

Internationalizing SAM: Using SAM for India-based Projects

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Overview

- Introduction to SERIIUS
- Motivation
- Implementation
- Ongoing work and Applications

The Vision of SERIIUS

To create an environment for cooperation & innovation
“**without borders**” to develop & ready emerging
revolutionary solar-electricity technologies...”



The Team – India & US Working Together

India

United States

Consortium Leads

Indian Institute of Science – Bangalore
Dr. Kamanio Chattopadhyay

National Renewable Energy Laboratory
Dr. David Ginley

Research Thrust Leadership

Indian Institute of Technology Bombay
Center for the Study of Science,
Technology and Policy

Sandia National Laboratories
RAND Corporation

Consortium Partners

Institutes and National Laboratories

International Advanced Research Centre for
Powder Metallurgy and New Materials
National Institute of Solar Energy

Lawrence Berkeley National Laboratory

University Partners

Indian Institute of Technology Madras
Indian Association for the
Cultivation of Science

Arizona State University
Binghamton University
Carnegie Mellon University
Colorado School of Mines
Colorado State University
Massachusetts Institute of Technology
Purdue University
Stanford University
University of Central Florida
University of Colorado Boulder
University of South Florida
Washington University in St. Louis

Industry Partners

Bharat Heavy Electricals Ltd.*
Cliques Developments Ltd.
GAIL (India) Limited
Hindustan Petroleum Corporation Ltd.
Infosys Ltd.
Moser Baer India Ltd.
Thermax Ltd.
Wipro Ltd.

Alpha Metals, Inc.
Corning Research and Development Corporation
Eastman Kodak Company
Interphases Solar
SemLux Technologies, Inc.
Sigma-Aldrich
Solarmar Energy, Inc.
Underwriters Laboratories



*New Partners - SERIIUS

SERIIUS aims to improve solar technology and deployment through 3 integrated research areas



SEI has included techno-economic modeling and analysis, including collaboration between NREL, RAND, and CSTEP to develop a “SAM for India v1.0”

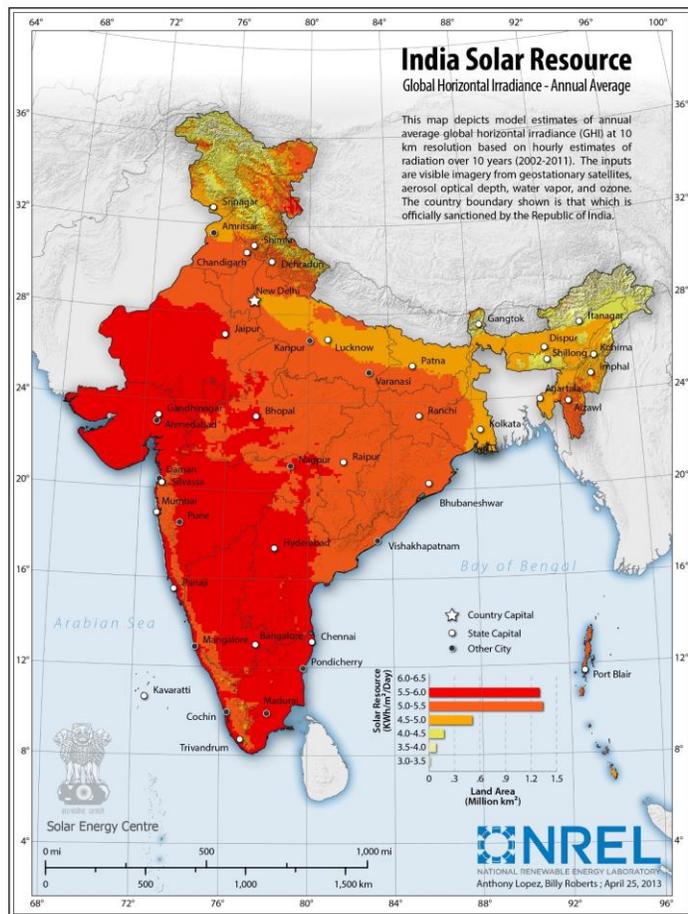
Purpose

Modify the existing SAM tool to facilitate ease of use in analyzing India-based projects with a particular focus on weather data and financial structure

