RAYTRON

MATERIALS / PROCUREMENT / ENGINEERING

Copper–Aluminum Composite PV Ribbon Buyer’s Guide

Choose the material. Prove the process.
Count the cost per watt.

A PRACTICAL GUIDE

For first-time buyers—and the process,
engineering and quality teams signing with them.

Materials → Specifications → Process → Cost per watt
Cost case: 0.26 mm finished · Equal price per tonne · Complete coating

Engineering Every Micron.

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Contents

From materials and dimensions to production trials, purchasing and acceptance.

01 | Start with the value—and the right denominator 3

02 | What it is: three layers, three jobs 4

03 | TOPCon, HJT, BC, SMBB and 0BB are not one classification 4

04 | CCA or HTCCA? “Stronger” is not the whole specification 5

05 | Copper content: write wt.% or vol.% before discussing the number 6

06 | Dimensions and copper cladding: specify the finished diameter 7

07 | Resistance and module power: PV runs on DC, not a skin-effect sales pitch 8

08 | Mechanical properties: the hardest ribbon does not win 9

09 | Solder, flux and stringer: qualify the combination 10

10 | Equal finished price per tonne: savings per module, watt and GW 11

11 | The “about 3 W on a 650 W module” example 15

12 | Sampling to production: five stages, not one impressive sample 15

13 | Reliability: not only “does it hold?”, but “what happens afterwards?” 16

14 | Incoming acceptance: make the certificate match the reel 17

15 | Production troubleshooting: investigate before assigning blame 17

16 | Packaging, storage and delivery: do not lose good material in the warehouse 18

17 | Standards and market access: separate material, module and application 19

18 | How to request quotations and compare suppliers 19

19 | Buyer FAQ 20

20 | Turn a reel of material into an approvable solution 22

Quick glossary 22

References and data notes 23

Choose the material. Prove the process. Count the cost per watt.

PV ribbon may look like a very small piece of metal, but procurement, process engineering, R&D and quality all have a vote. Procurement wants a better price. The stringer wants predictable feeding. The cells would prefer not to crack. The module still has to deliver its watts.

Copper–aluminum composite PV ribbon puts different materials to work: **aluminum carries part of the current, copper provides the outer metallic connection surface, and a process-compatible solder coating makes the joint.** Its purpose is not to impersonate copper. It is to reduce actual ribbon cost while meeting the requirements of a particular module.[1][3]

This guide is for buyers and engineers encountering the material for the first time. It covers round interconnect wire, flat interconnect ribbon and busbar ribbon inside crystalline-silicon modules. It does not cover external PV cable or field replacement of ribbon inside encapsulated modules.

Reading routes: material basics, Sections 1–5; specification selection, Sections 6–11; trials and purchasing, Sections 12–18; quick answers, Section 19.

TOPCon substitution—read this first: when replacing copper ribbon with the Raytron round CCA ribbon covered by this process route, the stringer's existing local ribbon-flattening operation MUST be disabled or bypassed. This is Raytron's process requirement based on feedback from Chinese module customers. See Section 9.[2]

> A good substitution improves the purchase order while keeping production and module performance within the agreed requirements.

01 | Start with the value—and the right denominator

Raytron's copper–aluminum composite ribbon has been used in modules totaling **more than 50 GW**. Some Chinese module-customer projects reduced **the purchasing cost of the replaced ribbon by more than 50%** compared with the previous copper-ribbon solution. Applications include BC and TOPCon module designs.[2]

The percentage uses the original purchasing cost of the ribbon being replaced.

Equal tonne prices can still save money. Section 10 calculates the complete coated mass of a 0.26 mm finished CCA50 wire with 15 µm radial solder. At equal tonne prices and net lengths, the model shows an interconnect-ribbon purchasing cost reduction of approximately **42.44%**.

Buyer's question	A useful comparison
Can equal prices per tonne still save money?	Compare complete finished mass per metre, including solder. At equal prices and net lengths, the reduction in purchased mass is the purchasing saving.
How much does each module save?	Compare finished-wire cost per metre, actual consumption, production losses and yield.
Will module power change?	Build matched module controls with comparable cells and bills of materials; compare the power distribution.

Buyer's question	A useful comparison
Can it run consistently?	Check speed, stoppages, wire breaks, joining quality and rework on the real stringer.
What about reliability?	Evaluate electrical and connection performance after the agreed thermal, humidity and other relevant tests.

There is no need to replace every copper component at once. A better starting point is **one clearly specified, meaningful-volume module model with an agreed comparison trial**.

02 | What it is: three layers, three jobs

A typical construction is **aluminum or a specified aluminum-alloy core → copper cladding → solder coating**. Copper and aluminum both conduct longitudinal current. The outer solder layer is selected to form the required connection to cell metallization and other interconnection surfaces.[1][3]

Term	What it means	What the order still needs
CCA	Copper-clad aluminum substrate	Copper fraction, core material, temper and electrical properties
HTCCA	Raytron's high-strength, aluminum-alloy-core CCA series	Actual tensile, yield, elongation and resistance requirements—not a temperature rating inferred from the name
Copper–aluminum composite PV ribbon	Composite substrate plus a joining-compatible solder coating	Form, connection position, substrate and finished dimensions, coating alloy
Interconnect ribbon / round interconnect wire	Material connecting cells	Pad layout, wire count, routing, spacing and stringing requirements
Busbar ribbon	Material connecting strings and the module collection circuit	Current path, length, bends and junction-box connection
"Alloy ribbon"	An incomplete commercial or technical description	Does "alloy" refer to the core, solder or an entirely different construction?

