

EDUCATIONAL OVERVIEW

Basics of Solar Panel Manufacturing: A Complete Guide

A factual, technical guide to solar module production — from cell to finished panel

Content Partner: J. v. G. technology GmbH

Turnkey solar module production lines — since 1997

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A Technical Overview: Solar Manufacturing Basics



Created as part of the PVKnowHow Knowledge Network



Prepared by J.v.G. Technology GmbH



European specialists in turnkey solar module production lines

Why Solar Manufacturing Knowledge Matters

Growing Global Demand

Clean energy targets are accelerating solar panel deployment worldwide

Complex Production Chain

Quality solar panels require tightly controlled multi-step manufacturing processes

Investment & Process Decisions

Understanding manufacturing basics drives smarter facility setup and cost control

Anatomy of a Solar Panel



PV Cells

Convert sunlight into electricity via semiconductor junction; most critical performance component



Tempered Glass

Protective front cover; transmits light while shielding cells from mechanical and weather damage



Encapsulant (EVA)

Ethylene Vinyl Acetate film bonds glass and cells; provides moisture and UV barrier



Backsheet

Rear protective film; provides electrical insulation and environmental resistance



Aluminum Frame

Structural support for mounting and handling; protects module edges



Junction Box

Houses electrical connections and bypass diodes on the module rear

PV Cell Manufacturing: Key Steps

1

Polysilicon Production

Silicon melted and solidified into high-purity blocks

2

Wafer Slicing

Blocks cut into thin wafers — mono- or polycrystalline

3

Cell Fabrication

Doping, texturing, and metallization create the semiconductor junction

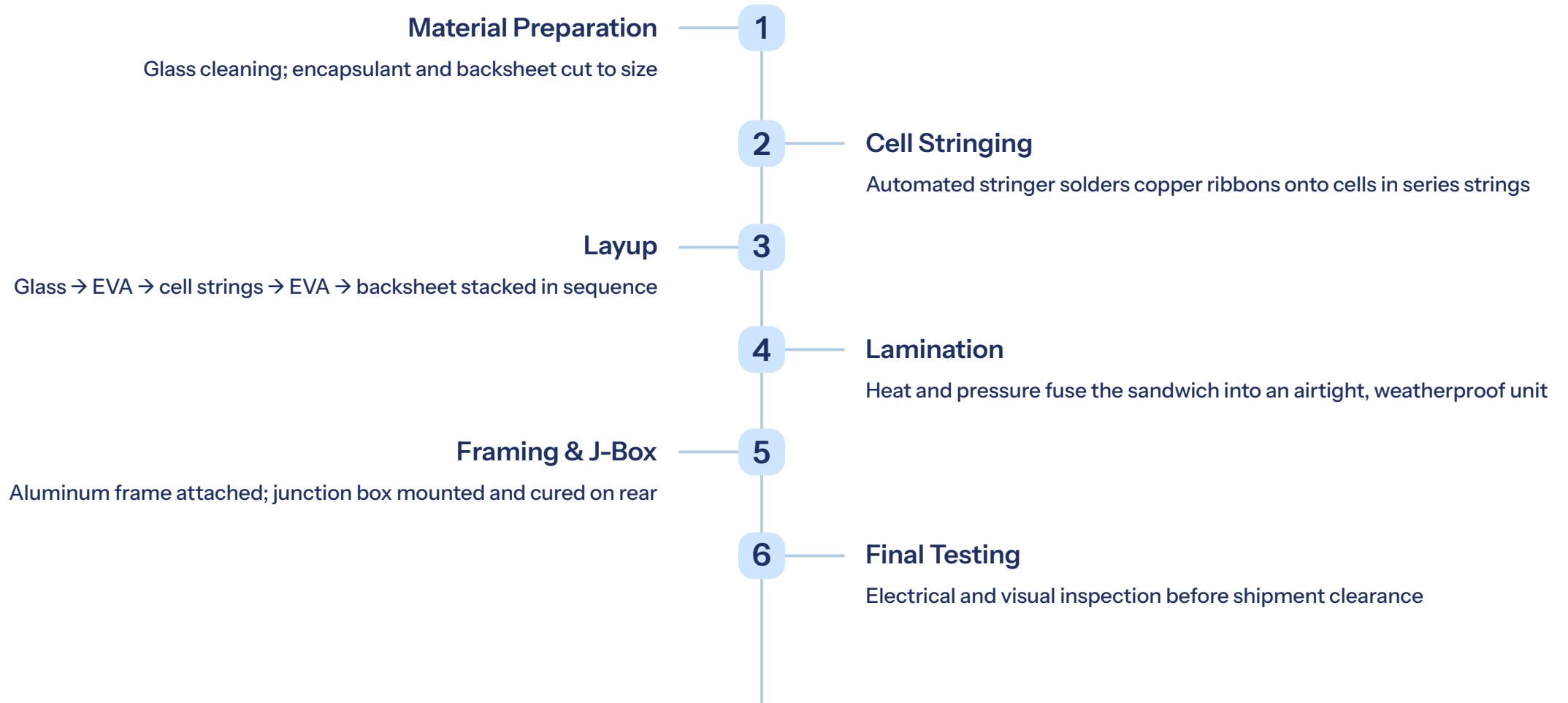
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Sorting & Testing

Cells sorted by efficiency class before module assembly

Monocrystalline wafers offer higher efficiency; polycrystalline wafers offer lower cost — both are widely used in standard module production lines.