Overview of Changes

- Expansion of location database
- Inclusion of India-specific finance elements
- Rupee denominated input and output display support
- Development of wizard walkthrough for new users

Addition of Locations



SAM 2017.4.11: C:/Users/sturner/AppData/Local/SAM/sam-2017.4.11/PV_for_India.sam

File Add PV Help

Photovoltaic, Single owner

Location and Resource

Module

Inverter

System Design

Shading and Snow

Losses

Lifetime

Battery Storage

System Costs

Financial Parameters

Time of Delivery Factors

Incentives

Depreciation

Simulate >

Parametrics P50 / P90

Stochastic Macros

Albedo - Sky Diffuse Model - Irradiance Data (Advanced)

Download a weather file from the NREL NSRDB

Download... Click Download and type a street address or latitude and longitude to download from the NREL NSRDB for United States and some international locations. downloaded file to the solar resource library so it will appear in the list below.

NSRDB all... NSRDB Map

Choose a weather file from the solar resource library

Click a name in the list to choose a file from the library. Type a few letters of the name in the search box to filter the list above.

Search for: Name

Name	Station ID	Latitude
India IND Jagdaipur (SUNY)	49640	19.05
India IND Jaipur (SUNY)	29259	26.95
India IND Jaisalmar (SUNY)	13089	26.95
India IND Jalgaon (SUNY)	28210	21.05
India IND Jodhpur (SUNY)	20012	26.25
India IND Karimnagar (SUNY)	40064	18.45

City: Time zone: GMT 5.5 Latitude:

State: Elevation: 0 m Longitude:

Country: India Data Source: SUNY Station ID: 20012

Data file: C:/SAM/2017.4.11/solar_resource/India IND Jodhpur (SUNY).csv

Annual Weather Data Summary

Global horizontal	5.69 kWh/m ² /day	Average temperature	27.3 °C
Direct normal (beam)	5.14 kWh/m ² /day	Average wind speed	2.0 m/s
Diffuse horizontal	2.21 kWh/m ² /day	Maximum snow depth	NaN cm

Visit SAM weather data website

Use a specific weather file on disk

Browse...

Check the box and click Browse to choose a weather file stored on your computer without adding it to the solar resource library. Supported weather file formats are SAM CSV, TMY2, TMY3, and EPW.

PV resource data

Where is your project located?

Choose a location from the selection box (or press 'OK' to use the default)

- India IND Hyderabad (SUNY)
- India IND Imphal (SUNY)
- India IND Indore (SUNY)
- India IND Itanagar (SUNY)
- India IND Jabalpur (SUNY)
- India IND Jagdalpur (SUNY)
- India IND Jaipur (SUNY)
- India IND Jaisalmar (SUNY)
- India IND Jalgaon (SUNY)
- India IND Jodhpur (SUNY)
- India IND Karimnagar (SUNY)
- India IND Kavaratti (SUNY)
- India IND Kedarnath (SUNY)
- India IND Kohima (SUNY)
- India IND Kolhapur (SUNY)