CCA is not a homogeneous alloy made by melting all the copper and aluminum together. Bare CCA conductor is also not automatically a finished PV interconnect ready for the stringer.

"Tin-coated" or "tinned" is often commercial shorthand. The coating may be tin–lead or another tin-based solder, rather than pure tin. **A silver-colored surface is not a chemical analysis.**

03 | TOPCon, HJT, BC, SMBB and 0BB are not one classification

These terms describe different aspects of a module. TOPCon and HJT describe cell technologies; BC describes a back-contact configuration; MBB, SMBB and 0BB describe metallization or interconnection approaches. A project can combine several of them.[4][5]

Project feature	Start by checking	Comparison priorities
PERC / TOPCon interconnection	Cell format, pads, wire count, individual cross-section and coating	Stringing, joints, EL and power; the TOPCon CCA round-wire route in this guide requires the original local flattening operation to be disabled/ bypassed
MBB / SMBB	Round-wire dimensions, positioning, tension and joint consistency	Breaks, displacement, optical shading and electrical loss
0BB	Actual joining method, solder or other connection system, fixation process	Finger contact, alignment, connection continuity and material compatibility
BC	Rear positive/negative layout, routing, insulation and bending positions	Electrode separation, conformity, stress and connection reliability
HJT / SHJ	Cell and metallization thermal budget, solder and flux	Measured temperature profile, wetting, peel performance and aged stability
Busbar circuit	Current path, effective cross-section, length and connection nodes	Circuit resistance, joints and local temperature rise

0BB does not mean zero interconnects. Removing conventional cell busbars does not give electricity permission to jump between cells. Nor does one unqualified solder recipe serve every 0BB process.[4]

Similarly, "suitable for HJT" needs more than a low-melting-point label. Alloy melting behavior, machine setpoint, actual joint temperature and the cell's thermal history are different quantities.[4]

04 | CCA or HTCCA? "Stronger" is not the whole specification

Start with the constraints: the resistance budget, available cross-section, feeding strength and assembly stress tolerated by the cells. HTCCA is not an automatic upgrade for every project. Higher tensile requirements and different electrical properties need to be considered together.[1]

The following values are taken from Raytron **Spec201910 Rev.4, released 15 September 2026**. Resistivity values are **substrate upper limits at 20°C**; density values are nominal references. They are not measured finished-product values or confirmation that every grade–geometry combination is stocked. [1]

Substrate grade	Maximum substrate resistivity, Ω·mm²/m	Nominal density, g/cm³
TU1 copper	0.017241	8.90
CCA30	0.027	3.42
CCA40	0.026	3.74
CCA50	0.025	4.15

Substrate grade	Maximum substrate resistivity, Ω·mm²/m	Nominal density, g/cm³
CCA60	0.024	4.64
CCA70	0.023	5.27
HTCCA30	0.029	3.42
HTCCA40	0.028	3.74
HTCCA50	0.027	4.15
HTCCA60	0.026	4.64
HTCCA70	0.025	5.27

In this document, CCA50 and HTCCA50 have the same reference density but different maximum resistivity. **Similar grade names do not imply identical electrical performance.**

Bare-conductor specifications, PV-substrate specifications and coated-product data may use different conditions. Order against one mutually approved specification, rather than selecting the most attractive number from each of several tables.

05 | Copper content: write wt.% or vol.% before discussing the number

Weight fraction, wt.%, describes copper's share of substrate mass. **Volume fraction, vol.%**, describes copper's share of substrate volume; for a uniform straight cross-section it also corresponds to copper area fraction. The percentages are not interchangeable.

Raytron's bare-material grades such as CCA30 and CCA40 use copper weight percentage.[3] A PV order should additionally state that the fraction applies to the uncoated composite substrate, specify its allowable range and test method, and resolve the original specification's Cu+Ag heading in the purchasing definition. Do not silently include the solder coating in the denominator.

The examples below use copper density 8.960 and aluminum density 2.705 g/cm³, excluding solder. Use the actual core density for an alloy-core calculation.[3]

Copper weight fraction	Calculated copper volume fraction
30 wt.%	Approximately 11.46 vol.%
40 wt.%	Approximately 16.75 vol.%
50 wt.%	Approximately 23.19 vol.%
60 wt.%	Approximately 31.17 vol.%
70 wt.%	Approximately 41.33 vol.%

50 wt.% copper is not 50 vol.% copper. Two quotations both saying "50%" may describe substantially different materials.

The lowest copper fraction is not automatically the best purchase, and the highest is not automatically the best value. Finished resistance, minimum local copper thickness, forming and joint performance—and ultimately cost per watt—are the deciding factors.

06 | Dimensions and copper cladding: specify the finished diameter

At minimum, distinguish **substrate dimensions before coating** from **finished dimensions after coating**.

Common nominal finished diameters are **0.22, 0.24 and 0.26 mm**. The dimensional, electrical and cost examples in this guide use a **0.23 mm substrate with a 15 µm radial solder coating**, equivalent to 0.015 mm on each side. The ideal finished diameter is:

> 0.23 + 2 × 0.015 = 0.26 mm

Here, **0.23 mm is the substrate diameter before coating; 0.26 mm is the finished diameter after coating**. The coating adds 0.03 mm across the diameter. The substrate and solder areas both enter the finished resistance and mass calculations.

Sections 6, 7 and 10 use this same geometry, so dimensions, resistance per metre and purchasing cost can be compared directly. State both substrate and finished dimensions on the quotation and drawing.

