Steinbeis Centre for Technology Transfer India

Training on

Grid Connected Rooftop PV Systems Technical & Economic Fundamentals

2018-Ahmadabad, Jammu, Shimla, Dehradun

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renac renewables academy

In cooperation with:

Steinbeis Centre for Technology Transfer India

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

www.renac.de

Rooftop Solar Designing and Case Studies

Overview of PVsyst Software

- Most widely used design software in the world
- Efficacy has been proven with ground data
- Tried and tested for last many years
- Mainly useful for energy simulation
- One time investment and lifetime use
- Purchase cost ~INR 1,00,000/- and Upgrade cost ~INR 35,000/- (2018)

Main Features

- **Preliminary design tool**
  Quick estimation of production for an early study of your installation
- **Project design tool**
  Detailed study, sizing and hourly simulation, results in a complete printable report
- **Databases**
  Meteo data and components management
- **Tool**
  Several educational tools and comparison of the simulation with measured results

Step 1: Choose Project Design, Grid Connected

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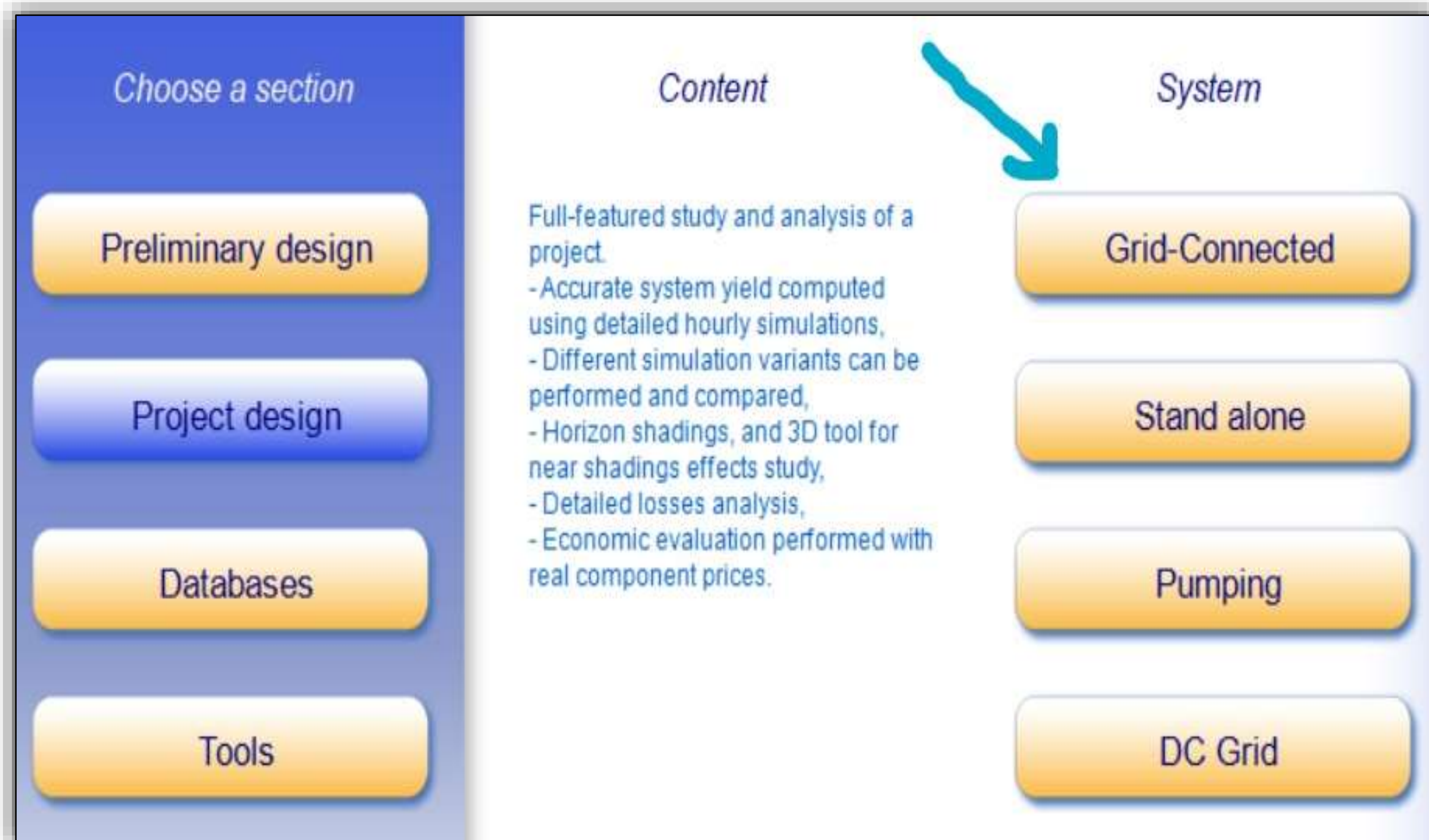
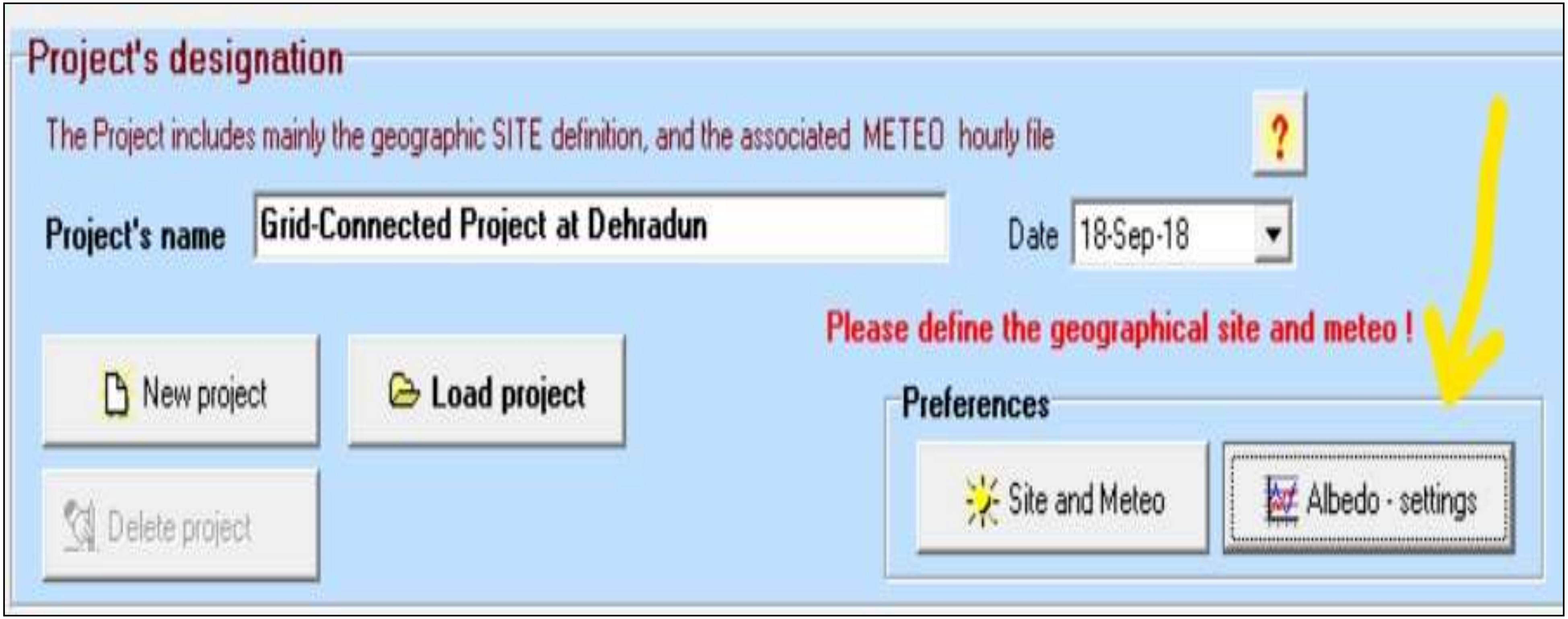


