# Solar Cell Shockley-Queisser Limit Calculator

Code written by:
Sidi Hamady
Dr. habil. Eng., Associate professor
Université de Lorraine, France
sidi.hamady@univ-lorraine.fr

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## Presentation and Requirements

The Shockley-Queisser limit is the maximum photovoltaic efficiency obtained for a solar cell with respect to the absorber bandgap.
The theory is described by W. Shockley and H. J. Queisser in Journal of Applied Physics 32 (1961).

To install the Shockley-Queisser limit calculator:
just download it:
from github: https://github.com/sidihamady/Shockley-Queisser
or from my website: http://www.hamady.org/photovoltaics/ShockleyQueisser.zip
unzip and use.

The distribution mainly includes:

Two main Python files:

- ShockleyQueisserCore.py implementing the calculator core functionality in the module classes, with a simple and easy-to-use graphical user interface.
- ShockleyQueisser.py implementing the program interface.

Two text files:

- SolarSpectrum_AM15G.txt containing the standard AM1.5 solar spectrum.
- ShockleyQueisserCurve.txt containing the Shockley-Queisser Efficiency vs Bandgap data.

Two figures:

- ShockleyQueisserCurve.pdf containing the Shockley-Queisser Efficiency vs Bandgap curve in PDF format (to integrate for example in a LaTeX document).
- ShockleyQueisserCurve.png containing the Shockley-Queisser Efficiency vs Bandgap curve in PNG format.

Three examples:

- ShockleyQueisserTJ.py for triple junction solar cell.
- ShockleyQueisserDJ.py for double junction solar cell.
- ShockleyQueisserCurve.py calculates and plots the efficiency of a PN junction solar cell with respect to the bandgap.

It is not necessary to know the Python language to use the program.

The basic requirements are found in any Linux distribution (and easily installed for Windows):

- Python version 2.7.x or later
- numpy version 1.5 or later
- scipy version 0.13.1 or later
- matplotlib version 1.3.x or later
- tkinter 8.5 or later

PS: for Windows, you can download a complete Python distribution from https://www.anaconda.com/distribution/

## HowTo

Start ShockleyQueisser.py interface:

from the command line prompt:
under Linux:

```
cd /path/to/ShockleyQueisser/
python -u ShockleyQueisser.py
```

under Windows (in the command prompt):

```
cd C:\path\to\ShockleyQueisser\
python.exe -u ShockleyQueisser.py
```

You have to add python to your PATH.

You can also execute ShockleyQueisser.py by double clicking on it (depending on the operating system settings), or from within your editor, if possible.

In the graphical interface, change the parameters you want (solar concentration, temperature and target bandgap) and press 'Calculate'.