Specification item	Recommended definition
Round wire	Substrate diameter and tolerance; finished diameter and tolerance; ovality requirement
Flat interconnect / busbar ribbon	Substrate thickness × width; finished dimensions; corner geometry, burrs and camber
Copper cladding	Volume fraction or explicitly defined weight fraction; minimum local copper thickness and inspection positions
Solder coating	Composition; single-side / radial thickness; local uniformity and coverage
Reel product	Continuous length, splice policy, reel drawing, winding and payoff direction

Rev.4 lists ±0.01 mm for substrate thickness/diameter, ±0.05 mm for flat-product width, a single-side/radial solder thickness of 15±5 µm, and flat-wire/busbar camber of ≤3 mm per 1,000 mm. These are that document's reference conditions. Finer geometries, high-speed lines or specific pad layouts may require separately agreed limits.[1]

Average copper fraction does not establish minimum local copper thickness. Eccentricity, rolled corners, bends and local defects need actual cross-section evidence. The ideal round-wire relation is useful only for a uniform concentric structure:

> Copper thickness = substrate diameter / 2 × [1 − √(1 − copper volume fraction)]

Do not apply it directly to flat or shaped sections. An exposed aluminum core at a cut end is inherent to the construction; unintended exposure along the wire surface, cracking or delamination is a different issue. Protection of cut ends through the joining, encapsulation and module design should be evaluated in the finished construction.[1][3]

07 | Resistance and module power: PV runs on DC, not a skin-effect sales pitch

Under the DC operating conditions of a PV module, both copper and aluminum conduct. "All the current stays in the copper skin, so it behaves exactly like copper" is not the correct explanation.

The most useful purchasing electrical question is: **what is the finished product's resistance per metre at 20°C?** Resistivity requires the real cross-sectional area to become resistance. An IACS value alone does not answer the question.[1]

For uniform straight material, use length L in m, area A in mm² and resistivity ρ in Ω·mm²/m:

> $R = \rho \times L / A$

Treating substrate and solder as effective longitudinal parallel paths:

> Resistance per metre $r = 1 / [A_{substrate} / \rho_{substrate} + A_{solder} / \rho_{solder}]$

> Finished effective resistivity $= r \times A_{finished}$

Consequently, adding a relatively low-conductivity solder coating can **reduce resistance per metre** while **increasing effective resistivity calculated over the full finished area**. The area definition explains the apparent contradiction.[1]

The finished-resistivity ranges in Rev.4 are modelled reference values, **not two-sided acceptance bands**. A measurement below a calculated lower endpoint is not, by itself, a reason for rejection. Apply the agreed finished-product resistance requirements for acceptance.[1]

A calculation with all its assumptions visible

Use the same 0.23 mm substrate diameter and 15 µm radial solder coating for both options, giving a 0.26 mm finished diameter. Take substrate resistivity as 0.017241 for copper and 0.025 for CCA50. Assume solder resistivity of 0.153 Ω·mm²/m, using the reference calculation scenario in Rev.4.[1]

Calculated quantity	Copper-substrate option	CCA50-substrate option
Substrate diameter, mm	0.23	0.23
Ideal finished diameter, mm	0.26	0.26
Substrate area, mm²	0.04155	0.04155
Finished resistance, Ω/m	Approximately 0.402	Approximately 0.576
Finished effective resistivity, Ω·mm²/m	Approximately 0.02136	Approximately 0.03056

The same-size materials can therefore have different resistance. **The percentage increase in ribbon resistance is not the percentage reduction in total module power.** This section and the cost calculation in Section 10 both use a 0.23 mm substrate and 0.26 mm finished diameter.

Module loss also depends on cell current, parallel interconnect count, distributed current collection, connection resistance and routing. Do not assign full module current to every fine wire along its entire length and then add all those losses. Optical shading and reflection belong in the module comparison too. [4]

For measurements, agree on four-terminal methodology, effective sample length, temperature correction and sampling positions. Fixture contact issues should not be mistaken for bulk material performance. Keep raw resistance, length, temperature and cross-section records, not only a converted number.

08 | Mechanical properties: the hardest ribbon does not win

Tensile strength describes resistance to breaking; proof/yield strength describes the stress associated with a specified permanent deformation; elongation describes extension before fracture. None substitutes for the others.

Sufficient strength helps handling and payoff. Excessive proof stress, springback or residual stress can work against conformity and thin cells. Very soft material can also create deformation and positioning problems. The objective is a production-and-module window, not a single-property championship.[4][5]

The following examples are from Rev.4. **Stress is calculated using finished metallic cross-sectional area.** Elongation and tensile values are minima; Rp0.2 values are maxima.[1]

Nominal substrate geometry	CCA: elongation / tensile / Rp0.2	HTCCA: elongation / tensile / Rp0.2
Round Ø0.24, 0.26, 0.28, 0.32 mm	≥20% / ≥120 MPa / ≤80 MPa	≥20% / ≥135 MPa / ≤95 MPa
Round Ø0.35 mm	≥20% / ≥125 MPa / ≤80 MPa	≥20% / ≥135 MPa / ≤85 MPa
Flat 0.16, 0.18, 0.25 × 0.6 mm	≥20% / ≥105 MPa / ≤80 MPa	≥20% / ≥135 MPa / ≤95 MPa
Busbar geometries listed in the specification	≥25% / ≥120 MPa / ≤120 MPa	≥25% / ≥140 MPa / ≤120 MPa

Do not extend one size's limits to every product. Gauge length, test speed, grips and area convention must also be consistent.