Step 2: Select New Project, Name it and Check Albedo



Step 3: Select Proper Albedo Value

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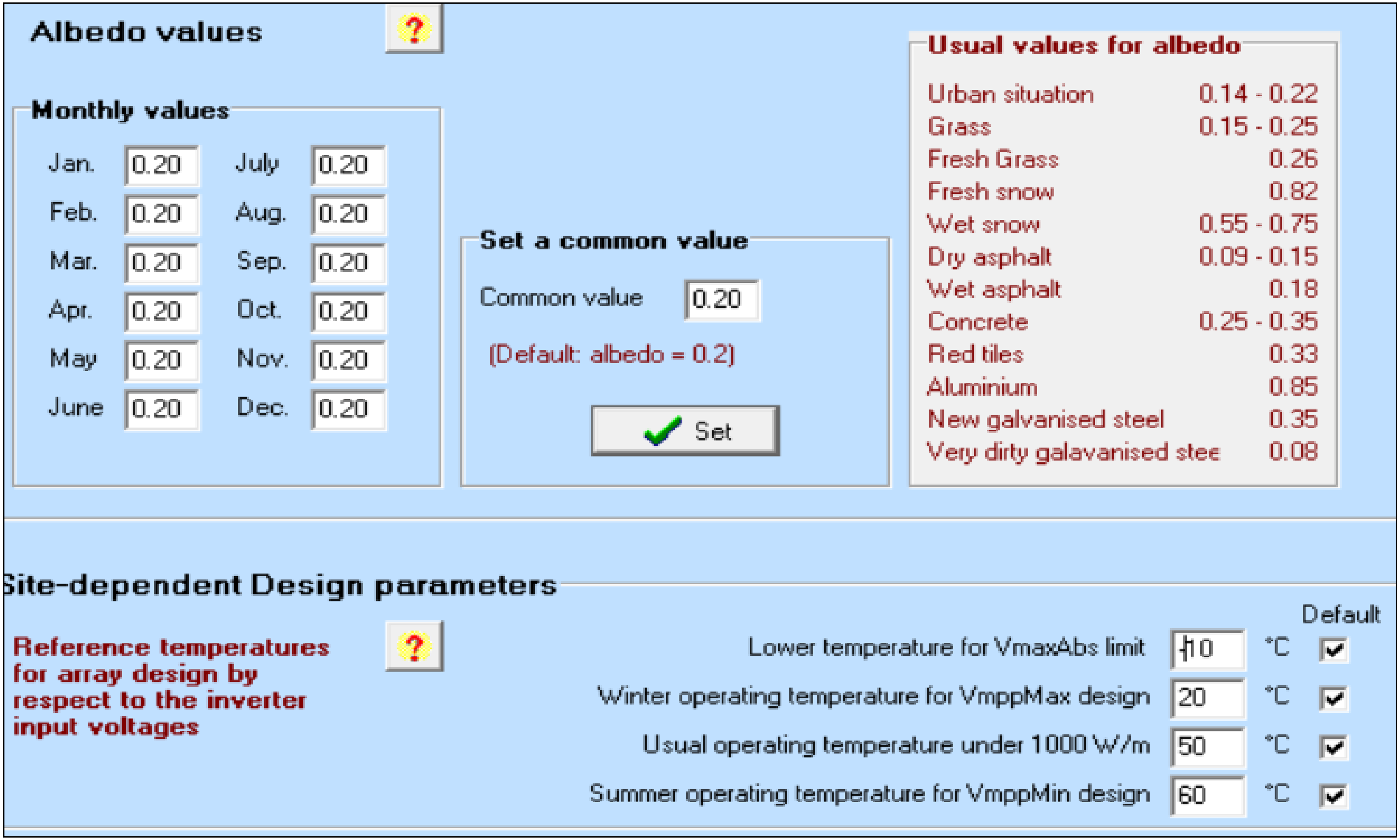
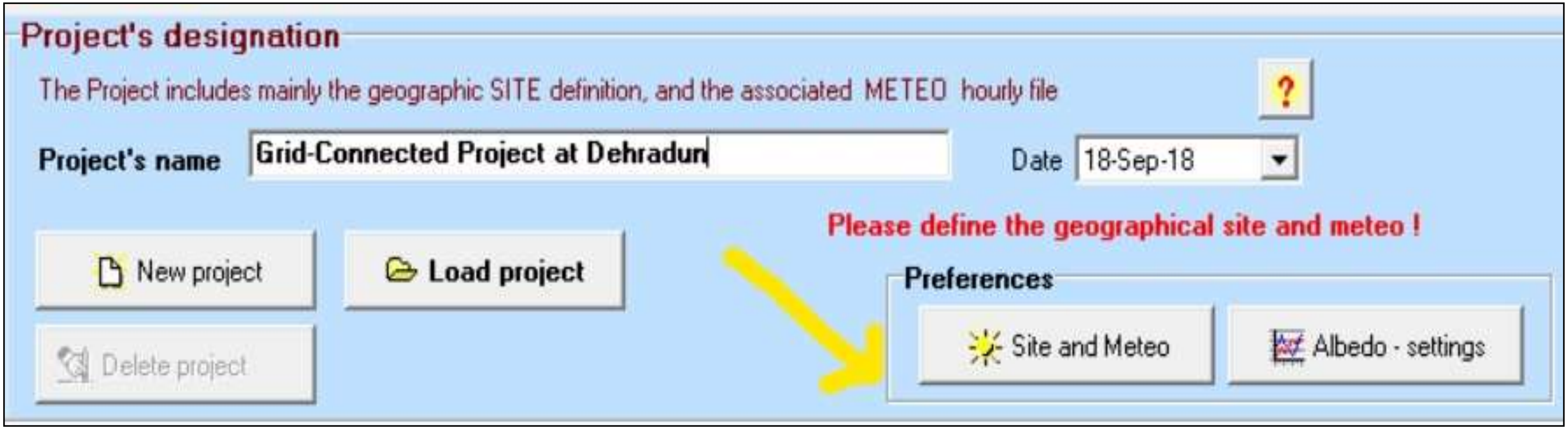
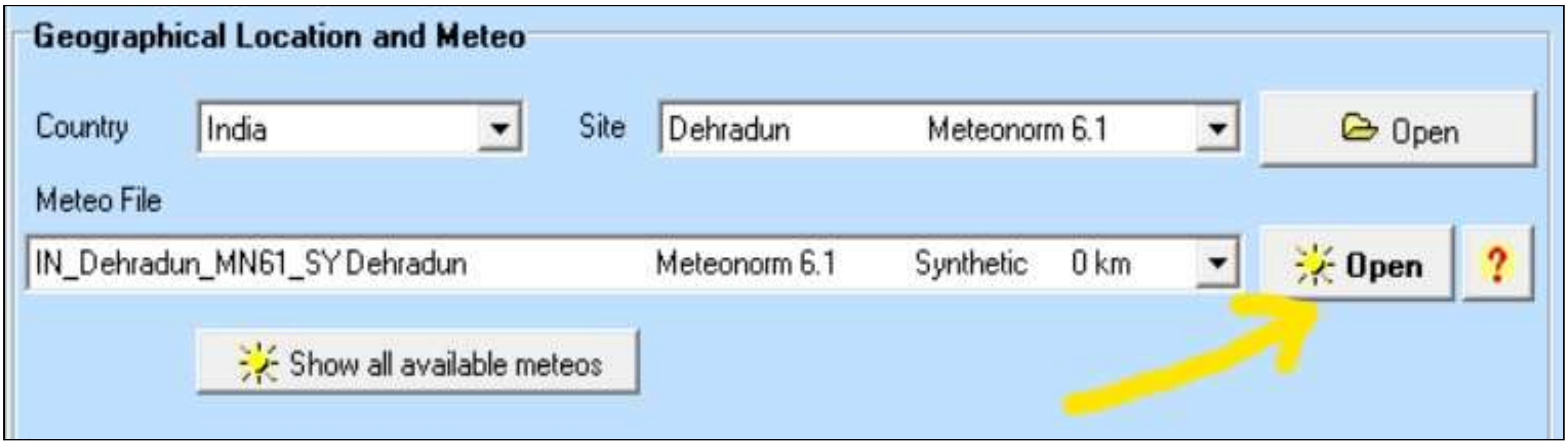


