Fraunhofer
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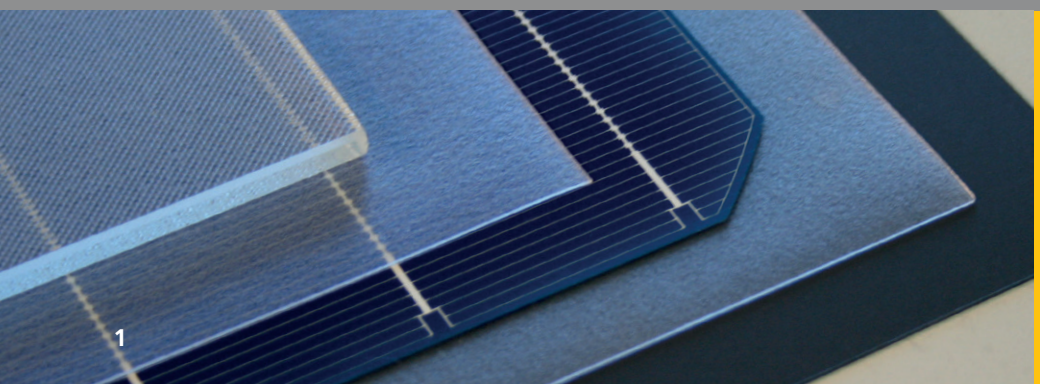
FRAUNHOFER INSTITUTE FOR SOLAR ENERGY SYSTEMS ISE



1 *Module power output is defined by module design and choice of materials.*

2 *The software SmartCalc.CTM calculates the cell-to-module efficiency ratio of solar modules in detail.*

SMARTCALC.CTM: PRECISE CELL-TO-MODULE ANALYSIS

The integration of solar cells into photovoltaic modules results in gains and losses that change the power and efficiency of the module in comparison to the initial solar cells. With SmartCalc.CTM Fraunhofer ISE provides a professional software solution to optimize solar modules and to analyze cell-to-module (CTM) gain and loss factors.

With the easy-to-use graphical user interface, PV module and material manufacturers can improve the design, efficiency and material combination of a PV module – from sketch to production.

Features of SmartCalc.CTM

- precise calculation of power and efficiency of photovoltaic modules
- detailed gain and loss factor analysis with conclusive display of results
- wide range of solar cell technologies
- several cell interconnection options
- flexible module layout
- predefined or customized materials with easy import functionality

SmartCalc.CTM is based on a simulation model that has been developed at Fraunhofer ISE since 2008. The long-term expertise in development, characterization and testing of PV technologies results in a CTM calculation with high precision.

The Fraunhofer ISE model consists of fifteen factors that govern the cell-to-module power and efficiency.

Benefits for Module and Material Manufacturers

- reduction of costly prototyping and time-consuming measurements
- improvement of module performance by optimal selection of materials
- "What-if analysis" and assessment of efficiency potentials of existing module designs
- benchmarking new concepts to current technologies from sketch
- target driven module optimization with focus on important cell-to-module factors

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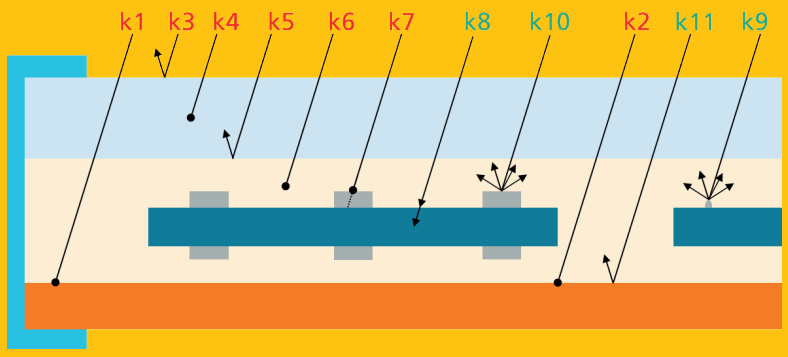

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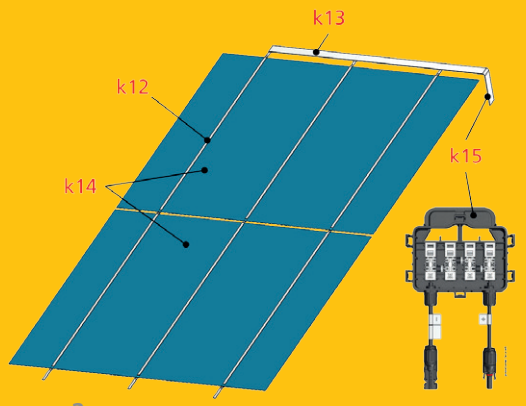

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Broad Range of Crystalline PV Technologies

SmartCalc.CTM can handle many different cell and module technologies:

- any crystalline cell technology
- bifacial and monofacial, front and back-contacted solar cells
- variable cell sizes and formats (in full and pseudo square)
- variable number of busbars and ribbons
- multi-wire interconnection
- shingle interconnection
- solder electrically conductive adhesives joints
- glass-backsheet and glass-glass setup
- encapsulation materials with different transmittance and UV cutoffs
- STC and real operation conditions

Concept of k-Factors

The cell-to-module power factor (k) represents the ratio of the module power to the initial power of the solar cells.

