

A Joint Venture Model for Investing in Ethiopia's Solar Manufacturing Sector

Optimizing Panel Durability Through Lamination

Content Partner: J. v. G. technology GmbH

Turnkey solar module production lines — since 1997

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Technical Overview: Joint Venture Models for Ethiopia's Solar Sector



Created as part of the PVKnowHow Knowledge Network



Prepared by J.v.G. Technology GmbH



European specialists in turnkey solar module production lines

Key Project Data

~135–1...

Temperature Range

Operating range for EVA crosslinking and encapsulant bonding

~20 min

Cycle Time

Typical lamination cycle: preheat, vacuum, press, cooling

~600/hr


Peak Throughput

Fully automated systems (IEA reference)

2 Types

Automation Levels

Semi-automatic and fully automated laminators

 Process: PV module lamination · Application: Solar module manufacturing · Source: PVKnowHow / J.v.G. Technology GmbH

What Is a PV Laminator?

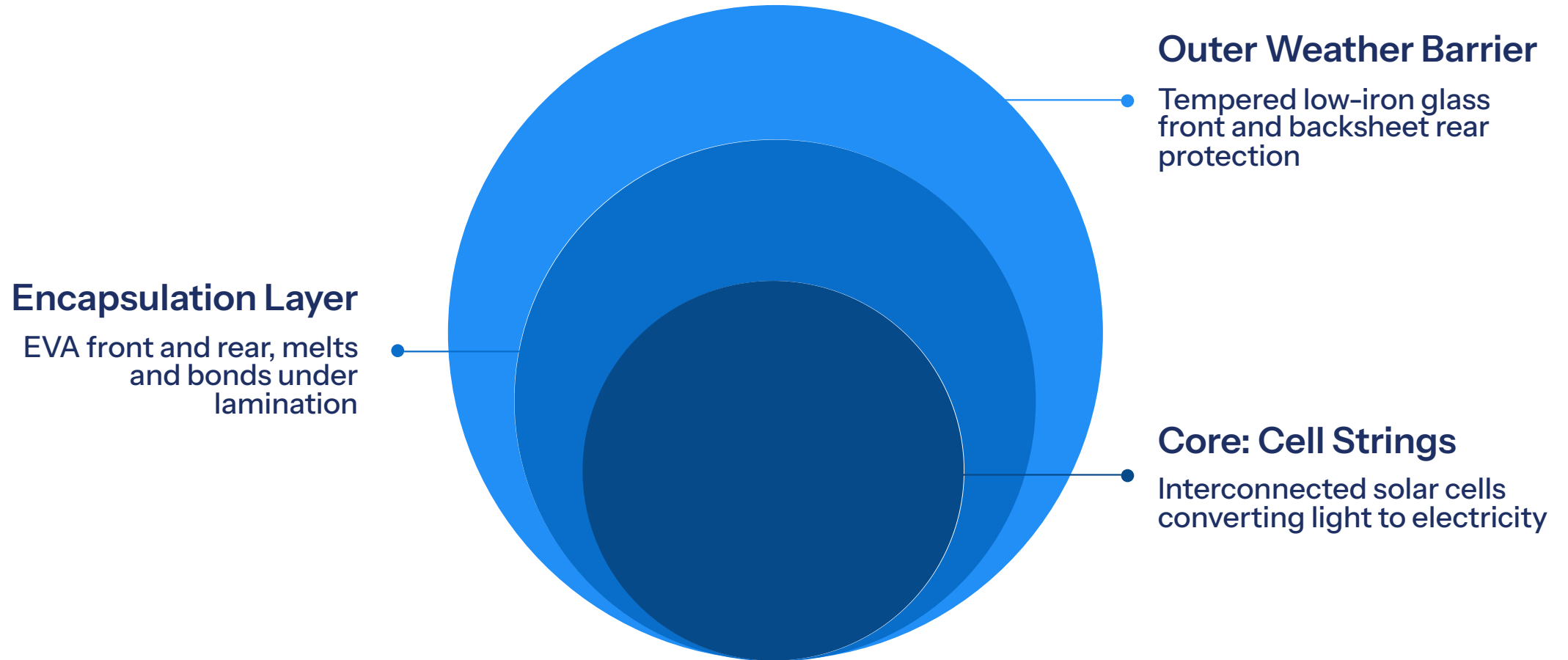
Definition

- A precision machine that bonds solar module layers under heat, vacuum, and pressure
- Operates within a sealed chamber to eliminate air inclusions
- Central step in crystalline silicon (c-Si) and thin-film PV manufacturing
- Produces the permanent, weatherproof laminate structure of a finished module

Why It Matters

- Protects solar cells from moisture, UV, and mechanical stress
- Determines long-term module reliability — 25+ year lifetime target
- Once laminated, rework is extremely difficult — quality must be ensured upstream
- Directly affects power output and certification compliance

Layer Structure of a Standard Solar Module



This five-layer sandwich — glass / EVA / cells / EVA / backsheet — is consolidated inside the laminator under heat and vacuum. The encapsulant melts, flows, and crosslinks to form an airtight, durable bond around the cell strings.