Step 4: Select Site and Meteo, Choose Meteonorm Data





Step 5: Choose Orientation

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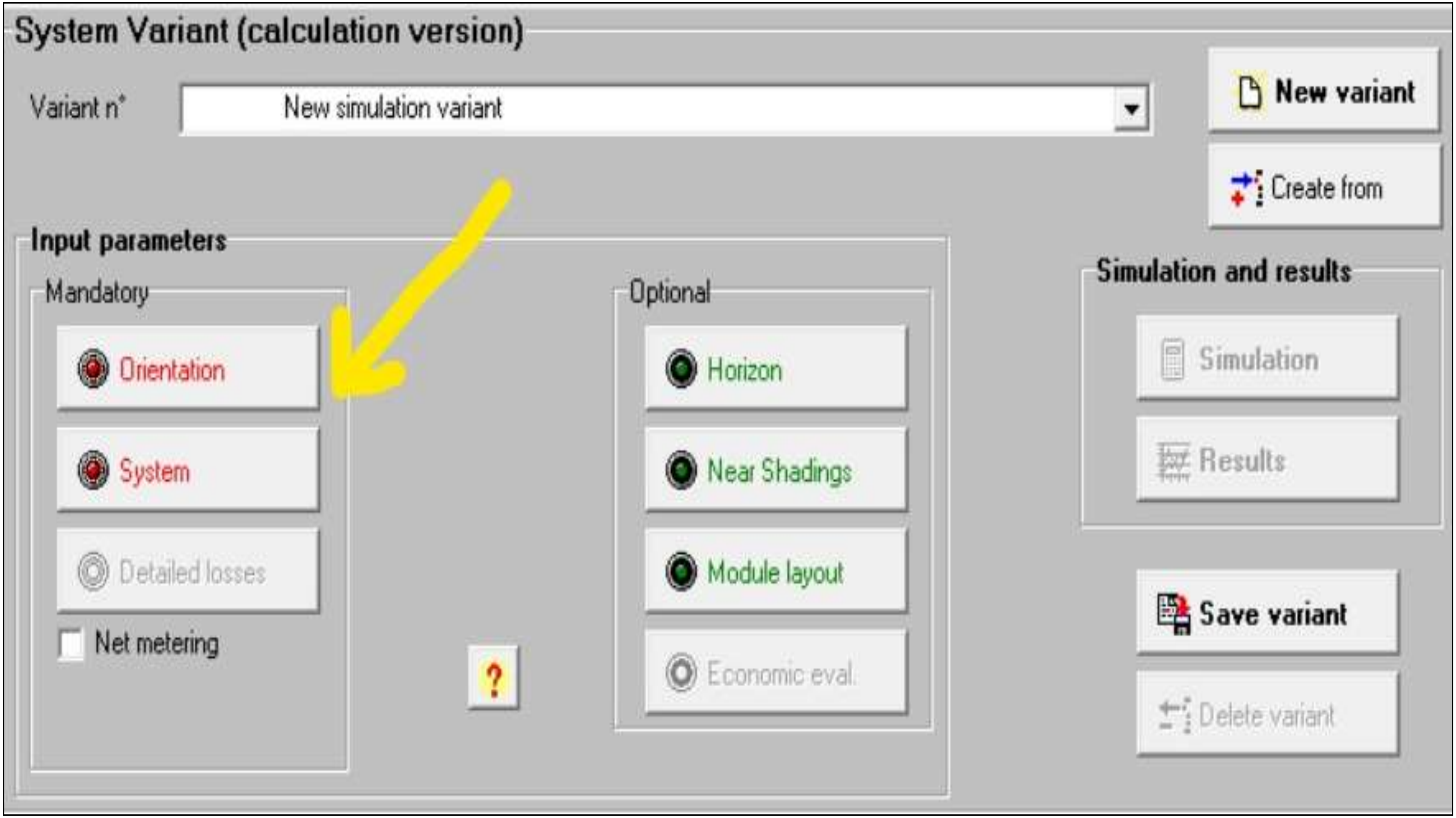
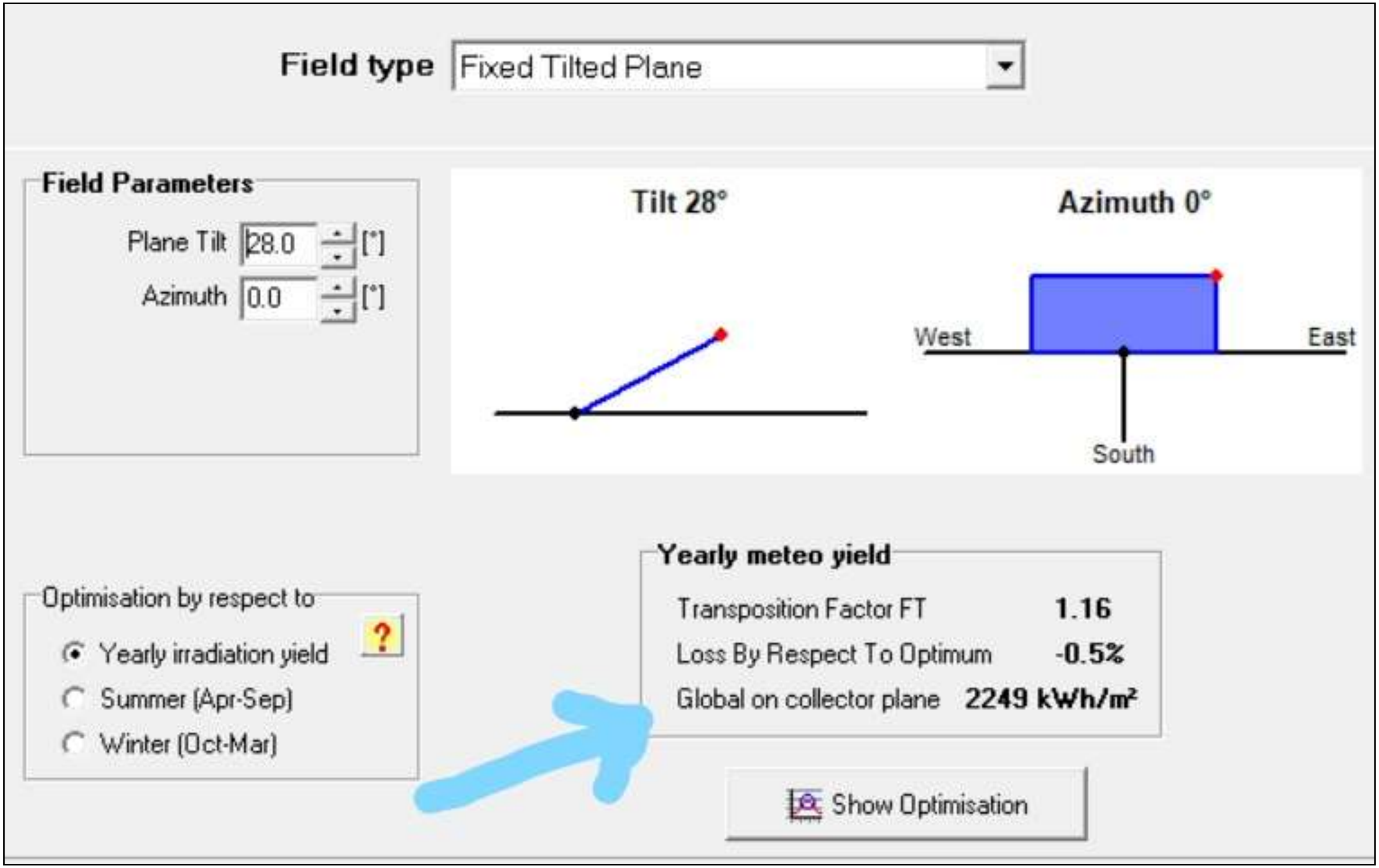
Technology Transfer India