MPa is not breaking force in newtons. Two wires with the same tensile strength but different areas have different breaking forces. Payoff settings also need appropriate allowance for dynamic loading and subsequent handling operations.

Why is local flattening unnecessary in this TOPCon route?

According to Raytron's feedback from numerous Chinese module customers, the aluminum core gives the CCA ribbon selected for this route greater compliance than the original copper ribbon. It conforms more readily at the cell-edge contact, helping reduce local loading and the associated microcrack risk. The local flattening operation originally used for copper is therefore unnecessary.[2]

Here, "softer" means **bending and contact compliance in the actual application**, not a claim that every CCA/HTCCA grade has a lower tensile strength or proof stress than every annealed copper grade. Core, copper layer, temper and geometry still matter. No unmeasured percentage reduction in microcracks is claimed. Fraunhofer ISE also identifies interconnection transitions and cell-edge loading as stress-optimization issues; that is background research, not a test of Raytron's product.[5]

The process instruction remains definite: in the TOPCon substitution route covered here, the original local flattening operation MUST be disabled or bypassed.[2]

09 | Solder, flux and stringer: qualify the combination

Rather than asking only "can it be soldered?", ask: **can it make consistent joints with our cells, machine and throughput, across an acceptable process window?**

Mandatory for this TOPCon route: disable or bypass copper-ribbon flattening

When replacing copper ribbon with the Raytron round CCA ribbon covered here, the stringer's existing local ribbon-flattening operation MUST be disabled or bypassed. Do not retain it by copying the copper recipe. This is Raytron's requirement based on extensive Chinese customer feedback—not an optional suggestion to experiment with.[2]

The original copper process locally reduces ribbon thickness and loading at the cell edge to reduce edge-cracking risk. A published patent likewise identifies inter-cell stress and edge cracking as problems addressed by local flattening.[17] The Raytron ribbon selected for this route relies on greater compliance instead; retaining the old action may damage the copper cladding. InfoLink's May 2025 research identified aluminum exposure as a risk when fine TOPCon SMBB composite wire undergoes flattening during stringing.[16]

Stage	Required action
Recipe change	Create the composite-ribbon recipe and disable/bypass local inter-cell flattening. A smaller flattening stroke is not the same as disabling it.
Action check	Equipment/process staff confirm that the wire is no longer flattened at that station; record the recipe revision and actual action.
First articles and pilot	With flattening off, check routing, tension, edge transition, joints, EL and power before normal production release.

This instruction concerns **the stringer's local flattening operation originally used for copper round wire**. It does not mean disabling normal soldering clamps, positioning or lamination, and it does not prohibit controlled manufacture of flat composite ribbon by the supplier. If the machine cannot disable or bypass this operation, have the equipment supplier resolve that before trials under this route.

The 2025 report describes a historical fine-wire/flattening obstacle. It must not be recast as a timeless ban on TOPCon CCA mass production. Raytron's instruction above reflects its subsequent field experience.[2] [16]

> A new material needs the right recipe—not every habit inherited from copper.

Rev.4 lists Sn60Pb40, Sn50Pb50, Sn43Pb43Bi14 and Sn32Pb43Bi25, with nominally pure tin available on request. These are different compositions, not a universal recommendation list for all cell technologies.[1]

Item	Action for purchasing and trials
Solder composition	State the complete alloy and limits; specify lead-free requirements and supporting evidence where required.
Coating thickness	Examine average and local coverage alongside joint volume and dimensional limits.
Flux	Check wetting, residues and compatibility with cell metallization and encapsulation materials.
Thermal profile	Measure temperature, time and cooling at the relevant joining locations; do not simply copy machine setpoints.
Pressure and alignment	Record tooling, tension, pad alignment and front/rear positional relationships.
Production speed	Validate at target throughput, not only with slow manual samples.

Smaller pads, thinner metallization and finer wires can narrow the tolerances for alignment, heating and solder volume.[4] Establish a baseline and change variables deliberately. Changing the ribbon, cell batch and flux simultaneously is a poor way to discover which variable mattered.

Low-temperature does not mean lead-free. Bismuth-containing does not mean lead-free. "Tinned" does not mean pure tin. Read the composition, not the implication of the name.

10 | Equal finished price per tonne: savings per module, watt and GW

Raytron's commercial experience indicates that finished prices by weight are often close. CCA ribbon has a higher solder mass fraction, and coating throughput and processing costs affect the finished price. This example uses **the same finished-product price per metric tonne for copper and CCA**.[22]

> The saving is not a cheaper kilogram. It is fewer kilograms for the same interconnection length.

10.1 | Fix the comparison: 0.26 mm means the finished diameter

Item	Conditions used here
Reference module	650 W; 132 half-cells; 6×22 layout; 16BB
Round interconnect length	451.2 m/module, a geometry budget—not a measured factory issue quantity
Both finished diameters	**0.26 mm after solder coating**
Radial / single-side solder thickness	15 µm, a nominal input—not a new measurement

Item	Conditions used here
Substrate diameter	**0.26 − 2×0.015 = 0.23 mm**
Composite substrate	CCA50: 50 wt.% copper in the substrate, approximately 23.19 vol.%
Solder	Sn60Pb40 for both options; the entire coating is not pure tin
Purchasing price	The same P per metric tonne of complete finished product; matching tax and delivery terms
Replacement scope	Round interconnect wire only; unchanged busbar ribbon is excluded

