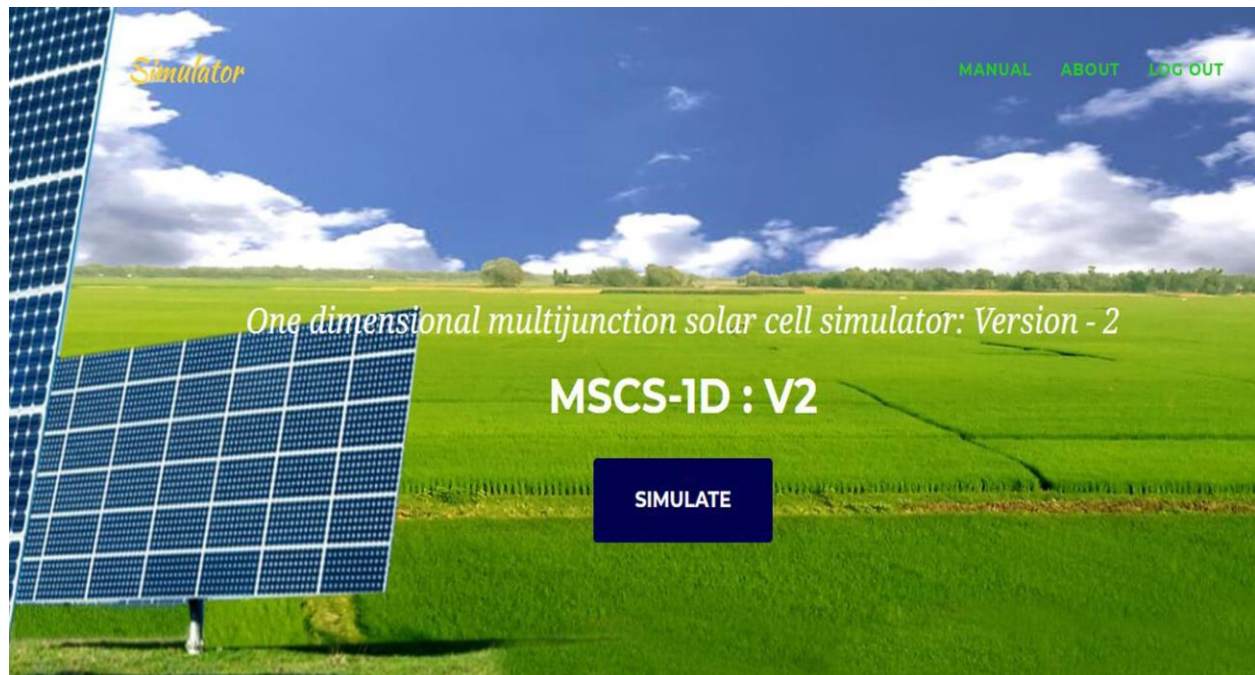


# MSCS-1D:V-2 user manual

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## Foreword

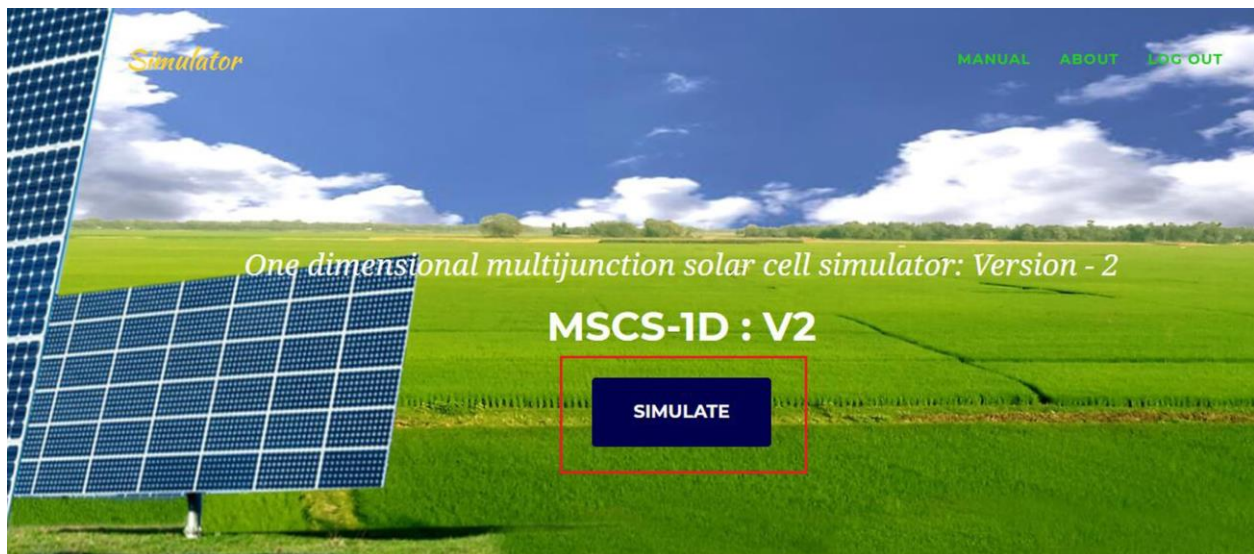
One dimensional multijunction solar cell simulator: version 2 (MSCS-1D: V-2) is developed by Advanced Photovoltaic Lab, Bangladesh Council of Scientific and Industrial Research (BCSIR). This work is financially supported by the Ministry of Science and Technology, the People's Republic of Bangladesh under Special Allocation Project (GRANT NUMBER: 39.00.0000.09.02.18-19/09/458/ID-57 Date: 14.01. 2019) and BCSIR Regular R&D Scope. This user manual is a guideline for the users to work with this MSCS-1D:V-2 simulator. For using this simulator, the user has either to register for securing password in online version or to install the simulation software from the download icon given in the homepage.