Step 6: Set Field Type and Optimized Orientation (Lat: Dehradun 30^0)



Step 7: Enter Planned Power and Select PV module from the internal database

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Step 8: Choose Proper Inverter from the PVsyst database

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Step 9: Define Various Losses

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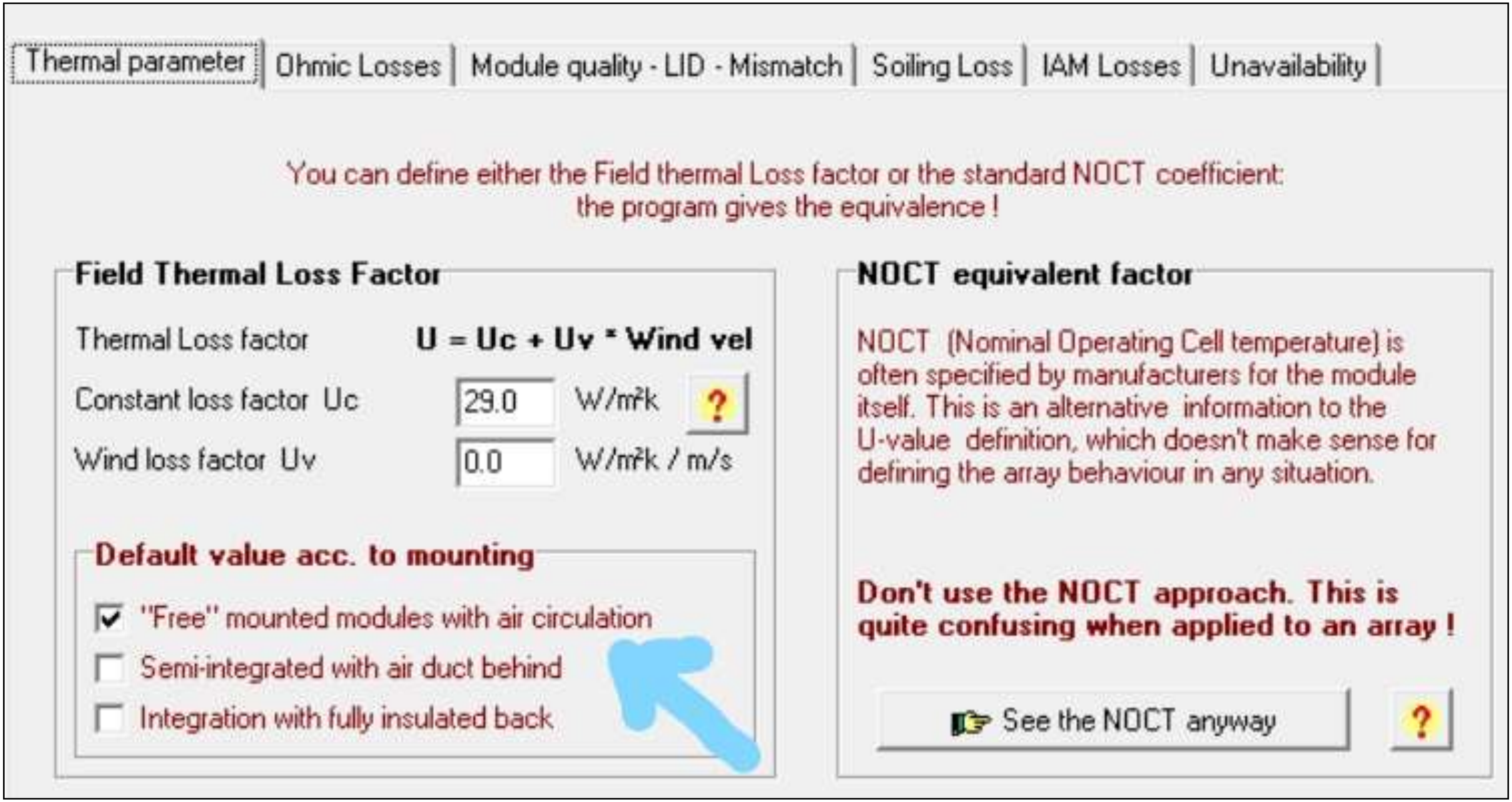

❖ LID (Light induced degradation) Initial 6 mth (p-Si: B^+ and O^2 Complex)