OK Cancel

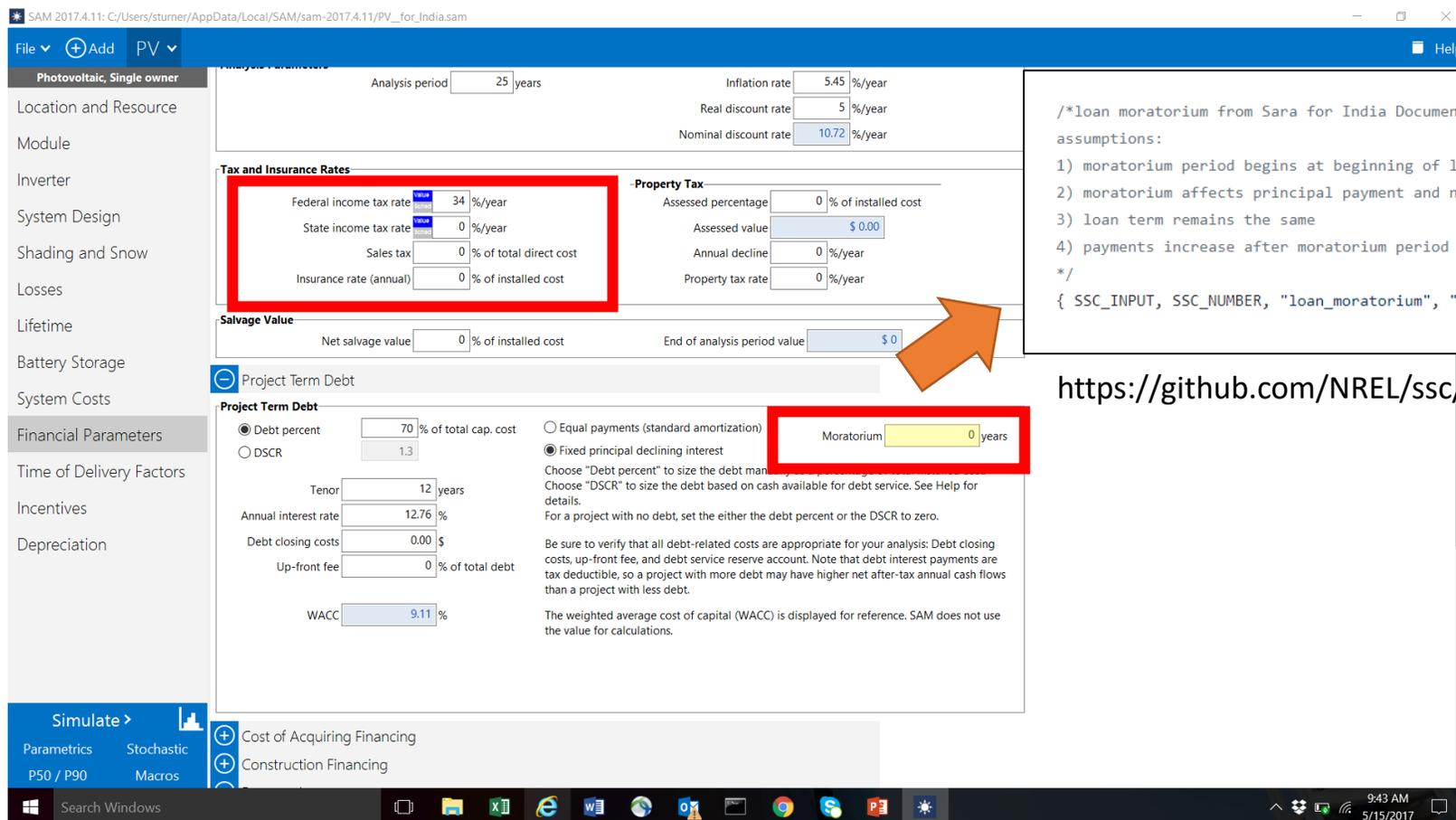
Refresh library

Folder settings...

Open library folder...

9:40 AM 5/15/2017

Improving Indian Finance Representation



SAM 2017.4.11: C:/Users/sturner/AppData/Local/SAM/sam-2017.4.11/PV_for_India.sam

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Time of Delivery Factors

Incentives

Depreciation

Simulate >

Parameters Stochastic

P50 / P90 Macros

Cost of Acquiring Financing

Construction Financing

Analysis period: 25 years

Inflation rate: 5.45 %/year

Real discount rate: 5 %/year

Nominal discount rate: 10.72 %/year

Tax and Insurance Rates

Federal income tax rate: 34 %/year

State income tax rate: 0 %/year

Sales tax: 0 % of total direct cost

Insurance rate (annual): 0 % of installed cost

Property Tax

Assessed percentage: 0 % of installed cost

Assessed value: \$ 0.00

Annual decline: 0 %/year

Property tax rate: 0 %/year

Salvage Value

Net salvage value: 0 % of installed cost

End of analysis period value: \$ 0

Project Term Debt

Debt percent: 70 % of total cap. cost

DSCR: 1.3

Tenor: 12 years

Annual interest rate: 12.76 %

Debt closing costs: 0.00 \$

Up-front fee: 0 % of total debt

WACC: 9.11 %

Equal payments (standard amortization)