The model uses the published format of the JA Solar JAM66D45-650/LB as its geometry reference: 650 W, 132 half-cells and 16BB. The 105 mm coverage input comes from cell dimensions recorded for the same series.[18][19]

Count the front and the rear. Inter-cell ribbon covers different surfaces of adjacent cells; counting only the wires visible in a front photograph misses physical length.[20]

Length component	Example calculation	m/module
Front-side coverage	132×16×105/1000	221.76
Rear-side coverage	132×16×105/1000	221.76
Inter-cell crossings	12 physical strings×10 gaps×16 wires×2 mm/1000	3.84
String-end extensions	12 strings×2 ends×16 wires×10 mm/1000	3.84
Total		**451.20**

Eleven cells per physical string, a 2 mm crossing path and 10 mm at each end are explicit geometric inputs. Actual pad setbacks, bend paths and cutting records take precedence. No arbitrary wastage allowance has been added.

10.2 | Calculate the whole coated wire—not only the lighter core

Use densities of 8.960 for copper, 2.705 for aluminum and 8.50 g/cm³ for Sn60Pb40 solder. The first two are Raytron's bare-material calculation constants; the solder value is retained from the manufacturer's physical data. This calculation does not mix in the rounded nominal densities in Section 4.[3][21]

> Substrate area = $\pi \times 0.23^2/4 = 0.041547563$ mm²

> Solder area = $\pi \times (0.26^2 - 0.23^2)/4 = 0.011545353$ mm²

> CCA50 density = $1/(0.5/8.960 + 0.5/2.705) = 4.155473639$ g/cm³

With these units, area in mm² × density in g/cm³ = mass in g/m. Calculate substrate and solder separately, then add them:

Calculated quantity	Copper-core finished wire	CCA50 finished wire
Substrate mass, g/m	0.372266	0.172650
Solder mass, g/m	0.098136	0.098136
Complete finished mass, g/m	**0.470402**	**0.270785**
Solder share of finished mass	**20.86%**	**36.24%**
Substrate per module, g	167.966	77.900
Solder per module, g	44.279	44.279
Finished purchase mass per module, g	**212.245**	**122.178**
Finished length per kilogram, m	2,125.84	3,692.96

Solder mass per metre is the same for both wires. Per tonne of finished wire, the copper-core version contains approximately 208.62 kg of solder and the CCA50 version contains 362.41 kg.[22]

The bare substrate is approximately 53.62% lighter, but the solder layer does not shrink with its mass. The complete finished product is **42.44% lighter**. The same weight supplies approximately 73.72% more length—a different denominator, not a 73.72% cost saving.

10.3 | Equal price per tonne gives a 42.44% interconnect purchasing saving

Let P be the common price in currency units per metric tonne of complete finished product. For 451.2 m, purchase masses are 0.212245231 kg and 0.122178329 kg:

> Copper purchasing cost/module = 0.212245231×P/1000

> CCA50 purchasing cost/module = 0.122178329×P/1000

> Saving/module = 0.090066902×P/1000

At equal tonne prices and equal net lengths, the common price cancels from the percentage:

> **Purchasing-cost reduction = 1 − 0.122178329/0.212245231 = 42.4353% ≈ 42.44%**

This is the saving on **the replaced round interconnect wire in this construction**. The denominator is the original copper wire's purchasing cost.

10.4 | The common tonne price determines the monetary saving

The table uses illustrative prices. Per-watt and per-GW savings use the original 650 W reference module.

Common price CNY/t	Copper CNY/ module	CCA50 CNY/ module	Saving CNY/ module	Saving CNY/ baseline W	Saving million CNY/baseline GW
80,000	16.98	9.77	**7.21**	**0.011085**	**11.0852**
100,000	21.22	12.22	**9.01**	**0.013856**	**13.8564**
120,000	25.47	14.66	**10.81**	**0.016628**	**16.6277**
150,000	31.84	18.33	**13.51**	**0.020785**	**20.7847**

Differences use unrounded calculations. **At an illustrative common price of CNY 100,000/t, the saving is about CNY 9.01/module, CNY 0.01386/baseline W or CNY 13.86 million/baseline GW.** At CNY 150,000/t, it becomes about CNY 13.51/module, CNY 0.02078/baseline W or CNY 20.78 million/baseline GW. The percentage remains 42.44% at both prices.

A tax-inclusive input produces a tax-inclusive purchasing difference; an ex-tax input produces an ex-tax difference. No tax rate is assumed here, and the two bases must not be mixed.

10.5 | Cross-check against tonnes purchased per GW

> Reference module count for 1 GW = $10^9/650$

Calculated quantity	Copper-core finished wire	CCA50 finished wire
Interconnect length/baseline GW	Approximately 694.15 million m	Approximately 694.15 million m
Finished purchases/baseline GW	**326.531 tonnes**	**187.967 tonnes**

The difference is **138.564 tonnes of finished ribbon per baseline GW**:

> **Saving/baseline GW = 138.564464684 tonnes × P per tonne**

The inputs are geometry or measured linear mass, actual consumption and the complete finished quotation.

10.6 | Replace four inputs with your own order data

Use your own **finished linear mass, actual net consumption, complete finished price per tonne and measured module power**. Monetary savings in the equal-price case scale linearly with the common price. When actual quotations differ, enter both:

> Saving/module = (copper finished kg/module × copper price/t − CCA finished kg/module × CCA price/t)/ 1000

> Ribbon saving/delivered W = old ribbon purchase cost/module ÷ old measured watts − new ribbon purchase cost/module ÷ new measured watts

Multiply the second result by 10^9 to obtain **ribbon-item savings for delivery of the same measured 1 GW**.