Screenshot under Windows:
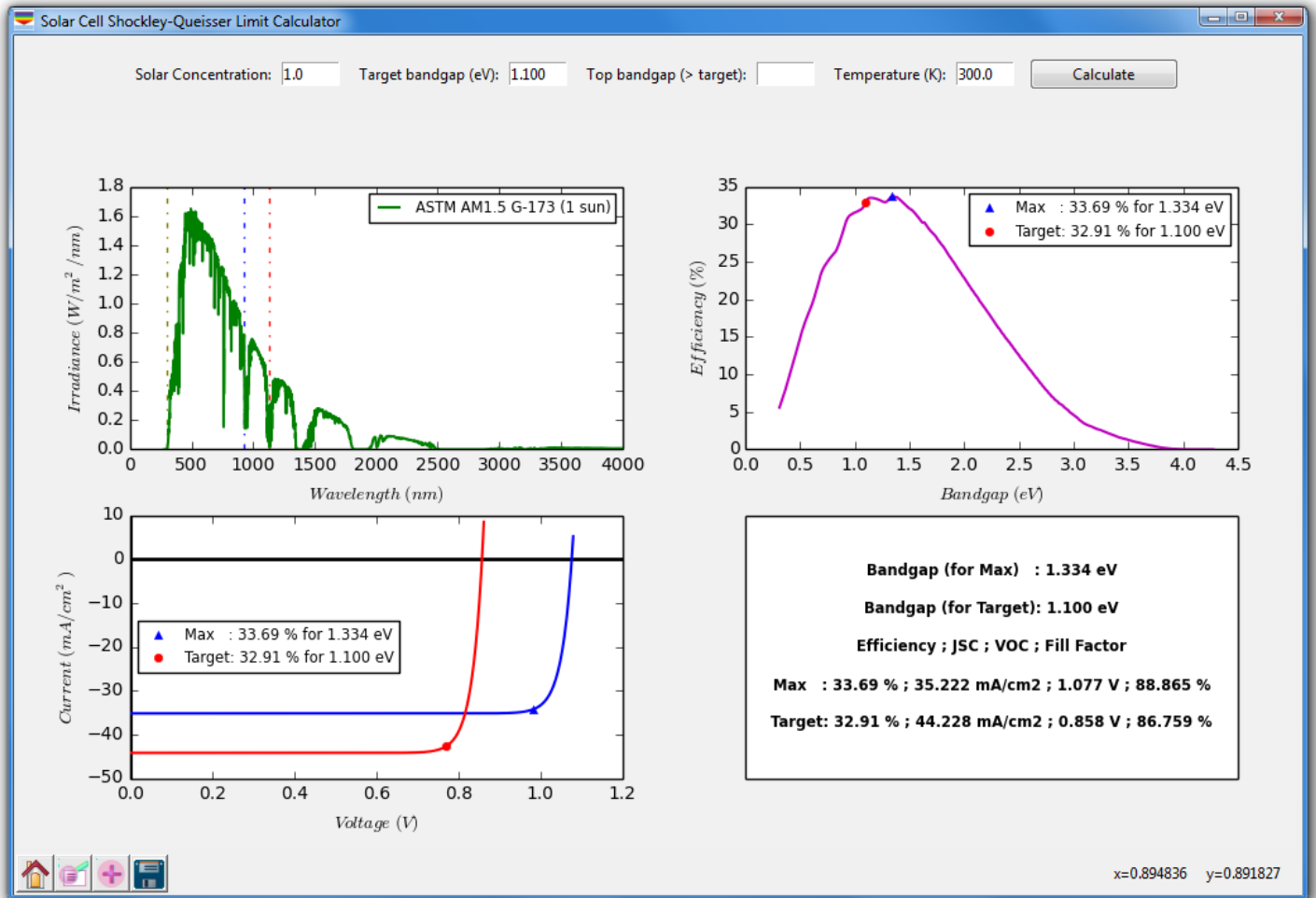


Screenshot under Linux:
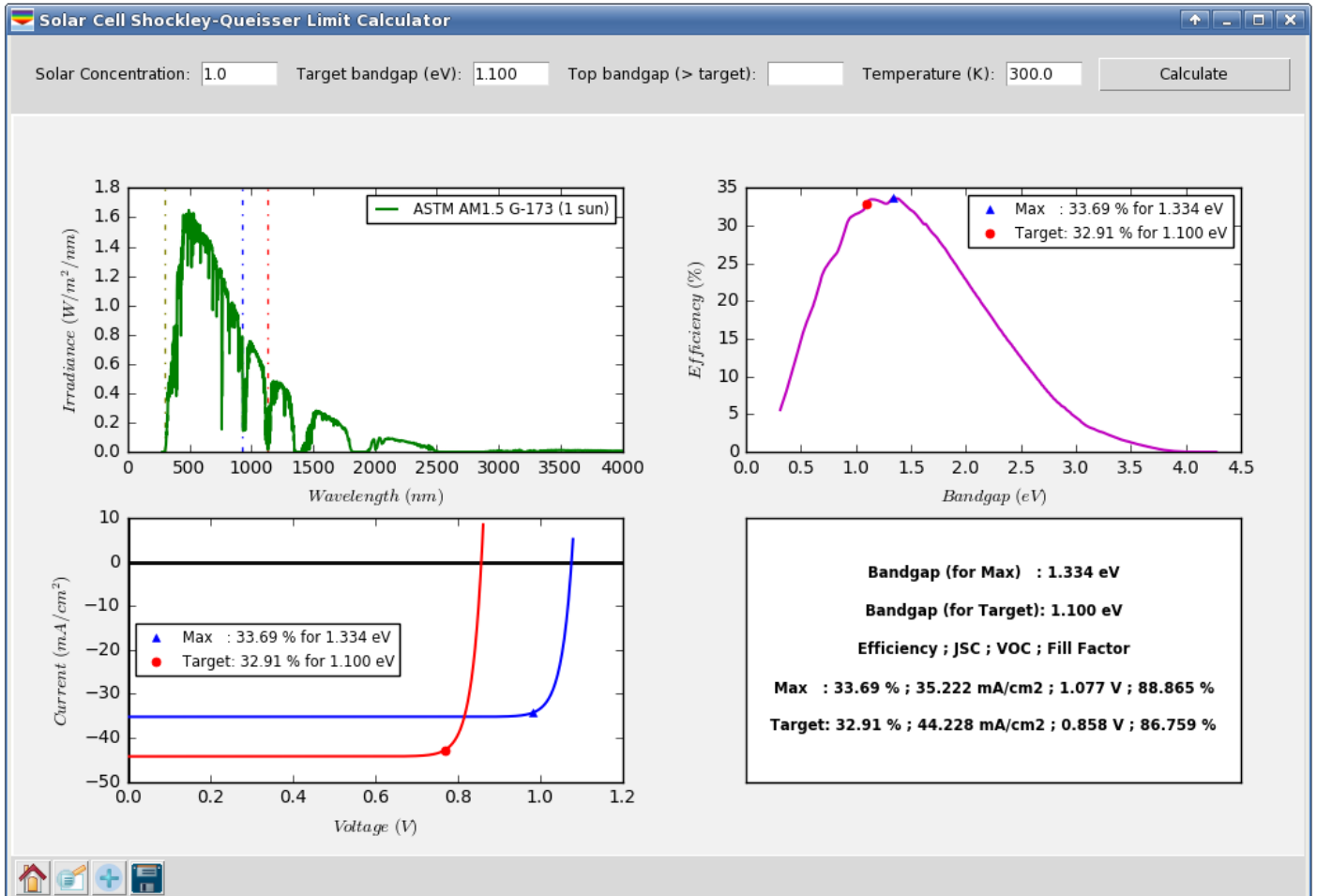
## HowTo: Multijunction solar cell