Fixed principal declining interest

Moratorium: 0 years

```
/*loan moratorium from Sara for India Documentation\India\Loan Moratorium
assumptions:
1) moratorium period begins at beginning of loan term
2) moratorium affects principal payment and not interest
3) loan term remains the same
4) payments increase after moratorium period
*/
{ SSC_INPUT, SSC_NUMBER, "loan_moratorium", "Loan moratorium period", "years", "", "Moratorium", "?=0", "INTEGER,MIN=0", "" },
```

https://github.com/NREL/ssc/blob/develop/ssc/cmod_singleowner.cpp

Making Modifications Easy to Access

 PV India.lk	7/27/2017 3:04 PM	LK File	26 KB
 PV_for_India.sam	9/15/2017 2:39 AM	System Advisor M...	50 KB
 pvforindiawizard.samreport	9/12/2017 2:23 AM	SAMREPORT File	82 KB
 Wind Wizard.lk	7/27/2017 3:04 PM		
 windwizard.samreport	7/27/2017 3:04 PM		



```

/*****/
/**          Set Costs          **/
/* could possibly do conversions.... skip fo now
// Assumptions 1 INR = 0.015 USD conversion rate 1/30/2017
checked 2/21/2018
convINRtoUSD = 0.015;
convINRtoUSD = in( "SAM calculates all values in USD. This
Wizard allows entries in INR assuming a INR to USD conversion
rate. Enter the desired conversion rate or hit enter.",
                convINRtoUSD,
                'Rupees to Dollars',
                [defaultX, defaultY]);
exitIf( convINRtoUSD <= 0 );
*/
// Get capital cost from user - all costs in BOS bucket per file
from Sara
// capCostINR = to_real(get('bos_equip_fixed')) / convINRtoUSD;

show_page('System Costs');

// Highlight resource selection box in UI
focusto('per_module');
geom = widgetpos('per_module');
transp( geom, 'yellow', 70 );
millisleep(500);

```

Rupee Input/Output Display Support

The screenshot shows the SAM software interface for a Photovoltaic, Single owner system. The 'Direct Capital Costs' section is active, displaying various cost components in rupees. A dialog box titled 'Capital Cost' is open, asking for the system's capital cost per Watt in rupees, with the value 53.12 entered.

Component	Units	Value	Unit	Value	Unit	Value
Module	5,544 units	0.2 kWdc/unit	997.9 kWdc	53.12 \$/Wdc		\$ 53,009,512.00
Inverter	227 units	4.0 kWac/unit	908.0 kWac	0.00 \$/Wdc		\$ 0.00
Battery bank	0.0 kWh dc		600.00 \$/kWh dc			\$ 0.00
Balance of system equipment		0.00 \$	0.00 \$/Wdc	0.00 \$/m ²		\$ 0.00
Installation labor		0.00 \$	0.00 \$/Wdc	0.00 \$/m ²		\$ 0.00
Installer margin and overhead		0.00 \$	0.00 \$/Wdc	0.00 \$/m ²		\$ 0.00
Subtotal						\$ 53,009,512.00
Contingency						\$ 0.00
Total direct cost						\$ 53,009,512.00

Component	% of direct cost	\$/Wdc	\$	Value
Permitting and environmental studies	0	0.00	0.00	\$ 0.00
Engineering and developer overhead	0	0.00	0.00	\$ 0.00
Grid interconnection	0	0.00	0.00	\$ 0.00
Total indirect cost				\$ 0.00

