid (?/ kWh).	
	•	•	Move to 'Financial' menu
	Check this and enter the subsidy percentage to simulate the impact	Enter the target bid value, to assess its viability. (Field provided only if 'Bid Analysis' is chosen in case definition)	

Figure 13: Operation cost, bid and subsidy components

(crrss	Fill in the cost related parameters as p discretion. Click on the fields to view v Click on tooltips for additional context	per user valid ranges.	Но	me About Publicat	ion Credits Feedback Cont	act Us Disclaimer	Logged in as Harshid Logout
Plant Details	Technology	OSA	M and Other Details		Financial	Reset	Simulate
'Financial' menu	Loan (Kelatid Det (%) 70 Moratorium Period (Yeam) 1	0	Loan Term (Y 10 Term Loan Inf 8.5	ears): terest Rate (%):	Working Capita 8.5	al Interest Rate (%):	Simulate Case
¢	Return on Equily During Loan Ferm (%) 20 Post Loan Term (%) 24		Taxes Income Tax 34 Minimum A 20	; Rate (%): Iternate Tax (%):			Simulato
	Depreciation During Lean Term (%): 5.8						

Figure 14: Financial parameters including loan, tax etc.

3.2 Inputs: Mini-Grid PV Plant

Figure 15 to Figure 26 illustrate the details of the inputs sequence for simulating a mini-grid plant post clicking 'Build New Case' button in Figure 4. The broad sequence of inputs for simulating the case is as follows:

- Case definition (Figure 15)
- Input-output mapping for simulating a mini-grid PV plant (Figure 16)
- Choosing location of interest and additional details (Figure 17 and Figure 18)
- Load, losses and plant-capacity details (Figure 19 and Figure 20)
- Choice of technology: PV module, PCU, battery & other details (Figure 21 and Figure 22)
- Plant-design details (Figure 23)
- Capital-cost-related components (Figure 24)
- Operation cost, subsidy, feed in tariff components (Figure 25)
- Financial parameters including loan, tax, etc. (Figure 26)

	Plant Design		
	Capacity Based Area Based (Future)		Choose the broad parameters o interest for plant design and
	Application		click on submit when completed
	🔘 Grid Connected Utility Plant 0 🔞 Mini Grid 0		
CHOOSE	Mini Grid	Choose between grid co and off grid mini grid s	nnected set-ups
OPTIONS	Grid Connected Mini Grid Off Grid Mini Grid		Subr
OF	Financial Assessment		
INTEREST	O Basic Viability O O Bid Analysis (for utility plants only) O	Feed in Tariff (for mini grid cases)	
	Technology		
	○ PV ● PV with Storage (only for mini grid cases)		
	Tracking		





 Not
 Click to choose location of interest

 Figure 16: Input-Output map for simulating a mini-grid PV plant



Figure 17: Choosing the location of interest



Figure 18: Choice of surface area









CONTEM		Home About Publication Credits Feedback Contact Us Disclaimer come Logged in as Harshid Logout
Load and Losses	Technology Plant Details Cost	O&M and Other Details Financial Reset Simulate
	Here we choose the desired PV module and a compatible Power Conditioning Unit Module	(PCU) for designing the plant. Power Conditioning Unit (PCU)
	Mutti Crystalline	Manufacture: Seiect Manufacturer
¢	Manufacturer: Model: Power Rating in Wp. Select Manufacturer	Model Power Rating in kW.
First, choose	Longth (m): Breadth (m):	Second, choose the PCU from the filtered set in order – Manufacturer and Model
drop down menu in order -	Module Type (m):	
Technology, Manufacturer and Model	Battery We now define the time window for battery support. The slider below indicates Day	Hours ranging from 0 to 23. In this version we focus only on lead acid battery based





Figure 22: Choice of technology, battery, and other details

Fill ir discr Click	n the 'Plant Details' parameters as per user etion. Click on the fields to view valid ranges. on tooltips for additional context	Но	me About Publication Credits Feedback	Contact Us Disclaimer STEP Lo	gged in as Harshid Logout
Load and Losses	Technology Plant Details	Cost	O&M and Other Details	Financial Reset	Simulate Show Advanced Options
Move to "Technology" menu	Array Height (m) 1.5 Ground Clearance (m): 0.5 Array Tit (Degrees). 28,791837 Array Orientation (Degrees). 0 Boundary Spacing	0 0 0		Length	Move to Cost' menu
	Along Longth (m):		Along Breadth (m):		