The program calculates the efficiency for a single junction solar cell but takes into account the part of solar spectrum already absorbed (for example in a top cell) through the Target top bandgap parameter. This is useful to calculate the overall efficiency in a multijunction solar cell. For example for double junction solar cell, follow the steps below:

1. set TargetBandgap to 1.65 eV and the TargetBandgapTop to 0, and calculate the corresponding efficiency and current-voltage characteristic.
2. set TargetBandgap to 0.95 eV and the TargetBandgapTop to 1.65, and calculate the corresponding efficiency and current-voltage characteristic.
   Deduce from the previous data the overall double junction solar cell efficiency.

Two examples are given below (for double and triple junction solar cells).

## HowTo: Command-line only mode

The calculator can be used in graphical (GUI) mode or command-line only mode. In command-line mode the results are printed out and saved in text files.

The command-line mode is useful to perform specific calculations such as multijunction solar cell efficiency.

Two multijunction solar cell examples are given in the included ShockleyQueisserTJ.py and ShockleyQueisserDJ.py files.
The execution of ShockleyQueisserTJ.py gives the following output:

```
calculating...
done. elapsed time = 6.172 sec.
=================================================================
Shockley-Queisser limit for T = 300.0 K and SC = 1.0 sun
Bandgap ; Efficiency ; JSC ; VOC ; Fill Factor
1.334 eV ; 33.69 % ; 35.222 mA/cm2 ; 1.077 V ; 88.865 %
=================================================================
-----------------------------------------------------------------
Target for T = 300.0 K and SC = 1.0 sun
Bandgap ; Efficiency ; JSC ; VOC ; Fill Factor
1.900 eV ; 24.97 % ; 16.927 mA/cm2 ; 1.607 V ; 91.855 %
-----------------------------------------------------------------
calculating...
done. elapsed time = 0.015 sec.
-----------------------------------------------------------------
Target for T = 300.0 K and SC = 1.0 sun
Bandgap ; Efficiency ; JSC ; VOC ; Fill Factor
1.400 eV ; 15.82 % ; 15.840 mA/cm2 ; 1.120 V ; 89.197 %
-----------------------------------------------------------------
calculating...
done. elapsed time = 0.000 sec.
-----------------------------------------------------------------
Target for T = 300.0 K and SC = 1.0 sun
Bandgap ; Efficiency ; JSC ; VOC ; Fill Factor
0.900 eV ; 10.36 % ; 19.154 mA/cm2 ; 0.647 V ; 83.660 %
-----------------------------------------------------------------
-----------------------------------------------------------------
Triple junction solar cell efficiency = 47.642 %
 with a nominal power of 47.660 mW/cm2
-----------------------------------------------------------------
```
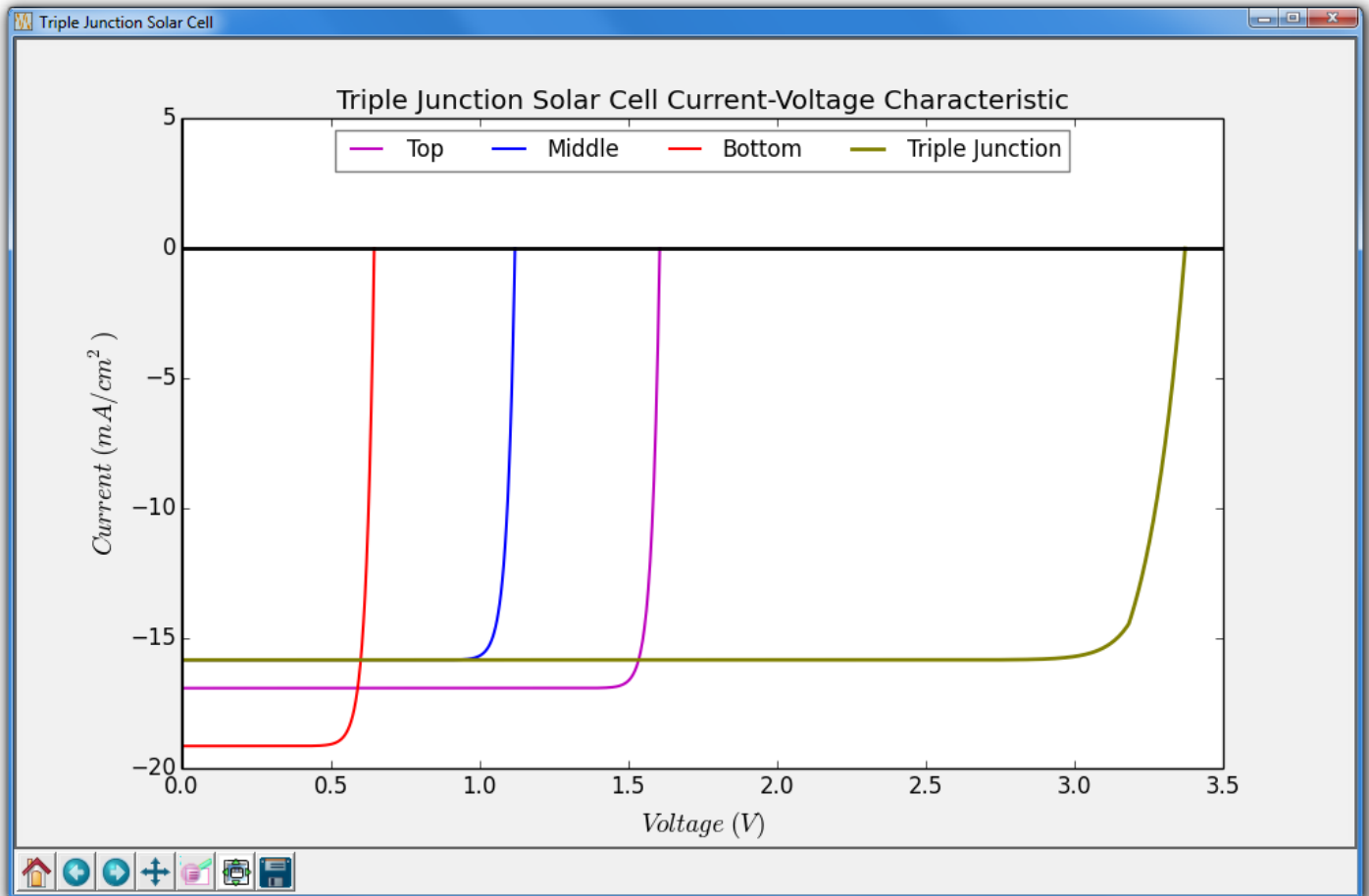
The execution of ShockleyQueisserDJ.py gives the following output (Efficiency of a double junction solar cell with respect to the top and bottom bandgap):