Handle returns, recoverable scrap, startup loss, rework and rejects consistently. Do not apply a second yield factor after calculating from actual net consumption and accepted output. Do not transfer the approximately 3 W difference from a separate 0.24 mm project into this 0.26 mm model.

For the TOPCon route, disable or bypass the original local flattening operation. Track any measured changes in throughput, maintenance, energy and yield separately from the ribbon cost calculation.[2]

11 | The "about 3 W on a 650 W module" example

Raytron has provided a TOPCon project comparison involving **650 W-class modules, nominal 0.24 mm CCA ribbon and nominal 0.24 mm copper ribbon, with an approximately 3 W power difference**. Relative to 650 W, that is approximately **0.46%**.[2]

Evaluate conductor resistance and module power separately. The electrical example in Section 7 and the cost example in Section 10 share a 0.23 mm substrate, 15 µm radial solder coating and 0.26 mm finished diameter. The nominal 0.24 mm project above retains its measured power comparison.

Use a correct recipe for each material. In the TOPCon CCA round-wire route covered here, local flattening must be disabled/bypassed. "Identical conditions" must not mean retaining an inappropriate copper operation for the composite.[2]

Choose the route that best fits the project constraints:

Route	Relevant constraint	Evaluate success through
Start with existing geometry	Limited freedom to change equipment, positioning or drawings	Actual module power, joining, yield and cost
Resize to a resistance target	A defined resistance budget with dimensional flexibility	Shading, pads, stress and equipment fit as well as resistance
Co-design the interconnection	Cell/module architecture can be modified	Copper fraction, shape, wire count, routing and coating together

For a bare, uniform substrate calculation, changing resistivity from 0.017241 to 0.025 gives an equal-resistance composite diameter of approximately **0.277 mm** in place of **0.23 mm copper**: $0.23 \times \sqrt{(0.025 / 0.017241)} \approx 0.277$ mm. Both values are substrate diameters before coating. Finished-wire selection also accounts for solder conduction, distributed current and optical effects.

12 | Sampling to production: five stages, not one impressive sample

The following is a suggested project workflow, not a standard-mandated sample size or timetable.

Stage	Work	Evidence before moving on
Align requirements	Fix the module, reference ribbon, constraints and objectives	One-page specification and acceptance objectives
Inspect the material	Dimensions, resistance/metre, copper and solder layers, tensile behavior and payoff	Sample identification and measured results

Stage	Work	Evidence before moving on
Establish the process	Confirm local flattening is disabled/ bypassed for the TOPCon CCA route; establish feeding and joining settings	Recipe/flattening-state record, joints and EL controls
Validate modules	Matched builds, power and reliability evaluation	Reports, explained differences and approved application scope
Pilot and production	Multiple reels/batches at actual throughput; complete change approval	Approved sample, controlled drawing, control plan and traceability

Keep cell source, power/current sorting, thickness, encapsulation materials and important process conditions comparable. Both copper and composite controls should use reasonable, fully recorded settings —not intentionally unfavorable settings for one option.

Power comparisons should address calibration, temperature, spectrum, measurement repeatability and uncertainty. Preserve individual-module distributions rather than selecting the best sample. IEC 60904-1 is the reference entry point for I–V measurement procedures.[6]

Sample counts, batches, test duration and release limits belong to the customer's quality and certification plan. A supplier's reel of sample wire cannot substitute for complete module approval.

13 | Reliability: not only "does it hold?", but "what happens afterwards?"

Plan checks around actual failure mechanisms, then establish test conditions through the applicable standards and certification plan.[7][8][9]

Check / test	Main question	Recommended records
Copper–aluminum and coating cross-sections	Local thin spots, cracking, separation or abnormal interfaces?	Scaled images, location and interpretation
Wetting and joint peel	Does this material/solder/ metallization combination produce stable joints?	Angle, speed, temperature, units, force distribution and failure location
EL and I–V	New cracks, connection abnormalities or power change?	Comparable before/after images and electrical data
Thermal cycling, TC	Do joints and connections survive repeated expansion and contraction?	Power, resistance, EL, appearance and destructive analysis where needed
Damp heat, DH	Are interfaces, encapsulation and connections stable in humid heat?	Power, resistance, corrosion and contact condition
Humidity-freeze, mechanical loading and other relevant tests	Problems under the specified environment or mechanical stress?	Records using the agreed sequence and criteria
Insulation, wet-leakage and other safety evaluation	Does the change affect module safety?	Reassessment within the applicable certification scope

"Peel force: 1 N" has limited value without a method. Separate 90° from 180°, individual wires from bundles, N from N/mm, and averages from minima. Record whether failure occurred in the solder interface, metallization, ribbon or silicon.

Short accelerated tests are not a direct conversion into years of outdoor use. IEC 61215 design-qualification results are not a quantitative prediction of module lifetime.[7] State the model, bill of materials, tests and results clearly; do not turn one report into a lifetime passport for every specification.