### Quick user manual of MSCS-1D: V-2

To simulate the efficiency and performance parameters of any multijunction solar cell, the user has to follow the steps bellow.

#### 1. Select the number of junction

1.1 Click simulate button shown in the outlined by red rectangle on home page.



1.2 The user will find the following pop-up window for selecting the number of junction.



1.3 The following dialog box will appear for selecting the junction number three

Simulator

Important info - new configuration -

Select and calculate

Junction 1

Junction 2

Junction 3

Junction-1

Material

Select one

$M_c$  (No of equivalent minima in the conduction band)

No of equivalent minima in the conduction band

$M_v$  (No of equivalent minima in the valence band)

No of equivalent minima in the valence band

$\mu_e$  (Electron Mobility) [m<sup>2</sup>/Vs]

Electron Mobility

$\mu_h$  (Hole mobility) [m<sup>2</sup>/Vs]

Hole mobility

$\lambda$  (Wavelength) [m]

Wavelength

$E_g$  (Bandgap) [eV]

Bandgap

$M_e^*$  (Elective mass of electron)

Me\*

$M_h^*$  (Elective mass of hole)

Mh\*

$\tau_{SRH}$  (Shockley-Read-Hall lifetime) [s]

Shockley-Read-Hall lifetime

$B$  (Direct band-band recombination coefficient) [s<sup>-1</sup>m<sup>-2</sup>]

Direct band-band recombination coeff

$C$  (sun concentration)

sun concentration

Name (if new material)

Name

$N_A$  (Acceptor concentration) [M<sup>-3</sup>]

Acceptor concentration

$N_D$  (Donor concentration) [M<sup>-3</sup>]

Donor concentration

$X_n$  (Thickness of n- layer) [m]

Donor concentration

$X_p$  (Thickness of p- layer) [m]

Thickness of p- layer

$I$  (irradiance)

Irradiance

result(Junction-1)

Short circuit current density (Jsc1)

Placeholder text

Open circuit voltage (Voc1)

Placeholder text

save Line Graph

## 2. Material (Junction-layer) selection for each junction

2.1 The user has to select the appropriate materials from the following combo box. This simulation software already has reserved some popular materials information and parameters.

**Material**

Select one

Select one

- GaInP2
- GaAs
- Ge
- GaAs.96Bi.04
- GaAs.95Bi.05
- GaAs.94Bi.06
- GaAs.92Bi.08
- Si.5714Ge.428

$\mu_e$  (Electron Mobility) [m<sup>2</sup>/Vs]

Shockley-Read-Hall lifetime

Electron Mobility

$B$  (Direct band-band recombination coefficient) [ $s^{-1}m^3$ ]

2.1 The software will populate all the parameters automatically except ‘irradiance value’ for the reserved materials.

Simulator

Important info - new configuration -

Select and calculate

Junction 1 Junction 2 Junction 3

**Junction-1**

Material: GaInP2

Name (if new material):