Losses are influenced by:

- geometrical effects, such as the inactive areas at the module edge and between solar cells
- optical effects, such as reflection and absorption within the front cover
- electrical effects, such as ohmic losses within cell and string interconnections

However, not only losses occur: Additional reflection of light onto the solar cell or reduced reflection from the encapsulated cell results in gains.

1 *Geometrical and optical CTM factors.*

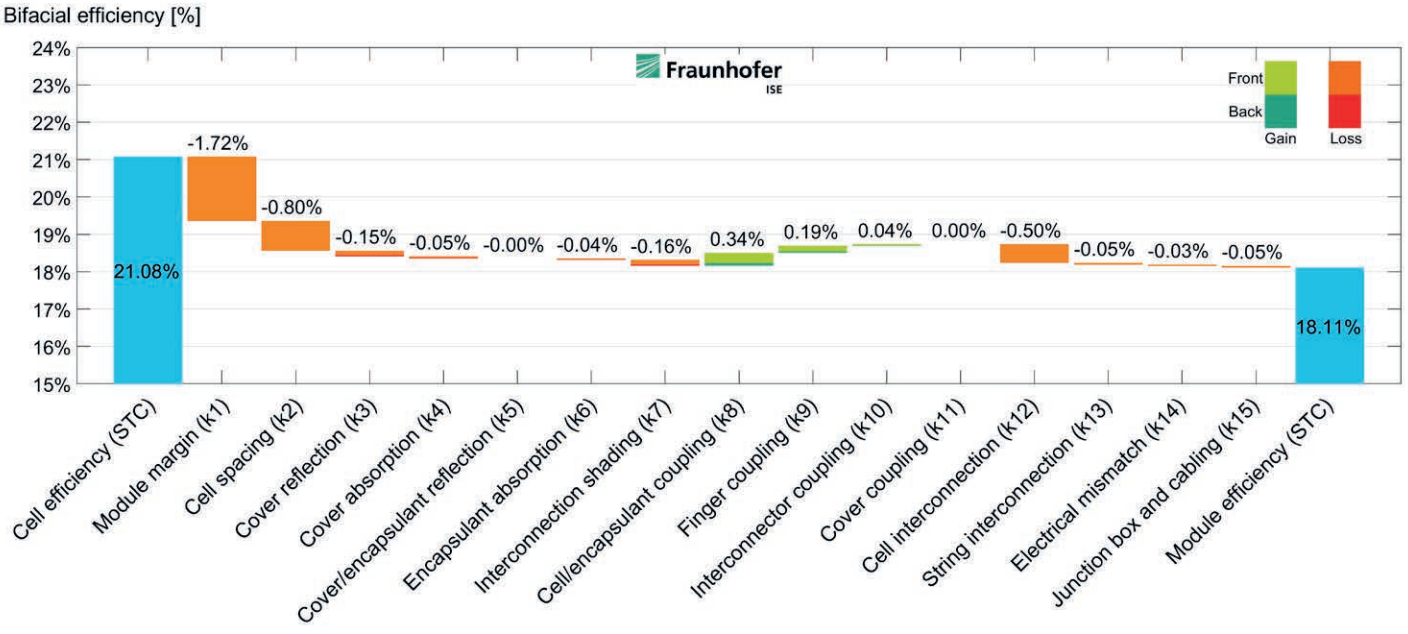
2 *Electrical CTM factors.*

Validation

SmartCalc.CTM is a validated tool with high accuracy. Modules have been analyzed with SmartCalc.CTM and simultanously characterized at our accredited CalLab PV Modules. The calculation models for single and multiple k-factors have been validated.

In order to keep pace with future module technology developments, we continually improve SmartCalc.CTM. Together with the software license, we offer consulting and R&D support for analyzing module materials and optimizing simulation results.

Additional information and a free demo version of SmartCalc.CTM are available at www.cell-to-module.com.



3 *Screenshot of SmartCalc.CTM with waterfall–chart, displaying the efficiency gains and losses for a bifacial PV module.*