❖ IAM (incident angle modifier) Losses due to angled reflection on surface

Step 10: Perform Simulation

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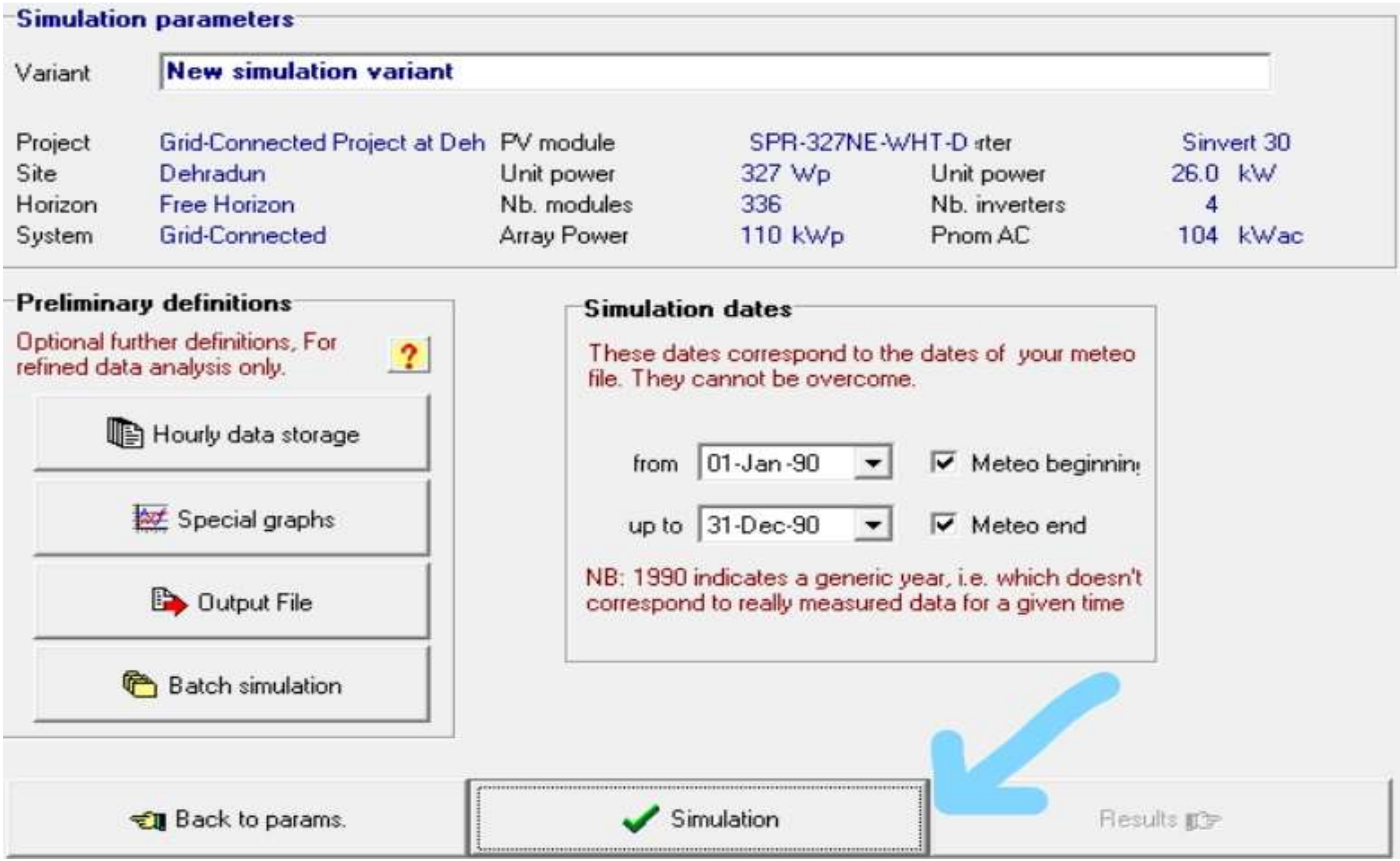
Step 11: Confirm Simulation



Step 12: Get Final Report and Print

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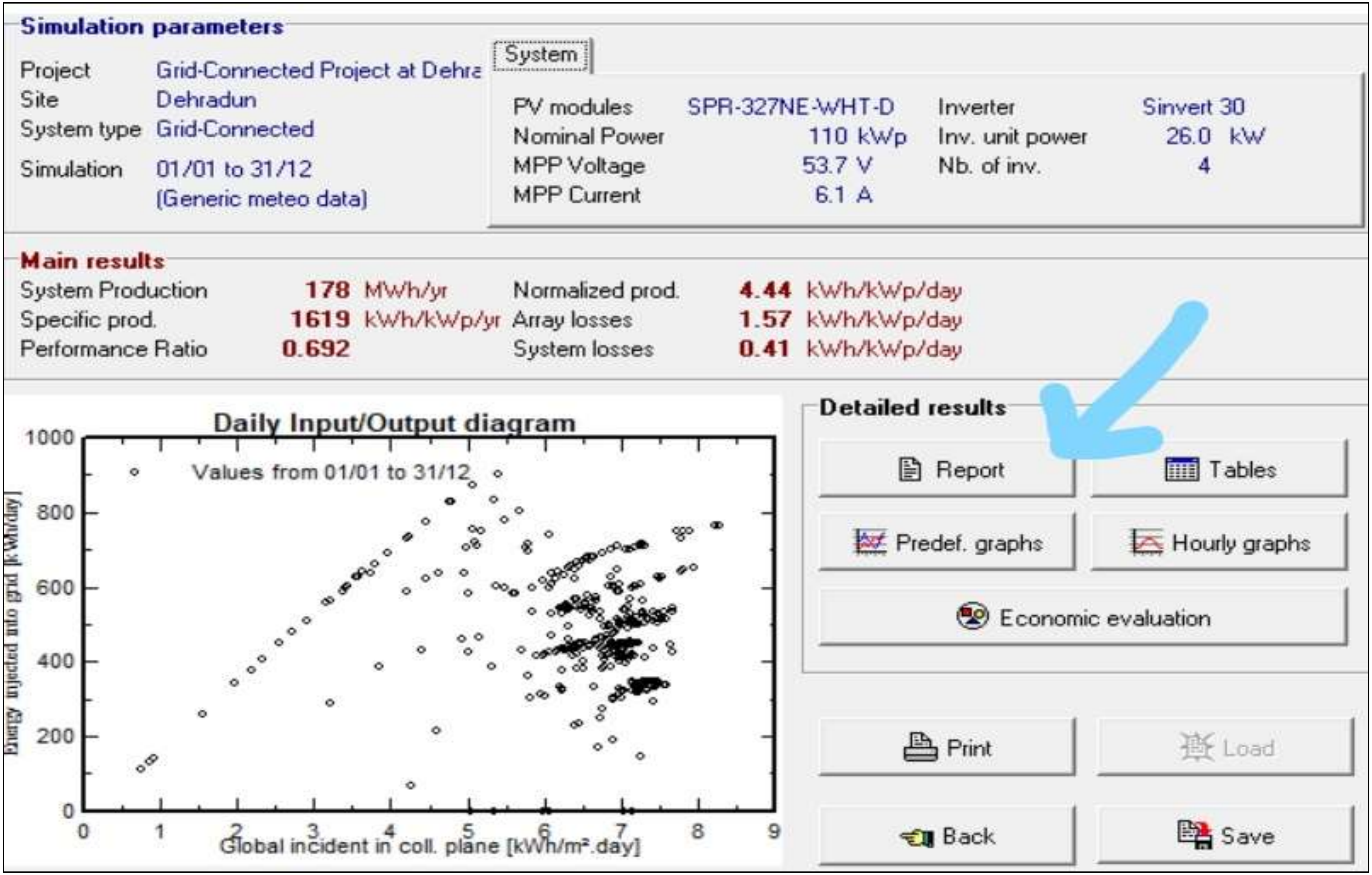

Step 13: Generate Report - Parameters

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Grid-Connected System: Simulation parameters