$M_c$  (No of equivalent minima in the conduction band): 1

$M_v$  (No of equivalent minima in the valence band): 3

$\mu_e$  (Electron Mobility) [m<sup>2</sup>/Vs]: 0.4

$\mu_h$  (Hole mobility) [m<sup>2</sup>/Vs]: 0.02

$\lambda$  (Wavelength) [m]: 6.5428e-7

$E_g$  (Bandgap) [eV]: 1.9

$M_e^*$  (Effective mass of electron): 1.4105e-31

$M_h^*$  (Effective mass of hole): 4.186000000000005e-31

$T_{SRH}$  (Shockley-Read-Hall lifetime) [s]: 0.00001

$B$  (Direct band-band recombination coefficient) [ $s^{-1}m^3$ ]: 7.5e-16

$C$  (sun concentration): 1

$N_A$  (Acceptor concentration) [m<sup>-3</sup>]: 1e+23

$N_D$  (Donor concentration) [m<sup>-3</sup>]: 2e+24

$X_n$  (Thickness of n-layer) [m]: 1e-7

$X_p$  (Thickness of p-layer) [m]: 2.08e-7

$I$  (irradiance): irradiance

result(Junction-1)

Short circuit current density (Jsc1)

Placeholder text

Open circuit voltage (Voc1)

Placeholder text

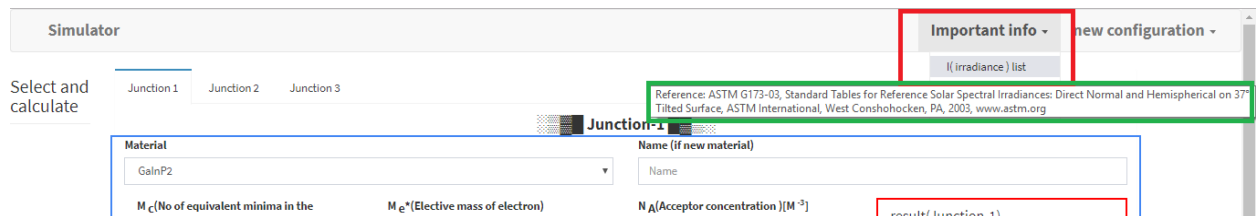
save Line Graph

### 2.3 For new materials (other than reserved)

For new materials the user has to input the name of those materials as well as all relevant parameters manually. Afterward the user can calculate and get similar types of result just like the reserved materials.

## 3. Input I (irradiance)

3.1 The user has to input the irradiance value. User can find the ASTM G-173-03 reference spectrum (irradiance value) from the following sub-menu **marked red**.



Find the suitable irradiance value from the ASTM G-173-03 reference spectrum and input it. (See the red rectangle below).