Component	Value	Unit	Value
Land area	5.9	acres	
Land purchase	\$ 0/acre		\$ 0.00
Land prep. & transmission	\$ 0/acre		\$ 0.00
Total land costs			\$ 0.00

Component	Value	Unit	Value
Sales tax basis, percent of direct cost	0	%	
Sales tax rate	0.0	%	\$ 0.00
Total indirect cost			\$ 0.00

Component	Value	Unit
Total installed cost	\$ 53,009,512.00	
Total installed cost per capacity	\$ 53.12/Wdc	

Wizard for New Users

SAM 2017.4.11: C:/Users/stumer/AppData/Local/SAM/sam-2017.4.11/PV_for_India.sam

File Add PV Help

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System Results for "PV" Case

Results Summary

Metric	Value
Levelized COG (nominal)	5.81 Rs/kWh
Net present value	Rs 5,472,114
Internal rate of return (IRR)	12.34 %
Year IRR is achieved	20
Minimum debt service coverage ratio (DSCR)	1.12

plot 1: LCOG Sensitivity (+/- 10%)

plot 2: Levelized cost of generation 5.80673Rs/kWh

year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
O&M capacity-based expense \$	Rs 0	Rs 698,544	Rs 738,501	Rs 780,743	Rs 825,401	Rs 872,614	Rs 922,528	Rs 975,297	Rs 1,031,084	Rs 1,090,062	Rs 1,152,413	Rs 1,218,331	Rs 1,288,020	Rs 1,361,694	Rs 1,439,583	Rs 1,521,927	Rs 1,608,982	Rs 1,701,015	Rs 1,798,313	Rs 1,901,177	Rs 2,009,924	Rs 2,124,8
Total federal tax depreciation \$	Rs 0	Rs 3,185,955	Rs 3,185,955	Rs 3,185,955	Rs 3,185,955	Rs 3,185,955	Rs 3,185,955	Rs 3,185,955	Rs 841,573													
Debt interest payment \$	Rs 0	Rs 4,740,009	Rs 4,345,009	Rs 3,950,008	Rs 3,555,007	Rs 3,160,006	Rs 2,765,005	Rs 2,370,005	Rs 1,975,004	Rs 1,580,003	Rs 1,185,002	Rs 790,002	Rs 395,001	Rs 0								
Interest earned on reserve accounts \$	Rs 0	Rs 217,211	Rs 217,652	Rs 218,119	Rs 218,613	Rs 219,134	Rs 219,686	Rs 220,269	Rs 220,885	Rs 221,537	Rs 222,226	Rs 222,954	Rs 223,725	Rs 224,539	Rs 225,399	Rs 226,309	Rs 227,271	Rs 228,288	Rs 229,363	Rs 230,500	Rs 231,702	Rs 232,9
Return on equity dollars \$	Rs 0	Rs 3,184,064	Rs 3,184,064	Rs 3,184,064	Rs 3,184,064	Rs 3,184,064	Rs 3,820,876															
Total LCOG costs \$	Rs 0	Rs 12,025,783	Rs 11,671,180	Rs 11,318,888	Rs 10,969,040	Rs 10,621,773	Rs 10,277,238	Rs 9,935,589	Rs 9,596,991	Rs 9,261,620	Rs 8,929,660	Rs 8,603,118	Rs 8,283,576	Rs 7,970,682	Rs 7,664,432	Rs 7,364,686	Rs 7,072,026	Rs 6,786,253	Rs 6,506,075	Rs 6,232,126	Rs 5,964,075	Rs 5,702,3

ROE: 202.853
O and M: 66.8187
Depreciation: 158.229
Reserve interest: 13.3132
Loan interest: 139.459

10:07 AM 5/15/2017

Ongoing Work and Future Applications

- Planned and Ongoing Activities
 - Application to degradation tradeoff analysis
 - Analysis of cost and degradation for panels in different climate conditions
 - Application to roof-top PV analysis