It has been simply believed that the monolithic tandem cells increase its efficiency by increase of the number of junctions. It is true in the cell tested by a single spectrum condition like the standard AM1.5G spectrum, although the cell efficiency levels off in excessive number of junctions. However, it has been acknowledged by field engineers that the performance ratio of multi-junction cells was worse due to spectrum mismatching influenced by fluctuation of spectrum conditions. Anyone cannot change the solar spectrum for increasing energy yield of specific PV system. For monolithic tandem structure, this mismatch loss increases by the increase of the number of junctions. Therefore, for attempting development of the new materials for new junctions, it will be helpful to estimate in advance if its increase really contributes to the annual energy yield.

The spectrum changes by air-mass (predictable), and fluctuation of atmospheric conditions (unpredictable). However, it is possible to estimate the distribution of atmospheric parameters by the measurement in various sites (top of Figure 1). Then, Monte Carlo simulations of the annual energy yield, using periodic variance of air-mass and fluctuation of atmospheric parameters given by weighted random numbers, was calculated to several types of the optimized multi-junction solar cells (bottom of Figure 2). Then, the “Disappointment chart” indicating probability of the yearly-averaged efficiency decreases despite the effort of increasing the number of junctions was generated (Figure 2).

The obtained conclusion was simple. Surprisingly, the annual energy yield drops at more than 4 or 5 junctions. This trend may be released by the increase of luminescent coupling and redundancy of the absorption band like the bottom cell in the lattice-matched 3-junction cell.

Figure 1: Flow-chart of the simulation. Top: Determination of atmospheric parameters and their distribution function. Bottom: Monte Carlo simulation of decision of the merit and demerit of increasing number of junctions.

Figure 2: Probability of “disappointment” to the effort of the number of junctions. Top: 1000 x CPV using DNI resource (series resistance is 5 mΩcm²). Bottom: Flat-plate using GTI resource (series resistance is 5Ωcm²).