Project :	**Dehradun 100kW Rooftop Solar Power**			
Geographical Site	**Dehradun**		Country	**India**
Situation	Latitude	30.3°N	Longitude	78.0°E
Time defined as	Legal Time	Time zone UT+5.5	Altitude	653 m
	Albedo	0.20		
Meteo data:	**Dehradun**	Synthetic - Meteonorm 7.1 (1981-2010), Sat=100%		

Simulation variant :	**New simulation variant**			
	Simulation date	19/09/18 20h47		

Simulation parameters

Collector Plane Orientation	Tilt	30°	Azimuth	0°
Models used	Transposition	Perez	Diffuse	Erbs, Meteonorm
Horizon	Free Horizon			
Near Shadings	No Shadings			

PV Array Characteristics

PV module	Si-mono	Model	**SPR-E19-310-COM**		
Original PVsyst database		Manufacturer	SunPower		
Number of PV modules		In series	14 modules	In parallel	23 strings
Total number of PV modules		Nb. modules	322	Unit Nom. Power	310 Wp
Array global power		Nominal (STC)	**99.8 kWp**	At operating cond.	90.6 kWp (50°C)
Array operating characteristics (50°C)		U mpp	681 V	I mpp	133 A
Total area		Module area	**525 m²**	Cell area	474 m²

Inverter	Model	**ECO 25.0-3-S**		
Original PVsyst database	Manufacturer	Fronius International		
Characteristics	Operating Voltage	580-850 V	Unit Nom. Power	25.0 kWac
Inverter pack	Nb. of inverters	4 units	Total Power	100 kWac

Step 14: Generate Report – 1st Year Data

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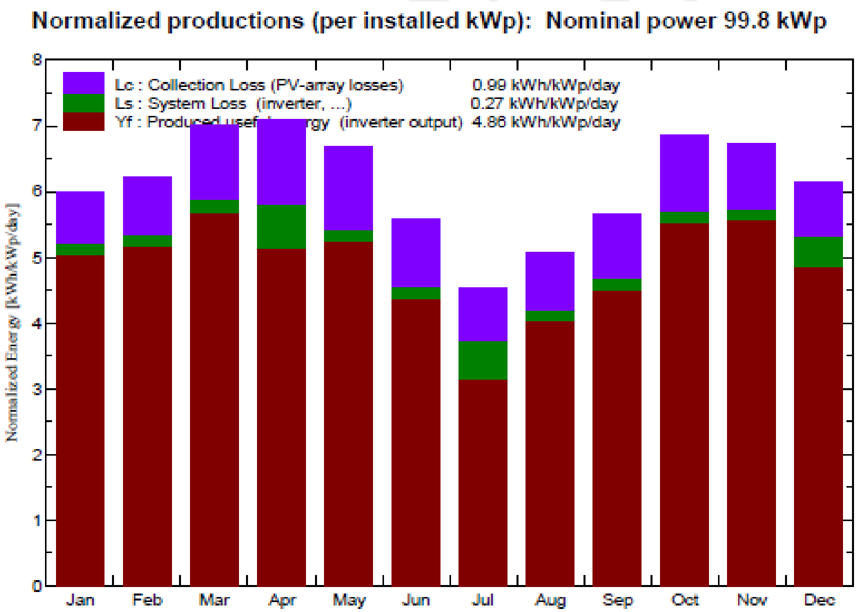
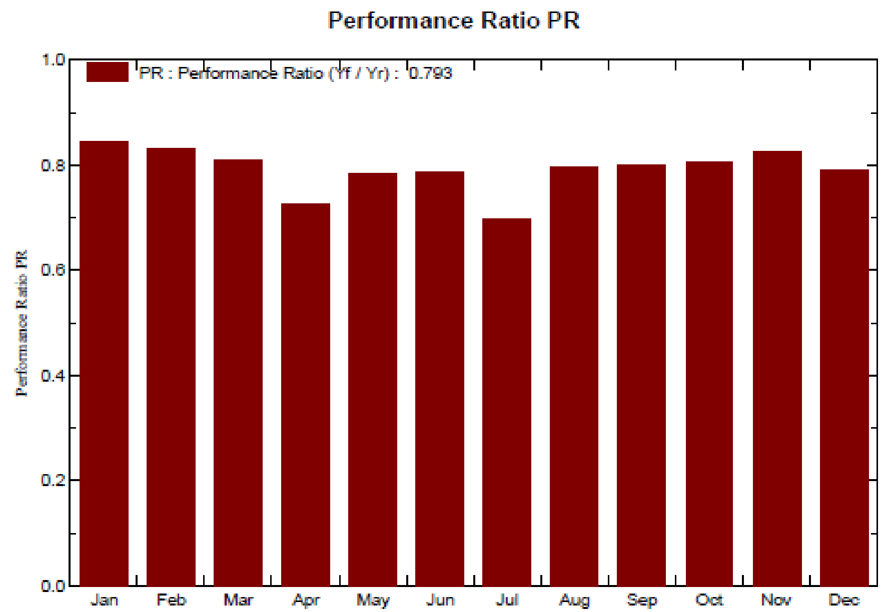
Project :	**Dehradun 100kW Rooftop Solar Power**			
Simulation variant :	**New simulation variant**			
Main system parameters	System type	**Grid-Connected**		
PV Field Orientation	tilt	30°	azimuth	0°
PV modules	Model	SPR-E19-310-COM	Pnom	310 Wp
PV Array	Nb. of modules	322	Pnom total	**99.8 kWp**
Inverter	Model	ECO 25.0-3-S	Pnom	25.00 kW ac
Inverter pack	Nb. of units	4.0	Pnom total	**100 kW ac**
User's needs	Unlimited load (grid)			
Main simulation results				
System Production	**Produced Energy**	**177074 kWh/year**	Specific prod.	1774 kWh/kWp/year
	Performance Ratio PR	79.3 %		





Step 15: Generate Report – Monthly Data

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	GlobHor kWh/m²	T Amb °C	GlobInc kWh/m²	GlobEff kWh/m²	EArray kWh	E_Grid kWh	EffArrR %	EffSysR %
January	121.8	12.29	185.6	176.4	16153	15641	16.57	16.05
February	129.2	15.17	174.3	165.5	14969	14474	16.35	15.81
March	184.5	20.25	217.8	206.3	18193	17616	15.91	15.40
April	204.2	25.13	212.8	200.8	17389	15405	15.57	13.79
May	221.3	27.87	207.3	194.7	16779	16204	15.41	14.89
June	185.1	27.74	167.0	156.3	13655	13145	15.57	14.99
July	153.3	26.79	140.1	131.2	11574	9742	15.73	13.24
August	161.4	26.06	156.8	146.9	12985	12482	15.78	15.17
September	155.6	24.73	169.3	159.5	14024	13524	15.78	15.22
October	164.6	22.08	212.5	201.8	17678	17123	15.84	15.34
November	133.0	17.03	202.2	192.0	17197	16665	16.20	15.70
December	118.0	13.37	190.6	181.1	16481	15053	16.47	15.04
Year	1931.9	21.57	2236.2	2112.4	187079	177074	15.93	15.08

Legends:

GlobHor	Horizontal global irradiation	EArray	Effective energy at the output of the array
T Amb	Ambient Temperature	E_Grid	Energy injected into grid
GlobInc	Global incident in coll. plane	EffArrR	Effic. Eout array / rough area
GlobEff	Effective Global, corr. for IAM and shadings	EffSysR	Effic. Eout system / rough area