Module Assembly: Step-by-Step



Key Equipment Requirements

Core Line Machines

- Stringer machine — cell tabbing and interconnection
- Layup station — material stacking
- Laminator — encapsulation under heat/pressure
- Framing machine — aluminum frame attachment
- Flash tester (IV curve tester) — electrical output verification
- EL tester — electroluminescence defect detection

Supporting Infrastructure

- Encapsulant & backsheet cutting equipment
- Glass washing and conveying systems
- Junction box soldering and curing station
- Conveyor and buffer systems between stations
- Climate-controlled production environment

❏ Equipment compatibility with current cell formats (e.g., larger wafer sizes) is a critical selection criterion for new lines.

Key Project Data

25–800

Scale Range (MW)

Entry-level refurbished / standard new / full-scale production

Semi → ...

Automation Level

Semi-automated to fully automated depending on capacity target

~95%

Material Cost Share

Cells, glass, encapsulant, backsheet, frame, and junction box dominate total cost

Global

Applicability

Model is region-adaptable; applicable to any general manufacturing context

Process	Solar module manufacturing (assembly + production line setup)
Key Components	PV cells, glass, backsheet, frame, junction box, encapsulant
Timeline	Depends on scale and automation level
Region	Global / General manufacturing context
Source	PVKnowHow / J.v.G. Technology GmbH

Cost Structure: What Drives Production Cost?

Materials (~95% of Total Cost)

- Dominant cost driver at all production scales
- Cells, glass, encapsulant, backsheet, frame, junction box
- Local sourcing vs. import logistics directly impacts margins

Overheads (~1 cent/W at 100 MW)

- Labor, energy, depreciation, and management costs
- Fixed cost per watt decreases as production scale increases
- Region-specific labor and energy rates are material variables

Working Capital Dynamics

- ~€800,000 required at 100 MW operational scale
- Inventory cycles and receivables management are critical
- Export-oriented models require robust cash flow planning

Automation Benefits in Module Production

Throughput Consistency

- Automated stringers eliminate manual soldering variation
- Higher module output per shift vs. manual lines

Defect Reduction

- Inline EL testing detects microcracks immediately after stringing
- Automated layup reduces cell breakage and contamination

Cost Efficiency at Scale

- Overhead per watt falls sharply from 25 MW to 100 MW+
- Semi-automated entry is viable; full automation justified at higher volumes

Process Traceability

- Automated lines enable batch-level data logging
- Supports root-cause analysis and IEC certification compliance

Common Production Defects & Root Causes

Defect Type	Cause	Prevention
Cell microcracks	Excess pressure or heat during stringing or lamination	Calibrated stringer settings; post-string EL test
Delamination	Incorrect laminator temperature profile or EVA quality	Process parameter validation; incoming material QC
Poor soldering	Contaminated ribbons or insufficient flux application	Automated flux dosing; ribbon quality checks
Contamination	Dust, fingerprints, or moisture during layup	Cleanroom discipline; glass washing verification
Incomplete cell coverage	Misaligned conductive paste during cell fab	Automated optical inspection (AOI) at cell entry
Frame misalignment	Incorrect framing machine settings or worn tooling	Regular tooling inspection; frame dimension checks

Testing & Quality Control

In-Process QC

- Incoming material inspection – cells, glass, EVA, backsheet
- EL test after stringing – detects microcracks before layup
- Visual inspection at each assembly stage

Final Testing

- Flash / IV-curve test – measures actual power output
- Electroluminescence (EL) test – reveals hidden internal defects
- Hi-pot (dielectric) test – verifies electrical insulation safety

Environmental Validation

- Thermal cycling – simulates hot/cold stress over module lifetime
- Humidity-freeze test – validates moisture resistance
- UV exposure test – confirms backsheet and encapsulant durability

- ❏ IEC 61215 and IEC 61730 are the internationally recognized standards for crystalline silicon module qualification and safety. Certification is required for most export markets.

Process Control Is the Foundation of Quality Output

Materials Dominate Economics

At ~95% of total production cost, cell and glass sourcing strategy is the primary lever for cost competitiveness — not machinery or labor alone.

Scale Drives Efficiency

Overhead per watt falls significantly as production volume scales from entry-level (25 MW) to standard (100 MW) and beyond. Semi-automated entry minimizes initial risk.

Process Control Determines Certification

Consistent, documented production methodology — supported by inline testing and traceability — is the critical enabler for IEC certification and market access.

📄 This presentation is based on a composite scenario derived from real manufacturing consulting experience. All data points are realistic but simplified for educational purposes. Source: PVKnowHow / J.v.G. Technology GmbH

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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