14 | Incoming acceptance: make the certificate match the reel

Initial supplier approval examines capability and systems. Batch release also needs evidence about the delivered material. A technical data sheet defines the delivery requirements; a batch inspection record reports what was measured on that batch.[1][10]

Acceptance item	Check
Identity and traceability	Grade, core, coating, drawing revision, batch and reel numbers agree.
Dimensions and appearance	Sample agreed positions; check diameter/thickness/width, solder beads, scratches, oxidation and missing coating.
Electrical	Record temperature and effective length; evaluate finished resistance/metre and variability.
Copper and solder layers	Inspect fractions, minimum local thickness, coverage and interfaces according to the control plan.
Mechanical	Compare tensile strength, Rp0.2 and elongation using consistent gauge-length and area conventions.
Payoff and packaging	Reel, winding, splices, net mass, length, vacuum seal and transport damage.
Documents	Batch report, applicable declarations and other contract-required evidence.

Missing solder exposing copper, unintended copper-cladding damage exposing aluminum, and an exposed core at a cut end are different conditions. Photographs and agreed defect samples often communicate acceptance criteria better than vague adjectives.

Define sample quantities, rejection criteria, retesting and the dispute laboratory in the order or inspection plan. This guide does not impose one arbitrary AQL on every product.

15 | Production troubleshooting: investigate before assigning blame

These are suggested investigation priorities, not diagnoses made from a symptom alone.

Symptom	Check first
More wire breaks	Actual diameter, breaking force, tension, damaged guides, reel snags and splices
Misalignment or poor conformity	Camber, springback, positioning, tooling, winding and tension variation
Poor wetting or weak joints	Surface condition, solder, flux, actual temperature and time
Lower peel results	Failure location, metallization, solder volume and process changes
New cell-edge cracks in EL / local aluminum exposure	In the TOPCon substitution, first confirm local flattening is actually disabled/bypassed; then check cell thickness, tooling, tension, thermal history and routing
Lower module power	First verify measurement and cell sorting, then material resistance, joints, alignment and optical effects
Resistance drift after aging	Cross-section/joint damage, corrosion paths, encapsulation and process changes
Reel-to-reel variation in one batch	Batch definition, within-/between-reel sampling, dimensions, coating distribution and payoff conditions

Retain an affected reel, a normal comparison reel and the actual process records. That is usually more useful than sending a photograph with the message "please explain".

16 | Packaging, storage and delivery: do not lose good material in the warehouse

Rev.4 specifies a clean, dry store without corrosive chemicals, at ≤35°C and ≤60% relative humidity. Under its stated constant-temperature, dry indoor conditions, shelf life is six months unopened under vacuum and three months after opening. Special solders, packaging and customer conditions follow the corresponding order; these periods are not a universal shelf-life claim for all coatings.[1]

Use first-in, first-out control and record opening dates. Moisture exposure, failed vacuum packaging or abnormal storage should trigger the quality procedure, even if the nominal expiry date has not arrived. When cold reels enter a warm humid area, avoid condensation when opening them.

Reels must fit the payoff equipment. Confirm bore, outside diameter, width, winding direction, winding pattern and allowable net mass. "A 160 reel" is not a complete drawing. Continuous length and splice policy also deserve a place in the RFQ.

For international orders, align currency, tax treatment, trade terms, freight, metal-pricing date and delivery location. Composite ribbon also contains solder and processing cost; a simple weighted copper-and-aluminum price is not a finished-product quotation.

17 | Standards and market access: separate material, module and application

Document	Main purpose	Purchasing use
Raytron specification and customer technical agreement	Material delivery requirements	Lock grade, geometry, temper, coating and acceptance.
GB/T 31985-2015	PV tin-coated ribbon product standard	Official catalog checked as current; examine the complete scope rather than assuming all CCA products are covered.
IEC 61215 series	Module design qualification and type approval	Evaluate the specified module construction.
IEC 61730 series	Module safety	Review construction and safety-test requirements.
IEC TS 62915:2023, with 2024 corrigendum	Retesting following module design/ material changes	Agree the relevant retesting with the certification body.
IEC 60904-1:2020	PV-device I–V measurements	Establish the measurement-method reference.
IEC 62941:2019	Module-manufacturing quality system	Control material selection, change and production consistency.

The official catalog consulted for this guide lists the GB/T 31985 revision project **20264584-T-339** as being drafted.[6–12]

When a customer specifies an association standard, obtain its **identifier, publisher, edition, implementation status and complete text** before adding it to the agreement. An "alloy ribbon" label, a patent or a draft document is not product certification.

Lead, lead-free requirements and export markets

First establish composition; then check the final product, destination and customer contract. EU RoHS excludes certain PV panels intended for professionally designed, assembled and installed systems for permanent use at a defined location. This is not a worldwide exemption for every lead-containing ribbon. Lead-free declarations, other chemical obligations, occupational health and customer restricted-substance lists remain separate matters.[13]

ISO 9001 addresses a quality-management system, not the module qualification of an individual ribbon. A material or module report does not automatically cover every geometry, factory, solder or market. For North American and other projects, follow the actual certification and material-change procedure.[8][14]

18 | How to request quotations and compare suppliers

For the first conversation, send six things: **cell/module design, connection position, current specification, non-negotiable constraints, target market and approximate volume.** A drawing or sample is usually more useful than ten adjectives.

Complete the following when the project moves into formal selection.