Step 16: Generate Report-Loss Diagram

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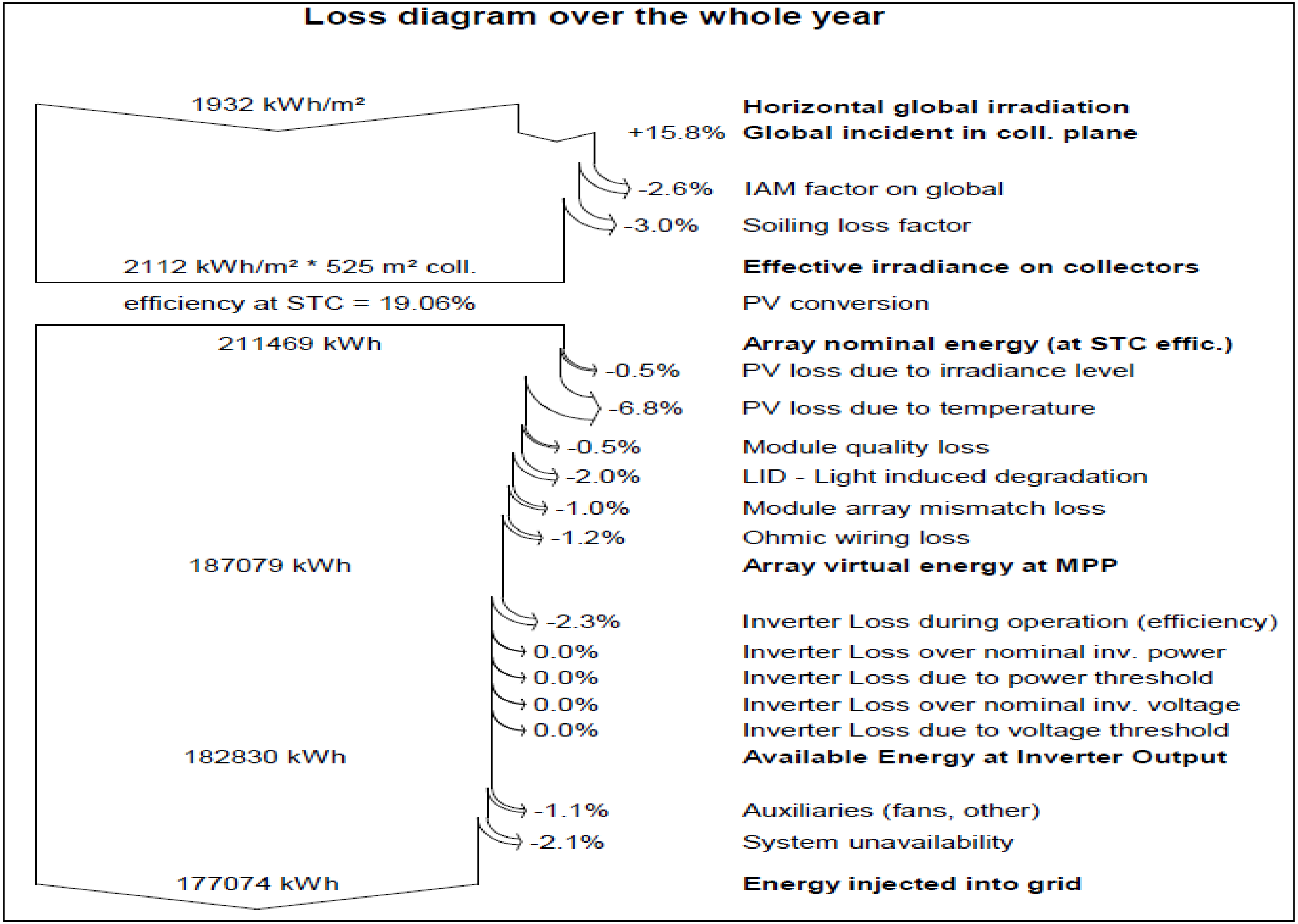

PR & CUF

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- Performance Ratio = Energy measured (kWh/Yr) / (Irradiance on the panel kWh/m^2/Yr x Active area of PV module m^2 x PV module efficiency %) **Represents Quality of Plant**

- Capacity Utilization Factor = Energy measured / (365 x 24 x Installed capacity of the plant) **Represents Time Behaviour**

Case Studies

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- **1 MW Chandrapur**
  - Total energy generation = 16,50,000 Units
  - Simulated CUF = 18.18%
  - Actual CUF = 18.835%
- **1.09 MW Punjab**
  - Total generation = 16,04,835 Units
  - Simulated CUF = 20.8%
  - Actual CUF = 16.79%

In terms of PR

- **Case 1: 250.42 kW Gandhinagar**
  - Energy generation: 39,858 Units
  - Simulated PR: 77.7%
  - Actual PR: 80.2 %

- PVsyst has conservative approach
- Safe for Business Decision

Other Tools Used for Pre Feasibility Analysis & Energy Prediction

- Google SketchUp
- HelioScope
- Sustainable by design

Google SketchUp

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- https://www.sketchup.com
- Google Sketchup Free https://www.sketchup.com/products/sketchup-free
- Google Sketchup Pro (INR 50,000) https://www.sketchup.com/products/sketchup-pro

Features:

- SketchUp Free is the easiest way to draw in 3D, now delivered in a web browser. Draw, orbit, push-pull: make anything you can imagine, however you envision it.
- SketchUp pro is useful from the earliest stages of design to the end of construction. Programming, diagramming, design development, detailing, documentation
- Video Demo

Google SketchUp Sample

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YouTube Video 4.49 minutes:
https://www.youtube.com/watch?v=wNRsEzcXsWQ