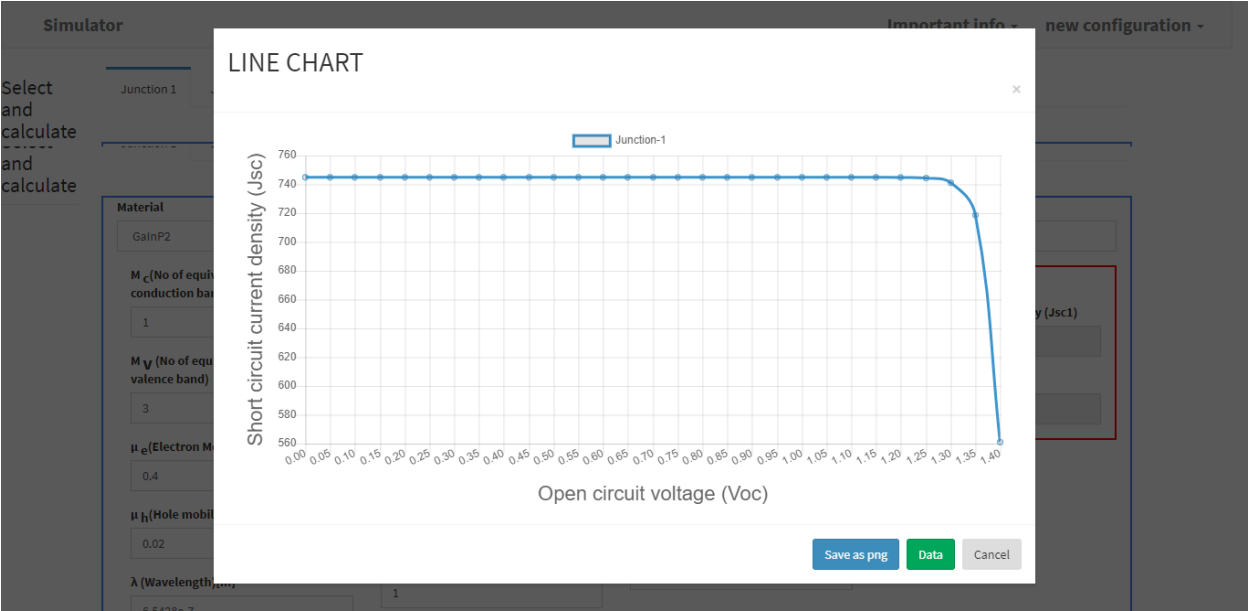
Material		Name (if new material)	
<div>Material</div> <div>GaInP2</div>		<div>Name (if new material)</div> <div>Name</div>	
<div>M<sub>c</sub>(No of equivalent minima in the conduction band)</div> <div>1</div>	<div>M<sub>e</sub>*(Elective mass of electron)</div> <div>1.4105e-31</div>	<div>N<sub>A</sub>(Acceptor concentration)[M<sup>-3</sup>]</div> <div>1e+23</div>	<div>result(Junction-1)</div> <div>Short circuit current density (Jsc1)</div> <div>Placeholder text</div> <div>Open circuit voltage (Voc1)</div> <div>Placeholder text</div> <div>save</div> <div>Line Graph</div>
<div>M<sub>v</sub>(No of equivalent minima in the valence band)</div> <div>3</div>	<div>M<sub>h</sub>*(Elective mass of hole)</div> <div>4.1860000000000005e-31</div>	<div>N<sub>D</sub>(Donor concentration)[M<sup>-3</sup>]</div> <div>2e+24</div>	
<div>μ<sub>e</sub>(Electron Mobility)[m<sup>2</sup>/Vs]</div> <div>0.4</div>	<div>T<sub>SRH</sub>(Shockley-Read-Hall lifetime)[s]</div> <div>0.00001</div>	<div>X<sub>n</sub>(Thickness of n- layer)[m]</div> <div>1e-7</div>	
<div>μ<sub>h</sub>(Hole mobility)[m<sup>2</sup>/Vs]</div> <div>0.02</div>	<div>B(Direct band-band recombination coefficient)[S<sup>-1</sup>M<sup>3</sup>]</div> <div>7.5e-16</div>	<div>X<sub>p</sub>(Thickness of p- layer)[m]</div> <div>2.08e-7</div>	
<div>λ(Wavelength)[m]</div> <div>6.5428e-7</div>	<div>C(sun concentration)</div> <div>1</div>	<div>I( irradiance )</div> <div>1415.30</div>	
<div>E<sub>g</sub>(Bandgap)[eV]</div> <div>1.9</div>			





4.2 Current voltage characteristics curve (J-V):

For finding the J-V characteristics curve, the user has to click “line graph” button shown below and the following curve will pop-up.



4.3 Export the simulated dataset:

There is an option for the user to find the dataset for further data analysis and graphing using any third party softwares, for example OriginLab, Excel etc. For that, one has to click “Data” button and export data set as excel or pdf format (see red rectangle).

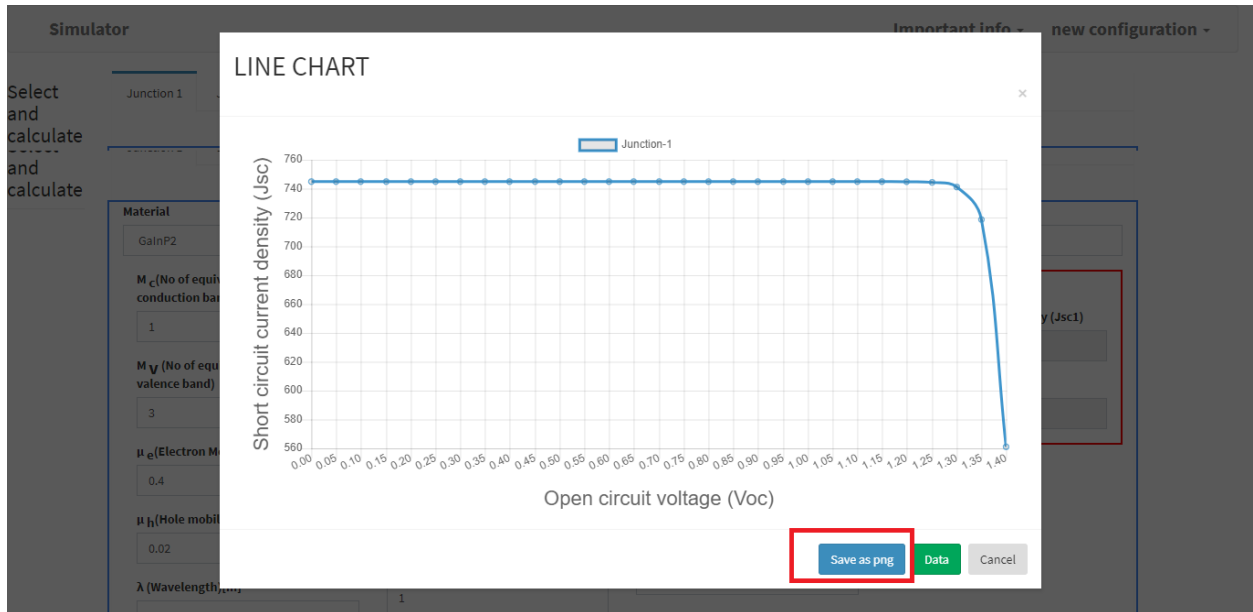
The figure shows the same 'LINE CHART' window, but with the data table displayed. The table has two columns: 'voc(X)' and 'Jsc(Y)'. The data points are as follows:

voc(X)	Jsc(Y)
0.00	744.90
0.05	744.90
0.10	744.90
0.15	744.90
0.20	744.90
0.25	744.90
0.30	744.90
0.35	744.90
0.40	744.90
0.45	744.90
0.50	744.90
0.55	744.90
0.60	744.90
0.65	744.90

A red rectangle highlights the 'Export as excel' and 'Export as PDF' buttons in the top right corner of the window. The background shows the simulator's material selection panel for GaInP2, with various physical parameters like  $M_c$ ,  $M_v$ ,  $\mu_e$ ,  $\mu_h$ , and  $\lambda$  listed.

#### 4.4 For downloading the graph:

The user can download graph as PNG format by clicking “Save as png” button



[N.B: By that process, user has to select the junction and calculate repeatedly for each junction]

Simulator Important info - new configuration -

Select and calculate

Junction 1 Junction 2 Junction 3

**Junction-1**

Material: GaInP2

Name (if new material):

Short circuit current density (Jsc1): 744.8989313222725

Open circuit voltage (Voc1): 1.4359687713281053

save Line Graph

Parameter	Value
$M_c$ (No of equivalent minima in the conduction band)	1
$M_v$ (No of equivalent minima in the valence band)	3
$\mu_e$ (Electron Mobility) [m <sup>2</sup> /Vs]	0.4
$\mu_h$ (Hole mobility) [m <sup>2</sup> /Vs]	0.02
$\lambda$ (Wavelength) [m]	6.5428e-7
$E_g$ (Bandgap) [eV]	1.9
$m_e^*$ (Elective mass of electron)	1.4105e-31
$m_h^*$ (Elective mass of hole)	4.1860000000000005e-31
$T_{SRH}$ (Shockley-Read-Hall lifetime) [s]	0.00001
$B$ (Direct band-band recombination coefficient) [s <sup>-1</sup> m <sup>3</sup> ]	7.5e-16
$C$ (sun concentration)	1
$N_A$ (Acceptor concentration) [m <sup>-3</sup> ]	1e+23
$N_D$ (Donor concentration) [m <sup>-3</sup> ]	2e+24
$X_n$ (Thickness of n-layer) [m]	1e-7
$X_p$ (Thickness of p-layer) [m]	2.08e-7
$I$ (Irradiance)	1415.30





## 5.2 Get graphical view:

The user will find several graphs (see the black- line rectangle)

Material		Name (if new material)	
Ge		Name	
$M_c$ (No of equivalent minima in the conduction band)	$M_e^*$ (Elective mass of electron)	$N_A$ (Acceptor concentration) [ $M^{-3}$ ]	<div>result(Junction-3)</div> <div>Short circuit current density (Jsc1)</div> <div>163.97466063348415</div> <div>Open circuit voltage (Voc1)</div> <div>0.12157541036275904</div>
1	1.4924e-30	1e+23	
$M_v$ (No of equivalent minima in the valence band)	$M_h^*$ (Elective mass of hole)	$N_D$ (Donor concentration) [ $M^{-3}$ ]	
1	2.5480000000000003e-31	2e+24	
$\mu_e$ (Electron Mobility) [ $m^2/Vs$ ]	$T_{SRH}$ (Shockley-Read-Hall lifetime) [s]	$X_n$ (Thickness of n- layer) [m]	<div>save</div> <div>Line Graph</div> <div>Print all info</div> <div>ALL GRAPH ▾</div> <div>voc vs jsc</div> <div>Sun Concentration vs Efficiency</div>
0.39	0.00001	4e-7	
$\mu_h$ (Hole mobility) [ $m^2/Vs$ ]	$B$ (Direct band-band recombination coefficient) [ $s^{-1}M^{-3}$ ]	$X_p$ (Thickness of p- layer) [m]	<div>TOTAL CELL PARAMETERS</div> <div>1 FOR 1 SUN CONCENTRATION</div> <div>Current Density, Jsc</div> <div>163.97466063348415</div>
0.19	7.5e-16	1e-7	
$\lambda$ (Wavelength) [m]	$C$ (sun concentration)	$I$ (irradiance)	
0.000001735	1	114.84	