Key Components of a PV Laminator

Heating System

- Oil or electric resistance heating of platens
- Uniform temperature across module surface ($\pm 5^{\circ}\text{C}$ tolerance)
- Operating range: $\sim 135^{\circ}\text{C}$ – 180°C

Vacuum System

- Sealed upper and lower chambers
- Controlled evacuation rate removes air and outgassing
- Alarm monitoring if vacuum cannot be reached in target time

Pressure / Press System

- Pneumatic or hydraulic membrane applies even surface pressure
- Three-step pressing control for consistent laminate quality
- Prevents uneven encapsulation and delamination at edges

Cooling & Control

- Active or passive cooling after lamination cycle
- PLC-based control with HMI touchscreen interface
- Parameters stored safely – manual override mode available

Types of PV Laminators: Semi vs. Fully Automated

Criterion	Semi-Automatic	Fully Automated
Loading / Unloading	Manual by operator	Robotic handling systems
Throughput	~100–300 modules/hour	Up to ~600 modules/hour
Best Suited For	Medium-scale production; lower capex	High-volume lines; minimized unit cost
Initial Investment	Moderate	Higher upfront, lower cost/module at scale
Process Control	Automated temp/pressure; manual loading	Fully integrated, computer-managed
Downtime Risk	Higher (manual load/unload cycle)	Lower (continuous flow possible)

Lamination Process Steps

1

1 — Pre-Inspection

Visual and EL inspection of cell strings before entering laminator

Rework is near-impossible after lamination

2

2 — Lay-Up & Loading

Glass / EVA / cells / EVA / backsheet assembled in sequence

Module loaded onto heated platen (manually or robotically)

3

3 — Heating & Vacuum

Chamber sealed; vacuum applied in controlled stages

EVA softens and begins to flow at ~135°C+

4

4 — Pressing & Crosslinking

Membrane pressure applied; EVA bonds all layers

Full crosslinking achieved at lamination temperature

5

5 — Cooling & Unloading

Module cooled (active or passive) before unloading

Post-lamination inspection: visual check and peel force test

Encapsulant Materials: Technical Comparison

EVA — Ethylene Vinyl Acetate

- Industry standard since the 1980s; well-proven in field
- Good adhesion, long lifetime; requires curing with UV stabilizers and cross-linking agents
- Most cost-effective option; widely compatible with standard laminators

TPO — Thermoplastic Polyolefin

- Growing adoption for glass-glass and bifacial module designs
- Superior UV resistance; water absorption <0.1%; no crosslinking additives needed
- Lower processing temperatures possible — energy savings potential

PVB / TPU — Thermoplastic Alternatives

- Available in sheet form; do not require curing
- Higher melt viscosity than EVA — process cycle times similar
- Used in specialty, architectural, and building-integrated PV applications

Performance & Quality Impact of Lamination

Efficiency Impact

- High-quality lamination can improve panel efficiency by 2–3% (NREL reference)
- Proper bonding reduces optical losses and cell microcracks
- Consistent encapsulation minimizes air bubbles that degrade output
- Platen temperature uniformity of $\pm 5^{\circ}\text{C}$ is sufficient for good gel content and adhesion

Durability & Reliability

- Lamination provides the primary weather barrier — moisture, UV, mechanical stress
- Correct vacuum timing prevents outgassing and bubble formation
- Process control measures (peel force, gel content tests) are critical in production
- Proper crosslinking is essential for 25+ year module lifetime

Benefits of Industrial PV Lamination

Efficiency

- Automated lamination ensures consistent, repeatable quality
- Fully automated systems: up to ~600 modules/hour throughput
- Reduced operator dependency; lower scrap rates

Durability

- Sealed laminate protects against all major environmental degradation factors
- Correct material selection supports 25+ year field lifetime
- Reduced delamination, yellowing, and moisture ingress risk

Cost-Effectiveness

- Higher automation reduces cost per module at volume
- Energy-efficient encapsulants (TPO) lower thermal processing costs
- Process reliability reduces warranty and field failure exposure

Laminator Selection Criteria

Production Volume

- Medium-scale (25–100 MW/yr): semi-automatic provides balance of cost and output
- High-volume (>200 MW/yr): fully automated systems justify higher capex
- Throughput target determines number of laminator units required in line

Material Compatibility

- Laminator must be configured for the target encapsulant (EVA, TPO, PVB)
- Module format (glass-backsheet vs. glass-glass) affects platen and vacuum configuration
- High-efficiency cell types (TOPCon, HJT) may require tighter temperature tolerances

Energy & Budget

- Oil-heated platens offer high uniformity; electric heating offers faster response
- Multi-chamber designs (preheat + laminate + cure) increase throughput and energy efficiency
- Total cost of ownership includes maintenance, consumables (belts, membranes), and downtime

Strategic Importance of Lamination in PV Manufacturing

1

Quality Gateway

Lamination is the point of no return — all upstream quality decisions are locked in permanently at this step

2

Line Bottleneck Risk

As the longest cycle-time step (~20 min), the laminator often defines overall line throughput and must be scaled accordingly

3

Certification Anchor

IEC-compliant lamination process is a prerequisite for module certification and market access in regulated markets (EU, US)

- ❑ An experienced European turnkey provider integrates lamination know-how into full-line process methodology — reducing the learning curve for new manufacturers entering production.

About the Content Partner

J. v. G. technology GmbH – The DESERT Company

Founded in 1997 in Bavaria, Germany. Family-owned engineering company specializing in turnkey solar module production lines.

More than 90 factory projects delivered worldwide.

On-site team training included – no prior manufacturing experience required.

Key areas:

Turnkey PV manufacturing lines | DESERT Technology® |
TÜV-certified module designs | Factory planning to production

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