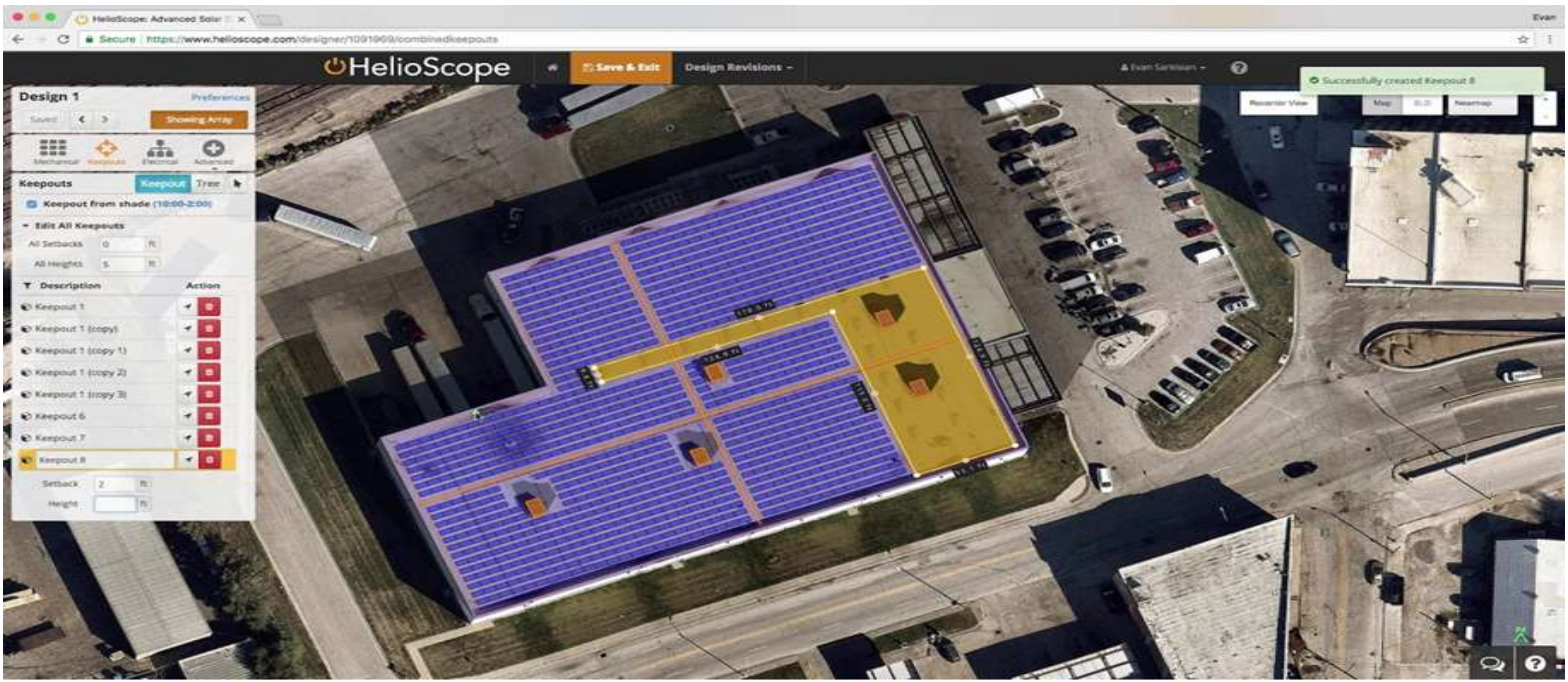
YouTube Video 2.56 minutes: https://youtu.be/Ee9zysWd9yo

HelioScope

- Latest software: Shading analysis, Shading loss analysis, CAD design, Energy simulation all clubbed together
- HelioScope layout and performance modeling tools are cloud-based and available globally
- Used for preliminary layouts, value engineering, energy yield calculations
- Used for projects of all sizes (residential, commercial, utility) and all countries
- Purchase cost INR 6,500/- monthly and INR 65,000/- annually

Helioscope : Youtube Videos

- Commercial Project: (5 minutes)
  https://www.youtube.com/watch?v=UTgre4il4Fo
- Residential Project: (5 minutes)
  https://www.youtube.com/watch?v=D4fHHMeBDDU



Sustainable by Design

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- Shading Analysis: Inter row spacing throughout the year
- Free of Cost Online Software: https://susdesign.com/
- Inputs:
  - Panel height: Vertical height of the physical panel
  - Panel thickness: Thickness of the panel
  - Panel spacing: Horizontal distance between rows of panels
  - Panel tilt: The tilt of the panels from horizontal
  - Latitude: The geographical latitude of location
- Cell Color Scheme: **Black** total shading, **White** complete sun, **Gray** partial shading, **Green** sun below horizon, **Blue** sun above horizon, but not shining on the panels

Sustainable by Design

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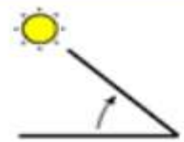
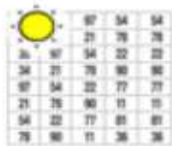
Design Tools

Sustainable By Design provides a suite of shareware design tools on sustainable energy topics:

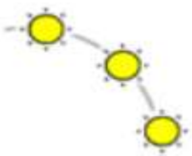
SUN ANGLE TOOLS



SunAngle
the premiere tool for solar angle calculations



SunPosition
calculates a time series of basic solar angle data



Sol Path
visualization of the path of the sun across the sky

OTHER TOOLS

Panel Shading
visualization of the shading of rows of flat panel collectors throughout the year

USA Climate Data
monthly climate data for about 250 U.S. cities

Sustainable by Design

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INPUTS

panel height	1.5	latitude	30 ° North ▼
panel thickness	0.04	show values	Shading % ▼
panel spacing	3	orientation	SOUTH ▼
panel tilt	28 °	surface slope	0 °

calculate

	MORNING									AFTERNOON								
	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	
Jan				72%	0%	0%	0%	0%	0%	0%	0%	0%	0%	71%				Jan
Feb				0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%				Feb
Mar				0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%				Mar
Apr			0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%			Apr
May			0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%			May
Jun			0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%			Jun
Jul			0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%			Jul
Aug			0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%			Aug
Sep			0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%			Sep
Oct				0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%				Oct
Nov				46%	0%	0%	0%	0%	0%	0%	0%	0%	0%	47%				Nov
Dec				92%	0%	0%	0%	0%	0%	0%	0%	0%	0%	92%				Dec
	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	
	MORNING									AFTERNOON								

Some Installations of

Rooftop Grid Connected Rooftop

Systems in India

Module	India Make
Aggregate Plant Capacity	404 kWp
Rooftop Owner	Manipal University
City	Jaipur
State	Rajasthan
Project Cost	Rs. 2.86 Cr
CFA through SECI	Rs. 86 Lakh

Module	India Make
Plant Capacity	115 kWp/85 kWp
Rooftop Owner	DMRC
Project Site	Anand Vihar/Pragati Maidan
City	Delhi

Module	India Make
Plant Capacity	130 kWp
Rooftop Owner	ISBT Kashmere Gate
City	Delhi
State	Delhi
Project Cost	Rs. 114.3 Lakhs
CFA through SECI	Rs. 30.3 Lakhs

Module	India Make
Plant Capacity	360 kWp
Rooftop Owner	Super Auto Forge Pvt., Ltd.,
City	Chennai
State	Tamilnadu
Project Cost	Rs. 3.06 Cr
CFA through SECI	Rs. 92 lacs

Module	India Make
Plant Capacity	100 kWp
Rooftop Owner	Rockwell Industries
City	Hyderabad
State	Telangana
Project Cost	Rs. 0.74 Cr
CFA through SECI	Rs. 22.2 lacs

Module	India Make
Plant Capacity	300 kWp
Rooftop Owner	IIT Madras
City	Chennai
State	Tamilnadu
Project Cost	Rs. 2.49 Cr
CFA through SECI	Rs. 75 lacs

Module	India Make
Plant Capacity	500 kWp
Rooftop Owner	Medanta Hospital
City	Gurgaon
State	Haryana
Project Cost	Rs. 4.15 Cr
CFA through SECI	Rs. 1.24 Cr

Module	India Make
Plant Capacity	100 kWp
Rooftop Owner	NIAS
City	Bengaluru
State	Karnataka
Project Cost	Rs. 83 lacs
CFA through SECI	Rs. 25 lacs

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1.0 MW Rooftop Plant at Punjab Engineering College, Chandigarh

Largest Rooftop Plant in the world on Single Roof

- *7.52MW plant installed by Larsen & Toubro construction in Punjab*
- *L&T installed more than 30,000 PV panels on the rooftop*
- *Power from the plant being fed to the local grid through a PPA signed with the state distribution company*
- ** Source L&T*

Live Demonstration Of Pvsyst Software With Real Example And Interaction With Participants

Thank You