a) J-V characteristics curve for all layers (junctions).

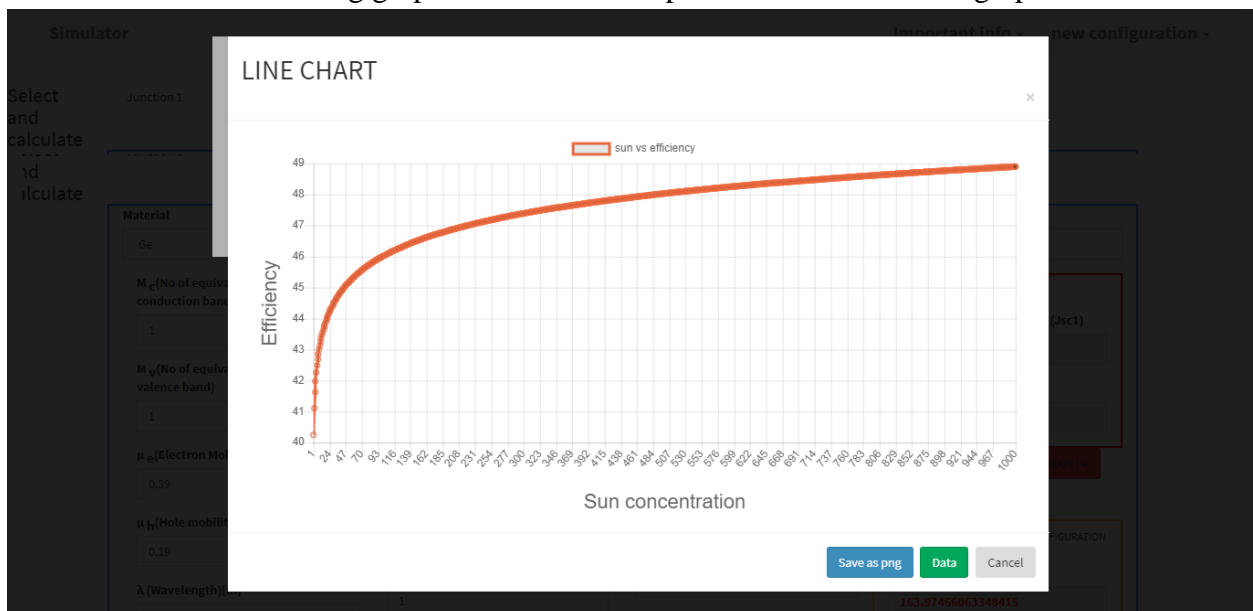


## b) Sun concentration Vs. Efficiency graph:

For this simulation, users ask at first, to select the airmass AM condition as AM 1.5D. User has to define the limit of the sun concentration 1 to 1000

The screenshot shows the 'Simulator' window with a dialog box for 'Sun concentration'. The 'Sun concentration(Minimum)' is set to 1 and 'Sun concentration(Maximum)' is set to 1000. A 'show' button is visible. In the background, the 'Material' section is set to 'Ge', and the 'result(Junction-3)' section shows 'Short circuit current density (Jsc1)' as 163.97466063348415.

User will find the following graph. One can also export data and download graph.



**Conclusion:** Using the above mentioned procedure, user can simulate the other configurations of multijunction. For that user need to select another configuration from following figure (see the red rectangle).

The screenshot shows the 'Simulator' window with the 'Junction-3' tab selected. A dropdown menu for 'new configuration' is open, showing options: 'No of Junction TWO', 'No of Junction THREE', 'No of Junction FOUR', and 'No of Junction FIVE'. The 'result(Junction-3)' section shows 'Short circuit current density (Jsc1)' as 163.97466063348415.

**Thank you !!!**