Topic	Information to provide
Module	Model, power target, cell dimensions/thickness/sorting, interconnect count and routing
Material	Candidate CCA or HTCCA, copper fraction convention, core and temper
Geometry	Substrate and finished diameter/thickness × width, tolerances, corners and minimum copper thickness
Coating	Alloy, single-side thickness, lead/lead-free requirement and flux
Electrical and mechanical	Finished resistance/metre, reference temperature, tensile, Rp0.2, elongation and test conditions
Production	Stringer, throughput, tension, thermal profile, pads/tooling; ability to disable/bypass local TOPCon flattening and the confirmed setting
Validation	Baseline, sampling plan, power, EL, peel, reliability and release criteria
Delivery	Sample amount, monthly demand, continuous length, reel, splice policy and destination
Commercial and documentation	Pricing basis, validity, traceability, inspection report, certificate scope and change notification

Copy-ready RFQ:

> We manufacture _____ modules using _____ cell/interconnection technology. The material to be replaced is located at _____; the current specification is attached. Dimension _____ refers to the substrate, and _____ to the finished coated product. We cannot change _____, but may adjust _____. Our main objective is _____. Stringer and target throughput: _____. Local-flattening disable/bypass status: _____. Destination market: _____. Estimated monthly demand: _____. Please propose a material/coating combination and provide finished resistance per metre, mechanical properties, cross-section and sampling information, packaging, and a quotation on matching delivery terms.

Compare suppliers on four practical points: **clear specifications, identifiable samples, repeatable production and reliable change notification**. Actual batch cross-sections and inspection data are more useful than "high conductivity, high strength, high reliability".

Specify that changes to core material, copper fraction, solder or agreed critical production conditions require approval. Define deviation approval, issue handling, retained samples and affected-batch traceability. Use the customer's established quality process rather than building a new maze of forms.[10]

19 | Buyer FAQ

Does it necessarily reduce module power?

Compare the power distribution of matched modules. Same-size resistance may increase, and the module result also depends on architecture, joining and optics.

Is a higher copper fraction always safer?

It affects conductivity, cladding and cost, but does not replace minimum-thickness, bonding or finished-module validation. Select a combination that meets the requirements—not simply the largest number.

Does the aluminum core carry no current?

It carries current. Under DC conditions, both metals conduct. PV selection should not rely on an "all current in the copper skin" claim.

Can matching size and color justify a direct substitution?

They may provide a geometric starting point, not production approval. Verify substrate/finished definitions, resistance, mechanics, coating composition and line performance.

Is HTCCA automatically suitable for higher temperatures?

No temperature rating follows from the abbreviation. It is a specified alloy-core series; thermal performance and reliability concern the complete material and module construction.[1][3]

Does TOPCon still need local flattening after switching to Raytron round CCA ribbon?

No. The original local flattening operation MUST be disabled or bypassed. Raytron's Chinese customer feedback indicates greater compliance at the cell edge for this aluminum-core route, making the copper flattening action unnecessary. Retaining it can also damage the cladding. Application compliance does not mean every tensile property of every grade is lower.[2][16]

Can disabling flattening immediately be booked as an extra saving?

Use measured changes in throughput, energy, maintenance and yield for the line being assessed.

Does copper cladding make corrosion impossible?

No. Evaluate cut ends, defects, moisture, residues and encapsulation together. Good cladding and encapsulation are design measures, not a reason to omit validation.

Do damp heat and thermal cycling prove an arbitrary lifetime?

They do not directly convert into years. They support evaluation of the tested construction; field environment and manufacturing consistency also matter.[7]

Does the existing module certificate automatically remain valid?

Follow the material-change procedure and agree the assessment with the certification body. As a ribbon supplier, Raytron cannot declare this unilaterally.[9]

How can equal prices per kilogram still produce savings per module?

The same connection length requires less finished purchase mass. Including the complete solder coating, Section 10 calculates 0.270785 g/m for CCA50 and 0.470402 g/m for copper. Equal prices per tonne and equal net lengths give approximately 42.44% lower purchasing cost.

Does less copper mean the same percentage reduction in carbon emissions?

No. Material sourcing, energy, manufacturing and transport affect the footprint. A public carbon-reduction claim needs a defined assessment boundary and data, not a renamed weight-saving percentage.

Can we change only the busbar ribbon and retain existing interconnect wire?

That can be evaluated as a separate project. Recalculate the collection circuit, joints and power, while still following the applicable module-change requirements.

20 | Turn a reel of material into an approvable solution

Selecting composite PV ribbon is not procurement searching alone for "cheaper copper". It is procurement, engineering and quality finding **a better-value interconnection material for this module**.

Send Raytron your current drawing or sample, cell/module design, connection position, destination market and approximate volume. Begin with the actual constraints; compare substrate, copper cladding, coating, geometry, process and cost, and define what the trial must demonstrate.

Explain the material clearly. Make the sample properly. Let accepted modules and cost data make the decision.

Engineering Every Micron.

Quick glossary

Term	Meaning in this guide
μm	Micrometre: 1 μm = 0.001 mm. Radial coating thickness is not the total diameter increase.
%IACS	Conductivity relative to the International Annealed Copper Standard—not a percentage of current-carrying capacity.
EL	Electroluminescence imaging, used to help identify cell cracks and connection anomalies.
I–V	Current–voltage characteristics, used to evaluate electrical performance and power.
BOM	Bill of materials: the specific cells, ribbon, encapsulation and other components, not just a model name.
TC / DH	Thermal cycling / damp-heat tests. Conditions and criteria follow the applicable test plan.
Rp0.2	0.2% proof stress: the stress associated with 0.2% permanent plastic extension.
MBB / SMBB / 0BB	Multi-busbar / super-multi-busbar / no conventional cell busbar. These labels alone do not specify the ribbon.
Finished resistance / mass per metre	Electrical resistance / mass of a unit length after coating—key inputs for comparing materials.
Yield	Accepted output divided by input. State the process boundary and denominator to avoid double-counting losses.

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Document version 1.2. Cost-model update: 6 November 2026.

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