Fill in Click toolt	n the 'Cost' parameters as per user discretion. on the fields to view valid ranges. Click on ps for additional context		Home About Publication Credits Feedback ContactUs Disclammer STEP Logged in as Harshid Logov	ut
Load and Losses	Technology Plant Details Cost		O&M and Other Details Financial Reset Simulate	
	We now define the various costs and expenses. These are categorised under Machinery, Machinery	Infrastrue	cture and Other expenses.	
	This includes the core electrical components like the PV modules, inverters or Power Con PV Module (¢ / Wp): 21 21	ditioning	Unit (PCU) and (Batteries for mini grid cases only). PCU or Invester Prior (* Lakhs / MWp). 30	
¢	Battery (¢ / k/Wh): 8000	0		
	Infrastructure		Other Expenses	
Move to 'Plant	Land (* Lakh/Acre): 5		Civil and General Works (* Lakh / MWp). 25 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	
Details' menu	PV Module Mounting Structure (* Lakhs / MWp): 30	0	Preliminary and Pre-operative Cosh (* Lakh / MYkjo) 25 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	
	Power Evacuation Infrastructure (* Lakhs / MWp): 40	0	Miscellaneous (* Laleh / MWp): 30 0	

Figure 24: Capital cost components

COTEM	Fill in the cost related parameters as per user discretion. Click on the fields to view valid ranges.	Home About Publication Credits Fee	edback Contact Us Disclaimer STEP Logged in as Harshid Logout							
Load and Losses	Technology Plant Details Cost	O&M and Other Details	Finandal Reset Simulate							
	Operation and Maintenance Cost This accounts for all expenses governing the day to expenses such as salaries, bills and spares.									
Cosť menu	O&M Cost For 1st Year (₹ Lakh/MWp):	O&M Escalation Rate Per Annum (%):								
	Check this and enter the subsidy Buck capta (%) Check this and enter the subsidy percentage to simulate the impact	Feed in Tariff								
	0	0	Move to							
	Tariff Enter the Tariff for buying power from provided only for grid connected min buy of Energy.	n grid (Field <u>1 grids</u>)	Enter the Tariff, to assess its viability. (Field provided only if <u>Teed</u> in Tariff' is chosen in case definition)							

Figure 25: Operation cost, subsidy, and feed-in tariff components

Č.	Fill in the cost related parameters as per user discretion. Click on the fields to view valid ranges. Click on tooltips for additional context			Home About Publication Credits	Feedback Contact Us Disclaimer 🔥	Logged in a	s Harshid Logout
Load and Losses	Technology Plant Details Cost			O&M and Other Details	Financial Rose	Show A	Simulate
	Loan Related Debt (%):		L	oan Term (Years):			Simulate Case
Move to 'O&M and Other Details' menu	70 Moratorium Peniod (Years): 1	0] ד 	10 iem Loan Interest Rate (%): 8.5	Working Capital Interest Rate (%): 8.5		
	Return on Equity During Loan Term (%).		Т	Taxes Income Tax Rate (%):			Simulate
	20 Post Loan Term (%): 24			34 Minimum Alternate Tax (%): 20			
	Depreciation						
	During Loan Term (%): 5.8						



4. Output-Screen Layout and Download

The post-simulation output screens have a generic layout for both utility-scale and mini-grid systems. There is no specific order to view the outputs. Provisions for performing a new simulation, as well as sub-menu tabs to navigate within the current tab, have been provided (mid-right end of the screen), as illustrated in Figure 27. Figure 28 presents a summary of the broad information covered under each tab.

We encourage the users to check the demo cases to understand the various outputs available for different case definitions, prior to building custom cases of interest.

Support text and tool tips (indicated in Figure 29) have been provided to add context to the outputs.



Figure 27: Layout of the output screens



Figure 28: Summary of details covered in each screen



Figure 29: Tooltips for additional context

Registered users can download the various outputs by clicking on the menu icon on the top ends of the graphs of interest. These are encircled and indicated in Figure 30, Figure 31, and Figure 32.



Figure 30: Output download menu icon type 1



Figure 31: Output download menu icon type 2



Figure 32: Output download menu icon type 3

Interested users can check the reports in the '<u>Publication</u>' section for accessing material which detail the mechanics of the tool.

5. Acknowledgements

We gratefully acknowledge the generous support provided by various institutions for the development of CSTEM PV. The development of the base version of CSTEM PV was supported by:

- Government of India Institutions: Ministry of New and Renewable Energy, and Department of Science and Technology
- Core Grants: Oak Foundation, and Think Tank Initiative of International Development Research Centre (IDRC)

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We thank the National Renewable Energy Laboratory, USA, for providing the weather data related to solar-energy modeling.

We also wish to thank our friends in the industry and academia for providing their valuable feedback. It would enable us to think ahead to cater to their respective needs.

About CSTEP

The Center for Study of Science, Technology and Policy (CSTEP) is one of India's leading think tanks. Our work is in the areas of climate, environment & sustainability, energy & power, AI for social impact, materials & strategic studies and computational tools for policymaking. Our research leverages innovative technology-based ideas to solve developmental challenges. We provide policy advice to Central and State Governments and are a part of various Government Committees. We collaborate with national and international research institutions to build a coherent narrative on policy challenges and solutions for India's sustainable development. CSTEP currently has over 140 employees working out of three offices in India. Our vision is to be the foremost institution for policy analysis in India.

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